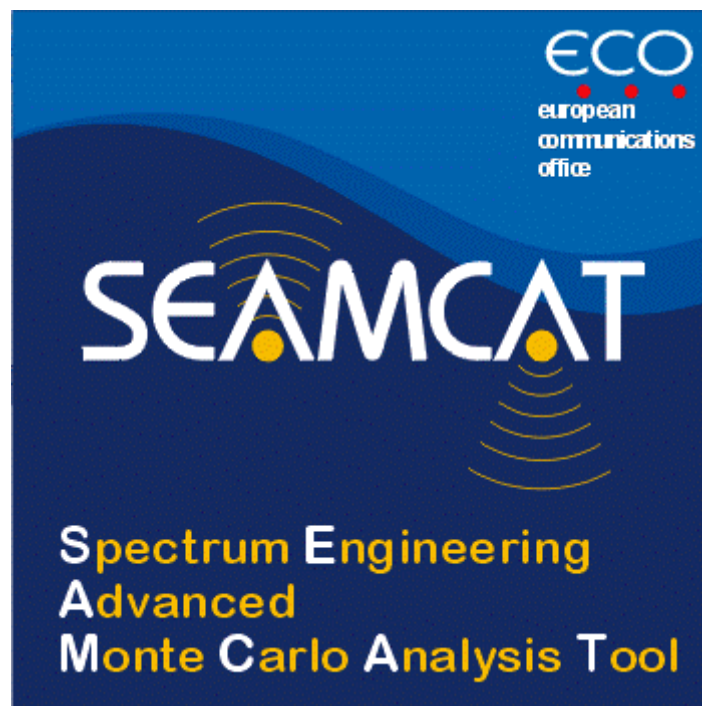# ECC Report **252**

SEAMCAT Handbook

Edition 2

Approved 29 April 2016

About the CEPT and ECO

The European Conference of Postal and Telecommunications Administrations (CEPT) is an organisation where policy makers and regulators from 48 countries across Europe collaborate to harmonise telecommunication, radio spectrum and postal regulations.

The European Communications Office (ECO) is the Secretariat of the CEPT. It provides advice and support to CEPT to help it to develop and deliver its policies and decisions in an effective and transparent way. Its core duties are to provide a European centre of expertise in electronic communications, to contribute to the work of the three CEPT committees and to manage CEPT's day-to-day activities.

ECO further supports CEPT member countries and other stakeholders providing a forum to debate and advance European communications policy for the benefit of all Europe's citizens.

Acknowldegment

For further enquiries

Any enquiries to the material in this document as well to the functioning of the SEAMCAT software may be addressed to ECO at:

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
3GPP	3rd Generation Partnership Project
ACS	Adjacent Channel Selectivity
ACIR	Adjacent Channel Interference Ratio
ACLR	Adjacent Channel Leakage Ratio
AP	Antenna Plugin
BS	Base Station
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
CDMAE	CDMA Engine
CEPT	European Conference of Postal and Telecommunications Administrations
CRP	Coverage Radius Plugin
CR	Cognitive Radio
DL	Downlink
dRSS	desired Received Signal Strength
DTH	Direct To Home
ECC	Electronic Communications Committee
ECO	European Communication Office
EPP	Event Processing Plugin
ETSI	European Telecommunications Standards Institute
E-UTRA	Evolved Universal Terrestrial Radio Access
FDD	Frequency Division Duplex
GSM	Global System for Mobile communication
GUI	Graphical User Interface
ICE	Interference Calculation Engine
ILR	Interfering link receiver
ILT	Interfering link transmitter
iRSS	interfering Received Signal Strength
It	Interefering link transmitter
ITU-R	International Telecommunication Union – Radiocommunication Sector

Abbreviation	Explanation
LTE	Long Term Evolution
MCL	Minimum Coupling Loss
NF	Noise Figure
OFDM	Orthogonal Frequency-Division Multiplex
OFDMA	Orthogonal Frequency-Division Multiple Access
PDF	Probability Distribution Function
PMP	Propagation model plugin
RF	Radio Frequency
Rx	Receiver
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
SINR	Signal to Infererence plus Noise Ratio
sRSS	sensing Received Signal Strength
STG	SEAMCAT Technical Group
sws	SEAMCAT WorkSpace
TDD	Time Division Duplex
TETRA	Terrestrial Trunked Radio
TS	Terminal Station
Tx	Transmitter
UE	User Equipment
UI	User Interface
UMTS	Universal Mobile Telecommunications System
VLR	Victim Link Receiver
VLT	Victim Link Transmitter
WG SE	Working Group Spectrum Engineering
WSD	White Space Device

EXECUTIVE SUMMARY

Introduction

SEAMCAT (Spectrum Engineering Advanced Monte Carlo Analysis Tool) is a statistical simulation model that uses a method of analysis called Monte Carlo to assess the potential interference between different radiocommunication systems such as broadcasting, point to point, point to multipoint, radar, Mobile networks, aeronautical and satellites.

This ECC Report is intended as a handbook on SEAMCAT for new users; to guide them from installation to carrying out advanced simulations, therefore the users will be refered to as "you". It is also intended as a reference for more experienced users by providing working guidance on different scenarios and advanced functions.

SEAMCAT is a radio spectrum system oriented software tool which allows you to build your own libraries (such as antennas, spectrum masks, propagation models, radio systems) or use those provided by other users to ease the effort to build complete scenarios for investigation. SEAMCAT is distributed with a predefined set of libraries, so that you do not need to reinvent the wheel every time you have studies to perform.

SEAMCAT is designed so that play/replay feature and plugins can help radio spectrum engineers to understandhow simulations are run or to extend algorithms.

The fundamental concept of SEAMCAT is to provideeasy sharing of radio spectrum compatibility studies (parameters, methods and results) within the CEPT by using a common interface. SEAMCAT is an open source tool and therefore freely available. SEAMCAT is widely used within the CEPT project teams, and also outside the CEPT globally by regulators, industry and academia. Scenarios can be studied, recreated and reconsidered by any of the interested parties using SEAMCAT. The only area for discussion arethe input parameters and the scenarios under investigation. Studies for investigation may cover and are not limited to:

- Sharing and compatibility studies on different equipment operating in the same or adjacent frequency bands;
- Assessing the impact of using different systems transmit and receive masks;
- Evaluation of limits applied e.g. for unwanted emissions, blocking or intermodulation products.

SEAMCAT version 5.0.0 and upward is a tool based on multicore processing allowing fast computation.

You can join the SEAMCAT community (Section 1.8) to contribute to the development of SEAMCAT and its libraries..

This ECC Report provides updated information compared to the material given in ERC Report 68 [7] which specified the original SEAMCAT alorithms.

Methodology

The radio spectrum is a limited resource and can only be used optimally if compatibility is assured between radio systems located in the same or adjacent frequency bands. The important criterion for radio compatibility is the difference between the wanted/desired signal level (victim link system) and any interfering signal levels in the victim link receiver's input. The most significant interference mechanisms are unwanted emissions from transmitters as well as blocking and intermodulation in the victim link receiver.

There are different approaches [17] to analyse these criteria, such as the Monte Carlo method as provided by SEAMCAT, and the Minimum Coupling Loss (MCL) method.

The Monte Carlo method is a statistical methodology to simulate processes by randomly taking values from a distribution. The term "Monte Carlo method" was coined in the 1940s by physicists working on nuclear weapon projects in the Los Alamos National Laboratory [9]. This approach was used for solving statistical problems and the code name given to the work was Monte Carlo.

A Monte Carlo simulation as used in this report is a statistical technique based upon the consideration of many independent events in time, space and frequency. For each event, or simulation trial, a scenario is built up using a number of different random variables that define the systems to be simulated (e.g. the location of the interferers with respect to the victim, the victim link's wanted signal strength, the channels/frequnecies of the victim and interferer use). If a sufficient number of simulation trials are considered then the probability of a certain event occurring can be evaluated with a high level of accuracy by taking the average result over all trials.

The flexibility in the model and its' supporting software implementation allow a quick yet reliable consideration of spatial and temporal distributions of the received signals and the resulting statistical probability of interference in a wide variety of scenarios.

Structure of this ECC Report
Section 1 to 2 of this document provides a general overview and description of the software.

Section 3 to 4 guides the beginner, step by step, on how to use SEAMCAT providing details about the software and the graphical interface.

Section 5 to 9 introduces and defines the various radio system input parameters that can be simulated in SEAMCAT.

Section 10 to 12 presents the various tabs, scenarios, event processing and results that are used when performing a spectrum sharing or compatibility study.

Section 13 addresses the library functionaility of SEAMCAT for simulating common transmitters, receivers, masks, antennas, propagation models, etc

Section 14 guides you through the plugin development that is made available to you so that you can develop your own algorithms and libraries compatible with the SEAMCAT run time environment.

ANNEX 1: to ANNEX 27: provides more details of the algorithms, interfaces and principles of sharing studies.

Quick Start in SEAMCAT

Download and Installation of SEAMCAT from www.seamcat.org

Platform independent (jar package)

(Windows, Linux, MAC)

Creating, opening and saving a workspace scenario (.sws file)
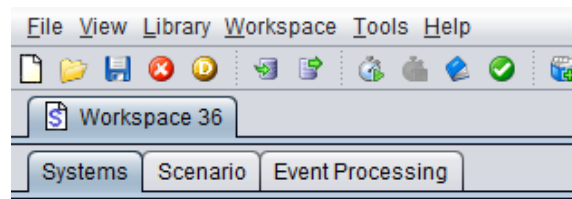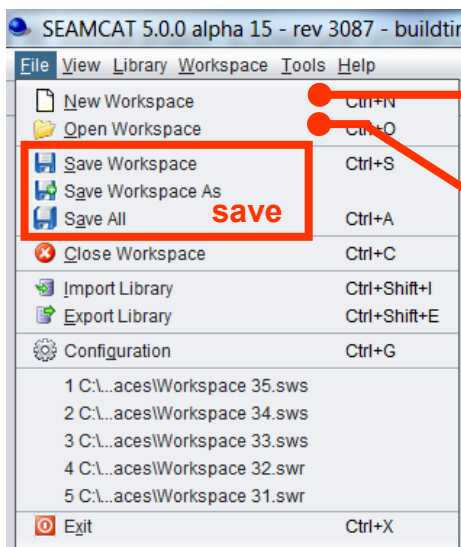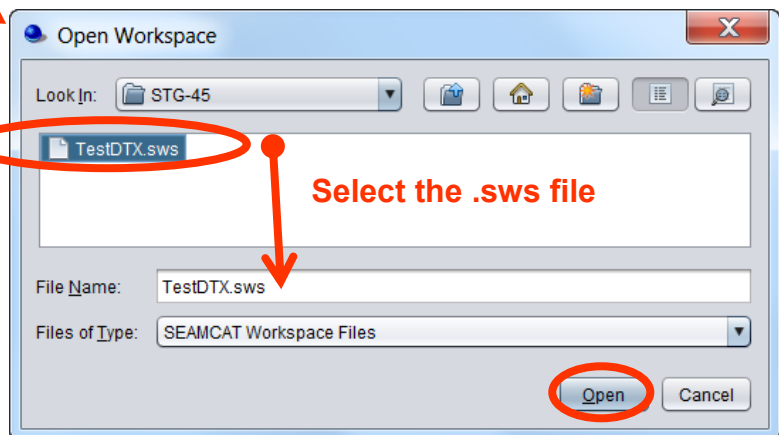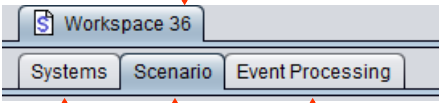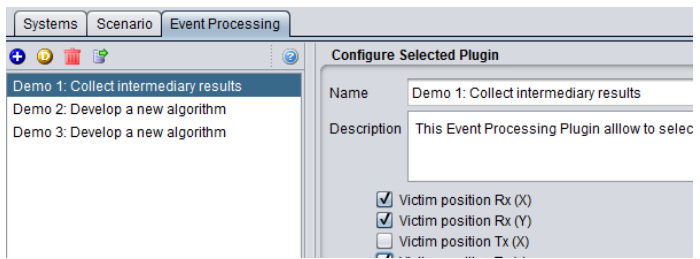
Workspace scenario (.sws file)

Worskspace storing the scenario only
Fields are editable
File saved as *.sws* (SEAMCAT Workspace Scenario)

The EPP (Event Processing Plugin) allows you to process intermediary
SEAMCAT results for each simulated event

Set the scenario, i.e. select the systems to use for the victim and interferer(s) as well as the path between the victim and the interfer(s), number of events, and option to run in debug mode

Set the characteristics of the systems to investigate (generic Tx, Rx and path between Tx/Rx or cellular general settings, positioning)

Systems that can be simulated in SEAMCAT

Generic Systems

Land Mobile
Short Range Devices
Terrestrial broadcasting

Point-to-Point and Point-to-Multipoint fixed systems
Earth based stations (e.g. DTH receivers) of satellite systems

Cellular Systems

CDMA (UMTS, CDMA 2000x, etc)
OFDMA LTE

dRSS

iRSS

Victim Link Receiver (VLR)

Victim System

Victim Link Transmitter (VLT)

Interfering Link Transmitter (ILT)

Interferer System(s)

Interfering Link Receiver (ILR)

Generic System Parametrisation

Receiver characteristics: (*sensitivity, bandwidth, antenna, blocking response, interference criteria, etc.***)**

Position and propagation model information between the Tx and the Rx

Workspace 36

Systems | Scenario | Event Processing

Generic System

System

Name: Generic System
Description:

Receiver | Transmitter | Transmitter to Receiver Path

General

Frequency [Constant(900.0)] [Distribution] MHz
☐ User-defined dRSS [Constant(0.0)] [Distribution] dBm

Transmitter characteristics (*power, antenna, spectrum emission mask, etc.***)**

Select library system

Generic System
CDMA UpLink System
CDMA DownLink System
OFDMA UpLink System
OFDMA DownLink System

Ok | Cancel | Help

● **Delete a system**
● **Duplicate a system**
● **Export a system to library**
● **Import a system from library**

Note: The frequency is overwritten at the "Scenario" tab level

CDMA/OFDMA System Parametrisation

CDMA/OFDMA settings (Rx/Tx setting*s, links, capacity, local environments, propagation model, pathloss correlation, etc.***)**

Workspace 36

Systems | Scenario | Event Processing

CDMA UpLink System

System

Name: CDMA UpLink System
Description:

General settings | Positioning

General

Frequency [Constant(900.0)] [Distribution] MHz

Cellular positioning (System settings, grid layout, mobile, base station)

Select library system

Generic System
CDMA UpLink System
CDMA DownLink System
OFDMA UpLink System
OFDMA DownLink System

Ok | Cancel | Help

Note: The frequency is overwritten at the "Scenario" tab level

Scenario Parametrisation

Select one victim from a list defined under the "system" tab

Workspace 36

Systems | Scenario | Event Processing

Victim System

Generic System | Frequency [Constant(900.0)] | Distribution

Frequency in "Scenario" overwrites settings in "Systems"

Select interferer system(s) from a list defined under the "system" tab

Interfering System Links

Link 1 (Generic System)

Frequency [Constant(900.0)] | Distribution

Transmitter to Victim Link Receiver Path | Transmi

Set the path characteristics between the victim and interfering system *(Relative positioning, density of interferers, pathloss correlation, propagation model)*

Interfering link iRSS

Change the system type

Generate multiple interfering links

Delete a link

Duplicate an interfering link

Add an interfering link to the scenario

Victim Receiver (VLR)

Interfering Link Transmitter (ILT)

Victim System

Interferer System(s)
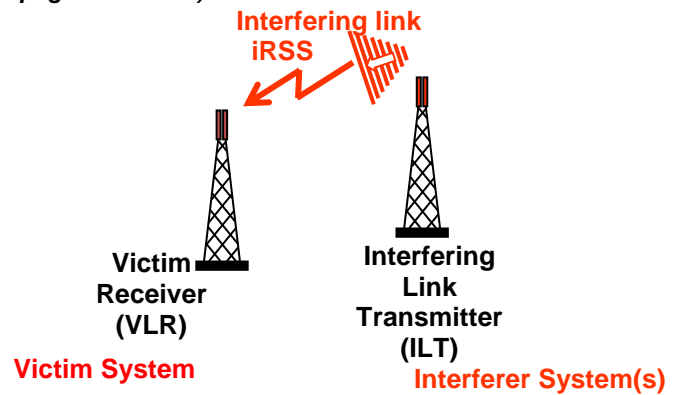
Workspace Results (.swr file)

Worskspace storing the results
Read only scenario
File saved as *.swr* **(SEAMCAT Workspace Result)**

Workspace 36 | Results[Workspace 36]

Outline | Results | Interference Calculations
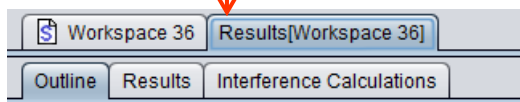
Interference calculation engine

List of all the results
Replay featurefor each event

Outline of the simulation with summary of the dRSS and iRSS calculation, graphical overview of the Tx/Rx position for the victim and interferer(s)

Workspace Results - Outline

- **Summary of the dRSS and iRSS results**
- **Progress bar to track the current task status and the system memory**
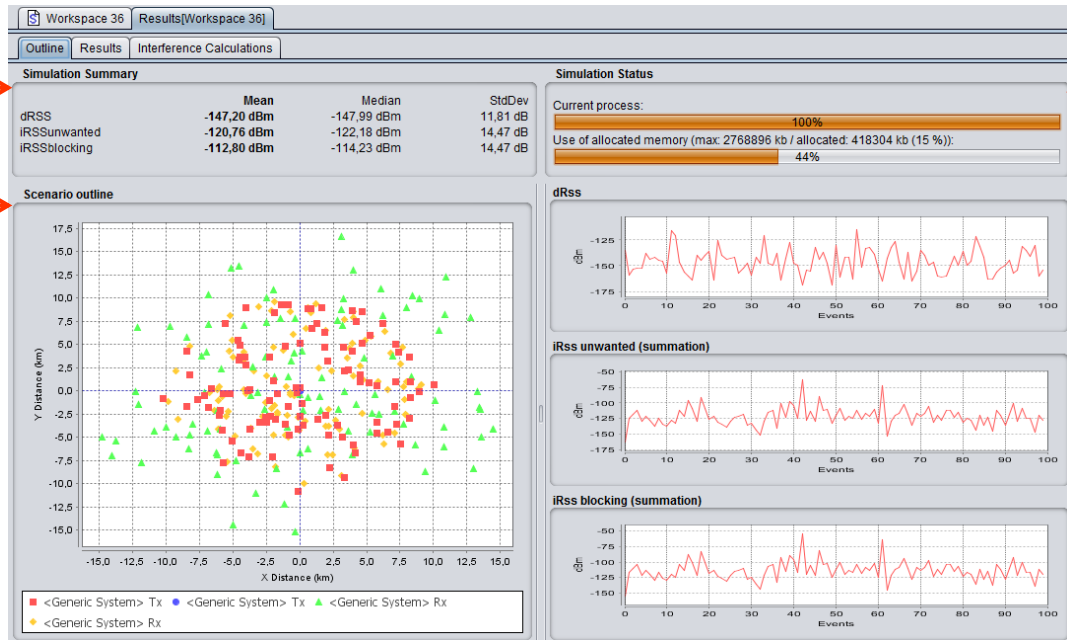
- **Display the victim and interfering link element for each snapshot**
- **Quick overview of the dRSS and iRSS during run time**

Workspace Results - Results

- **Play/Replay feature for one event**
- **Output vector from the SEAMCAT simulation**
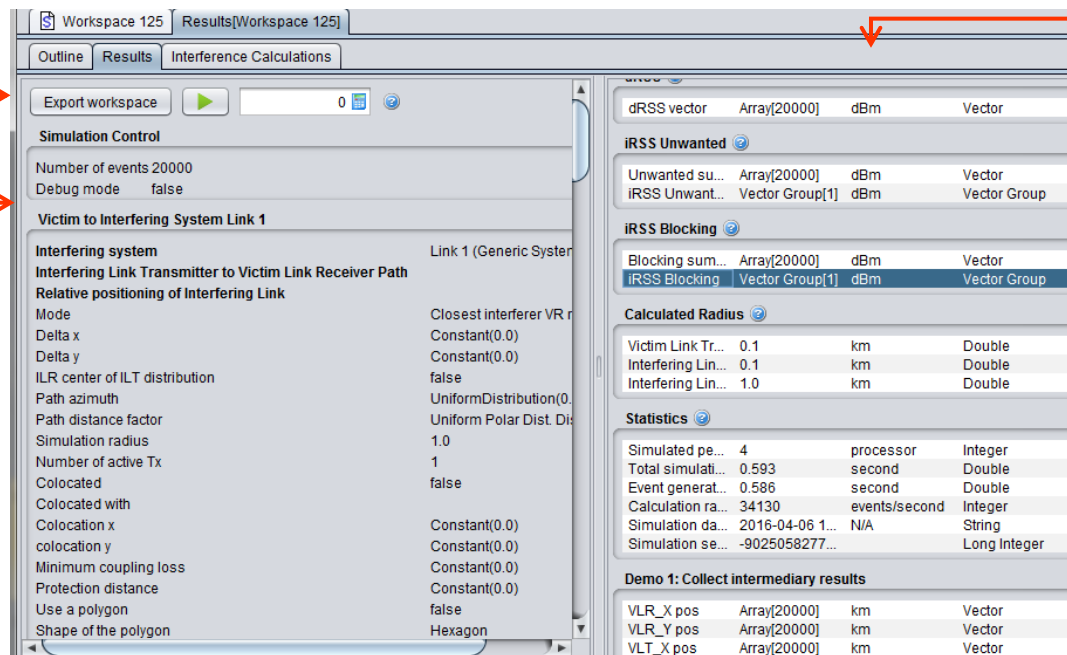
- **Input parameters used for these specific simulation results (read only)**
- **Display any output results of an EPP**
- **Statistics on the simulation process, time consumptions, number of processor used**

Workspace Results – Interference Calculations

Compatibility: Probability of interference as a single result
Translation: Probability of interference as a function of parameters
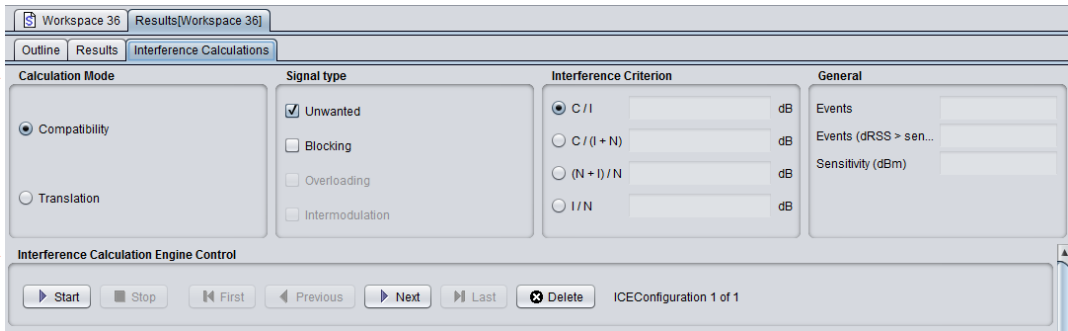
● **Control of the Interference Calculation Engine**

Compatibility: Probability of interference

Compatibility (single result)

Probability 0.175129533678756

17.5 % of probability of interference

Translation: Probability of interference as a function of parameters

Translation Parameters
- Blocking response level / Victim link
- Intermodulation response level / Victim link
- Power supplied / Interfering link 1

Results
Compatibility (single result)
Probability 0.0

Translation (probability function of translation parameter)

Batch environment: Run multiple workspaces simultaneously

File View Library Workspace Tools Help
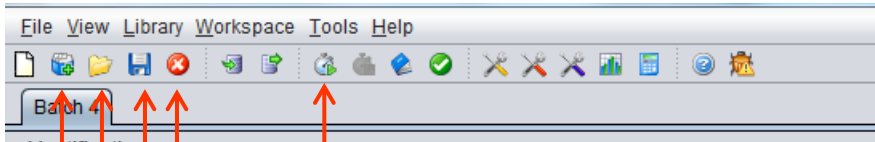
● **Run a batch**
● **Close a batch**
● **Save a batch**
● **Open a batch**
● **Start a new batch**

SEAMCAT batch file
Batch to be saved with workspace scenario (*.sbj* file)

Batch control: add new or existing workspace, export the workspace (save), delete and duplicate

Batch 4

Identification

Name   Batch 4
Description

Control

☑ Automatically save data when a workspace completes simulation

Workspaces

Workspace 39 Workspace 40 Workspace 41

Systems Scenario Event Processing
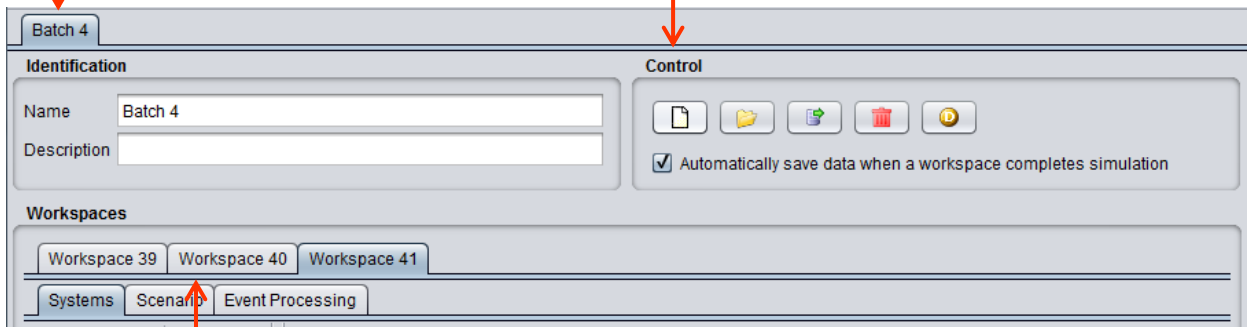
● **Set of workspaces included in the batch**

Batch results

List of main Interference results

SEAMCAT Batch Result file
To be saved as *.sbr* **file**

Workspace results to be saved as part of the batch result file

Batch 4 | Results[Batch 4]

Results | Results[Workspace 39] | Results[Workspace 40] | Results[Workspace 41]

Batch status

Batch simulation completed

Generic Victim

Name	Criterion	Unwanted	Blocking	Overloading	Intermodulation	Probability	#Events
Workspace 39	C/I	☑	☐	☐	☐	31,58%	20000
Workspace 40	C/I	☑	☐	☐	☐	27,03%	20000
Workspace 41	C/I	☑	☐	☐	☐	38,10%	20000

Analyse

Launch the analysis of the interference calculation

Results: dRSS and iRSS vectors
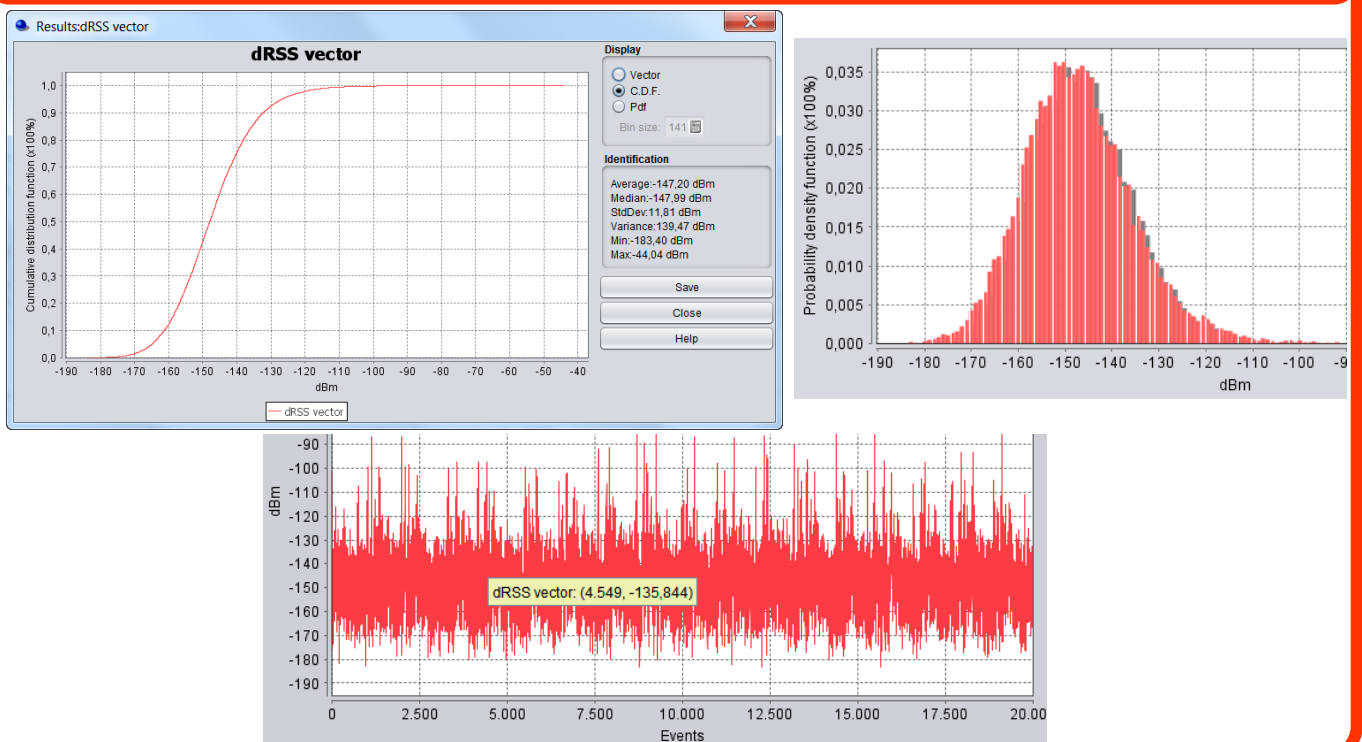
Compare vectors

Select the vectors to display from a list

from external files

from one workspace

from many workspaces

Libraries: Edit, Select

Built in system specific libraries

Built in and plugin libraries

Install plugins

Edit libraries

Library selection from the workspace

Libraries: Import, Export

Import/Export systems
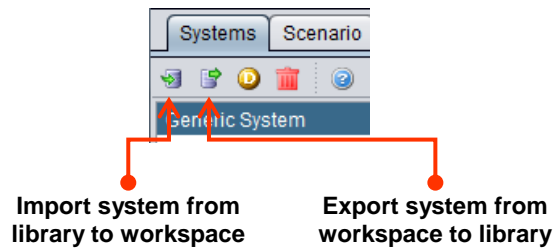
Import/Export systems components

Import system from library to workspace

Export system from workspace to library

Import system components from library to workspace

Export from workspace to library

Import/Export libraries

File View Library Workspace Tools Help

| Import Library | Ctrl+Shift+I |
| Export Library | Ctrl+Shift+E |

Import library

Look In: STG-46

library files.sli

File Name: library files

Files of Type: SEAMCAT Library Files

Export Libraries

Select All   Deselect All

Name	Type	Export
Generic System	System	☑
CDMA UpLink System	System	☑
CDMA DownLink System	System	☑
OFDMA UpLink System	System	☑
OFDMA DownLink System	System	☑

Select All System   Deselect All System

| Name | Type | Export |

Plugin generation

Antennas	Ctrl+Shift+A
Coverage Radius	Ctrl+Shift+C
Propagation Model Plugins	Ctrl+Shift+P
Event Processing Plugins	Ctrl+Shift+E

Configuration of various tyoes of plugin

Plugin Configuration

Name   All inputs

Description   Demo showing all possible input types

☑ Variations
☑ Vertical   Pattern
Horizontal   Pattern
☑ Spherical   Pattern
Integer   0
Distribution   [Constant(0.0)]   Distribution
Object Integer   0
☑ Opt double   0.0
A value   0.0   dB
☐ true/false
☐ True/False
Propagation   [Extended Hata]   Edit
Antenna   [Peak gain antenna]   Edit
Emission   [User defined ...]   Edit
Blocking mask   [Constant (0.0)]   Edit
String
Gender   Male
Function   [User defined ...]   Function

Large range of input parameters to implement

No limitation on the number of inputs

Receiver identification

Library

Name   DEFAULT_

Description

Menu overview

ID	Description
1	Create a new workspace
2	Create a new batch job
3	Open any SEAMCAT workspace file (.sws, .swr) or batch job (.sbj, .sbr)
4	Save a workspace or a batch file under the current working directory
5	Save as a workspace or a batch with a selectable filename
6	Save all the workspaces, batch files at once
7	Close the selected workspace or batch
8	Import library
9	Export library
10	Access the configuration of SEAMCAT (Home selection, Server settings)
11	History of open files
12	Exit SEAMCAT (this will close the SEAMCAT application)
13	Allows the tool bar to be displayed
14	Allows the status bar to be displayed
15	System library
16	Spectrum emission mask library
17	Receiver blocking mask library
18	Receiver library (Generic system only)
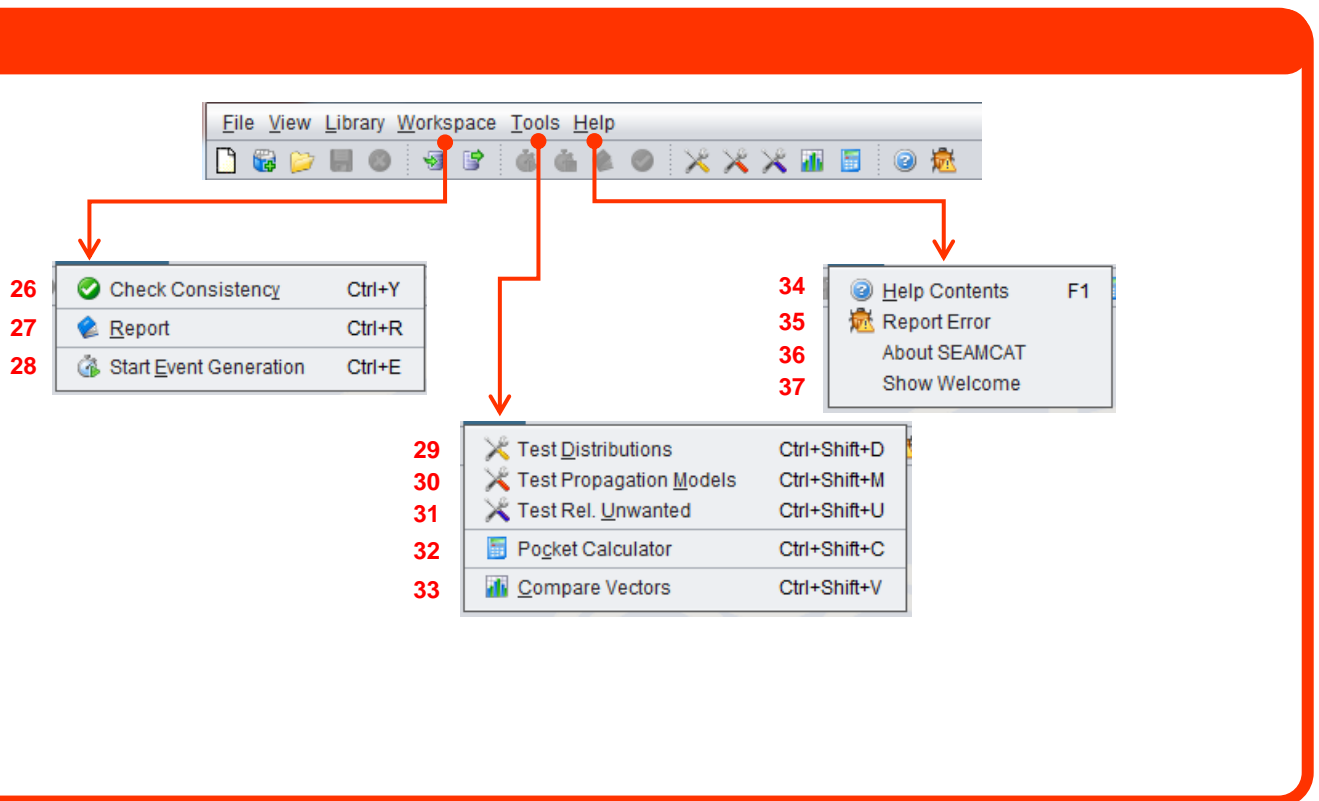
ID	Description
19	Transmitter library (Generic system only)
20	CDMA link level data library
21	Antenna plugin library
22	Coverage radius plugin library
23	Propagation model plugin library
24	Event processing plugin library
25	Install .jar plugins to SEAMCAT environment
26	To detect erroneous or inconsistent values in the scenario definition before running a simulation
27	Generate a SEAMCAT simulation report
28	Start a workspace or a batch simulation
29	Check the built-in distribution function
30	Check the built-in and plug-in propagation model
31	Check the unwanted emission function
32	Access pocket calculator feature
33	Plot and compare multiple vectors (results from current and other workspaces)
34	Help contents – redirect to the on-line manual
35	Procedure to report an error
36	About SEAMCAT
37	Enable/disable the display of the welcome window

1   INTRODUCTION

1.1   BACKGROUND TO SPECTRUM ENGINEERING

The radio spectrum is a limited resource and can only be used optimally if compatibility is assured between radiocommunications systems located in the same or adjacent frequency bands. For example, an important criterion for radio compatibility is the difference between the wanted and unwanted signal levels in the victim link receiver input. This parameter is used to derive a separation between the victim and interfering systems or services in geographical space or frequency domain. Considering only the adjacent bands, the most significant interference mechanisms are unwanted emissions from interfering transmitters as well as blocking and intermodulation in the victim link receiver.

A statistical simulation model based on the Monte-Carlo method has been developed within the CEPT Working Group Spectrum Engineering, named SEAMCAT® (Spectrum Engineering Advanced Monte-Carlo Analysis Tool). This software implementation allows quick yet reliable considerations of spatial distributions of the received signals and the resulting statistical probability of interference in a wide variety of scenarios. By adapting the operational conditions of radio systems with respect to the probability of exceeding the protection criterion, the most efficient use of the radio spectrum can be identified

SEAMCAT is software that simulates radio spectrum systems, allowing you to implement your own libraries or use those provided by other users to ease the effort to build complete scenarios for investigation. These libraries may contain predefined antenna patterns, spectrum emission masks,propagation models, complete radio systems, etc.

SEAMCAT version 5.0.0 and upward provides multicore processing allowing for fast computations.

You can join the SEAMCAT community to contribute to the development of the software and libraries, as explained in Section 1.8.

1.2   BASIC RF TERMINOLOGY

The following terminology has been developed to support the SEAMCAT simulation tool. While it is broadly in line with what is in use in ITU-R, ETSI, and CEPT, it may be expected that for other needs or documents, ETSI and CEPT/ECC will use different definitions, for example definitions more focused on specific equipment characteristics or aspects of such products.

1.2.1   Receiver thermal noise

The thermal noise (in Watts) expressed in power level is defined as:

$$N_0 \ (Watts) = k_B T B \qquad \qquad (Eq.\ 1)$$

where:

- k_B is the Boltzmann's constant 1.38×10^{-23} in joules per kelvin (J/K),
- T is the receiver absolute temperature in Kelvin (K),
- B is the bandwidth in Hertz (Hz) over which the noise is measured.

It can be seen that the noise power of eq1 is dependent on the temperature and on the bandwidth. This figure is then normally expressed in terms of dBm and is defined as:

$$N_0 \ (dBm) = -173.977 + 10*log10(systemBandwidth \ (Hz)) \qquad \qquad (Eq.\ 2)$$

The noise power spectral density of -173.977 dBm/Hz implies a temperature of 290 K.

1.2.2 Noise figure and Noise factor

Noise figure (NF) and noise factor (F) are measures of degradation of the signal-to-noise ratio (SNR), caused by components in a radio frequency (RF) signal chain. It is a number by which the performance of an amplifier or a radio receiver can be specified, with lower values indicating better performance.

The noise factor is defined as the ratio of the output noise power of a device to the portion thereof attributable to thermal noise. The noise factor is thus the ratio of actual output noise to that which would remain if the device itself did not introduce noise, or the ratio of input SNR to output SNR.

The noise figure is simply the noise factor expressed in decibels (dB).

$$NF = 10*log_{10}(F) \hspace{4cm} (Eq. 3)$$

1.2.3 Receiver noise floor

Any practical measurement will be subject to some form of noise or unwanted signal (thermal noise or interfering signals). The noise floor limits the smallest measurement that can be taken with certainty since any measured amplitude cannot on average be less than the noise floor.

The noise floor (N) is the level of noise introduced by the receiver system below which the signal that is being captured cannot be isolated from the noise, and is defined in dBm as:

$$N (dBm) = N_0 (dBm) + NF (dB) \hspace{3cm} (Eq. 4)$$

or in linear domain:

$$N (Watts) = 10^{\wedge}((-173.977 + 10*log_{10}(systemBandwidth (Hz)) + NF)/10) \hspace{0.5cm} (Eq. 5)$$

As an example, in SEAMCAT, for a receiver with a noise figure of 9 dB and a bandwidth of 5 MHz, the noise floor will be

-173.977 dBm/Hz +60 dB/MHz +10*log_{10}(5 MHz) = -98 dBm

Another example is that for a noise figure of 4 dB and a bandwidth of 200 kHz with thermal noise = kTB = -121 dBm, the noise floor is -117 dBm.

In SEAMCAT, the input is the distribution of the strength of the noise floor. This parameter is used for the probability calculation when the criteria is C/(N+I), (I/N) or (I+N)/N.

1.2.4 Receiver sensitivity

The sensitivity of a receiver is normally taken as the minimum input signal (S_{min}) required to produce an output signal with a specific signal-to-noise (S/N) ratio. S/N is a <u>required</u> minimum ratio, if N is increased, then S must also be increased to maintain the S/N ratio. The threshold value is chosen high enough above the mean noise level so that the probability of random noise peaks exceeding the threshold, and causing false alarms, is acceptably low. It is defined (in log domain/dB) as

$$Sensitivity = Noise\ Floor + Receiver\ protection\ ratio \hspace{2cm} (Eq. 6)$$

In SEAMCAT, the following equation (in log domain/dB) is applied:

$$Sensitivity = Noise\ Floor + C/(N+I) \hspace{3cm} (Eq. 7)$$

Where C/(N+I) is the carrier (or signal) to interference plus noise ratio as input to SEAMCAT. The S/N is equal to the C/(N+I) in the absence of any interferer.

In SEAMCAT, this is used in the calculation of the receiver attenuation in Sensitivity mode. See Annex A8.5 for further details.

1.2.5 Wanted signal: dRSS

The **victim's wanted signal strength/desired Received Signal Strength** (dRSS), corresponding to the carrier level (C), is calculated as a simple link budget between the victim link receiver (VLR) and the victim link transmitter (VLT) as described in ANNEX 4:.

1.2.6 Interfering signal: iRSS

The **interfering Received Signal Strength** (iRSS), corresponding to the interference level (I), is calculated as a link budget between the VLR and the interfering link transmitter (ILT) as described in ANNEX 5:.

The various interference mechanisms resulting in different iRSS (i.e. unwanted, blocking and intermodulation) are decribed in Section 1.4.5.

1.2.7 Bandwidth correction factor

When the bandwidth of the interferer and the victim are different, SEAMCAT automatically applies a bandwidth correction factor to calculate the unwanted emission power for a specific bandwidth.

The following example introduces an interferer transmitting 2 W. This is equivalent to 33 dBm (see conversion in Table 97). The amount of energy that a VLR receives in its bandwidth can be derived according to these two cases illustrated in Figure 1.
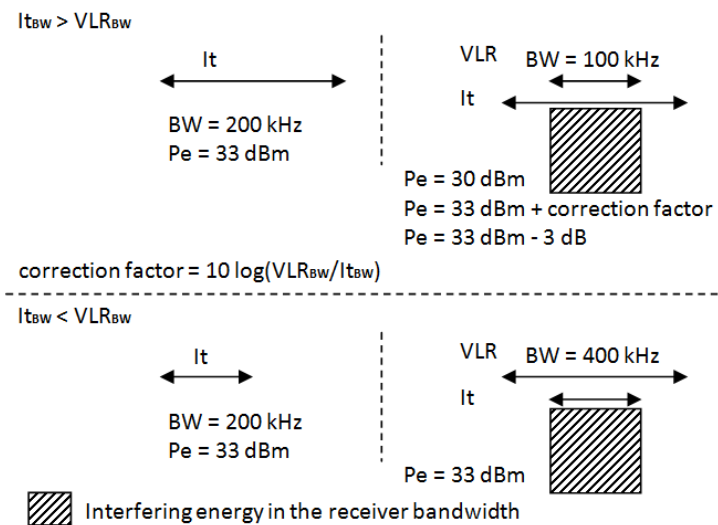
Figure 1: Illustration of the bandwidth correction factor

Further examples of correction bandwidth can be found in section 3.3.8.

1.2.8 Desensitisation

Desensitisation (D) of the receiver in the presence of an interfering signal, given in dB, corresponds to the 'noise rise' or 'noise augmentation' due to the interfering signal and is derived by the following equation in dB:

$$D = 10.\log_{10}[(i + n)/n] \qquad\qquad (Eq.\ 8)$$

and is equivalent in the linear domain to:

$$D = 10.\log_{10}[(10^{(N/10)} + 10^{(I/10)})] - N \qquad\qquad (Eq.\ 9)$$

To ensure proper operation, the receiver is designed to include a margin equal or lower than D which allows it to tolerate a certain level of interference (I) in the listened channel. This can be caused by co-channel and/or non-co-channel interference sources.

When running a radio network or a radio link, the objective is to maintain the signal to interference and noise ratio SINR equal to the sensitivity to noise ratio. This is illustrated in the following figure.
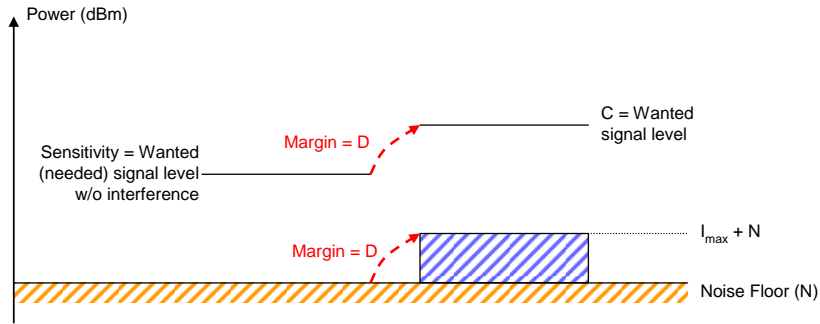
Figure 2: Desensitisation

An equivalent expression of the desensitization, (N+I)/N, is expressed as follows in terms of interference to noise ratio I/N in dB.

$$I/N = 10.\log_{10}(10^{D/10} - 1) \qquad\qquad (Eq.\ 10)$$

noting that in linear domain it is equivalent to:

$$i\,/\,n = [(i + n)\,/\,n] - 1 = 10^{D/10} - 1 \qquad\qquad (Eq.\ 11)$$

1.2.9   Blocking

The term "Blocking" is used in SEAMCAT to describe the capability of the victim receiver to receive a wanted modulated signal without exceeding a given degradation due to the presence of an unwanted input signal on a frequency other than the frequency of the wanted signal.

It has to be noted that most standards and specifications distinguish between the receiver selectivity given as Adjacent Channel Selectivity (ACS) for frequency offsets close to the centre frequency of the VLR, and Blocking (a term often associated with desensitisation) for frequency offsets far away from the centre frequency of the VLR. It is assumed that the receiver blocking performance is flat over the bandwidth of the interfering signal.

1.2.10   Adjacent channel selectivity (ACS)

The receiver selectivity is often given as Adjacent Channel Selectivity (ACS) – i.e. when the concept of "channel" has been defined for the system being considered. As the wording suggests, this parameter defines the requirement in case one single ILT is set at the centre frequency of the (first) adjacent channel. The values for the second and third adjacent channel are occasionally also defined by a standard. However, standards generally implicitly define the interfering signal as of the same system type as the victim, i.e. using the same bandwidth and generally the same or at least a similar modulation scheme.

1.2.11   In-band, out-of-band, spurious, unwanted emission

In-band emission is understood as relating to the necessary bandwidth.

The ITU-R Radio Regulations define the followings in Nos. 1.152, 1.144, 1.145 and 1.146:

1.152 Necessary bandwidth: For a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions.

1.144 Out-of-band emission: Emission on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious emissions.

1.145 Spurious emission: Emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions.

1.146 Unwanted emissions: Consist of spurious emissions and out-of-band emissions

These definitions are illustrated in the following figure (see also Figure 1 in ECC Recommendation (02)05 [18]):
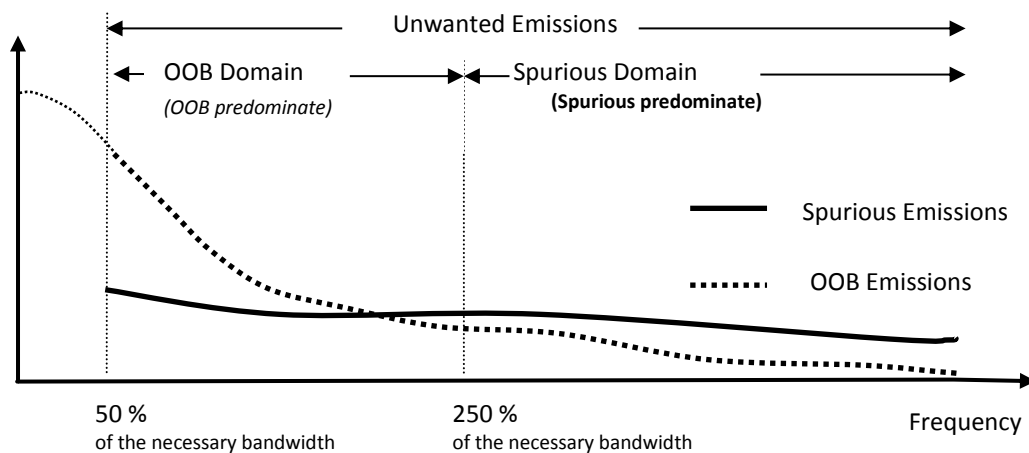
Figure 3: Il lustration of the OOB and Spurious Domains

1.2.12 Co-channel

A co-channel interference scenario can be illustrated as shown in figure below. In this case a part or the whole component of the interference is within the receiver bandwidth of the victim receiver.
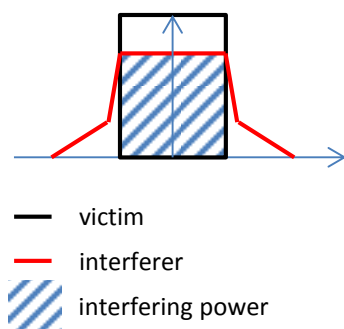
Figure 4: Co-channel interference scenario

1.3 MONTE-CARLO BASICS

The statistical methodology used as a basis for SEAMCAT is the Monte Carlo method. Statistical simulation methods may be contrasted to conventional analytical methods, which are typically applied to ordinary or partial differential

equations that describe some underlying physical or mathematical system. In many applications of the Monte Carlo technique, the physical process is simulated directly, and there is no need to even write down the differential equations that describe the behaviour of the system.

The Monte-Carlo simulation method is based upon the principle of taking samples of random variables from a given distribution. Before the simulation you need to define the distributions for all relevant parameters of the radiocommunications systems to be modelled (e.g. antenna heights, powers, operating frequencies, positions of the transceivers, etc.). Fixed values can be specified for parmaters which do not vary in the scenario (e.g. systems with specific frequnecies or heights). The technical specifications of the receiver and transmitter are generally extracted from relevant equipment standard (e.g. standards produced by ETSI, 3GPP, IEEE etc.).

SEAMCAT uses these distributions to generate random events. For each event, SEAMCAT stores the signal strength of the interfering and the desired signals calculated in dedicated data arrays. As a final step, you can derive the probability of interference by comparing the wanted and unwanted signals at the victim link receiver in each event to the relevant interference criterion, such as C/I.

The only requirement is that the physical or mathematical parameter can be described by a probability density function (¨PDF). Once the PDFs of the relevant parameters are known, the Monte Carlo simulation can proceed by randomly sampling them. Many simulation trials are performed with different random samples for each trial, and the desired result is taken as an average over the number of observations. In many practical applications, one can predict the statistical error in this average result, and hence an estimate of the number of Monte Carlo trials that are needed to achieve a given error.

SEAMCAT models one single victim link receiver (VLR) connected to a victim link transmitter (VLT) operating amongst a population of one or more interfering link transmitters (ILT) whichare linked to an interfering link receiver (ILR). These interferers may belong to the same system as the victim, a different system or a mixture of both. The locations of the interferers are distributed around the victim, either completely randomly or with some relation to the location of victim in a manner that can be specified by the user.

Figure 5 illustrates the terminology of the various elements that are simulated for (a) 'generic' systems (i.e. non-cellular) and (b) cellular systems.

(a) **(b)**
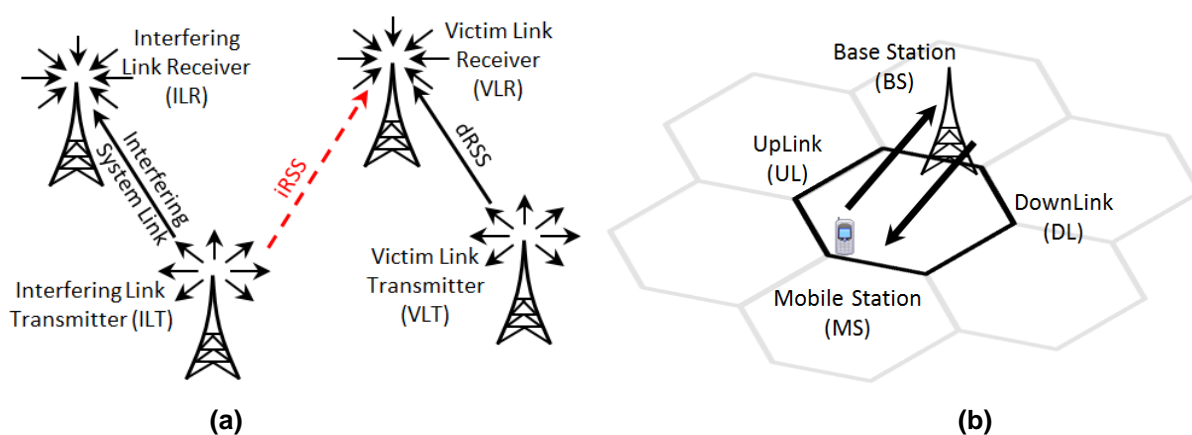
Figure 5: Terminology used in SEAMCAT (a) generic systems and (b) cellular systems

It is common practice to use a uniform random distribution for the locations. The density of interferers is set in line with the environment being modelled, i.e. an urban environment should have a higher density than a rural environment. Only a proportion of the interferers are active at any instance. This proportion may depend for example on the day of the week as well as the time of day. Figure 6 illustrates how the interferers and victim may appear for one simulation trial. Also illustrated is the victim link transmitter providing the victim's wanted signal (dRSS: desired Received Signal Strength).
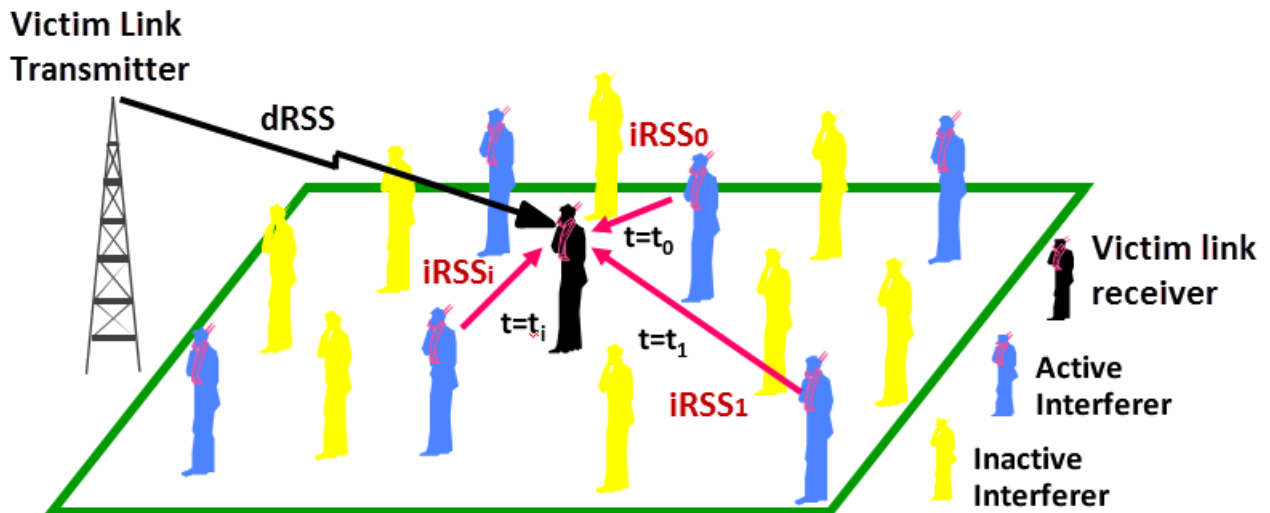
Figure 6: A typical victim and interferer scenario for a Monte Carlo simulation trial

For cellular simulations, the generation of events includes additional complexity - several iterations of a power control loop (CDMA) may be needed within each event, and some initial pre-calculations are required, such as the calculation of non-interfered (nominal) capacity. For victim CDMA systems the interference criterion is the excess outage, i.e. the percentage of previously served users disconnected as a result of the interference impact. For victim OFDMA systems the interference criterion is the bitrate loss, i.e. the percentage of bit-rate lost compared to a non interfered victim network.

1.4 INTERFERENCE CALCULATIONS IN GENERIC SYSTEMS

1.4.1 Introduction

In this section the interference calculations for 'generic' systems are described. Cellular systems (OFDMA and CDMA) use a different interference calculation method based on capacity loss which is described in more detail in ANNEX 15:

1.4.2 An illustration with C/I as interference criterion

The C/I ratio available at the victim receiver's input is computed using both the iRSS (Interfering Received Signal Strength) and the dRSS (desired Received Signal Strength),. Figure 7 illustrates the various signal levels used to determine whether or not interference is occurring.

Figure 7(a) represents the situation in case of no interference - the VLR is receiving the dRSS with some safe margin above its sensitivity level. The victim's signal level is the sum of the sensitivity and wanted signal margin l.

Figure 7 (b) illustrates the case of tolerable interference. The interference power iRSS adds to the noise floor power resulting in an increase of the noise floor. The example introduces an increase of 1 dB of the noise floor caused by an iRSS 6 dB below the noise floor. As a result the wanted signal margin is also reduced by 1 dB assuming a constant wanted signal power. However since the original wanted signal margin is much larger the interference is tolerable –i.e. the C/I ratio available at the receiver's input is larger than the S/N required for the operation of the system.

Figure 7(c) shows the case of interference which can not be tolerated – i.e. the operation of the system is impaired. The power sum of all the interfering signals including the noise floor of the receiver results in an insufficient wanted signal margin -, i.e. the C/I ratio available at the receivers input is less than the S/N ratio required for the intended operation.

The figure shows three diagrams labeled with L_{Rx} [dBm] axes:

(a) no interference: wanted signal (dRSS), wanted signal margin, receiver threshold Rx_{Th}, $S/N_{required}$, noise floor FkTB.

(b) tolerable interference: reduced wanted signal margin, desensitized receiver threshold $Rx_{Th}+1dB$, $C/I_{available} > S/N_{required}$, $S/N_{required}$, increased noise floor FkTB + 1 dB, FkTB + 1dB, I/N, I/N = - 6dB, iRSS.

(c) intolerable interference: desensitized receiver threshold, $S/N_{required}$, $C/I_{available} < S/N_{required}$, $iRSS_{\Sigma} \approx$ increased noise floor, $iRSS_{\Sigma}$-max for operation. distances between level (arrows) in [dB] Levels in [dBm]

Figure 7: Levels used to determine whether or not interference is occurring

As a receiver cannot distringuish between various sources of interference or noise, the sum of all interefing signals including the receiver noise floor has to be taken into account. The C/I ratio available at the receiver's input must be greater than the S/N required for the operation of the system if the interference is to be avoided. SEAMCAT checks for this condition and records whether or not degradation due to interference is occurring. This is illustrated further in Figure 8

The Monte Carlo technique works by considering many independent events in time (or in space). For each instant a scenario is built up using a number of different random variables, i.e. where the interferer is located with respect to the victim, the signal strength of the wanted signal, which channels the victim and interferer are using etc. If a sufficient number of simulation trials are considered then the probability of a certain event occurring can be calculated with a high level of accuracy.

In this way, the tool is able to quantify the ***probability of interference*** between radio systems and is able to help determine appropriate frequency arrangement rules or identify suitable limits for transmitter/receiver performance.

You can select the ***interfering modes*** (unwanted and blocking) as well as the ***interference criteria*** of your choice in SEAMCAT as shown in Figure 97 (p. 79).
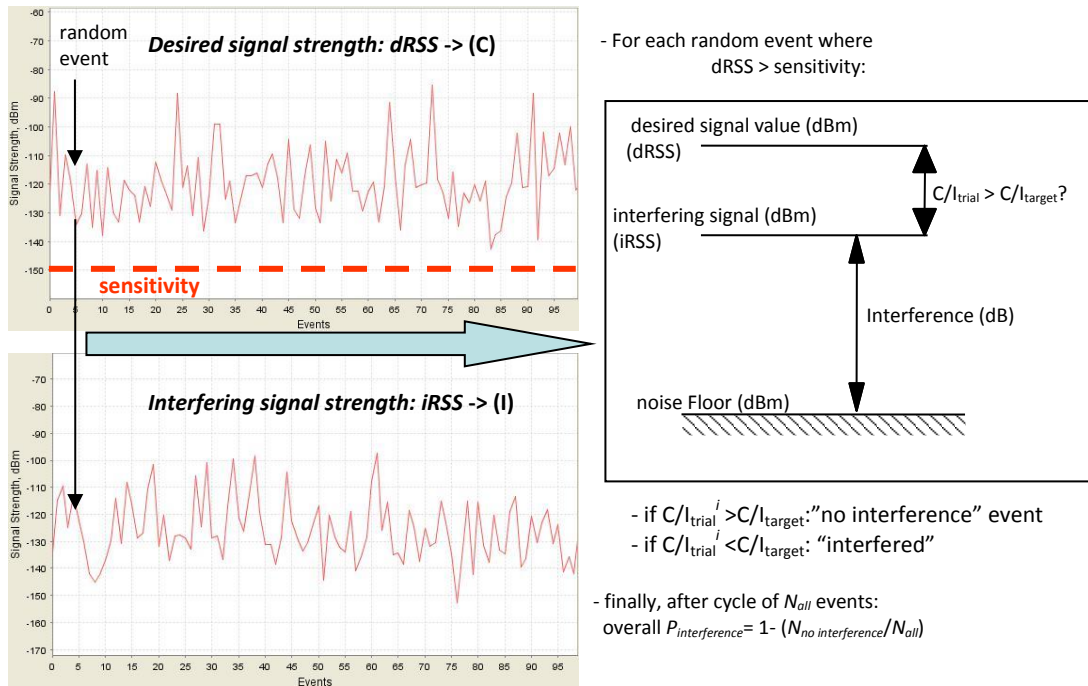
Figure 8: Illustrative summary of the interference criteria computation

1.4.3   Methodology associated to the interference criterion (C/I, C/(I+N), (N+I)/N, I/N)

Four interference criteria are considered within SEAMCAT:

- C/I   : Carrier to interference ratio;
- C/(I+N) : Carrier to interference plus noise ratio;
- (N+I)/N : Desensitisation;
- I/N   : Interference to noise ratio.

You can specify levels for all of these criteria as an input to your simulation. (Figure 9), but a single criteria needs to be chosen for the interference calculation (Figure 10). Multiple interference calculations are possible on the same set of results if you wish to use more than one criterion separately. In the example below the criterion for interference to occur for the VLR isa carrier to interference ratio (C/I) less than the minimum allowable value of 19 dB-

These parameters are also used in the evaluation of the two blocking modes (Protection ratio and Sensitivity, see section 1.4.5).

Figure 9: Interference criteria values that you provide as input to your simulation

Figure 10: Selection of the interference criteria used for the evaluation of interference (from the Interference Calculation Engine control panel)

1.4.4 Interference criteria relationship

C/I may vary typically from 9 dB (e.g. for QPSK) to 26 dB or higher (e.g. for 64QAM…). By introducing artificial noise iRSS on top of the noise floor (I/N), C/I is then desensitised by (N+I)/N resulting in C/(N+I). Note that the desensitisation is exactly the factor (N+I)/N (also = 1+I/N).

Further details of the relationship are given in ANNEX 3:.

Considering that

$$\left[\frac{C}{N+I}\right]_{dB} = \left[\frac{C}{I}\right]_{dB} - \left[\frac{N+I}{I}\right]_{dB} \text{ and } \left[\frac{N+I}{I}\right]_{dB} = \left[\frac{N+I}{N}\right]_{dB} - \left[\frac{I}{N}\right]_{dB} \qquad \textit{(Eq. 12)}$$

and assuming a C/I of 19 dB, the following examples may be considered:

- I/N = 0 dB, results in (N+I)/N = 3 dB and considering C/I = 19 dB, then C/(N+I) = C/I - 3 dB = 16 dB
- I/N = -6 dB, results in (N+I)/N ≈ 1 dB and considering C/I = 19 dB, then C/(N+I) = C/I - 7 dB = 12 dB
- I/N = -10 dB, results in (N+I)/N ≈ 0.4 dB and considering C/I = 19 dB, then C/(N+I) = C/I - 10 dB = 9 dB

- I/N = -20 dB, results in (N+I)/N = 0.04 ≈ 0.1 dB and C/I = 19 dB, then C/(N+I) = C/I - 20 dB = -1 dB

Note: *In case C/(I+N) is chosen as the protection criterion:*

if I/N ≤ -20 dB, the impact of the interferer is negligible compared to the noise floor (i.e. C/(I+N) ≈ C/N);

if I/N > 10 dB, then C/(I+N) ≈ C/I (i.e. the interferer is more dominant than the noise).
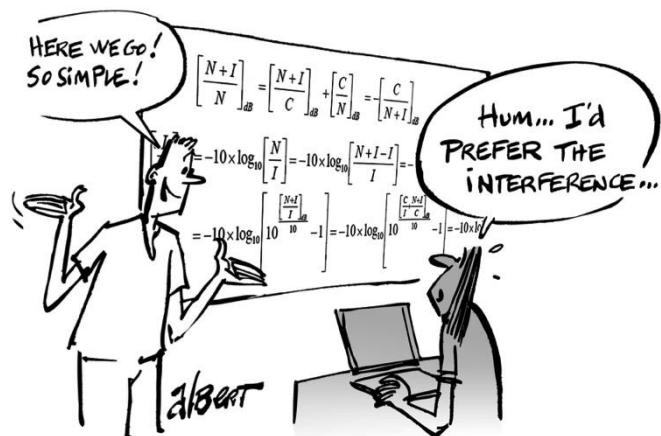
1.4.5 Unwanted emissions

The level of ***unwanted emissions*** (i.e. consisting of the out-of-band emissions and the spurious emissions [8] of the ILT) falling within the VLR receiver bandwidth (Figure 11) is determined using the interferer's transmit mask, the receiver bandwidth of the VLR, the interferer-to-victim frequency separation, the gains of the antennas and the propagation loss. The receiver experiences the unwanted power directly as additional noise in terms of I+N. There is no possibility in terms of filtering with which the receiver could reduce this impact by itself.

Note that the Rx bandwidth is taken into account in the unwanted calculation.

Further details on the unwanted emission mask are provided in ANNEX 6:. Details on the iRSS$_{unwanted}$ calculation are given in ANNEX 5:. The unwanted emission is also sometimes quantified using the term Adjacent Channel Leakage Ratio (ACLR) (see Annex A15.7).
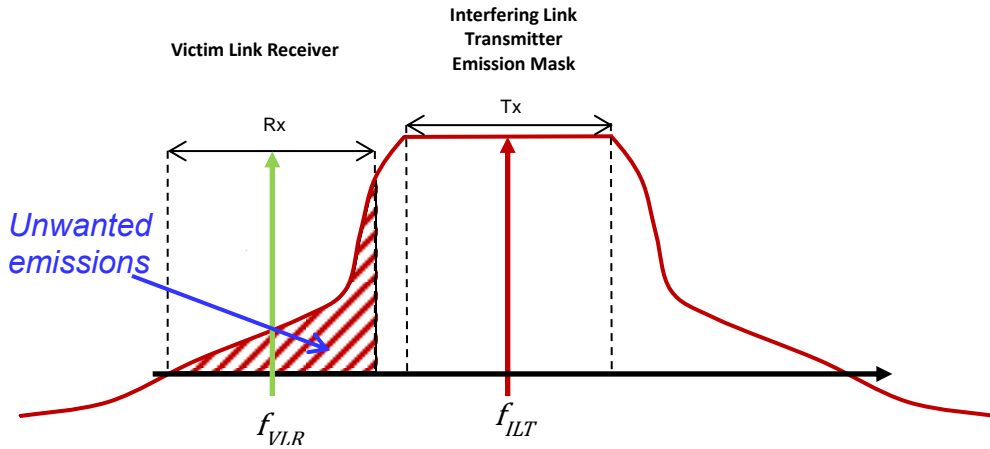
Figure 11: Illustration of the interference due to the unwanted emissions (i.e. the unwanted emissions of ILT falling in the receiver bandwidth of VLR)

1.4.6   Receiver blocking

The level of interference due to *receiver blocking* , i.e. the power captured from the transmissions of the interferer due to selectivity imperfections of the victim's receiver (**Figure 12**), is determined using the interferer's transmit power, the victim link receiver's blocking performance, the interferer/victim frequency separation, antenna gains and propagation loss. Details on the iRSS$_{blocking}$ calculation are given in ANNEX 5:.

Note that with SEAMCAT 5.0.1, the blocking attenuation is computed at the ILT frequency and that the ILT bandwidth is nowconsidered (see ANNEX 8:). There are 3 ways to calculate the blocking response which are described in more detail in ANNEX 8::

User Defined (dB):	$Att_{Blocking} = Block_{UD\ (dB)}$	*(Eq. 13)*
Protection Ratio (dB):	$Att_{Blocking} = Block_{PR\ (dB)} + C/(N+I)_{(dB)} + (N+I)/N_{(dB)} - I/N_{(dB)}$	*(Eq. 14)*
Sensitivity Mode (dBm):	$Att_{Blocking} = Block_{Sens\ (dBm)} - Sensitivity_{VLR\ (dBm)} + C/(N+I)_{(dB)} - I/N_{(dB)}$	*(Eq. 15)*
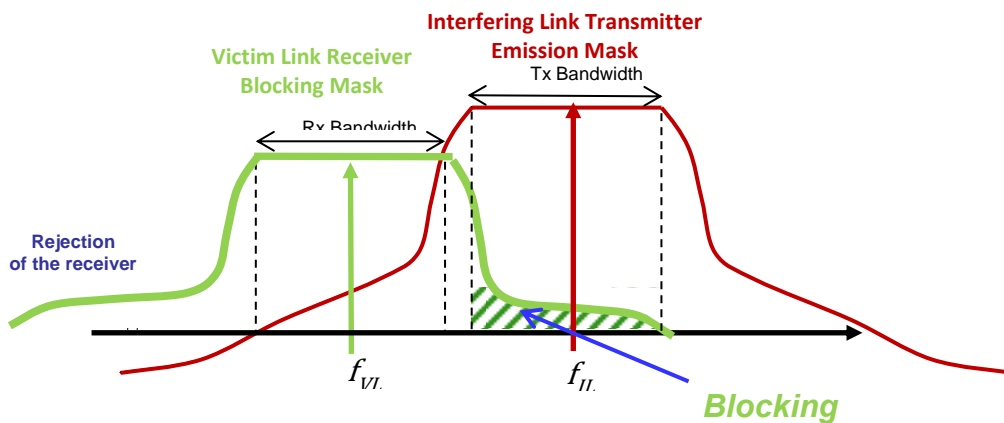
Figure 12: Illustration of the blocking of the victim link receiver (i.e. total emission power of ILT reduced by the blocking attenuation (selectivity) function of the VLR

1.4.7   Intermodulation

The *intermodulation interference*, i.e. the power of intermodulation products, reduced by the intermodulation attenuation function of the VLR can be used in interference calculations. See ANNEX 5: for further details.

1.4.8   Overloading

Overloading threshold is the maximum interfering signal level at which the receiver loses its ability to discriminate against interfering signals at frequencies other than that of the wanted signal. See Annex A2.2 for the use of overloading in interference calculation and Annex A5.4. for the $iRSS_{overloading}$ calculation.

1.4.9   Combined interference mechanism

The combination of the *unwanted emissions and receiver blocking* can also be studied simultaneously in SEAMCAT as depicted in Figure 13. See Annex A2.3 for further details.
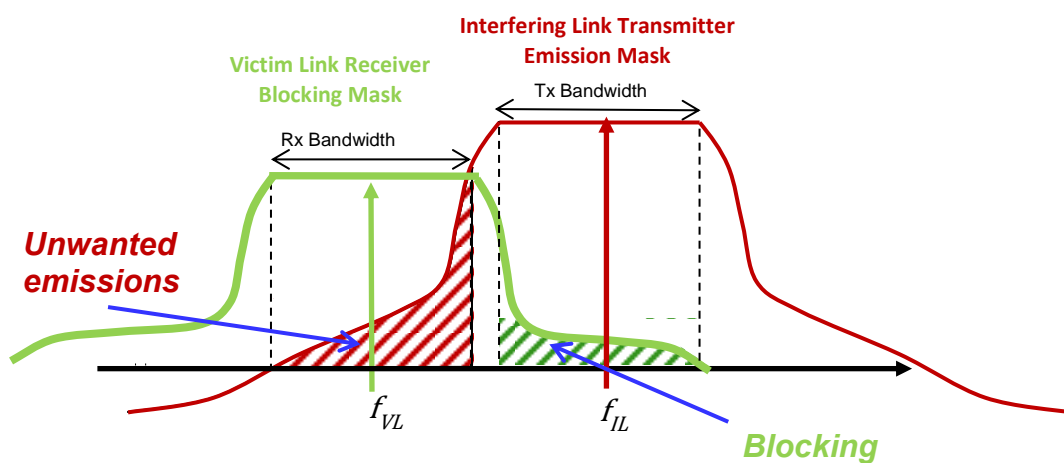
**Figure 13: Illustration of the combined unwanted emissions and
the receiver blocking mechanism in SEAMCAT**

1.4.10   Interference calculation

SEAMCAT calculates the probability of interference for generic (i.e. non-cellular) victim systems. Each sample of dRSS and iRSS generated during a simulation is compared against the relevant signal-to-noise criterion (specified in the scenario, such as C/N, C/N+I etc). The probability of interference is calculated for all events where the dRSS is greater than the sensitivity of the victim link receiver (*dRSS* > sens). This probability can be calculated for two different modes, as illustrated in Figure 271 of section 12.9:

- **Compatibility**: This mode provides a single-figure estimate of the probability of interference in a given interference scenario;
- **Translation**: This mode calculates probability of interference as a function of changing one of the following parameters:

1. Transmitter power of the interefering link transmitter;
2. Blocking response level of the victim link receiver;
3. Intermodulation rejection level for the victim link receiver.

1.5   APPLICABILITY OF SEAMCAT TO SPECTRUM ENGINEERING PROBLEMS

SEAMCAT can address virtually all radio interference scenarios on terrestrial[1] paths in both co-channel (sharing) and

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[1] It should be noted that certain scenarios involving aeronautical or satellite syste models are used.
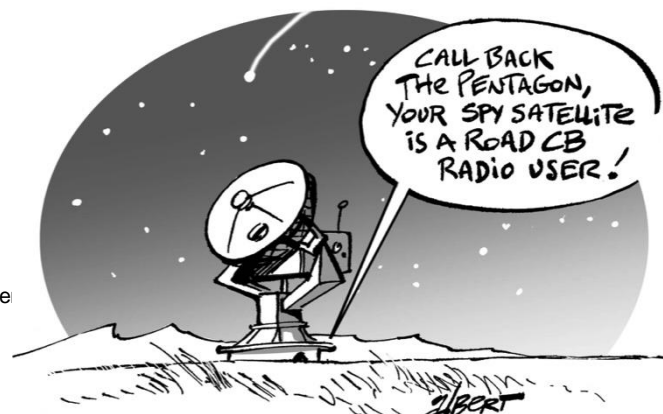
adjacent frequency (compatibility) interference studies. This flexibility is achieved by the way the system parameters are defined as variable (or constant) through their distribution functions. It is therefore possible to model even very complex situations by relatively simple variations of some elementary functions. A number of various radiocommunications services can be modelled using SEAMCAT, such as:

- Broadcasting: terrestrial systems and Earth stations of satellite systems;
- Fixed Services: Point-to-Point and Point-to-Multipoint fixed systems;
- Mobile Services: Land Mobile Systems, Short Range Devices and Earth based components of satellite systems.

Section 1.9 presents various radio systems that have been simulated in various ECC Reports.

In general, SEAMCAT may be used to address the following spectrum engineering issues:

- Sharing studies between different radio systems operating in the **same** frequency band;
- Compatibility studies between different radio systems operating in **different** frequency bands;
- Evaluation of transmitter and receiver masks;
- Evaluation of limits for certain system parameters, such as transmitter unwanted emissions (spurious and out-of-band), and receiver blocking or intermodulation levels.

SEAMCAT assumes flat Earth model for calculating path geometries and propagation losses, this limits the range of considered standard interference scenarios to terrestrial configurations and non-path-specific propagation models. Certain aeronautical and space-to-Earth paths can also be modelled if suitable propagation models are used.

1.6 UNDERSTANDING RADIO JARGON

Many common terms in RF engineering are used differently depending on the specific community where they are used. The following gives an example (non exhaustive) of the variety of terms that you can find.

C (i.e. the wanted signal level) is referred to in different radio standards and documents as follows. It is specified for a given sensitivity and a given desensitisation.

- Useful signal (ETSI TS 145.005 - Chapters 5.1.2 and 5.1.3);
- Wanted signal mean power (ETSI TS 136.104 - Table 7.5.1-1);
- Pw (ETSI TS 136.101 - Table 7.6.3.1-1);
- Prefsens + desensitisation (ETSI TS 136.104 - Table 7.5.1-1, ETSI TS 136.101 - Table 7.6.3.1-1) ;
- "C".

I_{OOB} (i.e. the allowed power of an interfering blocking signal as specified by the standard) is referred to in different standards as follows. It is specified for a given frequency offset, a given sensitivity and a given desensitisation.

- *Blocking signal level* (ETSI TS 145.005 - Table 5.1-2a);
- *Puw* (ETSI TS 136.101 - Table 7.6.3.1-1);
- *Interfering signal mean power* (ETSI TS 136.104 - Table 7.5.1-1).

Sensitivity is referred to in different standards as:

- *Reference sensitivity level* (ETSI TS 145.005 - Tables 6.2-1x);
- *Reference sensitivity* (ETSI TS 136.101 - Table 7.3.1-1);
- *Reference sensitivity power level* (ETSI TS 136.104 - Tables 7.2.1-1 and 7.2.1-2);
- *Prefsens* (ETSI TS 136.101 - Table 7.3.1-1, ETSI TS 136.104 - Tables 7.2.1-1 and 7.2.1-2).

1.7 SEAMCAT SOFTWARE

1.7.1 Installation using .jar package

SEAMCAT is an open source project developed using Java which means it can run on any operating system supported by Java. The SEAMCAT installation is started by clicking on the install link from www.seamcat.org and it is free of charge.

The .jar package is platform independent so that you can run SEAMCAT on either Mac OS, Linux or Microsoft Windows operating systems. You need to check on the website that you have the latest version installed.

It is required that you have the Java runtime environment (JRE) installed on your computer, available to download free of charge from www.java.com. The latest version is recommended.

1.7.2 SEAMCAT home directory and configuration panel ⚙

When you install SEAMCAT (5.0.0 and upward), a folder (SEAMCAT home directory) will be created so that every time you install a new version of SEAMCAT a subfolder with the version number will be created as shown in Figure 14. This is done automatically and can not be changed.
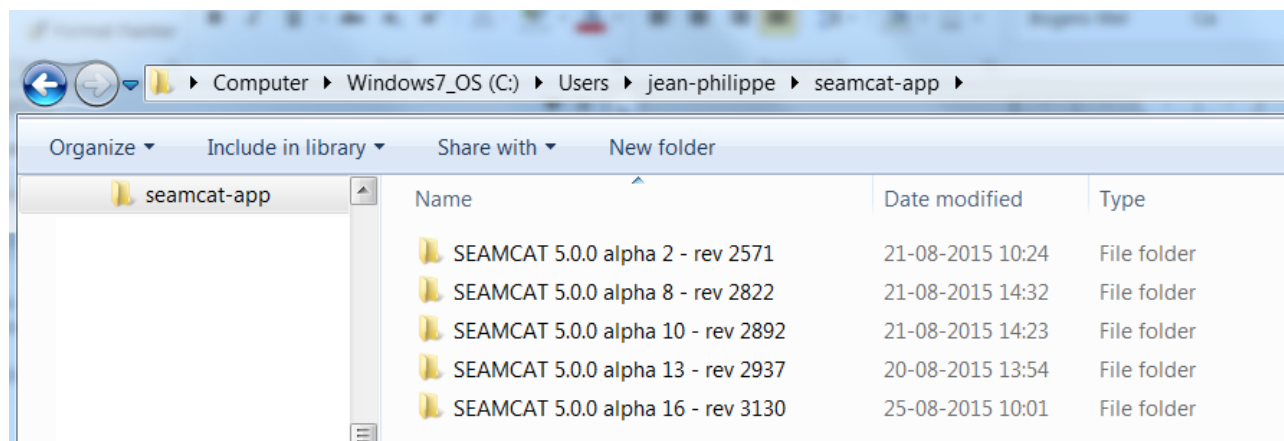
Figure 14: Illustration of the seamcat-app content

Each SEAMCAT version will have the structure as shown in Figure 15.

Figure 15: Content of a work directory

Table 1: Description of the content of the SEAMCAT home directory

Name of file/folder	Type	Description
logfiles	Folder	Contains the log file (.txt) generated when debug mode is used
reports	Folder	Contains the report files (.xml/.html/.xlsx) generated by the Report feature
temp	Folder	Contains temporary files used by SEAMCAT
workspaces	Folder	Default folder for creating new workspaces and saving result

Name of file/folder	Type	Description
		workspaces. This can be changed from the File menu
Default-library.sli	File	Contains the default library of SEAMCAT (systems, masks, antennas, etc.)
seamcat.log	File	Text file containing all the log information reported by SEAMCAT (errors, warnings etc.) . Note that the file may be appended with information everytime you launch SEAMCAT. You may wish to delete it from time to time. When deleted, it is automatically created next time you launch SEAMCAT.
settings.xml	File	Contains the settings of your SEAMCAT configuration including all settings related to external plugins

You can change however the location of the home directory in the SEAMCAT configuration panel accessible via general menu option <File/Configuration> (⚙) also using <CTRL+G>. Further information is given in Annex A20.1.

1.7.3 Java Source code

The source code for SEAMCAT is made available for scrutiny. The only condition for obtaining a copy of the source code is to sign a special **Source Code User Licence Agreement** and deliver it to ECO either by email (seamcat@eco.cept.org), fax or post. The procedure is described at: http://www.cept.org/eco/groups/eco/seamcat-source-code.

1.7.4 Multi processing power in SEAMCAT

As of version 5.0.0, SEAMCAT is able to run in multiprocessor environments to increase the computation speed. The more processors you have the less time you have to drink your coffee. Since the Monte Carlo simulation method considers that each event is independent from each other, events can therefore be distributed across all the processor cores of your machinein order to decrease the computation time. The EPP runs in parallel for each event.

If debug mode is used SEAMCAT runs on only one processor since parallel processing of the events would make the log file unreadable.

1.8 THE SEAMCAT COMMUNITY

1.8.1 SEAMCAT Technical Group (STG)

The SEAMCAT project is an ongoing WG SE (Working Group Spectrum Engineering) activity (Figure 16). The daily maintenance of the project and the SEAMCAT software is entrusted to the ECO. The project is funded by the signatories of the ECO council. The SEAMCAT Technical Group (STG) acts as the supervising committee and source of technical expertise. For further information on STG visit the CEPT web page: http://www.cept.org/ecc/groups/ecc/wg-se/stg.
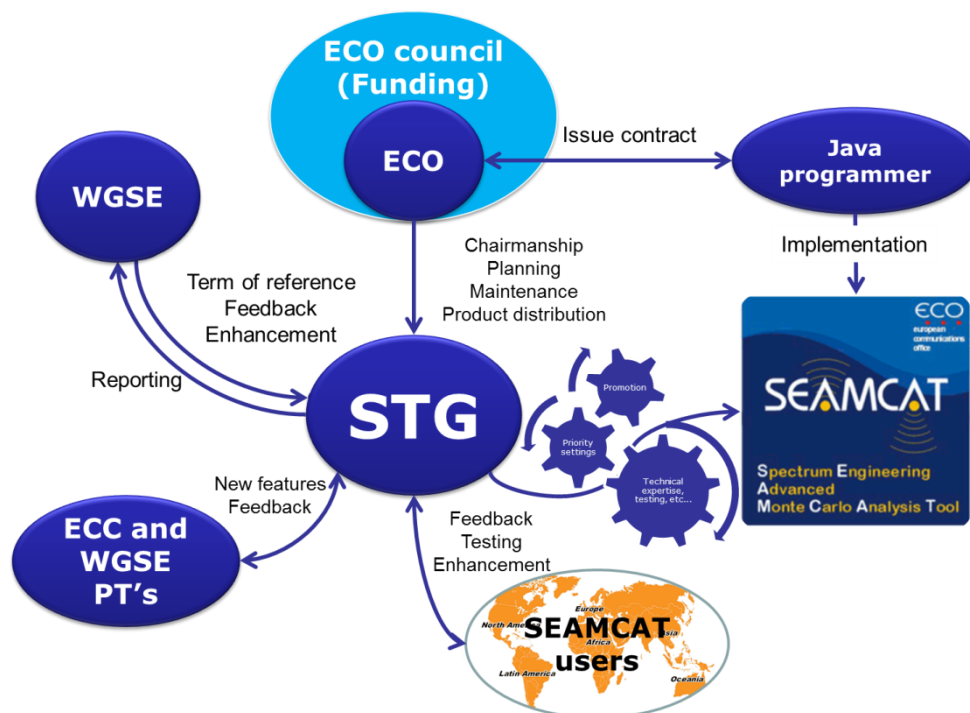
Figure 16: SEAMCAT project organigram and steakholders

1.8.2 SEAMCAT community – more than STG

In SEAMCAT, you can build your own library of components (systems, antennas etc.) or use those created by someone else. It is possible to use predefined antenna patterns, spectrum emission masks, and propagation models etc. which are available in the SEAMCAT library, so that you do not have to reinvent the wheel every time you have studies to perform. You can join the SEAMCAT community to contribute to this activity.

The SEAMCAT community is a forum where active SEAMCAT users like you can report feedback on the use and improvement of the tool (see Section 2.22). This includes the members of STG but also users from universities and organisations all around the world. This community has extended itself well beyond the CEPT borders as depicted in Figure 17.

You can contribute to the community by sharing workspaces, sharing and populating libraries, creating and sharing plugins (EPPs, propagation plugins, etc...) and contribute to ECC and CEPT reports with SEAMCAT simulations. Any plugins are automatically embedded, so you just have to send your workspaces by email.

The SEAMCAT application is open source and it is available free of charge.

The SEAMCAT community is accessible via different media:

- SEAMCAT email reflector (seamcat@list.cept.org):
  - To subscribe: mailto:seamcat-request@list.cept.org?subject=Subscribe;
  - To unsubscribe: mailto:seamcat-request@list.cept.org?subject=unsubscribe;
- STG-ECO forum (http://www.cept.org/ecc/groups/ecc/wg-se/stg/client/forum).
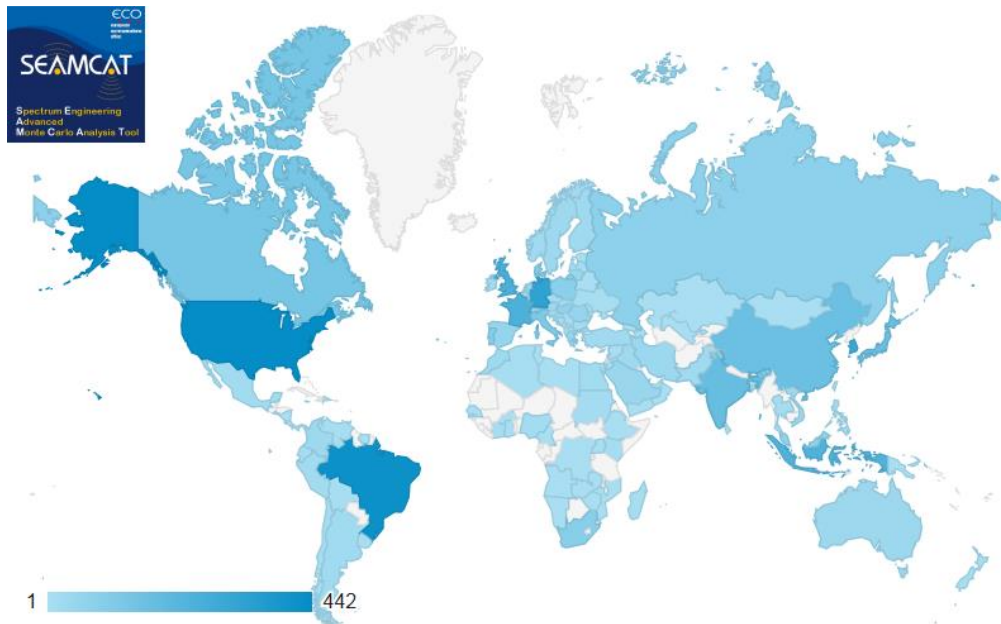
Figure 17: Usage of SEAMCAT within and outside the CEPT (downloads in 2014)

1.9 REFERENCE MATERIAL AND ECC/CEPT REPORTS

You will find existing workspaces (i.e. .sws files) which have been generated as part of some ECC report or CEPT reports activities at the following address www.ecodocdb.dk. These files are can be opened with the latest SEAMCAT version, with the following restrictions:

1. Post processing plugins created in previous versions are not compatible in version 5, as they were moved into Event Processing Plugins
2. The local environments, which were placed together with the propagation models in previous versions, are to be found in version 5 in the system link tab (ILT –> ILR path, VLT –> VLR path). These settings are not migrated from previous versions.

See ANNEX 21: for an overview of studies per technology where SEAMCAT was used from various ECC deliverables. An example is shown in Figure 18 for the ECC Report 122.
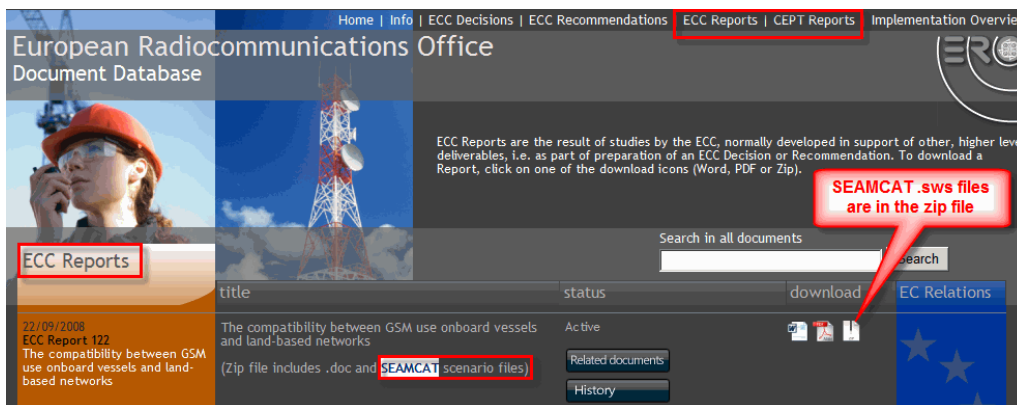
Figure 18: ECC database where .sws file used in producing ECC or CEPT report are stored
(see ANNEX 21: on p. 421)

2 GETTING AROUND IN SEAMCAT

2.1 QUICK BUTTONS TOOLBAR

A 'quick buttons' toolbar with access to the most commonly used features is avaialable at the top of the SEAMCAT interface window. The function of each button is shown in a tooltip whenever your mouse is moved over it. Certain buttons are inactive when the function is not applicable, e.g. the stop simulation button is active only during the run of a simulation. Inactive buttons are displayed dimmed.

Table 2: Overview of the buttons on the quick menu toolbar

	new workspace		export library		check the built-in and plugin propagation model
	new batch		start event generation (workspace or batch)		check the unwanted emission function
	open (workspace or batch)		stop event genetration (workspace or batch)		compare multiple vectors
	Save (save as, save all)		generate a report (xml or html file)		pocket calculator
	close workspace or batch		check the consistency of the workspace		on-line manual help contents
	import library		check the built-in distribution function		report bugs or enhancement

2.2 'WELCOME TO SEAMCAT' WINDOW

Every time SEAMCAT is launched, a welcome dialog box is displayed which allows you to select various options. (you can disable the welcome dialog box under File/Configuration). Your first step is typically to create a new workspace or open a previously created workspace. This is done by selecting 'New', 'Open' or 'Recently Used' (to open the most recent workspaces from the displayed list). 'New Batch' can be used to specify multiple sequential simulation runs using new or existing workspaces. 'Calc' launches the SEAMCAT calculator which is a convenient tool for common basic engineering calculations.
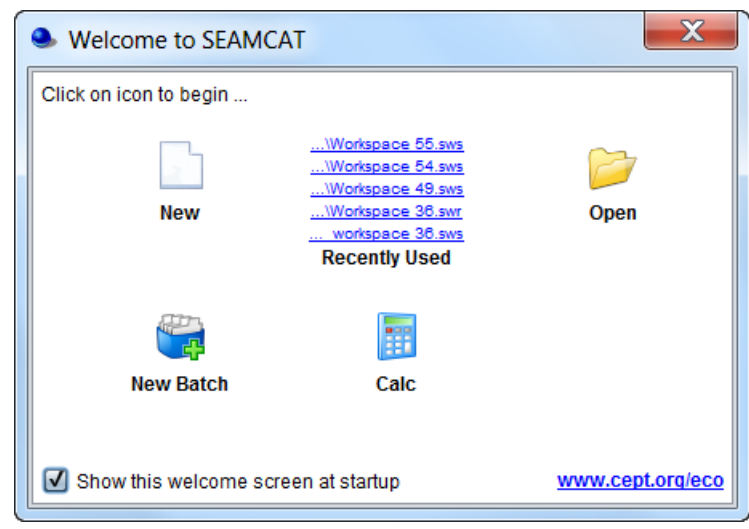
Figure 19: Welcome pop up window

When a new workspace is created, it will initially be automatically assigned a name 'Workspace xyz', where xyz is the serial number of the newly created workspace. You may change the workspace name at any time afterwards using Save or Save As. You can also rename the file in your file system - SEAMCAT will recognise the new name when loading the workspace.

You can have several workspaces open at the same time – different workspaces are shown as tabs at the top of the user interface. The size and position of the SEAMCAT subpanel graphical user interface (GUI) is minatained when you switch from one workspace to another for ease of comparison of workspaces.
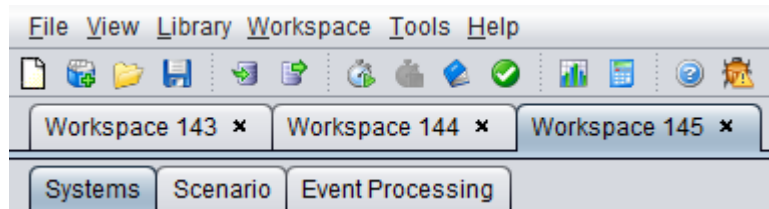
Figure 20: Several workspaces in different tabs

2.3   TYPICAL SEAMCAT WORK FLOW

When using SEAMCAT for a compatibility analysis, a typical workflowwould be asfollows:

1. Create or update a simulation workspace;
2. Set the simulation control parameters (number of events, debug mode or not);
3. Run a simulation;
4. Analyse the event generation results, modify the input scenario if necessary and re-run the event generation;
5. Perform one or more interference calculation runs;
6. Generate a simulation report.

Figure 21: Typical work flow when using SEAMCAT

In addition to these basic steps futher ones may be useful for different purposes:

▪ Save workspace as an XML compliant file for later (repeated) work or for sharing with other users;
▪ Create or update elements in the equipment library for repeatedly used equipment types;
▪ Import a library;
▪ Use of batch job, to serialise your work;
▪ Share your workspace with others;
▪ Use of an Event Processing Plugin for advanced scenario specific calculations.

2.4   SIMULATION WORKSPACE

2.4.1   Scenario workspace

A scenario workspace can be seen as a working environment for a given study where all input fields are editable. It consists of the following three tabs:

▪ **Systems**: This allows you to set the characteristic of the systems to investigate (generic Tx, Rx and path between Tx/Rx or cellular general settings, positioning);
▪ **Scenario**: This sets the simulation scenario, i.e. you can select the systems to be used as victim or interferer(s) as well as the path between the victim and the interfer(s), the number of events and optional selection of debug mode;
▪ **Event processing**: The event processing plugin (EPP) environment allows you to process intermediary SEAMCAT results for each simulated event. Some EPPs are available built in to the tool, but you can also create your own EPP.
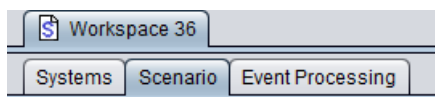
Figure 22: Illustration of the workspace scenario (Highest hierarchy level)

2.4.2 Results Workspace

When a simulation is performed, SEAMCAT automatically generates a separate workspace to contain the results which appears as a separate tab entitled 'Results[Workspace xyz]' and stores <u>read only information.</u>
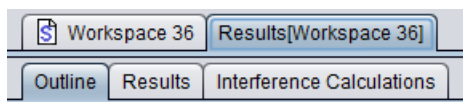
Figure 23: Illustration of the workspace results (Highest hierarchy level)

In the results workspace,, you are not able to edit any of the input fields. You can however select 'Export workspace', to generate and open a new workspace scenario entitled 'Exported Workspace xyz' :
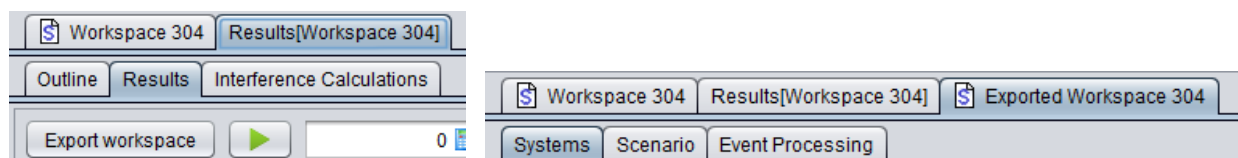
Figure 24: Illustration of exporting a results workspace into a scenario workspace

The results workspace consists of the following tabs depending on the scenario set-up:

- Outline: You can see the outline of the simulation with both a summary of the dRSS and iRSS calculation and a graphical overview of the Tx/Rx positions for the victim and interferer(s);
- Results: You have access to a list of all results generated by SEAMCAT and from the EPPs used in the simulation;
- Interference calculations: You are able to use the Interference calculation engine;
- CDMA Capacity Finding: This panel is only available when a CDMA system is used in the scenario. It indicates the non-interfered capacity (i.e. number of UEs) when the network is gradually filled up with UEs while measuring a specific system outage depending on uplink (UL) or downlink (DL) configuration;
- Cellular Structure: This panel is only available when a cellular system (CDMA or OFDMA) is used in the scenario. It shows the results of the cellular specific simulation – i.e. layout of the cells, position of users and indication of dropped users.
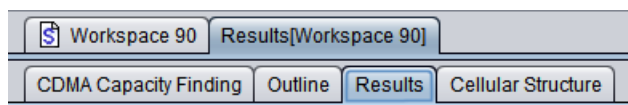
Figure 25: Results workspace with a Cellular system (the "CDMA capacity finding" is only available with CDMA simulation)

2.5 CREATE OR UPDATE A SIMULATION WORKSPACE

To start, you need either to create a new workspace (see **1** in Figure 25 or open an existing one (**2**).
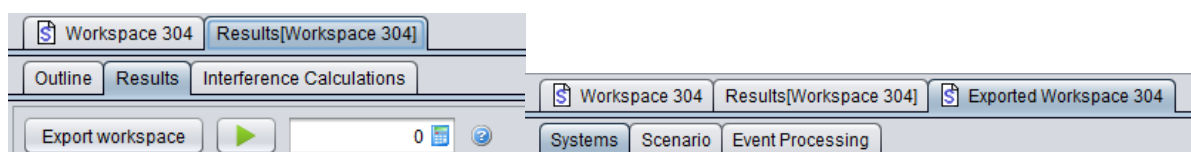
Figure 26: Illustration of how to create or open a workspace

A simulation scenario is a part of a scenario workspace, which defines all technical parameters of modeled links as well as some related modelling assumptions, such as physical (mutual) placement of transceivers,

propagation modelling settings and so on. Within SEAMCAT a simulation scenario is based upon the concept of links. A link stands for a pairing of one transmitter with one receiver[2] operating together in a given radiocommunication system. Such a link is also called a "system link".

When a new workspace is created, all of its scenario elements are populated with default values (representing a hypothetical interference case between two systems at 900 MHz, as shown in Figure 27). Therefore after creating a new workspace yourfirst step should be to review and modify the scenario parameters so that the resulting simulation scenario reflects the configuration of the radiocommunications systems to be simulated.

To create or update a simulation workspace, you need to follow the following steps:

1. Set the technical characterisitic of the various systems that you want to investigate. In the example of Figure 26 the first system is Generic and the second one is an OFDMA UL system. Do not forget to export your system to the library environment so that you can reuse your work next time.
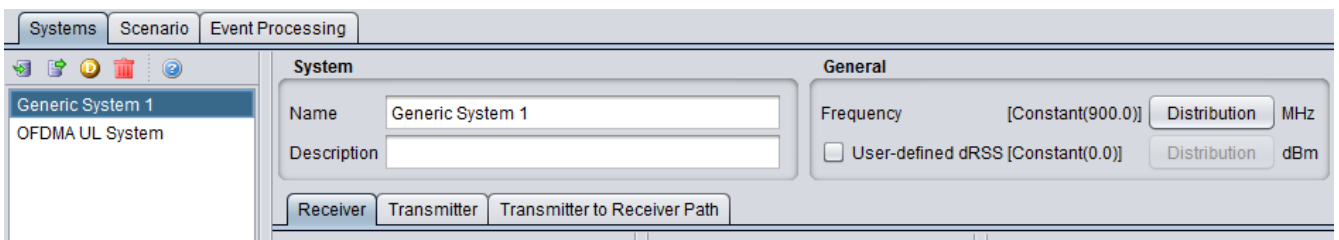
Figure 27: Setting various systems (import/export to library environment)
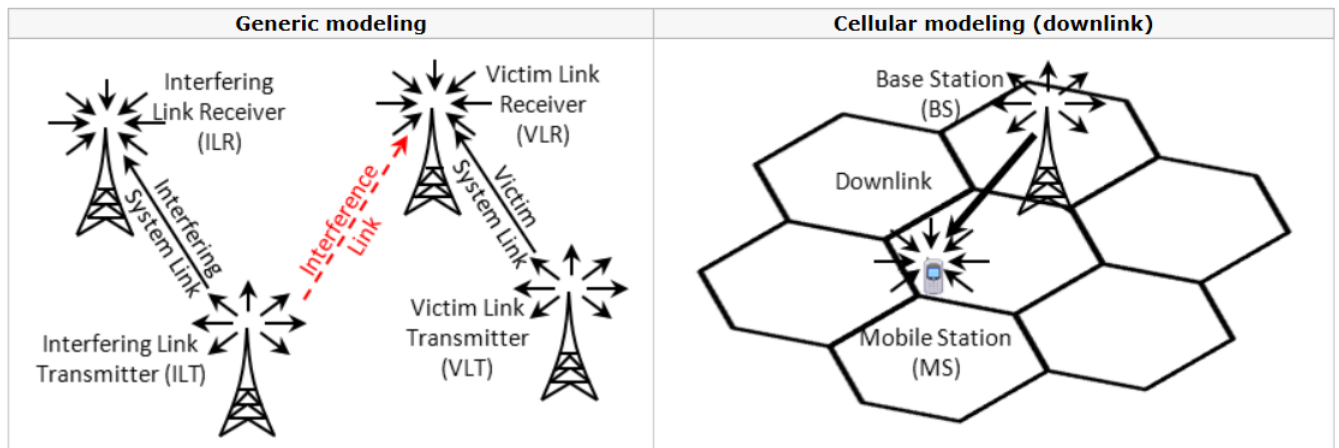
Figure 28: Overview of the various systems which can be simulated in SEAMCAT (i.e. Generic and cellular)

1. Set the scenario (see section 10);
2. Set the path characteristics between the victim and the interferer (relative position, interferer's density, path loss correlation and propagation model). You can also add, duplicate, etc... links;
3. In the simulation control panel you can both set the number of events to simulate and decide whether you want to run the simulation in the debug mode or not;
4. Having reviewed the scenario, you can run your simulation.

---

[2] Cellular systems with multiple receivers (downlink) or multiple transmitters (uplink) are handled differently

2.6 BATCH OPERATION 🖼

The SEAMCAT's Batch function allows automation of repetitive compatibility studies by scheduling several SEAMCAT simulations to be done in one run of the programme. This is done by setting up a simulation schedule with instructions on how to change certain variable scenario input parameters in several consecutive simulations. One typical example of using SEAMCAT batch functionality would be to perform multiple simulations in order to study interference probability on identical scenarios with only small frequency changes between them.

A new batch can be created directly from the quick menu button or you can open an existing batch file using the usual open icon. The following menu button can be used for the batch

Table 3: Overview of the batch operation menu buttons

	new batch		close workspace or batch
	open (workspace or batch)		start event generation (workspace or batch)
	save		stop event genetration (workspace or batch)

The batch environment, as shown in Figure 28 consists of 3 panels (#1), identification, control and Workspaces.
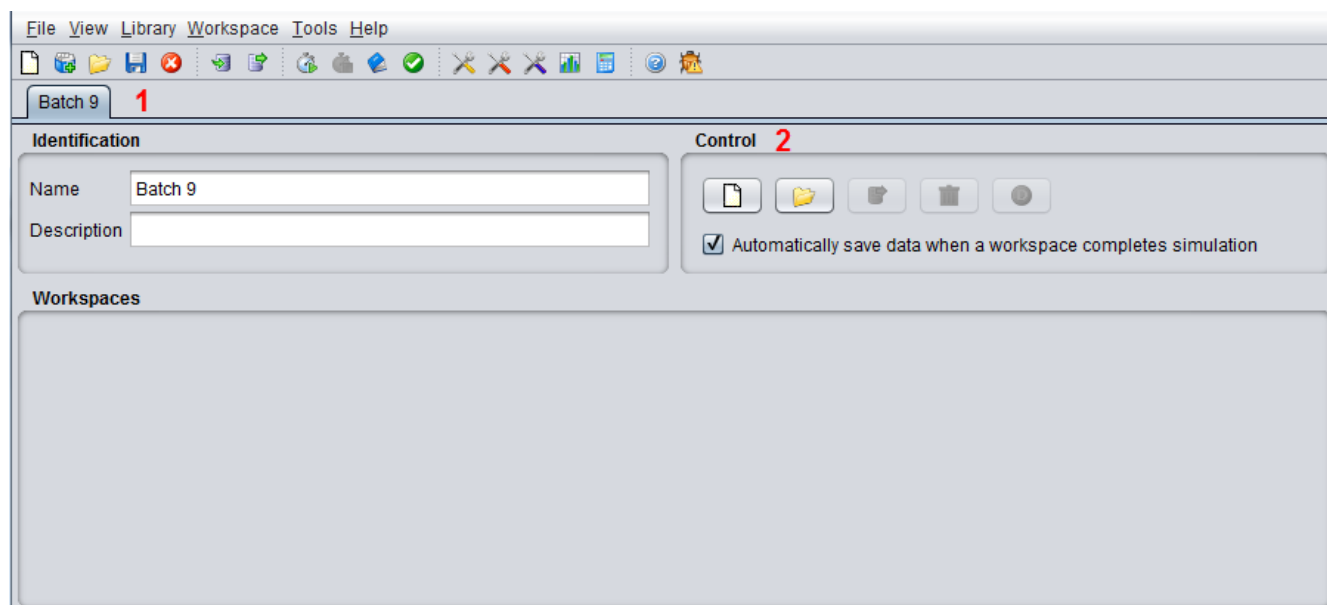
Figure 29: Batch environment

The control panel provides the following buttons dedicated to workspaces:

Table 4: Overview of batch control panel

	New workspace to add in the batch		Remove a workspace from the batch
	open a workspace to the batch		Duplicate a workspace inside a batch
	Save a workspace		

When you open several workspaces from the batch mode environment, you can change your parameters directly in the workspace with an unlimited number of times by adding new simulations to the batch schedule until the intended variation of input parameters is fully covered by all entries.

You have the possibity to save workspace results automatically after completing their simulation.
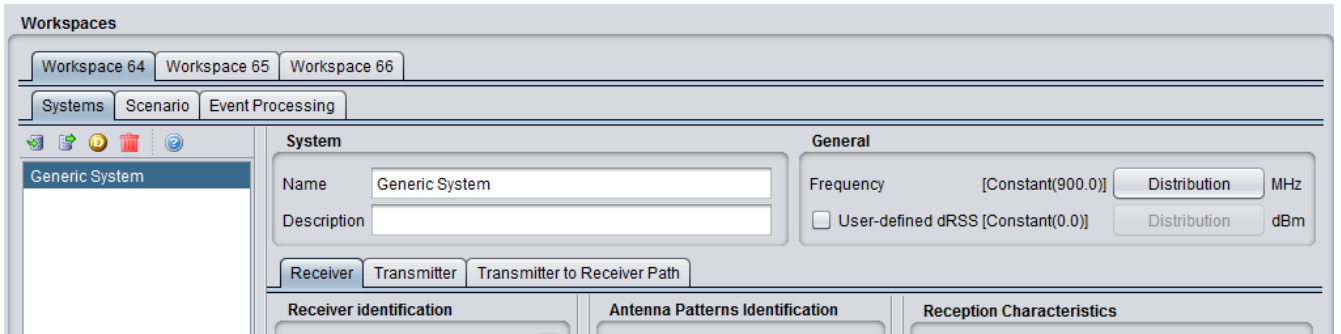
Figure 30: Workspaces panel, where you can load as many workspaces as your memory can handle

Batch results (Figure 29 #1) are available when the batch simulation is started. A result tab (#2) is by default active indicating the progress of the batch work (#3) and provides interference calculation engine capability (#5). When you press the analyse button the ICE is activated and the probability of interference is displayed (#6).

The results vectors for each workspace are also available (#4) for scrutiny.
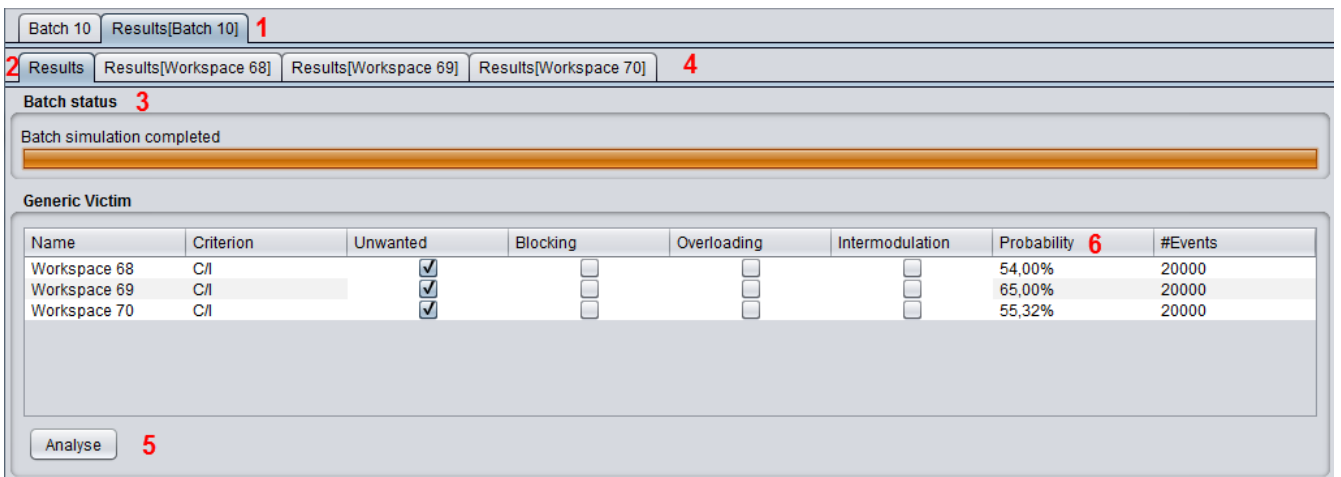
Figure 31: Batch results environment

If you have selected the "debug mode" and still run a batch, the batch will stop until you close the log window.

2.7 RUNNING AND STOPING A SIMULATION

A simulation is started when you click on the Start button of SEAMCAT toolbar (   ). The simulation starts and all other commands/buttons are, meanwhile, disabled except the stop button (   ). SEAMCAT automatically performs the consistency check of the scenario parameters before starting the event generation (see Section 2.9).

The simulation runs until the number of events has been performed or if you stop the simulation prematurely by pressing the stop button.

Figure 32: Menu bar during run time. You can stop the simulation at anytime

2.8 RUNNING FROM THE COMMAND LINE

A command line launch of SEAMCAT (i.e. without GUI) is possible using the same seamcat.jar file that you have downloaded. From the command line with a workspace file called "myWorkspace.sws" the following command will It will launch the workspace and save the results in myWorkspace.swr by default.

```
java -cp seamcat.jar org.seamcat.CommandLine myWorkspace.sws
```

Several options are possible. The result file name can be changed by using the option: result=otherName.swr and the number of events can be specified by using the option: events=12345. The example below uses all these parameters:

```
java -cp seamcat.jar org.seamcat.CommandLine Default-ws.sws result=commandLine.swr events=200000
```

2.9 CONSISTENCY CHECK

The consistency check function is run automatically before the start of an event in order to detect erroneous or inconsistent values in the scenario definition (see Figure 32). You can also trigger it manually as illustrated in Figure 33. The aim of the consistency check is to prevent runtime exceptions during the simulation due to incorrect input values.
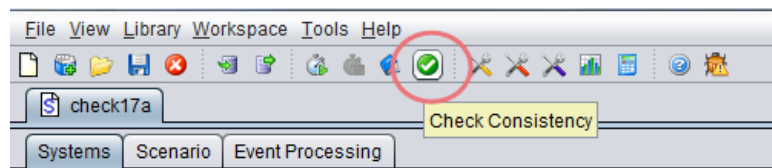
Figure 33: consistency check button in the quick menu bar

Figure 34: Manual triggering of the consistency check

The consistency check includes:

- Warnings if odd configuration are detected for random parameters, such as negative antenna height, etc;
- Consistency between inter-dependent parameters such as: C/I, C/(N+I), (N+I)/N, and I/N;
- Verification of the application range of propagation models.

In case it fails, the scenario consistency check will pop up a message window like the below
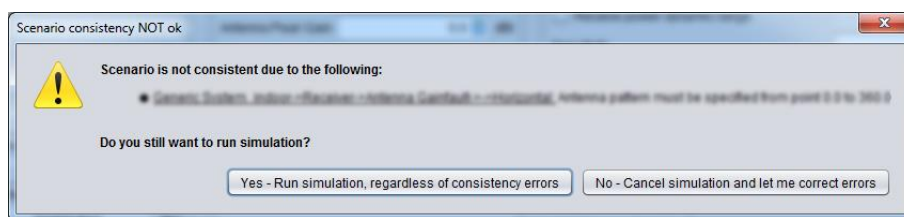
Figure 35: Scenario consistency check message

You may ignore the warnings, but you should be aware of the following:

- Consistency checks are generally connected to non valid values which cause runtime exceptions during the simulation
- Each runtime exception generates an appropriate error message which is recorded on the seamcat.log file (located on your SEAMCAT home directory):

```
(AntennaGainConfiguration.java:44[evaluate]) - Error evaluating plugin
org.seamcat.model.functions.FunctionException: Specified value (313.7921785343926) is outside bounds [0.0 to 270.0]
    at org.seamcat.function.DiscreteFunction.evaluate(DiscreteFunction.java:90)
    at org.seamcat.model.antenna.HorizontalVerticalAntenna.evaluate(HorizontalVerticalAntenna.java:43)
    at org.seamcat.model.antenna.HorizontalVerticalAntenna.evaluate(HorizontalVerticalAntenna.java:18)
    at org.seamcat.plugin.AntennaGainConfiguration.evaluate(AntennaGainConfiguration.java:42)
    at org.seamcat.simulation.generic.GenericVictimSystemSimulation.collect(GenericVictimSystemSimulation.java:182)
    at org.seamcat.model.engines.InterferenceSimulationEngine.single(InterferenceSimulationEngine.java:145)
    at org.seamcat.model.engines.InterferenceSimulationEngine$1.call(InterferenceSimulationEngine.java:75)
    at org.seamcat.model.engines.InterferenceSimulationEngine$1.call(InterferenceSimulationEngine.java:72)
    at java.util.concurrent.FutureTask.run(Unknown Source)
    at java.util.concurrent.ThreadPoolExecutor.runWorker(Unknown Source)
    at java.util.concurrent.ThreadPoolExecutor$Worker.run(Unknown Source)
    at java.lang.Thread.run(Unknown Source)
```

Note that the yellow marked header format can be changed as described in Annex 20.

▪ Logging the error messages takes time, hence it significantly increases the simulation time;
▪ Depending on the scenario (in particular the number of events simulated) the amount of the seamcat.log file might readily grow up to some tens of Mega Byte per simulation run.

It is therefore highly recommended to solve the reported issues prior to run the simulation. Further information on the meaning of consistency check and SEAMCAT error message is available in ANNEX 19:.

Section 14.3.2 presents the implementation of the consistency check in the source code and for plugin development and its graphical results.

2.10   SIMULATION CONTROL

The simulation control setting "number of events" is used to determine the number of events you want to simulate. The "Debug mode" feature is described in Section 2.14. These control settings are accessible from the Scenario tab.
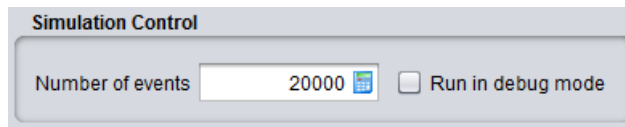
Figure 36: Simulation control

2.11   SIMULATION RESULTS OVERVIEW

Once a simulation is complete a workspace result (see Section 2.4.2) is automatically created within SEAMCAT where it is possible to extract any results vector. Depending on the nature of the victim system (i.e. generic, CDMA or OFDMA), the results vectors may vary. Further details about the nature of the results can be found in Section 12.

The bottom of the results panel contains the scenario statistics of the simulation's run (number of processor utilised, total simulation duration etc…). The statistics display is irrespective of the radio system simulated.

iRSS Unwanted ⓘ **Cellular results**			
External Interference (Reference cell), Unwanted	Array[10]	dBm	Vector
iRSS Selectivity			
External Interference (Reference cell), Selectivity	Array[10]	dBm	Vector
OFDMA Results ⓘ			
Average bitrate loss (ref. cell)	0.0	%	Double
Average bitrate loss (system)	75.208	%	Double
Non Interfered Bitrate, ref cell	Array[10]	kbps	Vector
Avg Non Interfered Bitrate, system	Array[10]	kbps	Vector
Avg Interfered Bitrate, system	Array[10]	kbps	Vector
SINR, Victim system	Array[10]	dB	Vector
SINR, Victim ref cell	Array[10]	dB	Vector
Interfered Bitrate, ref cell	Array[10]	kbps	Vector
Statistics ⓘ **Statistics results**			
Simulated performed on	4	processor	Integer
Total simulation duration	2.033	second	Double
Event generation duration	1.393	second	Double
Calculation rate	7	events/second	Integer
Simulation date	2015-11-12 14:59:09	N/A	String
Simulation seed	7129514379426885709		Long Integer

Figure 37 Overview of the results panel using a cellular victim system and the statistics panel

2.12   SAVING OPTIONS IN SEAMCAT

2.12.1   Saving workspace and batch 💾

You can save <CTRL+S> or "save as" your workspace (either scenario or results)/batch by using the default option SEAMCAT offers in the File menu. The file extension is appended automatically. These are SEAMCAT-specific file extensions. The .sws, .swr, sbj and sbr format are equivalent to a .zip file. Table 5 provides an overview and a description of the files contained per extension.

When you exit SEAMCAT without previously having saved or closed the workspace, you will be prompted whether any changes to the workspace should be saved.
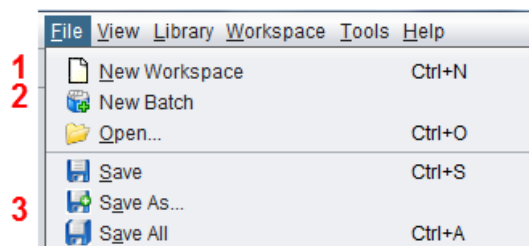
Figure 38: Illustration of how to create or open a workspace and its associated file name
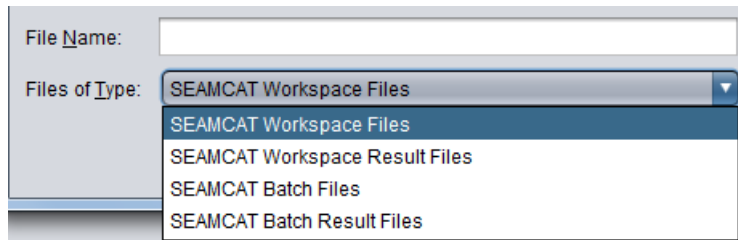
Figure 39: Saving options in SEAMCAT

Table 5: Saving options in SEAMCAT

SEAMCAT file type	SEAMCAT extension	Files contained
SEAMCAT **W**orkspace **S**cenario	.sws	Scenario.xml
SEAMCAT **W**orkspace **R**esults	.swr	Scenario.xml and results.xml
SEAMCAT **b**atch **j**ob	.sbj	Batch.xml
SEAMCAT **b**atch **r**esults	.sbr	Batch.xml and workspace xy_results.xml

2.12.2 Saving results – file extension

When you save your workspace results all your results are saved in the workspace. You can also save your vector results independently using one of the three different file extensions: Tab separated text, xls spreadsheet and xlsx spreadsheet. The various extension options are illustrated in Figure 40.
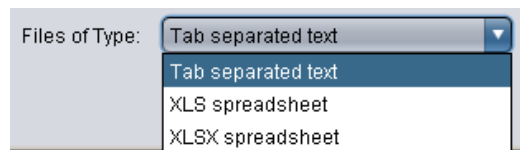
Figure 40: Example of saving options of the vector results

2.13 SIMULATION REPORT 📋

Any simulations that you are running and their results overview can be presented in a report. This report is automatically generated by SEAMCAT. Select the **Report command** from the Workspace menu, click on the Report icon of the toolbar (📋) or press <CTRL+R> to activate the **Report options** window:
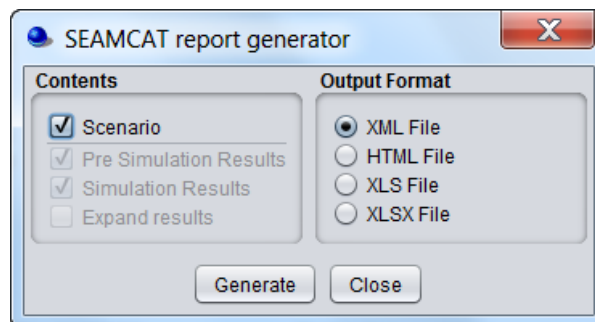
Figure 41: SEAMCAT report generator panel

In this dialog window, you can configure the contents of the generated report, by checking or un-checking following items:

- Scenario: It indicates whether all scenario parameters should be included or not;
- Pre Simulation results: Pre-simulation is a result group where a simulation can store results that are calculated before the simulation starts. This is used primarily for the cellular simulations were expensive calculations is conducted before the simulation begins (e.g. capacity findings for CDMA). For some simulation is can be empty. Currently the generic simulation has no need for presimulation results and therefore leaves the group empty;
- Simulation results: It indicates whether simulation control parameters should be included or not;
- Expand results: You can also choose to expand or not all tabular data by checking or unchecking the Expand tabular data option.

You can choose the output format of the report:

- XML File (default);
- HTML File;
- Excel File (.xls and .xlsx).

When you click on "Generate", a file is automatically generated in the "reports" folder under the SEAMCAT home directory (see Figure 15).

For all other data types the output is similar to their display in the workspace tree view except that couples of values defining user-defined random data, functions, and radiation patterns are fully expanded.

Figure 42: Example of a report generated in SEAMCAT in a html format

2.14   LOGGING FUNCTION FOR DEBUGGING

SEAMCAT allows two options to generate two distinct log files. An automatic SEAMCAT log that monitors the behaviour of the application, and a user debug log to check how the computation is performed.

seamcat.log: This log file is automatically generated by SEAMCAT and is intended to be used to debug the Java application mainly in case of a crash of the application or when an exception in the code occurs. You can select/browse the filename and directory from the SEAMCAT options and also the log level.
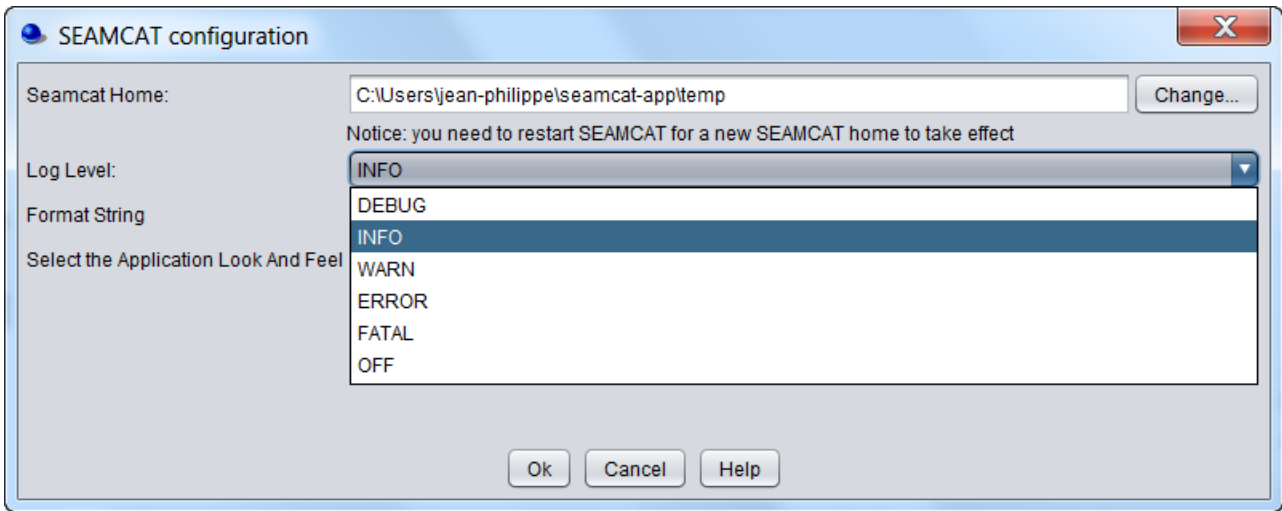
Figure 43: SEAMCAT configuration
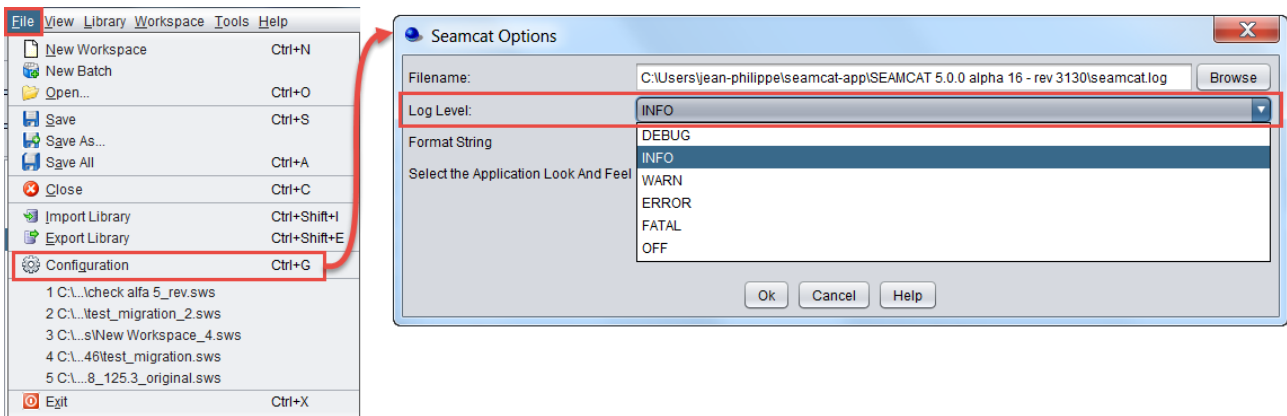
Figure 44: Seamcat.log log file automatically generated by SEAMCAT

Debug Mode: Running a simulation in "debug mode" Figure 45 is used for detailed check of the simulation process. Selecting this option, SEAMCAT will generate a log file where all interim results of simulations including what random values were generated for parameters defined as functions or distributions. This information is very useful for further inspection. The log file will be automatically stored in the sub-directory "Logfiles" of the main SEAMCAT directory. The debug option reduces the number of events to 5 events for the sake of limiting the size of log file. You may then review the generated log file using standard reading tools, such as Notepad, MS Windows, etc.
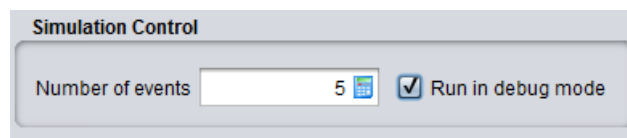
Figure 45: Selection of the debug mode

The output of the file (filename_date_number.log) is indicated at the bottom's right corner of the SEAMCAT application window (see Figure 46) as well as in the first line of the log display as shown in Figure 110.

Figure 46: Filename and directory output for the debug log file

An example fragment of such a debug mode log file is shown in Figure 47. You may want to ammend the setting for generating the log file in the SEAMCAT configuration panel as described in ANNEX 20:.
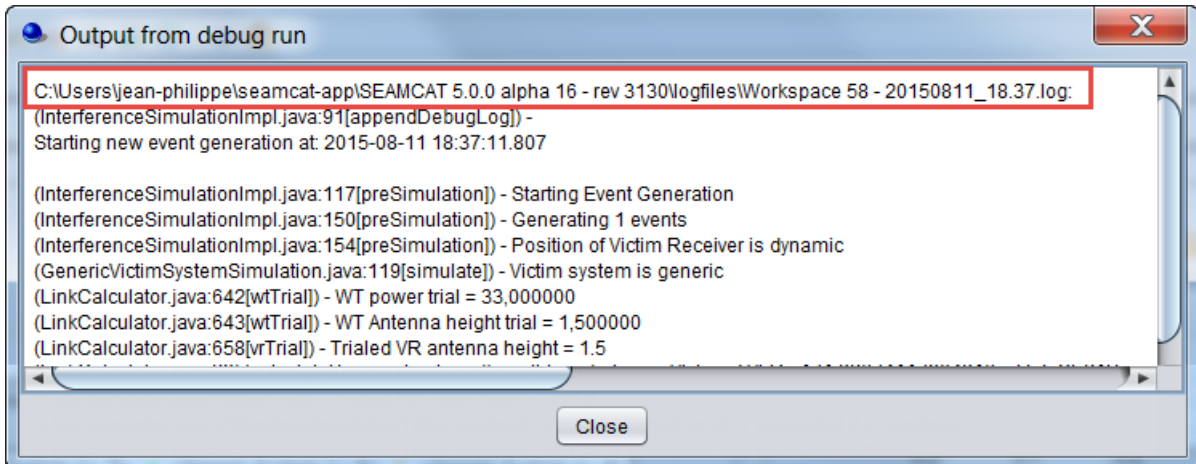
Figure 47: Example of a debug mode log file

2.15 PLAY/REPLAY AN EVENT ▶

In the Results tab, you have access to a list of all the results from SEAMCAT and from the EPPs used in the simulation and you have the option to "Play/replay" one event, and a log of the calculation will be made available.

When inspecting the dRSS or iRSS vector, you may identify an event that you would like to investigate and to replay. Then insert this number and click on the green triangle ▶. A new tab called <Replay [event = x]> will be created and will contain an "Event Result" panel on the left and a "Log Trace" on the right hand side. This log file is automatically saved under the "logfiles" folder in your home directory.
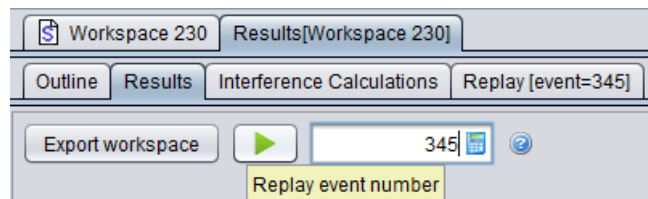
Figure 48: Illustration of the play/replay feature
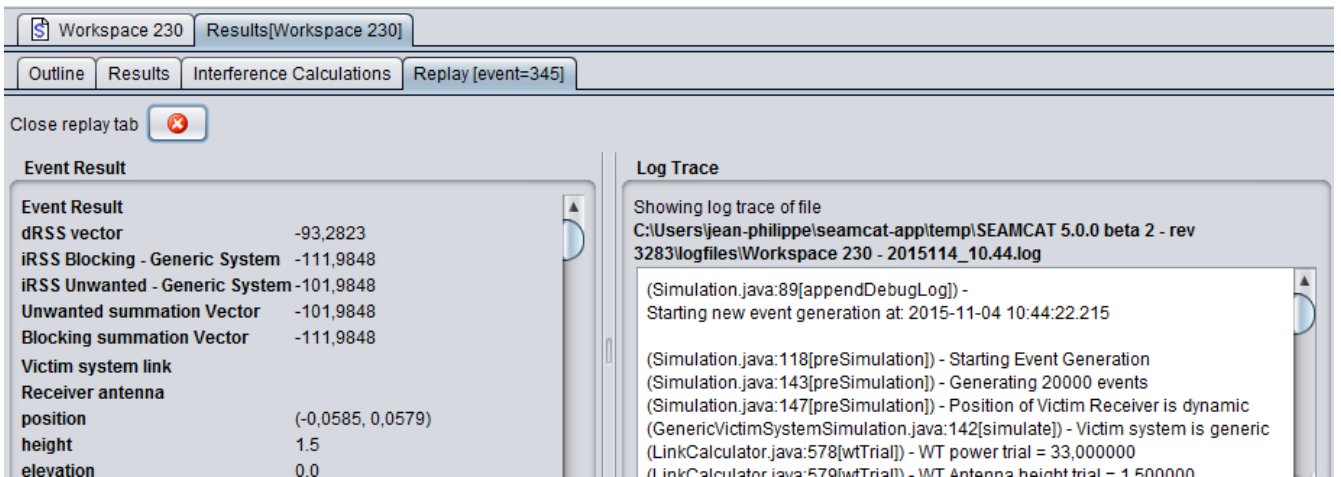
Figure 49: Illustration of the Replay tab with "Event Result" on the left and "Log Trace" on the right

Doing cellular system simulation the play/replay function allows you to re-run a specific event and redisplay a cellular structure layout as shown in Figure 50. Inspecting an event allows you to validate the configuration of the simulated workspace.
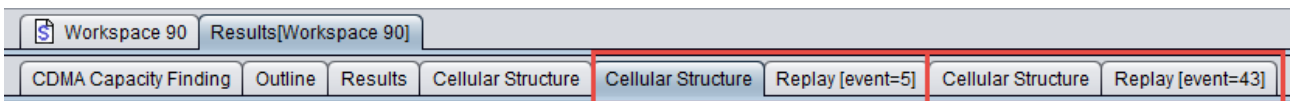
Figure 50: Example of the play/replay feature for a cellular network

2.16 TESTING PROPAGATION MODELS

You can perform a sanity check on the suitability of a propagation model by clicking on <Tools/Test Propagation Models> in the main menu of SEAMCAT, by clicking on the icon (✗) of the toolbar or by pressing <CTRL+SHIFT+M>. With this feature, you may also evaluate the result while using a certain propagation model. .
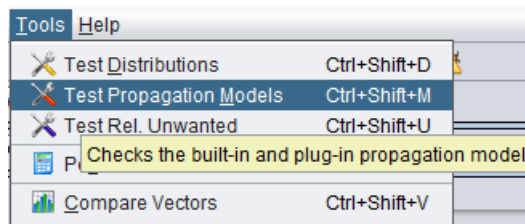
Figure 51: Access to testing propagation model

Choose the propagation model that you want to test. You are able to compare 2 or more propagation models with this interface. You can add or delete as many propagation models from the list on the left hand side as you want.

Figure 52 shows that the SEAMCAT resulting attenuation from the free space is 101.47 dB where the free space path loss is defined as:

$$L = 32.44 + 10\log_{10}\left(\left(\frac{\left(h_{tx} - h_{rx}\right)}{1000}\right)^2 + d^2\right) + 20\log_{10} f \text{ ,}$$

(Eq. 16)

where d is given in km and f is given in MHz. This results in

$$L = (32.44 + 10 \log(8) + 20 \log(1000)) = 101.5 \, dB$$
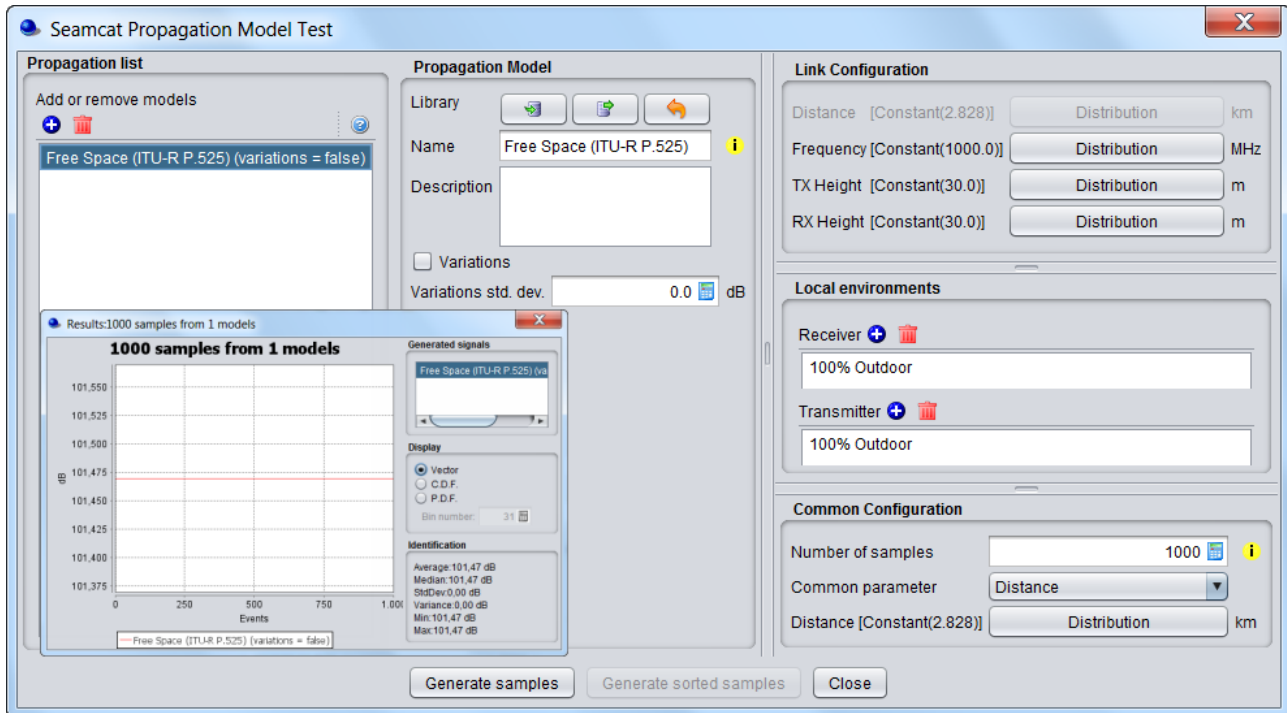
Figure 52: Illustration on to check the propagation model results

If you choose one parameter as a distribution (for instance distance), then the button <generate sorted samples > is activated. Pressing it enables you to plot your results according to a sorted X-axis from min to max.
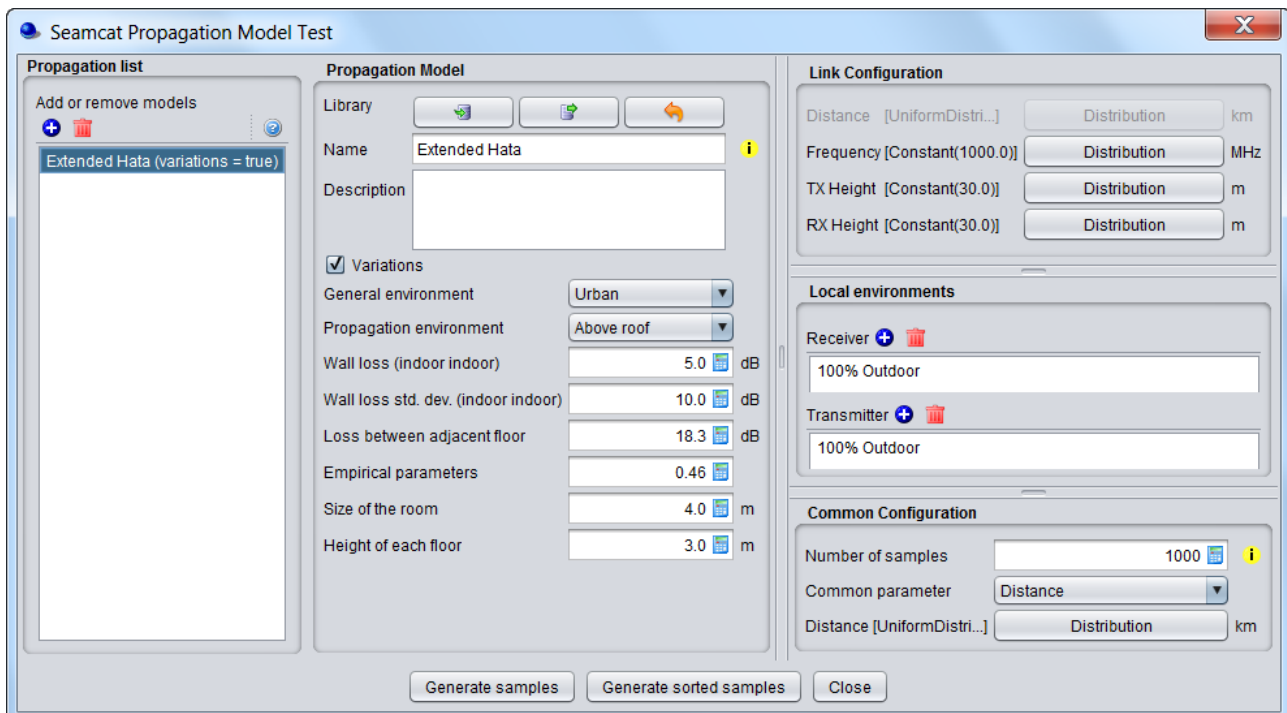
Figure 53: Activation of the "Generate sorted samples"

Finally click on <Generate samples> or <generate sorted samples> (depending which one is active) to view the results. If no results are displayed, check the Java console for any error messages.
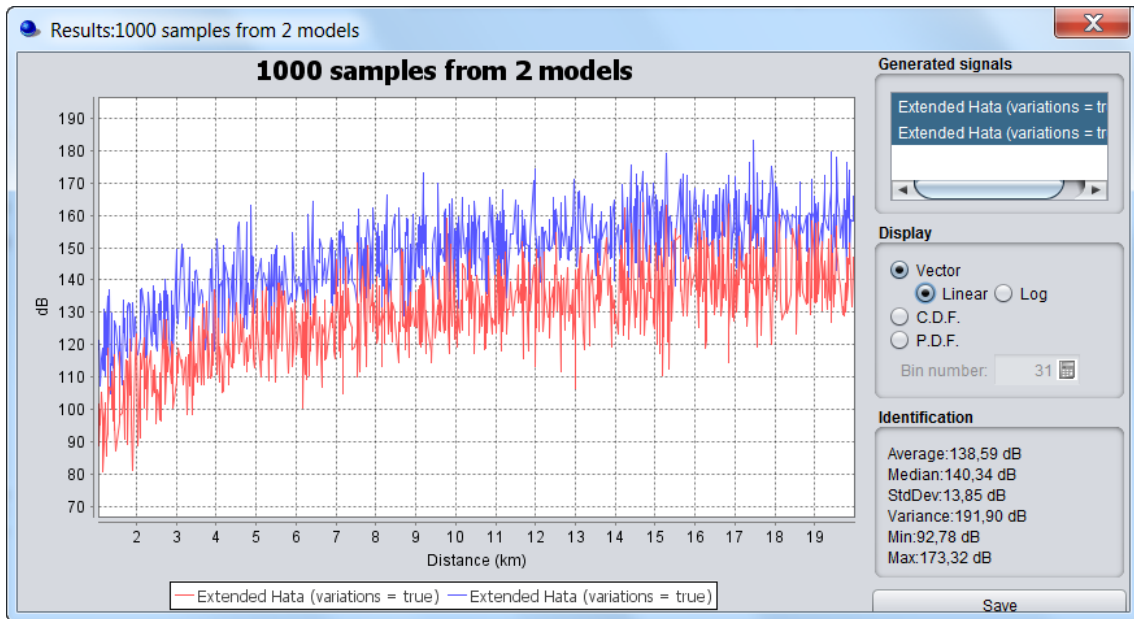
Figure 54 Example comparing 2 propagation loss using the "generate sorted samples". You can display the vector in linear or logarithmic scale

2.17   TESTING DISTRIBUTION FUNCTION

You can perform a sanity check on the distribution that you are using with the test distribution function from the menu bar of SEAMCAT. You may test the result of generating random values using a particular distribution type by selecting the <Test Distributions> command from the Workspace menu, by clicking on the icon of the toolbar ( ) or by pressing <CTRL+SHIFT+D>. This could be e.g. used to analyse the statistical qualities of generated random variables.
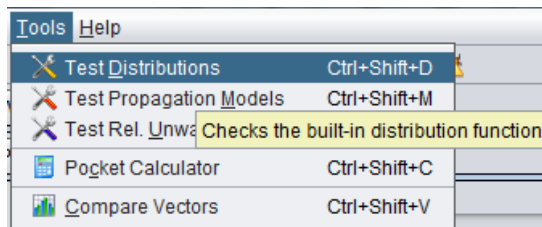
Figure 55: Access to testing unwanted emission function
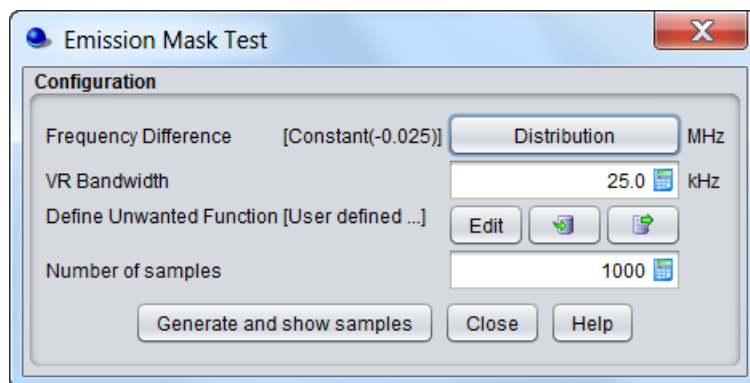
Figure 56: Illustration of the distribution check routine

2.18   TESTING UNWANTED EMISSION FUNCTION ⚒

You can perform a sanity check on the unwanted emission calculation by using the <Test Rel. Unwanted**>** emission function in the menu bar of SEAMCAT, by clicking on the icon of the toolbar (⚒) or by pressing <CTRL+SHIFT+U>. You may check the definition of unwanted emissions mask by calculating the actual unwanted emissions for given mask in a given VLR bandwidth applying a certain ILT-VLR frequency offset:
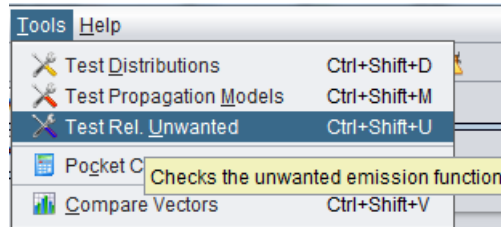
Figure 57: Access to testing unwanted emission function

This feature allows you to directly extract the uwanted emission by entering the frequency separation, the receiver bandwidth and the spectrum mask as shown in Figure 58.
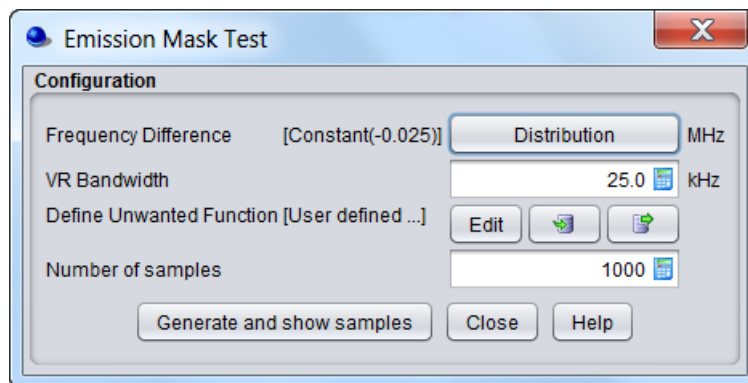
Figure 58: Illustration of the unwanted emission function check routine

2.19   MULTIPLE VECTORS COMPARISON 📊

You may want to see all the vectors (or a subset) that have been generated for one workspace or more. For this you can use the <Compare Vectors> command available by clicking this icon 📊 or by pressing <CTRL+SHIFT+V> to open the dialog box in Figure 59.

- You are able to display multiple vectors that are resulting from the simulations (batch or not);
- You can also add external vectors from a past simulation;
- You can change the text of the legend by double clicking on the vector.
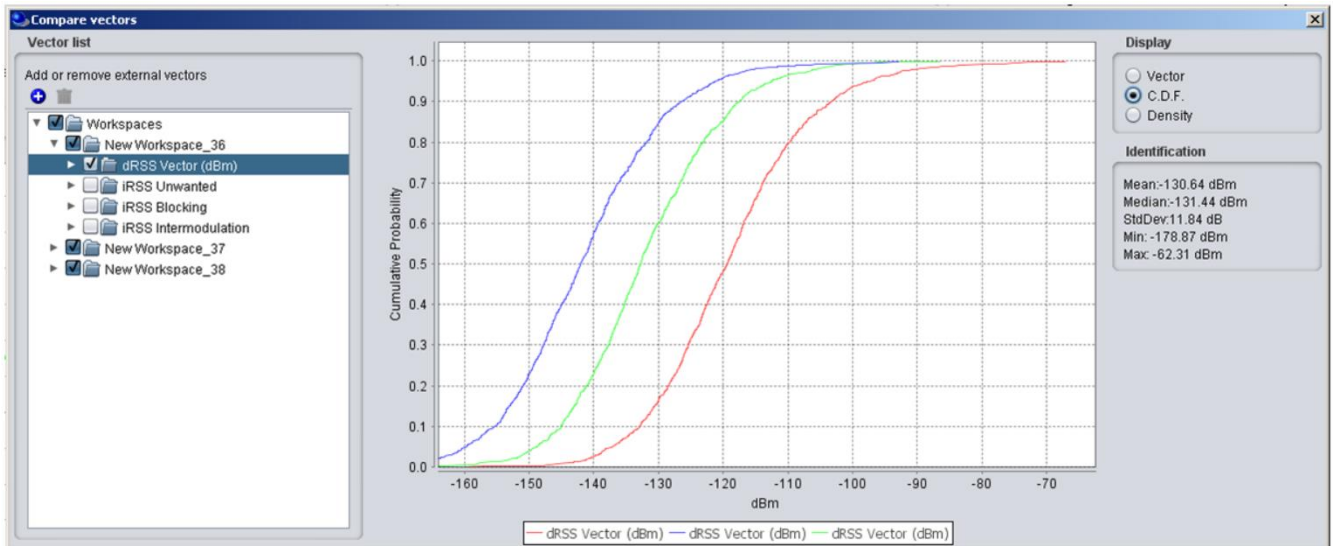
Figure 59: Illustration of the compare vectors feature

2.20 POCKET CALCULATOR

SEAMCAT contains a builtin pocket calculator. Select the command < Tool/Pocket Calculator> from the Workspace menu, click on the pocket calculator icon of the toolbar (▦) or CTRL+SHIFT+C to activate the Pocket calculator window:
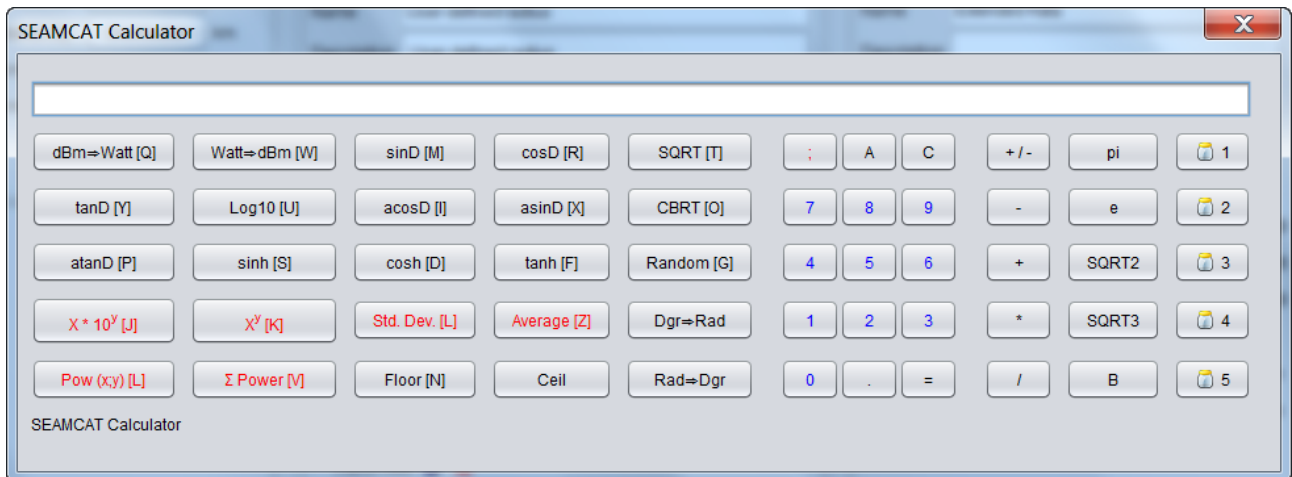
Figure 60: SEAMCAT pocket calculator

The calculator can also be accessed from the graphical user interface when a scalar is to be entered as shown in the example of Figure 61 with the wall loss attenuation of the Extended Hata propagation model.
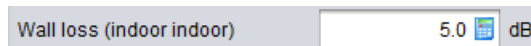
Figure 61 Access to the calculator from the GUI panel

2.21 ONLINE MANUAL HELP CONTENT

SEAMCAT provides you direct access to the online manual if you click on the following symbol. Each panel contains a specific link where detailed information on the feature or algorithm can be found. In case you need further information, clarification, supply additional information or advices to the manual which you believe could be useful for other users of SEAMCAT, you are encouraged to contact the ECO project manager at seamcat@eco.cept.org

2.22   REPORT ENHANCEMENT AND BUGS 🐞

The SEAMCAT tool is thoroughly tested but in an unlikely event you might need to report bugs or enhancements. You have 2 ways:

1. Send an email to seamcat@eco.cept.org by describing the error you found and attach relevant files (i.e. workspace files, screen shots, system log file etc… . Further information on the log file can be found in section 2.14, or alternatively;
2. You can create a ticket directly from the management system tractool (http://tractool.seamcat.org). Remember that you need to register in order to create a ticket.

2.23   INSTALLING PLUGINS INTO SEAMCAT

From the SEAMCAT library menu it is possible to install a library as a .jar file. By creating a new .jar entry and adding the file SEAMCAT will now include this plugin to be selectable when configuring scenarios.
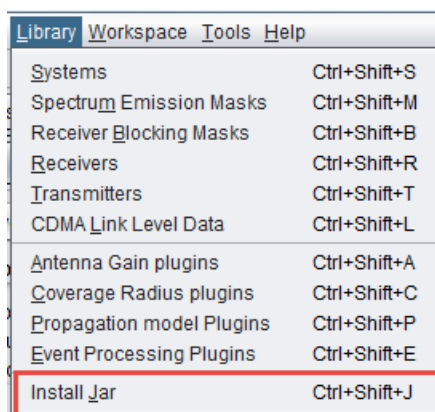
Figure 62: Installing plugins

After installation the installed plugin can be seen in the SEAMCAT library. Any plugins can be loaded from this interface (e.g. Propagation Model Plugin, Event Processing Plugin, coverage radius etc…). Further description on the library is available in section 13.
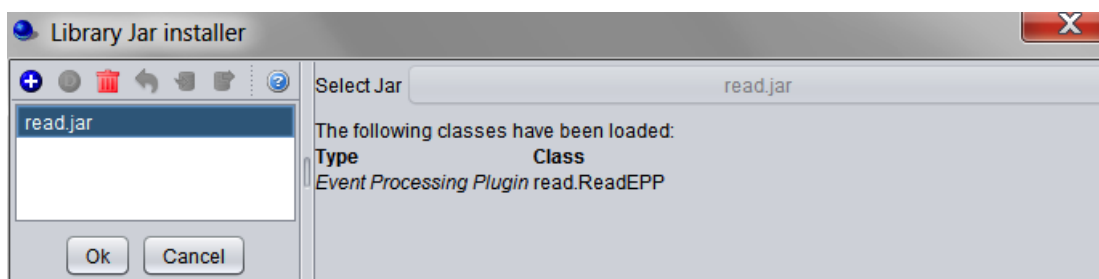
Figure 63 Library jar installer

3 EXAMPLE OF RUNNING A SIMULATION

3.1 SETTING THE SCENARIO

Running a simulation consists essentially in setting the input parameters of the victim and the interfering system according to your requirement. Similarly, you need to consider the requirement of the geographical location of the various systems. For this example, let's consider a fixed link, which is interfered by another fixed link as illustrated in Figure 64.

The Victim link transmitter and the Victim link receiver compose the "Victim link" and the Interefering link transmitter and the Interfering link receiver compose the "Interfering Link".
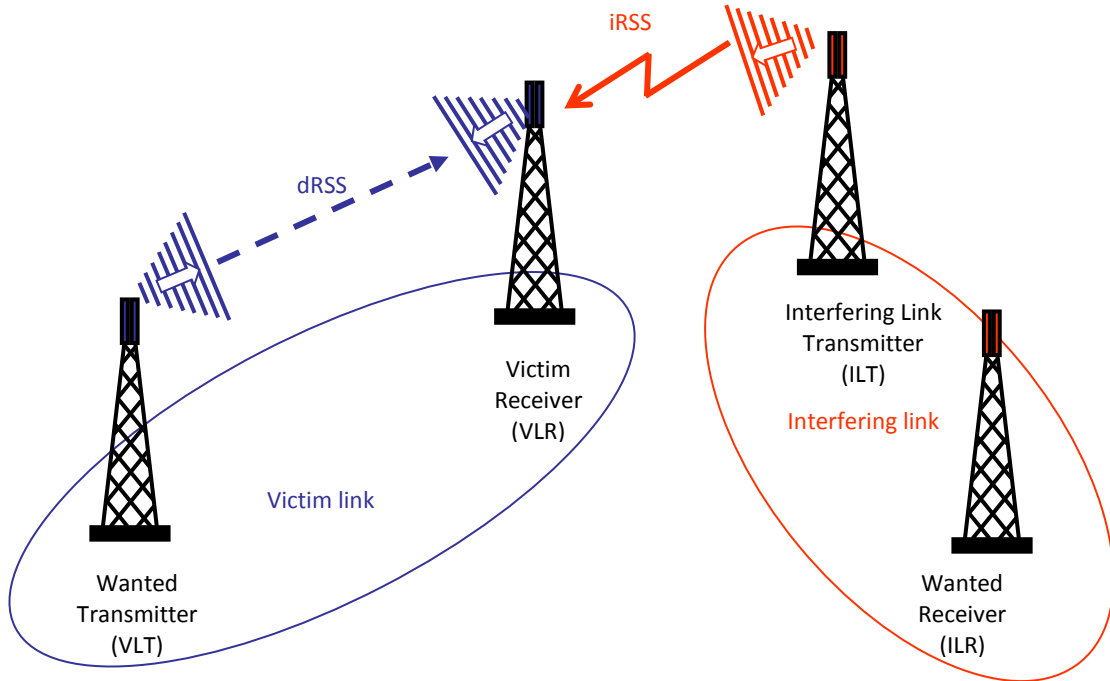
Figure 64 Example of Application of SEAMCAT

3.2 CALCULATING THE DRSS

In this section, you will learn how to ...

✓ **Define Victim link receiver (VLR)**
  ➢ **Operating frequency**
  ➢ **Receiver bandwidth**
  ➢ **Antenna characteristics**
  ➢ **Interference criteria**
  ➢ **Noise floor**

✓ **Calculate the dRSS**

✓ **Test propagation model**

✓ **Define Victim link transmitter (VLT)**
  ➢ **Tx power**
  ➢ **Antenna characteristics**

✓ **Launch simulation**

✓ **Position the VLT vs VLR**

✓ **Extract dRSS vectors**

3.2.1 Victim link

The victim parameter characteristics summarised in Table 6 should be entered into SEAMCAT.

Table 6: Characteristics of the victim link pair of receiver and transmitter

Parameters	Value	Units
Operating Frequency	1000	MHz
Transmitter power	30	dBm
Receiver bandwidth	200	kHz
Tx and Rx antenna type	Omni directional	
Tx and Rx antenna gain	9	dBi
Tx and Rx antenna height	30	m
C/I protection criteria	19	dB
C/(N+I) protection criteria	16	dB
(N+I)/N	3	dB
I/N	0	dB
Noise floor	-110	dBm

Each simulation workspace contains *one and only one* victim link.

3.2.2 System to be a victim

In order for you to set up your workspace, you need to first set the system that you will be using as victim. You need to set the characteristics of your receiver (that will be the **victim link receiver** (VLR)) and the transmitter (that will be the **victim link transmitter** (VLT)).

You can edit the system characteristics directly in the system tab. This is illustrated in the figure below.
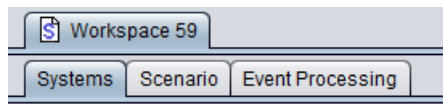
Figure 65 Access to the system environment

You can select a generic system from the "import system from library button" as shown Figure 67.
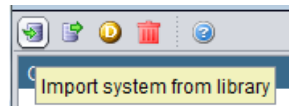
Figure 66: Import system from library button
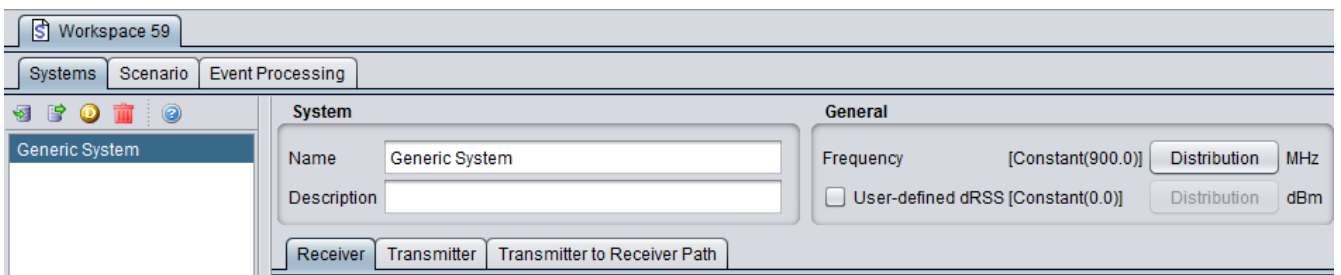
Figure 67: Selecting a system from library

First, let set the frequency of the victim. You can change the frequency from 900 MHz (default value) to 1000 MHz as described in Figure 68. We consider a constant value for this example, but in principle, you can choose any type of distribution.
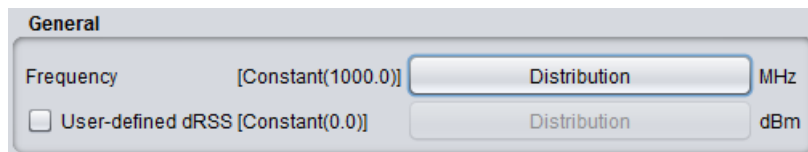
Figure 68: Example of setting up the operating frequency

3.2.3   Receiver

You need now to set the victim link receiver by selecting the receiver tab.
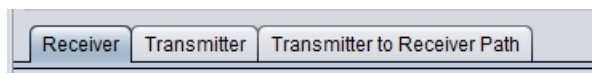
Figure 69: Selecting the receiver tab

The parameters should be field according to the value of Table 6.

- The noise floor is –110 dBm. (**#1** of Figure 70);
- The reception bandwidth is 200 kHz; (**#2** of Figure 70);
- To simulate an omni-directional antenna, you can leave blank the horizontal pattern or you can select the omni directional antenna from the library (**#3**). The antenna peak gain is to be set to a value of 9 dBi; (**#4**) (see Figure 71);
- The antenna height is 30 m; (**#5** of Figure 72);
- The interference criteria of the victim link receiver are a C/I of 19 dB, a C/(N+I) of 16 dB, a (N+I)/N criteria of 3 dB and a I/N of 0 dB; (**#6** of Figure 73).
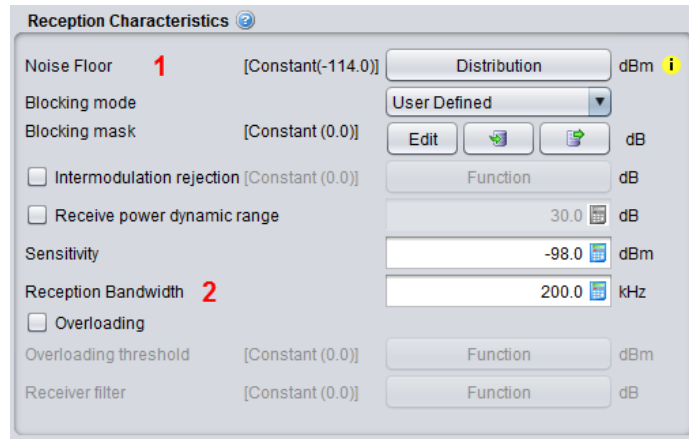
Figure 70 Setting the reception characteristic
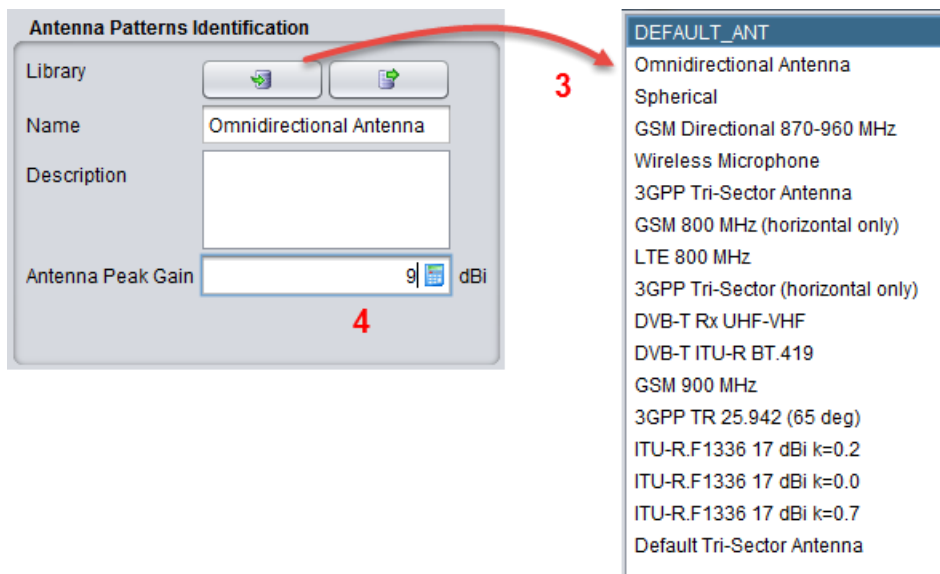
Figure 71: Setting the antenna pattern from the library and setting the peak gain to 9 dBi
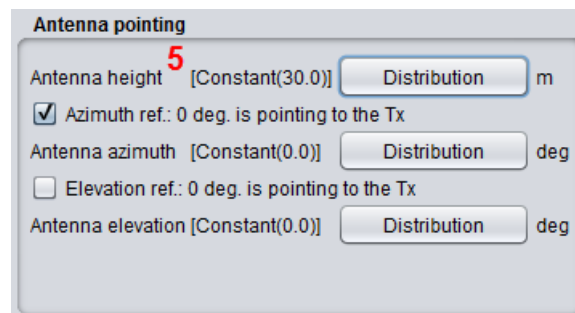
Figure 72: Setting the antenna height

Figure 73: Setting the interference criteria

3.2.4 Transmitter

You need now to set the victim link transmitter by selecting the transmitter tab
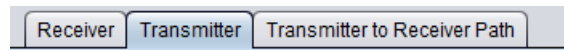
Figure 74: Selecting the transmitter tab

The parameters should be field such as

- The power is 30 dBm; (**#1** of Figure 75)
- An omni-directional antenna of 9 dBi is used;
- The antenna height is 30 m.
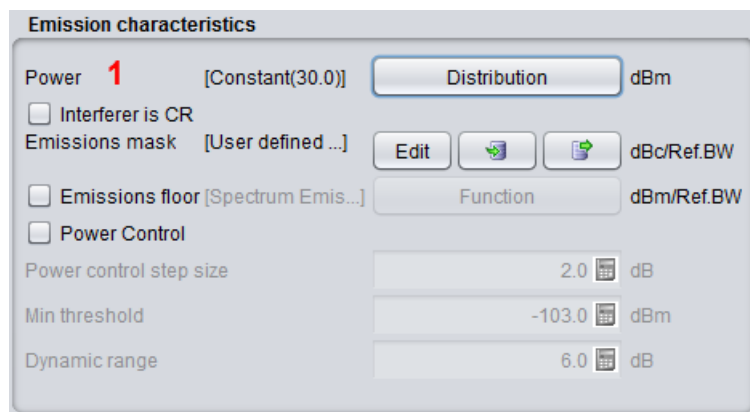
Figure 75: Example of setting up the victim link transmitter

3.2.5 Positioning the VLT vs VLR

You now need to consider the position of the transmitter to the receiver for the victim link.
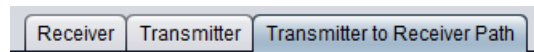
Figure 76: Selecting the Tx to Rx path tab

SEAMCAT allows you to locate the Victim link receiver and the Victim link transmitter in a fixed manner (correlated) or following some distribution (uncorrelated) as summarised in Figure 77. The input parameters are detailed in section 5.4, and the algorithms are detailed in ANNEX 13:.
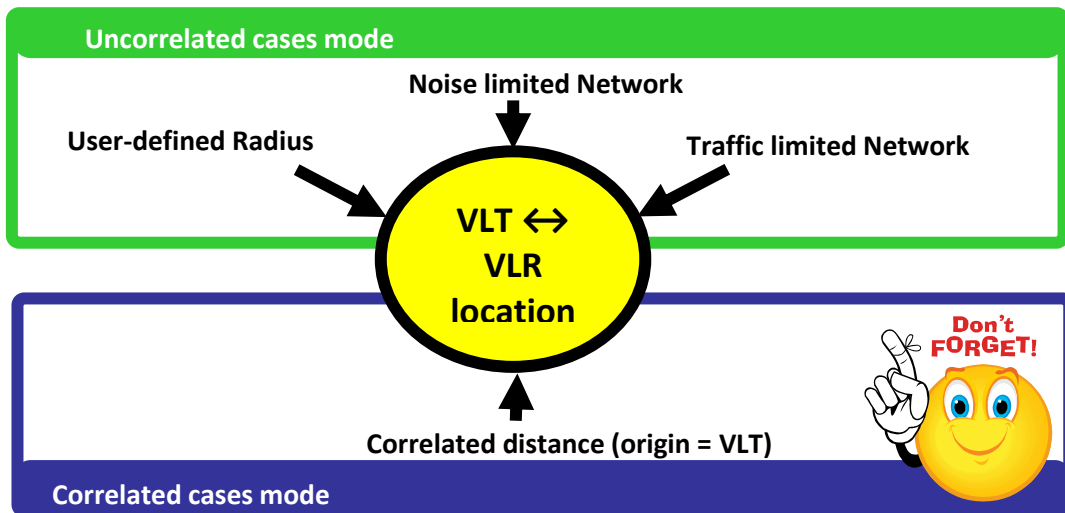
Figure 77: Summary of the VLT ↔ VLR location capability in SEAMCAT

In this exercise, you can set the distance between the **VLT** and **the VLR** as fixed (correlated distance) (x = y = 2 km) as illustrated in Figure 78.
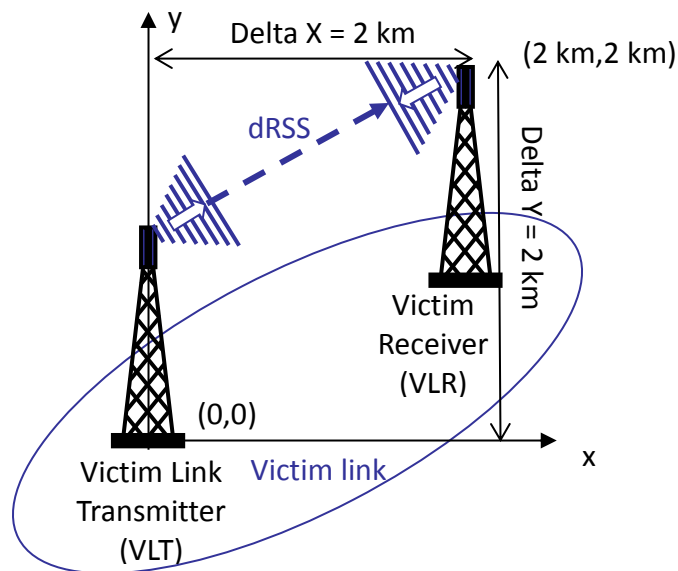
Figure 78: Distance between the Victim link transmitter and the Victim link receiver (Victim Link)

It is assumed that the Tx and Rx are both outdoor as shown in Figure 79.
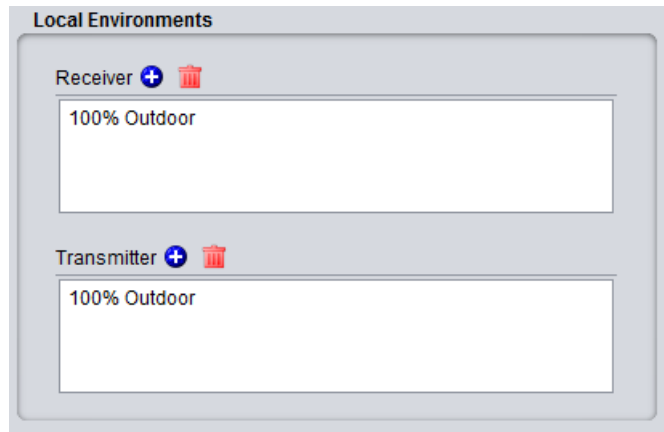
Figure 79: Example of setting up the outdoor/indoor ratio

For this, you need to select the correlated distance option of SEAMCAT as shown in Figure 80. In SEAMCAT, the origin of the coverage radius (see ANNEX 13:) is the **transmitter** (this is also reminded in the GUI) of the link.
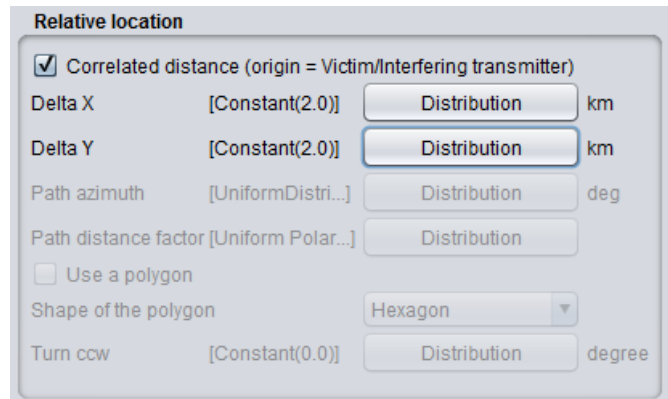
Figure 80: Illustration of the correlated distance in SEAMCAT

3.2.6   Selecting the propagation model

Now since you have defined both the transmitter and the receiver characteristics and the location between the two, you need to select the propagation model you need for the simulation.

To simplify our task, let us assume we need the free space model to calculate the attenuation between the Victim link receiver and the Victim link transmitter.

In addition, the Variation should be disabled as shown in Figure 81.
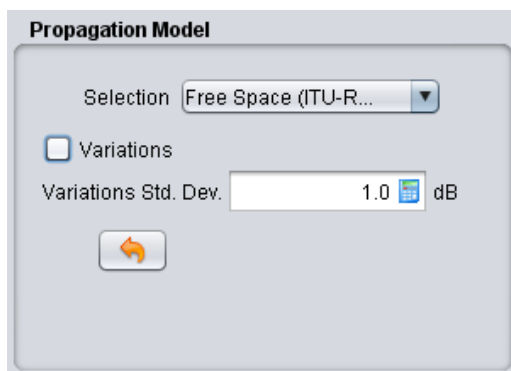
Figure 81: Example of setting up the free space propagation model for Step 1

3.2.7   Calculating the dRSS by hand

Using the Free space equation, you can easily derive the power received by the Victim link receiver dRSS:

$$dRSS = Pe + Ge + Gr - L \qquad\qquad (Eq.\ 17)$$
$$dRSS = 30 + 9 + 9 - (32.5 + 10\ log(8) + 20\ log(1000))$$
$$dRSS = -53.5\ dBm$$

Keep this calculation in mind, as we will compare it with what SEAMCAT calculates in the following sections.

3.2.8   Export/import your system to library

When you have completed setting your system you can export it to the library, so that the next time you need to study the same system you can reuse it by importing it from your library. That will save you time.

Figure 82: Example of importing/exporting a system to library

3.2.9   Selecting the victim in the Scenario

You need now to create the victim link. The only thing you need to do is to select the system of your choice into the victim link as shown in (**#1**) of Figure 83 under the "scenario" tab.

Note that the frequency field at the "scenario" tab level overwrite what was predefined at "system" tab level (**#2**).
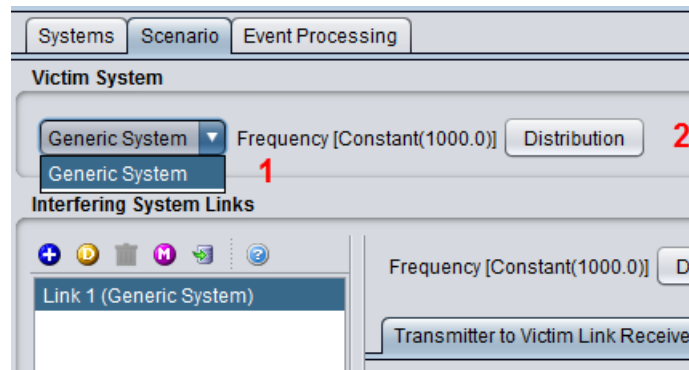
Figure 83: Setting the system of your choice to be the victim link in the "scenario" tab

3.3 CALCULATING THE IRSS

In this section, you will learn how to ...

✓ **Define Interefering link transmitter (It)**
  ➢ Tx power
  ➢ Antenna characteristics
  ➢ Set the emission bandwidth

✓ **Position the VLR vs It (i.e. Victim link vs Interfering link)**

✓ **Calculate the iRSS**

✓ **Relation between Emission bandwidth, reference bandwidth and VLR**

3.3.1 Interfering Links

The characteristics of the interefering system summarised in Table 7 should be entered into the SEAMCAT simulation scenario, and we will simulate only one interfering link.

Table 7: Characteristics of the interfering link pair of transmitter and receiver

Parameters	Value	Units
Operating frequency	1000	MHz
Transmitter power	33	dBm
Emission bandwidth	200	kHz
Reference bandwidth	200	kHz
Tx antenna type	Omni directional	
Tx antenna gain	11	dBi
Tx antenna height	30	m

3.3.2 System to be an interferer

Contrary to the victim link, is possible to set more than one interfering link in your simulation. A given simulation workspace must contain at least one interfering link.

You need first to edit the technical characteristics of the system(s) that you will use as interferer(s). You can have many links with the same system or with different systems. Figure 84 presents an example with 3 interfering links having each a different technical characteristic.
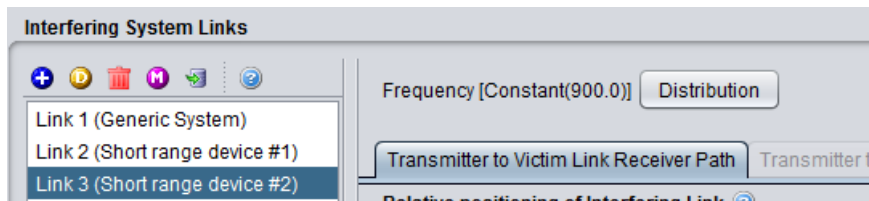
Figure 84: Example of generating multiple Interfering links

The frequency of 1000 MHz will be finally set at the "scenario" tab level (**#1**).
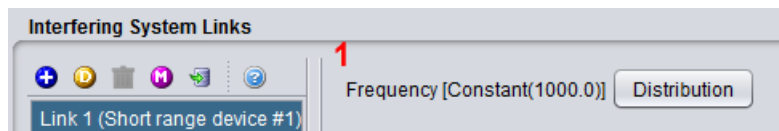
Figure 85: Setting up the operating frequency of the interfering link

3.3.3 Transmitter

You need now to set the victim link transmitter by selecting the transmitter tab:

- the Intereefering link transmitter uses a Power of 33 dBm; (**#1** of Figure 86)
- the Intereefering link transmitter uses an omni-directional antenna of 11 dBi gain; (**#2**)
- the Intereefering link transmitter uses an antenna height of 30m; (**#3**)
- the Intereefering link transmitter uses an emission bandwidth of 200 kHz and a reference bandwidth Bref = 200 kHz. (**#4**)

The emission bandwidth of 200 kHz is defined through the emission mask (see Figure 86). This interefering link transmitter emission mask is defined in dBc. Then, you should enter an attenuation given in a reference bandwidth, the corresponding power is derived using the following equation:

$$P(dBm/Bref) = Pe\ (dBm)+Att(dBc/Bref) \qquad\qquad (Eq.\ 18)$$

Where Pe is the power of the Intereefering link transmitter within the emission bandwidth (also know as the in-band power). The sign of Att(dBc/Bref) is explained in section A7.5. Then, in this example, within the emission bandwidth (200kHz- offset between –0.1 MHz and 0.1 MHz), the power is 33 dBm, if the reference bandwidth is supposed to be equal to the emission bandwidth then Att = 0 dBc/Bref, this gives:

$$33\ (dBm/200kHz) = 33 +0\ (dBc/Bref)$$

The attenuation in dBc should be taken equal to 0 dBc/200 kHz (the link between the mask given in a reference bandwidth and the mask defined in 1 MHz is explained in ANNEX 6:).
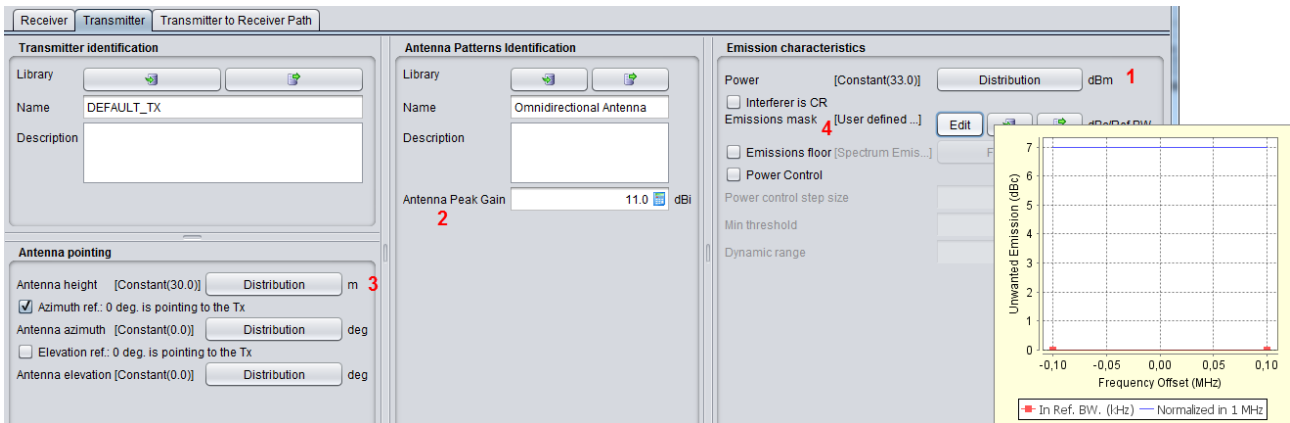
Figure 86: Setting up the interefering link transmitter
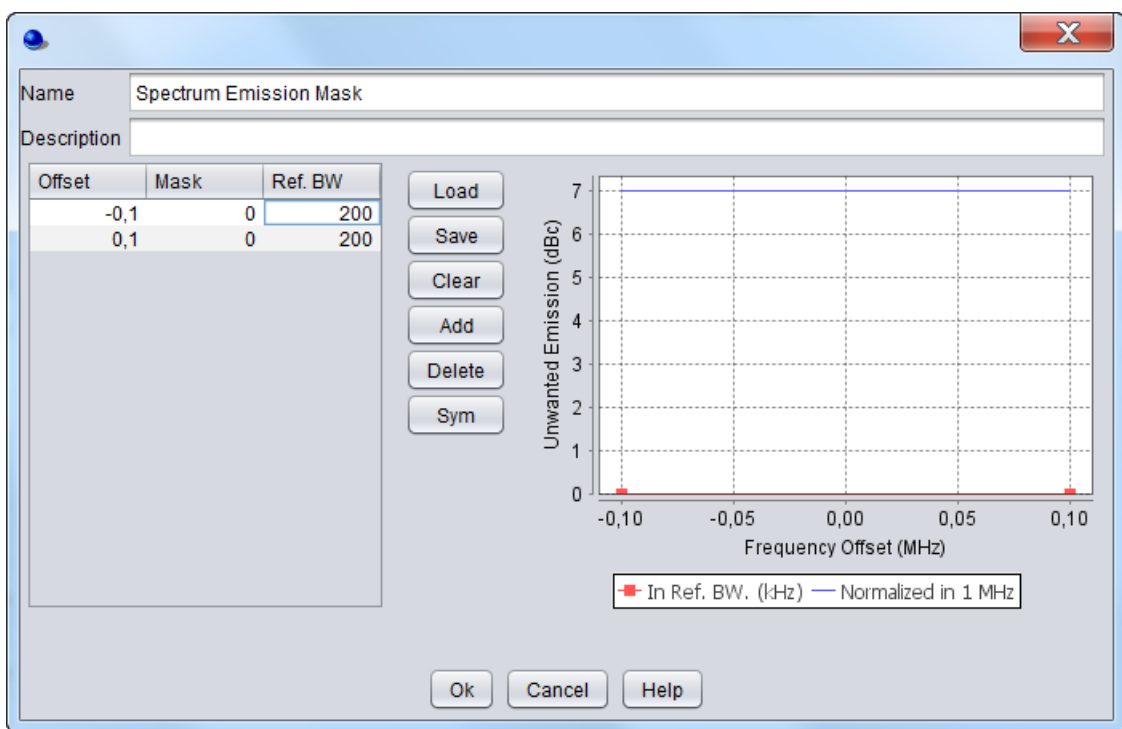
Figure 87: Spectrum emission mask settings

3.3.4 Receiver

For this exercise, the Power Control is not activated, therefore you do not need to fill in any information about the Interfering link receiver.

3.3.5 Positioning of the ILT vs ILR

Positioning of the ILT vs ILR is similar to positioning VLT vs VLR as described in Section 3.2.5.

It is required when the power control in the interfering link is simulated. In case the geometry of your scenario is depend on the position of the ILR (for instance ILR being at the center of the ILT distribution, or the victim link being fixed with respect to the ILR), it is also important to set it.

3.3.6 Positioning of the VLR vs ILT

SEAMCAT allows defining the relative location between the Victim link receiver and the Intereferring link transmitter as illustrated in Figure 88. The input parameters are detailed in section 10.3, and the algorithms are detailed in ANNEX 13:.

Uncorrelated cases mode

Uniform density (n_{active} interferers)

None (n_{active} interferers)

Closest (single interferer)

VLR ↔ ILT location

ILT

ILT/VLT

VLT

ILR/VLT

Don't FORGET!

Correlated cases mode
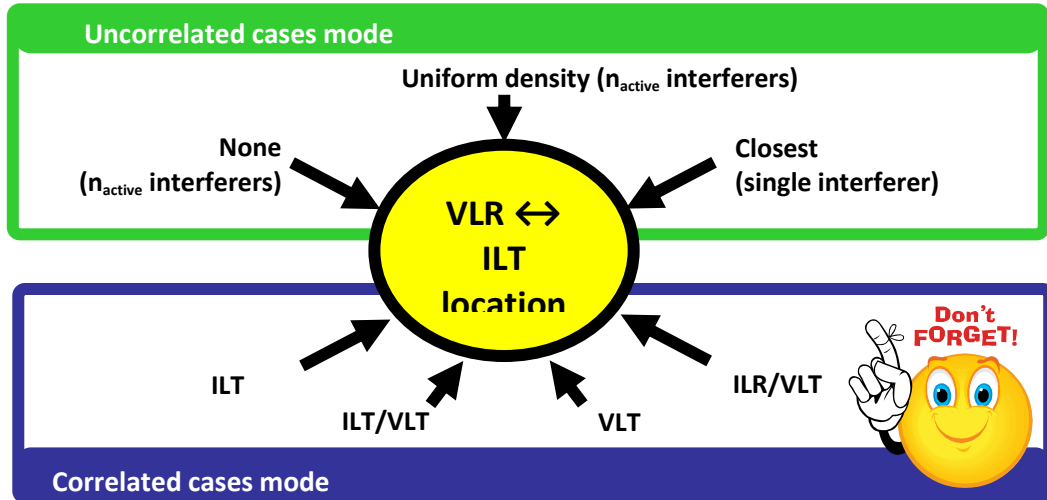
Figure 88: Summary of the VLR ↔ ILT location capability in SEAMCAT

In this exercise, the distance between the Intereferring link transmitter and the Victim link receiver as shown in Figure 89 is fixed by using the correlated distance as illustrated by Figure 90.

dRSS

iRSS

Interfering Transmitter (ILT)

Victim link

Delta Y = 4 km

Interfering link

Victim Link Transmitter (VLT)

Victim Link Receiver (VLR)

Delta X = 4 km

Interfering Link Receiver (ILR)
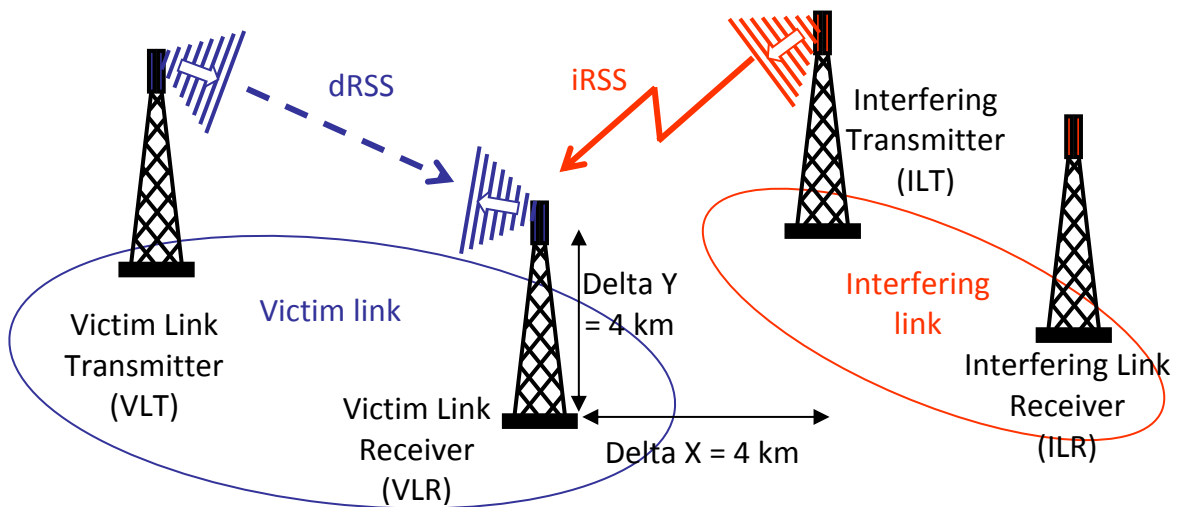
Figure 89: Distance between the Intereferring link transmitter and the Victim link receiver
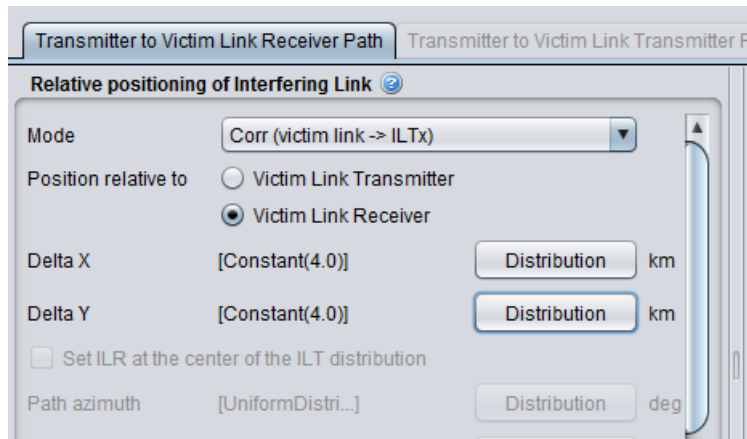
Figure 90: Excample of setting up the distance between the Intererefing link transmitter and the Victim link receiver in SEAMCAT. Here the ILT is positioned relative to the VLR

3.3.7 Calculating the iRSS by hand
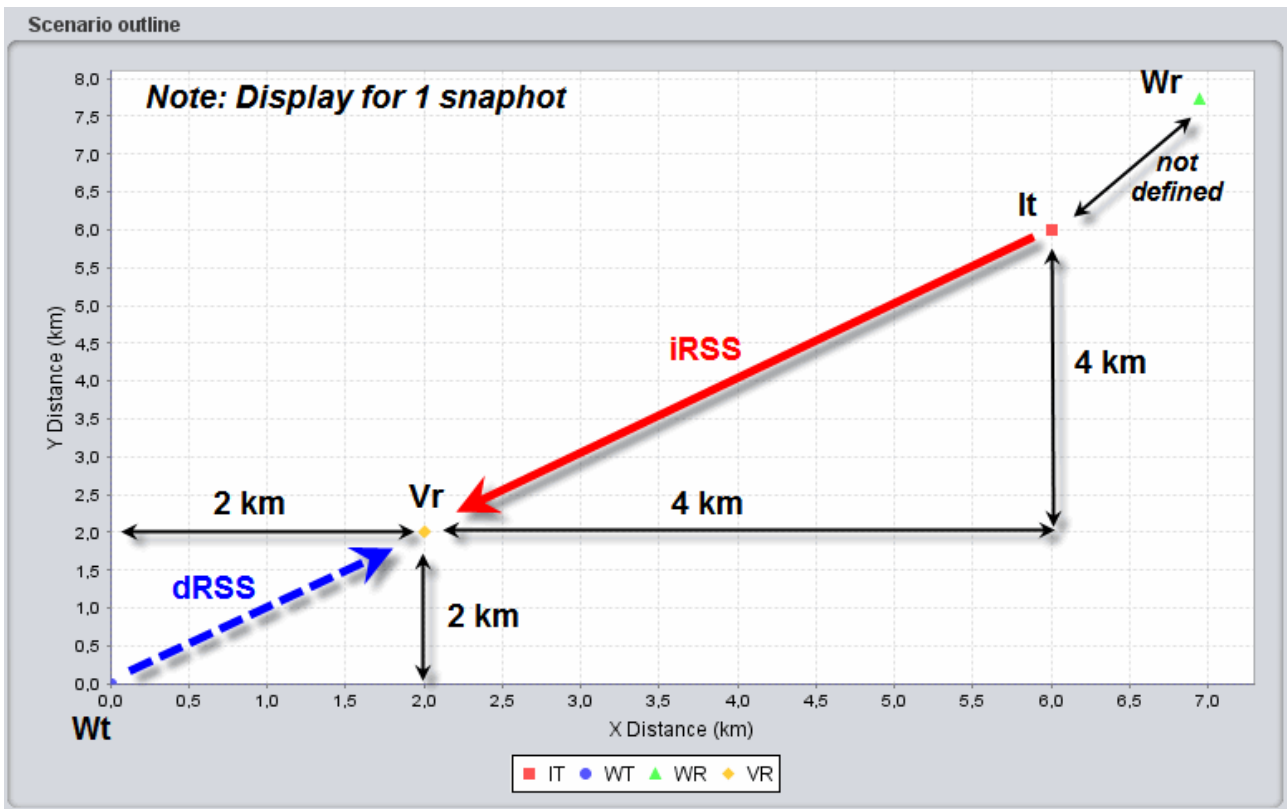
Figure 91: Illustration of SEAMCAT display (only 1 snapshot) of the various pair of transmitter and receiver and the dRSS and iRSS relationship

The attenuation between the Intererefing link transmitter and the Victim link receiver is simulated by using the free space model (Variation should be disabled). When the simulation is finished, SEAMCAT presents the positioning of the various pairs of transmitters and receivers as shown in Figure 91(only one snapshot is illustrated).

Using these assumptions, it is possible to derive the interfering power received by the Victim link receiver iRSS:

$$iRSS = Pe + Ge + Gr - L \qquad (Eq.\ 19)$$

$$iRSS = 33\ (dBm) + 11 + 9 - (32.5 + 10\ log(32) + 20\ log(1000))$$

iRSS = -54.5 dBm

3.3.8 Emission, reference, VLR bandwidth relationship and bandwidth correction factor

The proposed exercise considers the case where the VLR bandwidth is the same as the emission bandwidth and the reference bandwidth.

This section aims at illustrating the interaction between the emission bandwidth (It_{BW}), reference bandwidth (Bref), VLR bandwidth (VLR_{BW}) and any bandwidth correction factor. This section provides examples where these values are different and its' effect on the iRSS calculation.

3.3.8.1 Relationship between Emission bandwidth and Reference bandwidth

For a fixed VLR_{BW} = 200 kHz, and fixed It_{BW}= 200 kHz, the attenuation Att(dBc/Bref) will be different depending on the values of the Bref in order to achieve the same interference power level.

Case 1, It_{BW} > Bref :
Bref = 100 kHz, with Att = -3 dBc/Bref, iRSS = -51.48 dBm;

As mentioned in Section A7.5 on p.287, if the reference bandwidth is lower than the emission bandwidth then the attenuation must be defined with negative sign;

Case 2, It_{BW} = Bref :
Bref = 200 kHz, with Att = 0 dBc/Bref, iRSS = -54.49 dBm;

If the reference bandwidth is equal to the emission bandwidth then the attenuation should be set as zero.

Case 3, It_{BW} < Bref :
Bref = 400 kHz, with Att = 3 dBc/Bref, iRSS = -57.5 dBm;

If the reference bandwidth is larger than the emission bandwidth then the attenuation must be defined with positive sign;

3.3.8.2 Relationship between Emission bandwidth and Victim link receiver bandwidth

For a fixed Bref = 200 kHz and a fixed It_{BW}= 200 kHz, depending on the size of the VLR_{BW} a bandwidth correction factor is applied or not.

Case 4, It_{BW} = VLR_{BW}:
VLR_{BW} = 200 kHz, iRSS = -54.49 dBm;

Case 5, It_{BW} > VLR_{BW}:
VLR_{BW} = 100 kHz, iRSS = -57.5 dBm;
As shown in ANNEX 22: on p. 422, when the It_{BW} > VLR_{BW}, the interfering power in the VLR is reduced due a bandwidth correction factor automatically applied in SEAMCAT. As a results, the iRSS value decreases compare to a case where It_{BW} = VLR_{BW}.

Case 6, It_{BW} < VLR_{BW}:
VLR_{BW} = 400 kHz, iRSS = -54.49 dBm;
As illustrated in ANNEX 22:, when the It_{BW} < VLR_{BW}, there is no bandwidth correction factor applied to the interfering emitted power since the all the energy is "seen" by the VLR. Therefore the iRSS is equal to the case where It_{BW} = VLR_{BW}. Note also that since the emission bandwidth of the interferer is smaller than the victim, SEAMCAT will complain that the spectrum emission mask of the interferer is not defined with the range of the victim bandwidth, therefore you need to increase the out of band emission.
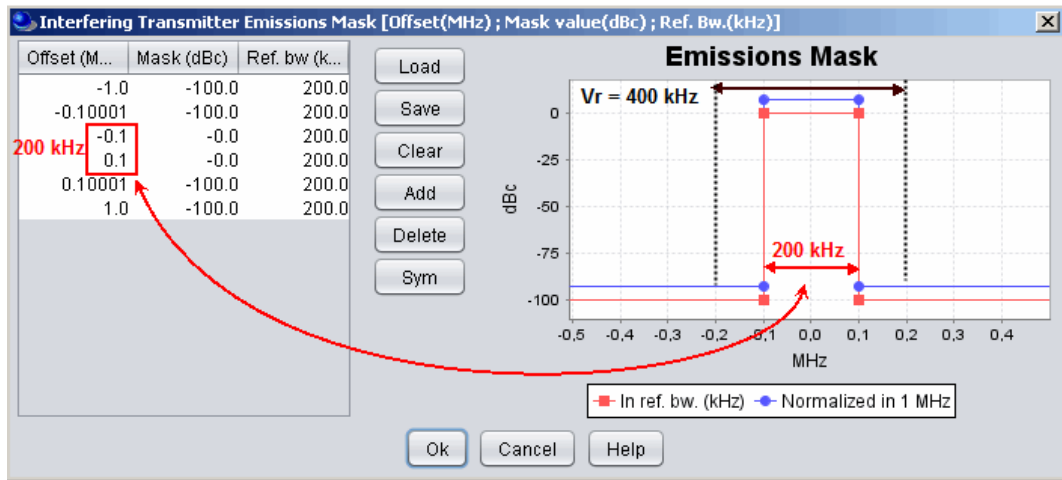
Figure 92: Illustration of the emission spectrum mask with respect to the VLR bandwidth in case 6

Case 7: This is the same as case 6 (VLR = 400 kHz and Bref = 200 kHz) except that the spectrum emission mask (emission bandwidth 200 kHz) has slopes on both sides (Figure 93) which generates higher interference compared to the case 6 and the iRSS = -53.44 dBm.
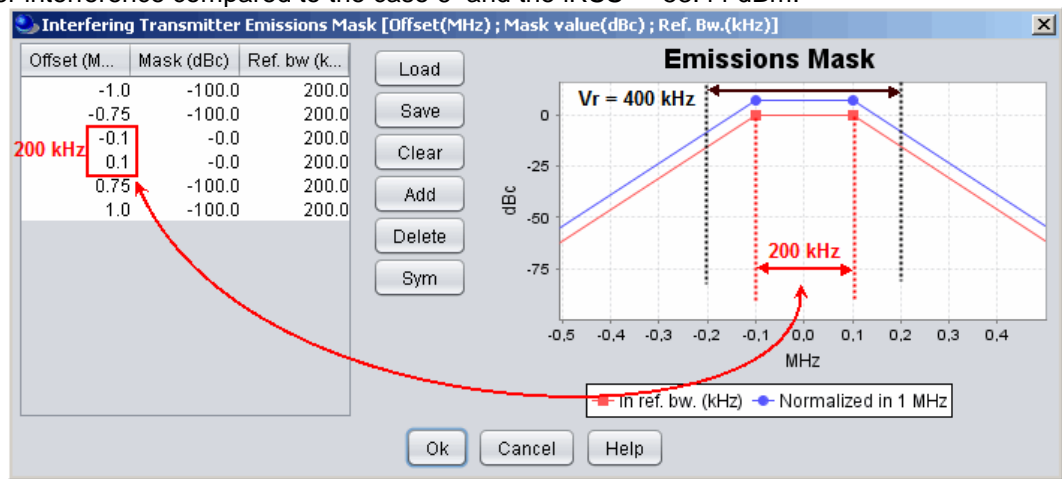
Figure 93: Illustration of case 7 and the "extra" interfering energy to the VLR due to the slope in the emission mask

3.4 LAUNCHING A SIMULATION

You can now launch a simulation. It should be noted that prior to beginning the simulation, SEAMCAT checks the consistency and suitability of certain input parameters (see ANNEX 19:).

Since the default operating frequency of the Interefering link transmitter is 900 MHz and the unwanted emission mask is not within the range of the Victim link receiver, SEAMCAT automatically complains and displays a warning window.
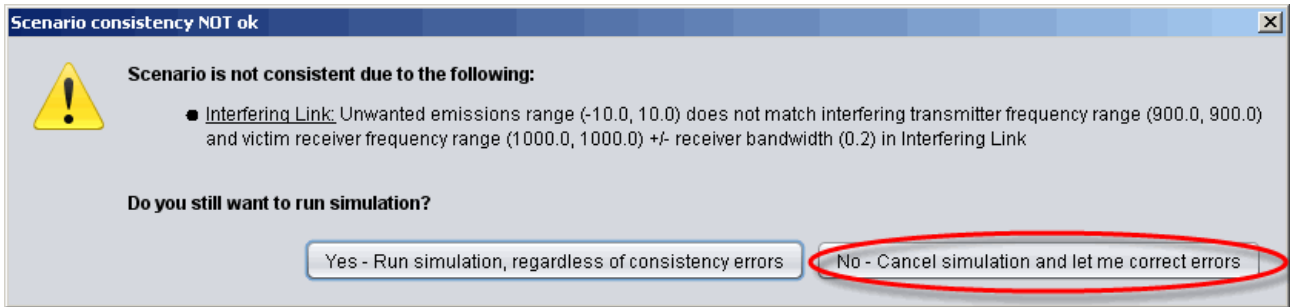
Figure 94: Consistency check warning being prompted because the operating frequency of the interferer is not set-up properly

Therefore, you should select "**No - Cancel simulation and let me correct errors**" and can define the operating frequency (1000 MHz) of the interfering link. These parameters do not affect the calculation of the dRSS. It is only to ensure that SEAMCAT does not experience any exceptions when running.

3.5 EXTRACT RESULTS VECTORS (DRSS, IRSS ETC…)

You can extract the dRSS vectors from the "Results" panel in the newly create workspace results in Figure 95.
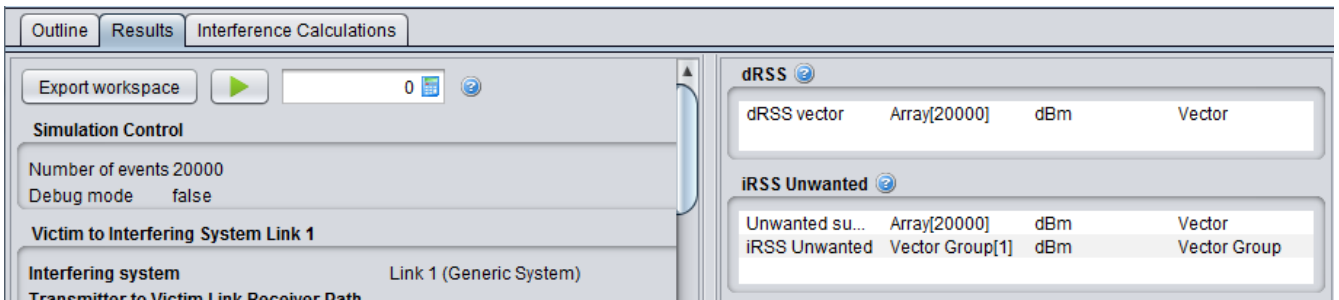
Figure 95: Results panel to extract any of the vectors generated by SEAMCAT
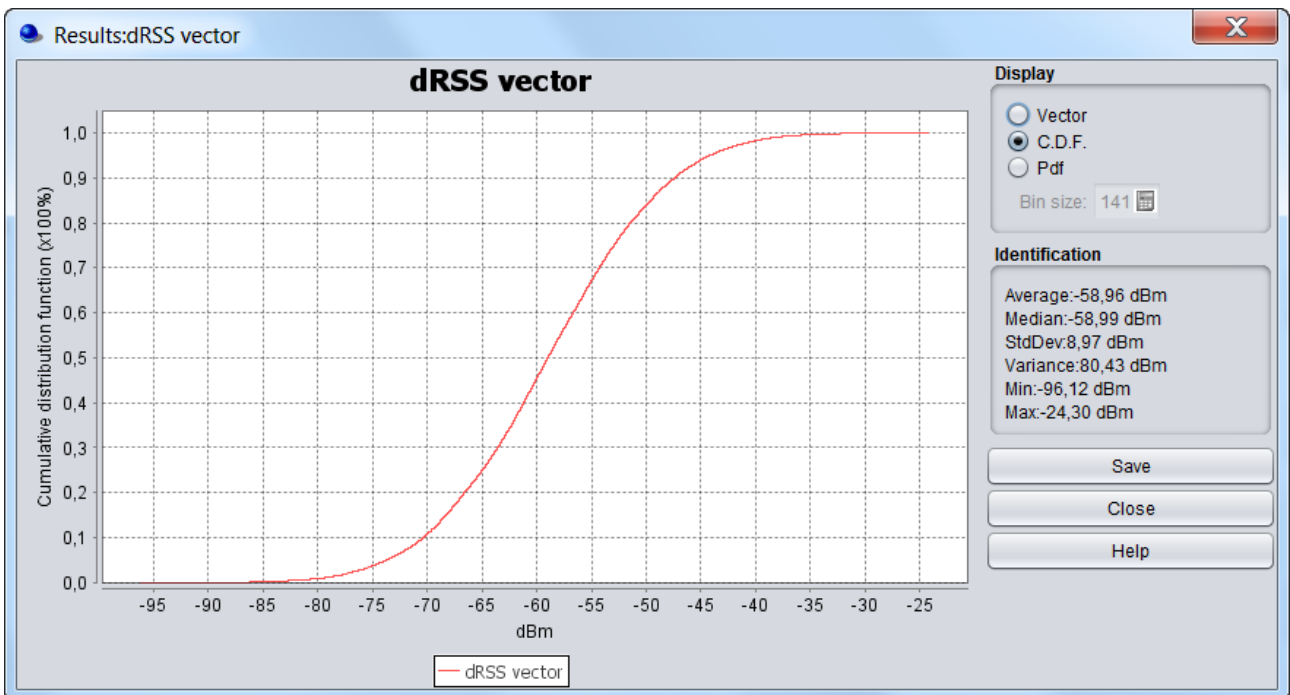
Figure 96: Example of the dRSS vector

When you double click on a result vector field (Figure 36 (**#1**)) the display panel as shown in Figure 96, gives you three options to display the results in vector (limited to 20.000 events), CDF and PDF format.

In addition you can see some statistical information such as average, median, standard deviation (StdDev), variance, min and max. You can find further information about this statistics (i.e. how they are computed) in Section A1.5.

3.6 CALCULATING THE PROBABILITY OF INTERFERENCE

After the simulation of events has been completed, SEAMCAT will have obtained and stored the dRSS and iRSS vectors. You may then proceed to evaluate the probability of interference for the simulated scenario using the interference calculation control panel as shown in Figure 97.
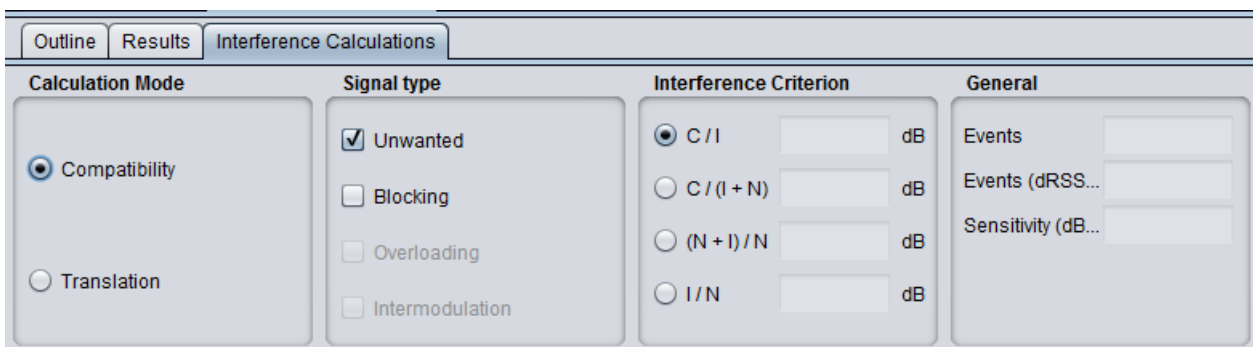
Figure 97: Interference calculation tabsheet

You can select any of the following parameters from the panel when you want to calculate the probability of interference:

- Calculation mode: compatibility or translation;
- Which type of interference signal is considered for calculation: unwanted, blocking, intermodulation or their combination;
- Interference criterion: C/I, C/(N+I), (N+I)/N or I/N:

3.6.1 Compatibility calculation mode

It is then possible to derive the C/I (i.e. dRSS/iRSS equivalent to dRSS-iRSS in dB):

$$dRSS/iRSS = -53.5-(-54.5) = 1 \ dB$$

Since the resulting C/I is below the protection criteria (19 dB), the probability of interference calculated by SEAMCAT (compatibility calculation mode) is equal to 1 as shown in Figure 98.
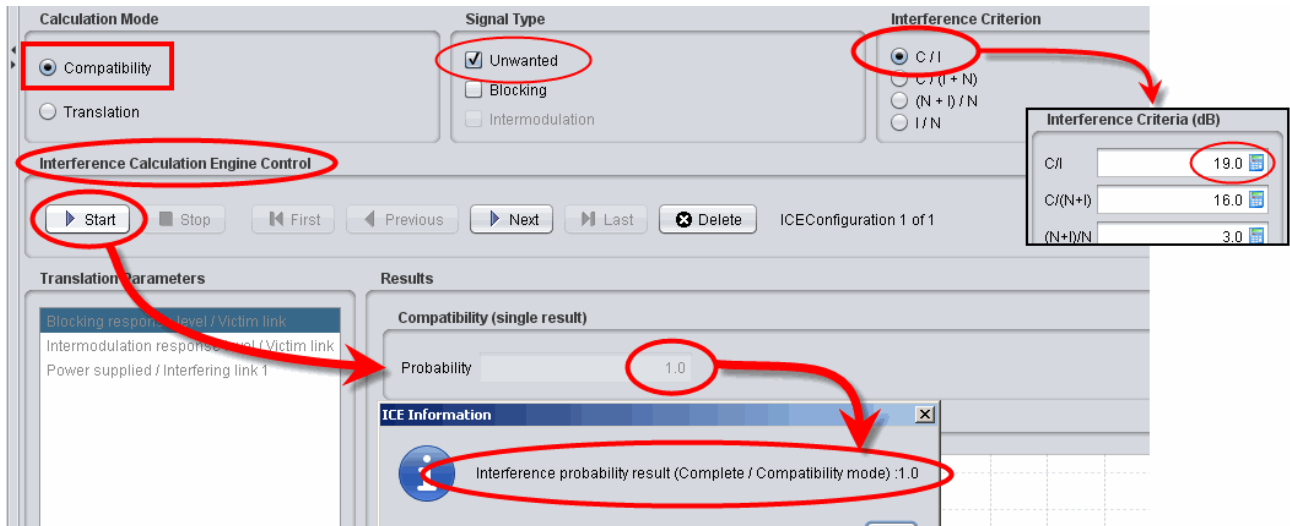
Figure 98: Probability of interference

3.6.2 Translation calculation mode

When the Translation mode is chosen, you may calculate and display a chart of the probability of interference as a function of one of the following input parameters:

- Output power of Interefering link transmitter;
- Blocking response level of Victim link receiver;
- Intermodulation response level of Victim link receiver.

The translation function, as shown as (**#1**) Figure 99 in, allows investigation of the probability of interference for varying power supplied (**#2**) to the interefering link transmitter. The power supplied (**#3**) to the interefering link transmitter should be equal to 15 dBm, which is 18 dB below the value used in the simulation (33 dBm). Effectively the C/I will be increased by 18 dB and reaches the level of 19 dB.
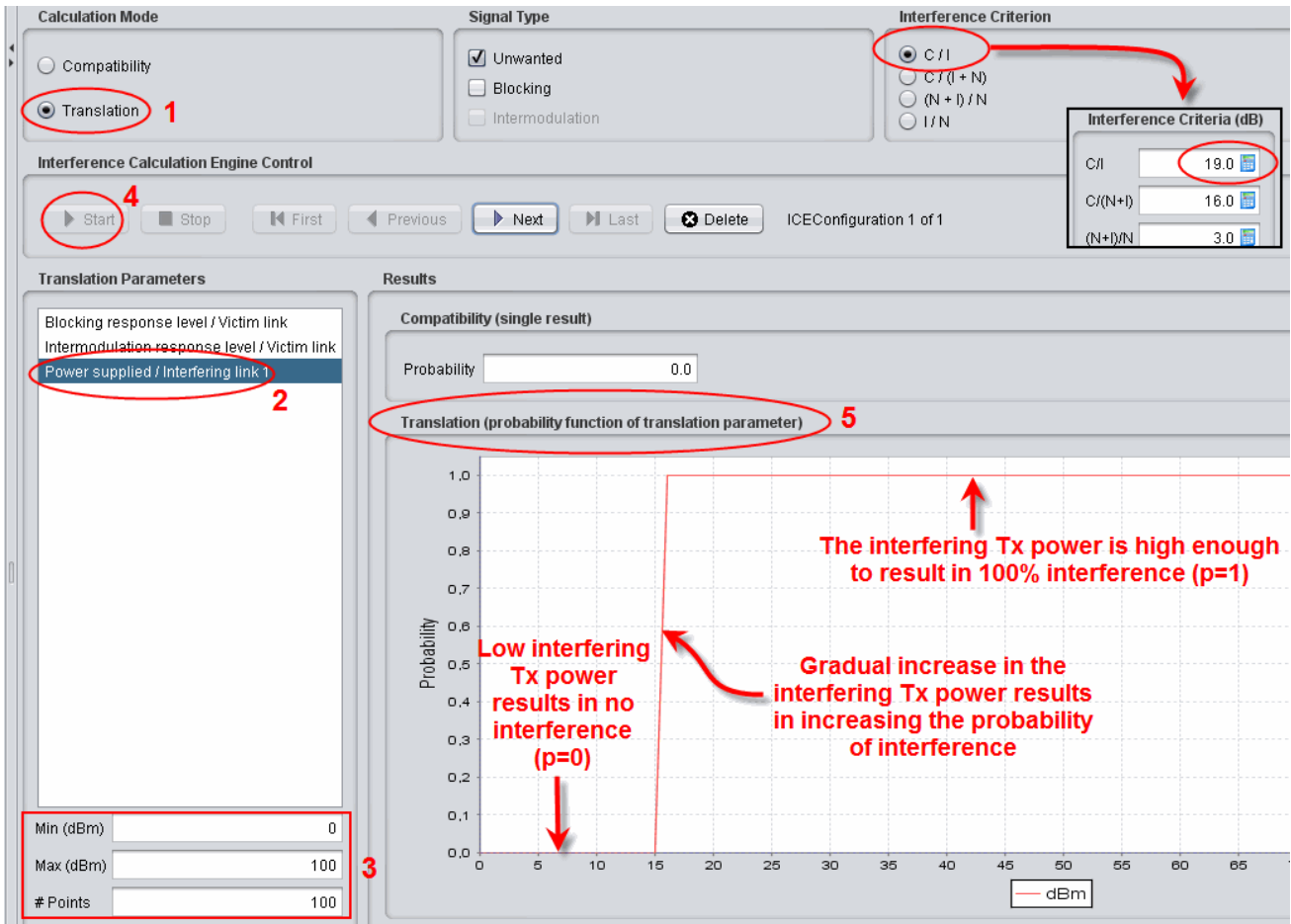
Figure 99: Translation function

3.6.3 Example of probability of interference calculation

You may choose the protection criteria to be used in the calculation of the probability of interference and the type of interference to be considered (unwanted and/or blocking).

Using the **unwanted mode**, it is possible to derive the C/I:

$$dRSS/iRSS_{unwanted} = -53.5- (-77.5) = 24\ dB$$

Since the resulting C/I is above the protection criteria (19 dB), the probability of interference calculated by SEAMCAT (Interference calculation) is equal to 0 (see Figure 100 (a)).

The same conclusion is reached by using the C/(N+I) criteria. It should be noted that SEAMCAT performs a consistency check (ANNEX 19:) between the interference criteria (ANNEX 3:).

It is also possible to derive the (N+I)/N= -77.5-(-100)= 22.5 (since I>>N). Since the (I+N)/N which is obtained is above the protection criteria (3 dB), the probability of interference calculated by SEAMCAT (Interference calculation) is equal to 1 (see Figure 100(b)).

The same conclusion is reached by using the I/N criteria.
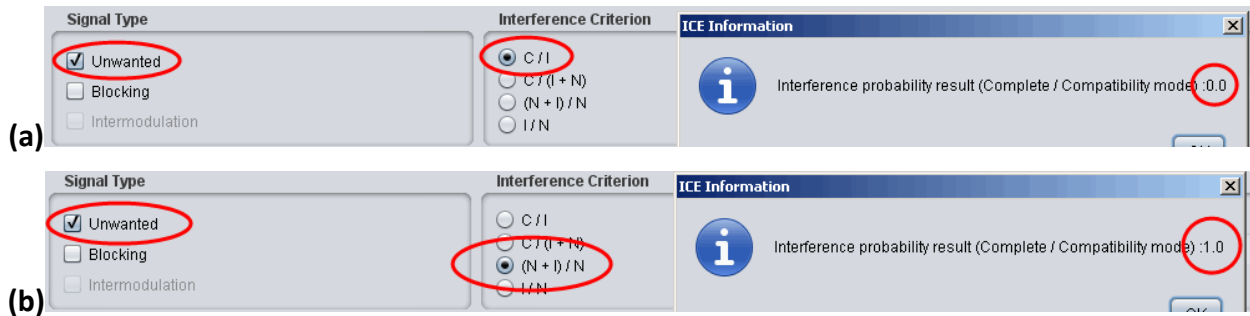
Figure 100: Probability of interference considering the impact of unwanted emissions for (a) C/I and (b) (N+I)/N

Using the blocking interference mode (protection ratio) it is then possible to derive the C/I:

$$dRSS/iRSS_{blocking} = -53.5 - (-113.5) = 60\ dB$$

Since the C/I obtained is above the protection criteria (19 dB), the probability of interference calculated by SEAMCAT (Interference calculation) is equal to 0 (see Figure 101(a)).

It is also possible to derive the (N+I)/N= -113.5-(-100)= -13.5. Since the (N+I)/N which is obtained is below the protection criteria (3 dB), the probability of interference calculated by SEAMCAT (Interference calculation) is equal to 0 (Figure 101(b)).
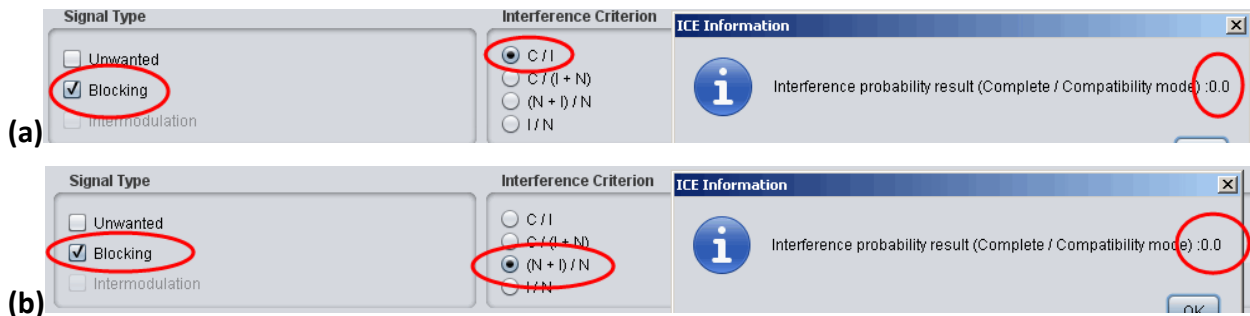
Figure 101: Probability of interference considering the impact of the receiver blocking response for (a) C/I and (b) (N+I)/N

Then, by taking into account the sum of the two signal types, the probability of interference becomes equal to 1 (due to the unwanted emissions) (see Figure 102.

Figure 102: Probability of interference considering the impact of unwanted emissions and the receiver blocking response

4 EXAMPLE OF CALCULATIONS

This section presents examples on how to use SEAMCAT to calculate Interference mechanism described in ANNEX 5:.

4.1 IRSS$_{UNWANTED}$

The following parameters should be changed in the simulation: (i) the interferer operates at 1000.3 MHz and (ii) outside the emission bandwidth, the attenuation is -23 dBc/200 kHz.

The corresponding power may derived using the known equation:

$$P(dBm/Bref)=Pe\ (dBm)+Att(dBc/Bref) \qquad (Eq.\ 20)$$

Then, in this example, outside the emission bandwidth (offset between –0.1 MHz and -1 MHz and between 0.1 MHz and 1 MHz), the power is equal to:

$$P = 33 +(–23(dBc/Bref)) = 10\ (dBm/200\ kHz)$$

The complete unwanted emission mask is provided in Figure 101.
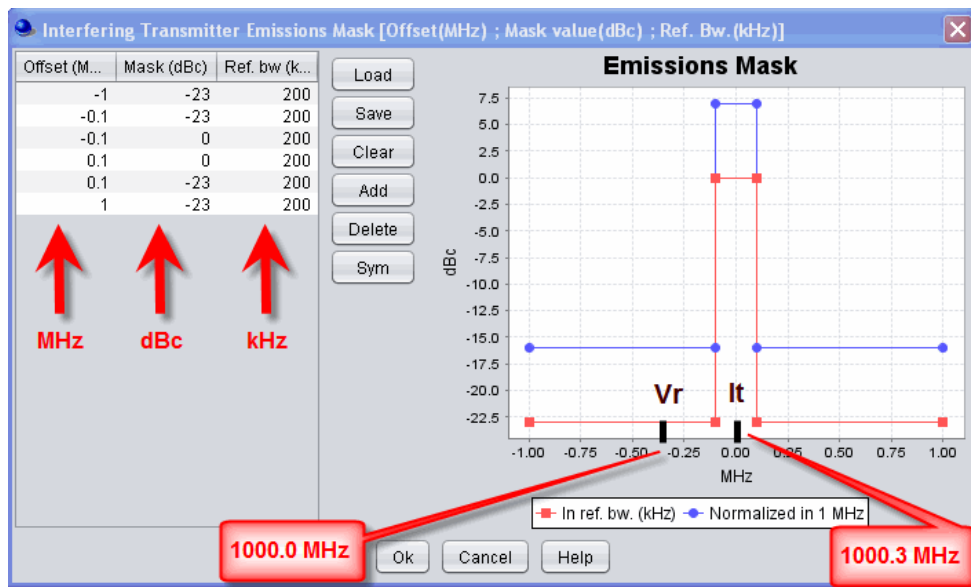
Figure 103: Unwanted emission mask

Using the previous assumptions, it is possible to derive the interfering power received by the Victim link receiver _within its bandwidth_ as described in ANNEX 5: on page 274. This is called the iRSS$_{unwanted}$:

$$iRSS_{unwanted} = P + Ge + Gr - L \qquad (Eq.\ 21)$$

$$iRSS_{unwanted} = 10\ (dBm/200\ kHz) + 11 + 9 - (32.5 + 10\ log(32) + 20\ log(1000))$$

$$iRSS_{unwanted} = -77.5\ dBm$$

This can be checked by running a simulation and displaying the iRSS$_{unwanted}$ signal as depicted in Figure 104.

In this example there is no bandwidth correction factor to be applied to the calculation of the iRSS_{unwanted} since the VLR bandwidth and the ILT reference bandwidth have the same value (i.e. 200 KHz).

Examples of correction bandwidth can be found in section 3.3.8

Figure 104: Mean iRSS_{unwanted}

4.2 IRSS$_{BLOCKING}$

For this exercise, the blocking response from the receiver has a positive sign as shown in Figure 105. Detailed information on the calculation of the iRSS$_{blocking}$ can be found in section A5.2 of ANNEX 5:.
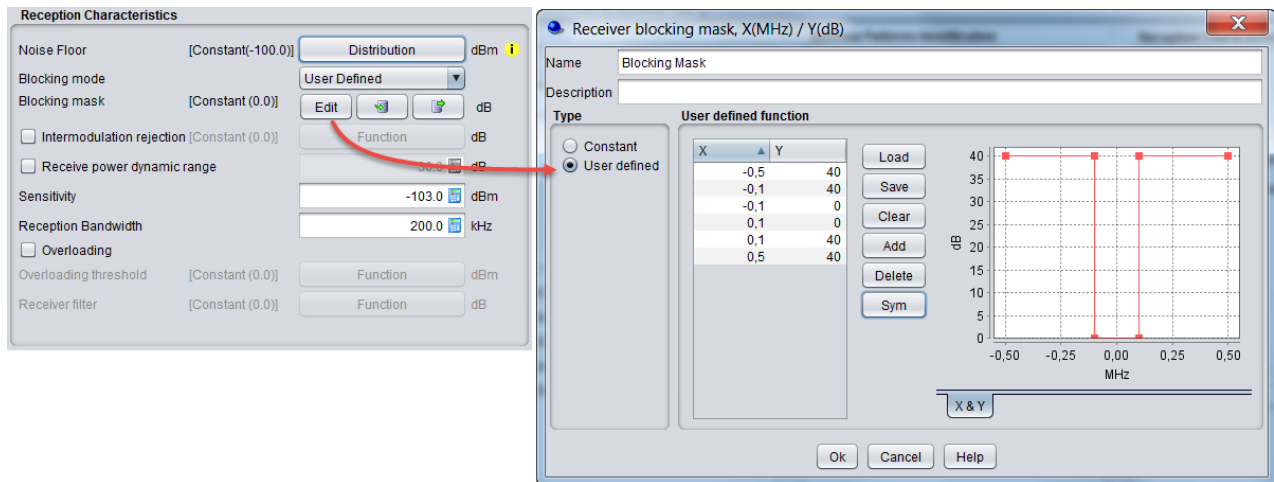
Figure 105:Definition of the receiver blocking response

4.2.1 User-defined mode

In this case, the Blocking is provided in dB and represents the attenuation of the receiver at a given frequency offset (see Figure 12). The resulting receiver attenuation equals the user-defined input values. Then, the iRSS$_{blocking}$ *at the interferer operating frequency* may be calculated as follows.

(**Note**: *The ILT bandwidth is not considered in the iRSS$_{blocking}$ calculation*):

$$iRSS_{blocking} (f_{it}) = Pe + Ge + Gr - L - Att (f_{it}) \qquad (Eq. 22)$$

$$iRSS_{blocking} = 33 \ (dBm) + 11 + 9 - (32.5 + 10 \log(32) + 20 \log(1000)) - 40(dB)$$

$$iRSS_{blocking} = -94.5 \ dBm$$

This can be checked by running a simulation and displaying the iRSS$_{blocking}$ in case of User-defined mode calculated by SEAMCAT. See the figure below.

Figure 106: Mean iRSS_blocking in case of User-defined mode

4.2.2 Sensitivity mode

In this calculation mode the function $block_{Max\ Interf\ Signal}(\Delta f)$ that you entered represents the absolute power level (in dBm) of maximum interfering signal (maximum acceptable interfering power), which might be tolerated by the receiver at a given frequency separation (see Figure 12).

In this case SEAMCAT calculates the receiver attenuation, Attenuation (Δf), to be applied to the interfering signal by using the following expression:

$$Attenuation(\Delta f) = block_{Max\ Interf\ Signal}(\Delta f)\ (dBm) - sens_{VLR}\ (dBm) + C/(N+I)\ (dB) - I/N\ (dB) \qquad (Eq.\ 23)$$

where:

- $\Delta f = (f_{ILT} - f_{VLR})$ is the frequency separation;
- $sens_{VLR}$ is the sensitivity of the VLR (dBm) as defined in the simulation scenario.

To achieve a realistic value, you may define the sensitivity ($sens_{VLR}$) as (see the figure below):

$$Sensitivity = Noise\ Floor + C/(N+I)$$

$$Sensitivity = -110\ dBm + 16 = -94\ dBm$$
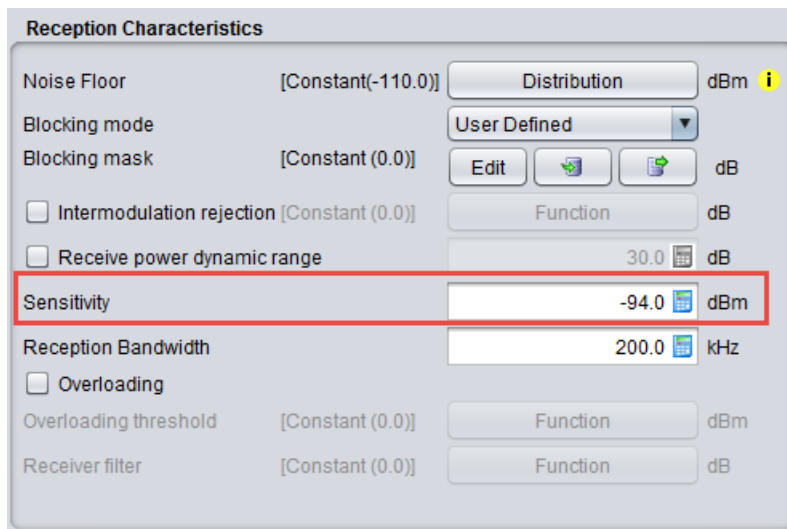
Figure 107: Setting up the sensitivity in SEAMCAT

Then the attenuation may be evaluated:

$$Attenuation\ (\Delta f) = 40 + 94 + 16 - 0 = 150\ dB$$

$$iRSS_{blocking} = Interfering\ Signal\ Level\ (f\ it) = -54.5 - 150 = -204.5\ dBm$$

This can be checked by running a simulation and displaying the iRSS_blocking in case of Sensitivity mode calculated by SEAMCAT see Figure 108.

Figure 108: Mean iRSS$_{blocking}$ in case of Sensitivity mode

4.2.3 Protection ratio

This mode is identical to the "sensitivity" mode since the only difference is that the Blocking value (relative to the noise floor) is provided in dB. The software processes the information using exactly the same method to obtain the value of the receiver attenuation (see Figure 12).

The function *block$_{Protection\ Ratio}$(Δf)* that you entered represents the protection ratio, i.e. the ratio of maximum acceptable level of interfering signal to the wanted signal level, at a given frequency separation.

In this case SEAMCAT calculates the receiver attenuation $a_{VLR}(\Delta f)$ to be applied to the interfering signal by using the following expression (see Figure 109):

$$Attenuation\ (\Delta f) = block_{Protection\ Ratio}(\Delta f)\ (dB) + C/(N+I)\ (dB) + (N+I)/N\ (dB) - I/N\ (dB)\ (Eq.\ 24)$$

$$Attenuation\ (\Delta f\ ) = 40 + 16 + 3 - 0 = 59\ dB$$

$$iRSS_{blocking} = Interfering\ Signal\ Level\ (f\ it\ ) = -54.5 - 59 = -113.5\ dBm$$

Figure 109: Mean iRSS$_{blocking}$ in case of Protection-ratio mode

4.3 IRSS$_{INTERMODULATION}$

The following graphics presents the input paremeters to activate when the intermodulation mechanism is to be investigated. The intermodulation rejection mask is expressed in dB versus frequency offset (MHz). Results details can be found in Section 12.3.3.
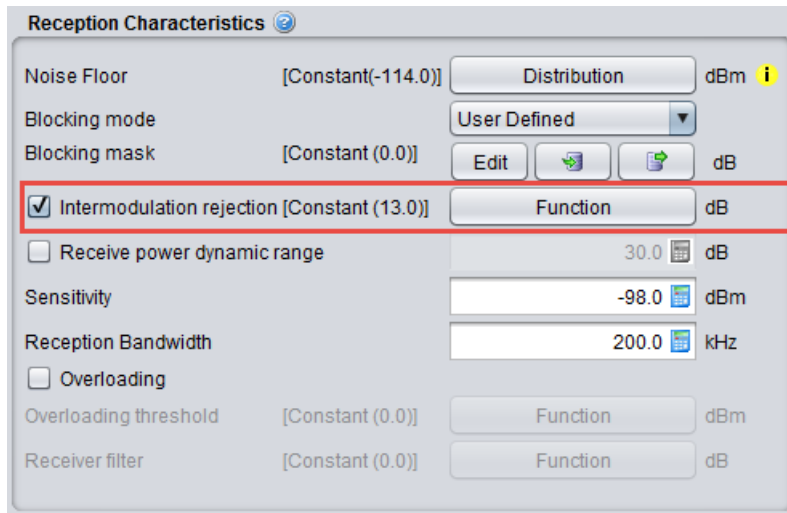
Figure 110: Activation of the intermodulaion feature in SEAMCAT

4.4 IRSS~OVERLAODING~

The following graphics presents the input paremeters to activate when the overloading mechanism is to be simulated.
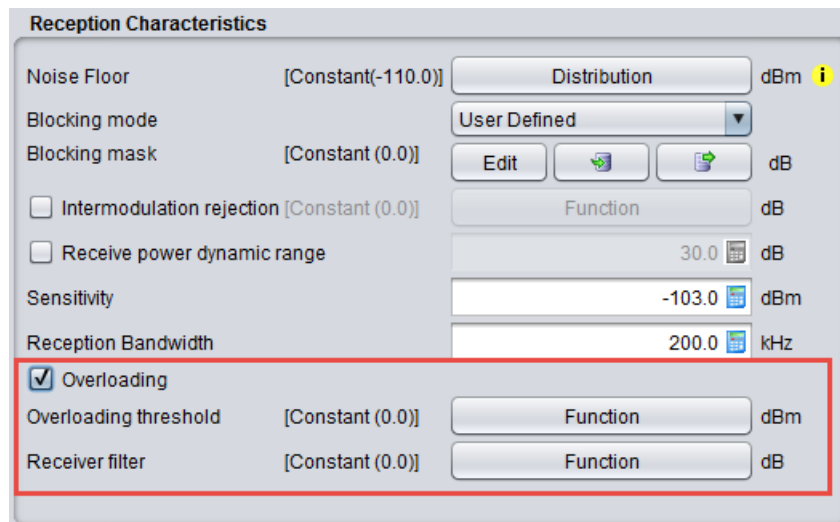
Figure 111: Activation of the overloading feature in SEAMCAT

The overloading mask is expressed in power (dBm) versus frequency offset (MHz) and is defined as a function in SEAMCAT.
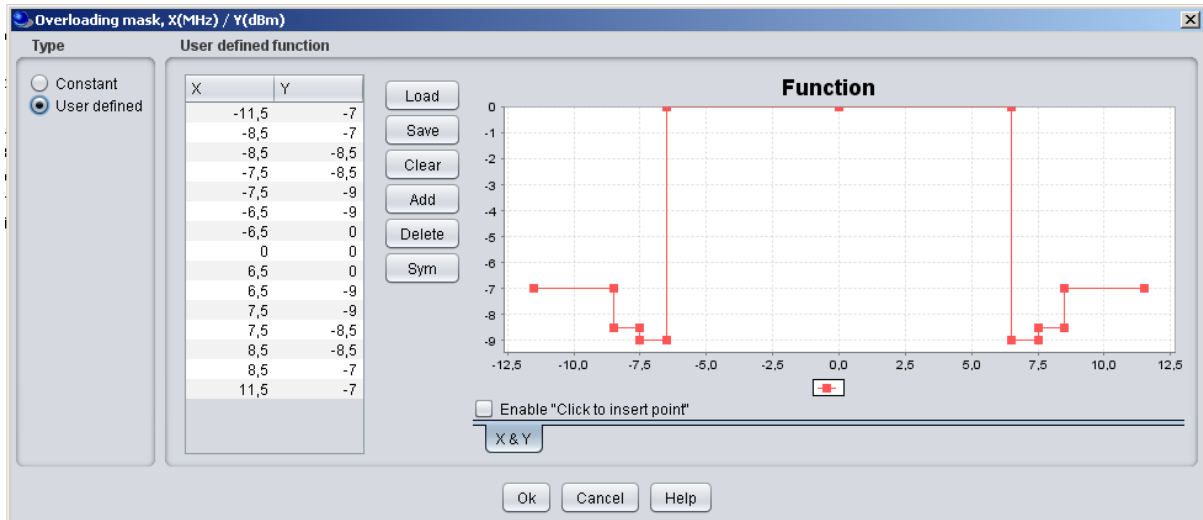
Figure 112: Setting of the overloading mask in SEAMCAT

The filtering of the receiver is expressed in power (dB) versus frequency offset (MHz) and is defined as a function in SEAMCAT (see Figure 113). It is set by default to a constant value of zero.

Note that if the blocking attenuation mode in user-defined and the overloading feature have been selected, then a consistency check will remind you that the actual blocking response and the receiver filter are the same element and they should not be accounted twice.
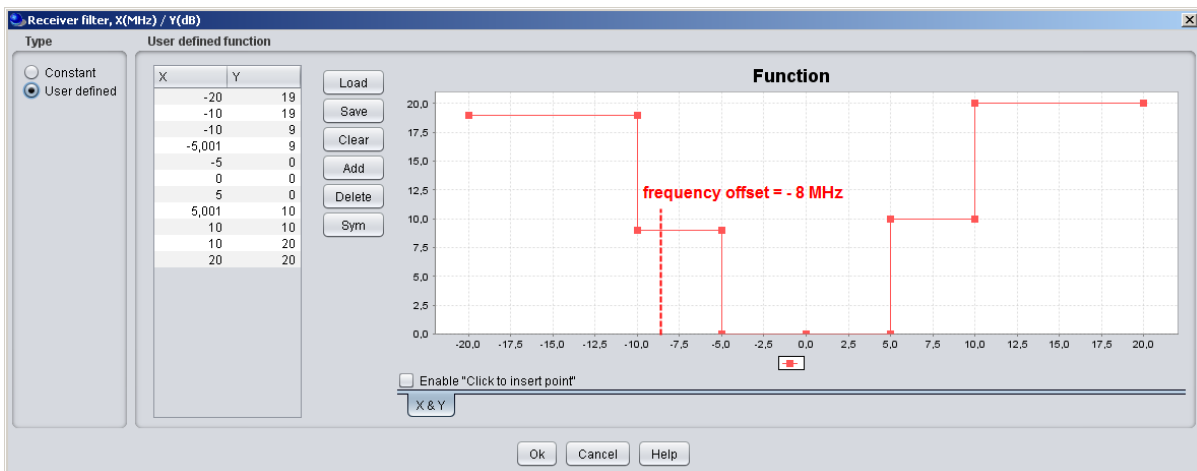
Figure 113: example of filling the Rx filter function

When a simulation is run the following results are extractable (see Section 12.3.4 for further details)

As an example, this means that for the following overloading mask presented in Figure 3 with a victim frequency of 908 MHz and an interfering frequency of 900 MHz, the delta frequency (i.e. frequency offset) is -8 MHz with an overloading treshold of -8.5 dB and a Rx filter value of 9 dB. This can be found from the log file as shown below in Figure 114.

```
(UnwantedInterference.java:308[itvrPropagationLossUnwanted]) - <org.seamcat.propagation.MaTaSE21MODEL> 106.94503255417716 = evaluate(900.0,0.33328590922/2908,1.3
(UnwantedInterference.java:157[itUnwantedEmissions]) - Interfering Transmitter Frequency = 900.0
(UnwantedInterference.java:158[itUnwantedEmissions]) - Victim Receiver Frequency = 908.0
(UnwantedInterference.java:159[itUnwantedEmissions]) - Victim Receiver Bandwidth = 0.2
(UnwantedInterference.java:160[itUnwantedEmissions]) - Relative Unwanted Emission = integrate((vFreq - iFreq), vrBandwidth) = -7.959800173440768 dBc
(BlockingInterference.java:...[itvrPropagationLossBlocking]) - interfering Transmitter power control - non-effective Transmitter power gain = ...
(BlockingInterference.java:...[itvrBudgetBlock]) - Rx receiver attenuation = 0.0
(BlockingInterference.java:...[itvrBudgetBlock]) - Not using power control
(BlockingInterference.java:104[irsSitvrBudgetBlock]) - iRSSValue = -73.94503255417716 = 33.0 + 0.0 - 106.94503255417716 - 0.0 + 0.0
(overloadingInterference.java:125[itvrPathAntGains]) - Interfering Transmitter Frequency = 900.0
(overloadingInterference.java:126[itvrPathAntGains]) - Interference Link - Rx -> Tx Azimuth = 283.2153522531489
(overloadingInterference.java:127[itvrPathAntGains]) - Interference Link - Rx -> Tx Elevation = 0.0
(overloadingInterference.java:128[itvrPathAntGains]) - Interference Link - Tx -> Rx Azimuth = 150.31617757231504
(overloadingInterference.java:129[itvrPathAntGains]) - Interference Link - Tx -> Rx Elevation = 0.0
(overloadingInterference.java:130[itvrPathAntGains]) - Victim Receiver Antenna Peak Gain = 0.0
(overloadingInterference.java:131[itvrPathAntGains]) - Victim Receiver -> Interfering Transmitter Antenna Gain:
(overloadingInterference.java:66[getIRSSOverloading]) - Victim receiver overloading calculations
(overloadingInterference.java:67[getIRSSOverloading]) - Interfering Transmitter power = 33,000000
(overloadingInterference.java:68[getIRSSOverloading]) - Interfering Transmitter -> Victim Receiver Antenna Gain = 0,000000
(overloadingInterference.java:69[getIRSSOverloading]) - Victim Receiver -> Interfering Transmitter Antenna Gain = 0,000000
(overloadingInterference.java:70[getIRSSOverloading]) - Interfering Transmitter -> Victim Receiver Path Loss = 106,945033
(overloadingInterference.java:71[getIRSSOverloading]) - Interfering Transmitter frequency 900,000000
(overloadingInterference.java:72[getIRSSOverloading]) - Delta frequency = -8,000000
(overloadingInterference.java:73[getIRSSOverloading]) - Victim Receiver Filtering = 9,000000          <-- Rx filter
(overloadingInterference.java:93[getIRSSOverloading]) - NOT using power control, iRSSValue = -82,945033 = 33,000000 + 0,000000 - 106,945033 - 9,000000 + 0,000000
(EGE.java:2189[simulateInterference]) - iRSS Unwanted = -81,903833
(EGE.java:2190[simulateInterference]) - iRSS Blocking = -73,945033
(EGE.java:2192[simulateInterference]) - iRSS Overloading = -82,945033
(EGE.java:690[notifyPositionListenersInterferingTransmitter]) - Interfering Transmitter position: (2.4651808222276714,0.2524286328681324)
(EGE.java:708[notifyPositionListenerswantedReceiver]) - wanted Receiver position: (-0.5639896071043968,4.399520845643726)
(EGE.java:2263[simulateInterference]) - Processed interferer #0
(EGE.java:2264[simulateInterference]) - *********************************************          frequency offset        overloading threshold
(EGE.java:2293[simulateInterference]) - Doing overloading summation
(EGE.java:2374[simulateInterference]) - There is 1 transmitter, using single iTx-mode
(EGE.java:2375[simulateInterference]) - rSum = -74,445033 (freq=900,000000, dFreq=-8,000000, iRSSO=-82,945033, oth=-8,500000)
```

<p align="center">Figure 114: Output from logfile</p>

4.5 COVERAGE RADIUS (VLR-VLT)

In this section the Free Space Model is used to derive the attenuation on the different paths and the Victim Link and Interfering Link operate at the same frequency – 1000 MHz – co-channel interference. Figure 115 presents an illustration of the various radii (i.e. coverage radius and simulation radius) that are used in SEAMCAT and with reference to the various pairs of transmitters and receivers used for a simulation.
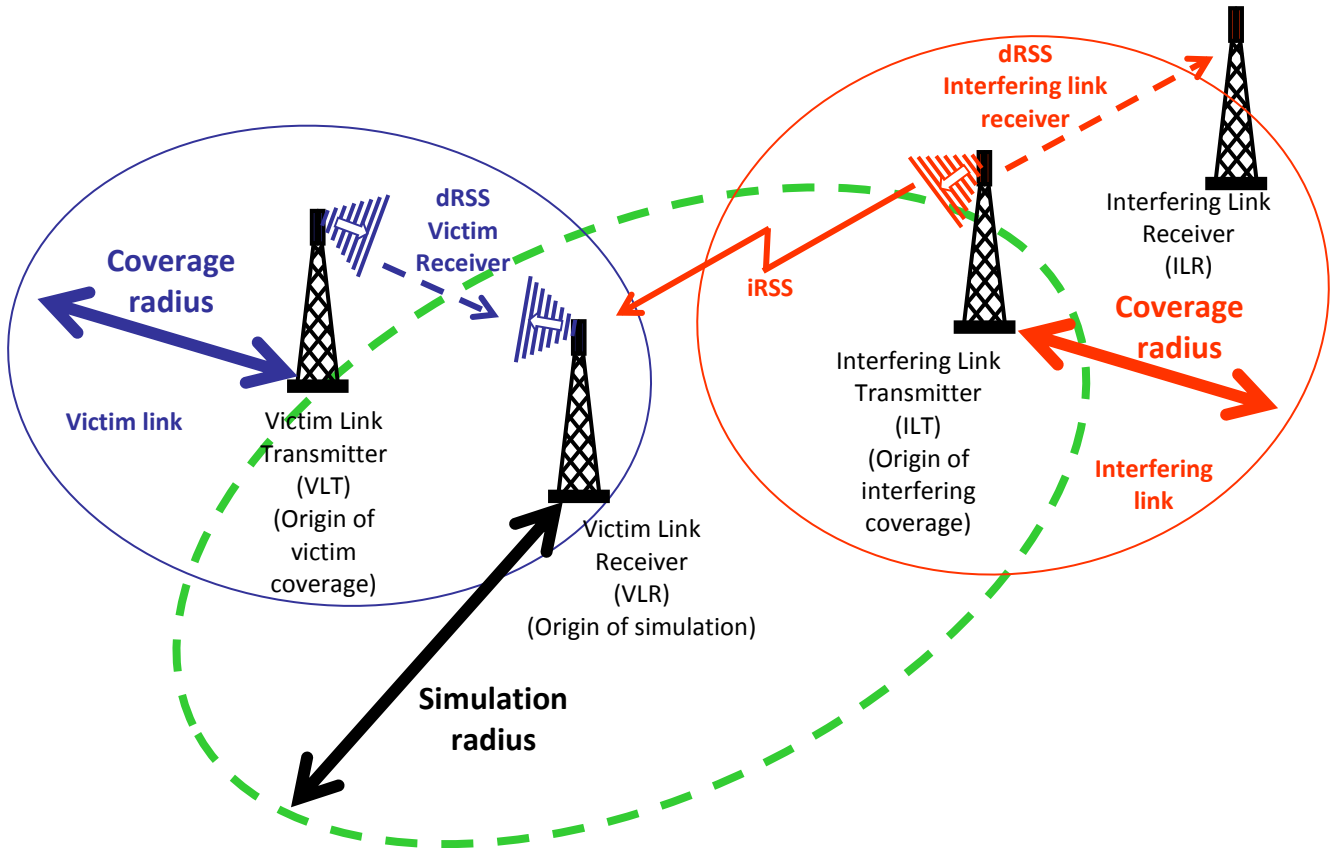
Figure 115: Illustration of the Coverage Radius and the Simulation Radius with respect to the pairs of transmitters and receivers of the victim and interfering links

The distance between the VLT and the VLR is referred to as the **coverage radius (R_{max}^{wt})** (see ANNEX 13:**)**.

In the case of mobile applications, the number of terminals that may transmit in a given cell of the network is given by:

$$n = dens_{max}. \pi \left(R_{max}^{wt} \right)^2 = \frac{n_{channels}. n_{userperchannel}}{cluster_{frequency}}$$ (Eq. 25)

The calculation of the coverage radius can be found in ANNEX 13:.

The cluster characterises the frequency re-use of a mobile network (see Figure 116).
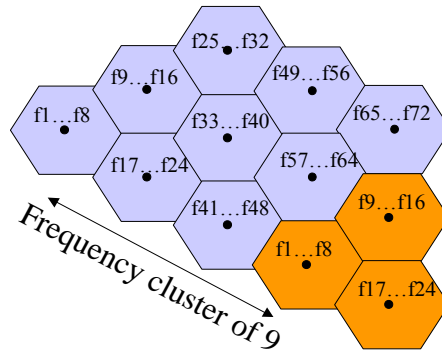
Figure 116: Frequency cluster

The victim link coverage radius (i.e. centred on the victim link transmitter) may then be calculated by using the formula below. Figure 117´presents how to set-up SEAMCAT.

$$R_{max}^{wt} = \sqrt{\frac{n_{channels} \, n_{userperchannel}}{\pi \, dens_{max} cluster_{frequency}}}$$ (Eq. 26)
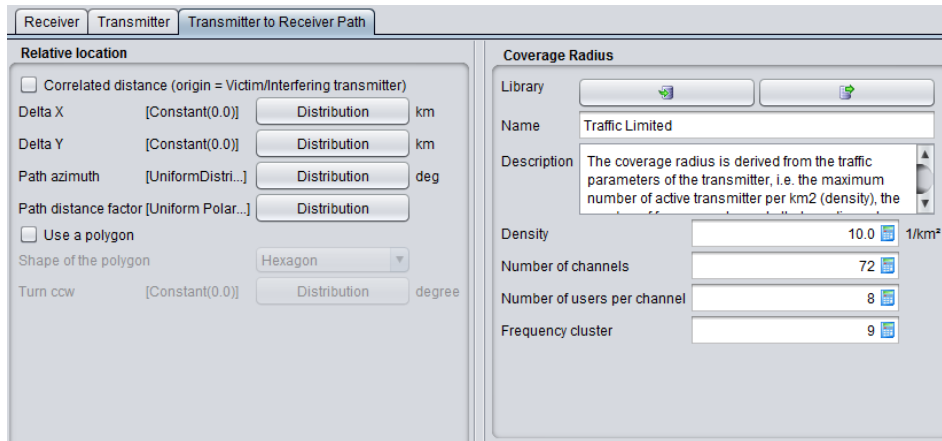
Figure 117: Calculation of the victim link coverage radius

$$R_{max}^{wt} = \sqrt{\frac{72 \times 8}{\pi \times 10 \times 9}} = 1.42 \text{ km}$$ (Eq. 27)

Figure 119 presents the results of the dRSS vector and the results in the coverage radius of the victim link.

The dRSS for a receiver located at the edge of the coverage area may be calculated:

dRSS = 30 (dBm) + 9 + 9 - (32.5 + 10 log(1.43^2) + 20 log(1000)) = -47.5 dBm
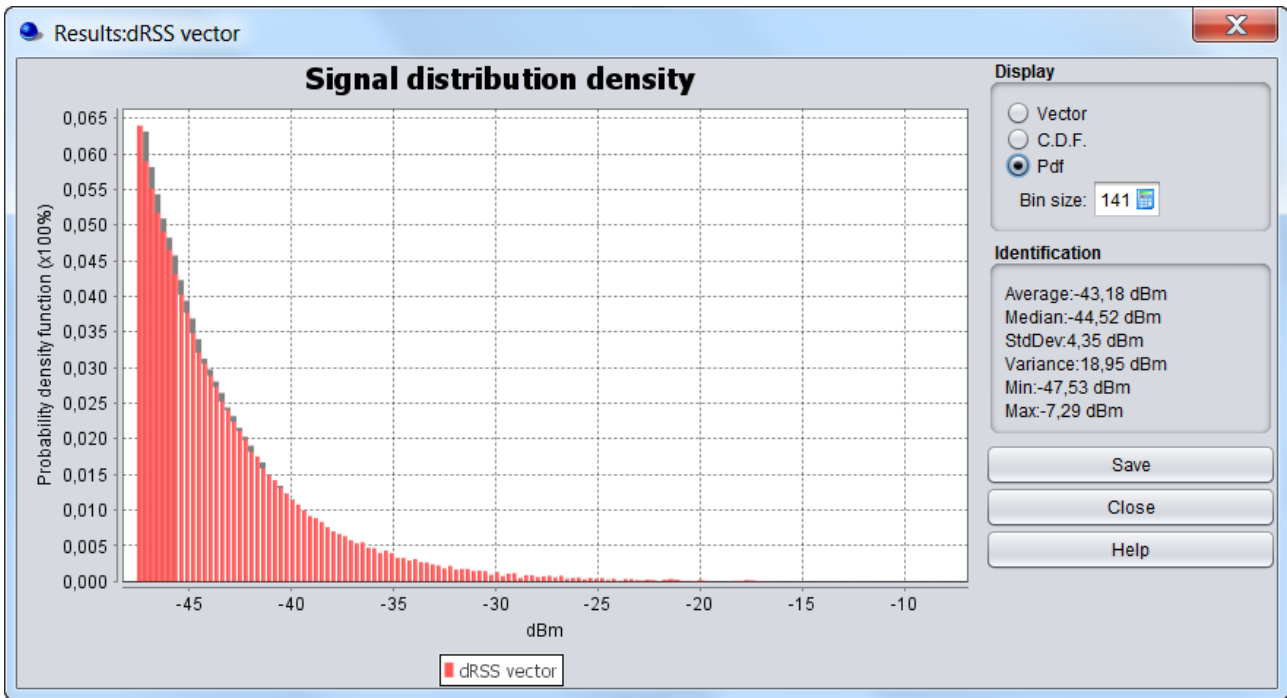
Figure 118: Resulting dRSS distribution

Figure 119: Calculation results of the victim link coverage radius
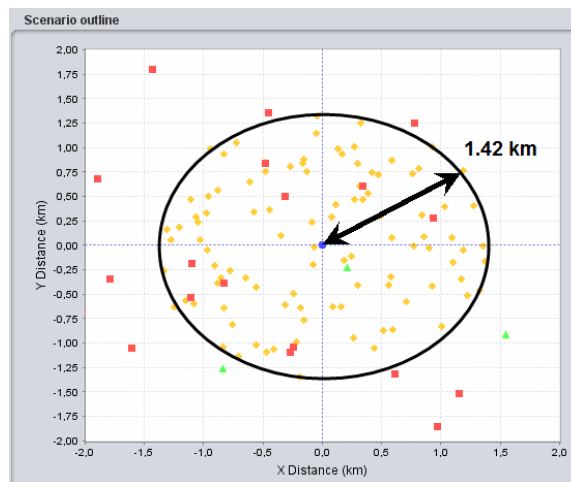
Figure 120: Illustration of the VLR and VLT positioning based on the traffic limited network coverage radius (ILT-red, ILR-green, VLR-yellow, VLT-blue)

4.6 SIMULATION RADIUS (ILT-VLR)

The distance between the Victim link receiver and the Interefering link transmitter is referred to as the **simulation radius** (see ANNEX 13:**)**. It can be defined as shown in Figure 121.
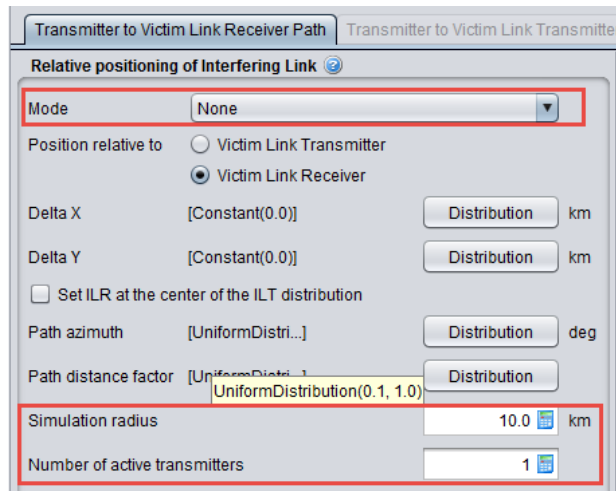
Figure 121: Definition of the minimum distance

Using this feature, the interefering link transmitter is located between 1 km (0.1 x 10 km) and 10 km (1 x 10 km) from the Victim link receiver as shown in the SEAMCAT display in Figure 122.
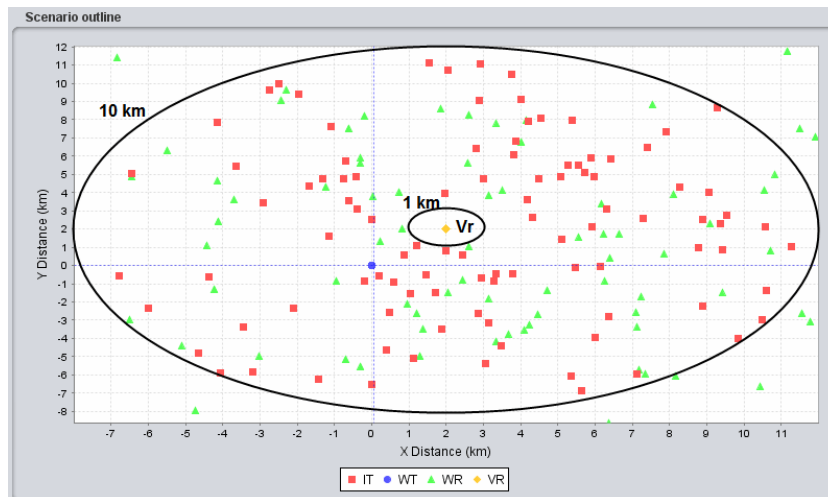
Figure 122: SEAMCAT display of the minimum distance (ILT-red, ILR-green, VLR-yellow, VLT-blue)

If the interefering link transmitter is located at 10 km, it is possible to derive the iRSS$_{unwanted}$:

$$iRSS_{unwanted} = 33 \ (dBm) + 11 + 9 - (32.5 + 10 \ log(10 \ x \ 10) + 20 \ log(1000))$$

$$iRSS_{unwanted} = 53 - 32.5 = 20.5 - 60 - 20 = \textbf{-59.5} \ dBm$$

If the interefering link transmitter is located at 1 km:

$$iRSS_{unwanted} = 33 \ (dBm) + 11 + 9 - (32.5 + 10 \ log(1) + 20 \ log(1000))$$

$$iRSS_{unwanted} = 53 - 32.5 = 20.5 - 60 = \textbf{-39.5} \ dBm$$

The iRSS$_{unwanted}$ extends from -59.5 dBm to -39.5 dBm as confirmed by Figure 123.
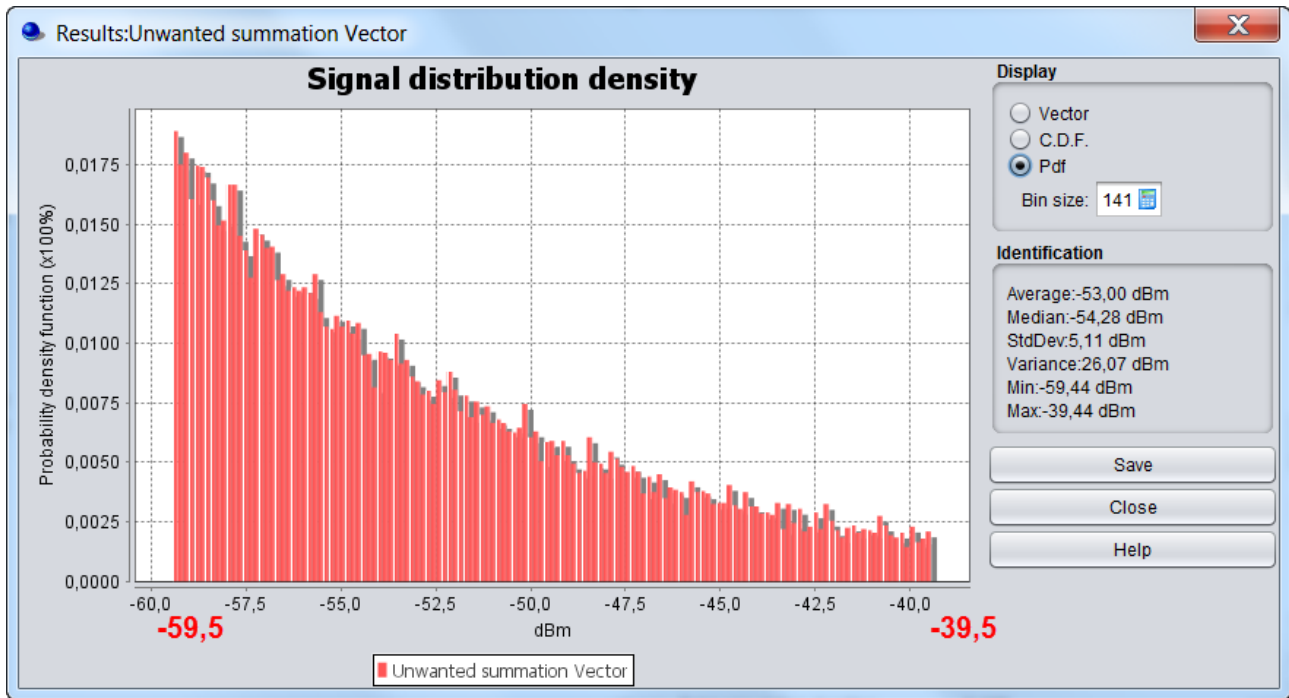
Figure 123: iRSS_unwanted

4.7 UNIFORM DISTRIBUTION OF ILT VS VLR

You may define a uniform deployment density of terminals/transmitters per km^2 (see ANNEX 13:**).** This can either be done by using the "**Uniform Density" mode** combined with the calculation of a simulation radius as described in section 4.7.1 and A13.2 or by using the "**none" mode** combined with the choice of uniform path polar distance as described in section 4.7.2.

4.7.1 Uniform density mode - simulation radius calculation

The number of active transmitters that will be uniformly located within the simulation radius is given by:

$$n_{active} = dens_{transmitter} . prob_{transmission} . \pi \left(R_{simulation} \right)^2 \qquad \text{(Eq. 28)}$$

Figure 124 presents the GUI with the input value.
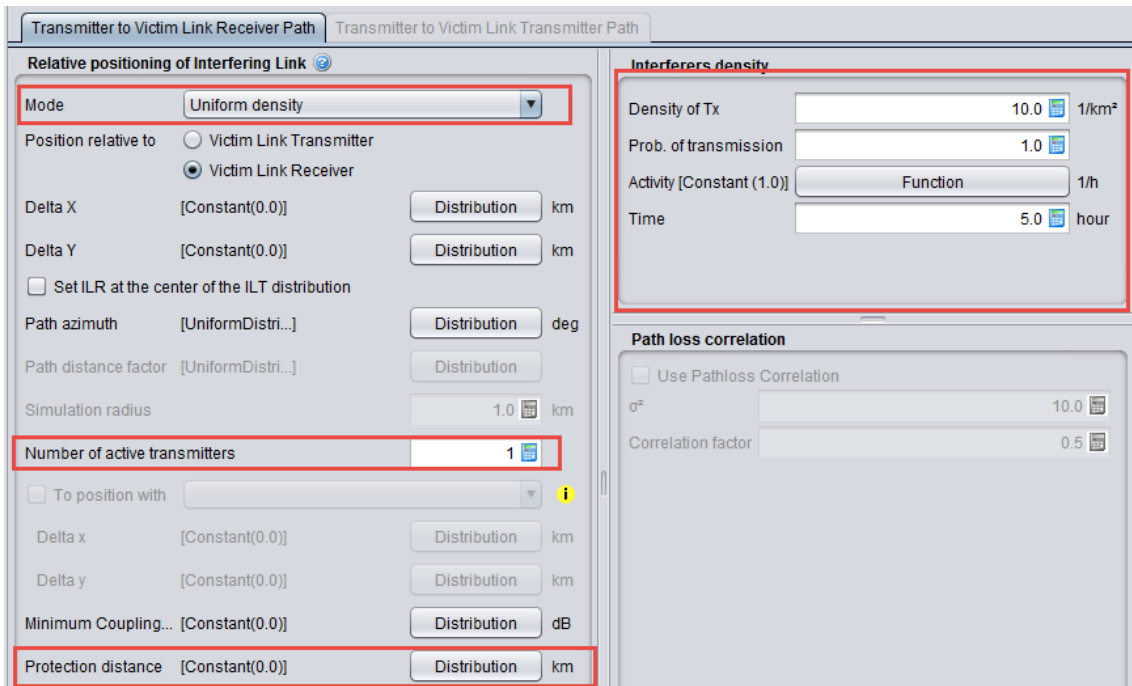
Figure 124: Setting up the simulation radius in SEAMCAT
(Note that the results of the simulation radius is displayed only after running simulation)

The simulation radius is calculated by using the following formula:

$$R_{simu} = \sqrt{\frac{n_{active}}{\pi\, dens_{it}^{active}.prob_{transmission}}}$$

(Eq. 29)

In the example of Figure 124, this gives:

$$R_{simu} = \sqrt{\frac{1}{\pi \times 10 \times 1}} = 0.178 \text{ km}$$
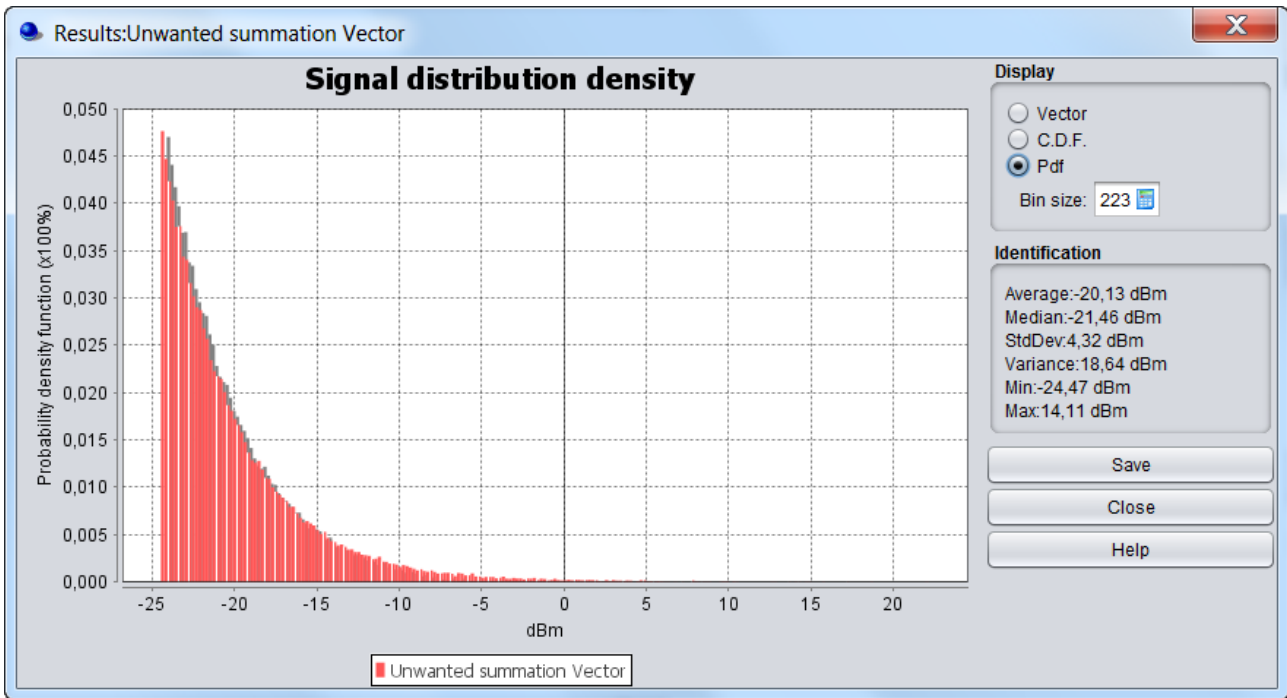
Figure 125: iRSS using the simulation radius for 1 active transmitter (R=0.178)

Figure 126: Calculated simulation radius with 1 active transmitter

Then for a ***single*** interefering link transmitter located at the edge of the simulation radius (R = 0.178 km), the iRSS$_{unwanted}$ may be calculated:

$$iRSS_{unwanted} = 33 \text{ (dBm)} + 11 + 9 - (32.5 + 10 \log(0.178^2) + 20 \log(1000)) = -24.5 \text{dBm}$$

When increasing the number of active transmitters to 10 (see Figure 127), the simulation radius becomes:

$$R_{simu} = \sqrt{\frac{10}{\pi \times 10 \times 1}} = 0.564 \text{ km}$$

Then, for a ***single*** interefering link transmitter located at the edge of that simulation radius (R = 0.564 km), the iRSS$_{unwanted}$ resulting from this terminal may be calculated as:

iRSS$_{unwanted}$ = 33 (dBm) + 11 + 9 - (32.5 + 10 log(0.564^2) + 20 log(1000)) = -34.5dBm

If 10 active terminals are located at the edge of the simulation radius, the iRSS$_{unwanted}$ may be calculated in the following way:

$$iRSS_{unwanted} = -34.6 \text{ (dBm)} + 10 \log(10) = -24.5 \text{ dBm}$$

Then the iRSS$_{unwanted}$ should be above -24.5 dBm as shown on Figure 128.
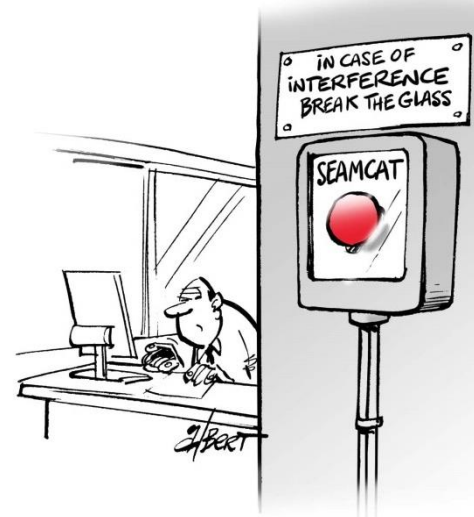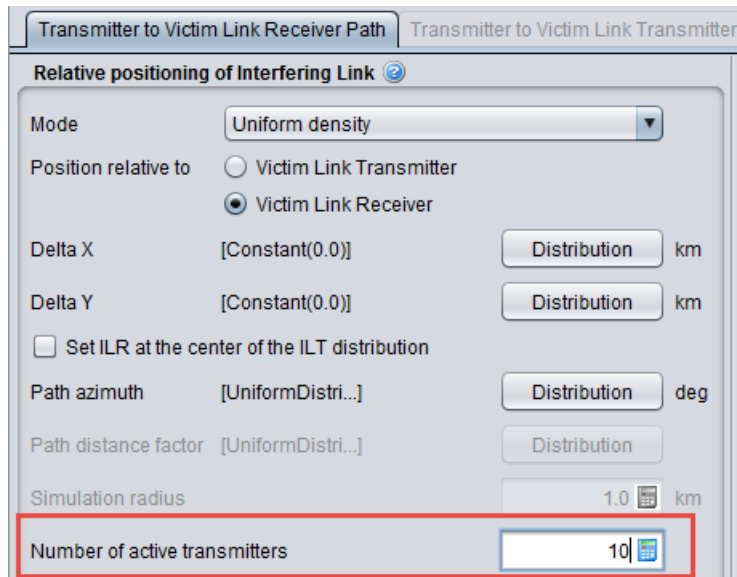
Figure 127: Setting up the simulation radius in SEAMCAT with a different number of active transmitters
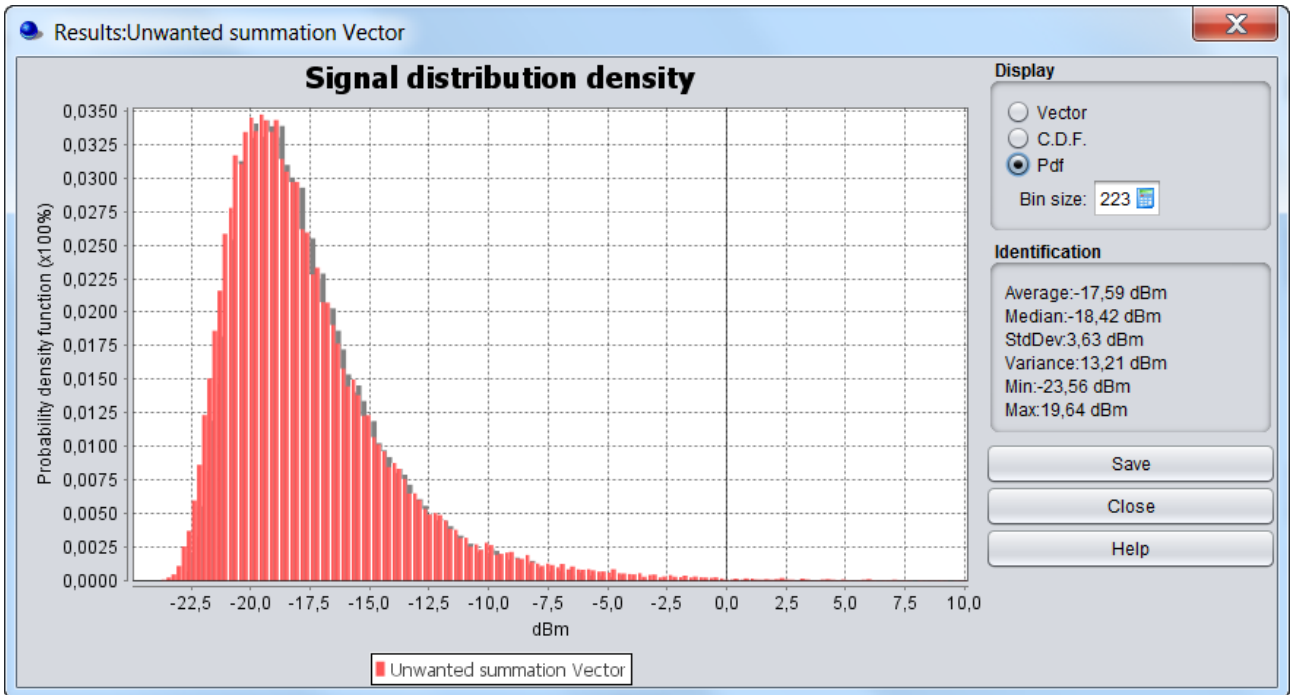
Figure 128: iRSS using the simulation radius calculated for 10 active interferers (R=0.564 km)

Figure 129: Calculated simulation radius with 10 active transmitters

4.7.2 "None" mode

When you select the "**None**" **mode** (see ANNEX 13:**)**, he can also define a Uniform density of terminal/transmitter by using the Uniform polar distance defined within the path distance factor and a uniform distributed path azimuth (0 to 360 deg).**Uniform polar distance** leads to uniformly distributed terminals in the **circular area** (area) and the **Uniform distance** leads to uniformly distributed terminals along the **radius** (line).

Then using a user-defined radius of 0.178 km and 1 interefering link transmitter (see Figure 130), it is possible to reproduce the results of section 4.7.1. Therefore, the same results as those given in Figure 125 are found as shown in Figure 131.

Figure 130: Uniform density using "None" mode
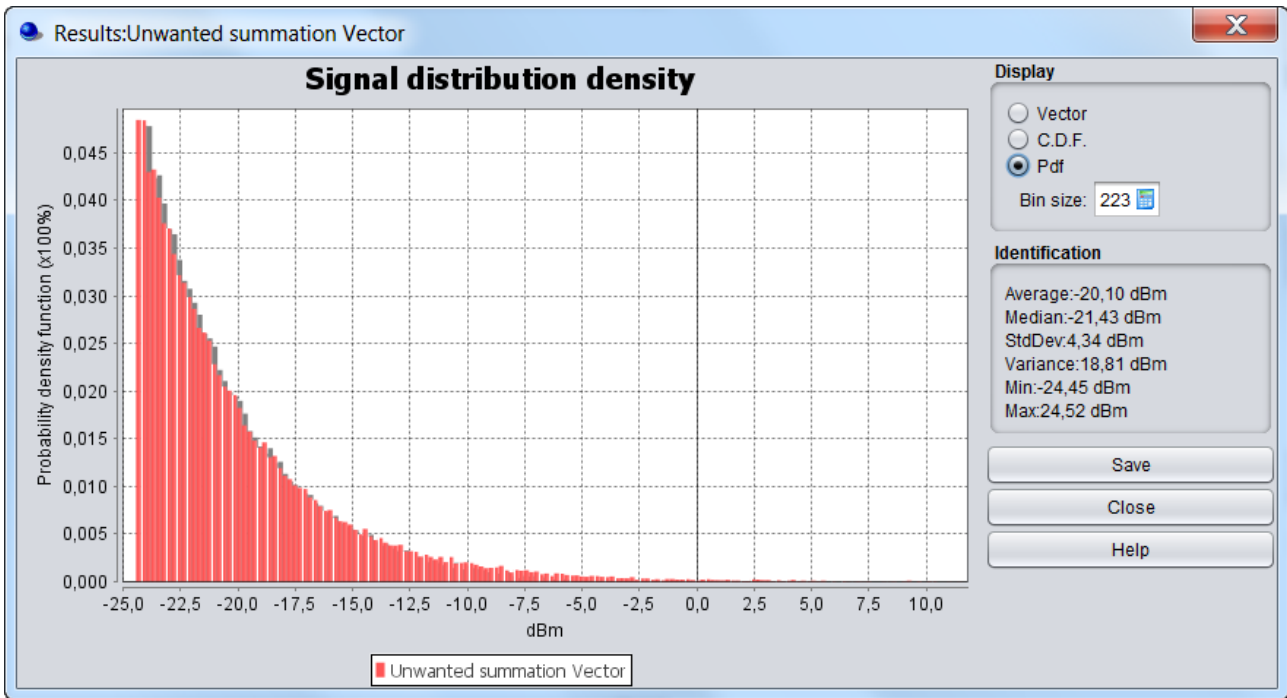
Figure 131: iRSS_unwanted / Uniform polar feature / 1 interefering link transmitter and simulation radius of 0.178 km (same results as in Figure 125)

Using a user-defined radius of 0.564 km and 10 interefering link transmitters, the same results as those given in Figure 128 are reached as shown in Figure 132.
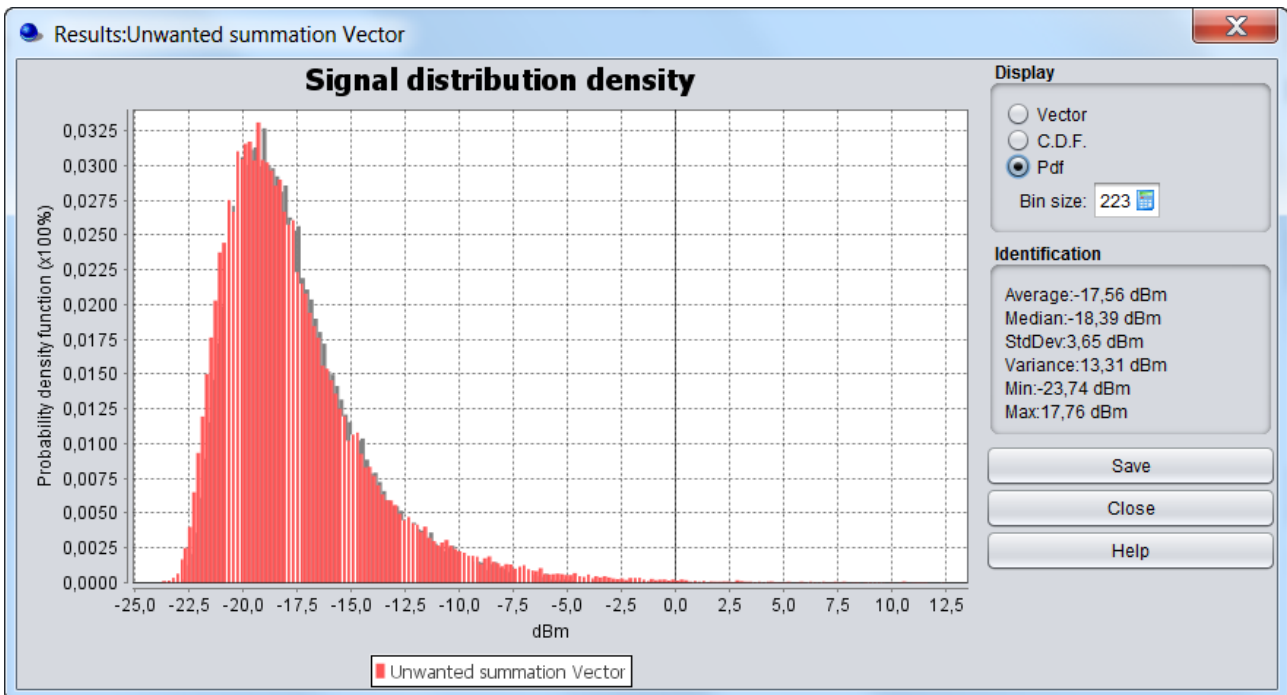
Figure 132: iRSS_unwanted / Uniform polar feature / 10 interefering link transmitter (same results as in Figure 125)

4.8 PROTECTION DISTANCE

If a minimum protection distance (d_0) between the victim link receiver and interefering link transmitter is introduced then the simulation radius may then be calculated by using the following formula:

$$R_{simu} = \sqrt{\frac{n^{active}}{\pi \times dens_{it}^{active} \, prob_{transmission}} + d_0^2} \qquad (Eq.\ 30)$$

Note: The calculation of the iRSS at each trial will be performed only if the location of the ILT satisfies the following condition $d_{it \rightarrow vr} \geq d_0$.

Figure 133 presents how to set-up SEAMCAT (See also A13.2 for further details).
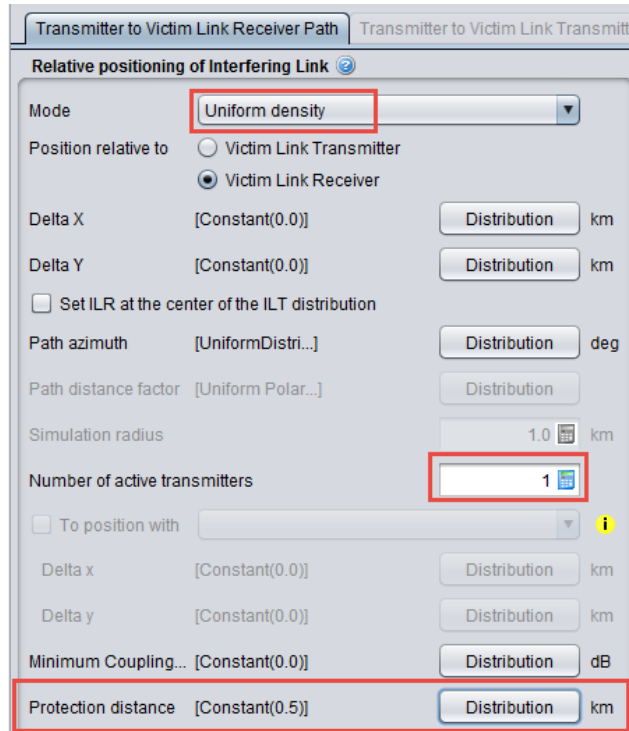
Figure 133: Setting up the protection distance related to the simulation radius with 1 active interferer

The simulation radius (see Figure 135) may then be calculated by using the following formula:

$$R_{simu} = \sqrt{\frac{1}{\pi \times 10} + (0.5)^2} = 0.531 \text{ km}$$

Figure 134: Calculated simulated radius
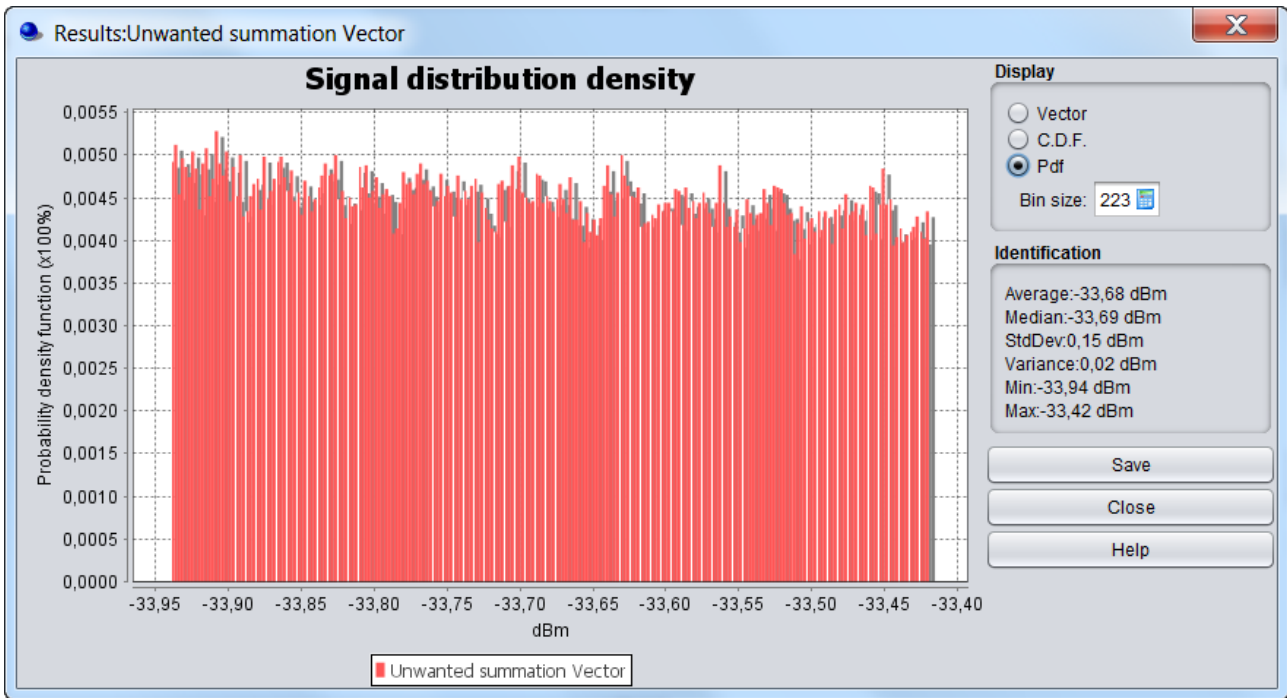
Figure 135: Calculation of the simulation radius and the iRSS$_{unwanted}$ using the protection distance
(*for 1 active interferer*)

If the distance between the VLR and the ILT is equal to the protection distance (0.5 km), then:

$$iRSS_{unwanted} = 33 \ (dBm) + 11 + 9 - (32.5 + 10 \ log(0.5 \ x \ 0.5) + 20 \ log(1000)) = -33.5 dBm$$

If the distance between the VLR and the ILT is equal to the simulation radius (0.531 km), then:

$$iRSS_{unwanted} = 33 \ (dBm) + 11 + 9 - (32.5 + 10 \ log(0.531 \ x \ 0.531) + 20 \ log(1000)) = -34 \ dBm$$

These results are in line with those depicted on Figure 135. We can then increase the number of active transmitters to 10 as shown in Figure 136.
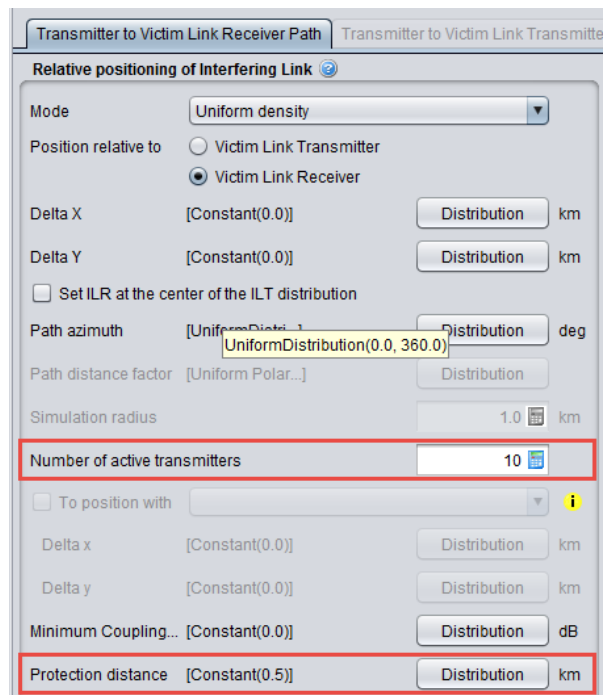
Figure 136: Setting up the protection distance related to the simulation radius with 10 active interferer

The simulation radius may then be calculated by using the following formula (see Figure 137 for the result):

$$R_{simu} = \sqrt{\frac{10}{\pi \times 10} + .5 \times 0.5} = 0.75 \ km$$
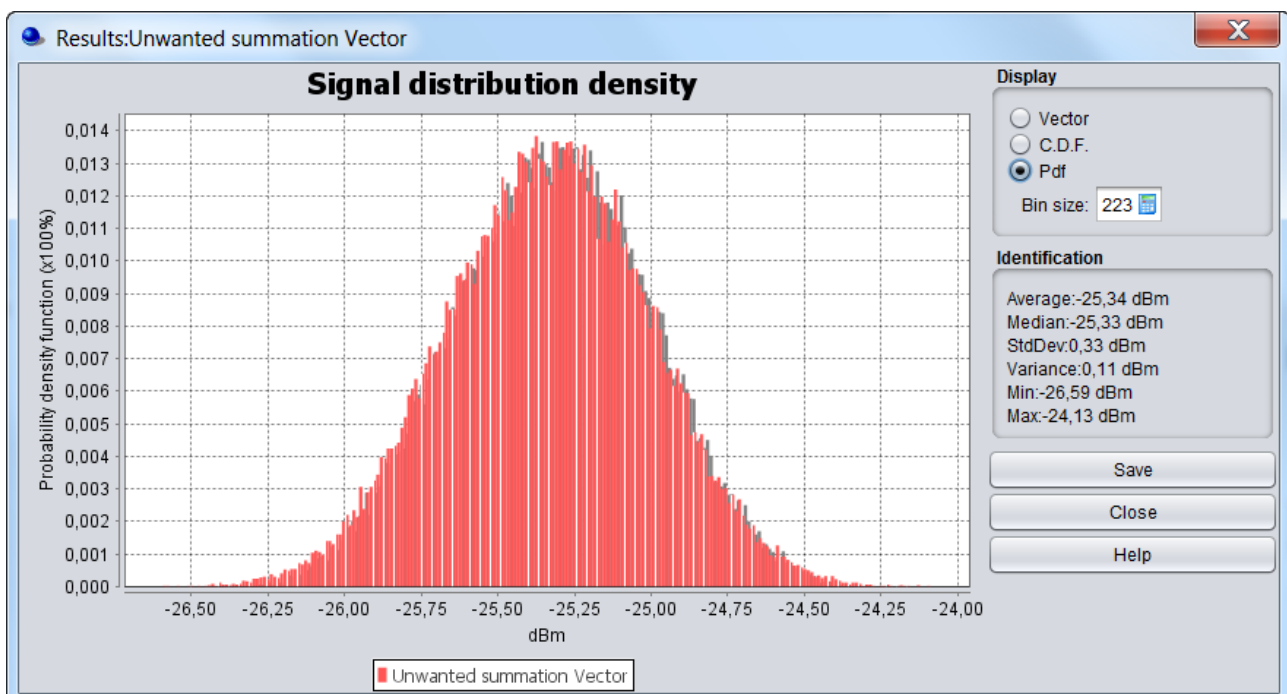
Figure 137: Calculation of the R_{simu} and the $iRSS_{unwanted}$ using the protection distance (*for 10 active interferer*)

If the distance between the VLR and a single ILT is equal to the protection distance, then:

$$iRSS_{unwanted} = 33\ (dBm) + 11 + 9 - (32.5 + 10\ log(0.5 \times 0.5) + 20\ log(1000)) = -33.5\ dBm$$

If the distance between the VLR and a single ILT is equal to the simulation radius, then:

$$iRSS_{unwanted} = 33\ (dBm) + 11 + 9 - (32.5 + 10\ log(0.75 \times 0.75) + 20\ log(1000)) = -37\ dBm$$

If 10 transmitters are deployed around the VLR then:

$$iRSS_{unwanted} = -37\ (dBm) + 10\ log(10) = -27\ dBm\ and\ iRSS_{unwanted} = -33.5\ (dBm) + 10\ log(10) = -23.5\ dBm$$

$$-27\ dBm < iRSS_{unwanted} < -23.5\ dBm\ (see\ Figure\ 137)$$

4.9 POWER CONTROL

Note: The power control is used only in this section. When considering other sections, the power control feature should be deactivated.

A power control feature is implemented within SEAMCAT. When this feature is activated it introduces a variation of the interefering link transmitter power. More details on the implementation of the power control in SEAMCAT is presented in ANNEX 14:.

When using the scenario provided in section 3 (Victim Link and Interfering Link operate at the same frequency 1000 MHz but with a interfering link receiver antenna gain should be equal to 11 dBi), it becomes possible to define the distance between the Victim link receiver and the Interefering link transmitter.

For simplification, we consider that the Victim link receiver and the Interefering link transmitter are defined using the following assumptions (1 km distance between the Victim and the Interefering link transmitter). This is illustrated in Figure 138.
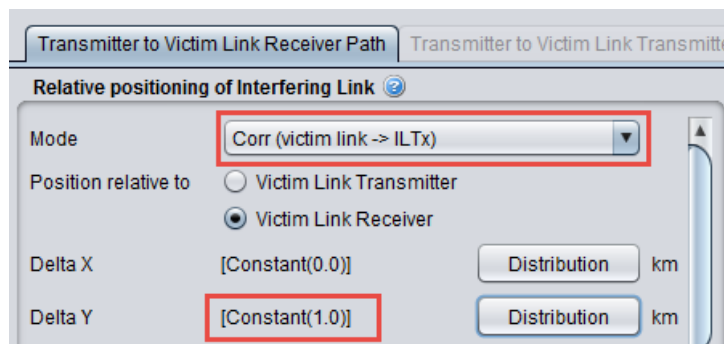
Figure 138: Setting up the distance between the Interfering and the Victim pair of transmitter and receiver

If the power control is not activated then the iRSS_unwanted is (see Figure 139):

$$iRSS_{unwanted} = 33\ (dBm) + 11 + 9 - (32.5 + 10\ log(1) + 20\ log(1000)) = -39.5\ dBm$$
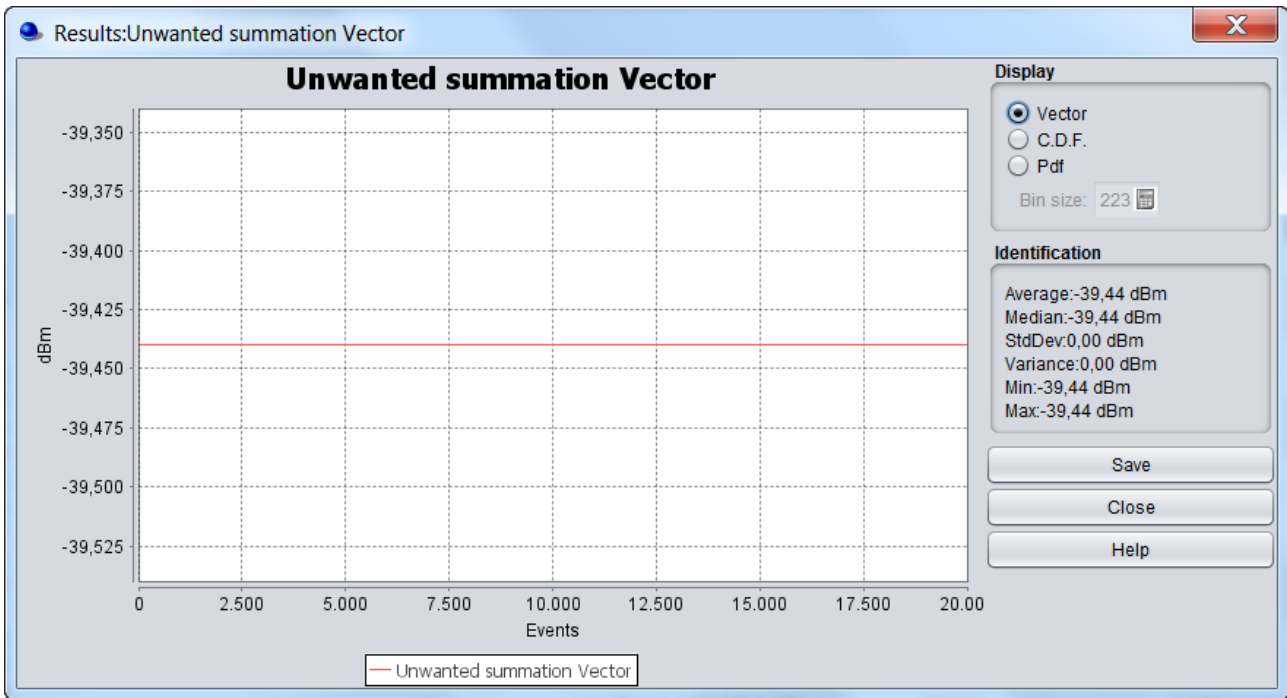
Figure 139: iRSS_unwanted without power control

The same assumption is used for the distance between ILT and the ILR (i.e. x = 0 km and y = 1 km) where the ILT is the (0,0) origin as shown in Figure 140.
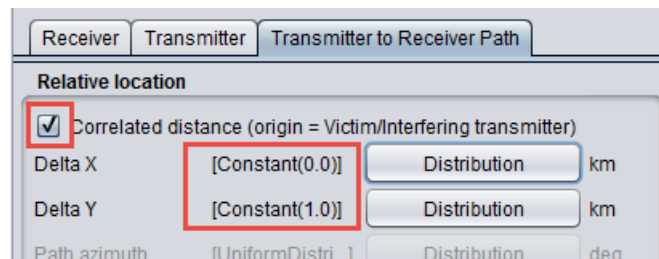
Figure 140: Setting up the distance between the Interefering link transmitter and the Interfering link receiver to evaluate the dRSS_Interfering link receiver.

The power received by the Interfering link receiver (dRSS_Interfering link receiver) is then:

$$dRSS_{Interfering\ link\ receiver} = 33\ (dBm) + 11 + 11 - (32.5 + 10\ \log(1) + 20\ \log(1000)) = -37.5\ dBm$$

You should not confuse the dRSS_Interfering link receiver and the dRSS_Victim link receiver. Figure 115 illustrates their differences.

The power control can be input as shown in Figure 141.
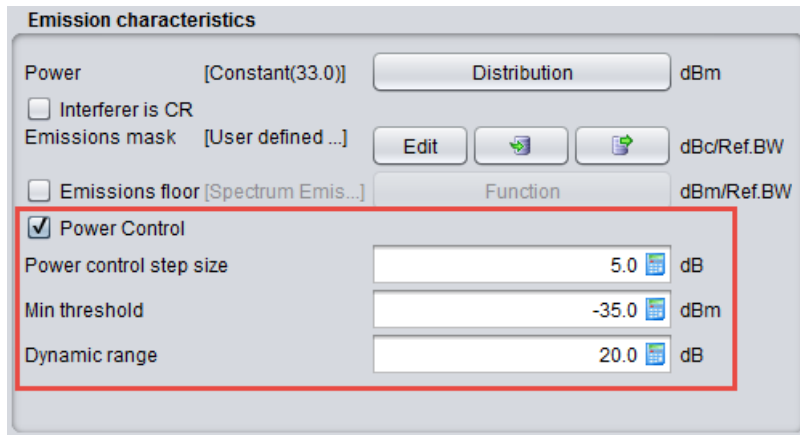
Figure 141: Setting up the power control for the interfering link.

Using these assumptions, the results of the simulation are the same as previously since the threshold (-35 dBm) is above the dRSS$_{\text{Interfering link receiver}}$(-37.5 dB). This corresponds to the Case 1 described in ANNEX 14:.

Now, if the threshold is decreased from –35 dBm to –50 dBm (see Figure 142)
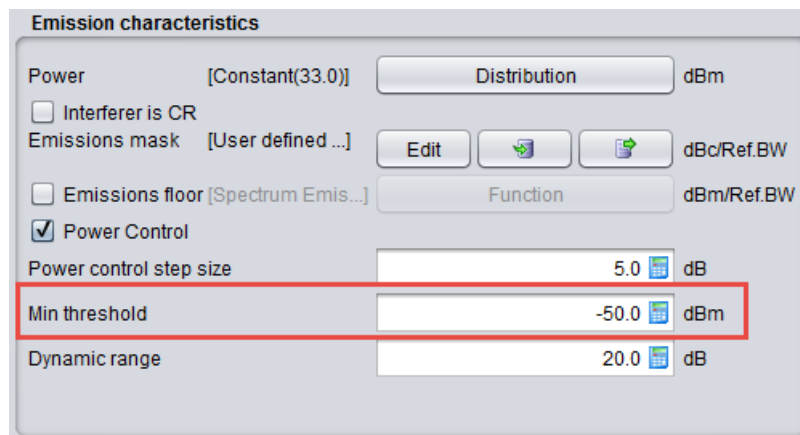
Figure 142: Reduction of the minimum threshold in the PC

Since, the power control feature is activated the gain of the power control is determined according to the guidance given in ANNEX 14: on page 330. Since the dRSS$_{\text{Interfering link receiver}}$ is –37.5 dBm and:

-50 dBm (PC $_{threshold}$) + 2 * PC $_{step}$ (5 dB) < –37.5 dBm < -50 dBm (PC $_{threshold}$) + 3 * PC $_{step}$ (5 dB)

The gain of the power control ($g_{it\,PC}$) is 10 dB (Case (i+1) in ANNEX 14:). This means that the iRSS$_{\text{unwanted}}$ will be decreased by 10 dB, i.e. :

$$iRSS_{unwanted} = \text{-39.5 dBm - } g_{it\,PC} \text{ = -49.5 dBm}$$

Finally, if the threshold is decreased from –50 dBm to –70 dBm, the power control feature is activated. Since the dRSS$_{\text{Interfering link receiver}}$ is –37.5 dBm, this results in:

-70 dB (PC $_{threshold}$) + 20 (PC $_{dyn}$) < –37.5 dBm

The gain of the power control is 20 dB (Case (n_step + 2) in ANNEX 14:). This means that the iRSS$_{\text{unwanted}}$ will be decreased by 20 dB, i.e. :

$$iRSS_{unwanted} = \text{-39.5 dBm - } g_{it\,PC} \text{ = -59.5 dBm}$$

4.10   ANTENNA GAIN

For simplification, we consider that the Victim link receiver and the Interefering link transmitter are defined using the following assumptions (again 1 km distance between the Interefering link transmitter and the Victim link receiver).

The iRSS$_{unwanted}$ is then:

$$iRSS_{unwanted} = 33 \text{ (dBm)} + 11 + Gr - (32.5 + 10 \log(1) + 20 \log(1000)) = -48.5 \text{ dBm} + Gr$$
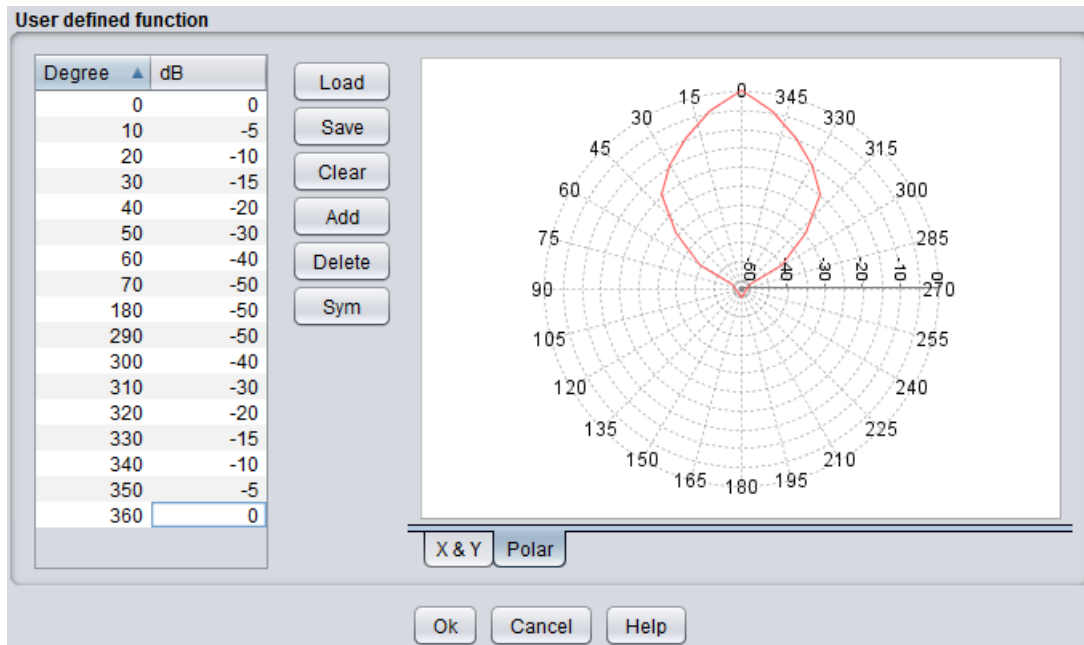
Figure 143: Definition of the antenna gain

In order to investigate the evolution of the iRSS versus the antenna radiation pattern with fixed location of the pairs of transmitters and receivers (i.e. to get random angle arrival and consequently random gain of the antenna radiation pattern), it is possible to rotate artificially the antenna pattern defined in Figure 143 in the azimuth domain. This can be done by rotating the antenna from 0 to 360 by applying a uniform distribution from 0 to 360 deg to the main beam direction (0 deg).
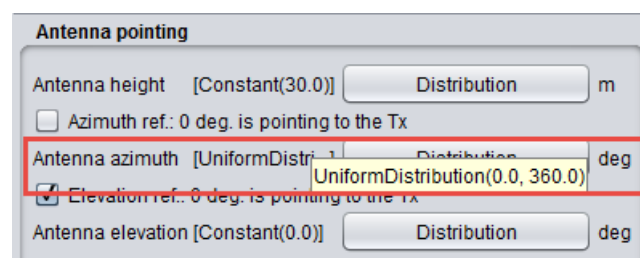
Figure 144: Setting up the rotation in the azimuth domain

The receiver antenna gain extends from 9 dB + (0 to -50 dB) meaning that it varies from +9 dB to -41 dB depending on the azimuth angle (Figure 144), the iRSS$_{unwanted}$ is then :

$$-89.5 \text{ dBm} < iRSS_{unwanted} < -39.5 \text{ dBm}$$

Results generated by SEAMCAT are presented in Figure 145.
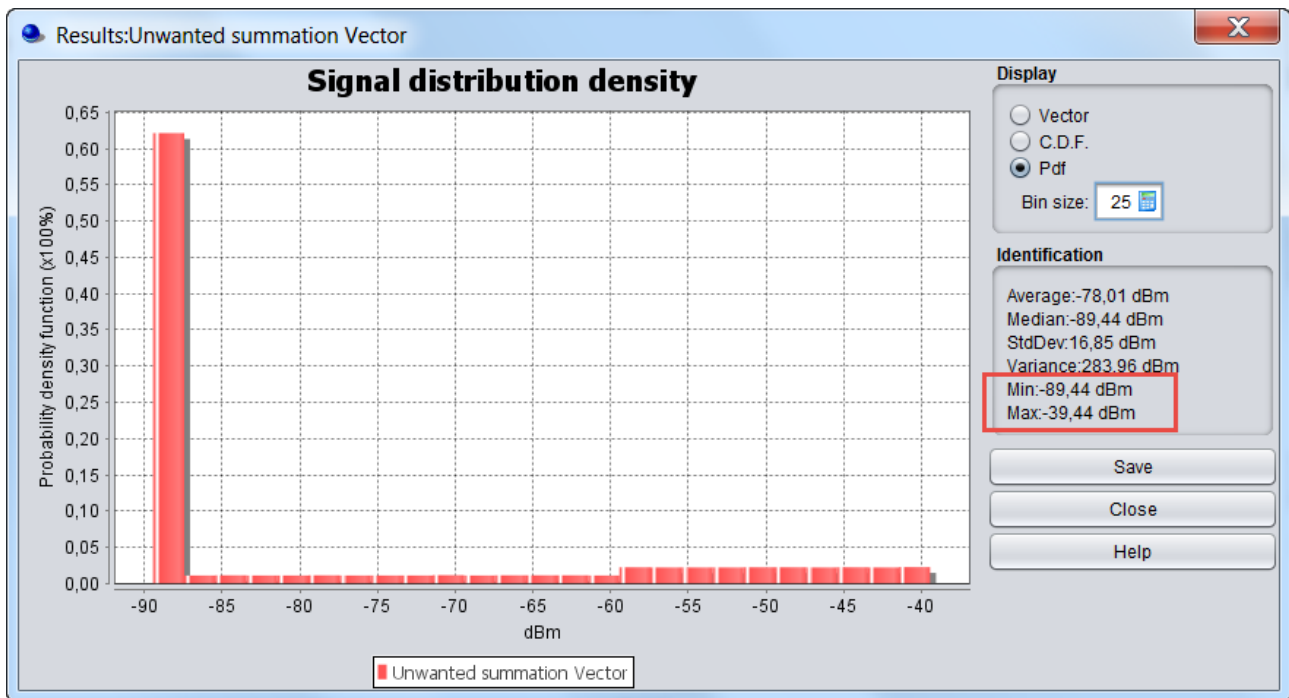
Figure 145: iRSS_{unwanted}

5   GENERIC MODULE

As mentioned earlier in this manual, you can address virtually all radio interference scenarios on terrestrial paths in both co-channel (sharing) and adjacent frequency (compatibility) interference studies. A number of various radiocommunications services can be modelled using the generic module:

- Broadcasting: Terrestrial systems and earth stations (e.g. DTH receivers) of satellite systems;
- Fixed services: Point-to-point and point-to-multipoint fixed systems;
- Mobile Services: Land mobile systems, short range devices and earth based components of satellite systems.

This flexibility is achieved by the way the system parameters are defined as variable (or constant) through their distribution functions. It is therefore possible to model even very complex situations by relatively simple variation of some elementary functions. This section explains the use of these parameters in SEAMCAT calculations, where appropriate.

The symbols and formatting conventions S means that the input value is in scalar form, D is a distribution, B is a Boolean (usualy a check box), and F is a function as a set of corresponding (X, Y) value pairs.

5.1   GENERIC SYSTEM TAB

This tab allows you to update all scenario parameters of for a generic system .

In the upper part of the tab, you have three panels.
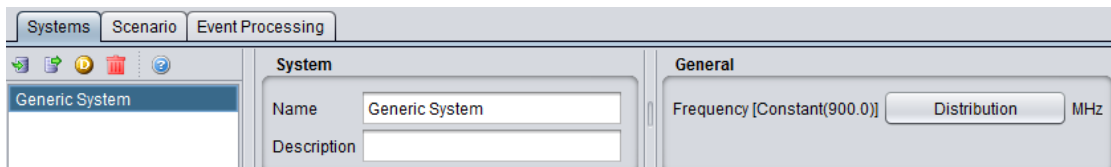
Figure 146: Generic system

5.1.1   System

You can name and write some description of the victim system you want to simulate.

5.1.2   General

You can enter the frequency. The frequency value is overwritten at the "Scenario" tab level.

Table 8: Generic system – General panel

Description	Symbol	Type	Unit	Comments
Frequency	f	D or S	MHz	Distribution of the centre frequency of the system

You have access to 3 sub tabs to set the generic system:

- Receiver: This will be used either as VLR or ILR;
- Transmitter: This will beused either as VLT or ILT;
- Transmitter to Receiver Path (i.e. either VLT → VLR or ILT → ILR).

5.2 RECEIVER

It can be the VLR or the ILR as illustrated in Figure 147.
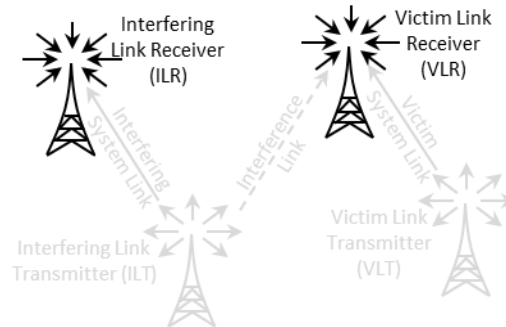
Figure 147: Receiver illustration as VLR or ILR

The receiver consists of 5 panels (Figure 148); Receiver identification, antenna pointing, antenna patterns identification, reception characteristics and interference criteria.

Figure 148: Receiver GUI

5.2.1 Receiver identification

This panel is a common interface that is reused in all other radio system.

Table 9: Receiver identification

Description	Symbol	Type	Unit	Comments
Library	-	Library	-	Allows to import/export the receiver characteristics from/to the library to/from the workspace
Name	-	Free text	-	Freely chose a name and a description for the receiver. Remember that you can export your setting to the library, so it is important that your description is accurate enough when you reuse your work, or if you share it.
Description	-	Free text	-	

5.2.2 Antenna pointing

This panel is a common interface that is reused in other radio system. It contains all information relative to the antenna other than the radiation pattern.

Table 10: Receiver antenna pointing GUI

Description	Symbol	Type	Unit	Comments
Antenna height	h	D or S	m	See ANNEX 11:
Azimuth ref. 0 deg is pointing to the Tx	-	B	-	when selected the antenna by default (i.e. for an antenna azimuth distribution of 0°) is pointing at the VLT. If not selected, it looks EAST.

Description	Symbol	Type	Unit	Comments
Antenna azimuth: Antenna alignment horizontal tolerance	δ^H	D or S	degree	This is the angle between the Rx main beam and the direction to Tx. E.g. if antenna azimuth=0, the Rx and Tx antennas are strictly aligned in the horizontal plane, see ANNEX 11:
Elevation ref. 0 is pointing to the Tx	-	B	-	when selected the antenna by default (i.e. for an antenna elevation distribution of 0°) is tilted towards the VLT. If not selected, it is set horizontal
Antenna elevation: Antenna alignment vertical tolerance	δ^V	D or S	degree	This is the vertical angle between the Rx main beam and the direction towards Tx. E.g. if antenna elevation=0, the Rx and Tx antennas are strictly aligned in the vertical plane, see ANNEX 11: on p. 312.

5.2.3 Antenna patterns identification

This panel is a common interface that is reused in all other radio system. It contains all information relative to the antenna radiation pattern:

Table 11: Antenna pattern identification

Description	Symbol	Type	Unit	Comments
Library	-	Library	-	Allows to import/export the antenna pattern from/to the library to/from the workspace
Name	-	Free text	-	
Description	-	Free text	-	
Antenna peak gain	G	S	dBi	The antenna are implemented as plugins, therefore see ANNEX 11: as separate guidance on the the radiation pattern.
Horizontal	-	Pattern	-	Pattern selection. See working range in ANNEX 11:.
Vertical	-	Pattern	-	Pattern selection. See working range in ANNEX 11:.

5.2.4 Reception characteristics

This panel consists in setting of the receiver characteristics of your generic system:

Table 12: Reception characteristics GUI

Description	Symbol	Type	Unit	Comments
Noise floor: define a distribution of the noise	N	D or S	dBm	See section 1.2.3 for further details

Description	Symbol	Type	Unit	Comments
floor				
Blocking mode	-	B	-	Blocking mode and associated blocking mask
Blocking response: Receiver frequency response (receiver blocking performance)	*blocking*	F (MHz)	dBm or dB depend. on mode	Receiver mask attenuation (positive or negative values depending on the chosen blocking mode, see below) versus frequency, see ANNEX 8:
Intermodulation rejection: Intermodulation response (intermodulation interference)	*intermod*	F (MHz)	dB	Receiver mask at the intermodulation frequency. (see Annex A5.3 for further details)
Receive power dynamic range	Pc_{max}	S	dB	Used in the calculation of the dRSS. It is the maximum range of the received power that the VLR can accept, in terms of the maximum receive power over the VLR's sensitivity threshold. If the trialled dRSS value exceeds $sens+Pc_{max}$, the dRSS is set to the latter value. See ANNEX 14:.
Sensitivity	*sens*	S	dBm/VLR reception bandwidth	Sensitivity of the receiver. See Section 1.2.4
Reception bandwidth: Operating bandwidth	*B*	S	kHz	Bandwidth of the receiver.
Overloading	-	B	-	When selected, the overloading calculation is performed. See Annex A5.4 for further details.
Overloading threshold	*Oth*	F (MHz)	dBm	Overloading threshold is the maximum interfering signal level, where close to that level the receiver loses its ability to discriminate against interfering signals at frequencies differing from that of the wanted signal
Receiver filter	*Rx_filter*	F (MHz)	dB	Filtering of the receiver (if any). The filtering of the receiver is by default 0 dB (similarly to the default blocking filtering value). It is used in connection with the overloading calculation.

5.2.5   Interference criteria

Section 1.4 presented the concept of interference criteria (*C/I, C/(N+I), (N+I)/N, I/N*) when the victimis a generic system. The consistency between these values is under your responsibility and that only one at a time is used in the interference calculation.

It is important to remember that these parameters are also used in the evaluation of the two blocking modes (Protection ratio and Sensitivity) as presented in See section 1.4.5.

SEAMCAT performs a consistency checking between the interference criteria as explained in ANNEX 3:.

Table 13: Interference criteria panel GUI

Description	Symbol	Type	Unit	Comments
Interference criteria	*C/I* *C/(N+I)* *(N+I)/N* *I/N*	S	dB	You can define at least one of these criteria. (C/I, C/(N+I), (N+I)/N, I/N). Then, you will choose one of these criteria for each interference probability calculation.
Calculate interference criteria	-	calculator	-	This feature allows you to evaluate the consistency between the entered interference criteria and proposes alternative solution that you can select.

The "calculate interference criteria" is a user friendly calculator for the interference criteria. It avoids conspicuous calculations, to increase the transparency and to avoid consistency check warnings because of the use of inconsistent sets of interference criteria values.

The calculation and selection of a consistent set of interference criteria is implemented. The calculator opens with the existing values in the interference criteria fields of the workspace. A checkbox (default: ON) allows to force the consistency of the C/(N+I) value with the workspace, i.e. the values 'Noise floor' and 'Sensitivity'. The relation between the values is given in the formula C/(N+I) [dB] = Sensitivity [dBm] – Noise floor [dBm]

The Interference Criteria Calculator displays all possible sets of consistent interference criteria rounded to one decimal. The same set is displayed only once. As a consequence of rounding, the displayed sets are differ at least 0.1 dB in one of the four values.

When you select the column of values you want and click ok, the values are copy/pasted to the "Interference criteria" panel.
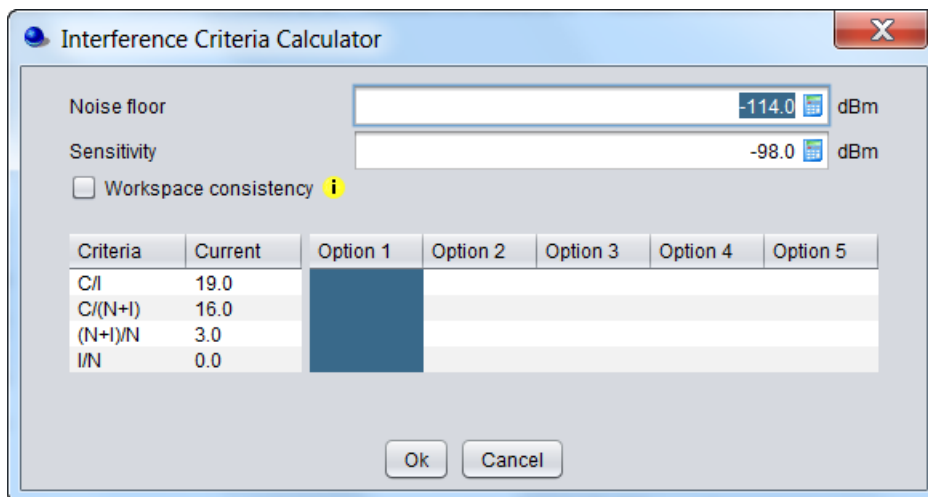
Figure 149: : Interference criteria calculator GUI

5.3 TRANSMITTER

It can be the ILT or the VLT as illustrated in .Figure 150
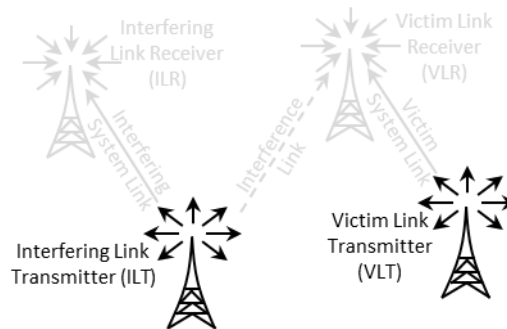
Figure 150: Transmitter illustration as ILT or VLT

It consists in 4 panels (Figure 151); Transmitter identification, antenna pointing, antenna patterns identification, emission characteristics.
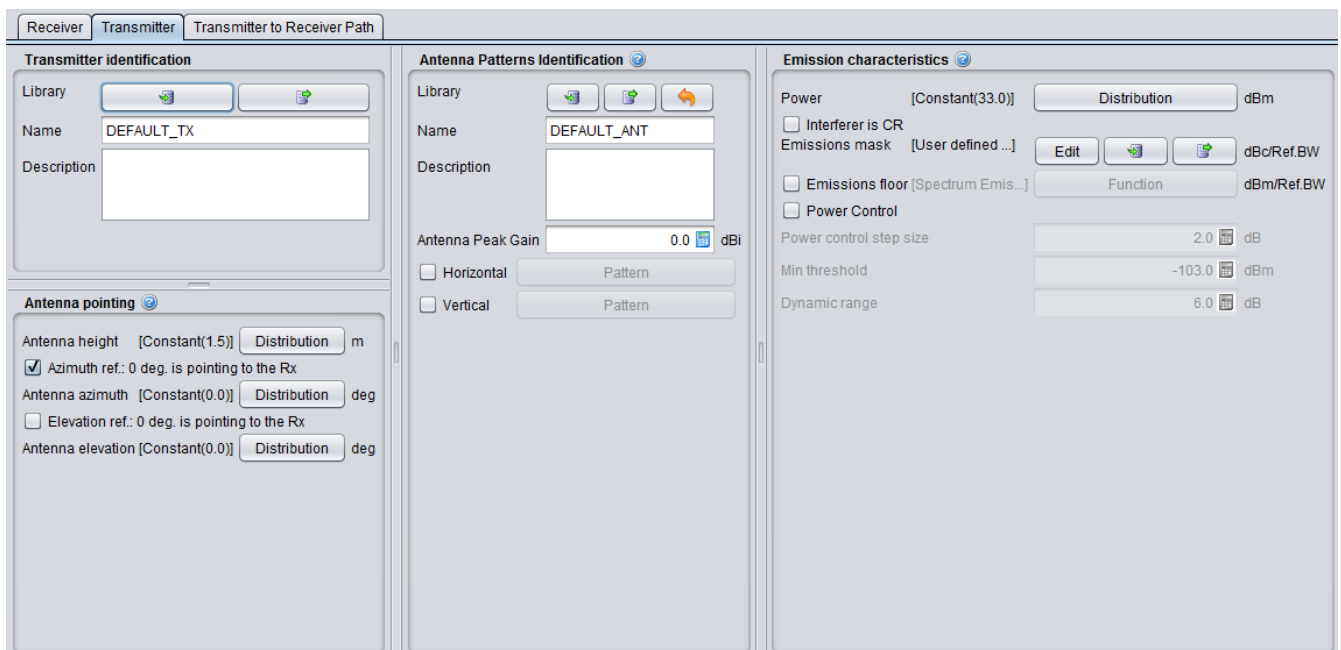
Figure 151: Transmitter GUI

5.3.1 Transmitter identification

This is the same panel as in section 5.2.1 so that transmitter characteristics can be imported/exported from/to the library to/from the workspace and you can freely chose a name and a description.

5.3.2 Transmitter antenna pointing

It contains all information relative to the antenna other than the radiation pattern. It is the same panel as for the receiver antenna pointing (Section 5.2.2). It points, in azimuth and in elevation, towards the Receiver.
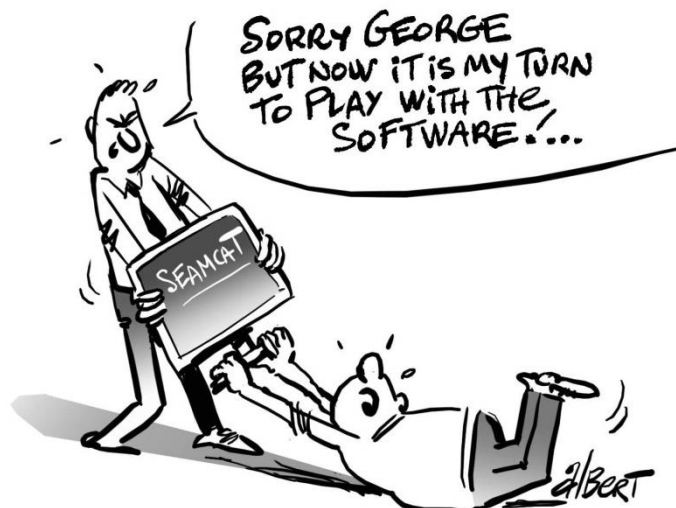
5.3.3 Antenna patterns identification

It contains all information relative to the antenna radiation pattern. It is similar to the receiver antenna patterns identification (Section 5.2.3).

5.3.4 Emission characteristics

This panel consists in setting of the emission characteristics of your generic system.

Table 14: Emission characteristics GUI

Description	Symbol	Type	Unit	Comments
Power	P	S or D	dBm	This is the transmitter power supplied of the generic system
Interfere is CR:		B		When the CR button is checked then it allows to set the emission characteristics of the VLT and ILT (used for the sRSS calculation only. See Section 6)
Emission mask:	emission_rel(f)	F (MHz)	dBc/ reference bandw. (MHz)	Define the mask of the transmitter, in the emission bandwidth and out of the emission bandwidth. It is the unwanted signal level from the ILT. (See ANNEX 7:)
Unwanted emissions floor: Noise floor signal level	emission_floor(f)	F(MHz)	dBm/ reference bandw. (MHz)	Define the minimum strength of the unwanted emissions. So the unwanted emissions equal to Max(P_{Tx} + Unwanted emission, Unwanted emissions floor) (see Annex A7.4)
Power control				If Power control is checked, the 3 following parameters have to be defined. This Power control is used to limit the output power of the transmitter (see ANNEX 14:)
Power control step size	PC_{step}	S	dB	
Min threshold	$PC_{threshold}$	S	dBm/ emission bandw	If the received power is lower than this threshold, then no power control takes place
Dynamic range	PC_{dyn}	S	dB	If the received power is higher than $Pc_{treshold}$ + Pc_{dyn} then the full power control takes place, i.e. the power is decreased by Pc_{dyn}

5.4 TRANSMITTER TO RECEIVER PATH

3 elements form the path between the VLR and the VLT or the ILR and ILT as illustrated in Figure 152.
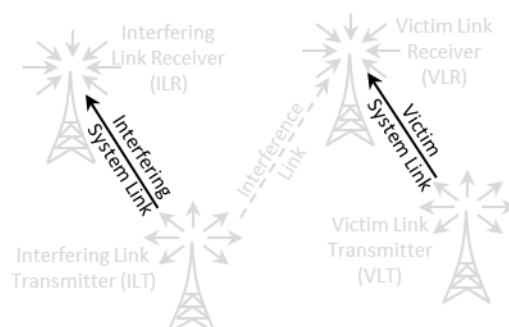
Figure 152: Transmitter to Receiver Path illustration

Figure 153: Transmitter to Receiver Path GUI

5.4.1 Relative location

▪ When the Correlated distance option is checked, it means that the positions of the receiver and transmitter are geographically fixed with respect to each other (e.g. co-located or constantly spaced base stations). The transmitter is considered a reference centre.
▪ When the correlated distance is unchecked, it means that the receiver is randomly moving around the transmitterYou have 2 primary options to define type of mutual placement of VLR with respect to VLT:

See ANNEX 12: for further details on the algorithm and conventions.
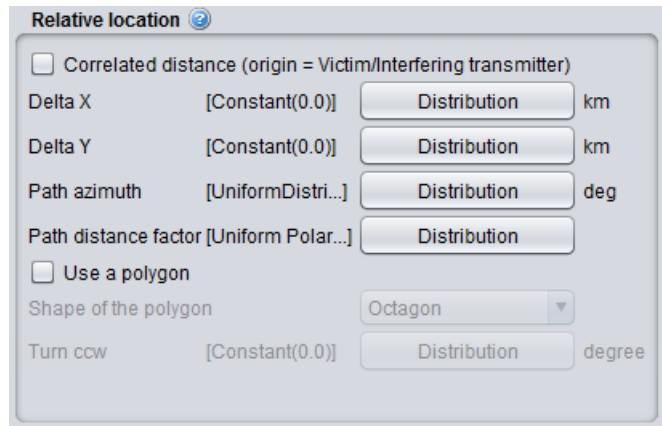
Figure 154: Relative location panel

Table 15: Relative location GUI

Description	Symbol	Type	Unit	Comments
Correlation distance	-	B	-	When checked, the only the Delta X and Y are editable.
Delta X	X	D	Km	Horizontal distance between the transmitter and receiver. It can be used to shift horizontally the distributed receivers.
Delta Y	Y	D	Km	Vertical distance between the transmitter and receiver. It can be used to shift vertically the distributed receivers.
Path azimuth	-	D	Degree	Horizontal angle for the location of the Rx respect to the Tx. If constant, the Rx's location will be on a straight line. If not, the location of the Rx will be on an angular area. (See Annex A12.3)
Path distance factor	-	D	-	Distance factor to describe path length between the Tx and the Rx. If the path factor is constant, the Rx will be located on a circle around the Tx. (See Annex A12.2)
Use of polygon	-	B	-	When this is checked, you can select other shape of deployement than the default circle
Shape of the polygon	-	B	-	You can select between hexagon (6 sides), heptagon (7 sides), Octagon (8 sides), Pentagon (5 sides), Rectangle (4 sides) and Triangle (3 sides)
Turn CCW	-	D	degree	Allows to rotate counter clock wise the selected polygon

5.4.2 Coverage radius

A coverage radius is calculated for both the victim link and the interfering link. It is the R_{max}^{VLT} for the victim link (VLR-VLT) and the R_{max}^{ILT} for the interfering link (ILR-ILT) (see Annex A13.1). The receivers will be randomly deployed within the area centred on the transmitter and delimited by the coverage radius if the non-correlated option is selected.

Three different modes are available for calculating the maximum radius .

- **User-defined radius** option allows you to enter the maximum radius directly (See Annex A13.1.1);

Figure 155: User-defined coverage radius dialog box

Table 16: Description on User-defined coverage radius

Description	Symbol	Type	Unit	Comments
Coverage radius	R_{max}	S	km	Input a coverage radius, and fix it with a path loss constant or make little variation around this radius. Useful to give a fixed value for the coverage radius. The origin of the coverage radius is the Victim link transmitter

- **Noise-limited network** option will calculate the coverage radius, based on the formula for noise-limited network. If this option is chosen, a set of input boxes will appear below allowing user to enter specific parameters required for this calculation. In this case it is considered that the coverage of the transmitter is limited only by propagation losses and other elements of link budget, with received signal operating at the very sensitivity limit. The detailed of the calculation is given in Annex A13.1.2.
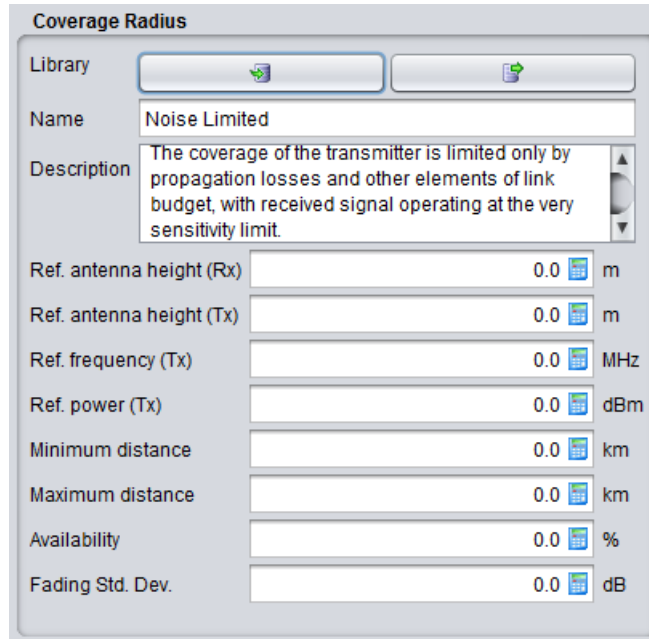
Figure 156: Noise limited network coverage radius dialog box

The coverage radius in the noise-limited network is defined by the parameters of Table 17. Note that the input parameter of the Noise-limited network interface are set to zero by default in purpose to allow you to define the radius independently from some parameters set elsewhere in the link.

Table 17: Description of the Noise limited network coverage radius user interface

Description	Symbol	Type	Unit	Comments
Reference antenna height (receiver):	h^0	S	m	The height used for coverage radius calculations. If a distribution is used to define the real height, the coverage radius would be different in each trial, here the value may be fixed.
Reference antenna height (transmitter):	h^0	S	m	The height used for coverage radius calculations.
Reference frequency	fVLR	S	MHz	
Reference power	P_{VLT}	S	dBm	
Minimum distance			km	
Maximum distance			km	
Availability			%	
Fading standard deviation			dB	
Reference percentage of time			%	

- **Traffic-limited network** option will calculate the coverage radius, based on the formula for traffic-limited network. If this option is chosen, a set of input boxes will appear below allowing user to enter specific parameters required for this calculation (See Annex A13.1.3).

Figure 157: Traffic limited network coverage radius dialog box

Table 18: Description of the traffic limited network coverage radius user interface

Description	Symbol	Type	Unit	Comments
Density	$dens_{max}$	S	$1/km^2$	Maximum number of active transmitter per km^2
Number of channels	$n_{channel}^{it}$	S		Number of frequency channels that a radio system provides
Number of users per channel	$n_{userperchannel}^{it}$	S		Number of MS per frequency channel provided by a radio system
Frequency cluster	$cluster_{frequency}^{it}$	S		Size of a group of frequency channels. See Figure 180 for illustrative details.

You should check the consistency of this parameter with the sensitivity, so that if a receiver is placed at given distance such as the maximum coverage radius, the received power is higher than the sensitivity for a reasonable percentage of time (availability).

5.4.3 Local environment

You can choose the probability of indoor or outdoor associated to the transmitters and receivers. This will map later to the propagation model that you will select. By default the transmitter and receiver are located outdoor. For each elements of the link, it is possible to add 🟢 or remove 🗑 a probablity of indoor.
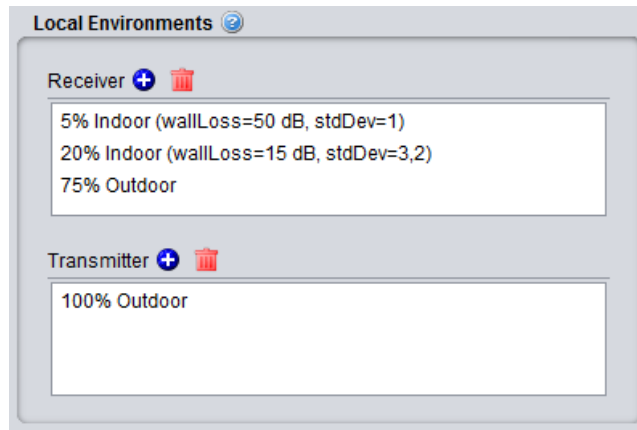
Figure 158: Example of setting up the outdoor/indoor ratio

You can edit the field by double cliking
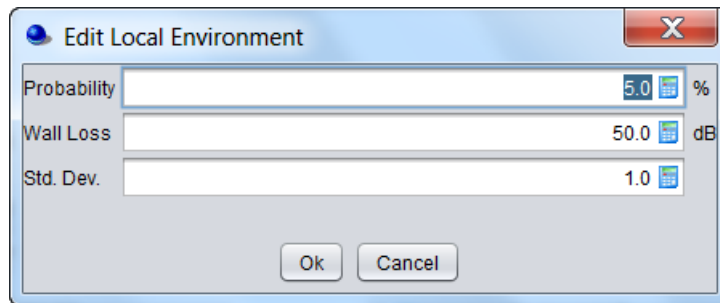
Figure 159: Graphical interface to edit the probability, wall loss and associated standard deviation

Table 19: Local environment and wall loss

Description	Symbol	Type	Unit	Comments
Local environment: Receiver	Indoor/ outdoor	-	-	Environment of the receiver antenna: outdoor, indoor It is used for both VLR and ILR
Local environment: Transmitter	Indoor/ outdoor	-	-	Environment of the transmitter antenna: outdoor, indoor It is used for both VLT and ILT
Probability	-	S	%	Probability that of a Tx or Rx to be indoor or outdoor
Wall loss	$Loss_{Rx}^{wall}$ or $Loss_{Tx}^{wall}$	S	dB	The attenuation due to indoor-outdoor external walls associated to the propagation model tha you have selected for the transmitter or the receiver
Std. dev.	σ_{Rx}^{wall} or σ_{Tx}^{wall}	S	dB	Wall loss stdandard deviation (indoor - outdoor) Wall loss standard deviation associated to the propagation model tha you have selected for the transmitter or the receiver

Note that when you open a workspace produced prior to SEAMCAT version 5.0.0, it is migrated to the newest SEAMCAT version you will have installed on your machine. In the case of the local environment, you may have the following warning that "local environments are skipped for multiple interefering links". This means that SEAMCAT was not able to automatically set the paramters of the local environment (most likely due to multiple interferers scenario). You will have to edit the local environment manually.
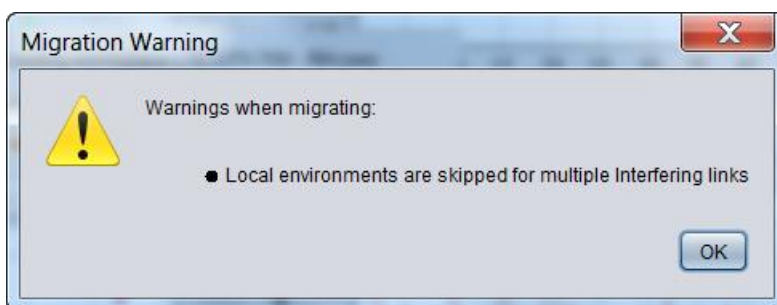
Figure 160: Migration warning on the local environment

5.4.4 Propagation Model

You can choose the suitable propagation model to be applied when calculating signal loss along the transmitter and the receiver path. A choice and settings of propagation models are presented in ANNEX 17:.

6 SPECTRUM SENSING AND COGNITIVE RADIO

6.1 INTRODUCTION

Cognitive radio is a technology which is being developed to bring greater efficiency, speed and reliability to users of wireless devices. The number of high powered wireless devices coming on to the market is increasing exponentially placing an unprecedented demand on the limited radio spectrum. Cognitive radio technology is seen as a potential solution to this problem as it identifies unused frequencies in a local area and switches a device to this temporarily to provide users with uninterrupted and faster mobile services.

In the following, CRS refers to Cognitive Radio Systems. One typical example of usage of CRS is in the so called "white spaces" (WS), which refers to frequency spectrum which is potentially available at a given time for further

utilisation within frequency spectrum originally planned another service (e.g. Broadcasting). Devices operating in the white spaces using cognitive radio features are called White Space Devices (WSD) [14].

6.2 SIMULATING SPECTRUM SENSING

The manual sets out how SEAMCAT can be used for spectrum sensing where the interfering devices (ILT) try to detect the presence of protected services (e.g. the VLT) transmitting in each of the potentially available channels. Spectrum sensing essentially involves conducting a measurement within a candidate channel to determine whether any protected service is present and transmitting. When a channel is determined to be vacant, sensing is typically applied to adjacent channels to identify what constraints there might be on transmission power, if any.

A key parameter for spectrum sensing is the detection threshold that is used by a cognitive device to detect the presence or the absence of a protected service's transmission. If it detects no emission above this threshold in a channel, the white space device (WSD, i.e. the It) is allowed to transmit, otherwise the WSD keeps silent or look into other channels. You can study this phenomenon in SEAMCAT, which enables multiple cognitive radio systems. The cognitive radio feature mainly introduces the detection threshold and the selection of the operating frequency of the WSD.

In SEAMCAT, the CRSs are assumed to be the interferers. A SEAMCAT workspace will contain only 1 victim system and 1 or many interferers. It is possible to assess the aggregated impact of interferers that can be either CR devices or not. The scenario allows the impact of spectrum sensing to be investigated where a cognitive radio device is activated nearby a victim system. Both the victim and the interfering dialogue interface should be filled to enable spectrum sensing in SEAMCAT. Figure 161 illustrates that the introduction of spectrum sensing requires an extra budget link called sensing Received Signal Strength (sRSS) which represents the signal which is transmitted by the VLT and is sensed by the It. Note that the It acts as a transceiver, meaning that when the energy is sensed though the bandwidth of the sensing device (i.e. the It), it is acting as a receiving device.

The sRSS (considering the unwanted mask of the DTT) at the channel m is calculated as described in ANNEX 6:.

It is assumed that the frequency of the interfering cognitive radio device is dependent on the frequency range defined for the victim. This means that when the CR module is activated, the interfering frequency function dialogue box is de-activated (#4 of Figure 231). Depending on how the victim frequency is defined (i.e. constant, discrete or distributed between f_{min} and f_{max}). SEAMCAT only allows the use of the following distributions: Constant, User defined, Uniform, User defined (stair).
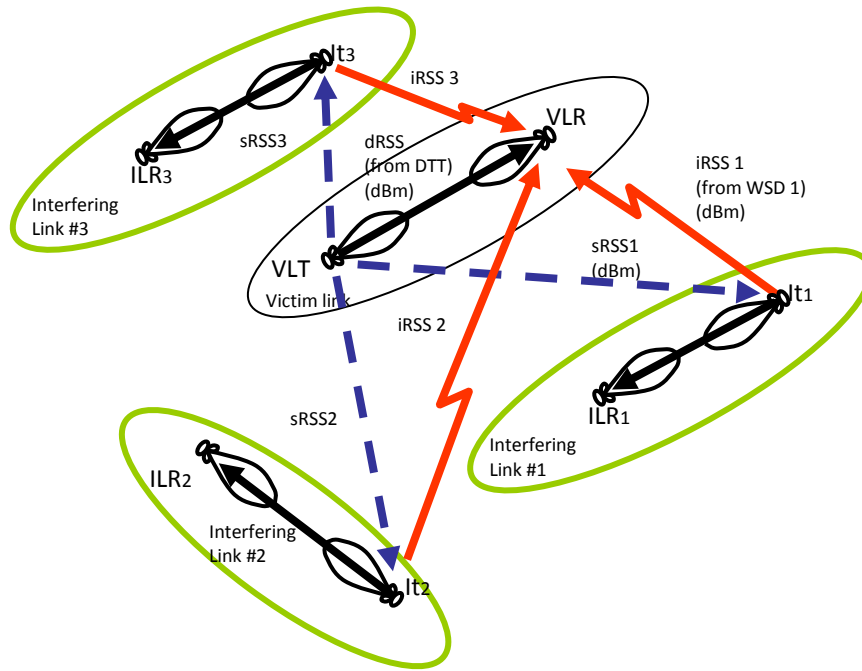
Figure 161: Illustration of 3 cognitive radio systems (WSD) and a victim system (sRSS is in blue)

6.3   INPUT SYSTEM PARAMETERS

For the sensing feature to be activated, both the victim and interferer transmitters have to have the "interferer is CR" selected (Figure 162). This will activate the spectrum sensing algorithm (see ANNEX 16:) and will allow you to set the transmitting characteristic of the victim link transmitter, i.e. the energy that the cognitive radio spectrum sensing device is to sense. You will be able to set the emission mask and the emission floor.
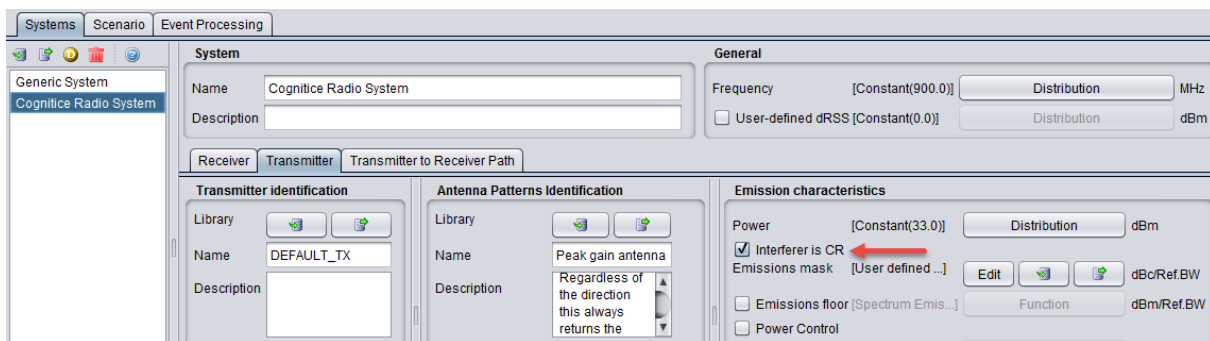
Figure 162: Selection of the CR algorithm

Table 20: Victim Link transmitter

Description	Symbol	Type	Unit	Comments
Interferer is CR		switch		When the CR button is checked then it allows to set the emission characteristics of the VLT (used for the sRSS calculation only)
Emission mask: Unwanted signal level (VLT)		F(MHz)	dBm/reference bandw. (MHz)	Define the mask of the transmitter, in the emission bandwidth and out of the emission bandwidth. Negative values in the relative mask

Description	Symbol	Type	Unit	Comments
				should be chosen in a way that the integration over the emission bandwidth results in the total emitted power. If constant mask, there is no emission outside of the bandwidth.
Unwanted emissions floor: Noise floor signal level		F(MHz)	dBm/ reference bandw. (MHz)	Define the minimum strength of the unwanted emissions. So the unwanted emissions equal to Max(Pwt + Unwanted emission, Unwanted emissions floor)

Note that the settings of the emissions mask and the emission floor is the same as for the interfering link (i.e. same units).
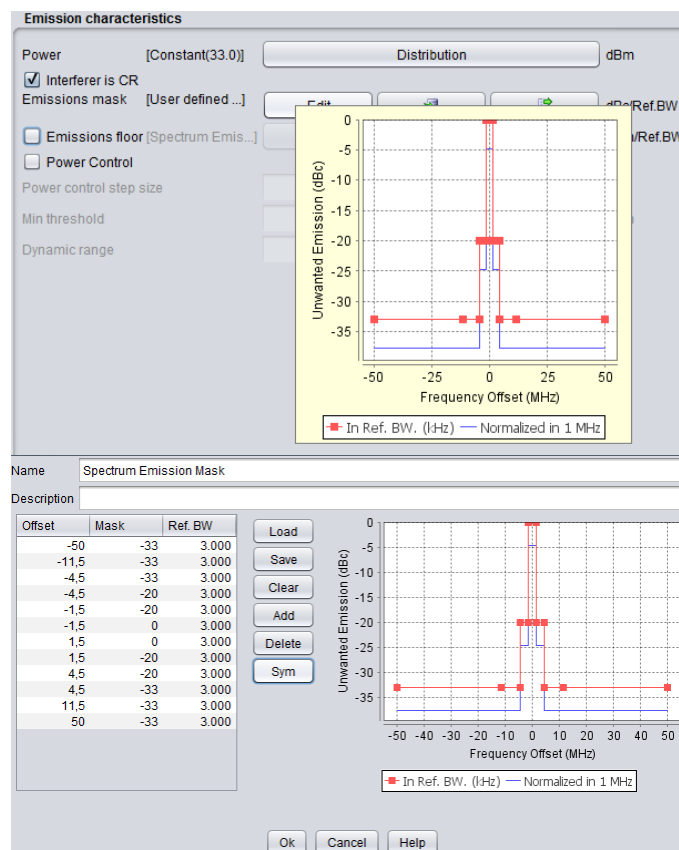
Figure 163: Activate the CR in the VLT (Victim Link) to consider its emission characteristics (i.e. used in the sRSS calculation)

6.4 SCENARIO PARAMETERS

In addidtion to the input system parameters, you also need to set charateristics of the spectrum sensing algorithm as described in Section 10.4.

6.5 EXAMPLES

At the end of the simulation, SEAMCAT provides a set of output vectors as presented in Section 12.4. The following subsections present examples on how to interpret the results.

6.5.1 All the channels are available

In such a scenario, the detection threshold is taken to a value of 0 dB (Figure 164) much higher than the sRSS level (average = -82.09 dBm) (Figure 165). Therefore, no victim system has been detected and the WSDs are allowed to transmit in any of the specified channels (Figure 166) per event.
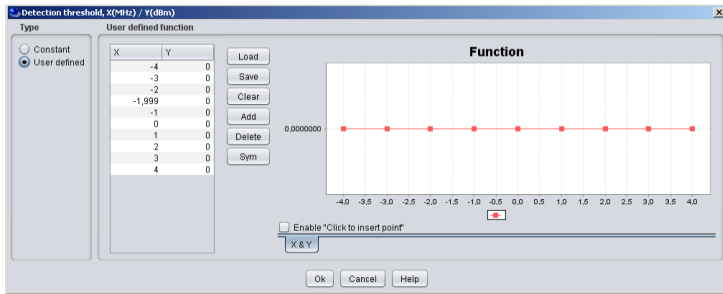
Figure 164: Selection of a high detection threshold
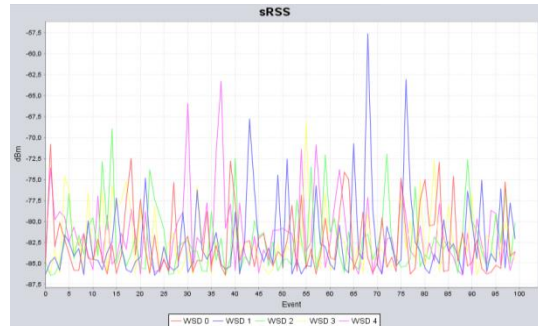
Figure 165: The sRSS values are well below the detection threshold, so no victim system have been detected

In such a case the e.i.r.p.used in the simulation is the Tx_{power} (=-33 dBm) + G_{max} (=0 dBi), meaning that the in-block e.i.r.p. limit does not apply. This means that whatever the frequency selected by the WSD its e.i.r.p.. is the same (Figure 168) (here assuming that the Power Control at the It is OFF).

Figure 166: The WSD can transmit anywhere in the victim frequency range
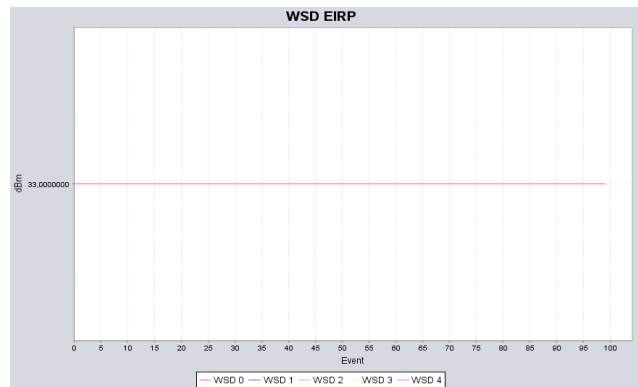
Figure 167: e.i.r.p. set to -33 dBm as set in the It, i.e. Tx_{power} (=-33 dBm) + G_{max} (=0 dBi), meaning that there were no limit applied to the It Tx power

Figure 169 illustrates that on average there are 1.17 WSDs active at 1000.5 MHz per event, 1.23 WSDs in 1001.5 MHz, 1.34 WSDs in 1002.5 MHz and 1.26 WSDs in 1003.5 MHz for the same out of 5 which were input to the simulation. In this case all the WSDs were active (but in different frequencies) since the sum equal to 5 (i.e. none of the WSDs have been turned off).
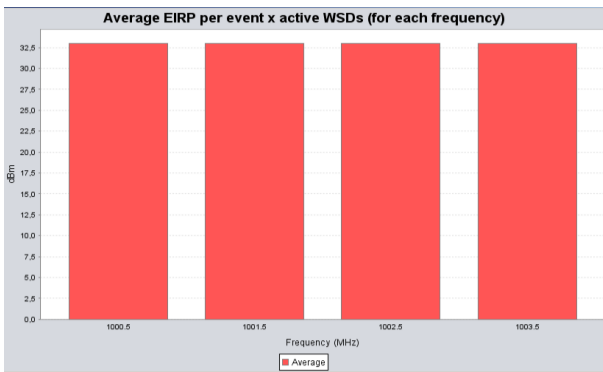
Figure 168: e.i.r.p. is the same irrespective of the frequency
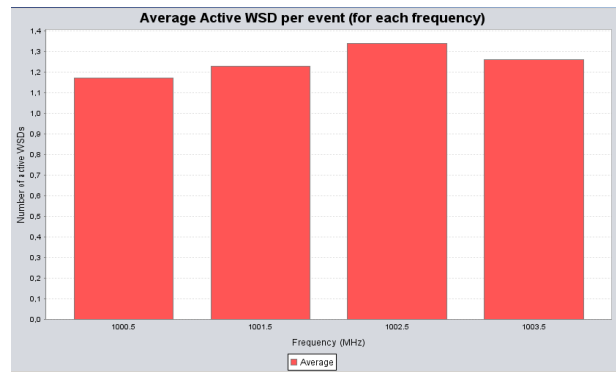
Figure 169: Illustration of the number of WSDs per frequency

6.5.2 All the channels are blocked

In such a scenario, the detection threshold is taken to a lower value compared to the sRSS and none of the WSDs are transmitting. In SEAMCAT, the Tx power is set to -1000 dBm (Figure 170). The WSD frequency is the same as the victim frequency per event.
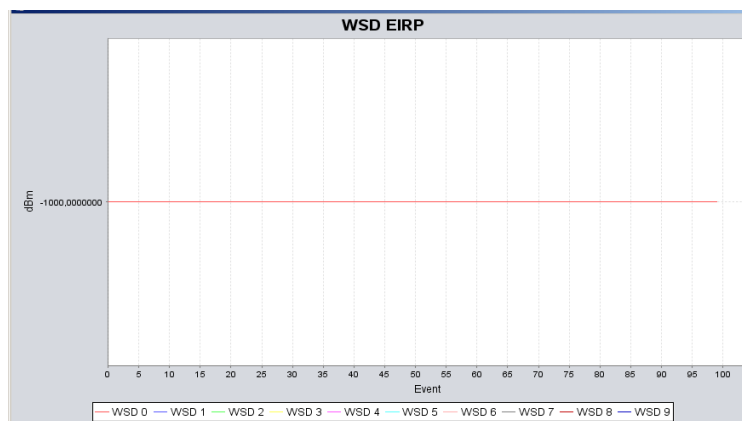
Figure 170: all the WSDs are off i.e. -1000 dBm

Note that in this specific case, the average e.i.r.p. and average WSDs per frequency can not be calculated and therefore can not be displayed as shown in Figure 172.
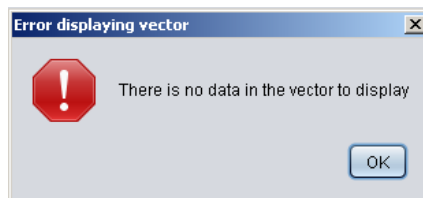
Figure 171: All the WSDs are off i.e. -1000 dBm

6.5.3 Some of the channels are blocked and some are available

This is a typical example. In such a scenario, the detection threshold is taken to a value of -80 dB (flat over the frequency range). This mean that when considering the sRSS of Figure 172, for some of the events, the

sRSS will be above that threshold and therefore some WSDs will be considered as off (which explains the -1000 dBm value in Figure 173 (b)) and the WSD frequencies are randomly distributed.
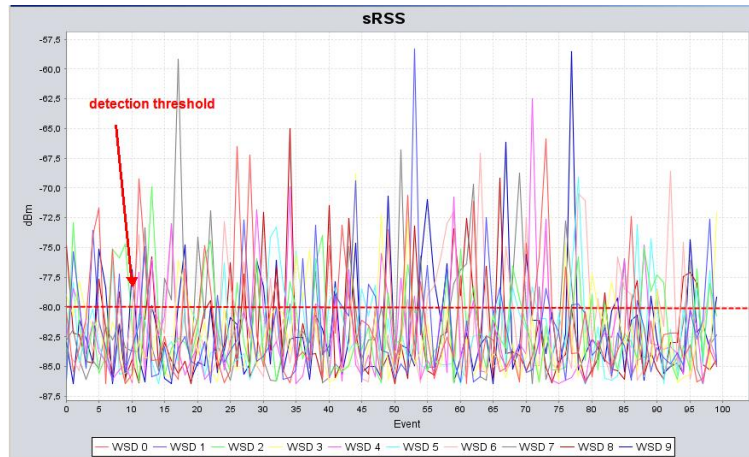
Figure 172: sRSS for 5 WSDs per event
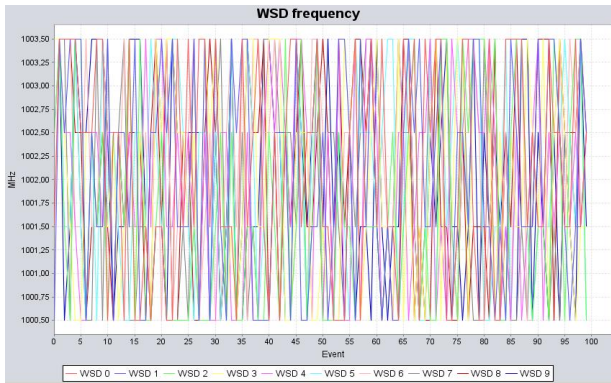
(a) WSD frequency
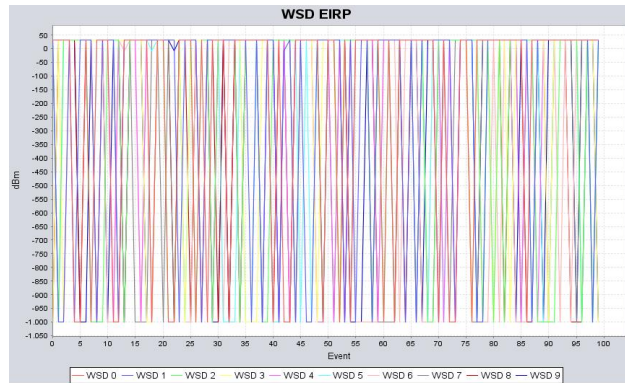
(b) WSD e.i.r.p.

Figure 173: Output results of the WSD in (a) frequency and (b) e.i.r.p.

In this case, one can see that all the channels were occupied in Figure 174. The WSDs were allowed to transmit with an e.i.r.p. of 33 dBm in the 3 middle channels (1000.3 MHz to 1000.7 MHz) while for the side channels less power was allowed (i.e. 24 dBm for 1000.1 MHz and 16.89 dBm for 1000.9 MHz).

Figure 174 (b) also indicates that not all the simulated WSDs were active (those having an e.i.r.p. of -1000 dBm), and that per event about only 1 WSD was active.
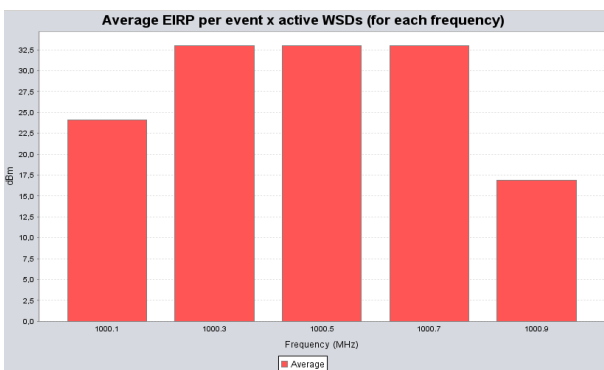
(a) average e.i.r.p.
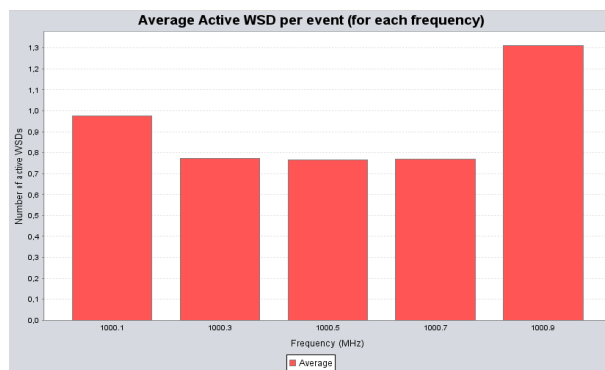
(b) average number of active WSDs

Figure 174: output results of the WSD in (a) frequency and (b) e.i.r.p.

7   CELLULAR NETWORK SIMULATION

7.1   INTRODUCTION

Whereas traditional simulation of non-CDMA or non-OFDMA systems is carried out in SEAMCAT by taking two pairs of transmitters-receivers and estimating signals received between them separately (i.e. without any form of feed-back influence), the simulation of cellular systems requires a much more complex process of power controlling in a fully loaded system, including impact from two tiers of neighbouring cells and, for victim cellular systems, the attempt by the system to level-out the interference impact.
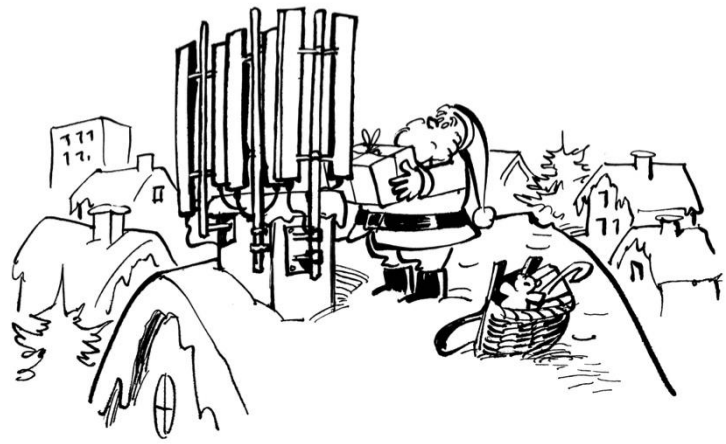
There are two different types of Monte-Carlo model that could be employed: a 'static' model, also referred to as a 'snapshot' model, and a 'dynamic' model. In a cellular network, connections will frequently arrive and leave the network during a given period of time. This causes fluctuating traffic and power levels. Principally, it is possible to carry out a dynamic Monte-Carlo taking into account this fluctuating traffic in real time. It can account for dynamical statistical characteristics; however it is extremely time consuming to run. In cases, where many scenarios need to be investigated, such long runtimes could become restrictive. Therefore, the snapshot model is preferred in such cases and selected for SEAMCAT. This model sets up a random distribution of users based on one instant in time in connection with a network configuration and considered service characteristics. A set of statistics which accurately reflects these scenarios is derived by simulating several such snapshots.

To investigate the coexistence of a mobile radio network with another radio technology in SEAMCAT, a snapshot of both victim and interfering systems is modeled at each event generation in SEAMCAT, which generates transmit power, interference levels as well as the probability of link success of the victim system for a given number of users at a time instant. It captures a snapshot of the UE powers in the network and the number of user links which can be successfully carried given these powers. In order to analyze the impact of the interfering network on the victim one, the success rates of the victim network in the presence and absence of the interfering system are compared.

The term UE or MS are used interchangeably in this manual. You should review and modify the input parameters of the cellular network for the particular scenario that is being simulated and more detailed can be found in publications such as [6], [4] or [5].

7.2   CDMA OVERVIEW

When simulating CDMA systems, SEAMCAT performs power controlling in a fully loaded system of all the MSs so that the impact from the neighbourhing two tiers is included (inter-cell interference), for victim CDMA systems, and the system level-out the inter-cell and external interference impact. The balancing of the overall system is performed by the CDMA power control algorithm.

When the CDMA system is the interferer, the UEs are balanced only once, the transmit powers and positions of relevant transmitters (BS or MS, depending on scenario) are used as interefering link transmitters for calculating the iRSS. If the CDMA system is a victim, the power balancing is done first without any external interferer, where the number of connected CDMA UEs is estimated, and then the external interferer is introduced and the CDMA system is re-balanced again. Afterwards the number of served users, compared with that before the introduction of interference was introduced, allows estimating impact of interference in terms of excess outage brought to the system. The combination of the above is applied when both victim and interferer systems are CDMA.

The term "CDMA" is used in this manual and in SEAMCAT environment in general to refer to any radio technology that employs the Code Division Multiple Access modulation scheme. The specific CDMA standard (e.g. CDMA2000-1X, or W-CDMA/UMTS) can be selected by incorporating the appropriate link level curves into the simulation scenario. Furthermore, at present, only the interference impact of/on "voice" can be studied using SEAMCAT.

7.3   OFDMA OVERVIEW

The simulation of OFDMA systems is similar to that of the CDMA systems, except that after the overall two-tiers cellular system structure (incl. wrap-around) is built and populated with mobiles, OFDMA replaces the CDMA power tuning process with an iterative process of assigning a variable number of traffic sub-carriers and calculating the overall carried traffic per base station.

The OFDMA module has been designed for a Long Term Evolution (LTE) network from 3GPP TR36.942 [10]. Therefore E-UTRA RF coexistence studies can be performed with Monte-Carlo simulation methodology.

7.4   TDD VS FDD SIMULATION

Note that TDD (Time Division Duplex)/FDD (Frequency Division Duplex) simulations are scenario dependent meaning that the direction of the interferer (UL or DL) to the victim will be studied. In this context, the time dependency is not simulated as it is not important. Therefore, SEAMCAT can already simulate this, since the worth case scenario is to be considered i.e. a FDD UL or DL scenario should give similar results as a TDD UL or DL simulation. Note however that to simulate TDD systems, the correct TDD characteristics would have to be filled in.

7.5   CELLULAR NETWORK POSITIONING

5 panels characterised the positioning of a cellular system. This panel is the same whether a CDMA (UL/DL) or OFDMA (UL/DL) is simulated.
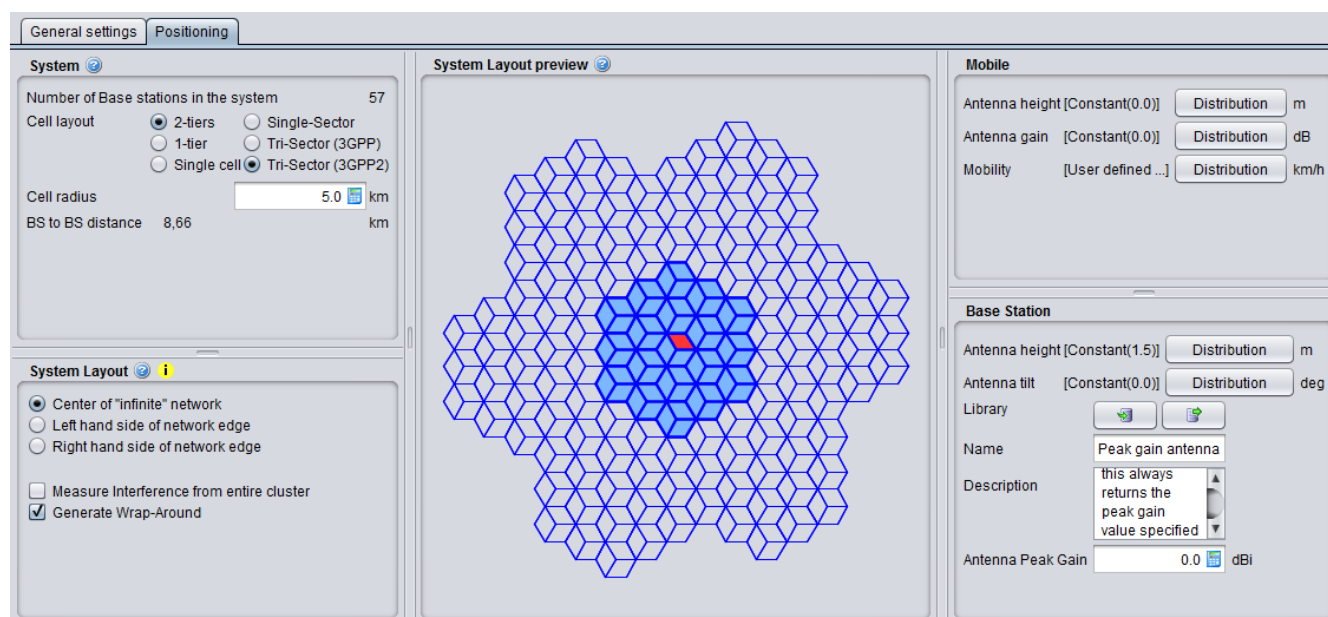
Figure 175: Cellular network positioning GUI

7.5.1   System

Initialy macro-cellular environment was implemented in SEAMCAT, but with time more flexibility was given to the tool to reproduce various topology options in cellular network (Figure 180). Cell sites are laid out in a hexagonal grid. Sites with omni-directional antennas are placed in the middle of the cells as depicted in Figure 176 and sites with tri-sector antennas are placed at the edge of the cells, where each site covers three cells. Figure 177 shows one of these cell sites (small hexagons in dashed lines) and that the arrows demonstrate the antenna orientation of each cell. The BS to BS distance (also refered as inter-site distance in the literature) is D. The cell radius R is equal to *D/sqrt(3)* in the omni-antenna case and is equal to *D/3* in the tri-sector antenna case. Both suburban scenario and urban scenario can be modeled with this cell configuration. The scenarios differ only in propagation conditions and in the cell radius.

A wrap around cluster is used to reduce the number of cells required in the simulations and consequently to enable faster simulation run times. The number of cell sites in the cluster is assumed to be 19 (19 cells in the

case of omnia-antenna and 57 cells in the case of tri-sector antenna), which appears to be appropriate for SEAMCAT simulation (see Section 7.6.3 for further details on wrap-around technique).
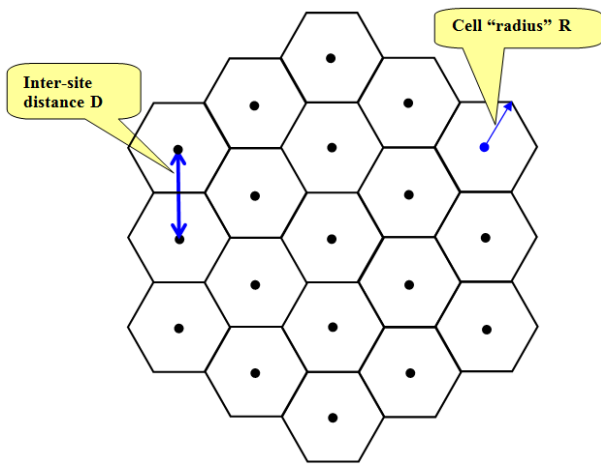
Figure 176: Macro-Cellular CDMA Network Deployment with Omni Antenna
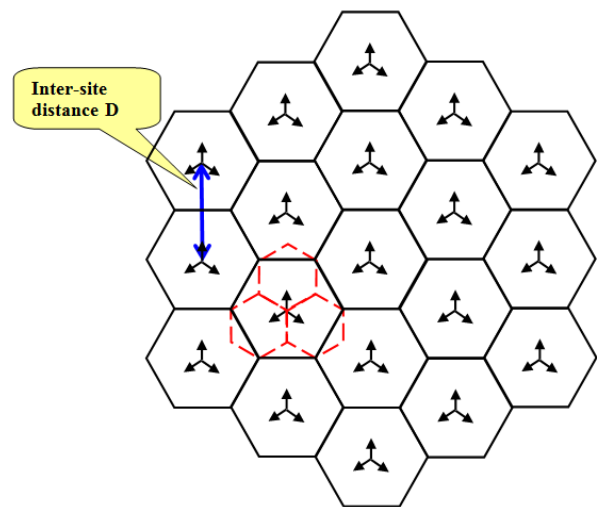
Figure 177: Macro-Cellular CDMA Network Deployment with Tri-Sector Antenna

Therefore SEAMCAT supplements a single considered CDMA / OFDMA cell with its Base Station (BS) two tiers of virtual cells to form a 19 cell (57 cell for tri-sector deployment) cluster, which is then populated with a certain number of mobile stations (MS) and a power control algorithm is then applied for balancing overall system, see Figure below:
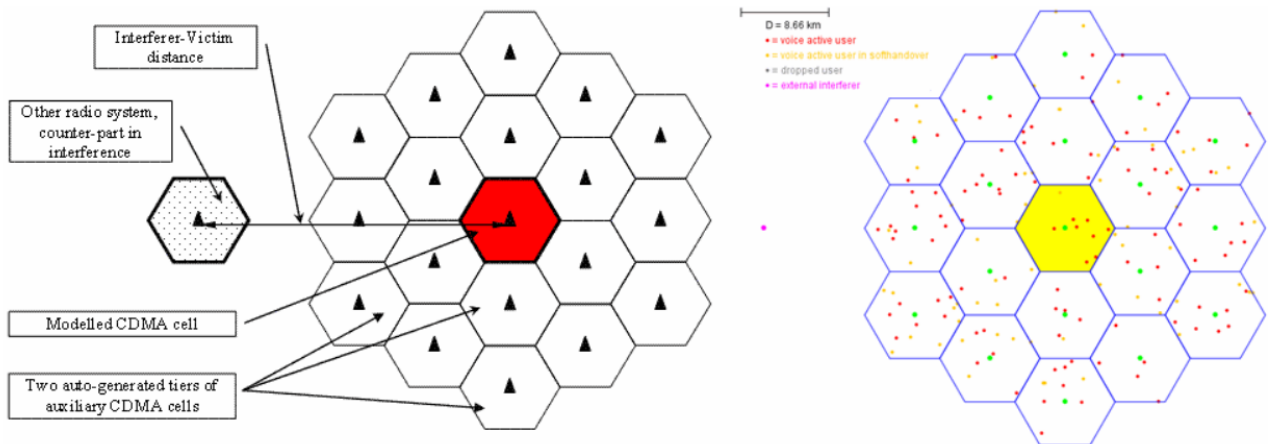
Figure 178: 19 cells omni setup

CDMA and OFDMA module shares common platform like the positioning of the cellular layout. The celular topology in SEAMCAT is composed of the "Cell layout" and the "Cell radius"a shown in Figure 180.
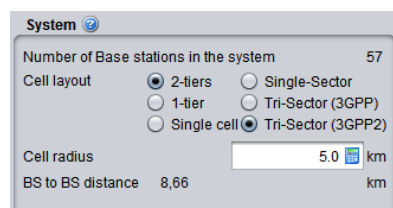
Figure 179: Cellular network positioning GUI

In the "Cell Layout" you can select 2 tiers, 1 tier or single cell layout. In addition, you can select between Omni dieectional (single sector), tri-Sector (3GPP) and tri-Sector (3GPP2).

The "Cell Radius" (km) is the size of the cell and defines also the BS to BS distance (i.e. inter-site distance).
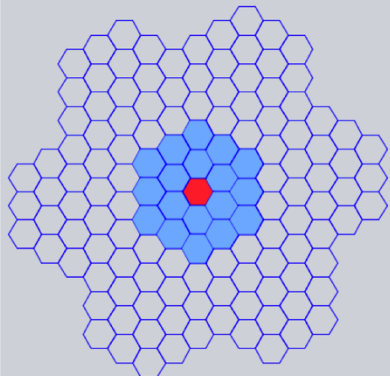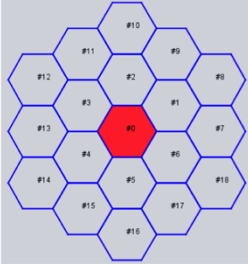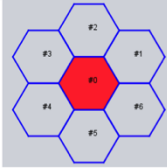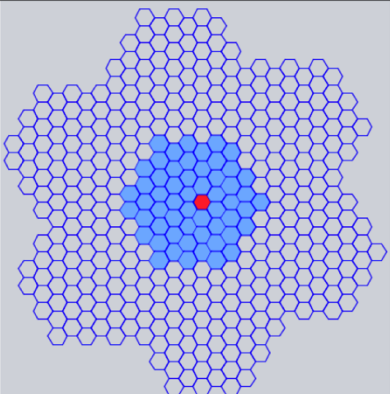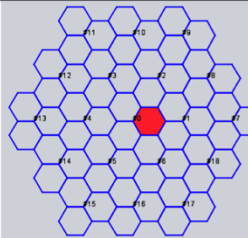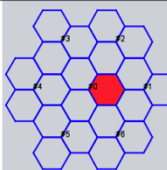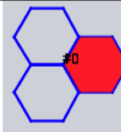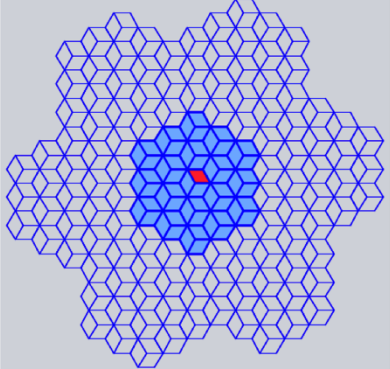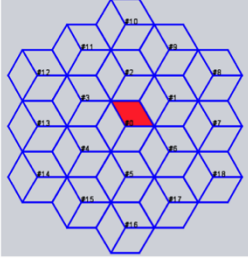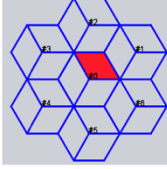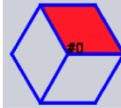
Sector configuration	2-tiers (with wrap around)	2-tiers (without wrap around)	1-tier	Single cell
Omni				
Tri-sector 3GPP				
Tri-sector 3GPP2				

Figure 180: Overview of the topology options in cellular network

Two types of hexagonal grids are used to represent cellular layout, there is the 3GPP (http://www.3gpp.org/) and the 3GPP2 (http://www.3gpp2.org/). The differences are illustrated in Figure 181 (3GPP) and in Figure 182 (3GPP2). The fundamental principal of the two approaches is that they share the same commonality for the BS to BS. Based on this same value, it is possible to extract the relationship of the cell range and cell radius between the two approaches.

Within the CEPT work, it is more common to use the 3GPP hexagonal grid, ECC Repport 82 [4] and ECC Repport 96 [5].

Figure 181 presents an example of the 3GPP approach:
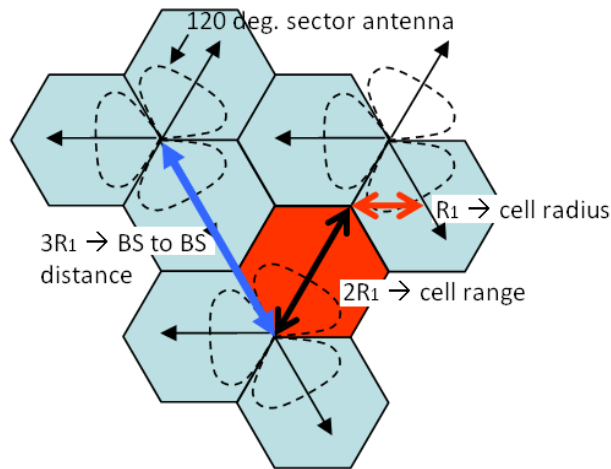
Figure 181: 3GPP illustration of the Cell Radius, Cell Range and BS to BS distance.

where: Cell Radius = R_1
            Cell Range = $2R_1$

BS to BS distance = $3R_1$

Figure 182 (a) and (b) illustrate the 3GPP2 approach for tri-sector and omni-sector respectively:

                      (a)   **(b)**
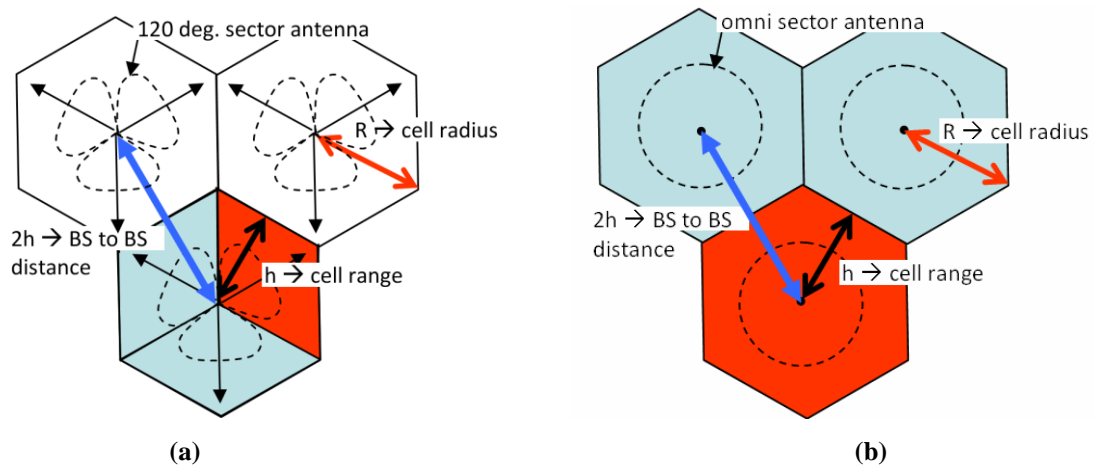
Figure 182: 3GPP2 illustration of the Cell Radius, Cell Range and BS to BS distance for (a) tri-sector case and (b) omni-sector case

where: Cell Radius = R   (Eq. 31)
            Cell Range = h = sqrt(R^2-R^2/4)

BS to BS distance = 2h

What is important is that the BS to BS station distance be the same between the 3GPP and the 3GPP2 approach, i.e. where 3R1= 2h which is equivalent to R = sqrt(3) R_1.

From there it is possible to extract the cell radius in SEAMCAT.

Table 21: Example of the distances relationship between 3GPP and SEAMCAT

	Urban Case	Rural Case
SEAMCAT cell radius (R)=	433 m	4330 m
SEAMCAT cell range (h)=	375 m	3750 m
Distance BS to BS (2h = 3 R_1) =	750 m	7500 m
3GPP cell range ($2R_1$) =	500 m	5000 m
3GPP cell radius (R_1) =	250 m	2500 m

7.5.2   System layout – reference cell selection

A singe cell consists of several MSs connected to their serving BS. The reference cell is a single cell that is surrounded by two tiers of virtual cells to form a 19 cells (or 57 cells for tri-sector deployment) cluster. This cells clutter is then populated with a certain number of MSs. The reference cell is by default at the center of the network, but you can modify it by selecting any cells you want. Part of configuring a CDMA or OFDMA network is selecting the reference cell. In SEAMCAT it is possible to choose between two network configurations (3GPP and 3GPP2, see Figure 180).

The reference cell in Figure 183 is used to calculate the effects of interference and to measure results and all non reference cells are used to provide a proper interference background to the reference cell. You can click on the cell that should be used as reference cell when gathering results. The red cell is the current selection.
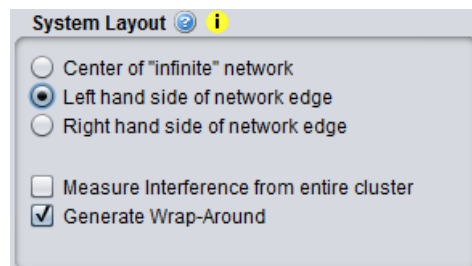
Figure 183: System layout - reference cell selection

Table 22: System layout GUI

Description	Symbol	Type	Unit	Comments
Center of infinite network	-	B	-	Quick access to predefined selection of reference cell. This only changes the selected reference cell – no other simulation parameter is changed.
Left hand side of network	-	B	-	Position the reference cell on the left hand side of the network. Can be used to reproduce border network layout.
Right hand side of network	-	B	-	Position the reference cell on the right hand side of the network. Can be used to reproduce border network layout.
Measure interference from entire cluster	-	B	-	See section 7.6.2
Generate wrap-around	-	B	-	See section 7.6.3

Normally the considered cellular system (CDMA or OFDMA) is modelled as endless network using the so called wrap-around technique. Alternatively, you may specify that the modelled cellular cell is laying at the edge of the network, in this case the cellular system will be modelled as if extending to one side only. The latter case may be suitable for simulation of geographically separated victim and interfering systems, like in cross-border scenarios as illustrated in Figure 184.
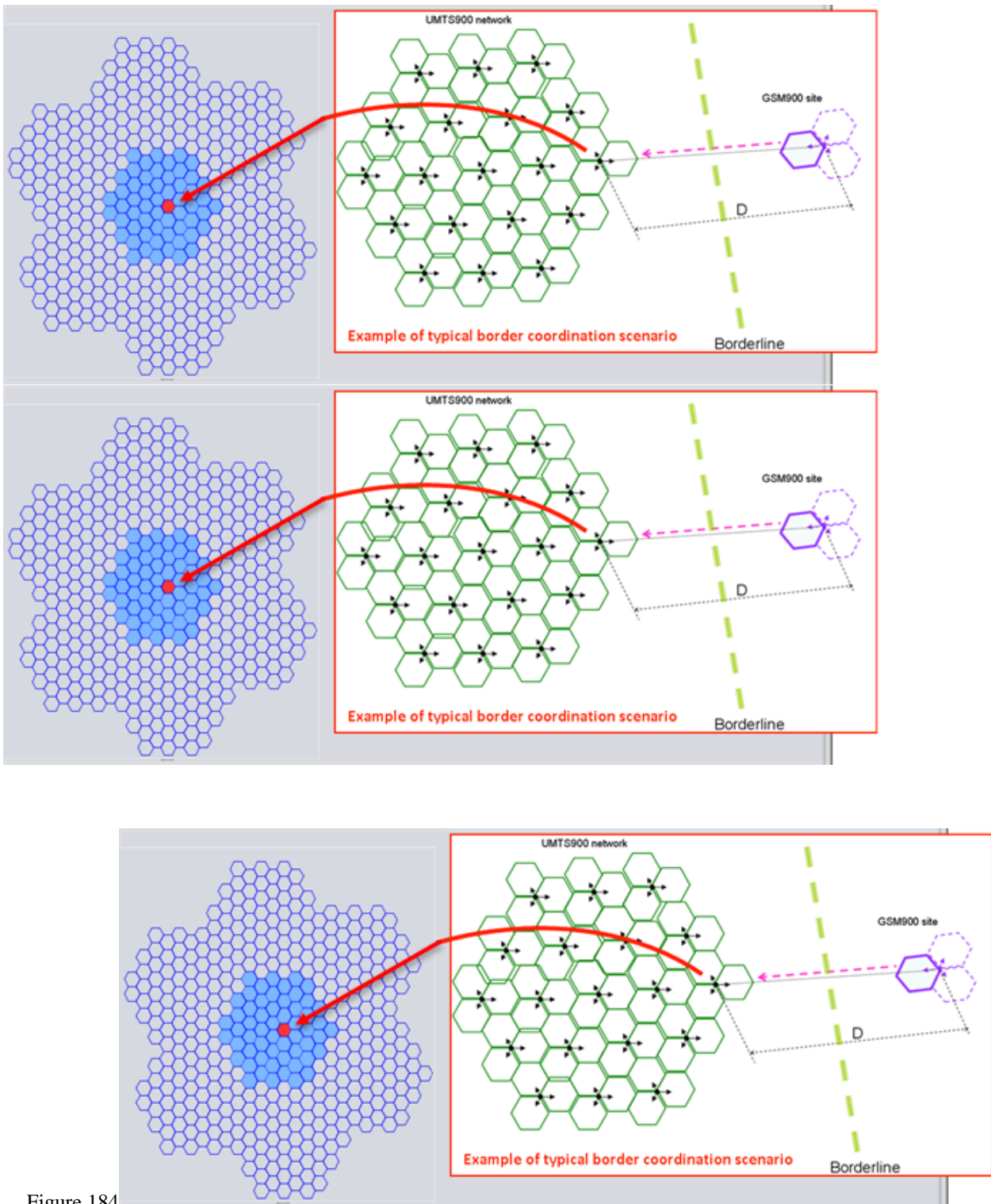
Figure 184: Example on how to set up the system layout to reproduce a border coordination scenario

7.5.3   System layout preview

You have the possibility to see a preview of the network you are simulating. You can click on the cell that should be used as reference cell when gathering results. The red cell is the current selection.
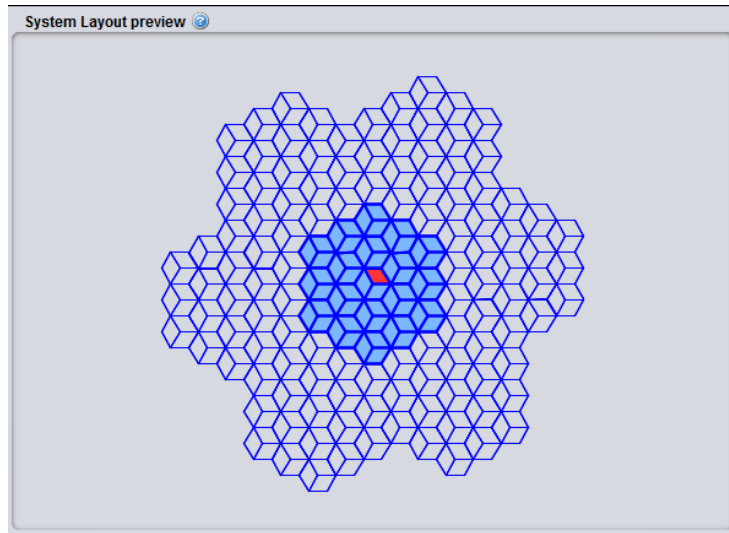
Figure 185: System layout preview

7.5.4   Mobile station
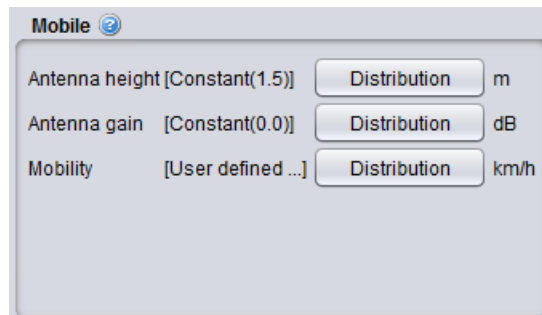
Figure 186: Cellular system – Mobile station GUI

Table 23: Cellular system – Mobile station parameters

Description	Symbol	Type	Unit	Comments
Antenna height	H_{MS}	D or S	m	Height of user terminal in meters. Note that the assumed antenna height definition (above ground, above local clutter, effective antenna height) should correspond to the selected propagation model.
Antenna gain	G_{Tx} , G_{Tx}	D or S	dB	An omni directional antenna pattern is assumed. Depending on the link direction, it can be either the gain of the Tx (UL) or the Rx (DL)
Mobility	-	D or S	Km/h	Distribution od speed among the users.Theese speeds have to conform to the speed options in the selected Link Level Data (Section 8.5). For simplicity SEAMCAT assumes four different speeds, assigned to mobile users with uniform probability: ▪ 0 km/h - No movement, ▪ 3 km/h - Walking, ▪ 30 km/h - Urban driving, 100 km/h - Motorway driving

7.5.5   Base station
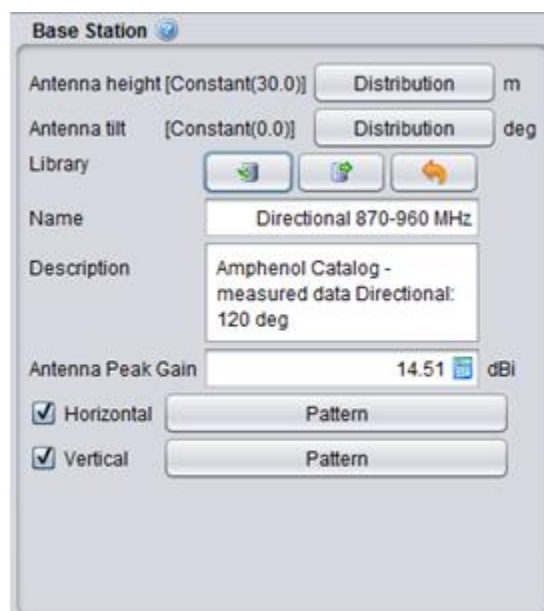
Figure 187: Cellular system – Base station GUI

Table 24: Cellular system – Base station parameters

Description	Symbol	Type	Unit	Comments
Antenna height	H$_{BS}$	D or S	m	Distribution used to determine height of BS. Note that the assumed antenna height definition (above ground, above local clutter, effective antenna height) should correspond to the selected propagation model
Antenna tilt	-	D or S	degree	Equivalent to a physical tilt of an antenna on a mast, (-) sign is a downtilt, (+) sign is an uptilt. See ANNEX 11: for further details and illustration.
Antenna pattern	-	Library	-	See Section 5.2.3

7.6 CDMA/OFDMA COMMONALITIES

7.6.1 Pathloss and Effective Pathloss

Path loss between each user and BS needs to be calculated within the cellular layout. In SEAMCAT, there is a distinction between the raw pathloss and the effective pathloss. The effective pathloss conisders the minumum coupling loss (MCL) as defined in 3GPP. The MCL is the parameter describing the minimum loss in signal between BS and UE or UE and UE in the worst case and is defined as the minimum distance loss including antenna gains measured between antenna connectors. Note that the effective path loss includes shadowing.

The effective pathloss is defined such as:

$$Effective\_pathloss(Tx, Rx) = \max\left(pathloss - G_{TX} - G_{Rx}, MCL\right) \qquad \text{(Eq. 32)}$$

where:

- G$_{Tx}$: antenna gain at the transmitter (Tx) in dBi.
- G$_{Rx}$: antenna gain at the receiver (Rx) in dBi.

The MCL is an input parameter to SEAMCAT. Typical values of MCL can be found in 3GPP documents (3). By default this value is 70 dB (i.e. typical value for Macro cell Urban Area BS <-> UE for frequency of 2000 MHz, e.g., there is a difference between 900 MHz and 2500 MHz with respect to MCL.) when defining the victim or interferer OFDMA system, but the default MCL value for generic interferer is set to 0 dB when assessing the interference between victim and interferer (ILT -> VLR path).

7.6.2 Measure interference from entire cluster

For a CDMA network used as an interferering network, when the "Measure interference from entire cluster" button is checked, all the transmitters of the CDMA network are used when simulating the interference (i.e. all 19/57 BS or all UEs in all the cells) to simulate the external interference. When it is not checked, it is only the reference cell which is the interferer. This feature only applies when a CDMA network is the source of interference.

When the interferer is OFDMA, it is assumed that the interference comes from the entire cluster and never from the reference cell only. This is true for both the downlink and the uplink. You can not select the option on the interface.

7.6.3 Wrap around feature and implementation

To analyze the behavior of a cellular network without inducing any artifacts due to boundary effects limitations, it is necessary to consider an infinite cellular network. In this case one cannot perform simulation techniques because the network model is not finite. It is necessary to apply a way of simulating and analyzing the infinite network using a finite model. Wrap-around is a model developed for this purpose.

By embedding a finite repeat pattern (cluster) from the infinite hexagonal lattice on a torus, we define in fact a mapping of all the clusters forming the lattice into a generic cluster. In other words, the cell layout is wrap-around to form a toroidal surface. In order to be able to perform this mapping, the number of cells in a cluster has to be a rhombic number $\rho_{i,j}$, defined by two "shifting" parameter i and j as

$$\rho_{i,j} = i^2 + j^2 + i \cdot j \qquad \qquad \textit{(Eq. 33)}$$

A toroidal surface is chosen because it can be easily formed from a rhombus by joining the opposing edges. In SEAMCAT , $\rho_{i,j} = 19$ with i=3 and j=2 is used. To illustrate the cyclic nature of the wrap-around cell structure, the cluster of 19 cells is repeated 8 times at rhombus lattice vertices as shown in Figure 188. Note that the original cell cluster remains in the center while the 8 clusters evenly surround this center set. From the figure, it is clear that by first cutting along the blue lines to obtain a rhombus and then joining the opposing edges of the rhombus a toroid can be formed. Furthermore, since the toroid is a continuous surface, there are an infinite number of rhombus lattice vertices but only a few selected have been shown to illustrate the cyclic nature.

In the wrap-around model considered, the signal or interference from any mobile station to a given cell is treated as if that mobile station is in the first 2 rings of neighboring cells. The distance from any mobile station to any base station can be obtained as follows:

1. Define a coordinate system such that the center of cell 1 is at (0,0).

2. The path distance and angle used to compute the path loss and antenna gain of a mobile station at (x,y) to a base station at (a,b) is the minimum of the following:

▪ Distance between (x,y) and (a,b);

▪ Distance between (x,y) and $(a + 3D/\sqrt{3}, b + 4D)$;

▪ Distance between (x,y) and $(a - 3D/\sqrt{3}, b - 4D)$;

▪ Distance between (x,y) and $(a + 4.5D/\sqrt{3}, b - 7D/2)$;

▪ Distance between (x,y) and $(a - 4.5D/\sqrt{3}, b + 7D/2)$;

▪ Distance between (x,y) and $(a + 7.5D/\sqrt{3}, b + D/2)$;

▪ Distance between (x,y) and $(a - 7.5D/\sqrt{3}, b - D/2)$,

where D is the inter-site distance.
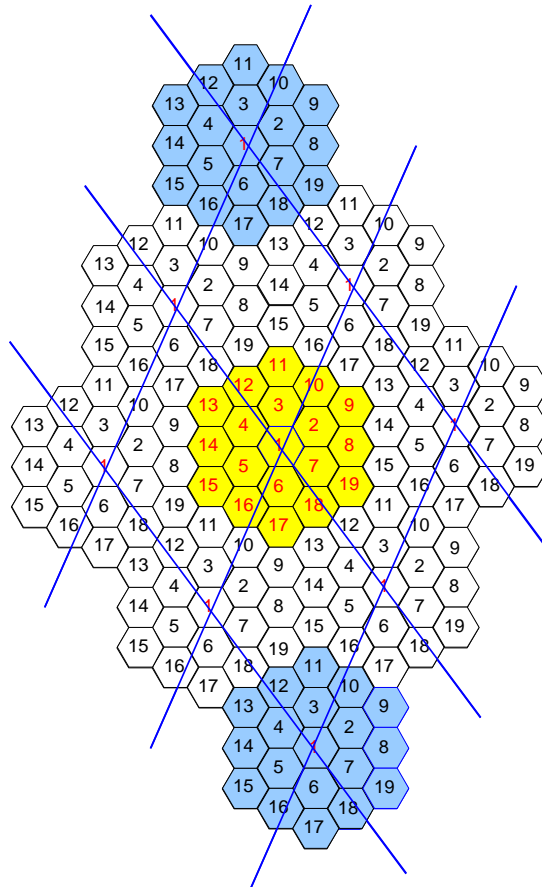
Figure 188: Wrap-around with '9' clusters of 19 cells showing the toroidal nature of the wrap-around surface

In the "ploting options" panel, you can toggle wrap-around plotting to allow easier selection of correct cell.
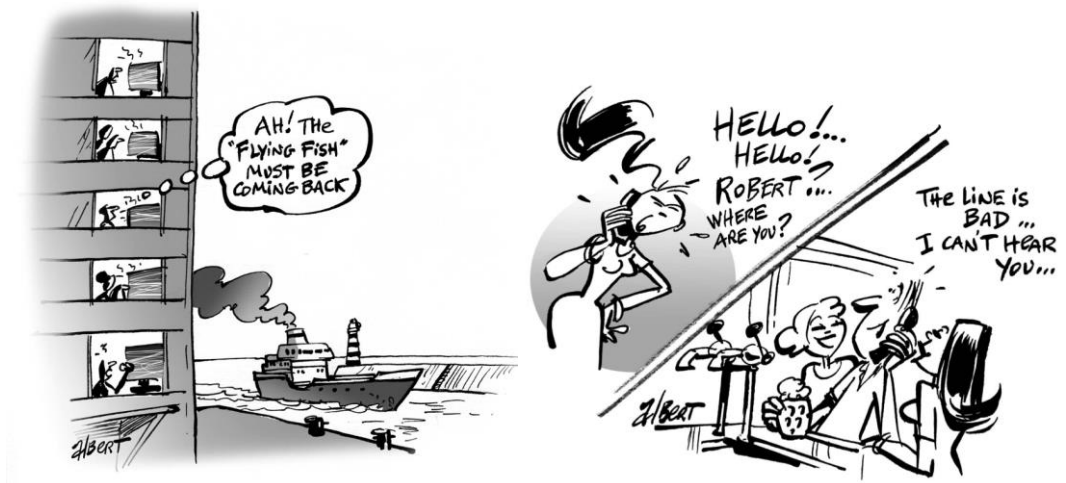
8 CDMA MODULE

8.1 INTRODUCTION

SEAMCAT allows the simulation of cellular networks employing Code Division Multiple Access modulation scheme. The specific CDMA standard (e.g. CDMA2000-1X, or W-CDMA/UMTS) can be selected by incorporating the appropriate link level curves into the simulation scenario. Only the interference impact of/on "voice" users can be studied using SEAMCAT. The CDMA examples given in this manual are based on 3GPP UMTS specifications.

CDMA and OFDMA share common panels and calculation. You are invited to consult Section 7.5 for the cellular topology, Reference Cell etc.. Section 7.6 for the Pathloss and Effective Pathloss definition etc.

8.2 CDMA SYSTEM TAB

Whether you want to simulate CDMA UL (uplink) or CDMA DL (downlink), you can import from the system library (Figure 189 – (a)), the cellular system you want (Figure 189 – (b)). You can also export the characteristics of your CDMA network to the library for later reuse.
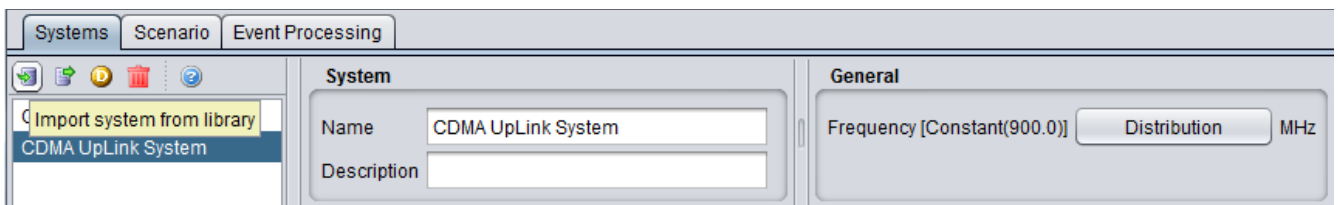
(a)

(b)

Figure 189: Selection of a CDMA cellular network from the system library

8.2.1 System

You can name and write some description of the CDMA system you want to simulate. It is the same layout as when a generic system is selected.

8.2.2 General

You can enter the frequency. The frequency value is overwritten at the "Scenario" tab level.

Table 25: General system panel

Description	Symbol	Type	Unit	Comments
Frequency	f	D or S	MHz	Distribution of the centre frequency of the system

It is used to define the necessary parameters for the modelling of CDMA systems. The CDMA interface has been split into 2 tabs.

8.3 GENERAL SETTINGS

The General settings tabsheet contains a range of CDMA system parameters as well as some parameters that depend on the modelled direction of CDMA link (uplink vs. downlink). 7 panels characterised the CDMA system. The below graphic represent the CDMA UL when a victim.
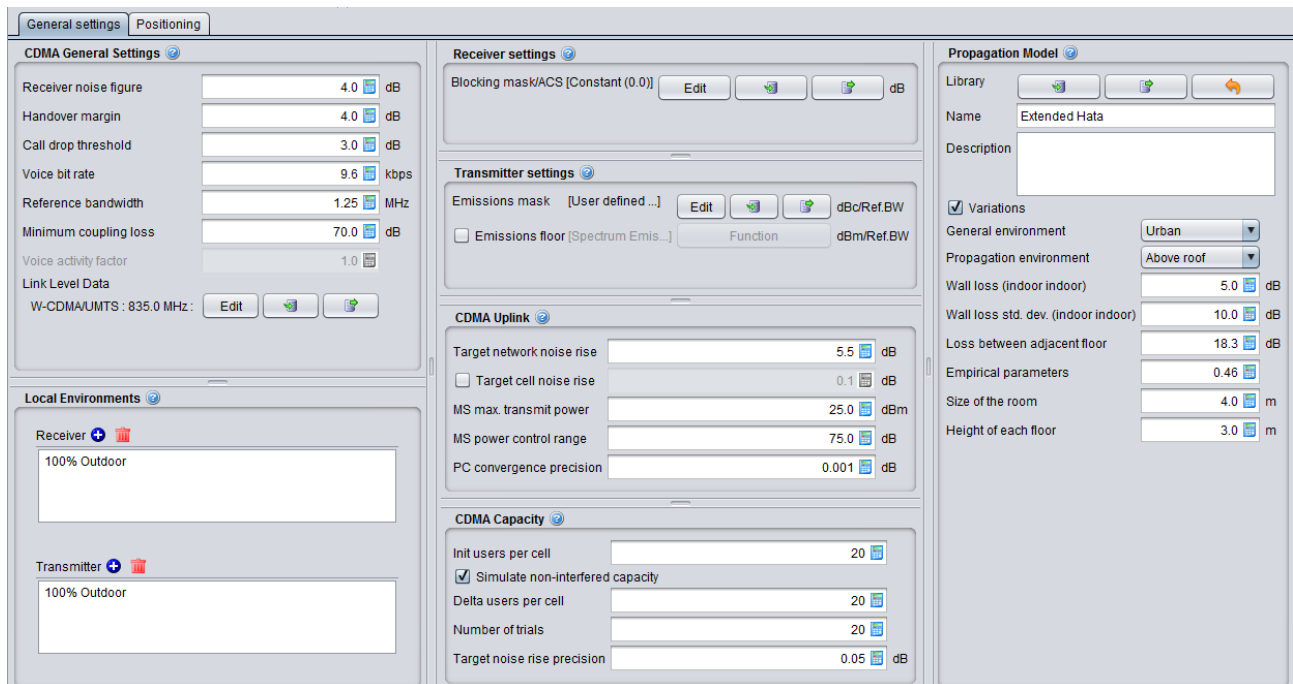
Figure 190: CDMA UL general settings

The only differences with CDMA DL are the following 2 panels (CDMA Downlink and CDMA Capacity).

Figure 191: CDMA DL general settings difference with CDMA UL

8.3.1 CDMA general settings

Table 26: CDMA general settings input parameters

Description	Symbol	Type	Unit	Comments
Receiver Noise Figure		S	dB	Equipment-specific noise figure of receiver. It is used to calculate the noise floor. See Section1.2.2
Handover margin		S	dB	Specifies the maximum difference between the links in users active list. The actual active-list selection is based on pathloss calculations.
Call drop threshold		S	dB	Threshold to determine call drops. It is used by the power control to determine if a user should be dropped when not meeting exact target requirement.
Voice bit rate		S	kbps	it is used to calculate the processing gain. See Section 8.7.1. processingGain = 10*log10(systemBandwidth (MHz) / voiceBitRate (kbps) * 1000);
Reference bandwith		S	MHz	Bandwidth of the system. It is the same for either UL or DL.
Voice activity factor	-	-	-	It is set to 1, i.e. 100% (all voice users that are generated are active). It is not editable.
Minimum Coupling Loss		S	dB	The minimum path loss. It is used in the calculation of the effective path loss depicted in section 7.6.1
Link Level Data		F		Drop-down selection of Link level data look-up functions from Library. It is user's responsibility to choose an appropriate set of data. See Section 8.5 for further details

8.3.2   Local environment

You can choose the suitable indoor and outdoor ratio for the mobile station to be used by the propagation model. Further details are presented in Section 5.4.3.

8.3.3   Receiver settings

This content of this panel depends whether CDMA system is a victim or an interfering system. If the CDMA is a victim, you will have to set the blocking mask. It is a shared interface with OFDMA.
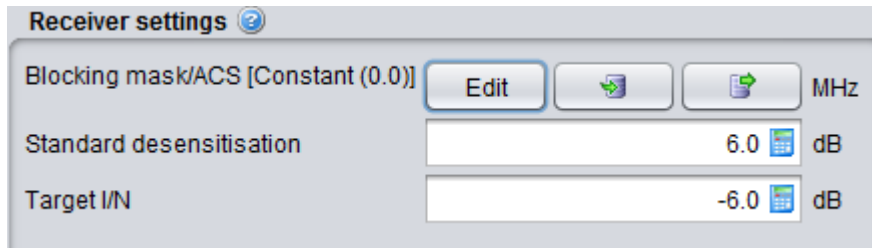
Figure 192: Cellular panel receiver settings

Table 27: Receiver settings of a cellular system

Description	Symbol	Type	Unit	Comments
Blocking mask/ACS: Receiver frequency response (receiver blocking performance)	*blocking*	F (MHz)	dB	It is similar to the blocking response depicted in Figure 12 except that it is to be set as user defined mode only. In case that the blocking mask is defined with negative values, the parameters Standard desensitization and I/N_target (described below) are used to compute the blocking mask used in the simulations.
Standard desensitization			dB	It is value of desensitization of the receiver as defined in the standards.
Target I/N			dB	It is the protection criteria used for the simulation.

8.3.4   Transmitter settings

This content of this panel depends whether CDMA system is a victim or an interfering system. If the CDMA is an interferer, you will have to set the spectrum emission mask and the emissions floor. It is a shared interface with OFDMA.
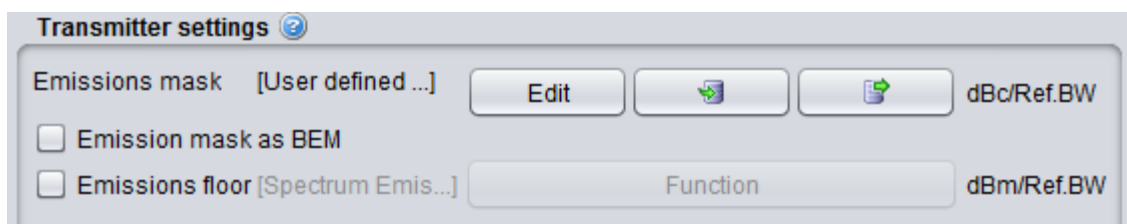
Figure 193: Cellular panel transmitter settings

When defining the Emission Mask (not as BEM) the units of the user defined mask are: Offset (MHz); Mask Values (dBc); Reference Bandwidth (kHz).

When defining the Emission mask as a Block Edge Mask (BEM), SEAMCAT sets to 0 dBi the peak gain of the transmitter antenna and uses the power entries of the Mask as e.i.r.p (already including the gain of the antenna). So, if the Emission mask is defiend as BEM, the units of the user defined mask are: Offset (MHz); Mask Values (dBm e.i.r.p.); Reference Bandwidth (kHz).

8.3.5 CDMA uplink

This is only available if CDMA UL selected.

Table 28: CDMA UL input parameters for the power control

Description	Symbol	Type	Unit	Comments
Target network noise rise		S	dB	Specific level of noise that the network is willing to handle, when this level is reached it starts removing UEs to reduce its noise level
cell noise rise selection		B	-	Select the algorithm that allow the cell selection based on a noise rise increased. If selected, then the measure of the noise rise per each cell is considered and the algorithm, recursively, tries to identify the number of affected cells due to a single source/cluster of interferers and remove users. If not selected, then the measure of the noise rise over the whole network is considered (See Section 8.7.6 for details)
Target cell noise rise		S	dB	Only available when Cell noise rise selection is active. It is set to 0.1 dB by default. The "cell noise rise" algorithm will assess whether to drop users from any cell in which the noise rise exceeds the threshold indicated above. The default value of 0.1 dB has been chosen to ensure that the analysis does not disregard any cases of interfered cells, since users may also be dropped as the consequence of a low noise rise.
MS maximum transmit power		S	dB	Maximum transmit power of the MS (i.e. the UE)
MS power control range		S	dB	Span of the fluctuation of the power
PC convergence precision		S	dB	In the uplink, each mobile station perfectly achieves the target C/I, Eb/N0_target, during the power control loop convergence, assuming that the maximum transmit (TX) power, max_MS_Tx_Pw, is not exceeded. Those mobile stations not able to achieve Eb/N0_target after convergence of the power control loop are considered in outage (i.e. they are dropped). The power control loop is considered to converge when all mobile stations are within the max_MS_Tx_Pw and their Tx power is adjusted by less than the "PC convergence precision" value for the last power balancing iteration.

8.3.6 CDMA downlink

This panel is available only if CDMA DL selected.

Table 29: CDMA DL input parameters for the power control

Description	Symbol	Type	Unit	Comments
Success threshold		S	dB	Threshold to determine perfect link quality.
Base Station Pilot Channel Fraction	*pilot_frac*	S	-	Fraction of max BS power allocated to pilot.
Base Station Overhead Channel Fraction	*Overhead_frac*	S	-	Fraction of max BS power allocated to overhead channels (paging, etc.).
Base Station maximum Broadcast Power		S	dBm	maximum Broadcast Power
Base Station maximum traffic channel fraction		S	-	Fraction of the maximum allowable broadcast power (per traff. chan. per BS). The maximum allowable traffic channel power is compared to the calculated transmit traffic channel power levels with respect to the Ec/Ior link level data for iterative adjustment in the DL power control.

8.3.7 CDMA capacity

The capacity of the simulated system (i.e. how many mobiles per cell should be generated in the system) is dependent on all other settings and cannot always be easily deducted from these. Therefore SEAMCAT has a feature that allows for automatic determination of capacity. This is also known as simulation of non interfered capacity and is enabled by default.
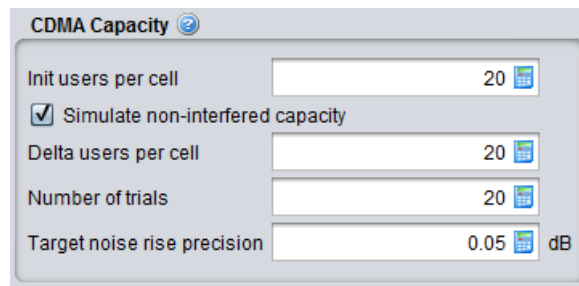
Figure 194: CDMA UL system - Determination of the optimum number of UEs (CDMA capacity)

In CDMA UL, the number of optimised users is being re-calculated for each event. It is recommended to run the "simulate non-interfered capacity" so that SEAMCAT can provide a "best" optimised value, this will optimise the computation time afterwards. If you are using another number you risk to create an overhead in your computation time without any change in the output results.
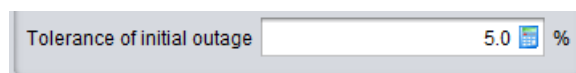
Figure 195: CDMA DL system - Determination of the optimum number of UEs (CDMA capacity)

Table 30: CDMA Capacity settings parameters (UL and DL)

Description	Symbol	Type	Unit	Comments
Simulate non interfered capacity	-	B	-	Toggles automatic capacity finding. If the option **Simulate non-interfered capacity** is <u>checked</u>, then the system will automatically simulate the 'optimal' number of the mobiles for given system configuration (type of system, bandwidth, cell sizes, etc). The optimum finding algorithm is developed to establish the loading that would correspond to approx. 80% of maximum system capacity. If this option is <u>unchecked</u>, you are free to set a constant user-defined average number of mobile users per cell especially if the optimal capacity for the current scenario is known (this is often the case when running consecutive simulations with the same system) there is no need to simulate – as the simulation process can be quite lengthy. When this checkbox is disabled SEAMCAT uses the value entered in 2 – "Users per cell" as the capacity per cell.
Init users per cell	-	S	-	If capacity simulation is enabled this indicates the starting point of the simulation. Selecting the right starting point can speed up the capacity finding. If capacity simulation is disabled the value in this field is the actual value used by SEAMCAT. SEAMCAT does NOT change this input value into the result of the simulation! Users per cell is equal to UE per Base Station. SEAMCAT consider each Base station as its own cell.
Delta users per cell		S	-	When SEAMCAT tries to find the optimal capacity it adjust the number of UEs per cell starting with this value. A proper value here can speed up capacity finding.
Number of trials		S	-	When finding the optimal capacity SEAMCAT runs this (i.e. Number of trials) many snapshots of every value of UEs per cell before deciding whether or not the current value is the optimal capacity. Generally larger numbers mean greater precision but also longer time needed by the algorithm.
Target noise rise precision		S	dB	**Uplink only** – the precision used when comparing the noise rise of the filled system with target noise rise set under the "CDMA Uplink" panel
Tolerance of initial outage		S	%	**Downlink only** – The tolerance of initial outage is the percentage of UEs that can be dropped before SEAMCAT determines that the tested number of UEs cannot fit into the system (i.e. 20 user_per_cell * 19 BS = 380 UEs, if 5% or less of 380 UEs are dropped, the system is considered able to handle/service 20 UEs per cell). SEAMCAT will adjust the value of UEs per cell untill a value is found which in 80% of the specified number of trials is able to handle the tested number of UEs per cell.This parameter allows for UEs in "extreme" pathloss situations to be "ignored" from the optimal capacity finding.

8.3.8   Propagation Model

You can choose the suitable propagation model to be applied when calculating signal loss along the transmitter and the receiver path. A choice and settings of propagation models are presented in ANNEX 17:.

8.4   POSITIONING

See section 7.5, common to CDMA and OFDMA on the positioning of BSs and MSs.

8.5   CDMA LINK LEVEL DATA

8.5.1   CDMA link level system mapping

Power control is a crucial mechanism in CDMA mobile radio networks, which needs to be modeled in SEAMCAT. It is a complex process involving various layers of signaling, measurement and modulation/demodulation procedures. It is not feasible to model signaling, link and chip level details of CDMA power control in network level simulations performed by SEAMCAT due to the complexity and CPU time constraints. Hence, it is necessary to adopt the two-step approach employed widely in the industry for the simulation of CDMA based systems.

The first step utilizes link level simulations that model fast fading channels, power control procedures and actual chip level algorithms to generate outputs that map channel power requirements to link quality (e.g. frame erasure rate, FER). Such simulations involve the knowledge of intricate details of the CDMA signaling procedures and modulation/demodulation methods.

Major CDMA vendors develop link level simulations and contribute their results to the standard bodies. Since the link level results are independent of most system level variations (cell sizes, amplifier ratings, antenna types, etc.), they are applicable to a wide variety of network configurations. The second step in the simulation of CDMA involves system level simulations that actually model the CDMA network on a macro scale. Since the required channel power vs. link performance data is available from the link level results, transmit power levels for CDMA channels can be calculated and utilized in the system level modelling of a CDMA network.

The approach described above enables the reuse of link level data to model various network configurations. Furthermore, through the use of the link level data, an accurate power control model is implicitly included in the system level simulations that run at moderate complexity.

The built-in CDMA Link level Data used in DL and UL can be found in Section 13.4.6. SEAMCAT allows you yo load your own library too.

8.5.2   CDMA DL Power Control Methodology (VOICE ONLY)

Figure 196 presents the dependency between the condition of a user in the network (the so called geometry), mobile speed and soft handover state of the UE that are needed to map a particular link quality to the channel power requirement.
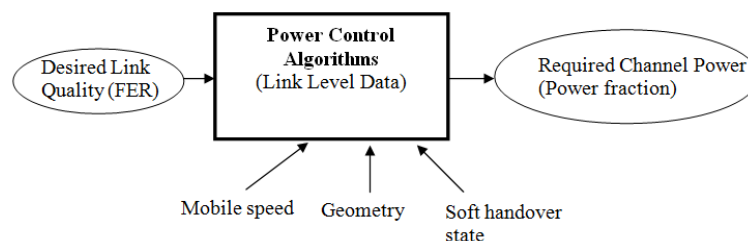
Figure 196: Power Control Module (high level)

All these factors determine the appropriate mapping of a particular link quality to the channel power requirement. For example, stationary users may require less power than moving users to attain the same link quality. Similarly, users connected to several BS's at the same time (soft handover) may require less power than users connected to a single BS to achieve the same link quality. Furthermore, users in favorable locations (high geometry) may again require less power than users that are in unfavorable locations (low geometry). Hence, link level data includes different mappings (look up tables) between link quality and

required power for different mobile speeds, geometries and soft handover states. Furthermore, in order to remove the dependency on the total BS power (may vary from system to system), the power requirements are reported as normalized power fractions (fraction of the total BS power).

Consequently, the link level data is used in modelling power control in a variety of conditions such as different mobile speeds, geometrical user distributions, soft handover characteristics and amplifier output power ratings. In CDMA Downlink, the link level is a function of Ec/Ior.

8.5.3   CDMA uplink Power Control Methodology in SEAMCAT (VOICE ONLY)

Performance characteristics of individual links to be used in the power control module of SEAMCAT are generated a priori from link level simulations. This usually includes several mappings between requested link quality (e.g. block error rate, BLER) and required transmit power of mobile stations/base stations. For generating such mappings in form of "look up tables", link level simulations involve multipath fading, physical layer transceiver algorithms, e.g. modulation/demodulation and coding/decoding, as well as power control procedures. Different mulipath fading channels (e.g. the ITU channel models) are used to model various configurations, e.g. indoor, outdoor, pedestrian, vehicular, etc.

In CDMA UL, the sum of received C/I values in two sectors should meet the C/I requirements specified by the link level simulation data. In CDMA Uplink, the link level is a function of Eb/No.

8.6   CDMA DOWNLINK - SIMULATION ALGORITHM

8.6.1   Simulation Methodology

The main goal of the downlink power control in SEAMCAT is to calculate the total BS output power and the success rate (% of calls with no link quality degradation) for a given snapshot of the system. BS output power is a key parameter in the scenarios where CDMA is the interferer. Success rate, on the other hand, is crucial in CDMA victim scenarios. One possible way to analyze the impact of other system interference on CDMA is to compare the success rates in the presence and absence of external interference.

A snapshot of the mutually existing systems is modeled at each event generation in SEAMCAT. Hence, at each event generation the power control algorithm should also be run for the CDMA cell, whether it is the victim or the interferer. This is illustrated in Figure 197. The setup block is inherited from the higher layers of SEAMCAT and consists of initializing the system parameters. The next step involves the generation of traffic for power control, calculation of appropriate path losses within the CDMA cell layout and determination of soft handover states. Power control is then performed by utilizing the link level data via an iterative process. Finally, necessary outputs are generated and fed into the interference calculation modules in SEAMCAT.
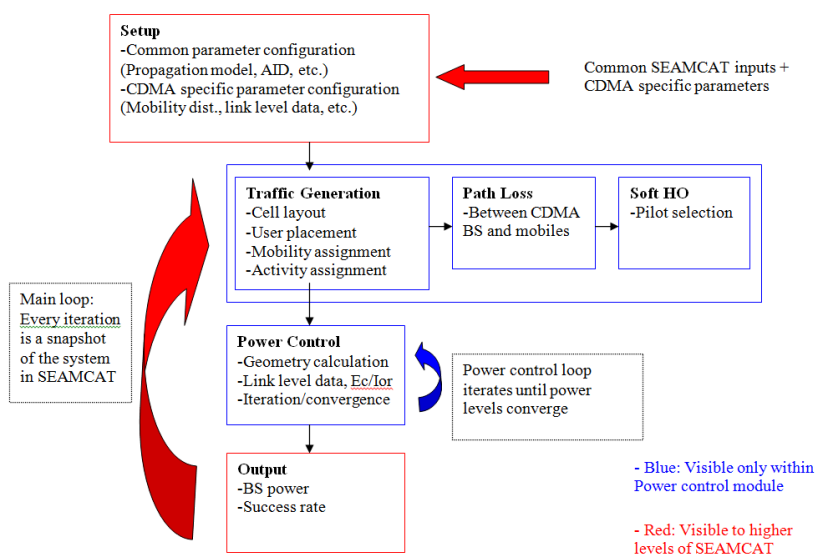
Figure 197: DL Power Control Simulation Methodology – Overview

For simplicity, the CDMA downlink power control methodology is described for omni-cells. However, extension to multi-sector cells is straightforward. In a multi-sector configuration, each sector should be treated in the same way a cell is treated in the omni configuration.

8.6.2 Traffic Generation

While the BS output power and the outage ratio is likely to be calculated for a single CDMA cell, accurate modelling of power control requires the consideration of inner-system interference generated by the surrounding tiers of CDMA cells. The significance of other cell interference in CDMA requires that at least two tiers surrounding the cell of interest be considered. However, BS power and outage statistics will only be collected from the center cell, which has the most accurate interference background (two surrounding tiers). Cells surrounding the center cell will not be visible to the higher levels of SEAMCAT and will only be used to generate the inner-system other-cell interference background for the center cell (Figure 198).

-Center cell - Included in SEAMCAT interference analysis: simulated mobiles and BS

- 1st Tier cells - Not visible outside power control: simulated mobiles and BS's

-2nd Tier cells- Not visible outside power control: artificial interference generators (not simulated)
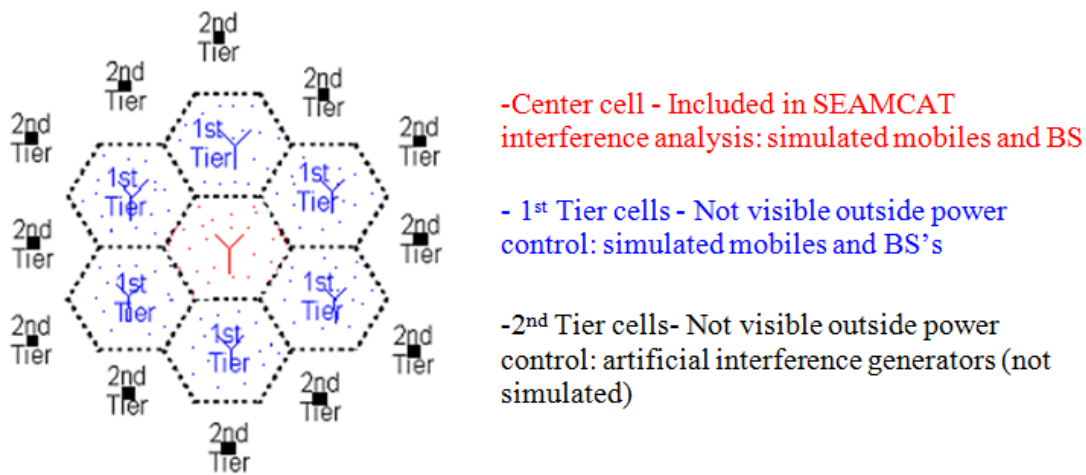
Figure 198: Cell layout for power control

The power control simulation time increases with the number of cells for which power control algorithm is run. One way to reduce the simulation time is to simulate only the center cell and the first tier around it with actual power control algorithms and use artificial interference generators for the second tier as shown in Figure 198. More specifically, the BS's in the center cell and the first tier go through the power control algorithms and calculate the precise power they need to transmit. Whereas, the BS's in the second tier are assigned an output power level to generate interference into the center cell and the first tier. If the output power level set for the second tier is reasonable, this approach will speed up the simulation considerably without sacrificing much from accuracy. Possible methods to determine the appropriate artificial interference level will be addressed later in the paper. Nevertheless, if more accurate results are desired, the second tier can also be simulated using actual power control. In that case, a third tier with artificial interference generators would further increase accuracy by presenting the second tier with a more realistic interference background. However, given the considerations on complexity, the layout shown in Figure 198presents the most appropriate balance between simulation speed and accuracy.

Since higher levels in SEAMCAT consider only a single CDMA cell, the cell layout shown in Figure 198 may need to be generated separately in the power control module. It is expected that the UE placement be done consistently with SEAMCAT's existing algorithms. However, once the UEs are placed, their mobility assignment should also be done. Actual mobility of the UEs cannot be simulated easily in a static simulation, but the effects of mobility on the channel power can be modeled in a limited sense. While the UEs will be treated at fixed locations within each snapshot, each will be assigned a speed to determine

their channel conditions (fast fading), which will be used in the determination of their channel power requirements. This allows the flexibility to simulate various system configurations (fixed, highway, pedestrian, etc.).

8.6.3   Soft Handover

A user may simultaneously be connected to multiple BS's in CDMA based systems (soft handover). Since soft handover affects the amount of power transmitted by each BS to a certain user, it is necessary to determine whether the UE is served by a single BS or multiple BS's. The actual determination of the soft handover state of a user and the corresponding channel power requirements may get complicated. Hence, a simplified soft handover algorithm is presented next, which captures the essence of soft handover effects while avoiding implementation of complex algorithms.

Base stations that are connected to a user are included in the "active set" of that user. A base station is initially selected to be in the "active set" based on the strength of its pilot signal versus the interference background. Each base station broadcasts a certain fixed percentage of its maximum power on the pilot channel. The interference background consists of the non-orthogonal energy received on the other channels of the base stations within the active set and the total broadcast power of the base stations that are not in the active set. The BS selection criterion, "pilot Ec/Io" is then defined as

$$\left(\frac{E_c}{I_0} \right)_i = \frac{pilot\_frac \times P_{Max,i}/W}{FN_0 + \sum_{allj} P_j/W + I_{ext}/W} \tag{Eq. 34}$$

with the following definitions:

- E_C is the chip energy received from ith BS;
- I_O is the spectral density of total received interference;
- *pilot_frac* is the fraction of BS power allocated to pilot;
- $P_{max,I}$ is the maximum receivable power from ith BS (max BS transmit power*path loss);
- W is the system bandwidth;
- P_j is the total received power from jth BS;
- F is the mobile station noise figure;
- N_0 is the thermal noise power density;
- I_{ext} is the external interference (out of system).Based on this selection criterion, the following simplified soft handover algorithm can be employed to assign soft handover states to each user:

For each user:

1. Add the BS with the strongest corresponding Ec/Io to the active set;
2. Add the BS with the second strongest corresponding Ec/Io to the active set if its Ec/Io is within 4 dB of the strongest Ec/Io.

Then the soft handover state of a user becomes the number of BS's in its active set, which is either one or two. Note that in actual systems, the active set of a user may have more than 2 BS's. However, in order to develop a unified methodology that can simulate various implementations of CDMA based systems and to avoid overwhelming complexity, this simplified approach is suggested. Several standards (including UMTS) present similar methodologies for simulations.

8.6.4   Power Control

As far as SEAMCAT is concerned, the actual CDMA power control algorithm looks merely like a black box that maps link quality to channel power. However, the mapping is not simply one-to-one. Depending on the conditions of the mobile user, the same link quality can map to different channel power requirements. A key parameter that determines the condition of a user is called the "geometry". The higher the geometry, the more favorable the UE's condition is. The geometry is defined as:

$$G = \frac{P_{active}}{N_0 + P_{other} + I_{ext}}$$

(Eq. 35)

with the following definitions:

- P_{active} is the total power received from BS's in the active set;
- N_O is the thermal noise;
- P_{other} is the total power received from BS's not in the active set;
- I_{ext} is the external Interference (out of system).The fractional power levels found in the link level data are defined for each user (channel) as:

$$\frac{E_c}{I_{or}} = \frac{P_{traff\_active}/W}{P_{total\_active}/W} = \frac{P_{traff\_active}}{P_{total\_active}}$$

(Eq. 36)

with the following definitions:

- P_{traff_active} is the total received traffic channel power from BS's in the active set
- P_{total_active} is the total power received from BS's in the active set

P_{total_active} is the sum of the total received power from the BS's in the active set including their pilot, overhead and all traffic channels. Whereas P_{traff_active} includes only the traffic channel power that is received from the BS's in the active for the particular user. In other words, a user's Ec/Ior shows the fraction of the total received power that is used for voice communication with that user. Based on this definition, the amount of traffic channel power received from a BS for a particular user can be derived from the Ec/Ior requirements reported in the link level data.

If user has only 1 BS in the active set (simplex), the power received from the BS is:

$$P_{traff} = P_{total\_active} \times E_c/I_{or}$$

(Eq. 37)

If user has 2 BS's in the active set (2-way soft handover), power received from one of the BS's is then:

$$P_{traff} = (P_{total\_active} \times E_c/I_{or})/2$$

(Eq. 38)

Note that symmetry between the two soft handover legs (links with BS's in the active set) is assumed. Therefore, when a user is connected to two BS's, it receives equal power from each link. The determination of the traffic channel power levels for each user cannot be done in a single step. The inherent assumption in equations 37 and 38 is that Ptotal_active is known. However, Ptotal_active itself is the sum of the pilot, overhead and all traffic channel power levels received from the BS's in the active set. Therefore, an iterative process is required to determine the individual traffic channel received power levels.
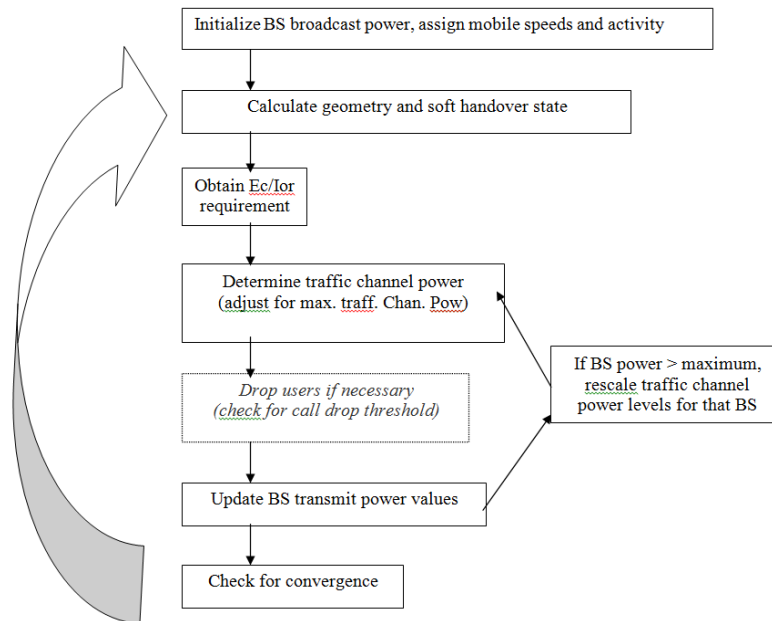
Figure 199: Power Control Loop

Figure 199 shows how the power control loop operates. The initial step is to initialize each BS in the cell layout (figure 1) by assigning total broadcast power levels. A figure around 70% of maximum BS power is appropriate. Note that for the simulated BS's, the total BS power will be updated at each iteration by the power control loop. After enough iterations, the power levels will converge to the correct values.

Once the initialization is complete, geometry and soft handover state for each user can be calculated based on the initial values of the BS broadcast levels. Then the Ec/Ior requirement for each active user can be obtained from the link level data using its mobile speed assignment, calculated geometry and soft handover state. Equations 37 and 38 can then be used to get the received traffic channel power levels for each user. Path loss information can then be used to determine the corresponding transmit channel power levels. However, the calculated transmit traffic channel power levels should be checked against the maximum allowable traffic channel power and transmit/receive levels should be adjusted if necessary. As a result of such an adjustment, a user may not meet its Ec/Ior requirement. Based on a "call drop threshold", such a user may be removed from the system if it meets the following criterion:

$$Achieved\ E_c/I_{or} < E_c/I_{or}\ requirement - Call\ drop\ threshold\ (dB) \qquad (Eq.\ 39)$$

The call drop threshold is set such that dropping a call is limited to extreme circumstances (thresholds less than 2dB are not recommended) and kept mostly as a safety measure to avoid a single user hogging the BS resources. In an actual system, calls are not dropped at the instant they fail to meet their link quality target. The system will tolerate quality degradation up to certain durations and at the same time avoid a single user to sacrifice the overall system performance by consuming all the BS resources (max. traff. chan. pow. setting). In fact, for systems that employ sufficient control of maximum traffic channel power, call drops may be avoided completely within the power control loop. Eventually, users not meeting their Ec/Ior target will be evaluated when the success rate of the system is calculated.

Once the transmit traffic channel levels are calculated, the broadcast power of each BS should accordingly be updated. If the total broadcast power of a BS turns out to be greater than its maximum allowable level, all traffic channels served by that BS should be scaled down so that the maximum BS power constraint is met. The scaling factor that should be applied to the traffic channel power levels can easily be calculated as:

$$Scaling = \frac{P_{max} - (pilot\_frac \times P_{max}) - (overhead\_frac \times P_{max})}{P_{calculated} - (pilot\_frac \times P_{max}) - (overhead\_frac \times P_{max})} \qquad (Eq.\ 40)$$

where:
- P_{max} is the maximum allowable BS power
- $P_{calculated}$ is the actual calculated BS broadcast power (including pilot and overhead).

Scaling is only done if $P_{calculated} > P_{max}$ and it is done only on the traffic channels; pilot and overhead power levels remain at a constant percentage of the maximum allowable BS power. For channels that go through the scaling, achieved E_c/I_{or} levels may not match the required E_c/I_{or} levels. Therefore, call drop criterion (if used) shown in equation 6 should also be checked after the scaling. The process is outlined in Figure 199.

This process describes a single iteration of the power control loop. After all the traffic channel power levels are determined and the BS levels are updated, the process should be repeated (with the new, more accurate BS broadcast levels). Convergence of the traffic channel power levels should be checked at the end of each iteration. The loop can be terminated once the traffic channel power of every simulated user in the network converges to the desired precision.

Signaling and other errors in power control are considered in the link level simulations. System level simulations do not consider additional errors and assume that each user is served with the required power level that is determined from link level data, provided that the BS has enough power to do so and the maximum traffic channel limit is not exceeded.

8.6.5 Success rate

The power control loop terminates when every BS broadcast power converges and traffic channel power level for every user is calculated. Therefore, both the BS output power and the success rate for the cell of interest (center cell in Figure 198) can be calculated. BS output power is the sum of the power in pilot, overhead and all traffic channels. Success rate is the percentage of calls that do not suffer quality degradation. The following process can be used to calculate both output metrics:

  i.   Power control loop is terminated (traffic power converges for every user)
  ii.   Final BS transmit power levels are calculated (sum of all traffic, pilot and overhead)
  iii.   Total BS broadcast power for the cell of interest is determined

(For each active user in the cell of interest)

  iv.   Final geometry is calculated based on BS power levels calculated in ii.
  v.   Traffic E_c/I_{or} target is determined based on geometries calculated in iv.
  vi.   Achieved E_c/I_{or} is calculated based on BS power levels calculated in ii.
  vii.   Success criterion is checked

$$\left(\frac{E_b}{N_r}\right)_{achieved} \overset{?}{\geq} \left(\frac{E_b}{N_o}\right)_{target} - \text{Success Threshold (dB)} \qquad (Eq.\ 41)$$

  viii.   Success rate is determined for the cell of interest

Success Threshold is usually a small figure such as 0.5dB. Users who miss their E_c/I_{or} targets by more than the threshold suffer link quality degradation. Note that if call drops occurred within the power control loop, they should also be considered when success rate is determined:

$$\text{Success Rate} = \frac{\#\,\text{users meeting success criterion}}{\text{Total}\,\#\,\text{of active users including call drops}} \qquad (Eq.\ 42)$$

8.7 CDMA UPLINK - SIMULATION ALGORITHM

The center cell site only is used to calculate the effects of interference. In spite of this fact, it is essential to consider the intra-system interference caused by other cells in the cluster for an accurate modelling of power control. The precise transmit power of all active mobile stations in the wrap-around cluster has to be calculated in the uplink power control loop.

8.7.1 Power Control

In CDMA networks, closed-loop fast transmit power control (TPC) is supported in uplink. The base station estimates the signal-to-interference ratio (C/I), measured in bit energy-to-noise density ratio E_b/N_0, and

compares it to a target value (E_b/N_0_target). If the estimated C/I is below E_b/N_0_target, the base station commands the mobile station to increase the transmit power; if the measured C/I is above E_b/N_0_target, it commands the mobile station to lower its power. The fast transmit power control works at a frequency of f Hz (1500 Hz for WCDMA and 800 Hz in CDMA2000 1x), thus the TPC commands are transmitted at 1/f s time intervals (0.667 ms for WCDMA and 1.25 ms for CDMA2000 1x).

In reality, the fast TPC is not ideal because of issues such as

- inaccuracies in the C/I estimates;
- transmit power control signaling errors;
- delay in the transmit power control loop.

Links level simulations take these errors into account and reflect their impacts on the link quality figures in the look up tables to be input to the power control module of SEAMCAT. Therefore, we assume a simple C/I based fast closed-loop TPC of traffic channels for uplink in the following.

In the uplink, each mobile station perfectly achieves the target C/I, Eb/N0_target, during the power control loop convergence, assuming that the maximum transmit (TX) power, max_MS_Tx_Pw, is not exceeded. Those mobile stations not able to achieve Eb/N0_target after convergence of the power control loop are considered in outage.

The local-mean Signal-to-interference power ratio in the uplink, $(C/I)_{UL}$, is calculated by multiplying the received signal power S by the processing gain G, and dividing the result by the total interference power I_{total}

$$\left(\frac{C}{I}\right)_{UL} = \frac{G \cdot S}{I_{total}}$$

(Eq. 43)

with

$$I_{total} = (1 - \beta) \cdot I_{intra} + I_{inter} + I_{out} + N_0$$

(Eq. 44)

I_{intra} is the intra-cell interference power, i.e. the interference generated by those mobile stations served by the same base station as the considered mobile station. I_{inter} is the inter-cell interference power from other radio cells. I_{out} is the interference power coming from the interfering system. N_0 is thermal noise (as well as spurious interference) contained in the receiver bandwidth, W, and β is an interference reduction factor due to the use of interference mitigation signal processing techniques in the uplink, e.g. Multi User Detection. No such interference mitigation technique is assumed in these considerations, therefore $\beta = 0$.

Assuming a mobile station power control range in the order of *MS_PC_Range* dB; the minimum TX power is therefore *max_MS_Pw_Tx – MS_PC_Range* dBm.

8.7.2 Soft and Softer Handover

The handover model proposed is a simplified soft handover. We assume that all base stations transmit with the same pilot power in downlink. Therefore, P_{L_fading} (path loss plus the shadow fading) is the only criterion for selecting the base stations belonging to the active set of a mobile station.

We assume that active set for a mobile station consists of two base stations; the base station with the strongest signal, i.e. the lowest P_{L_fading}, and the base station with the second strongest signal if its signal strength is within *Handover_Margin* dB of the strongest signal (in other words its P_{L_fading} is within *Handover_Margin* dB of the lowest P_{L_fading}).

In the case that base stations with omni-antenna are used at the cell sites, selection combining among the base stations in active set is performed and the base station with the strongest signal is selected as the serving base station of the mobile station. In the event of base stations with tri-sector antenna, similar procedure is applied, if the two sectors in the active set belong to different cell sites, else a maximal ratio combining is realized by summing the received signal powers. In the later case, the sum of received C/I values in two sectors should meet the C/I requirements specified by the link level simulation data. Because

during softer handover, the mobile station is usually in the overlapping coverage area of two adjacent sectors of the base station, it is reasonable to assume that it has symmetric links to both sectors in the active set. As a consequence, each sector needs to fulfill one half of the C/I requirement.

8.7.3 Voice Activity Factor

The voice activity factor is the measure of how long the non-silence period is to the overall time for voice communication as it reflects the fact that speech users are silent or speaking. In SEAMCAT, It is assumed that all connected users are speaking constantly during a simulated event. It is therefore set to 1 (i.e. 100%).

8.7.4 System loading

The following procedures can be used for system loading during simulation and preparation of simulation outputs.

System loading
To determine the number of active mobile stations *Act_MS* in the network:

1. Set up:

    I. Average traffic load in terms of a predefined number of users per cluster: *N_UL*

    II. standard deviation of log-normal shadowing $\sigma_{shadowing}$

    III. voice activity factor *Act_Factor (fixed to 100%)*

    IV. target maximum noise rise over the thermal noise in the network η_*target*

    V. target C/I (E_b/N_0_target) to fulfill service requirement depending on configuration and mobility (provided by link level simulations)

    VI. maximum transmit power of mobile station *max_MS_Pw_Tx*

    VII. power control range – *MS_PC_Rang*:

    VIII. In the case that the CDMA uplink is the victim link, add the received power from the interfering system to the thermal noise power

2. For each event:

    I. put down uniformly mobile stations at pseudo-random locations across the network and distribute speed among them

    II. Add a new mobile station in the set of active users in the network

        ➢ compute average path-loss from the mobile station to the base station of each cell

        ➢ generate a log-normal pseudo-random value to add to each of the path losses to model shadow fading

        ➢ perform a pseudo-random weighted coin-toss to determine voice activity, where 1 occurs with probability *Act_Factor*

        ➢ compute required received power at the base station to meet E_b/N_0_target, given interference from pre-existing mobiles and other sources ($\left(\dfrac{C}{I}\right)_{UL}$ and I_{total})

        ➢ compute required transmit power of the mobile station

        ➢ adjust the required transmit powers of the all existing mobile stations perturbed by addition of the new mobile station

> ➢ continue the adjustment until the convergence of power control loop is achieved. A convergence criterion could be that the variation of two consecutive transmit powers of each mobile station is within a predefined threshold.

> ➢ compare the number of active mobile stations, *Act_MS*, with *N_UL*

>> ▪ if *Act_MS ≥ N_UL* terminate the addition of a new mobile station in the network

>> ▪ else measure the average noise rise over the thermal noise η and compare it with the target noise rise limit η_target

>>> o if η_target is reached, terminate the addition of a new mobile station in the network

>>> o else add a new mobile station and go to step II

8.7.5 Outage calculation

Two conditions are counted as outage.

1. A mobile station, which is not able to transmit the required amount of power to meet the received E_b/N_0_target due to maximum power limitations. This mobile is counted as part of the specified traffic load *N_UL*. However, the mobile is assumed to be transmitting no power.
2. In the case of *Act_MS < N_UL*, no more mobile stations can be added to the set of active users because of noise rise limits. In this event, *N_UL - Act_MS* outages are counted.

For each event, the number of optimised users is being re-calculated

8.7.6 CDMA UL cell selection

For the CDMA UL, there are two algorithms selectable in SEAMCAT:

Recommended algorithm when the interferer is a cellular network or affecting many cells in a network: the noise rise (which is measured per cell) is averaged over the whole network. This way, the UEs with highest power over the whole victim network are removed in order to compensate the noise rise due to external interference (Section 8.7.4).

Recommended algorithm when the interferer affects one or a few cells in a network (e.g. a strong interferer located close to a small part of the victim network): the noise rise is calculated per cell. This algorithm works as follows:

1. The cells with highest noise rise are selected.
2. Recursively, cell per cell, the UEs with highest power in the cell are removed in order to level out the network noise rise (see Annex A15.3 for further details on the algorithm)

This algorithm allows investigating per event how many cells are being affected (see Section 12.5.3).

8.8 CAPACITY FOR CDMA SYSTEM

When starting a simulation involving one or more CDMA systems SEAMCAT will begin by checking if any of the CDMA systems have the "Simulate non interfered capacity" feature enabled (this is the default setting). The purpose of the "Simulate non interfered capacity" feature is to find the non interfered capacity system (i.e. how many mobiles per cell should be generated in the system before the introduction of an external interference) with the current configuration.

For each CDMA system needing to have its optimal capacity simulated the screen shown in Figure 200 and Figure 201 will appear for uplink and for downlink systems respectively.

8.8.1 CDMA Uplink capacity finding

In CDMA uplink, the capacity is found by gradually filling system with users until a certain average noise rise with the specified threshold noise rise is reached. The Noise rise is measured as the linear average of dB values – across all 19/57 base-stations. After every trial SEAMCAT calculates the average noise rise over

the total number of trials and if this value is above the threshold restarts the simulation with a lower value of users per cell.
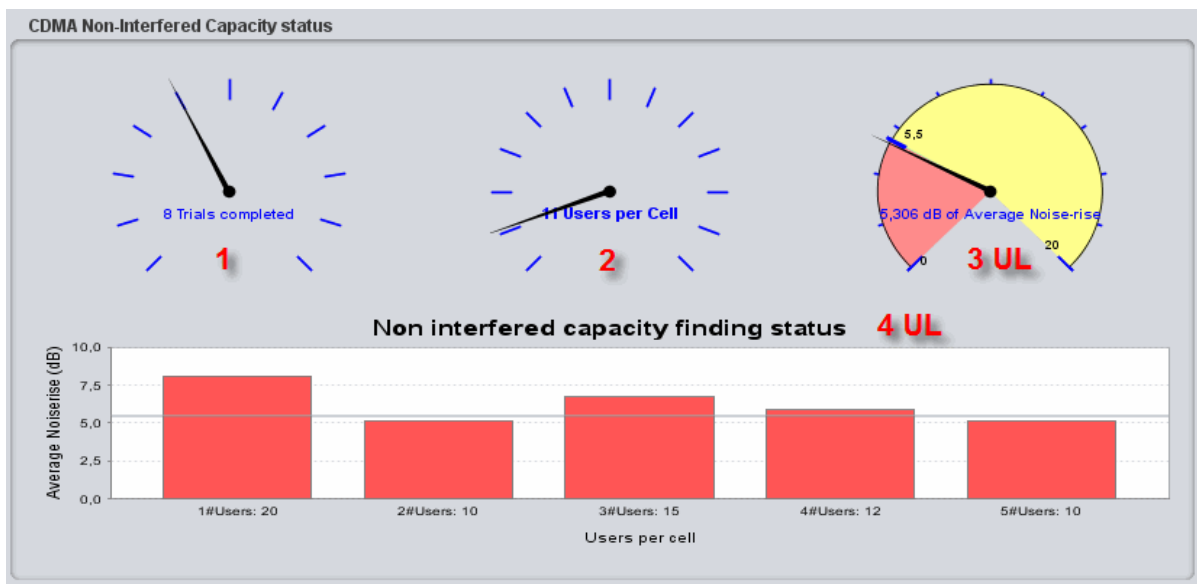

Figure 200: Uplink non-interfered capacity finding

Table 31: Elements of the uplink non-interfered capacity finding screen

ID	Description
1	This dial indicates the number of trials completed with the current capacity. This dial will range from 0 to the number of trials entered as value "4" on Figure 194.
2	This dial indicates the current number of users being tested. Range is dynamic and the dial is mainly intended as an easy visual indicator of values being tested.
3 UL	The needle shows the current value of average noise rise across the trials run. The red area indicates the noise rise is too low (too few users in the system) – the green area is the target noise rise (plus/minus) the tolerance specified. The yellow area indicates the average noise rise is too high (too many users in the system).
4 UL	The bar chart gives information on previous values tested. The Y axis is the average noise rise and the X axis is the number of users per cell being tested.

8.8.2　CDMA Downlink capacity finding

In CDMA downlink, the capacity is found by gradually filling system with users while measuring system outage. For every number of users a certain number of trials are run and then the number of "successful" trials is compared to a predefined success criterion. Only the number of trials is configurable by user – success criterion is fixed at 80%. This means that optimal capacity of a downlink system is defined as the capacity which the system is able serve without any outage in 80% of trials. This step can be quite time consuming. See ANNEX 15: to get a detailed description on how SEAMCAT determines "optimal capacity" for DL CDMA– using the values from Figure 195.

SEAMCAT tries to detect when no more trials with a tested value is needed to adjust to the next value. As an example, if 40 users per cell are being tested for 20 trials and the first 5 trials are unsuccessful it is not possible to reach 80% success rate and there is no need to simulate the last 15 trials. Regardless of the result of the last 15 trials SEAMCAT will conclude that fewer users per cell are needed. If more than 80% success rate is reached before all trials are simulated, there is no need to simulate the rest of the trials.
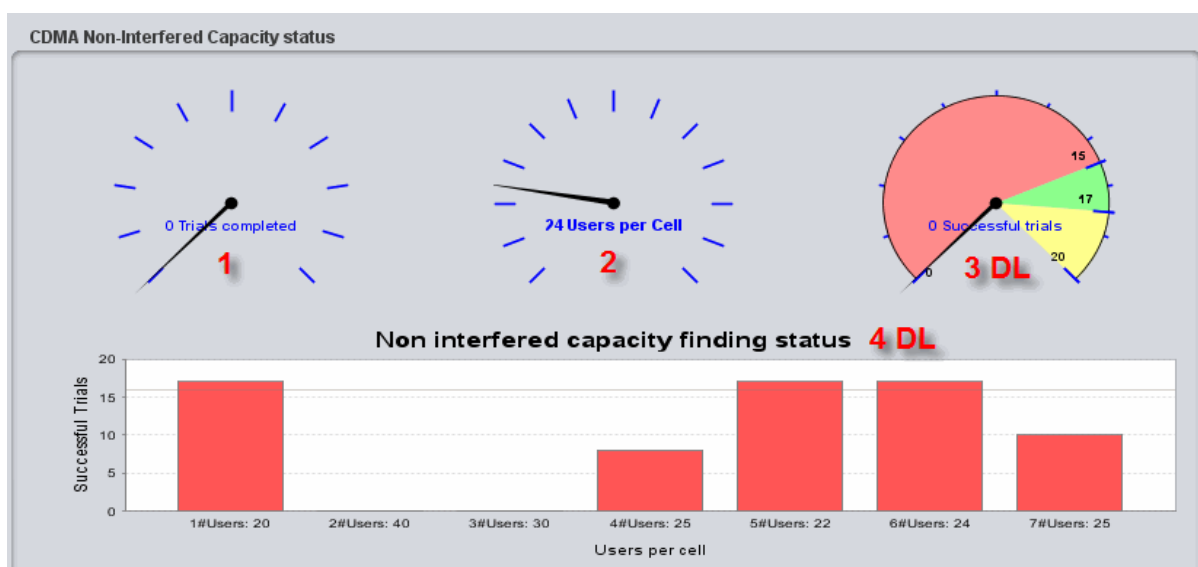
Figure 201: Downlink non-interfered capacity finding

Table 32: Elements of the downlink non-interfered capacity finding screen

ID	Description
1	This dial indicates the number of trials completed with the current capacity. This dial will range from 0 to the number of trials entered as value "4" on Figure 194. SEAMCAT does not always simulate all the trials – target is 80% success and if for example 5 out of 20 have already failed – SEAMCAT does not simulate the rest of the trials.
2	This dial indicates the current number of users being tested. Range is dynamic and the dial is mainly intended as an easy visual indicator of values being tested.
3 DL	The red area indicates that less than 80% has been reached (i.e. too many users in the system – or not all trials yet complete) – the green area is 80% (16 trials with the default settings). The yellow area indicates that more than 80% of the trials are successful (too few users in the system). SEAMCAT stops when this dial stops in the green area after all trials completed.
4 DL	The bar chart gives information on previous values tested. The Y axis is the number of successful trials and the X axis is the number of users per cell being tested.

9   OFDMA MODULE

9.1   INTRODUCTION

The current OFDMA module has been designed for a Long Term Evolution (LTE) network from 3GPP [10]. Therefore E-UTRA RF coexistence studies can be performed with Monte-Carlo simulation methodology.

The general simulation assumptions are presented in this section to provide a guideline on how to perform the coexistence simulation. This OFDMA LTE algorithm is assumes a 100% loaded system and each user is allocated with a fixed number of resource blocks. This is equivalent to modelling a Round Robin scheduler with full buffer traffic model and a frequency reuse of 1/1 (i.e. Single Frequency Network is assumed). The OFDMA algorithm as implemented in SEAMCAT takes into account the intra system interference into the reference cell, caused by UEs located in adjacent cells and using the same RBs but also caused by UEs located in the reference cell which are using different RBs.

The network layout is similar to the one used for CDMA. The methodology assumes that the UEs are deployed randomly in the whole network region according to a uniform geographical distribution. The wrap around technique is employed to remove the network deployment edge effects.

Note that if the OFDMA is a DL interferer, the OFDMA is simulated as in "traditional" simulation with the BSs transmitting at full power. This decreases the simulation time of a full OFDMA simulation. In OFDMA DL interferer, only the position of the BSs will be calculated because full transmit power is assumed. For all other simulations (including UL) scenarios full OFDMA network simulation is required. Consequently, some of the input parameter of the GUI interface have been grey-out when the OFDMA DL interferer case is selected.

Since it is arguable that some simulation assuming a rural environment would not need to assume full power transmission (i.e. full loaded network) when the system is DL and interferer, you may need to manipulate either the input power or the spectrum mask (or both) in order to simulate the DL interferer case for rural deployment.

9.2   OFDMA SYSTEM TAB

Whether you want to simulate OFDMA UL (uplink) or OFDMA DL (downlink), you can import ⬛ from the system library (Figure 189 – (a)), the cellular system you want (Figure 189 – (b)). You can also export ⬛ the characteristics of your OFDMA network to the library for later reuse.
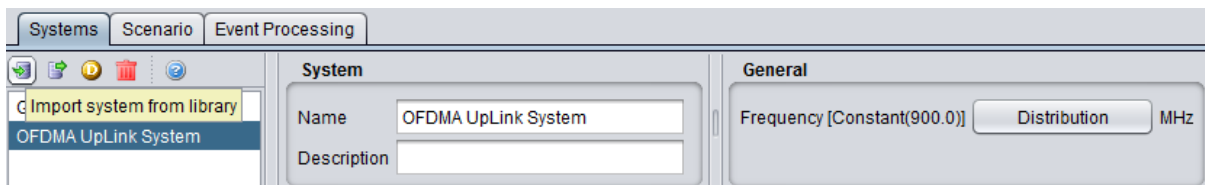
(a)
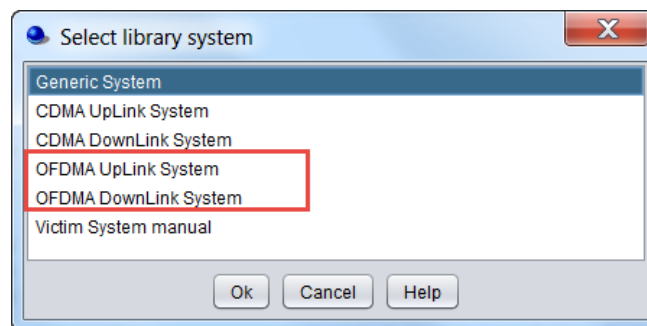
(b)

Figure 202: Selection of a OFDMA cellular network from the system library

9.2.1 System

You can name and write some description of the OFDMA system you want to simulate. It is the same layout as when a generic system is selected.

9.2.2 General

You can enter the frequency. The frequency value is overwritten at the "Scenario" tab level.

Table 33: General system panel

Description	Symbol	Type	Unit	Comments
Frequency	f	D or S	MHz	Distribution of the centre frequency of the system

It is used to define the necessary parameters for the modelling of CDMA systems. The CDMA interface has been split into 2 tabs.

9.3 GENERAL SETTINGS

The General settings tabsheet contains a range of OFDMA system parameters as well as some parameters that depend on the modelled direction of OFDMA link (uplink vs. downlink). 8 panels characterised the OFDMA system. The below graphic represent the OFDMA UL..
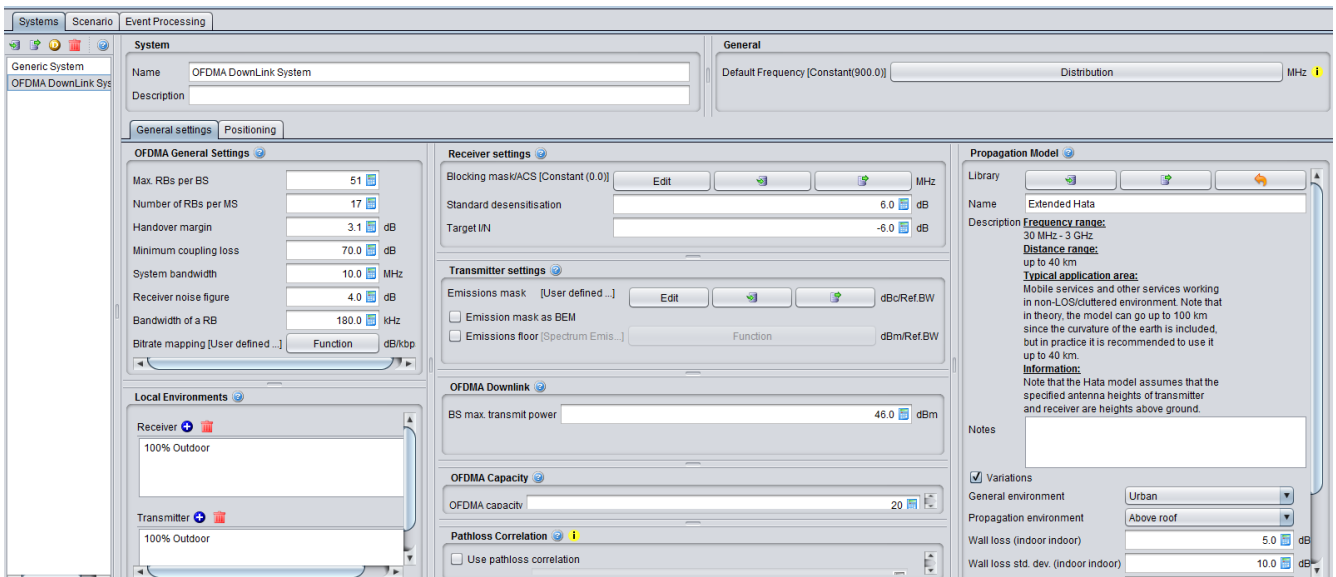

Figure 203: OFDMA general settings GUI

The only difference with OFDMA DL is the definition of the transmit power. The OFDMA DL does not have a power control algorithm.
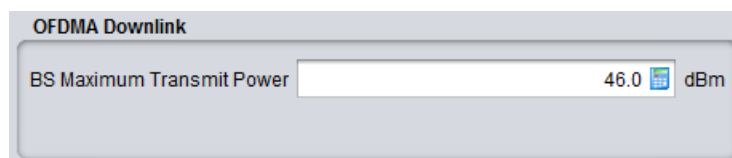

Figure 204: Transmit power in OFDMA DL

9.3.1 OFDMA general settings

They are similar for the OFDMA DL and UL.

Table 34: OFDMA general settings input parameters

Description	Symbol	Type	Unit	Comments
Max RBs per Base Station	-	S	-	Number of available Resource Blocks (RBs) per BS
Number of RBs per mobile	-	S	-	Number of RBs per UE. **Note the ratio of Max RBs per Base Station/ Number of RBs per mobile gives the number of active users per serving BS.**
Handover Margin			dB	Specifies the maximum difference, in dB, between the links in users active list. The actual active-list selection is based on pathloss calculations.
Minimum Coupling Loss		S	dB	The minimum path loss. It is used in the calculation of the effective path loss depicted in section 7.6.1
System bandwidth		S	MHz	When the OFDMA is the interferer and depending on the direction of the interfering OFDMA link to be simulated, you should pay attention to the emission bandwidth of the unwanted emission mask and the system bandwidth (see Section 9.3.4)
Receiver Noise Figure		S	dB	Equipment-specific noise figure of receiver. It is used to calculate the noise floor. See Section1.2.2
Bandwidth of RBs			MHz	
OFDMA LTE Link-to-system level mapping		F	-	The traffic (i.e. bit rate) per UE is a look up table used to map throughput in terms of spectral efficiency (bps per Hz) with respect to calculated SINR (= C/(I+N)) (dB) (Signal to Interference-plus-Noise Ratio) level. A drop-down selection of Link level data look-up 2 dimensions functions from Library. The OFDMA Link level data has the same formats for uplink and downlink but with different values as depicted in Section 9.5. This link level data (bitrate mapping) is user selectable and can be modified depending on the simulation to perform. You are responsible to choose an appropriate set of data.

9.3.2 Local environment

You can choose the suitable indoor and outdoor ratio for the mobile station to be used by the propagation model. Further details are presented in Section 5.4.3.

9.3.3 Receiver settings

This content of this panel depends whether OFDMA system is a victim or an interfering system. If the OFDMA is a victim, you will have to set the blocking mask. It is the same input as for CDMA, see Section 8.3.3.

9.3.4 Transmitter settings

This content of this panel depends whether OFDMA system is a victim or an interfering system. If the OFDMA is an interferer, you will have to set the spectrum emission mask and the emissions floor. It is the same input as for CDMA, see Section 8.3.4.

When the OFDMA is the interferer and depending on the direction of the interfering OFDMA link to be simulated, the the <u>emission bandwidth of the unwanted emission mask</u> and the <u>system bandwidth</u> may be different.

- In DL, the unwanted emission mask corresponds to the BS transmitting over all the RBs (i.e. the emission bandwidth is the same as the System Bandwidth input)
- In UL, the emission bandwidth (i.e. in-band part of the unwanted emission mask) corresponds to the UE transmitting over a number of RBs (i.e. the emission bandwidth is equal to the RB bandwidth x Number of RBs requested per user) while the system bandwidth is equal to the total RBs x RB bandwidth. Note that the system bandwidth is input to SEAMCAT and approximately RB bandwidth x the total Number of RBs (i.e. Max. subcarriers per BS input).
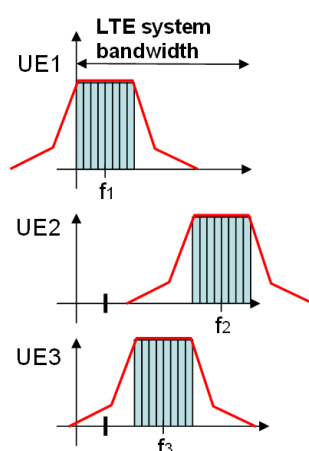

Figure 205: Illustration of the emission spectrum mask in UL for a LTE transmission

9.3.5 OFDMA uplink

This panel is available only if OFDMA UL selected and is the input parameters to the UL OFDMA power control described in Section 9.10.

Table 35: OFDMA UL power control input parameters

Description	Symbol	Type	Unit	Comments
Maximum allowed transmit power of mobile		S	dBm	Transmit power of the UE
Minimum transmit power of mobile		S	dBm	Minimum transmit power used in the power control.
Power Scaling Threshold		S		Used in the calculation of the path loss limit for the power control. It is a limit threshold compared to the value of the CDF used in the power control. With this power control scheme, the 1-" Power Scaling Threshold" percent of UEs will transmit at Pmax, i.e. are not power controlled

Description	Symbol	Type	Unit	Comments
Balancing factor (0<γ<1)		S		Balancing factor for UEs with bad channel and UEs with good channel.
Estimate coupling loss percentile	CL_{x-ile}	calculator		This calculator allows you to estimate the coupling loss percentile used in the simulation

9.3.6 OFDMA downlink

This panel is available only if OFDMA DL selected. There is no power control for OFDMA DL.

Table 36: OFDMA DL BS transmit power definition

Description	Symbol	Type	Unit	Comments
Base Station Maximum transmit power		S	dBm	Transmit power of the BS

9.3.7 OFDMA Capacity

The panel is similar for the OFDMA DL and UL.

Table 37: OFDMA capacity definition (i.e. number of UE from which active UEs will be selected)

Description	Symbol	Type	Unit	Comments
Users per BS		S	dBm	Defines how many mobiles per cell should be generated in the system. For each base station (BS), each UE will be added to served UE list of that BS. Depending on the propagation or handover conditions, a UE will either remain connected to the BS or will be disconnected. **THIS IS NOT the number of active users. The number of active users is the ratio of Max subcarriers per Base Station/ Number of subcarriers per mobile as described in** Table 34**.**

9.3.8 Propagation model

You can choose the suitable propagation model to be applied when calculating signal loss along the transmitter and the receiver path. A choice and settings of propagation models are presented in ANNEX 17:.

9.4 POSITIONING

See section 7.5, common to CDMA and OFDMA on the positioning of BSs and MSs.

9.5 LINK-TO-SYSTEM LEVEL MAPPING

A look up table is used to map throughput in terms of spectral efficiency (bps per Hz) with respect to calculated SINR (= C/(I+N)) (dB) level. This link level data (bitrate mapping) is user selectable and can be modified depending on the simulation to perform.
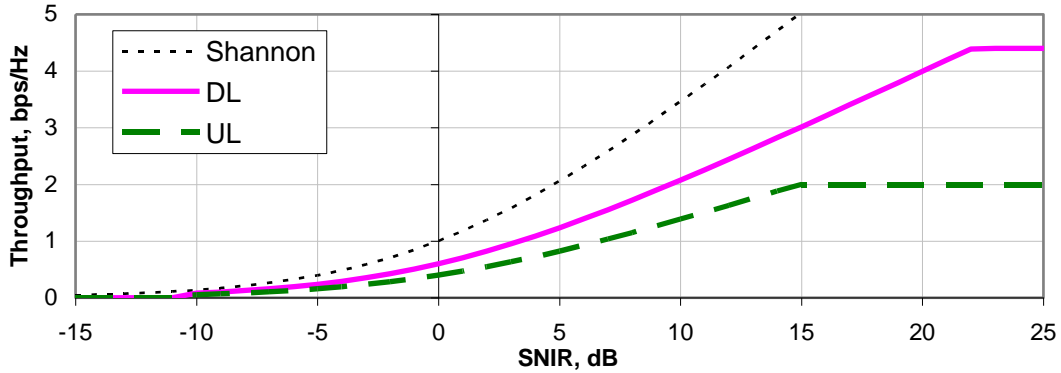
Figure 206: Throughput vs SINR for Baseline E-UTRA Coexistence Studies (source: [10])

9.6 ACHIEVED BIT RATE

The achieved bit rate is calculated as follows:

$$BiteRate_{[kbps]} = \frac{N_{Subcarriers\_per\_UE}}{N_{total\_subcarriers}} \times \left(x_{bps/Hz}\right)_{SINR} \times BW_{[MHz]} \times bps\_to\_kbps\_conversion \qquad (Eq. 45)$$

The achieved aggregate bit rate is calculated over all the mobiles connected to the reference cell.

9.7 DL C/I CALCULATION

The relationship between the contributors of the interference in a OFDMA network is illustrated in Figure 207
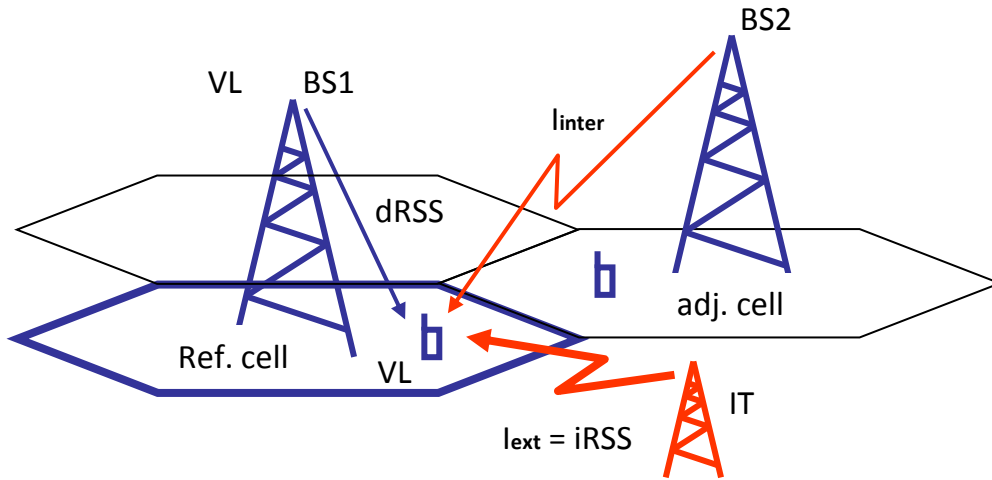

Figure 207: Illustration of the interference mechanism in the OFDMA module

Figure 207 illustrates the interference mechanism in the OFDMA module where the inter-system or also called self interference is noted "Iinter" and the interference from an "external" interference system is referred to as "Iext". In the SEAMCAT OFDMA implementation, the term "BS" and "cell" have the same meaning.

The C/I calculation in DL is calculated as

$$C/I = \frac{C(j,k)}{I(j,k)} \qquad (Eq. 46)$$

where *C(j,k)* is the received power at the *k*-th user from the serving BS, i.e., the *j*-th BS

$$C(j,k) = P_{BS}^{UE} \times effective\_pathloss(BS_j, UE_{j,k}) \qquad (Eq. 47)$$

and where P_{BS}^{UE} is the power of resource block and effective_pathloss is defined as in Section 7.6.1.

$I(j,k)$ is the sum of the interference power

$$I(j,k) = I_{inter}(j,k) + I_{ext}(j,k) + N \qquad \text{(Eq. 48)}$$

where

- $I_{inter}(j,k)$ is the adjacent cell interference (i.e. from the same victim system, i.e. denoted inter-system interference;
- $I_{ext}(j,k)$ is the interference from external interfering system(s) in adjacent channel, i.e interference power into this resource block including ACIR;
- N is the noise floor.

$$I_{inter}(j,k) = \sum_{l=1,l\neq j}^{N_{cell}} P_{BS}^{UE} \times effective\_pathloss(BS_l, UE_{j,k}), \qquad \text{(Eq. 49)}$$

$$I_{ext}(j,k) = \sum_{m=1}^{N} iRSS_{unwanted}(ILT_m, UE_{j,k}) \times iRSS_{blocking}(ILT_m, UE_{j,k}) \qquad \text{(Eq. 50)}$$

$I_{ext}(j,k)$ is the interference to the the victim $UE_{j,k}$ from N interfering link transmitters (ILT). Note that the ACIR (Adjacent Channel Interference Ratio) is implicitly taken into account when both unwanted and blocking mechanism are summed in the computation. The unwanted and blocking are defined as follow

$$iRSS_{unwanted}(ILT_m, UE_{j,k}) = iRSS_{unwanted}(over\ the\ size\ of\ the\ UE\ resource\ blocks) \qquad \text{(Eq. 51)}$$

for each of the victim $UE_{j,k}$'s frequency where the DL information is received. The ILT can be any generic systems or a BS/UEs of a cellular system.

$$iRSS_{blocking}(ILT_m, UE_{j,k}) = iRSS_{blocking}(over\ system\ bandwidth) \times \frac{N_{RB}}{M} \qquad \text{(Eq. 52)}$$

at the victim system frequency. Where N_{RB} is the number of RBs (i.e. subcarriers) requested per UE, and M is the maximum number of RBs per BS.

$$N = 10^{\left(\frac{(-173.977+10log10(N_{RB} \times RBs_{Bandwidth})+NoiseFigure_{UE})}{10}\right)} \qquad \text{(Eq. 53)}$$

where $NoiseFigure_{UE}$ is the noise figure of a UE.

9.8 UL C/I CALCULATION

The C/I calculation in UL is calculated so that $C(j,k)$ is the received power from the $UE_{j,k}$ at the j-th BS.

$$C(j,k) = P_t(j,k) \times effective\_pathloss(UE_{j,k}, BS_j) \qquad \text{(Eq. 54)}$$

where P_t is the transmit power of the UE in dBm (see UL Power control below) and effective_pathloss is defined as in Section 7.6.1..

The total interference to a UL cellular system is derived from

$$I(j,k) = I_{inter}(j,k) + I_{ext}(j,k) + N \qquad \text{(Eq. 55)}$$

where

- I_{inter} is the interference coming from UEs of the same system but from adjacent cells, i.e. the inter-system interference from other cells. Since a fully orthogonal system is assumed, only UEs which transmit in the

same frequency subcarriers will introduce interference to each other, hence only UEs in other cells with the same *k* index are considered;

- $I_{ext}(j,k)$ is the interference from external interfering system(s) in adjacent channel;
- *N* is the noise floor.

$$I_{\text{inter}}(j,k) = \sum_{l=1, l \neq j}^{N_{cell}} P_t(l,k) \times pathloss(UE_{l,k}, BS_j) \qquad \text{(Eq. 56)}$$

$$I_{ext}(j) = \sum_{m=1}^{N} iRSS_{unwanted}(ILT_m, BS_j) \times iRSS_{blocking}(ILT_m, BS_j) \qquad \text{(Eq. 57)}$$

$I_{ext}(j,k)$ is the interference to the the victim BS_j from N interfering link transmitters (ILT), where

$$iRSS_{unwanted}(ILT_m, BS_j) = iRSS_{unwanted}(over\ the\ size\ of\ the\ UE\ resource\ blocks) \qquad \text{(Eq. 58)}$$

for each of the victim BS_j's frequency where the UL information is received. The ILT can be any generic systems or a BS/UEs of a cellular system.

$$iRSS_{blocking}(ILT_m, BS_j) = iRSS_{blocking}(over\ system\ bandwidth) \times \frac{N_{RB}}{M} \qquad \text{(Eq. 59)}$$

at the victim system frequency. Where N_{RB} is the number of RBs (i.e. subcarriers) requested per UE, and M is the maximum number of RBs per BS.

$$N = 10^{\left(\frac{(-173.977 + 10log10(N_{RB} \times RBs_{Bandwidth}) + NoiseFigure_{BS})}{10}\right)} \qquad \text{(Eq. 60)}$$

where *NoiseFigure_{BS}* is the noise figure of a BS.

9.9 UL CALCULATION OF THE UE FREQUENCIES

The frequency of the UE in UL is calculated as follow

$$F_{UE} = F_{system} - \frac{BW_{system}}{2} + \frac{Diff}{2} + \left(\frac{(N_{RB}^{UE} \times BW_{RB})}{2} \times ((index_{link} \times 2) + 1)\right) \qquad \text{(Eq. 61)}$$

with Diff taking into account for any difference between the BWsystem and the effective bandwidth ($N_{RB}^{BS} \times BW_{RB}$) so that

$$Diff = BW_{system} - (N_{RB}^{BS} \times BW_{RB}) \qquad \text{(Eq. 62)}$$

where

- F_{UE}: Centre frequency of the UE;
- F_{system}: Frequency of the system (i.e. the network);
- BW_{system}: Bandwidth of the system;
- N_{RB}^{UE}: Number of Resource Blocks (RB) per mobile;
- N_{RB}^{BS}: Number of RB for the BS;
- BW_{RB}: Bandwidth of the RB;
- N_{UE}: Number of UEs in the system (calculated as NRB_BS/NRB_UE);
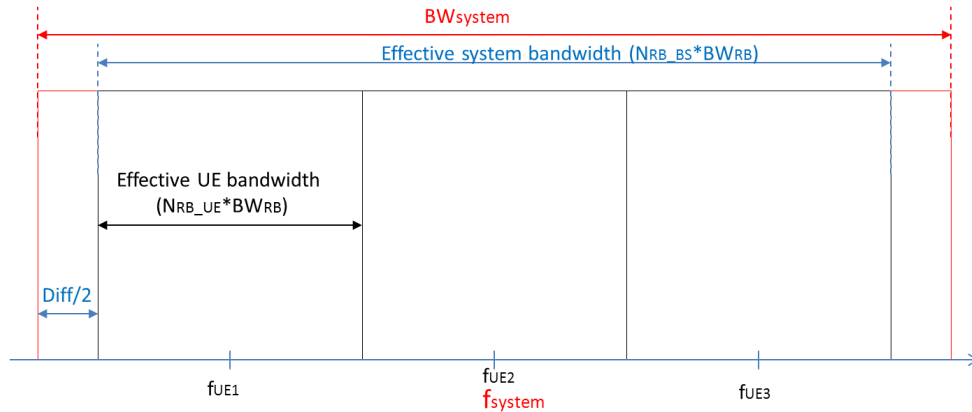- Index_{link}: Index of the specific link UE to serving BS (input to SEAMCAT). Index = [0, NUE-1].

Figure 208: Illustration of the calculation of the UE frequencies in UL

9.10 OFDMA UL POWER CONTROL

In OFDMA UL, the power control is applied to the active users (i.e. the mobile users with specific RBs) so that the UE Tx power is adjusted with respect to the effective path loss (i.e. based on the MCL) to the BS it is connected to. In 3GPP [10], the UL power control is defined so that the UE transmit power is set such as:

$$P_t = P_{max} \times \min\left\{1, \max\left[R_{min}, \left(\frac{CL}{CL_{x-ile}}\right)^{\gamma}\right]\right\}$$

(Eq. 63)

where:

- Pt is the UE Tx power in dBm;
- P_{max} is the maximum transmit power in dBm;
- R_{min} is the minimum power reduction ratio to prevent UEs with good channels to transmit at very low power level. R_{min} is set by P_{min} / P_{max}.
- CL is the effective path loss in dB for the UE from its serving BS;
- CL_{x-ile} is the x-percentile effective path loss (plus shadowing) value. CL_{x-ile} is defined here as the value in the CDF, which is greater than the effective path loss of x percent of the MSs in the cell from the BS (i.e. it corresponds to the parameter "power Scale Threshold". It is set by default to 0.9, but you can change it;
- γ is assumed to equal to 1 by default in SEAMCAT.

With this power control scheme, the 1-x percent of UEs that have a path-loss greater than CL_{x-ile} will transmit at P_{max}, i.e. are not power controlled. Annex A15.6 provides further information about the implementation and the usage of the OFDMA UL power control.

9.11 PATHLOSS CORRELATION

The concept of a simple correlation model for shadow fading has been widely adopted in LTE co-existence studies mostly employed in uplink case. The propagation attenuation is modelled as the product of the path loss and the shadow fading. The shadow fading is well approximated by a log-normal distribution. Let z denotes shadow fading in dB with zero mean and variance σ^2. Then the shadow fading of path from one UE to the **i-th** BS is expressed as

$$z_i = a {}^* x + b {}^* y_i ,$$

(Eq. 64)

where $a^2 + b^2 = 1$ and x and y_i are independent Gaussian distributed variables, both with zero mean and variance σ^2 . y_i and y_j for are independent as well.

Figure 209 presents how to set-up the pathloss correlation in SEAMCAT (only available for OFDMA). The panel is similar for the OFDMA DL and UL.
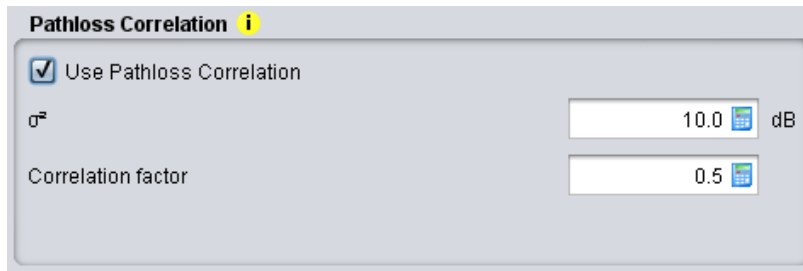
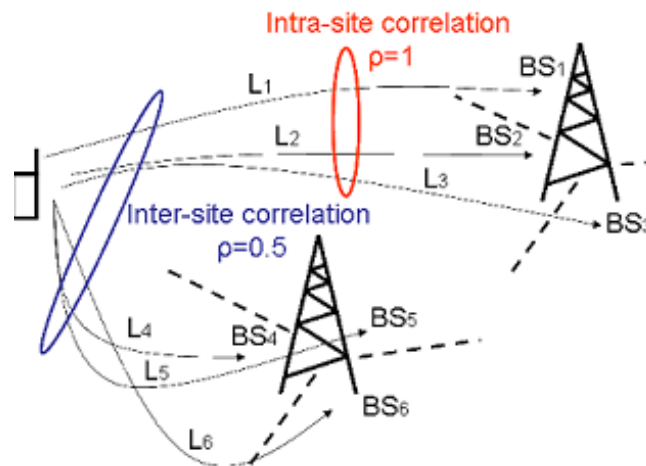**Figure 209: Illustration of the pathloss correlation – input parameters**

Figure 210: Illustration of the pathloss correlation principle

Thus, the correlation coefficient of the shadow fading from one UE to two different BSs, i.e., the **i-th** and **j-th** BS, is

$$\frac{E(z_i z_j)}{E(z_i^2)} = a^2$$

(Eq. 65)

In most LTE studies, $a = b = \frac{1}{\sqrt{2}}$ is assumed [10]. For cellular systems with three-sector antennas, the shadowing correlation between sites (equivalent to BS in Omni antenna system) is of 0.5 and correlation between sectors of the same site is consequently of 1.

10 SCENARIO

10.1 SETTING THE SCENARIO

A typical scenario consists of one victim link which describes the communication system being interfered and at least one interfering link which describes the interfering system(s) that may cause interference to the victim link. CDMA or OFDMA systems are modeled differently, using special algorithm that creates a grid of multiple cells.

Set the scenario by selecting what system will be the victim and what system will be the interferer. Remember that setting the frequency at the "scenario level" overwrite any settings at the "System level".
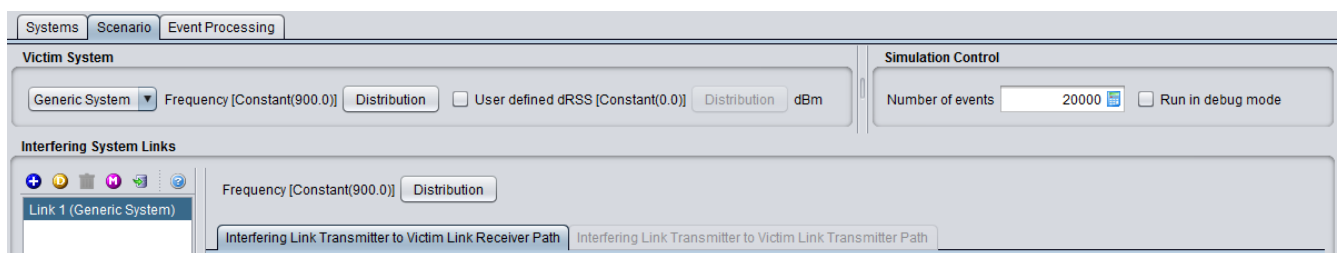
Figure 211: Setting the simulation scenario

You can also pre-defined the dRSS distribution that you want. When the User-defined dRSS (dBm) is selected, you have to set the value of wanted signal (dRSS) through the associated data entry field. In this case it overrides the dRSS calculation and will substitute the dRSS values by the results of trialling the user-defined dRSS distribution data. This way of defining dRSS is often used e.g. when victim link is deliberately set to operate at or close to victim link receiver's sensitivity threshold, etc.

Table 38: Simulation scenario – Victim System

Description	Symbol	Type	Unit	Comments
Frequency	f_{VLT} or f_{ILT}	D or S	MHz	Distribution of the centre frequency of the victim system or the interfering system links.
User defined dRSS:	dRSS	D or S (if constant)	dBm/VLR reception bandwidth.	If User-defined dRSS is checked, you then define a distribution of the desired Received Signal Strength. See ANNEX 4: for further details.

The simulation control is explained in Section 2.10.

10.2 MULTIPLE INTERFERERS GENERATION

You have 3 options to generate multiple interferers in SEAMCAT.

10.2.1 Generation of multiple interferer links with different systems

This option allows SEAMCAT to generate multiple interferers which may have the same or different technical characteristics from each other. The following menu buttons are available in the interfering system links control panel.

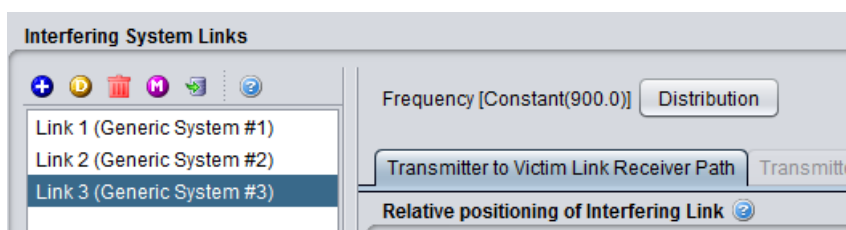|				
⊕	Add an interfering systems link to the scenario		Ⓜ	Generate multiple interfering links
Ⓓ	Duplicate an intereefering link		⬏	Change the selcted system type
🗑	Delete a link		❓	On-line manual help

Figure 212: Interfering system links control

Figure 213: Generation of multiple interferer links with different technical characteristics from each other

The feature **"to position with"** allows the deployment of a second type of interferer (for instance interfering link 1) for which the transmitters will be located at the same location as the transmitters of another type of interferers (i.e. interfering link 2 or interfering link 3). This feature is of interest since it allows deploying these two interferers at the same location (i.e. with the same coordinates) and these two transmitters could be transmitting at the same time while having different transmitter characteristics (e.g. emission mask, antenna radiation pattern…) or with a relative X, Y position set by DeltaX and DeltaY.
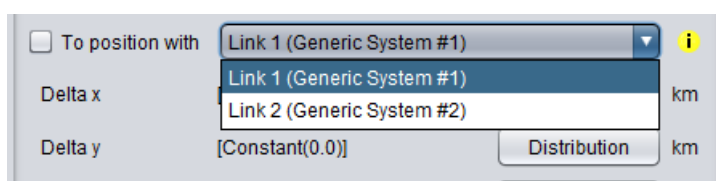

Figure 214: Possibility to position interferer links with one another

If for one interfering link (e.g. interfering link 1) the number of active transmitter is one, then for any extra interfering links, only one Tx is simulated. When the "to position with" feature is selected, any values are grey shaded and only one transmitter is simulated.

10.2.2   Auto-generation of multiple interfering links Ⓜ

This option corresponds to duplicate n times a specific interfering links on a circle or on a hexagonal grid as illustrated below in (a) and (b) respectively. It is available by clicking on (Ⓜ). These interferers have the same characteristics as the reference interfering link. It has the purpose of automatically generating a regular pattern of interfering links.
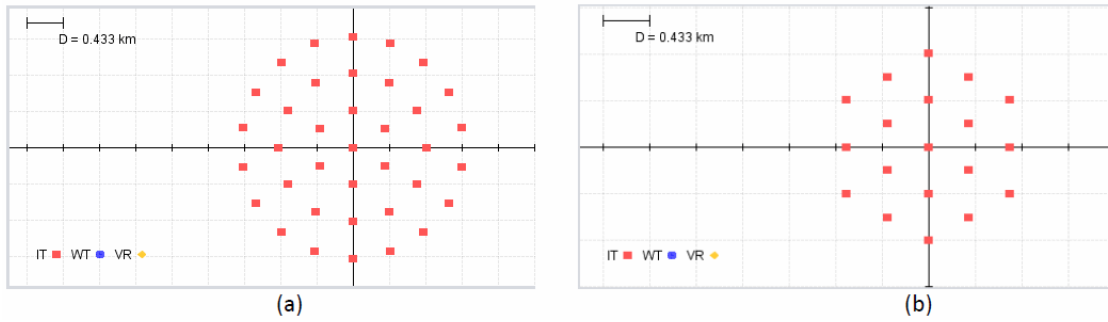
(a)   (b)

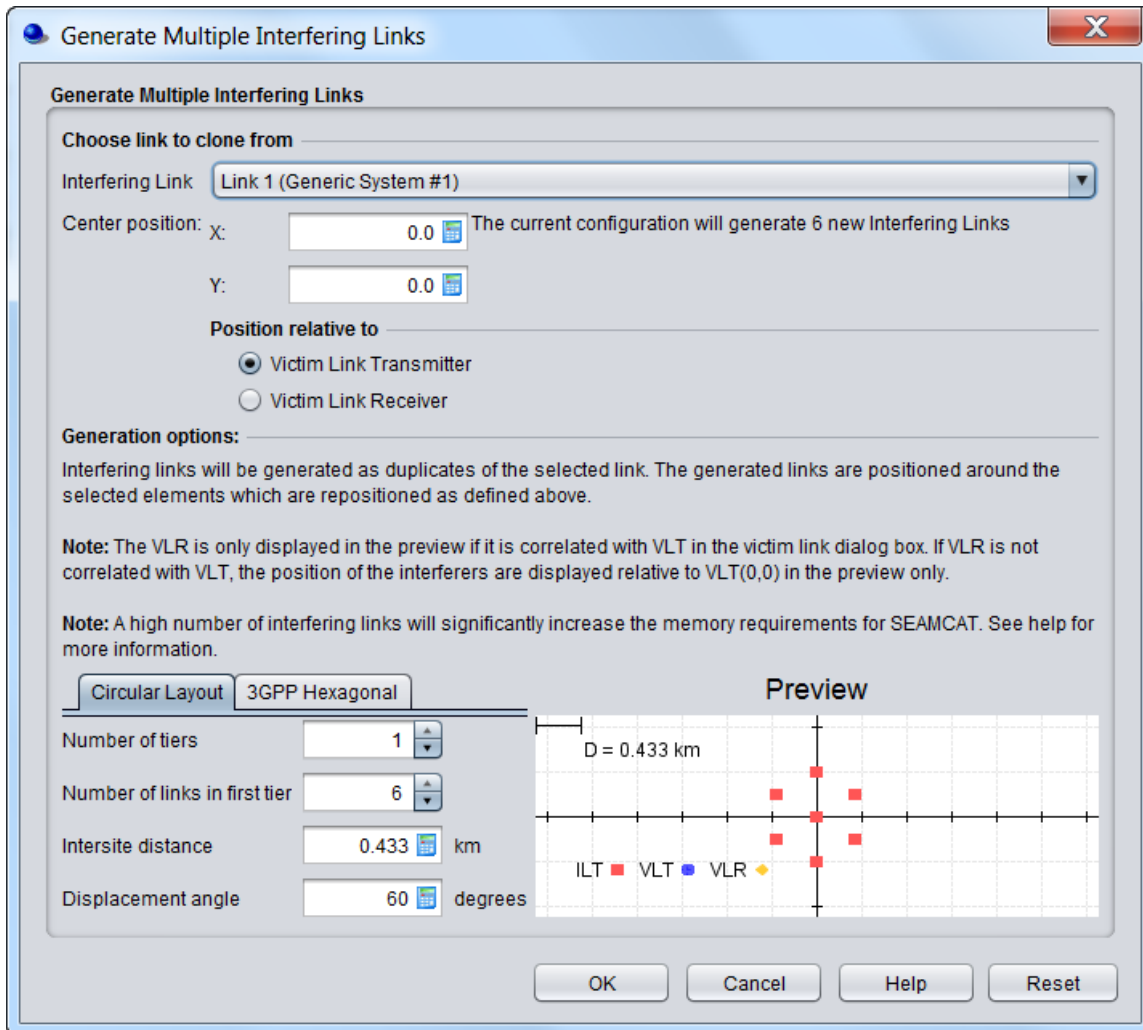**Figure 215: (a) Circular and (b) hexagonal layout**

Figure 216: Auto-generation of multiple interfering links

The multiple generate feature graphical interface consists of 3 parts:

- Selection of the reference interferer
- Relative position of this reference interferer to the victim link
- Layout preview of the new interferers

(a) Selection of the reference interferer
You can choose an interfering link that will be used to clone the new interferers.
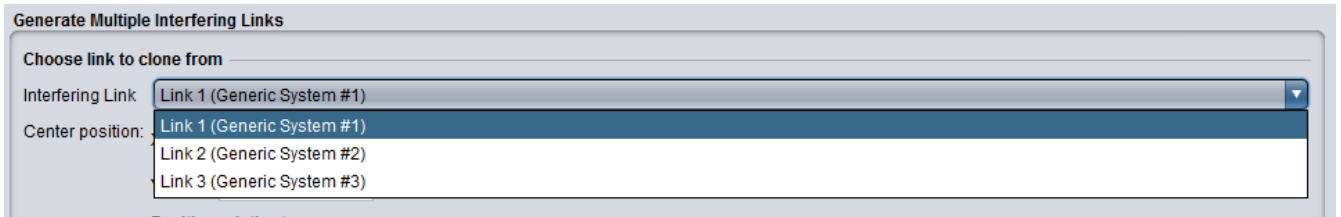
Figure 217: Selection of the reference interferers

In the Generate Multiple Interfering Link dialog box, when selecting ok, 6 new interferers will now be present in the workspace, centered to the selected interferer (i.e. interfering link 1).
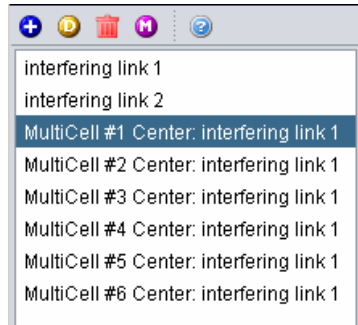

Figure 218: Generated new interferes, centered on interfering link 1

(b) Relative position of this reference interferer to the victim link
You can adjust the position of the interferers with respect to either the VLT (Victim link transmitter) or the VLR (Victim link receiver). When the generate multiple feature is run the relative positioning of interfering link mode (i.e. in the victim receiver to interfering transmitter path tab) is by default overwritten. In this case the center of the interferers is set to (1,1) to VLT.
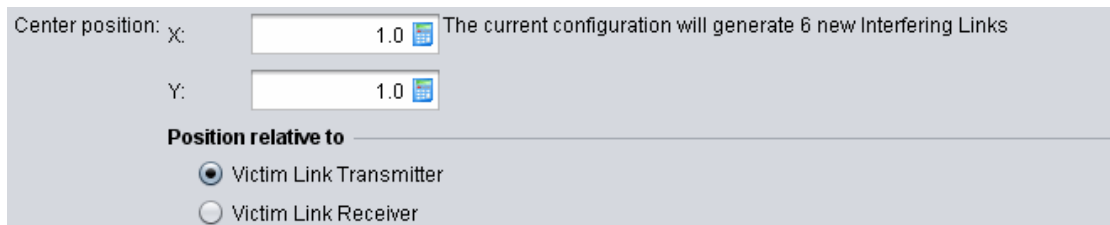

Figure 219: Relative position of the interferer to the VLR or VLT

(c) Layout preview of the new interferers
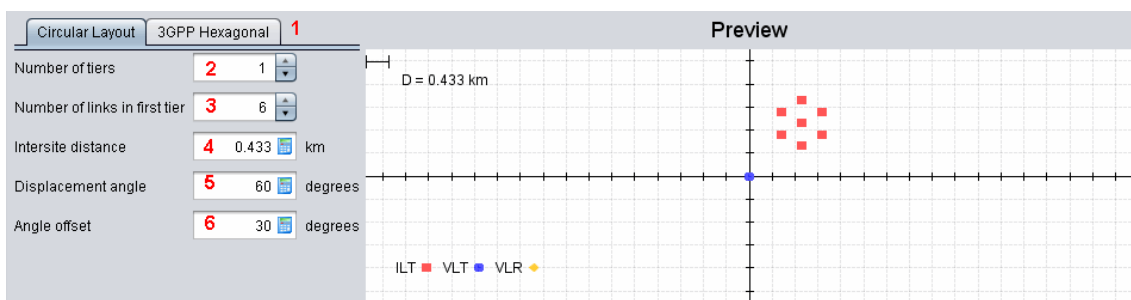As a results the preview will display the following illustration

Figure 220: Layout preview of the relative position of the interferer to the VLR or VLT

In the appearing dialog window, you may select the parameters described in .

Table 39: Generate Multiple Interfering Link GUI input parameters

Description	Symbol	Type	Unit	Comments
Circular or hexagonal layout	-	-	-	General circular or hexagonal layout
Number of tiers of generated multiple cells	-	S	-	You can generate as many tiers as you want
Number of links in the first tier	-	S	-	You can set the total number of links in the first tier
Intersite distance	D	S	km	Distance between 2 BSs
Displacement angle	θ	S	degree	Angle between the horizontal and the first BS (counter clockwise)
Angle offset		S	degree	Angle offset of the displacement angle

(d) Illustrative example of the generation of multiple interfering link

The below figure shows an example of scenario that may be used for estimating intra-service interference to a victim base station of cellular system from mobile transmitters operating in the next tier of co-channel cells of the same system.

The displacement angle is calculated automatically by the dialogue window by evenly spacing the specified number of cells around the 360 deg arc, but you may amend this angle. e.g. in order to achieve placement of multiple cells in a sector of less than 360 deg. The parameter angle offset may be used to specify the offset of an azimuth towards the first interfering cell with regard to the x-axis, as seen from the centre cell.

During the multiple link generation, the intersite distance parameter (0.433 km in the example), in combination with the specified initial offset angle, will overwrite the original coordinates (Delta X/Delta Y) in the Vr-It path tab setting of the Interfering links.
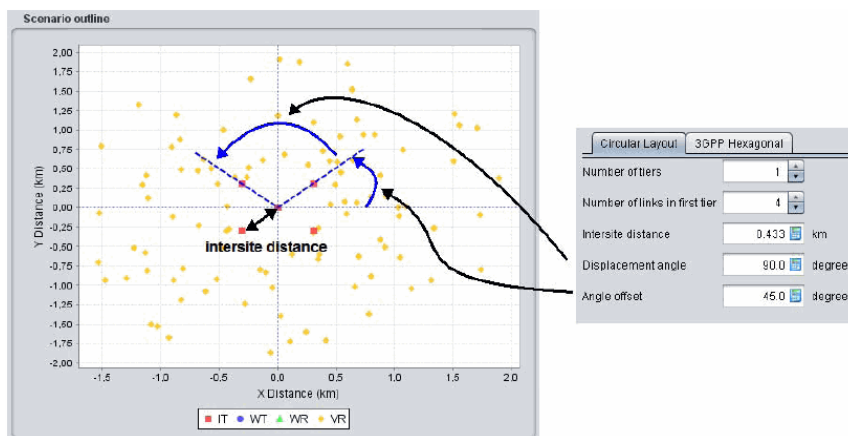

Figure 221: Example where 1 tier is used to position 4 interferers in a square shape (i.e. corners of a building) with the Vr positioned outside the square

10.2.3 Generation of interferers with the same characteristics

Within one interfering link, you can define a number of active interfering transmitters when the mode "None" or "Uniform density" is selected. These active transmitters have the same technical characteristics (i.e. a simple duplicate) and they are deployed spatially independently according to the mode selected. The iRSS result is stored as one vector (of size number of events) where for each event the iRSS value is the simple power summation of the number of active transmitters.

The number of active transmitters is directly used to compute the simulation radius (see Annex A13.2).
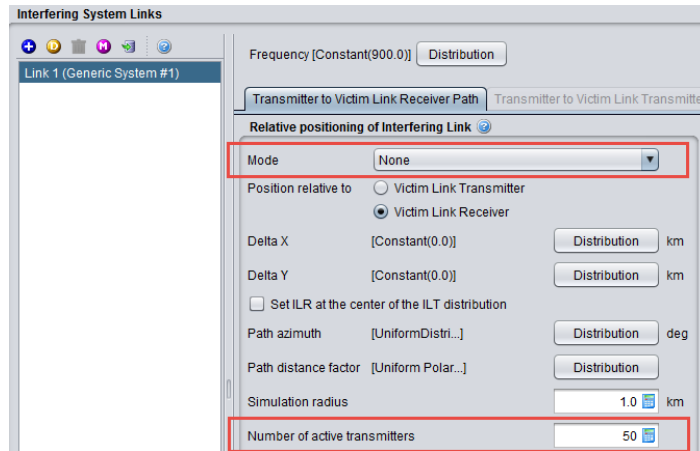

Figure 222: Generation of multiple interferers with the same characteristics and using a specific deployment mode

10.3   INTERFERING LINK TRANSMITTER TO VICTIM LINK RECEIVER PATH (ILT -> VLR)

The ILT to VLR path can have several combinations as shown in Figure 224. Four panels characterised the path between the ILT and ILR.
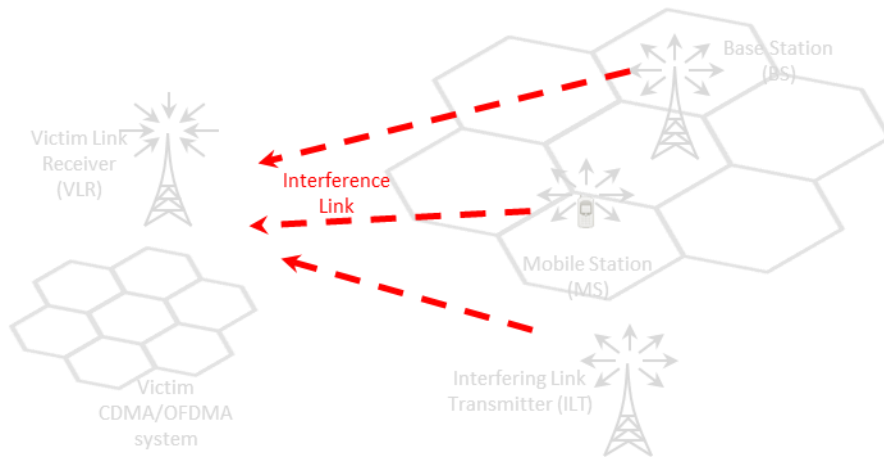

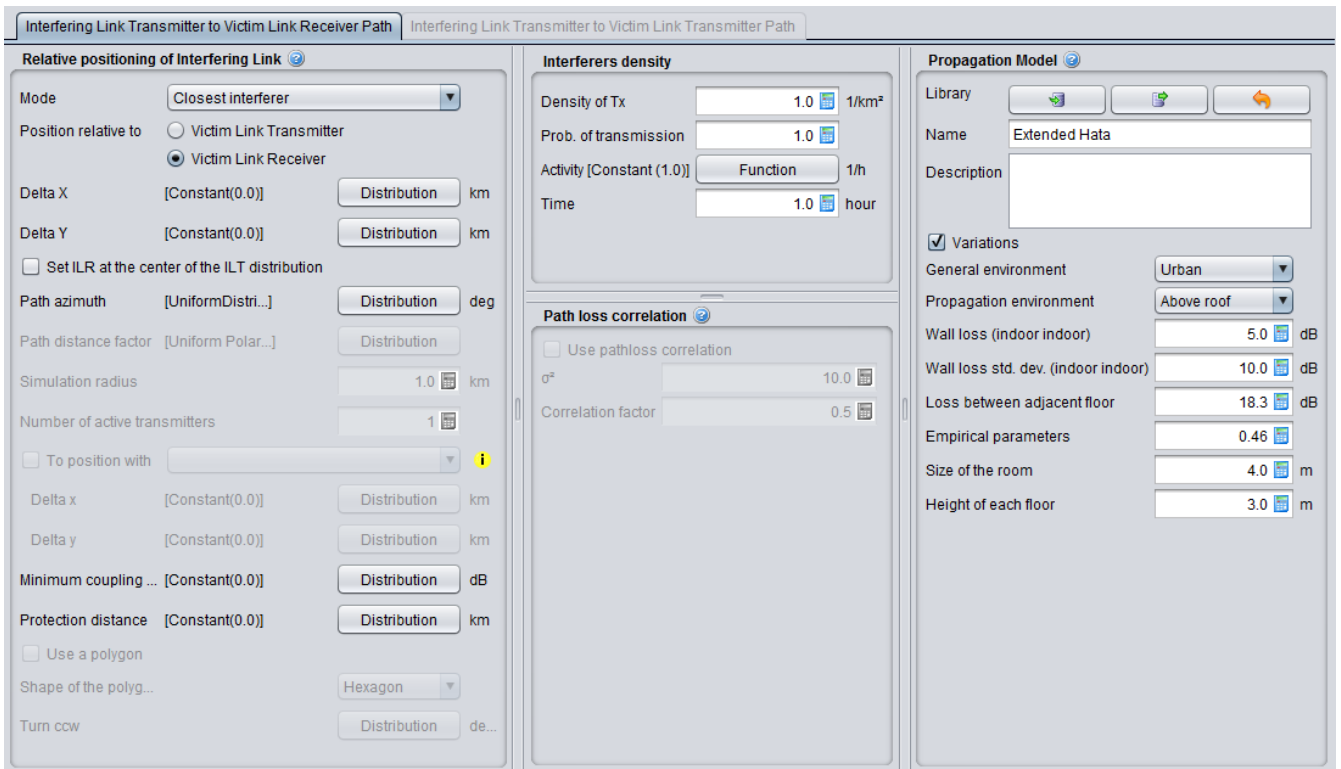**Figure 223: ILT to VLR path combination with generic and cellular system**

Figure 224: Transmitter to Victim Link Receiver Path (ILT -> VLR)

10.3.1 Relative positioning of interfering link (Generic system)

The relative position of the Victim Receiver (VLR) and the Interfering Transmitter (ILT) depends on the various options presented below. There is a unique simulation radius (R_{simu}) contrary to the 2 coverage radius (one for the victim and one for the interferer link). This is illustrated below in Figure 225 for a generic system interfering with a second generic system.

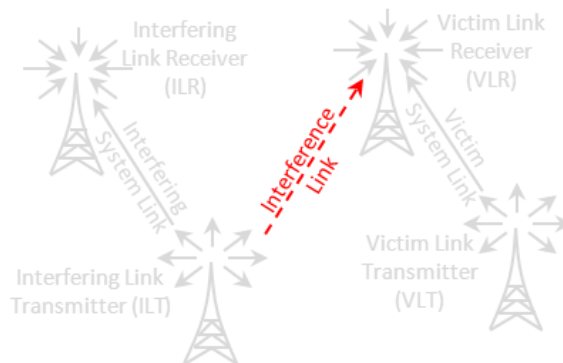See ANNEX 12: for further details on the algorithm and conventions.

Figure 225: Example of the simulation radius (VLR with ILT)

Depending on the system simulated several positioning options are possible when the generic system is the interferer and the victim is a generic system and cellular system as shown in Figure 226 and Figure 227 respectively.
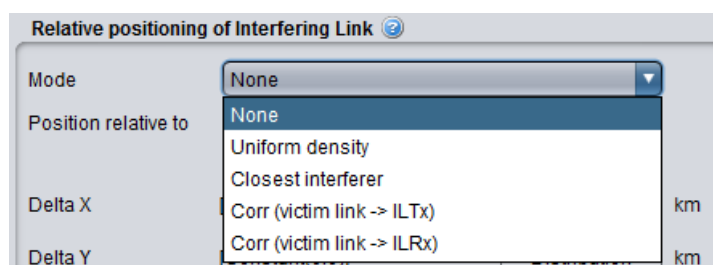
Figure 226: Relative positioning of a generic interfering link with a generic victim system

Each interfering signal calculation results from the contribution of

▪ **None**: n_{active} intererefing link transmitters located in a circular area with the simulation radius. You define yourself the radius. The random placement of the intererefing link transmitters in this area is defined by the path azimuth and the path distance factor parameters.
See Annex A13.2.1 for detailed algorithm.

Table 40: ILT-VLR path - none mode (generic vs generic)

Description	Symbol	Type	Unit	Comments
Position relative to VLT or VLR	-	B	-	Positioning of the distributed ILT with the origin being either on the Transmitter or Receiver of the victim link depending on the option selected.
Delta X	ΔX	D or S	km	Horizontal distance between the transmitter and receiver. It can be used to shift horizontally the distributed receivers.
Delta Y	ΔY	D or S	km	Vertical distance between the transmitter and receiver. It can be used to shift vertically the distributed receivers.
set ILR at he center of the ILT distribution	-	B	-	set the distance factor distribution of the ILT with regards to the VLR. It overwrites the settings in the transmitter to reveicer path of the interferer.
Path azimuth		D or S	Deg	Horizontal angle for the location of the ILT respect to the victim link. If constant, the Rx's location will be on a straight line. If not, the location of the Rx will be on an angular area. (See Annex A12.3)
Path distance factor		D or S		Distance factor to describe path length between the ILT and VLR. This factor will be multiplied by R_{simu} to obtain the coverage area. Therefore, the trialled distance between ILT and VLR will be R_{simu} *Path factor. E.g. if user enters a distribution 0…1, then the distance will be between 0 and R_{simu}. If the path factor is constant, the ILT will be located on a circle around the VLR which means that the distance between the ILT and VLR will not change
Simulation radius	R_{simu}		km	User defined
Number of active transmitter	n_{active}	S		If $n_{active}>1$, this will result in spatially-independent generation of the specified number of Its, whereas the resulting total iRSS strength will be obtained by simple power summation of the individual iRSS signal values.
Minimum coupling	MCL	D or S	dB	The minimum path loss. It is used in the calculation of the

Description	Symbol	Type	Unit	Comments
loss				effective path loss (Section 7.6)
Protection distance	d0	D or S	(km)	minimum protection distance between the victim link receiver and interefering link transmitter (Section A13.2.3)
Use of polygon				You are also able to select a polygon shape as an alternative to the default circle. A various selection of polygon is available. You are able to rotate counter-clock wise (ccw) the polygon shape.
Co-locate				This feature allows deploying two interferers at the same location and their two transmitters could be transmitting at the same time while having different transmitter characteristics (e.g. emission mask, antenna radiation pattern…)

- ▪ **Uniform density**: Each interfering signal calculation results from the contribution of n_{active} **interefering link transmitters** uniformly located in a circular area. The simulation radius is automatically derived from the density and activity of transmitters (see the Interferers density panels) in Annex A13.2.2.

Table 41: ILT-VLR path - Uniform density mode (generic vs generic)

Description	Symbol	Type	Unit	Comments
Position relative to VLT or VLR	-	B	-	Positioning of the distributed ILT with the origin being either on the Transmitter or Receiver of the victim link depending on the option selected.
Delta X	ΔX	D or S	km	Horizontal distance between the transmitter and receiver. It can be used to shift horizontally the distributed receivers.
Delta Y	ΔY	D or S	km	Vertical distance between the transmitter and receiver. It can be used to shift vertically the distributed receivers.
set ILR at he center of the ILT distribution	-	B	-	set the distance factor distribution of the ILT with regards to the VLR. It overwrites the settings in the transmitter to reveicer path of the interferer.
Path azimuth		D or S	Deg	Horizontal angle for the location of the ILT respect to the victim link. If constant, the Rx's location will be on a straight line. If not, the location of the Rx will be on an angular area. (See Annex A12.3)
Number of active transmitter	nactive	S		number of active interferers in the simulation (nactive should be sufficiently large so that the (n+1)th interferer would bring a negligible additional interfering power). If $n_{active}>1$, this will result in spatially-independent generation of the specified number of Its, whereas the resulting total iRSS strength will be obtained by simple power summation of the individual iRSS signal values.
Simulation radius	R_{simu}		km	*Note: the simulation radius value is readable only after each simulation*
Interferes density				A simulation radius is calculated, R_{simu}. Interefering link transmitters will be randomly deployed within the area centred on the Victim link receiver and delimited by the

Description	Symbol	Type	Unit	Comments
				simulation radius R_{simu}. If a protection is defined then Interefering link transmitters will be randomly deployed within the area centred in the Victim link receiver and delimited by the protection distance and the simulation radius R_{simu}. See Table 46 for information on the input parameter and Annex A13.2.2 for the calculation.
Minimum coupling loss	MCL	D or S	dB	The minimum path loss. It is used in the calculation of the effective path loss (Section 7.6)
Protection distance	d0	S	(km)	minimum protection distance between the victim link receiver and interefering link transmitter (Section A13.2.3)
Co-locate				This feature allows deploying two interferers at the same location and their two transmitters could be transmitting at the same time while having different transmitter characteristics (e.g. emission mask, antenna radiation pattern…)

- **Closest interferer**: Each interfering signal calculation results from the contribution of **just one interefering link transmitter**. This ILT is randomly placed in a circular area with a simulation radius derived from the density of interferers. See Annex A13.2.4 for detailed alogorithm.

Table 42: ILT-VLR path - Closest interferer mode (generic vs generic)

Description	Symbol	Type	Unit	Comments
Position relative to VLT or VLR	-	B	-	Positioning of the distributed ILT with the origin being either on the Transmitter or Receiver of the victim link depending on the option selected.
Delta X	ΔX	D or S	km	Horizontal distance between the transmitter and receiver. It can be used to shift horizontally the distributed receivers.
Delta Y	ΔY	D or S	km	Vertical distance between the transmitter and receiver. It can be used to shift vertically the distributed receivers.
set ILR at he center of the ILT distribution	-	B	-	set the distance factor distribution of the ILT with regards to the VLR. It overwrites the settings in the transmitter to reveicer path of the interferer.
Path azimuth		D or S	Deg	Horizontal angle for the location of the ILT respect to the victim link. If constant, the Rx's location will be on a straight line. If not, the location of the Rx will be on an angular area. (See Annex A12.3)
Number of active transmitter	nactive	S		number of active interferers in the simulation (nactive should be sufficiently large so that the (n+1)th interferer would bring a negligible additional interfering power). If $n_{active}>1$, this will result in spatially-independent generation of the specified number of Its, whereas the resulting total iRSS strength will be obtained by simple power summation of the individual iRSS signal values.
Simulation radius	R_{simu}		km	*Note: the simulation radius value is readable only after*

Description	Symbol	Type	Unit	Comments
				each simulation
Interferes density				The distance between the Victim link receiver and the Interefering link transmitter follows a Rayleigh distribution, where the standard deviation is given by σ. See Table 46 for information on the input parameter and Annex A13.2.4 for the calculation.
Minimum coupling loss	MCL	D or S	dB	The minimum path loss. It is used in the calculation of the effective path loss (Section 7.6)
Protection distance	d0	S	(km)	minimum protection distance between the victim link receiver and interefering link transmitter (Section A13.2.3)
Co-locate				This feature allows deploying two interferers at the same location and their two transmitters could be transmitting at the same time while having different transmitter characteristics (e.g. emission mask, antenna radiation pattern…)

- **Corr (victim link -> ILT) or Corr (victim link -> ILR):** It is called the correlated mode. It means that the positions of the receiver and transmitter are geographically fixed with respect to each other (e.g. co-located or constantly spaced base stations). In the following four cases of fixed placement, the relative location of the two pair of transmitter and receiver is described by dX/dY displacement, with the origin being either on the Transmitter or Receiver of the victim link depending on the option selected;

  - Corr (victim link -> ILT): fixed placement of the ILT either with respect to VLR or VLT;
  - Corr (victim link -> ILR): fixed placement of the ILR either with respect to VLR or VLT.

Table 43: ILT-VLR path – Correlated mode (generic vs generic)

Description	Symbol	Type	Unit	Comments
Position relative to VLT or VLR	-	B	-	Positioning of the fixed interefer transmitter (ILT) or receiver (ILR) with the origin being either on the victim link transmitter (VLT) or receiver (VLR) on the option selected.
Delta X	ΔX	D or S	km	Horizontal distance between the transmitter and receiver. It can be used to shift horizontally the distributed receivers.
Delta Y	ΔY	D or S	km	Vertical distance between the transmitter and receiver. It can be used to shift vertically the distributed receivers.
Minimum coupling loss	MCL	D or S	dB	The minimum path loss. It is used in the calculation of the effective path loss (Section 7.6)

In the case the victim system is a cellular system (CDMA or OFDMA, either UL or DL), the options are slightly changed as shown below.
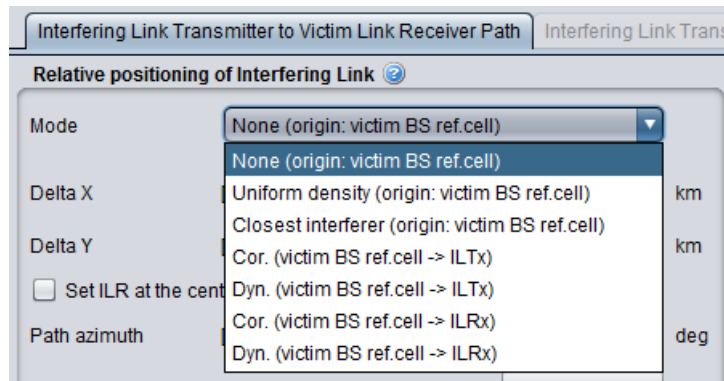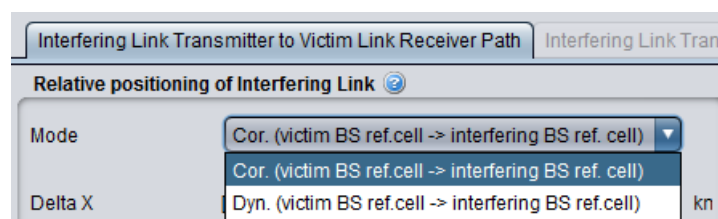
Figure 227: Relative positioning of a generic interfering link with a cellular victim system

Table 44: Desciption of the relative positioning of a generic interfering link with a cellular victim system

Mode	Same as in...	The reference point is…
None (origin: Victim BS rec.cell)	…Table 40	… the BS of the reference cell of the cellular network
Uniform density(origin: victim BS ref. cell)	…Table 41	… the BS of the reference cell of the cellular network
Closest interferer (origin: victim BS ref. cell)	…Table 42	… the BS of the reference cell of the cellular network
Cor. (victim BS ref.cell → ILTx	…Table 42	... the BS of the reference cell of the cellular network. This is the reference position of the ILT
Dyn. (victim BS ref.cell → ILTx	…Table 42	... the BS of the reference cell of the cellular network. This is the reference position of the ILT
Cor. (victim BS ref.cell → ILRx)	…Table 43	... the BS of the reference cell of the cellular network. This is the reference position of the ILR
Dyn. (victim BS ref.cell → ILRx)	… Table 43	... the BS of the reference cell of the cellular network. This is the reference position of the ILR

10.3.2 Relative positioning of interfering link (Cellular system)

The relative position of the Victim Receiver (VLR) and the Interfering cellular system depends on the various options presented below.
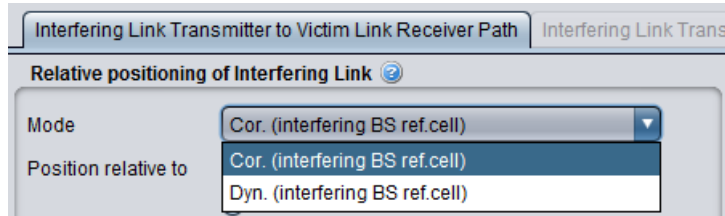
Figure 228: Relative positioning of a cellular interfering link with a generic victim system

- **Cor. (interfering BS ref. cell):** in which case the relative location is explicitly defined by the dX/dY values given in the scenario and the reference is the BS ref.cell. It is a similar mode as described in Table 43 where the BS ref.cell of the cellular interferer is position with respect to the VLT or VLR depending on the selection;
- **Dyn (interfering BS ref.cell):** this dynamic distance mode provides a a relative location that follows a uniform distribution in the distance and angle domain.

Table 45: ILT-VLR path – Correlated mode (cellular vs generic)

Description	Symbol	Type	Unit	Comments
Position relative to VLT or VLR	-	B	-	Positioning of the fixed interefer transmitter (ILT) or receiver (ILR) with the origin being either on the victim link transmitter (VLT) or receiver (VLR) on the option selected.
Delta X	ΔX	D or S	km	Horizontal distance between the transmitter and receiver. It can be used to shift horizontally the distributed receivers.
Delta Y	ΔY	D or S	km	Vertical distance between the transmitter and receiver. It can be used to shift vertically the distributed receivers.
Path azimuth	-	D or S	Deg	Horizontal angle for the location of the interfering BS ref.cell respect to the VLR or VLT
Path distance	-	D or S	km	Path length between the interfering BS ref.cell respect to the VLR or VLT .
Minimum coupling loss	MCL	D or S	dB	The minimum path loss. It is used in the calculation of the effective path loss (Section 7.6)

Figure 229: Relative positioning of a cellular interfering link with a cellular victim system

- **Cor. (victim BS ref.cell → interfering BS ref.cell):** It is the same mode as described in Table 43 but where the BS of the reference cell of the victim cellular network is the reference position of the BS of the reference cell of the interfering cellular network.

▪ **Dyn. (victim BS ref.cell → interfering BS ref.cell):** It is the same mode as described in Table 47, but where the BS of the reference cell of the victim cellular network is the reference position of the BS of the reference cell of the interfering cellular network.

10.3.3 Interferers density

The panel is activated if "Uniform density" or/and "closest interferer" mode is selected. See Annex A13.2.2 for more details on the calculation.

Figure 230: Interferers density panel (only in "Uniform density" and "closest interferer" mode)

Table 46: Setting up the interferes density

Description	Symbol	Type	Unit	Comments
Density of transmitters	$dens_{it}$	S	$1/km^2$	Maximum number of active transmitters per km^2
Probability of transmission	P_{it}	S	%	
Activity	$activity_{it}$	F	1/h	Temporal activity variation as a function of the time of the day (hh/mm/ss)
Time	time	S	hour	Time of the day. If the activity function (above), here it should be specified which hour (from the defined range of function) should be considered in a simulation

10.3.4 Pathloss correlation

The panel is activated if the victim is either OFDMA UL or OFDMA DL. It is decribed in more details in Section 9.11.

10.3.5 Propagation Model

You can choose the suitable propagation model to be applied when calculating signal loss between the ILT and the VLR. A choice and settings of propagation models are presented in ANNEX 17:.

10.4 INTERFERING LINK TRANSMITTER TO VICTIM LINK TRANSMITTER PATH (SPECTRUM SENSING)

10.4.1 Spectrum sensing characteristics

When the spectrum sensing is activated, the tab "Interfering link transmitter to victim link transmitter path" will become editable (#1 of Figure 231) and you can set the input parameters of the CR algorithm (#2). Note that the frequency of the interferer is disabled (#3). The purpose of the CR algorithm in SEAMCAT automatically

calculates the number of possible channels the WSD will operate in based on the operating frequency range of the victim system and its victim link receiver bandwidth (#4).

You can not simulate "OFDMA/CDMA" as a victim and have a CR interferer. The implementation only considers generic versus generic
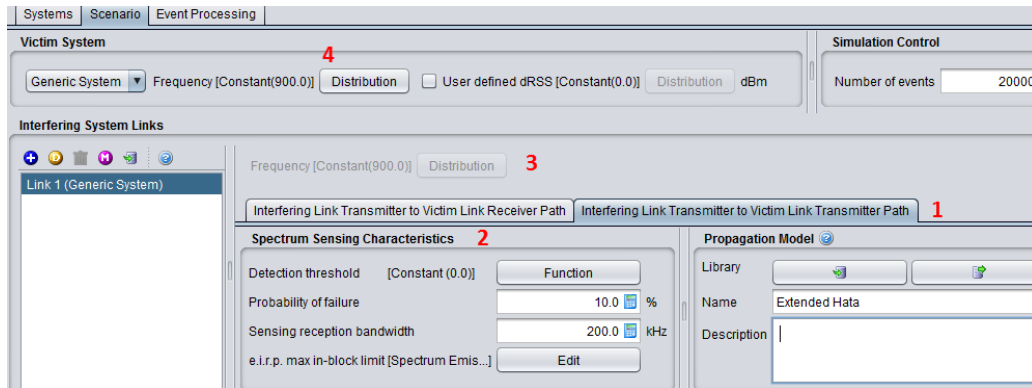
Figure 231: Example of the Cognitive Radio GUI selection - Input settings

When an interferer is set as a CR, the emission characteristics (i.e. transmitted power, emission mask and unwanted emission mask) have to be entered (see Section 6.3) and the spectrum sensing characteristics presented in Figure 232 have to be entered.
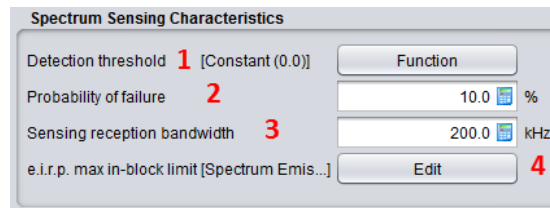
Figure 232: Setting the spectrum sensing characteristics in the Victim link transmitter to Interefering link transmitter Path

Table 47: Spectrum sensing characteristics

Description	Symbol	Type	Unit	Comments
Detection threshold:		F or S (offset)	dBm	Define the detection threshold for the spectrum sensing in a offset function. Either a constant value (i.e. flat over the spectrum) or as a user defined function as shown in #1 of Figure 232 illustrates the setting of the detection threshold (a) as a constant or (b) as a function. Figure 233 (c) illustrates where the offset refers to. Note the user-defined function is defined as offset with the victim frequency being the reference. The offset 0 is refered to the Victim frequency.
Probability of failure:		S	%	You can select this function as shown in **#2** of Figure 232. The probability of failure is given in percentage. In the illustration below a probability of failure of 10 % is entered. Positive value from 0 to 100.
Sensing reception bandwidth		S	kHz	Define the bandwidth of the sensing device (i.e. ILT). It is used in the calculation of the sRSS: This is a constant value given in kHz as shown in **#3** of Figure 232.
e.i.r.p. max In-block limit		F (offset)	Offset (MHz)/	Define the E.I.R.Pmax In-block limit to protect the victim system as an offset function where the offset 0 is refered to

Description	Symbol	Type	Unit	Comments
			Mask (dBm)/ Ref.BW (kHz)	the selected interfering frequency. The outcome of the algorithm set the allowed power at the ILT. It has the following components [offset, Mask, Ref.BW] where Offset in MHz is equivalent to the "DTT in use at" columns, Mask in dBm is the "In-block CR EIRP$_{max}$ limit" and Ref. BW is the bandwidth of the DTT as shown in **#4** of Figure 232. Note that SEAMCAT will normalise any value entered in the table to 1 MHz and convert back to the victim bandwidth.

10.4.2 Detection of threshold

In relation to the spectrum sensing results, if this CR detect that a victim system is in the vicinity it will select an appropriate operating frequency and it will lower its emission based on an e.i.r.p. max in block limit defined in the spectrum sensing characteristics. Figure 233 presents an example of the detection threshold (a) as a constant or (b) as a function and illustrates in (c) where the offset refers to and its evolution from event to event.

(a)

(b)

(c)
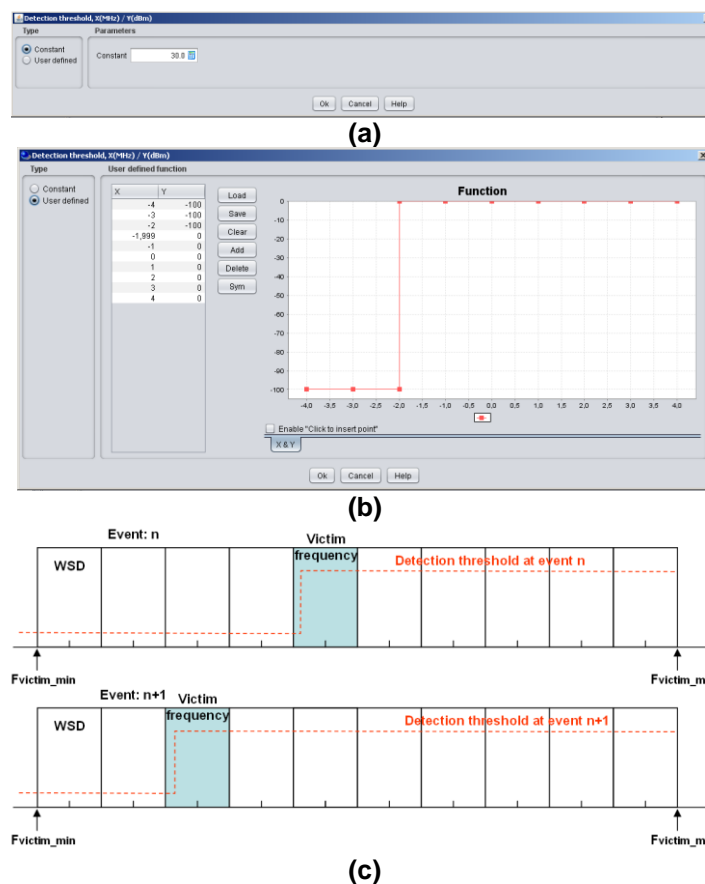
Figure 233: Example of the detection threshold (a) as a constant or (b) as a function and illustrates in (c) where the offset refers to

10.4.3 Probability of failure

This feature is input selectable (by default, it is de-activated).The probability of failure may account for the failure in selecting wrongly a *non_available* channel for one event.

This means that when a failure appears, a channel which was initially selected as occupied by a victim DTT becomes "wrongly" available for the WSD to transmit. This results in a "conflict" situation.

For instance with a defined $p_{failure}$, that means that for x total of WSD (initial input to SEAMCAT) there is $x*p_{failure}$ WSDs which will transmit in the victim frequency without power constraint. $p_{failure}$ is an input parameter.

10.4.4 Adjacent channel scenario – e.i.r.p. max. in-block limit

In the case where the WSDs are not allowed to transmit in the same operating frequency as for the victim DTT device, the WSDs can decide to transmit in the adjacent bands or channels. This scenario is illustrated in Figure 234 In this example the WSDs have sensed that in the channel 6 there is a victim system (here a DTT), therefore the WSDs will choose other channels to transmit.

The maximum permitted in-block and out-of-block e.i.r.p. of autonomous CRs would be specified as a function of the guard band with respect to DTT channels used in the local proximity of the CR. The available guard band would be identified by comparison of the detected DTT signal powers against a fixed detection threshold.
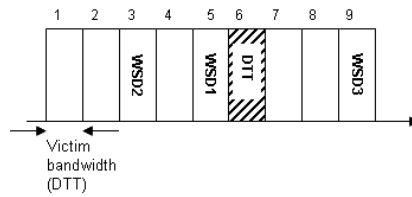
Figure 234: Illustration of WSD1 detecting a victim device in channel 6 and as a consequence decides to operate in channel 3 which is available

The purpose of the SEAMCAT simulation is to investigate the level of interference created by WSDs to the DTT victim device. Therefore the $iRSS_{unwanted}$ and $iRSS_{blocking}$ for a WSD will be computed.

As a reminder, the e.i.r.p. (Equivalent isotropically radiated power) is defined as:

$$e.i.r.p._{max} = P_{ILT} - L_c + G_{maxIt \rightarrow VLR}$$ (Eq. 66)

where L_c is the cable loss in dB. We will neglect L_c.

Extract the *Tx power = e.i.r.p. $_{max}$* - $G_{maxIt \rightarrow VLR}$ and calculate the $iRSS_{unwanted}$ and the $iRSS_{blocking}$ from the WSD to the victim DTT device. As a result, the interference calculation can be performed on the summation of the $iRSS_{unwanted}$ per channel and $iRSS_{blocking}$ per channel in the case where there are multiple active WSDs per channel. The determination of the e.i.r.p. max in-block limit is illustrated in Annex A16.2.

An example of In-block input values (dBm), is presented in Table 48 and Figure 235 illustrates how to set this parameter in SEAMCAT.

Table 48: Example of In-block CR e.i.r.p. max. emission limits as a function of guard band with respect to a victim DTT with channel bandwidth of 8 MHz (source SE43(10)18)

DTT in use at	In-block CR e.i.r.p. $_{max}$ limit (dBm)
co-channel	$-\infty$
$n \pm 1$	-12.8
$n \pm 2$	3.2
$n \pm 3$	11.2
$n \pm 4$	16.2
$n \pm 5$	20.2
$n - 6$	16.2

DTT in use at	In-block CR e.i.r.p. max limit (dBm)
$n + 6$	21.2
$n \pm 7$	22.2
$n \pm 8$	23.2
$n - 9$	4.2
$n + 9$	23.2
$n \pm 10$	24.2
$> n \pm 11$	25.2
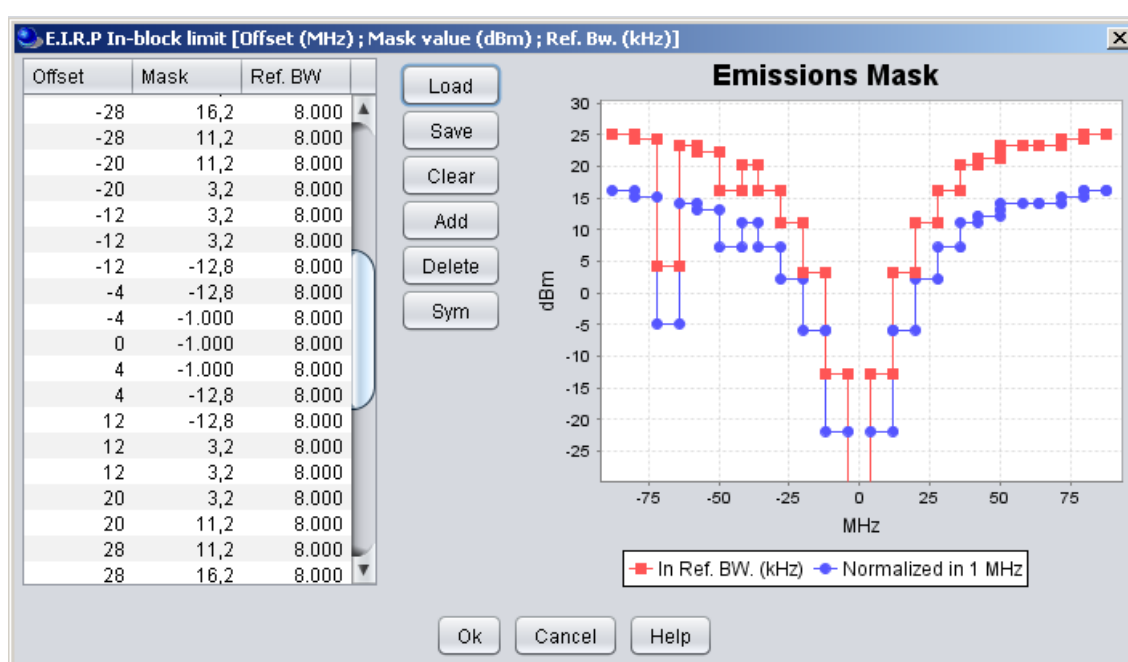
Figure 235: GUI of the In-block CR e.i.r.p. max limit (dBm)

10.4.5 Propagation Model

You can choose the suitable propagation model to be applied when calculating signal loss along the transmitter and the receiver path. A choice and settings of propagation models are presented in ANNEX 17:.

11   EVENT PROCESSING

11.1   EVENT PROCESSING CONCEPT

The Event Processing tab is the place in SEAMCAT where you can set the Event Processing Plugin (EPP). The EPP is a plugin that is given access to the EventResults, one by one, as they are produced by the simulation - an EPP can be viewed as an adjacent simulation. An EPP is allowed to inspect the scenario and the EventResult and based on this observation it can produce its own results. Once an EPP is installed in SEAMCAT it can be configured for any scenario possible.

Figure 236 depicts the basic flow of SEAMCAT for a single thread example i.e. One event result (Ri) is calculated at a time in sequence.

Figure 236: Flow of SEAMCAT

Each of the produced event results can be 'processed' by a plugin in the sense that it can make additional computation based on the event result and scenario settings. This has huge potential. Basically there is no limits to how this can be used!
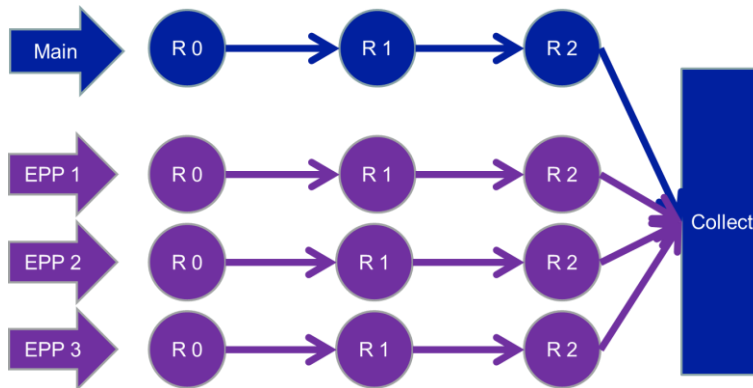
Figure 237: EPP Flow in SEAMCAT

EPPs have a dedicated thread to run in, and therefore run at the same time as the simulation runs as depicted in Figure 237. EPP inputs are exactly the same for other plugin inputs, but the EPP results are very different. The EPP can produce results like Single values, Vectors, Vector groups, Scatter diagrams, Barcharts.

11.2   EVENT PROCESSING GUI

The Event processing GUI consists of 2 main parts as shown in Figure 238. On the left hand side you can add (⊕) or duplicate (🟡) an EPP to the simulation, duplicate an EPP, remove (🗑) an EPP from the simulation and export (📑) an EPP.

There exist some predefined EPPs builtin stored in the library environment (Section 13.5.4) but you can also install your own EPP into SEAMCAT by loading your own .jar file (Section 2.23). The list of builtin EPPs is not exhaustive and will increase with time and needs of SEAMCAT comunity.

A dedicated section on how to develop your own EPP is given in Section 14.
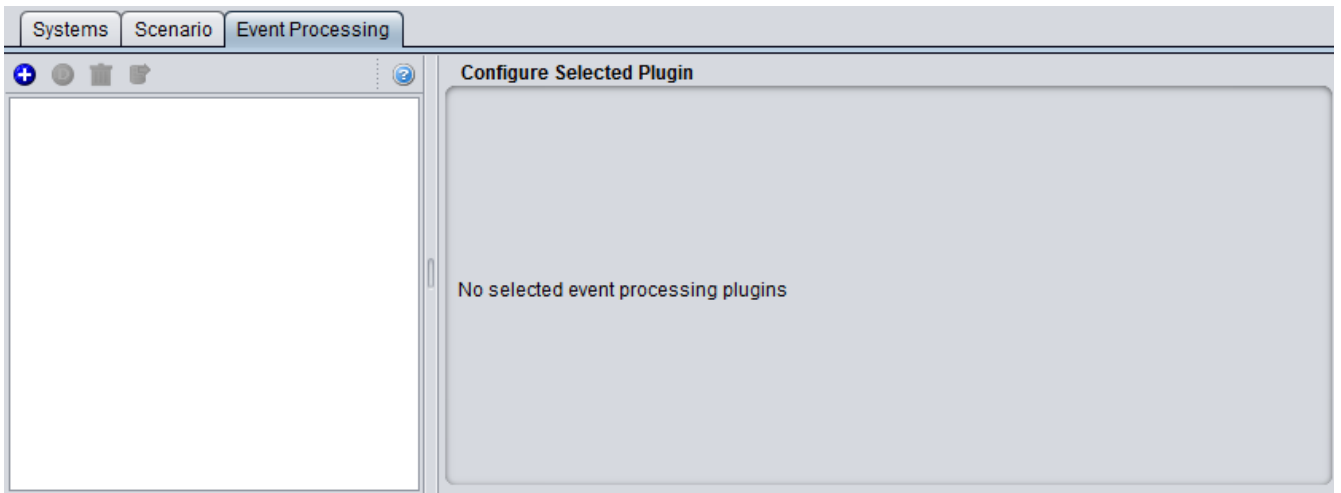
Figure 238: Event processing GUI

11.3 LOADING AN EPP TO A SIMULATION

To use EPP in a simulation go to the event processing tab and click the plus sign (Figure 239).
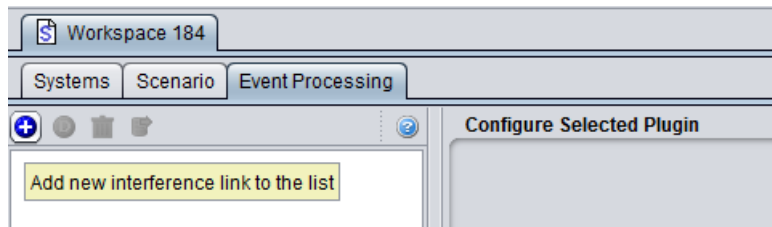
Figure 239: Using EPP in a workspace

You will be prompted with a list of available EPPs and their preview as shown in Figure 240.
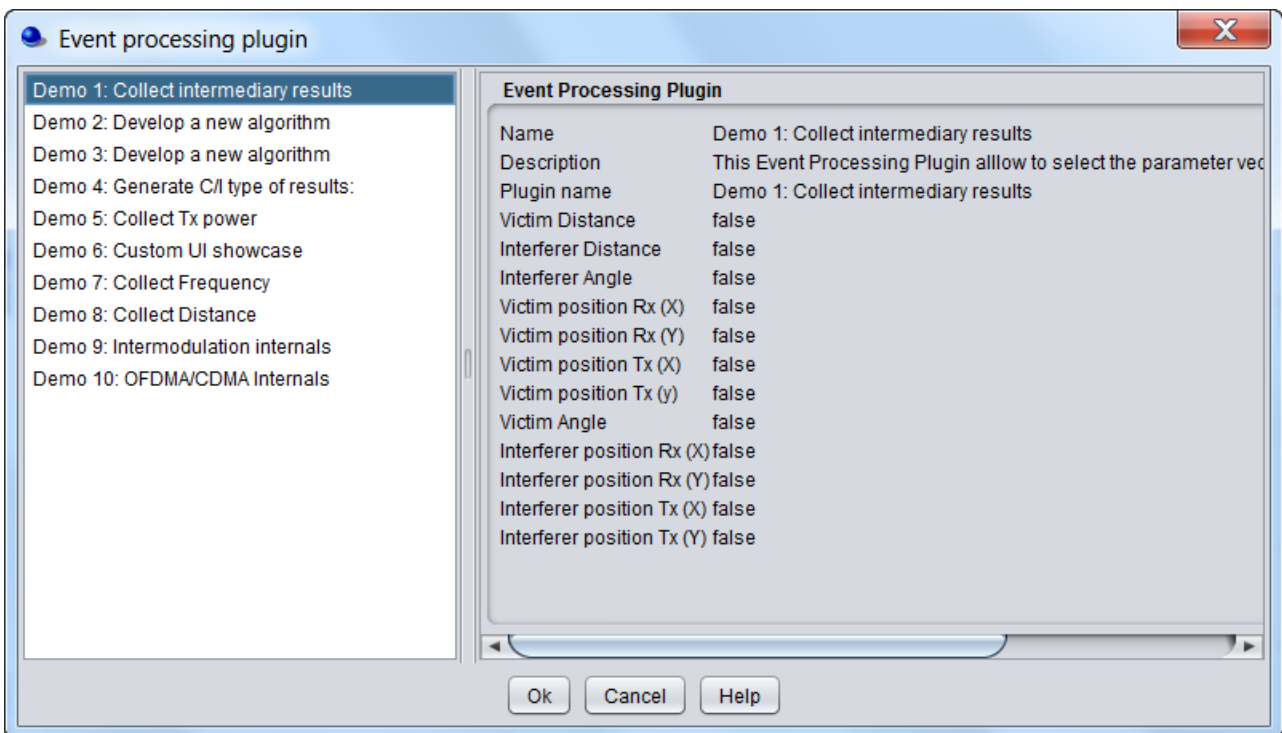
Figure 240: List of available EPPs

You can add as many EPPs as you want to your simulation.

11.4   CONFIGURING AN EPP

The EPP can be configured as wanted for this particular simulationas soon as it is loaded to the simulation workspace. In this example the EPP called "Demo 1: Collect intermediary results" is loaded. With this EPP, you can select the intermediary vector results that you want to display after simulation.
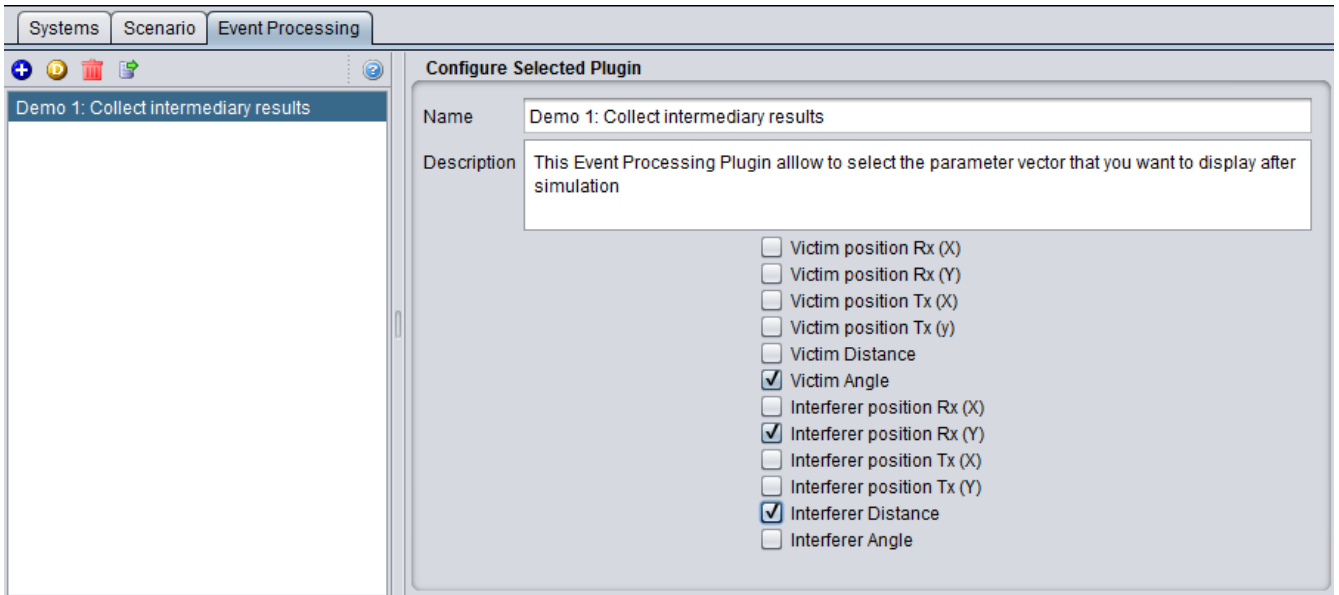
Figure 241: Configuring an EPP

In case an EPP is used in a simulation, it can return a set of result. The EPP results are described in Section 12.7.

12 RESULTS

12.1 SCENARIO OUTLINE

12.1.1 Simulation Summary

The simulation summary (left of Figure 242) gives you a quick access to the mean, median and standard deviation of the dRSS, iRSS unwanted and iRSSblocking

The mean is computed using the simulated results in dB. The median is computed using the simulated results converted to linear value and then the median is expressed in dB. The standard deviation (StdDev) is computed using the simulated results in dB. This is discussed in Annex A1.5.1

12.1.2 Simulation status

The progress bar (right of Figure 242) reflects the proportion of carried out events with respect to overall number of scheduled events.
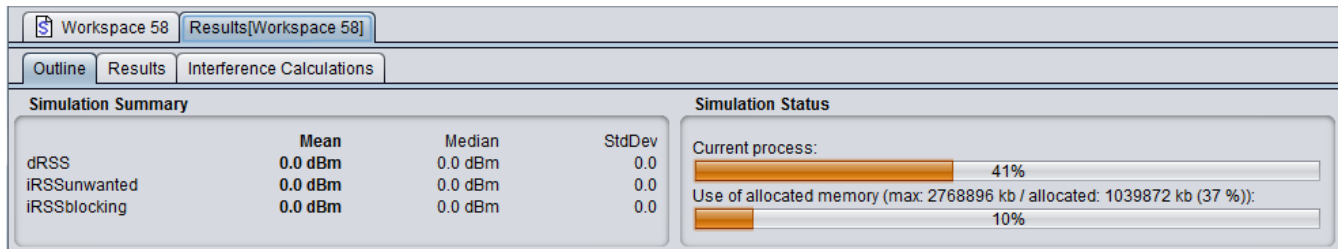
Figure 242: Simulation status

12.1.3 Generic system outline

During the event generation all involved transceivers (ILT, ILR, VLR and VLT) are plotted in graphical display window placed on the simulation outline tab page.
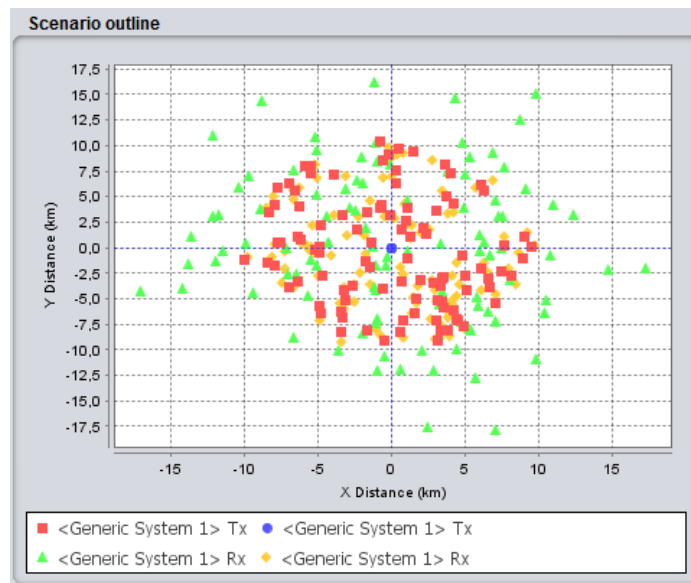
Figure 243: Example of "Scenario outline" for a generic system 1 vs generic system 2 type of simulation
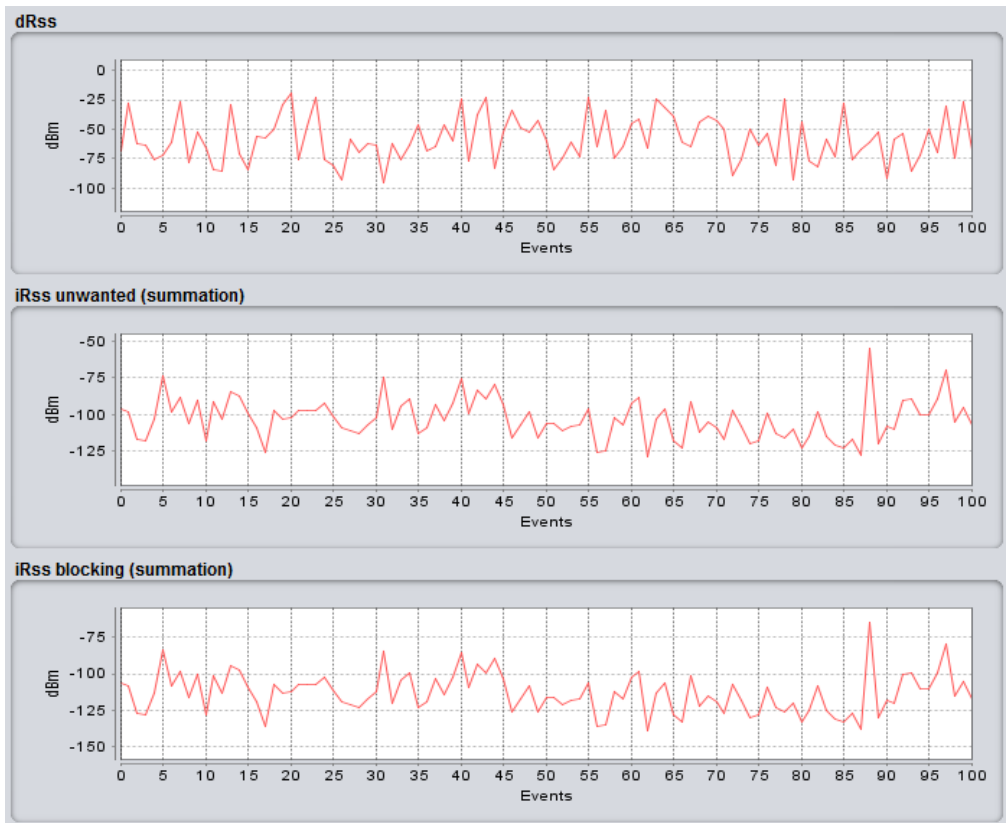
Figure 244: dRSS, IRSS samples

The dRSS and the iRSS vectors are shown for 100 events maximum to avoid overloading the memory and to speed the computation time. The iRSS is shown as a summation of all the interferers.

12.1.4 Cellular system outline

Once SEAMCAT has determined the number of UEs per cell (either through simulation of optimal capacity (see Figure 200 for UL and Figure 201 for DL) or by a value that you specify) the actual simulation of snapshots begins. As with all scenarios this causes SEAMCAT to show the scenario outline (Figure 245 for UL and Figure 246 for DL).
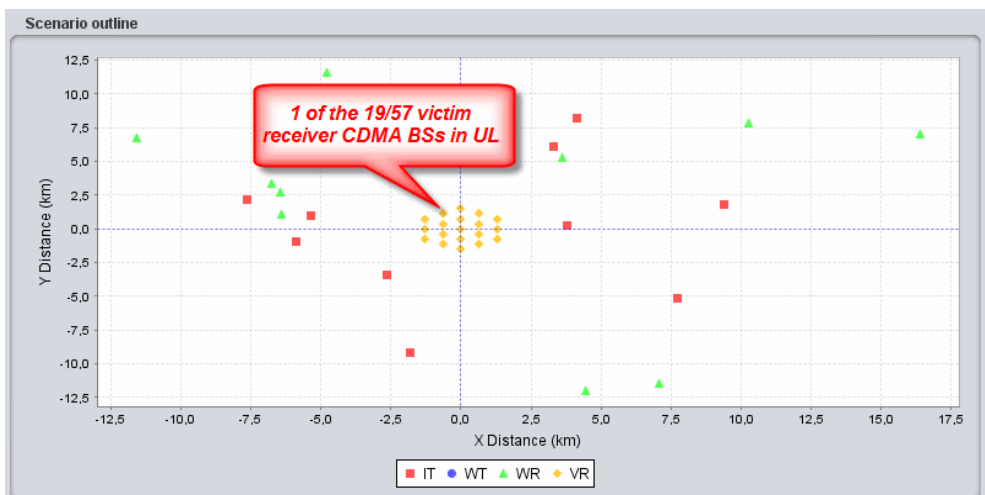
Figure 245: Example: CDMA Uplink as victim – Base-stations are shown as VLR (several snapshots are displayed)
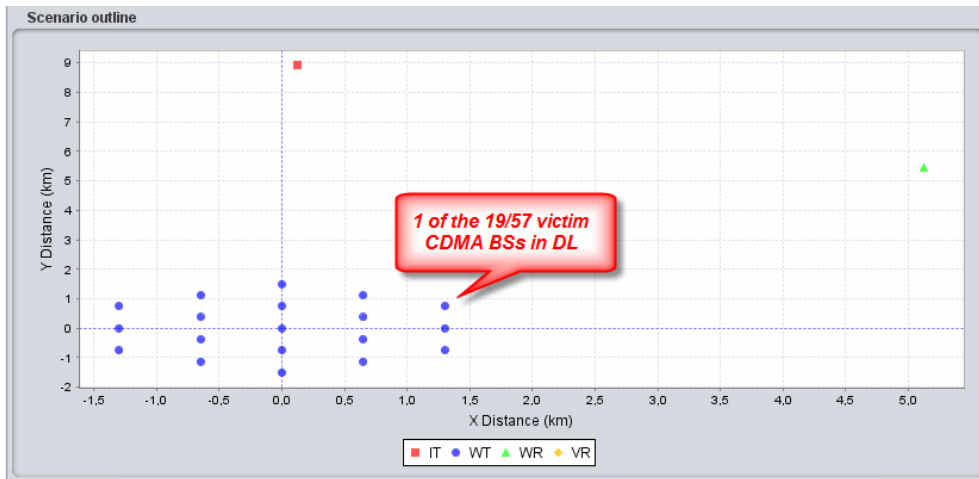
Figure 246: Example: CDMA Downlink as victim – Base-stations are shown as VLT (1 snapshot displayed here only)

Only CDMA base-stations will appear in the Scenario outline graph. Dependent on the scenario the base-stations positioning will appear as shown in Table 49.

Table 49: Role of the cellular element in the scenario outline

Scenario configuration	BS role	UE role	Positioning	Illustration
CDMA Downlink is victim	Victim link transmitter	Victim link receiver	Reference cell is positioned in (0,0)	
CDMA Uplink is victim	Victim link receiver	Victim link transmitter	Reference cell is positioned in (0,0)	
CDMA Downlink is interferer	Interefering link transmitter	Interfering link receiver	Relative to victim and reference cell	

Scenario configuration	BS role	UE role	Positioning	Illustration
CDMA Uplink is interferer	Interfering link receiver	Interefering link transmitter	Relative to victim and reference cell	

12.2 OVERVIEW OF OUTPUT RESULTS

Table 50 presents a summary of the ouput results for various victim systems.

Table 50: Interference criteria summary for various victim systems

Victim system	Intereference criteria
generic (i.e. non CDMA/OFDMA module)	Probability of interference based on C/I, C/(I+N), (N+I)/N, I/N
CDMA	Capacity loss (i.e. number of voice users being dropped)
OFDMA	Bitrate loss (i.e. number of bit rate lost compared to a non interfered victim network)

12.3 GENERIC MODEL RESULTS

After running a simulation with **generic system**, each of these signals is displayed with indicated array size (i.e. the number of valid generated events), unit and then the type (vector, double etc..).

When you double-click on one of the signals vector, the signal dialog window (see Annex A1.5) will display the signal in graphical form as well as its statistical features.

Figure 247: list of the output results for generic vs generic simulation

12.3.1 Generated signals results

- dRSS folder (ANNEX 4:) with dRSS vector;
- iRSS unwanted folder (ANNEX 5:) with as many iRSSunwanted vector for each interfering link and one vector for the sum;
- iRSS blocking folder (ANNEX 5:) with as many iRSSblocking vector for each interfering link and one vector for the sum.

12.3.2 Calculated radius

The calculated radius folder contains the values of the coverage and/or simulation radiuses calculated for the event generation when set to non-correlated (See ANNEX 13:).

12.3.3 Intermodulation results

iRSS intermodulation folder (Figure 248) with as many iRSSintermod vector for each combinatory couple in case there are more than one interfering link and one vector for the sum.

Figure 248: Intermodulation results folder

12.3.4 Overloading results

As a results of the equation described in Annex A5.4, for each events, at each frequency the sum of the iRSS$_{overloading}$ (iRSS$_{sum\_overloading}$) will be compared to the overloading treshold $O^{th}(f_i)$, at that frequency (f_i) and the difference, delta (in dB), will be stored.

▪ When delta ≥ 0, then the receiver is overloaded at that f_i (i.e. the rest of the frequency do not matter);
▪ When delta < 0, then the receiver is not overloaded at f_i.

If only one frequency is present, the iRSS$_{sum\_overloading}$ is compared to the $O^{th}(f_i)$ and the difference will be stored for that event. If more than one frequency is present, the strongest of the delta value will be present to the vector (i.e. irrespective of the frequency) , such that

for each event j (where dRSS > sensitivity){

for Frequency = i to number of total frequencies{ delta_max(j) = max(delta(f_i)); }   (Eq. 67)

}
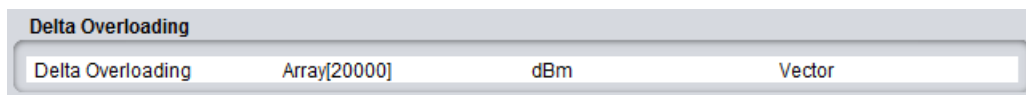
Figure 249: Overloading results folder

The output delta overloading vector is of the dimension delta x number of events
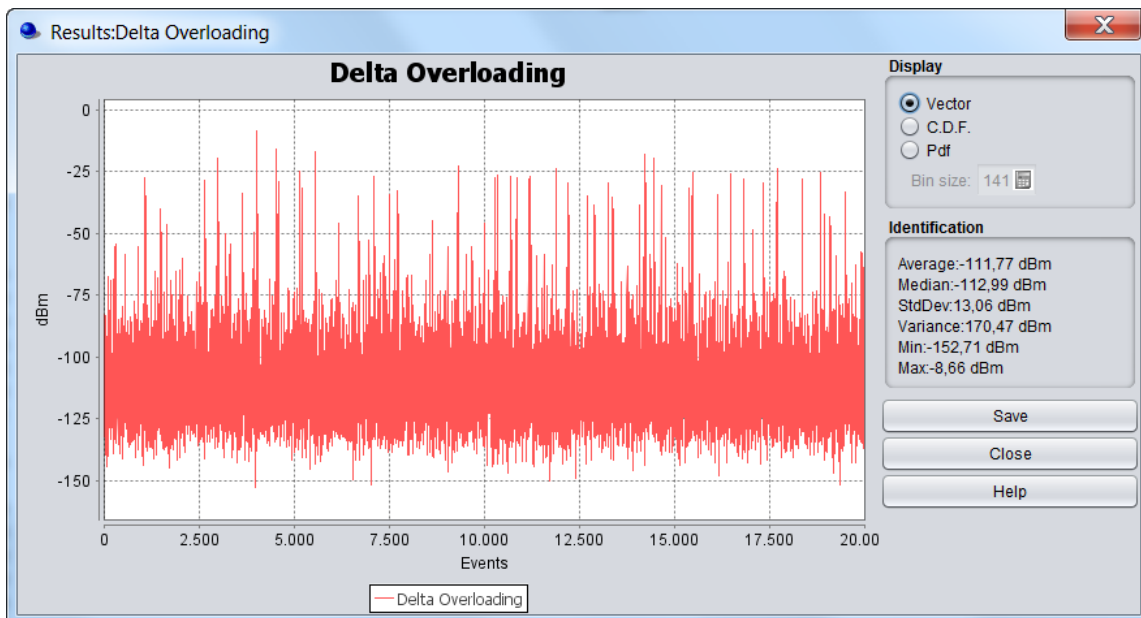
Figure 250: Delta overloading result vector

12.4   SPECTRUM SENSING RESULTS

When the cognitive radio mode is activated, SEAMCAT resturns the output vector shown in Figure 251 and described in Table 51.

Figure 251: Output vector for the CR

Table 51: Output results for CR simulation

#	Item	Description
1	sRSS	sRSS value calculated at the selected WSD frequency (i.e. where the WSD is allowed to transmit) for each of the event
2	WSD frequency	The actual selected frequency at which the WSDs are allowed to transmit as the result of the spectrum sensing algorithm
3	WSD e.i.r.p.	The actual selected e.i.r.p. at which the WSDs are allowed to transmit as the result of the spectrum sensing algorithm
4	Victim frequency	frequency at which the victim device transmits per event
5	Average e.i.r.p. per event x active WSDs (for each frequency)	average e.i.r.p. per event for all the active WSDs transmitting at a certain frequency
6	Average Active WSD per event (for each frequency)	

At the end of the simulation, SEAMCAT provides a set of output vectors as above. Then you can perform the interference probability calculation as previously described.

12.4.1 sRSS vector

The sRSS vector (dBm) is merely the sRSS value calculated at the selected WSD frequency (i.e. where the WSD is allowed to transmit) for each of the event. Figure 252 displays the vector for each WSD. You can select any or all of the WSD (**#1**). The same applies to the CDF and density graphs (**#2**).
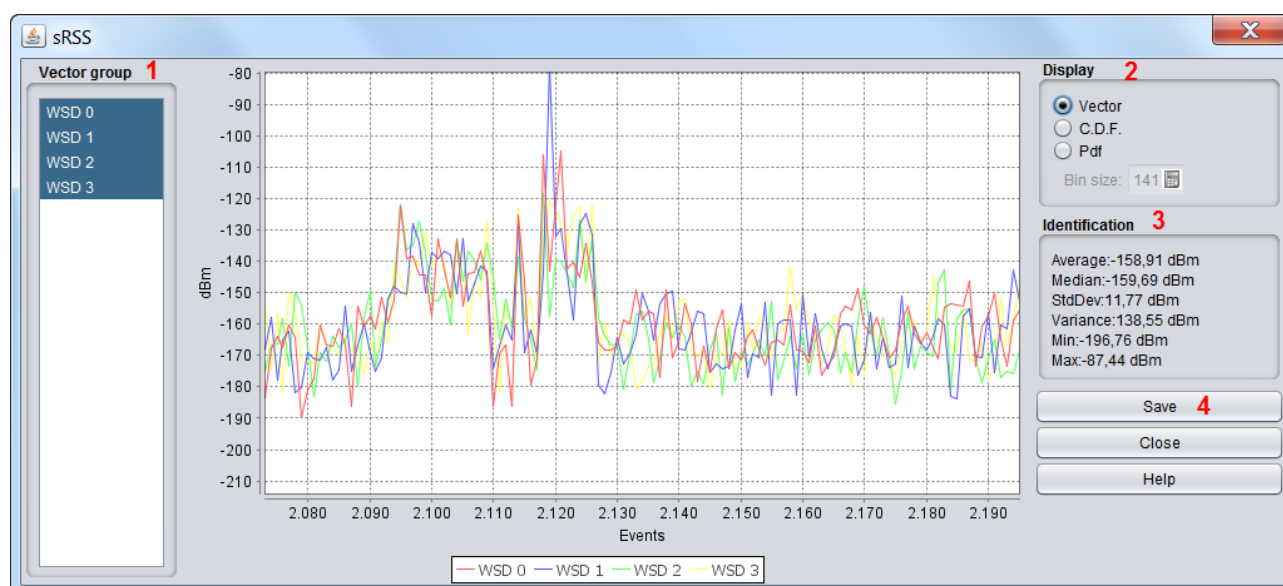
Figure 252: sRSS vector output

You are able to save the results (**#4**) as .txt file for further post-processing.

Figure 253: Saving format of the sRSS vector for post-processing

12.4.2 WSD frequency

This vector represents the actual selected frequency (MHz) at which the WSDs are allowed to transmit as the result of the spectrum sensing algorithm.

(a)   **(b)**
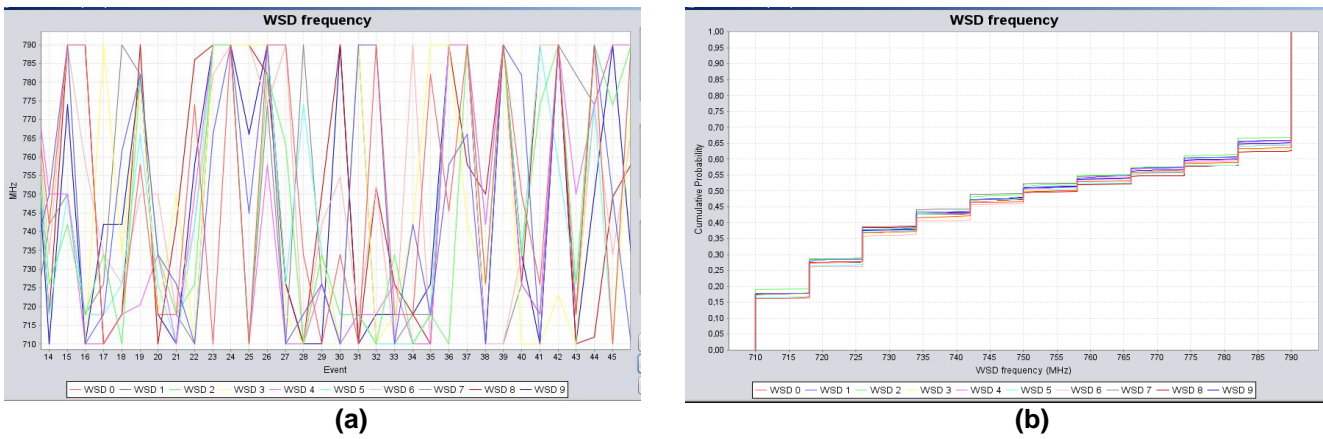
Figure 254: Frequencies where the WSDs are transmitting as (a) vector display and (b) CDF
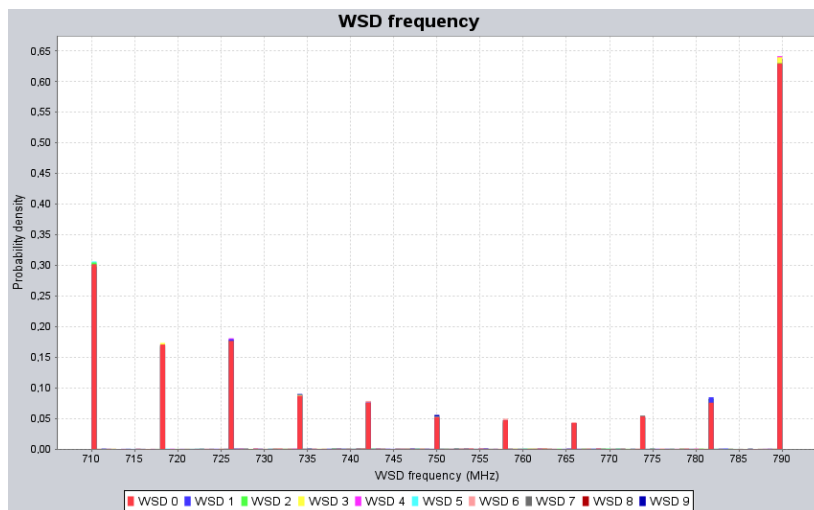
Figure 255: Density of the frequencies used by the WSDs

12.4.3 WSD e.i.r.p.

The actual selected e.i.r.p. (dBm) at which the WSDs are allowed to transmit as the result of the spectrum sensing algorithm. This vector displays the e.i.r.p. for each of the WSD for all the events. In the example

presented in Figure 256, the WSDs are transmitting with a e.i.r.p. between -10 and 20 dBm and -1000 dBm (equivalent to WSD switch off).
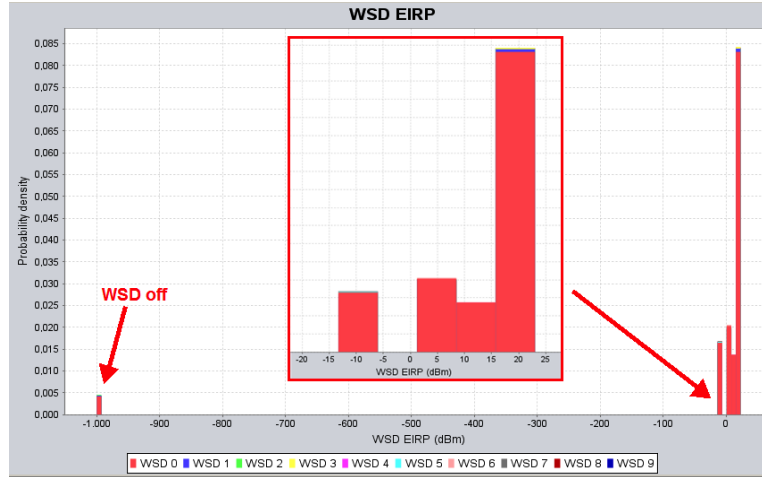
Figure 256: Example of the density of the e.i.r.p. per WSD

12.4.4 Victim frequency vector

The victim frequency vector (MHz) represents the frequency at which the victim device transmits per event.

12.4.5 Average e.i.r.p. per frequency

It presents the average e.i.r.p. per event (dBm vs MHz) for all the active WSDs transmitting at a certain frequency such that:

$$AvgEIRP_{f_j} = 10 \times \log_{10}\left[\frac{1}{N_{activeWSD} \times N_{events}} \sum_{i=1}^{N_{activeWSD} \times N_{events}} 10^{\frac{EIRP_i}{10}}\right]_{f_j} \qquad \text{(Eq. 68)}$$

Let us assume a different example from above, where 4 channels have been identified for the WSD to operate. Figure 257 shows that on average 33 dBm, for one event, was transmitted by the active WSDs at 1000.5 MHz , 8.82 dBm at 1001.5 MHz etc...
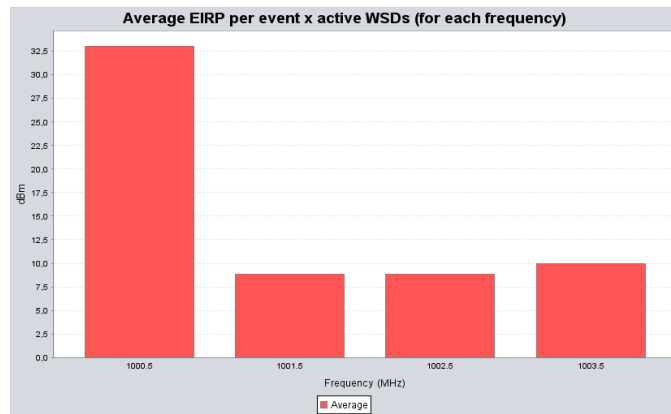
Figure 257: Average e.i.r.p. per frequency

12.4.6 Average active WSDs per frequency vector

It provides the average number of active WSD per event for a specific frequency:

$$NactiveWSD_{f_j} = \left[\frac{1}{N_{events}} \sum_{i=1}^{N_{events}} activeWSD_i\right]_{f_j} \qquad \text{(Eq. 69)}$$

Re-using the example of Figure 257, Figure 258 indicates that, with for instance 5 WSDs set as input parameters, an average of 0.63 WSDs were active at 1000.5 MHz (with 33 dBm e.i.r.p. Figure 257), 1.29 WSDs were active at 1001.5 MHz (with 8.82 dBm e.i.r.p. Figure 257), 1.57 active WSDs at 1002.5 MHz and 1.51 active WSDs at 1003.5 MHz. It can also be noted that in this particular example, the sum of the active WSDs across the selected frequencies is 5, meaning that all the simulated WSDs have been active and none have been turn off.
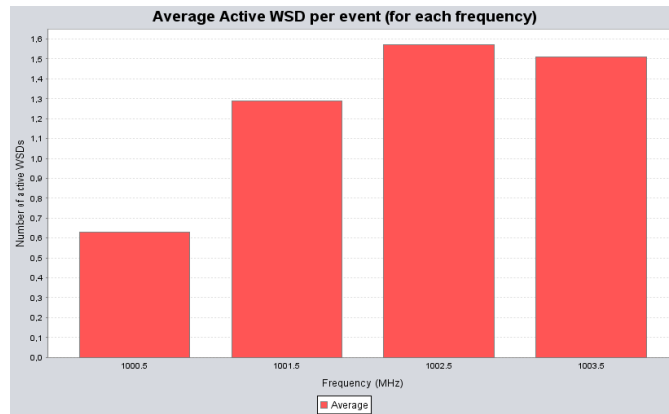
Figure 258: Average active WSDs per frequency

12.5 CDMA OUTPUT RESULTS

12.5.1 CDMA capacity finding

During the pre-simulation part, the system estimates the load of the network as shown in Figure 259. The results are presented as in Figure 260.
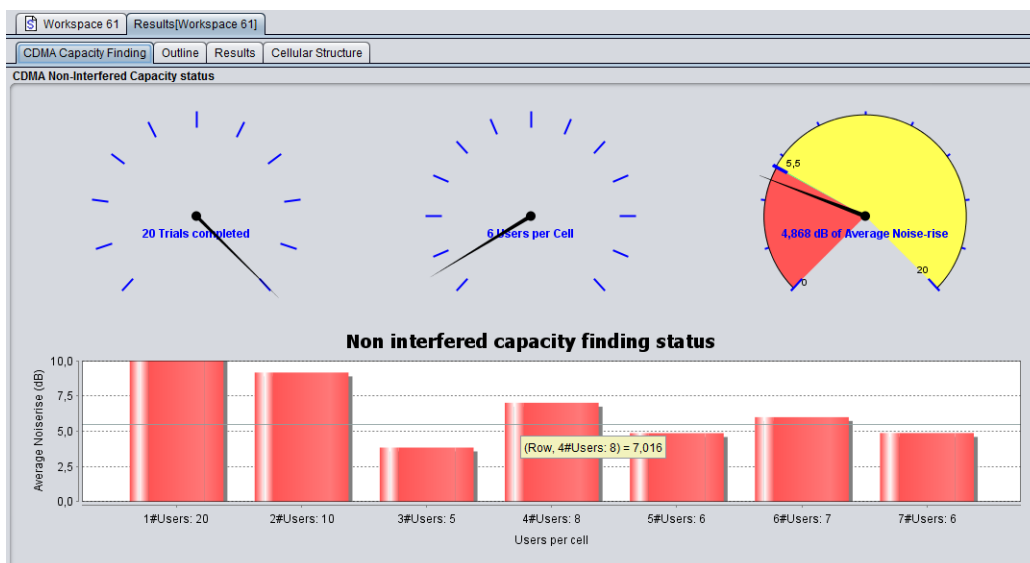
Figure 259: Example of the CDMA UL capacity finding status

Figure 260: Pre-simulated results (victim case)

12.5.2 CDMA results

Once SEAMCAT has completed the simulation, the results are shown as displayed in Figure 261, when the CDMA network is the victim. This figure presents the difference between the 2 steps power balancing process (1-initial power balancing, 2- power balancing after introduction of an external interference), that is to say " non-interfered capacity " is the number of UEs in the victim network prior to adding an external interferer and "interfered capacity" is the number of UE in the victim network after adding the external interference.

- Units: number of connected UEs;
- Initial capacity: Number of connected UEs before any external interference is considered;
- Interfered capacity: Results after External interference is applied;
- Excess outage, users: How many UEs were dropped due to external interference;
- Outage percentage: Percentage of UEs dropped due to external interference.

When the CDMA system is the interfering link, the total received power at the receiver in the victim link, due to the transmit power of all the active mobile stations in the three cells of the center cell site of the CDMA cluster, adjusted for spectral masks, etc., is counted as the interfering power in the victim link. Therefore, it is not necessary to keep track of any capacity loss in this case, unless the victim link is also a CDMA system.

CDMA Results

Average capacity loss (ref. cell)	10.894888444888448	%	Double
Average capacity loss (system)	10.522388059701491	%	Double
Non interfered capacity per cell	6.0		Double
Highest PC loop count	Array[10]	#	Vector
Non Interfered Capacity (active users o...	Array[10]	Active served users	Vector
Non Interfered Capacity (active users o...	Array[10]	Active served users	Vector
Non Interfered Capacity (active and ina...	Array[10]	Active and inactive served users	Vector
Non Interfered Capacity (active and ina...	Array[10]	Active and inactive served users	Vector
Initial Outage Percentage, system	Array[10]	%	Vector
Initial Outage Percentage, ref cell	Array[10]	%	Vector
Dropped before interference	Array[10]	users	Vector
Average network noise rise, (initial - no ...	Array[10]	dB	Vector
Average network noise rise, (initial)	Array[10]	dB	Vector
Average network rise, (resulting)	Array[10]	dB	Vector
Number of Affected Cells	Array[10]	Number of Affected Cells	Vector
Interfered Capacity (active users only), r...	Array[10]	Active served users	Vector
Interfered Outage Percentage, ref cell	Array[10]	%	Vector
Capacity Loss (based on dropped user...	Array[10]	%	Vector
Capacity Loss (active and inactive user...	Array[10]	%	Vector
Capacity Loss (active and inactive user...	Array[10]	%	Vector
Number of Dropped users, System	Array[10]	Dropped users	Vector
Number of Simulated users, System	Array[10]	Simulated users	Vector
Interfered Capacity (active users only), ...	Array[10]	Active served users	Vector
Interfered Capacity (active and inactive ...	Array[10]	Active and inactive served users	Vector
Interfered Capacity (active and inactive ...	Array[10]	Active and inactive served users	Vector
Interfered Outage Percentage, system	Array[10]	%	Vector
Capacity Loss (active and inactive user...	Array[10]	%	Vector
Excess outage (ref. cell)	Array[10]	Active served users	Vector
Excess outage (system)	Array[10]	Active served users	Vector

Figure 261: Example of the CDMA results display panel

Victim Pre Simulation

Non interfered capacity	6		Integer
Capacity finding	Bar Chart[7]	Average Noiserise (dB)	Bar Chart

Figure 262: Example of the CDMA results display panel

SEAMCAT is able to calculate (for CDMA) 3 losses:

1) Loss of UEs for the whole network based on the before and after number of UE

$$\text{System capacity loss} = 100 - (\text{interfered\_capacity}/ \text{non-interfered\_capacity})*100 \qquad \text{(Eq. 70)}$$

2) loss of UEs for the reference cell based on the before and after number of UE

$$\text{Ref cell capacity loss} = 100 - (\text{interfered\_capacity}/ \text{non-interfered\_capacity})*100 \qquad \text{(Eq. 71)}$$

3) loss of UEs for the whole network based on the total number of dropped UE

$$\text{System capacity loss} = \text{total\_dropped\_UE\_system}/\text{total\_simulated\_UE}*100 \qquad 7.$$

It is quite important to understand that there is not a 1-to-1 map between non-interfered active/interfered users and the dropped users. Dropped user can occurs at many level of the algorithm, it can be due to:

- "Unable to connect during first initialisation of UE" during the initialization (long before the step 2 balancing) but still it will be registered;
- During the balancing. For CDMA UL (no cell selection activated), when the noise rise is balanced, i.e. the number of UE is acceptable is reached after introduction of external interferers, then the BS estimates the signal-to-interference ratio (C/I), measured in bit energy-to-noise density ratio Eb/N0, and compares it to a target value (Eb/N0_target). If the difference between the estimated C/I and the Eb/N0_target, is higher than a call drop threshold, then the UE is dropped;
- "Eb/No requirement does not meet while scaling the channel power" during the scaling power.
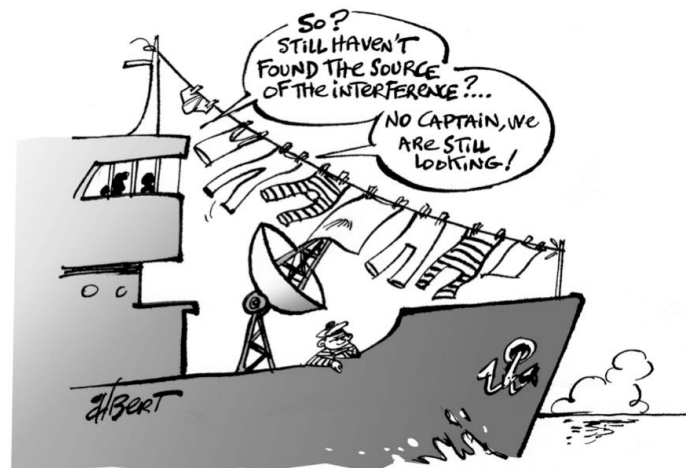
12.5.3   CDMA results for cell selection algorithm

When the CDMA "cell selection" algorithm is simulated, the following output vectors are also available for scrutiny:

- Average network noise rise (initial without external interference): value at step 1 (i.e. before the algorithm - see Annex A15.3.2)
- Average network noise rise (initial): value at step 5 (i.e. before the algorithm - see Annex A15.3.2)
- Average network noise rise (resulting): value at step 10 (i.e. after the algorithm - see Annex A15.3.2)
- The CDF of the capacity loss in the whole network (for each event, calculate the capacity loss in %).
- The CDF of the capacity loss in the reference cell per event
- The CDF of the capacity loss in the worst cell per event (the first strongest cell: selectedCell[1]). The cell-ID can be different from event to event but the capacity loss is to be extracted).
- The number of cells affected per event.

Average network noise rise, (initial - no Ext. interference)	Array[20]
Average network noise rise, (initial)	Array[20]
Average network rise, (resulting)	Array[20]
Number of Affected Cells	Array[20]
Interfered Outage Percentage, ref cell	Array[20]
Capacity Loss (based on dropped users), system	Array[20]
Capacity Loss (active and inactive users), system	Array[20]
Capacity Loss (active and inactive users), ref cell	Array[20]

12.6   OFDMA OUTPUT RESULTS

The results of the OFDMA simulation are given in terms throughput loss of the OFDMA victim. Figure 263 presents an overview of the simulation results. It consists of the achieved bitrate (with or without external interference) for the reference cell or the whole system.

A summary of the bit rate loss expressed in percentage for both the reference cell and the entire OFDMA network (i.e. the whole system) is also available. The percentage calculation is performed for each snapshot and the mean of the percentage over all the snaphsots is deduced.

OFDMA Results

Average capacity lo...	0.0	%	Double
Average bitrate loss...	0.0	%	Double
Average capacity lo...	0.0	%	Double
Average bitrate loss...	0.042	%	Double
Non Interfered Cap...	Array[100]	Active served users	Vector
Non Interfered Bitrat...	Array[100]	kbps	Vector
Non Interfered Cap...	Array[100]	Active served users	Vector
Avg Non Interfered ...	Array[100]	kbps	Vector
Dropped before inte...	Array[100]	users	Vector
Interfered Capacity, ...	Array[100]	Active served users	Vector
Avg Interfered Bitrat...	Array[100]	kbps	Vector
SINR, Victim system	Array[100]	dB	Vector
SINR, Victim ref cell	Array[100]	dB	Vector
Interfered Capacity, ...	Array[100]	Active served users	Vector
Interfered Bitrate, re...	Array[100]	kbps	Vector

Victim Pre Simulation

Coupling loss perc...	177.953208749687...	Double

Figure 263: Example of the OFDMA results display panel

12.7   EPP RESULTS

In case an EPP is used and it returns a set of result, they will also be included next to the statistic panel as shown in Figure 264. The EPP can also produce results like Single values, Vectors, Vector groups, Scatter diagrams, Barcharts.
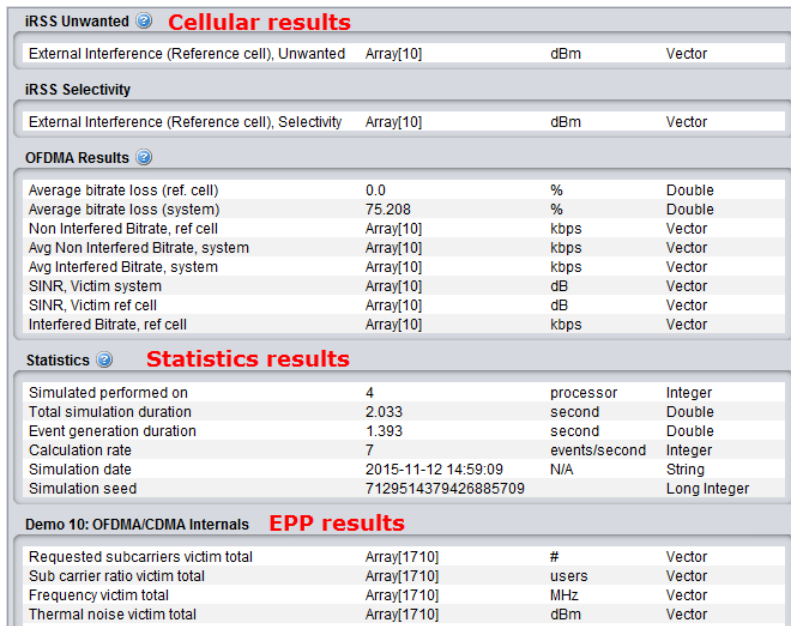
Figure 264: EPP results

12.8 CELLULAR STRUCTURE

When simulating CDMA or OFDMA systems, you will have access to the additional tab "Cellular structure", which will become active after completion of the simulation. This new tab allows you to inspect the internal details of CDMA/OFDMA cluster based on data on one event.

After a simulation these GUI parts are used to provide access to calculated results but also detailed insight into the last event of the simulation as illustrated in Figure 265, but you can reproduce any event using the play/replay feature (Section 2.15).

The "Summary of event #n" and "inspect selected element" panel of Figure 265 are shared components from the CDMA and OFDMA module.
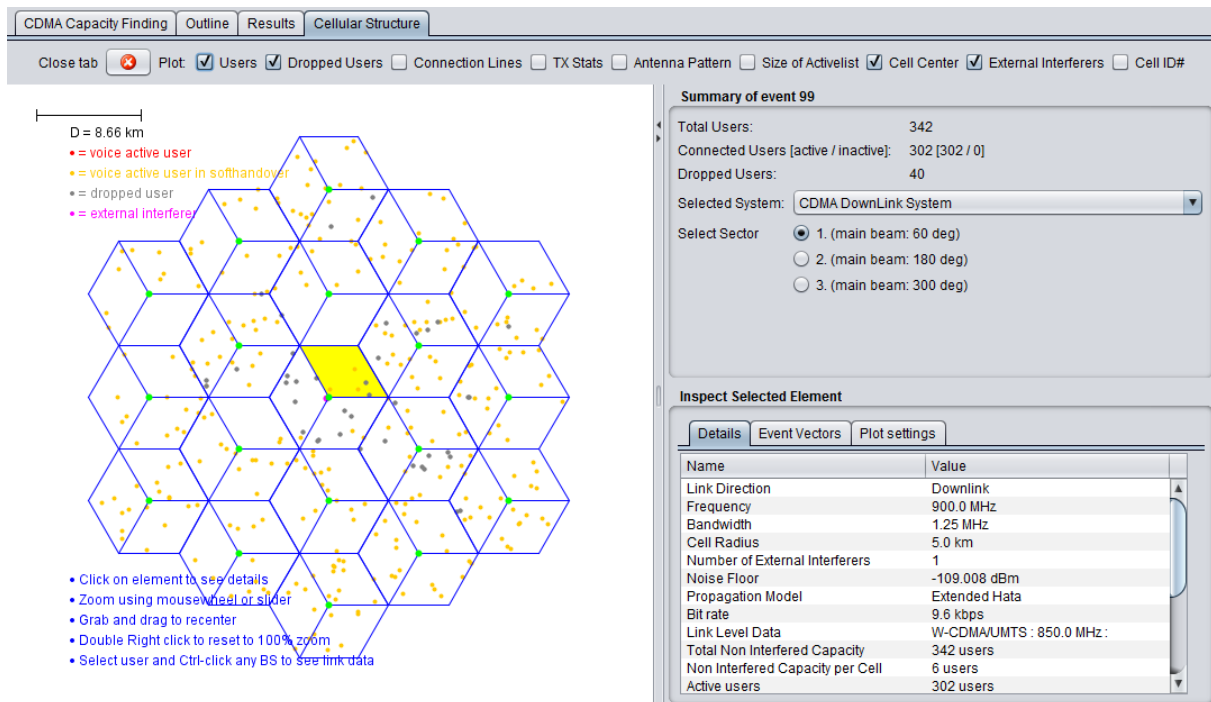
Figure 265: Example of the last event overview of the cellular network (CDMA)

12.8.1 Plot configuration

The top part of the detailed system information screen contains a range of checkboxes used to control which information is plotted (Figure 266). A full description of each checkbox is given in Table 52.

Figure 266: Plot configuration

Table 52: Plot configuration elements

Name	Description
Users	Plot active UEs across the entire system
Dropped users	Plot dropped UEs across the entire system
Connection lines	Plot active connections for all active UEs – this only shows if "UEs" are checked
TX stats	If system is downlink this toggles the display of the transmit power of each base-station. If system is uplink this toggles the display of the noise rise of each base-station as well as the total interference experienced by that base-station. Also the number of active UEs connected to each base-station is shown – regardless of link direction.
Antenna Pattern	Toggles a visual representation of the antenna pattern of the selected base-station. This is mostly interesting in tri-sector scenarios. The plot of the antenna pattern can be used to ensure that the correct sector is selected.
Cell centre	Toggles the display of base-station position within the cell.
External Interferers	Toggles the display of external interferers. This only has effect when CDMA is victim.
Cell ID#	Toggles the display of the internal SEAMCAT cell id next to the cell centre
Legend	Toggles the display of the legend in the top left part of the main plot area

The main part of the CDMA network Details window is used by the main plot. The plot shows a visual representation of the last snapshot and should be used to validate that the input parameters actually corresponds to the system that should be simulated. The plot allows for heavy user interaction. A very basic example is shown Figure 267 below.
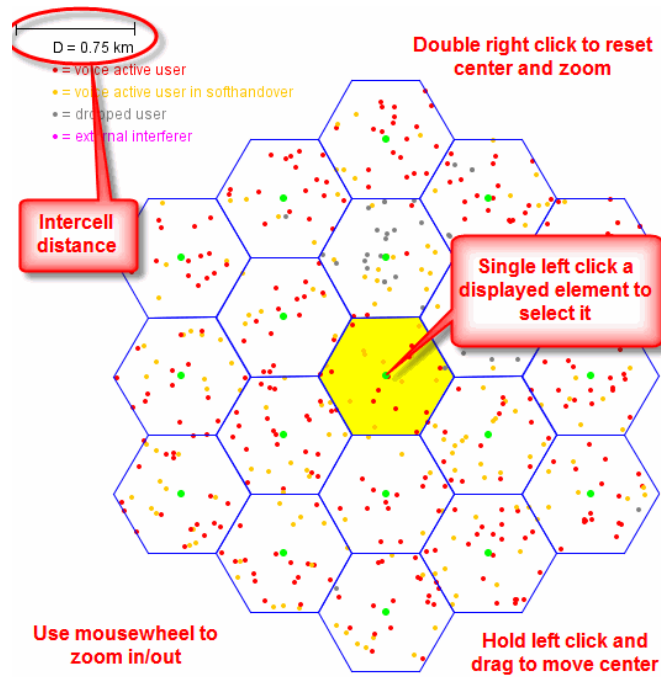
Figure 267: Main plot of CDMA network

12.8.2 Summary of event #n

The "Summary of event#n" panel provide a few metrics on the number of users simulated Figure 268.
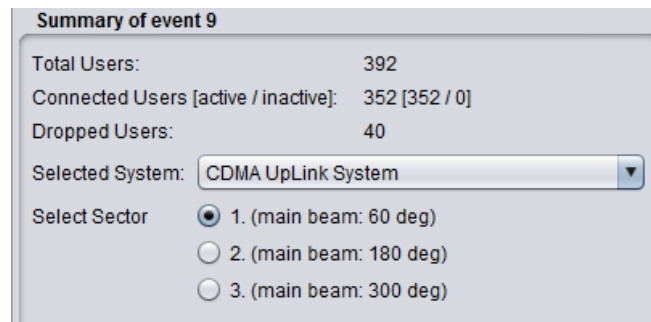
Figure 268: Event summary of cellular setup

Table 53: Snapshot summary description

Name	Description
Total Users	The total number of UEs in the system (number of BS x UEs per cell) for CDMA (active and dropped) and number of active users for OFDMA.
Connected Users (active/ inactive)	Number of UEs connected. In CDMA and OFDMA it is assumed that all users are active.
Dropped Users	Number of Ues dropped after power balancing. If CDMA is victim it is the number of Ues dropped after introduction of interference. Note that uplink CDMA drops Ues based on the average noise rise in the system – so it is possible for a single interferer to "shut-down" the entire system (causing all Ues to be dropped). In OFDMA, the purpose is to look at the bitrate/throughput loss and not to look at the number of dropped users, but it is possible to drop users depending on the input set-up.

Name	Description
Selected system	If more than one CDMA network is available in the scenario, a dropdown is used to select the system. You can choose to visualise either the victim or the interfering system which has been simulated. When you select the victim system, it is also possible to see the position of the interferer.
Selected sector	When tri-sector layout is used, it allows you to see the antenna pattern for the selected sector. Note that the antenna pattern should also be selected in the plot configuration (for vixualisation purpose only).

12.8.3   Inspect selected element

12.8.3.1   Detail

When an element of the main plot is selected, its detailed information is shown in a table. Further detailed asre presented in Annex A15.1 with respect to CDMA network, Detailed of voice users, cell.

Figure 269: Detailed information of each element of the main plot

12.8.3.2   Event Vectors

You are able to investigate some intermediary output vectors resulting from the cellular simulation.

For the position information (x,y) of the active UE details, all coordinates are always shown in the SEAMCAT coordinate system which by definition either the VLT or the victim reference cell in (0,0). Therefore, the position of the elements of an interfering CDMA or OFDMA system is based on the victim reference cell and not its "internal" reference cell.

Table 54: CDMA UL (a) and DL (b) snapshot vector for the last event

Table 55: Output vector results for CDMA UL

Name	Description
Calculated pathloss	Raw parthloss for all the active links (i.e. active UE to ist serving BS)
Distance to first BS	Distance from UE to its serving BS (first refer to cases where tri-sector is active)
Effective Pathloss to Ext. interferer (all victims, all interefers)	Effective pathloss between all the victims and all the external interferers
Effective pathloss, active links	Effective pathloss between all the victims and there respective serving BSs. Results of the below equation for all the active links
External interference, all cells	Sum of the iRSSblocking and iRSSunwanted at each victim cell
Geometry	Evaluate the Geometry for the active users for the all network
Inter System Interference	Evaluate the interference from your own network
Noise rise over the noise floor	Evaluate the Noise rise over the noise floor
Number of dropped users per BS	Evaluate the Number of dropped users per BS
Rx power, active links	Received power at the victim serving BS (UL) or active UE (DL) from its own system (used for investigating the inter-system interference from other cells)
Size of active list	Size of active list
Tx power external interferers	Tx power from the interferer
Tx power, active users	Tx power from its own system

Table 56:. Output vector results for CDMA DL (the rest of the vectors are like for the UL)

Name	Description
External interference, active users (all cells)	Evaluate the external interference on all the active users for the whole network
External interference, active users (ref cell)	Evaluate the external interference on all the active users for the reference cell only
External interference, dropped users (all cells)	Evaluate the external interference on all the dropped users for the whole network
External interference, dropped users (ref cell)	Evaluate the external interference on all the dropped users for the reference cell only

Table 57: OFDMA UL (a) and DL (b) snapshot vector for the last event

(a)

(b)
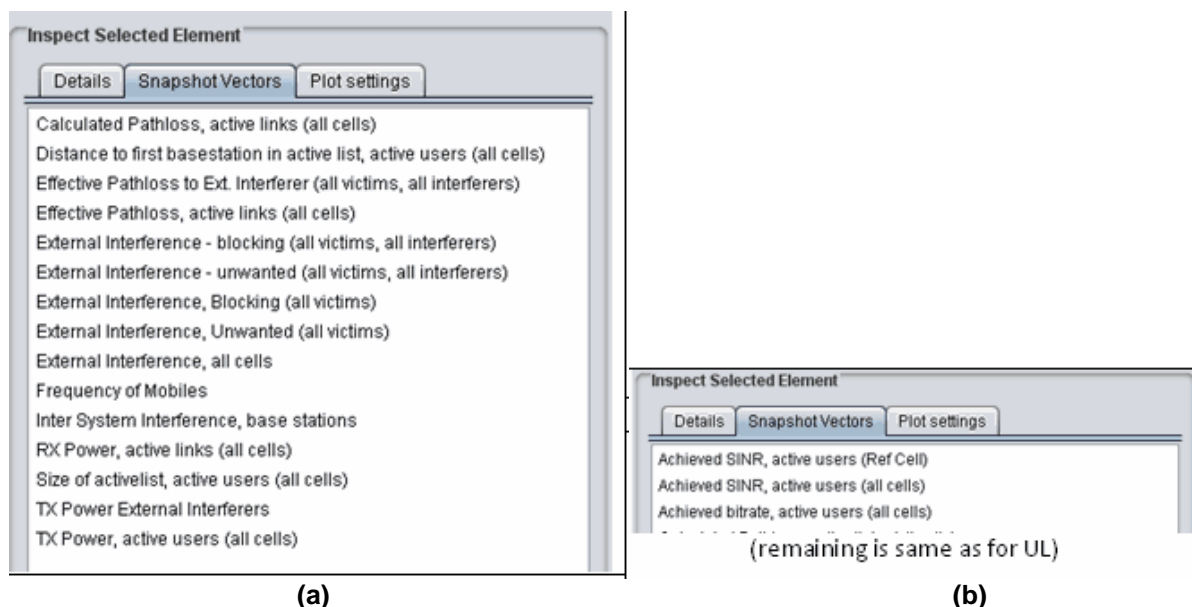
Table 58: Output vector results for OFDMA UL

Name	Description
Calculated pathloss	Raw parthloss for all the active links (i.e. active UE to ist serving BS)
Distance to first BS	Distance from UE to its serving BS (first refer to cases where tri-sector is active)
Effective Pathloss to Ext. interferer (all victims, all interefers)	Effective pathloss between all the victims and all the external interferers
Effective pathloss, active links	Effective pathloss between all the victims and there respective serving BSs. Results of the below equation for all the active links
External interference –blocking (all victims – all interferers)	iRSSblocking for each of the victim UE interferered by each interferer
External interference –unwanted (all victims – all interferers)	iRSSunwanted for each of the victim UE interferered by each interferer
External interference –blocking (all victims)	Aggregate external interference iRSSblocking for each of the victim UE. Sum over all the interferers
External interference –unwanted (all victims)	Aggregate external interference iRSSunwanted for each of the victim UE. Sum over all the interferers
External interference, all cells	Sum of the iRSSblocking and iRSSunwanted at each victim cell
Frequency mobiles	Vector of the frequency of the UE (in UL) for each active link
Inter System Interference	Evaluate the interference from your own network
Rx power, active links	Received power at the victim serving BS (UL) or active UE (DL) from its own system (used for investigating the inter-system interference from other cells)
Size of active list	Size of active list

Name	Description
Tx power external interferers	Tx power from the interferer
Tx power, active users	Tx power from its own system

Table 59: Output vector results for OFDMA DL (the rest of the vectors are like for the UL)

Name	Description
Achieved SINR, active users (ref cell)	Achieved SINR in the ref cell only
Achieved SINR, active users (all cells)	Achieved SINR for the all system
Achieved bitrate, active users (all cells)	Achieved bit rate for the all system

12.8.3.3 Plot settings

The plotting options control how the system is shown in the main plot area and how you select elements from the system. This potting option can be seen on the overview page Figure 270.
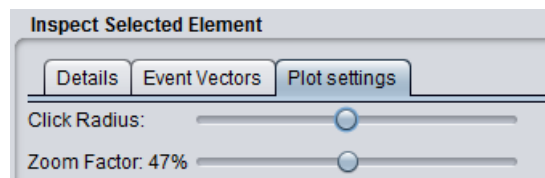
Figure 270: Plot settings

You can zoom in and out by using either the mouse wheel or the Zoom Factor slider. When clicking on a displayed item SEAMCAT tries to match the coordinates of the click to a CDMA element – selecting the first matched item. Elements are searched in the following order:

When SEAMCAT tries to match the click to an element it allows for a certain amount of uncertainty when matching the coordinates. This uncertainty is also called click radius to illustrate the effect of the actual click point being in the centre of a circle used to search for CDMA elements. You can adjust the "click radius" and in combination with the zoom this allows for all elements to be selected using the algorithm supplied above.

It is often the case that an element different than desired or no element at all is selected when clicking the plot. This problem is resolved by zooming in and possibly changing the click radius.

12.9 INTERFERENCE CALCULATIONS

12.9.1 Introduction

The Interference Calculation Engine (ICE) is that part of the SEAMCAT architecture which calculates for generic victim receiver the probability of being impacted by the sum of the simulated interference power. The calculated result is commonly called "Interference probability" or " probability of interference", in fact it is the probability of exceeding the limit of one of the interference criteria given for the victim receiver.

Regarding the definition of the Radio Regulations (RR) Article 1.166

The effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, manifested by any performance degradation, misinterpretation, or loss of information which could be extracted in the absence of such unwanted energy.

Administrations may have to distinguish between permissible interference (RR 1.167) and accepted interference (RR 1.168).

Details of the interference calculation algorithm are given in ANNEX 2:.

12.9.2 Interference calculation GUI

When the simulation is finished, the dRSS and the iRSS vectors are stored. You may proceed to use the facilities of the Interference Calculation Engine (ICE) in order to evaluate the probability of interference for the simulated scenario.

The probability of interference is calculated by the ICE with the following choice of input parameters:

- Calculation mode: compatibility or translation;
- Which type of interference signal is considered for calculation: unwanted, blocking, intermodulation, overloading or their combination;
- Interference criterion: C/I, C/(N+I), (N+I)/N or I/N.

If more than one interference calculation was done (i.e. with different combination of interference criterion), you may scroll through all of them by using the Previous / Next buttons.

Interference calculation results:

- single interference probability value (compatiblity mode);
- probability as function of the translation parameter (translation mode).

When the compatiblity mode is chosen, a single-figure estimate of the probability of interference is calculated;

When the Translation mode is chosen, you may calculate and display as chart the probability of interference as function of one of the following input parameters:

- Output power of Interfering transmitter;
- Blocking response level of Victim receiver;
- Intermodulation response level of Victim receiver.

You are able to save the results of the translation mode using the "save translation button".
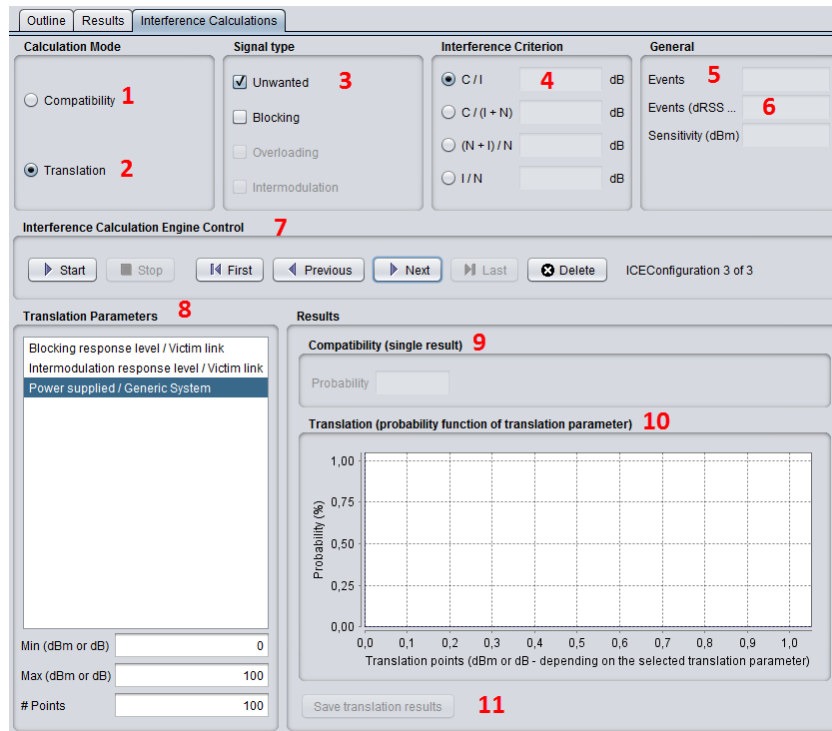
Figure 271: Interference calculation panel

Table 60: Parameters to calculate the probability of interference

ID	Description	Comments
1	Calculation mode/ Compatibility:	Compatibility: Gives the probability of being interfered by the Blocking interference and/or by the Unwanted interference and/or by intermodulation interference. The result is a probability of interference.
2	Calculation mode/ Translations:	In this case all the following parameters should be independent from frequencies: Receiver blocking response mask, Receiver intermodulation rejection mask, power distribution of interfering transmitter, Unwanted emission floor mask. Calculation of the probability of interference as a function of the reference parameters (Power supplied by the It for the unwanted, Blocking response level of the Vr for the Blocking, And intermodulation rejection level for the Vr). These parameters are varying on user-defined definition domain defined by the number of points where the software has to calculate the probability. The result is a graph.
3	Signal type	Choose the interference studied: Unwanted and/or Blocking and/or Intermodulation and Overloading in case simulated.
4	Interference criterion	Choose between C/I, C/(N+I), (N+I)/N, I/N)
5	Events	Total number of simulated events, in case Translation multiplied by the number of points
6	Events (dRSS > sensitivity)	It represents the number of events taken into account for the calculation. The accuracy of the calculated results relates to this ratio, i.e. the less this number the higher the inaccuracy.
7	Calculation control	Delete a result, and see the last results

ID	Description	Comments
8	Translation parameters: If translation was chosen	Number of points between the min and max, where the software will calculate the probability.
9	Result / Compatibility	Probability of interference: 1 - always interfered, 0 - never interfered
10	Result / Translation	Gives the graph, showing the resulting probability of interference vs. the selected values of translation parameter. The average of the graph depends of the number of points, but the higher the number is, the longer the calculations are.
11	Save translation button	You are able to save the results of the translation mode

12.9.3 Interference Calculation Engine Control

It allows you to calculate the probability of interference for several ICE configuration (i.e. different signal type, interference criteria, etc..) for the same simulation. Figure 272 presents two examples on how the control box is to be used. When several ICE configuration are computed, then you can jump from one to another without recomputing them by selecting the "**first**", "**previous**", "**next**" and "**last**" buttons.

(a)

(b)

(c)
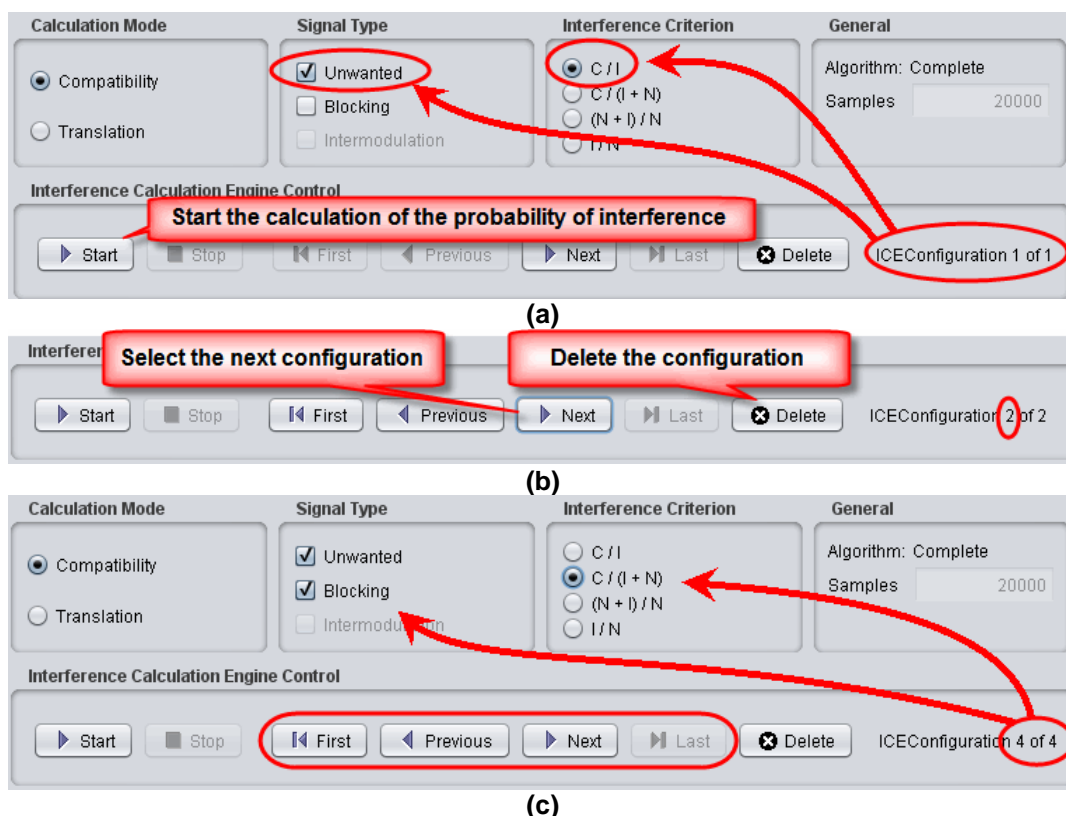
Figure 272: Example (a), (b) and (c) on using the Interference Calculation Engine Control

When the translation mode is activated, the overloading feature is deactivated as shown in Figure 273.
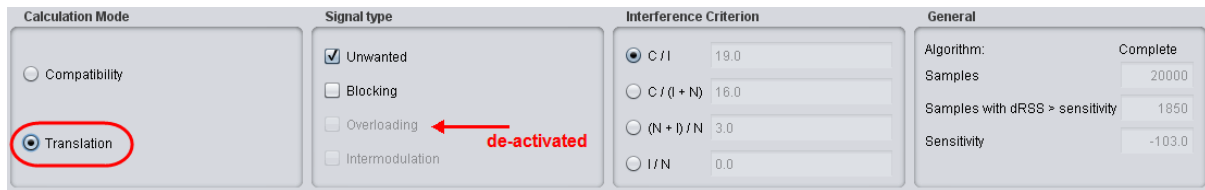
Figure 273: When translation is activated, the overloading feature is de-activated

13 LIBRARY OF SCENARIO ELEMENTS

13.1 LIBRARY OVERVIEW

SEAMCAT library is a useful tool for creating and storing various typical elements of interference scenario and later easily re-using them when creating complex scenarios. The SEAMCAT library allows creating such data templates for the following scenario elements:

Note that technical library management functions are available regardless of whether a simulation workspace has been loaded or not. The library can be saved in a separate file too so that you can also share them.

Figure 274: Overview of the SEAMCAT library elements

13.2 IMPORT / EXPORT A LIBRARY ELEMENT IN/FROM A WORKSPACE 🔲 🔲

Modification of existing (default) library elements as well as creation of new elements can be managed through the relevant options of Library menu. Once stored, the library elements may be then easily inserted into scenario by selecting a particular library element in the Definition field for relevant transceiver in either victim or interfering links, as illustrated in the following picture:

Figure 275: Import / export a library element in/from a workspace

Figure 276: Import / export a library to save or share your work

You can save your library on your local machine by "exporting" it. The libraries are saved under .sli file. You can select any libraries that you pocess (Figure 277), and you can select the folder where you want your data ro be saved using the file system chooser (Figure 278).
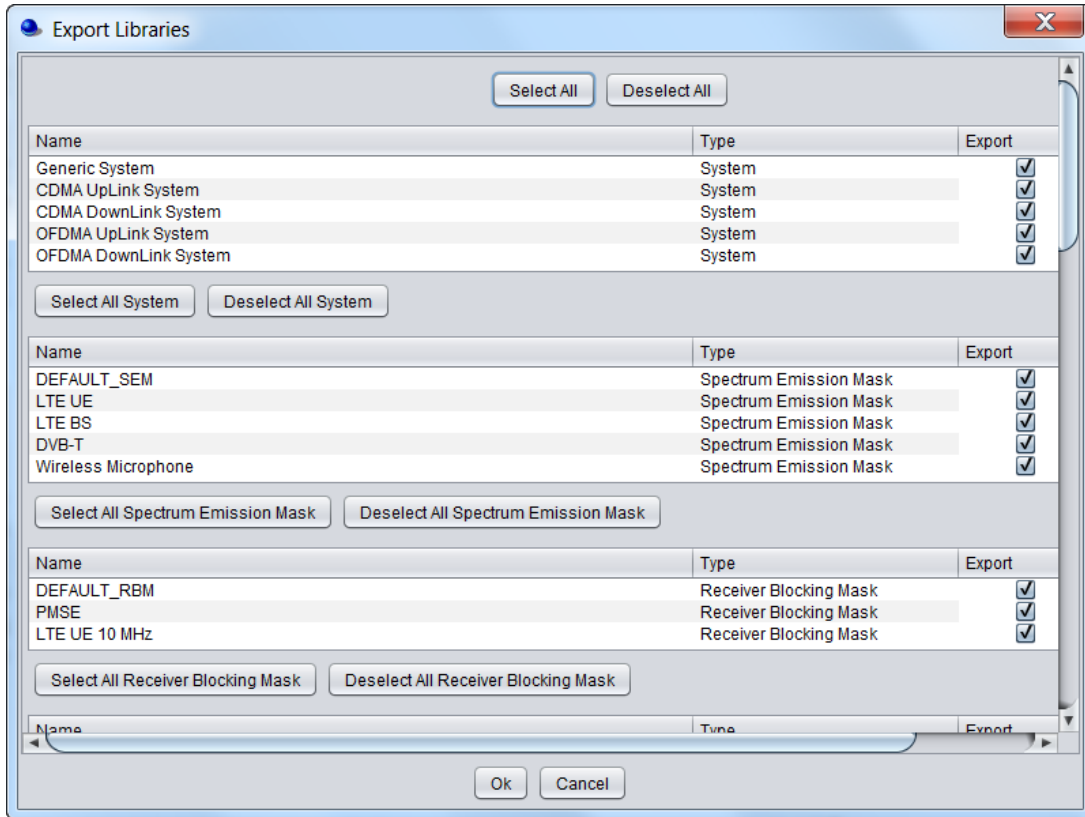
Figure 277: Export a library to your local machine
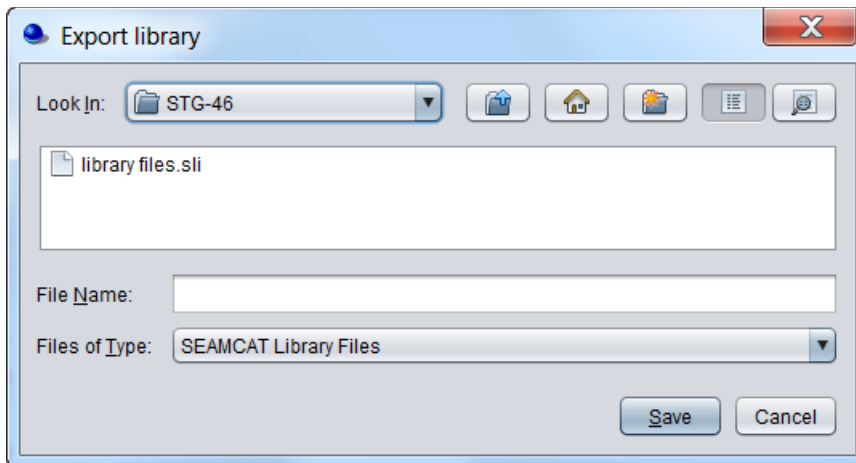
Figure 278: Select where the library should be saved.

You can aslo share your library by "importing" third party library to your SEAMCAT environment.
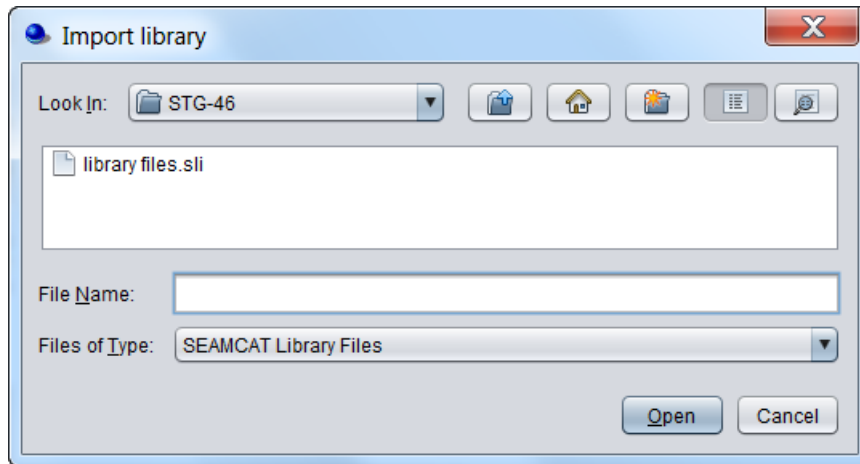
Figure 279: Import .sli files

Once a library element is **imported** ([icon]) into a given scenario, there remains no relational link between the original library element and its copy pasted into the workspace scenario. That is, if at some later stage you want to modify or suppress the library element, this by itself will not produce any change in replicas of that library element previously pasted into existing workspaces. Upon clicking the import button, you will have to chose from a drop down list the element that you want as shown below:

You can create a library from the workspace and **export** ([icon]) it to your library environment. SEAMCAT will automatically place the new element in the right library category.

13.3 EDIT AND SHARE LIBRARY ELEMENT [icons]

When you open a library from the workspace menu you will have the following interface (below is the antenna interface).

Figure 280: Example of the antenna interface library

All the library elements follow the **same** command feature [icons]. They are available for you to:

- **Create** a new antenna, click on [icon]

- **Delete** an existing antenna, select it in the list and click on [icon]

- **Duplicate** an existing antenna, select it in the list and click on [icon]. Reference of the new antenna is derived from the reference of the selected one by incrementing the integer suffix of that reference, if any, or adding character '1' to the end of the original name.

- **Reload** the pre-defined libraries (it will delete any entries that you may have made), click [icon];

- Get on-line **help** click [icon]

When adding a new elements, you need to enter the name (unique identifier), description of the elements as well as its technical parameters.
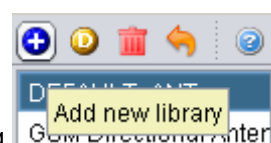
Note: Tooltip are available on the button to remember their meaning [image].

Once you have created a broad library of various elements, it might be especially useful to exchange this data, e.g. share with other members of the team working on studies of similar radiocommunications systems.

To share the created library, an export file may be created by using command **Export Library** in menu section **File**. When selecting this menu option, you will be offered a choice of defining the file name and the <u>entire</u> current library and a library copy will be unloaded to that file.
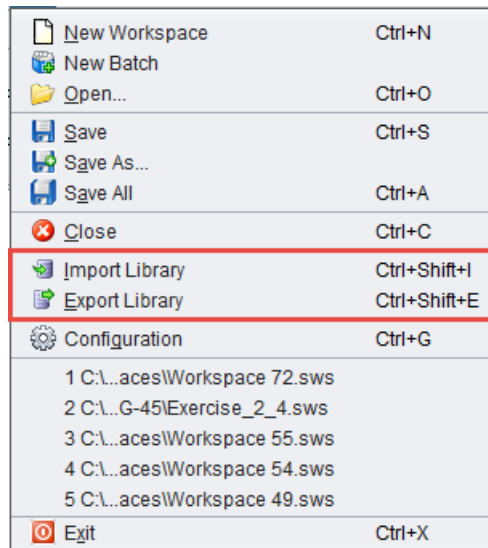
Figure 281: General import/Export library

The SEAMCAT library exchange files are saved using XML format and with unique file extension **.sli** (for Seamcat Library). Such library export file may then be distributed within the group of users and may be uploaded by any users via command **Import Library** on the **File** menu.

In case of collision of imported and existing library element names (e.g, there will always be a collision between the DEFAULT library elements saved in an exchange file and those existing in target SEAMCAT copy), you will be given a choice of either overwriting the existing elements, or importing colliding elements with different names.

13.4 LIBRARY ELEMENTS

13.4.1 System elements

To create or modify a library element containing parameters of a particular system, i.e. generic, cellular network like CDMA or OFDMA, select the system library lements command from the **Library pull-down menu** or directly **CTRL+SHIFT+S**.

A list of existing pre-defined systems (if you have not created any system before) will be selectable as shown in Figure 282 for generic system and Figure 283 for cellular systems (e.g. CDMA UL network).
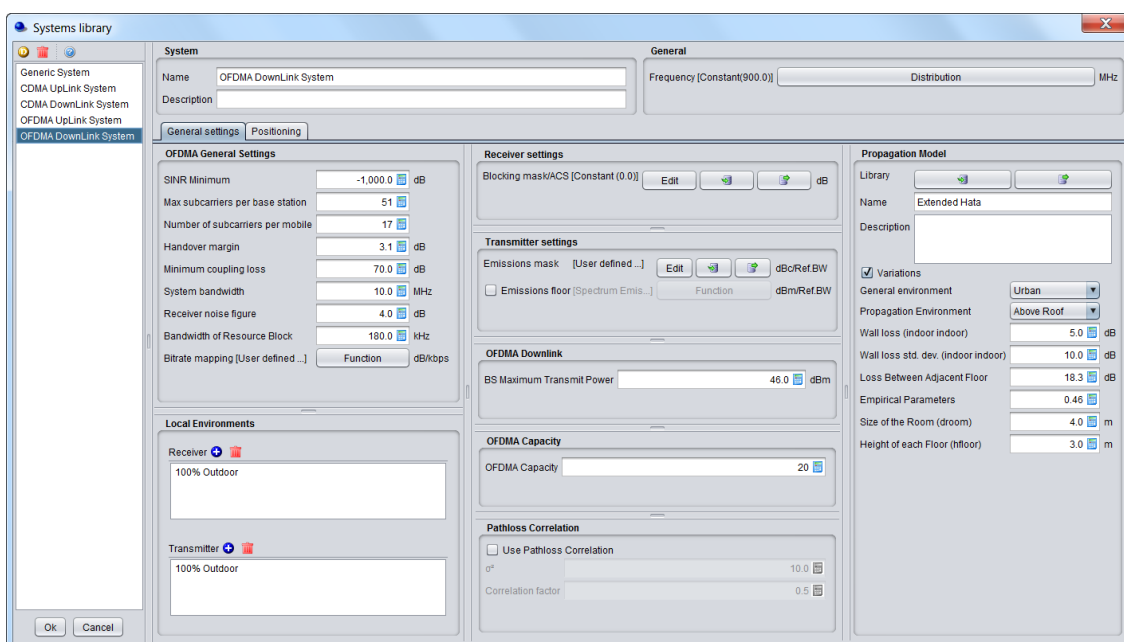
Figure 282: Example of generic System elements
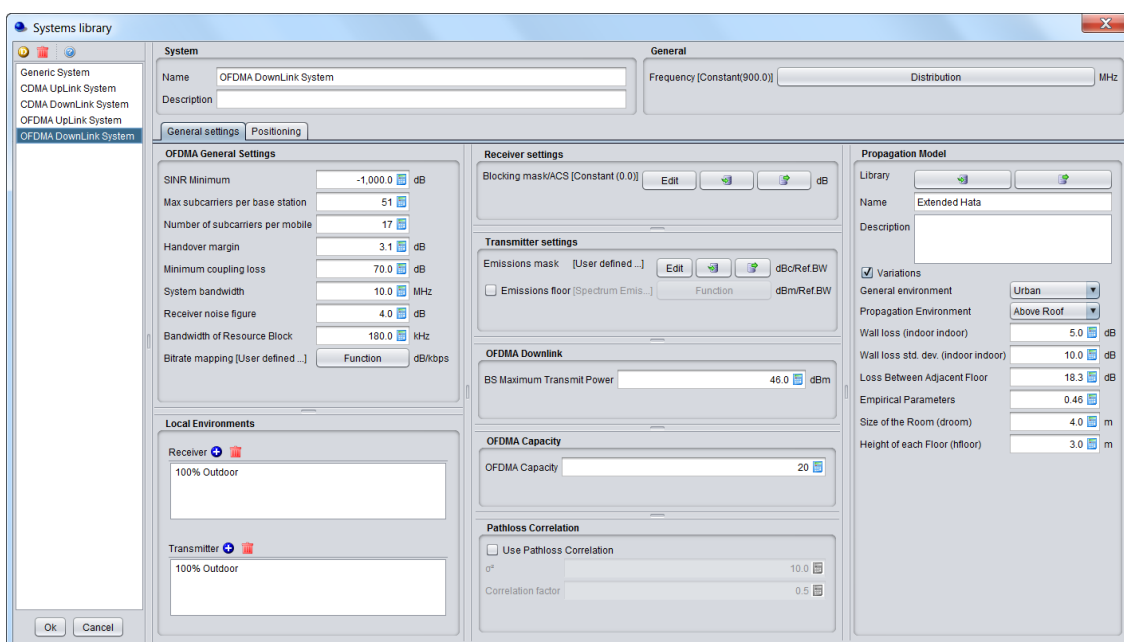
Figure 283: Example of CDMA UL System elements

When adding a new system, you need to enter the name (unique identifier) and a description.

Note: You can also create a system from the workspace and export it to your library environment.

13.4.2 Spectrum emission mask elements

To create or modify a library element containing parameters of a particular spectrum mask, select the **Spectrum emission masks** command from the **Library pull-down menu** or directly with **CTRL+SHIFT+S**.

A list of existing pre-defined spectrum emission mask (if you have not created any before) will be selectable as shown in the picture below. This is an example of a LTE UE (Table 6.6.3.1-2 of 3GPP TS 36.101) where the limit for the spurious emission domain (outside ± 12.5 MHz) applies to frequencies above 1000 MHz:
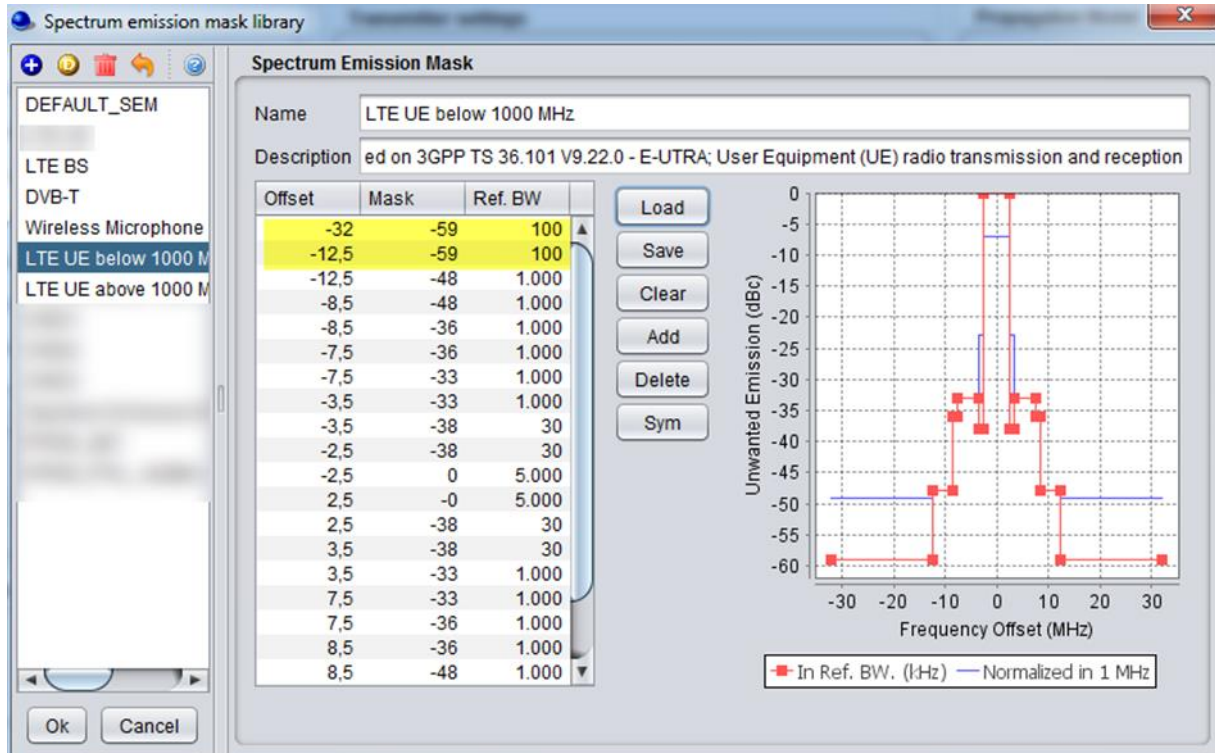
Figure 284: Spectrum emission mask library elements

When adding a new spectrum emission mask, you need to enter the name (unique identifier), description of its technical parameters.

Note 1: You can quickly scroll up and down and see the differences in the masks.

Note 2: You can create a mask from the workspace and export it to your library environment
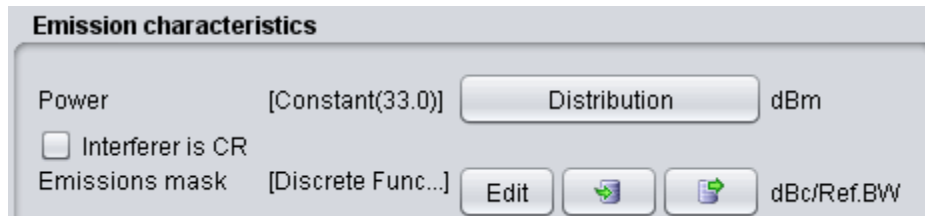
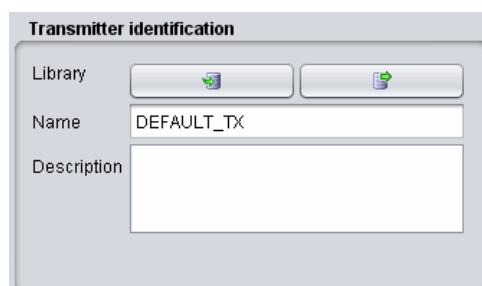**Figure 285: Example on how to import/export to/from the workspace/library for the spectrum emission mask**

13.4.3   Receiver blocking mask elements

To create or modify a library element containing parameters of a particular blocking mask, select the **Receiver blocking masks** command from the **Library pull-down menu** or directly with **CTRL+SHIFT+B**.

A list of existing pre-defined receiver blocking mask (if you have not created any before) will be selectable as shown in the picture below:
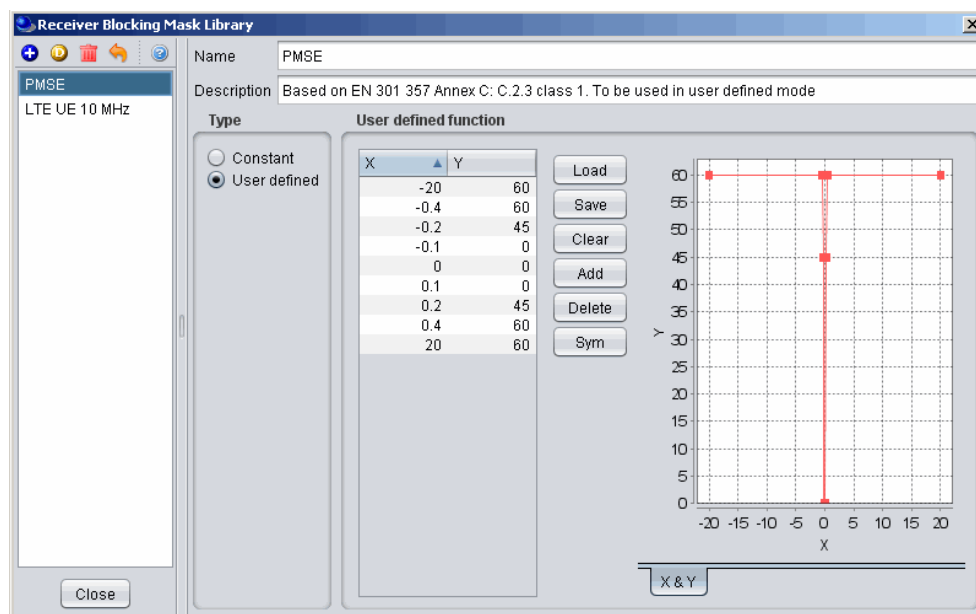
Figure 286: Receiver blocking mask library elements

When adding a new receiver blocking mask, you need to enter the name (unique identifier), description of its technical parameters .

Note 1: You can quickly scroll up and down and see the differences in the blocking masks.

Note 2: You can create a blocking mask from the workspace and export it to your library environment
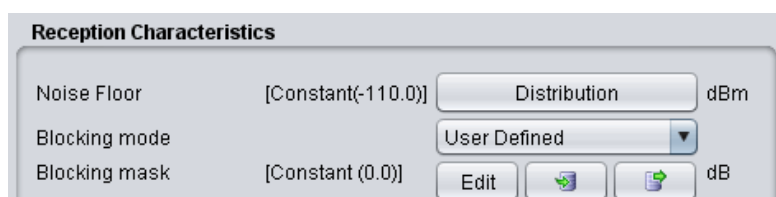
Figure 287: Example on how to import/export to/from the workspace/library for the receiver blocking mask

13.4.4 Receiver elements

To create or modify a library receiver element, select the **Receivers** command from the **Library pull-down menu** or directly with **CTRL+SHIFT+R**.

This activates the Receiver Library window which displays a list of existing receiver elements in the library. You will note that it is the same interface as in the workspace so that it is easy for you to fill. If you have not created previously a receiver, the list will contain only the DEFAULT receiver element:
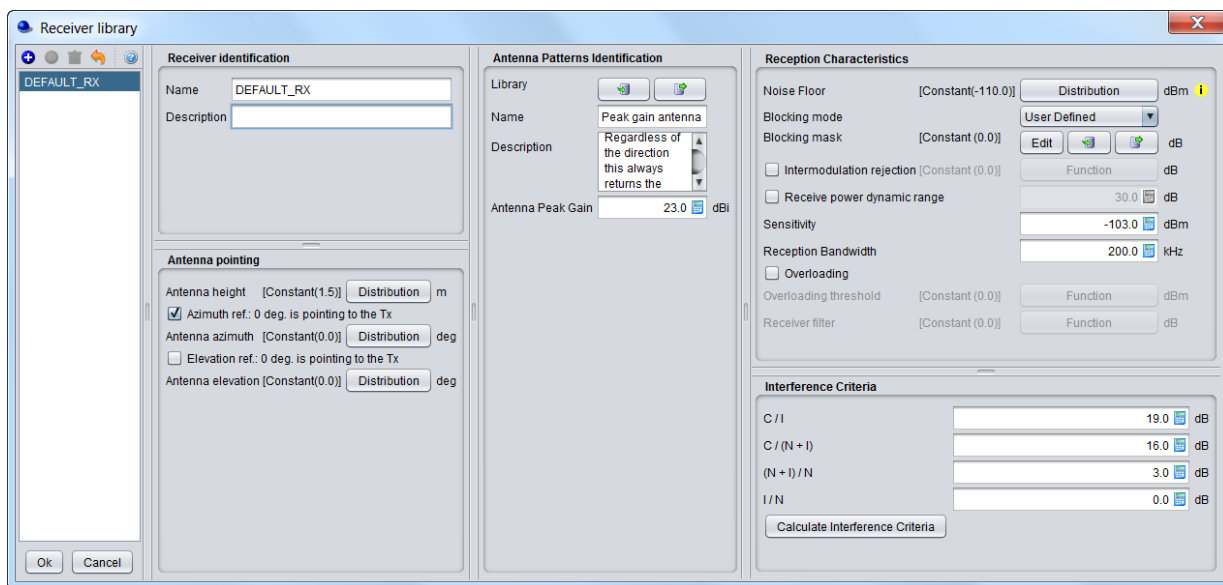
Figure 288: Receiver library elements

The parameters of receiver are grouped in 5 different panels:

- **Receiver identification**: to define receiver name (unique identifier), description;
- **Antenna pointing**: It contains all information relative to the antenna other than the radiation pattern (Please read here more about antenna azimuth/elevation settings);
- **Antenna patterns identification**: to define a specific antenna to be associated with that particular receiver. Note that you can select one of the existing antenna library elements or define completely new antenna parameters to be associated only with the given receiver;
- **Reception characteristics**: to define the basic receiver features, such as bandwidth, sensitivity, blocking (selectivity) function, etc.;
- **Interference criterion**: to define the required minimum C/I and/or other interference criterion, as appropriate.

Note 1: You can quickly scroll up and down and see the differences in the receivers.

Note 2: You can create a receiver from the workspace and export it to your library environment
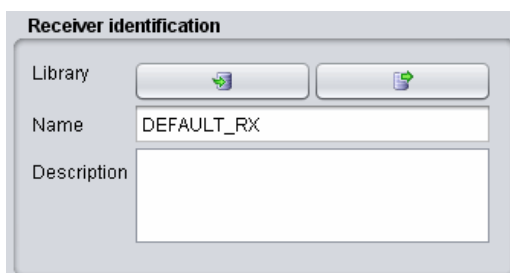
Figure 289: Example on how to import/export to/from the workspace/library for the receiver elements

13.4.5 Transmitter elements

To create or modify a library transmitter element, select the **Transmitters** command from the **Library pull-down menu** or directly with **CTRL+SHIFT+T**.

This activates the Transmitter Library window which displays a list of existing transmitter elements in the library. You will note that it is the same interface as in the workspace so that it is easy for you to fill. If you have not created previously a transmitter, the list will contain only the DEFAULT transmitter element:
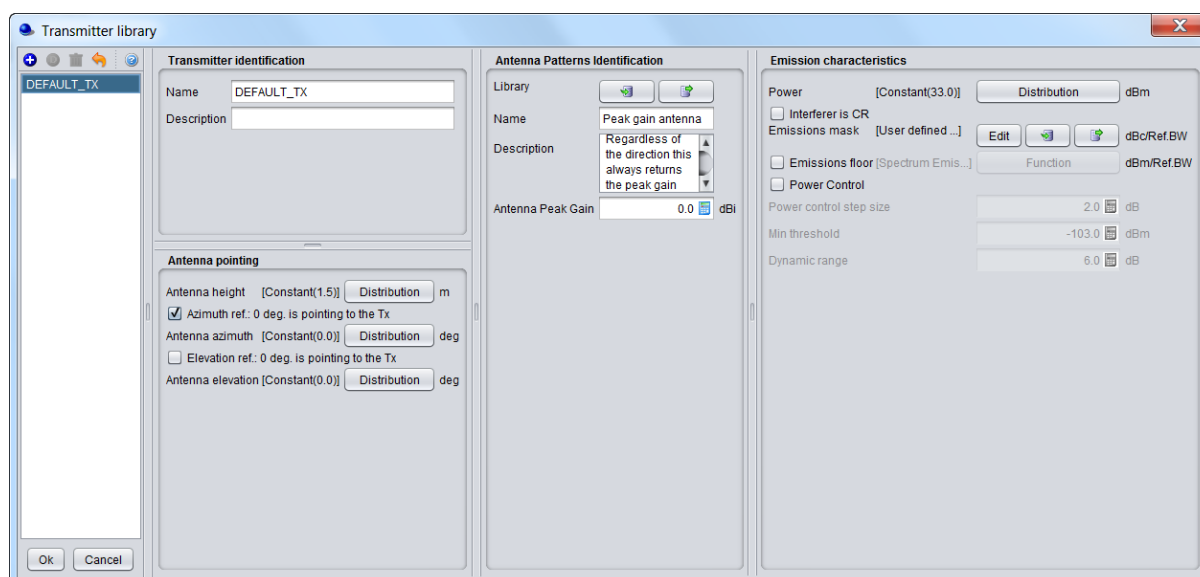
Figure 290: Transmitter library elements

The parameters of transmitter are grouped in 4 different panels:
- **Transmitter identification**: to define name (unique identifier), description;
- **Antenna pointing**: It contains all information relative to the antenna other than the radiation pattern;
- **Antenna patterns identification**: to define a specific antenna to be associated with that particular receiver. Note that you can select one of the existing antenna library elements or define completely new antenna parameters to be associated only with the given receiver;
- **Emission characteristics**: to define the basic transmission features, such as power, spectrum emission mask function, etc..

Note 1: You can quickly scroll up and down and see the differences in the transmitters.

Note 2: You can create a transmitter from the workspace and export it to your library environment

Figure 291: Example on how to import/export to/from the workspace/library for the transmitter elements

13.4.6   CDMA Link level data

To create or modify CDMA Link level data set, select the **CDMA Link level data** command from the **Library pull-down menu** or directly **CTRL+SHIFT+L**. This activates the CDMA Link level data window which displays a list of existing CDMA Link level data:
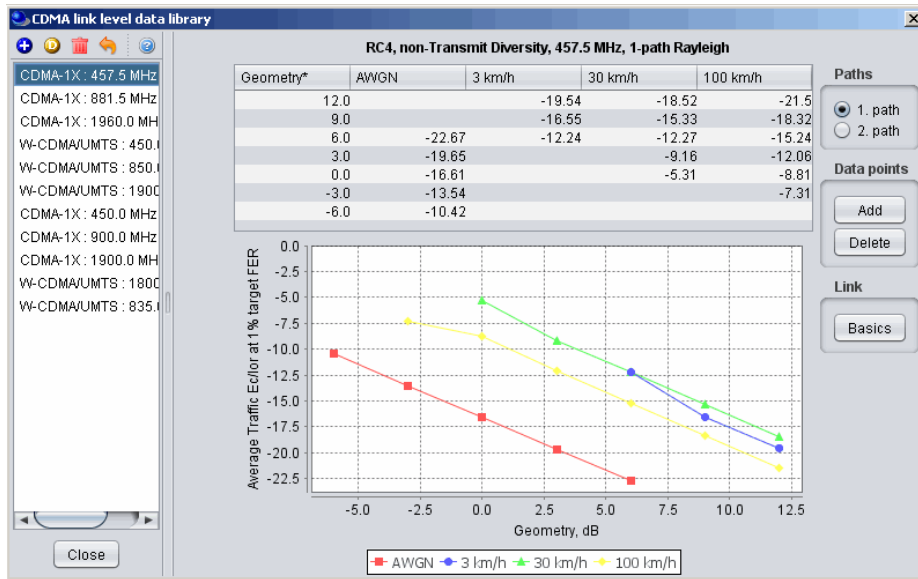
Figure 292: CDMA Link level data library elements

Regarding the library sets of CDMA Link level data, the default sets distributed within SEAMCAT library are understood to be sufficient to cover typical CDMA systems expected to be deployed in Europe and their respective frequency bands. You may defined any additional link level data to cover other types of CDMA systems. However, it is recommended that only users with advanced knowledge of CDMA systems develop the new CDMA Link level data for SEAMCAT simulations as several serious considerations should be undertaken before creating new Link level data:

▪ The SEAMCAT CDMA Link level data have different formats for uplink and downlink sections of CDMA link. In particular, the Link level data for **uplink** provides **Eb / No requirements**, whereas **downlink** data define the **Ec / Ior requirements**;

▪ You should check carefully that the newly created CDMA link level data is appropriate for the SEAMCAT's CDMA simulation methodology for the respective section of the link (uplink/downlink).

From the worskpace, you can select the library that you want to use as shown below.
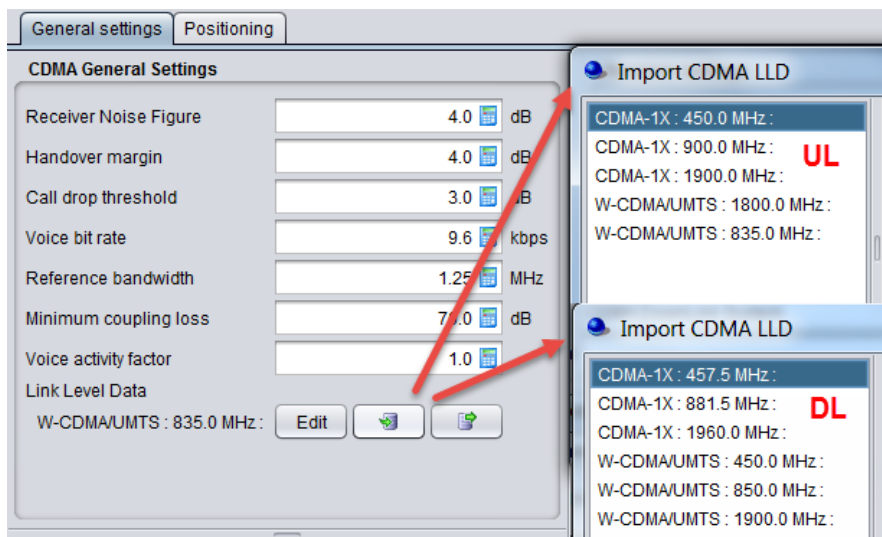
Figure 293: Example on how to import/export to/from the workspace/library for the CDMA Link Level data library elements

When adding or editing a data set, a table with data points is displayed and new data points entered will appear on the graph (for Downlink sets). For Downlink sets, every data point must as a minimum contain a geometry value, otherwise it is invalid and it will not be possible to leave the editing dialog.

Basic information about the link-level data set can be viewed and amended in by clicking **Basics** button in the sidebar of the edit window. This will display a new dialog.

**Note:** When _Ok_ is clicked in the basics dialog any information changed in this dialog will be saved immediately even if _Cancel_ is subsequently pressed in the overlying data point window.
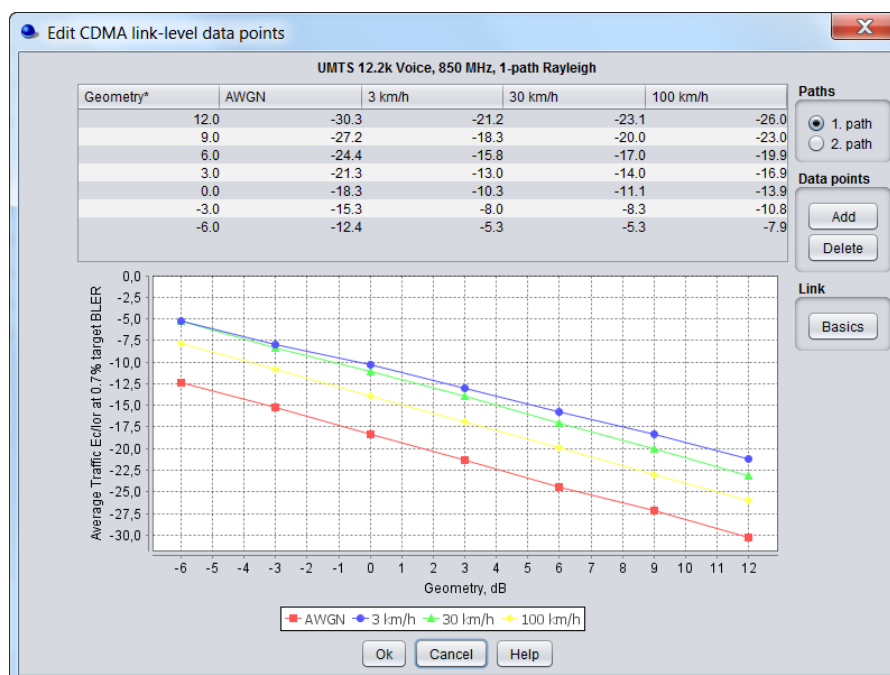
Figure 294: Example on how to edit a CDMA Link Level data element

13.5 LIBRARY PLUGINS

A detailed description on plugin development is available in section 14.

13.5.1 Antenna plugin elements

To create or modify a library element containing parameters of a particular antenna, select the **Antennas** command from the **Library pull-down menu** or directly with **CTRL+SHIFT+A**.

Since the antenna is implemented as a plugin, it is possible for you to include a new antenna plugin using the .jar installer and to add it to the list of existing pre-defined antennas (if you have not created any antennas before). Any of the antenna elements is then selectable as shown in the picture below:
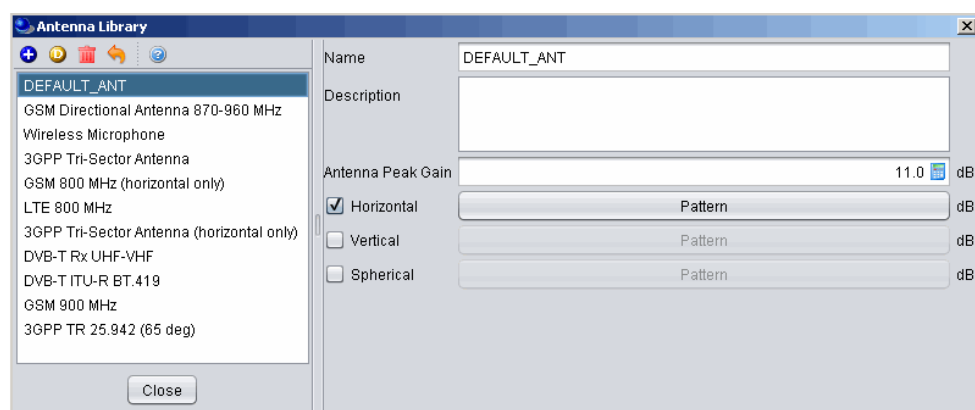
Figure 295: Example of the antenna library

When adding a new antenna, you need to enter the name (unique identifier), description of the antenna as well as its technical parameters - peak gain and one or more radiation patterns, as necessary. See Annex A11.6 for further details.

Note 1: You can quickly see the antenna pattern with mouse-over capability on top of the pattern button
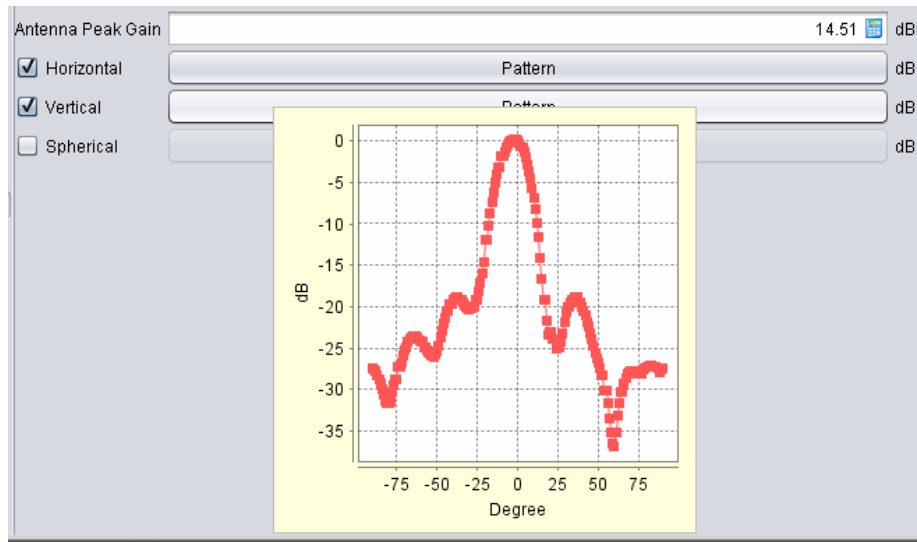
Figure 296: Quick over mouse preview of the pattern

Note 2: If none of the radiation patterns is checked, SEAMCAT will assume this being an omni-directional antenna.
Note 3: You can create an antenna from the workspace and export it to your library environment.

13.5.2 Coverage radius plugin elements

To create or modify a coverage radius element, select the **Coverage radius library** command from the **Library pull-down menu** or directly **CTRL+SHIFT+C**. This activates the Coverage radius library window which displays a list of existing Coverage radius library:
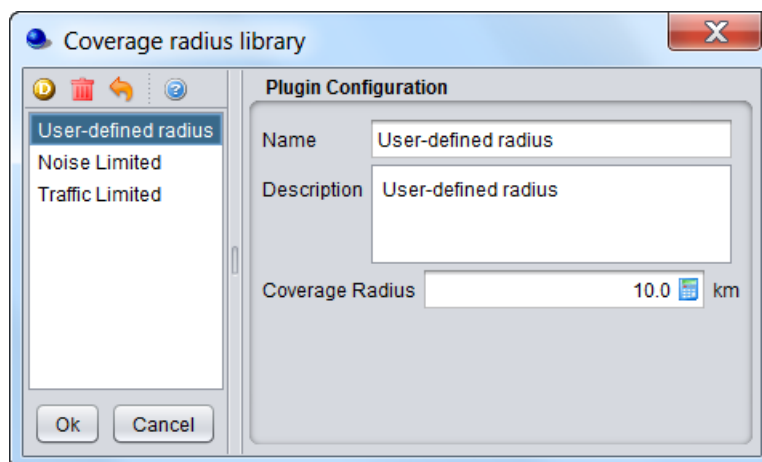
Figure 297: Example of the coverage radius plugin library

13.5.3 Propagation model plugin

To create or modify a library element containing parameters of a particular propagation model, select the **Propagation model** command from the **Library pull-down menu** or directly with **CTRL+SHIFT+P**.

Since the propagation models are implemented as plugin, it is possible for you to include a new propagation model using the .jar installer and to add it to the list of existing pre-defined models. Any of the propagation models is then selectable as shown in the picture below:
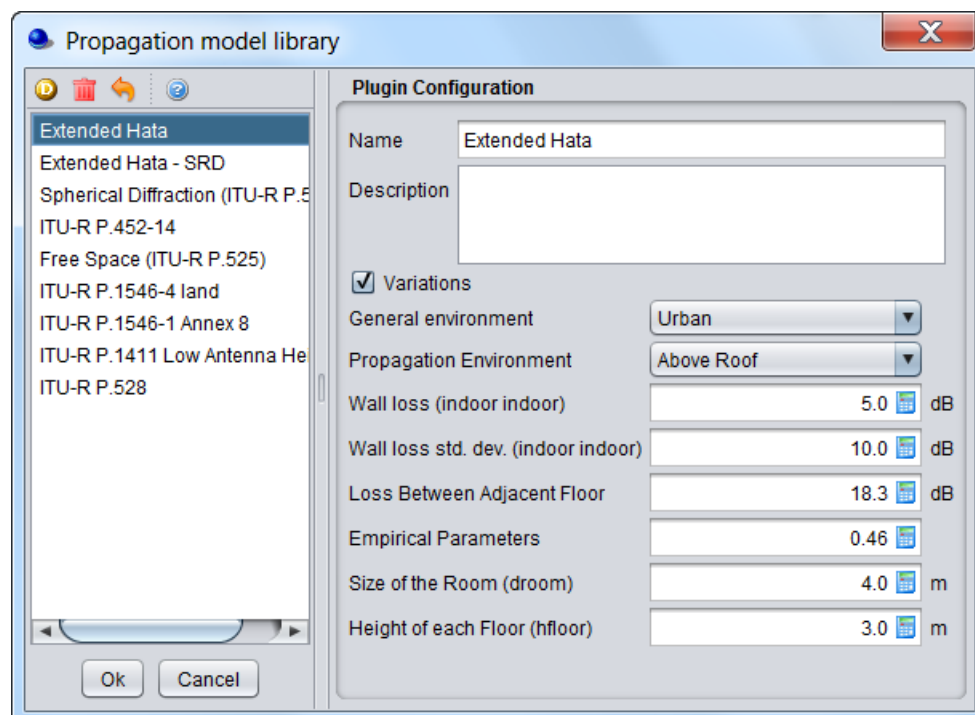
Figure 298: Example of the propagation model plugin library

More detailed information on specific propagation models is available in ANNEX 17:.

13.5.4   Event Processing Plugin

To create or modify a library element containing parameters of a particular event processing plugin, select the **event processing plugin** command from the **Library pull-down menu** or directly with **CTRL+SHIFT+E**. A list of available built-in event processing plugin is available in Figure 240.

14 PLUGIN DEVELOPMENT

14.1 SEAMCAT SOURCE CODE

Programming is all about detail so when looking at even simple code it can be bloated with irrelevant stuff, logging, error handling, comments.

Often, nitty gritty details hides the true purpose of a piece of code. So being able to navigate through souce code you need to understand what highlevel and lowlevel abstractions are made when designing and implementing the software.

In SEAMCAT we have abstractions like Systems, Simulations, Antennas and plugins but we need to have a good mental picture of how they relate to each other.

With SEAMCAT you can setup victim, setup a number of interferers, define interference properties, control the number of snapshots, simulate and inspect the collected results after the simulation. This is nothing new to a seasoned SEAMCAT user but that does not really help when the source code is to be navigated.

14.2 BACKGROUND AND TERMINOLOGY

The following terminology is used throughout this document.

- **System**: A radio system of SEAMCAT. Currently SEAMCAT supports two kinds of systems, i.e. Generic System and Cellular System (with four sub types available: CDMA UpLink, CDMA DownLink, OFDMA UpLink, OFDMA DownLink). However different, all systems has common traits such as frequency, receiver characteristics, transmitter characteristics, positioning, etc.
- **Victim system**: referred to as 'The victim' as there is only one victim for a simulation.
- **Interfering system**: a system that interferes with the victim system.
- **Interference link**: this is a constellation of a victim system and an interfering system. But it also includes configuration outside of systems, i.e. relative positioning of the systems, propagation model, specifics for system types such as user defined DRSS for generic system.
- **Scenario**: a complete configuration of a victim system and a list of interference links (and thereby a list of interfering systems).
- **Event** (or snapshot): a random trial of all distributions in a scenario.
- **EventResult**: from an event the system simulations apply calculations and produce a number of results, which is what we call the event result.
- **Simulation result**: the total result of combining all produced EventResults.

14.2.1 Understanding abstraction level

We can conceptually view SEAMCAT as a layered cake of abstractions. Knowing these different layers helps a lot in understanding how to navigate the source and how to understand SEAMCAT.
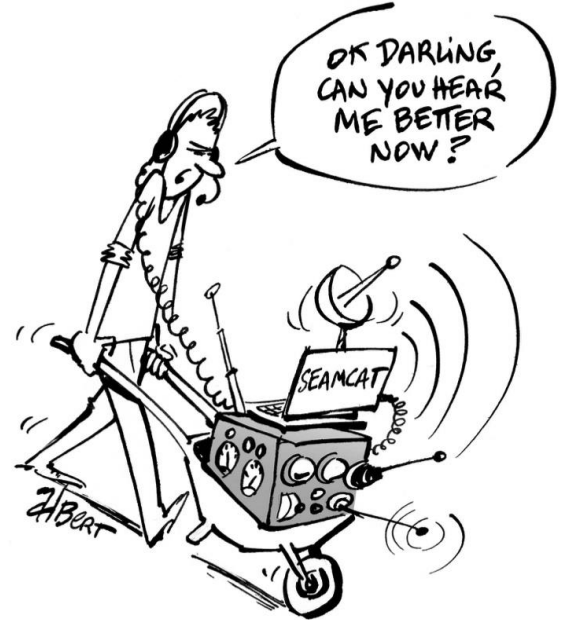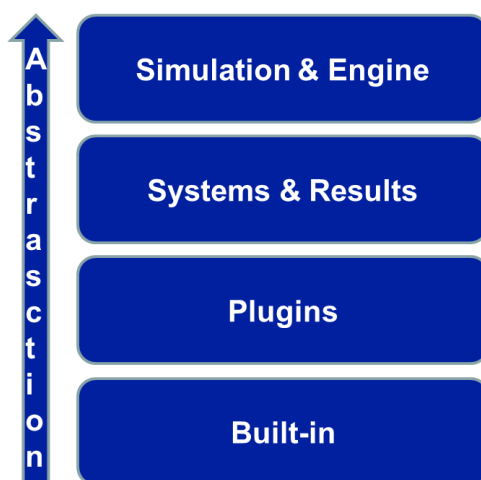
Figure 299: Abstraction level in SEAMCAT

So in a very high level of abstraction, the Monte Carlo simulation runs through the specified number of randomized events, which each produces an EventResult. Lastly it combines all these EventResults into a simulation result which can be inspected in SEAMCAT.

14.2.2 Simulation & Engine

We start at the highest abstraction: Simulation & Engine. If we forget about the specific system types and multiple interferers we get the conceptualized view of a scenario. A victim system can be interfered by an interfering system.

On a very high level of abstraction an interference simulation consists of

1. victim.simulate, i.e. Configure the victim system;
2. interferer.simulate, i.e. Configure the interference system;
3. and collect the interference results based on the settings of the two systems.

Figure 300: Abstraction level of an interference simulation

A closer look at the 3 steps: get the list of active receivers from the victim. Remember do not think of a specific system, if you for instance think of a Generic system you might say that this is never the case because there can be only one receiver. But there being only one is a special case of being many. And for Cellular systems there can definitely be many receivers (UE or BS). So the highlevel view of the algorithm is that there is a list of active receivers in the victim system.

Now we do the same (but opposite) for the interfering system: get the list of active transmitters. Again the list of active transmitters is the most general or highlevel notion of the algorithm which describes all possible cases (0, 1, or many).

Finally we combine all victim receivers with interfering transmitters and base the calculation of the interference with this as shown in Figure 301.
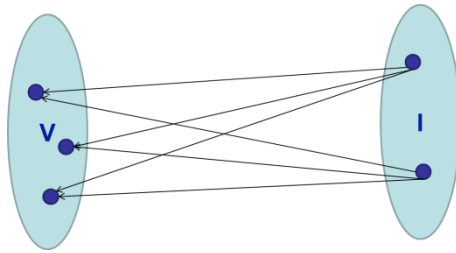
Figure 301: Abstraction level of IT->VR links

These IT->VR links are really what we are looking for and bases the interference calculations upon.

Given this the following results are possible:

- 0 – For some reason there was either 0 active receivers or 0 active transmitters in the victim, interfering system (respectively). Therefore we have no IT->VR links;
- 1 – There is precisely one active receiver and one active transmitter. This is most commonly the case for "generic-generic" simulations;
- Many – There are many IT->VR links either because the systems are generic with many active transmitters or cellular (or maybe it is a future system not invented yet).

We have certainly described a lot about how SEAMCAT works but at no point it was needed to talk about any systems specifics. Of course during a simulation the choise of system will very much affect how it is done, but conceptualized like this there is no need.

On the highest level of abstraction we have the Simulation & Engine. "Simulation" holds the scenario setup and various hook for starting and completing a snapshot while "Engine" runs a simulation by controlling the steps in the simulation
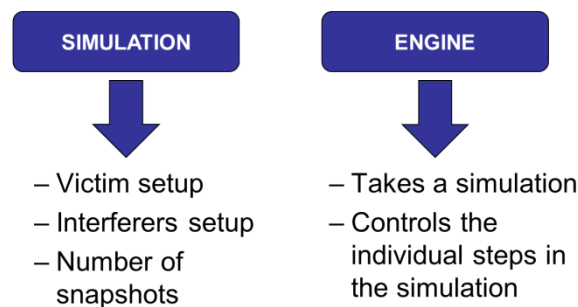
Figure 302: Simulation and Engine abstract representation

The figure below from the engine shows almost exactly the steps described above.

The real implementation is in InterferenceSimulationEngine.java take a look at it. Remind yourself that programming is all about details: there are so many other things going on than the actual loop.

```
public MutableEventResult single( VictimSystemSimulation victimSimulation, int eventNumber, Simulation simulation ) {
    fixSeed( simulation, eventNumber);

    MutableEventResult eventResult = new MutableEventResult(eventNumber, (WorkspaceScenario) simulation.getScenario());
    victimSimulation.simulate(eventResult);

    List<InterferenceLinkSimulation> iSims = new ArrayList<>();
    for (InterferenceLink interferenceLink : simulation.getScenario().getInterferenceLinks()) {
        InterferenceLinkSimulation iSim = simulation.getInterferenceLinkSimulation(interferenceLink);
        iSims.add(iSim);
        Point2D victimPos = victimSimulation.getSystemPosition( eventResult, interferenceLink);
        iSim.simulate(simulation.getScenario(), eventResult, interferenceLink, victimPos);
    }

    victimSimulation.collect(eventResult);

    simulation.eventComplete(eventResult, victimSimulation, iSims);

    return eventResult;
}
```

Figure 303: Engine code

The engine asks the simulation for the victim system simulation. So the simulation controls which victim simulation instance is handed to the engine, and the engine then uses that instance for doing its calculation. Therefore the engine is decoupled from the knowledge of which specific victim simulation is running (e.g. Cellular victim).

14.2.3 Packages

SEAMCAT has different modules. These are used to group certain classes of the code and handle dependencies between them. This is similar to the layers of abstraction where the engine only knows general system types but not specifics. Modules can be used to enforce such dependencies.

There are two main modules: model and application.

- Model holds all the abstract definitions that composes a System – Transmitter, Receiver, Antenna, Propagation model, Distribution, etc.;
- Application implements the SEAMCAT UI, simulations, Propagation Models, and basically ties everything together. We will descuss this structure in more detail later.
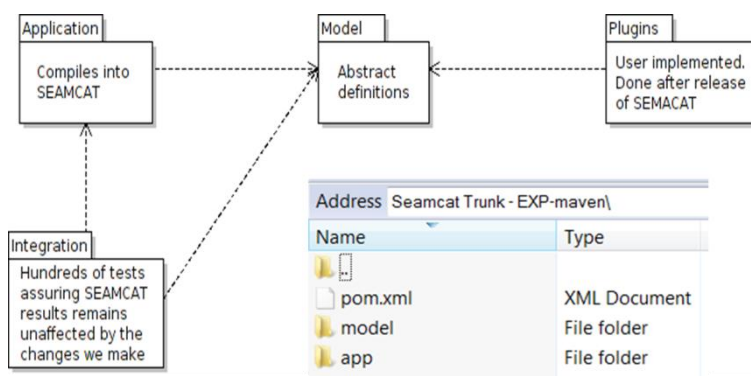
Figure 304: Modules of SEAMCAT

Inside a module we organize the software files in packages. It is similar to a folder and like a folder it contains the individual source code files. The names of the packages is helpful when nagivating the source code.

The packages of the model module.

- The names can be helpful when navigating the source code:
- Cellular and generic contains the definitions for the cellular and generic systems;

- Plugin holds the plugin definition for the mentioned types (Eventprocessing, Coverageradius, propagation etc…);
- Distribution, functions, and mathematics holds the distributions and other helper functions;
- Simulation and types holds the simulation results and general type definitions (Antenna, Receiver, RadioSystem, etc).

The packages of Application is more messy than the model. So here it is harder to know exactly where to go. The packages to know here is: scenario and simulation.

- Scenario contains the implementation of some of the types defined in Model;
- Similarly with simulation: here are the specific simulations e.g. CDMADownlinkVictimSimulation.

It is the very nature of code to change, but with a good design and understanding of the abstractions it should be easy to identify part that will change the least. Most of the dynamic parts of the code can be examined with runtime inspection by software development tools. Mechanism vs Policy is a software principle based on the fact that mechanism change infrequently whereas policies change all the time.

Mechanism is here the engine of SEAMCAT and policies are the plugins. The parts that changes behaviour are left open for developers.
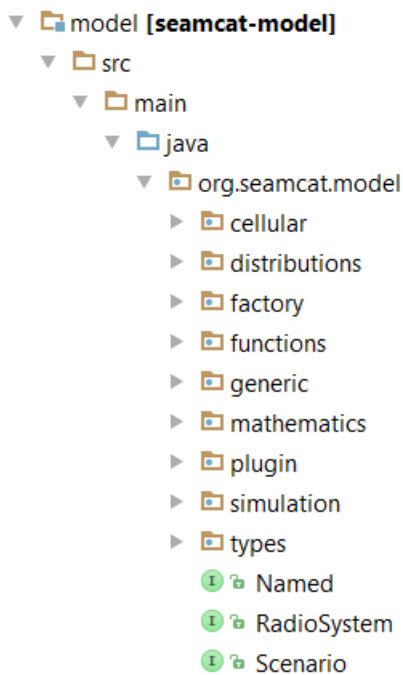
Figure 305: Packages of Model
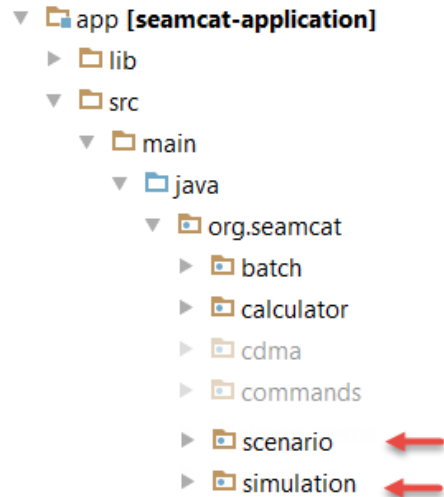
Figure 306: Packages of Application

14.2.4   System & Results

We move a step down in the abstraction level and look at system types. So far we have avoided the specific knowledge of the system type for the engine and simulation. This gives us power. Since the engine and simulation has been implemented without knowing the specificity of a system to simulate, we can now extend the system with new types. As long as the general system interface remains the same, adding new system types would not affect the engine or simulation at all!

The system has agnostic properties. With agnostic we mean that we are talking about a system in general – no mention of any specifics.

Remember that the Engine is system agnostic – it can calculate the interference regardless of the system type!

So what is a system? Basically a System contains Transmitter(s) and Receiver(s) and link(s) between these. Whenever we have a link a Propagation Model applies i.e. the connection from the transmitter to the receiver will suffer a loss how big this loss will be is determined by the Propagation Model.

Figure 307 is the Model-module code for a RadioSystem – the most abstracted version of a system. These definitions would therefore apply to any specific system but in the abstract definition there is no mention of Generic or Cellular specific properties. So generally speaking a RadioSystem has a frequency which is a distribution. It has a Receiver and a Transmitter. And importantly it defines a Link between the transmitter and receiver.

```java
public interface RadioSystem extends Named {

    String TX_RX_PATHLOSS = "path loss";
    String EFFECTIVE_PATHLOSS = "effective path loss";
    String UNWANTED_EMISSION_INTEGRATION = "Unwanted emission integration";

    Distribution getFrequency();

    Receiver getReceiver();

    Transmitter getTransmitter();

    // TransmitterReceiverPath getPath();
    Link getLink();

}
```

Figure 307: Model-module code for a RadioSystem

In SEAMCAT we use the workspace to define our interference setup. In code terms we call the workspace a Scenario. The Scenario is how the engine sees the workspace configuration. It is high on the abstraction scale because the engine cannot know anything about the details (and does not need to). It is an abstract immutable representation of the workspace. It is found in Scenario.java and is used by the Engine.

Running a SEAMCAT simulation produces results. The results fall into two categories 1) Simulation results and 2) Intermediate results

14.2.4.1 Simulation results:

SimulationResult is the result of running a SEAMCAT simulation. It holds all results that will be saved/loaded if the workspace is saved/loaded with results. It is represented by class: SimulationResult.java.

SEAMCAT shows all results in the 'Simulation Results' tab. It basically lists all the groups available in the SimulationResult class as shown in Figure 308.

The simulation result consists of several SimulationResultGroups. Each group can be seen on the tab 'Simulation Results'. A group is a set of results that logically belongs together. All simulation results are shown after the simulation has completed and can be inspected/saved/loaded in SEAMCAT. The group result holds the relevant results for this group. The result types can be of many different types: double, vector, xy-plot, etc. We will get back to these types in the EPP section. Group results can be found in the source file SimulationResultGroup.java.

14.2.4.2 Intermediate results - EventResult

A simulation is a series of randomized settings based on the scenario. In SEAMCAT it is called an EventResult. The EventResult is a placeholder during the simulation. It contains all information to be used by a simulation, e.g. positions of the elements in the system. Values in EventResult are used to produce the final SimulationResult.

The EventResult consists of many LinkResults. Every connection between a Tx and Rx is represented with a LinkResult. It could be inside the victim system, or it could be an interference link between the victim system

and one of the interfering systems: all represented by a LinkResult. It is by far the most important result is the LinkResult. It holds the intermediate results of a particular link (e.g.Tx,Rrx position). It can be seen in the file LinkResult.java.

dRSS			
dRSS vector	Array[20000]	dBm	Vector

iRSS Unwanted			
Unwanted summation Vector	Array[20000]	dBm	Vector
iRSS Unwanted	Vector Group[1]	dBm	Vector Group

iRSS Blocking			
Blocking summation Vector	Array[20000]	dBm	Vector
iRSS Blocking	Vector Group[1]	dBm	Vector Group

Calculated Radius			
Victim Link Transmitter - Cover...	10.0	km	Double
Interfering Link Transmitter 1 - ...	10.0	km	Double
Interfering Link Transmitter 1 - ...	1.0	km	Double

Statistics			
Simulated performed on	4	processor	Integer
Total simulation duration	0.197	second	Double
Event generation duration	0.197	second	Double
Calculation rate	101523	events/second	Integer
Simulation date	2015-09-24 13:11:41	N/A	String
Simulation seed	-5783335877110791674		Long Integer

Figure 308: Simulation results

14.2.4.3 Accessing data from EventResults

Results produced from a single snapshot of the simulation are stored in an object called EventResult. An EventResult contains both general results and results that are specific to the actual scenario. It is important to understand the basic structure of the EventResult and the general results in order to be able to develop own EPPs.

The most important result produced by the simulations is the LinkResult. A LinkResult represents an actual connection between a receiver and a transmitter. This is completely general so it could be a connection from a mobile station of a cellular network to a receiver of a generic system - we don't know this by looking at the LinkResult but if the scenario was setup with a CDMA UpLink victim and generic system as interferer the described LinkResult could occur.

A LinkResult contains the actual values of this connection, i.e. position of the receiver, position of the transmitter, the distance between them, the frequency, the path loss and effective path loss. By inspecting the LinkResult interface other similar values are documented.

Roughly said, the EventResult contains a collection of LinkResults. But as pointed out, a LinkResult does not tell you where in the scenario it is located. Therefore an EventResult provides a structure that helps the plugin developer navigate the LinkResult collection.

A LinkResult will occur in the following places:

- **Inside a system**: Is it for instance a generic system it will always be from the transmitter to the receiver. Is it a cellular system it depends on the link direction (up or down). In downlink cellular system a link will be from a base station to a mobile station - notice that in this case there are many more possibilities than in the generic case - we could have many base stations and many mobile stations.
- **Between two systems**: When such a LinkResult occurs it is attached with much more information than just the LinkResult. This is because a link between two systems is called an interference link and is exactly what SEAMCAT is about. So a LinkResult between two systems is a special class (extending the

LinkResult) called InterferenceLinkResult. It always goes from a transmitter in the interfering system to a receiver in the victim system.

- **Between two systems (sensing):** This is a special link that can occur if the victim system supports Cognitive Radio. In such a case a LinkResult can occur from a interfering system transmitter to a victim system transmitter.

As we now know what different LinkResult that can occur in a simulation, we are suited to understand the structure of an EventResult. The most important method in the class EventResult is the one with the signature: InterferenceLinkResults getInterferenceLinkResult(InterferenceLink link);

Let's break it down in order to fully understand what it does:

- the input argument InterferenceLink link: as stated earlier a scenario has a single victim system and a configured list of InterferenceLink(s). Each InterferenceLink identifies a specific interfering system. So the input argument specifies what InterferingLink we are interested in seeing the results from.
- return type InterferenceLinkResults: this is a container of many InterferingLinkResults. We will dig down into the details of this class soon.

So given a specific InterferenceLink from the scenario it gives you all the LinkResults (i.e. actual connections) representing this InterferenceLink so going from the interfering system (to a transmitter) of the InterferenceLink and to the victim system (to a receiver).

To summarize, given a scenario of for instance a generic victim system and three configured interference links, each interference link having CDMA UpLink as interference system. One particular EventResult can give you three different InterferingLinkResults, one for each of the interference links in the scenario. To get the InterferenceLinkResults you are interested in you have to use the corresponding InterferenceLink value from the scenario.

14.2.4.4 The class InterferenceLinkResults

The class InterferenceLinkResults gives the plugin developer the possibility to navigate all LinkResults produced by this sceario's InterferenceLink. It does to by its three methods listed below.

- getVictimSystemLinks(): returns a list of LinkResults from inside the victim system. If the victim system is a generic system, it will be a list of one element typically. If the system is of a cellular type, there will most likely be many LinkResults (the default setting for a cellular system is two tier, tri-sector, suggesting 57 base stations).
- getInterferingSystemLinks(): similar to the getVictimSystemLinks() for only for the interfering system. Notice that the interfering system is now singular, i.e. the interfering system, because we are inside a specific InterferingLink, which identifies a single interfering system.
- getInterferenceLinkResults(): this returns a list of InterferenceLinkResult elements. Notice that the size of this list is always the product of the size of the other two: if getVictimSystemLinks contains n elements and getInterferingSystemLinks contains m elements, getInterferingLinkResults will contain n*m elements.

14.2.5 Debug your code

A way to understand the code is to simply read through it. But this is very hard indeed and it is recommended to inspect the code when it is running. That way, variables can be inspected and execution flow is directly visible.

An example of a generic scenario with a breakpoint in GenericVictimSimulation.simulate is shown in Figure 309. In Intellij you set breakpoints by clicking in the margin of the file. This will cause a red dot to appear and when running in debug mode the code will freeze when that point is reached.

Tip: to find classes (i.e. to get the GenericVictimSystemSimulation.java) do Ctrl+N.

Figure 309: Code inspection - Setting breakpoints

SEAMCAT is launched in debug mode from Intellij. This is done by opening Seamcat.java and right-clicking on the class name. In the menu that appears choose 'Debug 'Seamcat.main()'.

Figure 310: Launch SEAMCAT in debug mode

SEAMCAT will now open and a scenario can be setup. When a scenario has been set up as wanted, the simulation is run by pressing the simulation start button.

Once the execution of the code reaches the point in the code where the breakpoint is set the execution will pause and the breakpoint will light up in Intellij (see Figure 311). Now the developer controls the execution flow.

The button panel below has different control buttons to handle the code flow: step over will go to the next line of code. Step into will go into the method on the line. This has to be tried a number of times before one masters this!
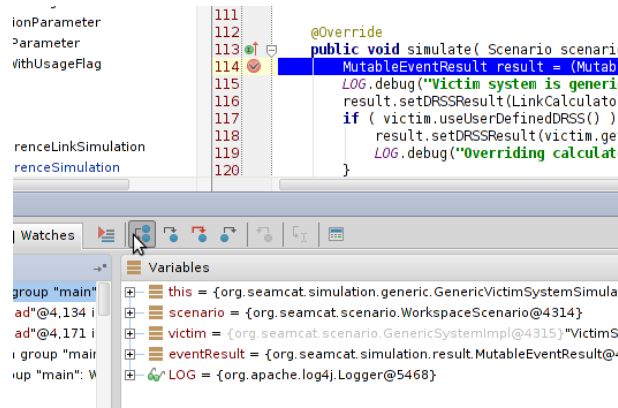
Figure 311: Catching breakpoint

The callstack shows how we got here in the code (Figure 312). This is extremely valuable for inspecting who calls who during the simulation. Here we see that we are coming from line 114 in GenericVictimSystemSimulation.java. This only apply during an active breakpoint i.e. When the code it temporary suspended.
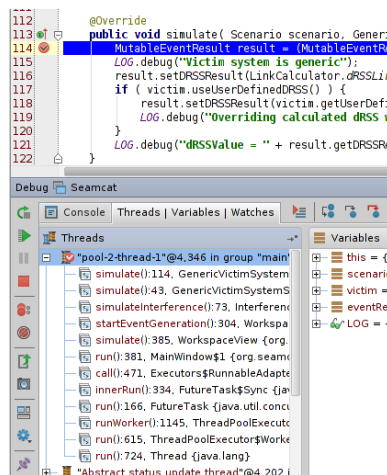
Figure 312: Callstack

The evaluate can be used to evaluate expression in the current code state. Here we take one of the variables eventResult and evaluates the expression eventResult.getDRSSResult(). This evaluates to the double value 0.0. This only applies when you have an active breakpoint.
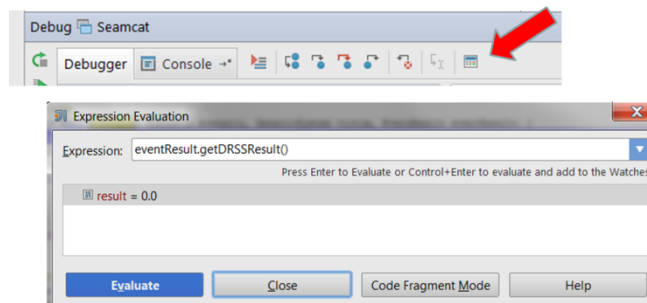
Figure 313: Expression evaluation

14.3 COMMONALITIES TO PUGLINS

We are now moving further down in the abstraction layers of Figure 299. Plugins (e.g. propagation model) are defined in the model module. So the application SEAMCAT uses this definition and uses the plugins in the simulation. Plugin developers can write plugins that are then used by SEAMCAT.
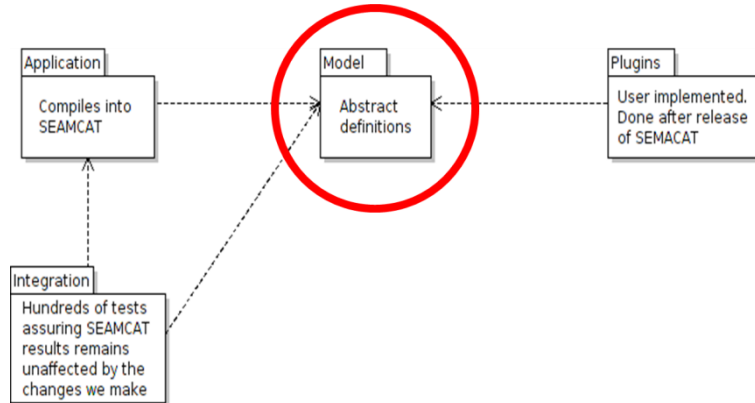
Figure 314: Modules of SEAMCAT

Plugins have been designed so that they follow common rules.

14.3.1 @Config – Annotation of Input interface

The input parameters to be used by plugins are defined through the interface *Input{}.* Inside this interface the different parameters are configured through the annotation *@Config*.

```
public interface Input {
    @Config(order = 1,name = "double")double ownDouble();
    double ownDouble = 88.;

    @Config(order = 2,name = "optional double")OptionalDouble opt();
    OptionalDouble opt = new OptionalDouble(false,333.);

    @Config(order = 3,name = "distribution")Distribution distri();
    Distribution distri = Factory.distributionFactory().getUniformDistribution(10.,100.);

    @Config(order = 4,name = "propagation model")PropagationModel pm();
}
```

Figure 315: Example of an input interface and @Config

Figure 316: display of the example

Each of these annotations is described in detail below:

- **order**
  defines the position on the input panel and must be therefore <u>unique</u>.
- **name**
  to show the user which the parameter is intended for
- <u>general</u>
  it has to be noted that without specifying a default vale, as for instance above for the propagation model, the default values of the corresponding types are applied. which are e.g. for
  double: 0.0
  distribution: constant 0.0
  function: constant 0.0
  propagation model: Extended Hata
  antenna: Antenna Peak Gain;

▪ **Factory**

allows you to create your own default setting for distributions, functions, antennas and propagation models. The implemented *DataExporter* allows you to the create tabular data sets and save these onto you hard disk.

14.3.2 Consistency check - *consistencyCheck()*

The description of the plugins (e.g. PMP, EPP etc..) in the GUI panel informs you about its scope of application and this should be accordingly considered when you define your scenario.

In order to prevent the plugins from reporting physically wrong results the validity of actual parameter values are checked during the calculations (Figure 317). In case parameter values exceed the valid range, appropriate exceptions, e.g. *RuntimeException*, stops the plugin from doing further calculations.

```
public class PMPexample implements PropagationModelPlugin<PMPexample.Input> {
    @Override
    public double evaluate(LinkResult linkResult, boolean b, Input input) {
        double loss = 0;
        if (linkResult.getTxRxDistance() > 1.0){
            throw new RuntimeException("distances larger than 1 km not allowed");
        }
        if (linkResult.getTxRxDistance() <= input.distanceToBp() / 1000.) {
            return (32.4 + 20 * Math.log10(linkResult.getFrequency())
                    + 10 * input.coeffBefore() * Math.log10(linkResult.getTxRxDistance()));
```

Figure 317: RuntimeException checker in the calculation codes

This can be avoided if you are informed about such conflicts before starting the simulation by checking the consistency of your plugins like it is done for the rest of the SEAMCAT workspace. Therefore the method *consistencyCheck()* is available to all the plugins.

The basic principle on that is quite simple: the more extensive the checks the less the risk of running into problems during the simulation.

For this, each type of plugins provides the same method consistencyCheck() to perform the recommended checks:

```
@Override
public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
    //TODO  section 8.2.2
}
```

Figure 318: Common method to perform checks

The referenced parameters are detailed as follow:

▪ **Scenario:**
settings of the systems used for the workspace. It holds the settings of the scenario as specified in the UI.

▪ **List<Object>:**
depending on the type of plugin it contains one or two objects which are either a Radio System or links which can be the system link, the interference link or the sensing link of generic systems. Corresponding details are described in the following sub-sections.

▪ **Input**
the input parameters of the plugin

▪ **Validator:**
provides the interface to the scenario check in returning the consistency check messages generated by the plugin

Concerning the List<Object> it is important to be aware of the applicability of plugins to the scenario components:

▪ an antenna plugin (AP) can be applied only to a radio system, i.e. a generic system or a cellular system
▪ a coverage radius plugin (CRP) can be applied only to a generic system
▪ a propagation model plugin (PMP) can be applied to the system link, the interference link and the sensing link

- an event processing plugin (EPP) and its custom user interface (custom UI) cannot be applied to any of the scenario components

Consequently, the default informations passed to the consistency check as List<Object> of the plugins are as follows:

1. for the antenna plugin (AP)
   0: the radio system
   1: the component applying the antenna, i.e. either the TX or the RX

2. for the coverage radius plugin (CRP)
   0: the generic system

3. for the propagation model plugin (PMP)
   0: the system link or the interference link in case not used for the sensing link

   or in case where the PMP is used for the sensing link
   0: the interference link
   1: the sensing link

4. for the event processing plugin (EPP) the List<Object> is always empty.
   note: the above numbers 0 and 1 are the list indices

This default information can be replaced or extended if the plugin is nested, i.e. if the plugin is used as an input parameter of another plugin (annotation, see the previous section 14.3.1).

In order to avoid conflicts on the consistency check it is therefore very important that all default instances of the plugin types are checked, for instance like this for a PMP:

```java
@Override
public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
    if (list.size() > 0) {
        for (Object o : list) {
            if (o instanceof RadioSystem) {
                //TODO anything about system link -> generic or cellular
            } else if (o instanceof InterferenceLink) {
                //TODO anything about interference link -> interfering system or victim system components
            } else if (o instanceof SensingLink) {
                //TODO anything about sensing link -> sensing characteristics
            }
        }
    }
}
```

Figure 319: Example of a PMP checking for the default instances

In case you apply nested plugins it is highly recommended to check the validity of these nested plugins inside the consistency check of your 'parent' plugin. The below example of an EPP which uses a nested PMP wants only to show the principle of checking input parameters:

```java
@Override
public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
    //TODO supposed that the default propagation model shall be the Free space propagation model
    if (!(input.pm().getConfiguration() instanceof FreespaceInput)){
        validator.error("Please set as default PMP the Free space propagation model");
    }
}
```

Figure 320: Example of checking the validity of a nested plugin

14.3.2.1 Example of a consistency check for a PMP

The default reference parameter List<Object> contains for the PMP up to two entries:

- a single entry for either an interference link or a system link: this includes the information about the components used for this link and the link conditions
- two entries for sensing links: the first provides the same information as the above single entry and the second contains the information about the sensing characteristics of CR

Let assume a fictive propagation model with the following restrictions

- antenna heights less than 25 m
- frequency range 45 MHz 250 MHz
- not applicable to cellular systems

An appropriate consistency check could look like this:

```java
@Override
public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
    Distribution antennaHeight, frequency;
    String consistencyMessage = "";
    double maxAntennaHeigt;
    if (list.size() > 1) {                  // workspace contains CR
        if (list.get(1) instanceof SensingLink) {
            SensingLink sensingLink = (SensingLink) list.get(1);
            // here you may check sensing characteristics
        }
    }
    if (list.get(0) instanceof InterferenceLink) {
        InterferenceLink interferenceLink = (InterferenceLink) list.get(0);
        if (interferenceLink.getVictimSystem() instanceof CellularSystem || interferenceLink.getInterferingSystem() instanceof CellularSystem) {
            validator.error("Model not applicable to cellular systems.");
            return;
        }
        frequency = interferenceLink.getInterferingSystem().getFrequency();
        if (frequency.getBounds().getMin() < 45.0 || frequency.getBounds().getMax() > 250.0)
            consistencyMessage += "<HtML><br/>Model valid in the frequency range 45 MHz ... 250 MHz";
        maxAntennaHeigt = Math.max(interferenceLink.getVictimSystem().getReceiver().getHeight().getBounds()
                .getMax(), interferenceLink.getVictimSystem().getTransmitter().getHeight().getBounds().getMax());
        maxAntennaHeigt = Math.max(maxAntennaHeigt, interferenceLink.getInterferingSystem().getReceiver().getHeight().getBounds().getMax());
        maxAntennaHeigt = Math.max(maxAntennaHeigt, interferenceLink.getInterferingSystem().getTransmitter().getHeight().getBounds().getMax());
        if (maxAntennaHeigt > 25.0) consistencyMessage += "<HtML><br/>max antenna heights restricted to 25 m";

    } else if (list.get(0) instanceof RadioSystem) {
        RadioSystem systemLink = (RadioSystem) list.get(0);
        if (systemLink instanceof CellularSystem) {
            validator.error("Model not applicable to cellular systems.");
            return;
        }
        frequency = systemLink.getFrequency();
        if (frequency.getBounds().getMin() < 45.0 || frequency.getBounds().getMax() > 250.0)
            consistencyMessage += "<HtML><br/>Model valid in the frequency range 45 MHz ... 250 MHz";
        maxAntennaHeigt = Math.max(systemLink.getReceiver().getHeight().getBounds().getMax(), systemLink.getTransmitter().getHeight().getBounds().getMax());
        if (maxAntennaHeigt > 25.0) consistencyMessage += "<HtML><br/>max antenna heights restricted to 25 m";
    }

    if (!consistencyMessage.isEmpty()) validator.error(consistencyMessage);
}
```

(Annotation: "stops performing other checks")

Figure 321: Example of a consistency check for a PMP

You could place some checks related to sensing characteristics which might have impact on the model. In case it is an interference link, the transmitter is ILT, for sensing links it is the VLT. This part is used only if the model is assigned to a system link, i.e. to the victim and / or to the interferer

The result of applying this model to the system link and the interference link could look like this:
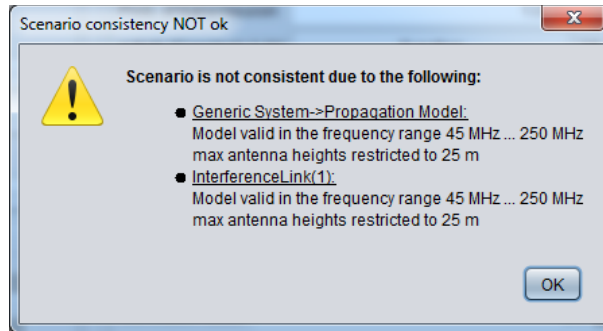
Figure 322: Output of the PMP consistency check

14.3.2.2   Example of a consistency check for an AP

The default reference parameter List<Object> contains for an AP always two entries:

- the first contains the information about the system including its link conditions
- the second the information about the component which uses the antenna, i.e. the receiver or the transmitter providing also information about the antenna

Let assume a fictive antenna model with the following restrictions:

- antenna height in the range 20 m … 60 m
- frequency range 400 MHz … 1000 MHz
- only for cellular systems

This could be checked for instance as shown below:

```java
@Override
public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
    if (list.get(0) instanceof GenericSystem) {
        validator.error("Applicable only to cellular systems.");
        return;
    } else if (list.get(0) instanceof CellularSystem){//to exclude any other type
        CellularSystem cellSystem = ((CellularSystem) list.get(0));
        if (cellSystem.getFrequency().getBounds().getMin() < 400.0 ||
                cellSystem.getFrequency().getBounds().getMax() > 1000.)
            validator.error("Valid requency range: 400 MHz ... 1000 MHz");
        if (list.get(1) instanceof Transmitter) {
            // not that on cellular systems an antenna can be assigned only to the BS
            if (((Transmitter) list.get(1)).getHeight().getBounds().getMin() < 20.0
            || (((Transmitter) list.get(1)).getHeight().getBounds().getMin() > 60.0 ))
                validator.error("Antenna height of the BS restricted to 20 m ... 60 m");
        }

        if (cellSystem.getReceiver().getHeight().getBounds().getMax() > 2.5)
            validator.error("<HtMl>You set the antenna height of the MS to " + cellSystem.getReceiver().getHeight().getBounds().getMax()
            + "<br/>which might conflict with the cell size of your system.");
    }
}
```

Figure 323: Example of a consistency check for a AP

which would generate a consistency warning message like this:
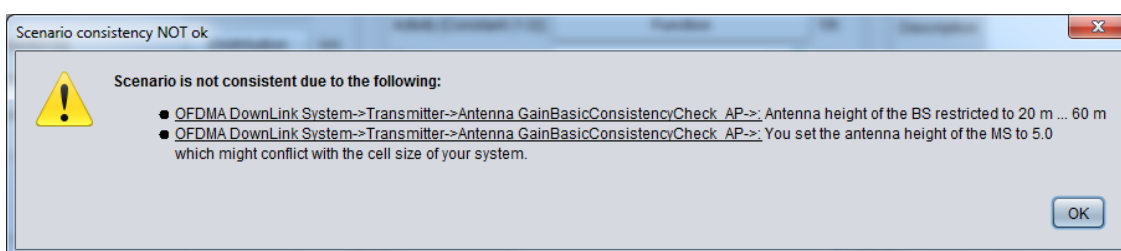
Figure 324: Output of the AP consistency check

14.3.2.3 *Example of a consistency check for an EPP*

Unlike the above plugin types the EPP plugin is not belong to a system or a link and therefore the List<Object> is empty. The functionality of the other reference parameters Scenario, Input and Validator remains as described above.

Let assume a fictive EPP with these restrictions:

- applicable only if the victim system is generic
- the coverage radius of the victim system shall not exceed 50 km
- the simulation radius of the EPP must not exceed the coverage radius of the victim system

Such a consistency check could be for instance implemented like this:

```
@Override
public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
    if (!(scenario.getVictimSystem() instanceof GenericSystem)) {
        validator.error("This EPP is applicable only if the Victim System is generic");
        return;
    }
    GenericSystem singleSystem = (GenericSystem) scenario.getVictimSystem();
    double coverage = singleSystem.getLink().getCoverageRadius().evaluate(singleSystem);
    if (coverage > 50.0)
        validator.error("The coverage radius of the victim system shall not exceed 50 km");

    if (input.radEPP() > coverage) validator.error("The simulation radios of the EPP" +
            " must not exceed the coverage radius of the victim system " +
            "(" + coverage + " km)").radEPP();

}
```

Figure 325: Example of a consistency check for an EPP

and would generate the below warning message:
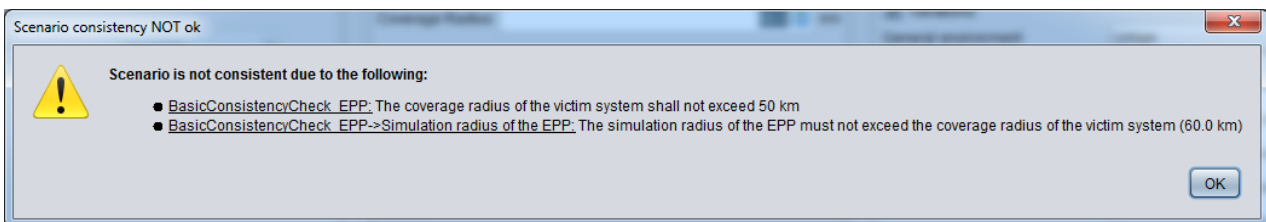
Figure 326: Output of the EPP consistency check

14.3.2.4 *Performing the consistency check on the workspace*

The consistency check is in general called in order to check the complete scenario when you start the simulation.

In case there is any warning, a corresponding message pops up like this:
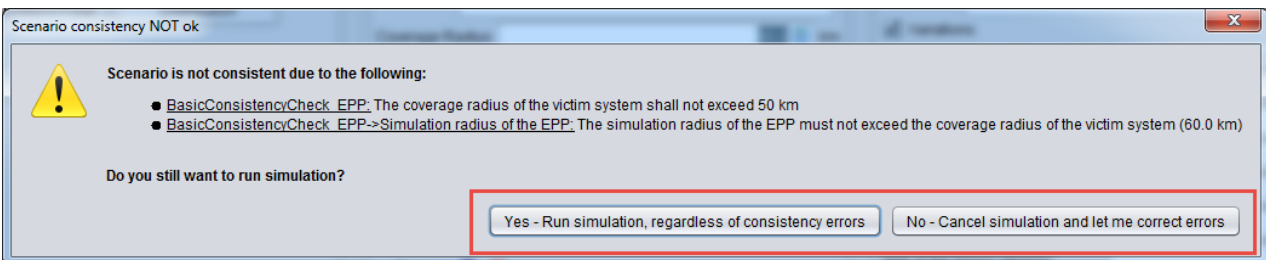
Figure 327: Examle of a message triggered at launch when a consistency check is triggered

Ignoring the warning message might cause crashing the simulation.

A second option to show the results of the consistency check is to manually activate it by hitting the Check consistency button as decribed in Section 2.9. This could prevent you from an unintended start of the simulation.

14.3.3 Logger functionalities for plugins

SEAMCAT provides the option to run a simulation in debug mode. With this, you are informed about all relevant calculation steps and the values used, in a similar manner than for the built-in methods. It is therefore advisable to implement this functionality also onto the your plugin in order to make it more transparent to third party users.

The implementation is simply done with this, but requires the apache log4j-1.2x.jar on your development environment:

```
private static final Logger LOG = Logger.getLogger(PMPexample.class);
```

Its application could look like this (from the above example):

```
public class PMPexample implements PropagationModelPlugin<PMPexample.Input> {

    private static final Logger LOG = Logger.getLogger(PMPexample.class);

    @Override
    public double evaluate(LinkResult linkResult, boolean b, Input input) {
        double loss = 0;
        if (linkResult.getTxRxDistance() > 1.0){
            throw new RuntimeException("distances larger than 1 km not allowed");
        }
        if (linkResult.getTxRxDistance() <= input.distanceToBp() / 1000.) {
            loss =  (32.4 + 20 * Math.log10(linkResult.getFrequency())
                    + 10 * input.coeffBefore() * Math.log10(linkResult.getTxRxDistance()));
        } else {
            double temp = 32.4 + 20 * Math.log10(linkResult.getFrequency())
                    + 10 * input.coeffBefore() * Math.log10(input.distanceToBp() / 1000.);
            loss = temp + 32.4 + 20 * Math.log10(linkResult.getFrequency())
                    + 10 * input.coeffBeyond() * Math.log10(linkResult.getTxRxDistance() - input.distanceToBp() / 1000.);
        }
        if (LOG.isDebugEnabled())LOG.debug("coefficient before: " + input.coeffBefore() + ", coefficient beyond:" + input.coeffBeyond());
        return loss;
    }
}
```

Figure 328: Example of logging in your plugin's code

It would generate the corresponding debug information as depicted in Figure 329. It is integrated automatically to the rest of the SEAMCAT code log file.

```
(LinkCalculator.java:614[pathAntGains]) - Link Transmitter Antenna Gain = 0.0
(PMPexample.java:41[evaluate]) - coefficient before: 2.0, coefficient beyond:3.5
(LinkCalculator.java:294[calculatePropagationLoss]) - pathloss between VLT and VLR= 152.8831841183612 = PMPe
(LinkCalculator.java:651[dRSSLinkBudgetDef]) - dRSS Value = -119.88318411836121 [(wtPower = 33.0) + (wtGain =
```

Figure 329: Output results of the plugin logger

14.4   PROPAGATION MODEL PLUGIN (PMP)

The propagation model is essential because it is involved in every link. Instead of providing implementations of this it is exposed as a plugin. With a PMP you have the flexibility to define what input fields is needed. In the computation you have access to the user field values and you can access the link settings. Given these inputs your PMP then has to compute the propagation loss and return that.

The interface *PropagationModelPlugin* provides the information about the link components it is assigned to, i.e. either the system link, the interference link or the sensing link, respectively. This information contains e.g. antenna heights, actual antenna gain, actual frequency, distance between the components, local environment etc. (on the below figure referenced as *LinkResult*). It will be built into a Java archive (.jar file) and can subsequently be installed in a running SEAMCAT.

The structure of the PMP is similar to other types of plugins. It is composed of the following:

3. **evaluate():** the core body of the PMP with the mathematical formulation of its physical behavior;
4. **consistencyCheck():** the check of consistency / validity of the input parameters ;
5. **description():** the unique name of the PMP and an optional description (but highly recommended in order to show the user its characteristics and its scope of application);
6. **Input:** the input parameters of the PMP (see section 14.3.1).

```
public class StructurePMP implements PropagationModelPlugin<StructurePMP.Input> {
    @Override
    public double evaluate(LinkResult linkResult, boolean b, Input input) {
1       return 0;
    }

    @Override
    public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
2
    }

    @Override
    public Description description() {
3       return null;
    }

4   public interface Input {
    }
}
```

Figure 330: basic structure of the PMP

The referenced parameters are detailed as follow (only different to the EPP, see section 14.7.2):

▪ **LinkResult**
  all information about the link condition that the PMP is assigned to
▪ **Boolean b** flag whether variations have to be considered by the model

An example of a PMP (simple Dual-Slop model, similar to IEEE 802.11 Model C) is presented below. Note that the consistency check is separately shown in section 14.3.2. The input parameter are presented in Figure 331 and the algorithm is presented in Figure 332. The panel of the simple Dual-Slop model in SEAMCAT is shown in Figure 333.

```
@Override
public Description description() {
    return new DescriptionImpl("PMPexample", "to show the calculation of a so called Dual-Slope model.\n" +
            "The model is applicable for distances up to 1 km." +
            "\nIt does not take account of the antenna heights. ");
}

public interface Input {
    @Config(order = 1, name = "Distance to break point", unit = "m")
    double distanceToBp();

    @Config(order = 2, name = "Loss coefficient before break point")
    double coeffBefore();

    @Config(order = 3, name = "Loss coefficient beyond break point")
    double coeffBeyond();

    double distanceToBp = 60.0;
    double coeffBefore = 2.0;
    double coeffBeyond = 3.5;
    boolean variations = false;
}
```

Figure 331: Description and input interface (The parameter variations can be pre-set by the PMP)

```java
public class PMPexample implements PropagationModelPlugin<PMPexample.Input> {
    @Override
    public double evaluate(LinkResult linkResult, boolean b, Input input) {
        double loss = 0;
        if (linkResult.getTxRxDistance() > 1.0){
            throw new RuntimeException("distances larger than 1 km not allowed");
        }
        if (linkResult.getTxRxDistance() <= input.distanceToBp() / 1000.) {
            return (32.4 + 20 * Math.log10(linkResult.getFrequency())
                    + 10 * input.coeffBefore() * Math.log10(linkResult.getTxRxDistance()));
        } else {
            double temp = 32.4 + 20 * Math.log10(linkResult.getFrequency())
                    + 10 * input.coeffBefore() * Math.log10(input.distanceToBp() / 1000.);
            loss = temp + 32.4 + 20 * Math.log10(linkResult.getFrequency())
                    + 10 * input.coeffBeyond() * Math.log10(linkResult.getTxRxDistance() - input.distanceToBp() / 1000.);
        }
        return loss;
    }
}
```

Figure 332: Algorithm implementation in the method *evaluate()* (the yellow marked condition lets the PMP stop calculations in case true, due to not consistent with the scope of application)

Figure 333: PMP configuration panel

14.5 ANTENNA PLUGIN (AP)

The interface *AntennaGainPlugin* provides, similar to the PMP, all information about the link it is assigned to, additionally all information about the parameters relevant for the antenna, for instance the height and azimuth and elevation angles as well as the local environment it is placed at.

The structure of the AP is similar to other types of plugins. It is composed of the following:

1. **evaluate():** returns the calculated antenna gain
2. **consistencyCheck():** see section 8.2.2
3. **description():** the unique name of the PMP and an optional description (but highly recommended in order to show the user its characteristics and its scope of application)
4. **Input:** see section 8.2.1

```
public class StructureAP implements AntennaGainPlugin<StructureAP.Input> {
    @Override
    public double evaluate(LinkResult linkResult, AntennaResult antennaResult, double v, Input input) {
 1      return 0;
    }

    @Override
    public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
 2  }

    @Override
    public Description description() {
 3      return null;
    }

    public interface Input {
 4  }
}
```

Figure 334: Basic structure of the AP

The referenced parameters are detailed as follow (only different to the EPP, see section 14.7.2, and the PMP, see section 8.6.3):

- **AntennaResult**:
  It contains the information about the parameters relevant for the antenna, for instance the height, azimuth and elevation angles as well as the local environment and position it is placed at
- **Double**   **v:**
  It is the peak gain of the antenna

There are basically two options to create antenna plugins

- **Static:**
  The plugin predefines static values of the antenna pattern and uses these for the calculation of the gain. You can, in addition, edit (i.e. modify / replace) the values on the system and / or antenna library level.
- **Dynamic:**
  The plugin dynamically calculates the antenna pattern (e.g. ITU-R Recommendation like ITU-R F.1336 etc…) using these for the calculation of the gain.

Simple examples are shown in section 14.5.1 (static) and section 14.5.2 (dynamic).

14.5.1 AP – static pre-set of the antenna pattern

The below example is just to show how such a plugin could be done. It is worth to mention that in most cases it would be more efficient to duplicate an existing Horizontal/Vertical antenna of the antenna library, modify the pattern and rename it accordingly.

```
public class AntennaPluginPattern implements AntennaGainPlugin<AntennaPluginPattern.Input> {
    @Override
    public double evaluate(LinkResult linkResult, AntennaResult antennaResult, double v, Input input) {

        return v + input.patternH().evaluate(antennaResult.getAzimuth());
    }

    @Override
    public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator, String s) {
        //TODO see section 8.2.2
    }

    @Override
    public Description description() {
        return new DescriptionImpl("AntennaPluginPattern","provides pre-defined horizontal antenna pattern");
    }

    public interface Input {
        @Config(order = 1,name = "Horizontal antenna pattern")Function patternH();
        Function patternH = Factory.functionFactory().discreteFunction(getPoints());
        double peakGain = 18.0;
    }

    public static List<Point2D> getPoints(){
        List<Point2D> points = new ArrayList<>();
        for (int i=0;i<=360;i++){
            points.add(new Point2D(i,-i*Math.random()));
        }
        return points;
    }
}
```

Figure 335: Simple example for static pattern

Figure 336: Configuration panel of the AP example with static pre-set of the antenna pattern
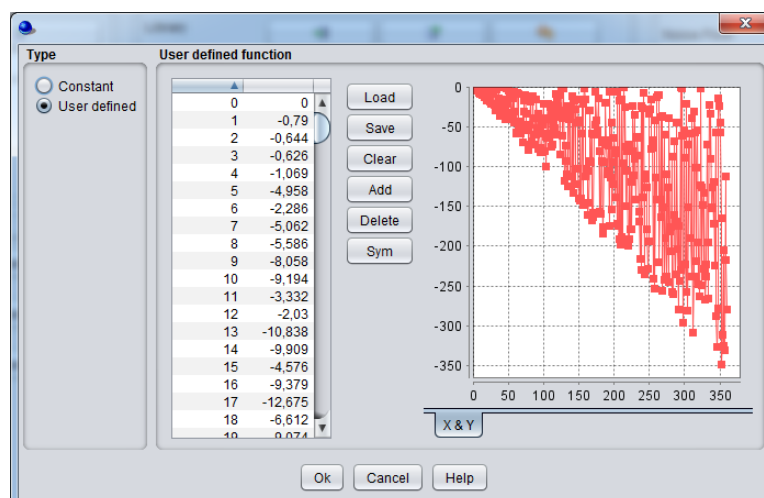
Figure 337: Example of (random) antenna pattern

14.5.2 AP – dynamic calculation of antenna gain

In several cases, the antenna pattern depends on operational conditions of the system the antenna is assigned to. For instance, cellular systems apply antennas with pattern dependent on the width of the sector that the antenna shall serve, or for the Fixed Service, the knowledge of the antenna pattern size, frequency is inherent to the workspace that you will simulate. Hence predefined set of pattern may not be adequate, and an antenna plugin that is able to provide the feasibility to generate appropriate pattern for each event would be more suited.

The example below shows a simplified antenna plugin that take into consideration an equation instead of a preset values. It has to be noted that is in fact not a valid antenna model.
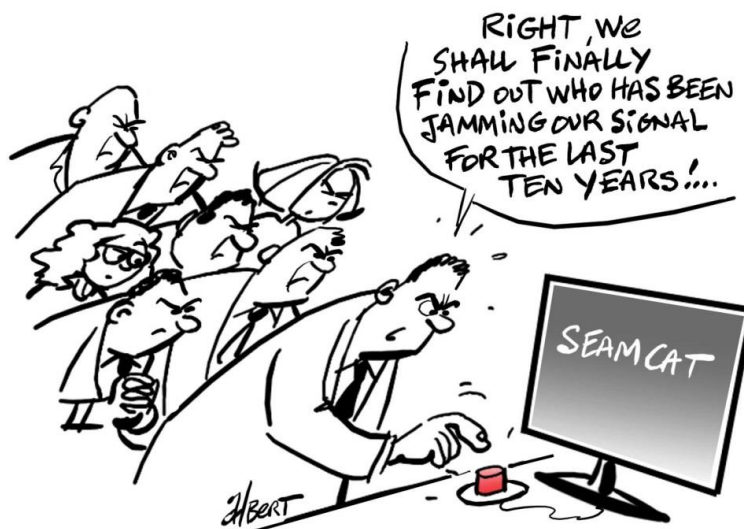
```java
public class AntennaPluginITU implements AntennaGainPlugin<AntennaPluginITU.Input>{
    private static final Logger LOG = Logger.getLogger(AntennaPluginITU.class);
    @Override
    public double evaluate(LinkResult linkResult, AntennaResult antennaResult, double peakGain, Input input) {
        double gain = 0;
        if (antennaResult.getAzimuth() > input.sector())gain = peakGain - 10*Math.log10(Math.pow(10,-input.kh()/10.));
        else if (antennaResult.getAzimuth() < 10)gain = peakGain;
        if (input.usePeak())gain += 3.;
        if (LOG.isDebugEnabled()){
            if (input.sector() > 140.)LOG.debug("a sector width of " + input.sector() + " degree shouldn't have been used.");
        }
        return Math.min(gain, peakGain);
    }

    @Override
    public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator, String s) {
        //TODO check for instance the sector width
        //TODO see section 8.2.1
    }

    @Override
    public Description description() {
        return new DescriptionImpl("AntennaPluginITU","shows the basics of a dynamic calculation of the antenna pattern\n" +
            "based on specifications like ITU-R Recommendations");
    }

    public interface Input {
        @Config(order = 1,name = "Sector width [range: 60 ... 140 degree]",unit = "degree")double sector();
        @Config(order = 2,name = "azimuth pattern adjustment factor [range: 0 ... 1]")double kh();
        @Config(order = 3,name = "Consider peak-side-lobe performance")boolean usePeak();
        double sector = 65.0;
        double kh = 0.7;
        boolean usePeak = false;
        double peakGain = 15.0;
    }
}
```

Figure 338: simple example for dynamic pattern

Figure 339: Configuration panel of the example

14.6 COVERAGE RADIUS PLUGIN (CRP)

Following the general plugin approach of SEAMCAT 5, the default coverage radius types 1) User-defined radius 2) Noise Limited and 3) Traffic Limited are implemented as plugins.

You may define your own coverage radius algorithms by doing an appropriate plugin. The coverage radius plugins are applicable **only** to Generic Systems.

The structure of this Coverage Radius Plugin is similar to other types of plugins. It is composed of the following:

1. evaluate(): algorithm of the calculation of the coverage radius;
2. consistencyCheck(): see section 14.3.2;
3. description(): the unique name of the coverage radius plugin and an optional description (but highly recommended in order to show the user its characteristics and its scope of application);
4. Input**:** the input parameters of the Coverage Radius Plugin, see section 14.3.1.

```java
public class StructureCRP implements CoverageRadiusPlugin<StructureCRP.Input> {
    @Override
    public double evaluate(GenericSystem genericSystem, Input input) {
        return 0;
    }

    @Override
    public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
    }

    @Override
    public Description description() {
        return null;
    }

    public interface Input {
    }
}
```

Figure 340: Basic structure of the coverage radius plugin

The referenced parameters are detailed as follow (only different to the EPP, the PMP and the AP):

- GenericSystem:
  contains all information about the system. i.e. its transmitter, receiver and the link conditions in between. It includes also for instance the information whether the system applies a user-defined dRSS, and if its distribution, too.

For simplification the already implemented Traffic Limited plugin is shown as example:

```java
public class TrafficLimitedNetworkCoverageRadius implements CoverageRadiusPlugin<TrafficLimitedNetworkCoverageRadius.Input> {

    private static final Logger LOG = Logger.getLogger(TrafficLimitedNetworkCoverageRadius.class);

    @Override
    public void consistencyCheck(Scenario scenario, List<Object> path, Input input, Validator<Input> validator, String pathType) {
        //To change body of implemented methods use File | Settings | File Templates.
    }

    @Override
    public double evaluate(GenericSystem genericSystem, Input input) {
        double rRmax = Math.sqrt(input.numberOfChannels() * input.numberOfUsers() / (Math.PI * input.density() * input.frequencyCluster()));

        if (LOG.isDebugEnabled()) {
            LOG.debug("Transceiver name: " + genericSystem.toString());
            LOG.debug("Density = " + input.density());
            LOG.debug("NumberOfChannels = " + input.numberOfChannels());
            LOG.debug("Number of users per channel = " + input.numberOfUsers());
            LOG.debug("Frequency cluster = " + input.frequencyCluster());
            LOG.debug("Coverage Radius (Traffic Limited) = " + rRmax);
        }
        return rRmax;
    }

    public interface Input {
        @Config(order = 1, name = "Density", unit = "1/km²")
        double density();

        @Config(order = 2, name = "Number of channels")
        int numberOfChannels();

        @Config(order = 3, name = "Number of users per channel")
        int numberOfUsers();

        @Config(order = 4, name = "Frequency cluster")
        int frequencyCluster();
    }

    @Override
    public Description description() {
        return new DescriptionImpl("Traffic Limited","The coverage radius is derived from the traffic parameters of the transmitter, i.e. the " +
                "maximum number of active transmitter per km2 (density), the number of " +
                "frequency channels that a radio system provides, the number of MS " +
                "per frequency channel provided by a radio system and the size of a " +
                "group of frequency channels (frequency cluster).");
    }
}
```

Figure 341: Traffic limited coverage radius as example
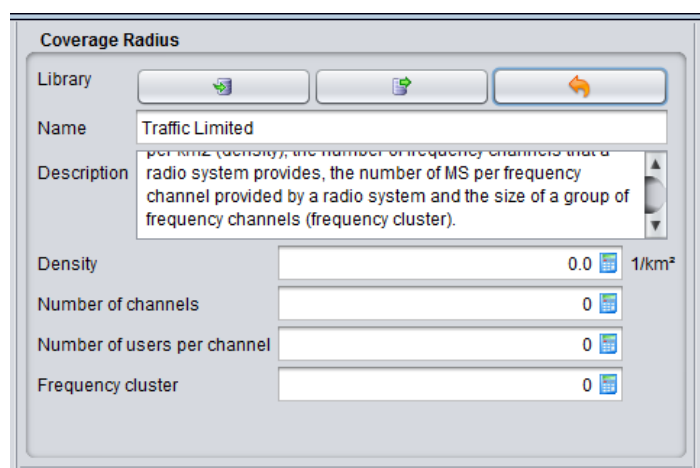
Figure 342: Configuration panel of Traffic Limited coverage radius

There are no specific predefined values for the Traffic Limited coverage radius plugin (e.g. set to zero) since generic systems parameters may generally differ from each other.

14.7 EVENT PROCESSING PLUGIN (EPP)

14.7.1 Overview

EPP follows the same principles of module and encapsulation as the PMP since it is the same plugin abstraction layer. Monte Carlo algorithm operates on a high level so that it randomize a setup (event), compute result for event, repeat desired number of times and collect a total result. This is very similar to how SEAMCAT operates on the highest level.

Notice that once an EPP is installed in SEAMCAT it can be configured for any scenario possible. It is therefore bad practice, when programming an EPP to assume anything about the scenario (e.g. the victim system is of a specific type). A re-usable EPP must be implemented in full generality assuming nothing about the scenario, and if something specific is required from the scenario, provide the necessary validation during the consistency check (e.g. if an EPP only works for a generic victim system - it should emit a warning during the consistency check phase allowing the user to abort the simulation).

An EPP has access to the scenario i.e. the complete setup of the simulation. Also it can access its defined input parameters. Interestingly it has an iterator where it can access the event results. An iterator is a Java construct that allows you to ask if it has more elements and get the next element – also this construct can be used in a for-loop. The interface of EPP shows that one must return a type ResultTypes. This is a container for all the results produced by the EPP.

In SEAMCAT, we have immutable state, and therefore, it does not matter at what time different components access it. All will read the same regardless of the interleaving. Suppose the person object was mutable, i.e. the name property could be changed. If there were several parallel threads that could access the same person object it would be really difficult to know what person.getName() would return. Null? "John", "Joe"?. For immutable state, time does not matter, parallel processing is possible.

14.7.2 Core EPP

The *EventProcessingPlugin* interface provides all simulated results as *EventResult* to the EPP and defines its basic structure as shown in Figure 343. It is composed of the following:

1. *evaluate()*: inside the method evaluate the code to be performed by the EPP results generated by the EPP are passed to the workspace by ResultTypes and displayed on the result panel
2. *consistencyCheck():* it allows the consistency check of the EPP reporting warning messages together with the consistency check of the workspace
3. *description():* the description is split into "name of the EPP"," description" (comma separated string variables)
4. *Input:* input parameters of the EPP

```
public class StructureEPP implements EventProcessingPlugin<StructureEPP.Input> {
    @Override
    public ResultTypes evaluate(Scenario scenario, Iterable<EventResult> iterable, Input input) {
[1]     return null;
    }

    @Override
    public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
[2]  }

    @Override
    public Description description() {
[3]     return null;
    }

[4] public interface Input {
    }
}
```

Figure 343: basic structure of the EPP

The referenced parameters are detailed as follow:

▪ **Scenario**
settings of the systems used for the workspace. It holds the settings of the interference scenario as specified in the UI. EventResult holds the results data which can be read and used to create new data. More interestingly it also holds intermediate data – this is data not exposed as results in SEAMCAT

▪ **EventResult**
all simulated results, for instance positions of all components, the path loss between components, the simulated antenna gains, the simulated vectors for dRSS and iRSS values etc… The EventResult holds data for any kind of scenario – i.e. Cellular victim and two generic interferers.

▪ List<Object>
due to the general concept of the plugins it is always referenced on the method *consistencyCheck* and contains information about the actual link. As an EPP is not belong to a link it is not applicable to EPPs and therefore empty

▪ **Input**
the parameters defined by the EPP and to be used by itself

▪ **Validator**
the interface to the workspace consistency check; the syntax for a warning message is like this: *validator.error("warning message");*

▪ String   s
similar to List<Object>, contains the information about the link type, e.g. Victim System Link, and not applicable to EPPs

▪ **Description**
unique name of the EPP which is displayed on EPP library panel for selection; optional description, in case empty the syntax has to be (pluginName,"")

▪ **ResultTypes**
results which the EPP may produce are reported to the result panel of SEAMCAT; the following types are available:
  ▪ Single Value Result (double, integer, long, string);
  ▪ Vector Result List<Double>);
  ▪ Vector Group Result (Map of List<Double>);
  ▪ Bar Chart;
  ▪ Scatter diagram.

14.7.3 Custom UI as result type of the EPP

In Figure 344, the annotation @CustomUITab(UI.class) binds the custom user interface (*CustomUI*) to the EPP. The *CustomUI* interface provides the option to generate basic graphical user interfaces without the need of creating your own UI panels. It additionally allows in a similar manner the implementation of user customizable action buttons (e.g. "ok", "cancel" etc…). It will be in general a separate .class file from the EPP .class file.

You may choose your own name for the public interface, like for instance the word *"Empty()"*, instead of "*Input*", as shown on Figure 344.

```
package org.seamcat.eventprocessing;

import ...

@CustomUITab(ExampleCustomUIEPP.class)
public class DemoEPP_6_CellularInternals implements EventProcessingPlugin<DemoEPP_6_CellularInternals.Empty> {

    public interface Empty{}

    @Override
    public void consistencyCheck(Scenario scenario, List<Object> path, Empty input, Validator<Empty> validator, String pathType) {
    }

    @Override
    public ResultTypes evaluate(Scenario scenario, Iterable<EventResult> results, Empty empty) { return null; }

    @Override
    public Description description() {
        return new DescriptionImpl("Demo 6: Custom UI showcase","Shows how to have a custom result that generates additional results");
    }
}
```

Figure 344: Example of a simple EPP (generating a custom User Interface)

In case the EPP contains more than one UI, the UIs are bound by an array of UI classes, e.g. @CustomUITab({UI_1.class, UI_2.class, …}) This is shown as an example in Figure 345.
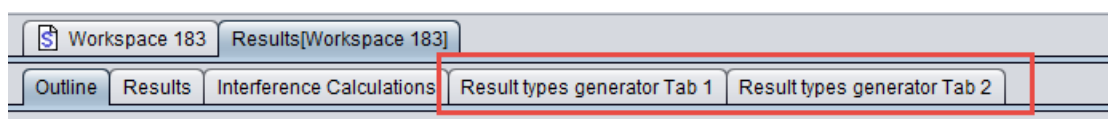
Figure 345: Example of an EPP generating 2 different custom User Interface

A basic CustomUI is composed of the following:

1. *getTitle()*: title of the UI, displayed as name of the corresponding tabulator of the result panel of SEAMCAT
2. *buildUI()*: this code constructs the panels and the actions to be performed by the custom UI
3. *panelDefinitions()*: It is the definition of the content of the panels of the custom UI

```
public class CustomUIstructure implements CustomUI {
    @Override
    public String getTitle() {
1       return null;
    }

    @Override
    public void buildUI(JPanel jPanel, Panels panels) {
2
    }

    @Override
    public PanelDefinition[] panelDefinitions() {
3       return new PanelDefinition[0];
    }
}
```

Figure 346: Basic structure of the custom UI

The core custom UI elements are detailed in the following section.

14.7.3.1 Panel definition

You can define multiple panel within the panelDefinitions() as shown in Figure 348. The below code corresponds to the sub panels of the custom UI where the input parameters are placed onto.

```
@Override
public PanelDefinition[] panelDefinitions() {
    return new PanelDefinition[]{
            new PanelDefinition<Left>("Parameters", Left.class),
            new PanelDefinition<Right>("Propagation Model", Right.class)
    };
}
```
input interfaces

Figure 347: Example of code to split the panels
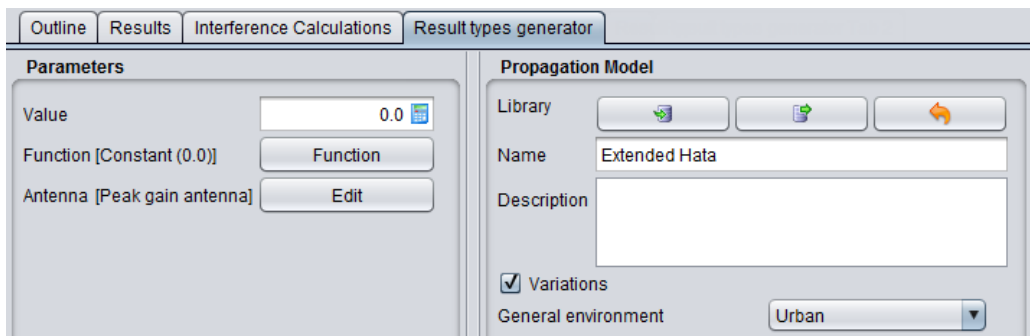
Figure 348: Example of multiple panel definition

These input interfaces have the same structure and annotation as shown in the above section 14.3.1. For the example of Figure 348, the code will look like this:

```
public interface Left {
    @Config(order = 1, name = "Value")
    double value();

    @Config(order = 2, name = "Function")
    Function function();

    @Config(order = 3, name = "Antenna")
    AntennaGain antenna();
}

public interface Right {
    @Config(order = 1, name = "Propagation")
    PropagationModel pm();
}
```

Figure 349: Example of code to insert input parameter for the "left" and "right" panels.

14.7.3.2 Method buildUI

Here you define the design of the custom UI.

```
@Override
public void buildUI(JPanel canvas, Panels panels) {
    this.panels = panels;
    JSplitPane split = new JSplitPane(JSplitPane.HORIZONTAL_SPLIT);
    split.add(panels.get("Parameters").getPanel());
    split.add(panels.get("Propagation Model").getPanel());
    canvas.setLayout( new BorderLayout() );
    canvas.add( split, BorderLayout.CENTER );
}
```

Figure 350: Example of code to split the panels

The above example splits the UI into two horizontally arranged sub panels which can be accessed through e.g. *ModelPanel<Left> leftPanel = panels.get("Parameters");*

14.7.3.3 @PostProcessing – Annotation of Custom UI

The post processing annotation generates an action button which lets the custom UI perform the actions defined by the method assigned to this button. The buttons cannot be de-activated ("greyed out") e.g. when building the UI or by the EPP. Hitting the button performs the action regardless any other thing.

Figure 347 presents that (1) the annotation is similar to the input interface and (2) the body of the method to be performed.

```
1  @PostProcessing(order = 1,name = "example of post processing")
   public void examplePostProcessing(Scenario scenario){
2      //TODO
   }
```

Figure 351: Example of @PostProcessing

The post processing annotation allows the following parameters:

- Scenario
  settings of the systems used for the workspace
- ResultTypes
  the result types generated by the "parent" EPP
- Interface input
  the input interface of the "parent" EPP
- SimulationResult
  all vectors and vector groups generated by the workspace.

The parameters are restricted to these four types. The call order is not relevant. An example of the @post processing feature is presented below where various output display can be selected like "scatter diagram", "bar chart", or a "vector group" as shown in Figure 352.
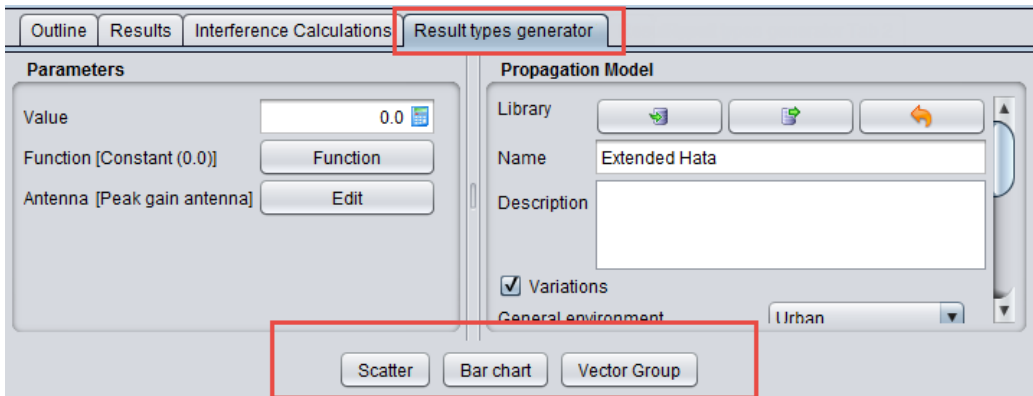
Figure 352: Example of creating 3 "action button" using @PostProcessing

The name of the button is the name of the annotation and an example of code is presented only for the "scatter" button in Figure 353. Similar @PostProcessing can be coded to create the "Bar chart" and "Vector Group".

```
@PostProcessing(order = 1, name = "Scatter")
public void scatter(Scenario scenario, ResultTypes allResults) {
    ScatterDiagramResultType type = new ScatterDiagramResultType("Scatter", "x", "y");
    Random random = new Random();
    for (int i = 0; i < 25; i++) {
        type.getScatterPoints().add(new Point2D(i, i * random.nextDouble()));
    }
    allResults.getScatterDiagramResultTypes().add(type);
}
```

Figure 353: Example of creating the scatter button and its associated action

14.7.3.4 Consistency check of the custom UI

As aforementioned, the post processing buttons are always enabled by default. In cases of more complex calculations to be performed by the custom UI, it might be advisable to prior check the consistency / validity of the input parameters of the custom UI.

Unlike the other plugins, the custom UI, as a result type of the EPP, does not provide its own consistency check. This needs to be designed by the developer of the EPP, as shown in
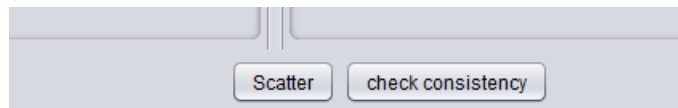
Figure 354: Example of creating your own "check consistency" in the custom UI, as a result type of the EPP

The example in Figure 355 shows a solution to code your own consistency check within @PostProcessing

```
@PostProcessing(order = 1, name = "check consistency")
public void checkConsistency(Scenario scenario) {
    //TODO do something to check consistency of the GUI parameters
    consistencyPassed = true;
    String msg = "";
    ModelPanel<Left> tLeft = getPanelLeft();
    double dd = tLeft.getModel().value();
    if (dd < 1000.) {
        msg = "<HtMl>Problem to do ....  due to <strong>value</strong> less than xyz.<br/>" +
                "You have to correct the input in order to proceed.";
    }

    ModelPanel<Right> tRight = getPanelRight();
    Object modelConfig = tRight.getModel().pm().getConfiguration();
    if (!(modelConfig instanceof FreespaceInput)) {
        if (!msg.isEmpty()) msg += "<br/><br/>Free space model required.";
        else msg = "<HtMl>Free space model required.";
    }

    if (!msg.isEmpty()) {
        consistencyPassed = false;
        JFrame frame = new JFrame();
        JOptionPane.showMessageDialog(frame, msg, "GUI consistency", JOptionPane.ERROR_MESSAGE);
        frame.dispose();
    }
}
```

Figure 355: Example on how to code your own consistency check within @PostProcessing

The flag "consistencyPassed" could be used to block other methods proceeding in case the check failed. If this flag is declared globally private, all methods of the class can access it. This flag is intended to give the other @PostProcessing the information about the consistency check.

The yellow marked code generates the below message:
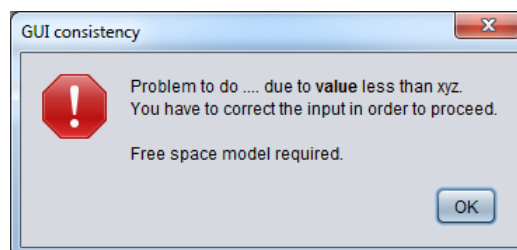
Figure 356: Example on how your own consistency would look like

14.8   FAQ ON PLUGIN DEVELOPMENT

Q: if I try to develop a propagation plugin that makes use of FreeSpace or Hata or P528 or any else, how do I do ?

A: you have to go through the **Factory** like this

```
Builder<HataInput> localInput = Factory.createBuilder(HataInput.class);
localInput.returnValue(input.genEnv()).generalEnvironment();
PropagationModel<HataInput> localHata = Factory.propagationModelFactory().getHataSE21(localInput.build(),input.variations());
double loss = localHata.evaluate(linkResult,false);
```

Figure 357: Example on accessing a PMP through *Factory.propagationModelFactory()* in the source code

The above example applies its own input annotations for 'General environment' and 'variations".

You may take the linkResult from the evaluate call of your propagation model or you can generate a new one by creating a new LinkResultImpl(), putting all relevant parameters of the link onto that.

ANNEX 1: DATA ELEMENTS

This annex lists all the data types used to defined the input parameters within SEAMCAT:

- **distributions** - for parameters modeled as random variables but also constant;
- **function** - for parameters modeled as user-defined functions (look-up tables, etc);
- **emission masks** - for transmission masks and similar parameters modeled as emission masks;
- **radiation pattern** - a special class of functions for defining antenna radiation patterns;
- **generated signals** - vectors representing the signal values generated during simulation.

A1.1 DISTRIBUTIONS

You have access to the distribution window from the [Distribution] button. This window is aimed at defining the statistical distribution function to be associated with the given variable parameter, which value would be randomly generated each time when starting a new event during simulation. This is the most oftenly used data type in SEAMCAT, as a majority of the parameters in the workspace scenario may be defined via distributions, with those randomly generated parameters providing the statistical essence of Monte-Carlo simulations in SEAMCAT. Further details can be found in ANNEX 10:.

The distribution entry dialog window looks like this:
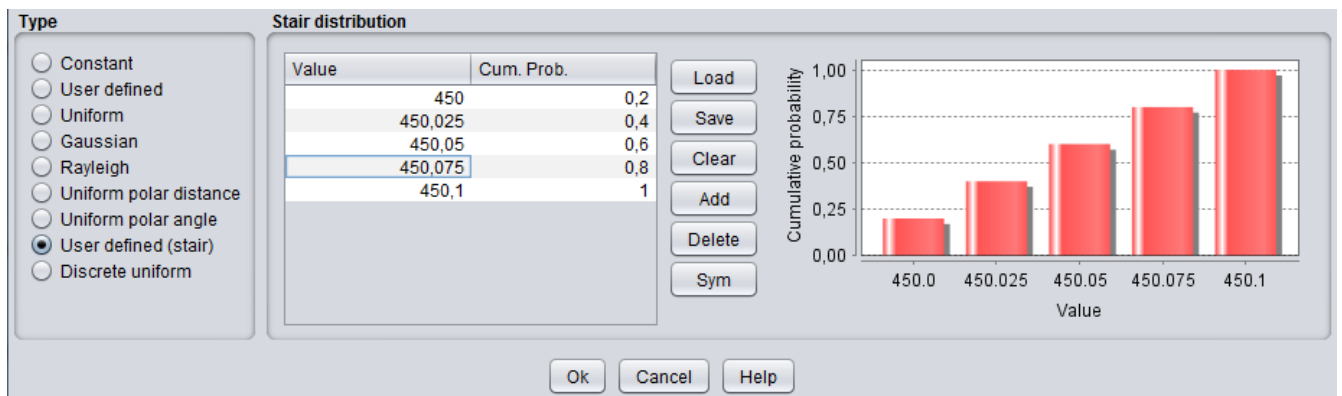
Figure 358: Example of the distribution GUI

A1.2 FUNCTION ENTRY

You have access to the Function window from the [Function] button. Function entry dialog window is used to define function-like parameters of simulation, such as blocking response or intermodulation rejection. This is how a function entry dialog box looks like:

Table 61: Description of the function options in SEAMCAT

Description	Comments
Constant	In this case the function always returns the same constant value
User-defined	It is defined by a sequence of points (x, y=f(x)) meaning that the input as many values as needed for abscissa and corresponding function response values, paying attention to units shown in the heading of the relevant function definition window
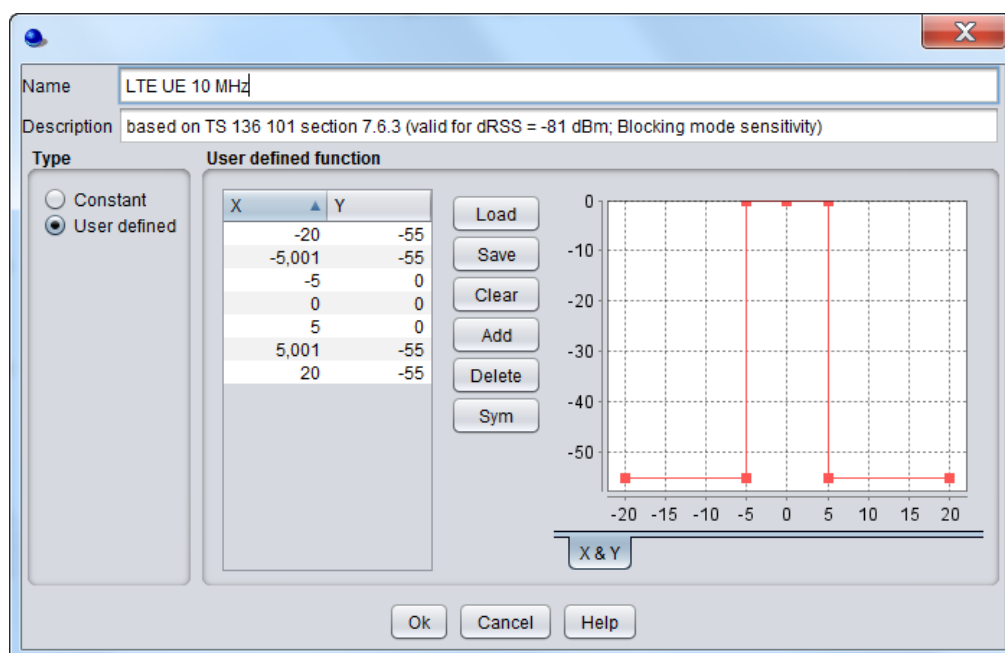
Figure 359: Example on how to edit a user defined function (i.e. like receiver blocking mask)

To enter a non-constant function, select User-defined item in the Type group box and enter the points defining the function in form of pairs (x, y=f(x)) in the function table:

Note: the range of entered data depends on the type of defined parameter, therefore you should carefully checked it. For example, for user-defined blocking function all entered values y=f(x) should be positive.

The following functions are available in the dialog window:

- **Add**: To add a new pair, click on Add button. Pairs are then automatically sorted by increasing x value;
- **Delete**: To suppress a pair, click on Delete button;
- **Sym**: To symmetrize a function, click on Sym button, this results in generating for each existing pair (x, y) a symmetric counterpart (-x, y), if it doesn't already exist;
- **Load**: click on the Load button to import a set of function values from a text file. This file must be formatted to contain one pair (x, y) per line, TAB separated;
- **Save**: press the Save button to export the current function table into a text file, e.g. for frequently used functions or for sharing with other users.

A1.3 EMISSIONS MASK

The emissions masks dialog window is designed to define parameters of the unwanted emission of the transmitter.
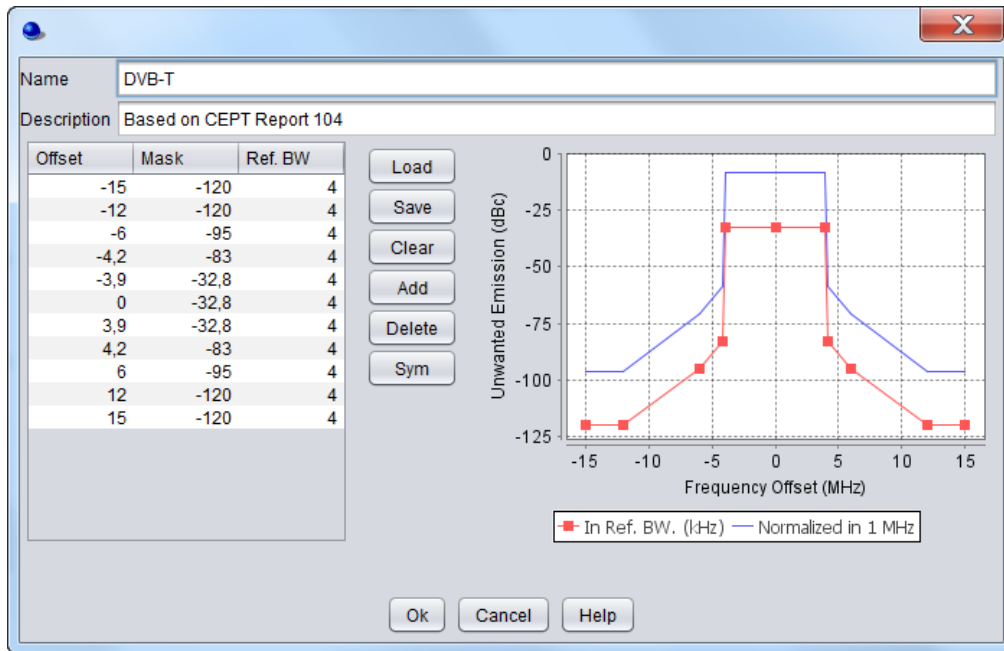
Figure 360: Example on how to edit a function (i.e. like spectrum emission mask)

An emissions mask function is always defined by a sequence of triplets (x, y = f(x), z) displayed in the emissions mask grid where f(x) stands for the relative emitted power (in dBc) at frequency offset x (expressed in MHz), measured in a reference bandwidth z (expressed in kHz). A full description of the calculation of total emissions is available in ANNEX 6:.

Two curves are displayed:

▪ Red curves: It shows the actual curve of the mask, for given reference bandwidth z, that is:

$$y = f(x) \qquad\qquad\qquad\qquad\text{(Eq. 72)}$$

▪ Blue curves: it shows the curve normalized in a reference bandwidth of 1 MHz, that is:

$$y = f(x) + 10\log(1000/z) \qquad\qquad\qquad\qquad\text{(Eq. 73)}$$

The blue curve is aimed to detect potential discontinuities in the definition of transmission mask, and is also the one which is used in actual simulations when integrating the total power of unwanted emissions, in order to overcome possible differences of victim and interferer bandwidthes.

The value of reference bandwidth is therefore extremely important as it has direct impact on the calculated unwanted emissions level. Unless the reference bandwidth is separately defined as a part of mask definition (e.g. for mask definitions in radio equipment standards, etc), you are advised to enter the total emissions bandwidth of intereferer transmitter (i.e. channel width) as value for reference bandwidth.

The following functions are available in the dialog window:

▪ **Add**: To add a triplet click on Add button. Triplets are then automatically sorted by increasing x value,
▪ **Delete**: To suppress a triplet at marker position, click on Delete button;
▪ **Sym**: To symmetrize a transmission mask, click on Sym button, this results in generating for each triplet (x, y, z) a symetric triplet (-x, y,z) if it doesn't already exist;
▪ **Load**: click on the Load button to load a mask from an external text file. This file must contain one triplet (x, y, z) per line, with values TAB separated;
▪ **Save**: If you want to save the defined mask for future re-use or sharing with other users, click on Save button to export the defined mask grid to a text file.

A1.4 ANTENNA

The pattern function is used to describe the radiation patterns of antennas. In the system definition windows, each transmitter and receiver of both victim and interfering links has an "Antenna Patterns Identification" panel, which allows you to define antenna parameters. The positioning of the antennas and its pointing convention in a scenario is described in ANNEX 11:.
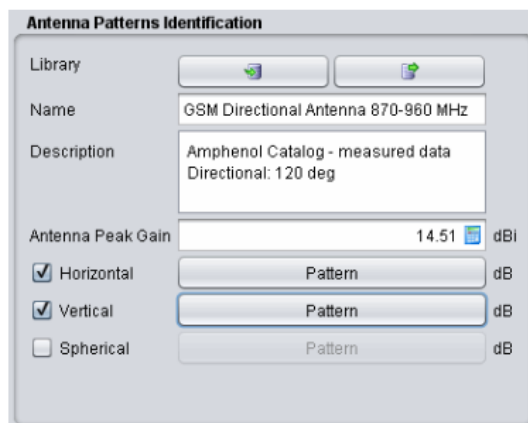
Figure 361: Antenna patterns identification GUI
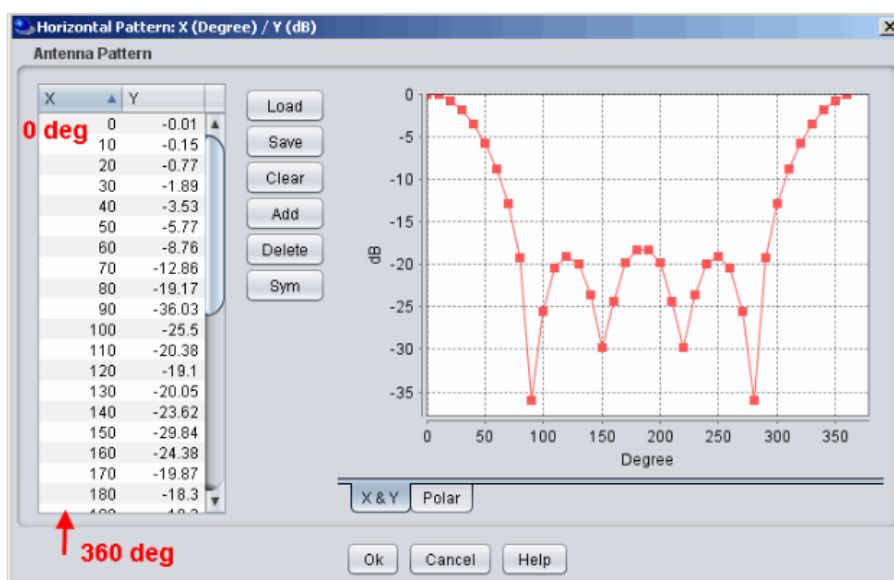
Figure 362: Defining antenna pattern, using XY coordinates system

A1.5 SIGNAL VECTORS

Signal display window is provided for visualisation of various signals produced by the event generation and link calculations. This window is activated when you double-click on the relevant vector element summarised in Section 12.

A1.5.1 Statistics

For each vector result, a set of statistics is available:

- Average: The average is computed using the simulated results in dB;
- Median: The median is computed using the simulated results in linear value. Then the Median is expressed in dB;
- Standard deviation (StdDev): The StdDev is computed using the simulated results in dB;

- Variance:it is the square of the StdDev in dBm;
- Min: It returns the minimum value of the vector results;
- Max: It returns the maximum value of the vector results.

A1.5.2 Visualisation

Three visualisation modes are available according to the option selected in the display radio box, i.e. vector, C.D.F or P.D.F. You may save each visualised data by pressing the "Save" button as explained below. Further details on the save extension (.txt, .xls, .xlsx) is also given in Section 2.12.

- Vector: this mode displays an events plot of the generated signal vector.
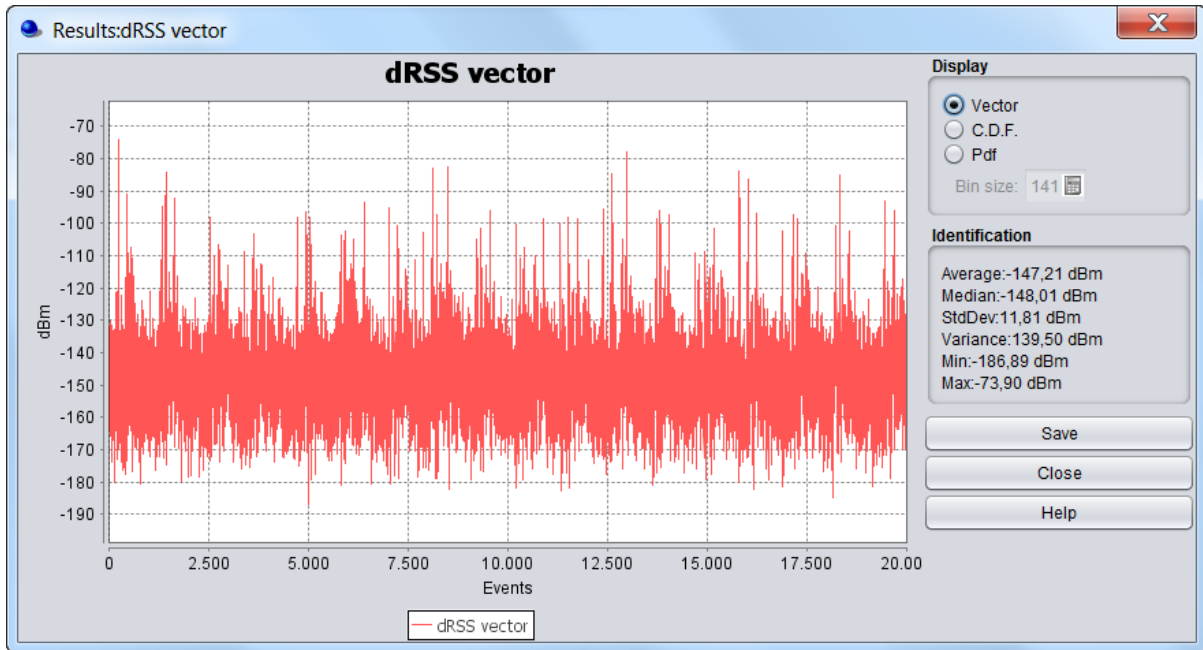
Figure 363: Vector GUI and the equivalent saved file in .txt

The format of the saved file is 1 column of the value (in the unit displayed) and it contains the entire number of event simulated.

```
dRSS vector
-36.439444706267636
-55.107048255598215
-83.47158754961393
-78.04113733356216
```

Figure 364: Format of the vector file

- C.D.F: this mode allows to display the Cumulative Distribution Function (CDF) of the generated signal. The CDF is computed on the generated signal vector raw data, i.e. as expressed in dBm and not on linear values.
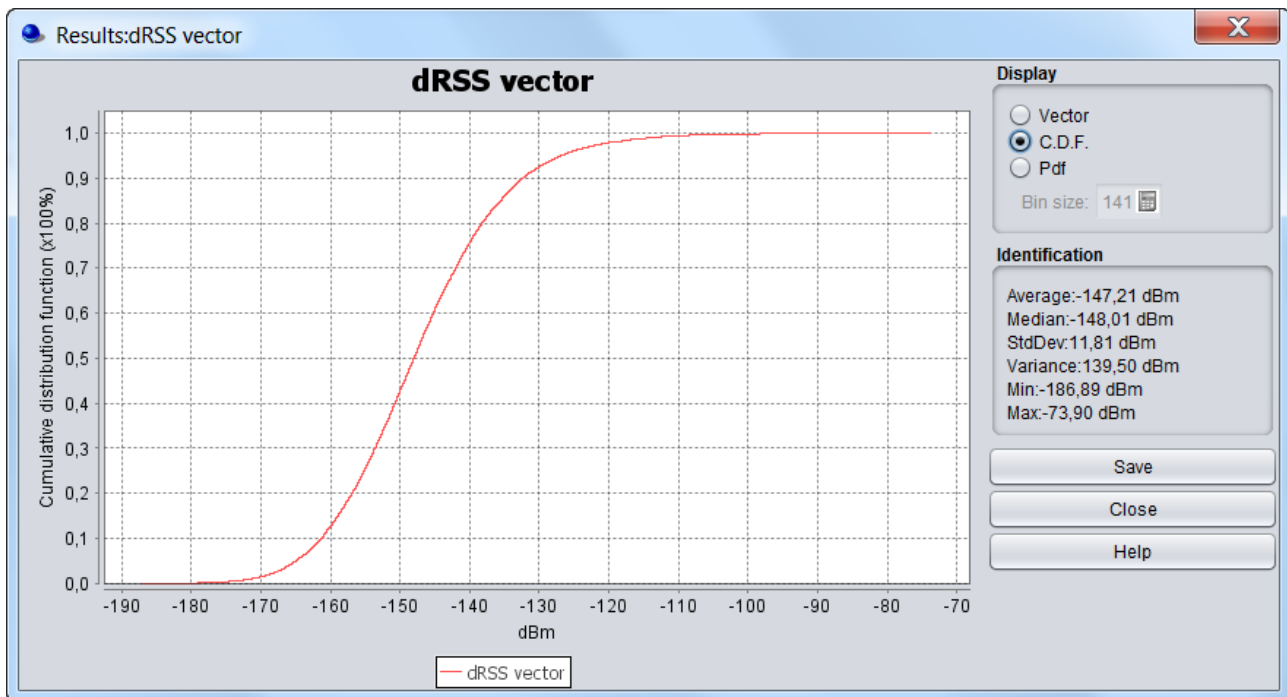
Figure 365: CDF GUI and the equivalent saved file in .txt

The format of the saved file is 2 columns. The first column contains the value in dBs and the second column contains the equivalent cumulative value.

```
dRSS vector      Cumulative
-36.439444706267636    0.8555953755841366
-55.107048255598215    0.5703788968443146
-83.47158754961393     0.12202097009577562
-78.04113733356216     0.1819495186118612
```

Figure 366: Format of the CDF file

▪ PDF/Density: this mode allows to display the distribution density (PDF) of the generated signal, i.e. a statistical histogram showing the square root of the number of given signal strength values. You can change the number of bin.
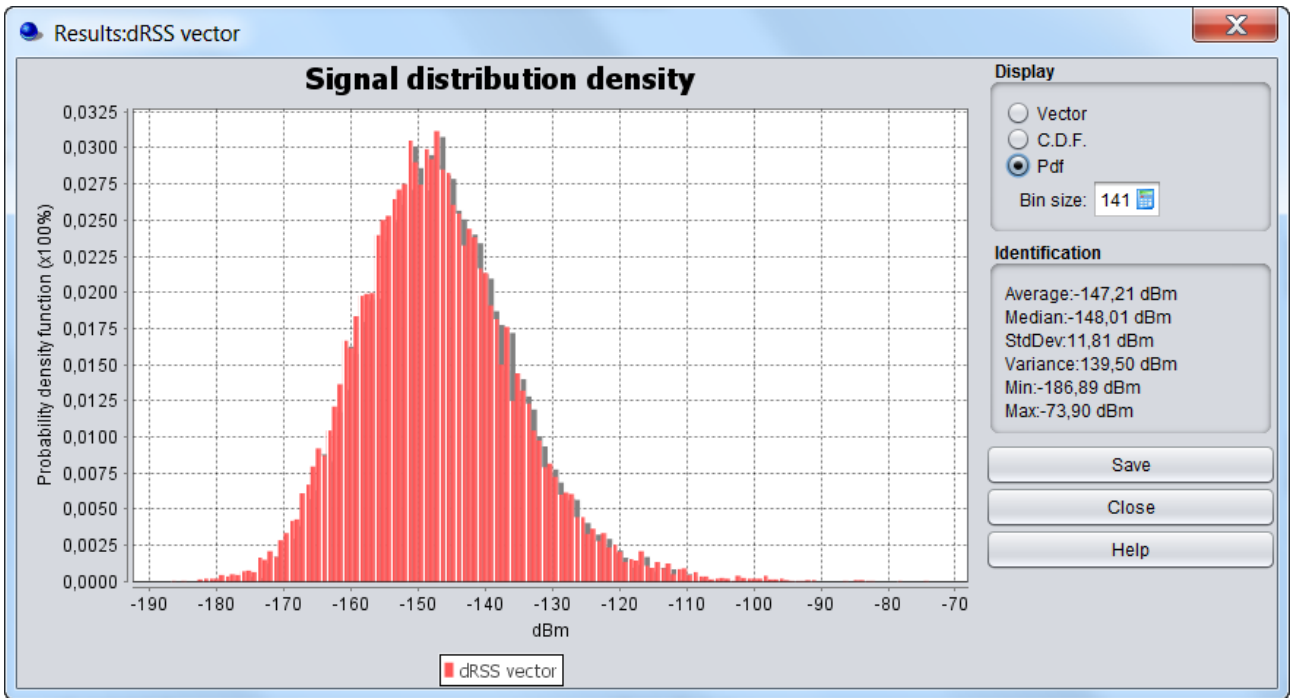
Figure 367: PDF GUI and the equivalent saved file in .txt

The format of the saved file is 2 columns. The first column contains the value in dBs and the second column contains the equivalent probability.

```
Bin        Probability
-125.3421316509745          5.0E-5
-124.42520193355429         5.0E-5
-123.50827221613409         0.0
-122.59134249871389         0.0
```

Figure 368: Format of the PDF file

ANNEX 2: INTERFERENCE CALCULATION ALGORITHM

The algorithm takes one-by-one the corresponding dRSS and iRSS vector results, sums the values from several iRSS vectors if there are more than one interfering link or if user have chosen more than one interference type (i.e. unwanted, blocking, and intermodulation), and then compares that composite iRSS value with dRSS value in that snapshot and with sensitivity floor in accordance with the chosen interference criteria (i.e. C/I, C/(I+N), I/N or I/(I+N)).

A2.1 GENERAL CASE

If the dRSS signal is above the sensitivity floor, it is counted as qualifying snapshot and if then the composite iRSS signal satisfies the criteria (e.g. if dRSS-iRSS>C/I), then the system notes that the given snapshot produced the non-interfered communication attempt.

SEAMCAT calculates the probability of interference (p_I) of the victim link receiver as follows:

$$P_I = 1 - P_{NI} \qquad \text{(Eq. 74)}$$

were p_{NI} is the probability of Non Interference (*NI*) of the receiver.

When a C/I criterion is considered, p_{NI} is defined as:

$$p_{NI} = P\left(\frac{dRSS}{iRSS_{comp}} > \frac{C}{I} \middle| dRSS > sens \right) \qquad \text{(Eq. 75)}$$

since by definition P(A|B)=P(A∩B)/P(B), p_{NI} becomes:

$$p_{NI} = \frac{P\left(\dfrac{dRSS}{iRSS_{comp}} > \dfrac{C}{I}, \quad dRSS > sens \right)}{P(dRSS > sens)} \qquad \text{(Eq. 76)}$$

with $iRSS_{comp} = \sum_{j=1}^{P} iRSS_j$ where *P* is the number of interferers (i.e. active transmitters).

Monte Carlo method is applied individually to the numerator and to the denominator of the expression of p_{NI}. The result obtained is an estimation of p_{NI} by using the following equations (p'_{NI}):

$$p'_{NI} = \frac{\dfrac{1}{M}\displaystyle\sum_{i=1}^{M} 1_{\left\{ \frac{dRSS(i)}{iRSS_{comp}(i)} > \frac{C}{I}, \quad dRSS(i) > sens \right\}}}{\dfrac{1}{M}\displaystyle\sum_{i=1}^{M} 1_{\{dRSS(i) > sens\}}} = \frac{\displaystyle\sum_{i=1}^{M} 1_{\left\{ \frac{dRSS(i)}{iRSS_{comp}(i)} > \frac{C}{I}, \quad dRSS(i) > sens \right\}}}{\displaystyle\sum_{i=1}^{M} 1_{\{dRSS(i) > sens\}}} \qquad \text{(Eq. 77)}$$

with *M* the number of events (or snapshots) and where

$$1_{\{condition\}} = \begin{cases} 1, & \text{if condition is satisfied} \\ 0, & \text{else} \end{cases} \qquad \text{(Eq. 78)}$$

Similarly, when a C/(I+N) criterion is considered, p_{NI} is defined as:

$$p_{NI} = \frac{P\left(\dfrac{dRSS}{iRSS_{comp}+N} > \dfrac{C}{I+N}, \quad dRSS > sens\right)}{P(dRSS > sens)} \qquad \text{(Eq. 79)}$$

When a (I+N)/N criterion is considered, p_{NI} is defined as:

$$p_{NI} = \frac{P\left(\dfrac{iRSS_{comp}+N}{N} > \dfrac{I+N}{N}, \quad dRSS > sens\right)}{P(dRSS > sens)} \qquad \text{(Eq. 80)}$$

When a I/N criterion is considered, p_{NI} is defined as:

$$p_{NI} = \frac{P\left(\dfrac{iRSS_{comp}}{N} > \dfrac{I}{N}, \quad dRSS > sens\right)}{P(dRSS > sens)} \qquad \text{(Eq. 81)}$$

A2.2 OVERLOADING CASE

N_{all} events are passing the dRSS criterion

For both Case 1 or Case 2, the probability of interference should be calculated in a two steps process:

- Step 1: calculate the probability of interference resulting from the overloading for a given total number of events where the dRSS > sensitivity.

  Among N_{all} events for which the dRSS criterion is met, $N_{overloaded}$ are interfered due to the overloading, the corresponding probability is:
  $P_{overloading} = N_{overloaded} / N_{all}$ or similarly $P_{overloading} = 1 - (N_{good\_overloading} / N_{all})$

- Step 2: for N_{all} - $N_{overloaded}$ the events which were not interfered in step 1, calculate the probability of interference resulting from blocking / unwanted emissions (the reference should be the total number of events where the dRSS > sensitivity).

  i.e. for (N_{all} - $N_{overloaded}$) events which passed Step 1, $N_{blocked}$ are interfered by unwanted or blocking or by the consideration of both phenomena (applying the current threshold for unwanted and blocking)

  $P_{blocking} = N_{blocked} / N_{all}$ or similarly $P_{blocking} = 1 - (N_{good\_blocking} / N_{all})$

The total probability of interference is the sum of those two probabilities (step 1 and step 2) of interference.

$$
\begin{aligned}
P_{tot} \quad &= P_{overloading} + P_{blocking} \qquad \text{(Eq. 82)}\\
&= N_{overloaded} / N_{all} + N_{blocked} / N_{all}\\
&= (N_{overloaded} + N_{blocked}) / N_{all}\\
&= 1 - ((N_{all} - N_{overloaded} + N_{blocked}) / N_{all}
\end{aligned}
$$

Note: overloading is only implemented in the victim receiving interface of "traditional" SEAMCAT, i.e. the overloading is not implemented where the victim is either CDMA or OFDMA. However, the impact of the interference from CDMA or OFDMA system should be taken into account when overloading is activated in the victim dialog box.

Note: overloading is not implemented for translation. When translation is selected in the ICE window, the overloading is button should be shaded to show that it is not active.

A2.3 INTERFERENCE CALCULATION COMBINATION

The Interference calculation panel allows you to extract the probability of interference from various combinations. They are summarised in Table 62.

Table 62: Summary of the calculation of the probability of interference resulting from the overloading

Signal type combination	Description
Unwanted only	Calculate the probability of interference by only considering the $iRSS_{unwanted}$
Blocking only	Calculate the probability of interference by only considering the $iRSS_{blocking}$
Blocking + unwanted	Calculate the probability of interference by considering both the $iRSS_{unwanted}$ and $iRSS_{blocking}$
Overloading only	Calculate the probability of interference resulting from the overloading only for a given total number of events where the dRSS > sensitivity. The resulting probability is $$P_{overloading} = 1 - (N_{good\_overloading} /N_{all})$$ and $$N_{good\_overloading} = N_{all} - N_{overloaded}$$ where: ▪ Nall is the number of event where dRSS > sensitivity, ▪ Ngood_overloading is the number of "good" events from overloading (i.e. not overloaded). ▪ Noverloaded is the number of event when the receiver is overloaded. e.g. For 100 events simulated, dRSS > sensitivity occurred for N_{all} (=70 events). Out of N_{all}, the overloading occurred for $N_{overloaded}$ (=30 events). Therefore the probability of interference of overloading only is $P_{overloading}$ =1-(40/70).
Overloading + blocking	Calculate the probability of interference resulting from the overloading and from the blocking for a given total number of events where the dRSS > sensitivity. The resulting probability is $$P_{overloading+blocking} = 1 - ((N_{good\_overloading+blocking})/N_{all})$$ and $$N_{good\_overloading+blocking} = N_{all} - N_{overloaded} - N_{blocked}$$ where: ▪ Nall is the number of event where dRSS > sensitivity, ▪ Ngood_overloading+blocking is the number of "good" events from the combined overloading and blocking mechanism. ▪ Noverloaded is the number of event when the receiver was overloaded. ▪ Nblocked is the number of event which were inpaired by blocking (i.e. receiver blocked). It is obtained from the comparison with the iRSSblocking and a specific interference criterion (C/I, I/N etc..) e.g. For 100 events simulated, dRSS > sensitivity occurred for N_{all} (=70 events). Out of N_{all}, the overloading occurred for $N_{overloaded}$ (=30 events). The $iRSS_{blocking}$ is then calculated over the (70-30=) 40 remaining events. Number of good events resulting from blocking, $N_{blocked}$, is based on the comparison between the $iRSS_{blocking}$ and a specific interference criterion over these 40 events. Let say that for $N_{blocked}$ = 25 events out of 40 the receiver is blocked. Therefore the probability of interference of the combined overloading and blocking is $P_{overloading+blocking}$= 1 - ((40 - 25)/70)
Overloading + blocking +	Same principle as above except that the $iRSS_{comp}$ (=$iRSS_{blocking}$+$iRSS_{unwanted}$) is considered in the comparison to a specific interference criterion

Signal type combination	Description
unwanted	
Overloading + unwanted	Same principle as above except that the $iRSS_{unwatnted}$ is compared to a specific criterion

ANNEX 3: RELATIONSHIP BETWEEN C/I, C/(N+I), (N+I)/N AND I/N

SEAMCAT performs a consistency checking between the interference criteria:

- Between C/I and C/N+I: C/I must be higher than C/N+I.
- Between C/I, C/(N+I), and (I+N)/I if these 3 parameters are defined.

$$\frac{N+I}{N} = 10\log_{10}\left[1 + \frac{1}{10^{\frac{\frac{C}{I} - \frac{C}{N+I}}{10}} - 1}\right] \pm \varepsilon \qquad \text{(Eq. 83)}$$

- Between C/I, C/(N+I), and I/N if these 3 parameters are defined.

$$\left[\frac{I}{N}\right]_{dB} = -10 \times \log_{10}\left[10^{\frac{\left[\frac{C}{I} - \frac{C}{I+N}\right]_{dB}}{10}} - 1\right] \pm \varepsilon \qquad \text{(Eq. 84)}$$

- Between I+N/I and I/N if these two parameters are defined.

$$\left[\frac{N+I}{N}\right]_{dB} = 10 \times \log_{10}\left[1 + 10^{\frac{\left[\frac{I}{N}\right]_{dB}}{10}}\right] \pm \varepsilon \qquad \text{(Eq. 85)}$$

For example, we may calculate the (N+I)/N when we know the value of C/I and C/(N+I). If we assume that:

$$C/I = 19 \ dB \qquad C/(N+I) = 16 \ dB$$

Using the equation:

$$\frac{N+I}{N} = 10\log_{10}\left[1 + \frac{1}{10^{\frac{\frac{C}{I} - \frac{C}{N+I}}{10}} - 1}\right] \qquad \text{(Eq. 86)}$$

This gives:

$$\frac{N+I}{N} = 10\log_{10}\left[1 + \frac{1}{10^{0.3} - 1}\right] = 3dB \qquad \text{(Eq. 87)}$$

Therefore, if the you provide a value for each of these parameters (C/I, C/(N+I) and (N+I)/N), SEAMCAT using the equation (1) checks the consistency of these parameters.

Taking into account this value of (I+N)/N and using the equation:

$$\left[\frac{N+I}{N}\right]_{dB} = 10 \times \log_{10}\left[\frac{N+I}{N}\right] = 10 \times \log_{10}\left[1 + \frac{I}{N}\right] = 10 \times \log_{10}\left[1 + 10^{\frac{\left[\frac{I}{N}\right]_{dB}}{10}}\right] \qquad \text{(Eq. 88)}$$

Considering

$$\left[\frac{I}{N}\right]_{dB} = 10 \times \log_{10}\left[\frac{I}{N}\right] = 10 \times \log_{10}\left[\frac{I+N-N}{N}\right] = 10 \times \log_{10}\left[\frac{N+I}{N} - 1\right] = 10 \times \log_{10}\left[10^{\frac{\left[\frac{N+I}{N}\right]_{dB}}{10}} - 1\right] \qquad \text{(Eq. 89)}$$

and that

$$\left[\frac{N+I}{N}\right]_{dB}=\left[\frac{N+I}{C}\right]_{dB}+\left[\frac{C}{N}\right]_{dB}=-\left[\frac{C}{N+I}\right]_{dB}+\left[\frac{C}{N}\right]_{dB} \tag{Eq. 90}$$

Therefore, this leads to

$$\left[\frac{I}{N}\right]_{dB}=-10\times\log_{10}\left[\frac{N}{I}\right]=-10\times\log_{10}\left[\frac{N+I-I}{I}\right]=-10\times\log_{10}\left[\frac{N+I}{I}-1\right]$$

$$\left[\frac{I}{N}\right]_{dB}=-10\times\log_{10}\left[10^{\frac{\left[\frac{N+I}{I}\right]_{dB}}{10}}-1\right]=-10\times\log_{10}\left[10^{\frac{\left[\frac{C}{I}+\frac{N+I}{C}\right]_{dB}}{10}}-1\right]=-10\times\log_{10}\left[10^{\frac{\left[\frac{C}{I}-\frac{C}{I+N}\right]_{dB}}{10}}-1\right] \tag{Eq. 91}$$

$$\left[\frac{I}{N}\right]_{dB}=-10\times\log_{10}\left[10^{0.3}-1\right]=0dB$$

The following default values for the C/I, C/(N+I), (N+I)/N and I/N of 19 dB, 16 dB, 3 dB and 0 dB respectively avoid the display of a warning. In case you are using inconsistent interference criteria value, you will see the following warning
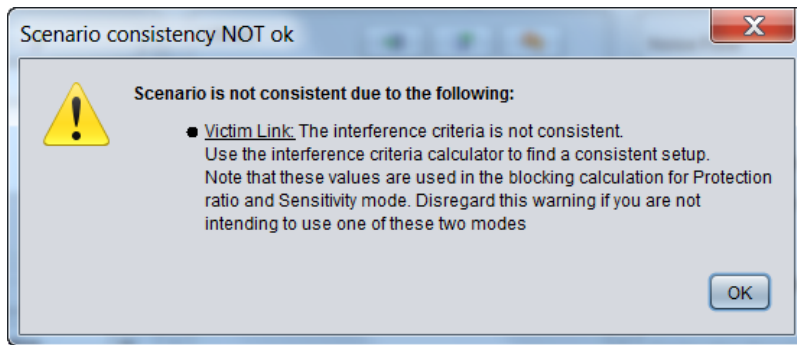
Figure 369: Interference criteria inconsistency warning

ANNEX 4: DRSS CALCULATION

A4.1 DRSS CALCULATION

For one single event, the instantaneous desired Received Signal Strength, $dRSS_{calc}$ is calculated as

$$dRSS = P_{VLT}^{output} - PL_{VLT \to VLR} + G_{VLR \to VLT} + G_{VLT \to VLR}$$ (Eq. 92)

where

- P_{VLT}^{output} : Power supplied to the VLT antenna;
- $G_{VLT \to VLR}$: VLT antenna gain in the direction of the VLR;
- $G_{VLR \to VLT}$: VLR antenna gain in the direction of the VLT;
- $PL_{VLT \to VLR}$: Path loss between the VLT and the VLR.

A4.2 POWER CONTROL

If the received signal can not exceed a given value, i.e. depending on the power control implemented in the victim system, the following applies $dRSS = min(dRSS_{calc}$, $sens+Pc_{max\ x}$). The power control implemented for the dRSS is described in ANNEX 14:.

A4.3 USER DEFINED DRSS

You can define a specific constant value or distribution of $dRSS$ in the Victim Link scenario window by selecting user defined dRSS. In this case the SEAMCAT overwrites the algorithms for the dRSS calculation and proceeds directly to calculation of $iRSS$.

ANNEX 5: IRSS CALCULATION

For the *iRSS* calculation *i* different interfering systems may be considered, each having some *n* active ILTs. The resulting interfering power in the VLR is computed as described below.

A5.1 UNWANTED CALCULATION

The calculation of the interfering signal strength (iRSS) values for each event for unwanted interference ($iRSS_{unwanted}$) is as follows where the *i-th* interferer signal is defined as

$$iRSS^i_{unwanted} = emission_{ILT}(f_{ILT} - f_{VLR}) + g^{PC}_{ILT} - max(PL_{ILT \to VLR} - G_{ILT \to VLR} + G_{VLR \to ILT}, MCL) \quad \text{(Eq. 93)}$$

The calculation is repeated for each defined interfering link so that the total $iRSS_{unwanted}$ is

$$iRSS_{unwanted} = 10 \times log10 \left(\sum_{i=1}^n 10^{\frac{iRSS^i_{unwanted}}{10}} \right) \quad \text{(Eq. 94)}$$

where for each interferer

- f_{ILT} : frequency of the ILT;
- f_{VLR} : frequency of the VLR;
- $emission_{ILT}(f_{ILT} - f_{VLR})$: relative emission mask which is a function of $\Delta f = (f_{ILT}, f_{VLR})$;
- g^{PC}_{ILT} : power control gain for the ILT with the power control function, see ANNEX 14:;
- $G_{ILT \to VLR}$: ILT antenna gain in the direction of the VLR;
- $PL_{ILT \to VLR}$: path loss between the interefering link transmitter *i* and the victim link receiver;
- $G_{VLR \to ILT}$: VLR antenna gain in the direction of the ILT.

In addition, relative emission mask is introduced to enable calculations of interference between systems in the same or adjacent bands. The real emission is always greater or equal than the absolute emission floor.

$$emission_{ILT}(f_{ILT} - f_{VLR}) = \max \left(P^{output}_{ILT} + emission\_rel_{ILT}(f_{ILT} - f_{VLR}) + g^{PC}_{ILT}, emission\_floor_{ILT}(f_{ILT} - f_{VLR}) \right)$$

$$\text{(Eq. 95)}$$

where

- P^{output}_{ILT} : power supplied to the ILT antenna (before power control);
- $emission\_rel_{ILT}(f_{ILT} - f_{VLR})$: relative emission as described in ANNEX 6:;
- $emission\_floor_{ILT}(f_{ILT} - f_{VLR})$: absolute emission floor.

A5.2 BLOCKING CALCULATION

The calculation of the interfering signal strength (iRSS) values for each event for unwanted interference ($iRSS_{blocking}$) is as follows where the *i-th* interferer signal is defined as

$$iRSS^i_{blocking} = P^{output}_{ILT} + g^{PC}_{ILT} - a_{VLR}(f_{ILT} - f_{VLR}) - max(PL_{ILT \to VLR} - G_{ILT \to VLR} - G_{VLR \to ILT}, MCL)$$

$$\text{(Eq. 96)}$$

The calculation is repeated for each defined interfering link so that the total $iRSS_{blocking}$ is

$$iRSS_{blocking} = 10 \times log10 \left(\sum_{i=1}^n 10^{\frac{iRSS^i_{blocking}}{10}} \right) \quad \text{(Eq. 97)}$$

where for each interferer:

- fVLR   : victim link operating frequency;
- fILT   : Interfering link operating frequency. Note that the trial of the dRSS frequency, fVLR, occurs only once for each simulation round, i.e. fVLR is trialled once, together with the VLT, VLR positions, the VLT transmit power and other distributions pertaining to the victim link. These values associated with the dRSS trial round then apply to all n trials of iRSS (where n is the number of interferers);
- P_{ILT}^{output} : power supplied to the ILT antenna (before power control).;
- g_{ILT}^{PC} : power control gain for the ILT with the power control function, see ANNEX 14:.
- $G_{ILT \rightarrow VLR}$: ILT antenna gain in the direction of the VLR;
- $G_{VLR \rightarrow ILT}$: VLR antenna gain in the direction of the ILT;
- $PL_{ILT \rightarrow VLR}$: path loss between the interfering link transmitter i and the victim link receiver;
- $a_{VLR}(f_{ILT} - f_{VLR})$: blocking attenuation of the victim link receiver, see ANNEX 8:.´;
- MCL : Minimum coupling loss given by the system parameter definition.

A5.3 INTERMODULATION REJECTION CALCULATION

ETSI defines the intermodulation response rejection as a measure of the capability of the receiver to receive a wanted modulated signal, without exceeding a given degradation due to the presence of two or more unwanted signals with a specific frequency relationship to the wanted signal frequency [16].

In SEAMCAT, it is called the intermodulation rejection, and in the presence of more than one interfering system applying its own frequency distribution, a theoretically unlimited number of intermodulation products exist, caused by the non-linearity of the VLR. In practice, just the products close to the frequency of the VLR are of importance, of which the products of the so called 3rd order[3] are the most dominant and therefore considered by SEAMCAT. The frequency conditions for the intermodulation products of the 3rd order are

$$f_0 = 2 \times f_1 \pm f_2 \tag{Eq. 98}$$

with

$$f_{VLR} - \frac{b}{2} \leq f_0 \leq f_{VLR} + \frac{b}{2} \tag{Eq. 99}$$

where
- b   : is the bandwidth of the VLR;
- f_0 : the trialed frequency of the victim system;
- f_1, f_2 : the trialed frequencies of pairs of interfering systems in case more than two systems are to be taken into account.

As an example consider a victim system with a desired signal at frequency f_0, a channel separation Δf and interfering signals E_{i1} and E_{i2} at frequencies $f_0 + n\Delta f$ and $f_0 + 2n\Delta f$, respectively. The receiver non-linearity produces an intermodulation product E_{if} of third order at the frequency f_0 as shown below in Figure 370.

$$f_0 = 2(f_0 + n\Delta f) - (f_0 + 2n\Delta f) \qquad n = \pm 1, \pm 2, ... \tag{Eq. 100}$$

---

[3] the order is given by the sum of the absolute values of the coefficients, here 2 + |1| = 3
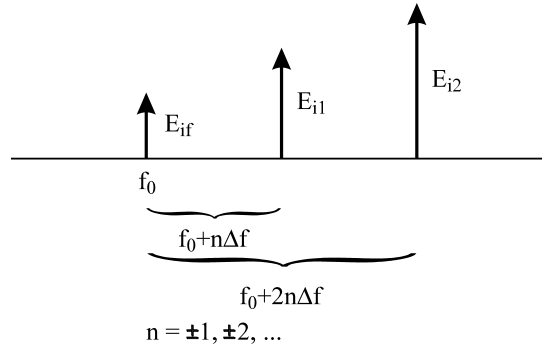
Figure 370: Illustration of intermodulation product E_{if} of third order at the frequency f_0

The signal strength E_{if} of the intermodulation product is given by

$$E_{if} = k E_{i1}^2 E_{i2}$$

(Eq. 101)

with some constant k to be determined. For signal levels (measured in dB), E_{if} becomes $iRSS_{intermod}^{i,j}$ and the equation above reads

$$iRSS_{intermod}^{i,j} = 2 iRSS_{i1} + iRSS_{i2} + 20 \times log(k)$$

(Eq. 102)

From the measurement procedure which is described e.g. in the ETSI standard ETSI 300-113, clause 8.8, we can derive the calculation algorithm. The method is similar to the contribution for blocking interference. ETSI 300-113 defines via the intermodulation response L_{imr} the interfering signal levels $iRSS_{i1} = iRSS_{i2}$ at which bit errors due to intermodulation just start to be recorded.
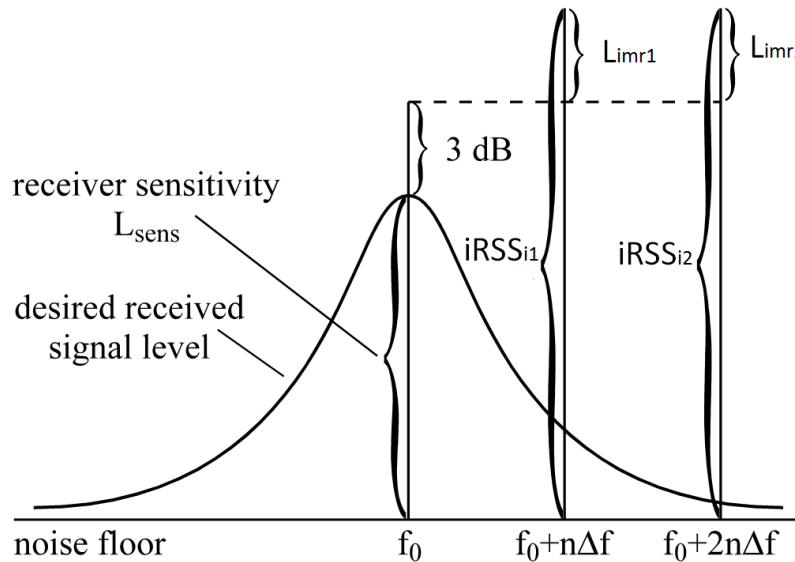
Figure 371: Illustration of intermodulation product from ETSI 300-113

This means, for $iRSS_{i1}$ and $iRSS_{i2}$, we have an intermodulation product $iRSS_{intermod}^{i,j}$ relative to the noise floor (0 dB), due to the noise augmentation (N+I)/N of 3 dB corresponds to an I/N of 0 dB. Transferring Figure 371 into a formula gives the relation

$$0 = 2(L_{imr1} + 3dB + L_{sens}) + (L_{imr2} + 3dB + L_{sens}) + 20 \log k$$

(Eq. 103)

from which we can derive the calculation algorithm for this example

$$iRSS_{intermod}^{i,j} = 2(iRSS_{i1} - L_{imr1}) + (iRSS_{i2} - L_{imr2}) - 3(L_{sens} + 3dB) \qquad \text{(Eq. 104)}$$

where for interferer i-th, at frequency *x*:

$$iRSS_{i,x} = P_{ILT}^{output} + g_{ILT}^{PC} + max(PL_{ILT \rightarrow VLR} - G_{ILT \rightarrow VLR} - G_{VLR \rightarrow ILT}, MCL) \qquad \text{(Eq. 105)}$$

where

- P_{ILT}^{output} : power supplied to the ILT antenna (before power control);
- g_{ILT}^{PC} : power control gain for the ILT with the power control function, see ANNEX 14:;
- $PL_{ILT \rightarrow VLR}$: path loss between the interfering link transmitter i and the victim link receiver;
- $G_{ILT \rightarrow VLR}$: ILT antenna gain in the direction of the VLR;
- $G_{VLR \rightarrow ILT}$: VLR antenna gain in the direction of the ILT;
- MCL : Minimum coupling loss given by the system parameter definition.

For any other consistent combination of (N+I)/N and I/N this becomes

$$iRSS_{intermod}^{i} = 2(iRSS_{i1} - L_{imr1}) + (iRSS_{i2} - L_{imr2}) - 3\left(L_{sens} + \left(\frac{N+I}{N} - \frac{I}{N}\right)\right) \qquad \text{(Eq. 106)}$$

For the computation of the intermodulation products in the victim link receiver two different interfering systems (i-th and j-th) are required and the total intermodulation product is

$$iRSS_{intermod} = 10 \times log10 \left(\sum_{i=1}^{n} \sum_{\substack{i=1 \\ i \neq j}}^{n} 10^{\frac{iRSS_{intermod}^{i,j}}{10}} \right) \qquad \text{(Eq. 107)}$$

where:

- $iRSS_{intermod}^{i,j}$: intermodulation product at the frequency f0;
- L_{imr} : the attenuation given by the input parameter 'Intermodulation rejection'. This attenuation applies inside the bandwidth of the VLR. It is therefore advisable to set a constant value as intermodulation rejection;
- L_{sens} : the sensitivity of the VLR given by the system parameter definition;
- $\frac{N+I}{N}$: Noise augmentation given by the system parameter definition;
- $\frac{I}{N}$: interference to noise ratio given by the system parameter definition.

In case the intermodulation product does not fit the frequency condition $f_{VLR} - \frac{b}{2} \leq f_0 \leq f_{VLR} + \frac{b}{2}$, a value of -1000 dBm is returned in SEAMCAT.

The EPP Demo9 (Figure 372) allows you to see the behaviour of this equation.
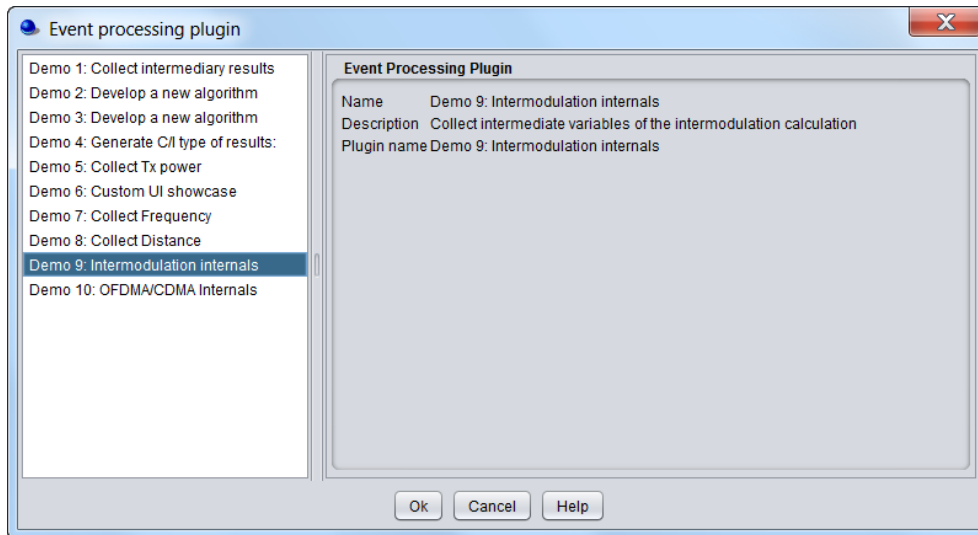
Figure 372: EPP Demo 9 – intermodulation internals

A5.4 OVERLOADING CALCULATION

SEAMCAT calculates the interfering signal resulting from the possible interfering system(s) at the interfering frequency as follows:

For each events{

If (dRSS > sensitivity){

Case 1: single source of interference

$$iRSS_{overloading} = P_{ILT}^{output} + g_{ILT}^{PC} - Rx\_filter + max(PL_{ILT \rightarrow VLR} - G_{ILT \rightarrow VLR} + G_{VLR \rightarrow ILT}, MCL) \quad \text{(Eq. 108)}$$

where:

- P_{ILT}^{output} : power supplied to the ILT antenna (before power control);
- g_{ILT}^{PC} : power control gain for the ILT with the power control function, see ANNEX 14:;
- $PL_{ILT \rightarrow VLR}$: path loss between the interfering link transmitter i and the victim link receiver;
- $G_{ILT \rightarrow VLR}$: ILT antenna gain in the direction of the VLR;
- $G_{VLR \rightarrow ILT}$: VLR antenna gain in the direction of the ILT;
- MCL : Minimum coupling loss given by the system parameter definition;
- Rx_filter : Filtering of the receiver (if any).

Note: The filtering of the receiver is by default 0 dB (similarly to the default blocking filtering value).

Case 2: multiple source of interference

2.1 If the interferers are operating at the same frequency, iRSS_overloading is sum of each of the iRSS_overloading calculated for each of the source of interference.

2.2 If the interferers are operating at different frequencies, an iRSS_overloading should be calculated considering all of the sources of interference for each frequency (i.e. the sum of the iRSS overloading is performed at the specific frequency). Each of the calculated iRSS_overloading should be compared with the different overloading threshold extracted from the overloading mask depending on the considered frequency offset.

}
else
{
skip this event.
}
}

A5.5 IRSS$_{UWANTED}$, IRSS$_{BLOCKING}$ AND IRSS$_{INTERMODULATION}$ CALCULATION FLOW CHART

Calculation of R_{simu}

Interferer $i = 1 : n$

Trial of relevant interferer parameters:
$f_{ILT}, h_{ILT}, \theta_{ILT \rightarrow VLR}, p_{ILT}^{supplied}, d_{ILT \rightarrow VLR}$

Power Control — yes

Calculation of: R_{ILT}^{max}

Trial of:
$h_{VLR}, g_{ILT \rightarrow VLR}, g_{VLR \rightarrow ILT}, d_{ILT \rightarrow VLR}$

no

$g_{ILT}^{PC} = 0$

Calculation of :
$PL_{ILT \rightarrow VLR}, g_{ILT}^{PC}$

Calculation of R_{max}

Calculation of:
$g_{ILT \rightarrow VLR}(f_{ILT}), g_{ILT \rightarrow VLR}(f_{VLR}), g_{VLR \rightarrow ILT}(f_{ILT}), g_{VLR \rightarrow ILT}(f_{VLR}), PL_{ILT \rightarrow VLR}(f_{ILT}), PL_{ILT \rightarrow VLR}(f_{VLR})$

Calculation of:

$$iRSS_{unwanted}^i = emission_{ILT}(f_{ILT} - f_{VLR}) + g_{ILT}^{PC} - max(PL_{ILT \rightarrow VLR} - G_{ILT \rightarrow VLR} + G_{VLR \rightarrow ILT}, MCL)$$

$$iRSS_{blocking}^i = P_{ILT}^{output} + g_{ILT}^{PC} - a_{VLR}(f_{ILT} - f_{VLR}) - max(PL_{ILT \rightarrow VLR} - G_{ILT \rightarrow VLR} - G_{VLR \rightarrow ILT}, MCL)$$

Calculation of intermodulation products
$i_{i,j}RSS_{intermod}$

$$iRSS_{block} = 10log\left(\sum_{i=1}^{n} 10^{\frac{i_iRSS_{block}}{10}}\right)$$

$$iRSS_{unwanted} = 10log\left(\sum_{i=1}^{n} 10^{i_iRSS_{unwanted}/10}\right)$$

$$iRSS_{intermod} = 10log\left(\sum_{i=1}^{n}\sum_{j=1,j\neq i}^{n} 10^{i_{i,j}RSS_{intermod}/10}\right)$$

Figure 373: irss due to unwanted and blocking calculation

ANNEX 6: SRSS CALCULATION

For one single event, the instantaneous sensing Received Signal Strength, s*RSS* is calculated as

$$sRSS(f_m) = P_{VLT}^{output}(f_m) - PL_{VLT \to ILT} + G_{VLT \to ILT} + G_{ILT \to VLT} \qquad \text{(Eq. 109)}$$

where
- $P_{VLT}^{output}(f_m)$: power supplied to the VLT antenna. The bandwidth of the sensing device (It) should be considered in the calculation. Note: The emission bandwidth of the VLT may be different from the ILT receiving bandwidth, therefore when the sRSS is to be calculated, a bandwidth correction factor is needed. PVLT is subject to power control. The emission spectrum mask of the VLT is provided in order to calculate PVLT at frequency fm;
- f_m : is the frequency of the sensing device;.
- $G_{VLT \to ILT}$: VLT antenna gain in the direction of the ILT;
- $G_{ILT \to VLT}$: ILT antenna gain in the direction of the VLT;
- $PL_{VLT \to ILT}$: Path loss between the VLT and the ILT.

ANNEX 7: UNWANTED EMISSIONS MASK

A7.1 SPECTRUM EMISSION MASK

The spectrum emission mask of a transmitter can be broken up as follows:

- Necessary bandwidth = width of the frequency band which is theoretically just sufficient to ensure the transmission of information.
- Occupied bandwidth = width of the frequency band such that, below the lower and above the upper frequency limits, the mean powers emitted are each equal to a specified percentage β/2 of the total mean transmitted power. The value of β/2 shall be taken as 0.5%.
- Out-of-band emission = emission on frequencies immediately outside the channel bandwidth which results from the modulation process and non-linearity in the transmitter, but excluding spurious emissions.
- Spurious emission = emission on frequencies which are outside the channel bandwidth and the level of which may be reduced without affecting the corresponding transmission of information, thus excluding out-of-band emission.
- Unwanted **emissions** = consist of out-of-band emission and spurious emission.
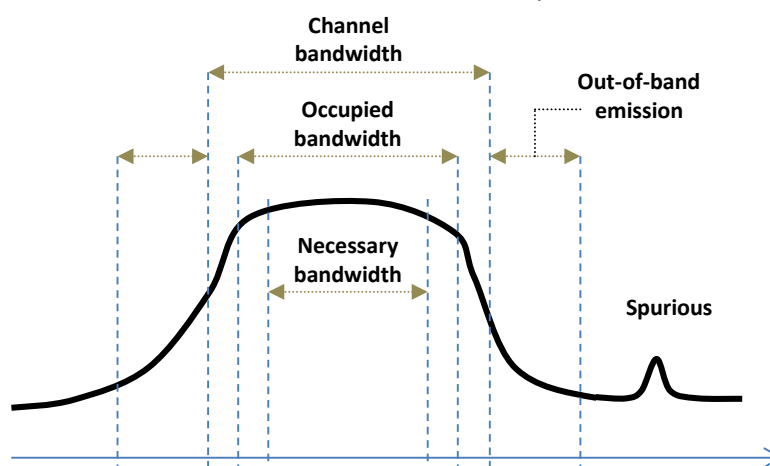
Figure 374: Illustration of a spectrum emission

The necessary bandwidth shall be considered to determine the maximum co-channel interference level that is acceptable by the receiver and the occupied bandwidth shall be considered to determine in which part of the channel 99% of the transmitted power is concentrated.

A7.2 UNWANTED EMISSION MASK

For the interefering link transmitter, an emission mask $emission_{it}$ is defined as a function of $\Delta f = f, f_{ILT}$ and can be defined as maximum power levels $emission_{ILT}(\Delta f)$ in reference bandwidth $b_S(\Delta f)$.

This mask can also be expressed as the maximum of

- the sum of the supplied interfering power $p_{ILT}^{supplied}$, a relative emission mask (containing the wanted transmission and all unwanted emissions including the emission floor depending on the power control) and the gain power control;
- or the absolute emission floor.

The relative emission mask is described by a **triplet** (frequency offset (MHz), relative emission level (dBc) and reference bandwidth (MHz)). The emission floor is defined later in this Annex.

The interefering link transmitter power $p_{ILT}^{supplied}$ (dBm) at f_{ILT} is used for evaluating the link budget with the interfering link receiver (i.e. power control).

A7.3 ILT EMISSIONS MASK

Figure 375 shows the principle of the determination of the interfering power. If $f_{ILT} = f_{VLR}$ then the interfering frequencies fall exactly in the receiving band of the victim link receiver (co-channel interference).

For simplification within the algorithms the mask function p_{m_it} is normalized to 1 Hz reference bandwidth:

$$p_{n\_ILT} = p_{m\_ILT}(\Delta f) - 10\log_{10}\left(\frac{b}{1Hz}\right) \tag{Eq. 110}$$

The bandwidth b is the bandwidth used for the emission mask. The total received interfering power $emission_{it}$ can easily be calculated by integration over the receiver bandwidth from $a = f_{VLR} - f_{ILT} - b_{VLR}/2$ to $b = f_{VLR} - f_{ILT} + b_{VLR}/2$

$$power_{ILT} = 10\log_{10}\left\{\int_a^b 10^{\left(p_{n\_ILT}(\Delta f)/10\right)}d\Delta f\right\} \tag{Eq. 111}$$

with p_{n_ILT} denoting the normalized mask in dBm/Hz. Using 1 Hz reference bandwidth the integral can be replaced by a summation

$$power_{ILT} = 10\log_{10}\left\{\sum_{i=a}^b 10^{\left(p_{n\_ILT}(\Delta f_i)/10\right)}\right\} \tag{Eq. 112}$$

where $power_{it}$ is given in dBm.

Note: The interfering power of a radio system having a different bandwidth can be estimated by the aforementioned algorithms. This calculation is only required for the interference due to unwanted emissions but not for blocking and intermodulation.

The figure shows an Unwanted Emission Mask with a Victim Receiver band. The horizontal axis markers are:

$(f_{VLR} - f_{ILT}) - \dfrac{b_{VLR}}{2}$ $(f_{VLR} - f_{ILT})$ $(f_{VLR} - f_{ILT}) + \dfrac{b_{VLR}}{2}$
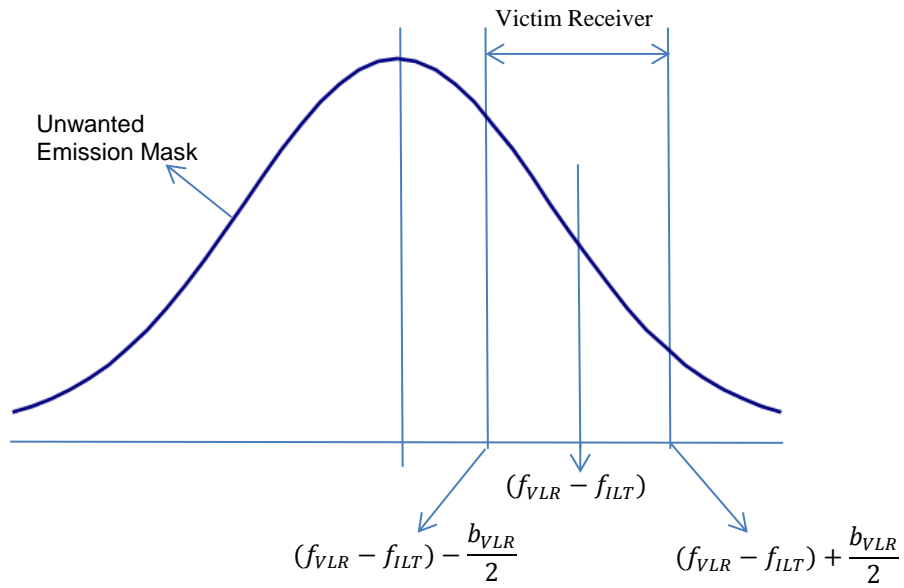
Figure 375: Integration of the unwanted emissions in the victim link receiver band

The total interfering power relative to carrier $emission\_rel_{it}$ can be calculated by integration over the receiver bandwidth from $a = f_{VLR} - f_{ILT} - b_{VLR}/2$ to $b = f_{VLR} - f_{ILT} + b_{VLR}/2$

$$emission\_rel_{ILT} = 10\log\left\{\int_a^b P_{rel}^{linear}(\Delta f)\,d\Delta f\right\} = 10\log\left\{\int_a^b 10^{\frac{P_{rel}^{dBc}(\Delta f)}{10}}\,d\Delta f\right\} \qquad \text{(Eq. 113)}$$

with P_{rel}^{dBc} denoting the normalized user-defined mask in dBc/Hz.

This mask is expressed as an array of $N+1$ points $(\Delta f_i, P_i)$ and assumed linear between these points.

$$P_{rel}^{dBc}(\Delta f) = P_i + \frac{\Delta f - \Delta f_i}{\Delta f_{i+1} - \Delta f_i}\left(P_{i+1} - P_i\right) \qquad \text{(Eq. 114)}$$

This leads to:

$$emission\_rel_{it} = 10\log\left\{\sum_{i=0}^{N-1}\int_{\Delta f_i}^{\Delta f_{i+1}} 10^{\frac{P_{rel}^{dBc}(\Delta f)}{10}}\,d\Delta f\right\} \qquad \text{(Eq. 115)}$$

where:

$$\Delta f_0 = a = f_{VLR} - f_{ILT} - B_{VLR}/2 \qquad \text{(Eq. 116)}$$

$$\Delta f_N = b = f_{VLR} - f_{ILT} + B_{VLR}/2 \qquad \text{(Eq. 117)}$$

Intermediate calculation

$$emission\_rel_i^{dBc} = \int_{\Delta f_i}^{\Delta f_{i+1}} 10^{\frac{P_{rel}^{dBc}(\Delta f)}{10}} d\Delta f$$

$$emission\_rel_i^{dBc} = 10^{\frac{P_i}{10}} \int_{\Delta f_i}^{\Delta f_{i+1}} \left[10^{\frac{P_{i+1}-P_i}{10(\Delta f_{i+1}-\Delta f_i)}} \right]^{(\Delta f - \Delta f_i)} d\Delta f$$

$$emission\_rel_i^{dBc} = \frac{10^{\frac{P_i}{10}}}{K^{\Delta f_i}} \int_{\Delta f_i}^{\Delta f_{i+1}} K^{(\Delta f - \Delta f_i)} d\Delta f \, , K = 10^{\frac{P_{i+1}-P_i}{10(\Delta f_{i+1}-\Delta f_i)}} \tag{Eq. 118}$$

$$emission\_rel_i^{dBc} = \frac{10^{\frac{P_i}{10}}}{K^{\Delta f_i}} \left[e^{\ln K} \right]_{\Delta f_i}^{\Delta f_{i+1}} = \frac{10^{\frac{P_i}{10}}}{\ln K} \left[K^{\Delta f_{i+1}-\Delta f_i} - 1 \right] \ln K = \frac{\ln 10}{10} \cdot \frac{P_{i+1} - P_i}{\Delta f_{i+1} - \Delta f_i}$$

$$emission\_rel_i^{dBc} = \frac{10}{\ln 10} \frac{10^{P_{i+1}} - 10^{P_i}}{P_{i+1} - P_i} (\Delta f_{i+1} - \Delta f_i) \tag{Eq. 119}$$

Eventually:

$$emission\_rel_{ILT} = 10 \log \left\{ \frac{10}{\ln 10} \sum_{i=0}^{N-1} \frac{(P_{i+1}^{linear} - P_i^{linear})(\Delta f_{i+1} - \Delta f_i)}{(P_{i+1}^{dBc} - P_i^{dBc})} \right\} \tag{Eq. 120}$$

A7.4 UNWANTED EMISSION NOISE FLOOR

The aforementioned formulas are also applicable to absolute emission floor $emission\_floor_{ILT}$ (dBm) . This emission floor mask can be described by a triplet (*frequency offset (MHz), emission floor (dBm), reference bandwidth (MHz)*).
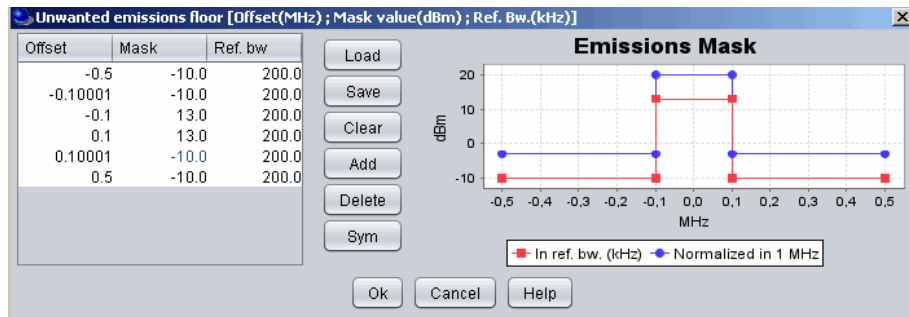
Figure 376: illustration of the emission mask and the unwanted emission floor mask

The real emission is bounded by the emission floor by the following equation and illustrated in Figure 377.

$$emission_{ILT} = \max(emission\_rel_{ILT} + p_{ILT} + g_{ILT}^{PC}, emission\_floor_{ILT}) \tag{Eq. 121}$$

Note that the value of the $emission\_floor_{it}$ is scaled to the VLR bandwidth. This means that assuming a VLR bandwidth of 200 KHz and the value of the Emission mask and Unwanted Emission floor as presented in Figure 376, the following $emisssion_{it}$ are calculated:

for a f_{ILT} = 900.3 MHz and f_{VLR} = 900.0 MHz:
    $emission_{ILT}$ = max (-30 + 5 + 0 , -10)
    $emission_{ILT}$ = -10 dBm;

for a f_{ILT} = 900.0 MHz and f_{VLR} = 900.0 MHz:
  $emission_{ILT}$ = max (0 + 5 + 0 , 13)
  $emission_{ILT}$ = 13 dBm;
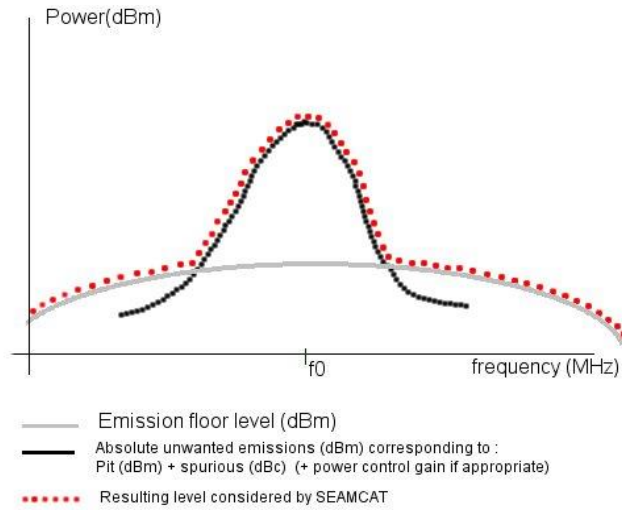
Figure 377: Resulting power level for the calculation of iRSS

A7.5 EXAMPLES OF DBC EMISSION MASK AND RELATION BETWEEN NORMALISED MASK AND REF. BW MASK

The following range of attenuation is considered, for a system of 30 dBm using a 20 kHz emission bandwidth. The reference bandwidth for the attenuation is 10 kHz. Within the emission bandwidth the reference bandwidth is taken equal to the emission bandwidth.

Table 63: Emission mask value as illustrated in Figure 378

Frequency offset	Attenuation in dBc
0 to 10 kHz	0
10 to less than 20 kHz	Min (p(dBW)+30, 36)
20 to less than 30 kHz	Min (p(dBW) + 40, 36)
30 to less than 40 kHz	Min (p(dBW) + 45, 40)
40 to less than 50 kHz	50

Figure 378, shows the "upper" part of the mask derived from Table 62, the whole mask is symmetric. The frequency offset is defined in MHz.
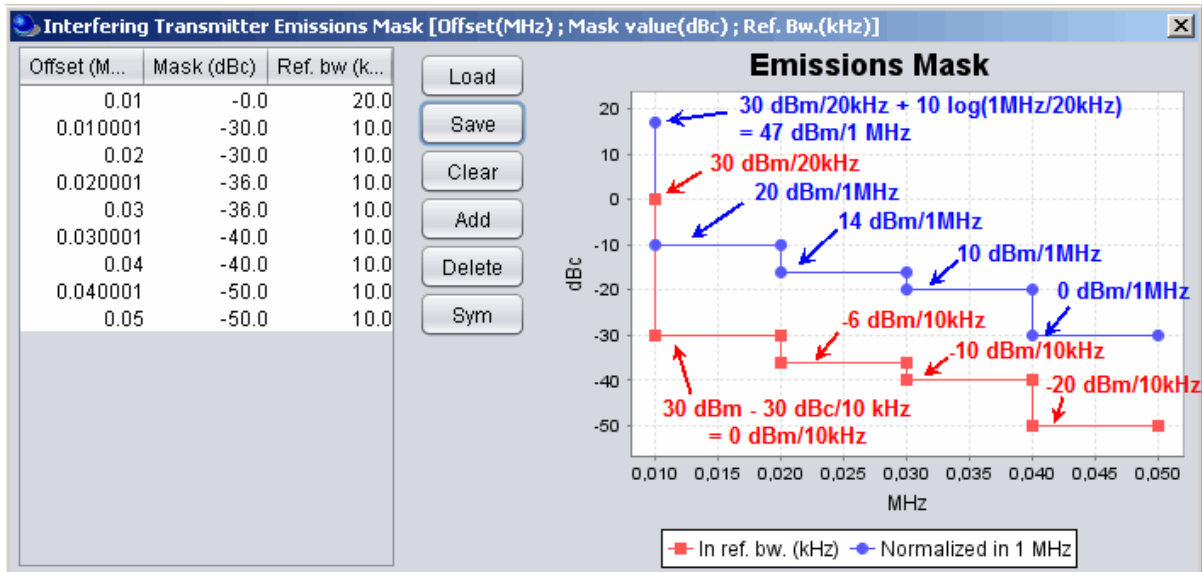
Figure 378: Example of "Upper part" of an Emission Mask in dBc

If the mask is symmetric, the whole mask may be obtained by using the "**Sym**" function in SEAMCAT as shown in Figure 379. N1 and N2 correspond to the same level of power and correspond to attenuation defined in dBc given in reference bandwidth (kHz) and normalised bandwidth (1 MHz) respectively.

$$N1 \ (dBm/Bref) = P \ (dBm) + Att1 \ (dBc/Bref) \qquad\qquad (Eq. \ 122)$$
$$N2 \ (dBm/1 \ MHz) = P \ (dBm) + Att2 \ (dBc/1 \ MHz)$$

where P is the Power within the emission bandwidth.

N1 (dBm/Bref) and N2 (dBm/1 MHz) represent the same level of power (P_i):

$$P_i \ (dBm) = N1 \ (dBm/Bref) + 10 \ log(Bref)$$
$$P_i \ (dBm) = N2 \ (dBm/1 \ MHz) + 10 \ log(1 \ MHz)$$

Therefore the relationship between the attenuations in dBc defined in reference bandwidth and in 1 MHz is given by:

$$Delta = N1 \ (dBm/1 \ MHz) - N2 \ (dBm/Bref)$$

$$Delta = P_i \ (dBm) - 10 \ log(Bref) - (P_i \ (dBm) - 10 \ log(1 \ MHz))$$
$$Delta = 10 \ log(\ (1 \ MHz)/(Bref) \ )$$

Note:

➢ *If the reference bandwidth is larger than the emission bandwidth then the attenuation must be defined with positive sign;*

➢ *If the reference bandwidth is lower than the emission bandwidth then the attenuation must be defined with negative sign;*

➢ *If the reference bandwidth is equal to the emission bandwidth then the attenuation should be set-up at zero.*
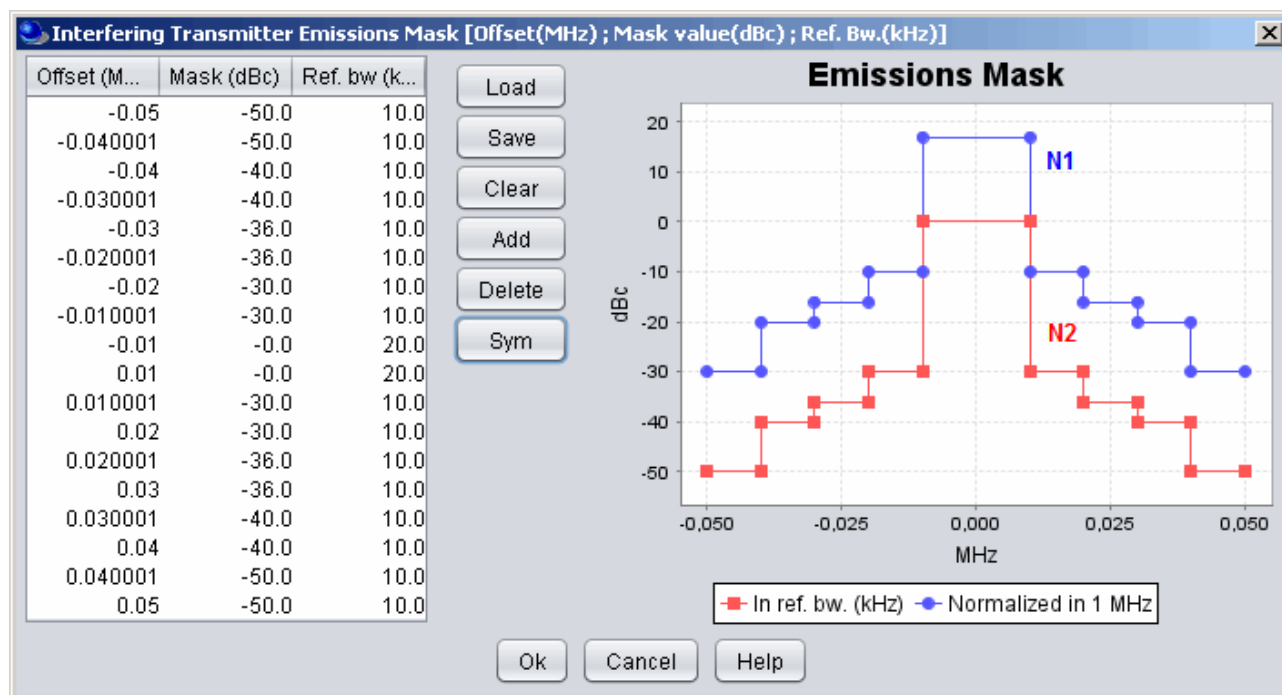
Figure 379: Link between the normalised mask and the mask given in reference bandwidth

A7.6 EXAMPLES OF CALCULATION USING DBC

The ITU-R Recommendation ITU-R SM.329 [2] on Unwanted emissions in the spurious domain provides a definition of dBc unit, which is defined as "Decibels relative to the unmodulated carrier power of the emission. In the cases which do not have a carrier, for example in some digital modulation schemes where the carrier is not accessible for measurement, the reference level equivalent to dBc is decibels relative to the mean power P. From this recommendation the following example is presented:

A land mobile transmitter, with any value of emission bandwidth, must meet an attenuation of *43 + 10 logP*, or *70 dBc*, whichever is less stringent. To measure the emissions the use of a reference bandwidth of 100 kHz is recommended for spurious emissions within the frequency range 30 to 1000 MHz.

With a measured total mean power of 10 W:
Attenuation relative to total mean power = 43 + 10 log(10) = 53 dB

The 53 dBc is less stringent than 70 dBc, so the 53 dBc value is used. Therefore, emissions must not exceed 53 dBc in a 100 kHz reference bandwidth, or converting to an absolute level: 10 dBW – 53 dBc = – 43 dBW in a 100 kHz reference bandwidth.

With a measured total mean power of 1 000 W:
Attenuation relative to total mean power = 43 + 10 log(1000) = 73 dB

The 73 dBc is more stringent than 70 dBc limit, so the 70 dBc value is used. Therefore, emissions must not exceed 70 dBc in a 100 kHz reference bandwidth, or converting to an absolute level: 30 dBW - 70 dBc = -40 dBW in a 100 kHz reference bandwidth.

A7.7 DEFINING A CDMA UNWANTED EMISSION MASK IN SEAMCAT (INTERFERING LINK)

A7.7.1 BS example

As an example of a BS spectrum emission masks (i.e. CDMA DL as interferer), TS 25.104 [1] have shown that different values may need to be considered depending on the BS maximum output power Table 64 presents Spectrum emission mask values, BS maximum output power P ≥ 43 dBm.

Table 64: Spectrum emission mask values, BS maximum output power P ≥ 43 dBm (from [1])

Frequency offset of measurement filter -3dB point, Δf	Frequency offset of measurement filter centre frequency, f_offset	Minimum requirement Band I, II, III, IV, V, VII, VIII, X	Additional requirements Band II, IV, V, X	Measurement bandwidth
2.5 MHz ≤ Δf < 2.7 MHz	2.515MHz ≤ f_offset < 2.715MHz	-14 dBm	-15 dBm	30 kHz
2.7 MHz ≤ Δf < 3.5 MHz	2.715MHz ≤ f_offset < 3.515MHz	$-14dBm - 15 \cdot \left(\dfrac{f\_offset}{MHz} - 2.715 \right) dB$	-15 dBm	30 kHz
(see note 3)	3.515MHz ≤ f_offset < 4.0MHz	-26 dBm	NA	30 kHz
3.5 MHz ≤ Δf ≤ Δfmax	4.0MHz ≤ f_offset < f_offsetmax	-13 dBm	-13 dBm 4	1 MHz

Assuming a BS Tx power of 43 dBm, the equation of Table 65 gives the SEAMCAT input as presented in XXX and as illustrated in Figure 380.

Note that for this example, we add the limit from Recommendation ITU-R SM.329 for frequency offset above 12.5 MHz [2].

Table 65: Example of derivation of 3GPP spectrum emission mask into a SEAMCAT input format (with addition of the ITU-R Rec. SM.329 limit)

Frequency offset of measurement filter -3dB point, Δf	Minimum requirement Band VIII	SEAMCAT (in ref/measurement bandwidth)	Measurement bandwidth
2.5 MHz ≤ Δf < 2.7 MHz	-14 dBm	43 – (-14) = 57	30 kHz
2.7 MHz ≤ Δf < 3.5 MHz	$-14dBm - 15 \cdot \left(\dfrac{f\_offset}{MHz} - 2.715 \right) dB$	Linear	30 kHz
(see note 3)	-26 dBm	43 – (-26) = 69	30 kHz
3.5 MHz ≤ Δf ≤ Δfmax	-13 dBm	43 – (-13) = 56	1 MHz
Above 12.5 MHz (ITU-R SM.329)	-36 dBm	43 – (-36) = 79	100 kHz
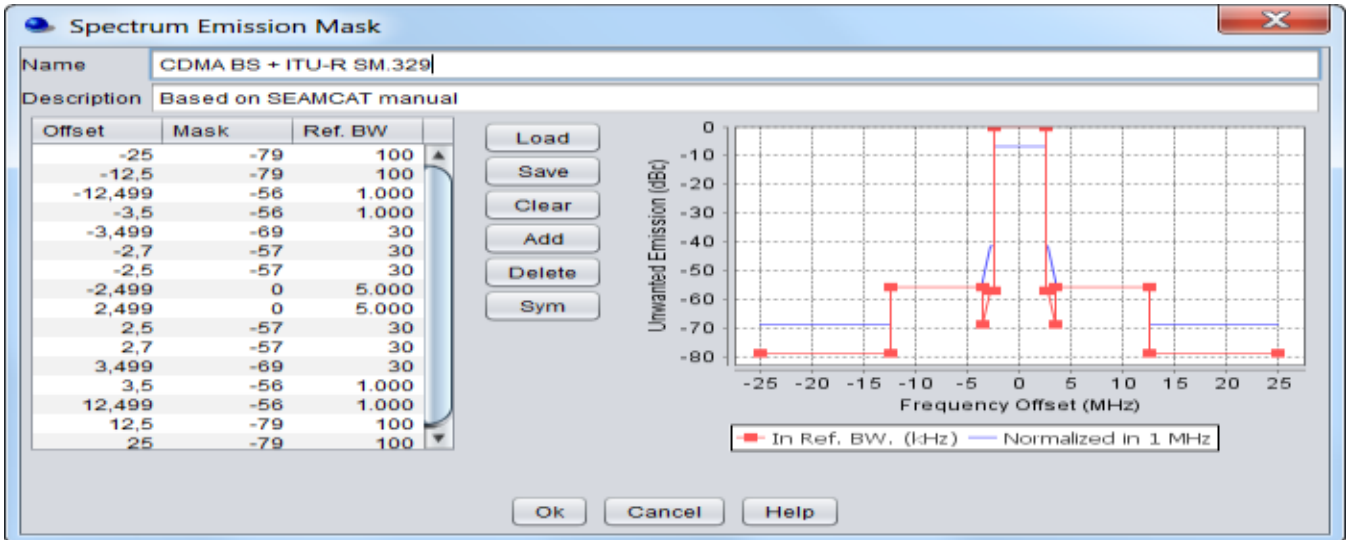
Figure 380: Illustration of the spectrum emission mask at the BS used in SEAMCAT and its derivation from the 3GPP specification and ITU-R SM.329 (for frequency offset larger than 12.5 MHz within the spurious emission domain in the frequency range 30 to 1000 MHz).

A7.7.2 UE example

As an example of a UE spectrum emission masks (i.e. CDMA UL as interferer), TS 25.101 [3] indicates that the power of any UE emission shall not exceed the levels specified in Table 66.

Table 66: Spectrum Emission Mask Requirement

Δf in MHz (Note 1)	Minimum requirement		Measurement bandwidth
	Relative requirement	Absolute requirement	
2.5 - 3.5	$\left\{-35-15\cdot\left(\dfrac{\Delta f}{MHz}-2.5\right)\right\}dBc$	-71.1 dBm	30 kHz (Note 2)
3.5 - 7.5	$\left\{-35-1\cdot\left(\dfrac{\Delta f}{MHz}-3.5\right)\right\}dBc$	-55.8 dBm	1 MHz (Note 3)
7.5 - 8.5	$\left\{-39-10\cdot\left(\dfrac{\Delta f}{MHz}-7.5\right)\right\}dBc$	-55.8 dBm	1 MHz (Note 3)
8.5 - 12.5 MHz	-49 dBc	-55.8 dBm	1 MHz (Note 3)
Note 1: Δf is the separation between the carrier frequency and the centre of the measurement bandwidth. Note 2: The first and last measurement position with a 30 kHz filter is at Δf equals to 2.515 MHz and 3.485 MHz. Note 3: The first and last measurement position with a 1 MHz filter is at Δf equals to 4 MHz and 12 MHz.			

Table 66 provides directly the values in dBc which are also the format for the SEAMCAT input. Therefore the values from Table 66 translate into SEAMCAT as illustrated in Figure 381.

Offset (M...	Mask (dBc)	Ref. bw (k...
-25	-57	100
-12,5	-57	100
-12,499	-49	1.000
-8,5	-49	1.000
-8,499	-49	1.000
-7,5	-39	1.000
-7,499	-39	1.000
-3,5	-35	1.000
-3,499	-50	30
-2,5	-35	30
-2,499	0	5.000
2,499	0	5.000
2,5	-35	30
3,499	-50	30
3,5	-35	1.000
7,499	-39	1.000
7,5	-39	1.000
8,499	-49	1.000
8,5	-49	1.000
12,499	-49	1.000
12,5	-57	100
25	-57	100
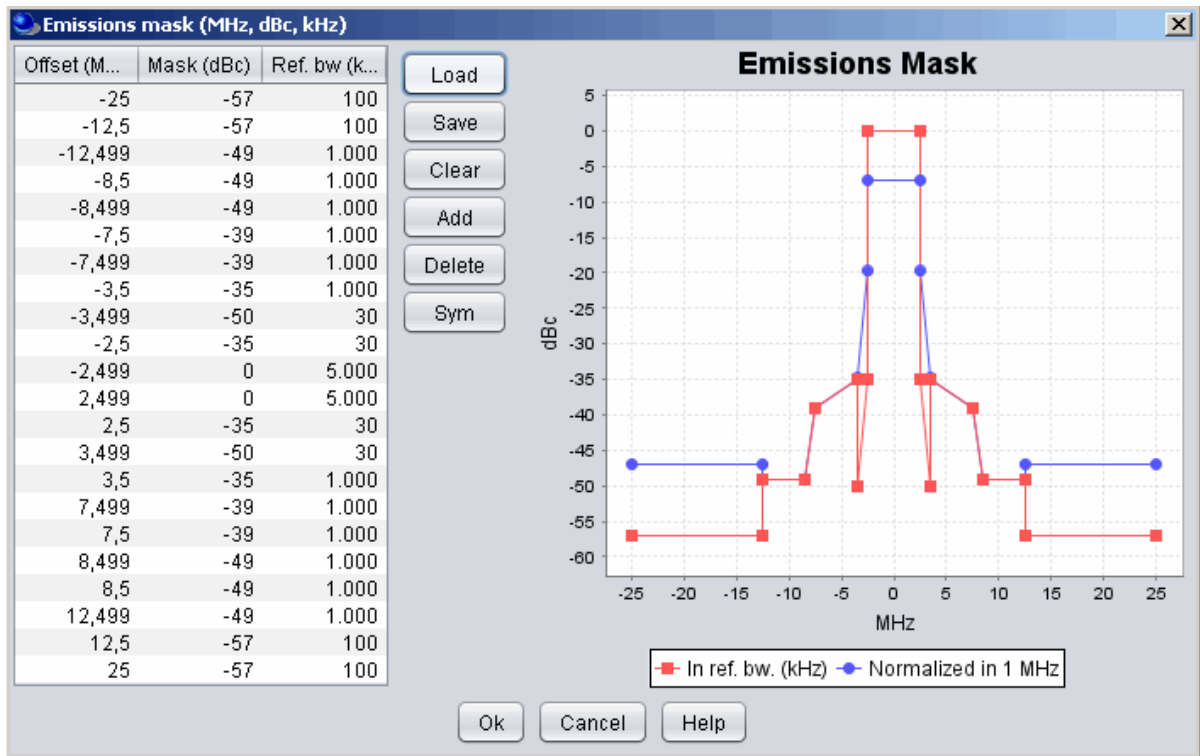
Figure 381: Illustration of the spectrum emission mask at the UE used in SEAMCAT and its derivation from the 3GPP specification and ITU-R SM.329 (for frequency offset larger than 12.5 MHz within the spurious emission domain in the frequency range 30 to 1000 MHz)
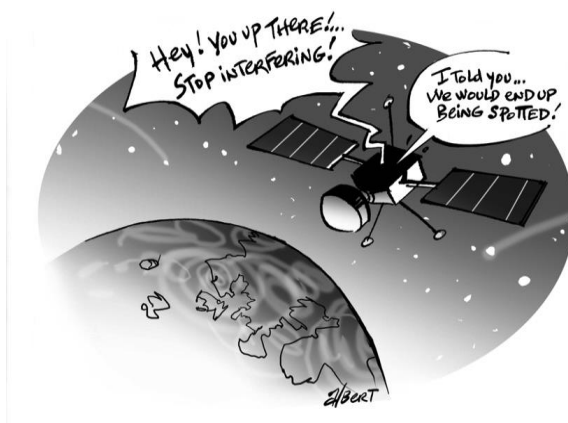
ANNEX 8: RECEIVER SELECTIVITY AND BLOCKING ATTENUATION

A8.1 BASIC CONCEPT

The receiver captures capturing some unwanted signals outside its own channel bandwidth because its filter is not ideal.
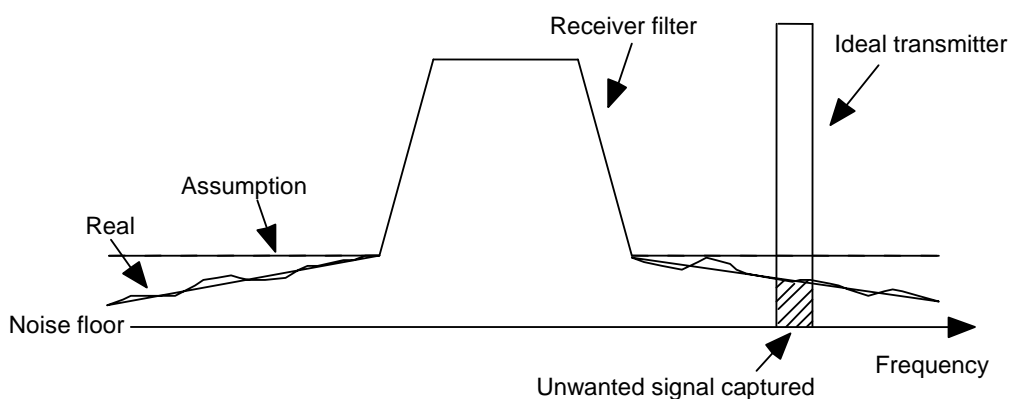
Figure 382: Illustration of the non-ideal receiver filter with respect to an ideal interfering link transmitter

For generic systems, SEAMCAT provides three modes of considering the impact due to blocking (see Section 4.2):

1. User-defined:the values of the blocking mask are expressed directly as a Blocking response (filter selectivity) in relative positive values (dB) (see **Figure 12**);
2. Protection ratio:
   the values of the blocking mask are expressed in relative positive values (dB);
   SEAMCAT considers the underlying protection criterion applied by the measurement procedure of used in typical standards when calculating the resulting blocking response
3. Sensitivity:
   the values of the blocking mask are expressed in absolute power levels (dBm);
   SEAMCAT considers the underlying protection criterion applied by the measurement procedure used in typical standards when calculating the resulting blocking response

For cellular systems, if blocking is spsecified as ACS (Adjacent Channel Selectivity), then it is effectively the same as the User-defined mode for generic systems.

In all cases SEAMCAT perceives receiver blocking as a mask, which is a function of frequency separation between interfering and desired signals $\Delta f=(f_{ILT}-f_{VLR})$, however you may also specify a constant value of blocking across the whole frequency range.
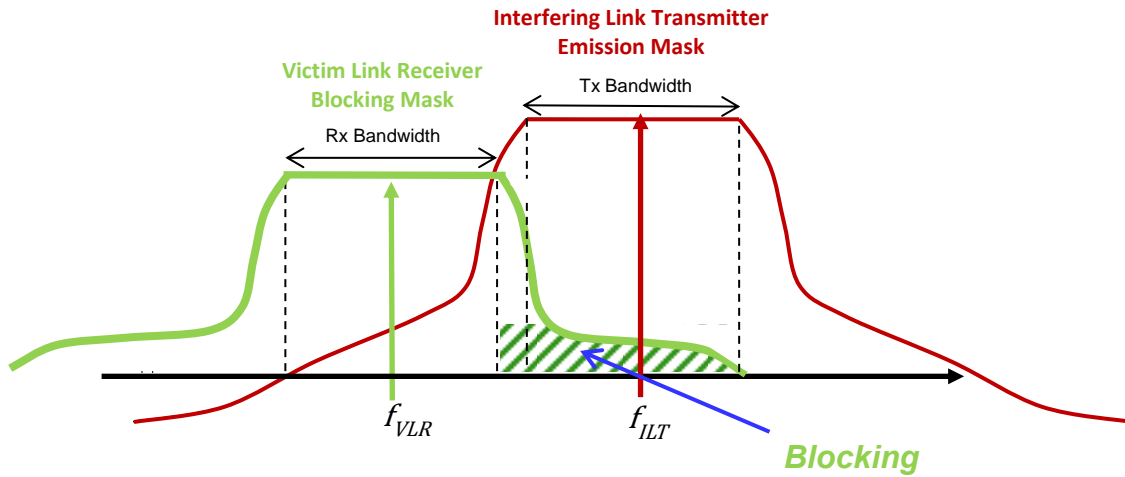
Figure 383: Blocking

When calculating the value iRSS_blocking, SEAMCAT applies the obtained receiver attenuation value a_VLR to the full power of the interfering signal and will consider the resulting power (interfering signal at receiver input less blocking attenuation) as in-channel noise floor increase of the VLR.

In practice, SEAMCAT integrates the interfering signal captured by the receiver, excluding the part of the interfering signal falling into the necessary bandwith of the receiver[4]). For this integration, both the bandwidth of the interferer and the bandwidth of the victim are taken into account.

A8.2 SCHEMATIC DESCRIPTION OF THE IRSS_BLOCKING ALGORITHM

This section describes the algorithm to be used to calculate iRSS_blocking depending on the overlap between the bandwidths of VLR and ILT. There are in total 5 main cases (see sections A8.2.1 to A8.2.5). For the details on the implementation of the integral, see section A8.2.6.

A8.2.1 Case 1: No overlap
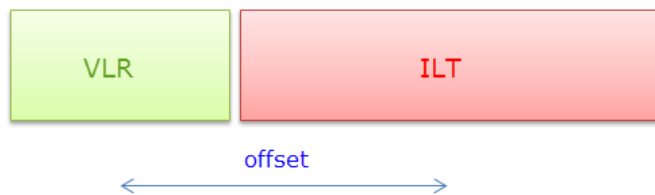
Figure 384: iRSS_blocking case 1: no overlap

$$blocking = \int_{i=lower}^{upper} maskValue_i \cdot dF$$

where:

lower: offset - BW_{ILT}/2 – emission mask asymmetry[5]
upper: lower + BW_{ILT}
dF: step size, e.g. min{0.1;(BW_{ILT})/20}

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[4] This algorithm was introduced in SEAMCAT 5.0.1
[5] requires the bounds of the bandwidth

A8.2.2 Case 2: Partial overlap with $f_{ILT} > f_{VLR}$
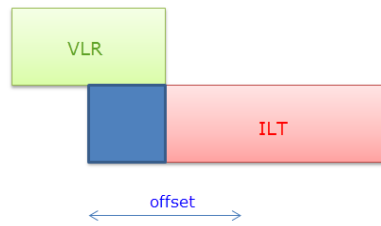
Figure 385: iRSS_blocking case 2: partial overlap with $f_{ILT} > f_{VLR}$

Note: the blue coloured range is covered by the iRSS_unwanted calculation and therefore not taken into account in the iRSS_blocking calculation.

$$blocking = \int_{i=lower}^{upper} maskValue_i \cdot dF$$

where:

lower: $BW_{VLR}/2$
upper: offset + $BW_{ILT}/2$ – emission mask asymmetry
dF: step size, e.g. min{0.1;(BWILT)/20}

A8.2.3 Case 3: Partial overlap with $f_{ILT} < f_{VLR}$
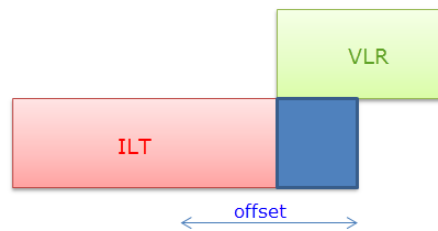
Figure 386: iRSS_blocking case 3: partial overlap with $f_{ILT} < f_{VLR}$

Note: the blue coloured range is covered by the iRSS_unwanted calculation and therefore not taken into account in the iRSS_blocking calculation.

$$blocking = \int_{i=lower}^{upper} maskValue_i \cdot dF$$

where:

upper: - $BW_{VLR}/2$
lower: – offset - $BW_{ILT}/2$ – emission mask asymmetry
dF: step size, e.g. min{0.1;(BW_{ILT})/20}

A8.2.4 Case 4: Total overlap with BW$_{VLR}$ < BW$_{ILT}$
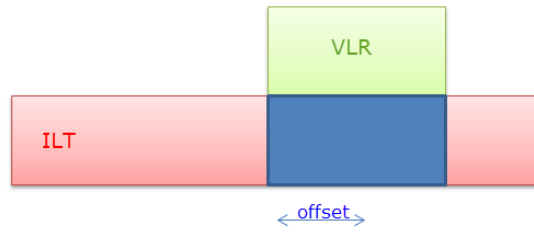
Figure 387: iRSS_blocking case 4: Total overlap with BW$_{VLR}$ < BW$_{ILT}$

Note: the blue coloured range is covered by the iRSS_unwanted calculation and therefore not taken into account in the iRSS_blocking calculation.

$$blocking = \int_{\substack{i=lower \\ \frac{BW_{VLR}}{2} < i < -\frac{BW_{VLR}}{2}}}^{upper} maskValue_i \cdot dF$$

where:

lower: offset - BWILT/2 – emission mask asymmetry
upper: lower + BWILT
dF: step size, e.g. min{0.1;BWVLR/5} 1)
           excluding the range fVLR ± BWVLR/2

Note that at least 3 samples are required for the range f$_{VLR}$ ± BW$_{VLR.}$

A8.2.5 Case 5: total overlap with BWVLR > BWILT
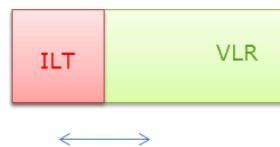
Figure 388: iRSS_blocking case 5: total overlap with BW$_{VLR}$ > BW$_{ILT}$

In this case, there is no blocking as the interference is completely covered by the unwanted calculation. The blocking attenuation is therefore set to 1000 dB.

A8.2.6 Implementation of the integral for iRSS_blocking

The integral requires positive values of the blocking mask, i.e. the blocking mode has to be considered first.

$$a_{blocking} = -10 * log_{10}\left(\sum_{f=lower}^{n \cdot dF} \frac{10^{\frac{-maskValue_f}{10}}}{BW_{ILT}} \cdot dF \right)$$

where:

$$n = \frac{range}{dF}$$

    and

$$range = upper - lower$$

The parameter maskValue(f) corresponds to the following equations (see section 1.4.6).

▪ For generic systems in user-defined mode, it corresponds to the mask specified in the receiver settings;

  maskValue(f) = BlockUD (dB).

▪ For generic systems defined with blocking modes different to user-defined (i.e. sensitivity and protection ratio);

  ▪ *Protection Ratio (dB):*

  maskValue(f) = *BlockPR (dB) + C/(N+I) (dB) + (N+I)/N (dB) - I/N (dB)*

  ▪ Sensitivity Mode (dBm):

  maskValue(f) = BlockSens (dBm) – SensitivityVLR (dBm) + C/(N+I) (dB) – I/N (dB)

▪ For cellular systems:
  ▪ If the mask is defined in positive values (ACS), then maskValue(f) corresponds to the mask specified in the receiver settings;
  ▪ If the mask is defined in negative values, then maskValue(f) corresponds to the calculated positive mask using the input parameters Standard Desensitization and I/N_target (see section A8.2.8).

A8.2.7 Considerations on the bandwidths used in the integral

Calculation of BW for GENERIC systems

The algorithm is based on the mask entries and takes the values as relative to the carrier (dBc) at the zero offset.
It consists of two loops, one for the upper part of the mask, the second for the lower part.

The loops stop if the relative power of the actual offset is less than the limit .

The lower and upper bound are saved as they are required by the calculation algorithm so that the blocking average takes account of symmetrical emission masks.

Calculation of BW for OFDMA

For a **Base Station**: the total number of resource blocks (max. RBs per BS) multiplied by the bandwidth of one resource block.

For a **User Equipment**: the bandwidth is: the number of RBs per MS (UE) multiplied by the bandwidth or one resource block.

Calculation of BW for CDMA

The algorithm uses the reference bandwidth of the system, which is the same for either BS or UE (user defined in CDMA general settings). .

A8.2.8 Conversion of negative blocking mask values in cellular receivers (OFDMA and CDMA)

In case of receivers of cellular systems (OFDMA and CDMA), if the mask has negative values, it needs to be converted using the following input parameters in the receiver settings:

▪ Standard desensitisation (for which the blocking mask values where derived);
▪ Target I/N (which depends on the scenario considered and can be extracted from the CEPT/ECC or ITU-R deliverables).

If the mask is entered as positive values then these parameters are not used.
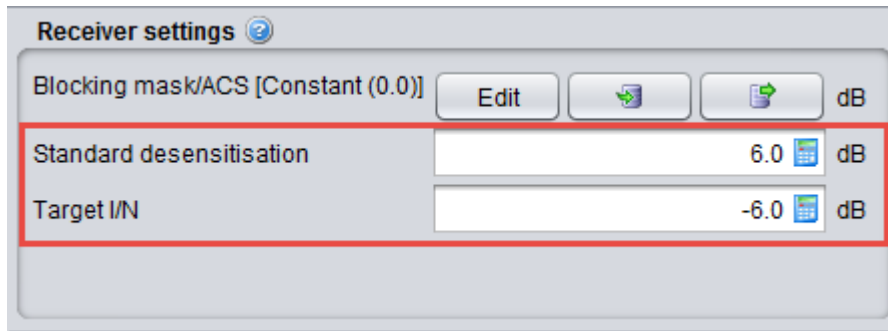
Figure 389: Input parameters for cellular receivers blocking masks

Default values of standard desensitisation and Target I/N are specified in the table below.

Table 67: Default values of standard desensitisation and Target I/N

	Standard Desensitization (dB)	Target I/N (dB)
OFDMA UL	**+6**	**-6**
OFDMA DL	**+6**	**-6**
CDMA UL	**+6**	**-6**
CDMA DL	**+3**	**-6**

The algorithm to convert negative blocking mask values is as follows:

$$\text{Blocking Response} = I_{OOB\_target} - \text{Noise floor} - I/N_{target}$$

where:

- I/N_{target} is always understood as 'target I/N of the victim', which is calculated for D_target (target desensitisation)
- Noise floor = 10*log(kTB) + F.
    - K= Boltzmann Constant
    - T = Noise temperature (Kelvin)
    - B = Receiver bandwidth in MHz
    - F = Noise Figure (dB)
    - I_{OOB_target} is calculated as follows :

$$I_{OOB\text{-}TARGET} = I_{OOB\text{-}STANDARD} - D_{STANDARD} + D_{TARGET}$$

where:

- $I_{OOB\text{-}STANDARD}$ = is the original blocking mask;
- $D_{STANDARD}$ = is the standard desensitisation for which the blocking mask values ($I_{OOB\text{-}STANDARD}$) were derived. It is an input of cellular receiver settings (see Figure 389).
- D_{TARGET} = 10*log10(10^(I/N_target/10)+1) ; where I/N_target is an input of cellular receiver settings.

Finally we obtain:

$$\text{Blocking Response} = I_{OOB\text{-}TARGET} - \text{Noise floor} - I/N_{target}, \textbf{which means:}$$

$$\text{Blocking Response} = I_{OOB\text{-}STANDARD} - D_{STANDARD} + D_{TARGET} - kTBF - I/N_{target}$$

A8.3 USER-DEFINED MODE

In this case, the receiver attenuation is a direct input with positive values in dB. Therefore SEAMCAT will take the receiver attenuation $a_{VLR}(\Delta f)$ values directly from the function (might be also constant value) that you entered.

$$a_{VLR}(\Delta f) = block_{Use\ defined}\ (\Delta f)\ \text{(dB)} \qquad \text{(Eq. 123)}$$

where $\Delta f = (f_{ILT} - f_{VLR})$
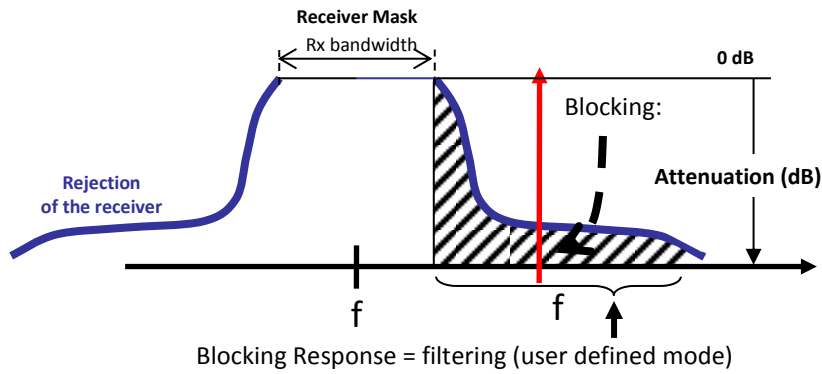
Figure 390: Illustration of blocking and the associated Blocking Response in a user defined mode
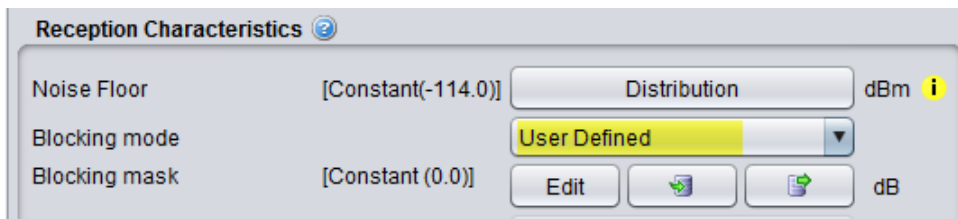
Figure 391: Setting up the blocking response in the user-defined mode

A8.4 PROTECTION RATIO

In this case, SEAMCAT takes the positive values of the blocking mask and considers the underlying measurement procedure (see for instance ETSI EN 300 113 (section 9 therein)) by this calculation:

$$a_{VLR}(\Delta f) = block_{protection_{ratio}}(\Delta f) + \frac{C}{N+I} + \frac{N+I}{N} - I/N \qquad \text{(Eq. 124)}$$

where

$block_{protection_{ratio}}$ the positive values in dB from the mask (2)
C/(N+I), (N+I)/N and I/N   the input parameters of the VLR
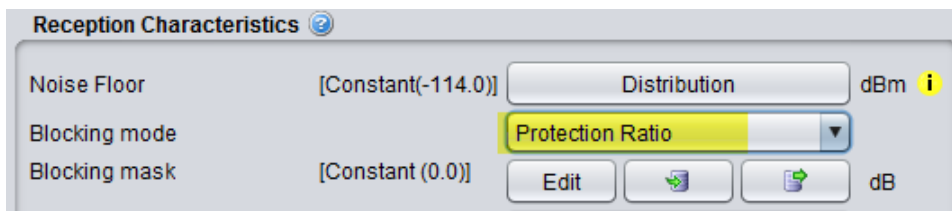
Figure 392: Setting up the blocking response in the Protection ratio mode

A8.5 SENSITIVITY

Similar to the Protection ratio mode, SEAMCAT calculates the resulting blocking response by

$$a_{VLR}(\Delta f) = block_{sensitivity}(\Delta f) - sensitivity_{VLR} + \frac{C}{N+I} - I/N \qquad \text{(Eq. 125)}$$

where

$block_{sensitivity}$	the absolute power limit in (mostly negative) dBm from the mask (2)
$sensitivity_{VLR}$	the input parameters of the VLR (3)
C/(N+I) and I/N	the input parameters of the VLR.
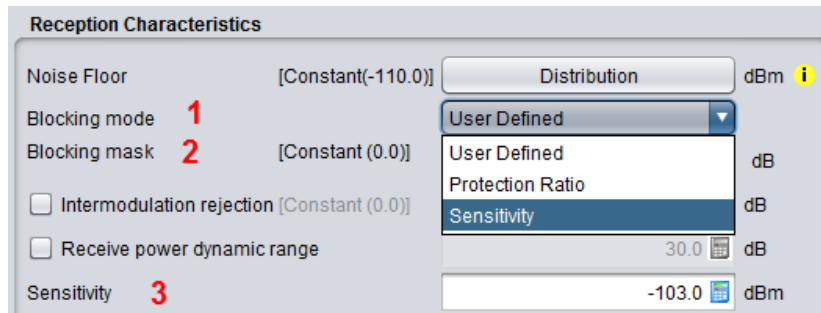
Figure 393: Setting up the blocking response in the *sensitivity* mode

A8.6 BLOCKING LEVEL MEASUREMENTS

To calculate the receiver attenuation in blocking response modes, the fundamental relationships between receiver sensitivity, wanted signal, unwanted signal (i.e. the interfering signal) and noise floor need to be established, based on the principle of measuring blocking as a level of adjacent interfering signal which results in reduction of output power from modulated useful signal by a certain limit.

This limit of acceptable wanted signal degradation is assumed to be 3 dB, based on suggestion in ITU-R SM.332-4 and the blocking measurement procedure described in ETSI EN 300 113. The latter procedure is briefly summarised as follows (see Figure 394):

- The ***wanted signal*** (Generator A) is switched on, tuned at receiver frequency and its level is adjusted to the level of maximum useable sensitivety of the receiver, which corresponds to BER=10^{-2} at the receiver output. The level of wanted signal is then further increased by 3 dB;
- The ***unwanted signal*** is added by switching on Generator B, with given frequency shift from receiver frequency, and its output level is first increased until a BER=10^{-1} or worse is obtained; then decreased again until the BER=10^{-2} is re-attained at the receiver output;
- The corresponding level of unwanted signal is noted. ***The "blocking" ratio is then expressed as ratio, in dB, of the level of unwanted signal to the level of wanted signal***;
- Test is repeated for other frequency shifts Δf.
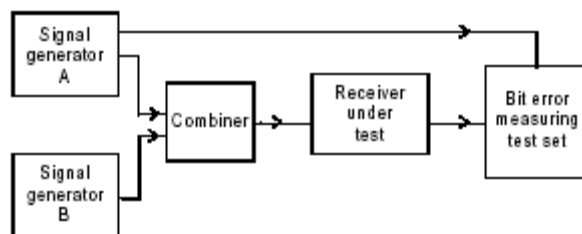
Figure 394: Blocking measurement arrangement (from ETSI EN 300 113)

A8.7 RECEIVER ATTENUATION AS ELEMENT OF BLOCKING RESPONSE

Based on the definition and measurement procedure of blocking, it is possible to obtain the receiver attenuation parameter $a_{VLR}(\Delta f)$ from the following fundamental relationships between wanted and unwanted signals, receiver sensitivity and noise, as observed when blocking event is triggered:
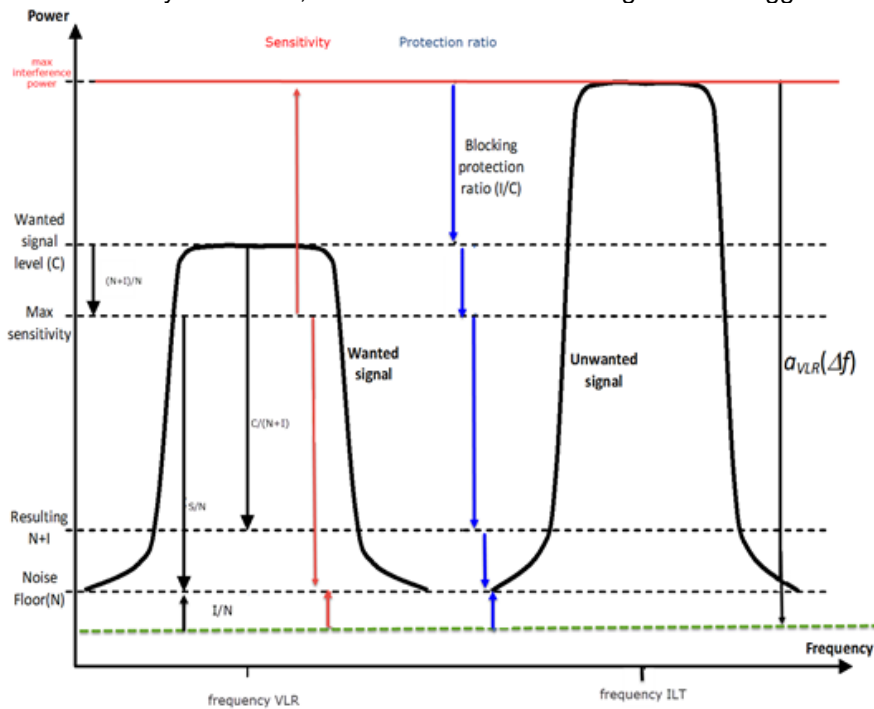
Figure 395: Relationship between signal levels when blocking occurs (Protection Ratio and Sensitivity modes)

Note: the coloured arrows show the relationship of the input parameters used for the calculation of the resulting blocking response ($a_{VLR}(\Delta f)$) and described in the sections above.

Examples:
VLR	noise floor:	-114 dBm
	sensitivity:	-98 dBm
	C/(N+I):	16 dB
	I/N:	-6 dB
	(N+I)/N	1 dB

a)   blocking mode "Sensitivity"
   limit: **-45 dBm**

$$a_{VLR}(\Delta f) = limit - sensitivity + \frac{C}{N+I} - \frac{I}{N}$$
$$a_{VLR}(\Delta f) = -45\ dBm - (-98)dBm + 16\ dB - (-6)dB$$
$$a_{VLR}(\Delta f) = 75\ \text{dB}$$

b)   blocking mode "Protection ratio"
   limit: **52 dB**

$$a_{VLR}(\Delta f) = limit + \frac{N+I}{N} + \frac{C}{N+I} - \frac{I}{N}$$
$$a_{VLR}(\Delta f) = 52\ dB + 1\ dB + 16\ dB - (-6)dB$$
$$a_{VLR}(\Delta f) = 75\ \text{dB}$$
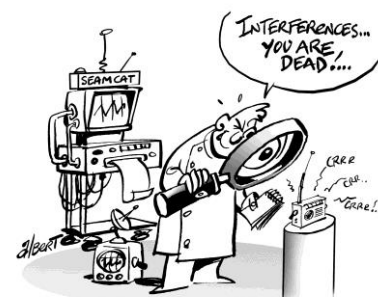
A8.8 CDMA / OFDMA SIMULATION: MULTIPLE ACS

Editors note: this section may be reviewed due to future updates in the implementation

As pointed out on the introduction to this Annex, the implemented algorithm for the calculation of the impact due to blocking supposes a constant (flat) shape of the blocking mask over the complete bandwidth of the interfering system. This approach might cause inaccuracies, in particular in case of larger bandwidths of the ILT.

When simulating cellular environment like LTE, the 3GPP standard provides different ACS values depending on the bandwidth of the interferer. For instance, it is known that LTE can support flexible channel bandwidth, 1.4MHz, 3MHz, 5MHz, 10MHz, 15MHz and 20MHz. Therefore, in order to be able to deal with more LTE co-existence scenarios in the future, it is unavoidable to support scenarios with different bandwidth interferers.

SEAMCAT is basically able to handle such a case. You may define scenario specific blocking masks, that means for each combination of VLR and ILT frequency allocations separate masks. Some guidance is given by e.g. ETSI TR 136 942 V12.0.0 (2014-10) on section 12.1.3.2. You should exercise caution and not mixing the ACIR (Adjacent Channel Interference Ratio) the standard is talking about with the blocking values required for the SEAMCAT masks.

A8.8.1 ACS mask definition for interfers with different bandwidths

Let's assume the following example of two interferers with two distinct bandwidths (10MHz and 5 MHz) which results in two ACS values. For this you would need to introduce an ACS "mask" so that it is defined at the specific interference frequencies for various interfering bandwidth and not to a same bandwidth. You need to define the ACS to the left for 10 MHz using the approximation of 3GPP TR36.942 (p75) and you can define the ACS for 5 MHz in the right hand side.
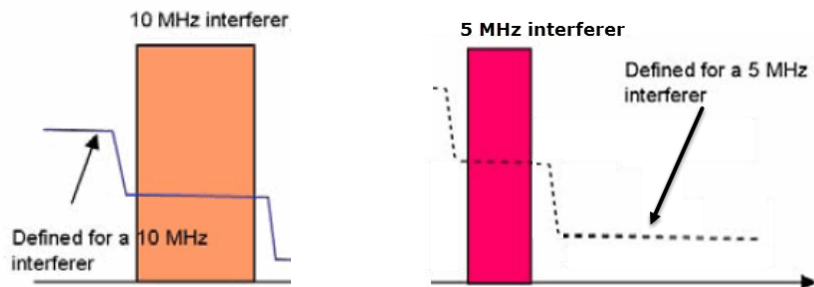
Figure 396: ACS mask examples for two interferers with different bandwidth

In the case where two interferers are geographically separated but transmitting at the same frequency, you can trick SEAMCAT by slightly shifting one of the frequency (a few kHz is enough) so that the value for a specific frequency is used in the simulation (see below).
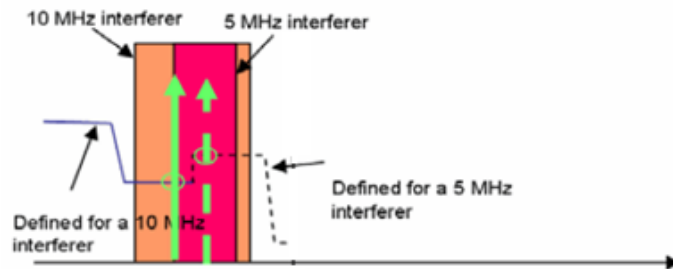
Figure 397: ACS mask definition (Case where two interferers are geographically separated but transmitting at the same frequency)

The only situation, where it would be difficult (but still feasible) is when the interfering frequency is distributed over a large bandwidth, then you would have to define the "other" ACS value elsewhere in the frequency domain and you may have 1-2 dB difference due to the propagation models (exact value to be assessed of course).

A8.8.2 Calculating the average ACS value

According to 3GPP TR36.942 p75, there are some example calculations of average ACS.

$$\frac{1}{10^{0.1 \times ACS_{average}}} = \frac{1}{40} \times \left(\frac{5}{10^{0.1 \times ACS_1}} + \frac{5}{10^{0.1 \times ACS_2}} + \frac{30}{10^{0.1 \times ACS_3}} \right) \qquad \text{(Eq. 126)}$$
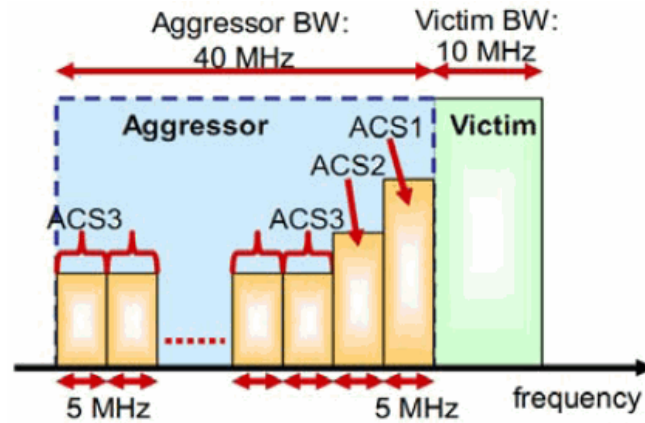
Figure 398: Calculating the average ACS value

ANNEX 9: : EXAMPLE OF RADIO STANDARDS

A9.1 ABOUT 3GPP AND ETSI SPECIFICATIONS

SINR, ACS, blocking levels or intermodulation thresholds are defined by 3GPP/ETSI for a given desensitization. These values are used for compliance testing to the specifications.

As an example, in GSM, tests related to blocking are performed with a desensitization of 20 dB for the two first adjacent channels, and of 3 dB for the following ones. In UMTS and LTE, the following table applies.

	1st adjacent 5 MHz block	Following adjacent 5 MHz blocks	Adjacent narrowband interferer
UMTS BS	6 dB	6 dB	6 dB
LTE BS	6 dB	6 dB	6 dB
UMTS UE	14 dB	3 dB	10 dB
LTE UE	14 dB	6 to 9 dB[6]	13 to 16 dB[6]

Table 68: Desensitization considered for testing ACS and blocking levels

It can be noted that the desensitization considered for testing varies upon the frequency offset, while the network is designed for a unique desensitization. Moreover, in section 7.5.1 of ETSI TS 125 101 and TS 136 101 related to the UE, the desensitization value is explicitly mentioned as a testing parameter.

A9.2 MOBILE COMMUNITY

A9.2.1 Blocking level determination methodology

The blocking parameters of a standard are specified for specific values used for compliance testing, which do not always correspond to typical operational values. In particular, blocking values are specified for desensitization values which may not correspond to the desired operational value for specific studies (e.g. 1 dB for BS and 3 dB for UE). It is therefore sometimes necessary to translate the Blocking Level IOOB-STANDARD defined by the standard for a desensitization DSTANDARD into the corresponding Blocking Level IOOB-TARGET for another desensitization DTARGET.

Coexistence analysis are conducted for a standard that provides a maximum power (Blocking Level) of an interfering signal received outside of the in-band, for a given frequency offset between the wanted signal and the interfering signal. This absolute blocking level IOOB-STANDARD is specified in the standard for a specific desensitization DSTANDARD. This is the case for the blocking specifications in UMTS and LTE standards (ETSI TS 125 101, TS 125 104, TS 136 101 and TS 136 104). It is also the case for the blocking specifications for the 3rd adjacent channel and the following ones in GSM (ETSI TS 145 005).

For studies considering C/(N+I) protection ratio, an example of blocking specifications for the first 2 adjacent channels can be found in GSM (ETSI TS 145 005).

A9.2.2 Derivation of blocking from a noise floor rise

When an interfering signal I$_{OOB}$ is applied to the RF input of a receiver outside of the receiver's bandwidth, the receiver will be interfered due to the non-perfect selectivity of the receiver's filter. However, the receiver's filter attenuate the interfering signal I$_{OOB}$ into an 'equivalent in-band interfering signal' I$_{IB}$.

---

[6] Depending on the LTE channel width

The receiver Blocking Response is defined as the receiver filter attenuation of signals outside of receiver's channel/band (in dB):

$$Blocking\ Response = I_{IB} - I_{OOB}$$

The present section derives the receiver Blocking Response from the Blocking Level specified in the standard.

Starting from:

$$D_{STANDARD} = 10.log_{10}[(i_{IB-STANDARD} + n)/n] \tag{Eq. 127}$$

$I_{IB-STANDARD}$ can be derived from the following equation in dB:

$$I_{IB-STANDARD} = N + 10.log_{10}[10^{\wedge}(D_{STANDARD}/10) - 1] \tag{Eq. 128}$$

noting that $i_{IB} / n = [(i_{IB} + n) / n] - 1 = 10^{D/10} - 1$

Blocking Response is then derived by the following equation:

$$Blocking\ Response = I_{IB-STANDARD} - I_{OOB-STANDARD} \tag{Eq. 129}$$

$$= N + 10.log_{10}[10^{\wedge}(D_{STANDARD}/10) - 1] - I_{OOB-STANDARD} \tag{Eq. 130}$$

From the Blocking Response, it is possible to derive the receiver Blocking Level for another value of desensitization.

In order to derive this new receiver Blocking Level, we assume that the Blocking Response is constant and fully linear over the complete range of desensitization from 0 to $D_{STANDARD}$.

$I_{IB-TARGET}$ can be derived from the following equation:

$$I_{IB-TARGET} = N + 10.log_{10}[10^{\wedge}(D_{TARGET}/10) - 1] \tag{Eq. 131}$$

$I_{OOB-TARGET}$ can be derived from the following equation:

$$I_{OOB-TARGET} = I_{IB-TARGET} - Blocking\ Response \tag{Eq. 132}$$

$$I_{OOB-TARGET} = 10.log_{10}[10^{\wedge}(D_{TARGET}/10) - 1] - 10.log_{10}[10^{\wedge}(D_{STANDARD}/10) - 1] + I_{OOB-STANDARD} \tag{Eq. 133}$$

$$I_{OOB-TARGET} = I/N_{TARGET} - I/N_{STANDARD} + I_{OOB-STANDARD} \tag{Eq. 134}$$

A9.2.3 Derivation from a protection ratio

This is the case for GSM, with regards to the 2 first adjacent channels.

In ETSI TS 145 005, Table 6.3-1 in section 6.3, protection ratios are specified in dB for a desensitization $D_{STANDARD}$ of 20 dB (see section 6.1).

- Co-channel, $[C/Ic]_{dB}$[7] = C - Ic = 9 dB
- First adjacent channel, $[C/Ia1]_{dB}$[7] = C - Ia1 = -9 dB
- Second adjacent channel, $[C/Ia2]_{dB}$[7] = C - Ia2 = -41 dB

These are the "blocking protection ratios".

---

[7] It should be noted that the standard refers to C/Ic and C/Ia that are equations in the linear domain, but specifies the values in dB, i.e. in the logarithmic domain.

The Blocking Response is given by the following equation:

$$Blocking\ Response = I_{IB-STANDARD} - I_{OOB-STANDARD}$$ (Eq. 135)
$$= (C - I_{OOB-STANDARD}) - (C - I_{IB-STANDARD})$$ (Eq. 136)
$$= (C - Ia) - (C - Ic)$$

$I_{OOB-TARGET}$ can then be derived from the following equation:

$$I_{OOB-TARGET} = N + 10.log_{10}[10^{\wedge}(D_{TARGET}/10) - 1] + (C - Ic) - (C - Ia)$$ (Eq. 137)

$$\mathbf{I_{OOB-TARGET} = N + I/N_{TARGET} + (C - Ic) - (C - Ia)}$$ (Eq. 138)

A9.3 FIXED SERVICES COMMUNITY

It is often recommended that FS characteristics are to be found in the Rec. ITU-R F.758-4 when FS frequency sharing with aircraft-mounted FSS Earth stations in the band 27.5-29.5 GHz is considered. Note that Rec. ITU-R F.758-4 has also been newly revised; the draft revision is currently in the final stage of being approved and publication of new version F.758-5 is expected soon. As specified in Annex 2 of its Section 4, the system parameters shown are not representative of any actual FS system, but represent an averaging or an expected range of values suitable for generic sharing/compatibility studies.

Stations FS5 and FS6 in the table 1 below have parameters in line with the Rec. ITU-R F.758-5.Also four other representative FS stations FS1, FS2, FS3 and FS4 can be proposed as given in in Table 1. FS1 and FS3 stations are representative of PP FS stations typically deployed, FS2 is representative of a longer than usual link operating in Scotland or Wales where the terrain is mountainous and hence an elevation angle of 5 degrees is appropriate, while FS4 is representative of a P-MP Hub station; P-MP subscriber stations are expected to have parameters similar to those valid for PP stations.

Antenna radiation patterns for FS-PP are usually assumed in sharing studies using the formulas in ITU-R F.699 (when a single FS system is considered as victim/interferer) or F.1245 (when averaging among a number of FS systems as victim/interferer). For P-MP it is recommended to use the ITU-R F.1336.

Table 69: Recommended FS characteristics for FS vs FSS studies

Parameter	FS1 (PP)	FS2 (PP)	FS3 (PP)	FS4 (P-MP)	FS5 (PP based on Rec. ITU-R 758-5)	FS6 (P-MP based on Rec. ITU-R 758-5)	Notes
RX antenna height	20 m	20m	20m	20m	Not specified, 20m is suggested	Not specified, 20m is suggested	
RX antenna pattern	ITU-R Rec. F.1245	ITU-R Rec. F.1245	ITU-R Rec. F. 1245	ITU-R Rec. F.1336	ITU-R Rec. F. 1245	ITU-R Rec. F.1336	Source: Rec F.758-5 (doc 5/BL/24)
Receiver noise figure, F	6 dB	6 dB	6 dB	6 dB	8 dB	8 dB	See note (1)8
RX frequency	28 GHz	28 GHz	28 GHz	28 GHz	24.25 – 29.50 GHz	24.25 – 29.50 GHz	
RX elevation angle	0°	5°	10°	0°	Not specified,	Not specified, 0°	

---

8 The System noise power density shall be obtained from the following equation:
N_0 (dBW/Hz)= F(dB) + 10*log10(kT$_0$)
Where : T_0 = 290 K, F is the noise figure and k is the Boltzmann constant it results:
N_0 (dBW/Hz) = F(dB) − 204 (dBW/Hz) or N_0(dBm/MHz) = F(dB) − 114 (dBm/MHz)

Parameter	FS1 (PP)	FS2 (PP)	FS3 (PP)	FS4 (P-MP)	FS5 (PP based on Rec. ITU-R 758-5)	FS6 (P-MP based on Rec. ITU-R 758-5)	Notes
					10° is suggested	is suggested	
RX peak gain	45 dBi	43 dBi	35 dBi	18 dBi		6.5 dBi	See note (2)9

Table 70: Recommended FS characteristics for FS vs FSS studies

The Spectrum Mask for P-P and P-MP can be found in EN 302 217-2-2 Annex A (table A4) and EN 302 326-2 (Section 5.3.4.1) respectively. Blocking information is available from EN 301 390 (Section 7).

With respect to antenna height for P-P, the BS and TS minimum antenna height are about 20 m and for P-MP, the BS minimum antenna height is about 20 m and the TS minimum antenna height is about 1.5 m.

For the antenna elevation, some countries reported an elevation range of 3 to 10 degree. Note that a range of maximum elevation angle from 15 to 30 degree has been reported in some countries in rare cases.

ECC Report 100 widely uses an I/N ≤ −10 dB; I/N ≤ −6 dB is there mentioned only for the protection of ENG/OB. FS systems (for both P-P and P-MP systems) commonly adopt I/N ≤ −10 dB as ITU-R SG5 has recently confirmed in the draft revision of Rec. F.758-4.

A9.4 SHORT RANGE DEVICES COMMUNITY

This section presents a non exhaustive lis of the basic standards for short range devices where technical parameters may be found.

- EN 300 220: Short Range Devices (SRD); Radio equipment to be used in the 25 MHz to 1 000 MHz; frequency range with power levels ranging up to 500 mW;
- EN 300 422: Wireless microphones in the 25 MHz to 3 GHz frequency range; (Assistive Listing Devices (ALD) standard)
- EN 300 328: Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques; (WLAN standard)
- EN 300 440: Electromagnetic compatibility and Radio spectrum Matters (ERM); Short range devices; Radio equipment to be used in the 1 GHz to 40 GHz frequency range; Part 1: Technical characteristics and test methods

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9 The difference between the peak gain values of stations FS1 and FS2 comes from the fact that a typical PP FS station with high elevation angle (10°) is usually employed for short-range links near hilly areas.

ANNEX 10: DISTRIBUTION
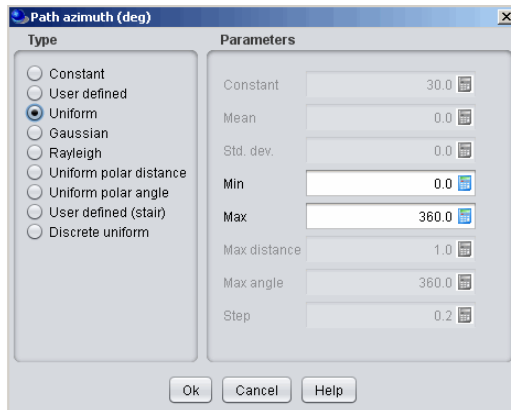
Figure 399: Distribution dialog box

The trials performed on all of the SEAMCAT distributions are based upon using internal Java pseudo-random number generator. All the below distributions are presented with their equations, working range, parameters and ouput result. They can all be tested using the "test distribution" feature (see Section 2.17).

A10.1 CONSTANT DISTRIBUTION

In this case a trial performed on this variable always returns the same constant value (may be integer or floating point)

A10.2 USER-DEFINED DISTRIBUTION

It is a continuous distribution defined by its cumulative distribution function (a distribution with values associated with probability), entered as pairs (x, y=F(x)):

$$F(X_i) = P(X < X_i) = \int_{-\infty}^{X_i} f_x(x)dx \qquad \text{(Eq. 139)}$$

The definition range of the input Prob. is between 0 and 1.

The example of Figure 400 returns frequency that will operate at 901.031 MHz, for another snapshot it will be 902.636MHz, for another one 905.893 MHz etc…
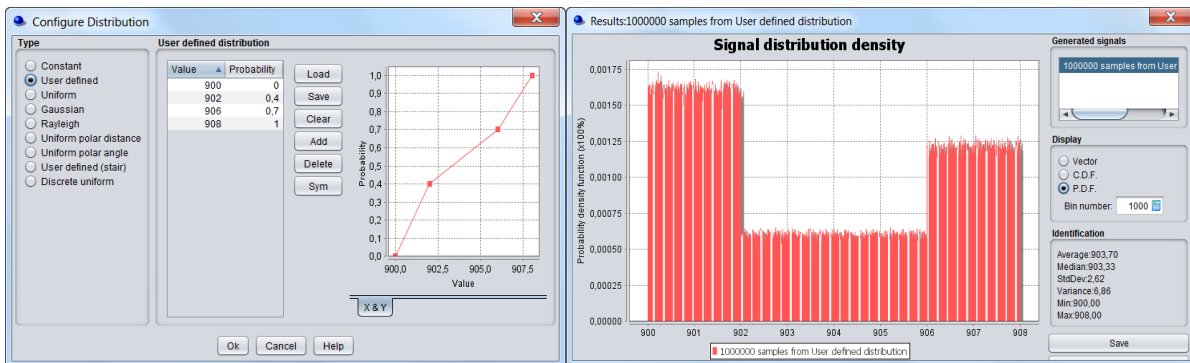
Figure 400: User defined distribution: parameters (left) PDF (right)

A10.3 UNIFORM DISTRIBUTION

It represents a continuous uniform distribution, with given min and max values, and all intermediate values having equal probability:

$$U\left(u_{\min}, u_{\max}\right) = \begin{cases} 1 & if \quad u_{\min} \le x \le u_{\max} \\ 0 & otherwise \end{cases}$$

(Eq. 140)

This example returns frequencies that will operate at 900.937 MHz, for another snapshot it will be 904.916 MHz, etc…
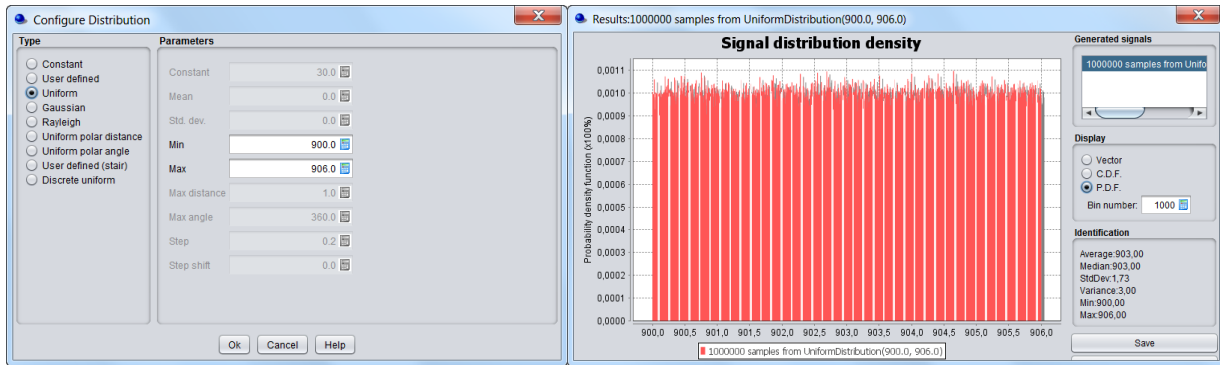
Figure 401: Uniform distribution: parameters (left) PDF (right)

The continuous nature of this function results in that the trial returns double floating point number within the range (min, max) with the same probability (0,1). This means that this function is not suitable e.g. to define frequency hopping pattern, since the latter would usually occur within a set of (pre-defined) discrete channels. Such cases can be modelled using Discrete uniform function described below.

A10.4 GAUSSIAN DISTRIBUTION

It is an ordinary Gaussian (Normal) distribution defined by mean m and standard deviation σ values:

$$G\left(m, \sigma\right) = \frac{1}{\sqrt{2\pi\sigma}} \exp\left(-\frac{\left(x-m\right)^2}{2\sigma}\right)$$

(Eq. 141)
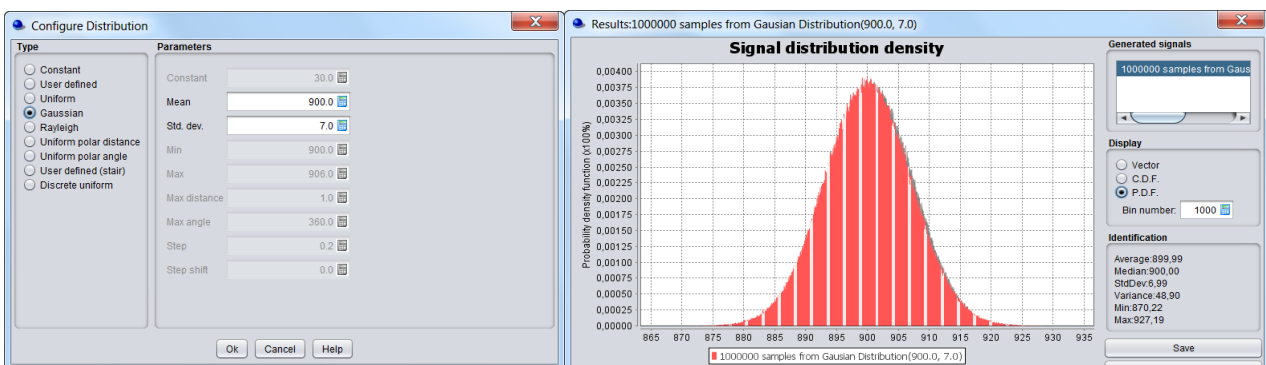
Figure 402: Gaussian distribution: parameters (left) PDF (right)

A10.5 RAYLEIGH DISTRIBUTION

It is an ordinary Rayleigh distribution defined via its min and standard deviation σ values:

$$R(\sigma) = \frac{r}{\sigma^2} \exp\left(-\frac{(r-\min)^2}{2\sigma^2}\right)$$

(Eq. 142)
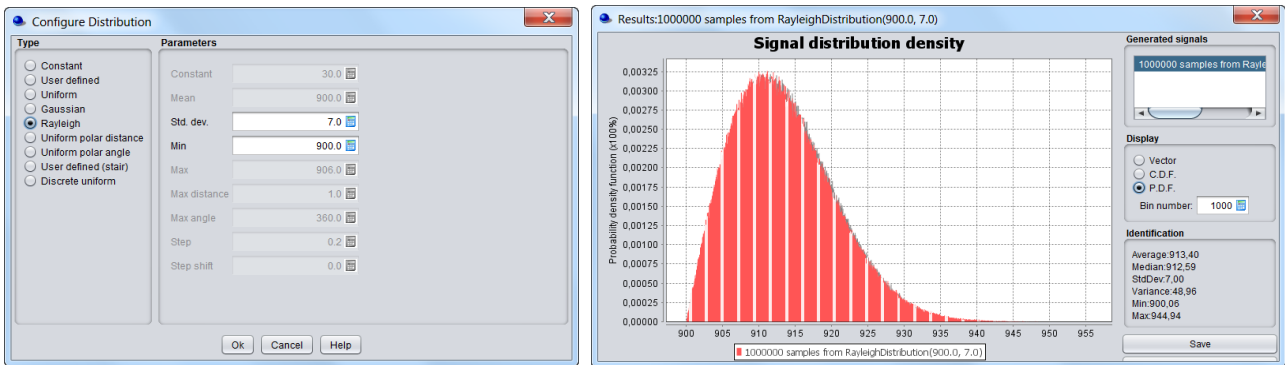
Figure 403: Rayleigh distribution: parameters (left) PDF (right)

A10.6 UNIFORM POLAR DISTANCE DISTRIBUTION

Uniform polar distance is a distribution function designed to define a random positioning of transmitter along the radius of coverage cell R (i.e. all the points are distributed over a circular area defined by max distance with the same probability), to achieve a random uniform distribution of transmitters within a circular area centred around a given zero-point.

This function has one parameter - max distance - and probability of distribution along that distance is defined as:

$$T(D(R)) = R \times \sqrt{T(U(0,1))}$$

(Eq. 143)

The uniform polar distance distribution is typically used for deriving distance factor used in calculation of the relative locations of transceivers within a link and between victim and interfering links. The result of the trial on such a distribution, the distance factor, is then multiplied by a coverage radius or simulation radius. Hence the default maximum value of R is set to 1, meaning that after multiplication of this random factor with the radius value, the resulting distance will be distributed uniformly along the entire coverage/simulation radius.

Note that this is equivalent to defining a uniform density of transmitters on a circular area together with uniform polar angle (with 360 deg) or uniform distribution in the angle domain (0,360 deg).
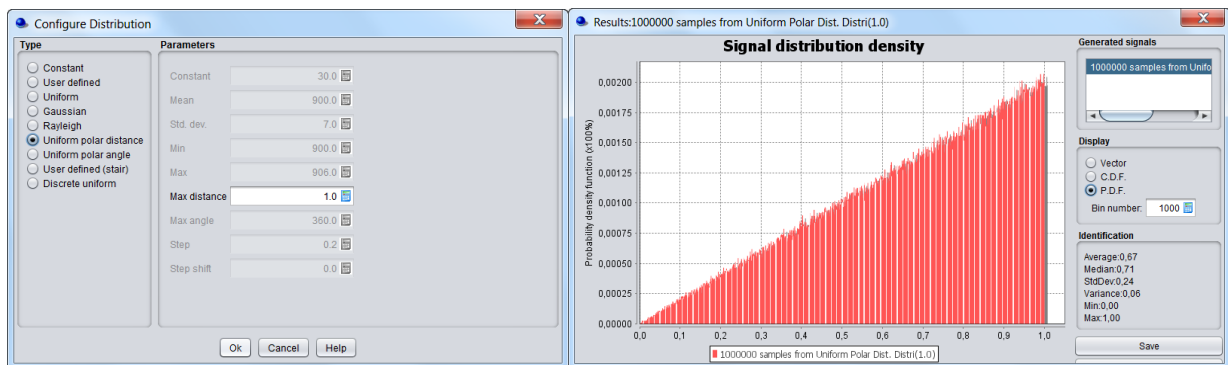
Figure 404: Uniform polar distance distribution: parameters (left) PDF (right)

A10.7 UNIFORM POLAR ANGLE DISTRIBUTION

The uniform polar angle is to be used along with "Uniform polar distance", this function is designed to describe a uniform distribution of transmitters within a circular area centred around a given zero-point. But whereas "Uniform polar distance" describes random distance to centre point, the "Uniform polar angle" function defines random angle (azimuth) of transmitter with regards to centre point.

This function has one input parameter - maximum angle A_{max} - and the generated random values will be placed with equal probability (uniform distrbution function) within the range $-A_{max}...A_{max}$.

This distribution is similar to uniform distribution but in the angle domain.
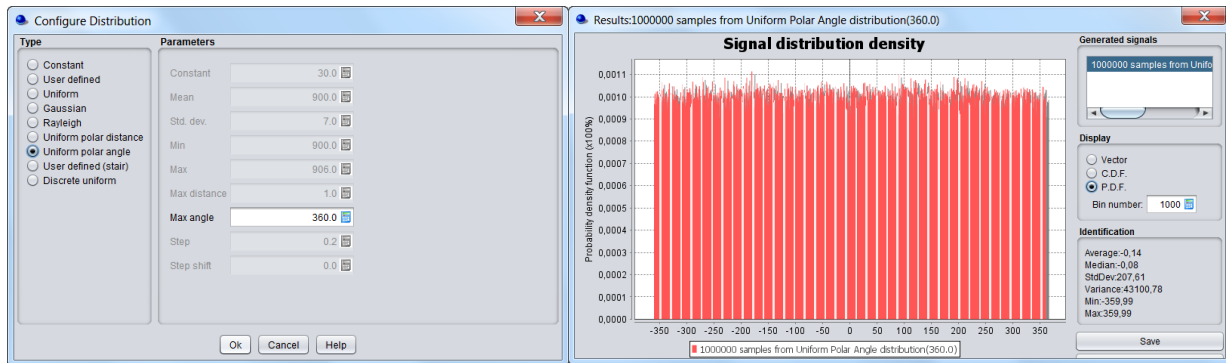
Figure 405: Uniform polar angle distribution: parameters (left) PDF (right)

A10.8 USER-DEFINED (STAIR) DISTRIBUTION

The user-defined (stair) is the discrete alternative of continuous User-defined function described above. The Stair function is defined through a discrete set of values $X_i, i = 1...N$ and associated probabilities $S(X_i)$. This is the pair of set $(X_i, S(X_i))$ where X_i represents all possible values that might be assigned to the variable, whereas $S(X_i)$ represents their cumulative probabilities:

$$S(X_i) = \sum_{j=1}^{i} P(X_i)$$

(Eq. 144)

Such a distribution will be entered in form of a list of couples $(X_i, S(X_i))$. Entering such a distribution in cumulated form allow to control that the sum of the probabilities is equal to 1.

The definition range of the input Cum. Prob. $(S(X_i))$ is (0, 1)

This example returns frequencies that will operate at 904 MHz, for another snapshot it will be 902 MHz, etc...
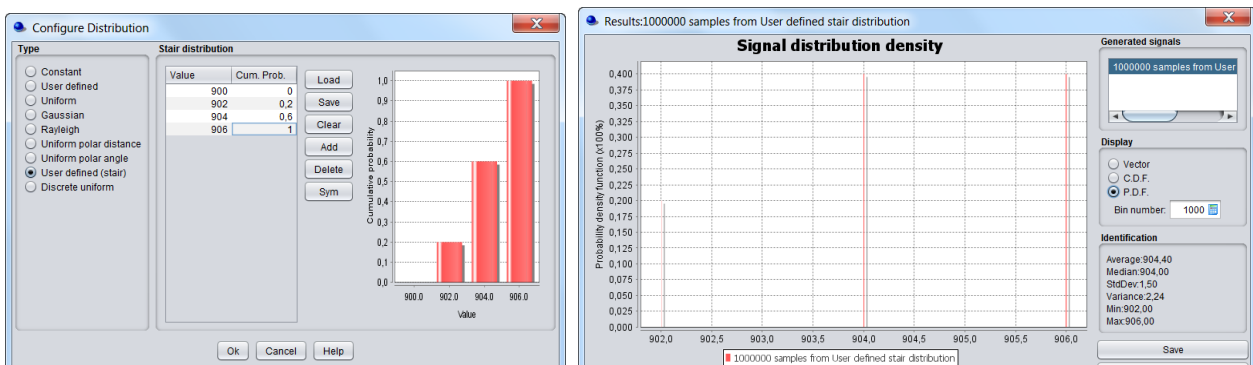
Figure 406: User defined (stair): parameters (left) PDF (right)

A10.9 DISCRETE UNIFORM DISTRIBUTION

The discrete uniform is the discrete alternative of the Uniform distribution described above. The Discrete uniform distribution is defined by the following parameters:

- Lower bound X_{min} of the distribution;
- Upper bound X_{max} of the distribution;
- Step S (e.g. channel spacing in the case of frequency distributions);
- Step shift Ss (e.g. to set the step values to the centre frequency of the channel).
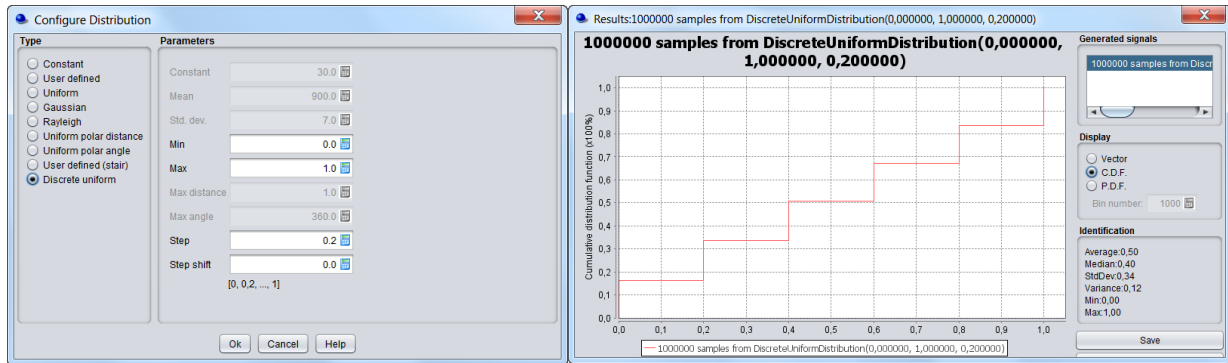
Figure 407: Discrete uniform distribution: parameters (left) CDF (right)

As a result, the generated discrete random parameter will be taking the following values:

$$X_i = X_{min} + (i \times S) + Ss \qquad \text{(Eq. 145)}$$

each value being assigned the same probability:

$$P(X_i) = \frac{1}{N} \qquad \text{(Eq. 146)}$$

with $i=1...N$

$$N = \frac{(X_{max} - X_{min})}{S} \qquad \text{(Eq. 147)}$$

The following examples, with a step shift of 0 and a step of 0.2, returns frequencies that will operate at 1000 MHz, for another snapshot it will be 1000.2 MHz, etc… the maximum value will be 1001 MHz
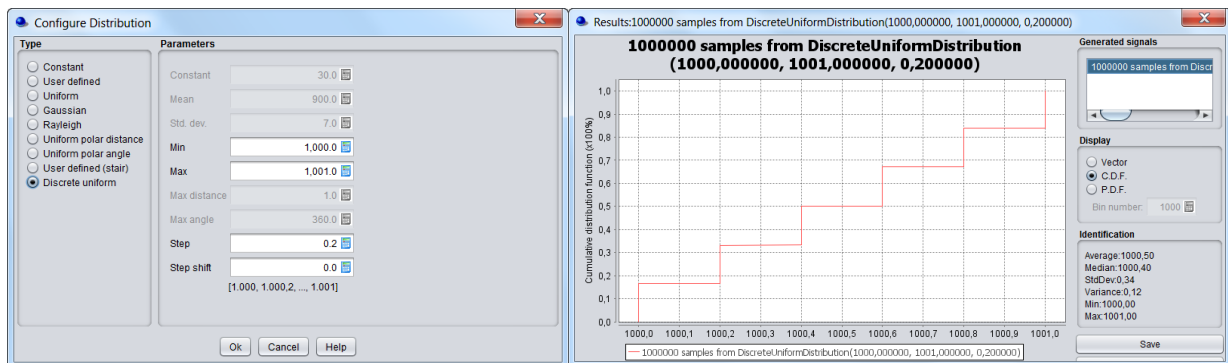
Figure 408: Discrete Uniform (with step 0)

Adding a step shift of 0.1 and keeping a step of 0.2, returns frequencies that will operate at 1000.1 MHz, 1000.3 MHz etc… with a maximum value of 1000.9 MHz.
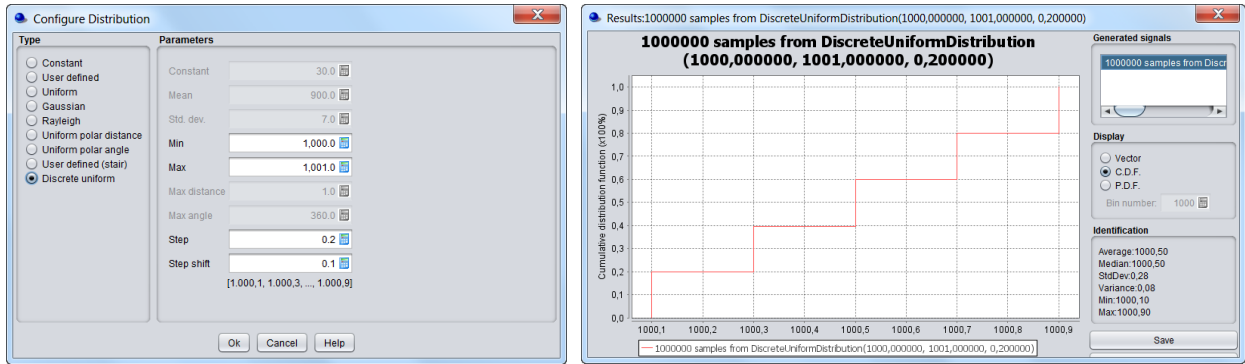
Figure 409: Discrete Uniform (with step 0.1)

ANNEX 11: : ANTENNA

A11.1 GRAPHICAL INTERFACES

For generic systems, the antenna modelling consists of two entities in SEAMCAT. You have the "Antenna Pointing" panel that defines the antenna height, the pointing in azimuth and in elevation and you have the "Antenna Patterns definition" panel as illustrated in Figure 410. These antenna pointing azimuth and elevation angles have impact only on the ultimate antenna gain applied in calculation of the link budget, but not on the mutual physical positioning of pair of transmitter and receiver. The latter is impacted by the "Path azimuth angle" parameter (see ANNEX 12:).

(a) **(b)**
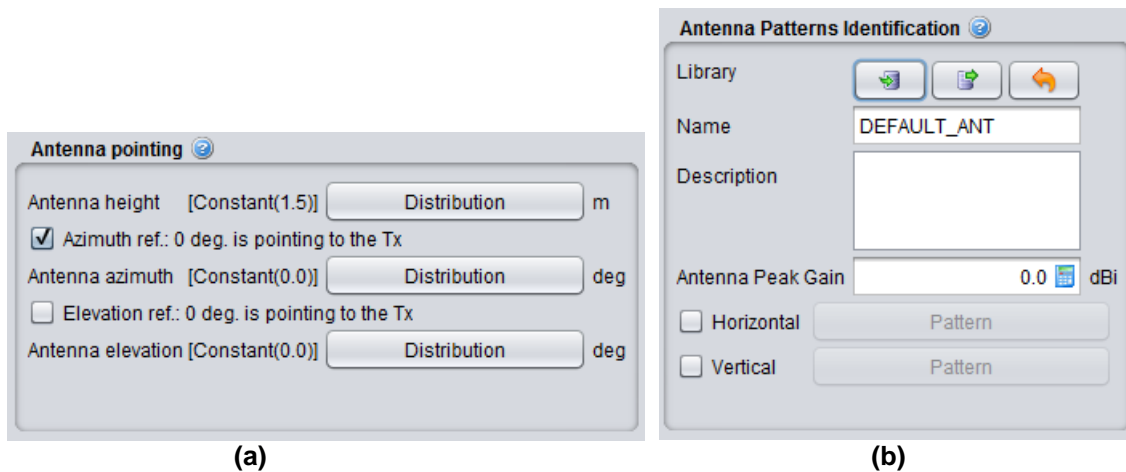
**Figure 410: Antenna pointing (a) and antenna patterns definition (b)
defining the antenna in generic system**

For cellular system, the antenna is defined in the mobile station or base station panel as shown in Figure 411.

(a) **(b)**
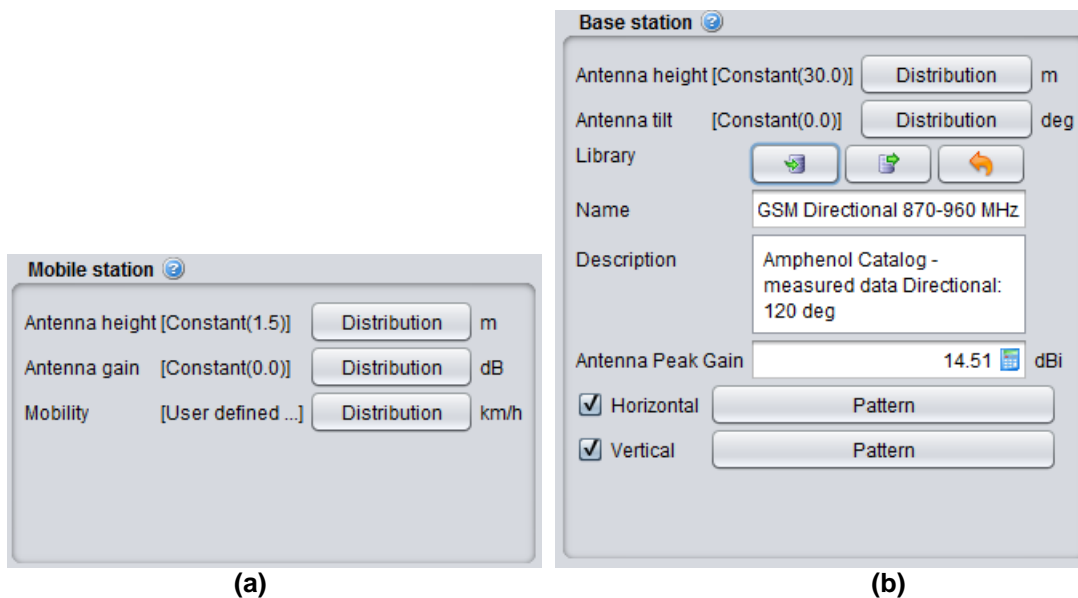
**Figure 411: Mobile station panel (a) and base station panel (b)
defining the antenna in cellular system**

A11.2 ANTENNA HEIGHT

The 'height of the antenna should correspond to its definition in the selected propagation model for that link (e.g. it might be the height above ground, effective height or height above local clutter).

A11.3 ANTENNA POINTING AZIMUTH REFERENCE AND ANTENNA AZIMUTH (WITHIN A LINK)

For the generic system, you can set, in the azimuth domain, whether an antenna is pointing or not at its opposite transceiver and how much of angle offset should your antenna have:

- The **antenna pointing azimuth** reference: In SEAMCAT you have two options to set the reference of the antenna pointing (➡). The antennas can either be pointing, i.e. the direction of the main beam is towards the Rx or the Tx, or be de-pointing, i.e. the direction of main beam is by default towards EAST. The control of the pointing and de-pointing of the antenna is only between the pair (VLT, VLR), and (ILT, ILR). The principle is illustrated for the victim system in the graphic of Figure 413 and applies also for the interfering system.
- The **antenna azimuth**: This distribution allows you to steer the antenna to a certain angle with respect to the **antenna pointing azimuth** reference. It is θ_{trial}.

A positive value is equivalent to counter-clockwise to the 0 deg reference
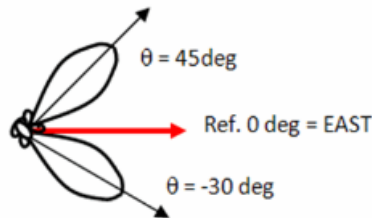
Figure 412: Azimuth angle convention

Unless some intentional meaning of antenna de-pointing is foreseen in simulation scenario, it is recommended to set always the antenna pointing and elevation angle parameters to const=0, meaning that the main beam of the antenna is directed towards the corresponding pair of transmitter and receiver in a link.

Pointing	Depointing
☑ Azimuth ref.: 0 deg. is pointing to the Rx Antenna azimuth [Constant(-0.0)] Distribution deg 	☐ Azimuth ref.: 0 deg. is pointing to the Rx Antenna azimuth [Constant(10.0)] Distribution deg
In this example, the VLR antenna is pointing towards the VLT by default (red arrow). You can then set a specific aziumth angle in order to steer the antenna away from the default	In this configuration, the "antenna azimuth" is set to 10 deg, which results in the main beam to be sligtly shifted from the EAST direction.

reference. It is set to 0 in the illustration. This parameter may be used either to add certain variable parameter to the final link budget due to random de-pointing of antennas (e.g. in mobile environment), or to show deliberate de-pointing of antenna (e.g. choosing a particular gain point on the antenna directivity pattern). In this case the antenna are pointing at each other. $$\theta_{Rx \rightarrow Tx} = \theta_{trial}$$ where	In this case the antennas are not pointing at each other and they are looking EAST. $$\theta_{Rx \rightarrow Tx} = \arcsin\left(\frac{Y_{Rx} - Y_{Tx}}{d_{Rx \rightarrow Tx}}\right) + \theta_{trial}$$

Figure 413: Illustration of the pointing and depointing in the azimuth domain

A11.4 ANTENNA POINTING ELEVATION REFERENCE AND ANTENNA ELEVATION (WITHIN A LINK)

Note: The antenna elevation algorithm is currently under revision. Text should be updated accordingly when the implementation is finalised.

For the generic system, you can set, in the elevation domain, whether an antenna is pointing or not at its opposite transceiver and how much of angle tilt should your antenna have:

- The **antenna pointing elevation** reference (➡) follows the same concept as for "antenna pointing azimuth". When selected, the antennas are pointing toward the opposite transceiver of the same link. If it is not selected, it means that the antenna reference is fixed to the horizontal plane.
- The **antenna elevation**: This distribution allows you to steer the antenna to a certain angle with respect to the **antenna pointing elevation** reference. Adding the **antenna elevation** component allows you to simulate a real life antenna down-tilt or up-tilt. It is φ_{tilt}. The depointing feature is very useful to simulate beamforming for instance.

A positive value is equivalent to counter-clockwise to the 0 deg reference, that is to say: **positive** = **up-tilt** to the 0 deg reference and **negative** = **down-tilt** to the 0 deg reference
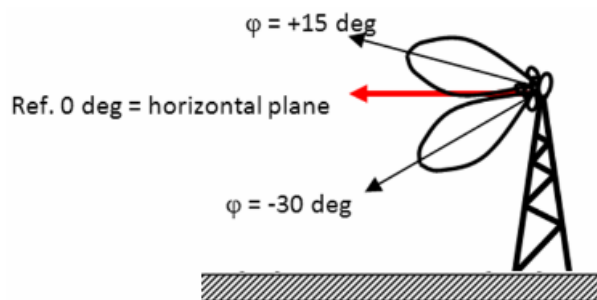
Figure 414: Elevation angle convention

Unless some intentional meaning of antenna de-pointing is foreseen in simulation scenario, it is recommended to set always the antenna pointing and elevation angle parameters to const=0, meaning that the main beam of the antenna is directed towards the corresponding pair of transmitter and receiver in a link.

Pointing	Depointing
In this case the antennas are pointing (i.e. tilted) at each other. $$\varphi_{Rx \to Tx} = \varphi_{tilt}$$	In this case the antennas are not tilted at each other, i.e. their 0 degree reference is the horizontal. $$\varphi_{Rx \to Tx} = \arcsin\left(\frac{H_{Rx} - H_{Tx}}{d_{Rx \to Tx}} \right) - \varphi_{tilt} \times \cos(\theta_{trial})$$ $\varphi_{tilt} \times \cos(\theta_{trial})$ is a correction to the angle that takes into account the azimuth angle so that the correct antenna gain is considered.
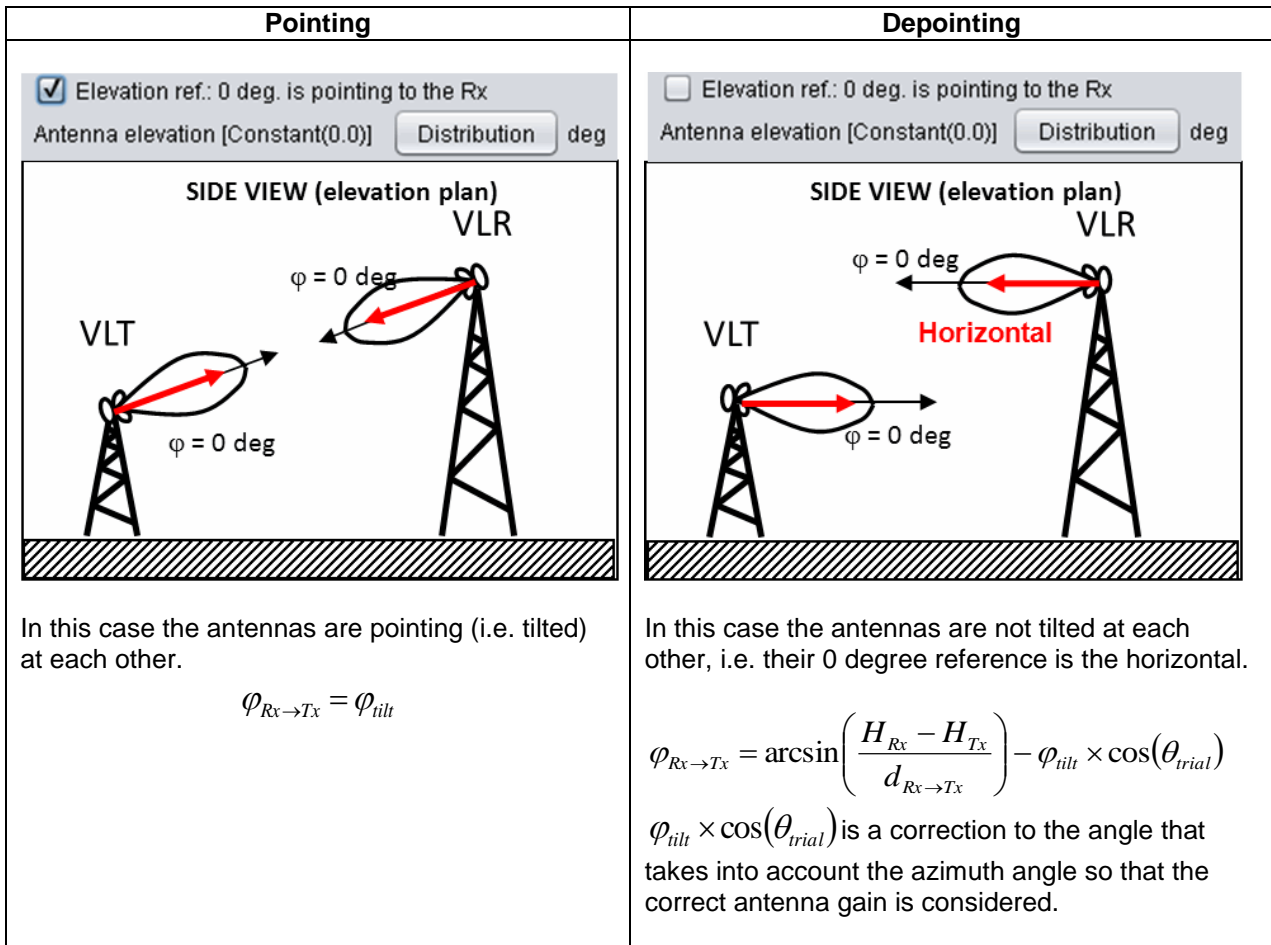
Figure 415: Illustration of the pointing and depointing effect in the elevation domain

For the cellular system the antenna tilt is defined at the base station as described in Section 7.5.5 and illustrated in Figure 416. It is equivalent to a physical tilt of an antenna on a mast, (-) sign is a downtilt, (+) sign is an uptilt.
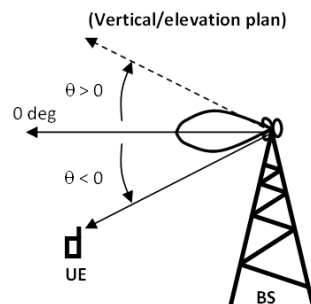
Figure 416: Illustration of the antenna tilt cellular system

A11.5 ANTENNA AZIMUTHS AND ELEVATIONS (ILT - VLR PATH)

As far as the Interfering Transmitter (ILT) - Victim Receiver (VLR) path is concerned, mutual angles and subsequent antenna discrimination angles/azimuths in horizontal plane are pre-determined by calculations already performed in the relative azimuths / elevation on the victim (VLT-VLR) and interferer (ILT-ILR) paths and with the setting of the relative positioning of the VLR with ILT.

At the same time, the vertical angles (tilt) of the antennas in the elevation plane are similarly assumed to be pre-determined during the antenna gain calculations for VLT-VLR and ILT-ILR paths.

For all angle calculations, the **azimuth reference** is the ILT-VLR path and the **elevation reference** is the horizontal plane.

A11.5.1 Calculation of antenna azimuths (ILT - VLR path)

The antenna azimuth (bearing, or discrimination angle) in the horizontal plane **from the VLR in the direction of the ILT** is derived from:

- $\alpha_{VLR \to VLT}$ - direction of the victim link (i.e. the relative angle between VLR and VLT),

- $\alpha_{VLR \to ILT}$ - direction of the VLR-ILT path. This direction may also be defined by X_{VLR}, Y_{VLR}, X_{ILT}, Y_{ILT}, absolute coordinates of the VLR and ILT.

- $\theta_{VLR \to VLT}$ - azimuth of the VLR antenna in the direction of the VLT,

through the following relationship:

$$\theta_{VLR \to ILT} = -\alpha_{VLR \to VLT} + \theta_{VLR \to VLT} + \alpha_{VLR \to ILT} \tag{Eq. 148}$$

$$\theta_{VLR \to ILT} = -\arctan\left(\frac{\Delta Y_{VLR \to VLT}}{\Delta X_{VLR \to VLT}}\right) + \theta_{VLR \to VLT} + \arctan\left(\frac{Y_{ILT} - Y_{VLR}}{X_{ILT} - X_{VLR}}\right) \tag{Eq. 149}$$

Similarly, the azimuth (in the horizontal plane) **from the ILT in the direction of the VLR** is derived from:

- $\alpha_{ILT \to ILR}$ - direction of the interfering link (i.e. the relative angle between ILT and ILR),

- $\alpha_{VLR \to ILT}$ - direction of the VLR-ILT path. This direction may also be defined by Xvlr, Yvlr, Xilt, Yilt, absolute coordinates of the VLR and ILT,

- $\theta_{ILT \to ILR}$ - azimuth of the ILT antenna in the direction of the ILR,

through the following relationship:

$$\theta_{ILT \to VLR} = \alpha_{ILT \to ILR} + \theta_{ILt \to ILR} - \alpha_{VLR \to ILT} \tag{Eq. 150}$$

$$\theta_{ILT \to VLR} = -\arctan\left(\frac{\Delta Y_{ILR \to ILT}}{\Delta X_{ILR \to ILT}}\right) + \theta_{ILT \to ILR} - \arctan\left(\frac{Y_{ILT} - Y_{VLR}}{X_{ILT} - X_{VLR}}\right) \tag{Eq. 151}$$

A11.5.2 Calculation of antenna elevations (ILT - VLR path)

The elevation of the VLR antenna in the direction of the ILT antenna is then derived from both the tilt and the azimuth angles as follows:

$$\varphi_{VLR \to ILT} = \varphi\left(h_{VLR}, h_{ILT}, d_{VLR \to ILT}\right) - \alpha\left(\varphi_{VLR}^{tilt}, \theta_{VLR \to VLT}\right) \tag{Eq. 152}$$

where:

- φ is the angle of the ILT antenna as seen from the VLR antenna:

$$\varphi\left(h_{VLR}, h_{ILT}, d_{VLR \to ILT}\right) = \arctan\left(\frac{h_{ILT} - h_{VLR}}{d_{VLR \to ILT}}\right) \tag{Eq. 153}$$

- The corrected tilt function α is defined as the tilt of the VLT antenna as seen through its VLR antenna:

$$\alpha\left(\varphi_{VLR}^{tilt}, \theta_{VLR \to VLT}\right) = \varphi_{VLR}^{tilt} \times \cos\left(\theta_{VLR \to VLT}\right) \tag{Eq. 154}$$

The elevation angle of the ILT antenna in the direction of the VLR antenna is then derived from both the tilt and azimuth angles as follows:

$$\varphi_{ILT \to VLR} = \varphi\left(h_{ILT}, h_{VLR}, d_{ILT \to VLR}\right) - \alpha\left(\varphi_{ILT}^{tilt}, \theta_{ILT \to ILR}\right) \tag{Eq. 155}$$

where:

- φ is the angle to the VLR antenna as seen from the ILT antenna:

$$\varphi\left(h_{ILT}, h_{VLR}, d_{ILT \to VLR}\right) = \arctan\left(\frac{h_{VLR} - h_{ILT}}{d_{ILT \to VLR}}\right) \tag{Eq. 156}$$

- The corrected tilt function α is defined as the tilt of the ILT antenna as seen through its ILR antenna:

$$\alpha\left(\varphi_{ILT}^{tilt}, \theta_{ILT \to ILR}\right) = \varphi_{ILT}^{tilt} \times \cos\left(\theta_{ILT \to ILR}\right) \tag{Eq. 157}$$

A11.6 ANTENNA PATTERNS DEFINITION
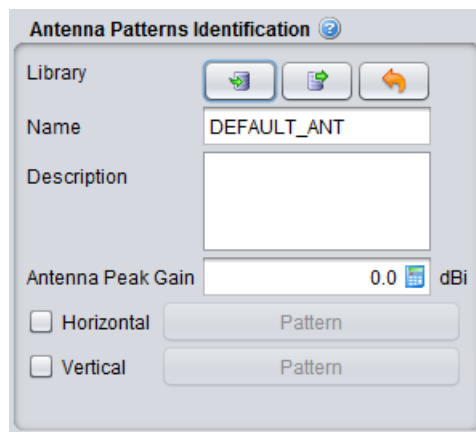
Figure 417: Antenna pattern identication dialog box

Table 71: Description of the Antenna pattern user interface in SEAMCAT

Description	Symbol	Type	Unit	Comments
Library	-	Library	-	Allows to import/export antennas from/to the library to/from the workspace
Name: name of the Antenna				
Description: comments on the antenna				
Antenna peak gain	gmax	S	dBi	Describes peak antenna gain, i.e. gain in the direction of maximum radiation (main lobe)
Horizontal patterns: Horizontal normalized antenna pattern	$g^V(\theta)$	F	dB/deg	Defined by pairs (φ, gH(φ)), where φ (deg, range 0...+360) describes the angular offset in horizontal plane with relation to the direction of maximum radiation, and gH(φ) describes the relative gain, related to the antenna maximum peak gain. *Note: gH(φ) values should be negative.* *Note: The antenna pattern range definition for CDMA has been modified to match the antenna patterns specified by 3GPP (deg, range -180...+180)*
Vertical patterns: Vertical normalized antenna pattern	$g^H(\varphi)$	F	dB/deg	Input angle values between –90° and 90°. For the gain, only input negative values relative to the Antenna peak gain.
Spherical patterns: Spherical normalized antenna pattern	$g^S(\phi)$			It describes the antenna spherical radiation pattern, defined by pairs (Φ, gS(Φ)), where Φ (deg, range 0...+180) describes the spherical angle, and gS(Φ) describes the relative gain, related to the antenna maximum peak gain. gS(Φ) values are negative and relative to the Antenna peak gain: *cos* Φ = cos (θ)*cos(φ)

To define the horizontal, vertical or spherical antenna patterns, the dialog window is similar to those used to enter the function dialog windows. However the important difference is that antenna pattern dialog windows do not allow to set Constant parameters, and they have two displays to present the entered data - the usual XY plane, and the Polar display. These are illustrated by two respective pictures below.
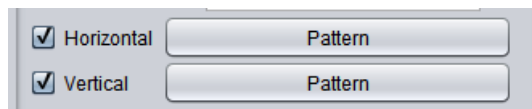
Figure 418: Antenna pattern dialog box
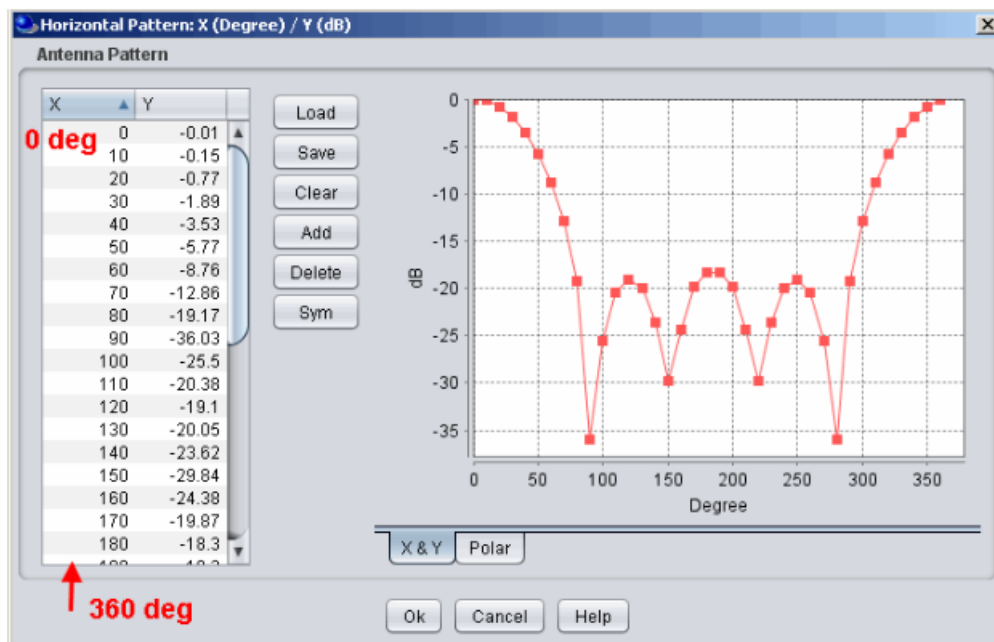
Figure 419: Defining antenna pattern, using XY coordinates system
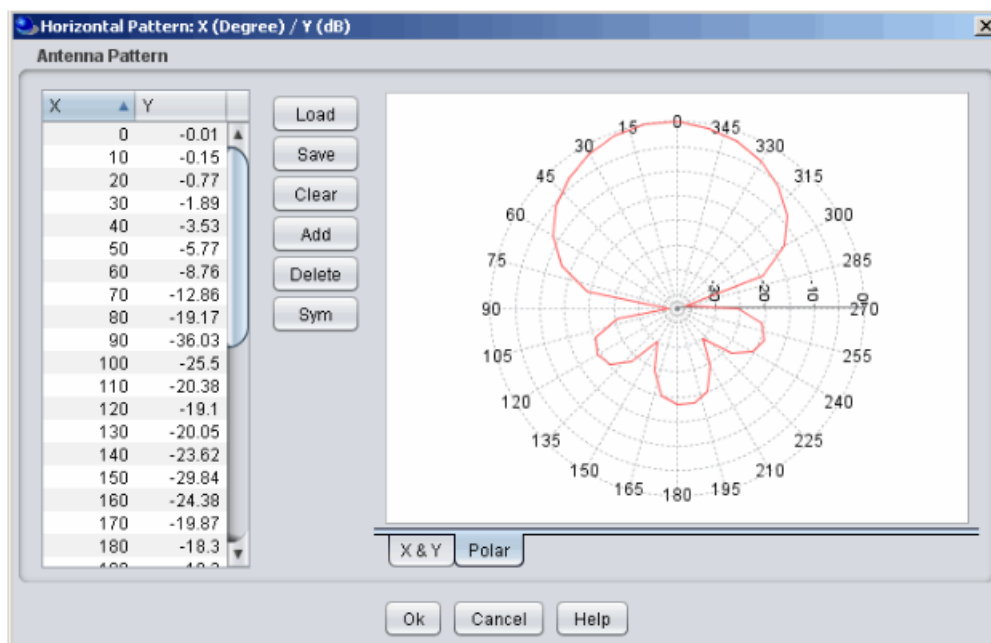
Figure 420: Defining antenna pattern, using Polar coordinates system

By default all antennas have 0 dBi gain and are non-directional, i.e. not having any directivity patterns associated. Depending on the type of antenna to be described in the scenario, you may define it by modifying the antenna gain and activating one or more of radiation patterns (e.g. user may feel it sufficient to activate horizontal pattern, but if the vertical discrimination is important, both vertical and horizontal patterns could be activated as well).

It is assumed that the frequency has no impact on antenna efficiency/gain, therefore antenna gains are calculated based on pure peak gain combined with necessary angular discrimination in case of directional antennas (i.e. antennas having radiation patterns assigned in the scenario).

Horizontal antenna pattern angle definition	Vertical antenna pattern angle definition	Spherical antenna pattern angle definition
positive = counter-clockwise to the 0 deg reference	positive = counter-clockwise to the 0 deg reference	positive = counter-clockwise to the 0 deg reference
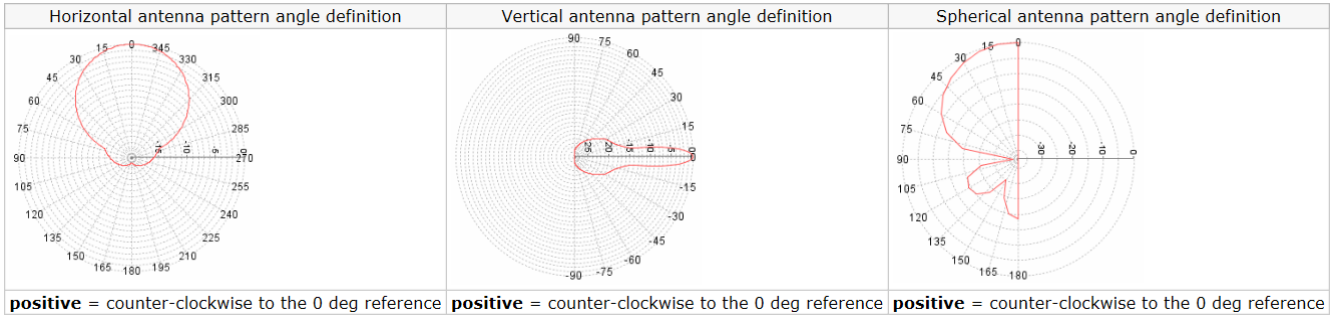
Figure 421: Horizontal, vertical and Spehrical antenna pattern convention

A11.7 ANTENNA GAIN

Most of the builtin antenna assumes that the frequency has no impact on the antenna efficiency/gain, therefore antenna gains are calculated based on pure peak gain combined with necessary angular discrimination in case of directional antennas (i.e. antennas having radiation patterns assigned in the scenario).

A11.7.1 If no spherical antenna pattern is defined:

The calculation of the antenna gain for a path between *Trx1* and *Trx2* is performed as follows:

Gain in horizontal plane: if horizontal antenna pattern is defined, then $g_{trx1 \to trx2}^{H} = f_{trx1}^{H-pattern}\left(\theta_{trx1 \to trx2}\right)$

Gain in vertical plane: if vertical antenna pattern is defined, then: $g_{trx1 \to trx2}^{V} = f_{trx1}^{V-pattern}\left(\varphi_{trx1 \to trx2}\right)$

When the two antenna patterns (horizontal and vertical) are selected, this means that the **Horizontal** and **vertical planes** are **combined** and SEAMCAT calculates the resulting antenna gain as a pseudo 3-D antenna gain . The calculation is based on the following approximation with a treshold value of 3 dB:

IF abs($g_{wr \to it}^{H} - g_{wr \to it}^{V}$) < *3 dB*

$$g_{wr \to it} = f(g_{wr}^{max}, g_{wr \to it}^{H}, g_{wr \to it}^{V}) = g_{wr}^{max} \times \sqrt{\frac{g_{wr \to it}^{H}{}^{2} + g_{wr \to it}^{V}{}^{2}}{2}} \quad \text{(in linear domain - not in dB)} \quad \text{(Eq. 158)}$$

else

$$g_{wr \to it} = g_{wr}^{max} \times \min(g_{wr \to it}^{H}, g_{wr \to it}^{V}) \quad \text{(in linear domain - not in dB)} \quad \text{(Eq. 159)}$$

A11.7.2 If spherical antenna pattern is defined:

The spherical-angle gain is calculated: $g_{trx1 \to trx2}^{S} = f_{trx1}^{S-pattern}\left(\arccos\left(\cos\left(\theta_{trx1 \to trx2}\right)\cos\left(\varphi_{trx1 \to trx2}\right)\right)\right)$

Total gain is then calculated as follows: $g_{trx1 \to trx2} = f\left(g_{trx1}^{max}, g_{trx1 \to trx2}^{S}\right) = g_{vr}^{max} \times g_{trx1 \to trx2}^{S}$

A11.8 ANTENNA LIBRARY

See Section 13.5.1

ANNEX 12: : RELATIVE POSITION

A12.1 OVERVIEW

The relative position between a transmitter and a receiver is described by its Distance, Azimuth and Delta X,Y when you have selected a decorrelated mode, or by Delta X, Y only when you have selected a correlated mode. The selection of this mode and input parameters are described in Section 5.4.1 (VLT-VLR or ILT-ILR) and Section 10.3.1 (ILT-VLR)

Distance: The distance between the Rx and the Tx ($d_{Tx\,to\,Rx}$) is calculated through multiplying a trialled **path distance factor** $T(D_{Tx\,to\,Rx})$ by the coverage radius R_{max} such as $d_{Tx\,to\,Rx} = T(D_{Tx\,to\,Rx}) \times R_{max}$

Azimuth: The azimuth $\alpha_{Rx\,to\,Tx}$ of the Tx-Rx path is calculated trough a trial of **path azimuth** according to the defined distribution:

$$\alpha_{Rx\,to\,Tx} = T(A_{Rx\,to\,Tx}) \tag{Eq. 160}$$

The relative positioning of the pair of Tx and Rx is calculated in Cartesian coordinates. The relative positioning is always expressed relatively to the transmitter and is defined as:

$$\Delta X_{Tx/Rx} = \Delta X + d_{Rx\,to\,Tx}\cos(\alpha_{Rx\,to\,Tx}) \tag{Eq. 161}$$
$$\Delta Y_{Tx/Rx} = \Delta Y + d_{Rx\,to\,Tx}\sin(\alpha_{Rx\,to\,Tx}) \tag{Eq. 162}$$

Consequently, assuming that one of the two pair of transmitter and receiver is fixed, it is then possible to use the relative positioning to determine the absolute location of the second pair of transmitter and receiver.

A12.2 PATH DISTANCE FACTOR

The path distance factor will be multiplied by the coverage radius R_{max}^{VLT} (or R_{max}^{ILT}) to obtain the coverage area.

Therefore, the trailed distance between Tx and Rx will be R_{max}^{VLT} *Path factor.

For instance, if you set the victim path distance factor as a uniform distribution 0…1, then the distance will be between 0 and R_{max}^{VLT}.

A12.3 PATH AZIMUTH

A12.4 REFERENCE POINT FOR THE VLTTO VLR AND ILT TO ILR POSITION

For the path azimuths in the VLT->VLR and ILT->ILR links, the reference point is a **transmitter (the VLT or ILT)** and the angle is from the positive direction of Ox axis to the path towards a corresponding receiver (VLR or ILR, respectively) in a link. As an example if you select a uniform path azimuth distribution between 0 deg and 90 deg (and a path distance factor set to Uniform polar dist. with a max. distance of 1), you will get the following distributions:

Similarly, for the case of the Victim Link System: **For the case of the Interfering Link System**
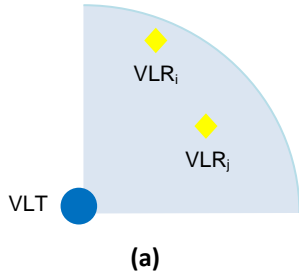
(a)   **(b)**
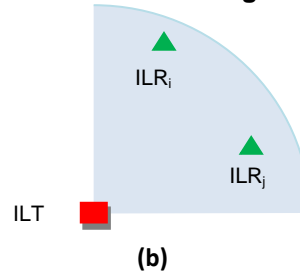
Figure 422: Illustration of the reference point for the VLT-VLR (a) and ILT-ILR (b)

Example 1: Pacman

Parameters	SEAMCAT simulation
Path Distance factor: Uniform Polar distance distribution with Max. distance: 1 **Path azimuth for ILT - ILR:** Uniform distribution with Min: -135 deg and Max: 115 deg	 **Figure 423: A pacman interfering link system**

Exemple 2: Hexagon:

You are also able to select a polygon shape as an alternative to the default circle. A various selection of polygon is available (see Section 5.4.1). You are able to rotate counter-clock wise (ccw) the polygon shape.

Parameters	SEAMCAT simulation
Path Distance factor: Uniform Polar distance distribution with Max. distance: 1 **Path azimuth for ILT - ILR:** Uniform. distribution Min: 0 ; Max: 360 Use a polygon : Active. Shape of the polygon: Hexagon Turn CCW: 0 deg	 **Figure 424: Interfering link system with hexagonal shape**

A12.5 REFERENCE POINT FOR THE VICLTIM LINK TO ILT POSITION

For the path azimuth used in describing relative Vicltim link to ILT positioning, the reference point can be set to the **VLR** or VLT (depending on the option chosen) and the angle between them (VLR or VLT) and the ILT is calculated between the positive direction of Ox axis and the path towards the ILT. For that, we have two options for the relative positioning of the Interfering Link:
- with respect to the VLT (Example 1 and 2);
- with respect to the VLR (Example 3).

Example 1:
In the case that the interfering link is positioned **with respect to the VLT** at a fixed distance in the x-axis (e.g. 0.2 Km) and a constant path azimuth of 45° we should expect the following distribution (the path distance factor is set to 1, so the product "path distance factor" x "simulation radius" = "simulation radius"):
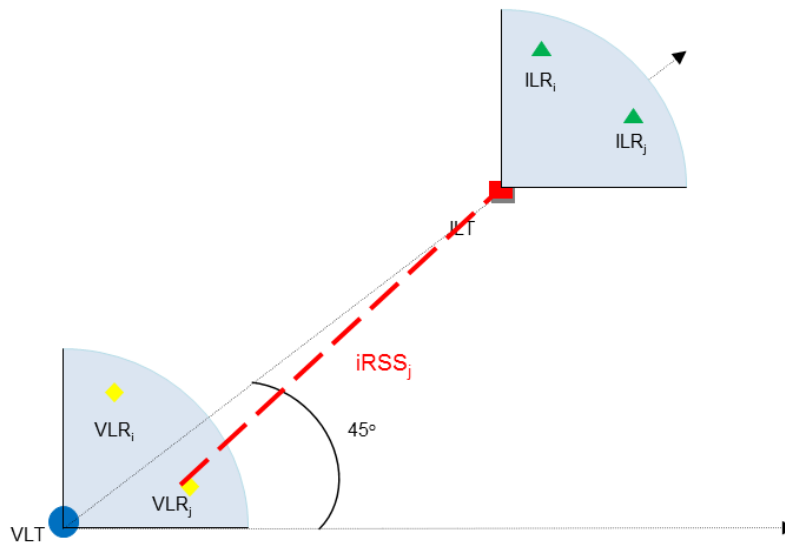
Figure 425: Positioning of the ILT with respect with VLT

Figure 426: Setting of the input parameter and SEAMCAT results when positioning of the ILT with respect with VLT

Example 2

In Example 1, the Δx and Δy are set to zero. If we select an offset (Δx, Δy), the relative position of the Interfering Link with respect to the Victim Link will shift the ILT distribution (red square) by Δx horizontally and Δy vertically. In the case that the ILT distribution is not a single point, an offset (Δx, Δy) will shift the centre of the ILT distribution accordingly.
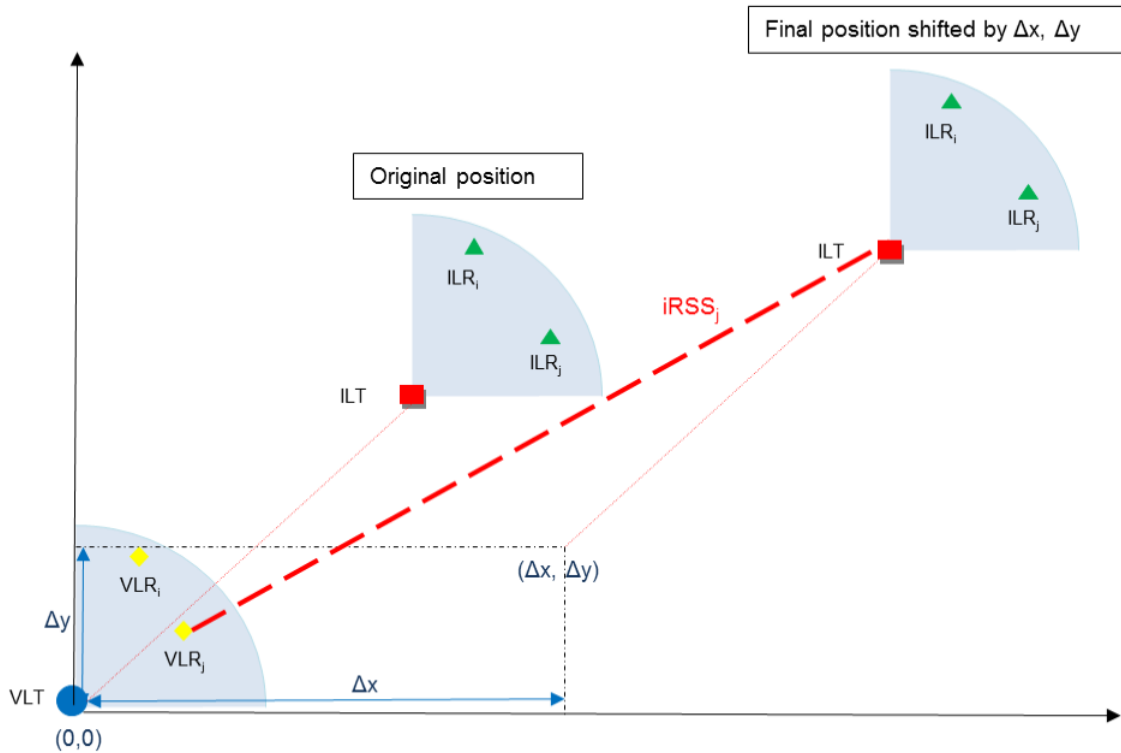
Figure 427: Positioning of the ILT with respect with VLT with a Δx and Δy
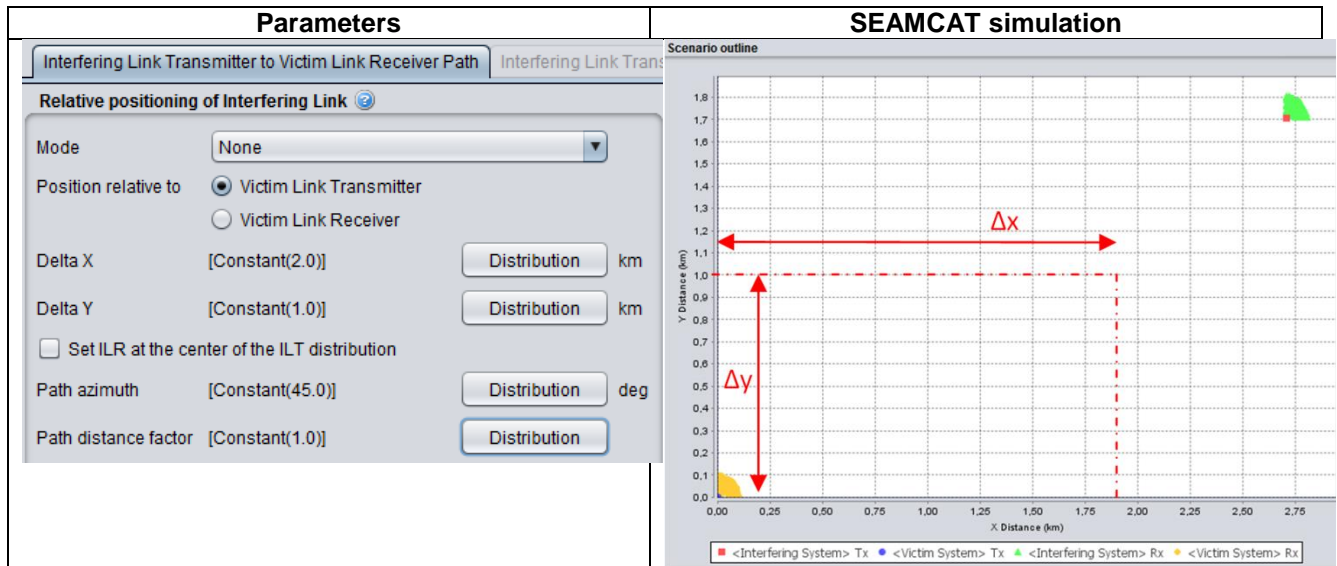
Figure 428: Setting of the input parameter and SEAMCAT results when positioning of the ILT with respect with VLT with a Δx and Δy

Example 3

In the case that the interfering link is positioned <u>**with respect to the VLR with**</u> a constant path azimuth of 45 deg, a constant path distance factor of 1, you should expect the following distribution:
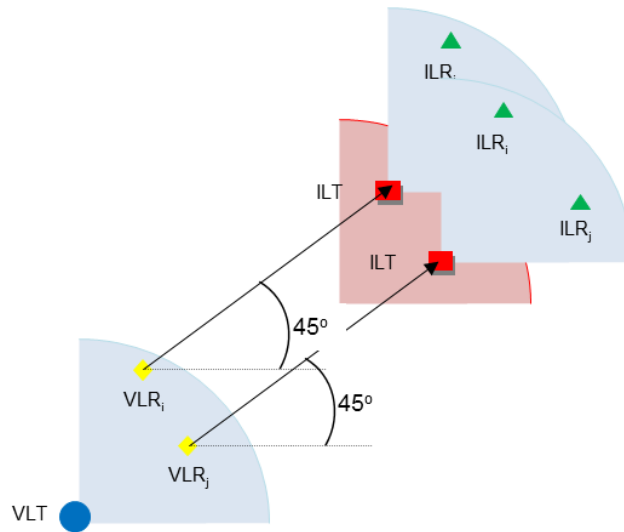
Figure 429: Positioning of the ILT with respect with VLR

Parameters	SEAMCAT simulation

Table 72: Setting of the input parameter and SEAMCAT results when positioning of the ILT with respect with VLR

ANNEX 13: : COVERAGE AND SIMULATION RADIUS

A13.1 COVERAGE RADIUS
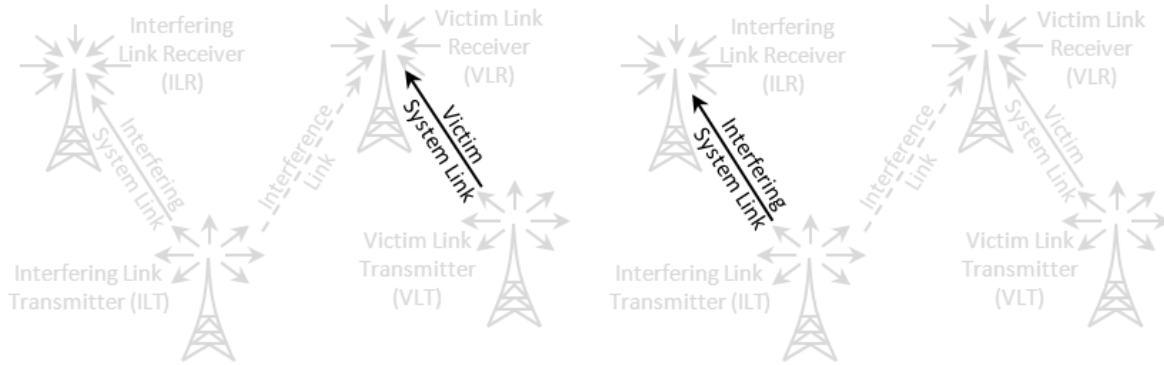
Figure 430: Representation of the coverage radius

Coverage radius parameter is used to describe the operational area of the victim R_{max}^{VLT} and/or interference R_{max}^{ILT} systems. SEAMCAT allows three modes for defining the coverage radius.

- User Defined radius (constant value)
- Noise-limited network (calculated at the start of events generation)
- Traffic-limited network (calculated at the start of events generation)

The coverage radius is implemented as plugin, which means that you can define your own coverage radius.

A13.1.1 User-defined coverage radius

This option allows you to enter the maximum radius directly where the origin of the coverage radius is the Victim link transmitter.

A13.1.2 Noise-limited network

Assuming that the received power is equal to the sensitivity of the victim link receiver, then the radius R_{max} can be determined for the wanted radio path by the following equation.

$$F_{median}(f_{vr},h_{vr},h_{wt},R_{max},env)+F_{slowfading}(X\%)=P_{wt}+g_{wt}+g_{vr}-sens_{vr} \qquad \text{(Eq. 163)}$$

where the path loss is defined by a median loss plus an additional term representing the distribution

$$p_{loss}=F_{median}+F_{slowfading}(X\%) \qquad \text{(Eq. 164)}$$

where:

- F_{median}: propagation loss not including slow fading, i.e. path loss without variations option;
- $F_{slowfading}(X\%)$: slow fading margin for X% coverage loss;

The distribution of the path loss p_{loss} can be expressed in a general way by the following equation:

$$Q(\mu + a, R_{max}) = y$$

where Q is the cumulative distribution for R_{max} and the resulting mean path loss μ and an additional path loss a due to availability or coverage y. The availability y of the system is linked to the coverage loss through the simple relation $y = 1 - x$. Assuming that slow fading can be approximated by log-normal distribution, i.e. median $\approx$ mean, the relation $a = b\sigma$ can be introduced where b stands for a multiple of the well known standard deviation σ. A few examples for illustration: At a 95 % coverage, b results in 1.96, for 99 % in 2.58, for 99.9 % in 3.29, or $b = 1$ 68 % coverage, for $b = 2$ for 95.5 %. The exact values can be easily determined by using the inverse Gaussian function.

Then the equation:

$$v(R_{\max})=P_{wt}+g_{wt}+g_{vr}-sens_{vr}-F_{median}(f_{vr},h_{vr},h_{wt},R_{\max},env)-b\sigma \qquad \text{(Eq. 165)}$$

The determination of the zero of function v, is made through a recursive method such as regula-falsi used in logarithmic scale which should yield a better precision. The solution of such a method provides:

$$\tilde{R}_{\max} = R_{\max 0} - \frac{R_{\max 0} - R_{\max 1}}{v(R_{\max 0}) - v(R_{\max 1})} v(R_{\max 0}) \qquad \text{(Eq. 166)}$$

In this case, formulas given for $F_{median}(f_{vr},h_{vr},h_{wt},R_{\max},env)+F_{slowfading}(X\%)=P_{wt}+g_{wt}+g_{vr}-sens_{vr}$ have to be inverted.

Note 1: Inverse of the normalised Gaussian cumulative distribution is implemented through a piecewise approximation.

Note 2: Ro to be set to 1 m (0.001 km)

Note 3: If after running the simulation it appears that the resulting coverage radius is equal or very close to the minimum distance or the maximum distance used in calculation of coverage radius, it is likely that there is a mistake in the values you provided. This can be solved by reducing the minimum distance or increasing the minimum distance used in calculation, so that the algorithm may find the corresponding coverage radius.

Note 4: When setting the R_{min}, R_{max} values, please observe the validity range as appropriate for the selected propagation model. Otherwise SEAMCAT will produce the error message when starting a simulation.

A13.1.3 Traffic-limited network

The coverage radius $R_{\max}^{it}$ (Interfering link) or R_{max}^{wt} (Victim link) is determined from the following equation:

$$\pi \times dens_{\max} \times \left(R_{\max}^{it}\right)^2 = \frac{n_{channels}^{it} \times n_{usersperchannel}^{it}}{cluster_{frequency}^{it}} \qquad \text{(Eq. 167)}$$

hence:

$$R_{\max}^{it} = \sqrt{\frac{n_{channels} \times n_{usersperchannel}}{\pi \times dens_{\max} \times cluster_{frequency}}} \qquad \text{(Eq. 168)}$$

A13.1.4 Coverage radius library

See Section 13.5.2.

A13.2 SIMULATION RADIUS

The simulation radius R_{simu} parameter is used to describe the radius of the coverage where the intererfering link transmitters are distributed around the victim link receiver.
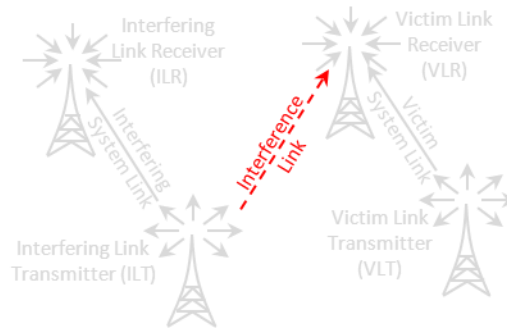
Figure 431: Representation of the Simulation radius

A13.2.1 None

In the option **None,** the R_{simu} defines the circular area where the ILTs are spread. In this case, the relative location of IT-VR is calculated as follows:

- Trial of the path distance factor according to the scenario setting for the VR-IT path;
- Calculation of the absolute distance as a product of the user-defined simulation radius (constant value that you define in VLR-ILT path settings) and the above path distance factor;
- Trial of the path azimuth angle according to the relevant distribution set in the scenario for VR-IT path. Based on that relative angle-distance information, the absolute positions could be established with reference to one known position (usually VR in this case).

A13.2.2 Uniform density mode

The **uniform density** mode uses the notion of simulation radius R_{simu} of the interfering transmitter which defines the circular area where the ILTs are spread. The IT-VR path R_{simu} is calculated at the very beginning of a simulation cycle and applied in all events. It is defined as:

$$R_{simu} = \sqrt{\frac{n^{active}}{\pi \times dens_{it}^{active}}}$$

(Eq. 169)

$dens_{it}^{active}$ is the density of active transmitters and is defined as

$$dens_{it}^{active} = dens_{it} \times p_{it}^{tx} \times activity_{it}(time)$$

(Eq. 170)

where:

- n^{active} - number of active transmitters set in the scenario for IT-VR path (n^{active} should be sufficiently large so that the $(n+1)^{th}$ interferer would bring a negligible additional interfering power);
- $dens_{it}$ - density of transmitters, 1/km2, user-defined parameter in the table **Interferers density** of VR-IT path;
- P_{it} - probability of transmission, user-defined parameter;
- $activity_{it}(time)$ - user-defined temporal activity function (a look-up table). The time value used for calculation is specified in parameter time.
- time - parameter defining which of the values in the above activity function should be used in calculations (e.g. if the $activity_{it}(time)$ function contains three pairs: (1;0.5), (2;0.7), (3; 0.9), and the time parameter is set to 2, then the $activity_{it}(time)$ function will be returning value 0.7).

In case you are given a fixed simulation radius with a defined density of active users, you can evaluate the number the n_{active} by using this equation which is derived from the equation above.

$$n_{active} = dens_{transmitter} . prob_{transmission} . \pi \left(R_{simulation} \right)^2$$

(Eq. 171)

When you set up your simulation, and the relevant input factor is the simulation radius, it is recommended to use the "None" mode instead of the "Uniform density" mode (In that case, you may simulate the activity of the transmitter, e.g. duty cycle, using the distribution of the transmit power). If you are more interested to consider as an input the density of users (i.e. without setting the simulation radius as input), it is recommended to use the "Uniform density" mode.

For this mode, the path distance factor is fixed to a uniform polar distance distribution with a maximum distance of 1 and is not editable.

A13.2.3 Protection distance

If a minimum protection distance (d_0) between the victim link receiver and interefering link transmitter is introduced then R_{simu} results (based on the uniform density mode) in:

$$R_{simu} = \sqrt{\frac{n^{active}}{\pi \times dens_{it}^{active}} + d_0^2}$$ (Eq. 172)

Each trial with $d_{it \rightarrow vr} < d_0$ will be rejected and repeated for another trial producing $d_{it \rightarrow vr} \geq d_0$.

A13.2.4 Closest interferer

In this mode, the ILT is randomly placed in a circular area, the simulation radius is automatically derived from the density and activity of transmitters. The influence of the closest interferer can be estimated by having a <u>distance</u> $d_{ILT \rightarrow VLR}$ following a Rayleigh distribution $R(\sigma)$ as defined in ANNEX 10: and where the parameter σ is related to the density of transmitters

$$\sigma = \frac{1}{\sqrt{2\pi \, dens_{it}^{active}}}$$ (Eq. 173)

where:

$$dens_{it}^{active} = dens_{it} \times p_{it}^{tx} \times activity_{it}(time)$$ (Eq. 174)

For this mode, the path distance factor is fixed to a Rayleigh distribution and is not editable.

ANNEX 14: : POWER CONTROL FUNCTION (FOR NON-CDMA ONLY)

A14.1.1 Power control in the interfering link

A power control feature is implemented within SEAMCAT for the interfering link (see example in Section 4.9). When this feature is activated, this introduces a power control gain for the interefer링 link transmitter, defined as:

$$g_{ILT}^{PC} = f_{PC}\left(P_{ILT}^{output}, G_{ILT \to ILR}, G_{ILR \to ILT}, PL_{ILT \to ILR}, PC_{threshold}, PC_{dyn}, PC_{step}\right)$$ (Eq. 175)

where:
- P_{ILT}^{output} : power supplied to the ILT antenna (before power control);
- $G_{ILT \to ILR}$: ILT antenna gain in the direction of the ILR;
- $G_{ILR \to ILT}$: ILR antenna gain in the direction of the ILT;
- $PL_{ILT \to ILR}$: path loss between the ILT and the ILR;
- $PC_{threshold}$: power control receiver threshold, if the received power is lower than this threshold, then no power control takes place (dBm);
- PC_{dyn} : power control dynamic range (dB);
- PC_{step} : steps of power control (dB).

The power received in the interfering link receiver results in:

$$p = P_{ILT}^{output} + G_{ILT \to ILR} + G_{ILR \to ILT} - PL_{ILT \to ILR}$$ (Eq. 176)

It distinguished between 3 cases:

Case 1 - (Received power below power threshold): $p \le PC_{threshold}$

$$g_{ILT}^{PC} = 0$$

Case (i+1) - (within power control limits): $PC_{threshold} + (i - 1) \times PC_{step} \le p < PC_{threshold} + i \times PC_{step}$

$$g_{ILT}^{PC} = -(i - 1) \times PC_{step}$$

where i is an integer ranging from 1 to $n_{step} = \frac{PC_{dyn}}{PC_{step}}$

Case (n_step +2) - (beyond power control limits): $p \ge PC_{threshold} + PC_{dyn}$

$$g_{ILT}^{PC} = -PC_{dyn}$$

A14.2 RECEIVED POWER DYNAMIC RANGE IN THE VICTIM LINK

The received power dynamic range in the victim link is a simplified power control mechanism which ensures only that a certain dRSS is not exceeded in the victim link receiver.

The "receive power dynamic range" input parameter (denoted Pc_{max} in Table 12) is the maximum range of the receive power that a victim link receiver can accept, in terms of the maximum receive power over the VLR's sensitivity threshold. This means that if the trialled dRSS value exceeds (sens+Pcmax), the $dRSS_{max}$ is set to the "sensitivity" + "Receive power dynamic range". Figure 432 (a) and (b) present an example on how to set the PC off and on respectively. Figure 433 (a) and (b) illustrates the effect of the power control in the victim link for PC off and on respectively.
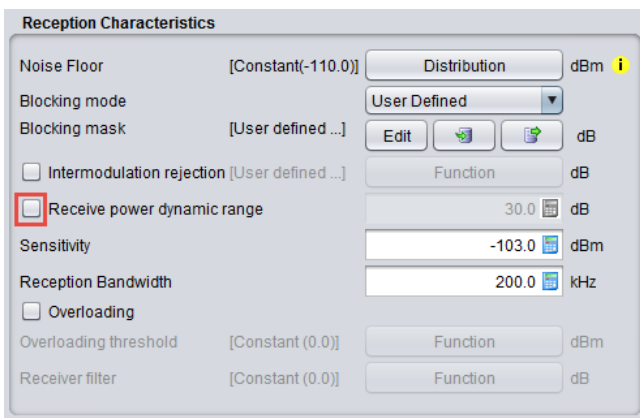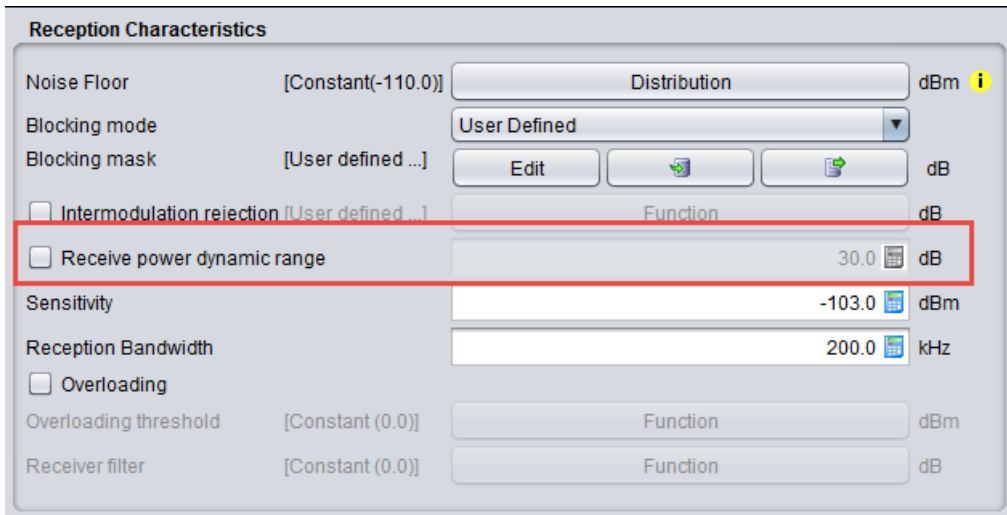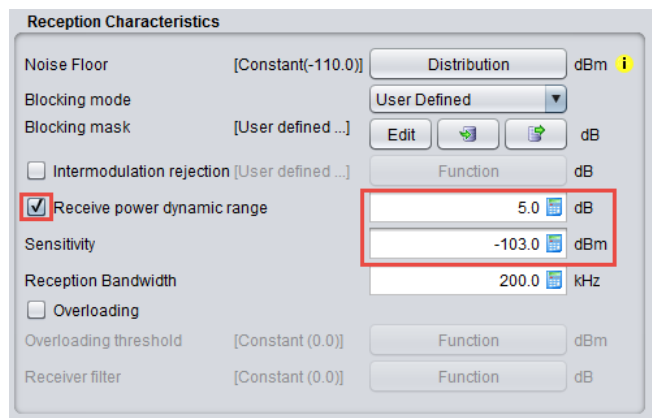
Figure 432: Setting up the received power dynamic range for the victim link (a) PC off (b) PC on
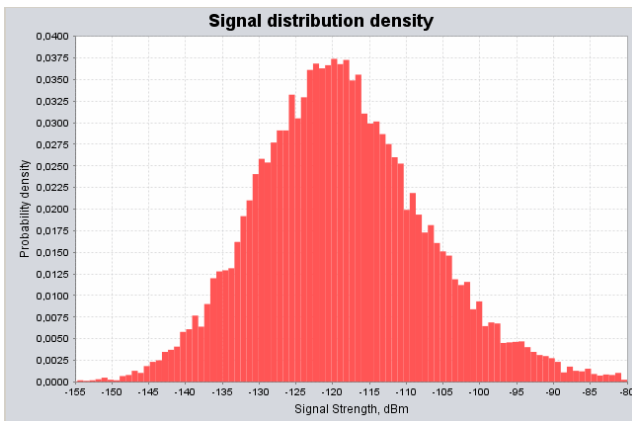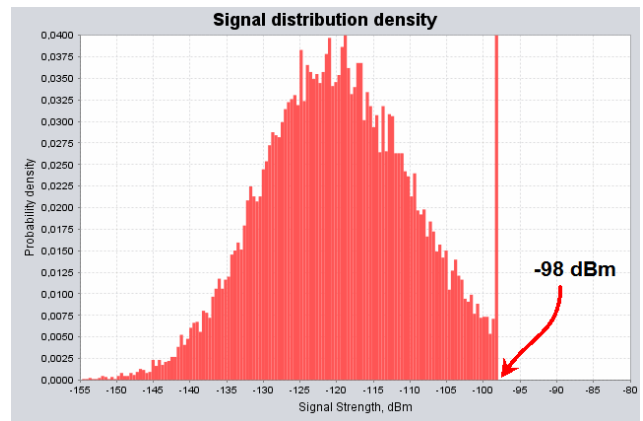
Figure 433: illustration of the received power dynamic range effect on the victim link
(a) PC off (b) PC on with a limit of -98 dBm = -103 dBm (sens) + 5 dB (Pc_{max})

ANNEX 15: : CELLULAR ALGORITHMS

A15.1 CELLULAR NETWORK DETAILED INFORMATION

When a scenario contains one or more CDMA networks SEAMCAT preserves the status of the simulated systems for the last event or for a specific event when using the play/replay feature (See section 2.15).

A15.1.1 Cellular network

When an item is selected in the main plot area its details are shown in the details table on the right handside of the "cellular structure" tab. The values shown depend on the type of element. When no element is selected the system itself is considered to be selected and the table is as shown in Figure 434.
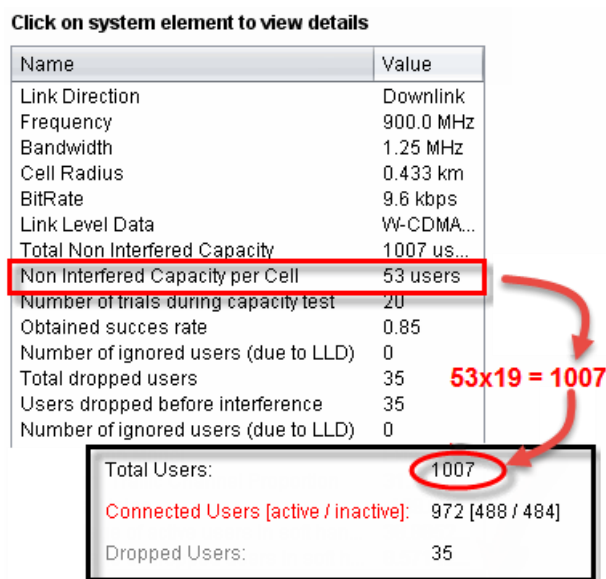
Figure 434: Downlink system details – see Table 73

Table 73: Downlink system details

Name	Description
Link direction	Link direction of the CDMA network
Frequency	Carrier frequency of the CDMA network
Bandwidth	Bandwidth of the system
Cell Radius	The cell radius of the CDMA network is based on 3GPP2 and is equivalent to R in the graphic below.
Bitrate	Bit rate of the system. It is used to calculate the system processing gain
Link Level Data	Used to map the link level simulation (bit level) to the system level simulation (SIR level)
Total non interfered capacity	Same value as shown in the Snapshot summary.
Non interfered	Number of active UEs when the CDMA network is balanced. **Note: This is the**

Name	Description
capacity per cell	**result of the optimal capacity finding simulation – and the value to extract and input to reuse the result.**
Number of trials during capacity test	The number of trials input parameter
Obtained success rate	The result of optimal capacity finding for the capacity used. This can be different than the target (0.8 for downlink and target noise rise for uplink) if the algorithm has detected narrow oscillation (back and forth between the same values). Please refer to the CDMA specification for more details on this algorithm.
Number of ignored users (due to LLD)	Link level values are extrapolated from the values input and there is a build in hard coded stop if a UE is requiring more than half of received signal to be the wanted signal. Any UEs requiring more than this limit is automatically dropped. This number counts the number of UEs in this snapshot dropped due to this limit.
Total dropped users	Total number of dropped UEs (both due internal and external interference)
Users dropped before interference	Number of UEs dropped by power balance before the introduction of external interference. Along with the total number of dropped UEs this gives insight into the impact of external interference compared to the internal interference.
Number of ignored users (due to LLD)	Duplicate – will be removed.
Propagation model	The name of the selected propagation model for the system.
Maximum traffic channel proportion	This is the maximum transmit power for a single traffic channel (UE) – deducted from the maximum transmit power for the base stations and the specified maximum traffic channel fraction.
Noise floor	Calculated value of the Noise Floor
Percentage of active users in soft-handover	Linear percentage of voice active UEs who are in soft-handover. This is very dependent on the selected propagation model.
Percentage of dropped users in soft-handover	Linear percentage of dropped UEs in soft-handover.

A15.1.2 Details of voice user

When a voice active UE is clicked, the details shown in Figure 436 (DL) and Figure 437 (UL) and Table 74Table 73 is shown.
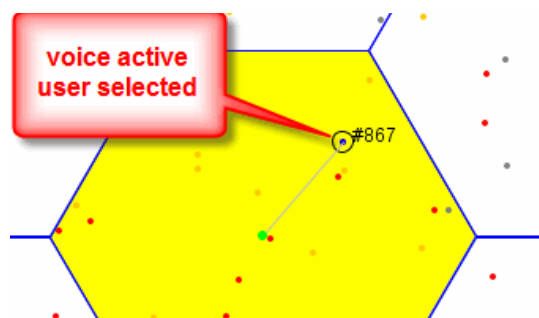
Figure 435: Details of voice active user – downlink

Connected - Voice Active User

Name	Value
Userid	292
Position	(-0.12296265071105...
Status	Connected
Speed	30.0 km/h
Multi-Path	1
Achieved CI	6.7 dB
Required Eb/No	6.7 dB
Transmit Power	-23.7368962514248...
Active List	1 connection(s)
Connection List	18 connection(s)
Is in softhandover	false
Total Power Received from Inactive Set	Not applicable
Total Power Received from Active Set	Not applicable
Traffic Channel Power	Not applicable
Distance to first cell in active list	2.082983815294755...
Angle to first cell in active list	266.6157494132617"
Elevation angle to first cell in active list	0.0"
Connected sector of first cell in active list	N/A - Cell is Omni dir...
Antenna Gain from first BS in active list	9.0 dB

Figure 436: Details of voice active user - downlink

Connected - Voice Active User

Name	Value
Userid	867
Position	(0.16439055...
Status	Connected
Speed	100.0 km/h
Geometry	9.720521153...
Achieved Ec/Ior	-23.992 dB
Required Ec/Ior	-24.0 dB
External interference	-116.879 dBm
Active List	1 connection(...
Connection List	18 connectio...
Is in softhandover	false
Total Power Received from Inacti...	-31.9186902...
Total Power Received from Active...	-22.1981689...
Traffic Channel Power	-46.1898062...
Distance to first cell in active list	0.252540960...
Angle to first cell in active list	49.38702854...
Elevation angle to first cell in acti...	0.0"
Connected sector of first cell in a...	N/A - Cell is ...
Antenna Gain from first BS in acti...	9.0 dB

Figure 437: Details of voice active user - uplink

Table 74: Parameters of voice active user details Details of inactive link

Name	Description
Userid	UE ID in the CDMA network
position	(x,y) information in km
status	The UE can be one of connected / dropped / Not allowed to connect.
Speed	Speed of the selected UE (from input distribution parameter)
Geometry	Calculated geometry. Please refer to CDMA specification for details.
Achieved E_b/N_o	Please refer to CDMA specification for details.
Required E_b/N_o	Extrapolated value from Link Level Data. Please refer to CDMA specification for details.
External Interference	The level of external interference experienced by this UE
Is in soft-handover	True or false
Total power received from inactive list	Sum of inner system interference. This is the sum of received power from all base stations to which the selected UE is NOT connected.
Total power received from active list	Sum of received power from connected base stations. This is includes the pilot power.
Traffic channel power	The sum of received traffic power from connected base stations. This is the wanted signal.
Distance to first cell in active set	Metric distance to the base station with the shortest distance in dB (pathloss)
Angle to first cell in active set	The Cartesian angle. Used when the base station antenna has a defined horizontal pattern
Elevation angle to	Only calculated and used when base station has a defined vertical pattern

Name	Description
first cell in active list	
Connected sector of first cell in active list	If tri-sector layout is used this indicates which sector the UE is connected to
Antenna gain from first BS in active list	Actual antenna gain to base station.
Multipath	Randomly selected value of 1 or 2 – used to determine Link Level Data.
Achieved CI	Please refer to CDMA specification for details.
Required Eb/No	Extrapolated value from Link Level Data. Please refer to CDMA specification for details.
Transmit power	The actual transmit power of this UE

When the active UE is selected (Figure 438), **CTRL and select any BS,** to display the details of the link between the two (Figure 439).

DL case   **UL case**
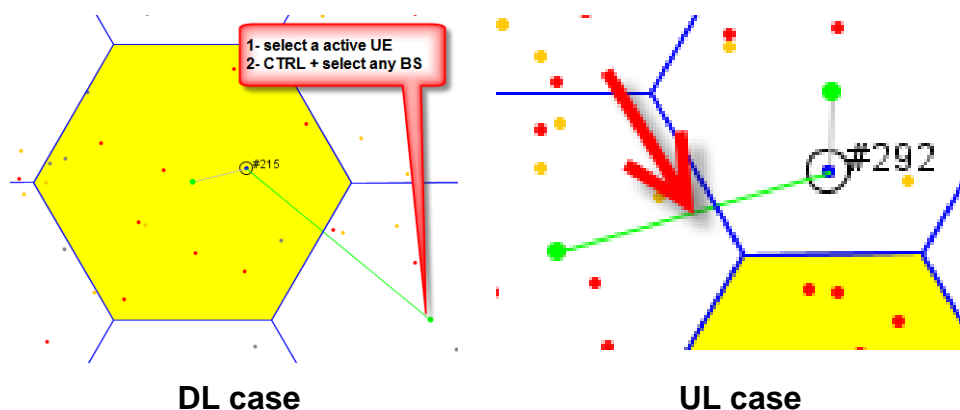
Figure 438: inactive link

Name	Value
Userid	215
In users active list	false
Cellid	6
Cell location id	6
Connected sector of cell location	0
User Position	(1.6965480686923329, 0.4285128419296461)
Cell Position	(7.5, -4.330127018922193)
Using WrapAround	false
Distance	7.504978857017966 km
BS antenna gain	9.0 dB
UE antenna gain	0.0 dB
Pathloss	123.35411282703316 dB
Effective Pathloss	123.35411282703316 dB
Horizontal Angle	140.64937328908627°
Vertical Angle	0.0°
Total Transmit Power	36.94308436746803 dBm
Power scaled down to max	false
Power scaled down to max by	
Total Received power	-77.41102845956513 dBm

Figure 439: Details of selected link

Table 75: Parameters of selected link details

Name	Description
Userid	UE ID of selected UE
In user active list	False or True
Cell id	ID of the selected base station
Cell location id	In tri-sector scenarios the cell id is not always equal to the cell id. The cell locations range from 1 – 19.
Connected sector of cell location	The connected sector of the selected base-station
User position	(X,Y) in km
Cell Position	(X,Y) in km
Using wrap-around	Is the link using wrap-around? Most often "long" connection are using wrap-around – but it really depends on the selected propagation model.
distance	The BS to UE distance
BS antenna gain	Calculated antenna gain for the base station
UE antenna gain	Antenna gain for the UE – input parameter
Path loss	Calculated pathloss in dB for the selected link.
Effective pathloss	Actual value of pathloss after adjustment for MCL
Horizontal angle	Angle from UE to BS
Vertical angle	Angle from UE to BS
Total transmit power	Transmit power of either base-station (downlink) or UE (uplink)
Total received power	Power received on this link by either base-station (uplink) or UE (downlink)

A15.1.3 Details of a cell

When **a BS is selected,** the following information is shown (Figure 440 and Figure 441 for UL and Figure 442 for DL).

Figure 440: BS selected

Figure 441: Downlink BS selected

Figure 442: Uplink BS selected

Table 76: Parameters of selected base-station

Name	Description	Link direction
Cell ID	ID of selected base-station	General
Transmit power	Transmit power of the BS	Downlink
Total interference	Sum of internal and external interference at the BS	Uplink
Number of served users	Sum of voice active and voice inactive UEs	General
Antenna Height	Value from the input distribution	General
Number of dropped users	UEs dropped from the base-station	General
Outage percentage	Fraction of connected UEs that were dropped	Downlink
Noise rise over Noise Floor	The noise rise experienced at the selected BS	Uplink
Position	(X,Y) in km	General
Pilot channel Power	Power for the pilot channel power as deducted from the pilot channel fraction and the maximum transmit power	Downlink

Name	Description	Link direction
Overhead channel power	Power for the overhead channel as deducted from the overhead channel fraction and the maximum transmit power	Downlink
Number of active users	Number of connected UEs who has this BS as their primary link.	Downlink
Intersystem interference	Sum of interference from all UE's not connected to this BS	Uplink
External interference, Unwanted	Unwanted part of external interference	Uplink
External interference, Selectivity	Selectivity part of external interference	Uplink
Active connections	Number users connected to this BS (primary and secondary links)	General
Is Reference cell	When TRUE, then it is the reference cell	General

A15.2 EXAMPLE ON DL CDMA "OPTIMAL CAPACITY"
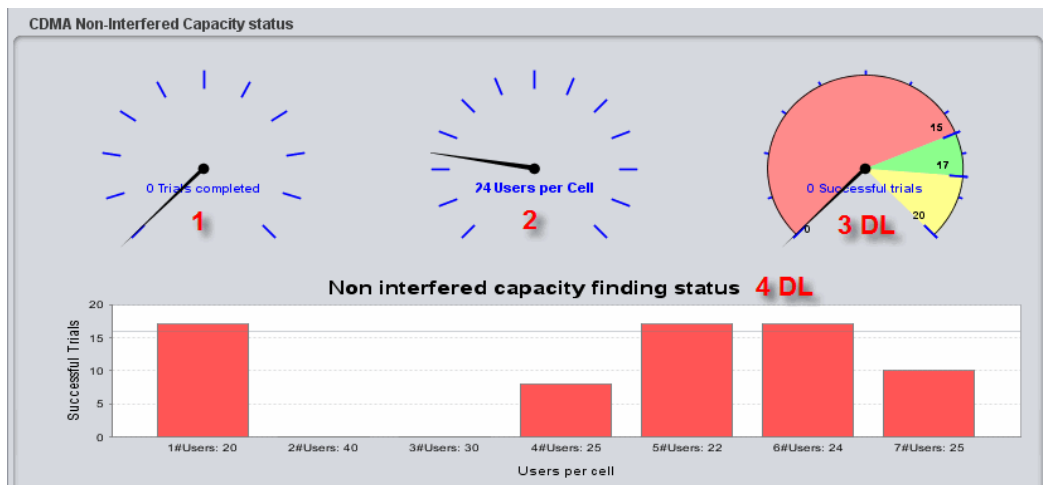
Figure 443: Non interfered capacity finding – Downlink

> ➢ Users (UEs) per cell = 20
> ➢ Number of trial = 20
> ➢ Delta number of users (UEs) per cell = 20
> ➢ Tolerance of initial outage: 5%
> ➢ Number of base stations = 19

1. Run [number of trials] with 20 UEs per cell
   a. Each "trial" consist of the following high-level steps:
      i. Generate CDMA system as specified in scenario
      ii. Add [UE per cell] x [number of base stations] = 380 UEs
      iii. Run power balancing without adding any external interference
      iv. After power balancing note if the percentage of dropped UEs is below 5%. [10]
      v. Count the number of successful trials and see if it is still possible to reach the 80% target.
         A. After 17 trials SEAMCAT concludes it is not possible to reach 80% and 20 UEs per cell is less than the specified systems optimal capacity[11]
         B. Adjust [UE per cell] by adding [delta UE per cell] (20 + 20 = 40) and go to step 2.
2. Run [number of trials] with 40 UE per cell
   a. Same as step (a) above – but now the system is filled with 40 x 19 = 760 UE and allowed outage is 5% of 760 (38 UEs)
         A. After running 5 trials of which none have been successful SEAMCAT determines that the system is filled with too many users
         B. Adjust [delta UEs per cell] by dividing with 2 (20/2 = 10)
         C. Adjust [UEs per cell] by subtracting [delta UEs per cell]   (40 – 10 = 30) and go to step 3
3. Run [number of trials] with 30 UEs per cell
   a. System is filled with (30 x 19 = 570) and tolerance is 28 UEs
         A. After running 5 trials of which none have been successful SEAMCAT determines that the system is filled with too many UEs
         B. Adjust [delta UEs per cell] by dividing with 2 (10/2 = 5)
         C. Adjust [UEs per cell] by subtracting [delta UEs per cell]   (30 – 5 = 25) and go to step 4
4. Run [number of trials] with 25 UEs per cell
   a. System is filled with (25 x 19 = 475) and tolerance is 23 UEs
         A. After running 10 trials 5 of them have been unsuccessful so SEAMCAT determines that the system is filled with too many UEs
         B. Adjust [delta UEs per cell] by dividing with 2 (5/2 ~ 3)
         C. Adjust [UEs per cell] by subtracting [delta UEs per cell]   (25 – 3 = 22) and go to step 5
5. Run of [number of trials] with 22 UEs per cell
   a. System is filled with (22 x 19 = 418) and tolerance is 20 UEs
         A. After 17 trials SEAMCAT concludes it is not possible to reach 80% and 20 UEs per cell is less than the specified systems optimal capacity
         B. Adjust [delta UEs per cell] by dividing with 2 (3/2 ~ 2)
         C. Adjust [UEs per cell] by adding [delta UEs per cell] (22 + 2 = 24) and go to step 6
6. Run of [number of trials] with 24 UEs per cell **(let's assume that it is the end of Figure 443)**
   a. *For the purpose of this example we assume that 24 UE per cell is the optimal capacity for the tested system*.
   b. After 20 trials we assume that 16 trials were successful – so optimal capacity finding is terminated and SEAMCAT starts the actual simulation.

---

[10] With 380 UEs in the system and a tolerance of 5%– no more than 19 UEs can be dropped during power balancing if trial is to be considered successful

[11] As more than 80% is already successful there is no need to simulate more trials

A15.3 CDMA UL – ENHANCEMENT TO ALLOW CELL SELECTION

A15.3.1 Flow chart
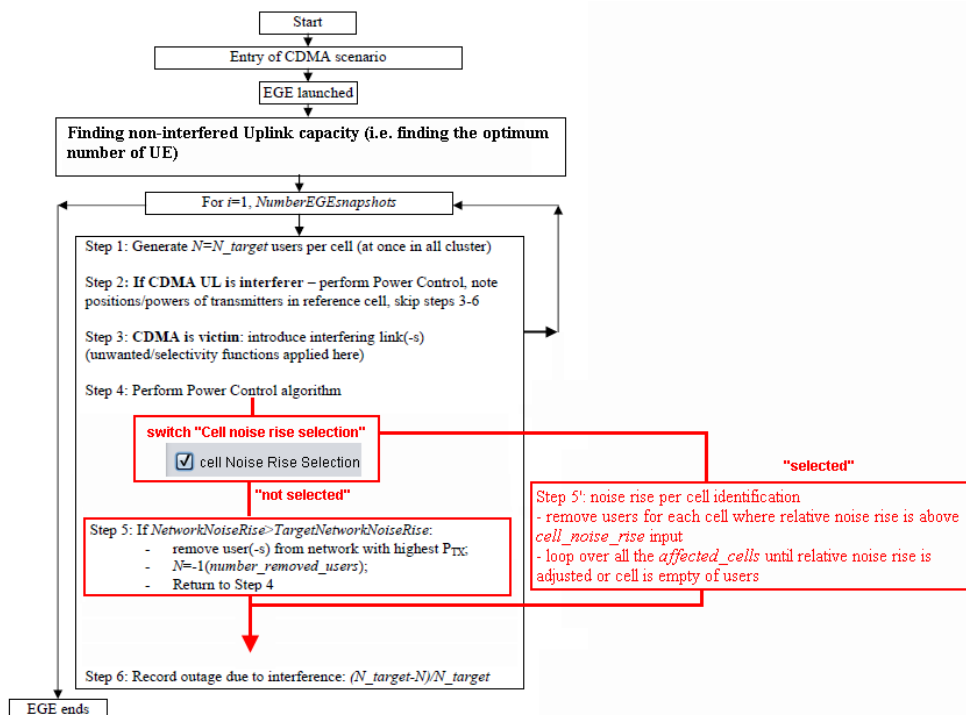
Figure 444: Flow chart of the CDMA UL "Cell selection" implementation (in red) with respect to the initial CDMA UL (in black)

A15.3.2 Algorithm

Convention: *i* is the index of the cells

1. Balance the power of the UE (i.e. set their Tx power) (*internalPowerBalance()*), the reference network capacity is calculated with the average noise rise reaching the defined threshold (i.e. *targetNetworkNoiseRise* input to SEAMCAT, usually 5.5 dB or 6dB) without external interference (i.e. *cellNoiseRiseInitial[i]*)
2. Calculate the average noise rise (with external interference) in the whole network and the noise rise in each cell (i.e. *cellNoiseRiseInterferer[i]*)
3. Arrange the active users in a list so that they are sorted based on their Tx power (i.e. *activeUsers*)
4. Calculate the relative cell noise rise which is the difference between noise rise with and without external interference for that cell.
   (i.e. *relativeCellNoiseRise[i] = - cellNoiseRiseInitial[i] + cellNoiseRiseInterferer[i]*)
5. If the network average noise rise is above the value of noise rise averaged in a network calculated in step 1 then <u>start the process of dropping users</u>.
6. Selection of the algorithm between 'average noise rise in a network' or ' noise rise per cell' (choice made by the SEAMCAT user)
7. 'Average noise rise in a network' selected
   While 'network average noise rise' > 'initial network average noise rise (step1)'
   - Remove user(s) from 'activeUsers list' (start with users having highest power level)
   - Re-optimize network (re-balance the power of the UEs) to achieve a new 'network average noise rise' value
   When 'while loop' finished, continue with step 12.
8. 'Noise rise per cell selected'
   Loop to identify the affected cells based on *relativeCellNoiseRise[i]*
   If - *cellNoiseRiseInitial[i] + cellNoiseRiseInterferer[i] > TargetCellNoiseRise* then Cell[i] is considered affected. The *TargetCellNoiseRise* (in dB) is an input to SEAMCAT set to a default value of 0.1 dB. You have the freedom of choosing a different value. The algorithm will select cells fulfilling above criteria

and assess those cells whether to drop users from those cells or not. The default value has been chosen to ensure that the analysis does not disregard any cases of interfered cells, since users may also be dropped as the consequence of a low noise rise. A list of affected cells is created (i.e. *selectedCell*).

9. Sort the list selectedCell so that the cell with the highest relative noise rise is the first element
10. Start loop over the sorted list selectedCells (starting from the first element)
    a. Extract the active users of selectedCell[i] from activeUsers into a list selectedCellActiveUsers (one list per cell)
    b. Calculate the current new noise rise for *selectedCell[i]* (i.e. *currentCellNoiseRise[i]*).
    c. Start removing (i.e. dropping) the active users from *selectedCellActiveUsers (by default the ActiveUsers list is reduced)*. The UE with strongest Tx power is removed first.
    d. Proceed with *internalPowerBalance()* over the remaining users for the whole network
    e. Calculate the new noise rise for *selectedCell[i]* (i.e. *currentCellNoiseRise[i]*).
       If *currentCellNoiseRise[i] >cellNoiseRiseInitial[i]*, continue until there is no more users or the cell noise rise is below or equal to *cellNoiseRiseInitial[i]*.
       Calculate the average network noise rise for output processing.
       If average noise rise below the *targetNetworkNoiseRise* exit the loop.
11. Outside the loop
12. Note that for each event the optimized number of UE is being re-calculated.
13. Produce:
    a) Save CDF of number of users in reference cell and whole network for initial optimized network (without external interference) and final optimized network
    b) The CDF of the capacity loss in the reference cell and in the whole network (for each event, calculate the capacity loss in %).
    c) The CDF of the capacity loss in the worst cell$_{per\ event}$ (the first strongest cell: *selectedCell[1]*). Only if 'Noise rise per cell selected'. The cell-ID can be different from event to event but the capacity loss is to be extracted).
    d) The number of cells affected per event.
    Only if 'Noise rise per cell selected'.
    e) Get vector of average network noise rise (initial optimized network (without external interference), initial optimized network (with external interference) and final optimized network)

A15.4 OFDMA DL ALGORITHM

The following describe the OFDMA DL algorithm presented in Section 9.7.

For i=1:# of snapshots
1. Distribute sufficiently many UEs randomly throughout the system area such that to each cell within the HO margin of 3 dB the same number K of users is allocated as active UEs.
   - Calculate the pathloss from each UE to all cells and find the smallest pathloss
   - Link the UE randomly to a cell to which the pathloss is within the smallest pathloss plus the HO margin of 3 dB
   - Select K UEs randomly from all the UEs linked to one cell as active UEs. These K active UEs will be scheduled during this snapshot.
   - Note: a full load system is assumed, namely, all available resource blocks (RBs) will be allocated to active UEs. And each UE is scheduled with the same number N of RBs. Thus, the BS transmit power per UE is fixed.
       - Let P_{BS}^{Max} denotes the maximum transmit power of BS
       - $M = N \times K$ is the number of all available RBs in each cell
       - P_{BS}^{UE} is the transmit power from BS to the active UE, and
       - $P_{BS}^{UE} = P_{BS}^{Max} \dfrac{N}{M}$.
2. Calculate DL C/I for all active UEs in all cells.
   - Loop over all cells from $j = 1$ to N_{cell} (the number of cells in the system area e.g. 57 for 19 sites with tri-sector antennas)

- Loop over all active UEs from $k = 1$ to K
- For the k-th active UE in the j-th cell (i.e. $UE_{j,k}$) its C/I is denoted by $\dfrac{C(j,k)}{I(j,k)}$,

3. Determine the throughput for each UE with its C/I according to the link-to-system level mapping.
4. Collect statistics.

A15.5 OFDMA UL ALGORITHM

The following describe the OFDMA UL algorithm presented in Section 9.8.

For i=1:# of snapshots
1. Distribute sufficiently many UEs randomly throughout the system area such that to each cell within the HO margin of 3 dB the same number K of users is allocated as active UEs
   - Calculate the pathloss from each UE to all cells and find the smallest pathloss
   - Link the UE randomly to a cell to which the pathloss is within the smallest pathloss plus the HO margin of 3 dB
   - Select K UEs randomly from all the UEs linked to one cell as active UEs. These K active UEs will be scheduled during this snapshot
   - Note: a full load system is assumed, namely, all available RBs will be allocated to active UEs. And each UE is scheduled with the same number N of RBs.
2. Perform UL power control
3. Calculate UL C/I for all active UEs in all cells.
   - Loop over all cells from $j = 1$ to N_{cell} (the number of cells in the system area e.g. 57 for 19 sites with tri-sector antennas)
   - Loop over all active UEs from $k = 1$ to K
   - For the k-th active UE in the j-th cell (i.e. $UE_{j,k}$) its C/I is denoted by $\dfrac{C(j,k)}{I(j,k)}$.
4. Determine the throughput for each UE with its C/I according to the link-to-system level mapping.
5. Collect statistics.

A15.6 IMPLEMENTATION OF THE OFDMA UL PC

A15.6.1 Introduction

There is no power control (PC) in OFDMA DL. The only PC is in the OFDMA UL and it is implemented following the description from TR36.942 [10].

5.1.1.5   CQI estimation

It is assumed that the CQI including external system interference is available before the scheduling process. This assumption is valid for the victim system only.

5.1.1.6   Power control modelling for E-UTRA and 3.84 Mcps TDD UTRA

No power control in downlink, fixed power per frequency resource block is assumed.

The following power control equation shall be used for the initial uplink (for E-UTRA and 3.84 Mcps TDD UTRA employing Enhanced UL) coexistence simulations:

$$P_t = P_{max} \times \min\left\{ 1, \max\left[R_{min}, \left(\frac{CL}{CL_{x-ile}} \right)^{\gamma} \right] \right\}$$

where P_{max} is the maximum transmit power, R_{min} is the minimum power reduction ratio to prevent UEs with good channels to transmit at very low power level, CL is the path coupling loss defined as max{path loss-G_Tx-G_Rx, MCL}, where path loss is propagation loss plus shadowfading, G_TX is the transmitter antenna gain in the direction of the receiver, G_RX is the receiver antenna gain in the direction of the transmitter and CL_{x-ile} is the x-percentile CL value. With this power control equation, the x percent of UEs that have the highest coupling loss will transmit at P_{max}. Finally, $0<\gamma<=1$ is the balancing factor for UEs with bad channel and UEs with good channel:

The parameter sets for power control are specified in table 5.3.

Table 5.3: Power control algorithm parameter

Parameter set	Gamma	CLx-ile			
		20 MHz bandwidth	15 MHz bandwidth	10 MHz bandwidth	5 MHz bandwidth
Set 1	1	109	110	112	115
Set 2	0,8	TBD	TBD	129	133

Further discussion and alignment concerning power control algorithms may be required after initial simulation results and further inputs from RAN WG1 are available

Figure 445: Extract from the 3GPP TR 36.942 [10]

The coupling loss (CL) is the effective path loss (Section 7.6.1) and is proportional to the cell size. Figure 446 illustrates an OFDMA UL for a single cell:
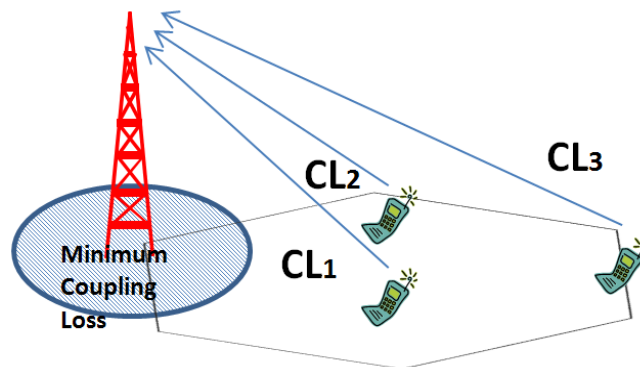
Figure 446: Illustration of the CL for a single cell

For one event, SEAMCAT calculates the CL for all the active UEs which are uniformly distributed over cells and the network. SEAMCAT gathers all the CL value and generate a CDF of it. The CL_xile value is taken out of this CDF for a certain percentile (xile = "power scaling threshold") and then fed into the equation. The power scaling threshold can be interpreted as the percentage of UEs Transmitting with less than the maximum power.

Figure 447 illustrates the CDF of the CL and the meaning of the X-ile with some illustrative numbers.
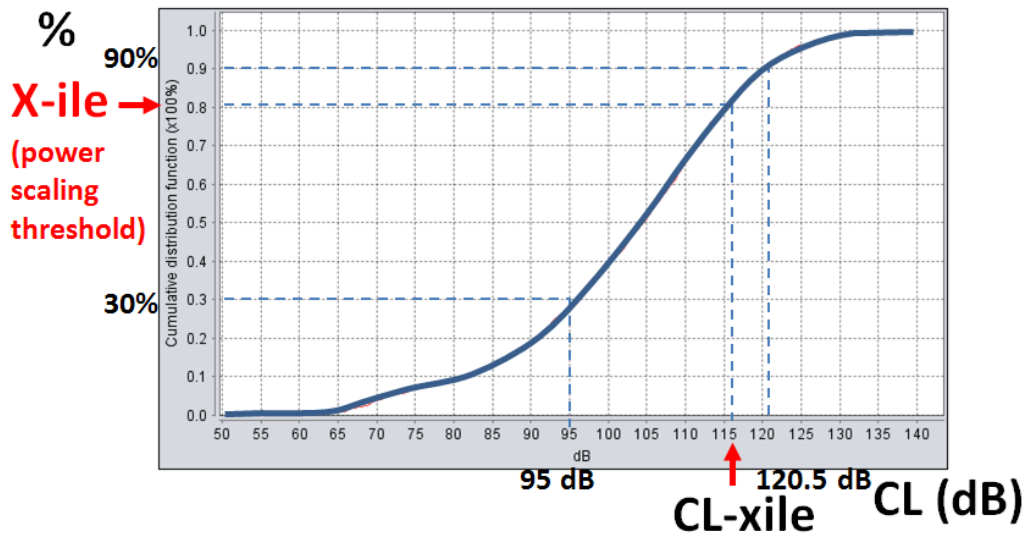
Figure 447: Illustration of the CDF of the CL and the meaning of the X-ile (with illustrative numbers)

The default value of 90% was taken while calibrating the tool with respect to the TR36.942 [10] example.

A15.6.2 What does it take for a UE to transmit full power ?

Assuming gamma = 1, for the UE to transmit full power, this means that Pt = Pmax

To achieve that you need to have min (1,max(Rmin,(CL/CL-xile))) = 1

in this case max(Rmin,(CL/CL-xile)) >1

with Pmax = 24 dBm and Pmin = -30 dBm, Rmin = 3.98107017055349725E-6 (linear value), therefore (CL/CL-xile) should be higher than 1.

For (CL/CL-xile) to be higher than 1, this means CL > CL-xile

So if the CL-xile =0.5 (50 %) then you are likely to have half of the UE transmitting full power.

Increasing the CL-xile, reduces the number of occurrence (i.e. number of UE) to have UEs transmitting full power. This is equivalent to reducing the red box in Figure 448.
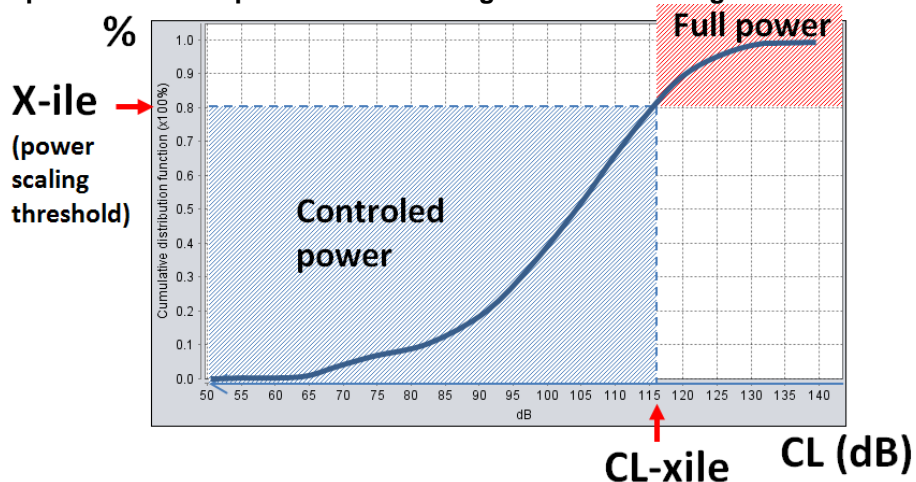
Figure 448: Illustration that if a UE has a CL higher than CL-xile, it transmit full power

A15.6.3 How can I check the distribution of the UEs' Tx power?

SEAMCAT allows you to check the OFDMA PC behaviour by extracting the Tx power of the UE for the last event.
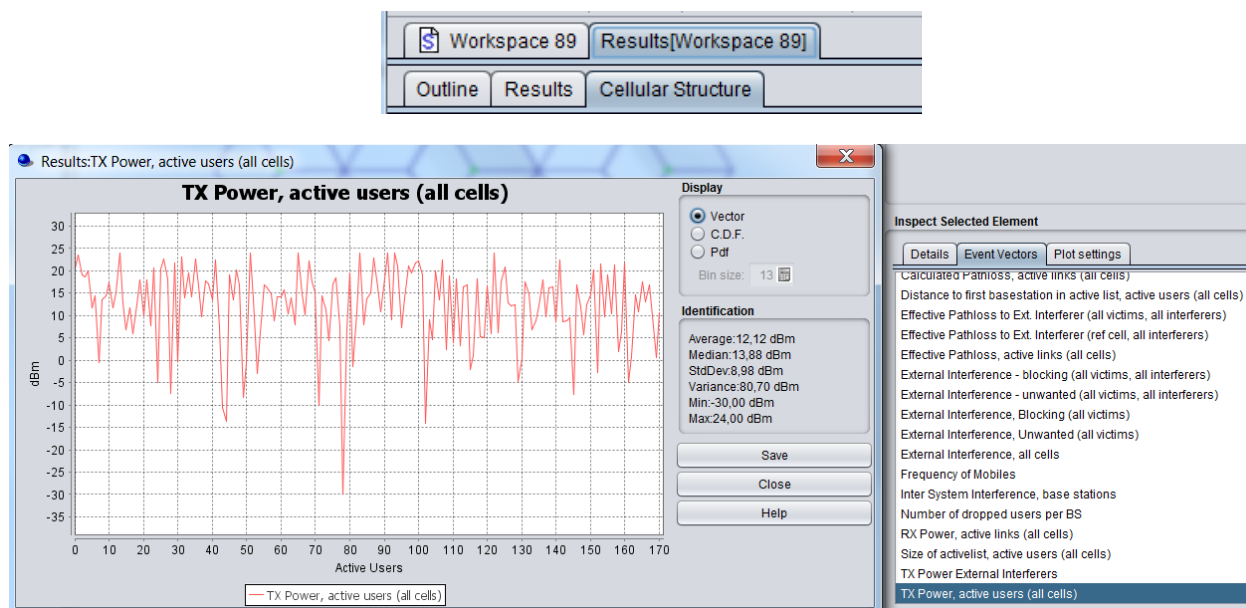
Figure 449: OFDMA TX power output vector

A15.7 ACS, ACLR AND ACIR APPROACH IN SEAMCAT

SEAMCAT does not use the ACIR methodology in its calculation since it has the flexibility to evaluates the unwanted and blocking either separatey or jointly.

- The ACLR as a single input is never used in any of the algorithm of SEAMCAT. The ACLR is calculated from the spectrum emission mask and only displayed as information when setting the spectrum mask of the interferer as;
- The ACS is considered in the victim link receiver blocking attenuation input field.

A15.7.1 ACIR methodology

Where an interferer transmits at a frequency that lies outside the nominal pass-band of the wanted signal, the level of interference experienced is a function of a) the interferer's spectral leakage, as defined by its emission power spectral density, and b) the frequency response of the filtering at the receiver. These two effects can be characterised by the interferer's adjacent-channel leakage ratio (ACLR) and the receiver's adjacent channel selectivity (ACS) respectively, as illustrated in Figure 450.

The combination of these two parameters, in the form of

$$ACIR = \frac{1}{\dfrac{1}{ACLR} + \dfrac{1}{ACS}}$$

(Eq. 177)

represents the fraction of the received interferer power which is experienced as interference by the receiver, and is referred to as the adjacent-channel interference ratio (ACIR).

The **ACLR** of a signal is defined as the ratio of the signal's power (nominally equal to the power over the signal's pass-band) divided by the power of the signal when measured at the output of a (nominally rectangular) receiver filter centred on an adjacent frequency channel. By setting up the unwanted emission mask in SEAMCAT, it is possible to display directly the ACLR (facility only available in the OFDMA module version).

The **ACS** of a receiver is defined as the ratio of the receiver's filter attenuation over its pass-band divided by the receiver's filter attenuation over an adjacent frequency channel. It can be readily shown that ACIR−1 = ACLR−1+ ACS−1. The victim link receiver blocking attenuation is used in SEAMCAT to input the ACS.

The **ACIR** is defined as the ratio of the power of an adjacent-channel interferer as received at the victim, divided by the interference power experienced by the victim link receiver as a result of both transmitter and receiver imperfections.

In other words, for a received interferer power at a frequency offset from the wanted signal, and for an ACIR (function of the frequency offset), the experienced interference power is reduced by the ACIR as sketched in Figure 450.
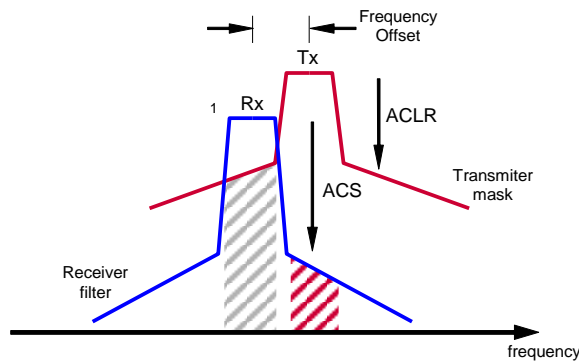
Figure 450: Interference as a result of limited ACLR and ACS

Note: This kind of description of the adjacent frequency bands parameters for compatibility issues is widely used in the 3GPP standardization.

A15.7.2 ACS (ACIR in DL)

In DL $ACIR^{-1}=ACLR_{BS}^{-1}+ACS_{UE}^{-1}$, and the dominant part of ACIR is due to the UE frequency selectivity (ACS) (i.e. $ACLR_{BS}$ is very large compare to ACS_{UE} and $ACIR \approx ACS_{UE}$. By varying the ACS of the victim link receiver, it is therefore possible to compare 3GPP methodology with SEAMCAT results.
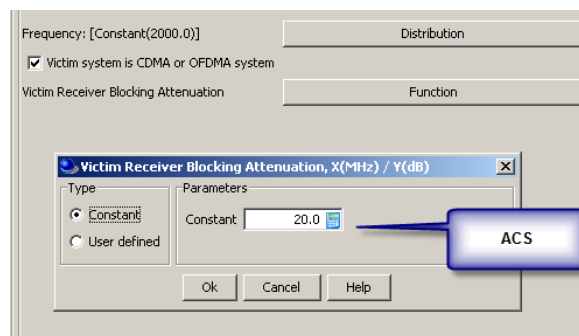
Figure 451: Illustration of the selection of the ACS

A15.7.3 ACLR (ACIR in UL)

The ACLR calculation is similar to the unwanted calculation BUT note that in 3GPP it is the integration of the interfering power in the adjacent channel where the bandwidth equal to the interfering emission bandwidth while the unwanted uses the victim bandwidth (See illustration from 3GPP TR36.942 [10]).
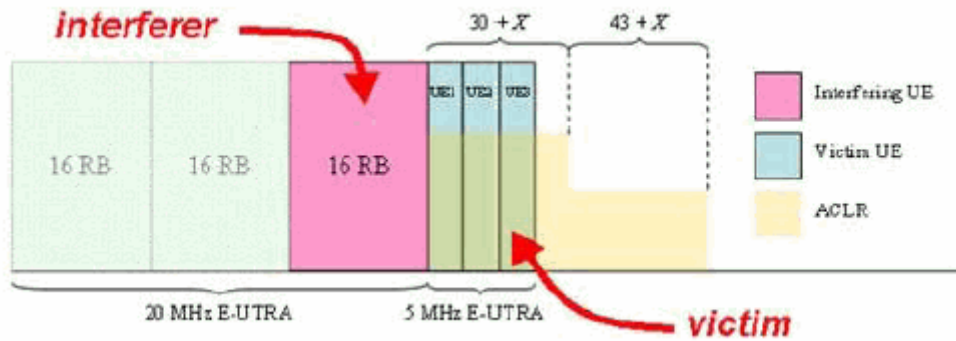
Figure 452: Illustration of the ACLR for a 20 MHz E-UTRA UE aggressor ro 5 MHz E-UTRA UE victims (TR36.942 [10])

In UL $ACIR^{-1}=ACLR_{UE}^{-1}+ACS_{BS}^{-1}$, and the dominant part of ACIR is due to the UE adjacent channel leakage (ACLR) (i.e. ACS_{BS} is very large compare to $ACLR_{UE}$ and $ACIR \approx ACLR_{UE}$. When the victim system is CDMA or OFDMA *only*, the spectrum mask at the interferer (whether it is a non-CDMA/OFDMA or CDMA/OFDMA module) will automatically display the ACLR.

This feature allows you to have an idea of the ACLR value with respect to the spectrum mask that you enter. This will help you in comparing external results that have been generated based on an ACIR methodology.
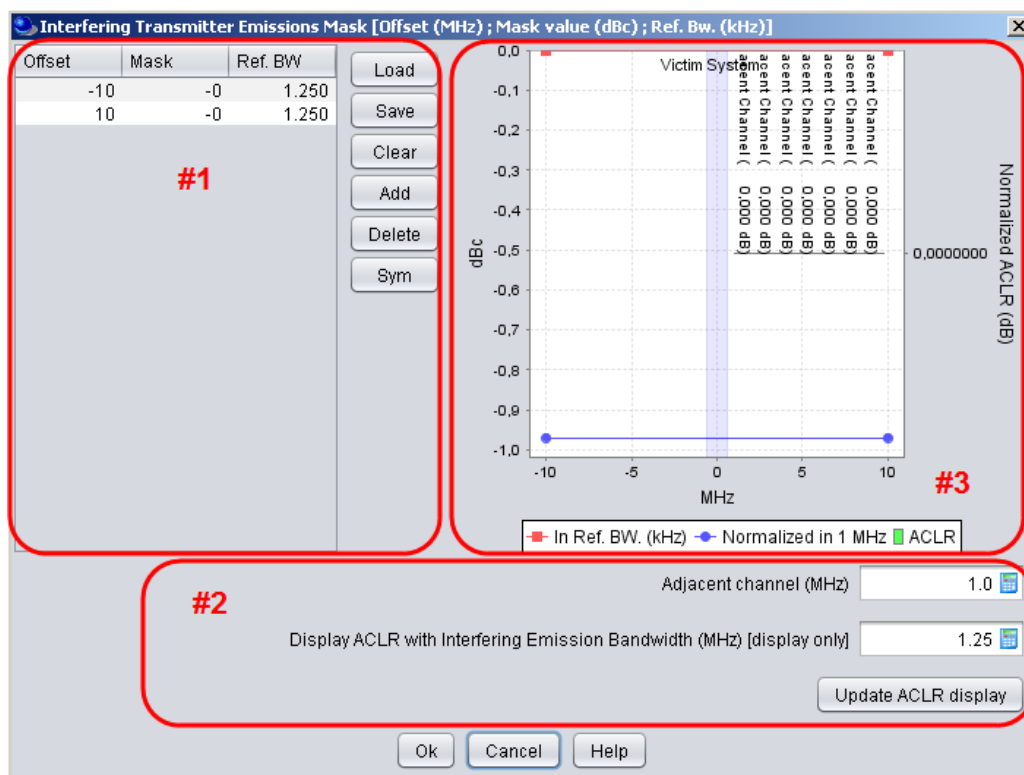
Figure 453: ACLR interface – default value

When the ACLR display is activated, the *Interefering link transmitter Emissions Mask* dialog box is composed of 3 important parts

- Part **#1** corresponds the usual set of the spectrum mask.
- Part **#2** corresponds to setting the ACLR parameters:
    - Adjacent channel (MHz) (default value = 1 MHz);
    - Emission bandwidth (MHz) (default value = 1.25 MHz);
    - Update display button;
    - Part **#3** corresponds to the display of the spectrum mask and the ACLR.

When you enter the mask, the ACLR is automaticaly calculated with the default ACLR setting parameter values.
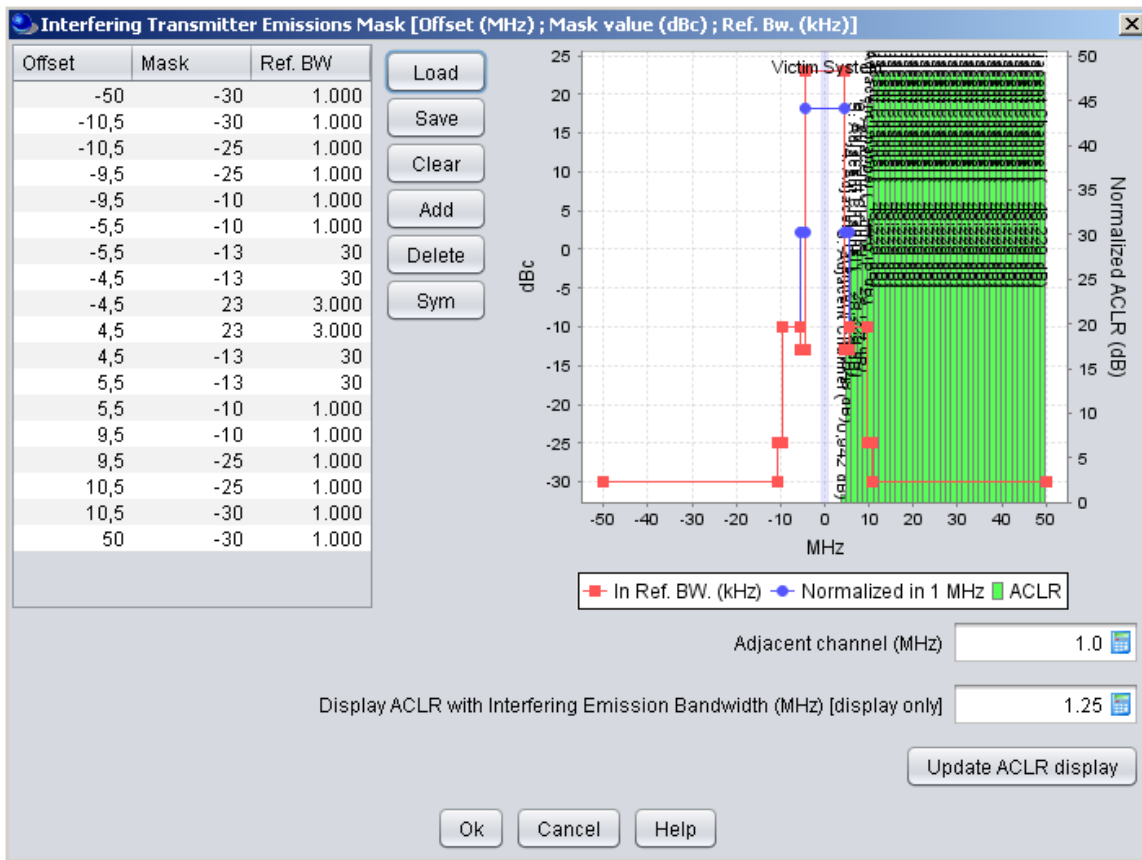
Figure 454: ACLR interface – with a spectrum mask – Step 1

For this example, assuming that the first adjacent channel starts at 4.5 MHz and the interfering emission bandwidth of the system is 9 MHz, you have to set the parameters as shown in Figure 455. The green bars represents *for information* the various ACLR depending on each of the adjacent channels (see Figure 456 for a zoom of the display). On the right hand side the axis represent the normalized ACLR in dB.
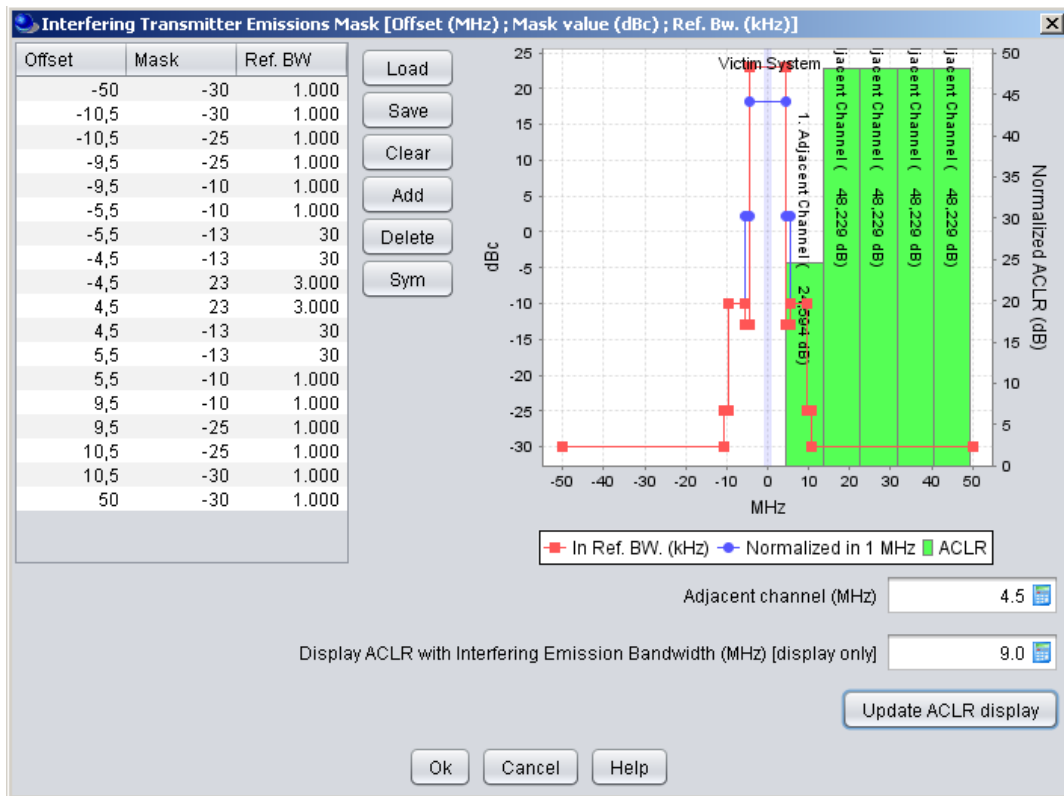
Figure 455: ACLR interface – with a spectrum mask – Step 2
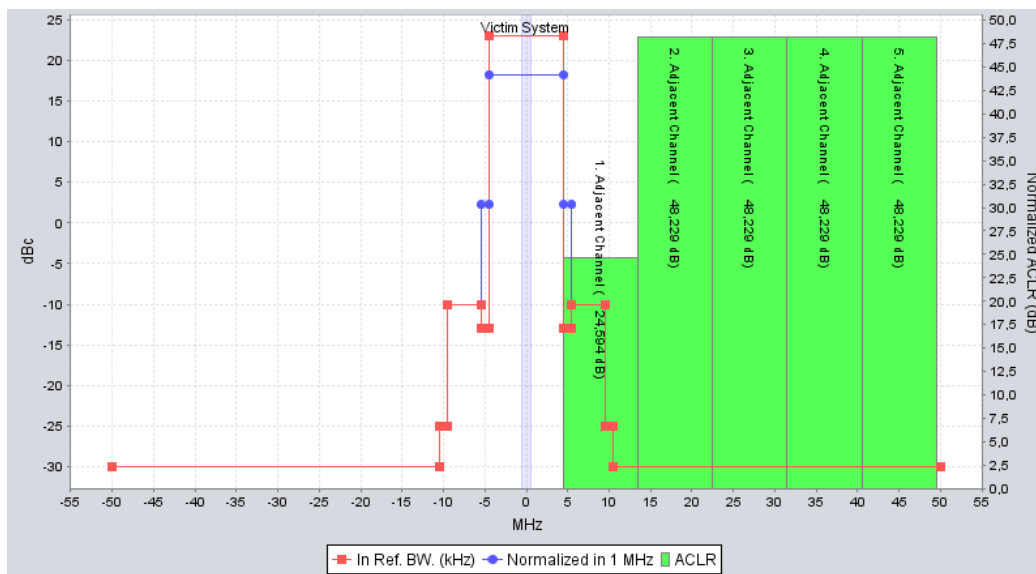
Figure 456: Zoom of the display

A15.7.4 ACLR for OFDMA UL as interferer

Note that for an OFDMA UL interfering system of 10 MHz, where there is 5 active users to simulate, the spectrum mask to set in SEAMCAT is defined over 2 MHz (10MHz / 5), but the ACLR is computed for the full system emission bandwidth. Therefore you would need to set:

- Adjacent channel = +1 MHz (if the victim frequency is higher than the interferer) or -1 MHz (if the victim frequency is lower than the interferer).
- Interfering Emission Bandwidth = 10 MHz

A15.7.5 Usage requirement

SEAMCAT allows you to define the spectrum as part of a spectrum range which can be strictly above or below the centre offset as shown in Figure 457.
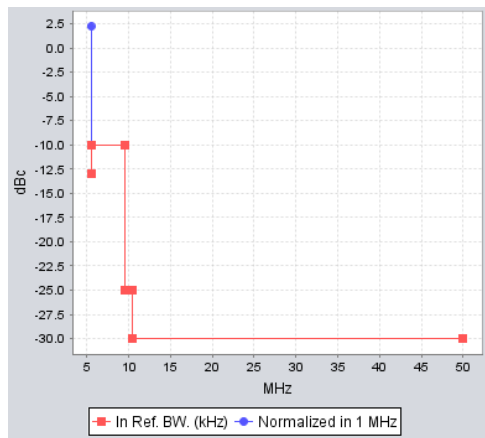
Figure 457: Portion of spectrum mask definition (i.e. excluding the center offset)

This flexibility creates a restriction in the ACLR display. It is because the ACLR display algorithm is normalized to the in-band power. Therefore, in order to generate the ACLR display it is necessary to have the spectrum mask being defined within the range of the system emission bandwidth (centered to the zero offset).

By default, in the case where a user would set the mask so that the ACLR would fail to compute, SEAMCAT will automatically disable the ACLR display functionality as shown in Figure 458.
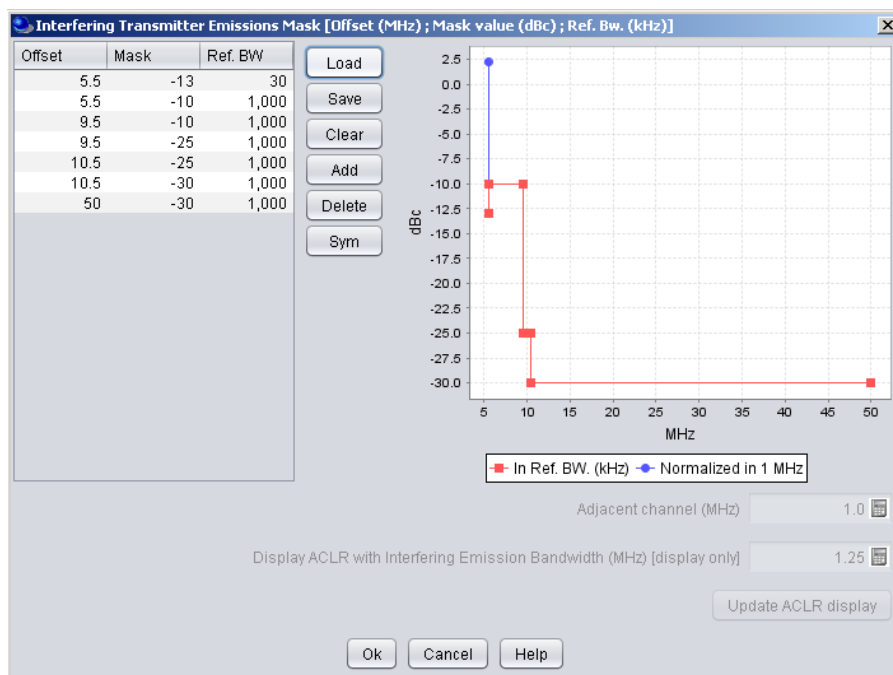
Figure 458: ACLR display functionality disabled due to the specific definition of the spectrum

ANNEX 16: : SPECTRUM SENSING ALGORITHM

A16.1 OVERALL ALGORITHM

Assuming ideal case, the basic proposal of a CR is as follows:
> if sRSS > Detection threshold -> WSD_{OFF} = no transmission = no interference
> if sRSS < Detection threshold -> WSD_{ON} = interference calculation is possible

STEP 1: Identification of the frequencies to be tested.
It is assumed that the frequency of the interfering WSD is dependent on the frequency range defined for the victim. This means that when the CR module is activated, the interfering frequency function dialogue box is deactivated.

M is the number of possible channels that the WSD will operates in.

One can consider following possible ways to define operating frequency for the victim device:

Victim frequency = constant

- interferer frequency = Victim frequency;
- M = 1

victim frequencies are discrete;
- the possible WSD frequencies that you defined;
- M equals the number of discrete inputs victim frequencies are distributed between f_{min} and $f_{max;}$
- The possible WSD frequencies are from $f_{min}+(M-1)$*victim bandwidth until f_{max} (i.e. assuming that f is the center frequency). Note that $(f_{min}+(M-1)$*victim$) \leq f_{max;}$
- Extract M WSD channels.

STEP 2: Assigned the WSD with a frequency
for each events{
Note: the victim operates at a single frequency f_v. Several interferers may be operating in various frequencies

if (dRSS > sensitivity){
   for each WSDs {
    for channel *m = 1 to M+1*(i.e. over all the WSD channels){

STEP 2.1: Calculate the sRSS
- Calculate the sRSS (considering the unwanted mask of the DTT) at the channel *m* (i.e. WSD at f_m and victim at *fv*) (see ANNEX 6:)

STEP 2.2: Identification of "available" channels
- Detect if a WSD is allowed to transmit (i.e. compare to threshold)
- Store the channels that are accessible as vector *available_channel*
- Store the channels that are not accessible as vector *non_available_channel*
   }

STEP 3: Probability of Failure (if activated)
- Failure status (either TRUE or FALSE) of this WSD is extracted as an event from a distribution. i.e. depending of the $p_{failure}$
- If this WSD has failure = TRUE, then it means that it will transmit in the victim frequency without power constraint
- Update the vectors *available_channel* and *non_available_channel* so that *non_available channel= 0* and *available_channel=1* and is the victim frequency.
- If this WSD has failure = FALSE, proceed without changing the vectors *available_channel* and *non_available_channel*

STEP 4: Select an available channel / determination of the WSD channel

    if (*non_available_channel* < 1) (i.e. all are available){

- No frequency is blocked, the max e.i.r.p. of the WSD is considered (i.e. e.i.r.p. deduced from the Tx and antenna gain of the WSD which are inputs to SEAMCAT.)
    - The WSD is placed randomly among the *available_channel*

    }

    else (i.e. one or more channels are blocked (i.e. non-available)){

    if (all channels are blocked){

        try another WSD → **back to STEP 2.1** *and store the number of inactive WSD*

        }

        else (not all the channels are blocked){

    if (single frequency case) (i.e. frequency = constant){

    No frequency is blocked, the max e.i.r.p of the WSD is considered (i.e. e.i.r.p deduced from the Tx and antenna gain of the WSD which are inputs to SEAMCAT.)

            }

            else {

Step 4.1: Apply the Table of Constraints

    For each of the *non_available_channel,* read the associated predefined table for which the "co-channel" row is synchronised to the non-available channel. Create a new e.i.r.p table with the dimension (number of rows: number of *non_available_channel*, number of columns: number of *available_channel*).

    for each of the *available_channel*{

                - Extract the lowest e.i.r.p from the table. This gives the vector (available channel, e.i.r.p).

Step 4.2: Determination of the WSD channel /e.i.r.p

- From this vector extract the couple (fi, "max e.i.r.p") the vector (available channel, e.i.r.p)
- if several channels are associated with the same "max e.i.r.p" , the WSD is placed randomly among the channels.

            }

          }

      }

    }

  } (end of the WSD loop)

Note: Now the active WSDs are assigned a frequency and a e.i.r.p.._max_.

STEP 5: Cumulate the frequency/ e.i.r.p of all the active WSDs for each event into a single vector.

Note: The below calculation is as normal to SEAMCAT

  for each active WSDs {

    Extract the *Tx power* = e.i.r.p $_{max}$ - $G_{maxIt \to VLR}$

    Calculate iRSS$_{unwanted}$ (i.e. victim at f_v)

    Calculate iRSS$_{blocking}$ (i.e. victim at f_v)

    Calculate iRSS$_{overlaoding}$ from the interfering WSD to the at the DTT victim link receiver frequency.

    }

$$\text{Calculate the } iRSS_{comp}^{unwanted} = \sum_{i=1}^{numberOfActiveWSD} iRSS_i^{unwanted} \qquad (\text{Eq. 178})$$

$$\text{Calculate the } iRSS_{comp}^{blocking} = \sum_{i=1}^{numberOfActiveWSD} iRSS_i^{blocking} \qquad (\text{Eq. 179})$$

Note: If none of the WSDs are active iRSS$_{comp}$ = -1000 dB (by default) to allow the interference calculation.

  }

```
    else{
        Skip this event
    }
}
```

A16.2 DETERMINATION OF THE E.I.R.PMAX IN-BLOCK LIMIT

The following presents the results of the SEAMCAT logfile, when the E.I.R.Pmax in-block limit is to be determined. For this example the following E.I.R.P$_{max}$ in-block limit is set in SEAMCAT
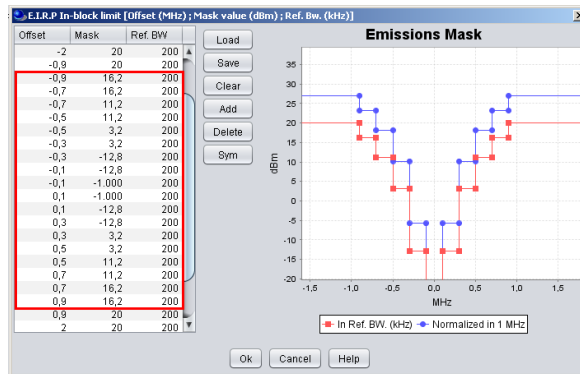
Figure 459: e.i.r.p.$_{max}$ in-block limit

The following log file is extracted and it shows the channel availability for one event and for one WSD (It no.1, WSD no. 0). In this case, this WSD would be allowed to transmit at 1000.1 and 1000.3 MHz, but it is not allowed to transmit in the 1000.5, 1000.7 and 1000.9 MHz. The Victim is placed at 1000.9 MHz.

Figure 460: Extract of the logfile
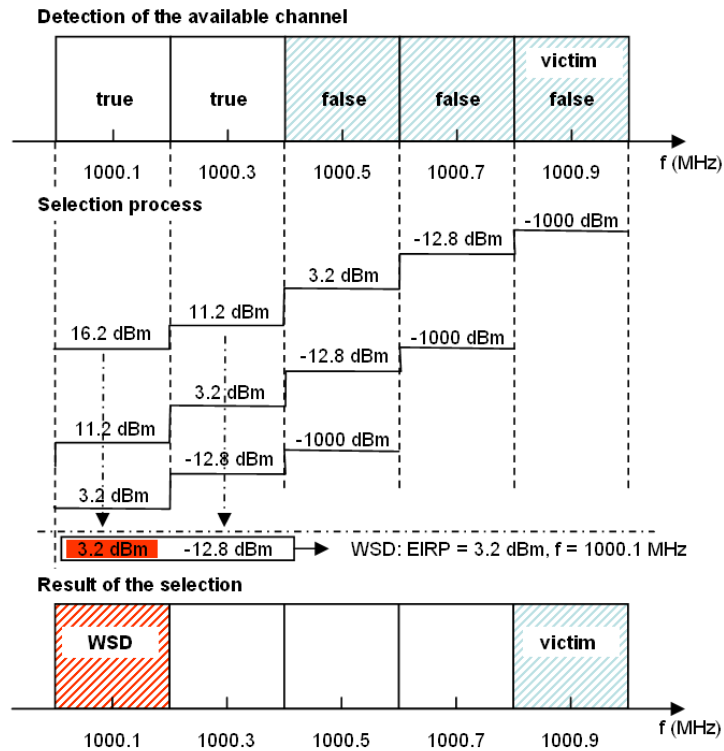
Figure 461: Illustration of the Selection process

ANNEX 17: : PROPAGATION MODELS

A17.1 INTRODUCTION

A17.1.1 Note on using propagation models

SEAMCAT has the mean to use in-built model but also the mean of programming user-defined propagation models. The plug-in concept was chosen to avoid the inherent format limitations of the earlier SEAMCAT versions interface and make the plugin model to work as fast as any in-built model.

To aid in the selection process, Table 77 provides an indication of the application ranges and typical areas of suitability of the in-built propagation models in SEAMCAT:

Table 77: Application ranges and typical areas for the various propagation models implemented in SEAMCAT

Model	Annex	Frequency range	Distance range	Typical application area
Free space loss	A17.2	Above 30 MHz	LOS-limited	Fixed links and other systems/paths were direct-LOS could be assumed
Extended Hata	A17.3	30 MHz - 3 GHz	Up to 40 km	Mobile services and other services working in non-LOS/cluttered environment . Note that in theory, the model can go up to 100 km since the curvature of the earth is included, but in practice it is recommended to use it up to 40 km.
Extended Hata-SRD	A17.4	30 MHz - 3 GHz	Up to 300 m	Short range links under direct-LOS assumption, important: antenna heights up to 3 m
Spherical diffraction (ITU-R P.452)	A17.5	Above 3 GHz	Up to and beyond radio horizon	Interference on terrestrial paths in predominantly open (e.g. rural) areas
ITU-R P.452-14	A17.6	about 0.7 GHz to 50 GHz	up to a distance limit of 10 000 km	Prediction method for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz, accounting for both clear-air and hydrometeor scattering interference mechanisms.
ITU-R P.1546: ▪ ITU-R Rec.P.1546-4 **ITU-R Rec.P.1546-1 (obsolete)**	A17.8 and A17.7 (obsolete)	30 MHz - 3 GHz	1-1000 km	Broadcasting and other terrestrial services, typically considered in cases with high mounted transmitter antenna (e.g. above 50-60 m). Note that ITU-R Rec.P.1546-4 proposes a solution where values of distances less than 1 km may occur and where short-range propagation model is not practicable and a simple means is required to converge towards free-space field strengths for arbitrarily short distances (see section 14 of ITU-R

Model	Annex	Frequency range	Distance range	Typical application area
				Rec.P.1546-4).
JTG5-6	A17.9	30 MHz - 3 GHz	>0 – 1000 km	similar to ITU-R P.1546-4 but covering the distances below 1 km
Longley Rice (ITM)	A17.10	20 MHz – 40 GHz	1 – 2 000 km	Antenna height from 5 cm to 3 km and surface refraction from 250 to 400 N
IEEE 802.11 Model C	A17.11			
ITU-R Rec. P. 1411	A17.12	300 MHz – 100 GHz	< 3 km	§ 4.3 of the recommendation; for propagation between terminals located from below roof-top height to near street level
ITU-R Rec. P. 528	A17.13	125 MHz – 15.5 GHz	> 0 – 1800 km	ground-air, ground-satellite, air-air, air-satellite, and satellite-satellite links
Propagation plug-in	A17.1.4	model specific	model specific	model specific

A17.1.2 Principal propagation mechanisms

ITU R P.452 presents in its overall description a summary of the principal propagation mechanism. It explains that interference may arise through a range of propagation mechanisms whose individual dominance depends on climate, radio frequency, time percentage of interest, distance and path topography. At any one time a single mechanism or more than one may be present. The principal interference propagation mechanisms are as follows:

- **Line-of-sight** (Figure 462): The most straightforward interference propagation situation is when a line-of-sight transmission path exists under normal (i.e. well-mixed) atmospheric conditions. However, an additional complexity can come into play when subpath diffraction causes a slight increase in signal level above that normally expected. Also, on all but the shortest paths (i.e. paths longer than about 5 km) signal levels can often be significantly enhanced for short periods of time by multipath and focusing effects resulting from atmospheric stratification (see Figure 463).
- **Diffraction** (Figure 462): Beyond line-of-sight (LoS) and under normal conditions, diffraction effects generally dominate wherever significant signal levels are to be found. For services where anomalous short-term problems are not important, the accuracy to which diffraction can be modelled generally determines the density of systems that can be achieved. The diffraction prediction capability must have sufficient utility to cover smooth-earth, discrete obstacle and irregular (unstructured) terrain situations.
- **Tropospheric scatter** (Figure 462): This mechanism defines the "background" interference level for longer paths (e.g. more than 100-150 km) where the diffraction field becomes very weak. However, except for a few special cases involving sensitive receivers or very high power interferers (e.g. radar systems), interference via troposcatter will be at too low a level to be significant.
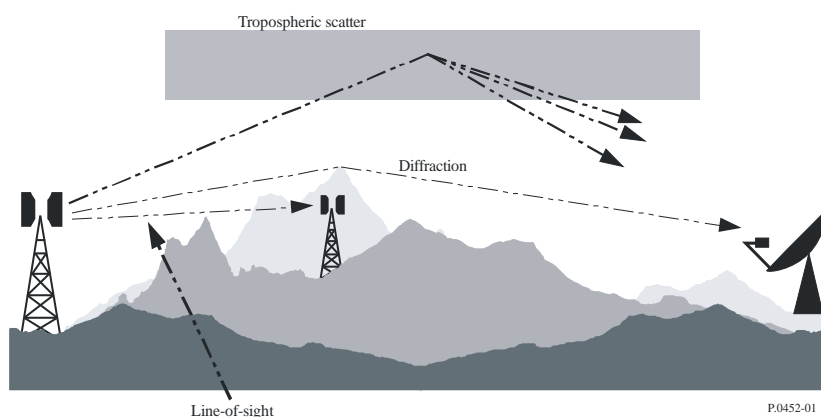
Figure 462: Long-term interference propagation mechanisms (Source: ITU-R P.452)

▪ **Surface ducting** (Figure 463): This is the most important short-term propagation mechanism that can cause interference over water and in flat coastal land areas, and can give rise to high signal levels over long distances (more than 500 km over the sea). Such signals can exceed the equivalent "free-space" level under certain conditions.
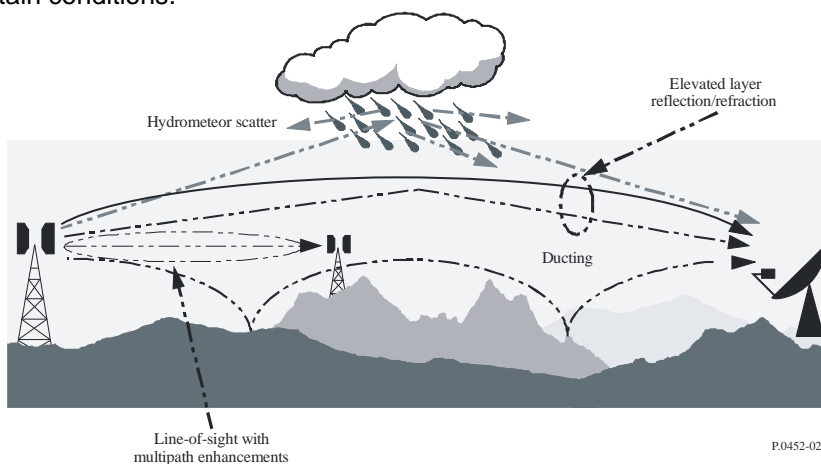
Figure 463: Anomalous (short-term) interference propagation mechanisms (Source: ITU-R P.452)

▪ **Elevated layer reflection and refraction** (Figure 463): The treatment of reflection and/or refraction from layers at heights up to a few hundred metres is of major importance as these mechanisms enable signals to overcome the diffraction loss of the terrain very effectively under favourable path geometry situations. Again the impact can be significant over quite long distances (up to 250-300 km).
▪ **Hydrometeor scatter** (Figure 463): Hydrometeor scatter can be a potential source of interference between terrestrial link transmitters and earth stations because it may act virtually omnidirectionally, and can therefore have an impact off the great-circle interference path. However, the interfering signal levels are quite low and do not usually represent a significant problem.

A17.1.3 Using the Extended Hata vs. P.1546 models

The most usually used SEAMCAT in-built propagation models in typical SEAMCAT scenarios are the **Extended Hata model** and the **ITU-R Rec. P.1546 model**. Therefore, when choosing between those two models, you should be aware of their similarities and differences:

▪ The **Hata model** (also referred to as Okumura-Hata) was originally developed for non-Line-Of-Sight (Non-LOS) paths in urban environments typical of mobile services - that is with low-height mobile terminals moving in cluttered environment.
▪ The **P.1546 model** was originally developed for broadcasting environment (at that time being the ITU-R Rec. P.370), however later, it was modified into a universal terrestrial propagation model, by approximating between the original P.370 curves and curves of other models, incl. those of Okumura-Hata model.

Therefore the **P.1546** and **Hata models** may yield comparable results at distances of some 10-40 km (the typical range of Hata model) in certain range of conditions and for certain combinations of transmitter and antenna heights.

Regarding the antenna heights it is important to keep in mind that the **Hata** and **P.1546** models use **different definitions of antenna heights**.

- The **Hata model** assumes simply the height of transmitting antenna above ground.
- The **P.1546 model** assumes that the height of transmitting antenna (h1, ht) is the effective height above the average height of terrain over the propagation path (taken between 3-15 km). In that regard it should be noted that SEAMCAT by itself does not have any knowledge about the actual terrain, therefore user should carefully consider the appropriate value of transmitting antenna height, following guidance in P.1546-1.

On the other hand, it should be noted that the **P.1546 model** does not have a distinction between urban and rural propagation conditions except when calculating correction for receiving antenna height. Thus, the setting of **URBAN**, **SUBURBAN** or **RURAL** environment when selecting P.1546 model simply leads to an assumption of certain **height of local clutter**, surrounding the receiver antenna. This is then compared with the height of receiver antenna and depending on their relationship, the appropriate correction will be made. For example, if the receiver antenna height is less than the assumed height of local clutter, then the propagation loss will increase.

By default SEAMCAT assumes the height of local clutter to be 10 m for both **RURAL** and **SUBURBAN** environment and 20 m for **URBAN** environment. In SEAMCAT, you are given the option to define its own local clutter height, which may be then different from the above default values. Therefore, when using **P.1546 model**, it is very important to consider the height of receiver antenna with regards to the assumed height of local clutter.

The figure below shows an example of how the median propagation loss calculated with **P.1546 model** would change depending on the height of receive antenna (h2), and how it compares with the corresponding **Hata model** results (the curves are for 600 MHz, 50% time, 50% locations, default local clutter setting in P.1546).
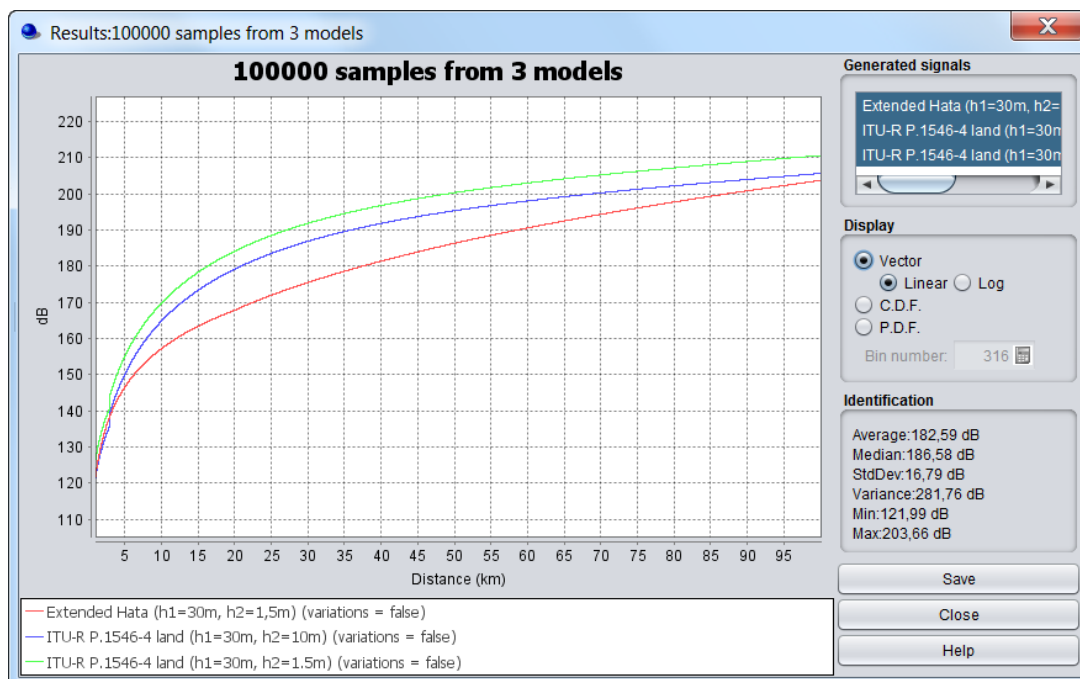
Figure 464: Comparison between P1546 and Hata model.

When the height of receiver antenna h2 in P.1546 is set to 1.5 m, which is much below the assumed height of local clutter (the default value of 10 dB was used in these simulations), then the propagation loss is much higher (by almost 20 dB) than the one generated with P.1546 for h2=10 m (i.e. when receiver antenna was

set equal to the height of local clutter). In the latter case, the P.1546 losses are quite close to the results produced with Hata model, especially for shorter distances.

A17.1.4 Propagation model plugin

You can define very complex propagation modelling with propagation model plugin using standard Java programming language.

The propagation model plugin is intended to allow you to create your own propagation models through a script describing the pass loss calculation. This script consists of a sequence of formulas conforming to a well-defined syntax and may be edited by means of standard text editor. Further details are found in Section 14.4.

A17.2 FREE SPACE

This model describes the theoretical minimum propagation path loss achievable in free space conditions. This model is appropriate to use on paths were unobstructed direct-Line-of-Sight propagation could be expected (e.g. point-to-point fixed service links, links over short distances in open areas, etc).
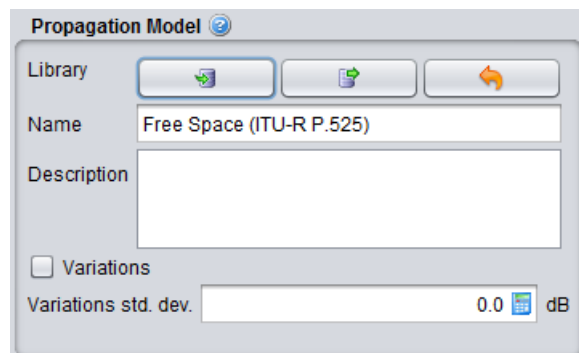
Figure 465: SEAMCAT Interface to the free space propagation model

For free space model the path loss is defined by:

$$L = 32.44 + 10\log_{10}\left(\left(\frac{\left(h_{tx} - h_{rx}\right)}{1000}\right)^2 + d^2\right) + 20\log_{10} f \qquad \text{(Eq. 180)}$$

The **variations** correspond to the standard deviation variations.

Note: The Free space model allows the possibility to include some variations in the similar manner as it is done for all other built-in models. If user wants to use just the median theoretical value, the variations option should be disabled.

Figure 466 illustrates when the variation is disabled (i.e. no std).
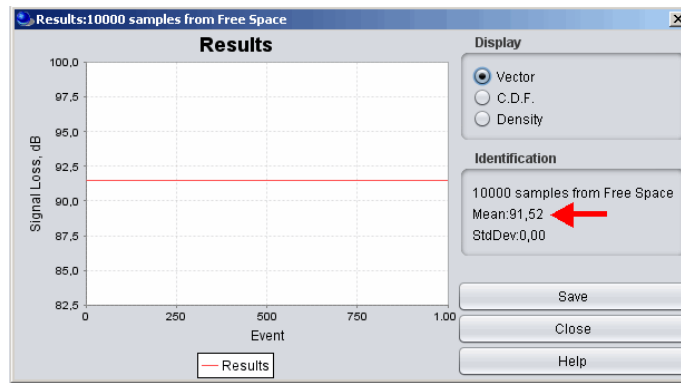
Figure 466: Example of the vector events of the Free Space when Variation is disabled (i.e. equivalent to σ = 0 dB) active (i.e. mean = 91.52 dB)

Figure 467 presents the Free Space when **Variation** is activated (std = σ = 2.5 dB). The value presented in Figure 466 and Figure 467 are extracted with the following parameters: $f = 900$ MHz, $d = 1$ km, $h_{tx} = h_{rx} = 10$ m.
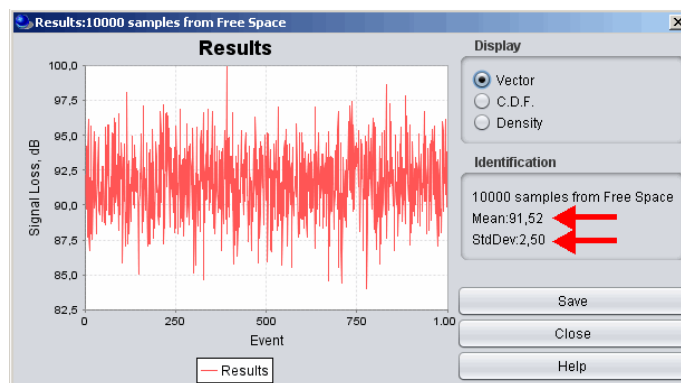
Figure 467: Example of Free Space results when the Variation (i.e. σ = 2.5 dB) is active (i.e. mean = 91.52 dB)

A17.3 EXTENDED HATA MODEL

The Hata model (also referred to as Okumura-Hata) was originally developed for non-Line-Of-Sight (Non-LOS) paths in urban environments typical of mobile services - that is with low-height mobile terminals moving in cluttered environment. In the SEAMCAT propagation library, you will find it under the name "Extended Hata".

The Hata-SRD variation was developed in CEPT within the Project Team SE24 for studies of Short Range Devices (SRD). The basis for modification was an assumption that although SRD devices are usually operated at low antenna heights (typically person-carried devices, i.e. with antenna height of ca. 1.5 m), but the interference would usually occur at relatively short distances (up to 100 m or so) when direct-Line-Of-Sight(LOS) or near-direct-LOS might be assumed. Therefore the Hata-SRD model includes adjusted expression of a certain parameter b(Hb), which in standard Hata model would introduce significant extra path loss when transmitter antenna height is much less than 30 m. It was found that this extra loss is not justified in the considered SRD scenarios of short range & direct-LOS communication/coupling. In the SEAMCAT propagation library, you will find it under the name "Extend Hata - SRD"
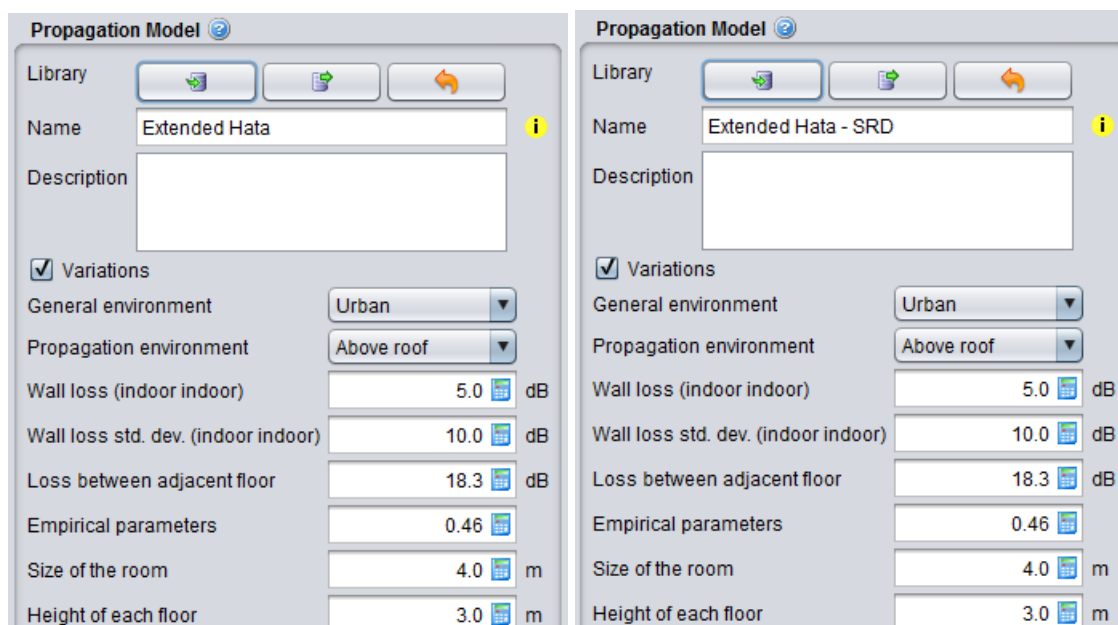
Figure 468: SEAMCAT Interface to the extended Hata propagation model (general model on the left) and its adapted version for SRDs (on the right)

Table 78: Description of the Extended Hata and Extended Hata (SRD) models

Description	Symbol	Type	Unit	Comments
Variation				Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc.
General environment				Environment of the propagation: urban, rural, suburban
Propagation environment				Environment of the propagation: Below roof, Above roof (used for standard deviation calculations) ONLY USED IF VARIATION OPTION IS CHECKED
Wall loss (indoor - indoor)		S	dB	
Wall loss std dev (indoor - indoor)		S	dB	
Loss between adjacent floor		S	dB	
Empirical parameters:	b			
Size of the room (d_{room})	d_{room}	S	m	
Height of each floor	h_{floor}	S	m	

A17.3.1 Outdoor-outdoor propagation

The Extended Hata model implemented in SEAMCAT calculates propagation loss between transmitter and receiver as:

$$f_{propage}(f, h_1, h_2, d, env) = L + T(G(\sigma))$$ (Eq. 181)

where:

  f : frequency (MHz)

  h1   : transmitter antenna height, m, above ground

  h2   : receiver antenna height, m, above ground

  d : distance between transmitter and receiver, km

  env : general environment attenuation (dB)

  L : median path loss (dB)

  ☐   : Variation in path loss (dB)

The validity ranges identified by COST 231 based on the original work of Okumura and Hata should be applied when using the Extended Hata model in SEAMCAT, i.e. H_m: 1 to 10m and H_b: 30 to 200m (Note that the H_b is assumed to be above roof top) where:

  $H_m = min\ (h_1, h_2)$

  $H_b = max\ (h_1, h_2)$

If H_m is below 1m, a value of 1m should be used instead. If H_b is above 200m, it might also lead to significant errors. This gives the possibility to use this model reciprocally (DL and UL) as described in Report ITU-R SM.2028-1.

Median path loss

Table 79: Description of the median path loss L depending on the distance

Dist. Range (km)	Env.	Frequency Range(MHz)	Median path Loss	
d < 0,04			$L=32.4+20\log(f)+10\log\left[d^2+\dfrac{(H_b-H_m)^2}{10^6}\right]$	(Eq. 182)
d > 0.1 km	Urban	30 < f ≤ 150	$L=69.6+26.2\log(150)-20\log(150/f)-13.82\log(\max\{30,H_b\})+$ $[44.9-6.55\log(\max\{30,H_b\})][\log(d)]^\alpha-a(H_m)-b(H_b)$	(Eq. 183)
		150 < f ≤ 1500	$L=69.6+26.2\log(f)-13.82\log(\max\{30,H_b\})+$ $[44.9-6.55\log(\max\{30,H_b\})][\log(d)]^\alpha-a(H_m)-b(H_b)$	(Eq. 184)
		1500 < f ≤ 2000	$L=46.3+33.9\log(f)-13.82\log(\max\{30,H_b\})+$ $[44.9-6.55\log(\max\{30,H_b\})][\log(d)]^\alpha-a(H_m)-b(H_b)$	(Eq. 185)
		2000 < f ≤ 3000	$L=46.3+33.9\log(2000)+10\log(f/2000)-13.82\log(\max\{30,H_b\})+$ $[44.9-6.55\log(\max\{30,H_b\})][\log(d)]^\alpha-a(H_m)-b(H_b)$	(Eq. 186)
	suburban		$L=L(\text{urban})$ $-2\cdot\left\{\log\left[(\min\{\max\{150;f\};2000\})/28\right]\right\}^2-5.4$	(Eq. 187)

Dist. Range (km)	Env.	Frequency Range(MHz)	Median path Loss	
	open area		$L = L(\text{urban})$ $-4.78 \cdot \left\{ \log\left[\min\left\{\max\{150; f\};2000\right\}\right]\right\}^2$ $+18.33 \cdot \log\left[\min\left\{\max\{150; f\};2000\right\}\right]$ -40.94	(Eq. 188)
0.04 < d < 0.1			$L = L(0.04) + \dfrac{[\log(d)-\log(0.04)]}{[\log(0.1)-\log(0.04)]} \times [L(0.1)-L(0.04)]$	(Eq. 189)

where:

$$a(H_m) = (1.1\log(f)-0.7) \times \min(10, H_m) - (1.56\log(f)-0.8) + \max\left(0, 20\log\left(\frac{H_m}{10}\right)\right) \qquad \textbf{(Eq. 190)}$$

$$b(H_b) = \min\left(0, 20\log\left(\frac{H_b}{30}\right)\right) \qquad \textbf{(Eq. 191)}$$

$$\alpha = \begin{cases} 1 & d \leq 20 \text{ km} \\ 1 + (0.14 + 1.87x10^{-4}\,xf + 1.07x10^{-3}H_b)(\log\frac{d}{20})^{0.8} & 20 \text{ km} < d < 100 \text{ km} \end{cases} \qquad \textbf{(Eq. 192)}$$

when L is below the free space attenuation for the same distance, the free space attenuation is used instead.

Variation in path loss

The variation in path loss is achieved by applying the log-normal distribution (slow-fading), i.e. a normal (Gaussian) distribution of logarithmic values. The relative standard deviation is given by the following equations:

Table 80: Variation in path loss

Dist. Range (km)	Propagation mode	Standard Deviation	
$d \leq 0.04 km$		$\sigma = 3.5$	
$0.04 km < d \leq 0.1 km$	above roof	$\sigma = 3.5 + \dfrac{(12-3.5)}{(0.1-0.04)} \times (d-0.04)$	(Eq. 193)
	below roof	$\sigma = 3.5 + \dfrac{(17-3.5)}{(0.1-0.04)} \times (d-0.04)$	(Eq. 194)
$0.1 km < d \leq 0.2 km$	above roof	$\sigma = 12$	
	below roof	$\sigma = 17$	
$0.2 km < d \leq 0.6 km$	above roof	$\sigma = 12 + \dfrac{(9-12)}{(0.6-0.2)}(d-0.2)$	(Eq. 195)
	below roof	$\sigma = 17 + \dfrac{(9-17)}{(0.6-0.2)}(d-0.2)$	(Eq. 196)
$0.6 km < d$		$\sigma = 9$	

A17.3.2 Indoor-outdoor propagation

The use of the modified Hata model for indoor-outdoor propagation introduces the following additional terms

Median path loss

$$L_{indoor-outdor}^{hata} = L_{outoor-outdor}^{hata} + L_{ew} \tag{Eq. 197}$$

where L_{ew} is the attenuation due to external walls. In the case the Rx is indoor then the L_{ew} is the wall loss defined at the Rx and when the Tx is indoor the wall loss defined at the Tx is considered.

Variation in path loss

Uncertainty on materials and relative location in the building increases the standard deviation of the log-normal distribution :

$$\sigma_{indoor-indoor}^{hata} = \sqrt{(\sigma_{outoor-outdor}^{hata})^2 + (\sigma_{Rx}^{wall})^2} \tag{Eq. 198}$$

when the Rx is indoor and Tx outdoor or

$$\sigma_{indoor-indoor}^{hata} = \sqrt{(\sigma_{outoor-outdor}^{hata})^2 + (\sigma_{Tx}^{wall})^2} \tag{Eq. 199}$$

when the Tx is indoor and Rx outdoor where σ_{Rx}^{wall} and σ_{Tx}^{wall} are the wall loss standard deviation defined at the Rx and Tx respectively.

A17.3.3 Indoor-indoor propagation

The use of the modified Hata model for indoor-indoor propagation introduces the following adjustments according to the relative location of the pair of transmitter and receiver.

Same-building condition

The first step is to estimate whether the transmitter and the receiver are located in the same building. This is done trough a statistic trial. Let us denote P the probability that the transmitter and the receiver are located in the same building. P is calculated according to the following scheme:

Table 81: Same-building probability

Dist. Range (km)	Same Building Probability
$d \leq 0.02km$	$P=1$
$0.02km < d \leq 0.05km$	$P = \dfrac{(0.05-d)}{0.03}$
$0.05km < d$	$P=0$

Transmitter and Receiver in different buildings

When transmitter and receiver are located in different buildings, the calculation mode is similar to the indoor-outdoor propagation mode but with doubled additional values.

Median path loss

$$L_{indoor-indoor}^{hata} = L_{outdoor-outdoor}^{hata} + 2 \times L_{ew} \tag{Eq. 200}$$

where

$$2 \times L_{ew} = Loss_{Rx}^{wall} + Loss_{Tx}^{wall} \qquad \text{(Eq. 201)}$$

Where $Loss_{Rx}^{wall}$ and $Loss_{Tx}^{wall}$ are the attenuation due to external walls as defined in the Rx and Tx side respectively.

Variation in path loss

$$\sigma_{indoor-indoor}^{hata} = \sqrt{(\sigma_{outoor-outdor}^{hata})^2 + \left((\sigma_{Rx}^{wall})^2 + (\sigma_{Tx}^{wall})^2\right)} \qquad \text{(Eq. 202)}$$

Transmitter and Receiver in same building
In this latter case a specific propagation model is used:

Median path Loss
The corresponding median path loss is given by the following formula :

$$L(indoor - indoor) = -27.6 + 20\log(\sqrt{(h_2 - h_1)^2 + (d)^2}) + 20.\log(f) + fix(\frac{d}{d_{room}}).L_{wi} + k_f^{\left[\frac{k_f+2}{k_f+1}-b\right]}.L_f$$
$$\text{(Eq. 203)}$$

with

$$k_f = \left| floor\left(\frac{h_2}{h_{floor}}\right) - floor\left(\frac{h_1}{h_{floor}}\right) \right| \qquad \text{(Eq. 204)}$$

where :

L_{wi} : loss of wall (default 5 dB)

L_f : loss between adjacent floor (default 18.3 dB)

b : empirical parameter (default 0.46)

d_{room} : size of the room (default 4 m)

h_{floor} : height of each floor (default 3 m)

h_2 : height of the transmitter (m)

h_1 : height of the receiver (m)

d : the distance between the transmitter and receiver (m)

Variation in path loss
Variation in path loss is modelled as an additional log-normal distribution, in order to take into account the uncertainty of building design, furniture of the rooms, etc. Typically it is set to 10 dB.

A17.4 EXTENDED HATA (SRD)

This model is a modified version of the Extended Hata model which was developed in CEPT for studies of Short Range Devices (SRD). The basis for modification was an assumption, that although SRD devices are usually operated at low antenna heights (typically person-carried devices, i.e. with antenna height of about 1.5 m), but the interference would usually occur at relatively short distances (up to 100 m or so) when direct- or near-LOS might be assumed.

The expression of $b(H_b)$ parameter in the standard Hata model, giving large extra losses for transmitter antenna heights below 30 m, was considered to be unnecessarily severe. Therefore the only difference between Hata-SRD and Hata model lies in the new expression for the antenna gain factor $b(H_b)$, which for Hata model is expressed as

$$b = min(0, 20 \log(Hb/30)); \qquad \text{(Eq. 205)}$$

to be replaced in Hata-SRD model by :

$$b = (1.1 \log(f) - 0.7) * min(10, Hb) - (1.56 \log(f) - 0.8) + max(0, 20 \log(Hb / 10));$$ (Eq. 206)

Note: *This expression assumes that antenna heights should not exceed 1.5-3 m.*

A17.5 SPHERICAL DIFFRACTION

A spherical propagation model based on various ITU-R Recs 452, 676 and 526 is applied in SEAMCAT for larger distances and higher frequencies
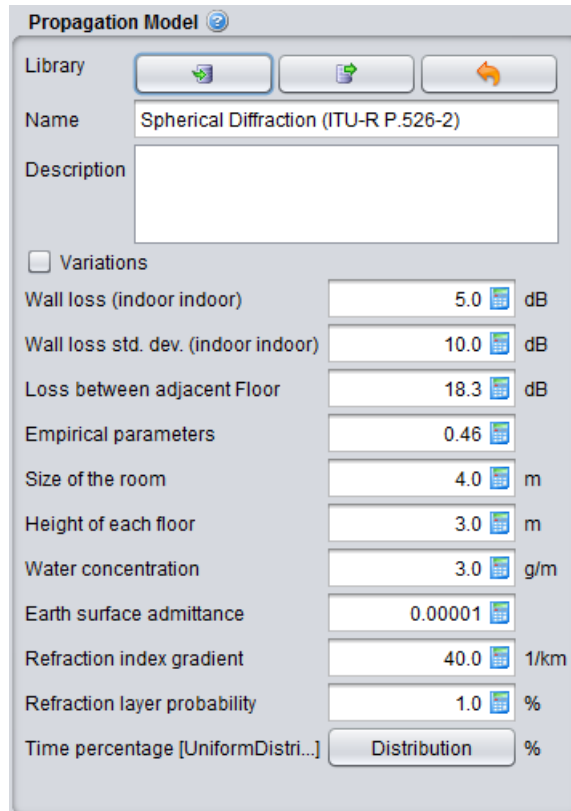
Figure 469: SEAMCAT Interface to the Spherical diffraction propagation model

Table 82: Spherical diffraction propagation model

Description	Symbol	Type	Unit	Comments
Variation				Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc.
Wall loss (indoor - indoor)		S	dB	
Wall loss std dev (indoor - indoor)		S	dB	
Wall loss (indoor - outdoor)		S	dB	
Wall loss std dev (indoor - outdoor)		S	dB	
Loss between adjacent floor		S	dB	
Empirical parameters:	b			
Size of the room	d_{room}	S	m	
Height of each floor	h_{floor}	S	m	
Water concentration		S	g/m^2	
Earth surface admittance				
Refraction Index gradient				
Refraction layer probability				
Time percentage (min)				
Time percentage (max)				

A17.5.1 Calculation Algorithm

According to ITU-R Rec. P.452-5 the median path loss between transmitter and receiver is given by the following equation:

$$L_{bd}(p) = 92.5 + 20\log f + 20\log d + L_d(p) + A_g \qquad \text{(Eq. 207)}$$

where:

$L_{bd}(p)$ is the basic loss in dB as function of the time percentage p in %

f is the frequency in GHz

d is the distance in km

$L_d(p)$ is the diffraction loss in dB as function of the time percentage p in %

A_g is the attenuation due to atmospheric gas and water in dB

A17.5.2 Attenuation due to atmosphere

The attenuation due to atmosphere is given by

$$A_g = [\gamma_O(f) + \gamma_w(\rho, f)]d \qquad \text{(Eq. 208)}$$

where:

$\gamma_O(f)$ linear attenuation due to dry air (oxygen) in dB/km

$\gamma_w(\rho, f)$ linear attenuation in dB/km due to water as function

                   of the water concentration ρ in g/m³, *default value: 3 g/m³*

Both terms can be approximated by the following equations according to ITU-R Rec. P.676-1:

- Attenuation due to water :

$$\gamma_w(\rho, f) = \left[0.050 + 0.0021\rho + \frac{3.6}{(f - 22.2)^2 + 8.5} + \frac{10.6}{(f - 183.3)^2 + 9} + \frac{8.9}{(f - 325.4)^2 + 26.3} \right] f^2 \rho\, 10^{-4} \qquad \text{(Eq. 209)}$$

      for f < 350 GHz

- Attenuation due to oxygen :

$$\gamma_O(f) = \left[7.19 \cdot 10^{-3} + \frac{6.09}{f^2 + 0.227} + \frac{4.81}{(f - 57)^2 + 1.50} \right] f^2\, 10^{-3} \qquad f \leq 57 \text{ GHz} \qquad \text{(Eq. 210)}$$

$$\gamma_O(f) = 10.5 + 1.5\,(f - 57) \qquad\qquad\qquad\qquad\qquad\qquad 57 < f \leq 60 \text{ GHz}$$

$$\gamma_O(f) = 15 - 1.2(f - 60) \qquad\qquad\qquad\qquad\qquad\qquad 60 < f \leq 63 \text{ GHz}$$

$$\gamma_O(f) = \left[3.79 \cdot 10^{-7}\, f + \frac{0.265}{(f - 63)^2 + 1.59} + \frac{0.028}{(f - 118)^2 + 1.47} \right] (f + 198)^2\, 10^{-3} \qquad \text{for } f > 63 \text{ GHz}$$

Note: For simplification a linear interpolation between 57 and 63 GHz is used. The maximum is 15 dB/km for 60 GHz.

A17.5.3 Attenuation due to diffraction

According to ITU-R Rec. P.526-2, the diffraction loss $L_d(p)$ can be derived by the received field strength E referred to the free space E_0 :

$$-L_d(p) = 20\log\frac{E}{E_0} = F(X) + G(Y_1) + G(Y_2) \qquad \text{(Eq. 211)}$$

with:

X is the normalized radio path between transmitter and receiver $X = 2.2\beta\, f^{\frac{1}{3}}\, a_e^{\frac{-2}{3}}\, d$

Y_1 is the normalized antenna height of the transmitter $Y = 9.6 \cdot 10^{-3}\, \beta\, f^{\frac{2}{3}}\, a_e^{\frac{-1}{3}}\, h_i$

Y_2 is the normalized antenna height of the receiver

where:

β is a parameter derived from the earth admittance factor K : β =1 for f > 20 MHz.

f is the frequency in MHz

a_e is the equivalent earth radius in km (definition see below)

d is the distance in km

h_i is the antenna height above ground in m with i =1 or 2 for the transmitter or receiver, respectively

The distance-dependent term $F(X)$ is given by the semi-empirical formula:

$$F(X) = 11 + 10\log(X) - 17.6X \qquad \text{(Eq. 212)}$$

The antenna height gain $G(Y)$ is given by the formula set:

$$G(Y) = 17.6(Y - 1.1)^{\frac{1}{2}} - 5\log(Y - 1.1) - 8 \qquad\qquad\qquad \text{for } Y > 2 \qquad \text{(Eq. 213)}$$

$$G(Y) = 20\log(Y + 0.1Y^3) \qquad\qquad \text{for } 10K < Y < 2$$

$$G(Y) = 2 + 20\log K + 9\log(Y/K)[\log(Y/K)+1] \qquad \text{for } K/10 < Y < 10K$$

$$G(Y) = 2 + 20\log K \qquad\qquad \text{for } Y < K/10$$

where K is the normalized earth surface admittance factor (see ITU-R Rec. P.526), default value: 10^{-5}

All frequencies used attenuation due to diffraction have the unit MHz in contrast to the attenuation due to atmosphere where GHz is applied.

A17.5.4 Equivalent Earth radius

The equivalent Earth radius a_e is considered to be dependent on the time percentage p according to :

$$a_e(p) = 6375\, k(p)$$

with the Earth radius factor $k(p)$ expressed as:

$$k(p) = k_{50} + (5 - k_{50})\frac{(1.7 - \log p)}{(1.7 - \log \beta_0)} \qquad \text{for } p < 50\%$$

$$k(p) = k_{50} \qquad\qquad \text{for } p > 50\%$$

and $\qquad k_{50} = \dfrac{157}{157 - \Delta N}$

where:

ΔN is the mean gradient of the radio refraction profile over a 1 km layer of the atmosphere from the surface. The *default value* is *40 unit/km* for Europe (standard atmosphere). This yields $k_{50} \approx 4/3$ and a_e = 8500 km.

Note :   The mean gradient is positive.

β_0 is the existence probability (in %) of the super-refractive layer ($\Delta N > 100$ unit/km) in the low atmosphere. *Default value: 1 % for Europe*.

Note :   The probabilities p and β_0 are denoted in %, i.e. a range of variety: 0...100 %.

Note :   *p* is set to *50%*, i.e. the median with respect to time is computed. Later versions may allow to choose a certain time percentage.

A17.5.5 Range of application

The following restrictions of the aforementioned spherical diffraction model are to be considered:
- When used for outdoor-outdoor environment the model presents no variations. On the contrary for indoor-outdoor or indoor-indoor configurations, checking or un-checking the variations checkbox adds or suppresses the variable component of the corresponding corrections;
- The frequency range should be larger than 3 GHz, with caution lower frequencies may be used but not below 300 MHz due to the surface admittance and polarisation effects;
- The model was developed for open (rural) area. Therefore, additional attenuation due to obstacles like buildings found in suburban or urban environment is not included;
- The loss due to rain is not covered;
- This model is applicable only for terrestrial radio paths.

A17.5.6 Indoor-outdoor propagation

The use of the spherical diffraction model for indoor-outdoor propagation introduces the following additional terms

Median path loss
The median path loss is increased by the attenuation due to external walls (L_{ew}):

$$L_{indoor\text{-}outdoor}^{sd} = L_{outdoor\text{-}outdoor}^{sd} + L_{ew} \qquad \text{(Eq. 214)}$$

Variation in path loss

Variation in path loss is already taken into account in the SD model, through the calculation of the equivalent earth radius. Thus additional variation due to uncertainty concerning materials and relative location of the transmitter and receiver is reflected by an additional lognormal distribution trial using the above defined σ_{add}.

$$f_{propag/indoor\text{-}outdoor}^{SD} = f_{propag/outdoor\text{-}outdoor}^{SD} + T(G(\sigma_{add})) \qquad \text{(Eq. 215)}$$

A17.5.7 Indoor-indoor propagation

The use of the Spherical Diffraction model for indoor-indoor propagation introduces different additional terms regard to the relative location of the transmitter and receiver.

Same-building condition

The Same-Building condition is determined in the same way as for the Modified Hata model (see section A17.3).

Transmitter and Receiver in different buildings

When transmitter and receiver are located in different buildings, the calculation mode is similar to the indoor-outdoor propagation mode but with doubled additional values for both median path loss and variation path loss.

> **Median path loss**
> The median path loss is increased by the attenuation due to external walls L_{ew}.
>
> $$L_{indoor\text{-}indoor}^{SD} = L_{outoor\text{-}outdoor}^{SD} + 2 \times L_{ew} \qquad \text{(Eq. 216)}$$

> **Variation in path loss**
>
> $$f_{propag/indoor\text{-}indoor}^{SD} = f_{propag/outdoor\text{-}outdoor}^{SD} + T(G(\sqrt{2}\sigma_{add})) \qquad \text{(Eq. 217)}$$

Transmitter and Receiver in same building

The calculation is the same as for the Modified Hata Model (see section A17.3).

A17.6 ITU-R REC. P.452-14

A17.6.1 Description of the model

ITU- R Recommendation P.452-16 contains an interference prediction procedure for the evaluation of the available propagation loss over unwanted signal paths between stations on the surface of the Earth for frequencies above about 0.1 GHz, with losses not exceeding for time percentages over the range $0.001 \leq p \leq 50\%$ and up to a distance limit of 10 000 km.

The models contained within Recommendation ITU-R P.452 work from the assumption that the interfering transmitter and the interfered-with receiver both operate within the surface layer of atmosphere. The procedure includes a complementary set of propagation models which ensure that the predictions embrace all the significant interference propagation mechanisms that can arise. Methods for analysing the radio-meteorological and topographical features of the path are provided so that predictions can be prepared for any practical interference path.
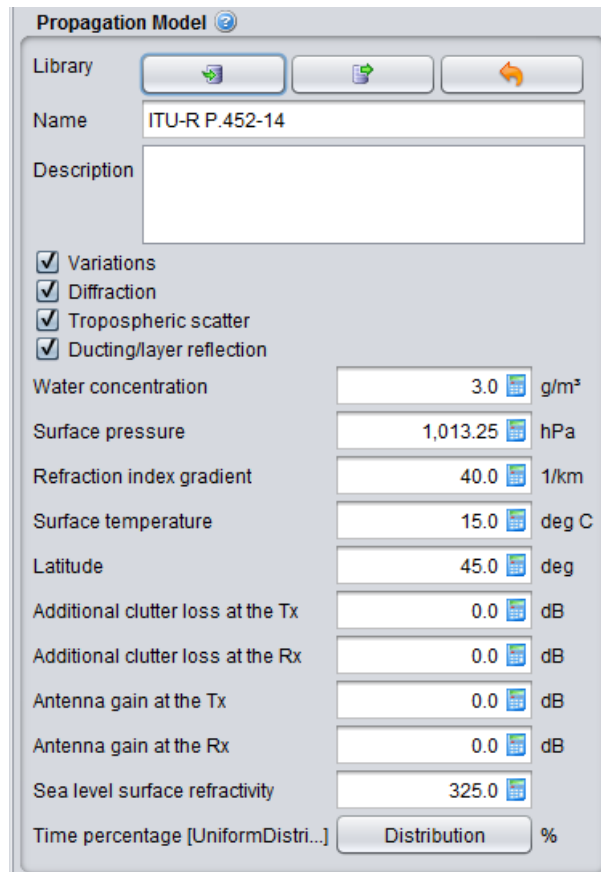
The clutter losses are designated as A_{ht} (dB) and A_{hr} (dB) for the interferer and interfered-with stations respectively. The additional protection available is height dependent, and is therefore modelled by a height-gain function normalized to the nominal height of the clutter. Appropriate nominal heights are available for a range of clutter types.

The correction applies to all clear-air predictions in this Recommendation, i.e. for all propagation modes and time percentages.

A basic problem in interference prediction (which is indeed common to all tropospheric prediction procedures) is the difficulty of providing a unified consistent set of practical methods covering a wide range of distances and time percentages; i.e. for the real atmosphere in which the statistics of dominance by one mechanism merge gradually into another as meteorological and/or path conditions change. Especially in these transitional regions, a given level of signal may occur for a total time percentage which is the sum of those in different mechanisms. The approach in this procedure has been to define completely separate methods for clear-air and hydrometeor-scatter interference prediction, as described in §§ 4 and 5 respectively of this recommendation.

The clear-air method consists of separate models for diffraction, ducting/layer-reflection, and troposcatter. All three are applied for every case, irrespective of whether a path is LoS or transhorizon. The results are then combined into an overall prediction using a blending technique that ensures for any given path distance and time percentage that the signal enhancement in the equivalent notional line-of-sight model is the highest attainable.

A17.6.2 Input parameters

Figure 470: SEAMCAT Interface to the ITU-R Rec. P.452-14 model

Table 83: ITU-R Recommendation P.452-4 propagation model

Description	Symbol	Type	Unit	Comments
Variation	-	boolean	-	Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc.
Diffraction	-	boolean	-	Select the diffraction component of the model
Tropospheric scatter	-	boolean	-	Select the tropospheric scatter component of the model
Ducting/layer reflection	-	boolean	-	Select the ducting/layer reflection component of the model
Water concentration	ρ	S	g/m^3	water vapour density for tropospheric study only
Surface pressure	P	S	hPa	Surface pressure (default 1013.25 hPa)
Refraction index gradient	ΔN	S	1/km	It is the average radio-refractive index lapse-rate through the lowest 1 km of the atmosphere, provides the data upon which the appropriate effective Earth radius can be calculated. Note that ΔN is a positive quantity.
Surface temperature	T	S	Degree Celsius	Surface temperature (default 15 degree Celsius)
Latitude	φ_t, φ_r	S	Degree	Latitude of station, used in the path centre location calculation
Additional clutter loss at the Tx	A_{ht}	S	dB	Additional clutter loss at the Tx
Additional clutter loss at the Rx	A_{hr}	S	dB	Additional clutter loss at the Rx
Antenna gain at the Tx	G_t	S	dB	Antenna gain of the Tx in the direction of the horizon along the great-circle interference path (dBi)
Antenna gain at the Rx	G_r	S	dB	Antenna gain of the Rx in the direction of the horizon along the great-circle interference path (dBi)
Sea level surface refractivity	N_0	S	-	The sea-level surface refractivity, is used only by the troposcatter model as a measure of location variability of the troposcatter scatter mechanism. As the scatter path calculation is based on a path geometry determined by annual or worst-month values of ΔN, there is no additional need for worst-month values of N_0. The correct values of ΔN and N_0 are given by the path-centre values as derived from the appropriate maps.
Time Percentage		D	%	Percentage time variability from which the field strengths value are exceeded

The longitude parameter of the ITU-R Rec P.452-4 is used for the computation of the position based on a grid point data file. In SEAMCAT it is not used as x and y coordinates are sufficient. The latitude, however is used in SEAMCAT in evaluation of the point incidence of anomalous propagation, β0 (%), for the path centre location where β0 (%) is the time percentage for which refractive index lapse-rates exceeding 100 N units/km can be expected in the first 100 m of the lower atmosphere. β0 (%) is used to estimate the relative incidence of fully developed anomalous propagation at the latitude under consideration.

A17.7 ITU-R REC. P.1546-1

This propagation model is kept in SEAMCAT for backwards the compatibility of former studies, although it is formally superseded.

A17.7.1 Description of the model

This is the point-to-area propagation loss model. There are two implementation of this recommendation in SEAMCAT (ITU-R Rec.P.1546-1 and ITU-R Rec.P.1546-4 (see next section)).

This recommendation replaced the original broadcasting propagation prediction curves given in recommendation ITU-R P.370. The adjusted P.1546 model is suitable for modelling propagation path loss in the broadcasting, land mobile and certain fixed services (e.g. those employing point-to-multipoint systems) in the frequency range 30 to 3 000 MHz and for the distance range 1 km to 1 000 km.

A few simplifications have been introduced for SEAMCAT implementation of the model:

- Restriction to propagation over land paths only;
- Flat terrain;
- No negative antenna heights.
-
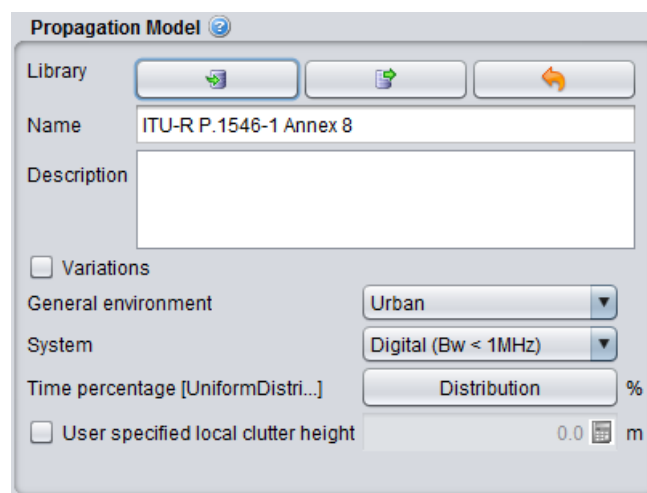
Figure 471: SEAMCAT Interface to the P1546-1 propagation model

Table 84: ITU-R Recommendation P.1546-1 propagation model

Description	Symbol	Type	Unit	Comments
Variation				Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc.
General environment				Environment of the propagation: urban, rural, suburban
System				Digital (BW<1MHz), Digital (BW>1MHz), Analogue
Time Percentage (min)				Minimum time variability from which the field strengths value are exceeded
Time percentage (max)				Maximum time variability from which the field strengths value are exceeded
use user specified local clutter height				User selectable clutter height value which overwrite any predefined value when selected

This propagation model is described in Recommendation ITU-R P.1546-1 Annex 8, which was developed based on the prior model in Recommendation ITU-R P.370. This is a propagation model for point-to-area prediction of field strength for the broadcasting, land mobile, maritime mobile and certain fixed services (e.g. those employing point-to-multipoint systems) in the frequency range 30 to 3000 MHz and for the distance range 1 km to 1000 km. The model provided in Recommendation ITU-R P.1546-1 should be used in the frequency range (30 to 3 000 MHz) and the same distance range (1 km to 1 000 km). The Land curves are implemented only. The sea curves or the mixed sea-land path are not implemented.

A17.7.2 Input parameters

Parameters of this propagation model are listed below:

Path dependant parameters (constant during a simulation for a given path) are:

- Time percentage: pt (%)
- Transmitter system : analogue/digital
- Transmitter bandwidth : B_t
- Global environment : rural, suburban, urban

Variable parameters (which vary for each event of a simulation):

- Effective height of transmitter antenna (see the Rec. P.1546-1 for definition): h_t (m)
- Receiver antenna height (above ground, see height of local clutter in section (6) below): h_r (m)
- Frequency f (MHz)
- Distance d (km)

A17.7.3 Algorithm

For calculation of the path loss according to Recommendation ITU-R P.1546-1 Annex 8 the following procedure is followed:

1. Check range of application of the propagation model regarding time percentage, frequency, distance, and antenna height:
- Time percentage : $1\% < pt < 50\ \%$
- Frequency : $30\ \text{MHz} < f < 3\ 000\ \text{MHz}$
- Distance : $0.001\ \text{km} < d < 1000\ \text{km}$
- Transmitter antenna height : $0\ \text{m} < h_t < 3000\ \text{m}$
- Receiver antenna height : $1\ \text{m} < h_r < 3000\ \text{m}$

2. Determination of lower and higher nominal percentages pt_{inf} and pt_{sup}:
   If $t < 10$ then $pt_{inf} = 1\ \%$ and $pt_{sup} = 10\ \%$ else $pt_{inf} = 10\ \%$ and $pt_{sup} = 50\ \%$

3. Determination of the lower and higher nominal frequencies :
   If $f < 600$ MHz then $f_{inf} = 100$ MHz and $f_{sup} = 600$ MHz else $f_{inf} = 600$ MHz and $f_{sup} = 2000$ MHz

4. If $h_t \geq 10$ m: calculate field strength $E(f = f, d, h_t, h_r, t)$ 4):

   4.1) Calculation of the four following field strengths:
   - $E(f = f_{inf}, d, h_t, h_r, pt_{inf})$
   - $E(f = f_{sup}, d, h_t, h_r, pt_{inf})$
   - $E(f = f_{inf}, d, h_t, h_r, pt_{sup})$
   - $E(f = f_{sup}, d, h_t, h_r, pt_{sup})$

   according to the procedure described in steps 4.1.1. to 4.1.4.

   4.1.1) Calculate the dimensionless parameter k, function of the required transmitter height, h_t:

   $$k = \frac{\log\left[\dfrac{h_t}{9.375}\right]}{\log(2)} \qquad \text{(Eq. 218)}$$

   4.1.2) Determine from the following table the set of parameters a_0 to a_3, b_0 to b_7, c_0 to c_6 and d_0 to d_1 to be used according to <u>nominal values</u> of frequencies and time percentages:

Table 85: Parameters a_0 to a_3, b_0 to b_7, c_0 to c_6 and d_0 to d_1

Frequency	100 MHz			600 MHz			2 000 MHz		
pt %	50	10	1	50	10	1	50	10	1
a_0	0.0814	0.0814	0.0776	0.0946	0.0913	0.0870	0.0946	0.0941	0.0918
a_1	0.761	0.761	0.726	0.8849	0.8539	0.8141	0.8849	0.8805	0.8584
a_2	−30.444	−30.444	−29.028	−35.399	−34.160	−32.567	−35.399	−35.222	−34.337
a_3	90.226	90.226	90.226	92.778	92.778	92.778	94.493	94.493	94.493
b_0	33.6238	40.4554	45.577	51.6386	35.3453	36.8836	30.0051	25.0641	31.3878
b_1	10.8917	12.8206	14.6752	10.9877	15.7595	13.8843	15.4202	22.1011	15.6683
b_2	2.3311	2.2048	2.2333	2.2113	2.2252	2.3469	2.2978	2.3183	2.3941
b_3	0.4427	0.4761	0.5439	0.5384	0.5285	0.5246	0.4971	0.5636	0.5633
b_4	1.256E-7	7.788E-7	1.050E-6	4.323^E-6	1.704^E-7	5.169^E-7	1.677E-7	3.126E-8	1.439E-7
b_5	1.775	1.68	1.65	1.52	1.76	1.69	1.762	1.86	1.77
b_6	49.39	41.78	38.02	49.52	49.06	46.5	55.21	54.39	49.18
b_7	103.01	94.3	91.77	97.28	98.93	101.59	101.89	101.39	100.39
c_0	5.4419	5.4877	4.7697	6.4701	5.8636	4.7453	6.9657	6.5809	6.0398
c_1	3.7364	2.4673	2.7487	2.9820	3.0122	2.9581	3.6532	3.547	2.5951
c_2	1.9457	1.7566	1.6797	1.7604	1.7335	1.9286	1.7658	1.7750	1.9153
c_3	1.845	1.9104	1.8793	1.7508	1.7452	1.7378	1.6268	1.7321	1.6542
c_4	415.91	510.08	343.24	198.33	216.91	247.68	114.39	219.54	186.67
c_5	0.1128	0.1622	0.2642	0.1432	0.1690	0.1842	0.1309	0.1704	0.1019

Frequency	100 MHz			600 MHz			2 000 MHz		
c_6	2.3538	2.1963	1.9549	2.2690	2.1985	2.0873	2.3286	2.1977	2.3954
d_0	10	5.5	3	5	5	8	8	8	8
d_1	−1	1	2	1.2	1.2	0	0	0	0

4.1.3) Calculate the unblended to maximum value field strength, E_u, at the distance, d, and transmitting height, h_t, as follows:

$$E_u = p_b \cdot \log \left[\frac{10^{\frac{E1+E2}{p_b}}}{10^{\frac{E1}{p_b}} + 10^{\frac{E2}{p_b}}} \right]$$

(Eq. 219)

where: $p_b = d_0 + d_1 \cdot \sqrt{k}$

and: $E1 = \left(a_0 \cdot k^2 + a_1 \cdot k + a_2\right) \cdot \log(d) + 0.1995 \cdot k^2 + 1.8671 \cdot k + a_3$

and: $E2 = E_{ref} + E_{off}$

where:

$$E_{ref} = b_0 \left[\exp\left[-b_4 \cdot 10^\xi \right] - 1 \right] + b_1 \cdot \exp \left[-\left(\frac{\log(d) - b_2}{b_3} \right)^2 \right] - b_6 \cdot \log(d) + b_7$$

where:

$$\xi = \log(d)^{b_5}$$

and:

$$E_{off} = \frac{c_0}{2} \cdot k \cdot \left[1 - \tanh\left[c_1 \cdot \left[\log(d) - c_2 - \frac{c_3^{\ k}}{c_4} \right] \right] \right] + c_5 \cdot k^{c_6}$$

4.1.4) Calculate the blended to the free space value of field strength, E_b, at the distance, d, and transmitting height, h_t, as follows:

$$E_b = p_{bb} \cdot \log \left[\frac{10^{\frac{E_u+E_{fs}}{p_{bb}}}}{10^{\frac{E_u}{p_{bb}}} + 10^{\frac{E_{fs}}{p_{bb}}}} \right]$$

(Eq. 220)

where:

E_{fs} is the free-space field strength

E_{fs} = 106.9 − 20 log(d)   dB(μV/m)

p_{bb} is a blend coefficient set to value 8.

4.2) Calculation of the field strength $E(f, d, h_t, h_r, pt_{inf})$ using log-linear interpolation in frequency range:

$E = E_{inf} + (E_{sup} − E_{inf}) \log(f/f_{inf})/\log(f_{sup}/f_{inf})$ (dB(μV/m))

(Eq. 221)

where:

E_{inf}: $E(f= f_{inf} , d, h_t, h_r, pt_{inf})$

E_{sup}: $E(f = f_{sup}, d, h_t, h_r, pt_{inf})$

4.3) Dual calculation for the field strength $E(f, d, h_t, h_r, pt_{sup})$ using log-linear interpolation in frequency range:

$$E = E_{inf} + (E_{sup} - E_{inf}) \log(f/f_{inf})/\log(f_{sup}/f_{inf}) \quad (dB(\mu V/m)) \quad \text{(Eq. 222)}$$

where:

E_{inf}: $E(f = f_{inf}, d, h_t, h_r, pt_{sup})$

E_{sup}: $E(f = f_{sup}, d, h_t, h_r, pt_{sup})$

4.4) Calculation of the field strength $E(f, d, h_t, h_r, pt)$ using log-linear interpolation formula in time percentage range :

$$E = E_{sup}(Q_{inf} - Q_t)/(Q_{inf} - Q_{sup}) + E_{inf}(Q_t - Q_{sup})/(Q_{inf} - Q_{sup}) \quad (dB(\mu V/m)) \quad \text{(Eq. 223)}$$

Where: ($Q_i(x)$ being the inverse complementary cumulative normal distribution function):

$Q_t \quad = Q_i(pt/100)$

$Q_{inf} \quad = Q_i(pt_{inf}/100)$

$Q_{sup} \quad = Q_I(pt_{sup}/100)$

$E_{inf} \quad = E(f, d, h_t, h_r, pt_{inf})$

$E_{sup} \quad = E(f, d, h_t, h_r, pt_{sup})$

5. For a transmitting/base antenna height $\mathbf{h_t}$ less than 10 m, determine the field strength for the required height and distance using following method

The procedure for extrapolating field strength at a required distance d km for values of h_t in the range 0 m to 10 m is based on smooth-Earth horizon distances in km written as $d_H(h) = 4.1\sqrt{h}$, where h is the required value of transmitting/base antenna height h_t in metres.

For $d < d_H(h_t)$ the field strength is given by the 10 m height curve at its horizon distance, plus ΔE, where ΔE is the difference in field strengths on the 10 m height curve at distances d and the h_t horizon distance.

For $d \geq d_H(h_t)$ the field strength is given by the 10 m height curve at distance Δd beyond its horizon distance, where Δd is the difference between d and the h_t horizon distance.

This may be expressed in the following formulae where $E_{10}(d)$ is the field strength in dB(μV/m) calculated for transmitter antenna 10 m and for a distance d (km) according to the procedure described in step 4:

$$E = E_{10}(d_H(10)) + E_{10}(d) - E_{10}(d_H(h_t)) \qquad dB(\mu V/m) \quad d < d_H(h_t)$$
$$= \quad E_{10}(d_H(10) + d - d_H(h_t)) \qquad dB(\mu V/m) \quad d \geq d_H(h_t)$$

If in the latter equation $d_H(10) + d - d_H(h_t)$ exceeds 1 000 km, even though $d \leq 1 000$ km, E_{10} may be found from linear extrapolation for log(distance) of the curve, given by:

$$E_{10} = \quad E_{inf} + (E_{sup} - E_{inf}) \log(d/D_{inf})/\log(D_{sup}/D_{inf}) \qquad dB(\mu V/m)$$

where:

D_{inf}:   penultimate tabulation distance (km)

D_{sup}:   final tabulation distance (km)

E_{inf}:   field strength at penultimate tabulation distance (dB(μV/m))

E_{sup}:   field strength at final tabulation distance (dBμV/m))

Note: this recommendation is not valid for distances greater than 1 000 km. This method should be used only for extrapolating for $h_t < 10$ m.

6. If the receiving antenna height h_r is not equal to the height of representative clutter at its location (denoted R), correct the field strength as follows:

The field-strength values given by the land curves and associated tabulations in this recommendation are for a reference receiving antenna at a height, R (m), representative of the height of the ground cover surrounding the receiving/mobile antenna, subject to a minimum height value of 10 m.

The SEAMCAT always assumes the height of local clutter R, depending on the propagation environment set in the model selection window:

Table 86: Default clutter height in the P1546-1 (when clutter height option not activated)

Selected environment	Assumed height of local clutter, m
Rural	10
Sub-urban	10
Urban	20

If the receiving antenna height, h_r (m), is different from the assumed R value, as shown in Table 86 , a correction shall be added to the field strength taken from the curve.

Where the receiving antenna is adjacent to land account should first be taken of the elevation angle of the arriving ray by calculating a modified representative clutter height R' (m), given by:

$$R' \quad = \quad R \quad \text{(m)} \qquad\qquad \text{for } h_t \leq 6.5d + R \qquad \text{(Eq. 224)}$$
$$= (1\ 000\ d\ R - 15\ h_t)/(1\ 000\ d - 15\ )\ \text{(m) for } h_t > 6.5d + R \qquad \text{(Eq. 225)}$$

where h_t is in metres and distance d is in km.

The value of R' must be limited if necessary such that it is not less than 1 m.

When the receiving antenna is in an **urban** environment the correction is then given by:

$$\text{Correction} = (6.03) - J(v) \qquad\qquad \text{dB} \qquad\qquad \text{for } h_r < R$$
$$= K_{hr} \log(h_r /R') \qquad\qquad \text{dB} \qquad\qquad \text{for } h_r \geq R \qquad \text{(Eq. 226)}$$

where $J(v)$ is given by :

$$J(v) = \left[6.9 + 20\log\left(\sqrt{(v-0.1)^2 + 1} + v - 0.1 \right) \right] \qquad \text{(Eq. 227)}$$

where:

v	=	$K_{nu} \sqrt{(h_{dif}\ \theta_{clut})}$
h_{dif}	=	$R' - h_r$ (m)
θ_{clut}	=	arctan $(h_{dif} /27)$ (degree)
K_{hr}	=	$3.2 + 6.2 \log(f)$
K_{nu}	=	$0.0108 \sqrt{f}$
f	=	frequency (MHz)

Where the receiving antenna is adjacent to land in a rural environment the correction is given by the above equation (3) for all values of h_r.

If the required distance is equal to or greater than d_{10}, then again the correction for the required value of h_2 should be calculated using above equation (2) with R' set to 10 m.

If the required distance is less than d_{10}, then the correction to be added to the field strength E should be calculated using:

Correction	= 0.0	dB	$d \leq d\ (h_r)$	(Eq. 228)
	= $(C_{10})\ \log(d/d_{hr})/\log(d_{10}/d_{hr})$	dB	$d_{hr} < d < d_{10}$	

where:

C_{10}:   correction for the required value of h_r at distance d_{10} using equation (2) with R' set to 10 m,

d_{10}:   distance at which the path just has 0.6 Fresnel clearance for h_r = 10 m

calculated as $D_{06}(f, h_t, 10)$ as given in note 2

d_{hr}:   distance at which the path just has 0.6 Fresnel clearance for the required value of h_r

calculated as $D_{06}(f, h_t, h_r)$ as given in note 2

This recommendation is not valid for receiving antenna heights, h_r, less than 1 m.

7.   Add a log-normal term $G(\sigma_L)$ corresponding to the variability in the percentage of locations :

Values of standard deviation for digital systems having a bandwidth less than 1 MHz and for analogue systems are given as a function of frequency by:

$$\sigma_L = K + 1.6 \log(f) \qquad dB \tag{Eq. 229}$$

where :

K   =   2.1 - for mobile systems in urban locations;

          3.8 - for mobile systems in suburban locations or amongst rolling hills;

          5.1 - for analogue broadcasting systems.

For digital systems having a bandwidth of 1 MHz or greater, a standard deviation of 5.5 dB should be used at all frequencies.

8.   If necessary, limit the resulting field strength to the maximum value calculated as follows:

The field strength must not exceed a maximum value E_{max} given by:

$E_{Max} = E_{fs}$ dB(μV/m)   for land paths

where E_{fs} is the free space field strength for 1 kW e.r.p. given by:

$$E_{fs} = 106.9 - 20 \log(d) \quad (dB(\mu V/m)) \tag{Eq. 230}$$

9) Convert field strength to path loss using following formula:

$$L_b = 77.2 - E\, 20 \log f \quad (dB) \tag{Eq. 231}$$

where:

L_b: basic transmission loss (dB)

E: field strength in dB(μV/m) measured with a transmitting power of 1 W e.i.r.p.

f: frequency (MHz).

Note 1: The following approximation to the inverse complementary cumulative normal distribution function, $Qi(x)$, is valid for $0.01 \leq x \leq 0.99$:

$Q_i(x) = T(x) - \xi(x)$ if x $\leq$ 0.5

$Q_i(x) = -\{T(1-x) - \xi(1-x)\}$ if x > 0.5

where:

$$T(x) = \sqrt{[-2 \ \ln(x)]}$$

$$\xi(x) = \frac{[(C_2 \cdot T(x) + C_1) \cdot T(x)] + C_0}{[(D_3 \cdot T(x) + D_2) \cdot T(x) + D_1] \cdot T(x) + 1}$$

C_0 = 2.515517
C_1 = 0.802853
C_2 = 0.010328
D_1 = 1.432788
D_2 = 0.189269
D3 = 0.001308

Note 2: the path length which just achieves a clearance of 0.6 of the first Fresnel zone over a smooth curved Earth, for a given frequency and antenna heights h_t and h_r, is given approximately by:

$$D_{06} = \frac{D_f\, D_h}{D_f + D_h}\ \text{km}$$

where:

D_f:	frequency-dependent term	
=	$0.0000389\, f\, h_1\, h_2$	km
D_h:	asymptotic term defined by horizon distances	
=	$4.1(\sqrt{h_t} + \sqrt{h_r})$	km
f:	frequency (MHz)	
h_t, h_r:	antenna heights above smooth Earth (m)	

In the above equations, the value of h_t must be limited, if necessary, such that it is not less than zero. Moreover, the resulting values of D_{06} must be limited, if necessary, such that it is not less than 0.001 km.

Note 3: the case h_t is less than zero described in the recommendation is not handled.

Note 4: no correction due to terrain clearance angle is implemented.

A17.8 ITU-R REC. P.1546-4

A17.8.1 Input parameters
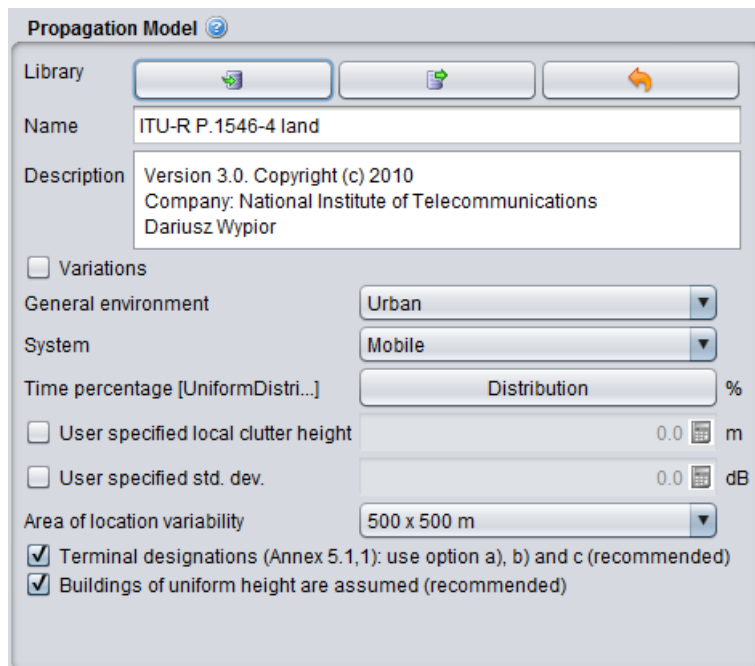
Figure 472: SEAMCAT Interface to the P1546-4 propagation model

Table 87: ITU-R Recommendation P.1546-4 propagation model

Description	Symbol	Type	Unit	Comments
Variation				Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc.
General environment				Environment of the propagation: urban, rural, suburban, dense urban
System				Mobile, broadcasting digital and braodcasting analogue
Time Percentage (min)				Minimum time variability from which the field strengths value are exceeded
Time percentage (max)				Maximum time variability from which the field strengths value are exceeded
use user specified local clutter height				User selectable clutter height value which overwrite any predefined value when selected
use user specified standard deviation				User selectable standard deviation value which overwrite any predefined value when selected
Area of location variability				500x500 m, < 2km radius, < 50 km radius
Terminal designations				When selected the algorithm will consider the option a), b) and c) of ITU-R. 1546-4 Annex 5 §1.1. By default it is selected.

This propagation model is fully described in Recommendation ITU-R P.1546-4. Only the land path is implemented. The sea path and the mixed sea/land path are not implemented. The ranges of application are the same as for the P1546-1.

A17.8.2 Algorithm

The terminal designations

This propagation model is not reciprocal with respect to designations of the transmitting/base station and the receiver/mobile station/terminal. It is primarily intended for use with broadcasting and mobile services where the transmitter/base antenna is above the level of local clutter.

When it is used to calculate the coverage of, or for the coordination of, broadcasting and/or base-to-mobile stations, then the actual transmitting/base station should be treated as the "transmitting/base". For this the SEAMCAT user has to deselect the "Terminal designation" switch.

In other cases, whch is the default setup in SEAMCAT, where there is no a priori reason to consider either terminal as the transmitting/base, then the selection of which terminal to designate as the transmitting/base station for the purposes of this propagation model can be as follows:

a)   if both terminals are below the levels of clutter in their respective vicinities, then this model will not give accurate predictions to the problem at hand. Users should seek guidance from other, more appropriate, ITU-R Recommendations. Note that SEAMCAT will prompt you with a warning message;

b)   if one terminal is in an open location or above the surrounding clutter, whereas the other terminal is below the level of clutter, then the open/uncluttered terminal should be treated as the transmitting/base station for the purposes of actual identity as the transmitter/base or receiver/mobile;

c)   if both terminals are open/uncluttered, then the terminal with the greater effective height should be treated as the transmitting/base station for the purposes of this Recommendation.

As noted above, this model is not reciprocal. However, in some special cases, it may be treated as such. For these particular cases, for example, which may be encountered for the monitoring and prediction of receiver/mobile-to-transmitter/base coverage and/or interference, it may be useful, under items b) and c) of the previous discussion, to designate that terminal in the open location, which should also always have the higher effective height, as the transmitter/base as the "high" antenna, whilst designating the terminal in the cluttered location as the receiver/mobile as the "low" antenna, without regard to which terminal is actually the transmitter/base and receiver/mobile. Users of this model should note, for the purposes of calculation, that if these "high" and "low" designations are to be used, the high antenna termination will always be synonymous with (and equivalent to) the transmitter/base station's effective height, h1, whilst the low antenna termination will always be synonymous with (and equivalent to) the receiver/mobile's height, h2, with the same qualifier, in the subsequent calculation of field strength or basic transmission loss.

Maximum field-strength values
The field strength must not exceed a maximum value E_{max} as described in P1546-1. In principle any correction which increases a field strength must not be allowed to produce values greater than these limits for the family of curves and distance concerned. However, limitation to maximum values should be applied only where indicated in Annex 6 of the ITU-R P.1546-4.

Determination of transmitting/base antenna height, h1
The transmitting/base antenna height, h_1, to be used in the calculation depends on the type and length of the path and on various items of height information, which may not all be available.

For land paths, the effective height of the transmitting/base antenna, h_{eff}, is defined as its height in metres over the average level of the ground between distances of 3 and 15 km from the transmitting/base antenna in the direction of the receiving/mobile antenna. Where the value of effective transmitting/base antenna height, h_{eff}, is not known it should be estimated from general geographic information. This model is not valid when the transmitting/base antenna is below the height of surrounding clutter.

The value of h_1 to be used in calculation should be obtained using the method given in § 3.1, 3.2 or in § 3.3 of P1546-4 as appropriate.

Land paths shorter than 15 km
For land paths less than 15 km one of the following two methods should be used:

Terrain information not available
In SEAMCAT, no terrain information is available. Therefore, the value of h_1 is calculated according to path length, d, as follows:

$$h_1 = h_a \qquad\qquad \text{m for } d \leq 3 \text{ km} \qquad\qquad \text{(Eq. 232)}$$

$$h_1 = h_a + (h_{eff} - h_a)(d-3)/12 \qquad\qquad \text{m for } 3 \text{ km} < d < 15 \text{ km}$$

where h_a is the antenna height above ground (e.g. height of the mast).

Land paths of 15 km or longer
For these paths:

$$h_1 = h_{eff} \qquad\qquad\qquad \text{m} \qquad\qquad\qquad \text{(Eq. 233)}$$

Transmitting/base antenna height, h1, in the range 10 m to 3 000 m
If the value of h_1 coincides with one of the eight heights for which curves are provided, namely 10, 20, 37.5, 75, 150, 300, 600 or 1 200 m, the required field strength may be obtained directly from the plotted curves or the associated tabulations. Otherwise the required field strength should be interpolated or extrapolated from field strengths obtained from two curves using:

$$E = E_{inf} + (E_{sup} - E_{inf})\log(h_1/h_{inf})/\log(h_{sup}/h_{inf}) \qquad \text{dB(µV/m)} \qquad \text{(Eq. 234)}$$

where:

h_{inf} :   600 m if h_1 > 1200 m, otherwise the nearest nominal effective height below h_1

h_{sup} :   1200 m if h_1 > 1200 m, otherwise the nearest nominal effective height above h_1

E_{inf} :   field-strength value for h_{inf} at the required distance

E_{sup} :   field-strength value for h_{sup} at the required distance.

The field strength resulting from extrapolation for h_1 > 1200 m should be limited if necessary such that it does not exceed the maximum defined in § 2 of P1546-4.

This model is not valid for h_1 > 3000 m.

Interpolation of field strength as a function of distance
Figures 1 to 24 of ITU-R P.1546-4 show field strength plotted against distance, d, the range 1 km to 1 000 km. No interpolation for distance is needed if field strengths are read directly from these graphs. For greater precision, and for computer implementation, field strengths should be obtained from the associated tabulations (see Annex 1 of ITU-R P.1546-4, § 3). In this case, unless d coincides with one of the tabulation distances given in Table 1, the field strength, E (dB(μV/m)), should be linearly interpolated for the logarithm of the distance using:

$$E = E_{inf} + (E_{sup} - E_{inf})\log(d/d_{inf})/\log(d_{sup}/d_{inf}) \qquad \text{dB}(\mu\text{V/m}) \qquad \text{(Eq. 235)}$$

where:

d :   distance for which the prediction is required

d_{inf} :   nearest tabulation distance less than d

d_{sup} :   nearest tabulation distance greater than d

E_{inf} :   field-strength value for d_{inf}

E_{sup} :   field-strength value for d_{sup}.

This model is not valid for values of d less than 1 km or greater than 1 000 km.

Interpolation and extrapolation of field strength as a function of frequency
Field-strength values for the required frequency should be obtained by interpolating between the values for the nominal frequency values of 100, 600 and 2000 MHz. In the case of frequencies below 100 MHz or above 2 000 MHz, the interpolation must be replaced by an extrapolation from the two nearer nominal frequency values. For most paths interpolation or extrapolation for log (frequency) can be used, but for some sea paths when the required frequency is less than 100 MHz it is necessary to use an alternative method.

For land paths, and for sea paths where the required frequency is greater than 100 MHz, the required field strength, E, should be calculated using:

$$E = E_{inf} + (E_{sup} - E_{inf})\log(f/f_{inf})/\log(f_{sup}/f_{inf}) \qquad \text{dB}(\mu\text{V/m}) \qquad \text{(Eq. 236)}$$

where:

f :   frequency for which the prediction is required (MHz)

f_{inf} :   lower nominal frequency (100 MHz if f < 600 MHz, 600 MHz otherwise)

f_{sup} :   higher nominal frequency (600 MHz if f < 600 MHz, 2 000 MHz otherwise)

E_{inf} :   field-strength value for f_{inf}

E_{sup} :   field-strength value for f_{sup}.

The field strength resulting from extrapolation for frequency above 2 000 MHz should be limited if necessary such that it does not exceed the maximum value given in § 2 of ITU-R P.1546-4.

For sea paths where the required frequency is less than 100 MHz an alternative method should be used, based upon the path lengths at which 0.6 of the first Fresnel zone is just clear of obstruction by the sea surface. An approximate method for calculating this distance is given in § 17 of ITU-R P.1546-4.

The alternative method should be used if all of the following conditions are true:

- The path is a sea path.
- The required frequency is less than 100 MHz.
- The required distance is less than the distance at which a sea path would have 0.6 Fresnel clearance at 600 MHz, given by $D_{06}(600, h_1, 10)$ as given in § 17 of P1546-4.

If any of the above conditions is not true, then the normal interpolation/extrapolation method given by equation (14) should be used.

If all of the above conditions are true, the required field strength, E, should be calculated using:

$$E = E_{max} \quad \text{dB(μV/m)} \qquad\qquad\qquad \text{for } d \le d_f$$

$$= E_{df} + (E_{d_{600}} - E_{d_f})\log(d/d_f)/\log(d_{600}/d_f) \quad \text{dB(μV/m)} \qquad \text{for } d > d_f$$

where:

$\quad E_{max}$: maximum field strength at the required distance as defined in § 2 of P1546-4

$\quad E_{d_f}$: maximum field strength at distance d_f as defined in § 2 of P1546-4

$\quad d_{600}$: distance at which the path has 0.6 Fresnel clearance at 600 MHz calculated as $D_{06}(600, h_1, 10)$ as given in § 17 of P1546-4

$\quad d_f$: distance at which the path has 0.6 Fresnel clearance at the required frequency calculated as $D_{06}(f, h_1, 10)$ as given in § 17 of P1546-4

$\quad E_{d_{600}}$: field strength at distance d_{600} and the required frequency calculated using equation (14).

Interpolation of field strength as a function of percentage time
Field-strength values for a given percentage of time between 1% and 50% time should be calculated by interpolation between the nominal values 1% and 10% or between the nominal values 10% and 50% of time using:

$$E = E_{sup}(Q_{inf} - Q_t)/(Q_{inf} - Q_{sup}) + E_{inf}(Q_t - Q_{sup})/(Q_{inf} - Q_{sup}) \quad \text{dB(μV/m)} \quad \text{(Eq. 237)}$$

where:

$\quad t$: percentage time for which the prediction is required

$\quad t_{inf}$: lower nominal percentage time

$\quad t_{sup}$: upper nominal percentage time

$\quad Q_t =$ $Q_i(t/100)$

$\quad Q_{inf} =$ $Q_i(t_{inf}/100)$

$\quad Q_{sup} =$ $Q_i(t_{sup}/100)$

$\quad E_{inf}$: field-strength value for time percentage t_{inf}

$\quad E_{sup}$: field-strength value for time percentage t_{sup}

where $Q_i(x)$ is the inverse complementary cumulative normal distribution function.

This model is valid for field strengths exceeded for percentage times in the range 1% to 50% only. Extrapolation outside the range 1% to 50% time is not valid.

A method for the calculation of $Q_i(x)$ is given in Annex 5, § 15 of ITU-R P.1546-4.

Correction for receiving/mobile antenna height
The field-strength values given by the land curves and associated tabulations in this model are for a reference receiving/mobile antenna at a height, R (m), representative of the height of the ground cover

surrounding the receiving/mobile antenna, subject to a minimum height value of 10 m. Examples of reference heights are 20 m for an urban area, 30 m for a dense urban area and 10 m for a suburban area.

Table 88: Default clutter height in the P1546-4 (when clutter height option not activated)

Selected environment	Assumed height of local clutter m
Rural	10
Sub-urban	10
Urban	20
Dense urban	30

Where the receiving/mobile antenna is on land account should first be taken of the elevation angle of the arriving ray by calculating a modified representative clutter height R' (m), given by:

$$R'=(1\,000dR-15_{h1})/(1\,000d-15) \qquad \text{m} \qquad \text{(Eq. 238)}$$

where h_1 and R (m) and distance d (km). Note that for $h_1 < 6.5d + R$, $R' \approx R$. The value of R' must be limited if necessary such that it is not less than 1 m.

when the receiving/mobile antenna is in an urban environment the correction is then given by:

$$\text{Correction} = 6.03 - J(\nu) \qquad \text{dB} \qquad \text{for } h_2 < R' \qquad \text{(Eq. 239)}$$

$$= K_{h2}\log(h_2/R') \quad \text{dB} \qquad \text{for } h_2 \geq R'$$

where $J(\nu)$ is given by equation (12a), and:

$$\nu = K_{nu}\sqrt{h_{dif}\,\theta_{clut}}$$

$$h_{dif} = R'-h_2 \qquad \text{m}$$

$$\theta_{clut} = \arctan(h_{dif}/27) \qquad \text{degrees}$$

$$K_{h2} = 3.2+6.2\log(f)$$

$$K_{nu} = 0.0108\sqrt{f}$$

$$f:\qquad \text{frequency (MHz)}.$$

In cases in an urban environment where R' is less than 10 m, the correction should be reduced by $K_{h2}\log(10/R')$. Where the receiving/mobile antenna is on land in a rural or open environment the correction is given by equation $= K_{h2}\log(h_2/R')$ for all values of h_2 with R' set to 10 m.

Correction for short urban/suburban paths

If a path of length less than 15 km covers buildings of uniform height over flat terrain, a correction representing the reduction of field strength due to building clutter should be added to the field strength. The correction is given by:

$$\text{Correction} = -3.3(\log(f))(1-0.85\log(d))(1-0.46\log(1+h_a-R)) \qquad \text{(Eq. 240)}$$

where h_a is the antenna height above ground (m) (i.e. height of the mast) and R is representative of the height of the ground cover surrounding the receiving/mobile antenna as defined in § 9 of P1546-4, which also represents the height of ground cover surrounding the transmitting/base antenna. This correction only applies when d is less than 15 km and $h_1 - R$ is less than 150 m.

Variation in path loss

Values of standard deviation are dependent on frequency and environment, and empirical studies have shown a considerable spread. Representative values for areas of 500 m × 500 m are given by the following expression (In SEAMCAT it is understood that the below equation only applies to the Mobile system and not to the Broadcasting systems):

$$\sigma_L = K + 1.3\log(f) \qquad \text{dB} \qquad \text{(Eq. 241)}$$

where:

$K =$ 1.2, for receivers with antennas below clutter height in urban or suburban environments for mobile systems with omnidirectional antennas at car-roof height

$K =$ 1.0, for receivers with rooftop antennas near the clutter height

$K =$ 0.5, for receivers in rural areas

$f :$ required frequency (MHz).

In SEAMCAT depending on the selected system the standard deviation is defined as follow:

Mobile: when "< 2 km radius" and "< 50 km radius" is selected, 4 dB and 8 dB are added to the calculated standard deviation respectively. This responds to the note of the Recommendation stating that if the area over which the variability is to apply is greater than 500 m × 500 m, or if the variability is to relate to all areas at a given range, rather than the variation across individual areas, the value of σ_L will be greater. Empirical studies have suggested that location variability is increased (with respect to the small area values) by up to 4 dB for a 2 km radius and up to 8 dB for a 50 km radius.

Broadcasting, digital: the standard deviation is set to a constant value of 5.5 dB. No correction is added.

Broadcasting, analogue: The standard deviation is defined as follow and no correction is added:

$$\sigma_L = 5.1 + 1.6\log(f) \qquad \text{dB} \qquad \text{(Eq. 242)}$$

In addition, SEAMCAT allows you to select a standard deviation value which overwrites any predefined value when selecting the "**use user specified standard deviation"** switch.

A17.9 JTG5-6

A17.9.1 Description of the model

A propagation model, as developed in JTG 5-6 (http://www.itu.int/md/R07-JTG5.6-C/en) has been implemented in SEAMCAT which combines the ITU-R P.1546, Extended Hata and Free space depending on the distance.

A17.9.2 Interpolation ambiguity

In parallel to the development of the JTG 5-6 plugins for CPG PTD, similar activities in SE42 (CEPT project team under WGSE closed in 2010) were on-going and in the course of the development of the plugins an ambiguity was found with respect to the interpolation between 100 m and 1 km and the 40 m to 100 m (see details in Doc. ECC/CPG11 PT-D(09)024).

Therefore, there was a need to develop two plugins to be made available based on the following figure:
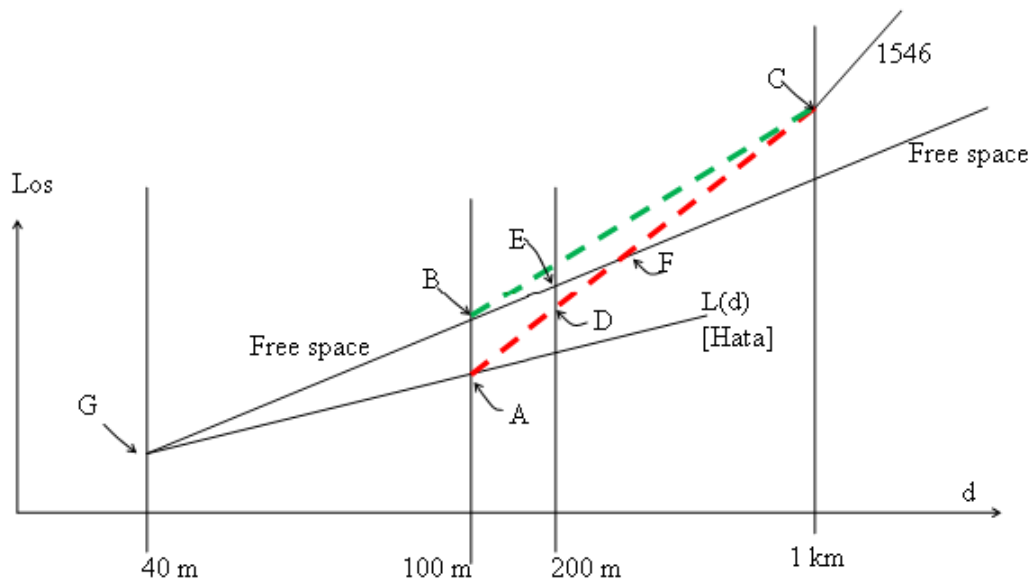
Figure 473: Interpolation ambiguity (red: original WP3K/JTG 5-6/54, green: SE42 modification)

- **JTG56** (based on the WP3K/JTG 5-6/54 document) where the interpolation is between the local Hata and P1546_1km and where the loss is max of (interpolated value, free space)). This is equivalent to the red curve of the illustrative figure.
- **JTG56** (based on SE42 modification) is the same as above but with a modification to the interpolation as agreed in SE42 where the interpolation is made between max(hata,free space) and P1546_1km and loss is directly the interpolated value. Finally the loss is max (loss, free space). This is equivalent to the green curve of the illustrative figure above.

The selection between the two implementations is presented in the GUI of the JTG5-6 below:
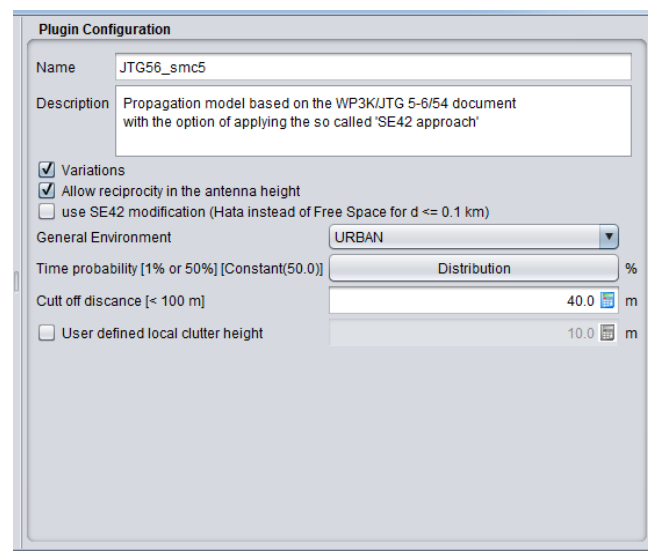
Figure 474: GUI of the JTG5-6

Table 89: JTG 5-6 propagation model

Description	Symbol	Type	Unit	Comments
Variation				Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc.
Allow reciprocity in the antenna height				
Use the SE42 modification (hasta instead of Free space for d<=0.1km)				
General environment				Environment of the propagation: rural, suburban, urban.
Time probability[1% or 50%]				time probability: 50 % and 1% for the interfering path. (P.1546)
Cut off distance[<100m]				
User defined local clutter height				

A17.9.3 Assumptions on the Plugin to CPG PTD (-> JTG 5-6):

- Outdoor to outdoor - Frequency : implemented to varie from 600 MHz to 2000 MHz as indicated in 3K/54.
- Tx Antenna heights (H_Tx): 30 m to 200 m
- Rx antenna heights (H_Rx): 1.5 m to 10 m
- standard deviation (stddev): hard coded value of 5.5 dB for all distances if H_Rx > clutter height. If H_Rx < clutter height and if H_Tx < Clutter height, the stddev = 7 dB (for all the distances). The use of hard coded value means that the shadowing effect is always activated.

Note on assumptions
- This plugin considers a limitation to free space in all cases (i.e. both Hata (ITU-R Report SM.2028-1) and P.1546-3 (ITU-R Recommendation P.1546-3))
- In the current plugin, the correction factor in eq.29 of section 10 of Annex 5 of Rec ITU-R P.1546-3 has been removed. This equation is not discussed in 3K/54.
- Since in Annex 7 to Document 5-6/53 the environment (i.e. Urban, Suburban and Rural) are within square brackets, it was decided to be generic in the implementation of the plugins and to include the all cases by using the same frequency correction factor as the already existing built in SEAMCAT hata model.
- The models that are used in the plugin are only for outdoor – outdoor scenario.

A17.10 LONGLEY RICE (ITM)

A17.10.1   Description of the model

ITM propagation model also know as Longley-Rice was developed to estimate radio transmission loss over irregular terrain for VHM, UHF, SHF frequency band. Computing of signal loss based on electromagnetic theory and on statistical analyses. It has been complemented by empirical dependences, during tests and measurements.

ITM model has two modes of working. *Point-to-Point* mode needs details of terrain profile. *Area prediction mode* - which is describe below - use estimation of parameters based on empirical medians. Area prediction mode is interesting for using, due to it can be implements to SEAMCAT system.

The basic input parameters such as: Antennas height, frequency, terrain irregularity determines computing method. Algorithm can be divided into three areas (determined by a function of the distance): A) Line-of-sight range (understood as uninterrupted visibility of the bulge of the Earth Plane, but which may be obscured by obstacles on the route), B) Diffraction range, C) Scatter range. In the first range to loss computing used Geometric-optics rays theory. In the second range used Fresnel-Kirchoff knife-edge diffraction theory. In the third range used Forward scatter theory.

The Longley-Rice (Area prediction mode) propagation model was originally implemented for SEAMCAT in the National Telecommunications Institute (Poland) in co-operation with the Wrocław University of Technology. The task was performed under Research Project of the Polish Ministry of Science and Higher Education entitled: Next generation teleinformatics services - technology, application and market aspects (no. PBZ-MNiSW-02/II/2007).

The SEAMCAT implementation of the Longley-Rice (Irregular Terrain Model) assumes a propagation model in area prediction mode (i.e. no need for terrain profile details to make a path loss calculation).The ITM model returns predicted median attenuation of a radio signal, regarding not only statistical terrain, system, climate parameters but also variability of the signal in time and in space, assuming a level of confidence. Longley-Rice computes path loss into three regions:

- Line-of-sight range;
- diffraction range;
  and
- scatter range (In distance between 1 – 2000 km).

ITM model is based on electromagnetic theory and on statistical analysis, the original model was developed in 1960's in the USA.

At the beginning necessary geometry parameters are calculated, based on input parameters. Then, depending on the range in which the transceiver and receiver are, ITM model compute reference attenuation A_{ref} – the median attenuation relative to a free space. Reference attenuation is a function of distance d, what is illustrated below. On cumulative attenuation comprises reference attenuation and attenuation of quantailes $A(q_T, q_L, q_s)$ – which are calculated based on normal distribution, as variability of time, localization, reliability.
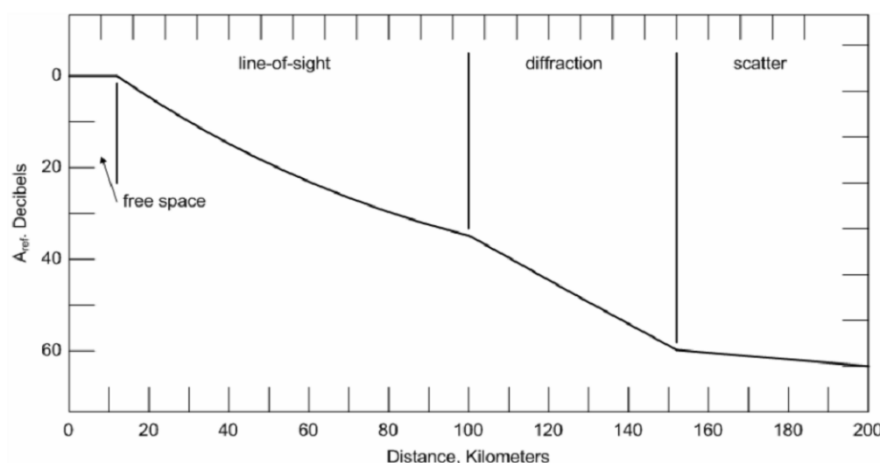
Figure 475: Reference attenuation as function of distance

A17.10.2   Working conditions

Longley-Rice model works correct in given frequency ranges, antenna heights, distance, surface refraction, as shown in Table 87.

Table 90: Range of ITM model correctly working

Parameter	Range
Frequency	20 MHz – 40 GHz
Antenna height	5 cm – 3 km
Distance	1 – 2 000 km
Surface refraction	250 -400 N

A17.10.3   Input Parameters

In order to make correctly calculations using the Longley-Rice propagation, model should take into account a number of input parameters describing the weather phenomena, system parameters, sitting criteria, statistical criteria which was shown in the table below.
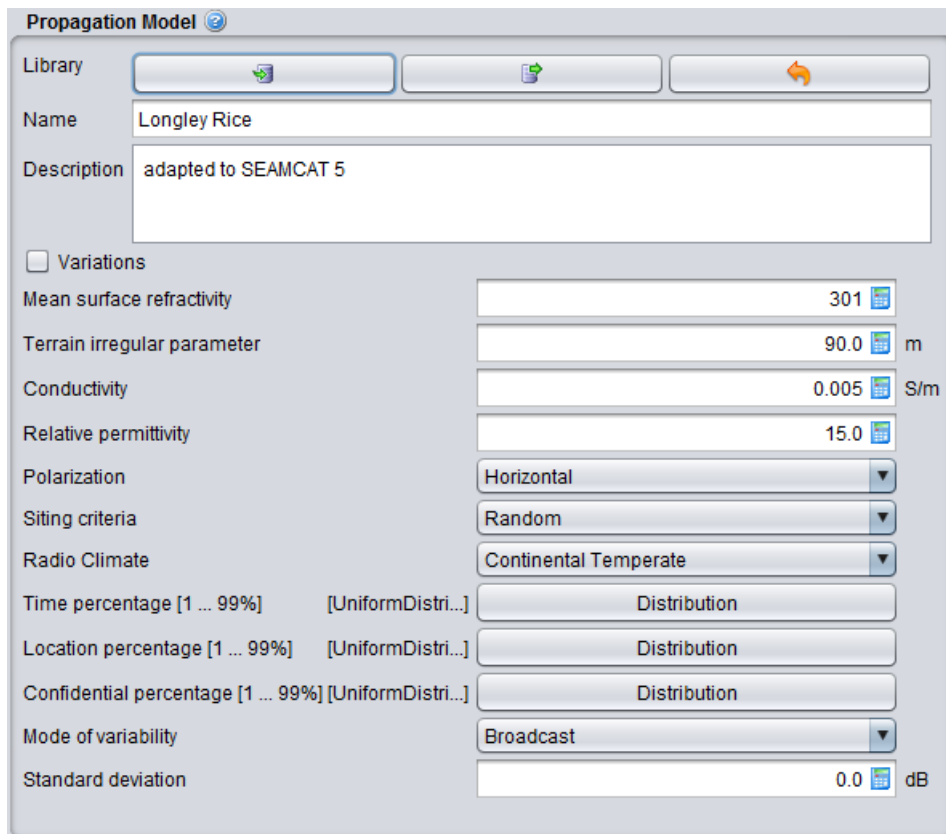
Figure 476: GUI of the Longley Rice

Table 91: Longley Rice propagation model

Description	Symbol	Type	Unit	Comments	
Variation	-	B	-	Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc.	
Mean surface refractivity (Ground refractivity)	-	S	Ns	Equatorial Continental Subtropical Maritime Subtropical Desert Continental Temperate Maritime Temperate over land Maritime Temperate over sea	360 320 370 280 301 320 350
Terrain irregularity parameter	-	S	M	Flat Plains Hills Mountains Rugged mountains	0 30 90 200 500
Electrical ground Conductivity	-	S	S/m	Average ground Poor ground Good ground Fresh water Sea water	0.005 0.001 0.020 0.010 5
Relative permittivity	-	S		Average ground Poor ground Good ground Fresh water Sea water	15 4 25 81 81
Polarisation	-	List	-	0 – horizontal, 1- vartical	
Sitting Criteria	-	List	-	Random, Careful, Very Careful	
Radio climate	-	List	-	Equatorial Continental Subtropical Maritime Subtropical Desert Continental Temperate Maritime Temperate over land Maritime Temperate over sea	
Time percentage	-	D or S	%	0.01 – 0.99	
Location percentage	-	D or S	%	0.01 – 0.99	
Confidential percentage	-	D or S	%	0.01 – 0.99	
Mode of variability	-	List	-	Single, individual, broadcast	
Standard deviation	Std. dev.	S	dB		

A17.11 IEEE 802.11 MODEL C (MODIFIED)

The IEEE 802.11 (Model C) [1] was used in the development of the ECC Report 131Annex 2 [2] to characterise all TS-TS radio propagation in the Monte Carlo studies.

Note: the "modified" term to the plugin refers to the fact that the algorithm has been implemented to ensure that you set most of the input parameters.

A17.11.1   Assumptions

Measurements results reported in the literature indicate that the presence of people across the propagation link between a transmitter and a receiver could cause additional loss (of up to 20 to 30dB), as a result of body loss or multi-path interference due to body scattering.

In circumstances where the spatial density of TSs is high (as in the geometries investigated in ECC Report 131), the probability of TS-TS path blocking is also high, and hence the TS-TS path can no longer be treated as line-of-sight. Consequently, a path loss model with a greater exponent is more suitable than the free space path loss model for the characterisation of TS-TS links in dense hotspots.

In ECC Report 131, the mean path loss is characterised by a dual-slope model with a break point at 5 m. In addition, the log-normal distributed shadowing with standard deviations of 3 dB and 4 dB is assumed in ECC Report 131 for separations of less than 5 metres and greater than 5 metres respectively

Where the calculated path loss is less than free space attenuation for the same distance, the free space attenuation is used instead.

A17.11.2   Equation

The mean path loss is characterised by a dual-slope model with a break point d_{BP}, an exponent of 2 for all distances less than d_{BP}, and an exponent of 3.5 otherwise. In short, the mean path loss, L, in dB is

$$L(d) = \begin{cases} L_{FS}(d) & [dB] \quad d < d_{BP} \\ L_{FS}(d_{BP}) + 35 \times \log\left(\dfrac{d}{d_{BP}}\right) & [dB] \quad d \geq d_{BP} \end{cases} \qquad \text{(Eq. 243)}$$

where d is the separation between the transmitter and receiver in kilometres, d_{BP} = 0.005 is the break-point in km (i.e. 5 m), and L_{FS} is free space path loss.

$$L_{FS} = 32.4 + 10 \times \log_{10}\left(\frac{(h_{Tx} - h_{Rx})^2}{1e^6} + d^2\right) + 20 \times \log_{10}(f) \qquad \text{(Eq. 244)}$$

where h_{Tx} and h_{Rx} are the height of the transmitter (Tx) and receiver (Rx) respectively and are expressed in m. d is the distance between the Tx and Rx and is expressed in km. f is the frequency and is expressed in MHz.

The log-normal distributed shadowing with standard deviations is applied to the pathloss calculated.

This propagation model is used to calculate terminal-terminal interference and takes account of shadowing losses due to objects between the two terminals, but does not explicitly account for any loss from near-field objects, such as the person carrying the equipment.

Figure 477: GUI of the IEEE 802.11 Model C (modified)

Table 92: IEEE 802.11 Model C (modified) propagation model

Description	Symbol	Type	Unit	Comments
Variation	-	B	-	Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc.
Distance to break point	BP	S	m	
Log-Normal distribution before BP	-	S	dB	
Log-Normal distribution after BP	-	S	dB	

A17.12 ITU-R REC. P. 1411

A17.12.1 Description of the model

ITU-R P.1411 [13], in §4.3, proposes a model for Tx and Rx antenna heights between 1.9 and 3 m in the UHF band (from 300 MHz to 3 GHz) and distances up to 3 000 m. This model allows SEAMCAT to investigate scenario where a propagation model in urban environment when both transmitter and receiver antennas are low height antennas i.e. located near to the ground (below roof-top height to near street level).

This situation is depicted as the paths between D and F, D and E, B and E, or E and F in Figure 478. It includes both LoS and NLoS regions, and models the rapid decrease in signal level noted at the corner between the LoS and NLoS regions. The model includes the statistics of location variability in the LoS and NLoS regions, and provides a statistical model for the corner distance between the LoS and NLoS regions. Figure 478 illustrates the LoS, NLoS and corner regions, and the statistical variability predicted by the model.

A17.12.2 Working conditions

This model is recommended for propagation between low-height terminals where both terminal antenna heights are near street level well below roof-top height, but are otherwise unspecified. It is reciprocal with respect to transmitter and receiver and is valid for frequencies in the range 300-3 000 MHz. The model is based on measurements made in the UHF band with antenna heights between 1.9 and 3.0 m above ground, and transmitter-receiver distances up to 3 000 m.
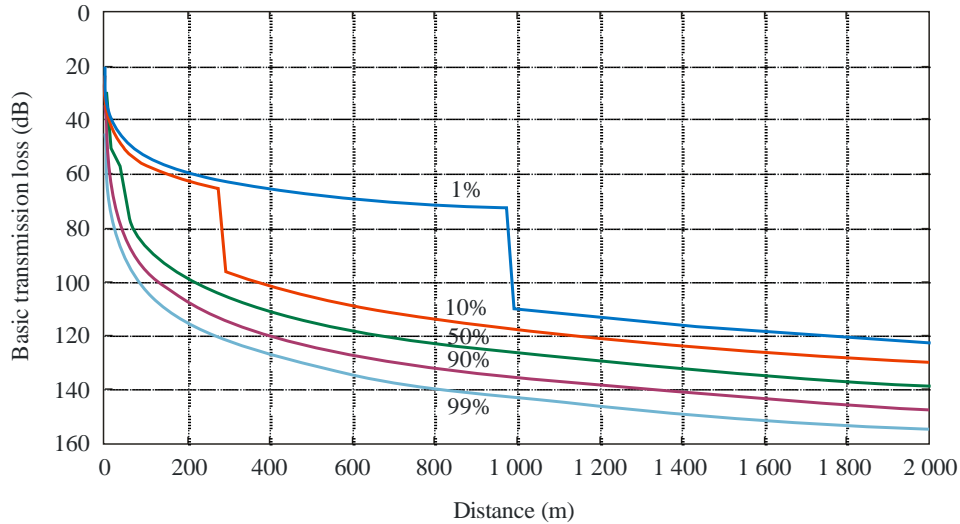
P.1411-05

Figure 478: Curves of basic transmission loss not exceeded for 1, 10, 50, 90 and 99% of locations (frequency = 400 MHz, suburban)

A17.12.3 Algorithm

The parameters required are the frequency f (MHz) and the distance between the terminals d (m).

Step 1: Calculate the median value of the line-of-sight loss:

$$L_{LoS}^{median}(d) = 32.45 + 20 \log_{10} f + 20 \log_{10}(d/1\,000)$$

(Eq. 245)

Step 2: For the required location percentage, p (%), calculate the LoS location correction:

$$\Delta L_{LoS}(p) = 1.5624\sigma\left(\sqrt{-2\ln(1-p/100)} - 1.1774\right)$$

with σ = 7 dB

(Eq. 246)

Alternatively, values of the LoS correction for p = 1, 10, 50, 90 and 99% are given in Table 93

Step 3: Add the LoS location correction to the median value of LoS loss:

$$L_{LoS}(d,p) = L_{LoS}^{median}(d) + \Delta L_{LoS}(p)$$

(Eq. 247)

Step 4: Calculate the median value of the NLoS loss:

$$L_{NLoS}^{median}(d) = 9.5 + 45 \log_{10} f + 40 \log_{10}(d/1\,000) + L_{urban}$$

(Eq. 248)

L_{urban} depends on the urban category and is 0 dB for suburban, 6.8 dB for urban and 2.3 dB for dense urban/high-rise.

Step 5: For the required location percentage, p (%), add the NLoS location correction:

$$\Delta L_{NLoS}(p) = \sigma N^{-1}(p/100)$$

with σ = 7 dB

(Eq. 249)

$N{-}1(.)$ is the inverse normal cumulative distribution function. An approximation to this function, good for *p* between 1 and 99% is given by the location variability function Qi(x) of Recommendation ITU-R P.1546. Alternatively, values of the NLoS location correction for p = 1, 10, 50, 90 and 99% are given in Table 93.

Table 93: Table of LoS and NLoS location variability corrections

p (%)	ΔL_{LoS} (dB)	ΔL_{NLoS} (dB)	d_{LoS} (m)
1	−11.3	−16.3	976
10	−7.9	−9.0	276
50	0.0	0.0	44
90	10.6	9.0	16
99	20.3	16.3	10

Step 6: Add the NLoS location correction to the median value of NLoS loss:

$$L_{NLoS}(d,p) = L_{NLoS}^{median}(d) + \Delta L_{NLoS}(p)$$

(Eq. 250)

Step 7: For the required location percentage, p (%), calculate the distance d_{LoS} for which the LoS fraction F_{LoS} equals p:

$$d_{LoS}(p) = 212\left[\log_{10}(p/100)\right]^2 - 64\log_{10}(p/100) \qquad \text{if } p < 45$$
$$d_{LoS}(p) = 79.2 - 70(p/100) \qquad\qquad\qquad \text{otherwise}$$

(Eq. 251)

Values of d_{LoS} for p = 1, 10, 50, 90 and 99% are given in Table 93. This model has not been tested for p < 0.1%. The statistics were obtained from two cities in the United Kingdom and may be different in other countries. Alternatively, if the corner distance is known in a particular case, set $d_{LoS}(p)$ to this distance.

Step 8: The path loss at the distance d is then given as:

a) If d < d_{LoS}, then L(d, p) = L_{LoS}(d, p)
b) If d > d_{LoS} + w, then L(d, p) = L_{NLoS}(d, p)
c) Otherwise linearly interpolate between the values L_{LoS}(d_{LoS}, p) and L_{NLoS}(d_{LoS} + w, p):

$$L_{LoS} = L_{LoS}(d_{LoS}, p)$$
$$L_{NLoS} = L_{NLoS}(d_{LoS} + w, p)$$
$$L(d, p) = L_{LoS} + (L_{NLoS} - L_{LoS})(d - d_{LoS})/w$$

A17.12.4   Input parameters

The input parameters for this model are as follow:
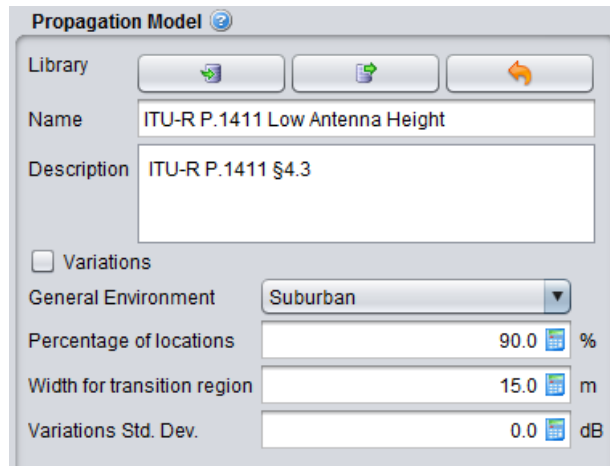
Figure 479: GUI of the ITU-R P.1411 §4.3

Table 94: ITU-R P.1411 §4.3 propagation model

Description	Symbol	Type	Unit	Comments
Variation	-	B	-	Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc.
General environment	-	-	-	Environment of the propagation: urban, suburban, Dense Urban/High Rise Dense Urban/High-Rise means high buildings, thus buildings are spaced. "Dense" is to be interpreted in terms of people grouping, not buildings grouping. This explains the reason why attenuation is less in Dense Urban/High Rise than in Urban)
Percentage of locations	-	S	%	Percentage of locations : from 1 to 99
Width for transition region	-	S	m	Average street width : typical value is 15 m
Variations std. dev.	-	S	dB	

A17.13 ITU-R REC. P. 528

A17.13.1   Description of the model

ITU-R P.528 contains a method for calculating path loss in the frequency range from 125 to 15500 MHz for ground-air, ground-satellite, air-air, air-satellite, and satellite-satellite links. It provides an interpolation method from a sets of curves and a set of curves.

A17.13.2 Working conditions

The implementation in SEAMCAT contains a consistency check of input parameters. It produces error messages if input parameters are not in the range specified by ITU-R P.528 i.e.:

- Minimum (ground) antenna height :   [1.5-1 000] m;
- Maximum (aero) antenna height: [1 000-20 000] m;
- Frequency: [125-15 500] MHz;
- Time percentage: 1-95] %;
- Distance: [0-1800] km.

A17.13.3 Algorithm

The ITU-R P.528 recommendation Annex 2 describes separate stages of the calculation. A step-by-step description of the overall interpolation method is given in § 8 of that Annex. Section 2 gives the calculation for field strength from the transmission loss value(s) taken from the curves in Annex 3. Sections 3 to 8 of this Annex describe how to interpolate for distance, h1, h2, frequency and percentage time.

A17.13.4 Input parameters

Input parameters are the heights of the antennas above mean sea level, and the frequency which is obtained from SEAMCAT internal calculation. You need to set the time percentage on the model GUI.
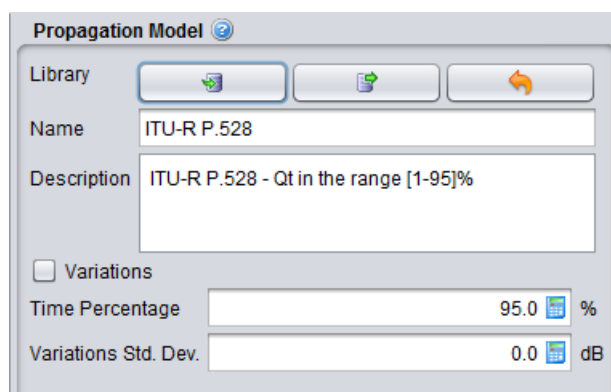
Figure 480: GUI of the ITU-R P.528

Table 95: ITU-R P.528 propagation model

Description	Symbol	Type	Unit	Comments
Variation	-	B	-	Variation in path loss takes into account the uncertainty of building design, furniture, room size, etc.
Time percentage	-	S	%	Percentage of locations : from 1 to 99
Variations std. dev.	-	S	dB	

ANNEX 18: PLUGIN: COMPILATION AND DEBUGING

A18.1 JAVA AND MAVEN

A18.1.1 Java

Go to Sun or Oracle website and search for downloading the Java Development kit (JDK). You will get to download a .zip file. Note that the version of the JDK are changing quite regularly, therefore the version presented in this manual may not be up-to-date when you read it, but the spirit is the same. The JDK (Java development kit) includes the JRE (Java Runtime Environment).

A18.1.2 Installing a compiler: Example with Apache maven

You can download Apache Maven at http://maven.apache.org/download.cgi and save it under your program files (if you work under Microsoft OS).
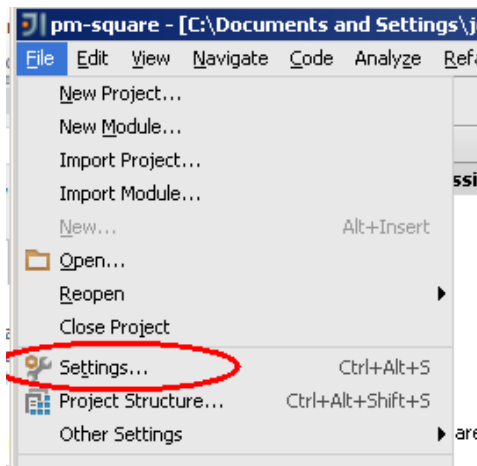
Figure 481: Set Maven in your poject. Select File -> Settings
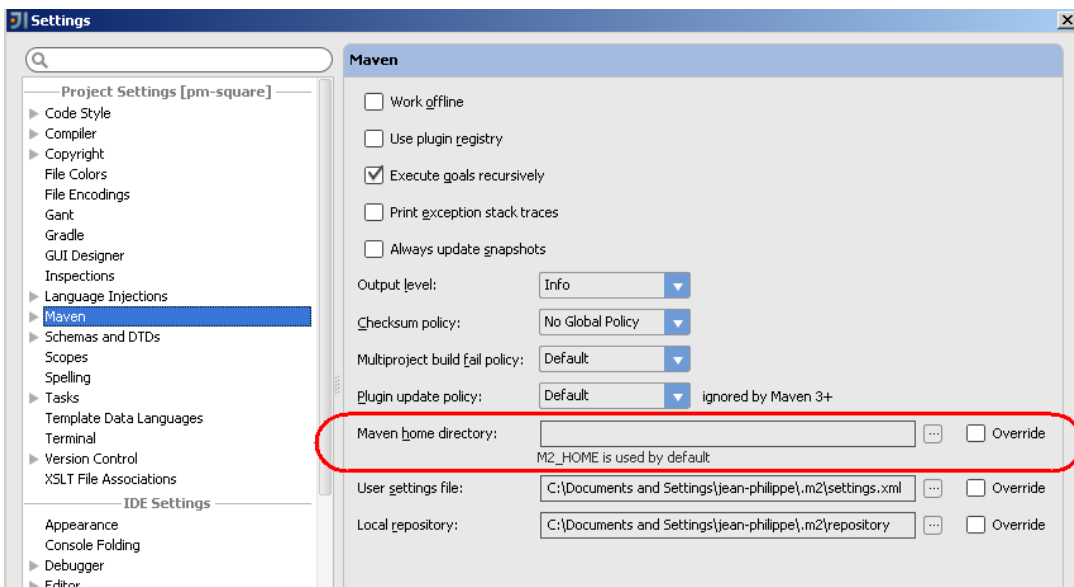
Figure 482: Click on override for the "Maven home directory field"

Select "apache-maven-3 xx" (or above) from your file system.

A18.2 ASSOCIATE SEAMCAT-MODEL-5.0.0.JAR TO YOUR PROJECT

SEAMCAT supports custom written plugins. You need to develop your own plugin using a Java development environment (IDE) for instance IDEA Intellij.

When creating a plugin you need to have the library seamcat-model-5.0.0.jar associated to your project. This file is needed if you want to be able to see the SEAMCAT model interface.

The Java dependencies (.jar file) needed for you development can be downloaded from the official download page under "Plugin development".
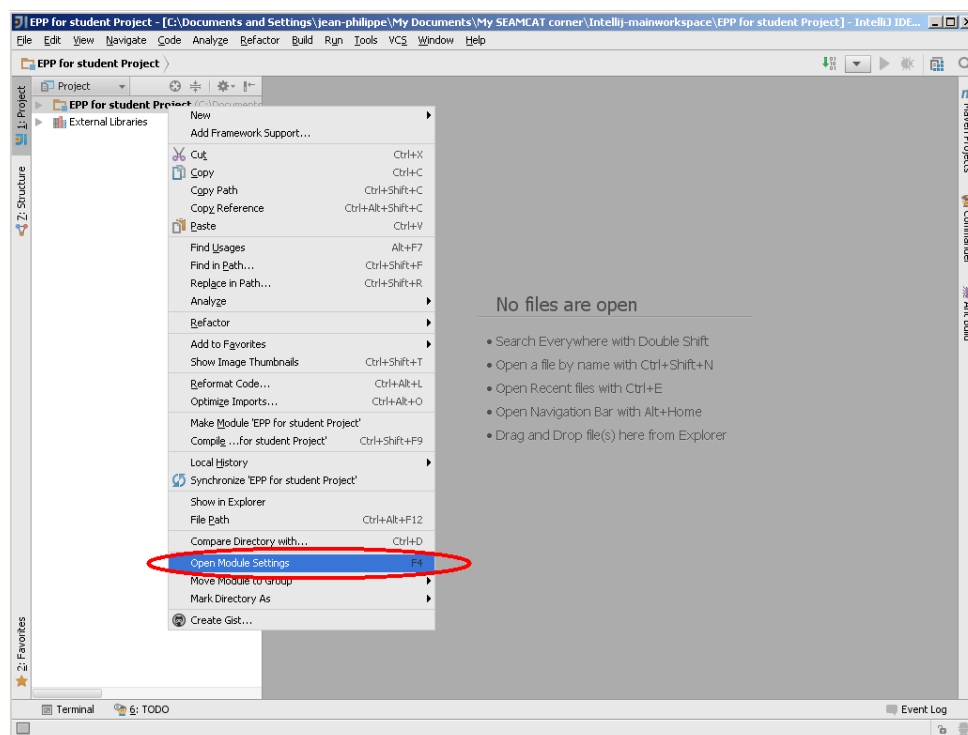
Figure 483: Go to "Open Module Settings"
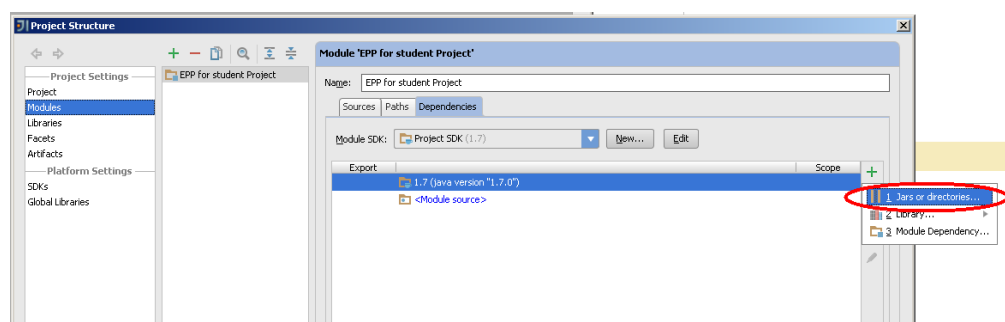
Figure 484: Click the green cross on the right handside and select "Jar or directories"

Go and fetch the .jar file from your file system (you need to download it from the official SEAMCAT web page to get the latest version)
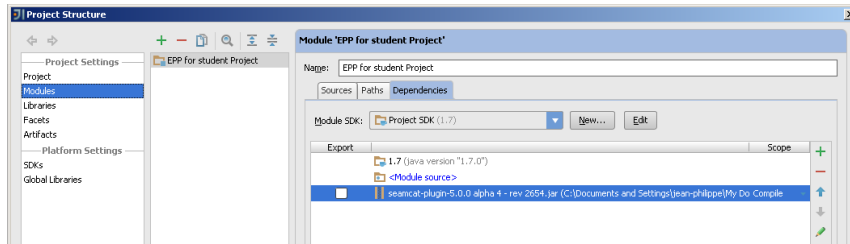
Figure 485: list of dependencies

You can also see it under the "External Libraries", just below your project
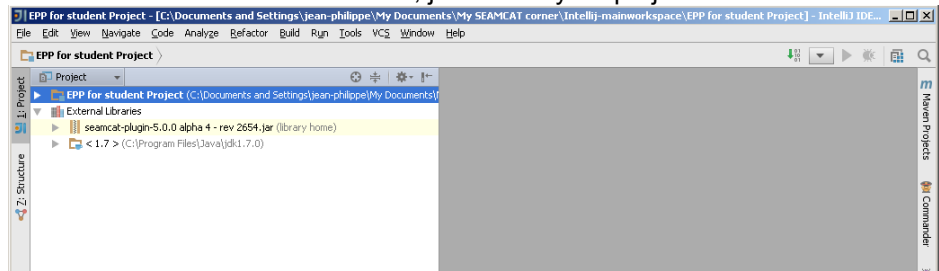
Figure 486: External libraries

A18.3 DEVELOP A PLUGIN

We want to develop a PMP that calculates the path loss as an increasing function starting from 0 (when the distance is 0) and growing towards infinity at the square of the distance times a distribution given as input by the user. In pseudo code something like the following:

path loss = dist(tx, rx)^2 * distribution.trial()

Note: This is just an example and not a real propagation model.

The following prerequisites are assumed:
- basic understanding of Java;
- intellij IDEA is installed and used for development;
- maven 3 (3.0.0 or above) is installed;
- seamcat-model-5.0.0.jar is downloaded.

A18.3.1 Setting up the project

Setting up the project is done using maven and uses the template project found in the **plugin-template.zip**.
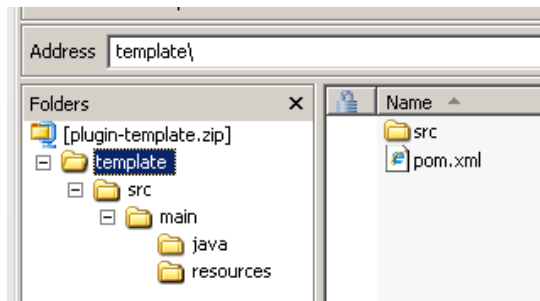
Figure 487: Example in setting up a project

Unzip this file and name the main directory "pm-square". The contents of the unzipped folder is an empty Java project with maven configuration for the project dependencies and instructions on how to create a .jar file.

After importingthe intellij project, it is important that the local maven repository knows about seamcat-model-5.0.0.jar dependency. Follow the instruction of section A18.2. The local maven repository will now contain the needed dependency and with intellij the project can now be imported. Do this by opening intellij and choose File<New<Project from Existing Sources-t.
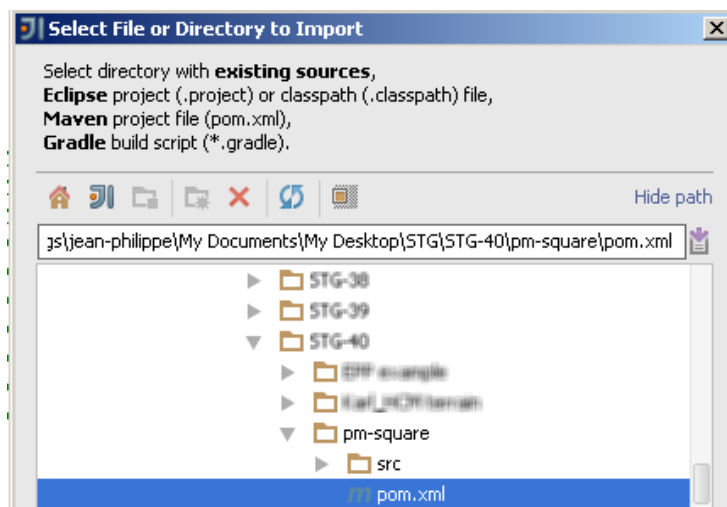
Figure 488: Select the pom.xml file in the 'pm-square' folder.

Go through the various windows

A18.3.2 Development

We first create a package named 'com.example.pmsquare' for the plugin classes. This is done by right clicking the 'src/main/java' folder and selecting new->package.
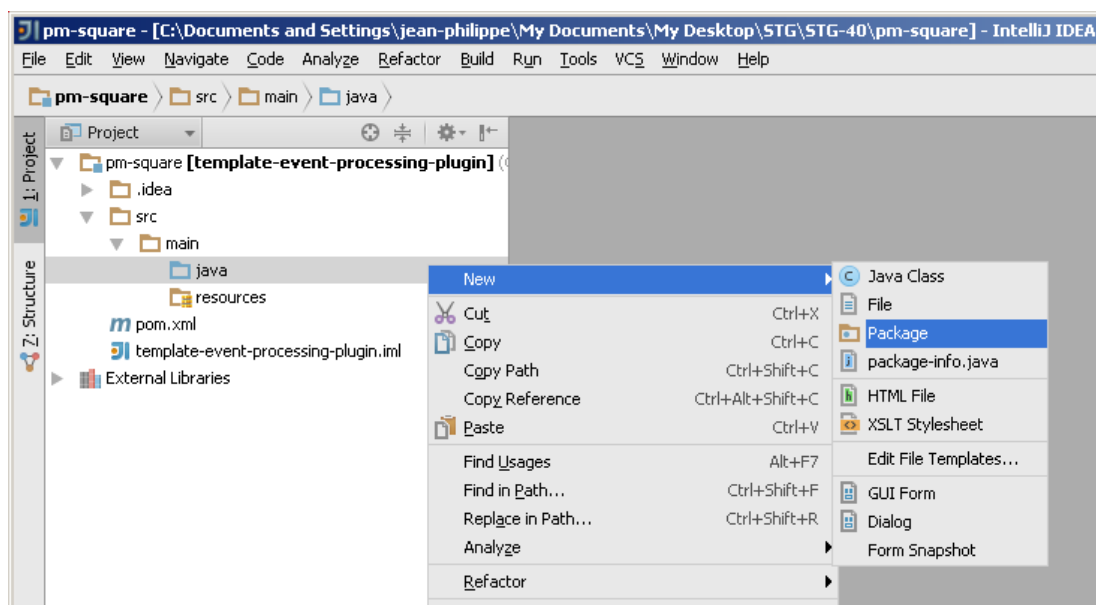
Figure 489: create a package named 'com.example.pmsquare' for the plugin classes
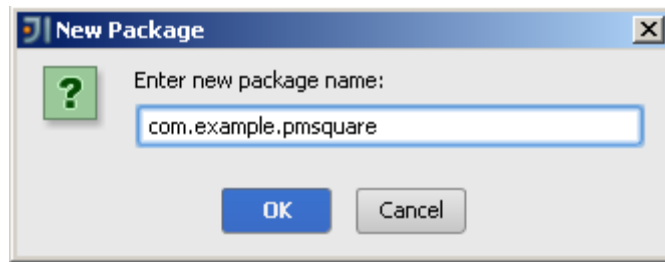
Figure 490: Write com.example.pmsquare in the dialog that appears
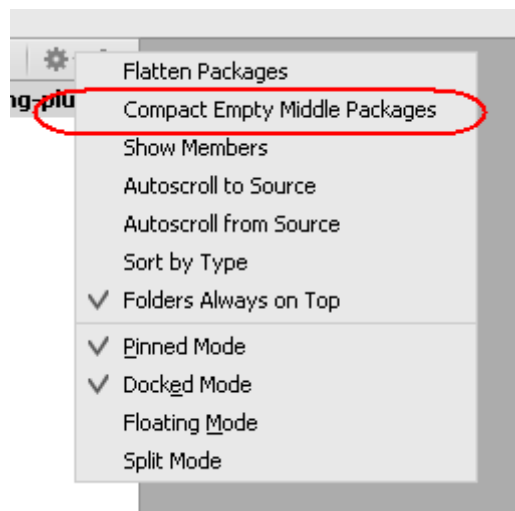
Figure 491: Remember to have the "Compact Empty Middle Packages" unchecked in the view settings , so that you can see the tree structure
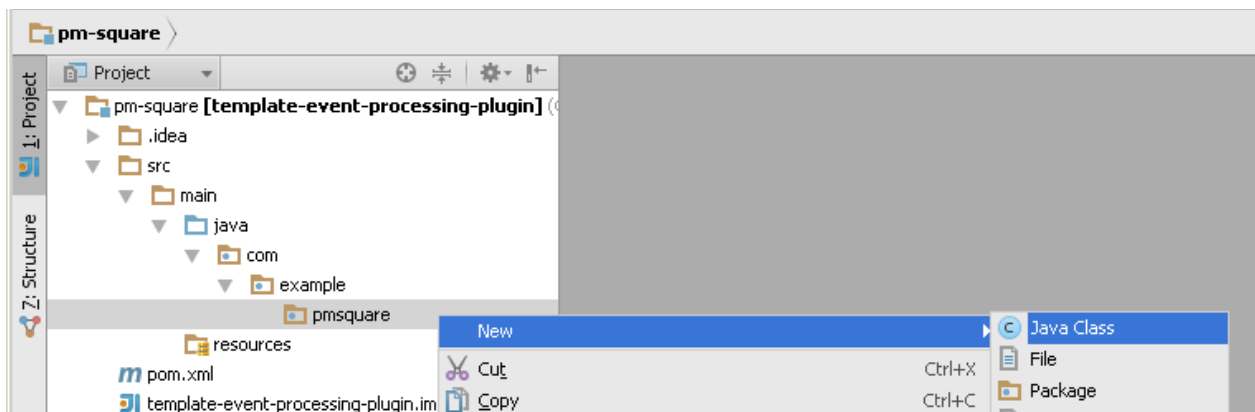
Figure 492: On the PMSsquare folder now right click again to create a java class called PMSquare
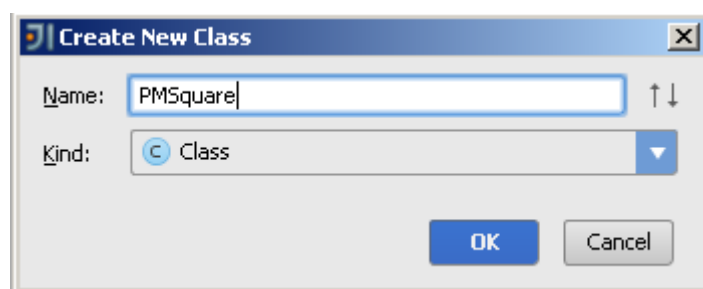
Figure 493: create a java class called PMSquare
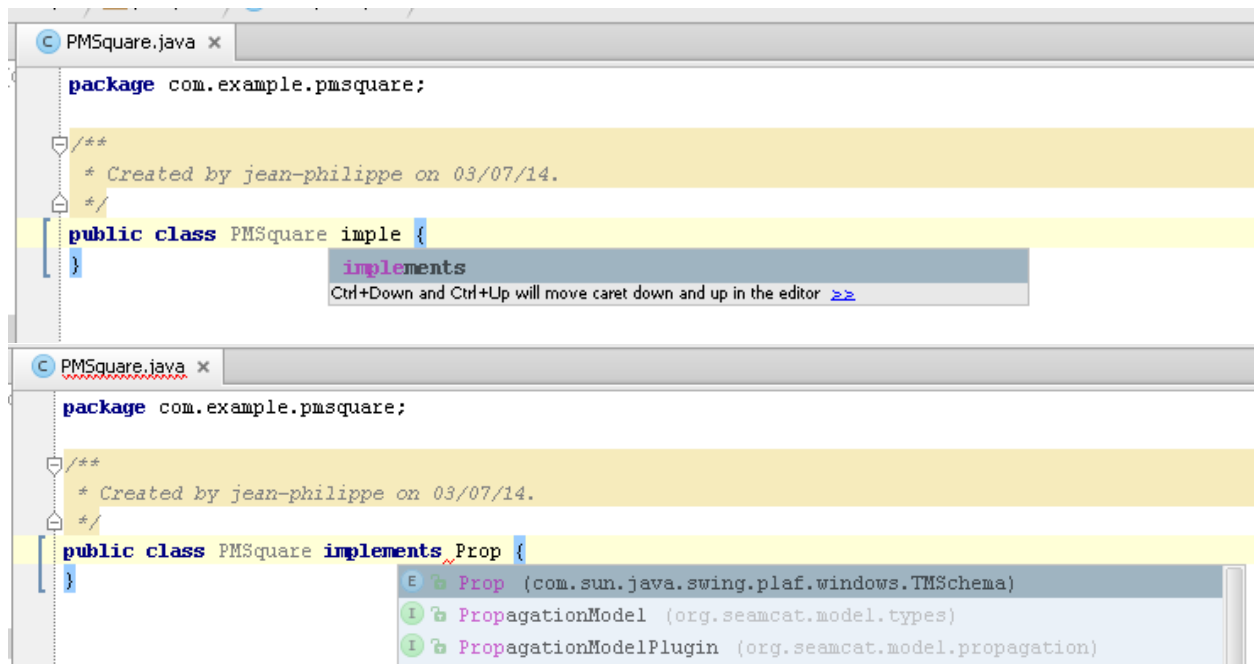
**Figure 494: Make PMSquare class implement PropagationModelPlugin
(and auto implement the needed methods)**
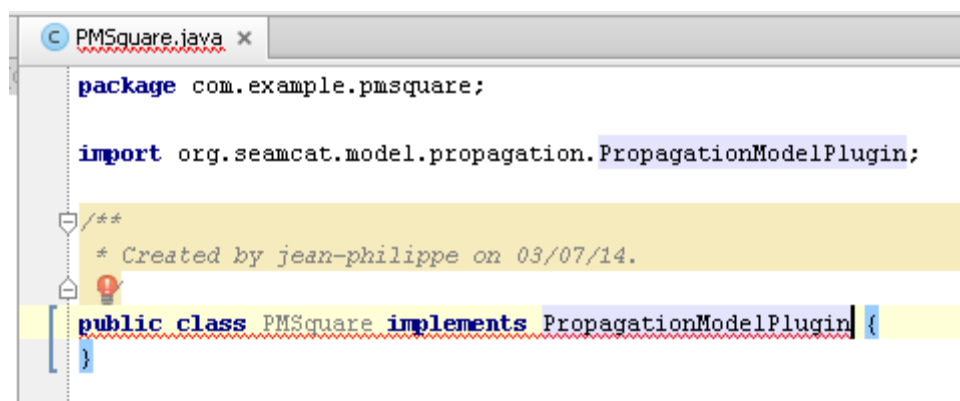
Figure 495: Press ALT + enter (on PC)
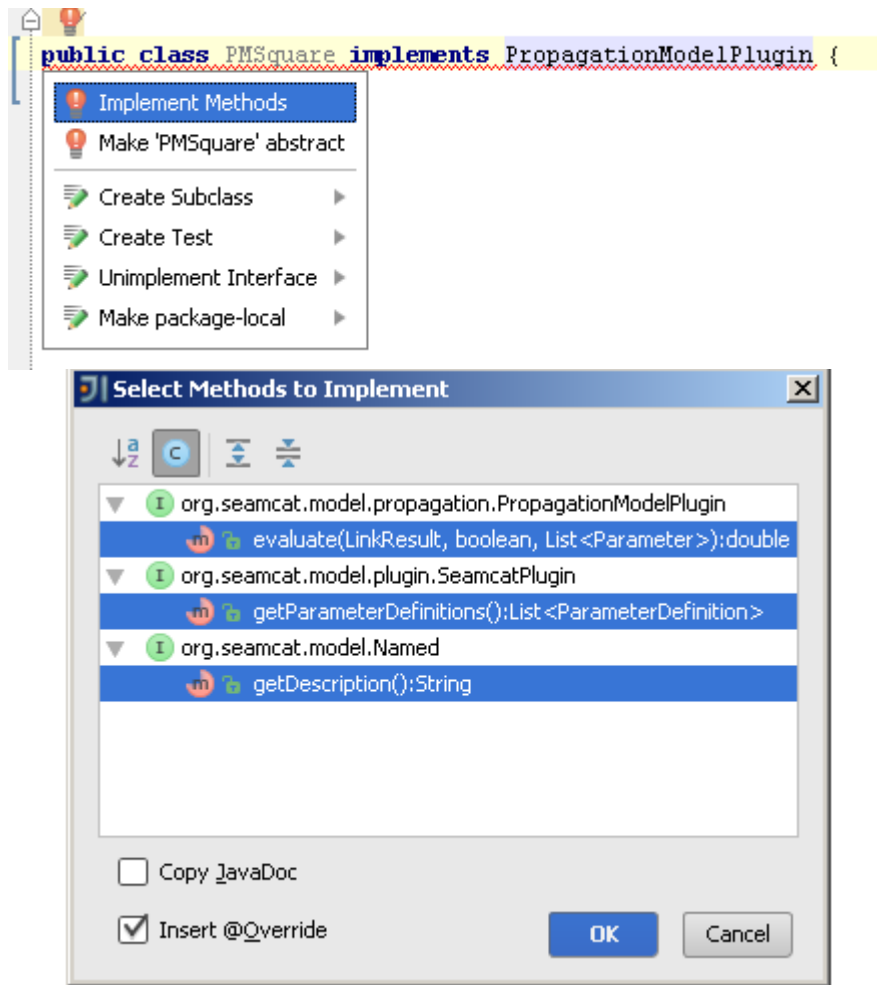
Figure 496: Select "implement methods" to auto implement the interface
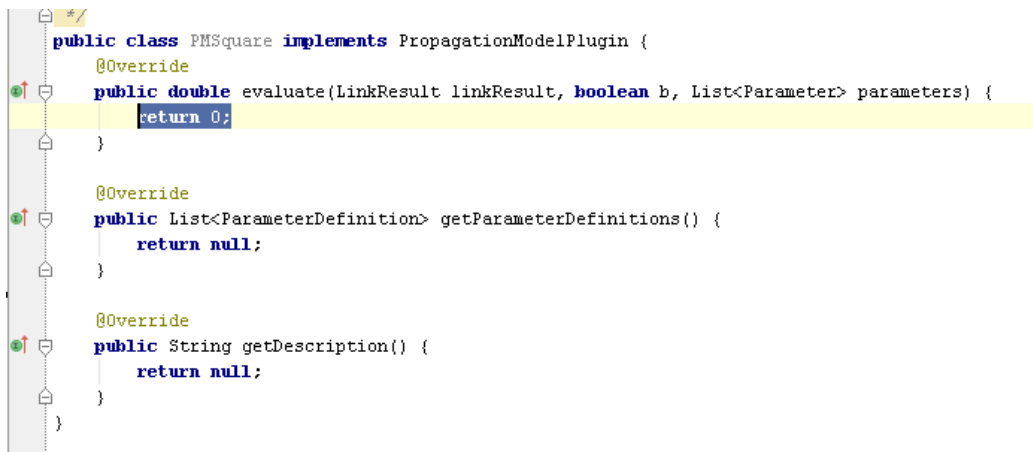
Figure 497: Results of the auto implementation

A18.3.3 Building & Installing

The project is packaged into a .jar file by running the maven command 'install'. This can be done either from the intellij maven tab (on the far right there is a vertical tab called Maven - unfold and double click on "install"). Or it can be done from a command terminal by standing in the folder where the pom.xml file is located and write mvn clean install.
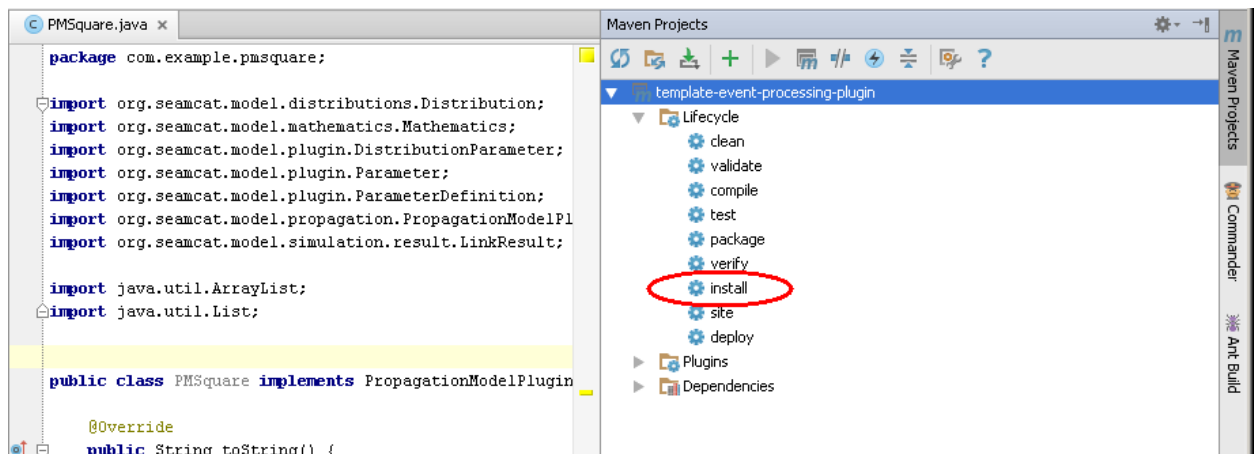
Figure 498: The successful run of the 'install' command will produce a target folder containing the resulting .jar file

You may have warning complaining of a wrong "Maven Home directory" configuration. This is because your maven home directory is not set properly. Click on the "configuration dialog" link, which will lead you to the Maven setting panel.
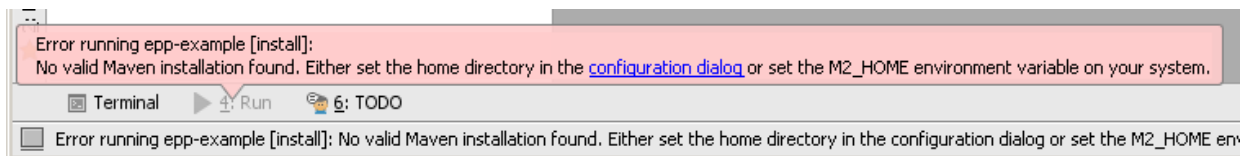
Figure 499: The successful run of the 'install' command will produce a target folder containing the resulting .jar file

When your "Maven Home directory" is set properly, double click on "Install" again, you can see that the compilation starts

If you have uploaded the latest version of the SEAMCAT interface for plugin, then IntellijIdea will by default use it (even though it has been generated from another project).

If the compile works without failure you should get a "BUILD SUCCESS"
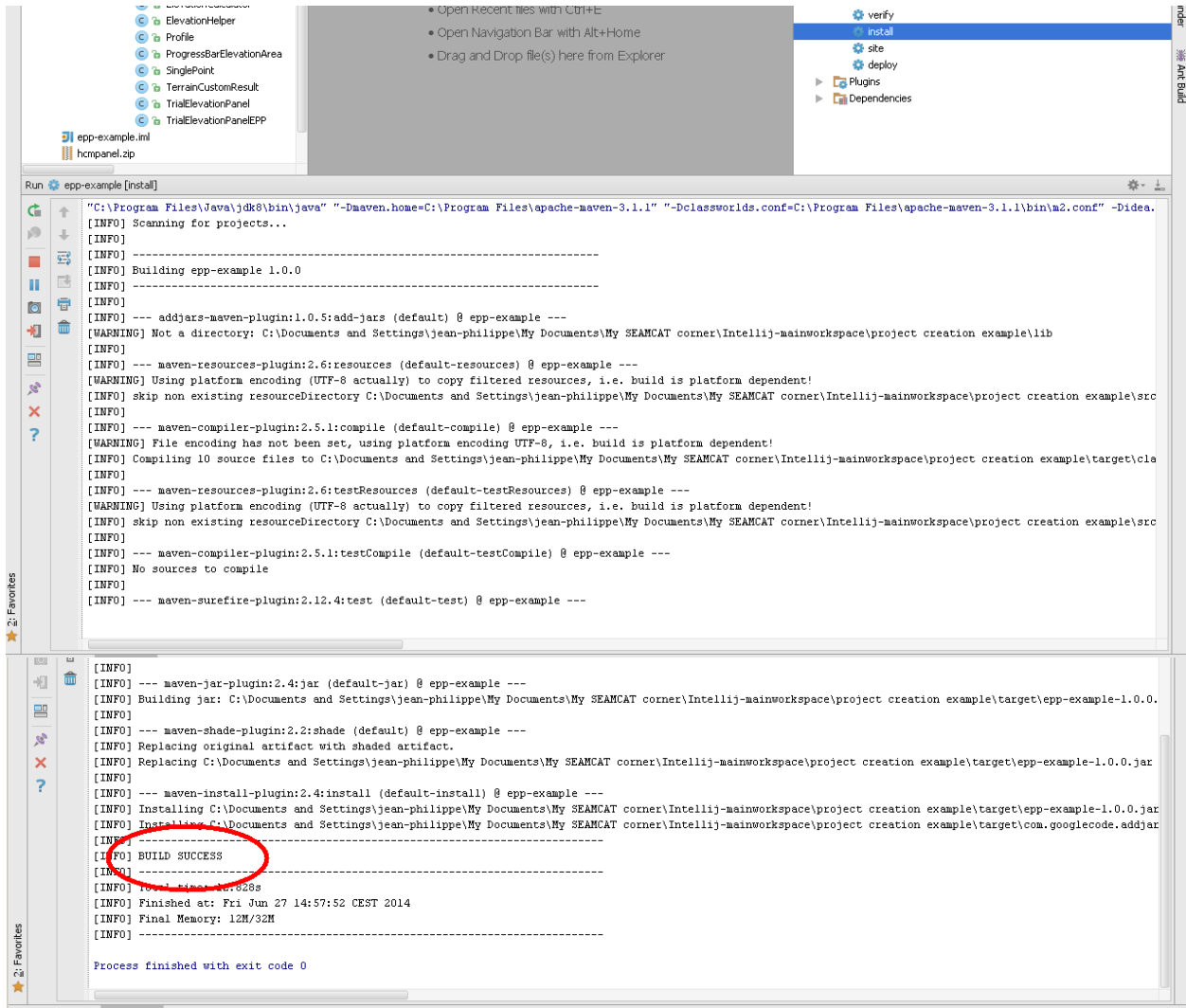
Figure 500: Compilation status

IntellijIdea/maven created a Target folder where you can see the .jar that has been created. You can then upload that .jar into SEAMCAT.
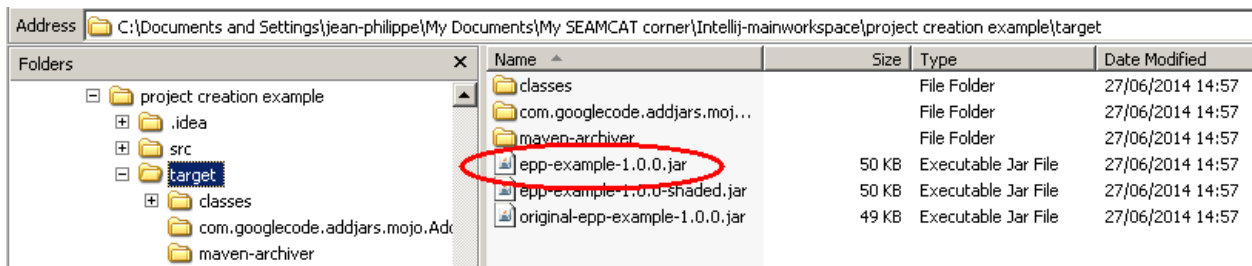
Figure 501: Target folder

You are now ready to install your .jar plugin into SEAMCAT.

A18.4 HOW TO DEBUG YOUR PLUGIN

You need to have the following installed on your machine
1. Intellij (version 12 and forward) with SEAMCAT setup and running in debug mode;
2. The source code of the plugin project;
3. The plugin .jar file installed in the running SEAMCAT application.

To debug the plugin code the jar file of the plugin and the source code must be associated with the SEAMCAT project. This is done by doing the following steps:

1. From the SEAMCAT intellij project open the project structure (menu "File -> Project Structure ...");
2. From the "Project Settings" choose "Libraries";
3. Choose "Attach files or Directories" (by clicking the green plus sign on the right);
4. First attach the .jar file of the plugin (this will attach the binary code of the plugin to your SEAMCAT project);
5. Second attach the root directory of the plugin project (this will attach the source code of the plugin).
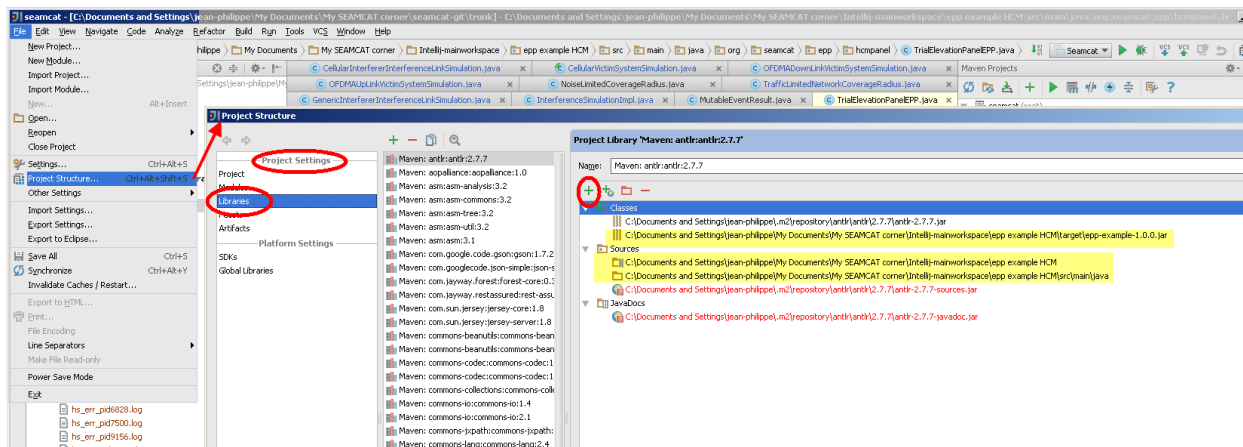
Figure 502: How to associate a plugin .jar to its source code

You should now be able to open the plugin class from the SEAMCAT project. Press Ctrl-n and type the name of the plugin class you want to debug (note that the auto-complete may not work, so you need to write the full filename). This should open the source file of the plugin class and breakpoints should be possible to set normally.

Notice that if you make changes to this file it will be out of sync with the binary file running from within SEAMCAT. So eventual bugs to be fixed will have to be done inside the plugin project AND then subsequentially built and installed in SEAMCAT to be tested.

A18.5 EXAMPLE OF PMP

This simple example of a Propagation Model Plugin applies Free Space propagation loss with its default distance factor of 2, in case the antenna heights of TX and RX are greater than the limit given by the input annotation 'Height of antenna', otherwise it applies the factor given by the input annotation 'Distance coefficient'. If 'variation' is selected it uses the standard deviation given by the input annotation 'Standard deviation'.

It aims to show:
▪ the basic structure of a propagation plugin which is creating its own Input interface
▪ how to set up basic consistency checks
▪ how to define input annotations including tool tip information

Note that for simplicity Runtime Exceptions have not been included

The structure details are:
1. **calculation of the resulting path loss**
2. **consistency check**
   a. the validity of the input parameter 'Distance coefficient';
   b. whether the value of the input parameter 'antenna height' conflicts with the antenna heights set on the system if the PMP is used for the system link or
   c. if the PMP is used for the interference link;
3. description
   a. unique name of the plugin – **must not be empty;**

    b.   optional but recommended description of the plugin characteristics;
4. **Input** annotations
    note that the value of 'variations' is either selecting or deselecting the variations by default.

```java
public class PMPexample implements PropagationModelPlugin<PMPexample.Input> {
    public double evaluate(LinkResult linkResult, boolean variation, Input input) {
        double loss = 0;
        double distanceFactor = 2.; //default free space
        if (linkResult.txAntenna().getHeight() <= input.ha()) distanceFactor = input.coeff();
        if (linkResult.rxAntenna().getHeight() <= input.ha()) distanceFactor = input.coeff();
        loss = 32.44 + 20 * Math.log10(linkResult.getFrequency())
                + distanceFactor
                * 10 * Math.log10(linkResult.getTxRxDistance() * linkResult.getTxRxDistance()
                + (linkResult.txAntenna().getHeight() - linkResult.rxAntenna().getHeight())
                * (linkResult.txAntenna().getHeight() - linkResult.rxAntenna().getHeight()) / 1e6);

        if (variation) {
            loss += Factory.distributionFactory().getGaussianDistribution(0, input.stddev()).trial();
        }
        return loss;
    }

    public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
        if (input.coeff() <= 2.) validator.error("Distance coefficient should be greater than 2.0");
        if (list.size() > 0) {
            Bounds hTX = null, hRX = null;
            if (list.get(0) instanceof RadioSystem) {
                hTX = ((RadioSystem) list.get(0)).getTransmitter().getHeight().getBounds();
                hRX = ((RadioSystem) list.get(0)).getReceiver().getHeight().getBounds();
            } else if (list.get(0) instanceof InterferenceLink) {
                hTX = ((InterferenceLink) list.get(0)).getInterferingSystem().getTransmitter().getHeight().getBounds();
                hRX = ((InterferenceLink) list.get(0)).getVictimSystem().getReceiver().getHeight().getBounds();
            }
            if (null != hTX && hTX.getMax() < input.ha())
                validator.error("TX antenna height must be greater than " + input.ha() + " m");
            if (null != hRX && hRX.getMax() < input.ha())
                validator.error("RX antenna height must be greater than " + input.ha() + " m");
        }
    }

    public Description description() {
        return new DescriptionImpl("PMPexample", "PMP example for section A.19");
    }

    public interface Input {
        @Config(order = 1, name = "Height of antenna", unit = "m", toolTip = "Height of the antenna below which the distance coefficient applies")
        double ha();

        @Config(order = 2, name = "Distance coefficient", toolTip = "replaces the default factor of 2 of the Free space propagation model")
        double coeff();

        @Config(order = 3, name = "Standard deviation", unit = "dB")
        double stddev();

        double ha = 2.5;
        double coeff = 3.5;
        double stddev = 5.5;
        boolean variations = true;
    }
}
```

Figure 503: PMP example source code

You may notice that for the generation of the random Gaussian distribution value of the standard deviation the built-in Factory.distributionFactory() has been used.
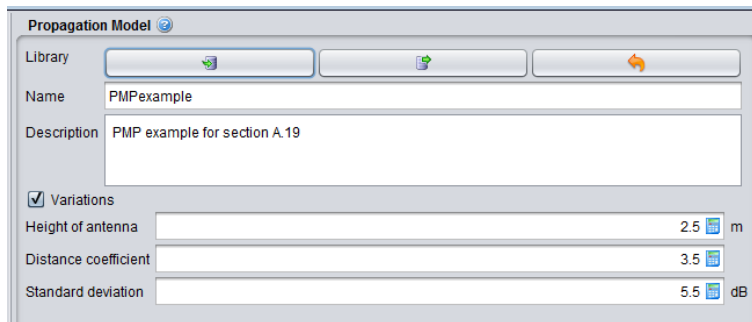
Figure 504: PMP example configuration panel
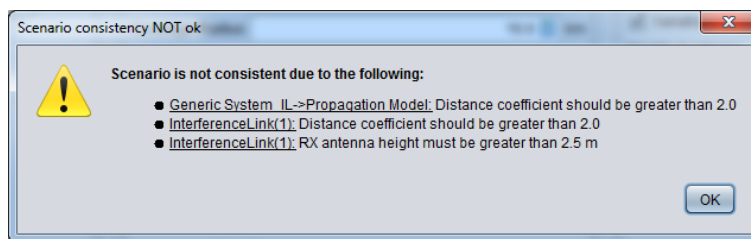
Figure 505: PMP example consistency check warnings

A18.6 EXAMPLE OF AP

This simple example of an Antenna plugin modifies within a given beam width the resulting antenna gain proportional to the ratio of the actual distance and the distance 'of adaption'.

It aims to show
- the basic structure of an antenna plugin which is creating its own Input interface;
- how to set up basic consistency checks;
- how to define input annotations including tool tip information.

Note that for simplicity Runtime Exceptions have not been included.

The structure details are:
5. **calculation** of the resulting antenna gain
6. consistency check
      a. the validity of the input parameter 'beam width';
      b. whether the value of the input parameter 'adaptive distance' conflicts with the coverage radius, taking account of the path distance factor;
      c. the valid system type applying this antenna.
7. description
      a. unique name of the plugin – **must not be empty;**
      b. optional but recommended description of the plugin characteristics;
8. **Input** annotations
    note that the value 'peakGain' is setting the default value of the plugin.

```
public class APexample implements AntennaGainPlugin<APexample.Input> {
    public double evaluate(LinkResult linkResult, AntennaResult antennaResult, double peakGain, Input input) {
        double gain = peakGain;
        // TODO combine azimuth and elevation
        double phi = Mathematics.acosD(Mathematics.cosD(antennaResult.getElevation())
                * Mathematics.cosD(antennaResult.getAzimuth()));
        if (linkResult.getTxRxDistance() <= input.adaptionDistance() && phi <= input.beamWidth()/2.){
            gain = peakGain * linkResult.getTxRxDistance()/input.adaptionDistance();
        }
        return gain;
    }

    public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
        if (input.beamWidth() < 10.) validator.error("Tha AP example expectes a beam width of at least 10 degree");
        if (list.size() > 0) {
            if (list.get(0) instanceof GenericSystem) {
                GenericSystem system = (GenericSystem) list.get(0);
                GenericLink link = (GenericLink) system.getLink();
                if (link.getCoverageRadius().evaluate(system)
                        * link.getRelativeLocation().getPathDistanceFactor().getBounds().getMax()
                        < input.adaptionDistance())
                    validator.error("Range of gain adaption must not be larger than the coverage radius");
            } else if (list.get(0) instanceof CellularSystem) {
                validator.error("APexample not applicable to cellular systems");
            }
        }
    }

    public Description description() {
        return new DescriptionImpl("APexample", "Example for Section A.19");
    }

    public interface Input {
        @Config(order = 1, name = "Beam width", unit = "degree", toolTip = "3 dB beam widht")
        double beamWidth();

        @Config(order = 2, name = "Range of gain adaption", unit = "km",
                toolTip = "up to this distance the antenna gain is modified inside the beam width")
        double adaptionDistance();

        double beamWidth = 12.;
        double adaptionDistance = 2.5;
        double peakGain = 25.;
    }
}
```

Figure 506: Antenna Plugin example source code
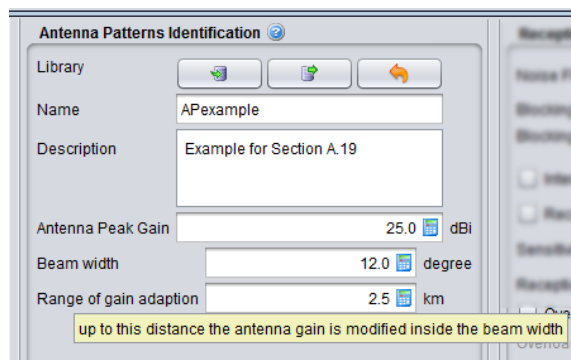
Figure 507: Antenna Plugin configuration panel
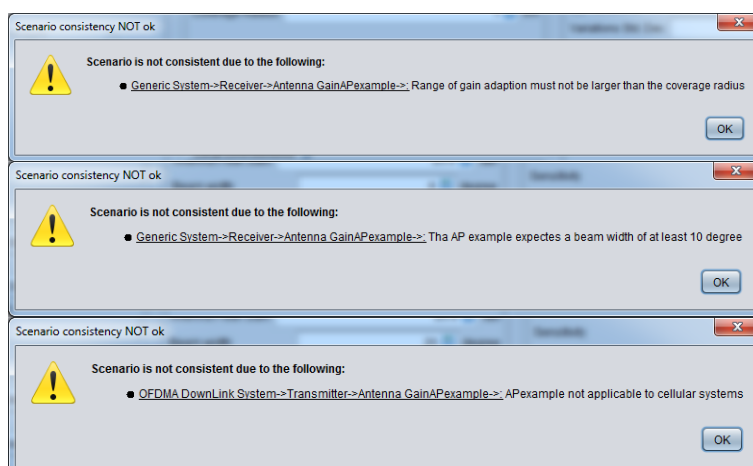
Figure 508: Consistency check warning messages

A18.7 EXAMPLE OF EPP

The basics of the structure of an EPP and its components are shown on Section 8.6, therefore these details are not repeated on this section.

The example wants to show
- how to collect simulated data
- how to generate own results based on the collected data
- how to provide additional information using a custom UI assigned to the EPP (see Section A.19.3.1)
- how to apply user defined buttons onto the custom UI which might be used also for a 'user defined consistency check' of the custom UI (see Section A.19.3.2)

The following capabilities are implemented onto the example:
- collect data required for the calculation of the distribution of C/(N+I) for each interference link separately
- generate a vector group containing the distribution vectors
- do a user defined consistency check on the custom UI
- let the custom UI calculate the probability of exceeding a given limit for the C/(N+I) criterion and let the UI show the result on its panel

On the main part of collecting data the following is done:
Note the annotation on top binding the custom UI to this EPP
1. in case the consistency warning regarding the not supported cellular systems has been ignored, the EPP stops and puts onto the result panel the appropriate message;
   this could be understood as "Runtime exception"
2. takes the required values of the victim
3. collects the interference power of each active interfering transmitter;
   it has to be pointed out that for a real plugin the bandwidth of the victim receiver alone wouldn't be sufficient to determine whether co-channel is to consider or not
4. puts the calculated distribution of C/(N+I) for each interference link as vector group onto the result panel

```
@CustomUITab(CustomUIexample.class)                I
public class EPPexample implements EventProcessingPlugin<EPPexample.Input> {
    public ResultTypes evaluate(Scenario scenario, Iterable<EventResult> iterable, Input input) {
        ResultTypes types = new ResultTypes();
        double victimBandwidth = 0;
        if (scenario.getVictimSystem() instanceof GenericSystem) {
            victimBandwidth = scenario.getVictimSystem().getReceiver().getBandwidth();
        } else {
            types.getSingleValueTypes().add(new StringResultType("No results", "due to "
                + scenario.getVictimSystem().getName() + " as victim"));
            return types; // breaks
        }
        List<String> keys = new ArrayList<String>();

        Map<String, List<Double>> cni = new LinkedHashMap<String, List<Double>>();
        for (EventResult result : iterable) {
            double dRSS = result.getValue("dRSS vector");
            double victimFrequency = result.getVictimSystemLinks().get(0).getFrequency();
            double noise = result.getVictimSystemLinks().get(0).getRxNoiseFloor();
            for (InterferenceLink link : scenario.getInterferenceLinks()) {
                String key = link.getInterferingSystem().getName();
                InterferenceLinkResults linkResult = result.getInterferenceLinkResult(link);
                List<Double> rCNI = new ArrayList<Double>();
                for (int i = 0; i < result.getInterferenceLinkResult(link).getInterferenceLinkResults().size(); i++) {
                    InterferenceLinkResult sublink = result.getInterferenceLinkResult(link).getInterferenceLinkResults().get(i);
                    double sum = 0;
                    double iRSSunw = sublink.getRiRSSUnwantedValue();
                    double iRSSblock = sublink.getRiRSSBlockingValue();
                    sum += Math.pow(10, iRSSunw / 10.) + Math.pow(10, noise / 10.);
                    if (Math.abs(victimFrequency - sublink.getFrequency()) > (2 * victimBandwidth)) {// not co-channel
                        sum += Math.pow(10, iRSSblock / 10.);
                    }
                    ensureDouble(key, cni).add(dRSS - 10 * Math.log10(sum));
                }
                if (!keys.contains(key)) keys.add(key);
            }
        }

        VectorGroupResultType gCNI = new VectorGroupResultType("C/(N+I)", "dB");
        for (String key : keys) {
            gCNI.addVector(new NamedVectorResult(key, new VectorResult(cni.get(key))));
        }
        types.getVectorGroupResultTypes().add(gCNI);
        return types;
    }
```

Figure 509: EPP example source code (without other implemented methods)

```
public void consistencyCheck(Scenario scenario, List<Object> list, Input input, Validator<Input> validator) {
    if (scenario.getVictimSystem() instanceof CellularSystem)
        validator.error("Victim: EPP example valid only for Generic Systems");
    if (scenario.numberOfEvents() < 10000) validator.error("<HtMl>" + scenario.numberOfEvents()
        + " events might be too less to generate a sufficient accurate result.<br/>" +
        "You may ignore this in particular if a cellular uplink is used as interferer.");
}
```

Figure 510: EPP example source code (consistency check)

```
private List<Double> ensureDouble(String name, Map<String, List<Double>> container) {
    if (!container.containsKey(name)) {
        container.put(name, new ArrayList<Double>());
    }
    return container.get(name);
}
```

Figure 511: EPP example source code (selecting the map entry)

A18.7.1 Example of extracting generic system intermediary results

The example shows the main core of the EPP Demo 8 which purpose is to collect intermediary distance results from a generic system.

You can see in yellow highlighted code (line 27) the mechanism to extract the distance between the VLT and the VLR.

You can see in violet highlighted code (line 32) the mechanism to extract the distance between the ILT and the VLR.

```
21        public ResultTypes evaluate(Scenario scenario, Iterable<EventResult> results, Input input) {
22            ResultTypes types = new ResultTypes();
23
24            double[] frequencyVictim = new double[scenario.numberOfEvents()];
25            Map<String,List<Double>> frequencyInterferer = new HashMap<>();
26            for (EventResult result : results) {
27                frequencyVictim[result.getEventNumber()] = result.getVictimSystemLinks().get(0).getTxRxDistance();
28                for (InterferenceLink link:scenario.getInterferenceLinks()){
29                    String key = link.getInterferingSystem().getName();
30                    for (int i=0;i<result.getInterferenceLinkResult(link).getInterferenceLinkResults().size();i++){
31                        InterferenceLinkResult subLinkResult = result.getInterferenceLinkResult(link).getInterferenceLinkResults().get(i);
32                        ensureNameDouble(key,frequencyInterferer).add(subLinkResult.getTxRxDistance());
33                    }
34                }
35            }
```

Figure 512: EPP example of extraction of distance for the victim and the interfering link

A18.7.2 Example of a EPP with custom UI

The main part of the custom UI (as a reminder: it is a result type of the EPP) is quite simple:

it gets [1] the panels which are defined in [2] and specified in [3] and puts these together to the custom UI as horizontally split pane. There is no further action on that part.

```
public class CustomUIexample implements CustomUI {
    private Panels panels;
    private ModelPanel<Left> panelLeft;
    private boolean consistencyPassed;
    public JTextField getTextField() {
        return textField;
    }
    private JTextField textField;

    public String getTitle() {
        return "CustomUIexample";
    }

    public void buildUI(JPanel canvas, Panels panels) {
        this.panels = panels;
        JSplitPane split = new JSplitPane(JSplitPane.HORIZONTAL_SPLIT);
 [1]    split.add(panels.get("Parameters").getPanel());// left
        split.add(getResultPanel());// right          (a)
        ModelPanel<Left> panelLeft = panels.get("Parameters");
        setPanelLeft(panelLeft);// make it available to other methods
        canvas.setLayout(new BorderLayout());
        canvas.add(split, BorderLayout.CENTER); // set UI
    }

    public PanelDefinition[] panelDefinitions() {
        return new PanelDefinition[]{
 [2]            new PanelDefinition("Parameters", Left.class)
        };
    }

    public interface Left {
        @Config(order = 1, name = "Criterion to be checked", values = "C/(N+I)")
        String criterion();

        @Config(order = 2, name = "Limit of protection criterion", unit = "dB")
        double limit();

        @Config(order = 3, name = "Check the sum of the interference links")
 [3]    boolean checkSum();

        @Config(order = 4, name = "Link number to be checcked", toolTip = "number on the list of interference links on the scenario")
        int number();

        boolean checkSum = false;
        int number = 1;
        double limit = 19.;
    }
```

Figure 513: custom UI source code (without other implemented methods)

The right panel [a] is unlike the left panel not an annotation interface, its construction is described on Section A18.7.4

A18.7.3 Post Processing buttons on the Custom UI

User defined post processing buttons are generated through the annotation @PostProcessing as shown on Section 14.7.3.3. How to apply a 'consistency check' feature to the post processing is basically shown on Section 14.7.3.4.

This example uses one post processing as (stand alone) consistency check which is inherently used by the other one which performs the calculation of the probability of exceeding the criterion limit.

```
@PostProcessing(order = 1, name = "check consistency")
public void checkConsistency(Scenario scenario, ResultTypes allResults) {
    //TODO consistency
    consistencyPassed = true;
    String msg = "";
    if (!getPanelLeft().getModel().criterion().contains("I/N")) {
        if (getPanelLeft().getModel().limit() <= 0) {
            msg = "<HtMl>The criterion limit must not be less than or equal to zero.<br/>";
        }
    } else if (panelLeft.getModel().limit() > 70) {
        msg = "<HtMl>The criterion limit should not be greater than 70 dB.<br/>";
    }
    if (!getPanelLeft().getModel().checkSum()) {
        if (getPanelLeft().getModel().number() > scenario.getInterferenceLinks().size()) {
            if (msg.isEmpty())
                msg = "<HtMl>Only " + scenario.getInterferenceLinks().size() + " links can be chosen.<br/>";
            else msg += "Only " + scenario.getInterferenceLinks().size() + " links can be chosen.<br/>";
        }
    }
    if (!msg.isEmpty()) {
        consistencyPassed = false;
        msg += "You have to correct the input in order to proceed.";
        getTextField().setBackground(Color.white);
        getTextField().setText("");
        showWarning(msg);
    }
}
```

Figure 514: custom UI source code (consistency check)

The post processing "calculate probability"
1. takes the distribution vectors generated by the EPP and
2. derives the probability of exceeding the given limit and
3. puts the result onto a text field of the right panel.

For simplicity the functionality 'summation vector' has not been implemented.

```
@PostProcessing(order = 2, name = "calculate probability")
public void calculate(Scenario scenario, ResultTypes allResults, SimulationResult simulationResult) {
    //TODO calculate
    checkConsistency(scenario, allResults);
    if (consistencyPassed) {
        double exceeds = 0;
        List<Double> tCNI = new ArrayList<Double>();
        List<VectorGroupResultType> vectorGroups = allResults.getVectorGroupResultTypes();
        if (!getPanelLeft().getModel().checkSum()) {
            for (VectorGroupResultType vectorGroupResultType : vectorGroups) {
                if (vectorGroupResultType.getName().contains("C/(N+I)")) {
        1           VectorResult vCNI = vectorGroupResultType.getVectorGroup().get(getPanelLeft().getModel().number() - 1).getVector();
                    double[] val = vCNI.asArray();
                    Arrays.sort(val);
                    int pos = Arrays.binarySearch(val, getPanelLeft().getModel().limit());
                    if (pos < 0)
        2               pos = Math.max(0, Math.abs(pos + 1));// gets the last position before the limit fits
                    exceeds = (double) pos / val.length * 100.;
                    exceeds = (int) (exceeds * 10 + 0.5) / 10.;
                }
            }
        } else {
            String msg = "<HtMl>The capability of checking the sum is not implemented yet.<br/>";
            consistencyPassed = false;
            getTextField().setBackground(Color.white);
            getTextField().setText("");
            showWarning(msg);
            exceeds = Double.NaN;
        }
        if (exceeds < getPanelLeft().getModel().limit()) getTextField().setBackground(Color.green);
        3  else getTextField().setBackground(Color.red);
        getTextField().setText(String.valueOf(exceeds + " %"));
    }
}
```

Figure 515: custom UI source code (calculation)

A18.7.4 User defined panel (right panel)

```java
private JPanel getResultPanel() {
    JPanel resultPanel = new JPanel();
    GridBagLayout gridBagLayout = new GridBagLayout();
    gridBagLayout.columnWidths = new int[]{0, 0, 0, 0, 0, 0};
    gridBagLayout.rowHeights = new int[]{0, 0, 0};
    gridBagLayout.columnWeights = new double[]{0.0, 0.0, 0.0, 0.0, 1.0, Double.MIN_VALUE};
    gridBagLayout.rowWeights = new double[]{0.0, 0.0, Double.MIN_VALUE};
    resultPanel.setLayout(gridBagLayout);

    JSeparator separator = new JSeparator();
    GridBagConstraints gbc_separator = new GridBagConstraints();
    gbc_separator.insets = new Insets(0, 0, 5, 5);
    gbc_separator.gridx = 0;
    gbc_separator.gridy = 0;
    resultPanel.add(separator, gbc_separator);

    JLabel lblProbabilityOfExceeding = new JLabel("Probability of exceeding the limit");
    GridBagConstraints gbc_lblProbabilityOfExceeding = new GridBagConstraints();
    gbc_lblProbabilityOfExceeding.insets = new Insets(0, 0, 5, 5);
    gbc_lblProbabilityOfExceeding.gridx = 1;
    gbc_lblProbabilityOfExceeding.gridy = 1;
    resultPanel.add(lblProbabilityOfExceeding, gbc_lblProbabilityOfExceeding);

    textField = new JTextField();
    GridBagConstraints gbc_textField = new GridBagConstraints();
    gbc_textField.insets = new Insets(0, 0, 0, 5);
    gbc_textField.gridx = 3;
    gbc_textField.gridy = 1;
    resultPanel.add(textField, gbc_textField);
    textField.setColumns(10);

    return resultPanel;
}
```

Figure 516: custom UI source code (user defined panel construction)
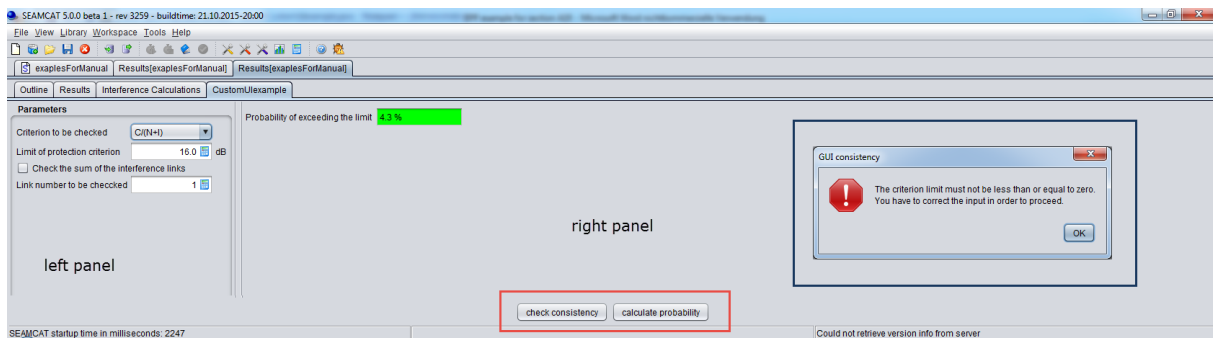
Figure 517: custom UI (with an example of a constancy warning)

A18.7.5 Example of intermediary results

When you develop your own plugin, you are able to auto-complete the list of available temporary parameters. For instance in an IntelJIdea development editor, if you press **CTRL+**SPACE an auto complete of the victimResult is availbale.

First, of course, you will need to assign what victimResult is in such a manner:

LinkResult victimResult = linkResult.getVictimSystemLinks().get(0);

Figure 518 presents an example of the content of an auto-complete of a variable of the type LinkResult
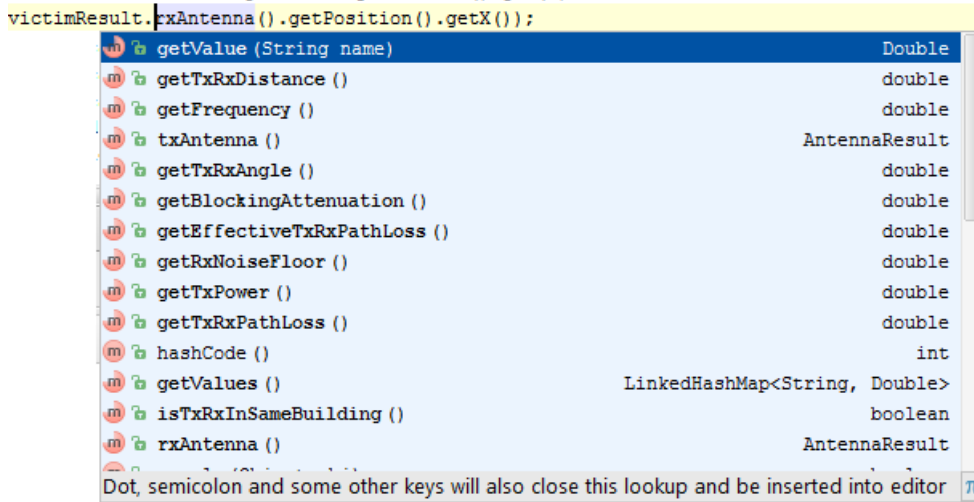
**Figure 518: Example of content of the LinkResult interface
(auto-complete "CTRL+SPACE" in IntelJidea)**

The EPP allows you to access interemediary results. The following is a non-exhaustive list of the LinkResult interface:

AntennaResult rxAntenna():   Receiver antenna results in the direction of the transmitter
AntennaResult txAntenna():   Transmitter antenna results in the direction of the receiver
double getTxRxAngle():   Angle between transmitter and receiver
double getTxRxDistance():   Distance between transmitter and receiver.
double getTxRxPathLoss():   Path loss between transmitter-receiver path.
double getEffectiveTxRxPathLoss():   Effective Path loss between transmitter-receiver path.
double getBlockingAttenuation():   get the blocking attenuation;
double getTxPower():   get the transmitter power
double getFrequency():   get the frequency of the system
boolean isTxRxInSameBuilding():   indicates if the Tx or Rx is in the same building (from propagation model)
double getRxNoiseFloor()   get the receiver noise floor

Similarly, if you look one level down in the RxAntenna() that is follows an AntennaResult interface, you will see further parameters listed:
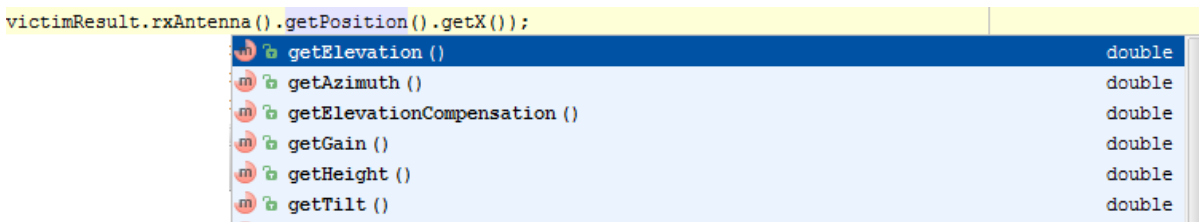
**Figure 519: Example of content of the AntennaResult interface
(auto-complete "CTRL+SPACE" in IntelJidea)**

And likewise, if you look into the getposition() that is follows a Point2D interface, you will have the choice to select either getX() or get(Y) for the X and Y position of the received antenna of the victim.
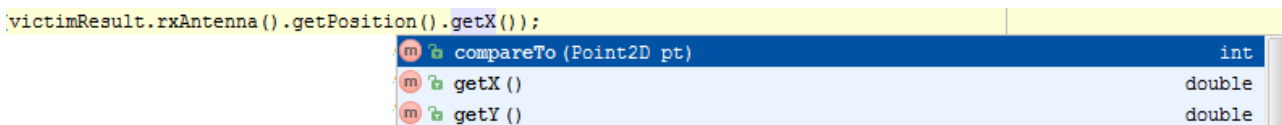
**Figure 520: Example of content of the Point2D interface
(auto-complete "CTRL+SPACE" in IntelJidea)**

ANNEX 19: : CONSISTENCY CHECK (EXAMPLES)

A19.1 FREQUENCY OUT OF RANGE CONSISTENCY CHECK

When you set-up the operating frequency of the ILT and the VLR so far apart that the ILT emission mask and the VLR mask do not overlap as illustrated in Figure 521, the consistency warning message of Figure 522 is prompted by SEAMCAT for you to correct it.
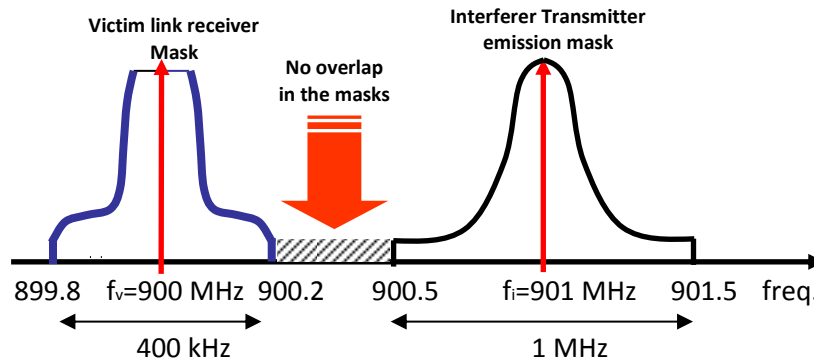
Figure 521: Illustration of the warning displayed in Figure 522
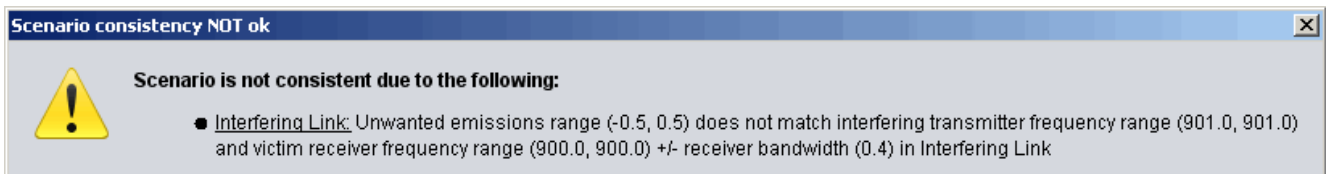
Figure 522: Frequency out of range consistency check warning

Solution: modify the operating frequencies or the size of the spectrum masks so that an overlap is occurring.

A19.2 HORIZONTAL PATTERN OUT OF RANGE CONSISTENCY CHECK

You erroneously specified the horizontal pattern for instance in the range of 0 ... 270 degrees:
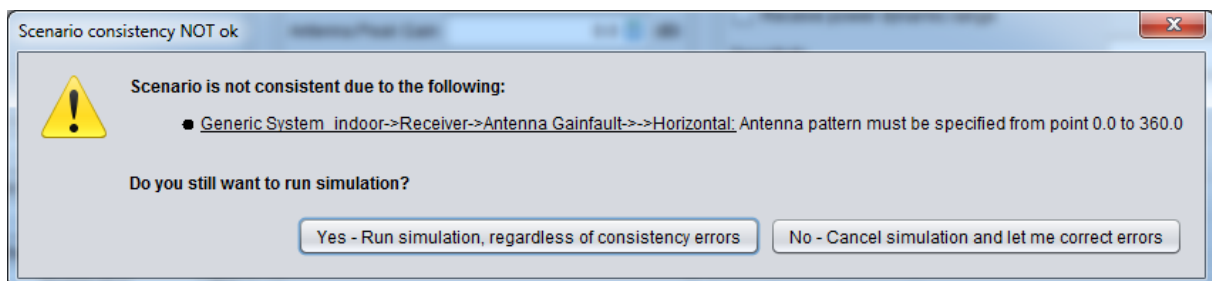
Figure 523: Antenna pattern range consistency check warning

Solution: set the antenna pattern correctly or choose a valid antenna.

A19.3 EXTENDED HATA PROPAGATION MODEL OUT OF RANGE CONSISTENCY CHECK:

You tried to apply the Extended Hata model to the interference link of a scenario which uses frequencies below 30 MHz:
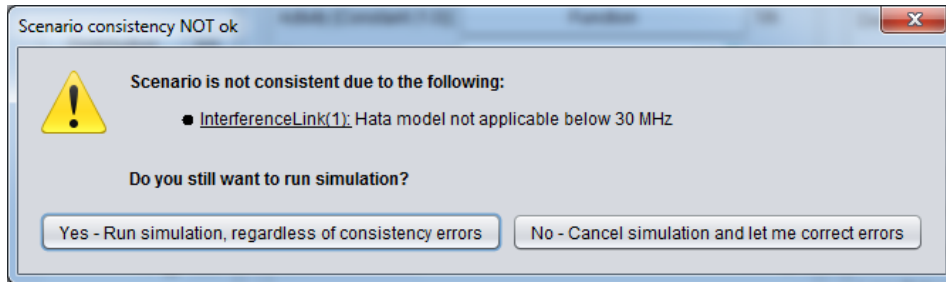
Figure 524: Propagation model range consistency check warning

Solution: apply for instance the Free Space propagation model to the interference link.

ANNEX 20: : DEBUG INFORMATION

A20.1 SEAMCAT CONFIGURATION

The SEAMCAT configuration panel is accessible via general menu option <File/Configuration> (⚙) also using <CTRL+G>, which opens the following dialog box:
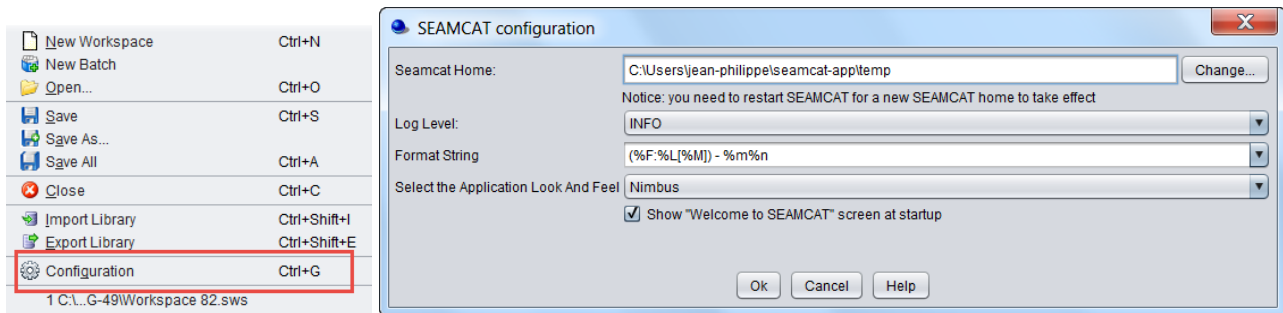
Figure 525: Access to the SEAMCAT configuration window

On the General tab the following options are available for controlling the logging function:
- SEAMCAT home: This option allows you to define the SEAMCAT home directory where log file, report folder etc.. are placed (see Section 1.7.2);
- Log level: You may chose from among the log level options DEBUG, INFO, WARN, ERROR, FATAL or OFF;
- Format string: Format pattern of the log statements. You may select a pattern and you may also edit a pattern from the list. Newly edited patterns are added to the list;
- Select the application look and feel: Here you select from various display themes of SEAMCAT (Nimbus theme is recommended);
- The checkbox option < Show the "welcome to SEAMCAT" screen at startup > activates a dialog box which opens each time SEAMCAT is started (see Section 2.2).

A20.2 DEBUG INFORMATION FORMAT

In debug mode only, we recommend selecting the Log Level: DEBUG and Format String: {(%F:%L[%M]) - %m%n} which would result in the most deep level of reporting where
- %F represents the name of the Java class;
- %L the location inside this class (line number);
- %M the name of the method;
- %m the explaining message;
- %n the evaluated number(s) – if any.

On the SEAMCAT configuration panel you have the option of choosing one of the below format settings:
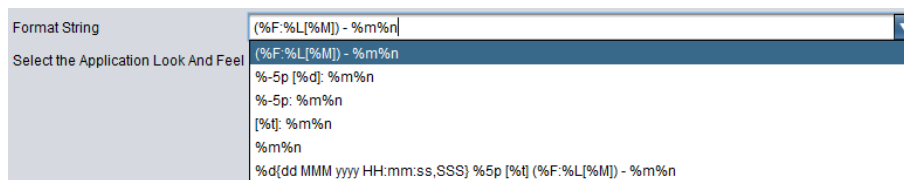
Figure 526: Options of format strings for the debug information

where (additionally)
- %-5p   represents the first 5 digits of the information type (here DEBUG) at the leading left
- %5p   the first 5 digits of the information type (here DEBUG) at the actual position

- %d the default time format (yyyy-mm-dd HH:mm:SS,sss)
- %d (..)   a specified time format
- %t the running thread

Notes:
1. This format is also applied to the header of the information recorded by the seamact.log file (see Annex 19).
2. In addition to the predefined selection, the format string field is also editable and you may modify the Format String according to your demands.

A20.3 DEBUG INFORMATION FORMAT SETTINGS:

Figure 527: Examples of format strings for the debug information

ANNEX 21: : REFERENCE MATERIAL AND WORKSPACES ECC/CEPT REPORTS

The following table summarises studies where SEAMCAT has been used and to give examples on how different technologies have been implemented.

The scenarios and parameters contained in these reports should only be used as an initial guide when you are starting to develop your simulation.

The following reports can be found at the ECO web site www.erodocdb.dk

	Technology													Power flux density	Interference criteria				
	UMTS	UWB	DVB-T	FS	GSM	GSM-R	PL	PMR	PWMS	RAS	RNS	Satellite	TETRA		C/I	C/(I+N)	(N+I)/N	I/N	Capacity loss
ECC Report 076				X										X					
ECC Report 093 CEPT Report 16	X				X											X		X	
ECC Report 096	X					X									X				
ECC Report 099								X				X			X				
ECC Report 104			X					X							X				
ECC Report 121				X					X									X	
ECC Report 122 CEPT Report 28	X				X											X		X	X
ECC Report 123		X								X								X	
ECC Report 128							X				X	X						X	

Table 96: List of ECC Report/CEPT Report containing SEAMCAT workspaces

ANNEX 22: : DB CONVERSION TABLE

Table 97: Conversion table

Linear	dB
2	3 dB
4	6 dB
8	9 dB
16	12 dB
10	10 dB
20	13 dB
100	20 dB
1000	30 dB
25	100/4= 20 dB - 6 dB= 14 dB
2000	1000*2 = 30 dB + 3 dB = 33 dB
50	100/2=20 dB – 3 dB = 17 dB

ANNEX 23: HOW TO MAKE THE MOST OF THE SEAMCAT FIGURES

Tip 1: If you want to know the properties, to change the titles name or to resize the axis of the graphic **right click** on the graph and you will get:
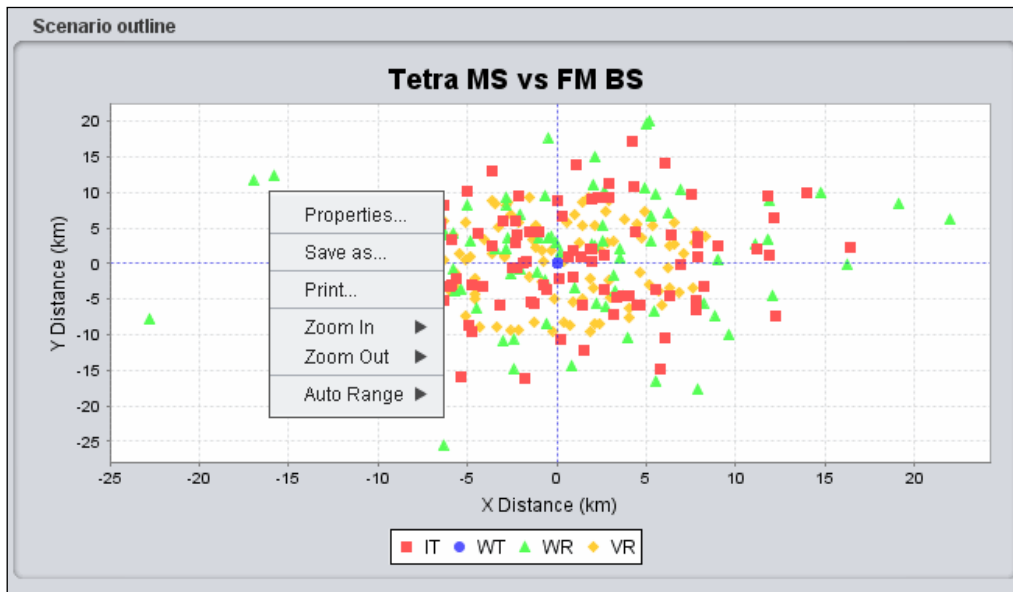
Figure 528: Illustration on how to get the properties dialog box of a graph
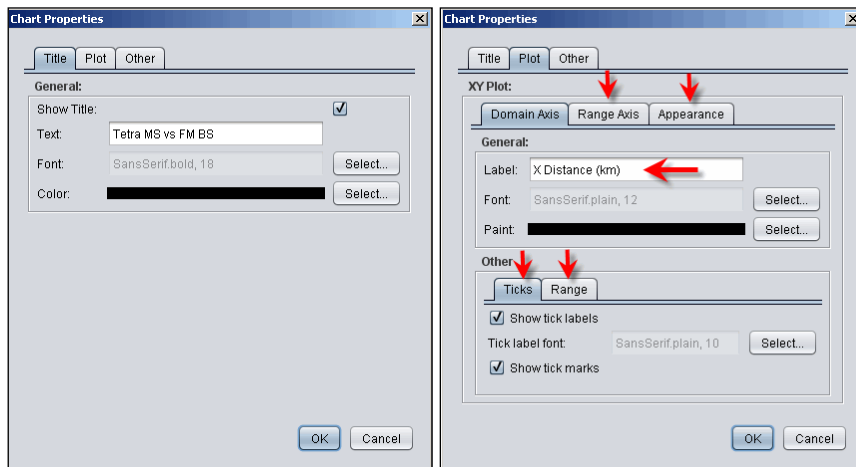
Figure 529: Illustration on changing the chart properties

Tip 2: To **Zoom in**: right (or left) click on the mouse and select the area that you want to zoom on.

Tip 3: To **Zoom out**: right (or left) click on the mouse move toward the upper left corner.

Tip 4: In case, it is difficult to see some colors like yellow in the figure below it is possible to change the background color. You need to right click, select properties, plot, appearance and then background paint.
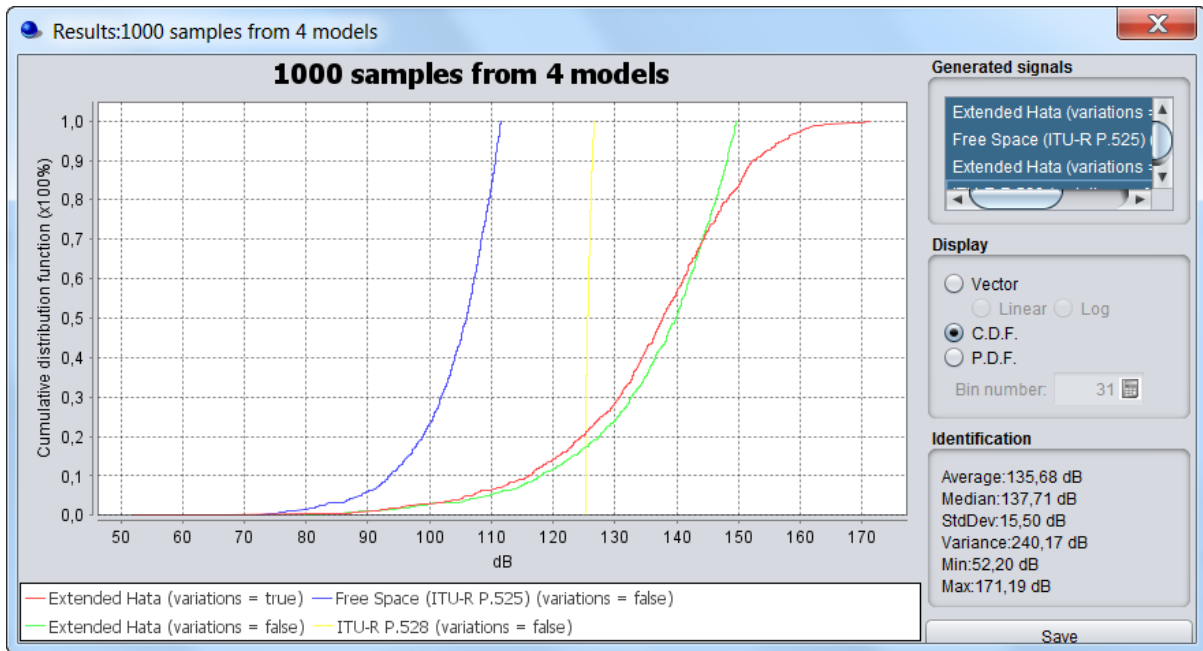
Figure 530: Illustration of default white background color
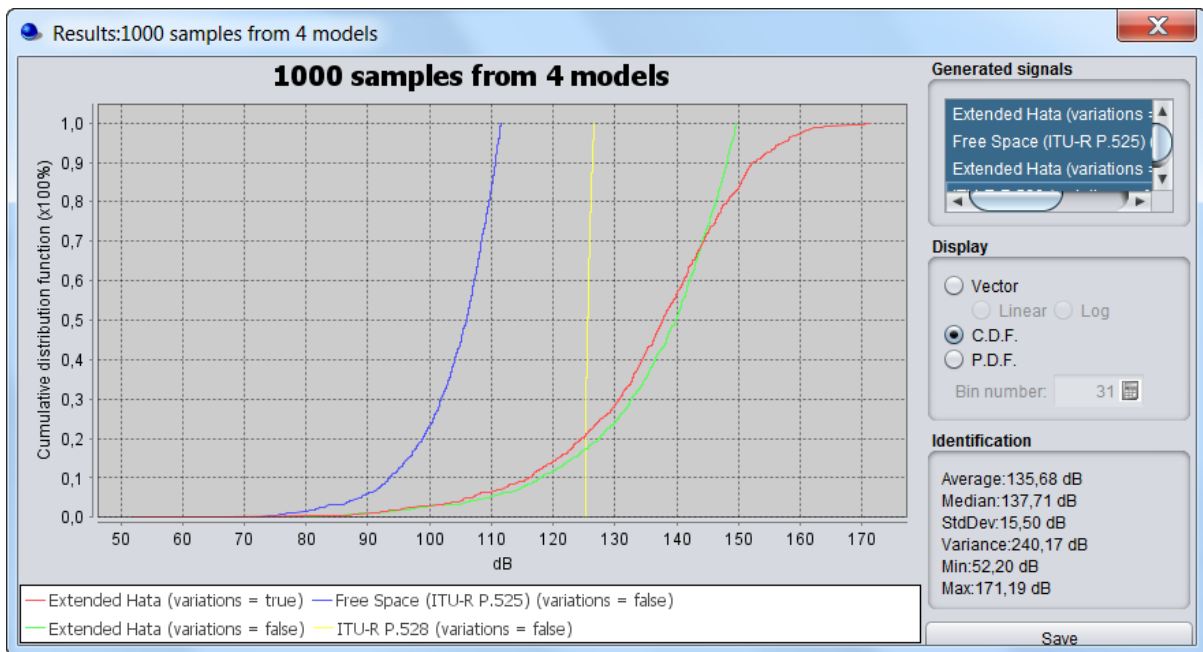
Figure 531: Illustration of light grey background color

ANNEX 24: : EXAMPLE - TETRA MS INTERFERERS THE BS OF THE ANALOGUE FM PMR

A24.1 SCENARIO OVERVIEW

This section provides an example of sharing studies including an analysis of a TETRA MS interfering with an FM BS, based on the information provided in the ERC Report 104 on "Adjacent Band Compatibility Of 400 MHz TETRA And Analogue FM PMR – An Analysis Completed Using MONTE CARLO Based Simulation Tool". This scenario involves a population of TETRA mobile stations interfering with a victim FM base station as shown in Figure 532. In all of the simulations the victim FM system is assumed to have a **7.8 km** cell radius which provides a 90 % area availability.
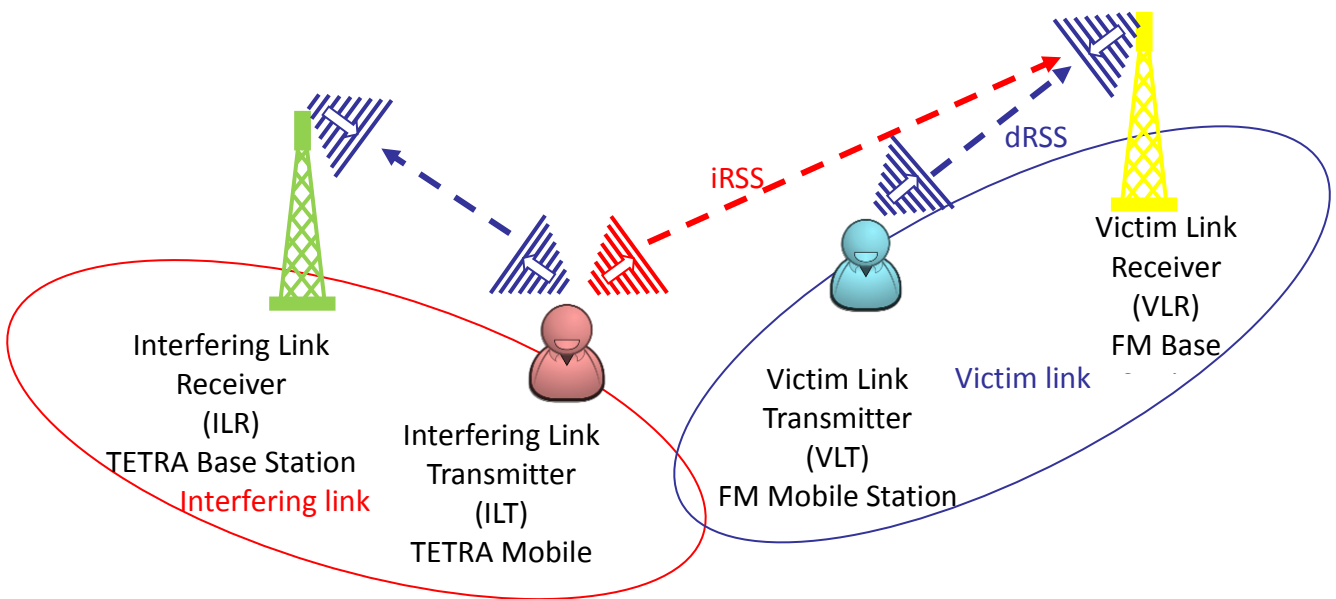
Figure 532: Scenario of the simulation

Figure 533 illustrates the band plan assumed for this investigation. 2 MHz of spectrum has been allocated to the up-link of TETRA and directly adjacent to this, 2 MHz has been allocated to FM.
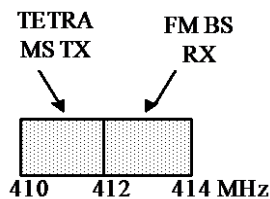
Figure 533: Band allocations of TETRA MS and FM BS systems

The purpose of this example of simulation is to use SEAMCAT to obtain the probability of interference resulting from unwanted emissions of the TETRA Mobile Stations falling at the frequency where the FM Base Station is operating.

A24.2 CHARACTERISTICS OF THE SYSTEMS

A24.2.1 Victim link characteristics – FM

The victim FM system is assumed to have a 7.8 km cell radius which provides a 90% area availability. The reception bandwidth of the FM BS victim link receiver is equal to 8 kHz. Based on information provided in ERC Report 104 for FM system based on 12.5 kHz channel spacing, the following characteristics are used to describe the FM equipment:

Table 98: Parameters assumed for 12.5 kHz FM systems

Parameter	Mobile Station	Base Station
Channel Spacing	**12.5 kHz**	12.5 kHz
Transmit Power	37 dBm	**44 dBm**
Receiver Bandwidth	**8 kHz**	**8 kHz**
Antenna Height	**1.5 m**	**30 m**
Antenna Gain	**0 dBi**	**9 dBi**
Active Interferer Density Range	**Variable**	**Variable**
Receiver Sensitivity	**- 107 dBm**	- 110 dBm
Receiver Protection Criterion (C/I)	**21 dB**	21 dB
Power Control Characteristic	Not used	Not used

Note 1: This exercise assumes that the noise floor is small compared to the interfering signal (I).
Note 2: The Noise Floor can be obtained using the following equation (see ERC Report 68 [7]):

Noise Floor = Sensitivity – Receiver Protection Ratio

Table 99: Receiver blocking for 12.5 kHz FM systems

Frequency Offset	Base Station
Any frequency	- 23 dBm

A24.2.2 Interfering link characteristics – TETRA

The interfering TETRA system is assumed to have a 18 kHz emission bandwidth and a channel spacing which is equal to 25 kHz. The distribution in terms of frequency use over the 2 MHz band is taken as a uniform distribution, where each channel is being assigned the same probability. Based on information provided in ERC Report 104 for TETRA system based on 25 kHz channel spacing, the following characteristics are used to describe the TETRA equipments:

Table 100: Parameters used to model the TETRA systems

Parameter	Mobile Station	Base Station
Channel Spacing	25 kHz	**25 kHz**
Transmit Power	**30 dBm**	**40 dBm**
Receiver Bandwidth	**18 kHz**	**18 kHz**
Antenna Height	**1.5 m**	30 m
Antenna Gain	**0 dBi**	**11 dBi**
Active Interferer Density Range	**Variable**	**Variable**
Receiver Sensitivity	**- 103 dBm**	**- 106 dBm**
Receiver Protection Criterion (C/I)	**19 dB**	**19 dB**
Power Control Characteristic	**5 dB steps to a maximum of 15 dB. Threshold = - 86 dBm**	**Not used**

Table 101: Unwanted emissions for TETRA systems (measurement bandwidth of 18 kHz) (intererfing link transmitter)

Frequency Offset	30 dBm Mobile Station	Attenuation in dBc
25 kHz	- 30 dBm	**60**
50 kHz	- 36 dBm	**66**
75 kHz	- 36 dBm	**66**
100 - 250 kHz	- 45 dBm	**75**
250 - 500 kHz	- 50 dBm	**80**
> 500 kHz[12]	- 70 dBm	**100**

A24.3 ASSUMPTIONS

Starting from the characteristics provided above, some "reference" hypothesis might be used to obtain a first set of results.

A24.3.1 Distribution of the Mobile Stations (MS) and propagation model

It is assumed that all mobile stations are located **uniformly distributed in the areas** around their base stations. For worst case consideration a rural area may be assumed.

A24.3.2 TETRA network

A 2 MHz band is available for TETRA systems of 25 kHz channel spacing, therefore a total of 80 channels are available. It is supposed that only one TETRA MS terminal may use the same frequency at a given time.

---

[12] The level of unwanted emissions is supposed to be constant for frequency offset higher than 500kHz

The frequency cluster is taken equal to 9, this leads to have 80/9 = 8.88 frequency per cell available. Then up to 9 terminals may be deployed in a TETRA cell.

If the TETRA cell is a traffic limited network and the density of terminals is equal to 5 terminals per km², then the coverage radius is given by the following formula (see ERC Report 68 or User Documentation):

$$R_{max}^{wt} = \sqrt{\frac{n_{channels} \, n_{userperchannel}}{\pi \, dens_{max} cluster_{frequency}}}$$ (Eq. 252)

The radius of the cell of the interfering system is given by

R = sqrt((80*1) / (3.14*5*9)) = 0.7523 km.

Figure 534 describes a TETRA network based on the above assumptions.
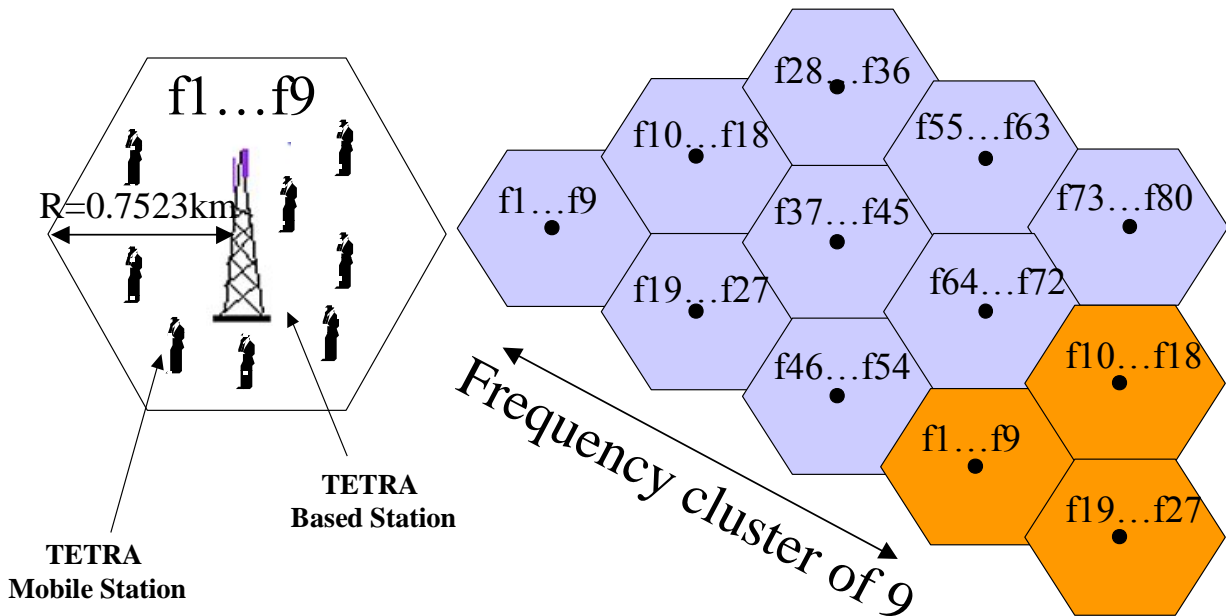
Figure 534: TETRA network based on these assumptions

A24.3.3 Interference situation

As a worst case assumption, we may suppose that, the FM BS station will be based in the TETRA cell where the channel (411.9875 MHz) operating close to the edge of the TETRA band is used. The same probability is assigned to each channel available in the TETRA cell. Then the frequency plan in this cell starts from 410.0125 MHz up to 411.9875 MHz with a step of 25 kHz x 9. A discrete uniform distribution for frequency can be selected, e.g., between 410.0125 MHz and 411.9875 MHz having a step of 25 kHz (see ANNEX 10: for a description of the discrete uniform distribution).

If there is no spatial correlation between the elements of the victim system and the elements of the interfering system then the simulation radius of the simulation is given by the formula:

$$R_{simu} = \text{radius of the area where interferers are uniformly spread}$$

$$R_{simu} = \sqrt{\frac{n^{active}}{\pi \, dens_{it}^{active}}}$$ (Eq. 253)

We have to consider 9 active interferers with a density of 5 terminals/km². Then the radius of simulation area results in:

$$R = sqrt(9 / (3.14 \times 5)) = 0.7569 \text{ km.}$$

The FM Base Station, which is the victim link receiver, is supposed to be operating at 412.00625 MHz, that is the centre of the first channel, i.e. no guard interval is assumed.

A24.3.4 Emission mask

The total emission of the interefering link transmitter consists of

- The wanted signal within the defined bandwidth corresponding to a frequency offset of ± 50 % of the emission bandwidth $It_{BW;}$
- The out-of-band emission caused by the modulation within, e.g. ± 50...250 % of $It_{BW;}$
- The spurious emission outside these ranges.

This means the mask to be defined has to cover this whole range. This allows co-channel consideration as well.

It should be noted that the TETRA MS unwanted emissions mask is not defined for frequency offsets below 12.5 kHz. Considering the channel spacing of 25 kHz and assuming 0 dBc/18 kHz in that range, then in the undefined range between 12.5 and 25 kHz, a linear interpolation between 0 and 60 dBc attenuation will be performed. It should also be taken into account that the reference bandwidth (18 kHz) used for the mask is identical to the bandwidth of the interfering system (see ANNEX 6:).

A24.4 PROBABILITY OF INTERFERENCE

Based on the above assumptions the probability of interference (C/I criteria and unwanted emissions + blocking are taken into account) is about 1.1 % when the PC is "on" and about 8.1 % when the PC is "off".

A24.5 WORKSPACE SETTING

In this chapter, only the necessary inputs are mentioned. All other parameters are not required.

1. SYSTEMS:

1.1 FM as Victim Link

- Name: FM
- Frequency: Constant 412.00625 MHz (channel spacing)

1.1.1   Transmitter: FM MS (VLT)

Transmitter Identification

- Name: FM-MS

Antenna pointing

- Antenna height: _____
- Antenna azimuth: 0...360 degrees, uniform
- Antenna elevation: 0 degrees, constant   (horizontal direction)

Antenna Pattern Identification

- Description: Omni-directional
- Antenna peak gain: _____

Emission Characteristics

- Power: _____

1.1.2 Receiver: FM BS (VLR)

Receiver Identification
- Name: FM-BS

Antenna pointing
- Antenna height: _____
- Antenna azimuth: 0...360 degrees, uniform
- Antenna elevation: 0 degrees, constant   (horizontal direction)

Antenna Pattern Identification
- Description: Omni-directional
- Antenna peak gain: _____

Reception Characteristics

- Noise floor: _____ (Noise Floor =Sensitivity – C/I)
- Blocking mode: Sensitivity
- Blocking mask: -23 dB, constant
- Intermodulation rejection: 0 dB, constant
- Sensitivity: _____
- Reception bandwidth: 8 kHz
- Overloading: NO

Interfering Criteria
- C/I: 21 dB (if only C/I, then C/(N+I) and (I+N)/N are not required)
- C/(I+N):   21dB (C/(N+I) required only for selected Blocking-Mode)

1.1.3   Transmitter to Receiver path (VLT - > VLR)

Relative location
- Correlation: None
- Path azimuth VLR: Uniform distribution 0 to 360 degrees
- Path distance factor: Uniform polar, 1*cell radius

Coverage radius
- Cell radius mode: User-defined radius
- Fixed radius: _____

Local environment:

- Receiver: 100% outdoor
- Transmitter: 100% outdoor

Propagation model
- Model: Extended Hata
- Variation: Yes
- General environment: _____
- Propagation environment: ABOVE ROOF (with a 30 m FM BS-Antenna height)

1.2   TETRA as Interfering Link

- Name: TETRA
- Frequency: 410.1875…411.9875 MHz, uniform

1.2.1. Transmitter: TETRA MS (ÍLT)

Transmitter Identification

- Name: TETRA-MS

Antenna pointing

- Antenna height: _____
- Antenna azimuth: 0...360 degrees, uniform
- Antenna elevation: 0 degrees, constant (horizontal direction)

Antenna Pattern Identification

- Description: Omni-directional
- Antenna peak gain: _____

Emission Characteristics

- Power: _____
- Emission Mask:
  Unwanted mask: Offset in MHz, power in dBc referred to Reference bandwidth

-10.0000	-100.0000	18.0000
-0.5010	-100.0000	18.0000
-0.5000	-80.0000	18.0000
-0.2510	-80.0000	18.0000
-0.2500	-75.0000	18.0000
-0.1000	-75.0000	18.0000
-0.0750	-66.0000	18.0000
-0.0500	-66.0000	18.0000
-0.0250	-60.0000	18.0000
-0.0125	0.0000	18.0000
0.0125	0.0000	18.0000
0.0250	-60.0000	18.0000
0.0500	-66.0000	18.0000
0.0750	-66.0000	18.0000
0.1000	-75.0000	18.0000
0.2500	-75.0000	18.0000
0.2510	-80.0000	18.0000
0.5000	-80.0000	18.0000
0.5010	-100.0000	18.0000
10.0000	-100.0000	18.0000

- Transmitting bandwidth: 18 kHz (Bandwidth < channel)
- Reference bandwidth: 18 kHz
- Unwanted emission floor: NO
- Power control:
  - Power Control step size: 5 dB
  - Min Threshold: -86 dBm
  - Dynamic Range: 15 dB

1.2.2 Receiver: TETRA BS (ILR)

Receiver Identification

- Name: TETRA-BS

Antenna pointing

- Antenna height: _____
- Antenna azimuth: 0...360 degrees, uniform
- Antenna elevation: 0 degrees, constant (horizontal direction)

Antenna Pattern Identification

- Description: Omni-directional
- Antenna peak gain: _____

Reception Characteristics

- Noise floor: _____ (Noise Floor = Sensitivity – C/I)
- Blocking mode: User defined
- Blocking mask: 0 dB, constant
- Intermodulation rejection: 0 dB, constant
- Sensitivity: _____
- Reception bandwidth: _____
- Overloading: NO

Interfering Criteria

- C/I: 19 dB (if only C/I, then C/(N+I) and (I+N)/N are not required)
- C/(I+N):   16 dB (C/(N+I) required only for selected Blocking-Mode)
- (N+I)/N: 3 dB
- I/N: 0 dB

1.2.3   Transmitter to Receiver path (ILT - > ILR)

Relative location
- Correlation: None
- Path azimuth VLR: Uniform distribution 0 to 360 degrees
- Path distance factor: Uniform polar 1*cell radius

Coverage radius

- Cell radius mode: Traffic limited network
- Density (terminals per Km2): _____
- Nr. of channels: _____
- Nr. of users per channel: 1
- Frequency cluster: _____

Local environment:

- Receiver: 100% outdoor
- Transmitter: 100% outdoor

Propagation model
- Model: Extended Hata
- Variation: Yes

- General environment: _____
- Propagation environment: ABOVE ROOF (with a 30 m TETRA BS-Antenna height)

2. SCENARIO

2.1. VICTIM SYTEM

- Victim System: FM
- Frequency: Constant, 412.00625

2.2. SIMULATION CONTROL

- Number of events: 20 000

2.3. INTERFERING SYSTEM LINKS

- Link1: TETRA
- Frequency: 410.1875…411.9875 MHz, uniform

2.4 ILT -> VLR path

Relative positioning of the interfering link

- Mode: Uniform density
- Position relative to: Victim Link Receiver
- Delta X: Constant, 0
- Delta Y: Constant, 0
- Set ILR at the centre of the distribution: NO
- Path azimuth: Uniform distribution, 0 to 360 degrees
- Number of active transmitters: 9
- Minimum coupling loss: Constant, 0
- Protection distance: Constant, 0

Interferers density

- Density of Tx: _____ (*1/Km^2)
- Probability of transmission: 1
- Activity: Constant, 1
- Time: 1 hour

Propagation Model

- Model: Extended Hata
- Variation: Yes
- General environment: _____
- Propagation environment: ABOVE ROOF (with a 30 m FM BS-Antenna height)

3. RESULTS

Test of the simulation
Calculated radius

- Coverage radius (wanted system):   7.8 km
- Coverage radius (interfering system 1):   0.7522 km
- Simulation radius 1:   0.7569 km

Generated Signals
PC "on"

- dRSS: mean: _____(-69.9 dBm),   std: _____(11.68 dB)
- $iRSS_{unwanted}$:   mean: _____(-127.5 dBm), std: _____(10.86 dB)

- $iRSS_{blocking}$:   mean: _____(-144.6 dBm), std: _____(7.13 dB)

PC "off"

- dRSS: mean: _____(-69.8 dBm),   std: _____(11.78 dB)
- $iRSS_{unwanted}$:   mean: _____(-112.6 dBm), std: _____(10.84 dB)

- $iRSS_{blocking}$:   mean: _____(-129.6 dBm), std: _____(7.19 dB)

Interference calculation/ICE calculation

- Interference Criteria: C/I
- Compatibility mode: Yes (Probability of interference)
- Unwanted emissions: Yes
- Blocking: Yes

Result

PC "on"
- Probability of interference: _____ (~1 %)

PC "off"
- Probability of interference: _____ (~8.4 %)

ANNEX 25: : ANSWERS TO THE TETRA VS FM PMR EXAMPLE

Note: See the questions of this exercise in section ANNEX 24:.

SEAMCAT parametrisation of simulation scenario TETRA versus FM.

1. SYSTEMS:

1.1 FM as Victim Link

- Name: FM
- Frequency: Constant 412.00625 MHz (channel spacing)

1.1.2   Transmitter: FM MS (VLT)

Transmitter Identification

- Name: FM-MS

Antenna pointing

- Antenna height: 1.5 m, constant
- Antenna azimuth: 0...360 degrees, uniform
- Antenna elevation: 0 degrees, constant   (horizontal direction)

Antenna Pattern Identification

- Description: Omni-directional
- Maximum gain: 0 dBi

Emission Characteristics

- Power: 37 dBm, constant

1.1.2 Receiver: FM BS (VLR)

Receiver Identification

- Name: FM-BS

Antenna pointing

- Antenna height: 30 m, constant
- Antenna azimuth: 0...360 degrees, uniform
- Antenna elevation: 0 degrees, constant   (horizontal direction)

Antenna Pattern Identification

- Description: Omni-directional
- Maximum gain: 9 dBi

Reception Characteristics

- Noise floor: -131 dBm, constant(=Sensitivity – C/I)
- Blocking mode: Sensitivity
- Blocking mask: -23 dB, constant
- Intermodulation rejection: 0 dB, constant
- Sensitivity: -110 dBm

- Reception bandwidth: 8 kHz
- Overloading: NO

Interfering Criteria

- C/I: 21 dB (if only C/I, then C/(N+I) and (I+N)/N are not required)
- C/(I+N):   21dB (C/(N+I) required only for selected Blocking-Mode)

1.2.4 Transmitter to Receiver path (VLT - > VLR)

Relative location
- Correlation: None
- Path azimuth VLR: Uniform distribution 0 to 360 degrees
- Path distance factor: Uniform polar, 1*cell radius

Coverage radius

- Cell radius mode: User-defined radius
- Fixed radius: 7.8 km

Local environment:

- Receiver: 100% outdoor
- Transmitter: 100% outdoor

Propagation model

- Model: Extended Hata
- Variation: Yes
- General environment: RURAL (results in lowest path attenuation)
- Propagation environment: ABOVE ROOF (with a 30 m FM BS-Antenna height)

1.3 TETRA as Interfering Link

- Name: TETRA
- Frequency: 410.1875…411.9875 MHz, uniform

1.2.2. Transmitter: TETRA MS (ÍLT)

Transmitter Identification

- Name: TETRA-MS

Antenna pointing

- Antenna height: 1.5 m, constant
- Antenna azimuth: 0...360 degrees, uniform
- Antenna elevation: 0 degrees, constant   (horizontal direction)

Antenna Pattern Identification

- Description: Omni-directional
- Maximum gain: 0 dBi

Emission Characteristics

- Power: 30 dBm, constant
- Emission Mask:
  Unwanted mask: Offset in MHz, power in dBc referred to Reference bandwidth
  -10.0000   -100.0000   18.0000

-0.5010	-100.0000	18.0000
-0.5000	-80.0000	18.0000
-0.2510	-80.0000	18.0000
-0.2500	-75.0000	18.0000
-0.1000	-75.0000	18.0000
-0.0750	-66.0000	18.0000
-0.0500	-66.0000	18.0000
-0.0250	-60.0000	18.0000
-0.0125	0.0000	18.0000
0.0125	0.0000	18.0000
0.0250	-60.0000	18.0000
0.0500	-66.0000	18.0000
0.0750	-66.0000	18.0000
0.1000	-75.0000	18.0000
0.2500	-75.0000	18.0000
0.2510	-80.0000	18.0000
0.5000	-80.0000	18.0000
0.5010	-100.0000	18.0000
10.0000	-100.0000	18.0000

- Transmitting bandwidth: 18 kHz (Bandwidth < channel)
- Reference bandwidth: 18 kHz
- Unwanted emission floor: NO
- Power control:
  - Power Control step size: 5 dB
  - Min Threshold: -86 dBm
  - Dynamic Range: 15 dB

1.2.2   Receiver: TETRA BS (ILR)

Receiver Identification

- Name: TETRA-BS

Antenna pointing

- Antenna height: 30 m, constant
- Antenna azimuth: 0...360 degrees, uniform
- Antenna elevation: 0 degrees, constant (horizontal direction)

Antenna Pattern Identification

- Description: Omni-directional
- Maximum gain: 11 dBi

Reception Characteristics

- Noise floor: -125 dBm, constant(=Sensitivity – C/I)
- Blocking mode: User defined
- Blocking mask: 0 dB, constant
- Intermodulation rejection: 0 dB, constant
- Sensitivity: -106 dBm
- Reception bandwidth: 18 kHz
- Overloading: NO

Interfering Criteria

- C/I: 19 dB (if only C/I, then C/(N+I) and (I+N)/N are not required)

- C/(I+N):   16 dB (C/(N+I) required only for selected Blocking-Mode)
- (N+I)/N: 3 dB
- I/N: 0 dB

1.3.3 Transmitter to Receiver path (ILT - > ILR)

Relative location
- Correlation: None
- Path azimuth VLR: Uniform distribution 0 to 360 degrees
- Path distance factor: Uniform polar 1*cell radius

Coverage radius
- Cell radius mode: Traffic limited network
- Density: 5
- Nr. of channels: 80
- Nr. of users per channel: 1
- Frequency cluster: 9

Local environment:
- Receiver: 100% outdoor
- Transmitter: 100% outdoor

Propagation model
- Model: Extended Hata
- Variation: Yes
- General environment: RURAL(results in lowest path attenuation)
- Propagation environment: ABOVE ROOF (with a 30 m TETRA BS-Antenna height)

2. SCENARIO

2.1. VICTIM SYTEM

- Victim System: FM
- Frequency: Constant, 412.00625

2.2. SIMULATION CONTROL

- Number of events: 20 000

2.3. INTERFERING SYSTEM LINKS

- Link1:   TETRA
- Frequency: 410.1875…411.9875 MHz, uniform

2.4 ILT -> VLR path

Relative positioning of the interfering link
- Mode: Uniform density
- Position relative to: Victim Link Receiver
- Delta X: Constant, 0
- Delta Y: Constant, 0
- Set ILR at the centre of the distribution: NO
- Path azimuth: Uniform distribution, 0 to 360 degrees
- Number of active transmitters: 9

- Minimum coupling loss: Constant, 0
- Protection distance: Constant, 0

Interferers density
- Density of Tx: $5 * 1/Km^2$
- Probability of transmission: 1
- Activity: Constant, 1
- Time: 1 hour

Propagation Model

- Model: Extended Hata
- Variation: Yes
- General environment: RURAL(results in lowest path attenuation)
- Propagation environment: ABOVE ROOF (with a 30 m FM BS-Antenna height)

2. **RESULTS**

Test of the simulation
Calculated radius

- Coverage radius (wanted system):   7.8 km
- Coverage radius (interfering system 1):   0.7522 km
- Simulation radius 1:   0.7569 km

Generated Signals
PC "on"

- dRSS: mean: -69.9 dBm,   std: 11.68 dB
- $iRSS_{unwanted}$:   mean: -127.5 dBm,   std: 10.86 dB
- $iRSS_{blocking}$:   mean: -144.6 dBm,   std: 7.13 dB

PC "off"

- dRSS: mean: -69.8 dBm,   std: 11.78 dB
- $iRSS_{unwanted}$:   mean: -112.6 dBm,   std: 10.84 dB
- $iRSS_{blocking}$:   mean: -129.6 dBm,   std: 7.19 dB

Interference calculation/ICE calculation

- Interference Criteria: C/I
- Compatibility mode: Yes (Probability of interference)
- Unwanted emissions: Yes
- Blocking: Yes

Results

PC "on"
- Probability of interference: 1 %

PC "off"
- Probability of interference: 8.4 %

ANNEX 26: : LIST OF REFERENCES

[1]   3GPP Technical Specification TS 25.104 (Release 7), Base Station (BS) radio transmission and reception (FDD), 2005-12

[2]   Recommendation ITU-R SM.329: Unwanted emissions in the spurious domain

[3]   3GPP Technical Specification TS 25.101 (Release 7), User Equipment (UE) radio transmission and reception (FDD), 2005-12

[4]   ECC Report 82: Compatibility study for UMTS operating within the GSM 900 and GSM 1800 frequency bands

[5]   ECC Report 96: Compatibility between UMTS 900/1800 and systems operating in adjacent bands

[6]   WCDMA for UMTS by Holma and Toskala (Wiley)

[7]   ERC Report 68: Compatibility studies in the band 5725-5875 MHz between Fixed Wireless Access (FWA) systems and other systems

[8]   Radio Regulation RR.1.146

[9]   Nicholas Metropolis (1987), "The beginning of the Monte Carlo method", Los Alamos Science (1987 Special Issue dedicated to Stanislaw Ulam): 125–130, http://library.lanl.gov/la-pubs/00326866.pdf

[10] 3GPP - TR 36.942: LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Radio Frequency (RF) system scenarios.

[11] ITU-R Report SM. 2028-1: Monte Carlo simulation methodology for the use in sharing and compatibility studies between different radio services or systems.

[12] "Other-Cell Interference in Cellular Power-Controlled CDMA", Andrew J. Viterbi, Audrey M. Viterbi, and Ephraim Zehavi, IEEE Transactions on Communications, vol.42, No. 2/3/4, p1501-1504, 1994.

[13] Recommendation ITU-R P.1411-7, Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz

[14] ECC Report 159, Technical and operational requirements for the possible operation of cognitive radio systems in the 'white spaces' of the frequency band 470-790 MHz

[15] ECC Report 138, Measurements on the performance of DVB-T receivers in the presence of interference from the mobile service (especially from UMTS).

[16] EN 300 113-1 (2011-11), Electromagnetic compatibility and Radio spectrum Matters (ERM); Land mobile service; Radio equipment intended for the transmission of data (and/or speech) using constant or non-constant envelope modulation and having an antenna connector; Part 1: Technical characteristics and methods of measurement

[17] ERC Report 101, A comparison of the minimum coupling loss method, enhanced minimum coupling loss method, and the Monte-Carlo simulation

[18] ECC Recommendation (02)05: Unwanted emissions

ANNEX 27: : GLOSSARY

Terminology used in the software and in this manual is:

3GPP	The 3rd Generation Partnership Project prepares, approves and maintains globally applicable technical specifications and technical reports for the evolved 3rd generation and beyond mobile system known as UMTS and LTE/E-UTRA. 3GPP also maintains the technical specifications and technical reports for GSM, including GPRS and EDGE.
3GPP2	The 3rd Generation Partnership Project 2 for the North American and Asian interest.
ACIR	Adjacent Channel Interference Ratio is defined as the ratio of the power of an adjacent-channel interferer, to the power measured after a receive filter in the adjacent channel and is a result of both transmitter and receiver imperfections.
ACLR	Adjacent Channel Leakage (Power) Ratio. The ACLR of a signal is defined as the ratio of the signal's power to the power of the signal when measured at the output of a (nominally rectangular) receiver filter centred on an adjacent frequency channel.
ACS	Adjacent Channel Selectivity (ACS) is a measurement of a receiver's ability to process a desired signal while rejecting a strong signal in an adjacent frequency channel. ACS is defined as the ratio of external interference to the interference appearing at a receiver input.
Active list (CDMA module)	Different for each UE. When a UE is dropped in the network, it connects to all the BS (i.e. 19 or 57). The connect procedure involves the calculation of the path loss. The UE sort all the connections by path loss so that the first item of the list is the one with the shortest path loss. In the CDMA module only two BSs which are within the handover margin can be added to the active list. In the OFDMA module, there is no limitation on the number of BSs
C	represent the desired signal received from the Victim link transmitter
BS	In a cellular system the Base Station/Base Transceiver Station terminates the radio interface.
CDMA	Code Division Multiple Access (CDMA) is a multiple access scheme for digital radio, to send voice, data, and signalling data between mobile phones and cell sites. CDMA channels are defined with codes and permit many simultaneous transmitters on the same frequency channel.
Coverage Radius	Radius of the coverage where receivers are distributed around the transmitter of the same link
e.i.r.p.	Equivalent isotropically radiated power (e.i.r.p) or, alternatively, effective isotropic radiated power is the amount of power that would have to be emitted by an isotropic antenna (that evenly distributes power in all directions and is a theoretical construct) to produce the peak power density observed in the direction of maximum antenna gain.
Interfering link:	link, which creates interference into the Victim link receiver
Interefering link transmitter (It)	transmitter within the considered Interfering Link
I	represents the interfering power received by the Victim link receiver
LTE	Long Term Evolution is the name given to a project within the Third Generation Partnership Project (3GPP) to enhance the Universal Mobile Telecommunications System (UMTS) mobile phone standard. The resulting E-UTRA (Evolved Universal Terrestrial

	Radio Access) radio interface is based on orthogonal frequency division multiple access (OFDMA) for the downlink and single carrier frequency division multiple access (SC-FDMA) for the uplink.
N	represent the noise floor
OFDM	Orthogonal Frequency-Division Multiplexing (OFDM) is a digital multi-carrier modulation scheme, which uses a large number of closely-spaced orthogonal sub-carriers. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation) at a low symbol rate, maintaining data rates similar to conventional single-carrier modulation schemes in the same bandwidth.
Optimal Capacity (CDMA module)	The number of UEs per cell that a given CDMA network is able to serve under "ideal" conditions without any external interference
Simulation radius	Radius of the coverage where Interefering link transmitters are distributed around the Victim link receiver.
Victim link	a studied link containing transmitter and receiver
Victim link receiver (VLR)	receiver within the considered Victim Link
Interfering link receiver (ILR)	receiver within the considered Interfering Link.
Victim link transmitter (VLT)	transmitter within the considered Victim Link

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History

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