ECC REPORT 122

Electronic Communications Committee (ECC)
within the European Conference of Postal and Telecommunications Administrations (CEPT)

THE COMPATIBILITY BETWEEN GSM USE ONBOARD VESSELS AND LAND-BASED NETWORKS

Vilnius, September 2008

0 EXECUTIVE SUMMARY

This Report studied the co-existence of GSM systems, operating in the 900 and 1800 MHz bands, used onboard vessels (known as GSMOBV or as MCV – Mobile Communications onboard Vessels) in territorial waters with land-based GSM and UMTS systems. Also co-existence with RSBN systems used by some CEPT countries for aeronautical radio navigation was considered.

Note that the following issues are beyond the scope of this Report:

- possibility of operation of the GSMOBV system in internal waters, harbours and ports;
- operation within territorial waters of backhaul connection (e.g. satellite link) from GSMOBV to its serving land-based network node.

The Report establishes different interference scenarios and considers the results of MCL and SEAMCAT simulations for these various scenarios. The results show compatibility between GSMOBV and land-based systems can be achieved provided the following conditions are met:

- the System shall not be used closer than 2 NM from the baseline;
- only indoor v-BS antenna(s) shall be used between 2 and 12 NM from the baseline;
- DTX[1] has to be activated on the GSMOBV uplink;
- the timing advance[2] value of v-BS must be set to minimum;
- all v-MS shall be controlled to use the minimum output power (5 dBm in 900 MHz and 0 dBm in 1800 MHz bands);
- Within 2-3 NM from the baseline the v-MS receiver sensitivity and the disconnection threshold (ACCMIN[3] & min RXLEV[4] level) shall be ≥-70 dBm/200 kHz;
- Within 3-12 NM from the baseline the v-MS receiver sensitivity and the disconnection threshold (ACCMIN & min RXLEV level) shall be ≥-75 dBm/200 kHz;
- the v-BS emissions measured anywhere external to the vessel (i.e. at ship perimeter or on its open deck areas) shall not exceed -80 dBm/200 kHz (assuming a 0 dBi measurement antenna gain);

Alternatively, if the above requirements are not met, then the GSMOBV system must be switched-off when entering the territorial sea at 12 NM from the baseline.

[1] DTX (discontinuous transmission, as described in GSM standard ETSI TS 148.008)
[2] Timing advance (as described in GSM standard ETSI TS 144.018)
[3] ACCMIN (RX_LEV_ACCESS_MIN, as described in GSM standard ETSI TS 144.018)
[4] RXLEV (RXLEV-FULL-SERVING-CELL , as described in GSM standard ETSI TS 148.008)

Table of contents

The compatibility between GSM use onboard vessels and land-based networks

1 INTRODUCTION

The GSM system onboard vessels (e.g. cruise liners, ferries, cargo ships), hereinafter referred to as "the System" or GSMOBV, enables onboard use of GSM mobile terminals beyond the reach of coastal coverage of land-based GSM networks. The operation of the System in internal waters, harbours and ports is beyond the scope of this Report.

The System is to be operated on a secondary basis, i.e. not to cause interferences to other authorised systems and not to claim protection from these other systems.

This Report studies the compatibility between the System and land-based networks with the intention to find technical requirements for the System, so that it will not cause harmful interference to land-based networks and so that land-based mobile terminals are not connected to the System, when the System is in use at the territorial waters.

This study has considered co-existence of GSMOBV systems with the land-based GSM/UMTS-900 and GSM/UMTS-1800 implementation, plus co-existence of GSMOBV with RSBN systems, which are operating in the frequency band 862 – 960 MHz under RR 5.323 was considered. The operation of the backhaul link (e.g. satellite link) is outside the scope of this Report.

Protection of other land-based systems (networks operating in other frequency bands) has not been considered because the System itself will not use any bands other than the GSM-900 and GSM-1800 band, and any transmissions from onboard user terminals of those other systems would only happen in the presence of the signal from the relevant land-based network, i.e. within service coverage of those networks.

Note: In this Report, whenever SEAMCAT calculations are used, they were made with SEAMCAT version 3.1.42.

2 GSM SYSTEM ONBOARD VESSELS

2.1 System description

The vessel-BS (v-BS) of GSMOBV serves roaming GSM mobile stations (vessel-MS, or v-MS) carried by ship passengers or crew by providing connectivity in the GSM-900 and/or GSM-1800 frequency band.

The GSM related equipment installed on a ship consists of the following main parts:

Cabinet with main equipment for:

- Control system
- Interface to satellite
- GSM base transceiver stations (BTS)
- GPS receiver

Antenna System

- Cabling and antenna(s)

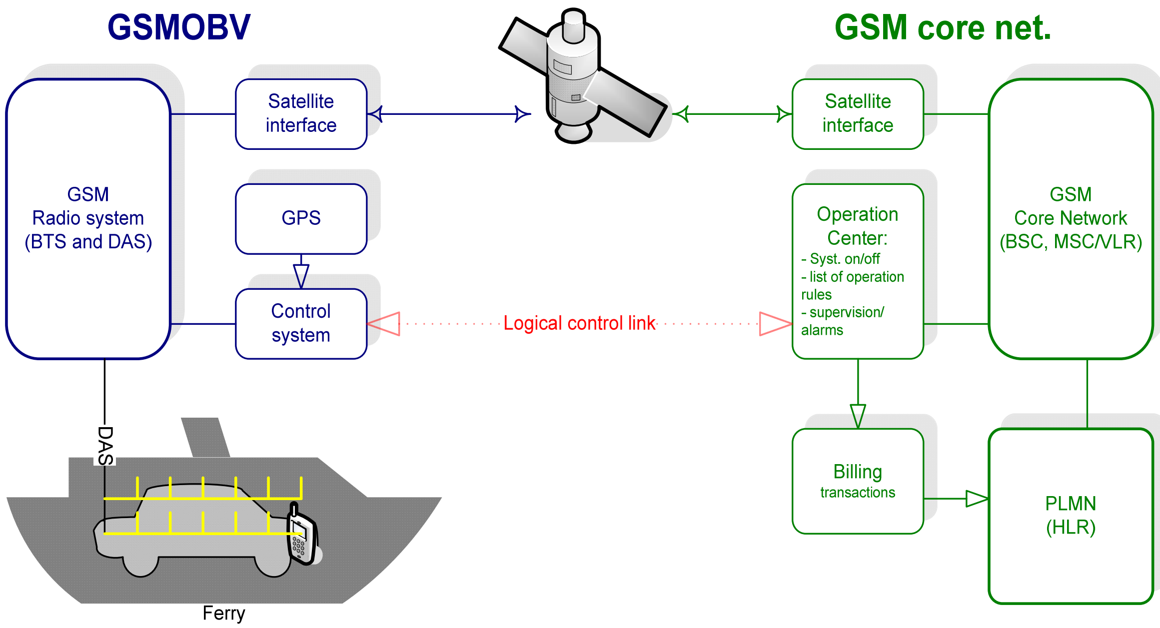


Figure 1: GSMOBV system

<u>Equipment Cabinet</u>

The GSM related equipment is installed in a suitable cabinet. Typically this cabinet is mounted in the data communications/satellite communications room onboard. It is from here the distributed antenna system must be spread.

<u>Satellite Interface onboard</u>

The interface with the satellite system onboard the ship is done with a standard multiplexer.

<u>Distributed Antenna System (DAS)</u>

On a ship requiring a larger coverage area for GSMOBV, a DAS may be used to spread the GSM radio signal, from one or several transceivers, throughout the ship with a number of low power antenna points ensuring required coverage onboard. To control disabling and enabling of the outside antenna, it is connected to a separate remote unit.
In addition, attenuators are connected on the coaxial antenna feed cable in the situation where further power limiting is required. It was assumed that a leaky cable system was not a typical installation in a GSMOBV system.

DAS Components:

- **Main unit** located in the cellular cabinet
- **Extended units**: located in various locations onboard
- **Remote units**: located near antenna ends, will normally feed multiple antennas
- **Coaxial cables**: between remote units and antennas
- **Various attenuators**: to reduce power fed to antenna
- **Antennas**: typically omni-directional, ceiling mounted antennas

Cable Types:

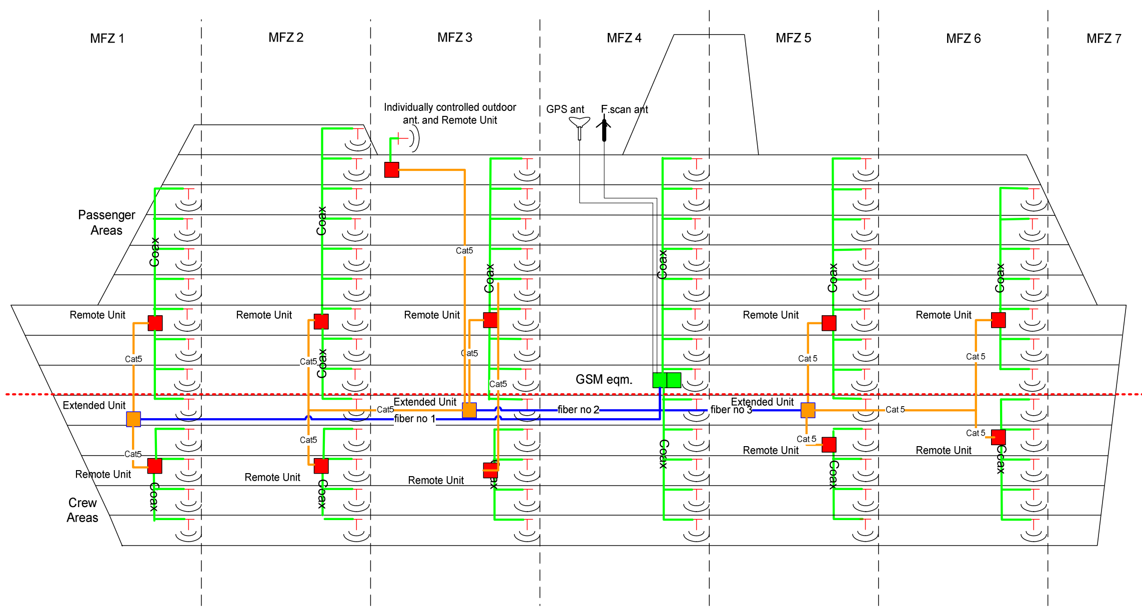
- Ethernet cable. (**yellow** cable in diagram)
- Coaxial cable. (**green** cable in diagram)
- Optical fiber. (**blue** cable in diagram)

Antenna types:

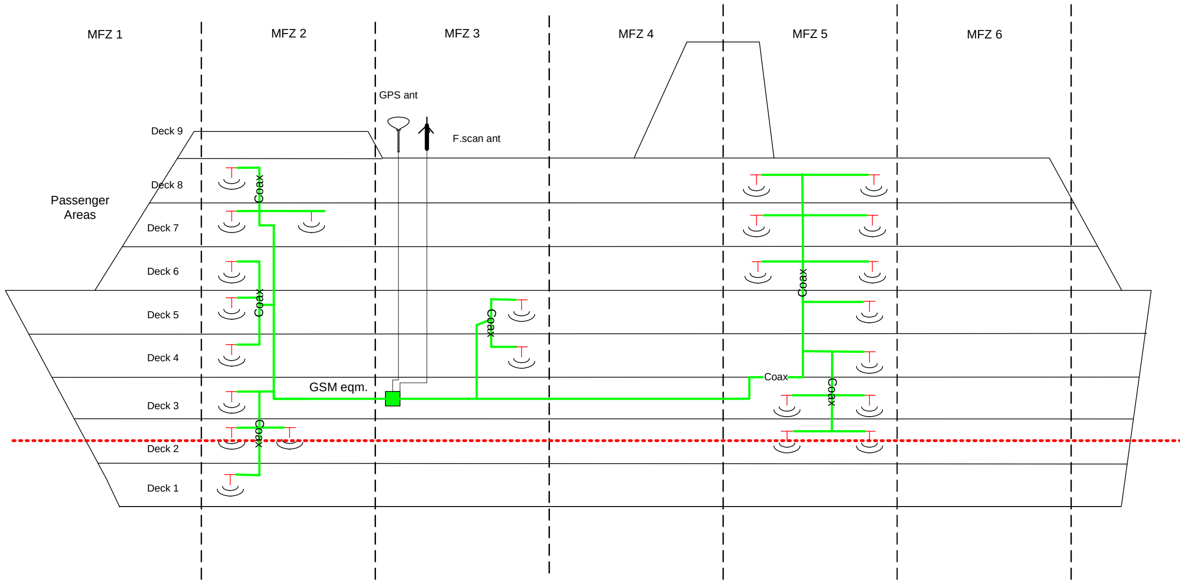
	Typical GSMOBV cellular antenna Diameter 109 mm, depth 30 mm, weight 170g The output signal level is ~1mw (1 milliwatt).
	GPS antenna Diameter 140 mm, Height 180 mm; 500 with mounting bracket included. Weight 450 g, 1150 with bracket.

DAS Engineering Examples:

A site survey is performed prior to installation, gathering required information for engineering of the DAS onboard.



(a) Example 1: DAS schematics for ship utilizing fiber optical, Ethernet, and coaxial cables



(b) Example 2: DAS schematics for ship utilizing coaxial cables

Figure 2: Distributed antenna system (DAS) examples

Control System

The onboard GSM network is exclusively operated by the control system and the service provider operations center.

The control system contains a detailed set of rules of operation for all the regions where vessels sail. This entails automatic:

- system switch-off/on when crossing defined boundaries
- where the GSMOBV system is authorized to operate in territorial seas, it must re-configure operation of the GSMOBV as required by authorization conditions, such as:
  - tune frequency(ies);
  - disable outside antenna points;
  - activate any necessary mitigation mechanisms, as provided for in the authorization.

Input from the GPS unit, included in the system, is used to continuously keep track of the vessel's location.

This implies that the crew onboard has no means of controlling the operation of the GSM system with one exception: they can turn it off by a main switch. In order to turn the system back on the operations center will have to be contacted.

Onboard GSM Base Stations

GSM access onboard a vessel is to be provided by one or more pico-cell BTS (vessel-BS). The vessel-BS operates in the GSM-900 and/or GSM-1800 frequency band.

2.2 Protection of the land-based networks

The operation of the System should not cause harmful interference to land-based networks. This could be ensured:

- Through activation of the System beyond the certain minimum distance from the baseline; and
- By control of the installation and power management of vessel-BSs and vessel-MSs, it is possible to avoid or minimise to certain levels emissions from the System beyond the vessel;
- By other means of interference mitigation, explored in this Report.

The land-based GSM and UMTS networks to be protected are those operating in frequency bands:

- 880-915 MHz (uplink)/ 925-960 MHz (downlink)
- 1710-1785 MHz (uplink)/ 1805-1880 MHz (downlink).

Protection of other land-based systems (networks operating in other frequency bands) is not required because the System itself will not use bands other than the GSM-900 and GSM-1800 band, This is without prejudgement to compliance of the System with unwanted emission limits. Note that the operation of the satellite backhaul link is outside the scope of this Report.

3 DEFINITIONS

3.1 Geographical definitions

The internal waters are understood as being on the landward side of the geographic "baseline" (as defined in UNCLOS, 1982, Article 8) as illustrated below in Figure 3.

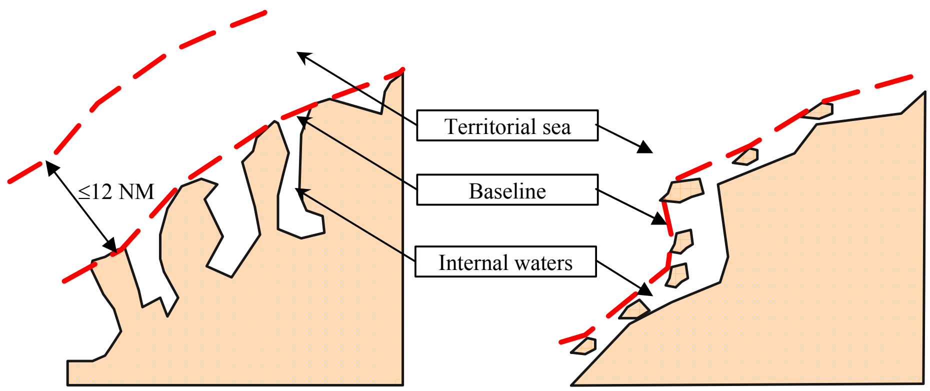


Figure 3: Illustration of baseline between internal waters and territorial sea (NM – nautical miles)

3.2 Acronyms, abbreviations and definitions

ACCMIN	Minimum received signal level for accessing the network
AMR	Adaptive Multi-rate
BS	Base Station
BSC	Base Station Controller
BTS	Base Transceiver Station
BCCH	GSM carrier which contains the Broadcast Control Channel
C	Carrier
CDF	Cumulative Distribution Function
CDMA	Code Division Multiple Access
DAA	Detect and Avoid
DAS	Distributed Antenna System
DRC	Downlink Receive Control
dRSS	desired Received Signal Strength (SEAMCAT)
DTX	Discontinuous Transmission
e.i.r.p.	Equivalent Isotropically Radiated Power
FDD	Frequency Division Duplex
FH	Frequency Hopping
GPS	Global Positioning System
GSM	Global System for Mobile communications
GSMOBV	GSM onboard vessel (system)
HLR	Home Location Register
I	Interference

iRSS	interfering Received Signal Strength (SEAMCAT)
LAC	List of Available Channels
l-	land-based- (prefix)
l-BS	GSM Base Station located on the ground
l-MS	GSM Mobile Station located on the ground
l-Node B	UMTS base station located on the ground
l-UE	UMTS User Equipment located on the ground
LOS, LoS	Line-Of-Sight
MCL	Minimum Coupling Loss
MCV	Mobile Communications onboard Vessels
MS	Mobile Station
MSC	Mobile Switching Centre
MSL	Mean Sea Level
N	Noise
NA	Not Applicable
NM	Nautical Mile (=1.852 km)
PLMN	Public Land Mobile Network
PRMG	Instrumental landing system
PSD	Power Spectral Density
Receiver Noise Figure (dB)	Receiver noise figure is the noise figure of the receiving system referenced to the receiver input. (According to official 3GPP Vocabulary TR21.905)
Receiver Sensitivity (dBm)	This is the signal level needed at the receiver input that just satisfies the required Eb/(No+Io). According to official 3GPP Vocabulary TR21.905.
RSBN	Short-range radio navigation system
RXLEV	Received Signal Level
SEAMCAT	Spectrum Engineering Advanced Monte-Carlo Analysis Tool (free software tool available from www.ero.dk/seamcat), the version used in simulations of this Report is v. 3.1.42
TCH	Traffic Channel
Terminal	General term given to a handheld device capable of connecting to a public mobile network
TDD	Time Division Duplex
UE	User Equipment
v-	vessel- (prefix)
v-BS	GSM base station located onboard vessel
v-MS	GSM mobile station located onboard vessel
v-UE	UMTS User Equipment located onboard vessel
UMTS	Universal Mobile Telecommunications System
UTRA	UMTS Terrestrial Radio Access
VLR	Visitor Location Register
WCDMA	Wide Band CDMA (UTRA FDD)
3GPP	Third Generation Partnership Project

Table 1: Acronyms and abbreviations used in the report

4 TECHNICAL PARAMETERS AND INTERFERENCE CRITERIA FOR THE SYSTEMS

The following input parameters were used for the compatibility study between GSMOBV operating in GSM900/1800 bands and land-based systems: GSM900/1800 and UMTS900/1800. Most of the parameters and their values are taken from the Tables 10 and 11 of the ECC Report 93.

Parameter		**GSM900**		**GSM1800**		**UMTS900**[1]		**UMTS1800**[1]	
		MS	**BS**	**MS**	**BS**	**UE**	**Node B**	**UE**	**Node B**
Antenna input Power	dBm / channel	33	43	30	43	21/24[3]	33[2]	21/24[3]	33[2]
Antenna input Power, GSMOBV	dBm / channel	5	-6[5]	0	-6[5]				
Receiver bandwidth	kHz	200	200	200	200	3840	3840	3840	3840
Reference System noise figure (taken from values quoted in standards)	dB	12	8	12	8				
Typical System noise figure (operator quoted "typical" values)	dB	7	4	7	4				
Reference Noise level (taken from values quoted in standards)	dBm / channel	-109	-113	-109	-113	-96	-103	-96	-103
Typical Noise level ("typical" operator values)	dBm / channel	-114	-117	-114	-117				
Reference Receiver Sensitivity (taken from values quoted in standards)	dBm / channel	-102	-104	-102	-104	-114	-121	-114	-121
Typical; Receiver Sensitivity ("typical" operator values)	dBm / channel	-105	-108	-105	-108				
Interference criterion I (C/(N+I))	dB	9	NA	9	9				
Interference criterion II (I/N)	dB	-6	NA	-6	-6				
Channel Spacing	kHz	200	200	200	200	5000	5000	5000	5000
Maximum antenna gain[4]	dBi	0	15	0	18	0	15	0	18
Maximum antenna gain GSMOBV	dBi	0	2	0	2				
Antenna height (above ground)	m	1.5	20	1.5	20				
Antenna heights (above mean sea level (MSL)) GSMOBV	m	15/20/30	15/20/30	15/20/30	15/20/30				

Table 2: Parameters used in the studies

Notes:
[1] Assumed "typical" values given awaiting commercial product information.
[2] Typical operator power levels for the UMTS pilot channel = max Input power (43 dBm) -10 dB = 33 dBm as per UMTS defined testing procedures.
[3]Maximum UE transmit powers values quoted to be used for the following simulations:

- Maximum UE transmission power value for simulations on the impacts for the support of voice service = 21 dBm (assumes UE power class 4);
- Maximum UE transmission power value for simulations on impacts for the support of non voice service = 24 dBm

[4]The same maximum antenna gain is assumed for UMTS as for GSM.
[5]Typical antenna input power is –6 dBm for existing GSMOBV systems.

The reference values taken from standards documentation are based on the 3GPP specifications.

5 PROPAGATION MODELS

5.1 Free Space path loss model

The received power p_R is given by the transmitted power level p_T, antenna gains and the basic free space path loss L_{bf} (ITU-R Rec P.525-2):

$$p_R = p_T + g_T + g_R - L_{bf}$$
$$p_R = p_T + g_T + g_R - 32.4 - 20\log f - 20\log d \qquad (1)$$

Where
- p_R Received power in dBm,
- p_T Transmitted power level in dBm
- g_R Antenna gain of the receiving antenna in dBi
- g_T Antenna gain of the transmitting antenna in dBi
- f Frequency in MHz
- d Distance in km

It should be noted that the free space path loss is the upper limit in all propagation curves in ITU-R Recommendation P. 1546-2. For very short distances (less than 2 km), both models are identical for all transmitting heights.

5.2 ITU-R Rec P.1546-2 propagation model

The received field strengths $E(d, h_1)$ for sea path for 50 % of time, 600 and 2000 MHz, receiving height h_2 =10m and 1 kW ERP (corresponding to 62.1 dBm EIRP) are contained as function of different transmitting antenna heights h_1 from 10 to 1200 m and distances d in the Figures 12 and 20 in ITU-R Recommendation P.1546-2, respectively. For different frequencies, receiving antenna heights and transmitted power levels, some corrections have to be introduced:

$$E_{corr} = E(d, h_1) - \Delta f + \Delta p + \Delta h_2 \qquad (2)$$

where
- E field strength level at the receiver in dB(µV/m)
- Δh_2 =0dB for h_R =10m (worst case for open area)
- $\Delta f = 20\log(900/600) = 3.5$ dB for 900 MHz
- $\Delta f = 20\log(1800/2000) = -0.9$ dB for 1800 MHz
- $\Delta p = 62.1 - (p_T + g_T + g_R)$ dB

Where
- p_T Transmitted power in dBm
- g_R Antenna gain of the receiving antenna in dBi
- g_T Antenna gain of the transmitting antenna in dBi
- f Frequency in MHz

Assuming an isotropic receiving antenna, the received power can be calculated according to the following equation:

$$E(d, h_1) = p_R + 77.2 + 20\log f \qquad (3)$$

Where p_R Received power in dBm

The equation (3) inserted in (2) and using the graphs in the Figures 12 or 20 in ITU-R Recommendation P.1546-2, respectively, the minimum separation distances can be determined.

5.2.1 Mixed sea – land paths

The determination of the field strength for mixed path is provided in Recommendation ITU-R P.1546-2 Annex 5 section 8:

$$E = (1 - A) \cdot E_{land}(d_{total}) + A \cdot E_{sea}(d_{total})$$

where

E	Field strength level at the receiver in dB(µV/m)
E_{land}	Field strength for propagation over land (Figure 9 for 600 MHz and 17 for 2000 MHz)
E_{sea}	Field strength for propagation over sea (Figure 12 for 600 MHz and 20 for 2000 MHz)
d_{total}	Path length in km
A	Mixed path interpolation factor (Fig. 26 in ITU-R Rec. P.1546-2)

Assuming 10 % propagation over land and 90 % over sea, the impact of land can be estimated for different antenna heights, distances and for 600 and 2000 MHz. The results are contained in the following Table 3.

d_{total}	f = 600 MHz				f = 2000 MHz			
	h_1 = 10m		h_1 = 37.5m		h_1 = 10m		h_1 = 37.5m	
	Sea only	10 % land	Sea only	10 % land	Sea only	10 % land	Sea only	10 % land
2 km	100.3	99.4	100.9	100.2	100.8	99.9	100.9	100.3
10 km	74.2	72.9	83.4	82.2	84.2	82.3	86,4	85.1
20 km	62.0	60.6	70.5	69.3	67.8	66.4	75.9	73.6

Table 3: Computed examples of mixed path field strength in dB(µV/m), reference ITU-R Rec. P.1546-2

For all considered cases the error is about 2 dB and smaller for short paths and/or greater antenna heights. Increasing the land portion increases the path loss or reduces the received field strength further.

Summarizing: The worst-case approach, sea only, is chosen further in this study. The real received field strength will be slightly smaller.

5.2.2 Transmitting / base antenna height

The determination and application of transmitting / base antenna height are discussed in Recommendation ITU-R P.1546-2 Annex 5 section 3 and 4.

For sea paths h_1 is the height of the antenna above sea level. For land paths, the effective height of the transmitting/base antenna is the height 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 terrain information is available and assuming sea between the stations, h_1 results in:

$$h_1 = h_a + h_{terrain}$$

h_a	Height of the antenna above ground in m (as given in Table 2)
$h_{terrain}$	Height of the terrain at the antenna site

Assuming propagation over sea, the impact of additional terrain heights is estimated for different distances and for 600 and 2000 MHz. It is further assumed, there are no obstacles between the transmitting and receiving antenna. The results are contained in the following Table 4.

	Free space	f = 600 MHz, h_1 in m					d f = 2000 MHz, h_1 in m				
		10	37.5	75	150	300	10	37.5	75	150	300
2 km	100.9	100.3	100.9	100.9	100.9	100.9	100.8	100.9	100.9	100.9	100.9
10 km	86.9	74.2	83.4	86.3	86.8	86.9	84.2	86.4	86.8	86.9	86.9
20 km	80.9	62.0	70.5	75.6	80.0	80.8	67.8	75.8	79.1	80.8	80.9

Table 4:Computed examples of sea path field strength in dB(µV/m) for different transmitting / base antenna heights, reference ITU-R Rec. P.1546-2

The results illustrate that for very short distances and/or antenna heights of more than 75 m above sea level, the free space model is a very good approximation. Using free space only, the error is less than about 3 dB for distances less than 10 km and antenna heights greater 37.5 m above sea level. Due to the greater clearance of the 1st Fresnel zone, the error is smaller for higher frequencies.

Summarizing: If the transmitting / base antenna mounted close to the sea with line-of-sight and the terrain height above sea level is in the same order or greater than the antenna height above ground, the received field strength is approaching the free space value. For simplification of the study, the antenna height above ground could be set equal to the height above sea level.

5.2.3 Receiving / mobile antenna height

In Recommendation ITU-R P.1546-2 Annex 5 section 9, it is recommended for sea path, i.e. where the receiving/mobile antenna is adjacent to sea (line-of-sight), to use no correction for antenna heights, $h_2 \geq 10$ m. Considering clutter loss, e.g. in urban area, or smaller antenna heights than 10 m, the path loss increases.

Summarizing: The case h_2 = 10 m as assumed in Eq. (2) represents the worst case.

5.3 Propagation models used in SEAMCAT studies

Due to the fact that P.1546 model implemented in SEAMCAT does not have sea path option, a free-space model was used instead as a worst case fallback option. Also Hata model was used for some specific cases such as propagation in cluttered environment of the ship for scenario 3 (HATA SRD model) and when modelling signal distribution inside affected land-based networks (rural propagation model).

6 SCENARIOS

This report has considered two separate co-existence studies, carried using different methodologies and modelling approaches, which are presented as separate annexes:

- Annex 1 presents a co-existence study based on MCL methodology, which analyses the occurrence of worst-case static situations;
- Annex 2 presents a co-existence study based on application of statistical Monte-Carlo simulation approach using SEAMCAT software, which makes an assumption of uniformly random distribution of ship/GSMOBV anywhere within the 0-12 NM distance from victim land-based GSM system or within short segments near the shore during slow approach/departure phases;
- Annex 3 presents a statistical co-existence study between GSMOBV and expected in the near future deployment of UMTS-900/1800 systems.

The comparative analysis and summary of findings of those three studies is discussed in the following sub-sections.

6.1 Scenario 0: Coverage of the land-based networks at sea and its effects

This scenario is used to estimate the distance from shore, where a MS is still able to connect to the land-based network. It should be noted that this is not an interference situation, but it will be used as a reference situation for some of the compatibility studies.

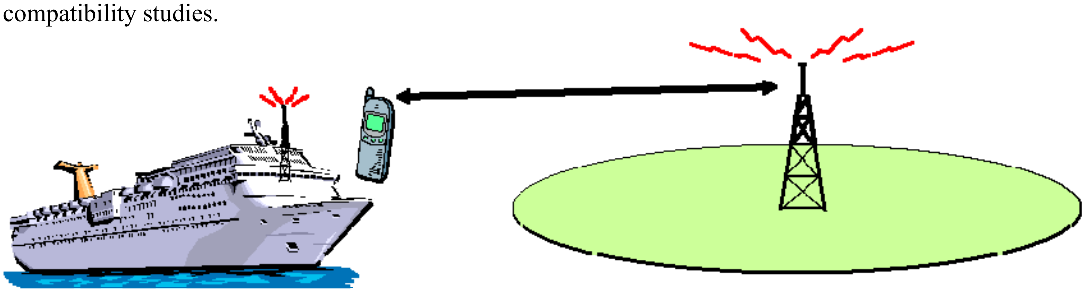


Figure 4. Scenario 0: Coverage in territorial waters by the land-based network

This scenario considers an essentially static marginal condition of achieving maximum possible range of coverage of coastal waters by l-BS:

- the study reported in Annex 1 considered the case of coverage by a single l-BS without consideration of intra-service noise and shows that the coverage would be possible up to the inherent GSM coverage limits of 35 km (70 km for extended cell implementation) from the coastal l-BS;
- the study reported in Annex 2 (using SEAMCAT in static mode) considered the coverage of land-based GSM network if the intra-system co-channel noise was considered by placing a set of regularly spaced co-channel l-BS (belonging to three tiers of the 7/21 re-use pattern, with 20-30 km distance between cells using the same frequency group) along the coast. The coverage of such noise-limited network was shown to be in the order of 4-6 km (assuming Free Space Loss over sea path) from the coastal l-BS. In reality this distance could be somewhat greater due to real propagation loss being more severe than modelled by Free Space Loss model;
- the study reported in Annex 3 does not have modelling for Scenario 0 as the available SEAMCAT module for statistical simulation of CDMA systems does not allow pre-determined placement of mobile terminals within coverage area, thus the precise cut-off distance of coastal coverage by land-based UMTS network could not be determined.

6.2 Scenario 1: Impact of the v-MS on the l-BS

This scenario is used to calculate the impact of the v-MS on the l-BS. Note, that the affected land-based system might be either GSM or UMTS system operating in the same frequency band as the GSMOBV.

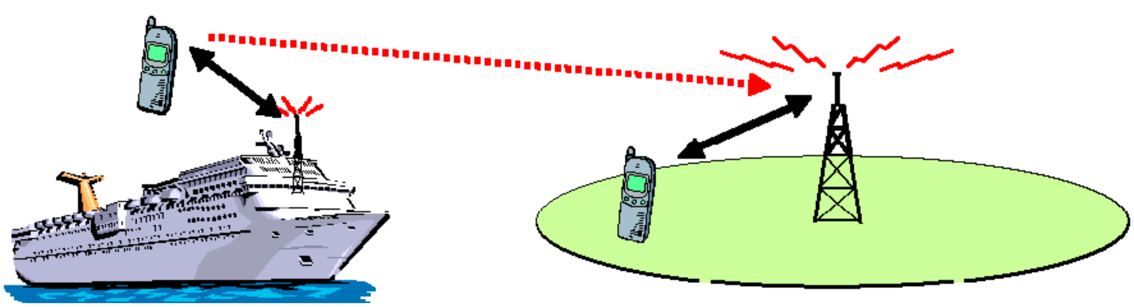


Figure 5: Scenario 1: Impact of the v-MS on the l-BS

This scenario was shown by all reported studies to be the most likely cause of potential interference. All studies have found that unless some mitigation factors are applied, this scenario would provide a level of unacceptable interference within territorial waters (see Annexes 1, 2 and 3).

The different sensitivity analysis carried by the different studies allows making the following recommendations for suitable mitigation factors:

- the GSMOBV might operate as close as 2.8 km (1800 MHz) or 11 km (900 MHz) to the coast if v-MS signal could be attenuated by at least 25 dB due to hull attenuation derived from indoor and below-deck location (see Annex 1), or

- the probability of co-channel operation might be greatly reduced by applying the spreading of interference with Frequency Hopping (FH) operation of GSMOBV (see Annexes 2 and 3), or, alternatively, employing the Detect And Avoid (DAA) (see Section 7.7) feature at GSMOBV;
- ACCMIN & DRC (see Section 7.7).

Regarding the assumption of ship hull attenuation on v-MS signal, it should be noted that while the placement of v-BS and hence their signal attenuation could be controlled by the GSMOBV operator, practical enforcement of the indoor operation of v-MS may only be achieved by applying the procedure with setting parameters for all v-MS during their connection to GSMOBV network and then monitoring the received signal strength during the entire call duration (e.g. DRC). This setting should be associated with an automatic disconnection of the v-MS, when the level received from the v-BS is less than the ACCMIN value. The principle of using ACCMIN option is described in section 7.4.

6.3 Scenario 2: Impact of the v-BS on the l-MS

This scenario is used to calculate the impact of the v-BS on the l-MS/l-UE. Note, that the affected land terminal might belong to either GSM or UMTS system operating in the same frequency band as the GSMOBV.

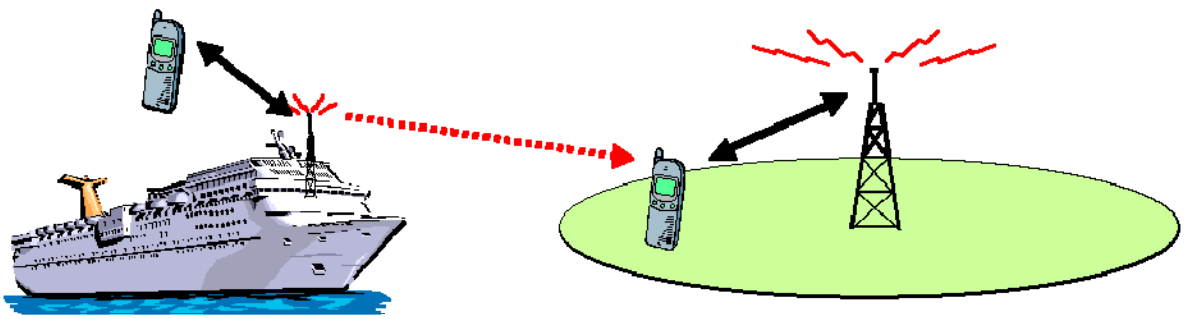


Figure 6: Scenario 2: Impact of the v-BS on the l-MS

This scenario was shown to provide significantly less potential of interference than the situation in Scenario 1, but nevertheless requiring reliance on certain mitigation factors as follows:

- the GSMOBV might operate as close as 0.2 km (1800 MHz) or 0.5 km (900 MHz) to the coast if v-BS signal is attenuated by 25 dB due to its indoor and below-deck location (see Annex 1), or
- the DAA feature is employed to avoid co-channel operation of GSMOBV and land-based GSM systems.

Notably, using FH at GSMOBV in this Scenario would not reduce the probability of interference due to potential danger of collision between two static BCCH channels used by both GSMOBV and land-based systems. However considering the large total available number of channels in the bands, probability of such collision would be reduced.

6.4 Scenario 3: Possibility of the l-MS to connect unintentionally to the v-BS

This scenario is used to calculate the possibility of the l-MS to connect unintentionally to the GSMOBV. This scenario can also be seen as an "unwanted roaming" situation.

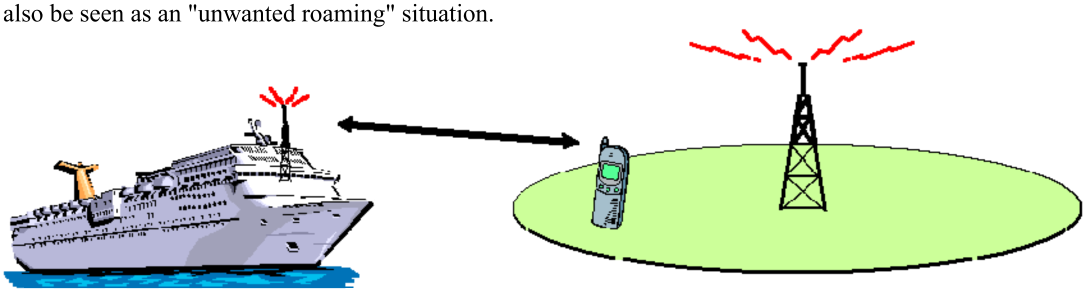


Figure 7: Scenario 3: Possibility of the l-MS to connect unintentionally to the v-BS

Results reported in Annex 1 show that the minimum separation distance required to avoid the possibility of l-MS roaming onto the GSMOBV system may be reduced to 0.1-0.2 km if the v-BS signal could be attenuated by at least 20-25 dB due to its indoor and below-deck operation.

The GSMOBV might also employ the timing advance mechanism available in GSM BS (implementation might be system/vendor specific) to deny the connection for MSs requiring timing advance larger than 1 step, thus limiting the maximum possible distance of v-BS where a v-MS is able to be connected to 500 m.

6.5 Scenario 4: Impact of the v-BS (connected to v-MS) on the MS located onboard vessel but connected to l-BS

Scenario 4 is a special case of scenario 2.

This scenario is used to calculate the impact of the v-BS on a MS, which is carried onboard vessel but still maintains connection to the land-based network. This situation is envisaged while ship is located in the areas of coastal coverage by land-based networks, as established by Scenario 0. Note, that the affected MS/UE might be connected to either GSM or UMTS system operating in the same frequency band as the GSMOBV.

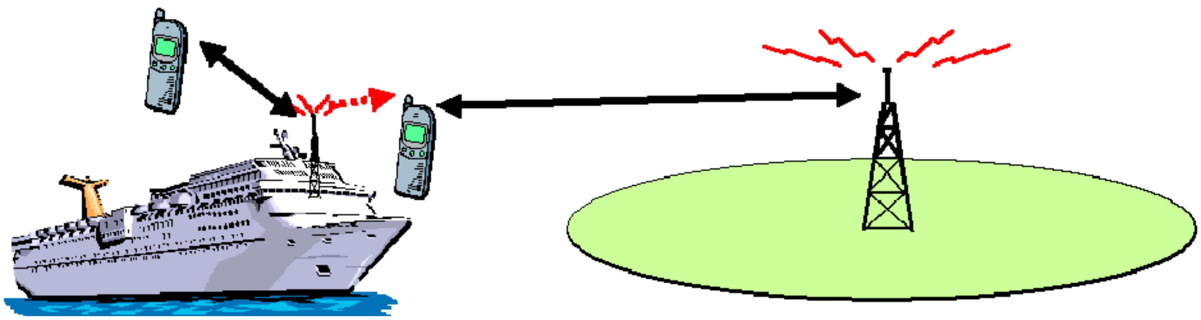


Figure 8: Scenario 4: Impact of the v-BS (connected to v-MS) on the MS located onboard vessel but connected to l-BS

This is another of most critical scenarios on par with Scenario 1 and use of some interference mitigation is necessary in this case. The suitable mitigation factors are the same as outlined for Scenario 1.

6.6 Interference to RSBN system

Short-range navigation (RSBN) and Instrument landing systems (PRMG) are in operation in some European countries in the frequency band 862 – 960 MHz under the additional allocation to the Aeronautical Radio Navigation Service on a primary basis under RR № 5.323. At present such systems are principal navigation and landing aids for aircraft of different purposes in some countries within the CEPT indicated in the above-mentioned RR footnote.

RSBN systems use the following frequency bands overlapping with GSM frequencies:

- 905.1 – 932.4 MHz – to transmit signals from ground-based navigation beacons of RSBN system and to receive signals by RSBN airborne receivers (azimuth and course channels),
- 939.6 – 966.9 MHz – to transmit signals from ground-based navigation beacons of RSBN system and to receive signals by RSBN airborne system (glide pass and distance channels).

Figure 9 shows overlapping RSBN and GSM/E-GSM frequency bands in the 900 MHz band.

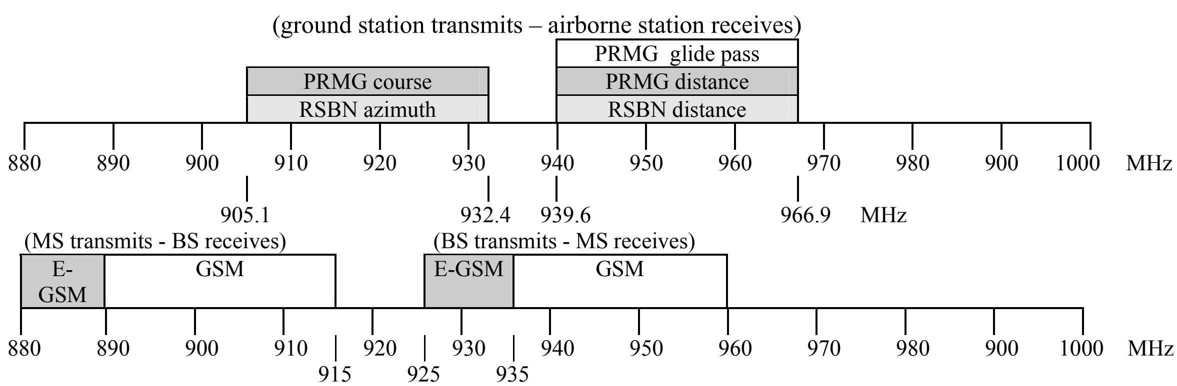


Figure 9: Frequency overlap between RSBN and GSM/E-GSM in the 900 MHz band

The analysis of Fig. 9 shows three different interference scenarios of impact of GSM/E-GSM transmitters on RSBN receivers:

- impact of GSM MS on RSBN airborne receivers (azimuth and course channels);
- impact of E-GSM BS on RSBN airborne receivers (azimuth and course channels);
- impact of GSM BS on RSBN airborne receivers (glide path and distance channels).

Protection of RSBN airborne receivers from potential interference from GSM/E-GSM-900 MS and BS located on-board vessels in each particular case depends on different factors, such as:

- operational mode of RSBN system («navigation» or «landing»);
- distance and location of a vessel equipped with GSM/E-GSM-900 BS relative a radio beacon and associated RSBN airborne receivers;
- service area of a specific radio navigation beacon;
- required protection criteria at the input of RSBN airborne receivers (depending on system operational mode and a channel in use).

Taking into account continuous changing of position of a vessel, equipped with GSM/E-GSM-900 BS, relative to a navigation beacon and associated RSBN airborne receivers, it would be reasonable to consider a general case of protection of RSBN airborne receivers.

This could be obtained through a single level of field strength (for 50% of locations, 10% of time and receiving antenna height of 3 m), generated by the GSM/E-GSM-900 equipment on-board a vessel, at the country's border line which using RSBN, including 12-mile zone of territorial waters, where applicable. This criterion is contained in Recommendation T/R 25-08 used to plan networks in the Land Mobile Service, and can be used, in principle, for the protection of RSBN airborne receivers.

Value of field strength (for 50% of locations, 10% of time and receiving antenna height of 3 m), generated by the GSM/E-GSM equipment on-board a vessel, required to provide for interference-free operation of RSBN airborne receivers is given in Table 5 below.

Antenna height (m)	% location (%)	% time (%)	Required field strength (dBμV/m)	Distance from the coast baseline of the countries listed in RR 5.323 (nautical miles)
3	50	10	19 Equiv. dBm=-117 + Ga (dBi)	Up to 12

Table 5: Value of field strength generated by the GSM/E-GSM-900 equipment on-board a vessel, required to provide for interference-free operation of RSBN airborne receivers

It should be noted that there is an ERC Report 81, which covers the basic principle of sharing between the GSM-900 and ARNS (RSBN) systems at the 900 MHz band. It includes necessary geographical separation distances between GSM BS and the RSBN receiver for the different RSBN operating modes, but its applicability in the case of GSMOBV is not assessed.

7 OTHER MITIGATION FACTORS AND ADDITIONAL CONSIDERATIONS

7.1 Detect and Avoid (DAA)

This is the feature that would require GSMOBV system to scan repeatedly all GSM spectrum within its operational band(s) in order to establish and maintain updated the list of channels occupied by land-based systems. The DAA scanner should have an antenna installed at sufficiently exposed location above ship deck clutter in order to ensure unobstructed reception from all sides. However its specification and details of implementation might be vendor-specific. The detailed description of requirements to DAA operation for GSMOBV including its algorithm is provided in Annex 4.

7.2 Frequency Hopping (FH)

FH is a standard feature available in most modern GSM systems, however its applicability and details of implementation might be vendor-specific.

In order to be effective in the considered interference cases, the GSMOBV should implement the FH in the following manner:

- The GSMOBV should have at least two transceivers (GSM radio channels) employed, one used for static BCCH channel and one for the synthesized FH operation carrying TCH channel used for traffic;
- The transmissions from v-MS would be allowed on static BCCH channel only to effectuate the random access procedure (i.e. requesting the call activation or responding to paging calls). Once the communications with v-BS has been established, the v-MS call should be placed on the FH channel. In other words, the static channel carrying BCCH should be used only for that sole purpose and no traffic should be allowed within its remaining time slots.

Further detailed requirements to FH in GSMOBV are described in Annex 5.

7.3 Ship hull attenuation

The interference signals from indoor v-BS and v-MS could be attenuated by the body structures of the vessel (hull, walls, doors, windows, etc.). Different hull attenuation values must be considered due to the different materials that might come in a way of GSMOBV emissions emanating from inside the ship. For example, there is not the same level of attenuation when the v-MS is close to a big panoramic window as when the v-MS is used somewhere in deep inner corridors of the ship. Therefore interference analysis contained in annexes considered different hull attenuation factors, such as 5, 10, 15, 20, 25 dB.

Under all circumstances, the mitigation by ship hull attenuation may be considered reliable measure against v-BS emissions. It may be implemented by restricting the operation of GSMOBV system to within inner areas of the ship, i.e. employing v-BS with antennas located indoor and below the upper decks.

Provided that GSMOBV might also have installations in outdoor/open areas on upper deck areas, the requirement to apply ship hull attenuation within the territorial waters shall be implementable through disabling operation of outdoor v-BS as described in section 2.1.

The applicability of ship hull attenuation to emissions from v-MS is more problematic, due to an assumption that even if some weak signal from indoor v-BS could leak to outdoor deck areas, this might allow attachment of v-MS located on the open decks. And since it was shown that v-MS emissions (Scenario 1) are one of the major causes of concern for interference to land-based networks, therefore the whole idea with using ship hull attenuation for v-MS emissions was seen as somewhat unreliable. To resolve this uncertainty, it was proposed to use the ship hull attenuation measure only in combination with certain additional features for controlling the positioning of v-MS on a ship, as discussed in the following section 7.4.

7.4 External emission limit combined with ACCMIN/RXLEV

To ensure the enforcement of ship hull attenuation or equivalent extra attenuation on the emissions from both the v-BS and v-MS, it was proposed to use the following combination of measures:

- to define the external emission limit at the ship exterior (e.g. both at the perimeter of the vessel and on its open deck areas) – this would determine the placement of v-BS and its antennas inside the ship;
- then artificially degrade the sensitivity of v-MS receiver (and the MS disconnection threshold) so as to make it worse than the external limit for v-BS emissions by certain margin – this would ensure that v-MS could be operated within GSMOBV only while located inside the ship.

Based on experience with real installation of pilot GSMOBV systems, this report proposes to use the external emissions limit of -80 dBm. Based on the studies presented in this Report, it was shown that the ship hull attenuation should be in the order of 5-10 dB (depending on distance from vessel to baseline). Therefore it is proposed to set the v-MS sensitivity/disconnection threshold to -70 dBm or -75 dBm, which would correspond to provision of ship hull attenuation of 10 dB or 5 dB respectively.

This concept is illustrated in Fig. 10.

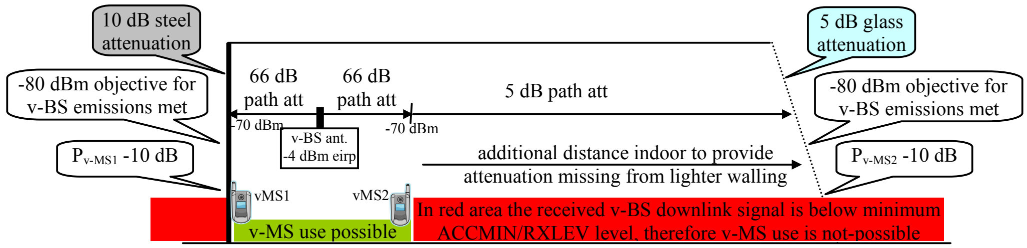


Figure 10: Ensuring attenuation of v-MS emissions through combining external emission limit for v-BS (-80 dBm) and ACCMIN/RXLEV minimum level of (-70 dBm). Figure depicts a hypothetic scenario on one floor of a ship as if it being flanked by steel partition on one side and glass window on the other side.

The critical part of this scheme is to control the sensitivity of v-MS throughout the different phases of call. This could be done by jointly exploiting two standard GSM features, as described below.

ACCMIN

The feature called ACCMIN (or RXLEV_ACCESS_MIN) is used to control the sensitivity of v-MS during the initial attachment of v-MSs to v-BS. It allows setting a value of received power level so that a MS is not allowed to access a given cell if its received control channel power is below the ACCMIN value. The ACCMIN could be set from 47 to 110 where 47 would correspond to a minimum received signal strength of -47 dBm for accessing the cell, and 110 (the default value) would correspond to a minimum required power level of -110 dBm.

So if the GSMOBV system would program all registered v-MSs to set their ACCMIN parameter to a certain value which is higher than the defined external emission limit, then the v-MSs would not be able to initiate the call with the v-BS unless they are brought inside the ship and closer to the v-BS antenna, where the received power level start exceeding the ACCMIN setting.

RXLEV

The feature RXLEV (in full RXLEV-FULL-SERVING-CELL) is a part of the standard MS measurement reporting procedures needed in GSM system. RXLEV is reported by MS routinely during the call within the MEASurement REPort (MEAS REP) message (described in 3GPP TS 148.008). This message is sent in each or every second SACCH block, i.e. every 480-960 ms. The MEAS REP incorporates the parameter RXLEV-FULL-SERVING-CELL, which contains measurement result of downlink signal from serving BS.

Thus during the call, v-BS could monitor the RXLEV-FULL-SERVING-CELL value and if its mean drops below the level corresponding to the ACCMIN setting, this will mean that during the call v-MS was brought outside the allowed connectivity area and will be disconnected from v-BS immediately following the MS release procedure (detailed in 3GPP TS 148.008).

In summary, by combining the external limit for v-BS emissions with ACCMIN/RXLEV setting it will be possible to ensure that v-MS is only allowed to operate (to establish initial connection and maintain the call) if it is physically located within the indoor coverage area of GSMOBV system. The difference between the external emissions limit and ACCMIN/RXLEV limit represents the margin that corresponds to the guaranteed value of additional attenuation applied to v-MS emissions emanating from the vessel.

7.5 Discontinuous transmission

The Discontinuous Transmission (DTX) function is a standard feature of modern GSM networks. DTX function senses when speaker makes a pause (e.g. listening to the other end of conversation or during natural conversational pauses) and stops the transmission during those pause periods. This function has become wide spread in modern GSM MS due to its two-fold positive impact: saving battery life and contributing to an overall reduction of noise in a network. In GSMOBV DTX can therefore also be prescribed as additional inherent mitigation feature for reducing interference potential to land-based networks. The simulations provided in this Report have assumed DTX voice activity factor of 0.4, which is known to be a standard industry average value that was previously used in similar studies in the CEPT (e.g. ECC Report 96) and ITU-R (e.g. ITU-R Recommendation M.1184).

In the SEAMCAT simulations, the DTX functionality is a standard setting for CDMA systems, whereas for non-CDMA systems, it could be programmed by appropriately setting the duty cycle (i.e. step function, 40% of time of voice activity) for power of the interfering transmitter.

7.6 Additional considerations

Half rate AMR codecs could be used by the GSMOBV systems to the extent possible in order to reduce the overall the effective loading of the radio channels.

The timing advance mechanism available in GSM BS (implementation might be system/vendor specific) may be used to limit the cell size, limiting the maximum possible distance from the v-BS, where a v-MS is able to be connected, to 500 m. This is important for the scenario 3.

7.7 Analyses of applicability of the different mitigation techniques

In order to establish which of the mitigation factors might assist in addressing different co-existence scenarios, below the Table 6 provides a comparative analysis of different mitigation factors considered in this Report.

Factors (Note 1):	**DAA**	**FH - 64 channels**	**External emissions limits & ACCMIN/RXLEV**
Requirement expressed as:			Indoor operation of v-BS + ext. v-BS emissions limit of –80 dBm + ACCMIN/RXLEV value of –70/-75 dBm
Means of implementation	Needs extra hardware	Standard GSM feature, but needs more than one v-BS transmitter installed, thus not always feasible	Careful v-BS antennae placement and power distribution design needed to comply with outdoor emission limit. ACCMIN setting is a standard GSM feature, but further in-call power level management would need additional v-BS software functions.
Means of enforcement	Inspection of the system design needed	Inspection of the system design needed	Both inspection of the system design and measurements needed
Scenario 1	Effectively avoids interference	Reduces interference probability to below 1% at 1 NM to shore	Effectively avoids interference, incl. possibility of controlling v-MS placement and signal attenuation
Scenario 2	Effectively avoids interference	Reduces interference probability to below 1% at 1 NM to shore	Effectively avoids interference (probability nearing 0%)
Scenario 3	Not useful	Not useful	If external emissions limit is defined "anywhere outdoors the ship", this will effectively limit connectivity zone to inner ship areas
Scenario 4	Effectively avoids interference	Reduces probability of interference to below 1%	Reduces probability of interference to 1-2% when ship hull attenuation is 20-25 dB

Note 1: Mitigation factors like DTX, timing advance and AMR are not treated here, since the DTX and timing advance features are assumed to be mandatory and the AMR is only indirectly assisting measure.

Table 6: Comparative analysis and applicability of different mitigation factors

Based on these analysis and observations, it may be noted that all of the considered mitigation factors are very useful in decreasing the potential for interference. However, it was observed that DAA mechanism remains questionable due to concerns about reliability of the detection of the busy channels, especially in the case of land-based UMTS network deployments. Concerning FH, it is recognised that there are technical difficulties to apply it over the whole band with a sufficient number (like 32 or 64) of channels. Therefore this Report recommends ACCMIN/RXLEV based methods for the GSMOBV operations. Overall conclusions shall be formulated in the next section 8.

8 CONCLUSIONS

Based on the analyses and assumptions made in this Report, it may be recommended that GSMOBV may be authorized for use in the territorial waters on the following conditions:

- the System shall not be used closer than 2 NM from the baseline;
- only indoor v-BS antenna(s) shall be used between 2 and 12 NM from the baseline;
- DTX[5] has to be activated on the GSMOBV uplink;
- the timing advance[6] value of v-BS must be set to minimum;
- all v-MS shall be controlled to use the minimum output power (5 dBm in 900 MHz and 0 dBm in 1800 MHz bands);
- Within 2-3 NM from the baseline the v-MS receiver sensitivity and the disconnection threshold (ACCMIN[7] & min RXLEV[8] level) shall be ≥-70 dBm/200 kHz;
- Within 3-12 NM from the baseline the v-MS receiver sensitivity and the disconnection threshold (ACCMIN & min RXLEV level) shall be ≥-75 dBm/200 kHz;
- the v-BS emissions measured anywhere external to the vessel (i.e. at ship perimeter or on its open deck areas) shall not exceed -80 dBm/200 kHz (assuming a 0 dBi measurement antenna gain);

Alternatively, if the above requirements are not met, then the GSMOBV system must be switched-off when entering the territorial sea at 12 NM from the baseline.

[5] DTX (discontinuous transmission, as described in GSM standard ETSI TS 148.008)
[6] Timing advance (as described in GSM standard ETSI TS 144.018)
[7] ACCMIN (RX_LEV_ACCESS_MIN, as described in GSM standard ETSI TS 144.018)
[8] RXLEV (RXLEV-FULL-SERVING-CELL , as described in GSM standard ETSI TS 148.008)

ANNEX 1: RESULTS OF MCL SIMULATIONS OF GSMOBV INTERFERENCE SCENARIOS

1. Introduction

This annex presents the results of simulations addressing the various scenarios described in the section 5 of this report. All the results provided in this annex are based on MCL (point-to-point) budget link simulations. Two propagation models were used, depending on the scenarios: Free Space Loss (Recommendation ITU-R P.525) and the Recommendation ITU-R P.1546-2. When the latter is utilized, the assumptions of section 6 of this report (correction factors) are used.

The Excel files used for the MCL calculations are available in a zip-file at the www.ero.dk next to this Report.

2. Scenario 0

The purpose of this scenario is to establish the range of reliable coverage of coastal waters by land-based GSM networks. The assumptions are based on a single base station situated on the coastline. The parameters are given in the Table A1.1 prior to the results.

	900	1800	MHz
GSM BS PSD	43	43	dBm/200 kHz
BS maximum transmitting antenna gain	15	18	dBi
MS receiving antenna gain	0	0	dBi
MS sensitivity (typical operator value)	-105	-105	dBm/200 kHz
Propagation loss required	163	166	dB
Corresponding distance (using the P.1546-2 model)			
Delta_f	3,52	-0,92	dB
Delta_p	4,10	1,10	dB
Delta_h2	0,00	0,00	dB
E_corr	31,86	39,32	dB(µV/m)
Distance	60	40	km

Table A1.1: Coverage of a l-BS over the coastal waters

The Free Space Loss model was not used in scenario, as the model is not to be appropriate for a non-line of sight situation (the curvature of the earth is not taken into account in the model). Therefore, the Recommendation ITU-R P.1546-2, which is more appropriate in this particular scenario, was used.
It should be noted that GSM systems are designed for a maximum distance of 35 km (70 km in some extended range versions) due to the effect of round-trip delay on GSM TDMA timing.

However, to establish a relationship between the distances of table A1.1 and the GSM coverage over the sea, the link back from the mobile station and the base station should be taken into account:

	900	1800	MHz
GSM MS PSD	33	33	dBm/200 kHz
MS transmitting antenna gain	0	0	dBi
BS maximum receiving antenna gain	15	18	dBi
BS sensitivity (typical operator value)	-108	-108	dBm/200 kHz
Propagation loss required	156	159	dB
d(using the P.1546-2 model)			
Delta_f	3.52	-0.92	dB
Delta_p	14.10	11.10	dB
Delta_h2	0.00	0.00	dB
E_corr	38.86	46.32	dB(µV/m)
d(using the P.1546-2 model)	50	35	km

Table A1.2: Capability of a l-MS (situated on the sea) to connect to a l-BS

Tables A1.1 and A1.2 show that the coverage area by l-BS could extend up to several tens of km for outdoor terminals, if impact of intra-system noise is not considered.

It should also be noted that the results of table A1.1 takes into account the maximum gain of the l-BS antenna.
Considering an antenna pattern based on the Recommendation ITU-R F.1336-2, see Fig. A1.1, the results vary with respect to the considered azimuth, as given in table A1.3.

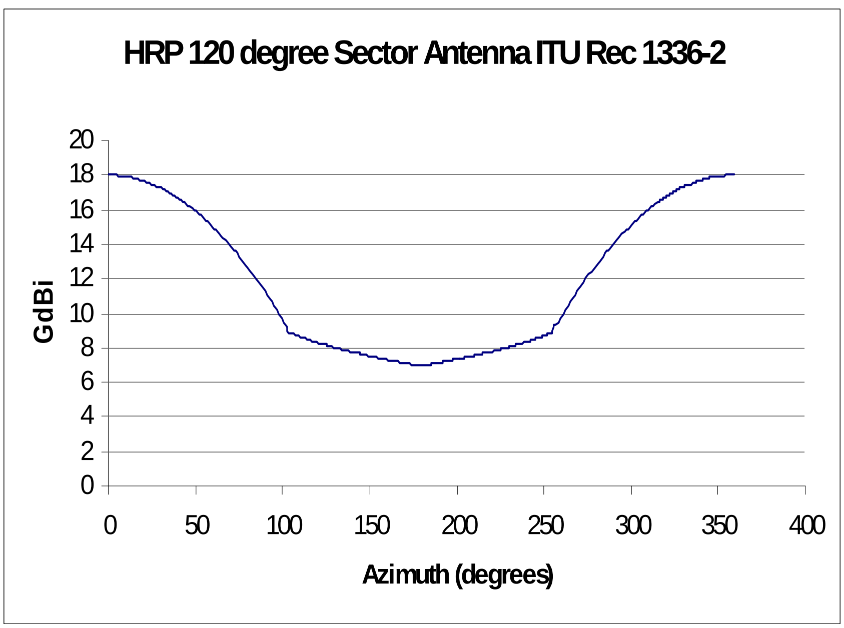


Figure A1.1: Antenna pattern of a GSM base station (Recommendation ITU-R F.1336-2)

The signal level, at various distances from the transmitter, is derived from the Recommendation ITU-R P.1546-2 (50% time curves). A sample of the power values (dBm/GSM channel) at various azimuths/distances from the land based BS is given in Table A1.3.

Azimuth\Distance	5 km	10 km	15 km	20 km
0 degrees	-51.8705	-58.9065	-64.6335	-70.6375
90	-58.6205	-65.6565	-71.3835	-77.3875
135	-62.0007	-69.0367	-74.7637	-80.7677
180	-62.9052	-69.9412	-75.6682	-81.6722

Table A1.3: Sample of power values received from land-based network at various azimuth/distances from l-BS

Taking into account a GSM receiver sensitivity of -105 dBm/200 kHz at 1800 MHz, as shown in section 4 of this report ("typical" operator values), it can be concluded that the coverage is ensured far beyond 20 km.

3. Scenario 1

This scenario assesses the impact of a v-MS on a l-BS.

The results of Table A1.4 are based on the assumption of section 4 of this report. The interference criterion is C/I = 9 dB. The propagation losses have been calculated with the Recommendation ITU-R P.1546-2 (sea path, 50% time). The v-MS has been placed on the sundeck (L_{hull} = 0 dB) as well as inside the ship, assuming different attenuation for the hull (varying from 5 to 25 dB). The co-channel situation, as well as the adjacent channel situation, has been considered. However, if there is no dedicated mean specifically enforced to avoid the co-channel situation, only the co-channel results are relevant.

Distances depending on the L_{hull} (Attenuation of the hull)				
F	**1800**		**900**	
L_{hull} = 0 dB (mobile station situated on the sundeck)				
d , Sea 50 % time, co-channel	23 km	12.42 NM	28 km	15.12 NM
d , Sea 50 % time, 1st Adj.	6,5 km	3.51 NM	12 km	6.48 NM
d , Sea 50 % time, 2nd Adj.	2,3 km	1,24 NM	4 km	2.16 NM
L_{hull} = 5 dB				
d , Sea 50 % time Co-channel	18 km	9.72 NM	29 km	15.6 NM
d , Sea 50 % time 1st Adj.	3.6 km	1.94 NM	12 km	6.48 NM
d , Sea 50 % time 2nd Adj.	1.36 km	0.73 NM	7 km	3.78 NM
L_{hull} = 10 dB				
d , Sea 50 % time Co-channel	15 km	8.10 NM	24 km	12.9 NM
d , Sea 50 % time 1st Adj.	2 km	1.08 NM	9 km	4.86 NM
d , Sea 50 % time 2nd Adj.	-	-	4,2 km	2.27 NM
L_{hull} = 15 dB				
d , Sea 50 % time Co-channel	8 km	4.32 NM	17 km	9.18 NM
d , Sea 50 % time 1st Adj.	1.3 km	0.70 NM	6.5 km	3.51 NM
d , Sea 50 % time 2nd Adj.	-	-	2.6 km	1.40 NM
L_{hull} = 20 dB				
d , Sea 50 % time Co-channel	5.2 km	2.81 NM	15 km	8.09 NM
d , Sea 50 % time 1st Adj.	-	-	4 km	2.15 NM
d , Sea 50 % time 2nd Adj.	-	-	1.4 km	0.75 NM
L_{hull} = 25 dB				
d , Sea 50 % time Co-channel	2.8 km	1.51 NM	11 km	5.94 NM
d , Sea 50 % time 1st Adj.	-	-	2.2 km	1.19 NM
d , Sea 50 % time 2nd Adj.	-	-	-	-

Table A1.4: Calculated distances to comply with the interference criterion (C/I = 9 dB) in Scenario 1

Another way of showing the impact of a v-MS (on the sundeck, i.e. L_{hull} =0 dB) on a l-BS is to place the vessel at 12 nautical miles and assess the area in which the interference criterion is not satisfied. For that purpose, the parameters of section 4 have been considered together with an interference criterion (I/N) of -6 dB, as well as the Recommendation ITU-R P.1546-2 associated with a real terrain data model. Figure A1.2 shows the area in which the I/N exceeds -6 dB for GSM 1800; it has to be noted that this criterion is exceeded even in land up to 2.3 km.

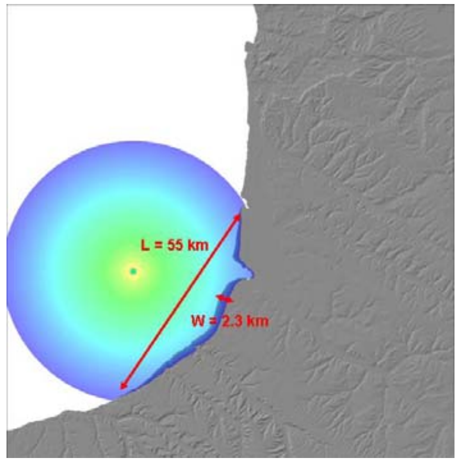


Figure A1.2: Area in which the I/N from v-MS exceeds -6 dB (Calculated for GSM 1800 with a typical noise level)

Table A1.5 extends this result to the standard noise level as well as for GSM900:

	Distance of the vessel to the coast with 32.5° directivity similar to a 3 dB attenuation	
	12 NM	
Interference area for the typical protection level of GSM 1800 BS	W = 2.3 km	L = 55 km
Interference area for the standard protection level of GSM 1800 BS	W = 1.4 km	L = 47 km
Interference area for the typical protection level of GSM 900 BS	W = 6.8 km	L = 86 km
Interference area for the standard protection level of GSM 900 BS	W = 4.7 km	L = 74 km

Table A1.5: Size of the area in which the I/N exceeds -6 dB

The table A1.5 clearly shows that a l-BS is interfered by a v-MS situated of a sundeck of a vessel, even if the vessel is placed at 12 nautical miles. However it should be noted that this analysis did not consider the possible actual level of intra-system noise in the land-based network.

4. Scenario 2

This scenario assesses the interferences from a v-BS to l-MS. It can be a l-MS situated deeper in-land (however, the proposed propagation models may not be applicable), as well as on the shore or on the sea (fisherman or sailor on a boat for instance). The technical parameters are those based on section 4. Different hull attenuation values have been considered. The calculations were conducted for GSM 900 as well as for GSM 1800. The interference criterion is a C/I of 9 dB.

v-BS power	dBm/200 kHz	-6											
v-BS Maximum antenna gain	dBi	2											
g-MS antenna gain	dBi	0											
MS sensitivity (typical operator value)	dBm/200 kHz	-105											
C/I	dB	9											
Maximum interference	dBm/200 kHz	-114											
Frequency	MHz	900	1800	900	1800	900	1800	900	1800	900	1800	900	1800
Hull attenuation	dB	0	0	5	5	10	10	15	15	20	20	25	25
Propagation loss required	dB	110	110	105	105	100	100	95	95	90	90	85	85
Corresponding distance (using the Free Space Loss model)													
Distance	km	8.4	4.2	4.7	2.4	2.7	1.3	1.5	0.7	0.8	0.4	0.5	0.2
Corresponding distance (using the P.1546-2 model)													
Delta_f	dB	3.5	-0.9	3.5	-0.9	3.5	-0.9	3.5	-0.9	3.5	-0.9	3.5	-0.9
Delta_p	dB	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1
Delta_h2	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E_corr	dB(µV/m)	84.9	95.3	89.9	100.3	94.9	105.3	99.9	110.3	104.9	115.3	109.9	120.3
Distance	km	5.0	4.0	4.0	2.0	2.7	1.3	1.5	0.7	0.8	0.4	0.5	0.2

Table A1.6: Calculated distances to comply with the interference criterion (C/I = 9 dB) for Scenario 2

5. Scenario 3

This scenario assesses the possibility for a l-MS to connect unintentionally to the v-BS. The same parameters and criterion as those of scenario 2 have been used. Results are given in Table A1.7.

For example of how to interpret these results, it may be suggested that in order to avoid any unwanted roaming of a l-MS on a GSMOBV cell, a minimum separation distance of 0.3 km together with a hull attenuation of 20 dB has to be respected at 900 MHz.

v-BS power	dBm/200 kHz	-6											
v-BS Maximum antenna gain	dBi	2											
g-MS antenna gain	dBi	0											
MS sensitivity (typical operator value)	dBm/200 kHz	-105											
Frequency	MHz	900	1800	900	1800	900	1800	900	1800	900	1800	900	1800
Hull attenuation	dB	0	0	5	5	10	10	15	15	20	20	25	25
Propagation loss required	dB	101	101	96	96	91	91	86	86	81	81	76	76
Corresponding distance (using the Free Space Loss model)													
Distance	km	3.0	1.5	1.7	0.8	0.9	0.5	0.5	0.3	0.3	0.1	0.2	0.1
Corresponding distance (using the P.1546-2 model)													
Delta_f	dB	3.5	-0.9	3.5	-0.9	3.5	-0.9	3.5	-0.9	3.5	-0.9	3.5	-0.9
Delta_p	dB	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1	66.1
Delta_h2	dB	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
E_corr	dB(µV/m)	93.9	104.3	98.9	109.3	103.9	114.3	108.9	119.3	113.9	124.3	118.9	129.3
Distance	km	3.0	1.5	1.7	0.8	0.9	0.5	0.5	0.3	0.3	0.1	0.2	0.1

Table A1.7: Minimum separation distances to avoid any unwanted roaming of a l-MS on the GSMOBV cell

6. Scenario 4

This scenario assesses the interference from a v-BS to a mobile station situated on the vessel and connected to a land-based network. The propagation model used is the free space loss and the interference criterion is I/N = -6 dB.
Both GSM 1800 (Table A1.8) and GSM 900 (Table A1.9) have been taken into account. Both typical and standard noise floor have been considered. Also, a range of 0 to 25 dB has been taken for the hull attenuation.

The result shows some minimum separation distances to respect between the v-BS and the l-MS located on vessel but connected to the l-BS.

	Free space loss required for a typical receiver	Free space loss required for a standard receiver	Separation distance required	Separation distance required
	dB	dB	km	km
For l-MS et v-BS outdoor	116	111	5.2	2.9
For l-MS outdoor and v-BS indoor with 5 dB penetration loss	111	106	2.9	1.6
For l-MS outdoor and v-BS indoor with 10 dB penetration loss	106	101	1.6	0.9
For l-MS outdoor and v-BS indoor with 15 dB penetration loss	101	96	0.9	0.5
For l-MS outdoor and v-BS indoor with 25 dB penetration loss	91	86	0.291	0.164

Table A1.8: Minimum separation distances for Scenario 4 for GSM 1800

	Free space loss required for a typical receiver	Free space loss required for a standard receiver	Separation distance required	Separation distance required
	dB	dB	km	km
For l-MS et v-BS outdoor	116	111	10.1	5.7
For l-MS outdoor and v-BS indoor with 5 dB penetration loss	111	106	5.7	3.2
For l-MS outdoor and v-BS indoor with 10 dB penetration loss	106	101	3.2	1.8
For l-MS outdoor and v-BS indoor with 15 dB penetration loss	101	96	1.8	1.0
For l-MS outdoor and v-BS indoor with 25 dB penetration loss	91	86	0.568	0.320

Table A1.9: Minimum separation distances for Scenario 4 for GSM 900

Considering the two tables above, in order to avoid harmful interferences, there is a need to consider an attenuation of 25 dB between the v-BS and a l-MS on the deck as well as a separation distance of 164 m at 1800 MHz and 320 m at 900 MHz. It seems impossible to achieve those on the vast majority of vessels. However it should be noted that this analysis did not consider the possible actual level of intra-system noise in the land-based network.

7. Conclusion of the MCL calculations

All these MCL calculations show that the operation of GSMOBV needs to respect a large separation distances between GSMOBV equipments and land-based equipments. Those distances are not consistent with an operation within the territorial waters of a country, unless specific interference mitigating measures are taken, such as those listed in the conclusions of this report.

ANNEX 2: RESULTS OF SEAMCAT SIMULATIONS OF GSMOBV INTERFERENCE SCENARIOS

1. Introduction

This annex presents the results of SEAMCAT simulations addressing the various scenarios listed in the this report on GSMOBV for potential interference from ship-based GSM systems into land-based GSM systems.

The SEAMCAT files used for the calculations are available in a zip-file at the www.ero.dk next to this Report.

2. Scenario 0

The purpose of this scenario is to establish the range of reliable coverage of coastal waters by land-based GSM networks. The proposed methodology uses a notion that the coverage would be only limited by the inter-cell interference, i.e. interference signals emanating from nearby cells that use the same frequency (group) as the reference (victim) cell. The following analysis is based on assumption that the near-cost l-BS are positioned as elements of a standard cellular grid. The analysis considers only those l-BS stations that are:

- positioned at the very edge of the grid, created by cutting off the grid by coastal line; and,
- be part of the first two tiers of co-channel cells around the reference cell.

An outline of this scenario is shown below in Fig. A2.1. Note that only two neighbouring BSs on each side of the reference cell were considered because it was felt that the two nearest co-frequency cells would be contributing most to the inter-cell interference.

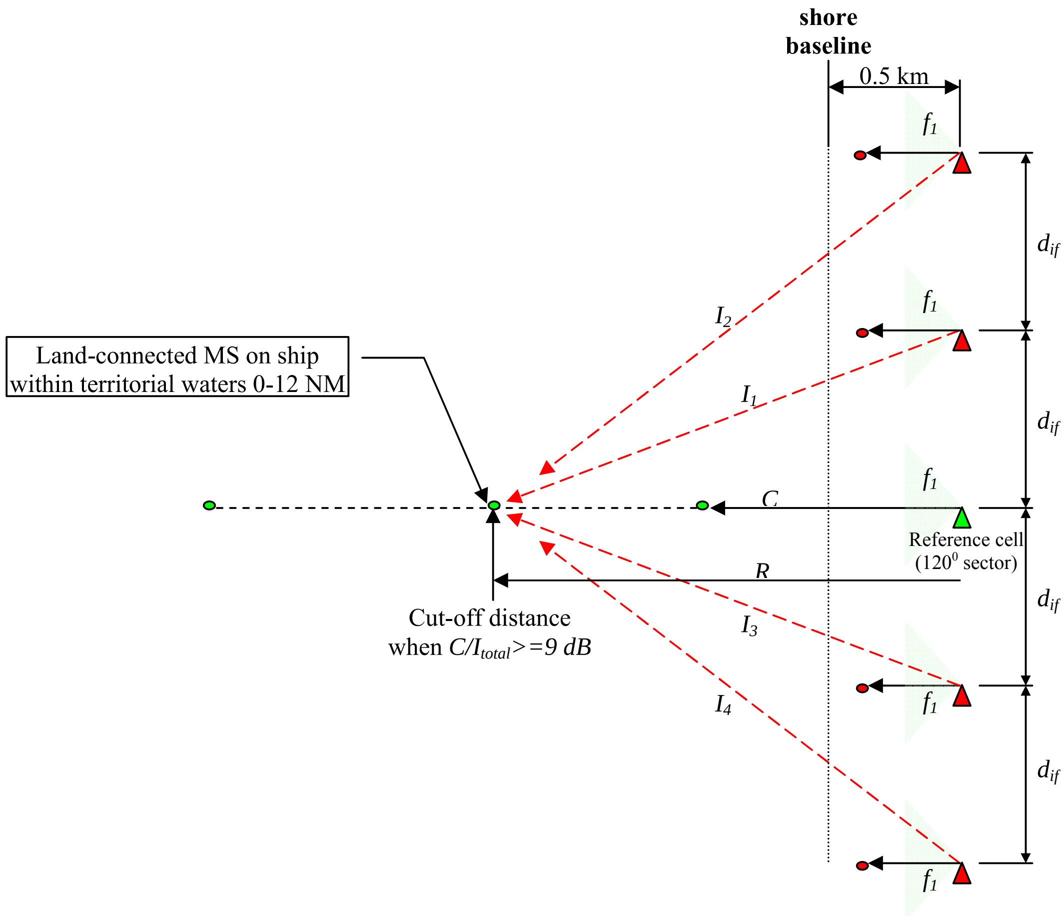


Figure A2.1: Outline of SEAMCAT simulation representing Scenario 0

In this Figure, d_{if} is the distance between cells using the same frequency f_1.

The following simplifications of the SEAMCAT scenario were made, representing the most favourable conditions for serving the coastal waters:

- directional antenna of l-BS looks directly towards the sea, placed at the reasonably short distance from shore, representing scenario of serving the "beach area";
- reference land-connected MS on ship is positioned along the main beam of servicing cell;
- rural deployment scenario on land was considered, corresponding to largest possible inter-cell distance;
- the propagation path loss within reference path (C) as well as on interference paths (Ii) was calculated using Free Space Model[9].

The cut-off distance (i.e. the range where an MS would loose the connection with serving l-BS) was calculated on downlink, assuming C/I=9 dB criterion, which corresponds to interference criterion used in other scenarios of this report[10]. However, differently than in other scenarios, only median C and I values were calculated (i.e. without fading variations introduced by the path loss model). This was done in order to account for the fact that the MS location algorithms used in GSM system for deciding on MS hand-over and disconnection would use averaging of signal strength and link quality measurements.

The above scenario was programmed into SEAMCAT and the resulting SEAMCAT scenario files are attached hereafter, for cases of GSM-900 and GSM-1800 MHz. However, due to the fact that in this scenario we need to establish the single cut-off distance rather than area-based probability factor, the static simulations were made for single R values one at a time, until the cut-off distance was discovered. It therefore may be concluded, that the same results should be obtained by performing an MCL check for the same scenario configuration.

In accordance with assumption of rural area deployment, the distance between co-frequency cell was derived from considering two inter-cell distances of 10 km and 15 km and frequency re-use scheme 7/21, i.e. leading to assumption of the same frequency being deployed in every second cell, thus giving d_{if}=20 and 30 km.

Simulating this scenario in SEAMCAT returned the following results, as shown in Tables A2.1 and A2.2.

***R*, km**	**900 MHz**			**1800 MHz**		
	Mean *C*, dBm	Mean *I*, dBm	*C/I*, dB	Mean *C*, dBm	Mean *I*, dBm	*C/I*, dB
3	-43.4	-55.4	12	-49.1	-61.1	12
4	**-45.9**	**-54.9**	**9**	**-51.6**	**-60.7**	**9.1**
5	-47.8	-54.6	6.8	-53.6	-60.3	6.7

Table A2.1: Results of SEAMCAT simulations for relative *C* and *I* strength at various *R* and d_{if}=20 km

***R*, km**	**900 MHz**			**1800 MHz**		
	Mean *C*, dBm	Mean *I*, dBm	*C/I*, dB	Mean *C*, dBm	Mean *I*, dBm	*C/I*, dB
3	-43.4	-59.5	16.1	-49.1	-65.2	16.1
4	-45.9	-59.1	13.2	-51.6	-64.8	13.2
5	-47.8	-58.8	11	-53.6	-64.5	10.9
6	**-49.4**	**-58.5**	**9.1**	**-55.1**	**-64.2**	**9.1**
7	-50.8	-58.2	7.4	-56.5	-63.9	7.4

Table A2.2: Results of SEAMCAT simulations for relative *C* and *I* strength at various *R* and d_{if}=30 km

In conclusion, it may be noted that the coverage distance of land GSM networks with theoretical 5-7.5 km cell radius would be in the order of 4-6 km into coastal waters, at which distance the C/I criterion becomes equal to 9 dB due to effect of interference-limited network.

[9] It was previously agreed to use the sea-path option of the ITU-R Recommendation P.1546 for interference path simulations, however P.1546 implemented in SEAMCAT does not have sea path option, therefore it was decided to use Free Space (FS) model because (a) for transmitter antenna height of 30 m the propagation curves of FS and P.1546 are anyway the same until around 5 km, and (b) for distances greater than 5 km the FS model would provide the pessimistic estimate of the probability of interference.

[10] The criterion used in other scenarios is *C/(N+I)*, however in this scenario the *N* contribution could be disregarded as insignificant

The coverage of 4-6 km in coastal waters may appear rather small compared with land-based coverage by the same cells, it could be explained by the impact of favourable propagation conditions over the seas, which carry equally well the wanted and interfering signals.

3. Scenario 1

This scenario describes the possibility that the v-MS is interfering into victim l-BS receiver (uplink). The possible outline of how this might be programmed in SEAMCAT is as shown below in Fig. A2.2:

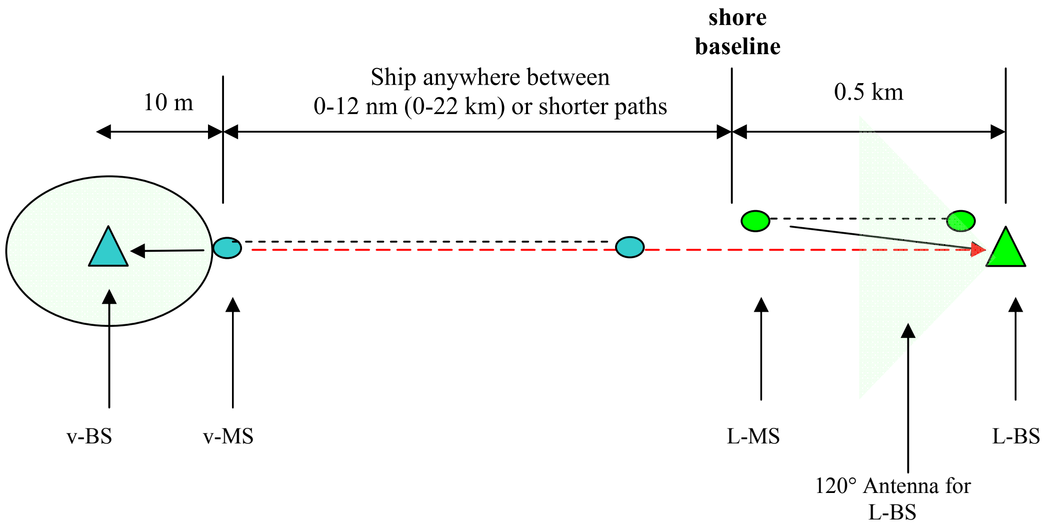


Figure A2.2: Outline of SEAMCAT simulation representing Scenario 1

The corresponding SEAMCAT terms for those used in Figure A2.2 are given below:

Casual Term	SEAMCAT Term
v-BS	Wanted Rx
v-MS	Interfering Tx
L-MS	Wanted Tx
L-BS	Victim Rx

The following simplifications of the SEAMCAT scenario were made, representing the worst-case assumptions:

- victim l-BS antenna looks towards the sea (hence towards the interfering v-MS), placed at the reasonably short distance from shore, representing scenario of serving the "beach area";
- no frequency hopping was assumed for interfered channel of l-BS, e.g. representing the worst case of static BCCH channel; in GSM network
- ship is located along the straight line normal to shore (e.g. as if heading straight to harbour), heading directly into victim l-BS;
- the v-MS was assigned the maximum transmit power of 0 dBm for GSM-1800 and 5 dBm for GSM-900, assuming Power Control was used to set the MS power to minimum;
- the propagation path loss within victim link (l-MS to l-BS) was calculated using Hata model, while the interfering link (v-MS to l-BS) was calculated using the Free Space Model (see footnote[1] in Scenario 0 for the choice of propagation model).

As a possible option of employing some mitigation factor, the scenario assumed that GSMOBV might be required to employ Frequency Hopping (synthesized FH[11], standard feature in modern GSM systems) for carrying the v-MS traffic. I.e. a v-MS would only send an initial call request over BCCH and after initiating the call the traffic would be immediately switched to the second transceiver using frequency hopping group of traffic channels. It was stated that it

[11] Synthesized FH means that one physical transmitter is used, the operating frequency of which is changed with each transmitted TDMA frame. The other, less-used FH mode is a rigid "base-band FH" where transmission is switched between separate transmitters each tuned to different frequency.

would be feasible to implement GSMOBV hopping over up to 64 channels. The attached SEAMCAT scenario for simplicity assumes hopping group of either 32 or 64 consecutively adjacent channels, however in reality the hopping group may be spread evenly over the entire GSM band, e.g. by using every second channel or so. It was assumed that the GSMOBV system was designed in order to support all communication on the frequency hopping transceivers, or that new communication would not be feasible when all the time slot of the Frequency Hopping transceiver are fully used.

It was also assumed that v-MS has activated Discontinuous Transmission (DTX) function. The simulations provided below have assumed DTX voice activity factor of 0.4.

The above scenario was programmed into SEAMCAT and the resulting SEAMCAT scenario files are attached hereafter, for cases of GSM 900 and GSM 1800 MHz.

Simulating this scenarios in SEAMCAT and applying interference probability check using C/(N+I)=9 dB criteria, returns the following results shown in Table A2.3.

	900 MHz	**900 MHz**	**1800 MHz**	**1800 MHz**
	no DTX	DTX enabled	no DTX	DTX enabled
Probability of interference from one v_MS transmitter (without FH)	11.3%	4.6%	8.5%	3.3%
Probability of interference from one v_MS transmitter with synthesized FH over 32 channels	0.6%	0.3%	0.5%	0.2%
Probability of interference from one v_MS transmitter with synthesized FH over 64 channels	0.3%	0.1%	0.2%	0.1%

Table A2.3: Results of SEAMCAT simulations for probability of interference from v-MS Tx to L-BS Rx, when GSMOBV equipped ship is randomly located anywhere within 0-12 NM

In accordance with the above scenario settings, these results could be interpreted as probability of interference from v-MS Tx into l-BS Rx when GSMOBV-equipped ship operates anywhere within territorial sea. Comparison of results without FH and with FH in Table A2.3 clearly demonstrates that without mitigation factor such as FH, the probability of interference would be unacceptably high unless some minimum protection distance to shore was considered. Results obtained for the case with FH activated prove that FH provides the significant reduction of interference probability. Regarding the choice of number of channels in frequency hopping pool, results in Table A2.3 demonstrate that hopping over 64 channels improves the probability of interference by a factor of 2 or more, therefore 64 channels hopping raster should be recommended as a minimum option.

However, it is also necessary to consider cases when the ship may be located near the coast and l-BS for considerable periods of time, e.g. in the initial phases of departing from port or when slowly navigating into the port on arrival. Therefore the above study was complemented by studying the sub-cases with restricted ship movement areas. The results of SEAMCAT simulations for ship/GSMOBV moving within reduced path segments is provided below in Tables A2.4 (for cases without FH) and A2.6 (for cases with FH employed).

Distance from shore	GSM 900MHz		GSM 1800MHz	
	no DTX	DTX	no DTX	DTX
0-1 NM	54.8%	22.4%	51.4%	20.3%
1-2 NM	28.9%	11.5%	24.6%	9.9%
2-3 NM	19.1%	7.6%	15.5%	6.2%
3-4 NM	13.5%	5.3%	10.5%	4.2%
4-5 NM	10.0%	4.1%	7.5%	3.0%
5-6 NM	7.7%	3.2%	5.8%	2.5%
6-7 NM	6.0%	2.4%	4.8%	1.9%
7-8 NM	5.4%	2.0%	3.8%	1.4%
8-9 NM	4.4%	1.7%	3.0%	1.2%
9-10 NM	3.4%	1.5%	2.6%	1.0%
10-11 NM	3.0%	1.0%	2.0%	0.9%
11-12 NM	2.5%	1.0%	1.8%	0.7%

Table A2.4: Probability of interference from v-MS Tx to l-BS Rx without FH, when GSMOBV ship is randomly located within restricted path segments near the coast

As may be seen from the Tables A2.3 and A2.4 above, the use of the DTX function at v-MS provides a significant reduction of the interference potential, therefore the DTX function should be considered a must for a GSMOBV uplink and was implemented in all remaining simulations.

The following tables show the results for various ship hull attenuation factors.

	Probability of Interference with land BS with 5 dB ship hull attenuation			
Distance from shore	**GSM 900MHz**		**GSM 1800MHz**	
	Without DTX	**With DTX**	**Without DTX**	**With DTX**
0-1NM	**43.9%**	**17.9%**	**40.1%**	**16.1%**
1-2NM	**18.0%**	**7.0%**	**15.1%**	**5.9%**
2-3NM	**10.4%**	**4.0%**	**8.1%**	**3.2%**
3-4NM	**6.3%**	**2.5%**	**5.0%**	**2.0%**
4-5NM	**4.7%**	**1.8%**	**3.3%**	**1.2%**
	Probability of Interference with land BS with 10 dB ship hull attenuation			
Distance from shore	**GSM 900MHz**		**GSM 1800MHz**	
	Without DTX	**With DTX**	**Without DTX**	**With DTX**
0-1NM	33.5%	13.2%	29.8%	11.6%
1-2NM	9.7%	3.9%	7.7%	2.9%
2-3NM	4.8%	1.8%	3.7%	1.4%
3-4NM	2.7%	1.1%	2.0%	0.6%
4-5NM	1.8%	0.7%	1.2%	0.5%
	Probability of Interference with land BS with 20dB ship hull attenuation			
Distance from shore	**GSM 900MHz**		**GSM 1800MHz**	
	Without DTX	**With DTX**	**Without DTX**	**With DTX**
0-1NM	15.3%	6.0%	13.1%	5.0%
1-2NM	2.1%	0.7%	1.1%	0.5%
2-3NM	0.6%	0.3%	0.3%	0.1%
3-4NM	0.3%	0.1%	0.1%	0.08%
4-5NM	0.1%	0.04%	0.1%	0.02%

Table A2.5: Probability of interference from v-MS Tx to l-BS Rx without FH and with different ship hull attenuation, when GSMOBVship is randomly located within restricted path segments near the coast

The results show that attenuation of the v-MS signal from the vessel significantly reduces the probability of interference with the l-BS.

Probability of interference (with FH over 17, 32 and 64 channels and DTX enabled at v-MS), when GSMOBV moves within following distance from shore	900 MHz			1800 MHz		
	FH 64 channels	FH 32 channels	FH 17 channels	FH 64 channels	FH 32 channels	FH 17 channels
0-1 NM	0.5%	1.1%	2.15%	0.4%	0.9%	1.6%
1-2 NM	0.3%	0.5%	1.2%	0.2%	0.5%	0.9%
2-3 NM	0.2%	0.3%	0.8%	0.2%	0.3%	0.6%
3-4 NM	0.1%	0.3%	0.6%	0.1%	0.2%	0.3%
4-5 NM	0.1%	0.2%	0.4%	0.1%	0.1%	0.3%

Table A2.6: Results of SEAMCAT simulations for probability of interference from v-MS Tx to L-BS Rx, when GSMOBV ship is randomly located within restricted path segments near the coast

Analysing results of simulations provided in Table A2.6, it may be concluded that using GSMOBV with FH allows achieving reasonably low probability of interference even on approach paths near the coast. It should be also noted that in reality the probability of interference should be further lowered due to additional mitigation factors not considered in above studies:

- interference mitigation effect due to attenuation of v-MS signals by ship hull attenuation. Limiting the v-MS usage to indoor location inside the ship may be obtained by employing the DRC mechanismoption as described in section 8 in this report,
- propagation over sea path being worse than Free Space Loss modelled above, for distance greater than 5 km
- use of synthesized FH for traffic channel at the victim l-BS. However, the BCCH remain always static channel, and FH is not always available depending on the amount of spectrum allocated to the land base operator.

It has to be noted though that the above results correspond to a v-BS architecture containing only one TCH (which means a maximum of 8 simultaneous communications or 16 in case of using half-rate AMR codecs). As it is likely that such architecture is under-dimensioned for a scenario involving GSMOBV deployment on a large cruise ship, the following Tables A2.7-9 give the results corresponding to the use of several TCH. The following results are given for two, three and four TCH (BCCH excluded).

Probability of interference (with FH over 17, 32 and 64 channels and DTX enabled at v-MS), when GSMOBV moves within following distance from shore	900 MHz			1800 MHz		
	FH 64 channels	FH 32 channels	FH 17 channels	FH 64 channels	FH 32 channels	FH 17 channels
0-1 NM	0.9%	2.1%	4.0%	0.9%	1.6%	3.1%
1-2 NM	0.5%	1.2%	2.1%	0.5%	1.0%	1.5%
2-3 NM	0.3%	0.7%	1.4%	0.3%	0.6%	1.1%
3-4 NM	0.3%	0.5%	1.0%	0.2%	0.3%	0.8%
4-5 NM	0.2%	0.3%	0.7%	0.2%	0.3%	0.5%

Table A2.7: Results of SEAMCAT simulations for probability of interference from v-MS Tx to L-BS Rx, when GSMOBV ship is randomly located within restricted path segments near the coast FOR TWO TCH

Probability of interference (with FH over 17, 32 and 64 channels and DTX enabled at v-MS), when GSMOBV moves within following distance from shore	**900 MHz**			**1800 MHz**		
	FH 64 channels	**FH 32 channels**	**FH 17 channels**	**FH 64 channels**	**FH 32 channels**	**FH 17 channels**
0-1 NM	1.4%	3.1%	6.0%	1.5%	2.8%	5.3%
1-2 NM	0.9%	1.7%	3.1%	0.7%	1.3%	2.4%
2-3 NM	0.5%	1.2%	2.1%	0.5%	0.8%	1.6%
3-4 NM	0.4%	0.7%	1.5%	0.3%	0.5%	1.1%
4-5 NM	0.3%	0.5%	1.2%	0.2%	0.4%	0.8%

TableA2.8: Results of SEAMCAT simulations for probability of interference from v-MS Tx to L-BS Rx, when GSMOBV ship is randomly located within restricted path segments near the coast FOR THREE TCH

Probability of interference (with FH over 17, 32 and 64 channels and DTX enabled at v-MS), when GSMOBV moves within following distance from shore	**900 MHz**			**1800 MHz**		
	FH 64 channels	**FH 32 channels**	**FH 17 channels**	**FH 64 channels**	**FH 32 channels**	**FH 17 channels**
0-1 NM	2.1%	3.8%	7.8%	1.9%	3.4%	6.6%
1-2 NM	1.1%	2.3%	4.0%	0.9%	1.8%	3.4%
2-3 NM	0.7%	1.4%	2.7%	0.6%	1.2%	2.3%
3-4 NM	0.4%	1.0%	2.0%	0.4%	0.8%	1.4%
4-5 NM	0.3%	0.8%	1.5%	0.2%	0.6%	1.0%

TableA2.9: Results of SEAMCAT simulations for probability of interference from v-MS Tx to L-BS Rx, when GSMOBV ship is randomly located within restricted path segments near the coast FOR FOUR TCH

Analyzing results provided in Tables A2.7-9, it may be noted that if the option of FH with 64 channels was employed and some minimum separation distance from shore was assumed (e.g. 1 NM), the probability of interference would still remain reasonably low even when up to 4 TCH transmitters were used by GSMOBV.

However, the initial estimates by GSMOBV operators indicated that it is unlikely that more than two TCH transmitters (BCCH excluded) would be needed for GSMOBV installations, even those serving large cruise ships. This is because it is intended to use GSMOBV configured with half-rate AMR voice codecs, which allows placing up to 32 simultaneous voice communications in two physical TCH channels.

4. Scenario 2

In this scenario the v-BS is interfering into victim l-MS receiver (downlink). The possible outline of how this might be programmed in SEAMCAT is as shown below in Fig. A2.3, which is broadly similar to the set-up used for Scenario 1, but with exchanged interferer and victim assignment:

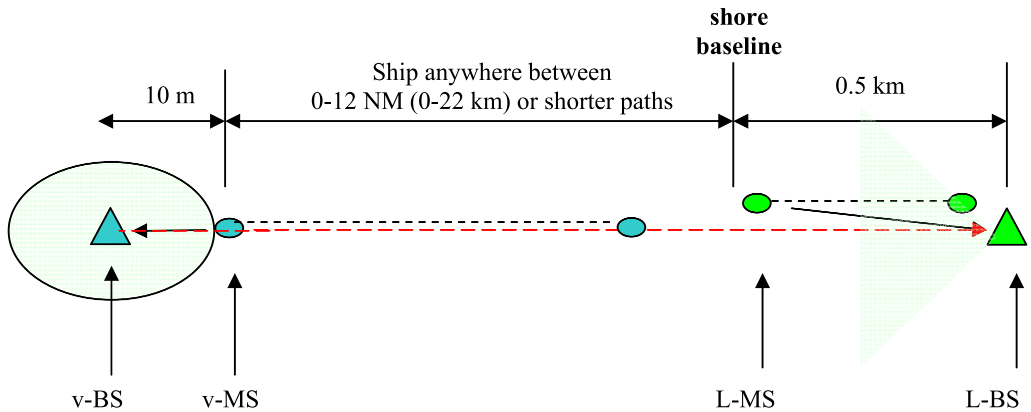


Figure A2.3: Outline of SEAMCAT simulation representing Scenario 2

The corresponding SEAMCAT terms for those used in Figure A2.3 are given below:

Casual Term	SEAMCAT Term
v-BS	Interfering Tx
v-MS	Wanted Rx
L-MS	Victim Rx
L-BS	Wanted Tx

The following simplifications of the SEAMCAT scenario were made, representing the worst-case assumptions:

- victim l-MS (with non-directional antenna) is positioned randomly near the shore, within the service area of seaward looking l-BS (distance of 0.5 km);
- no frequency hopping was assumed at victim receiver l-MS, e.g. representing a realistic case of receiver listening to static BCCH or TCHchannel;
- ship is located along the straight line normal to shore (e.g. as if heading straight to harbour), heading directly into victim system's service area;
- zero hull penetration loss was assumed for the v-BS emissions, to cater for worst case scenario of e.g. installing v-BS behind (retractable) glass walls in an upper deck restaurant, etc.;
- neither Power Control nor Frequency Hopping were employed at the interfering v-BS transmitter;
- it was assumed that v-BS transmitter is fully loaded with traffic, i.e. all eight time slots of TCH channel are used. This would correspond to 7-8 Erl loading of v-BS transceiver (or more if half rate AMR codecs are used),;
- the propagation path loss within victim link (l-MS to l-BS) was calculated using Hata model, while the interfering link (v-BS to l-MS) was calculated using Free Space model[1].

Note that regarding the installation of v-BS on a ship, it was assumed that a v-BS antenna was installed with input power (-6 dBm) and gain (2 dBi) as specified in Table 2 of Section 4.

The above scenario was programmed into SEAMCAT and the resulting SEAMCAT scenario files are attached hereafter, for cases of GSM 900 and GSM 1800 MHz.

Simulating this scenarios in SEAMCAT and applying interference probability check using C/(N+I)=9 dB criteria, returns the following results shown in Table A2.10.

GSMOBV distance to shore	900 MHz	1800 MHz
0-12 NM	0.02 %	0.04 %
0-1 NM	0.50 %	1.1 %
1-2 NM	0.05 %	0.1 %

Table A2.10: Results of SEAMCAT simulations for probability of interference from sea-BS Tx to land-MS Rx (0-12 NM distance to shore)

Note that the probability of interference is higher in 1800 MHz band due to the fact that in 900 MHz more powerful l-MS generate better C (carrier power) statistics at the victim receiver, therefore I (interference power) contribution from v-BS has lesser impact. The difference in path loss between the two bands is not that significant when using Free Space model assumed in these simulations.

It may be seen from the Table A2.10 that the probability of interference will be reasonably low in all cases, especially if some minimum separation distance (e.g. 1 NM) may be assumed. Note that the real probability of interference may be further reduced thanks to significant ship hull attenuation that would be typical for most v-BS installations, and also due to real traffic loading of the v-BS, that may be less than the maximum loading assumed above.

5. Scenario 4

In this scenario v-BS is interfering into victim l-MS receiver located aboard the GSMOBV equipped ship. The possible outline of how this might be programmed in SEAMCAT is as shown below in Fig. A2.4:

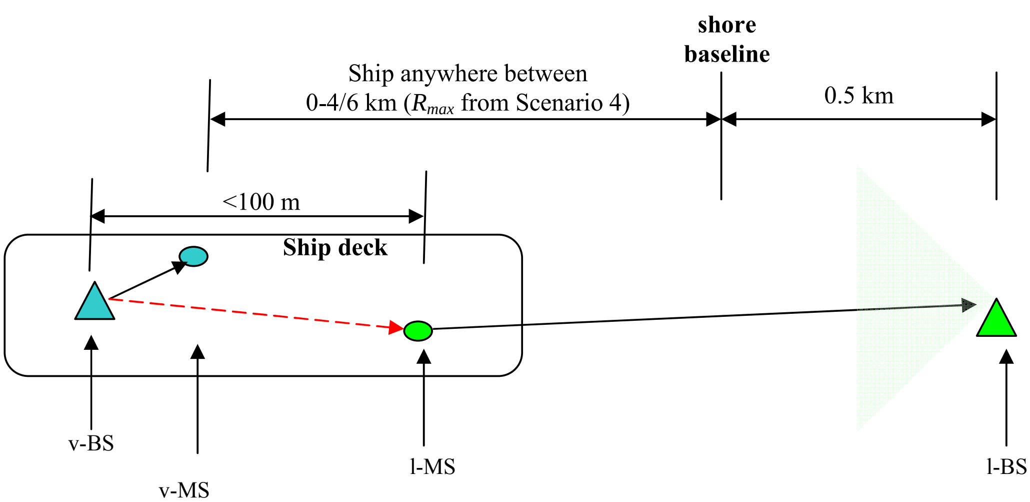


Fig. A2.4: Outline of SEAMCAT simulation scenario representing Scenario 4

The corresponding SEAMCAT terms for those used in Figure A2.4 are given below:

Casual Term	SEAMCAT Term
v-BS	Interfering Tx
v-MS	Wanted Rx
L-MS	Victim Rx
L-BS	Wanted Tx

The following simplifications of the SEAMCAT scenario were made, representing the worst-case assumptions:

- victim l-MS (with non-directional antenna) is positioned randomly on the ship deck, within 100 m of the GSMOBV v-BS;
- no frequency hopping was assumed at victim receiver l-MS, e.g. representing a realistic case of MS receiving static BCCH or TCH channel;

- ship is located along the straight line normal to shore (e.g. as if heading straight to harbor), with the maximum distances of 4 km (**d_{if}=20 km)** and 6 km (**d_{if}=30 km)**, which corresponds to the maximum service area distances calculated in Scenario 0;
- neither Power Control nor Frequency Hopping were employed at the interfering transmitter;
- the propagation path loss within interference link was calculated using Hata-SRD model, which should be suitable for predicting path loss on short range cluttered deck environment. The victim link over sea was calculated using Free Space model, following the same logic as for sea paths in previous scenarios.

Note that the power and antenna settings for v-BS were set in the same manner as described in Scenario 2.

The above scenario was programmed into SEAMCAT and the resulting SEAMCAT scenario files are attached hereafter, for cases of GSM-900 and GSM-1800 MHz.

Simulating this scenarios in SEAMCAT and applying interference probability check using C/(N+I)=9 dB criteria, returns the following results shown in Table A2.11.

	maximum distance (km)	**900 MHz**	**1800 MHz**
Probability of interference (C/N+I=9 dB)	4	21.3 %	19.2 %
Probability of interference (C/N+I=9 dB)	6	28.13 %	25.87 %

Table A2.11: Results of SEAMCAT simulations for probability of interference from v-BS to l-MS located on ship

The results reported in Table A2.11 indicate the significant level of interference, which appears natural for such short range between interferer and victim, both confined on a single ship. Therefore, it would be absolutely necessary to employ an additional mitigation technique on the GSMOBV, such as the Frequency Hopping proposed in Scenario 1 or attenuation of v-BS signals by ship hull and walls. Impact of those two mitigation factors was studied by additional simulations, reported below in Tables A2.12-13.

	maximum distance (km)	**900 MHz**	**1800 MHz**
Probability of interference with FH-32 ch	4	1.2 %	1.0 %
	6	1.5 %	1.3 %
Probability of interference with FH-64 ch	4	0.6 %	0.5 %
	6	0.8 %	0.7 %

Table A2.12: Results of SEAMCAT simulations for probability of interference from v-BS to l-MS located on ship when FH is employed

	maximum distance (km)	**900 MHz**	**1800 MHz**
Probability of interference with ship hull attenuation of 5 dB	4	12.1 %	11.1 %
	6	18.4 %	16.5 %
Probability of interference with ship hull attenuation of 10 dB	4	5.9 %	5.5 %
	6	10.0 %	8.8 %
Probability of interference with ship hull attenuation of 15 dB	4	2.5 %	2.1 %
	6	4.6 %	3.9 %
Probability of interference with ship hull attenuation of 20 dB	4	1.0 %	0.8 %
	6	1.7 %	1.6 %
Probability of interference with ship hull attenuation of 25 dB	4	0.3 %	0.2 %
	6	0.7 %	0.6 %

Table A2.13: Results of SEAMCAT simulations for probability of interference from v-BS to l-MS located on ship when certain ship hull attenuation of v-BS signal

When FH is employed at v-BS, the only additional interference potential would come in case of co-channel collision with the single static BCCH channel employed at v-BS, but considering the total available number of channels in the bands, probability of such collision would be just 1/124 for GSM-900 and 1/374 for GSM-1800.

It may be further noted that in reality, even if the case of co-frequency collision occurs, both GSM land and ship systems shall react in order to cure the situation:

- the l-MS would sense deterioration of signal quality and would either:
    - if it were in passive (listening mode) – it would camp on another BCCH if one is available (e.g. the one from neighboring cell on land, that would use the different set of channels), or
    - if it were in active mode, i.e. with call taking place, the system would also hand the call over to a neighboring cell (if one is available);
- the GSMOBV and its served v-MS would receive even more interference from land GSM system than other way around - note that the above statistics also mean that in ca. 70-80% of cases the signal from l-BS will be more than 9 dB above the signal from v-BS, thus rendering the communication between v-BS and v-MS impossible.

ANNEX 3: RESULTS OF SEAMCAT SIMULATIONS OF GSMOBV INTERFERENCE TO UMTS-900/1800

1. Introduction

This Annex presents the results of simulations addressing the various scenarios established in this report to analyze potential interference from GSMOBV into future land-based UMTS-900/1800 systems.

Parameters of modeled land-based UMTS systems were established in accordance with the main parameters set out in Table 2. In addition to those, several other secondary yet important parameters needed for SEAMCAT simulations were assumed as follows:

Parameter	Value
Voice activity factor (DTX)	0.4
Voice bitrate	12.2 kbps (Note 1)
Link Level Data sets	W-CDMA 1 % FER
Target network noise rise for CDMA Uplink	6 dB
UMTS BS' adjacent channel selectivity/blocking rejection	68 dB (Note 2)
UMTS cell radius	5 km (Note 3)
Cell type	3-sector, 3GPP 120^o antenna
Initial UMTS capacity, MS per sector (Note 4)	44– Uplink (Scenario 1) 53 – Downlink (Scenario 2)
Propagation model for links inside victim CDMA system	Extended Hata – rural environment
Propagation model for interference path over sea	Free Space Loss

Note 1: only voice communication channel is modelled in SEAMCAT CDMA module for certain simplification reasons (i.e. providing stable, non-bursty communication);
Note 2: derived from 3GPP TS 25.104, for minimum frequency offset 2.7 MHz for adjacent channel interference from narrowband interferer;
Note 3: This is an average cell radius value taken from ECC Report 82;
Note 4: values derived using SEAMCAT's in-built module for non-interfered capacity finding.

Table A3.1. Additional parameters used to define victim UMTS systems

It should be further noted that interference impacts CDMA system differently than a "traditional" system. In non-CDMA system such as GSM, the victim is passive with regards to incoming interference and violation of C/I criterion at victim receiver is considered as the trigger for interference occurrence.

But when victim is a CDMA system, it may use its inherent power tuning mechanism trying to compensate for interference up to a point when relevant network resources reach their limits and the victim system starts to disconnect some of the earlier associated mobiles. The interference here is therefore measured not in terms of probability of exceeding the C/I criterion, but the probability of certain excess capacity loss in victim CDMA system. In order to model this power tuning process correctly, the SEAMCAT builds a cluster of 19 CDMA sites and further complements it for the effect of "endless network" by applying a certain "wrap-around" technique.

But for the cases of interference from beyond the network edge, the SEAMCAT has feature allowing to disable part of wrap-around structure and model reference cell at the very edge of the network. This option was also used in the presented simulations of interference from GSMOBV, as shown in Fig. A3.1 below.

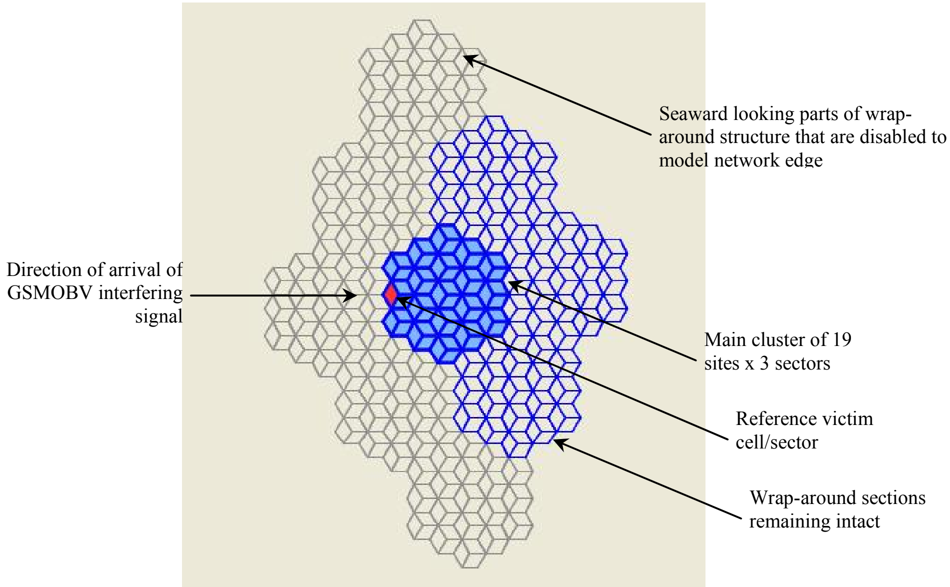


Figure A3.1: SEAMCAT's CDMA network edge set-up used for GSMOBV studies

It may be clearly seen from Fig. A3.1 that the used outline of CDMA network layout and the choice of seaward looking cell as a worst-case victim cell corresponds to the principles and general setup of simulations of GSMOBV vs land-based GSM networks, reported in Annex 2.

2. Scenario 0

The purpose of this scenario is to establish the range of reliable coverage of coastal waters by land-based networks. The previous annexes analyzed this issue for single-cell as well as for noise-limited cellular coverage from GSM-900/1800 MHz. Unfortunately, it appears not possible to analyze with SEAMCAT the Scenario 0 for the case of land-based UMTS-900/1800 MHz networks. This is because SEAMCAT models a victim CDMA cell as a part of uniform cluster with all deployment elements like mobile placement being defined on the network level. Thus it is not possible to steer the deployment of mobiles in a particular cell in any predetermined manner that would allow analyzing "gradation of coverage" in a given cell.

However, since the Scenario 0 is anyway designed just for supportive function and is not an interference scenario by itself, therefore inability to apply it for the case of UMTS networks was not felt critical. The only interference scenario that required reference to Scenario 0 findings is the Scenario 4, and as shown later in this annex the Scenario 4 is also not possible to simulate with SEAMCAT.

3. Scenario 1

This scenario describes the possibility that the v-MS is interfering into victim l-BS receiver (uplink). The physical outline of this scenario was derived by positioning a ship with interfering v-MS onboard along the direct line normal to the shore, in the bore sight of the victim cell antenna. An illustrating picture taken from the actual SEAMCAT simulation status window is shown below in Fig. A3.2.

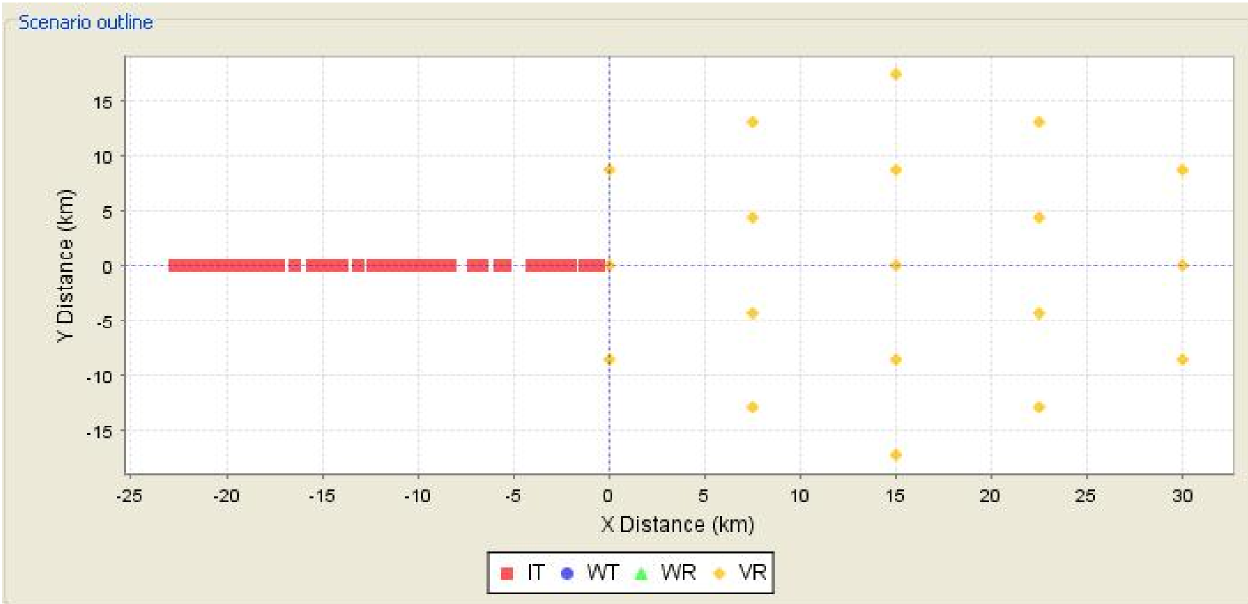


Figure A3.2 Outline of SEAMCAT simulation representing Scenario 1

Correspondence between SEAMCAT terms used in Fig. A3.2 and the casual terms used in this report are given below, for the case of the Scenario 1:

Casual Term	**SEAMCAT Term**
v-BS	Wanted Rx (WR) – not visible on Fig. 2 due to co-location/overlap with IT
v-MS	Interfering Tx (IT)
l-MS	Wanted Tx (WT) – numerous CDMA MSs are not plotted by SEAMCAT in order not to clog the screen
l-BS	Victim Rx (VR) – CDMA BS in uplink

The following simplifications of the SEAMCAT scenario (representing the worst-case assumptions) were made, consistently with similar provisions made for relevant scenario of interference into land-based GSM:

- victim l-BS antenna looks towards the sea (hence towards the interfering v-MS), placed at the reasonably short distance from shore, representing scenario of serving the “beach area”;
- ship is located along the straight line normal to shore (e.g. as if heading straight to harbour), heading directly into victim l-BS;
- the v-MS was assigned the maximum transmit power of 0 dBm for GSM-1800 and 5 dBm for GSM-900, assuming Power Control was used to set the v-MS power to minimum.

It should be also noted that the standard GSM MS DTX feature was considered operational in v-MS (GSM uplink), resulting in v-MS activity factor of 0.4.

Similarly with Scenario 1 in Annex 2, this case also considered possibility of using FH at GSMOBV. The number of channels in FH pool was again chosen to be 32 or 64, but, differently from the scenario with GSM victim, in this case it was realized that the FH channels should be evenly spread across the entire frequency range, in order to minimize the occurrences of hopping into single broad UMTS channels. This simulation was not taking account the fact that several UMTS channels should be used at the same location.

The above scenario was programmed into SEAMCAT and the resulting SEAMCAT scenario files are attached hereafter, for cases of UMTS-900 and UMTS-1800 MHz.

Simulating these scenarios in SEAMCAT returns the following results of excess capacity loss in the victim reference cell using only one UMTS Channel as shown in Table A3.2 for GSMOBV ship located randomly within 0-12 NM from shore.

Interferer	Victim on shore	
	UMTS-900 MHz	UMTS-1800 MHz
v-MS without FH	7 %	1.7 %
v-MS with FH - 32 channels (*)	0.7 %	0.1 %
v-MS with FH - 64 channels (*)	0.6 %	0.0 %

(*) Note: In the 900 MHz band FH channels evenly distributed over entire GSM & E-GSM range.

Table A3.2: Simulated excess outage in UMTS reference cell using a single carrier due to emissions from v-MS operating at a GSMOBV ship randomly located anywhere within 0-12 NM (DTX enabled for GSMOBV)

In accordance with the above scenario settings, these results could be interpreted as probability of outage capacity from v-MS Tx into l-BS one channel Rx when GSMOBV-equipped ship operates anywhere within territorial sea. Comparison of results without FH and with FH in Table A3.2 clearly demonstrates that without mitigation factor such as FH, the probability of interference would be unacceptably high in case of GSMOBV operating in 900 MHz band.

Results obtained with FH prove that it provides significant reduction of probability outage capacity to one CDMA carrier. Regarding the choice of number of channels in frequency hopping pool, results in Table A3.2 do not show any strong evidence for increasing number of FH channels, as long as all FH channels are evenly distributed across the entire frequency range, as was assumed in the above simulations. The probability of outage of capacity with FH would increase when several carriers are used by the reference UMTS-BS.
As a further step, similarly to what was done for the case of interference into land-based GSM, it was felt useful to consider cases when the ship may be located near the coast and victim l-BS for considerable periods of time, e.g. in the initial phases of departing from port or when slowly navigating into the port on arrival.

Therefore the above study was complemented by studying the sub-cases with restricted ship movement areas, considering cases of ship location within short path segments from shore, which should be representing worst cases of the described near-the-coast navigation of the ship.

The results of SEAMCAT simulations for ship/GSMOBV moving within those reduced journey segments is provided below in Table A3.3 (for case without FH) and in Table A3.4 (with FH activated).

Interference from v-MS **without FH**, when GSMOBV is operated at the distance from shore:	Victim on shore	
	UMTS-900 MHz	UMTS-1800 MHz
0-1 NM	14.5 %	12.0 %
1-2 NM	14.3 %	3.7 %
2-3 NM	14.0 %	1.6 %
3-4 NM	10.8 %	1.0 %
4-5 NM	6.9 %	0.6 %
5-6 NM	5.0 %	0.4 %
6-7 NM	3.8 %	0.2 %
7-8 NM	2.8 %	-
8-9 NM	2.2 %	-
9-10 NM	1.6 %	-
10-11 NM	1.2 %	-
11-12 NM	1.0 %	-

Table A3.3: Simulated excess outage in UMTS reference cell due to emissions from v-MS without FH, when GSMOBV ship is located within restricted path segments nearing the coast

	Excess outage (capacity losses)			
GSMOBV FH mode:	**FH-32 channels (*)**		**FH-64 channels (*)**	
Range of GSMOBV ship movement, NM from shore	**UMTS-900**	**UMTS-1800**	**UMTS-900**	**UMTS-1800**
0-1	2.6 %	0.8 %	1.7 %	0.5 %
1-2	1.9 %	0.2 %	1.7 %	0.2 %
2-3	1.4 %	0.0 %	1.6 %	0.0 %
3-4	0.9 %	0.0 %	1.1 %	0.0 %
4-5	0.6 %	0.0 %	0.9 %	0.0 %

Note: In the 900 MHz band FH operating over entire GSM & E-GSM range.

Table A3.4: Single carrier UMTS capacity loss due to interference from v-MS employing FH, when GSMOBV ship is randomly located within restricted path segments near the coast

Analyzing results of simulations provided in Table A3.4, it may be concluded that with FH employed, the probability of outage from v-MS to one carrier land-based UMTS uplink would be reasonably low even if GSMOBV-equipped ship were to be operating in the immediate proximity to coast. However, it is important to note, that this simulation demonstrated clear preference for FH channels be spread as widely as possible across the relevant band. It can be seen from the Table A3.3 that the probability of interference to land-based UMTS1800 is less than 1.0 %, when the distance from the shore is greater than 3 NM in the absence of FH.

It should be also noted that in reality the probability of interference should be lower than reported in Table A3.4 due to that realistic propagation over sea path would be worse than Free Space Loss model used in the reported simulations for distance greater than 5 km.

Case with GSMOBV DAA vs. UMTS

During the consideration of employing DAA, one question came up relating to the observation that part of the 5 MHz UMTS carrier emission is below the noise floor. So the question was what impact this would have on the efficiency of DAA operations, given that the DAA sensor is not likely to detect very low emission levels near the edges of UMTS channels.

A hypothesis was made that those near-the-edge-regions of UMTS channels might not be detected as occupied channel by the DAA system and could therefore become used by the GSMOBV system. This concept of "not detectable by DAA pocket" is illustrated in Fig. A3.3 below.

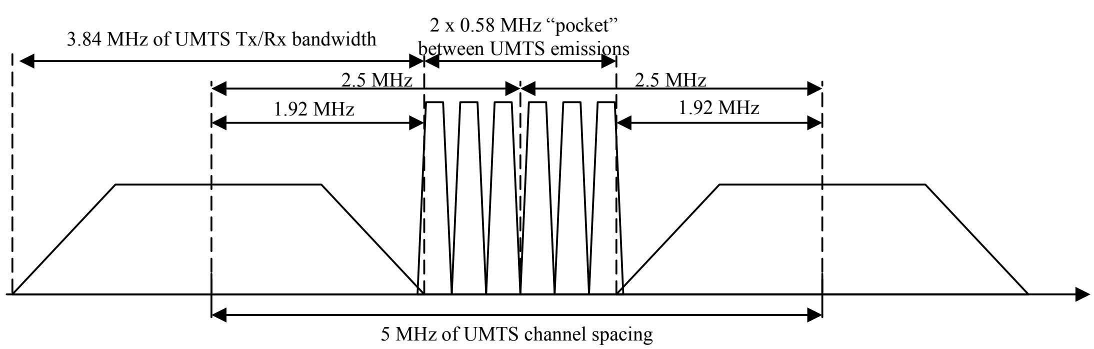


Figure A3.3: Appearance of "not detectable by DAA pockets" for GSMOBV operation near the edges of UMTS channels as a result of DAA mechanism applied in order to estimate the impact on UMTS emissions

The above scenario was simulated in SEAMCAT by modifying the workspaces used for Scenario 1. The assumption was made that the GSMOBV DAA receiver would detect the main part of the UMTS carrier above noise floor (e.g. 3.84 MHz wide emissions) and interpret them as 19 adjacent "busy GSM channels", but would consider near-edge low emission as "unoccupied GSM channels", which it could assign to FH pool of GSMOBV channels. So the worst case assumption was made that the entire GSM band was utilized by UMTS channels, therefore GSMOBV would only have access to the aforementioned "pockets" between the main emissions. Accordingly, Scenario 1 was modified so that the FH channel set was made either:

- Case 1: of 6 GSMOBV channels in the nearest "pocket" (i.e. starting at 2.0 MHz centre frequency offset from victim UMTS carrier), as illustrated in Fig. A3.3, or
- Case 2: of 18 channels placed in the three nearest "pockets", as shown in Fig. A3.4.

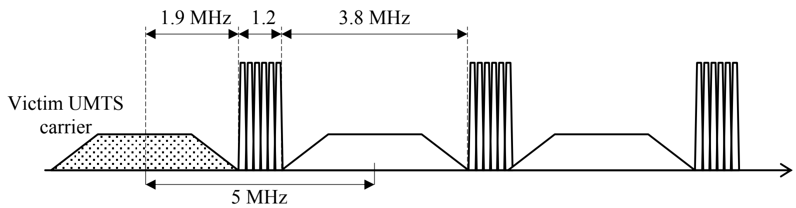


Figure A3.4: Modeled scenario with GSMOBV FH 18 channels placed in three "not detectable pockets"

Results of simulations for the above two co-existence case were as follows:

Interferer	Excess outage in victim	
	UMTS-900 MHz	UMTS-1800 MHz
Sea-MS with FH in 6 channels between 2 UMTS carriers, GSMOBV ship at 0-1 NM from shore	2 %	0.7 %
Sea-MS with FH in 3x6 channels between adjacent UMTS carriers, GSMOBV ship at 0-1 NM from shore	0.5 %	0.1 %

Table A3.5: Simulated excess outage in UMTS reference cell due to emissions from sea-MS operating in "not detectable pockets" between adjacent UMTS carriers, ship located within 0-1 NM from shore

It may be seen from Table A3.5 that even if GSMOBV channels were restricted to a single "not detectable pocket" adjacent to the victim UMTS carrier, the interference impact (capacity loss) is quite low.

In reality, the interference would be further reduced because the DAA would identify similar pockets between all UMTS channels, thus populating FH pool with more than 6 channels, and all additional channels would be further removed from a particular victim UMTS channel. This effect is well illustrated by the Case 2 reported in Table A3.5.

4. Scenario 2

In this scenario the indoor v-BS is interfering into victim l-MS receivers (downlink). The geographical outline of this scenario is identical to that shown in Fig. A3.2, but with interferer being v-BS rather than v-MS and victim being l-MSs rather than l-BS.

The following simplifications of the SEAMCAT scenario were made, representing the worst-case assumptions:

- victim l-MSs (with non-directional antenna) are positioned randomly near the shore, within the service area of seaward looking l-BS (area radius 0.5 km);
- ship is located along the straight line normal to shore (e.g. as if heading straight to harbour), heading directly into victim system's service area;
- zero hull penetration loss was assumed for the indoor v-BS emissions, to cater for worst case scenario of e.g. installing v-BS behind (retractable) glass walls in an upper deck restaurant, etc.;
- neither Power Control nor Frequency Hopping were employed at the interfering transmitter;
- it was assumed that indoor v-BS transmitter is fully loaded with traffic, i.e. all eight time slots of TCH channel are used;
- the propagation path loss within victim link (l-MS to l-BS) was calculated using Hata model, while the interfering link (v-BS to l-MS) was calculated using Free Space model, as in all previous SEAMCAT simulations.

Note that regarding the installation of indoor v-BS on a ship, it was assumed that a indoor v-BS antenna was installed with input power (-6 dBm) and gain (2 dBi) as specified in Table 2.

Simulating these scenarios in SEAMCAT showed near zero interference impact in terms of excess outage in victim single carrier UMTS systems, as shown in Table A3.6.

Interferer	**Excess outage in victim**	
	UMTS-900	**UMTS-1800**
GSMOBV ship **at 0-1 NM** from shore	0 %	0 %

Table A3.6: Results of simulations for excess outage in UMTS downlink due to interference from sea-BS

In accordance with the above scenario settings, these results could be interpreted as probability of interference from indoor v-BS Tx into l-UE Rx when GSMOBV-equipped ship operates within 0-1 NM from shore. It is obvious that v-BS emissions are not likely to cause interference to UMTS downlink even at very short distances from shore.

It may be expected that in real life the additional safeguards would be inherent in this scenario, such as a significant ship hull attenuation (when v-MS is inside the ship)that would be typical for most v-BS installations, and also due to any reductions in real traffic loading of the v-BS below the maximum loading assumed above.

5. Scenario 4

In this scenario v-BS is interfering into victim l-MS receiver located aboard the GSMOBV equipped ship. Unfortunately, this scenario is also impossible to model with SEAMCAT due to similar reasons as described previously for Scenario 0, i.e. because the way CDMA systems are simulated in SEAMCAT does not allow to control placement of interference to individual MSs.

ANNEX 4: DETECT AND AVOID (DAA) MECHANISM IN GSMOBV

1. Aim of DAA mechanism

The DAA mechanism (module) of a GSMOBV installation could be designed and implemented so as to ensure fully automatic and periodic detection of channels employed by land-based systems such as GSM-900/1800 and UMTS-900/1800. The purpose of the DAA mechanism is twofold:

- setting of the GSMOBV operational channels in the identified locally unused channels; and/or,
- shutting down the GSMOBV system if no available channels are identified initially or whenever number of available channels becomes insufficient, e.g. upon gradual approach towards coastline.

The correct operation of DAA mechanism could be ensured by implementation of the following set of essential requirements to its functioning.

2. Scanned frequencies & scanning rate

The DAA module should be designed to scan the frequency band(-s) of land-based l-BS transmissions corresponding to the frequency band employed for GSMOBV operation:

- the DAA of GSMOBV designed to work in GSM-900 frequency band should scan all the channels in frequency band:
  - 925-960 MHz, from f_c=925.2 up to 959.8 MHz, in 200 kHz steps;
- the DAA of GSMOBV designed to work in GSM-1800 frequency band should scan all the channels in the frequency band:
  - 1805-1880 MHz, from f_c=1805.2 up to 1879.8 MHz, in 200 kHz steps.
- The channel scan rate should be chosen so as to ensure efficient detection of GSM emissions, e.g. 200 channels per second with a resolution of 200 kHz that would allow measurement time in each channel of 5 ms to detect emission bursts in any of the 8 GSM time slots.

GSMOBV systems designed to operate in both the GSM-900 and the GSM-1800 bands could have two DAA modules scanning and establishing separate pools of available channels in both of the above identified bands.
In case of land-based UMTS systems, the detection threshold for DAA was chosen so (see Appendix of this annex) as to reliably detect the UTRA carriers (3.84 MHz width) and interpret them as an extended set of adjacent "occupied GSM channels".

3. Types of DAA receivers

The devices used as DAA receivers could be of two types:

a. Standard option would be to use band scanner that has a simple power measurement function. Such receiver should be measuring received power of emissions in the 200 kHz channel, without any regard to the type of emission;
b. "Intelligent scanner", which in addition to the aforementioned power measurement mechanism would have a receiver for GSM signals, which could be used to identify land-based GSM emissions, to synchronize with them, and to decode any necessary information from BCCH transmissions. This receiver could be in particular used for determining the C/I of the received GSM signal and using this information as an additional criterion for deciding, whether given channel is suitable for GSMOBV operation.

4. DAA operation algorithm

1. Before activation of the GSMOBV system within territorial waters, the first complete scan of the relevant band(-s) identified in section 2 shall be made;
2. The measurement should establish:
   - at least: the received power level, in dBm/200 kHz,
   - and, in the case of using "intelligent scanners": its ambient C/I value can be measured, in dB, on a given channel;

3. During the initial scan DAA should record the channels as available and include them in the List of Available Channels (LAC) only if:
   - the measured channel power level is less than -98 dBm/200 kHz in GSM-1800 band[12], or
   - the measured channel power level is less than -103 dBm/200 kHz in GSM-900 band[1], or,
   - for identified GSM emissions when using “intelligent scanner”, C/I is less than 6 dB;
4. In the case where a ship contains both GSMOBV 900 and 1800 capabilities, the DAA should contain one LAC per frequency band;
5. Then the GSMOBV operation may be initiated only if the initially established LAC size is at least 2N, where N is the minimum number of channels needed for operation of GSMOBV;
6. When activated, GSMOBV will choose the operational frequency(-ies) randomly from within the LAC;
7. After the initial set-up, the complete scan of relevant band(-s) should be repeated at least every 5 min and the LAC shall be updated in accordance with latest observations as follows:
   - Frequency channels should be identified as not available and removed from the LAC immediately when:
     i. the measured channel power level increases above -88 dBm/200 kHz in GSM-1800 band[1], or
     ii. the measured channel power level increases above -93 dBm/200 kHz in GSM-900 band[1], or
     iii. for identified GSM emissions when using “intelligent scanner”, C/I becomes more than 9 dB;
   - Frequency channels not listed in LAC can only be added to LAC again when:
     i. the measured channel power level drops below -98 dBm/200 kHz in GSM-1800 band[1], or
     ii. the measured channel power level drops below -103 dBm/200 kHz in GSM-900 band[1], or]
     iii. for identified GSM emissions when using “intelligent scanner”, C/I becomes less than 6 dB.
   - Frequencies that are used for GSMOBV operation during the given cycle, are skipped by the DAA scanner and not assigned to an updated LAC;
8. After each repetitive scan of frequency bands, the GSMOBV should re-assign the operating frequency (-ies) to LAC channel(-s) identified as available during the latest scan so that also the frequencies used by GSMOBV in previous cycle could be checked for appearance of new emissions in the next scan. This process is illustrated by the following diagram, where τ is the band scan time, μ is the channel re-assignment time:

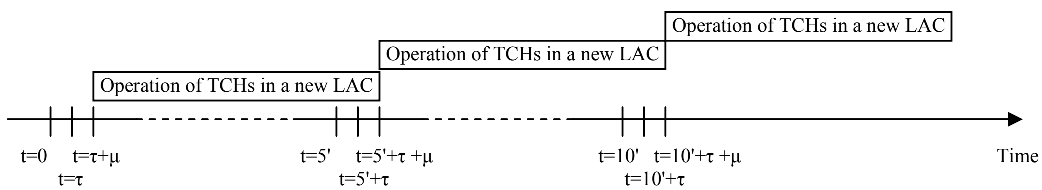


Figure A4.1: Re-assignment process of operating frequencies

   This provision will ensure that the channels used by GSMOBV are periodically released for checking whether they have not become occupied by land-based systems.

9. The steps 7-8 should be repeated continuously as long as the ship equipped with GSMOBV operates in the authorized area within the territorial waters;
10. After each consecutive scan of the frequency band, the GSMOBV system should be switched off if the number of free channels remaining (recorded) in LAC becomes less than N. Noting the provision in step 8 above, this rule will actually mean that the total number of available channels required for sustainable GSMOBV operation will always remain at least 2N, as each consecutive scan will be skipping channels used by GSMOBV in that cycle from recording in a new LAC. This is consistent with the condition of original activation of the system, as described in step 5 above.

5. Installation requirements

The DAA scanner should have an antenna installed at sufficiently exposed location above ship deck clutter in order to ensure a more reliable detection of occupied channels from all sides of the vessel.

[12] See justification for free/busy channel identification thresholds in the Appendix to this Annex

6. Illustrative examples

The following examples of scans taken by prototype DAA systems designed for GSMOBV illustrate the results of the DAA scan actions and the resulting GSMOBV operation settings.

Figure A4.2 is an example of single run of GSM-1800 MHz band taken at larger distance from shore, showing a large number of available channels. The outcome of such scan will be that normal GSMOBV operation shall be allowed and operational frequencies shall be chosen from the identified free channels.

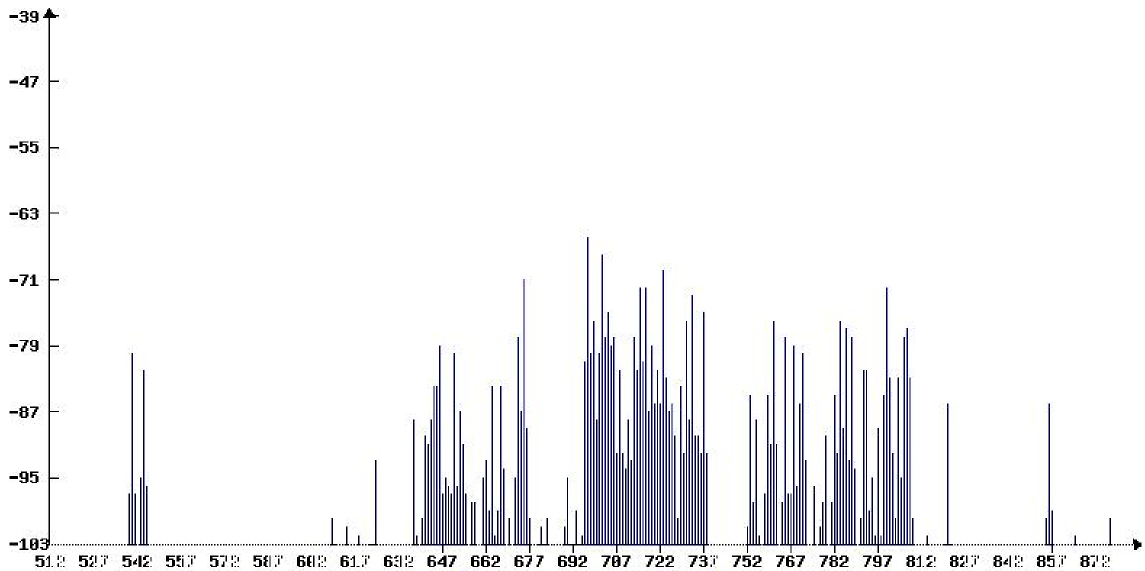


Figure A4.2: An example of a channel scan at 1800 MHz band far from shore

Figure A4.3 is an example of accumulated data after several scans of GSM-1800 band, taken along the route near the large port, showing that most channels are occupied. The outcome of such scan will be that GSMOBV shall be switched off, unless the few identified available channels (e.g. like pool of channels around ch855 in the example below) are sufficient for operation of GSMOBV, in accordance with condition in DAA algorithm steps 4.5 and 4.10 above.

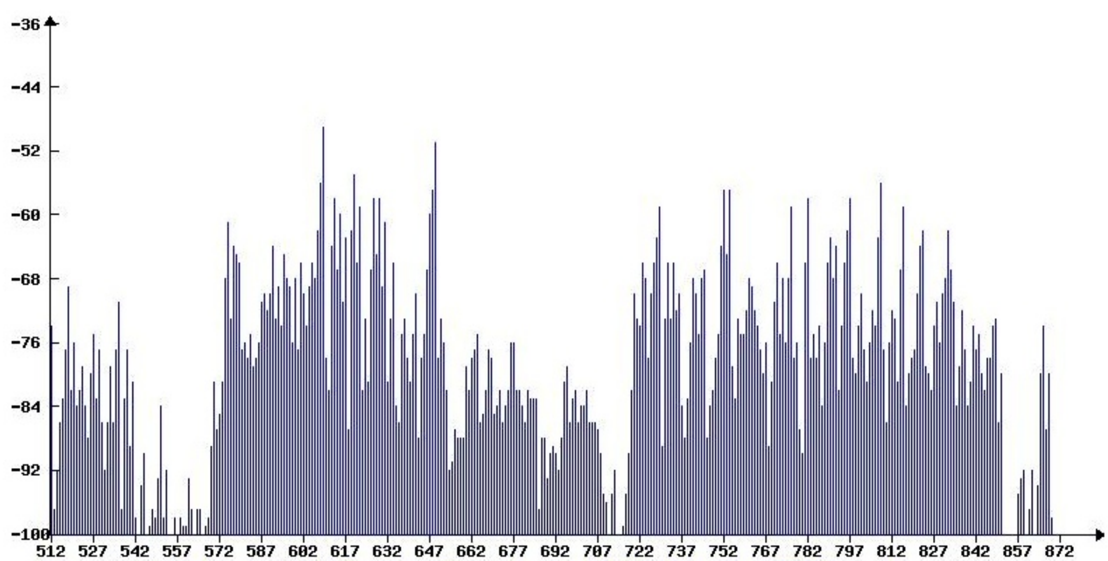


Figure A4.3: An example of a channel scan at 1800 MHz band close to shore

Appendix to Annex 4: Definition of certain parameters for the DAA mechanism

Introduction

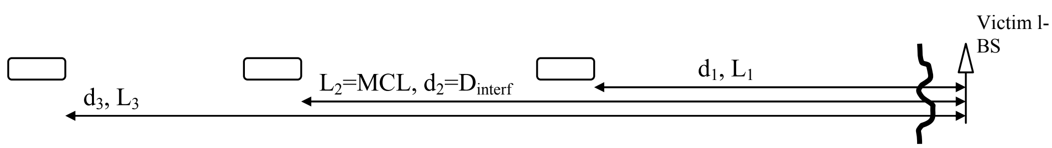
The following sections are meant to provide some supporting justification for the choice of various operational parameters as well as some additional clarifications of the proposed DAA concept.

Choosing the threshold received power value for identifying busy channels

The DAA mechanism would scan the GSM spectrum with the aim of identifying channels that are used by the land-based GSM and/or UMTS systems (i.e. "busy channels"). It is therefore of utmost importance to decide as to what measured power level should be sufficient to indicate with certainty that a given channel is occupied by land-based system.

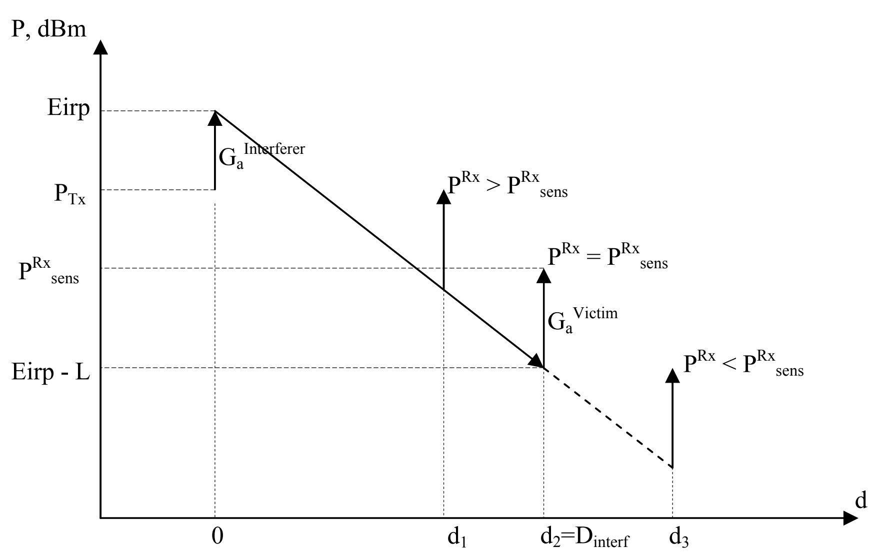
In order to answer this question, it would be important first to consider the overall context of operating DAA. The main purpose of DAA is to choose a channel for GSMOBV where operation of GSMOBV transmitters would have minimal or no impact on operation of land-based GSM system. and/or UMTS and where roaming to the GSM land-based networks would be available on board It is also important to remember the fact that, as a matter of principle, there are no un-occupied land-based GSM channels, due to long-lasting congestion of GSM spectrum. Thus it is just a question of finding those channels that are not used near the area of GSMOBV operation.

Let us depict the situation graphically. Imagine that ship is moving with regards to the cost. It does not matter in this consideration whether ship is moving towards the coast or from the coast, what is important is that the ship could be located at various distances from the coastal victim l-BS:



It is obvious, that the interference will start (or stop) occurring when ship crosses a certain minimum separation distance (d_2) from victim l-BS, that corresponds to a distance where the path loss L_2 becomes equal to the necessary Minimum Coupling Loss. It is therefore the purpose of DAA to discover real interference distance of land-based network where the path loss becomes equal to MCL.

Let us then depict the power diagram showing the condition of MCL violation:



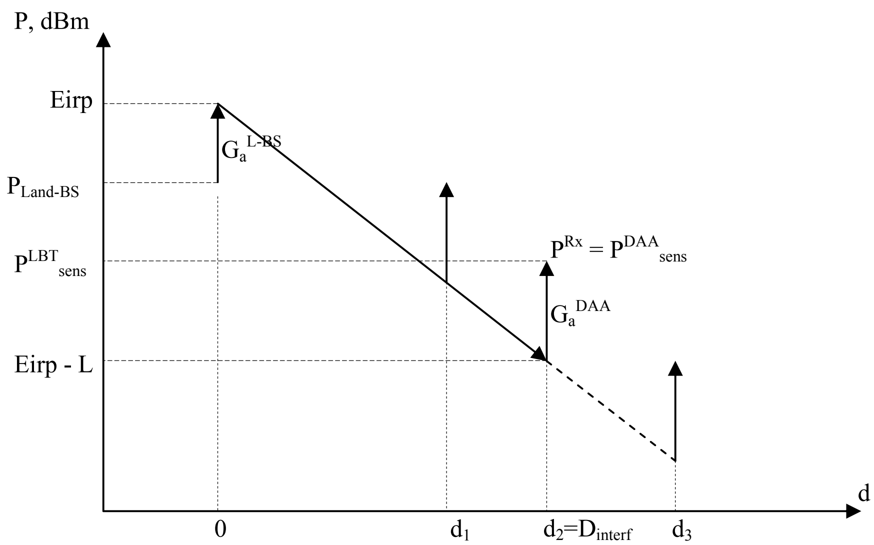
This clearly shows that for all distances beyond D_{interf} the increasing path loss will yield received interference power below the victim's sensitivity level[13], whereas any distances smaller than D_{interf} will have lower path loss that will make received interference power larger than victim's sensitivity level, thus causing interference.

The critical path loss that would trigger interference could be from this diagram derived as follows (note that this is exactly the same expression used to define the MCL):

$$L_{Interference} = MCL = P_{Tx}^{Interferer} + G_a^{Interferer} + G_a^{Victim} - P^{Rx}_{Sens} \qquad (1)$$

This means, that the minimum separation distance is directly linked to the necessary minimum path loss – which is exactly what is meant by the Minimum Coupling Loss concept. So the functioning of DAA in effect attempts discovering MCL in real time.

Let us now depict the power budget diagram in the opposite direction, i.e. the power of l-BS emissions received by the DAA receiver at the same ship distances d_1, d_2 and d_3. Note that of course identical distances correspond to having the same path loss values L_1, L_2 and L_3 correspondingly.



Similarly as L was expressed for the case of interference appearance conditions above, here we could similarly express the minimum L for detecting the emissions of l-BS:

$$L_{discovery} = P_{L\text{-}BS} + G_a^{L\text{-}BS} + G_a^{DAA} - P^{DAA}_{Sens} \qquad (2)$$

Now, in order to define the DAA sensitivity threshold, it is possible to merge the two previously described power budgets in one inter-related system by requiring that <u>the DAA would be discovering emissions of the L-BS at distance $d=D_{interf}$</u>, i.e. at the point starting from which emissions of served GSMOBV system would start triggering interference in land-based system. It is easy to deduce that for such condition the $L_{discovery}=L_{interference}$=MCL. One could then easily merge expressions (1) and (2) as follows:

$$P_{Tx}^{Interferer} + G_a^{Interferer} + G_a^{Victim} - P^{Rx}_{Sens} = P_{L\text{-}BS} + G_a^{L\text{-}BS} + G_a^{DAA} - P^{DAA}_{Sens}$$

And then express it for DAA busy channel detection threshold P^{DAA}_{Sens}:

$$P^{DAA}_{Sens} = P_{L\text{-}BS} + G_a^{L\text{-}BS} + G_a^{DAA} - P_{Tx}^{Interferer} - G_a^{Interferer} - G_a^{Victim} + P^{Rx}_{Sens} \qquad (3)$$

Then noting that the most critical GSMOBV interference scenario where DAA should be offering interference mitigation is the Scenario 1, where interferer is v-MS and Victim is l-BS. This would mean that:

---

[13] Note that in this document it is proposed referring to sensitivity level as interference threshold since this could be used universally both for GSM and UMTS victim stations. However, other interference threshold could be used, e.g. I/N, if established.

- $G_a^{Interferer}$ = 0 dBi;
- $G_a^{Victim} = G_a^{L\text{-}BS}$.

Finally, by defining DAA receiver threshold before antenna in order to eliminate the DAA antenna gain from the regulatory limits, the expression (3) could be simplified to:

$$P^{DAA}_{Sens}\text{ (before antenna)} = P_{L\text{-}BS} - P_{Tx}^{v\text{-}MS} + P^{Rx}_{Sens} \qquad (4)$$

Substituting in expression (4) relevant values for powers and sensitivity as defined in Table 2 of this report, we may derive the following set of DAA sensitivity thresholds:

1. For GSM-900:
   a. $P_{L\text{-}BS}$= 43 dBm;
   b. $P_{Tx}^{Interferer}$= 5 dBm;
   c. P^{Rx}_{Sens}= - 108 dBm (typical sensitivity of BTS);
   d. $\mathbf{P^{DAA}_{Sens}}$ (before antenna) = 43 – 5 – 108 = **- 70 dBm**;
2. For GSM-1800:
   a. $P_{L\text{-}BS}$= 43 dBm;
   b. $P_{Tx}^{Interferer}$= 0 dBm;
   c. P^{Rx}_{Sens}= - 108 dBm (typical sensitivity of BTS);
   d. $\mathbf{P^{DAA}_{Sens}}$ (before antenna) = 43 – 0 – 108 = **- 65 dBm**;
3. For UMTS-900 victim land-based systems:
   a. $P_{L\text{-}BS}$= 33 dBm/3.84 MHz (**Note**[14])= 20.2 dBm/200 kHz;
   b. $P_{Tx}^{Interferer}$= 5 dBm/200 kHz;
   c. P^{Rx}_{Sens}= - 121 dBm/3.84 MHz (reference sensitivity of Node-B), which in the case of a single narrowband interferer is equivalent to dispersed impact from -108.2 dBm/200 kHz signal;
   d. $\mathbf{P^{DAA}_{Sens}}$ (before antenna) = 20.2 – 5 – 108.2 = **- 93 dBm/200 kHz**;
4. For UMTS-1800 victim land-based systems:
   a. $P_{L\text{-}BS}$= 33 dBm/3.84 MHz (**Note**[2])= 20.2 dBm/200 kHz;
   b. $P_{Tx}^{Interferer}$= 0 dBm/200 kHz;
   c. P^{Rx}_{Sens}= - 121 dBm/3.84 MHz, which in the case of a single narrowband interferer is equivalent to dispersed impact from -108.2 dBm/200 kHz signal;
   d. $\mathbf{P^{DAA}_{Sens}}$ (before antenna) = 20.2 – 0 – 108.2 = **- 88 dBm/200 kHz**.

Given that the regulations established for GSMOBV deployment should be future-proof, it may be suggested to use the UMTS detection levels as "channel busy" detection thresholds for DAA operation:

- In GMS-900 MHz band: $P_{Rx}^{DAA} > -93$ dBm/200 kHz;
- In GSM-1800 MHz band: $P_{Rx}^{DAA} > -88$ dBm/200 kHz.

It may be further suggested, that for declaring any channel as free, the detected power level should drop below some further reduced thresholds, e.g. by 10 dB. This would introduce a hysteresis into detection system, thus avoiding oscillation of the decision making mechanism around a single threshold. Therefore it is possible to derive the following "free channel" received power values:

- In GMS-900 MHz band: $P_{Rx}^{DAA} < -103$ dBm/200 kHz;
- In GSM-1800 MHz band: $P_{Rx}^{DAA} < -98$ dBm/200 kHz.

Regarding the detection of UMTS channels, it may be further clarified that as a result of using the given above detection values, that had been adjusted for bandwidth difference, the wideband UMTS channels would be identified by LBT simply as a set of adjacent busy "GSM channels".

It may be observed that in the parts of the 5 MHz channel raster that are outside the region of the main 3.84 MHz UTRA emissions, the emissions of a land-based Node B will be naturally below the noise floor which may lead to DAA identifying those regions as available GSM channels. This case is considered in scenario 1 of Annex 3.

[14] Note that the 33 dBm output power for Node-B includes adjustment for possible reduction by 10 dB due to power control. The nominal output power is 43 dBm.

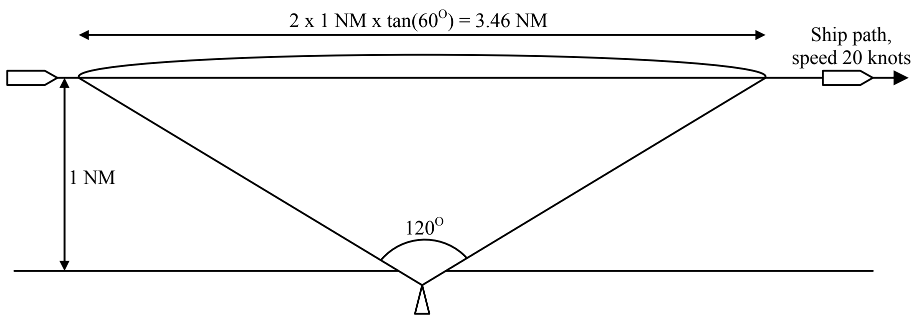
DAA scan rate and scan repetition period

Another aspect of DAA operation that is important for ensuring reliable detection of busy land-based GSM channels is the rate of scan. It is obvious that the scans should be as frequent as possible, yet the measurement time in an analysed GSM channel should be long enough for detecting bursty GSM emissions.

It may be therefore proposed to start deriving the necessary scan rate from observation of minimum measurement time in each analysed channel. This may be derived from assumption that the measurement time should be long enough to span across all 8 GSM time slots, in order to be able to identify emission burst in at least one of the time slots. Given the GSM time slot duration of 577 μs and 8 time slots frame of 4.615 ms, it may be thus suggested that the minimum channel measurement time be 5 ms, which would provide a slight margin above the frame duration.

This would then mean that the necessary scan rate should be in the order of 200 channels/second.

Considering the scan repetition period, this may be chosen so as to provide a compromise between the desire of having it longest possible (to minimize the transient effects of re-tuning channel set in GSMOBV) and the need to ensure that LAC is kept well updated in case busy channels change due to ship movement between coverage zones of different land-based cells. To consider the latter limitation, the worst case may be assumed if ship were to traverse the coverage zones of land-based cells while moving parallel to shore, close to coastal line, as shown in the figure below.



It may be seen that if ship traverses the cell at 1 NM from coast (assuming l-BS is placed right at the coastal line), it will have to cover the distance of 3.46 NM before entering another cell (that uses other set of channels). Given the ship is moving at average cruising speed of 20 knots (20 NM/h), this would mean that the minimum time to cross one cell at 1 NM along the coast would be 10 min. The necessary scan repetition period may be chosen somewhat shorter than that, to provide for additional detection margin. Therefore, a value of 5 min (i.e. on average the scan would be performed at least twice while moving across a cell) would appear a reasonable compromise. Given the unavoidable overlapping of neighbouring cells, the DAA should be identifying the frequencies use in next cell to be passed before entering the nominal boundaries of that cell.

From operational point of view an assumption could be made that an average phone call will typically last approx 2min. Therefore when scan repetition period is set to 5 minutes as compared to shorter periods, a larger number of calls would statistically start and end within a single scanning period. This would provide for reducing signalling load on the GSMOBV system and decreasing the number of calls that may be dropped during re-configuration of frequencies, thus leading to a much better service and end user experience for customers.

ANNEX 5: FREQUENCY HOPPING (FH) MECHANISM IN GSMOBV

1. Aim of FH

The Frequency Hopping (FH) is an additional feature of GSMOBV implementation, which may be chosen for reducing the interference from GSMOBV into land-based networks.

FH is a standard feature in GSM systems, therefore its implementation in GSMOBV should as a matter of principle follow the standard features described in GSM standards and implemented in the standard off-the-shelf Base Station equipment employed in GSMOBV. The purpose of this annex is just to highlight the specific GSMOBV FH options that are of relevance to mitigating interference to land-based networks.

Note, that FH mechanism is used only in v-BS transmitters carrying traffic channels (TCH), whereas transmitter used to carry control channel (BCCH) should be assigned static frequency. In this case the physical radio channel carrying BCCH should be configured to carry only signalling and not any voice/data communication traffic.

2. Functioning of FH in GSMOBV

The FH implemented in GSMOBV v-BS should have the following settings:

- FH should be used in synthesized mode, i.e. one v-BS transmitter constantly changing its operating frequency;
- FH hopping rate should be 217 hops per second (i.e. frequency changed with every transmitted TDMA frame);
- Change of operating frequencies (channels) should follow the pseudo-random pattern;