CEPT ECC
Electronic Communications Committee

ECC Report 364

Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 6425-7125 MHz

approved 24 January 2025

0 EXECUTIVE SUMMARY

This Report contains sharing and compatibility studies between Wireless Access Systems including Radio Local Area Networks (WAS/RLAN, also called RLAN in this Report) Low-Power Indoor (LPI) and Very Low Power (VLP) and existing incumbent systems in the 6425-7125 MHz band.

Studies have been performed based on a WAS/RLAN deployment model similar to the one used in ECC Report 302 [1] and ECC Report 316 [2], albeit with updated parameters (Scenario A) and with the addition of a second scenario aiming at investigating also denser usages of WAS/RLAN (Scenario B). Each scenario has three deployment assumptions: Low, Mid and High. By defining the active RLAN densities as proportional to the population density, this model allows the consideration of multiple-entry interference studies in both site-general and site-specific approaches. The WAS/RLAN deployment model is based on projections such as population, data consumption per person during busy hour, and the market penetration of WAS/RLAN devices up to the year 2030 (assumed to be a mature market).

0.1 SHARING BETWEEN WAS/RLAN AND FIXED SERVICE

0.1.1 Results of Minimum Coupling Loss studies

Minimum Coupling Loss (MCL) calculations have been performed for urban and suburban areas[1] with no terrain profile. The investigated WAS/RLAN heights were 1.5 m and 7.5 m. Both outdoor and indoor cases were considered with a constant FS bandwidth (Rx BW = 40 MHz) and variable WAS/RLAN-bandwidth (Tx BW = 40 MHz to 320 MHz) are studied to account for different bandwidth overlap factors. The effect of varying FS heights (30 m, 40 m, 75 m) was also investigated.

Median values were used for building entry loss (Recommendation ITU-R P.2109 [11]) for traditional buildings/houses and for clutter loss (Recommendation ITU-R P.2108 [8]).

The study identified the locations where a single WAS/RLAN could possibly exceed the protection criterion within a keyhole shaped area (consisting of a circle with a relatively small radius and a peak area which has a relatively large extent down the boresight). The results show that the peak radius (maximum distances) in the outdoor cases is between 0.9 km and 11.3 km and for the indoor scenario it is maximum of 3.3 km. The circle radius (minimum distances) does not change to any significant amount and is between 0 km and 0.3 km for indoor use cases and 0.3 km to 0.7 km for outdoor use cases. The height level of the FS receiver has an impact on the separation distances (peak radius).

The results in the outdoor/indoor use cases show that the distances become smaller as the WAS/RLAN bandwidths increase due to the decreasing spectral power density of the WAS/RLAN.

MCL calculations have revealed critical scenarios, but did not allow final conclusions to be made about the statistical likelihood of occurrence of those scenarios. Therefore, statistical studies based on Monte Carlo method were carried out.

0.1.2 Results of Monte Carlo studies

In this Report, Monte Carlo studies used two different approaches:

- Joint location/time Monte Carlo: The location and time dependent parameters used in the calculations are randomly sampled at each Monte Carlo event (jointly changed), independently of each other. The output of this approach is expressed as percentage of events (location and time mixed) exceeding a protection threshold (e.g. I/N of -10 dB);
- Separated location/time Monte Carlo: The location dependent parameters are randomly sampled in a separated loop (morphologies loop) from the time dependent parameters (time loop). The output of this approach is expressed in terms of percentage of morphologies exceeding a time dependant protection criterion (e.g. I/N of -10 dB exceeded less than 20% of the time).

[1] Rural scenarios were not studied in this Report, but were studied in ECC Report 302 [1].

The methodologies of each approach are described in more detail, in each study of this Report.

It should be noted that the statistical results from the Monte Carlo simulations range from respecting the FS interference protection criteria, to low probabilities of exceeding the criteria. Although in rare cases, a combination of factors such as WAS/RLAN located near the line of sight (coordinates and relative height) of the FS radio link, and/or unfavourable conditions (e.g. clutter loss, building entry loss and *e.i.r.p.*) may lead to potential exceedance of the FS protection criteria.

At the time of writing this Report, work was ongoing in ECC to provide a generic methodology for deriving protection criteria for any source of time-varying interference into an FS receiver. Within this activity, the studies consider how FS receivers perform in the presence of pulse/burst type interference, with and without Adaptive Coding and Modulation (ACM). Therefore, it should be noted that the conclusions of that ongoing work may have impact on the results of the sharing between WAS/RLANs and FS and that further investigation of the impact of beacon signals may be required.

0.1.2.1 Site-general Monte Carlo studies

Some of the combinations of parameters considered in the site-general studies may not actually exist in the field. In particular, one verification conducted for a city of 6000 inhabitants per square kilometre highlighted that some parameter combinations did not correspond to any fixed links deployed in this area. Thus, unless based on national data, not all the combinations in the range used in the site-general studies should be considered as representative and combinations that actually occur in practice should be considered on a case-by-case basis.

A relationship between population density and some FS deployments was found (see section 4.1.2). Only a very small percentage of associated FS receivers are located in areas of population density greater than 3000 inhabitants/km^2 and urban areas of greatest population density have antennas located higher off the ground than those with lower population densities.

Site-general study A

Study A is a site-general Monte Carlo study aiming at assessing whether the long-term protection criterion and the Fractional Degradation in Performance (FDP) are met when LPI WAS/RLAN indoor (with accidental LPI being outdoor) and VLP WAS/RLAN are simultaneously in operation.

The studies have considered the city of Frankfurt, which is a large dense German city with surrounding suburban and rural area. The size of the simulation radius was limited by the radio horizon (i.e. 59 km). The three different WAS/RLAN density deployment models of Scenario A (Mid, Low and High) were considered. The results of the study are computed taking into account all the possible statistical combination in terms of position, population density, FS height and FS antenna gain from real data set from the German administration.

Results from large number of joint location/time Monte Carlo events show that the long-term protection threshold (I/N =-10 dB for less than 20% of the runs) is respected for all the cases even with accidental outdoor LPI. The FDP values obtained for site-general FS link with and without automatic transmit power control (ATPC) are all below 10%. In other words, the results show that the probability of an FS link being degraded is very rare.

Furthermore, additional simulations using the separated location/time Monte Carlo method were performed on the two cases that exhibited the worst aggregated I/N distribution in the joint location/time study. The long-term protection criteria of -10 dB at 20% of the time is respected for both of these cases. Also, for the case with high FS antenna height, this methodology did not detect any exceedance of the FDP protection criterion (FDP < 10%). For high FS receiver antenna, the maximum FDP value is 2%. For the case with low FS antenna height, the percentage of fixed RLAN morphologies where the FDP does not exceed the 10% FDP criterion is 99.2%, 99.5% and 99.6%, depending on the fade margin of the FS link (23 dB, 29.7 dB and 40.3 dB, respectively). The results from the fixed RLAN morphologies studied show that the percentage of morphologies where the FDP is exceeding 10% for a FS link is less than 0.8% (for the minimum 5%-ile fade margin (FM)) or 0.4% (for the minimum 95%-ile FM).

The FDP value obtained from joint location/time Monte Carlo and the median FDP value from separated location/time Monte Carlo are similar for all studied cases.

Site-general study B

This study uses a similar environment as site-general study A (with separated location/time), but an alternative method to assess the potential interference to FS.

The simulations are single entry, but the outputs are processed in order to get results for whole deployments (equivalent to multiple entry) described in Scenarios A and B. The method can be summarised as follows: given the single-entry probability of exceeding the 10% FDP (from simulation, checking against the FDP protection criterion), and assuming that interference events from different WAS/RLANs are statistically independent, the probability of the FDP criterion being exceeded when multiple WAS/RLANs are deployed is computed. The core assumption is that, in practice, the instances of high aggregate interference power seen at any point in time by an FS receiver are dominated by a single WAS/RLAN contribution.

The overall probability of any WAS/RLAN exceeding the FS protection criterion, when a full WAS/RLAN deployment is considered, is derived from the single WAS/RLAN probability considering the total number of active WAS/RLANs based on the population density.

Using Recommendation ITU-R F.699 [33] and random polarisation loss, for the 30 m FS antenna height, the exceedance rate of the 10% FDP ranges from 1.16% to 16.54% (FM = 23 dB), depending on the WAS/RLAN density scenario and the FS antenna gain. For the 45 m height FS antennas, the exceedance rate ranges from 0.40% to 9.23% (FM = 29.7 dB). For the 79 m height FS antennas, the exceedance rate ranges from 0.11% to 3.82% (FM = 40.3 dB).

Using Recommendation ITU-R F.1245 [5] and fixed polarisation loss, for the 30 m FS antenna height, the exceedance rate of the 10% FDP ranges from 0.27% to 3.88% (FM = 23 dB), depending on the WAS/RLAN density scenario and the FS antenna gain. For the 45 m height FS antennas, the exceedance rate ranges from 0.06% to 1.20% (FM = 29.7 dB). For the 79 m height FS antennas, the exceedance rate ranges from 0.01% to 0.23% (FM = 40.3 dB).

Site-general study C

This study utilises the separated location/time Monte Carlo method to assess the long-term protection criterion and FDP at the FS receiver resulting from the deployment of WAS/RLAN devices in a circular area with a radius of 5 km. The number of interfering WAS/RLAN devices around an FS receiver were derived using High WAS/RLAN deployment assumptions from Scenario B. Four different population densities of 3000, 6000, 12000 and 18000 inhabitants per square km were used. Three different FS antenna heights were considered, 30 m, 40 m, and 79 m, coupled with FS antenna gains of 36 dBi and 46 dBi and three FS links of length 20 km, 32 km, and 50 km, respectively.

The compatibility was evaluated by assessing the exceedance rate of the two protection criteria i) long-term protection criterion of I/N=-10 dB not to be exceeded by more than 20% of time, and ii) the FDP not to exceed 10%.

The results show that higher population densities result in a higher exceedance rate of the two protection criteria. The exceedance rate for the long-term protection criterion ranges from 0% to 30.63% and for the FDP ranges from 0% to 34.80% (for a range of FM values between 30 dB and 51 dB). Under the considered combinations of the different parameters, it can be further recognised that for FS receivers with lower antenna gains (hence higher sidelobes) and/or lower antenna heights, the exceedance rate is more likely to increase. The exceedance rates for the studied FS links utilising ATPC are similar to the ones without ATPC.

Site-general study D

Study D is a site-general study involving an FS link receiver deployed in the middle of a simulation zone where population density is about 5400 inhabitants/km^2. This value is among the highest in the CEPT countries.

Several assumptions were investigated and in almost all joint location/time Monte Carlo simulations both long-term and FDP criteria are respected. It is only when assuming the High WAS/RLAN deployment assumptions of Scenario B (high market adoption of the WAS/RLAN in the upper 6 GHz) coupled with a low FS fade margin and a low FS peak antenna gain that the FDP criterion could be exceeded by a few percent, while in the very vast majority of the studied cases, the FDP is well below the 10% threshold resulting in a feasible FS link operation in presence of WAS/RLAN.

A separated location/time Monte Carlo analysis showed that topologies having a combination of many factors where a WAS/RLAN was in close vicinity of the FS receiver (main beam), and with a (relative) high height compared to the FS receiver height, and with a high transmit power seen by the FS receiver, and with a low building entry loss may cause the FDP criteria to be exceeded when the FS fade margin is low. This site-general study of a dense city centre showed that the likelihood of exceedance is highly dependent upon having all those conditions being fulfilled and is low even for a link with a limited fade margin (3% for Scenario A and 5.5% for Scenario B for fade margin of 13 dB) and is highly site-specific.

0.1.2.2 Site-specific study

This analysis considered a site-specific study of 26 real links selected in the United Kingdom (UK), France, Lithuania and the Czech Republic, using High WAS/RLAN deployment assumptions from Scenario A. This study considered a simulation area extended over 150 km simulation radius. In addition to real FS positions and characteristics (length, antenna heights and gains, etc.), the study also used precise maps of real population density around the FS receiver. For propagation losses calculations, the terrain profile around the FS receiver was taken into account. For the UK links, real building positions and height were also considered to model indoor WAS/RLAN in the first two kilometres distance.

This joint location/time Monte Carlo simulation study has shown that none of the links have exceeded the long-term protection threshold of -10 dB I/N for more than 20% of the runs. Furthermore, the fractional degradation in performance analysis showed that for all the links, the FDP value remained below the 10% threshold criterion.

0.2 SHARING BETWEEN WAS/RLAN AND FIXED-SATELLITE SERVICE (EARTH-TO-SPACE)

Simulations have been assessed on all possible satellite beam types: a Global, a Regional, a Zone and two Spot Beams. The study also used precise maps of real population density. Results have shown that in all cases studied using High WAS/RLAN deployment assumptions from Scenario A, the I/N for all satellite receivers is more than 15 dB below the -10.5 dB threshold. This is consistent with the results already obtained in the lower 6 GHz band (5945-6425 MHz) and that led to ECC Decision (20)01 [34] in that band.

0.3 SHARING BETWEEN WAS/RLAN AND FIXED-SATELLITE SERVICE (SPACE-TO-EARTH)

Monte Carlo site-specific sharing studies were conducted between WAS/RLAN and FSS downlink for all the four ground stations in Europe, using High WAS/RLAN deployment assumptions of Scenario A. In addition to the real ground stations positions and characteristics (e.g. height, gain), the studies also used precise maps of real population density around the FSS ground station receiver. The studies for the ground stations in Spain, Greece and Estonia were conducted with no WAS/RLANs located within 325 m, 500 m and 350 m from the ground stations, respectively, to reflect that there are no buildings within these zones, while in France WAS/RLAN were placed inside real buildings within a distance of 8 km from the ground station receiver. For propagation losses calculations, the terrain profile around the ground station was taken into account. Studies have shown that all stations respected the protection criterion of I/N = −10.5 dB not to be exceeded for more than 20% of the time.

0.4 COMPATIBILITY WITH OTHER APPLICATIONS IN THE BAND

0.4.1 Compatibility between WAS/RLAN and Radio Astronomy Service

Site-specific Monte Carlo simulations using Scenarios A and B were performed around four radio astronomy sites in CEPT.

Results suggest that some radio astronomy sites may require protection and, in these cases, appropriate technical mitigation measures could be applied to prevent interference from WAS/RLAN to the radio astronomy service (RAS). Other sites do not require such measures. The study also suggests that sharing between RAS and WAS/RLAN is unlikely to become a cross-border issue.

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

Abbreviation	Explanation
ACM	Adaptive Coding Modulation
AF	Activity Factor
AGL	Above ground level
AP	Access Point
ATPC	Automatic Transmit Power Control
AWGN	Additive White Gaussian Noise
BEL	Building entry loss
BL	Body Loss
BW	Bandwidth
CCDF	Complementary Cumulative Distribution Function
CDF	Cumulative Distribution Function
CEPT	European Conference of Postal and Telecommunications Administrations
CL	Clutter loss
CLC	Corine Land Cover
DL	Downlink
DSM	Digital surface model
DTM	Digital terrain model
ECA	European Common Allocation
ECC	Electronic Communications Committee
e.i.r.p.	Effective Isotropic Radiated Power
ePMP	External propagation model plugin
EPO	Error Performance Objective
ESF-CRAF	Committee on Radio Astronomy Frequencies of the European Science Foundation
FCC	Federal Communication Commission
FDP	Fractional Degradation in Performance
FM	Fade Margin
FPS	Frame Per Second
FS	Fixed Service

Abbreviation	Explanation
FSPL	Free Space Path Loss
FSS	Fixed-Satellite Service
GIS	Geographic Information System
GPW	Gridded Population of the World
GSO	Geostationary orbit
HDR	High Dynamic Range
HTTP	HyperText Transfer Protocol
IEEE	Institute of Electrical and Electronics Engineers
I/N	Interference to noise ratio
ITU	International Telecommunications Union
JRC	Joint Research Centre of the European Commission
JRC GHS-POP	Joint Research Center Global Human Settlement population data
LEO	Low Earth orbit
LOS	Line of sight
LPI	Low power indoor
maser	Microwave Amplification by Stimulated Emission of Radiation
MCL	Minimum Coupling Loss
MCS	Modulation and Coding Scheme
MEO	Medium Earth orbit
MERLIN	Multi-Element Radio-Linked Interferometer Network
MIMO	Multiple input multiple output
MPEG	Moving Picture Experts Group - Dynamic Adaptive Streaming over HTTP
MSS	Mobile-satellite service
NFM	Net Fade Margin
NLOS	Non line of sight
OFDM	Orthogonal Frequency Division Multiplexing
PDF	Probability distribution function
pfd	Power flux density
PSD	Power Spectral Density
RAS	Radio Astronomy Service
RF	Radio Frequency
RLAN	Radio Local Area Networks
RR	Radio Regulations

Abbreviation	Explanation
Rx	Receiver
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
SEDAC	NASA’s Socioeconomic Data and Applications Center
SISO	Single input single output
SKAO	Square Kilometre Array Observatory
SRTM	Shuttle Radar Topography Mission
TCP	Transmit control protocol
Tx	Transmitter
U6GHz	upper 6 GHz
UL	Uplink
UN	United Nations
VLBI	Very Long Baseline Interferometry
VLP	Very Low Power
WAS/RLAN	Wireless Access Systems including Radio Local Area Networks

1 INTRODUCTION

This Report studies the technical conditions under which Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) could operate and coexist with existing services in the 6425-7125 MHz band, ensuring certainty of continued operation, development, and protection of existing incumbent services.

This Report contains sharing and compatibility studies between WAS/RLAN Low Power Indoor (LPI) and Very Low Power (VLP) and existing incumbent systems in the 6425-7125 MHz band. Studies have been performed based on a WAS/RLAN deployment model similar to that used in ECC Report 302 [1] and ECC Report 316 [2], albeit with updated parameters (Scenario A) and with the addition of a second scenario (Scenario B).

2 ALLOCATIONS AND APPLICATIONS IN THE BAND 6425-7125 MHZ AND ADJACENT BANDS

2.1 FREQUENCY BAND ALLOCATIONS AND USE

Table 1 provides an extract of the current European Common Allocation (ECA) Table (ERC Report 25 [3]) in the 6425-7125 MHz band. In the second column it shows that among others, a primary mobile service allocation exists in this band. Other primary services in the band are:

- Fixed service;
- Fixed-satellite service (Earth-to-space);
- Fixed-satellite service (space-to-Earth).

Table 1: Extract of the European Common Allocation Table for the frequency band 6425-7125 MHz

Frequency band	Allocations/Applications
5925-6700 MHz	Allocations:, FIXED, FIXED-SATELLITE (EARTH-TO-SPACE) (**5.457A**), MOBILE (**5.457E**), Earth Exploration-Satellite (passive) **5.149**, **5.440**, **5.458** Applications: ESV, VSAT, Fixed, ITS , Passive sensors (satellite), RLAN, Radio astronomy, TLPR, LPR, UWB applications
6700-7075 MHz	Allocations: FIXED, FIXED-SATELLITE (EARTH-TO-SPACE) (SPACE-TO-EARTH) (**5.441**), MOBILE (**5.457E**), Earth Exploration-Satellite (passive) **5.458**, **5.458A**, **5.458B** Applications: FSS Earth stations, Feeder links, Fixed, Video PMSE, Passive sensors (satellite), TLPR, LPR, UWB applications
7075-7145 MHz	Allocations: FIXED, MOBILE (**5.457E**), Earth Exploration-Satellite (passive) **5.458** Applications: Fixed, Video PMSE, Passive sensors (satellite), LPR, UWB applications

5.149: In making assignments to stations of other services to which the bands:

13 360-13 410 kHz,	4 950-4 990 MHz,	102-109.5 GHz,
25 550-25 670 kHz,	4 990-5 000 MHz,	111.8-114.25 GHz,
37.5-38.25 MHz,	6 650-6 675.2 MHz,	128.33-128.59 GHz,
73-74.6 MHz in Regions 1 and 3,	10.6-10.68 GHz,	129.23-129.49 GHz,
150.05-153 MHz in Region 1,	14.47-14.5 GHz,	130-134 GHz,
322-328.6 MHz,	22.01-22.21 GHz,	136-148.5 GHz,
406.1-410 MHz,	22.21-22.5 GHz,	151.5-158.5 GHz,
608-614 MHz in Regions 1 and 3,	22.81-22.86 GHz,	168.59-168.93 GHz,
1 330-1 400 MHz,	23.07-23.12 GHz,	171.11-171.45 GHz,
1 610.6-1 613.8 MHz,	31.2-31.3 GHz,	172.31-172.65 GHz,
1 660-1 670 MHz,	31.5-31.8 GHz in Regions 1 and 3,	173.52-173.85 GHz,
1 718.8-1 722.2 MHz,	36.43-36.5 GHz,	195.75-196.15 GHz,
2 655-2 690 MHz,	42.5-43.5 GHz,	209-226 GHz,
3 260-3 267 MHz,	48.94-49.04 GHz,	241-250 GHz,
3 332-3 339 MHz,	76-86 GHz,	252-275 GHz
3 345.8-3 352.5 MHz,	92-94 GHz,	
4 825-4 835 MHz,	94.1-100 GHz,	

are allocated, administrations are urged to take all practicable steps to protect the radio astronomy service from harmful interference. Emissions from spaceborne or airborne stations can be particularly serious sources of interference to the radio astronomy service (see Nos. 4.5 and 4.6 and Article 29). (WRC-07)

5.440: The standard frequency and time signal-satellite service may be authorized to use the frequency 4 202 MHz for space-to-Earth transmissions and the frequency 6 427 MHz for Earth-to-space transmissions. Such transmissions shall be confined within the limits of ± 2 MHz of these frequencies, subject to agreement obtained under No. **9.21**.

Frequency band	Allocations/Applications
5.441: The use of the bands 4 500-4 800 MHz (space-to-Earth), 6 725-7 025 MHz (Earth-to-space) by the fixed-satellite service shall be in accordance with the provisions of Appendix **30B**. The use of the bands 10.7-10.95 GHz (space-to-Earth), 11.2-11.45 GHz (space-to-Earth) and 12.75-13.25 GHz (Earth-to-space) by geostationary-satellite systems in the fixed-satellite service shall be in accordance with the provisions of Appendix **30B**. The use of the bands 10.7-10.95 GHz (space-to-Earth), 11.2-11.45 GHz (space-to-Earth) and 12.75-13.25 GHz (Earth-to-space) by a non-geostationary-satellite system in the fixed-satellite service is subject to application of the provisions of No. **9.12** for coordination with other non-geostationary-satellite systems in the fixed-satellite service. Non-geostationary-satellite systems in the fixed-satellite service shall not claim protection from geostationary-satellite networks in the fixed-satellite service operating in accordance with the Radio Regulations, irrespective of the dates of receipt by the Bureau of the complete coordination or notification information, as appropriate, for the non-geostationary-satellite systems in the fixed-satellite service and of the complete coordination or notification information, as appropriate, for the geostationary-satellite networks, and No. **5.43A** does not apply. Non-geostationary-satellite systems in the fixed-satellite service in the above bands shall be operated in such a way that any unacceptable interference that may occur during their operation shall be rapidly eliminated. (WRC-2000)	
5.457A: In the frequency bands 5 925-6 425 MHz and 14-14.5 GHz, earth stations located on board vessels may communicate with space stations of the fixed-satellite service. Such use shall be in accordance with Resolution **902 (Rev.WRC-23)**. In the frequency band 5 925-6 425 MHz, earth stations located on board vessels and communicating with space stations of the fixed-satellite service may employ transmit antennas with minimum diameter of 1.2 m and operate without prior agreement of any administration if located at least 330 km away from the low-water mark as officially recognized by the coastal State. All other provisions of Resolution **902 (Rev.WRC-23)** shall apply. (WRC-23)	
5.457E: The frequency bands 6 425-7 125 MHz in Region 1 and 7 025-7 125 MHz in Region 3 are identified for use by administrations wishing to implement the terrestrial component of International Mobile Telecommunications (IMT). This identification does not preclude the use of these frequency bands by any application of the services to which they are allocated and does not establish priority in the Radio Regulations. Resolution **220 (WRC-23)** applies. The frequency bands are also used for the implementation of wireless access systems (WAS), including radio local area networks (RLANs). (WRC-23)	
5.458: In the band 6 425-7 075 MHz, passive microwave sensor measurements are carried out over the oceans. In the band 7 075-7 250 MHz, passive microwave sensor measurements are carried out. Administrations should bear in mind the needs of the Earth exploration-satellite (passive) and space research (passive) services in their future planning of the bands 6 425-7 075 MHz and 7 075-7 250 MHz.	
5.458A: In making assignments in the band 6 700-7 075 MHz to space stations of the fixed-satellite service, administrations are urged to take all practicable steps to protect spectral line observations of the radio astronomy service in the band 6 650-6 675.2 MHz from harmful interference from unwanted emissions.	
5.458B: The space-to-Earth allocation to the fixed-satellite service in the band 6 700-7 075 MHz is limited to feeder links for non-geostationary satellite systems of the mobile-satellite service and is subject to coordination under No. **9.11A**. The use of the band 6 700-7 075 MHz (space-to-Earth) by feeder links for non-geostationary satellite systems in the mobile-satellite service is not subject to No. **22.2**.	

2.2 DEPLOYMENT OF OTHER APPLICATIONS BY CEPT ADMINISTRATIONS

Table 1 also shows that in addition to the primary services, some other services and applications can make use of the 6425-7125 MHz band.

2.2.1 Radio astronomy

The frequency band 6650.0-6675.2 MHz is used for observations of methanol (CH3OH). This transition of methanol is a very powerful cosmic maser found exclusively in regions where massive stars form. It is widely observed in Europe using single dishes, Multi-Element Radio-Linked Interferometer Network (MERLIN) interferometry and Very Long Baseline Interferometry (VLBI).

Furthermore, at 6030 MHz and at 6035 MHz excited-OH (Hydroxyl; the main transition of Hydroxyl is the 1667 MHz and 1665 MHz lines, also significant for Radio Astronomy studies) is observed in a maser state and also in absorption, organised in star-forming regions. These regions provide valuable information on the physical parameters, including the elusive magnetic fields of the environment where the massive star is forming, at a stage before the visible light can emerge through the dust.

The footnote RR No. **5.149** includes the band 6650-6675.2 MHz but does not include 6030 MHz and 6035 MHz.

3 WAS/RLAN IN THE UPPER 6 GHZ FREQUENCY RANGE

3.1 TECHNICAL CHARACTERISTICS OF WAS/RLAN IN THE BAND 6425-7125 MHZ

3.1.1 Transmitter Output Power / Radiated Power

WAS/RLAN devices used in different applications will have different power levels and will be associated with different technologies. Based on current market share projections, the dominant technology is likely to be IEEE 802.11-based. Two device categories for WAS/RLAN are envisaged as per ECC Report 302 [1] and ECC Report 316 [2]:

- Low Power Indoor (LPI);
- Indoor/outdoor Very Low Power (VLP).

The simulations in this Report are based on the baseline scenario of 1% outdoor VLPs and 99% of LPI, as per ECC Report 316, with some slight modifications, taking into account some accidental LPI client outdoor usage.

The normalised antenna gain distributions for WAS/RLANs to be used in sharing studies are given in Annex 1 for WAS/RLAN Access Points (AP/LPI) and for WAS/RLAN VLP/LPI Clients with and without body loss. These tables depict a maximum antenna gain normalised to 0 dBi.

To obtain the *e.i.r.p.* distributions, Table 37, Table 38 and Table 39 from Annex 1 should be used together with one indoor/outdoor distribution. This Report uses the indoor/outdoor distribution from Table 2 for sharing studies with incumbents. A detailed derivation of the indoor/outdoor distribution is available in Annex 1, where the overall indoor/outdoor distribution can be found in Table 40.

In all studies carried out in this Report, the WAS/RLAN *e.i.r.p.* is not reduced by averaging over the RF activity factor.

Table 2: WAS/RLAN indoor/outdoor and *e.i.r.p.* distributions

Device type		Total indoor	Total outdoor	*e.i.r.p.* distribution
LPI Clients	With Body Loss	21.10%	0.21%	200 mW + normalised antenna gain distribution from Table 39
	Without Body Loss	2.37%	0.00%	200 mW + normalised antenna gain distribution from Table 38
VLP	With Body Loss	9.00%	1.00%	25 mW + normalised antenna gain distribution from Table 39
AP (LPI)	Without Body Loss	66.32%	0.00%	200 mW + normalised antenna gain distribution from Table 37
Total		98.79%	1.21%	

3.1.2 WAS/RLAN antenna heights

Typical antenna height depends on the regions (urban, suburban and rural) where users are located.

The WAS/RLAN weighted height distribution for indoor and outdoor is given in ECC Report 302 [1], section 3.1.2 and in ECC Report 316, section 4.2.1.3. In this Report, the indoor WAS/RLAN height distribution of ECC Report 316 is retained, while the outdoor WAS/RLAN height distribution is retained from ECC Report 302. Given that distributions are needed according to the urban, suburban and rural categories and not according to the number of households per city, a simplified indoor height distribution based on ECC Report 316 is given in the Table 3. This distribution was generated considering that cities containing more than 25k households are categorised as urban and below are suburban. The rural distribution was given as standalone in ECC Report 316 [2].

Table 3: WAS/RLAN height probabilities for urban/suburban/rural (indoor average based on ECC Report 316 category and outdoor from ECC Report 302)

Floor	Height (m)	Urban	Suburban	Rural	Outdoor
ground	1.5	32.25	53.81	71.03	95
1	4.5	23.02	25.93	25.43	2
2	7.5	13.23	7.87	1.66	2
3	10.5	9.78	5.13	1.01	0.5
4	13.5	7.19	3.06	0.52	0
5	16.5	5.11	1.41	0.13	0
6	19.5	3.86	1.09	0.1	0
7	22.5	2.78	0.81	0.07	0
8	25.5	1.83	0.56	0.04	0
9	28.5	0.99	0.34	0.01	0.5

3.1.3 Bandwidth

The 6 GHz band is a 'greenfield' band for WAS/RLAN systems and is expected to be used for high and very high data-rate applications. Correspondingly, increased use of 80, 160, and 320 MHz wide channels is expected. Table 4 shows a prediction for the distribution of WAS/RLAN channel bandwidths used in the 6 GHz band. Comparing to the bandwidth distribution in ECC Report 302, it is expected that use of the 20 MHz channels will remain the same for control and higher power spectral density (PSD) applications and usability of the 40 MHz channels will be considerably reduced. Use of the 80 MHz channels will remain the same and high data-rate applications will be using mainly either 160 MHz or 320 MHz channel bandwidth.

Table 4: Bandwidth distribution

Channel Bandwidth	20 MHz	40 MHz	80 MHz	160 MHz	320 MHz
WAS/RLAN device percentage	10%	5%	30%	35%	20%

Figure 1 shows the WAS/RLAN channel set defined by IEEE 802.11 (from IEEE 802.11be D5.0 [47]) starting from 6425 MHz, which are used in Table 5.

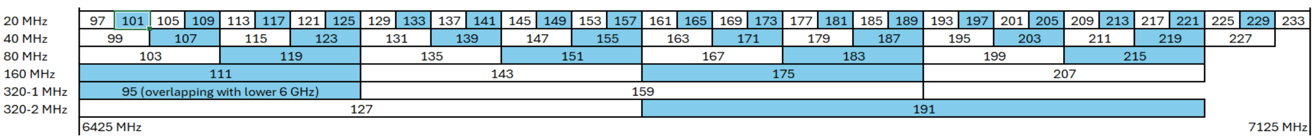


Figure 1: WAS/RLAN channel plan in the Upper 6 GHz Band (IEEE 802.11be D5.0 [47])

Table 5: Channel set

Channel Bandwidth	# of channels	Channel set
20 MHz	35	97, 101, 105, 109, 113, 117, 121, 125, 129, 133, 137, 141, 145, 149, 153, 157, 161, 165, 169, 173, 177, 181, 185, 189, 193, 197, 201, 205, 209, 213, 217, 221, 225, 229, 233
40 MHz	17	99, 107, 115, 123, 131, 139, 147, 155, 163, 171, 179, 187, 195, 203, 211, 219, 227
80 MHz	8	103, 119, 135, 151, 167, 183, 199, 215
160 MHz	4	111, 143, 175, 207
320 MHz	2	95 (overlapping with lower 6 GHz), 159, 127, 191

3.2 WAS/RLAN DEPLOYMENT MODEL

This section sets out a busy hour deployment model for WAS/RLAN in Europe. The vast majority of licence exempt wireless traffic occurs during the busy hours 19:00-23:00 local time [1]. For a conservative and simplified analysis, this model focuses on video consumption in the residential environment, as this has a higher projected data rate demand per person than the corporate and public hotspot environments.

The RLAN deployment model assumes that the total RLAN traffic carried within CEPT countries over the 6425-7125 MHz frequency band is:

- For Scenario A: 90, 150, and 230 MBytes/hour/person during the busy hour (low, mid, and high respectively). This is consistent with the consumption by each person involved in the busy hour RLAN traffic, of a ~4.5 Mbps (HD) video stream[2], as was assumed in ECC Report 302, annex 7 [1];
- For Scenario B: 135, 217 and 362 MBytes/hour/person during the busy hour (low, mid, and high respectively). This is consistent with the consumption by each person involved in the busy hour RLAN traffic, of a ~4.6 Mbps (4K) video stream[3].

The WAS/RLAN deployment factors for this study in the upper 6 GHz are listed in Table 7.

Depending on the simulation set-up, other factors may be needed for Monte Carlo simulations, such as the WAS/RLAN bandwidth overlapping factor, using the methodology from ECC Report 302, annex 2 [1].

3.2.1 Elaboration of WAS/RLAN deployment model parameters

The following subsections set-out an explanation of inputs to the WAS/RLAN deployment model summarised in Table 7.

---

[2] This figure is obtained by dividing the data demand per person by the ratio of population using RLAN during the busy hour to the total population (using all factors of Table 7 but the RF activity factor), and multiplying by 8 and dividing by 3600 to convert from Mbytes/hour/(active person) to Mbits/s/(active person).

[3] Computed with the same methodology as for Scenario A using parameters from Scenario B. The video stream bitrate was 9.1 Mbps in the simulations of ANNEX 12:, but further processing leading to the RF AF value makes it equivalent to 4.6 Mbps in the Monte Carlo simulations involving Scenario B.

3.2.1.1 Population of Europe projected for 2030

The RLAN deployment model used in this Report relates the number of instantaneously transmitting RLAN in a given zone proportionally to the population in said zone. This means that projections of CEPT population for 2030 is needed. To do so, in this Report, two sources of information were used, depending on the studies:

- the Gridded Population of the World V4 (GPWv4) data from NASA's Socioeconomic Data and Applications Center (SEDAC) [26], re-projected according to the UN populations projections figures [24];
- the Joint Research Centre Global Human Settlement population data (JRC GHS-POP) [15], which gives projected population (up to 2030) in a granular geographical manner. It is worth noticing that projections are also derived from the UN World Population Prospects [24].

3.2.1.2 Assignment of population to urban, suburban and rural environments

Two methods were used in this Report in order to assign population to a rural, suburban or rural environment. The first one is as in ECC Report 302, where the total population of Europe is assigned to environments as follows:

- Urban: 50%;
- Suburban: 27%;
- Rural: 23%.

This assignment allows to deduce the category of each population pixel, based on the population data used in the previous section.

The second method, that can only be used in site-specific studies, uses Corine Land Cover data [27]. Note that this geographical database can also be used to assign a clutter type (as used, for instance, in Recommendation ITU-R P.452 [6]) to a zone.

3.2.1.3 Percentage of devices operating in licence exempt spectrum

This percentage of wireless devices operating in licence exempt spectrum in Scenario A is set to 90% as per with ECC Report 302, based on the share of internet traffic supplied using licence exempt frequency bands [28].

In Scenario B, it is assumed that this factor is already covered by the busy hour factor (used in order to determine the share of active RLAN devices during busy hour, see section 3.2.1.6), and is consequently set to 100%.

3.2.1.4 Market adoption factor

The market adoption factor represents the percentage of WAS/RLAN links capable of operation at 6 GHz.

For Scenario A, parametric inputs of 25%, 32% and 50% were used for the market adoption factor, as defined in ECC Report 302. The Low value of 25% assumes a slow adoption of 6 GHz equipment, the Mid value of 32% is based on market projections and the High value of 50% assumes rapid adoption of 6 GHz technology. The market adoption factors used are the same as those presented in ECC Report 302 and were to provide estimates for the 6-year period from when devices are able to be placed on the European market. A rationale for the 32% input value is given in ECC Report 302, annex A3.3 [1].

For Scenario B, parametric inputs of 28%, 36% and 60% were used for the market adoption factor. The low and mid values were taken from ECC Report 302 and multiplied by a 1.11 factor, leading to 28% low and 36% mid. The high value comes from an estimation for a future market adoption factor for RLAN devices based on ABI research estimates of WiFi shipments figures for 5 GHz capable RLAN devices post 2010 until 2026 [30]. This assessment assumed a future market adoption factor of 5 GHz capable devices to be around 80% in 2026, and plateauing thereafter, to indicate a mature market. Assuming a similar trend for devices operating in the upper 6 GHz would translate to this value being reached in 2050. Based on this value, it was also assumed that since two RLAN devices are needed to form a link, a high value of $80\% \times 80\% \approx 60\%$ was used.

3.2.1.5 Upper 6 GHz factor

The upper 6 GHz factor is the share of RLAN devices capable of operating in the upper 6 GHz band that actually transmit in a channel of this band:

$$\text{U6GHz factor} = \frac{\#\text{U6GHZ capable RLAN devices operating in U6GHz}}{\#\text{Total U6GHZ capable RLAN devices}}$$

As it is not possible to directly compute this ratio, different proxies were used to estimate this factor.

In Scenario A, consistently with ECC Report 302, the upper 6 GHz factor is computed as the ratio of $7125 - 6425 = 700$ MHz of available spectrum in the upper 6 GHz band to $83 + 200 + 255 + 480 + 700 = 1718$ MHz of total available spectrum for RLAN in CEPT if the upper 6 GHz frequency band gets opened to RLAN (in addition to the 2400-2483 MHz, 5150-5350 MHz, 5470-5725 MHz, 5945-6425 MHz and 6425-7125 MHz frequency bands). This gives a value of 40.75%.

The upper 6 GHz factor in Scenario A assumes a uniform distribution of the probability of using a given channel, in any of the frequency band available for an RLAN. In practice, the channel frequency and bandwidth choice are implementation specific, and dictated by many factors such as propagation, data demand, congestion, available radios, etc.

In Scenario B, it is considered that not all bandwidth is equally desirable, as shown in Table 6. Also, the number of channels of a given bandwidth is not uniform among frequency ranges available for RLANs (for example, there is no 160 or 320 MHz channels in the 2400-2483 MHz band). These two available data points are used to derive the upper 6 GHz factor of Scenario B to be 47% (see Table 6), assuming the number of channels available for IEEE 802.11 systems (including the upper 6 GHz band).

Table 6: Computation of upper 6 GHz factor in Scenario B

	20 MHz	40 MHz	80 MHz	160 MHz	320 MHz
Total number of available channels (Note 1)	81	40	18	9	6
Number of available channels in U6GHz (see Figure 1) (Note 1)	35	17	8	4	3.5
Bandwidth distribution (see Table 4)	10%	5%	30%	35%	20%
Probability of selection in U6GHz	4.32%	2.13%	13.33%	15.56%	11.67%
Upper 6 GHz factor for Scenario B	**47%**				
Note 1: Based on the number of 20/40/80/160/320 MHz channels available in most CEPT countries for IEEE 802.11 systems and assuming 40 MHz overlapping in 2.4 GHz, and the two sets of 320 MHz channels defined for the (upper and lower) 6 GHz band, see Figure 1 and Table 4.					

3.2.1.6 Busy hour factor

The Busy Hour Factor (BHF) describes the percentage of WAS/RLAN that actively operate during the busy hour. In ECC Report 302, parametric inputs of 50% and 62.7% for the busy hour factor were used, taking account that there was some uncertainty so that a parametric input was considered appropriate.

ITU-R Joint Task Group 4-5-6-7 considered 62.7% to be the average busy hour factor over urban, suburban and rural areas. A 2015 study by the European Commission's Joint Research Centre (JRC) concluded that a BHF of 62.7% was a realistic value [29].

For the above reasons, the BHF values of 50% and 62.7% are retained.

3.2.1.7 Radio frequency activity factor

The radio frequency (RF) activity factor (AF) denotes the percentage of time a WAS/RLAN device actually transmits an RF signal reflecting the non-continuous nature of load-based communications. The RF AF is mostly governed by the overall load of the network and the maximum data rates of the data stream that is transmitted and the chosen Modulation and Coding Scheme (MCS). Other factors that influence the total RF AF include packet losses/retransmits, the overhead of management/control frames and other implementation-specific behaviours. The RF AF is intended to simulate the average activity per person during the busy hour.

Scenario A uses the same value as ECC Report 302 [1] of 1.97% for RF AF, where the RF AF was derived by considering the overall communication network demand for European countries in the busy hour and that around 90% of that demand in the busy hours would be from RLANs connected to fixed networks (busy hour demand related to home networks). In the studies related to ECC Report 302, after completing the necessary calculations it was decided that a reasonable proxy to reflect the demand per person was to assume each active person would be watching an HD video. This value of 1.97% was decided upon after looking at the results of measurements carried out for RLAN network traffic involving IEEE 802.11ac devices transmitting an HD video clip in an 80 MHz channel, reduced to compensate for an average bandwidth of 94 MHz. More information can be found in its ECC Report 302, annex 7. Since then, new standards such as IEEE 802.11be are currently entering the market, and these new standards look to increase the maximum bitrates achievable (by use of 4096-QAM and/or a 320 MHz channel), therefore it is assumed that this will contribute to lower RF AF values in the future when networks are using these new standards.

In Scenario B, a value of 2.45% is used. This value comes from network simulations which assumed that each active person would be watching a 4K video, taking into account non-perfect propagation and different codecs, using an 80 MHz channel (see Annex 12). The simulation was able to show that it can match the RF AF of ECC Report 302 when put into a similar configuration. However, the final value for streaming 4K video is computed as the mean of the RF AF of the two devices involved in the transmission, while the value in Scenario A considers the sum.

3.2.1.8 Number of instantaneously transmitting devices

The total number of instantaneously transmitting devices in a given zone ($N_{\text{Active RLAN}}$) is given by the product of the population in the given zone (N_{pop}) with the factors in Table 7:

$$N_{\text{Active RLAN}} = N_{\text{pop}} \cdot F_{\text{licence exempt}} \cdot F_{\text{U6GHz}} \cdot F_{\text{Market adoption}} \cdot F_{\text{Busy hour}} \cdot F_{\text{RF AF}}$$

Table 7: WAS/RLAN deployment model factors

	Scenario A			Scenario B		
	Low	Mid	High	Low	Mid	High
Wireless devices operating in licence exempt spectrum ($F_{\text{licence exempt}}$)	90%			100%		
Upper 6 GHz factor (F_{U6GHz})	40.75%			47%		
Market Adoption factor (6 GHz capable devices, $F_{\text{Market adoption}}$)	25%	32%	50%	28%	36%	60%
Busy Hour factor ($F_{\text{Busy hour}}$)	50%	62.7%	62.7%	50%	62.7%	62.7%
RF Activity factor per person ($F_{\text{RF AF}}$)	1.97%			2.45%		
Product of RLAN deployment model factors	0.09%	0.14%	0.23%	0.16%	0.26%	0.43%

4 SERVICES AND APPLICATIONS IN THE 6 GHZ FREQUENCY RANGE

4.1 FIXED SERVICE

4.1.1 Fixed Service system parameters and assumptions

Table 8 lists the relevant typical Fixed Service (FS) parameters in this band.

Table 8: Typical FS parameters in this band

Parameter/model	Values
Antenna height	30, 40, 75 metres
Antenna gain	34, 40, 46 dBi
Link length	20, 40, 60 kilometres
Feeder loss	1.3 dB
Fade margin (FM)	13-31 dB (5% percentile), 15-45 dB (mode)
Net fade margin (NFM)	10-20 dB (5% percentile), 15-32 dB (mode)
ATPC Range associated to the NFM	15-20 dB
Channel spacing and receiver noise bandwidth	40 MHz
Antenna pattern	Recommendation ITU-R F.699 [33] for single-entry interference Recommendation ITU-R F.1245 [5] for aggregate interference
Receiver noise figure	4.5 dB or 5 dB
Protection requirement	The long-term protection criterion with a value of I/N=-10 dB (see Recommendation ITU-R F.758, table 5 [4]) that should not be exceeded for more than 20% of time. Fractional Degradation in Performance (FDP) (Annex 10 and Annex 11) as given in Recommendation ITU-R F.1108, Annex 3 [35] should not exceed 10% of the total Error Performance Objectives (EPO)

Depending on the simulation implementation, further parameters like the BW overlapping factor may be required. ECC Report 302, annex 2 [1] contains the methodology used to derive the BW overlapping factor with a 40 MHz victim receiver.

4.1.2 More information on FS deployments in CEPT

4.1.2.1 Number of FS links and FS link lengths

Information on number of FS links and FS link lengths were reported by 26 CEPT administrations for the latest revision of ECC Report 173 [23].

The number of FS links in the 6425-7125 MHz range can be derived from ECC Report 173, annex 1.6.

4.1.2.2 Information on population density around FS links

Some site-general studies are using different combination of FS links locations versus surrounding population density and FS height. This section presents the actual statistics of the population density surrounding an FS receiver based on real FS database in four representative CEPT administrations.

Based on real FS links receivers' databases, the statistics of surrounding population density is assessed using a 30 arcsecond resolution database, extrapolated to 2030 using UN projection data. The aim is to be able to interpret the risk of interference and the likelihood of the scenarios presented in the site-general studies.

The population density per km^2 around the FS receiver was determined over an approximately 10x10 km box, centred at the FS receiver. This size was chosen as it corresponds to the 5 km radius simulation area used in some site-general studies in the Report. The size of the simulation box may change depending on the position of the FS, as the pixels of the population database are 30 arc seconds which corresponds to 1 km only at the equator. The used database is the Grided Population of the world [25] extrapolated to 2030 according to the UN population forecast [24].

The methodology is as follows:

1 Filter the FS database and retain stations operating only in the upper 6 GHz band;

2 For each FS station;

   2.1: Create the simulation box centred at the FS station coordinates;

      2.2: Compute the total population in the obtained simulation box;

      2.3: Deduce the population density by dividing the total population over the simulation box area;

      2.4: Store the obtained value;

3 Generate the CDF.

This study was performed on four real FS database from four different CEPT countries. For confidentiality reasons, since all those databases are not public, the results are presented in an anonymous manner, as Administration 1, Administration 2, etc.

The obtained results are depicted as CDFs in Figure 2. The following observations can be done:

- For Administration 1, 97% of the FS receivers are located in areas with a population density less than 2500 inhabitants/km^2;
- For Administration 2, 97% of the FS receivers are located in areas with a population density less than 1350 inhabitants/km^2;
- For Administration 3, 97% of the FS receivers are located in areas with a population density less than 4800 inhabitants/km^2;
- For Administration 4, 99.3% of the FS receivers are situated in areas with a population density less than 3000 inhabitants/km^2.

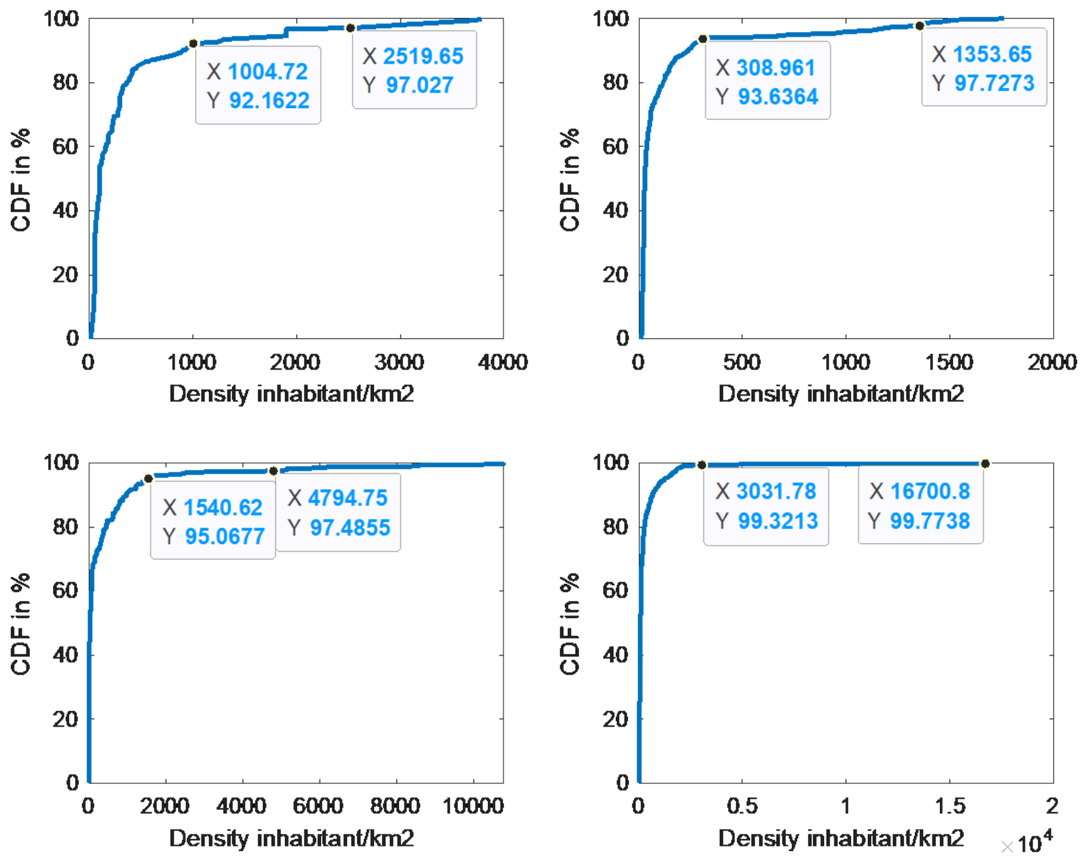


Figure 2: CDF of the population density around upper 6 GHz stations in four different CEPT administrations

Table 9 contains interpolated values from the above curves for the population densities used in some site-general studies of this Report.

Table 9: Extract of the likelihood of having a station in an area with a population density higher or equal a given population density value

P(X)>Den (inhabitant/km^2)	Administration 1	Administration 2	Administration 3	Administration 4
3000	2%	0%	2.87%	0.68%
6000	0%	0%	1.50%	0.38%
12000	0%	0%	0%	0.28%
18000	0%	0%	0%	0%
Total number of considered links	740	440	1034	1021

4.1.2.3 Further analysis on correlation between population density around FS link and FS antenna height

In addition to the above study, an assessment of the real population density around real FS sites and FS height has been performed, for the city of Munich (Germany) based on the German administration's FS database. The population density is based on infas360 database [32]. Average population density for Munich city is 4868 inhabitants/km². The city of Munich is selected because it is the German city with the highest average population density.

Statistics out of 33 FS sites equivalent to about 144 FS links could be assessed. Several FS stations can be located on each of the FS site. These sites are located within a 50 km radius from Munich city centre.

For each FS site a radius of 5 km has been considered where the population density has been derived (i.e. total population divided by 78 km²). As expected, the area with the largest population density is equivalent to FS sites located in the city centre.

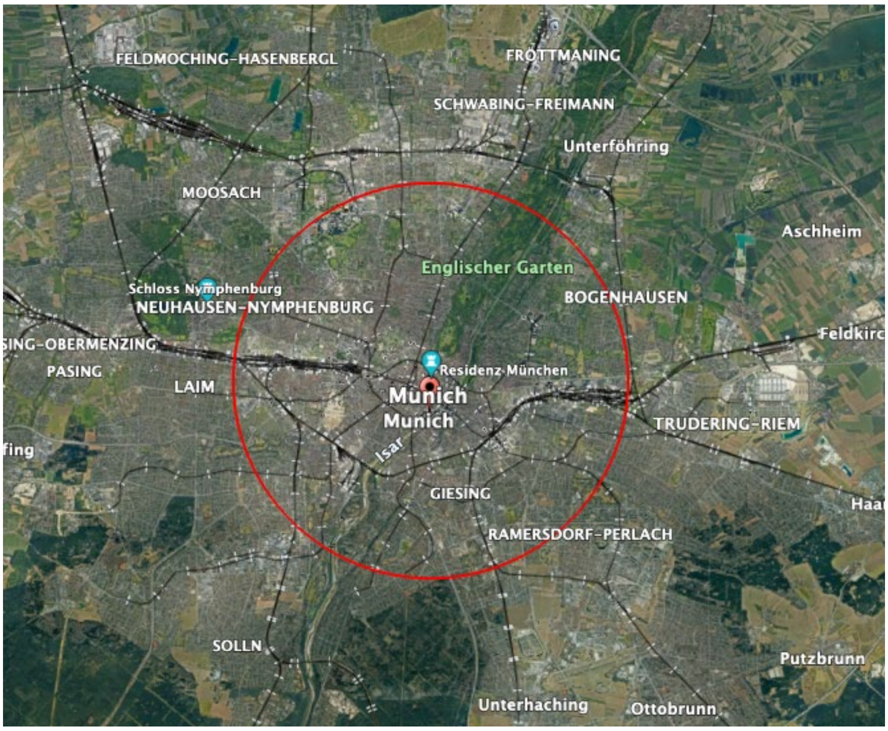


Figure 3: City of Munich - Example of a FS site located in the city centre and delimitation of population density within a 5 km radius circle (in red)

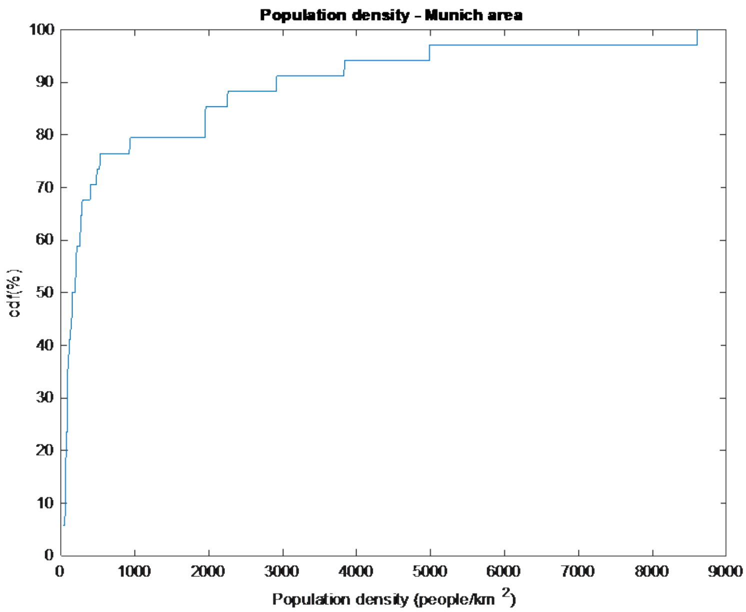


Figure 4: Population density around the FS sites located in Munich

The results of the CDF indicate that 97% of the FS receiver are located in areas where the population density is below 6000 inhabitants/km^2.

A detailed assessment shows that only one FS site, located in the city centre of Munich, exhibits a population density above 6000 inhabitants/km^2 (i.e. 8613 inhabitants/km^2). For this site the height is 86.5 m. There is no FS height of 30 m or 40 m associated with population density above 6000 inhabitants/km^2. In fact, for FS height below 40 m, the average population density is 242 inhabitants/km^2.

The second highest population density from the database is below 6000 inhabitants/km^2 (i.e. 4989 inhabitants/km^2) with a FS height of 50 m. For the Munich area, the average FS height is 55 m, and the average population density within 5 km radius of each site is 936 inhabitants/km^2.

4.1.3 Effect of interference from pulse/burst signals on FS receiver performance

At the time of writing this Report, work is still being carried out in ECC to provide a generic methodology for deriving protection criteria for any source of time-varying interference into an FS receiver. Within this activity, the studies are investigating how current FS receivers perform in the presence of pulse/burst type interference, with and without Adaptive Coding and Modulation (ACM).

As part of the ongoing work in ECC, measurements that analysed the impact of periodic burst signals, such as RLAN beacon signals, on FS links operating in the 6 GHz band, have been received and discussed, but not concluded upon. One measurement was performed in the field with a real FS link receiver and an LPI AP placed outdoors[4], while three measurements were performed in a laboratory environment in a conducted mode. The results of these measurements suggest that some pulsed/bursty signals (e.g. beacon signals with and without traffic on top) may have a more noticeable interference effect than noise-like/continuous signals at the same I/N level, for the specific measurements setup and FS equipment tested.

Therefore, it should be noted that the conclusions of the ongoing work may have impact on the results of the sharing between RLAN and FS and that further investigation of the impact of RLAN beacons may be required.

4.2 FIXED-SATELLITE SERVICE (FSS), EARTH-TO-SPACE

4.2.1 FSS Earth-to-space parameters and assumptions

Studies were already conducted in ECC Report 302 [1] and have shown that the protection criterion is fulfilled. In this Report, five other representative beams were analysed for the sake of completeness (Table 10).

Table 10: FSS Earth-to-space studied beams

Satellite Beam	Satellite Longitude	Satellite Pointing Direction	G/T Contour Model	Peak G/T (dB/K)
Global Beam	25° E	Nadir	Recommendation ITU-R S.672-4 (*recommends* 1) Beamwidth (2 x ψ_0) = 15° Gain max (G_{max}) = 22 dBi	-5.99 (T = 630 K)
Regional Beam	64° E	52.622286° N 2.150199° W	Recommendation ITU-R S.672-4 (annex 1, section 2.4.1-b) Beamwidth (2 x ψ_0) = 6° Equivalent Peak Gain (G_{ep}) = 28 dBi	-1.12 (T = 400 K)
Spot Beam 1	64° E	52.622286° N	Recommendation ITU-R S.672-4	11.98

[4] Outdoor usage of LPI WAS/RLAN is not compliant with ECC Decision (20)01 [34]. In this Report, the same conditions of use as in ECC Decision (20)01 are assumed.

		2.150199° W	*recommends* 1 (circular beam) Beamwidth (2 x ψ_b)= 0.8° L_N = -25 Peak Gain (G_m) = 38 dBi	(T = 400 K)
Spot Beam 2	64° E	52.622286° N 2.150199° W	Recommendation ITU-R S.672-4 ANNEX 1's section 1.1 Beamwidth (2 x ψ_0)= 2.6° L_s = -25 Peak Gain (G_m) = 36.4 dBi	10.38 (T = 400 K)
Zone Beam	64° E	53.273313° N 6.229937° W	Recommendation ITU-R S.672-4 *recommends* 1 (circular beam) Beamwidth (2 x ψ_b)= 4.6° L_N = -25 Peak Gain (G_m) = 32 dBi	5.98 (T = 400 K)

4.3 FIXED-SATELLITE SERVICE (FSS), SPACE-TO-EARTH

4.3.1 FSS system space-to-Earth parameters and assumptions

The frequency band 6700-7075 MHz is allocated to the FSS globally (space-to-Earth) for feeder links for non-geostationary satellite systems of the mobile-satellite service (MSS). The use of this band by feeder links for non-geostationary satellite systems in the mobile-satellite service is not subject to No. **22.2** as per footnote RR No. **5.458B**.

The parameters in Table 11 are used for FSS space-to-Earth as a victim.

Table 11: FSS space-to-Earth receiver's parameters

Parameter	Value
Frequency range	6875-7055 GHz
Noise bandwidth	1.23 MHz
Antenna diameter d	5.5 m
Peak receive antenna gain Gmax	50 dBi
System receiver noise temperature	130 K
Minimum earth station elevation angle	Acquisition – 5 degrees; Communication – 10 degrees

4.4 OTHER APPLICATIONS IN THE BAND

4.4.1 Radio Astronomy

The footnote RR No. **5.149** recognises the use of 6650-6675.2 MHz by the Radio Astronomy Service, while not providing any allocation and any rights to these usages. RR No. **5.149** urges administrations to "take all practicable steps to protect the radio astronomy service from harmful interference".

Observations of the methanol (CH_3OH) maser[5] line in the RR No. **5.149** band 6650.0-6675.2 MHz are of utmost importance to radio astronomers around the world. With RR No. **5.149**, the ITU-R recognised the importance of methanol observations in the 6.6 GHz band. Since then, the methanol line has become extremely important for the observation of star formation in its earliest stages. In fact, its detection and study in the inner parts of star forming regions is the principal way for astronomers to investigate stellar genesis. Methanol is also one of the few species that produce strong masers, which allows to detect it over cosmic distances, e.g. in the core of active galaxies orbiting super-massive black holes, and thus providing insights into black hole physics and the high-energy processes in their vicinity.

There are 18 radio astronomy stations operating in 8 CEPT countries in the 6650−6675.2 MHz band as listed in the Table 12.

Table 12: List of CEPT countries with RAS stations operating in the frequency band 6650−6675 MHz

RAS station	Country	Geographic longitude	Geographic latitude
Effelsberg	Germany	06° 53′ 01.0″	50° 31′ 29.4″
Wettzell		12° 52′ 38″	49° 08′ 42″
Medicina	Italy	11° 38′ 49″	44° 31′ 15″
Noto		14° 59′ 20″	36° 52′ 33″
Sardinia		09° 14′ 42″	39° 29′ 34″
Irbene	Latvia	21° 51′ 18″	57° 33′ 13″
Westerbork	Netherlands	06° 36′ 15″	52° 55′ 01″
Yebes	Spain	–03° 05′ 13″	40° 31′ 28.8″
Onsala	Sweden	11° 55′ 04″	57° 23′ 35″
Bleien	Switzerland	08° 06′ 43.3″	47° 20′ 23.7″
Jodrell Bank	UK	–02° 18′ 26″	53° 14′ 10″
Pickmere		–02° 26′ 42″	53° 17′ 20″
Darnhall		–02° 32′ 09″	53° 09′ 24″
Knockin		–02° 59′ 49″	52° 47′ 26″
Defford		–02° 08′ 39″	52° 06′ 03″
Cambridge		00° 02′ 14″	52° 10′ 01″
Goonhilly*		–05° 11′ 00″	50° 03′ 02″
Chilbolton*		–01° 26′ 19″	51° 08′ 42″
Note *: Planned operations			

Protection criteria for RAS are defined in Recommendation ITU-R RA.769-2 [12] and are shown in Table 13.

[5] Microwave Amplification by Stimulated Emission of Radiation: The maser is based on the principle of stimulated emission. When atoms or molecules have been induced into an excited energy state, they can amplify radiation at a frequency particular to the atoms or molecule used as the masing medium (similar to what occurs in the lasing medium in a laser). In radio astronomy, cosmic masers are widely observed in OH, H_2O, SiO, CH_3OH and others.

Table 13: Radio astronomy technical parameters

System Parameter	Value	Remarks
Integration time	2000 s	
Side lobe gain, G_r	0 dBi	According to Recommendation ITU-R RA.769-2, only side lobe receptions need to be considered
Threshold interference level Spectral power, $P_{lim,v}$ Spectral pfd, $S_{lim,v}$	 -176 dB (mW/MHz) -228 dB (W/m^2/Hz)	For spectroscopic observations: interpolated from Recommendation ITU-R RA.769-2, Table 2
Antenna height, h_{rt}	Height of focal point	The average receiving feed's height above ground of the particular telescope is to be used.

5 SHARING BETWEEN WAS/RLAN AND PRIMARY SERVICES IN THE BAND

5.1 SHARING WITH THE FIXED SERVICE

5.1.1 Studies performed outside CEPT

A number of national regulatory authorities have authorised WAS/RLAN deployments in the band 6.425-7.125 GHz. In the United States, for example, the Federal Communication Commission (FCC) considered sharing and coexistence studies, including field measurements, in the frequency band 5.925−7.125 GHz. The FCC disposition of these studies and resulting decisions are documented in [21] and [22].

5.1.2 Single interferer MCL Analysis

5.1.2.1 Introduction

It is assumed that an FS station is the victim receiver (Rx) and an RLAN AP is the interfering transmitter (Tx). In a single interferer analysis considering the system parameters provided in previous sections, the horizontal distances are determined at which the protection criterion of I/N = -10 dB is exceeded.

The following MCL formula is used:

$$P_{\mathrm{Tx}_{\mathrm{EIRP}}} - L_{\mathrm{Path}} - L_{\mathrm{Clutter}} - L_{\mathrm{BEL}} + G_{\mathrm{Rx}} + 10 \cdot \log_{10}\left(\frac{B_{\mathrm{Rx}}}{B_{\mathrm{Tx}}}\right) \leq 10 \cdot \log_{10}(kT_0B) + NF_N + \frac{I}{N}$$

where:

- $P_{\mathrm{Tx}_{\mathrm{EIRP}}}$ is the radiated power (*e.i.r.p.*) of the RLAN transmitter;
- L_{Path} is the attenuation caused by the path of transmission;
- L_{Clutter} is the attenuation caused by obstacles in the path of transmission;
- L_{BEL} is the attenuation caused by walls when the RLAN transmitter is located inside a building;
- G_{Rx} is the antenna gain of the FS receiver in direction of the RLAN transmitter;
- NF_N is the noise figure of the FS receiver;
- $\frac{I}{N}$ is the protection criterion (interference-to-noise ratio = $(I - N)$);
- B_{Tx} is the transmitter bandwidth;
- B_{Rx} is the receiver bandwidth.

5.1.2.2 Methodology

In the following, calculations were done for an area around a Fixed Service (FS) receiver (Rx) which is placed at the position (0,0) and main beam directed to the right. The impact of an interferer is determined on each point of the area, considering that the WAS/RLAN antennas are omni-directional and using Recommendation ITU-R F.699 [33] for FS.

The resulting diagrams in Figure 5 through Figure 8 are displayed in azimuth plane (top view). The coloured areas show the results that are above or below the interference criterion or called the power threshold (Nlimit). The parameters used and the results are listed below the plots. It appears that the interference area consists of two main regions: one defined by the peak radius and the other defined by the circle radius.

Peak radius results represent the maximum range of interference due to the height difference between RLAN and FS receiver, assuming smooth Earth.

Circle radius results represent the minimum range of interference received from the side lobes of the FS receiver. This means that there is horizontal and vertical discrimination.

Main beam to main beam results represent the MCL calculation, where neither vertical nor horizontal geometry was considered. These distances are the highest.

Only urban and suburban scenarios were studied. Rural scenarios were not studied in this Report but were studied in ECC Report 302 [1].

5.1.2.3 Propagation Model

The following propagation model was used for urban and suburban scenarios:

- Free space path loss (FSPL) model was used for the distances from 0 m to 55 m;
- From 55 m to 1000 m, Recommendation ITU-R P.1411-12 [37] model was used as line of sight (LOS);
- From 1000 m, the Recommendation ITU-R P.452-17 [6] was used as a non-line of sight (NLOS) case. The clutter loss model, described in Recommendation ITU-R P.2108-1 [8], was used for distances greater than 1000 m.

5.1.2.4 Parameters

Table 14: MCL Parameters

Parameter	Value	Comment/ Reference
Frequency	6775 MHz	Centre frequency of the proposed band
RLAN power (*e.i.r.p.*)	14 dBm (VLP outdoor) 23 dBm (LPI indoor)	Table 2
RLAN bandwidths	40 MHz – 320 MHz	Table 4
RLAN Antenna pattern	isotropic	Simplified assumption for single interferer case.
RLAN Antenna gain	0 dBi	
RLAN Antenna height	1.5 m / 7.5 m	ECC Report 302 / Table 3
FS Antenna height	30 m, 40 m, 75 m	Table 8
FS Antenna gain	46 dBi	Table 8
FS Receiver Noise Figure	4.5 dB	Table 8
FS Feeder loss	1.3 dB	Table 8
FS bandwidth	40 MHz	Table 8
FS Antenna Pattern	Recommendation ITU-R F.699 [33] (single-entry interference)	Table 8 (ECC Report 302, table 18)
FS Protection criterion: I/N	-10 dB	Long-term: not exceeded for more than 20% of time ECC Report 302/ECC Report 316 [2]
Percentage of locations (*p*) for clutter loss L_{Clutter}	50 %	Recommendation ITU-R P.2108-1 (clutter loss), section 3.2 (ECC Report 302, section 6.2)

Parameter	Value	Comment/ Reference
Probability (*p*) of building entry loss (L_{BEL})	50 %	Recommendation ITU-R P.2109-2 [11] (ECC Report 302, section 6.2)
Time percentage (*p*)	20 %	Recommendation ITU-R P.452-17 (ECC Report 302) Recommendation ITU-R P.1411-12 (ECC Report 302)

5.1.2.5 Results

MCL calculations have been done assuming smooth Earth in the calculation area. The RLAN heights are 1.5 m and 7.5 m. The weighted average of the RLAN height distribution in Table 3 (Urban case) is 7.5 m. The resulting plots illustrate the horizontal plane giving an indication from which position the RLAN transmitter is introducing an interference level equal to the amount of the power thresholds (Nlimit).

In the following, the outdoor/indoor urban cases with constant FS bandwidth (Rx BW=40 MHz) and variable RLAN-bandwidths (Tx BW=40 MHz to 320 MHz) are studied to account for different bandwidth overlap factors. Further the effect of varying FS heights at 30 m, 40 m, 75 m was studied.

The building entry loss (Recommendation ITU-R P.2109-2) was calculated for traditional buildings/houses and varies between 17 dB and 35.5 dB. The probability that the loss would not be exceeded was set at 50%. The building entry loss also depends on the elevation angle of the path on the building facade (degrees above the horizon). The range for the elevation angle is from 0.5 to 90 degrees.

A percentage of locations of 50% was assumed for the clutter loss (Recommendation ITU-R P.2108-1). The clutter loss is 32.5 dB.

The results in the outdoor/indoor use cases show that the separation distances become smaller as the RLAN (Tx) bandwidths increase. This can be clearly seen in the main beam to main beam and peak radius results. The reason for this is the decreasing spectral power density of the RLAN (Tx).

The main beam to main beam distances are independent of the Rx heights. The influence of the height of the FS receiver (Rx) plays a decisive role on the separation distances.

Table 15: Result table for outdoor use cases, urban/suburban scenario with RLAN heights of 1.5 m / 7.5 m

Bandwidths (Tx)	FS Heights (Rx)	Distances Main beam to main beam	Distances Peak radius (Maximum distances)	Distances Circle radius (Minimum distances)
40 MHz	30 m	11.1 km / 11.7 km	10.9 km / 11.3 km	0.7 km / 0.7 km
40 MHz	40 m	11.7 km / 11.7 km	10.7 km /11.0 km	0.7 km / 0.7 km
40 MHz	75 m	11.7 km / 11.7 km	0.9 km / 0.9 km	0.7 km / 0.7 km
320 MHz	30 m	3.9 km / 3.9 km	1.0 km / 1.0 km	0.3 km / 0.3 km
320 MHz	40 m	3.9 km / 3.9 km	1.0 km / 1.0 km	0.3 km / 0.3 km
320 MHz	75 m	3.9 km / 3.9 km	1.0 km / 1.0 km	0.3 km / 0.3 km

Table 16: Result table for indoor use cases, urban/suburban scenario with RLAN heights of 1.5 m / 7.5 m

Bandwidths (Tx)	Heights of FS (Rx)	Distances Main beam to Main beam	Distances Peak radius (Maximum distances)	Distances Circle radius (Minimum distances)
40 MHz	30 m	4.5 km / 4.5 km	1.0 km / 3.3 km	0.3 km / 0.3 km
40 MHz	40 m	4.5 km / 4.5 km	1.0 km / 1.0 km	0.3 km / 0.3 km
40 MHz	75 m	4.4 km / 4.4 km	1.0 km / 1.0 km	0.2 km / 0.2 km
320 MHz	30 m	1.5 km / 1.5 km	1.0 km / 1.0 km	0.1 km / 0.1 km
320 MHz	40 m	1.5 km / 1.5 km	1.0 km / 1.0 km	0.1 km / 0.1 km
320 MHz	75 m	1.5 km / 1.5 km	1.0 km / 1.0 km	0.0 km / 0.0 km

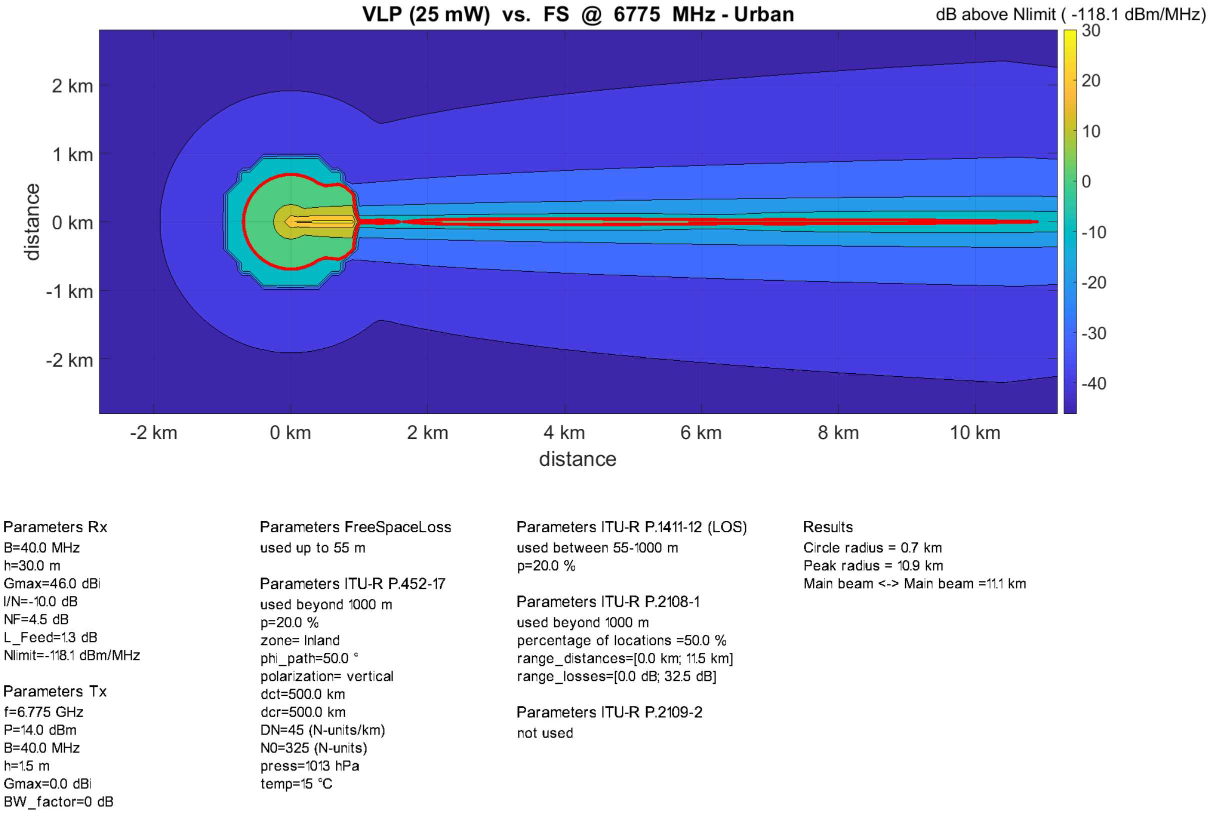


Figure 5: Outdoor use case with WAS/RLAN antenna height 1.5 m

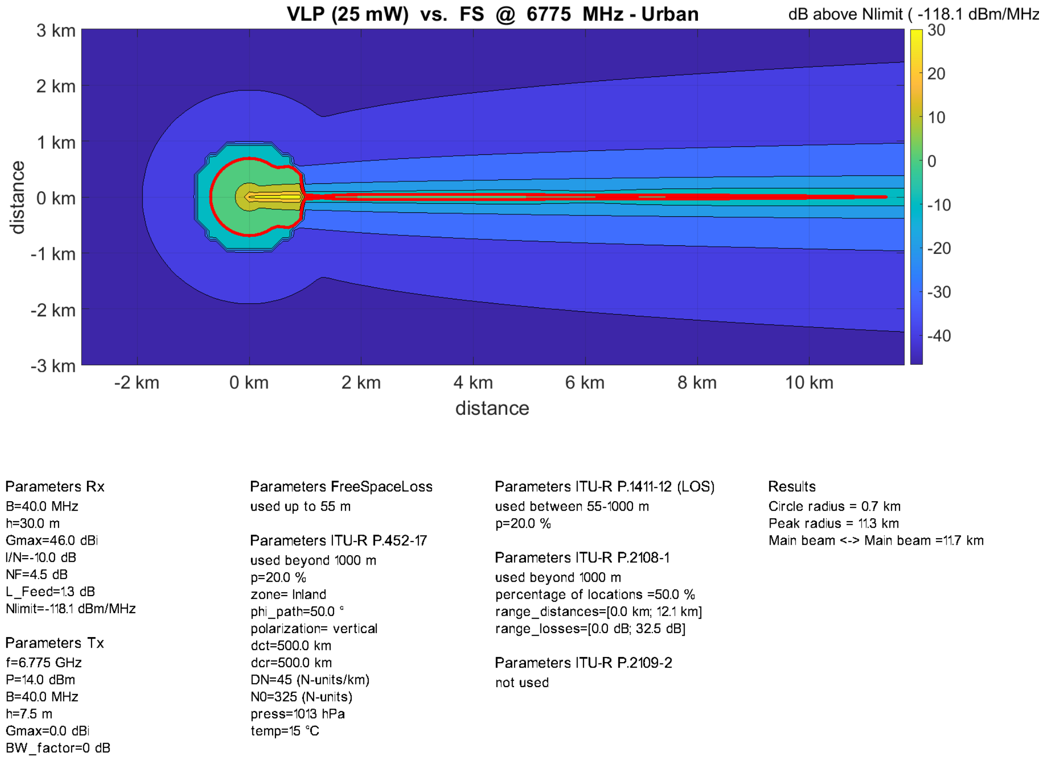


Figure 6: Outdoor use case with WAS/RLAN antenna height 7.5 m

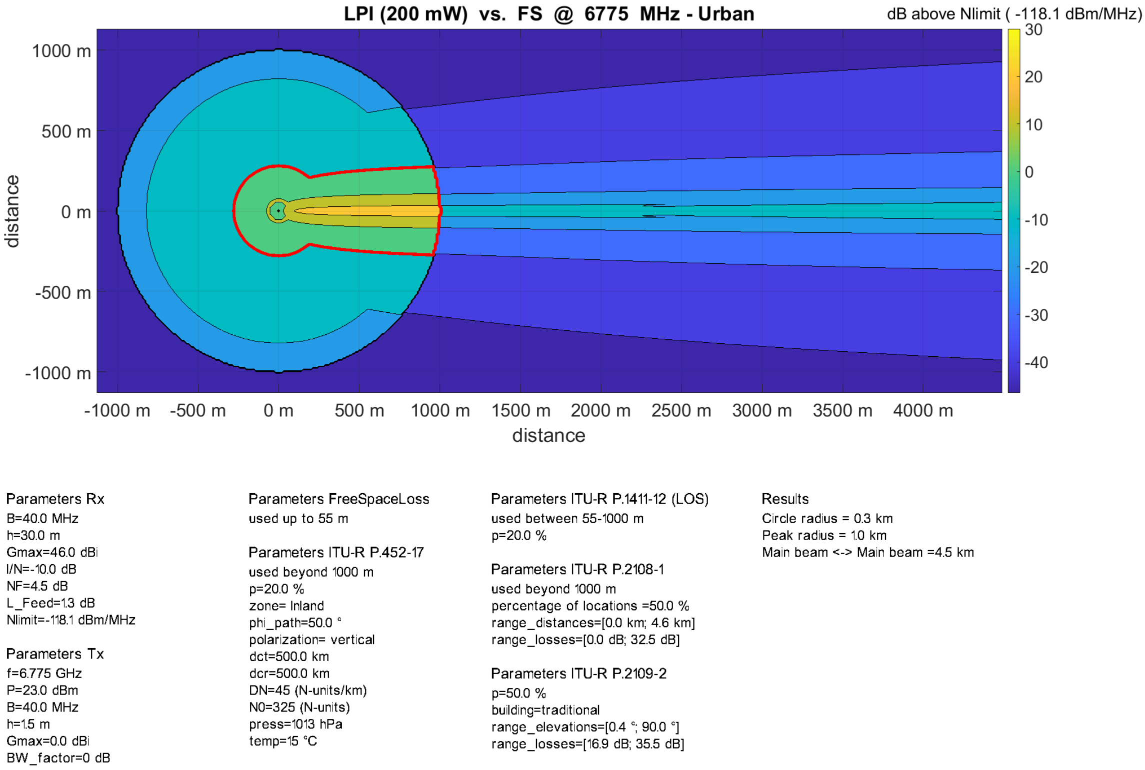


Figure 7: Indoor use case with WAS/RLAN antenna height 1.5 m

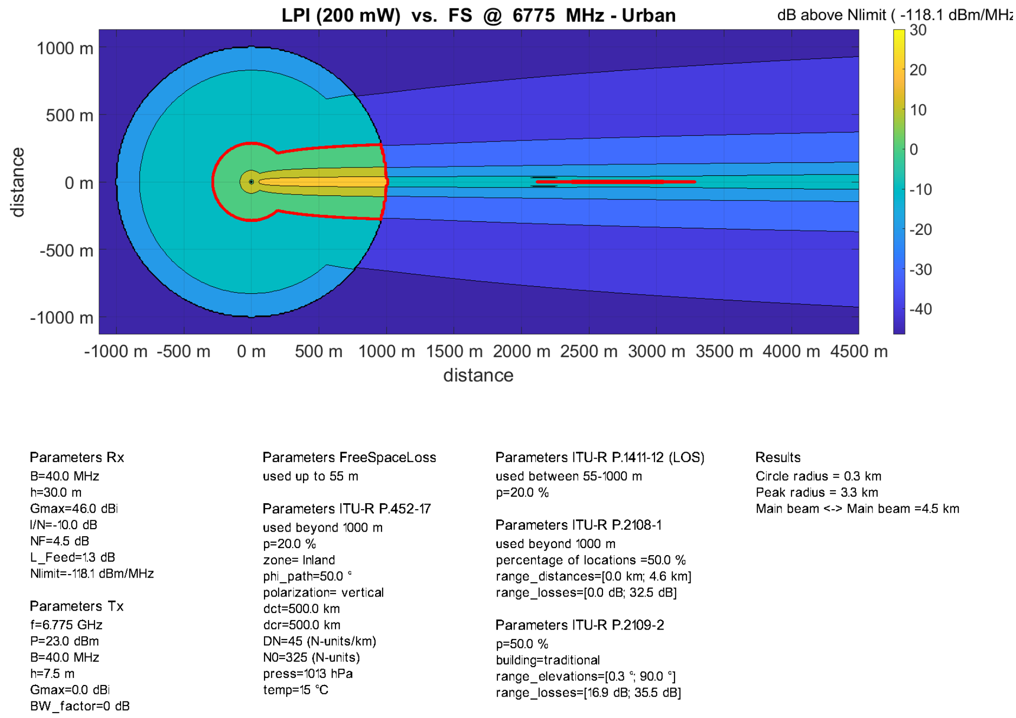


Figure 8: Indoor use case with WAS/RLAN antenna height 7.5 m

5.1.2.6 Conclusion

MCL calculations were carried out with WAS/RLAN heights set at 1.5 m and 7.5 m, where the height of 7.5 m is the weighted average of the height distribution in Table 3 under urban scenario. The effect of varying FS heights (30 m, 40 m, 75 m) is investigated, the peak radius (maximum distances) in the outdoor cases was found between 0.9 km and 11.3 km and for the indoor scenario reached a maximum of 3.3 km. The circle radius does not change significantly and is between 0 km and 0.3 km for indoor use cases and 0.3 km to 0.7 km for outdoor use cases. Also, MCL calculations have shown that the FS receiver height and WAS/RLAN Tx bandwidths have an impact on the separation distances (peak radius). Only urban and suburban scenarios were studied. Rural scenarios were not studied here but were studied in ECC Report 302 [1].

5.1.3 On Monte Carlo approaches used in this Report

In this Report, Monte Carlo studies used two different approaches:

- Joint location/time Monte Carlo: Location and time dependent parameters used in the calculations are randomly sampled at each Monte Carlo event (jointly changed), independently of each other. The output of this approach is expressed as percentage of events (location and time mixed) exceeding a protection threshold (e.g. I/N of -10 dB);
- Separated location/time Monte Carlo: Location dependent parameters are randomly sampled in a separated loop (morphologies loop) from the time dependent parameters (time loop). The output of this approach is expressed in terms of percentage of morphologies exceeding a time dependant protection criterion (e.g. I/N of -10 dB exceeded less than 20% of the time).

The methodologies of each approach are described in detail, in each study, later in this Report.

5.1.4 On FS link parameters in site-general studies

Some of the combinations of parameters considered in the site-general studies may not actually exist in the field. In particular, one verification conducted for one of the locations considered for a city of 6000 inhabitants per square kilometre highlighted that some parameter combinations did not reflect any fixed links deployed.

Thus, unless based on national data, not all the combinations in the range used in the site-general studies should be considered as representative and combinations that actually occur in practice should be considered on a case-by-case basis.

More information on FS links deployments in CEPT, including the number of FS link lengths can be found in section 4.1.2.1. The relationship between higher population density and real FS antenna height and higher population density and percentage of some FS receivers can be found in section 4.1.2.2 and 4.1.2.3. Only a very small percentage of FS are located in areas of population density greater than 3000 inhabitants/km^2 and areas of greatest population density have antennas located higher off the ground than those located in lower population densities.

5.1.5 Site-general study A

While this study, detailed in Annex 2 is site-general, a geographical position is needed to assess the fractional degradation in performance (FDP) of the FS link. Here, the geographical position of the city of Frankfurt was selected as it matches the population density used in the simulation.

Site-general joint location/time Monte Carlo simulations have been performed using 10 million events to assess whether the long-term protection criterion and FDP are met when low power WAS/RLAN (LPI) are indoor (with accidental LPI being outdoor) and very low power (VLP) WAS/RLAN are outdoor and both in operation simultaneously.

The studies have considered Frankfurt, which is a large dense German city with surrounding suburban and rural areas. The size of the simulation radius[6] is limited by the radio horizon (i.e. 59 km). The studies focused on WAS/RLAN deployment with the highest building height distribution as benchmark, different antenna peak gain (33.6 dBi and 45.5 dBi), different FS antenna heights (i.e. 30 m, 45 and 79 m), and three different WAS/RLAN density deployment models of Scenario A. In total 8 different configurations/cases were investigated. The results of the study are computed taking into account all the possible statistical combinations in terms of position, population density, FS height, FS antenna gain from real data set from the German administration.

The FS receiver is located in the centre of the simulation area. The urban, suburban and rural area are simulated using rings around the FS receiver. The RLANs are randomly distributed within the simulation area according to each ring. For low FS antenna heights, the height distribution of the RLAN considered the Fresnel zone. An exclusion zone of 20 m is considered.

The transmission loss is computed using a combination of Recommendation ITU-R P.525 [10] from 0 to 40 m, WINNER II model [9] (i.e. statistical model which includes built-in clutter) from 40 m to 1 km, and the Recommendation ITU-R P.2001 model from 1 km to the radio horizon. The clutter loss models consist of Recommendation ITU-R P.2108 for urban and suburban and Recommendation ITU-R P.452-17 rural clutter model (village centre). Indoor modelling captures building entry loss (BEL) using Recommendation ITU-R P.2109.

The methodology, to derive the number of RLANs transmitting in-band into the FS receiver, follows the same procedure as in ECC Report 302 and ECC Report 316 (Scenario A). the equivalent number of instantaneously transmitting WAS/RLANs used in the simulations is a function of the wireless devices operating in licence exempt spectrum factor, the upper 6 GHz factor, the market adoption factor (6 GHz capable devices), the busy hour factor, the RF Activity factor, the bandwidth overlap factor. 98.8% of devices are considered indoor and 1.2% outdoor.

For this study, the Fade Margin (FM) and the Net Fade Margin (NFM) values are extracted from the database of the German administration. The values represent the 5%-ile and 95%-ile of the minimum FM and NFM distribution and the mode value (i.e. the most used value). FM and NFM combined together range from 11 dB to 40.3 dB. The values are specific for Germany and provide a realistic picture because they are coming from statistics of real links for different link lengths including 24.48 km. Note that the NFM values are lower than the FM by the ATPC range.

---

[6] A large simulation radius, i.e. up to the radio horizon, captures all the aggregated effects from the WAS/RLANs in order to fully account for the long-term interference effect.

The I/N results and the FDP results have been used as a metric to quantify the interference. The FDP is calculated from a) the I/N distribution and b) the fade distribution that the FS receiver experiences due to multipath. The fade at the FS receiver is computed using Recommendation ITU-R P.530 and is dependent the link characteristics (coordinates, FS heights, link length, FS link availability/FM/NFM). The exact coordinates of German FS links are confidential, therefore for the P_0 calculation of Recommendation ITU-R P.530 [38], a coordinate in the Hessen state was used.

Results from large number of joint location/time Monte Carlo events (i.e. 10 million) show that the long-term protection threshold (I/N=-10 dB for less than 20% of the runs) is respected for all the cases even with accidental outdoor LPI. The FDP values obtained for site-general FS link with and without ATPC are all below 10%. In other words, the results show that the probability of a FS link being degraded is very rare.

The joint location/time Monte Carlo simulations carried out used location- and time-based distributions for calculating a percentage of interference. Therefore, results are in terms of location-time percentage and not in terms of time percentage only.

Furthermore, site-general separated location/time Monte Carlo simulations have been performed, which are meant to address specifically fixed interferers separately to mobile interferers. In the context of this study, fixed interferers are RLAN access point (AP) and the client RLAN devices are mobile. Fixed RLAN AP devices are modelled using the separated location/time simulation, and the RLAN client devices are modelled separately using the joint location/time Monte Carlo simulation.

When a separated location/time simulation is launched, a total number of fixed RLAN APs is derived from parameters that are non time-dependent (i.e. the RF activity factor is not used). These fixed RLAN APs form a morphology pool (i.e. a pool of RLAN devices with specific (x,y,z) position morphology). This pool contains active and non-active fixed RLAN APs. The number of active APs is dependent of the AF. A number of active APs will be selected from that morphology pool. The morphology pool does not change in time, but the selection of what is active and what is not active is time dependent. Several morphology pools will need to be investigated to have enough statistics in the morphology-event domain. For this study, 5000 different fixed RLAN morphology-events (i.e. location) have been investigated.

For each time instant, an aggregated I/N is calculated over the active RLAN of the morphology pool where the propagation loss varies with time and where clutter loss, BEL loss, Tx power, antenna gains, antenna heights do not vary with time. This leads to a distribution of aggregated I/N in the “pseudo” time domain (i.e. pseudo because real time information is not available for WINNER II model). One million time-events have been considered for each morphology-event in this study

Finally, for each morphology-event, the total aggregated I/N time-event is the linear summation of I/N from RLAN AP and I/N from RLAN client devices. A single FDP is therefore derived for each morphology-event. With all the various morphology-events, statistics of the FDP are presented in this Report.

Two cases out of eight, that exhibited the worst aggregated I/N distribution, have been investigated with the separated location/time methodology. The long-term protection criteria of I/N=-10 dB at 20% of the time is respected for both of these cases.

For the case with high FS antenna height, the 5000 FDP values did not exceed 10%. For high FS receiver, there is no risk of degradation from RLAN to the FS link because the maximum FDP value is 2%.

For the case with low FS antenna height, the percentage of fixed RLAN morphologies, where the FDP did not exceed 10%, is 99.2% for FM = 23 dB, 99.5% for FM = 29.7 dB and 99.6% for FM = 40.3 dB. The results from the fixed RLAN morphologies studied show that the percentage of morphologies where the FDP exceeds 10% for a FS link is less than 0.8% (for the minimum 5%-ile FM) or 0.4% (for the minimum 95%-ile FM).

The FDP value obtained from joint location/time Monte Carlo and the median value from separated location/time Monte Carlo are similar for all cases.

5.1.6 Site-general study B

This study uses a similar environment as site-general study A, with separated location/time as in Annex 2, but an alternative method to assess the potential interference to Fixed Service. Details of this study are available in Annex 3.

A first set of simulation results are obtained using the parameters from site-general study A, with the following modifications:

- FS antenna pattern is Recommendation ITU-R F.699 which is for single-entry interference;
- Polarisation loss is randomised according to ECC Report 302, section 6.3.1 Step 2;
- Simulation area is 1 km radius around the FS site;
- Only FDP protection criterion was assessed.

A second set of simulation results are obtained using Recommendation ITU-R F.1245 for the FS antenna pattern, and a fixed 3 dB polarisation loss. Hence for this set the only differences to study A are the 1 km simulation radius, and that only FDP protection criterion was assessed.

The simulations are single entry, but the outputs are processed in order to get results for whole deployments (equivalent to multiple entry) described in Scenarios A and B. The method can be summarised as follows: given the single-entry probability of exceeding the 10% FDP (from simulation, checking against the FDP protection criterion), and assuming that interference events from different RLANs are statistically independent, the probability of the FDP criterion being exceeded when multiple RLANs are deployed is computed. The core assumption being that, in practice, the instances of high aggregate interference power seen at any point in time by an FS receiver are dominated by a single RLAN contribution.

The method is based on a single entry I/N threshold level that will lead to the fact that the 10% FDP criterion is exceeded. For the example links evaluated in the study, this threshold is translated in the range 6.7 dB to 7.5 dB for 1.97% RF activity factor (used in RLAN deployment Scenario A), and 5.8 dB to 6.5 dB for 2.45% RF activity factor (used in RLAN deployment Scenario B). If there is an RLAN that reaches this I/N level, the protection criterion is exceeded.

The probability of a randomly dropped RLAN to reach an I/N level exceeding the threshold is evaluated with a joint location/time Monte Carlo simulation. The simulation is single-entry, with a single RLAN per drop evaluated for the I/N at that random location inside the simulation area. The I/N statistics of the simulation are used to evaluate the probability of an RLAN location exceeding the I/N threshold level. The percentage of RLAN locations exceeding the I/N threshold level depend on the FS antenna height and antenna gain. For the Recommendation ITU-R F.699 antenna pattern and random polarisation loss, this ranges from 0.0011% (79 m FS height, 45.5 dBi antenna gain, RLAN deployment Scenario A) to 0.044% (30 m FS height, 33.6 dBi antenna gain, RLAN deployment Scenario B). For the Recommendation ITU-R F.1245 [5] antenna pattern and 3 dB polarisation loss, this ranges from 0.0013% (79 m FS height, 45.5 dBi antenna gain, RLAN deployment Scenario A) to 0.0097% (30 m FS height, 33.6 dBi antenna gain, RLAN deployment Scenario B).

The overall probability of any RLAN exceeding the FS protection criterion when a full RLAN deployment is considered is derived from the single RLAN probability considering the total number of active RLANs based on the population density.

Using Recommendation ITU-R F.699 and random polarisation loss, for the 30 m FS antenna height, the exceedance rate of the 10% FDP ranges from 1.16% to 16.54% (FM = 23 dB), depending on the RLAN density scenario and the FS antenna gain. For the 45 m height FS antennas, the exceedance rate ranges from 0.40% to 9.23% (FM = 29.7 dB). For the 79 m height FS antennas, the exceedance rate ranges from 0.11% to 3.82% (FM = 40.3 dB).

Using Recommendation ITU-R F.1245 and fixed polarisation loss, for the 30 m FS antenna height, the exceedance rate of the 10% FDP ranges from 0.27% to 3.88% (FM = 23 dB), depending on the RLAN density scenario and the FS antenna gain. For the 45 m height FS antennas, the exceedance rate ranges from 0.06% to 1.20% (FM = 29.7 dB). For the 79 m height FS antennas, the exceedance rate ranges from 0.01% to 0.23% (FM = 40.3 dB).

5.1.7 Site-general study C

This study utilises the separated location/time Monte Carlo method to assess the long-term protection criterion and FDP at the FS receiver resulting from the deployment of WAS/RLAN devices in its vicinity, with both systems operating on the same frequency. The study is site-general where typical FS receiver parameters as depicted in Table 79 have been used. The FS receiver was assumed to be at the centre of a circle of radius 5 km and RLANs have been randomly deployed around the FS receiver. The density of RLANs within the circular area has been chosen according to the population densities of the major cities in CEPT countries. Therefore, population densities of 3000, 6000, 12000 and 18000 inhabitants per square km have been selected to represent different cities [20]. Specifically, Helsinki, Milan[7], Barcelona and Paris were selected due to their approximately similar population densities in the order mentioned above. Figure 9 shows an example of simulation area with an FS receiver at the centre, and WAS/RLAN devices randomly deployed, with some actively transmitting.

While this study is site-general, a geographical position is needed to assess the FDP. Here, the geographical positions of the cities of Helsinki (Longitude: 24.9354°, Latitude: 60.1695°), Milan (Longitude: 9.18951°, Latitude: 45.46427°), Barcelona (Longitude: 2.2167°, Latitude: 41.3173°) and Paris (Longitude: 2.3522°, Latitude: 48.8566°) were selected as they match the population density used in the simulation. It is worth mentioning that no real links were used as there was no information available to confirm if any real FS links similar to the ones studied are deployed in those cities. Section 4.1.2 gives more information about FS deployment in CEPT.

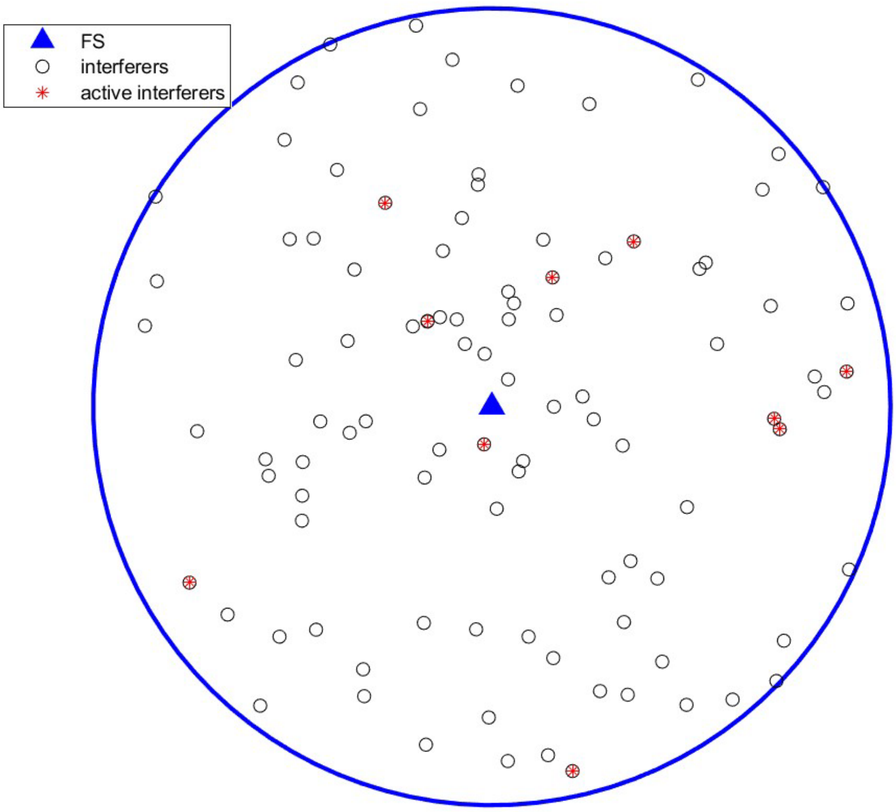


Figure 9: Example of separated location/time Monte Carlo topology

[7] Although Milan has a population density of 7500 inhabitants per square km, a conservative value of 6000 inhabitants per square km was considered in the study.

In separated location/time Monte Carlo method, the time-dependent and location-dependent random variables are separated. Thereafter, time-dependent random variables are processed to calculate the CDF or PDF of I/N at the FS receiver, which in turn are used to assess the protection criteria. Hence, at each location-iteration the protection criteria (the long-term and FDP) are assessed and statistics of pass and fail values is provided.

The simulation methodology, results and conclusion of this study are highlighted in the following sections. The detailed study can be found in Annex 4.

5.1.7.1 Simulation methodology

The simulation flow used in the study is outlined as follows:

1 FS link characterisation

Define an FS link with the technical characteristics from Table 82. The position of the FS receiver is set to (0,0).

2 RLAN characterisation

Define RLAN devices according to their types, set technical characteristics to the device types.

3 Initiate the location loop

3.1. Initiate all the location-dependent variables

As per the simulation radius, calculate the total number of RLANs overlapping FS bandwidth. Starting from 20 m distance from the FS receiver, randomly deploy RLANs. For each of the dropped RLAN, calculate FS antenna gain, propagation loss depending upon the distance from FS receiver (WINNER II assuming only location variability, Recommendation ITU-R P.452 is a function of time), clutter-loss, BEL and polarisation loss.

3.2. Initiate time loop

3.2.1. Initiate all the time dependent variables.

3.2.2. Out of all the deployed RLANs in step 3.1., randomly activate the RLANs according to the RF activity factor. Calculate the propagation loss (Recommendation ITU-R P.452), if applicable.

3.3. End time loop

3.4. Collect the I/N values obtained over the time loop.

3.5. Assess the protection criteria based on the obtained I/N statistics which corresponds for the current location iteration.

3.5.1. Form the CDF/PDF of the I/N values obtained and verify against the long-term protection criterion

3.5.2. Calculate the FDP value (The outage due to fading at the FS receiver is computed using Recommendation ITU-R P.530.

4 End location loop.

5 Gather statistics of how many of the location iterations have passed/failed the protection criteria from all the tested location iterations.

5.1.7.2 Results

The results were expressed in terms of percentage of location morphologies exceeding the protection criteria, defined later on as exceedance rate.

Each location iteration was validated against the long-term protection criterion of I/N=-10 dB not exceeding for more than 20% of time and the FDP not exceeding 10%. The calculation for the results of long-term protection criterion was straightforward: each I/N vector derived from the location iteration was compared against the criterion. If the 20% of the I/N vector values were less than -10 dB, then result is pass, otherwise, it is a fail.

The simulations were performed for the four sets of cases each for the population densities of 3000, 6000, 12000 and 18000 inhabitants/km^2 These cases are as follows:

- FS gain: 34 dBi, FS height: 30 m;
- FS gain: 46 dBi, FS height: 30 m;

- FS gain: 46 dBi, FS height: 40 m;
- FS gain: 46 dBi, FS height: 79 m.

Three types of typical link lengths were considered based on the FS heights. A short-haul link of length 20 km was chosen for an FS height of 30 m, while medium and long-haul links of length 32 km and 50 km were chosen for FS heights of 40 m and 79 m, respectively.

Table 17 shows the combined results for both the interference criteria, long-term and FDP without ATPC. The last column shows the percentage of deployments that have exceeded the long-term or FDP. This value is always lower bounded by the minimum value between the exceedance rate of the long-term protection criterion or FDP since some of the simulated deployment may break only one of the criteria or both.

Further analysis assessing the effect of ATPC (using 15 dB and 20 dB) showed no difference between the cases with and without ATPC for the links under consideration.

Table 17: Long-term protection criterion and FDP results

Link	Radius (km)	Population Density (inhabitants/ km²)	FS Gain (dBi)	FS Height (m)	Link Length (km)	Exceedance rate for Long-Term Protection Criterion	Exceedance rate for FDP
1,1	5	3000	34	30	20	0%	3.5%
1,2	5	3000	46	30	20	0%	1.5%
1,3	5	3000	46	40	32	0%	0.6%
1,4	5	3000	46	79	50	0%	0%
2,1	5	6000	34	30	20	0%	7.17%
2,2	5	6000	46	30	20	0%	7.17%
2,3	5	6000	46	40	32	0%	1.63%
2,4	5	6000	46	79	50	0%	0.4%
3,1	5	12000	34	30	20	1.53%	18.47%
3,2	5	12000	46	30	20	2.67%	10.5%
3,3	5	12000	46	40	32	0.3%	4.3%
3,4	5	12000	46	79	50	0%	0.2%
4,1	5	18000	34	30	20	23.57%	34.80%
4,2	5	18000	46	30	20	30.63%	21.97%
4,3	5	18000	46	40	32	5%	11.17%
4,4	5	18000	46	79	50	0%	0.93%

5.1.7.3 Conclusion

This study utilises the separated location/time Monte Carlo method to assess the long-term protection criterion and FDP at the FS receiver resulting from the deployment of WAS/RLAN devices in a circular area with a radius of 5 km. The number of interfering WAS/RLAN devices around an FS receiver were derived using High parametric values from Scenario B. Four different population densities of 3000, 6000, 12000, 18000 inhabitants per square km were used. Three different FS antenna heights were considered, 30 m, 40 m, and 79 m, coupled with FS antenna gains of 36 dBi and 46 dBi and three FS link lengths 20 km, 32 km, and 50 km, respectively.

The compatibility was evaluated by assessing the exceedance rate of the two interference protection criteria i) long-term protection criterion of I/N=-10 dB not to be exceeded by more than 20% of time, and ii) the fractional degradation in performance (FDP) not to exceed 10%. The exceedance rate was calculated from the number of location iterations exceeding the criterion out of the total iterations.

The results show that higher population densities result in a higher exceedance rate of the two protection criteria. The exceedance rate for the long-term protection criterion ranges from 0% to 30.63% and for the FDP ranges from 0% to 34.80% (for a range of FM values between 30 dB and 51 dB). Under the considered combinations of the different parameters, it can be recognised that for FS receivers with lower antenna gains (hence higher sidelobes) and/or lower antenna heights, the exceedance rate is more likely to increase. The exceedance rates for the studied FS links utilising ATPC are similar to the ones without ATPC.

5.1.8 Site-general study D

This study used a Monte Carlo approach to analyse the interference caused by WAS/RLAN systems operating in the 6425-7125 MHz frequency range on a FS link deployed in the centre of a dense city with about 5400 inhabitants/km^2 distributed in a large area of about 606 km^2.

A customised simulator based on the source code of SEAMCAT was used to assess the WAS/RLAN impact on both the long-term and the fractional degradation in performance (FDP) protection criteria of FS links.

Since this was a site-general study, no precise FS link parameters or terrain data were used. Instead, the general parameters of an FS link (described in Table 8) were assumed. In the same manner, the fade margin (FM) being unknown, a wide range of values was considered (from 13 to 45 dB, consistent with Table 8).

5.1.8.1 FS and WAS/RLAN deployment model

A population density of about 5400 inhabitants/km^2 was considered, dropped uniformly inside a circular area of 13.89 km radius modelling a dense city centre and leading to about 3.3 million inhabitants living in this area (around 606 km^2). Such population density is one of the highest in the CEPT countries. An FS link of 20 km was considered with its receiver located in the centre of this WAS/RLAN circular drop zone as show in Figure 10.

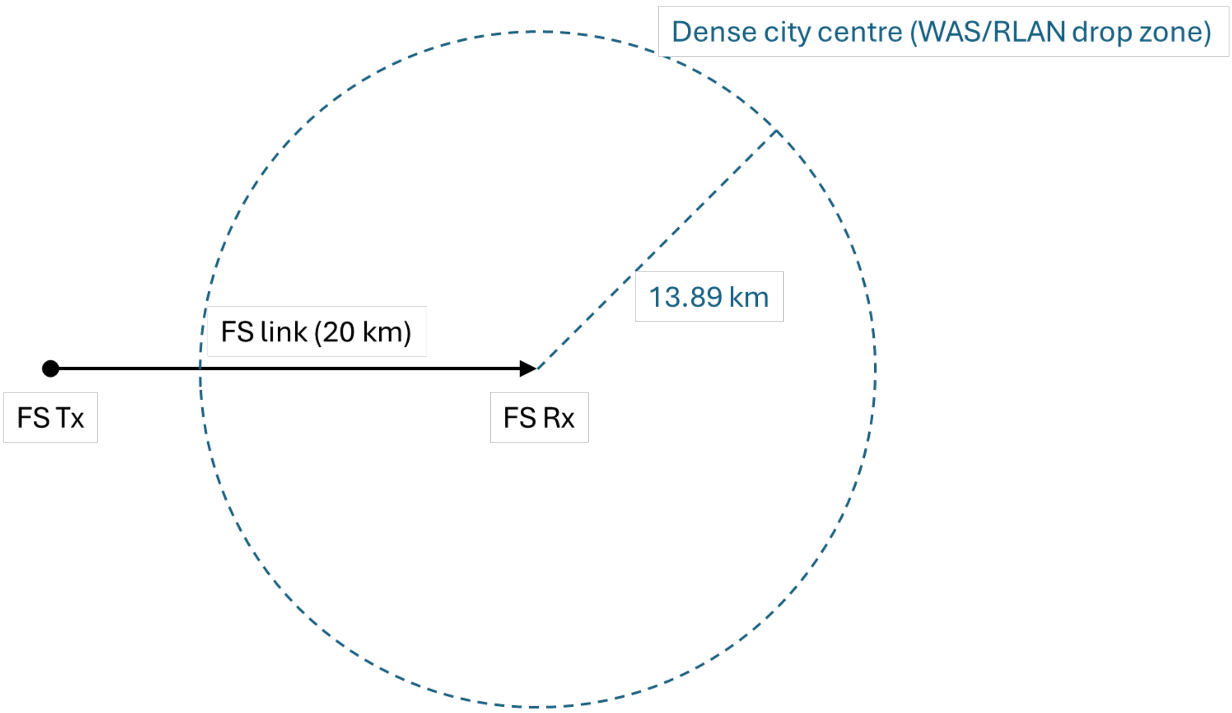


Figure 10: Dense city model area (WAS/RLAN drop zone)

In each Monte Carlo event, a number of instantaneously transmitting WAS/RLAN are dropped inside the WAS/RLAN drop zone. WAS/RLAN were dropped outside the first Fresnel zone of the FS link (modelled as an ellipsoid in the 3D space).

Both Scenario A and its sensitivity counterpart Scenario B were investigated using their “High” assumptions regarding the upper 6 GHz market adoption.

Table 18 gives the number of instantaneously transmitting WAS/RLANs to drop both indoor and outdoor in each run.

Table 18: WAS/RLAN deployment model based on “High” assumptions

Parameters	Scenario A	Scenario B
Simulation radius (km)	13.89	
Total population	3277451	
Market Adoption factor (6 GHz capable devices)	50.00%	60.00%
Busy Hour factor	62.70%	
Wireless devices operating in licence exempt spectrum	90.00%	100.00%
Upper 6 GHz factor	40.75%	47.00%
Number of Upper 6 GHz transmissions	376828.62	579499.22
RF Activity factor	1.97%	2.45%
Bandwidth overlapping factor	23.95%	
Number of instantaneously transmitting WAS/RLANs	1779	3402
Number of instantaneously transmitting WAS/RLANs indoor	**1757**	**3360**
Number of instantaneously transmitting WAS/RLANs outdoor	**22**	**42**

No WAS/RLANs were dropped within a 20 metres radius from the FS and the 1st Fresnel zone around the FS link was cleared. A height offset (h_{offset}) of 1.5 m was added to each WAS/RLAN height to take into account the ceiling when assessing if it was dropped inside the Fresnel exclusion zone or not.

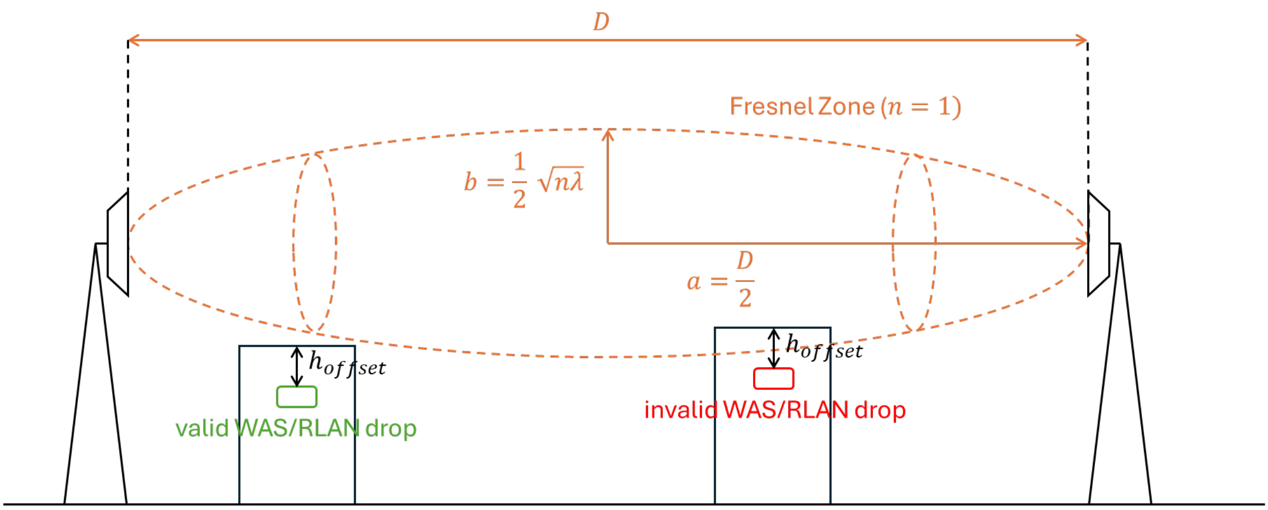


Figure 11: Fresnel exclusion zone definition

5.1.8.2 Main simulation results

While this study is site-general, a geographical position is needed to assess the FDP. Here, the geographical position of the city of Madrid (Longitude: -3.70261°, Latitude: 40.4165°) was selected as it matches the population density used in the simulation. It is worth mentioning that no real links were used and/or there was no information available to confirm if any real FS links similar to the ones studied are deployed in this city. Section 4.1.2 gives more information about FS deployment in CEPT.

Several FS parameters were investigated to assess the interference of a WAS/RLAN deployment. For each parameter investigated, I/N statistics were collected using 5 million events from Monte Carlo simulations and used to assess both the long-term protection criterion (I/N = -10 dB not exceeded for more than 20% of time) and the fractional degradation in performance criterion (FDP below 10%).

A Monte Carlo analysis with separate location and time variabilities was also performed on a reduced WAS/RLAN drop zone (5 km radius instead of 13.89 km). It involved 200 topologies each having 100000 time-events to be able to assess the FDP criterion per topology.

Annex 5 has all those simulation results, but the main findings of this study is in Figure 12 where both protection criteria are assessed for the lowest and the highest FS peak antenna gain, assuming an FS height of 40 metres and 3 dB of polarisation mismatch.

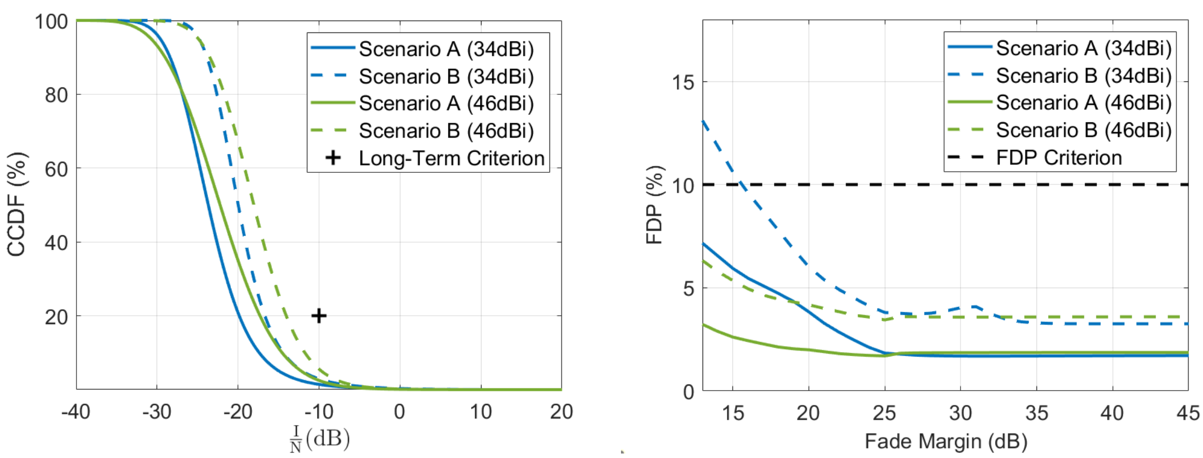


Figure 12: FS protection criteria assessment for different values of the FS receivers peak antenna gain: long-term (left) and FDP vs FM (right)

In all scenarios and configurations, the long-term protection criterion (left) is respected. For Scenario A, the FDP criterion (right) is respected for all FS configuration (and FM). For Scenario B, it is only for an FS peak antenna gain of 34 dBi that the FDP can exceed the 10 % threshold when the FM is low (below 16 dB), otherwise the FDP criterion is respected in all other cases. For a dense city as the one studied, whose population density is one of the highest in the CEPT countries, the choice of a low FM (about 15 dB) seems unlikely to be coupled with a low antenna gain (34 dBi).

5.1.8.3 Conclusions

This site-general study involves an FS link receiver deployed in the middle of a simulation zone where population density is about 5400 inhabitants/km^2. This value is among the highest that can be found in CEPT countries.

Several assumptions were investigated and in almost all cases, WAS/RLAN respect both long-term and FDP criteria (assuming the first Fresnel zone being cleared). It is only when assuming the highest deployment of Scenario B (high market adoption of the WAS/RLAN in the upper 6 GHz) coupled with a low FS fade margin and a low FS peak antenna gain that the FDP criterion could be exceeded by few percent, while in the very vast majority of the studied cases, the FDP is well below the 10% threshold resulting in a feasible FS link operation in presence of WAS/RLAN.

A location and time analysis showed that topologies having a combination of many factors where a WAS/RLAN was in close vicinity of the FS receiver (main beam), and with a (relative) high height compared to the FS receiver height, and with a high transmit power seen by the FS receiver, and with a low building entry loss may cause the FDP criteria to be exceeded when the FS fade margin is low. This site general study of a densely populated city centre showed that the likelihood of exceeding the FDP criterion is highly dependent upon having all those conditions being fulfilled and is low even for a link with a limited fade margin (3% for Scenario A and 5.5% for Scenario B for fade margin of 13 dB) and is highly site-specific.

5.1.9 Site-specific study

This analysis presents site-specific RLAN sharing studies with the point-to-point FS in the upper 6 GHz band (6425–7125 MHz). This analysis extends the sharing and compatibility studies performed in ECC Report 302 and ECC Report 316 between WAS/RLAN systems and existing incumbent systems in 5925-6425 MHz to the upper 6 GHz band.

The studies attempt to quantify and qualify the risk of exceeding the long-term and Fractional Degradation Performance (FDP) protection criteria.

This study considers a selection of real FS receivers in the following countries:

- United Kingdom;
- France;
- Lithuania;
- Czech Republic.

This study considered a simulation area extended over 150 km simulation radius, leading to a total area of 70685 km^2. In addition to the fact of considering real FS positions and characteristics, the study also considered the real population density around the FS receiver with pixels as precise as 1 km^2. For propagation losses calculations, the terrain profile around the FS receiver was simulated according to the SRTM database [14]. When possible, real building positions and height are also taken into account to model indoor WAS/RLAN.

A detailed study description is available in Annex 6.

5.1.9.1 Technical characteristics of WAS/RLAN in the upper 6 GHz frequency range

WAS/RLANs were modelled as follows.

1 The transmitter radiated power distribution used in these simulations is depicted in Table 41.
2 The WAS/RLAN antenna height distribution used is depicted in Table 3. For the FS receivers in the UK, within approximately 2 km of each FS receiver, the indoor WAS/RLANs are dropped over the buildings per the UK building database and assigned a height per that building. For distances greater than 2 km of each FS receiver, the indoor WAS/RLAN height distribution is derived from the UK building database [39] over the simulation region (see Table 99 in Annex 6).
3 The bandwidth distribution takes into account channels of 20 MHz, 40 MHz, 80 MHz, 160 MHz and 320 MHz with the associated weights defined in Table 4.

Table 19 summarises the WAS/RLAN deployment model and specifies the total number of instantaneously transmitting devices within the CEPT countries during the ‘busy hour’, according to Scenario A. The UN projected population of CEPT in 2030 [24], including ‘all ages’ and ‘ages 10 to 90 years old’, are considered as indicated in Table 19. The table includes parametric inputs (Low, Mid and High) for the busy hour factor and the market adoption factor. Therefore, Low, Mid and High values of instantaneously transmitting devices are given for each scenario.

Table 19: RLAN deployment Models used in the simulations

	Ages 10-90			All Ages		
	Low	Mid	High	Low	Mid	High
Total UN projected Population of CEPT 2030 (ages 10 to 90 years old)	609 503 000			688 447 000		
Wireless devices operating in licence exempt spectrum (remainder operating in licensed spectrum)	90%			90%		
Busy Hour Factor	50%	62.70%	62.70%	50%	62.70%	62.70%
6 GHz Factor (Upper 6 GHz / (Upper 6 GHz + 5 GHz + 2.4 GHz)) (%)	40.75%			40.75%		
Market Adoption Factor (6 GHz capable devices)	25%	32%	50%	25%	32%	50%
RF Activity Factor Per Person	1.97%			1.97%		
Instantaneously Transmitting Devices	550455	883547	1380542	621752	997986	1559353

Two sets of simulations are run, one assuming a population of ‘all ages’ and another assuming a population of ‘ages 10 to 90’ as a sensitivity analysis, based only on the High deployment assumptions.

In each simulation iteration, the instantaneously transmitting devices are dropped in proportion to the population density based on the 30-arcsecond Gridded Population of the Word database with no WAS/RLAN placement over water.

As in ECC Report 302, the total population of CEPT has been assigned to urban, suburban and rural environments as follows:

- Urban: 50%;
- Suburban: 27%;
- Rural 23%.

5.1.9.2 Fixed service parameters

The fixed service parameters were based on the country database depending on where the studied link is situated. In the absence of any parameter, values from Table 8 section 4.1.1 were used.

5.1.9.3 Propagation model

Table 20 summarises the propagation models used for the FS simulations.

Table 20: Summary of propagation models for FS study

Scenario	Propagation Model for RLANs in Urban/Suburban	Propagation Model for RLANs in Rural
Distance < 40 m	Free Space Path Loss (FSPL)	

Scenario	Propagation Model for RLANs in Urban/Suburban	Propagation Model for RLANs in Rural
40 m ≤ Distance < 1 km	WINNER II LOS/NLOS For WAS/RLAN in Urban and Suburban, C2 and C1 WINNER II models are used respectively.	Recommendation ITU-R P.452-17 (3 arcsecond SRTM terrain database) + Recommendation ITU-R P.452-17 Clutter Loss (if the distance and angle conditions are met) Recommendation ITU-R P.452-17 Clutter Loss Category: ▪ Deciduous Tree, Mixed-Tree Forest or Coniferous Tree if the European Environment Agency's Corine Land Cover (CLC)[8] indicates as such ▪ Else, Village Center Clutter
Distance ≥ 1 km	Recommendation ITU-R P.452-17 (3arcsecond SRTM terrain database) + Recommendation ITU-R P.2108-0 Clutter Loss	

5.1.9.4 Simulation results: Long-term protection criterion

For each of the administrations, five million (5000000) iterations of a Monte Carlo simulation were performed to determine the aggregate I/N at each of the FS receive locations. For each iteration, the active WAS/RLANs were deployed randomly in accordance with section 5.1.9.1.

Figure 13 shows the percentage of 5000000 iterations for each of the 7 FS receivers located in the UK where the I/N from all WAS/RLANs (indoor + outdoor) exceeded the I/N level on the x-axis for the 'all ages'. The results indicate that the long-term protection criterion was met for all the FS receivers.

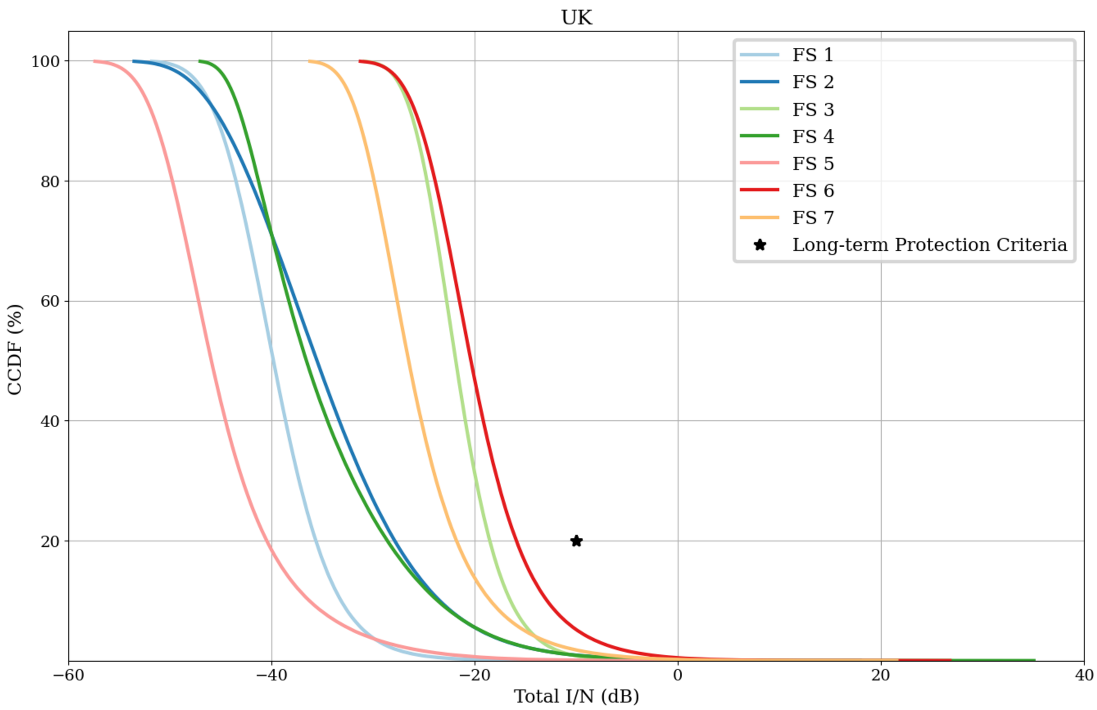


Figure 13: Complementary CDF of total I/N for the 'all ages' scenario, UK links

[8] Used the latest version of this database as of May 2023, U2018_CLC2012_V2020_20u1.tif.

Figure 14 shows the percentage of 5000000 iterations for each of the 6 FS receivers located in France where the I/N from all WAS/RLANs (indoor + outdoor) exceeded the I/N level on the x-axis for the ‘all ages’. The results indicate that the long-term protection criterion was met for all the FS receivers.

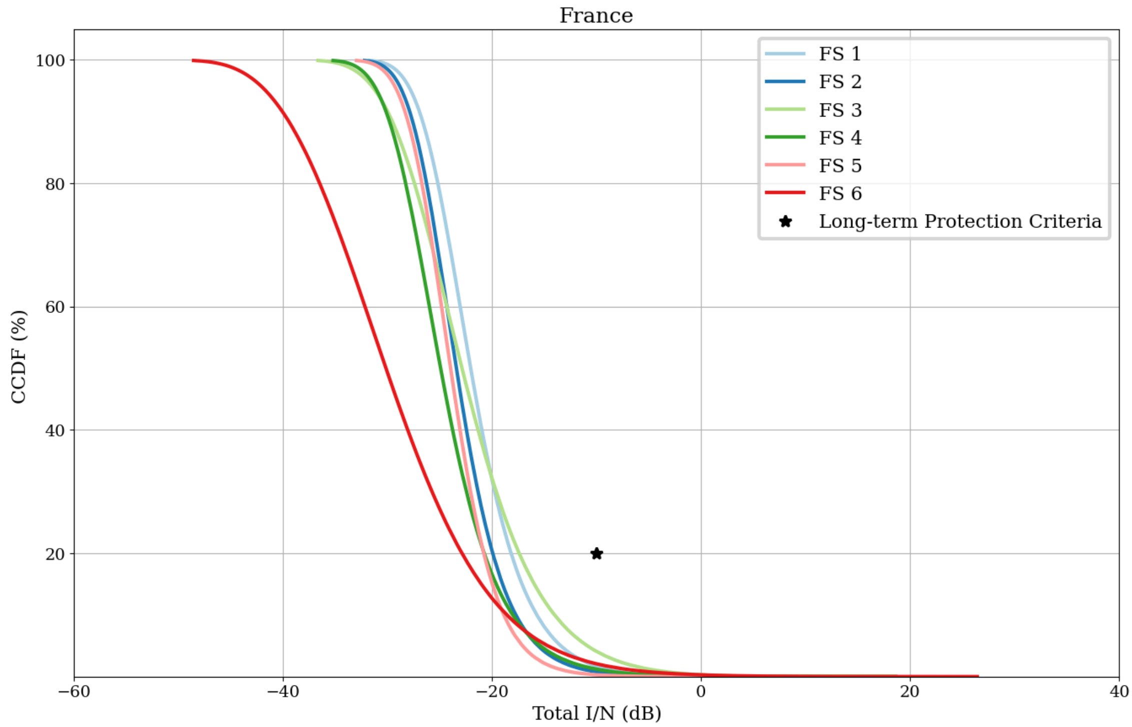


Figure 14: Complementary CDF of total I/N for the ‘all ages’ scenario, France links

Figure 15 shows the percentage of 5000000 iterations for each of the 7 FS receivers, situated in Lithuania, where the I/N from all WAS/RLANs (indoor + outdoor) exceeded the I/N level on the x-axis for the ‘all ages’. The results indicate that the long-term protection criterion was met for all the FS receivers.

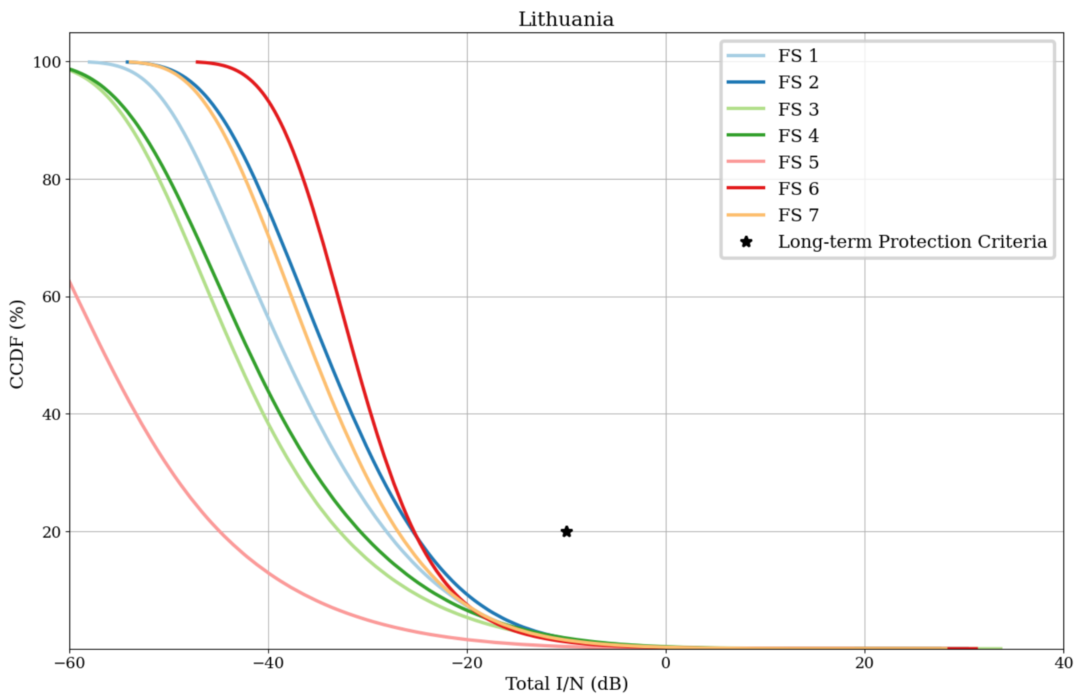


Figure 15: Complementary CDF of total I/N for the ‘all ages’ scenario, Lithuania links

Figure 16 shows the percentage of 5000000 iterations for each of the 6 FS receivers, situated in the Czech Republic, where the I/N from all WAS/RLANs (indoor + outdoor) exceeded the I/N level on the x-axis for the 'all ages' scenario. The results indicate that the long-term protection criterion was met for all the FS receivers.

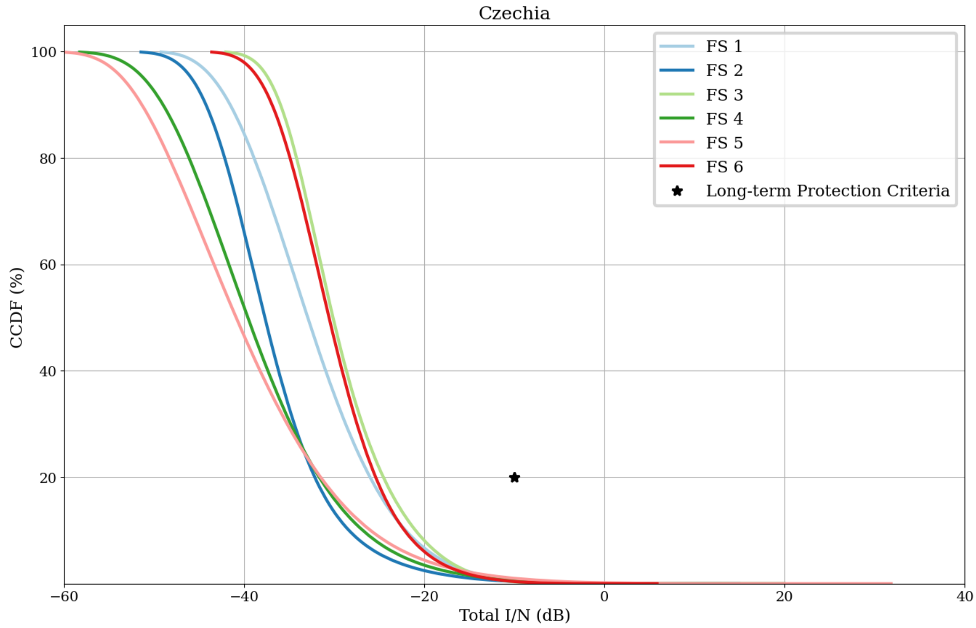


Figure 16: Complementary CDF of total I/N for the 'all ages' scenario, Czech Republic links

5.1.9.5 Simulation results: FDP Protection Criterion

Table 21 shows the FDP values for each of the FS receivers studied in the UK, using the I/N distribution from the 5 million iterations (as shown in Figure 13 above), the links' actual fade margins (from the UK database) and the fade distributions from Recommendation ITU-R P.530, for the 'all ages' scenario respectively. The tables show the total FDP values, where,

$$\mathrm{FDP}_{\mathrm{total}} = \mathrm{FDP}_{\mathrm{long-term}} + \mathrm{FDP}_{\mathrm{short-term}}$$

As indicated, for the 'all ages', FDP ranges from 0.02% (FS ID 1) to 6.66% (FS ID 4).

As it can be observed, all the studied links meet the 10% FDP criterion and thus, no impact on the FS operation is to be expected.

Table 21: FDP from 5 million iterations for the UK links

FS ID	Actual Fade Margin (dB)	$\mathrm{FDP}_{\mathrm{total}}$ (all ages)
1	15	0.02%
2	15	1.09%
3	15	1.70%
4	15	6.66%
5	24.25	0.03%
6	28.90	4.43%
7	29.27	1.30%

Table 22 shows the FDP values for each of the FS receivers studied in France using the I/N distribution from the 5 million iterations (as shown in Figure 14 above), the links' fade margins (calculated using Recommendation ITU-R P.530 and the link data from the French database and assuming 99.99%[9] availability) and the fade distributions from Recommendation ITU-R P.530, for the 'all ages' scenario respectively. The tables show the total FDP values.

As indicated, for the 'all ages,' total FDP ranges from 0.66% (FS ID 5) to 2.82% (FS ID 3).

As it can be observed, all the studied links meet the 10% FDP and thus, no impact on the FS operation is to be expected.

Table 22: FDP from 5 million iterations, for the France links

FS ID	Fade Margin (dB)	FDP_{total} (all ages)
1	24.13	1.68%
2	23.98	1.08%
3	39.53	2.82%
4	25.44	0.72%
5	26.27	0.66%
6	36.09	2.44%

Table 23 show the FDP values for each of the FS receivers studied in Lithuania, using the I/N distribution from the 5 million iterations (as shown in Figure 15), the links' fade margins (calculated using Recommendation ITU-R P.530 using the link data from the Lithuania database and assuming 99.999% availability) and the fade distributions from Recommendation ITU-R P.530, for the 'all ages' scenario respectively. The tables show the total FDP values.

As indicated, for the 'all ages,' total FDP ranges from 0.23% (FS ID 5) to 4.52% (FS ID 7).

As it can be observed, all the studied links meet the 10% FDP criterion and thus, no impact on the FS operation is to be expected.

Table 23: FDP from 5 million iterations, for the Lithuania links

FS ID	Actual Fade Margin (dB)	FDP_{total} (all ages)
1	34.1	1.10%
2	38.8	1.63%
3	34.8	4.07%
4	32.7	1.93%
5	38.3	0.23%
6	39.7	1.55%
7	29.4	4.52%

[9] The 99.99% availability was chosen to get the links' Fade Margins within France's minimum and maximum fade margins with this band.

Table 24 show the FDP values for each of the FS receivers studied in the Czech Republic, using the I/N distribution from the 5 million iterations (as shown in Figure 16), the links' fade margins (calculated using Recommendation ITU-R P.530 using the link data from the Czech Republic database and assuming 99.999% availability) and the fade distributions from Recommendation ITU-R P.530, for the 'all ages' scenario respectively. The high Fade margins form some of the links is due to those FS links being very long (e.g. 40 to 58 km). The tables show the total FDP values.

As indicated, for the 'all ages,' total FDP ranges from 0.24% (FS ID 2) to 1.39% (FS ID 5).

As it can be observed, all the studied links meet the 10% FDP criterion and thus, no impact on the FS operation is to be expected.

Table 24: FDP results, for the Czech Republic links

FS ID	Actual Fade Margin (dB)	FDP_{total} (all ages)
1	41.84	0.39%
2	40.24	0.24%
3	39.88	0.32%
4	25.89	0.34%
5	44.01	1.39%
6	36.61	0.28%

5.1.9.6 Simulation results: Sensitivity analysis for a scenario with a 10-90 year old ages population category

A sensitivity analysis was assessed by considering only the population portion aged between 10-90 years, but did not show significant impact on the results.

5.1.9.7 Conclusions

This analysis considered a site-specific study covering some real links selected in the UK, France, Lithuania and the Czech Republic. The links were selected in densely populated surrounding areas. This joint location/time Monte Carlo simulation study with 5 million runs has shown that none of the links have exceeded the long-term protection threshold of -10 dB I/N for more than 20% of the runs. Furthermore, all the links exhibited an FDP below the 10% threshold criterion.

5.2 SHARING WITH THE FIXED-SATELLITE SERVICE (EARTH-TO-SPACE)

This section presents RLAN sharing studies with Fixed-Satellite Service (FSS) uplinks in the upper 6 GHz band (6425-7125 MHz). This analysis extends the sharing and compatibility studies performed in ECC Report 302 [1] between WAS/RLAN systems and existing incumbent systems in 5925-6425 MHz to the upper 6 GHz band.

The studies attempt to quantify and qualify the risk of exceeding the I/N protection criterion. It has to be noted that studies in ECC Report 302 have already shown that WAS/RLANs operating in the lower 6 GHz band under ECC Decision (20)01 [34] respect the protection criterion for FSS uplink (UL) with large margins.

The detailed description of the study is available in Annex 7.

5.2.1 Technical characteristics of WAS/RLAN in the upper 6 GHz frequency range

The WAS/RLANs were modelled as follows:

1. The transmitter radiated power distribution used in these simulations is the one in Table 41;
2. The WAS/RLAN antenna height distribution is in Table 3;
3. The bandwidth distribution takes into account, channels of 20 MHz, 40 MHz, 80 MHz, 160 MHz and 320 MHz with the associated weights in Table 4.

In addition to this, the WAS/RLAN deployment model described in Section 3.2.1 was used to deploy the active WAS/RLANs.

Table 25 and Table 26 summarise the WAS/RLAN deployment model and specify the total number of instantaneously transmitting devices within the CEPT countries during the busy hour using the UN projected population [24] of CEPT in 2030 including ‘all ages’ and ‘ages 10 to 90 years old’, respectively. Each Table includes parametric inputs (Low, Mid and High) for the busy hour factor and the market adoption factor. Therefore, Low, Mid and High values of instantaneously transmitting devices are given for each scenario.

In addition, Table 27 and Table 28 show the total population (for ‘all ages’ and ‘ages 10 to 90’ respectively) and the resulting number of instantaneously transmitting WAS/RLAN devices – using the ‘High’ factors from Table 25 – for the remaining countries and continents visible from any of the satellites, with the following considerations:

- The number of active WAS/RLAN devices in Africa, Asia and Oceania is divided further by a factor of 4 to reflect the delay in maturity of WAS/RLANs deployment at 6 GHz;
- For Asia, Americas and Oceania, the number of active WAS/RLAN devices reflect the values over Americas up to 62.5° West longitude, and Asia/Oceania up to 146° East longitude to exclude regions outside the satellites’ view.

Two sets of simulations are run, one assuming population of ‘all ages’ and another assuming population of ‘ages 10 to 90.’

In each simulation iteration, the instantaneously transmitting devices are dropped in proportion to the population density based on the 30 arcsecond Gridded Population of the World database [26].

Table 25: Summary of the WAS/RLAN deployment model (all ages)

	Low	Mid	High
Total UN projected Population of CEPT 2030 (all ages) [24]	688 447 000		
Wireless devices operating in licence exempt spectrum (remainder operating in licensed spectrum)	90%		
Busy Hour Factor	50%	62.70%	62.70%
Upper 6 GHz Factor (Upper 6 GHz / (Upper 6 GHz + 5 GHz + 2.4 GHz))	40.75%		
Market Adoption Factor (6 GHz capable devices)	25%	32%	50%
RF Activity Factor Per Person	1.97%		
Instantaneously Transmitting Devices	621752	997986	1559353

Table 26: Summary of the WAS/RLAN deployment model (ages 10 to 90 years old)

	Low	Mid	High
Total UN projected Population of CEPT 2030 (ages 10 to 90 years old) [24]	609 503 000		
Wireless devices operating in licence exempt spectrum (remainder operating in licensed spectrum)	90%		
Busy Hour Factor	50%	62.70%	62.70%
Upper 6 GHz Factor (Upper 6 GHz / (Upper 6 GHz + 5 GHz + 2.4 GHz)) (%)	40.75%		
Market Adoption Factor (6 GHz capable devices)	25%	32%	50%
RF Activity Factor Per Person	1.97%		
Instantaneously Transmitting Devices	550 455	883 547	1 380 542

Table 27: Summary of the WAS/RLAN deployment model for FSS study (using population of all ages)

Continent	2030 population	Number of instantaneously transmitting WAS/RLAN devices
Deployment assumption	--	High
Europe	736 574 215	1 668 362
Africa	1 710 666 359	968 678
Asia	4 958 807 420	2 807 663
Americas and the Caribbeans	1 090 881 324	601 078
Oceania	49 212 010	14 016

Table 28: Summary of the WAS/RLAN deployment model for FSS study (using population of ages 10 to 90 years old)

Continent	2030 population	Number of instantaneously transmitting WAS/RLAN devices
Deployment assumption	--	High
Europe	662 870 567	1 501 421
Africa	1 264 013 906	715 757
Asia	4 299 116 829	2 434 148
Americas and the Caribbeans	950 453 476	523 702
Oceania	41 989 007	11 959

5.2.2 Technical characteristics of FSS uplink

The representative FSS beams of Table 10 were studied, which include a Global, a Regional, a Zone and two Spot Beams.

Satellites receiver parameters are provided per 1 MHz, thus the analysis has been applied to a 1-MHz satellite channel in the middle of the upper 6 GHz band, from 6774 MHz to 6775 MHz. The results will be the same across any other 1-MHz satellite channel within the upper 6 GHz band.

The FSS protection criterion that is based on an I/N methodology, is the same as the one used in ECC Report 302, section 4.2.2, set to I/N=-10.5 dB.

5.2.3 Propagation models

The same propagation models as in ECC Report 302, section 5.2.2 are used except that for conservativeness, no clutter is assumed for rural WAS/RLANs, even though the WAS/RLANs at low elevation angle towards the satellite would most likely incur clutter from trees and/or buildings.

5.2.4 Methodology

The study follows the methodology from ECC Report 302, Study A in section 7.1.1.

Interference from WAS/RLAN deployments into FSS satellite receiver is simulated using a Monte Carlo simulation of the WAS/RLAN deployment generated from the various probability distributions given in Section A7.2.

The simulation is performed according to the following steps:

1 Data setup:
   - 1.1. Define the simulation region and create a database of population density at points within the simulation region;
   - 1.2. Transform population data over the simulation region to active WAS/RLAN device population probability distribution over the simulation region;
   - 1.3. Specify the orbital slot of the FSS satellite receiver and the G/T values over the simulation region;
   - 1.4. Specify the FSS satellite channel to simulate.

2 Monte Carlo iteration
   - 2.1. Generate a random layout of WAS/RLANs using the device population probability distribution;
   - 2.2. Generate the clutter loss, building entry loss, and transmission loss values between each WAS/RLAN and FSS satellite receiver in accordance with the propagation modelling set out in section A7.3.2;
   - 2.3. Compute the aggregate interference from all co-channel WAS/RLANs into the FSS satellite receiver for the simulated FSS channel.

3 Iterate
   - 3.1. Record I/N values for the FSS channel on each iteration and write the results to a file.

4 Plot the CDF of the recorded I/N values.

5.2.5 FSS uplink Simulation Results

From 100 Monte Carlo simulation iterations, the CDF of the aggregate I/N over all indoor and outdoor WAS/RLANs within the satellite's view to the 1-MHz FSS channel is generated for each of the four FSS beams. Figure 17 and Figure 18 show the CDFs for the five beams for the two simulated scenarios, population of 'all ages' and 'ages 10 to 90 years old,' respectively. The vertical shape of the CDF curves indicates that there is minimal variability over the 100 iterations meaning that more iterations are not needed. The protection criterion is met for all beams under all scenarios.

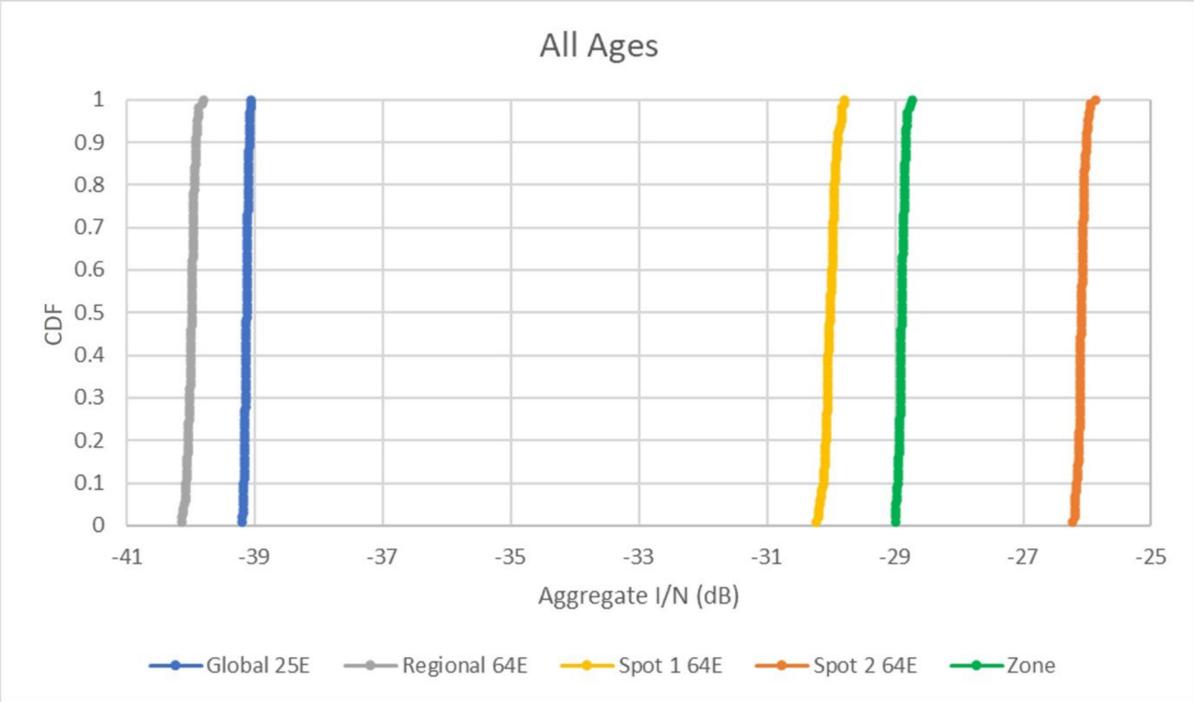


Figure 17: CDF of aggregate I/N for the five FSS beams (all ages)

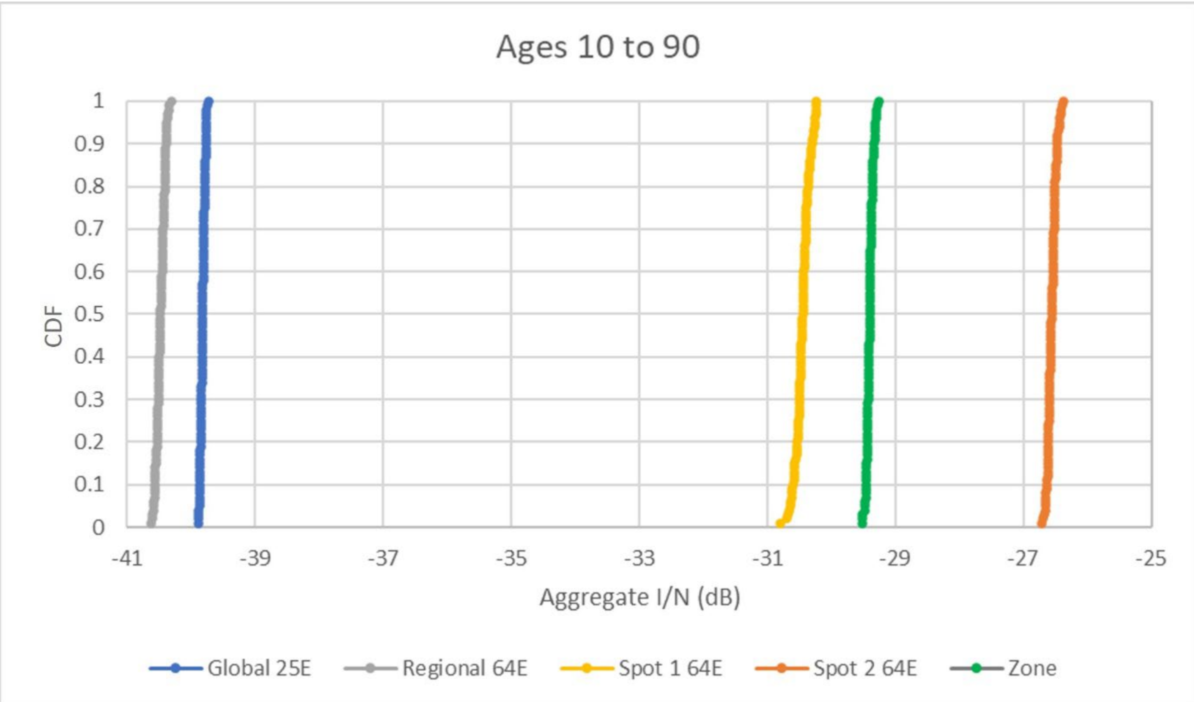


Figure 18: CDF of aggregate I/N for the five FSS beams (ages 10 to 90)

5.2.6 Summary of the sharing study between WAS/RLAN and FSS

Simulations have assessed all possible beam configurations: a Global, a Regional, a Zone and two Spot Beams. Results have shown that in all cases studied under WAS/RLAN assumptions for the High Scenario A in the upper 6 GHz Band, the I/N for all satellites is more than 15 dB below the -10.5 dB threshold. It can be concluded that a deployment of WAS/RLANs will not impact the operation of the FSS uplinks in the

6425 - 7125 MHz band. This confirms the results already obtained in the lower 6 GHz band and that led to ECC Decision (20)01 [34] in that band.

5.3 SHARING WITH THE FIXED-SATELLITE SERVICE (SPACE-TO-EARTH)

The frequency band 6 700-7 075 MHz is allocated to the FSS globally (space-to-Earth) for feeder links for non-geostationary orbit satellite systems (non-GSO) of the mobile-satellite service (MSS). The use of this band by feeder links for non-GSO systems in the MSS is not subject to No. **22.2** as per footnote RR No. **5.458B**.

There are currently a limited number of earth stations (space-to-Earth) in the bands 6725-7025 MHz, 7025-7075 MHz, operating with Low Earth Orbit (LEO) and Medium Earth Orbit (MEO) satellites.

Due to the foreseen satellite usage described above, the total number of receiving Earth stations using the 6700-7075 MHz feeder link allocation will increase but will remain limited in Europe.

In this section, site-specific Monte Carlo studies are presented, using real ground station positions, population data matrix with 1km^2 resolution and SRTM [14] terrain data with 90 m resolution. Real building positions and height are considered where available.

5.3.1 Systems characteristics and elements of methodology

5.3.1.1 FSS downlink characteristics

Site-specific studies were performed considering Earth stations located in Europe. All these Earth stations are communicating with the non-GSO MSS constellation known as HIBLEO-X, defined by the following Walker Delta parameters 52: 48/8/7.5. The FSS downlink (DL) characteristics used in this study are those in Table 11 in section 4.3.1.

In the analysis for sharing between WAS/RLAN and FSS in this Report, the FSS protection criterion used is I/N = -10.5 dB not to be exceeded for more than 20% of time.

Other protection criteria for FSS are currently being discussed in ITU-R at the time of writing this Report.

The minimum simulation time for the HIBLEO-X constellation shall be 4 days, with a step of 10 seconds. This period is considered sufficient to model actual system operation. The 10 second time step corresponds to approximately 0.6 degrees that is consistent with Gateway antenna characteristics.

For the sake of example, Figure 19 depicts the number of visible satellites (with an elevation angle greater than 10°) during the simulation period. It can be observed that most of the time, the ground station is in communication with 4 satellites simultaneously. Taking into account that, for diversity reasons, a ground station location includes most of the time three to four antennas, all the elevations representing links with the different satellites are recorded at each time step and considered for the simulations.

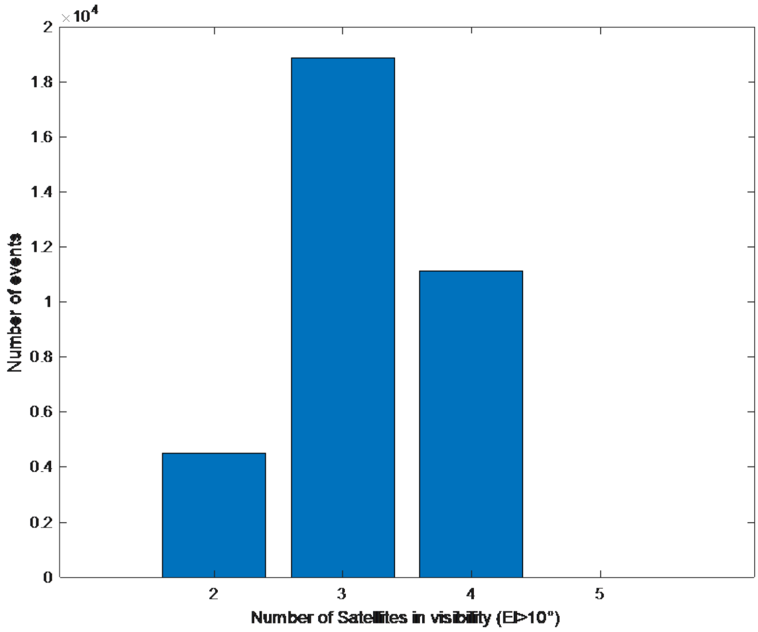


Figure 19: Number of simultaneously visible satellites with elevation > 10°, from the ground station situated in Aussaguel, France

Considering the visible satellites above 10° elevations, the stored elevations of those satellites are shown in a bi-variate histogram in Figure 20. One can observe that for azimuths between –50° to 50°, the satellites are seen at high elevations, this has a significant impact on the simulation results as these azimuths represents the heading to the closest urban area which is Toulouse. Thus, the Toulouse area, for example, will be visible to the ground station at side lobes only.

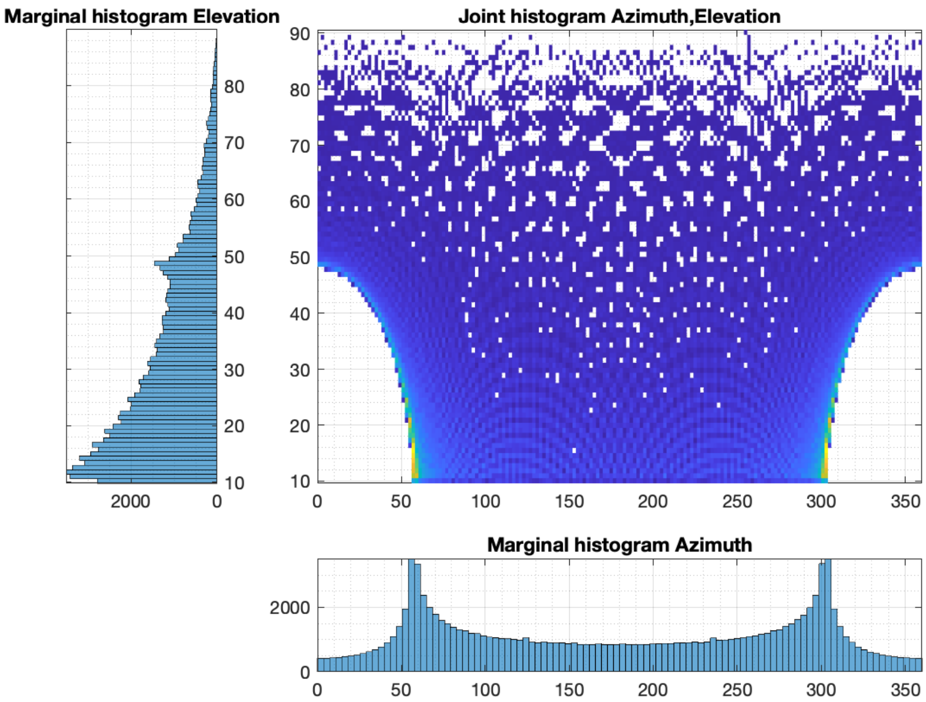


Figure 20: Marginal and joint histograms of elevation and azimuth, all satellites in visibility above 10° elevation from Aussaguel station, France

5.3.1.2 WAS/RLAN characteristics

The WAS/RLAN *e.i.r.p.* distribution is in Annex 1, Table 41. The WAS/RLAN heights distribution is according to Table 3. The WAS/RLAN bandwidth distribution is according to Table 4.

The methodology on the overlap bandwidth factor in ECC Report 302, annex 2 [1] is used to derive the portion of RLANs falling into a channel of 1.23 MHz, resulting into an overlapping factor of 23.08%.

This results into the below WAS/RLAN density table (Table 29) for Scenario A, whereas only the high case scenario was studied later.

Table 29: WAS/RLAN active devices falling into one FSS DL channel of 1.23 MHz width for Scenario A

	Low	Mid	High
Wireless devices operating in licence exempt spectrum (remainder operating in licenced spectrum)	90%		
Busy Hour Factor	50%	62.70%	62.70%
Upper 6 GHz Factor (Upper 6 GHz / (Upper 6 GHz + 5 GHz + 2.4 GHz)) (%)	40.75%		
Market Adoption Factor (6 GHz capable devices)	25%	32%	50%
RF Activity Factor Per Person	1.97%		
BW overlapping factor (1.23 MHz)	23.08%		
RLAN active per person	0.000208	0.0003346	0.000523

5.3.1.3 Simulation area, population density and urban/suburban/rural classification

Four ground stations in Europe were chosen for this study:

- France;
- Greece;
- Spain;
- Estonia.

Each ground station has its own specificities in terms of surrounding terrain relief but also population density. The considered simulation area ensured a latitude/longitude rectangle covering a 40 km radius circle.

Looking at the geographical location of the ground stations some exclusion zones were applied, where no indoor RLAN would be active in accordance to the built-up area around the station. This exclusion zone varies from one ground station to another, as follows:

- Greece: 500 m;
- Spain: 320 m;
- Estonia: 350 m;
- France: deployment according to real buildings positions, see Section 5.3.1.6.

The simulations were based on a population density with 30 arcsecond resolution (1 km at equator) extrapolated to 2030 downloaded from the JRC website [15].

The pixels were categorised into urban, suburban and rural based on the population density and according to the following apportionment:

- Urban 50%;
- Suburban 27%;
- Rural 23%.

5.3.1.4 Propagation scenario

The propagation scenario in Table 30 was used in the simulations.

Table 30: Propagation model used in the simulation

Horizontal Distance	Propagation Model	For Indoor only	Clutter
$0\ \text{m} \leq d < 40\ \text{m}$	Free space	Recommendation ITU-R P.2109 (70% traditional, 30% modern, uniform distribution of probability from 1 to 99%)	not applicable
$40\ \text{m} \leq d < 1000\ \text{m}$	WINNER II model	Recommendation ITU-RP.2109 (70% traditional, 30% modern, uniform distribution of probability from 1 to 99%)	LOS and NLOS ratio probability determination is inherent to the WINNER II model
$d \geq 1000\ \text{m}$	Recommendation ITU-R P.2001-4 (time percentage: uniform distribution 0% to 100%) Using SRTM data 90 m resolution or Recommendation ITU-R P.452-17 (time percentage: uniform distribution 0% to 100% truncated at 50% max) Using SRTM data 90 m resolution	Recommendation ITU-R P.2109 (70% traditional, 30% modern, uniform distribution of probability from 1% to 99%)	For urban and sub-urban: Recommendation ITU-R P.2108-1 (Location percentage: uniform distribution) For rural: Use the Recommendation ITU-R P.452-17 clutter model (high crop fields, sparse houses at both ends)

5.3.1.5 Monte Carlo simulation algorithm

1 Define the ground station location and the satellite constellation parameters

2 Simulate the constellation, and store the azimuth and elevation of visible satellites above a given elevation (>10°) for a sufficient period of time

3 Determine the simulation area around the ground station (40 km in this case)

4 Start a loop over stored satellite positions and for each position, using the bearing of the ground station (elevation, azimuth), perform the following inner-steps:

4.1. Deduce the number of active RLANs according to the population density of the pixel and the number of active RLANs per person (see Table 121). This number of active RLANs is generated according to a binomial distribution with parameters N=pixel population count (rounded to nearest integer) and probability of success p=number of active RLAN per person. Once done, scatter these active RLANs inside the pixel, and store if the RLAN is urban, suburban or rural

4.2. Using the different distributions, allocate to each RLAN an *e.i.r.p.*, a height and indoor/outdoor operation;

4.3. Using the ground station bearing and RLAN position (latitude, longitude, height), compute the ground station gain towards each RLAN;

4.4. Compute the aggregate I/N at the ground station according to the following equation, where G_r represents the ground station gain towards RLAN(i), L_b the transmission loss according to Recommendation ITU-R P.452 or Recommendation ITU-R P.2001, L_c the clutter loss, L_{bel} the building entry loss if it applies (indoor devices), pol is the polarisation mismatch of 3 dB, and BW_{factor} is the bandwidth correction factor:

$$\frac{I}{N}(dB) = 10\log_{10}\left(\sum_{i=1}^{N} 10^{EIRP(i)+G_r(i)-L_b(i)-L_c(i)-L_{bel}(i)-pol-BW_{factor}}\right) - N$$

4.5. Store the I/N values and repeat all sub-steps 4 for the decided time period;

5 Generate the Complementary Cumulative Distribution Function (CCDF), using the stored I/N values.

5.3.1.6 Specific case of the ground station in France

For the French ground station, the RLANs inside the first 8 km around the ground station are picked only in positions where a building exists. To do so, the French building data base BD TOPO [31] was used. This also allows dropping RLANs with a realistic height, since the database contains the building height as well.

5.3.2 Simulation results

Four real ground station locations in Europe were studied, which are located in rural areas with very low surrounding population densities.

The obtained CCDF of I/N observations over 20 days of simulations for Greece, Spain and Estonia and 8 days for France are shown in Figure 21. It can be observed that the protection criterion is never exceeded for all stations. The results also show that there is no difference between using Recommendation ITU-R P.2001-4 with a percentage of time ranging uniformly between 0 and 100% or using Recommendation ITU-R P.452-17 with a percentage of time ranging uniformly between 0 and 100% but capped at 50%.

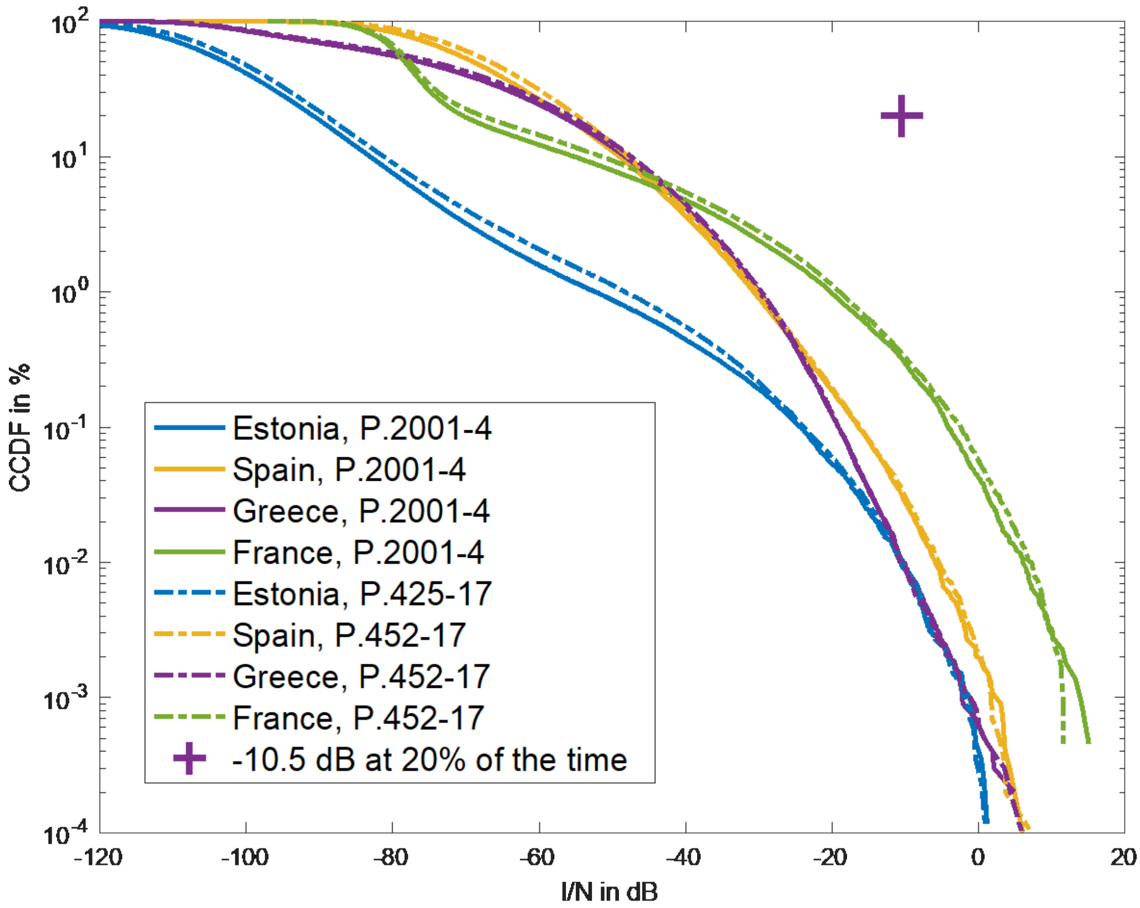


Figure 21: Obtained CCDF of observed aggregated I/N over the simulation time period

5.3.3 Conclusion

Monte Carlo sharing site-specific studies were conducted between WAS/RLAN and FSS DL for all four ground stations in Europe, under Scenario A (High) assumptions. In addition to the fact of considering real ground stations positions and characteristics (e.g. height, gain), the study also considered the real population density around the FSS receiver with resolution as precise as 1 km^2. The studies for the ground stations in Spain, Greece and Estonia were conducted with no WAS/RLANs located within 325 m, 500 m and 350 m around the ground stations, respectively, to reflect that no buildings are within these zones, while in France WAS/RLAN drops were performed within real building positions for the first 8 km distance. For propagation losses calculations, the terrain profile around the ground station was simulated according to the SRTM database [14]. Studies have shown that all stations respected the protection criterion of I/N=-10.5 dB not to be exceeded for more than 20% of the time.

6 SHARING AND COMPATIBILITY BETWEEN WAS/RLAN AND OTHER SERVICES/APPLICATIONS IN THE BAND

6.1 SHARING WITH RADIO ASTRONOMY

Out of the 18 Radioastronomy stations operating in the CEPT, the 4 following stations were studied in Annex 9, as a good proxy for a range of environmental conditions:

- The Effelsberg 100-m telescope is situated in a valley in the German Eifel mountains, a sparsely populated area. However, at distances of about 30 and 40 kilometres, there are the major cities Bonn and Cologne.
- The Jodrell Bank Observatory (JBO) is located in a relatively densely populated area close to Manchester (UK) on rather flat terrain.
- The Sardinia Radio Telescope (SRT) is on an elevated location in southern Sardinia, not far from the capital Cagliari in a mountainous area. Compared to the other sites under study, it has the lowest population count in the simulated area.
- The Westerbork Synthesis Radio Telescope (WSRT) is situated on very flat land in the Netherlands, surrounded by many villages in relatively open terrain and several larger urban centres and cities at some distance.

The coordination/exclusion zone required to protect a radioastronomy site was studied, with the results in Table 31.

Table 31: Required exclusion zone radii in kilometres for the studied RAS stations and deployment scenarios

RAS Station	Scenario A			Scenario B		
	Low	Mid	High	Low	Mid	High
Effelsberg 100-m	<1	<1	<1	<1	<1	<1
Jodrell Bank Observatory	84.5	84.5	108.5	97.5	110.5	118.5
Sardinia Radio Telescope	<1	<1	<1	<1	<1	2.8
Westerbork	26.5	24.5	30.5	25.5	33.5	36.5

The results indicate that:

- Site-specific studies are needed to determine the coordination zone required around a RAS site.
- The derived coordination distances suggest that RLAN-RAS coordination is unlikely to be a cross border issue and is more likely to remain a local/national issue.

For RAS sites requiring protection, technical mitigation measures could be applied such as:

- Country determination capability;
- Geographical exclusion or coordination zones;
- RLAN power restrictions;
- RLAN restriction of operation within 6650.0−6675.2 MHz.

7 CONCLUSIONS

This Report contains sharing and compatibility studies between Wireless Access Systems including Radio Local Area Networks (WAS/RLAN, also called RLAN in this Report) Low-Power Indoor (LPI) and Very Low Power (VLP) and existing incumbent systems in the 6425-7125 MHz band.

Studies have been performed based on a WAS/RLAN deployment model similar to the one used in ECC Report 302 [1] and ECC Report 316 [2], albeit with updated parameters (Scenario A) and with the addition of a second scenario aiming at investigating also denser usages of WAS/RLAN (Scenario B). Each scenario has three deployment assumptions: Low, Mid and High. By defining the active RLAN densities as proportional to the population density, this model allows the consideration of multiple-entry interference studies in both site-general and site-specific approaches. The WAS/RLAN deployment model is based on projections such as population, data consumption per person during busy hour, and the market penetration of WAS/RLAN devices up to the year 2030 (assumed to be a mature market).

7.1 SHARING BETWEEN WAS/RLAN AND FIXED SERVICE

7.1.1 Results of Minimum Coupling Loss studies

Minimum Coupling Loss (MCL) calculations have been performed for urban and suburban areas[10] with no terrain profile. The investigated WAS/RLAN heights were 1.5 m and 7.5 m. Both outdoor and indoor cases were considered with a constant FS bandwidth (Rx BW = 40 MHz) and variable WAS/RLAN-bandwidth (Tx BW = 40 MHz to 320 MHz) are studied to account for different bandwidth overlap factors. The effect of varying FS heights (30 m, 40 m, 75 m) was also investigated.

Median values were used for building entry loss (Recommendation ITU-R P.2109 [11]) for traditional buildings/houses and for clutter loss (Recommendation ITU-R P.2108 [8]).

The study identified the locations where a single WAS/RLAN could possibly exceed the protection criterion within a keyhole shaped area (consisting of a circle with a relatively small radius and a peak area which has a relatively large extent down the boresight). The results show that the peak radius (maximum distances) in the outdoor cases is between 0.9 km and 11.3 km and for the indoor scenario it is maximum of 3.3 km. The circle radius (minimum distances) does not change to any significant amount and is between 0 km and 0.3 km for indoor use cases and 0.3 km to 0.7 km for outdoor use cases. The height level of the FS receiver has an impact on the separation distances (peak radius).

The results in the outdoor/indoor use cases show that the distances become smaller as the WAS/RLAN bandwidths increase due to the decreasing spectral power density of the WAS/RLAN.

MCL calculations have revealed critical scenarios, but did not allow final conclusions to be made about the statistical likelihood of occurrence of those scenarios. Therefore, statistical studies based on Monte Carlo method were carried out.

7.1.2 Results of Monte Carlo studies

In this Report, Monte Carlo studies used two different approaches:

- Joint location/time Monte Carlo: The location and time dependent parameters used in the calculations are randomly sampled at each Monte Carlo event (jointly changed), independently of each other. The output of this approach is expressed as percentage of events (location and time mixed) exceeding a protection threshold (e.g. I/N of -10 dB);
- Separated location/time Monte Carlo: The location dependent parameters are randomly sampled in a separated loop (morphologies loop) from the time dependent parameters (time loop). The output of this approach is expressed in terms of percentage of morphologies exceeding a time dependant protection criterion (e.g. I/N of -10 dB exceeded less than 20% of the time).

[10] Rural scenarios were not studied in this Report, but were studied in ECC Report 302 [1].

The methodologies of each approach are described in more detail, in each study of this Report.

It should be noted that the statistical results from the Monte Carlo simulations range from respecting the FS interference protection criteria, to low probabilities of exceeding the criteria. Although in rare cases, a combination of factors such as WAS/RLAN located near the line of sight (coordinates and relative height) of the FS radio link, and/or unfavourable conditions (e.g. clutter loss, building entry loss and *e.i.r.p.*) may lead to potential exceedance of the FS protection criteria.

At the time of writing this Report, work was ongoing in ECC to provide a generic methodology for deriving protection criteria for any source of time-varying interference into an FS receiver. Within this activity, the studies consider how FS receivers perform in the presence of pulse/burst type interference, with and without Adaptive Coding and Modulation (ACM). Therefore, it should be noted that the conclusions of that ongoing work may have impact on the results of the sharing between WAS/RLANs and FS and that further investigation of the impact of beacon signals may be required.

7.1.2.1 Site-general Monte Carlo studies

Some of the combinations of parameters considered in the site-general studies may not actually exist in the field. In particular, one verification conducted for a city of 6000 inhabitants per square kilometre highlighted that some parameter combinations did not correspond to any fixed links deployed in this area. Thus, unless based on national data, not all the combinations in the range used in the site-general studies should be considered as representative and combinations that actually occur in practice should be considered on a case-by-case basis.

A relationship between population density and some FS deployments was found (see section 4.1.2). Only a very small percentage of associated FS receivers are located in areas of population density greater than 3000 inhabitants/km^2 and urban areas of greatest population density have antennas located higher off the ground than those with lower population densities.

Site-general study A

Study A is a site-general Monte Carlo study aiming at assessing whether the long-term protection criterion and the Fractional Degradation in Performance (FDP) are met when LPI WAS/RLAN indoor (with accidental LPI being outdoor) and VLP WAS/RLAN are simultaneously in operation.

The studies have considered the city of Frankfurt, which is a large dense German city with surrounding suburban and rural area. The size of the simulation radius was limited by the radio horizon (i.e. 59 km). The three different WAS/RLAN density deployment models of Scenario A (Mid, Low and High) were considered. The results of the study are computed taking into account all the possible statistical combination in terms of position, population density, FS height and FS antenna gain from real data set from the German administration.

Results from large number of joint location/time Monte Carlo events show that the long-term protection threshold (I/N =-10 dB for less than 20% of the runs) is respected for all the cases even with accidental outdoor LPI. The FDP values obtained for site-general FS link with and without automatic transmit power control (ATPC) are all below 10%. In other words, the results show that the probability of an FS link being degraded is very rare.

Furthermore, additional simulations using the separated location/time Monte Carlo method were performed on the two cases that exhibited the worst aggregated I/N distribution in the joint location/time study. The long-term protection criteria of -10 dB at 20% of the time is respected for both of these cases. Also, for the case with high FS antenna height, this methodology did not detect any exceedance of the FDP protection criterion (FDP < 10%). For high FS receiver antenna, the maximum FDP value is 2%. For the case with low FS antenna height, the percentage of fixed RLAN morphologies where the FDP does not exceed the 10% FDP criterion is 99.2%, 99.5% and 99.6%, depending on the fade margin of the FS link (23 dB, 29.7 dB and 40.3 dB, respectively). The results from the fixed RLAN morphologies studied show that the percentage of morphologies where the FDP is exceeding 10% for a FS link is less than 0.8% (for the minimum 5%-ile fade margin (FM)) or 0.4% (for the minimum 95%-ile FM).

The FDP value obtained from joint location/time Monte Carlo and the median FDP value from separated location/time Monte Carlo are similar for all studied cases.

Site-general study B

This study uses a similar environment as site-general study A (with separated location/time), but an alternative method to assess the potential interference to FS.

The simulations are single entry, but the outputs are processed in order to get results for whole deployments (equivalent to multiple entry) described in Scenarios A and B. The method can be summarised as follows: given the single-entry probability of exceeding the 10% FDP (from simulation, checking against the FDP protection criterion), and assuming that interference events from different WAS/RLANs are statistically independent, the probability of the FDP criterion being exceeded when multiple WAS/RLANs are deployed is computed. The core assumption is that, in practice, the instances of high aggregate interference power seen at any point in time by an FS receiver are dominated by a single WAS/RLAN contribution.

The overall probability of any WAS/RLAN exceeding the FS protection criterion, when a full WAS/RLAN deployment is considered, is derived from the single WAS/RLAN probability considering the total number of active WAS/RLANs based on the population density.

Using Recommendation ITU-R F.699 [33] and random polarisation loss, for the 30 m FS antenna height, the exceedance rate of the 10% FDP ranges from 1.16% to 16.54% (FM = 23 dB), depending on the WAS/RLAN density scenario and the FS antenna gain. For the 45 m height FS antennas, the exceedance rate ranges from 0.40% to 9.23% (FM = 29.7 dB). For the 79 m height FS antennas, the exceedance rate ranges from 0.11% to 3.82% (FM = 40.3 dB).

Using Recommendation ITU-R F.1245 [5] and fixed polarisation loss, for the 30 m FS antenna height, the exceedance rate of the 10% FDP ranges from 0.27% to 3.88% (FM = 23 dB), depending on the WAS/RLAN density scenario and the FS antenna gain. For the 45 m height FS antennas, the exceedance rate ranges from 0.06% to 1.20% (FM = 29.7 dB). For the 79 m height FS antennas, the exceedance rate ranges from 0.01% to 0.23% (FM = 40.3 dB).

Site-general study C

This study utilises the separated location/time Monte Carlo method to assess the long-term protection criterion and FDP at the FS receiver resulting from the deployment of WAS/RLAN devices in a circular area with a radius of 5 km. The number of interfering WAS/RLAN devices around an FS receiver were derived using High WAS/RLAN deployment assumptions from Scenario B. Four different population densities of 3000, 6000, 12000 and 18000 inhabitants per square km were used. Three different FS antenna heights were considered, 30 m, 40 m, and 79 m, coupled with FS antenna gains of 36 dBi and 46 dBi and three FS links of length 20 km, 32 km, and 50 km, respectively.

The compatibility was evaluated by assessing the exceedance rate of the two protection criteria i) long-term protection criterion of I/N=-10 dB not to be exceeded by more than 20% of time, and ii) the FDP not to exceed 10%.

The results show that higher population densities result in a higher exceedance rate of the two protection criteria. The exceedance rate for the long-term protection criterion ranges from 0% to 30.63% and for the FDP ranges from 0% to 34.80% (for a range of FM values between 30 dB and 51 dB). Under the considered combinations of the different parameters, it can be further recognised that for FS receivers with lower antenna gains (hence higher sidelobes) and/or lower antenna heights, the exceedance rate is more likely to increase. The exceedance rates for the studied FS links utilising ATPC are similar to the ones without ATPC.

Site-general study D

Study D is a site-general study involving an FS link receiver deployed in the middle of a simulation zone where population density is about 5400 inhabitants/km^2. This value is among the highest in the CEPT countries.

Several assumptions were investigated and in almost all joint location/time Monte Carlo simulations both long-term and FDP criteria are respected. It is only when assuming the High WAS/RLAN deployment assumptions of Scenario B (high market adoption of the WAS/RLAN in the upper 6 GHz) coupled with a low FS fade margin and a low FS peak antenna gain that the FDP criterion could be exceeded by a few percent, while in the very vast majority of the studied cases, the FDP is well below the 10% threshold resulting in a feasible FS link operation in presence of WAS/RLAN.

A separated location/time Monte Carlo analysis showed that topologies having a combination of many factors where a WAS/RLAN was in close vicinity of the FS receiver (main beam), and with a (relative) high height compared to the FS receiver height, and with a high transmit power seen by the FS receiver, and with a low building entry loss may cause the FDP criteria to be exceeded when the FS fade margin is low. This site-general study of a dense city centre showed that the likelihood of exceedance is highly dependent upon having all those conditions being fulfilled and is low even for a link with a limited fade margin (3% for Scenario A and 5.5% for Scenario B for fade margin of 13 dB) and is highly site-specific.

7.1.2.2 Site-specific study

This analysis considered a site-specific study of 26 real links selected in the United Kingdom (UK), France, Lithuania and the Czech Republic, using High WAS/RLAN deployment assumptions from Scenario A. This study considered a simulation area extended over 150 km simulation radius. In addition to real FS positions and characteristics (length, antenna heights and gains, etc.), the study also used precise maps of real population density around the FS receiver. For propagation losses calculations, the terrain profile around the FS receiver was taken into account. For the UK links, real building positions and height were also considered to model indoor WAS/RLAN in the first two kilometres distance.

This joint location/time Monte Carlo simulation study has shown that none of the links have exceeded the long-term protection threshold of -10 dB I/N for more than 20% of the runs. Furthermore, the fractional degradation in performance analysis showed that for all the links, the FDP value remained below the 10% threshold criterion.

7.2 SHARING BETWEEN WAS/RLAN AND FIXED-SATELLITE SERVICE (EARTH-TO-SPACE)

Simulations have been assessed on all possible satellite beam types: a Global, a Regional, a Zone and two Spot Beams. The study also used precise maps of real population density. Results have shown that in all cases studied using High WAS/RLAN deployment assumptions from Scenario A, the I/N for all satellite receivers is more than 15 dB below the -10.5 dB threshold. This is consistent with the results already obtained in the lower 6 GHz band (5945-6425 MHz) and that led to ECC Decision (20)01 [34] in that band.

7.3 SHARING BETWEEN WAS/RLAN AND FIXED-SATELLITE SERVICE (SPACE-TO-EARTH)

Monte Carlo site-specific sharing studies were conducted between WAS/RLAN and FSS downlink for all the four ground stations in Europe, using High WAS/RLAN deployment assumptions of Scenario A. In addition to the real ground stations positions and characteristics (e.g. height, gain), the studies also used precise maps of real population density around the FSS ground station receiver. The studies for the ground stations in Spain, Greece and Estonia were conducted with no WAS/RLANs located within 325 m, 500 m and 350 m from the ground stations, respectively, to reflect that there are no buildings within these zones, while in France WAS/RLAN were placed inside real buildings within a distance of 8 km from the ground station receiver. For propagation losses calculations, the terrain profile around the ground station was taken into account. Studies have shown that all stations respected the protection criterion of I/N = −10.5 dB not to be exceeded for more than 20% of the time.

7.4 COMPATIBILITY WITH OTHER APPLICATIONS IN THE BAND

7.4.1 Compatibility between WAS/RLAN and Radio Astronomy Service

Site-specific Monte Carlo simulations using Scenarios A and B were performed around four radio astronomy sites in CEPT.

Results suggest that some radio astronomy sites may require protection and, in these cases, appropriate technical mitigation measures could be applied to prevent interference from WAS/RLAN to the radio astronomy service (RAS). Other sites do not require such measures. The study also suggests that sharing between RAS and WAS/RLAN is unlikely to become a cross-border issue.

ANNEX 1: NORMALISED WAS/RLAN ANTENNA GAIN DISTRIBUTIONS

A1.1 INTRODUCTION

The WAS/RLAN *e.i.r.p.* distribution used in this Report is based on measured WAS/RLAN antenna patterns.

Two categories of devices were considered:

1. Low power indoor (LPI) access points (APs);
2. Client devices including both LPI devices with and without body loss (BL) and very low power (VLP) devices with BL.

For the AP category, the measured data were extracted from several manufacturer datasheets with measured antenna patterns, while for the client devices category, data were gathered by performing laboratory measurements on different clients under different scenarios.

A1.2 AP/CLIENT/VLP APPORTIONEMENT MODEL

A1.2.1 Derivation of a model including VLP traffic from ECC Report 302 baseline

ECC Report 302 [1] and ETSI TR 103 524 V1.1 [40] were based on the devices' distribution in Table 32.

Table 32: Distribution of each category of device

Device type	
LPI Clients	26.32%
Consumer AP	66.31%
Enterprise AP	2.63%
Gaming AP	4.74%
Total	**100.00%**

However, VLP devices were not considered during the ECC Report 302 elaboration. To reflect their contribution, the overall traffic was therefore apportioned as 90% LPI devices (all categories) and 10% VLPs as per ECC Report 316 [2], leading to Table 33 considered in this Report.

Table 33: Distribution of each category of devices including VLP

Device type	
LPI Clients	23.68%
LPI Consumer AP	59.68%
LPI Enterprise AP	2.37%
LPI Gaming AP	4.27%
VLP	10.00%
Total	100.00%

A1.2.2 Body loss application

The body loss (BL) applies only to two categories of devices: the VLPs and the portable LPI clients (battery-powered). For the VLPs, the BL will apply to all devices. Only a small portion of LPI clients will be fixed (i.e. not portable) and not used in close proximity to the human body, like smart TVs for example. Thus, a small percentage of the LPI clients will not be subject to BL when deriving the overall *e.i.r.p.* distribution. Considering the market forecast for smart TVs and desktop computers, 10% of LPI clients are considered not to be subject to BL.

Table 34: Percentage of LPI clients subject to Body loss

Device type	% of total traffic	With BL	Without BL
LPI Clients	23.68%	90%	10%
Resulting percentage	--	**21.31%**	**2.37%**

A1.3 INDOOR VS OUTDOOR DEVICES REPARTITION

All APs are assumed to be indoor following the definition in ECC Decision (20)01 [34], as they are power supplied from a wired connection, have integrated antennas and are not battery powered.

LPI clients are intended to be used permanently indoor. To reflect some accidental outdoor misuse of battery-powered LPI clients, a certain percentage of LPI client traffic will be outdoor. ETSI TR 103 524 [40] considered that under outdoor authorised regulation, the percentage of outdoor devices is estimated to be 2% (including both AP and clients). Given the fact that outdoor usage is not intended in this band and that all outdoor clients are due to accidental and momentary operation, a percentage of 1% of portable LPI clients traffic will be considered in the derivation of the *e.i.r.p.* distribution (leading to 1% x 90% x 23.69% = 0.213% of total traffic).

Regarding accidental outdoor use of LPI clients, since those are battery-powered and portable, it is assumed that their outdoor usage is performed in close proximity to the human body. Therefore, all of them (100%) are subject to body loss. Table 35 explains how the situation is apportioned.

Table 35: Client devices repartition, indoor/outdoor and with or without BL

	Total LPI client 23.68%			
	90% with BL		**10% no BL**	
	1% outdoor	**99% indoor**	**100% indoor**	**Total**
Resulting traffic of total	0.213%	21.099%	2.368%	23.680%
Resulting percentage of LPI clients	0.900%	89.100%	10.000%	100.000%

While VLP devices can operate both indoors and outdoors, most of their usage is expected to happen indoors. Hence, as per ECC Report 316, the percentage of indoor usage is assumed to be 90%, while the other 10% will be outdoors.

Finally, the overall repartition for indoor/outdoor is depicted in Table 36.

Table 36: Traffic repartition per category of device

Device type			Traffic %	Indoor	Outdoor	Total indoor	Total outdoor
LPI Clients	With BL	90%	2.31%	99%	1%	21.1%	0.21%
	Without BL	10%	2.37%	100%	0%	2.37%	0.00%
VLP	With BL		10%	90%	10%	9.00%	1.00%
Consumer AP			59.68%	100%	0%	59.68%	0.00%
Enterprise AP			2.37%	100%	0%	2.37%	0.00%
Gaming AP			4.27%	100%	0%	4.27%	0.00%
Total			100.00%			**98.79%**	**1.21%**

A1.4 ACCESS POINT ANTENNA GAIN DISTRIBUTION

A1.4.1 Source of data

The measured antenna patterns were gathered from the following APs:

- Consumer AP: Linx Technologies ANT-W63WS1 Series Blade-Style Dipole Wi-Fi 6 Antenna;
- Consumer AP: Linx Technologies ANT-W63-FPC-LH Series Flexible Embedded Wi-Fi 6/6E FPC Antennas;
- Consumer AP: Linx Technologies ANT-W63-MSA-TH1 Stamped Metal Wi-Fi 6/6E Antenna;
- Consumer AP: Linx Technologies ANT-W63-MON-ccc Wi-Fi 6 Monopole Whip Antenna;
- Consumer AP: Linx Technologies ANT-W63WS4-ccc Hinged Blade Wi-Fi 6/6E Antenna;
- Enterprise AP: CISCO C9136I integrated;
- Gaming AP: High-class anonymous manufacturer.

For all consumer APs, the sources were full antenna datasheets, all publicly available at the time of this Report.

A1.4.2 Extraction of vectorised plots from antenna datasheets

The previously mentioned antenna datasheets provide antenna diagram measurements in vector format within the PDF. Hence, the vectorised plots were extracted from the datasheet PDFs, and processed to extract the exact measured values. One example is given in Figure 22 and Figure 23.

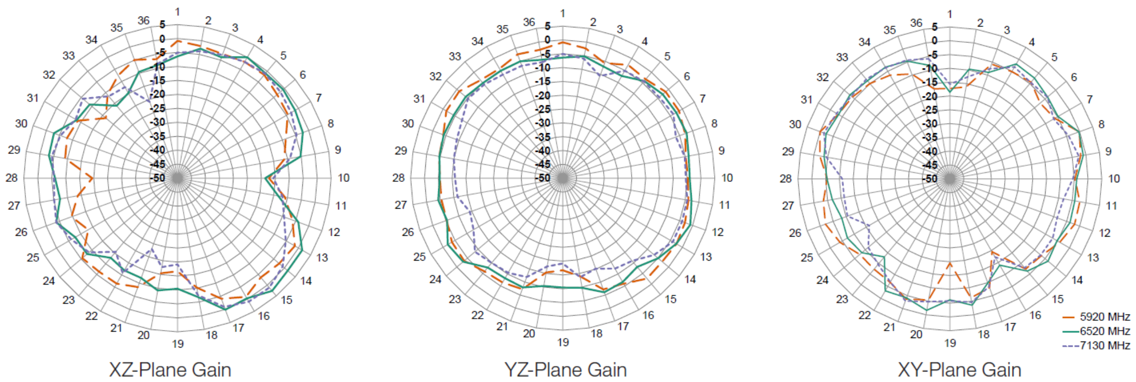


Figure 22: Antenna diagrams from datasheet for ANT-W63-MON-ccc, Straight

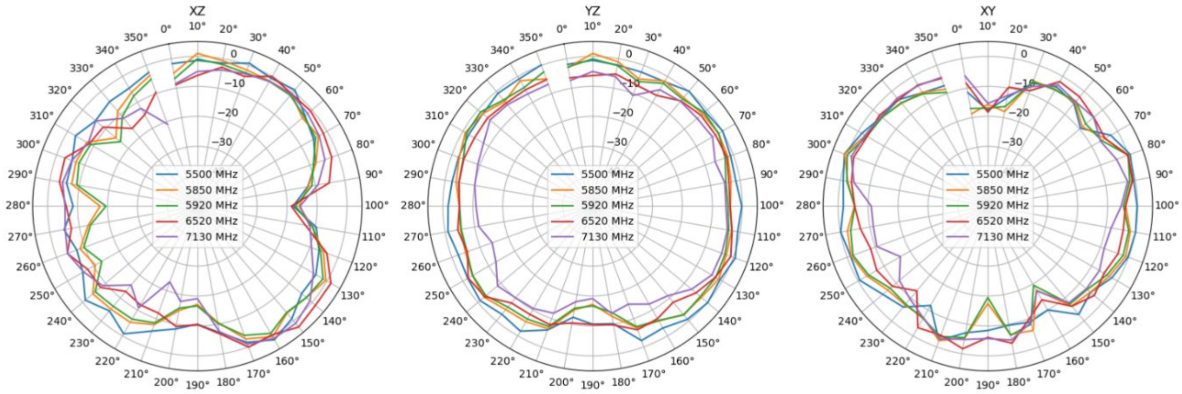


Figure 23: Extracted antenna diagrams ANT-W63-MON-ccc, Straight

A1.4.3 Restriction to the 6425-7125 MHz frequency band

Although all measurements can be extracted from the datasheets, only the ones using a frequency included in the 6425-7125 MHz frequency range were used to derive the distribution of consumer AP diagrams.

For Enterprise AP and Gaming AP, antenna patterns for only one frequency were available which was in the 6425-7125 MHz frequency range.

A1.4.4 Normalisation to 0 dBi

All related antenna diagrams were first normalised to 0 dBi. This was done by subtracting the maximum antenna gain:

- For each consumer AP antenna pattern, the maximum antenna gain was the one declared in its corresponding datasheet for the 5945-7125 MHz range.
- For Enterprise and Gaming AP, the maximum was taken among the antenna gain pattern provided.

A1.4.5 Concatenation

All normalised antenna diagrams of a given AP category were concatenated into a single measurement vector. This vector was then used to derive a single distribution for this AP category. The overall distribution for AP was then derived according to the apportionment in Table 32.

A1.4.6 Distribution derivation

Using the overall measurement vector, a distribution is derived using the histogram method with bins width equal to 1 dB. This granularity was chosen in order to fit to the original curve as much as possible, while avoiding large gaps between one bin and another.

The obtained normalised gain distribution, including Consumer AP, Gaming AP and Enterprise AP, is shown in Table 37.

Table 37: Normalised AP antenna gain distribution (G_{min} < gain ≤ G_{max})

G_{min} (dB)	G_{max} (dB)	Probability (%)
-31	-30	0.10
-30	-29	0.07
-29	-28	0.21

G_{min} (dB)	G_{max} (dB)	Probability (%)
-28	-27	0.05
-27	-26	0.11
-26	-25	0.36
-25	-24	0.74
-24	-23	0.65
-23	-22	0.92
-22	-21	0.59
-21	-20	1.25
-20	-19	1.24
-19	-18	2.32
-18	-17	1.97
-17	-16	2.63
-16	-15	3.61
-15	-14	3.61
-14	-13	4.71
-13	-12	5.98
-12	-11	7.05
-11	-10	6.66
-10	-9	7.82
-9	-8	8.68
-8	-7	8.47
-7	-6	8.83
-6	-5	8.44
-5	-4	4.32
-4	-3	3.08
-3	-2	1.86
-2	-1	1.81
-1	0	1.86

A1.5 VLP/CLIENT DEVICES ANTENNA GAIN DISTRIBUTION

In order to derive the antenna gain distributions of client devices and VLPs, the data from the measurement campaign depicted in ECC Report 355, annex 6 [48] were used.

The same approach as for the AP was applied, except that the data were provided in a matrix file and there was no need for digitalisation. In addition to this, the data for each client device were normalised relative to the maximum gain obtained under the free space platform.

In rare cases, change of radiation pattern due to proximity to body may result in small gain in some direction(s) (see Table 39). As expressed in Table 36, the LPI client can contribute to the antenna gain distribution either with BL for portable devices or without for other kinds of devices. The VLPs contribute always with BL. Thus, two types of distribution are needed: one without body loss for LPI clients only (Table 38), and another one with body loss for VLPs and LPI clients (Table 39).

Table 38: Normalised LPI client antenna gain distribution without body loss (G_{min} < gain ≤ G_{max})

G_{min} (dB)	G_{max} (dB)	Probability (%)
-27.00	-26.00	0.17
-26.00	-25.00	0.15
-25.00	-24.00	0.23
-24.00	-23.00	0.21
-23.00	-22.00	0.34
-22.00	-21.00	0.48
-21.00	-20.00	0.64
-20.00	-19.00	1.07
-19.00	-18.00	2.06
-18.00	-17.00	2.20
-17.00	-16.00	2.08
-16.00	-15.00	2.73
-15.00	-14.00	3.91
-14.00	-13.00	4.98
-13.00	-12.00	4.84
-12.00	-11.00	5.98
-11.00	-10.00	6.27
-10.00	-9.00	9.19
-9.00	-8.00	9.04
-8.00	-7.00	9.23
-7.00	-6.00	8.70
-6.00	-5.00	7.48

G_{min} (dB)	G_{max} (dB)	Probability (%)
-5.00	-4.00	6.47
-4.00	-3.00	5.31
-3.00	-2.00	3.27
-2.00	-1.00	2.42
-1.00	0.00	0.56

Table 39: Normalised VLP/ LPI client antenna gain distribution with body loss (G_{min} < gain ≤ G_{max})

G_{min} (dB)	G_{max} (dB)	Probability (%)
-52.00	-51.00	0.001
-51.00	-50.00	0.001
-50.00	-49.00	0.001
-49.00	-48.00	0.001
-48.00	-47.00	0.001
-47.00	-46.00	0.002
-46.00	-45.00	0.005
-45.00	-44.00	0.005
-44.00	-43.00	0.005
-43.00	-42.00	0.011
-42.00	-41.00	0.064
-41.00	-40.00	0.048
-40.00	-39.00	0.154
-39.00	-38.00	0.131
-38.00	-37.00	0.235
-37.00	-36.00	0.216
-36.00	-35.00	0.261
-35.00	-34.00	0.418
-34.00	-33.00	0.291
-33.00	-32.00	0.557
-32.00	-31.00	0.633
-31.00	-30.00	0.872
-30.00	-29.00	0.891
-29.00	-28.00	1.632

G_{min} (dB)	G_{max} (dB)	Probability (%)
-28.00	-27.00	1.776
-27.00	-26.00	1.485
-26.00	-25.00	2.125
-25.00	-24.00	2.324
-24.00	-23.00	2.451
-23.00	-22.00	2.626
-22.00	-21.00	2.358
-21.00	-20.00	2.763
-20.00	-19.00	3.883
-19.00	-18.00	3.640
-18.00	-17.00	4.637
-17.00	-16.00	5.080
-16.00	-15.00	4.598
-15.00	-14.00	4.244
-14.00	-13.00	4.216
-13.00	-12.00	4.490
-12.00	-11.00	4.460
-11.00	-10.00	4.755
-10.00	-9.00	5.078
-9.00	-8.00	5.507
-8.00	-7.00	4.680
-7.00	-6.00	5.277
-6.00	-5.00	4.310
-5.00	-4.00	2.913
-4.00	-3.00	2.054
-3.00	-2.00	1.108
-2.00	-1.00	0.449
-1.00	0.00	0.227
0.00	1.00	0.051

A1.6 RESULTING INDOOR/OUTDOOR ANTENNA E.I.R.P. DISTRIBUTION

For Monte Carlo simulations requiring a distribution categorised as indoor/outdoor, Table 36 can be used together with the associated maximum *e.i.r.p.* of each category as defined in ECC Decision (20)01, as shown in Table 40.

Table 40: WAS/RLAN indoor/outdoor and *e.i.r.p.* distributions

Device type		Total indoor	Total outdoor	*e.i.r.p.* distribution
LPI Clients	With Body Loss	21.10%	0.21%	200 mW + normalised antenna gain distribution from Table 39
	Without Body Loss	2.37%	0.00%	200 mW + normalised antenna gain distribution from Table 38
VLP	With Body Loss	9.00%	1.00%	25 mW + normalised antenna gain distribution from Table 39
AP (LPI)	Without Body Loss	66.32%	0.00%	200 mW + normalised antenna gain distribution from Table 37
Total		98.79%	1.21%	

The resulting mixed distribution is given in Table 41. Since the distribution in Table 39 depicts some positive gain (even after normalisation), the distribution below may exceed the maximum allowed *e.i.r.p.* of 200 mW (by 1 dB at maximum) because it captures body losses and, in some rare occurrences, this loss can actually be a gain.

Therefore, this mixed distribution is to be interpreted as the power in the air (including body loss) and not as *e.i.r.p.* distribution *stricto sensu*. In reality, such exceedance will never happen as manufacturers will always consider some margin to ensure that they respect the maximum allowed *e.i.r.p.* during the certification process.

Table 41: Resulting mixed *e.i.r.p.* in the air (dBm) considering the contribution of each category of devices according to Table 2 (*e.i.r.p.* min < *e.i.r.p.* ≤ *e.i.r.p.* max)

e.i.r.p. min (dBm)	*e.i.r.p.* max (dBm)	Indoor	Outdoor
-38	-37	0.00011471	1.2746E-05
-37	-36	7.6485E-05	8.4983E-06
-36	-35	7.6485E-05	8.4983E-06
-35	-34	7.6485E-05	8.4983E-06
-34	-33	7.9653E-05	8.8503E-06
-33	-32	0.00017714	1.9682E-05
-32	-31	0.0004681	5.2011E-05
-31	-30	0.0004681	5.2011E-05
-30	-29	0.00042156	0.00004684
-29	-28	0.00127928	0.00011494

e.i.r.p. min (dBm)	*e.i.r.p.* max (dBm)	Indoor	Outdoor
-28	-27	0.0059718	0.00064539
-27	-26	0.00449058	0.00048081
-26	-25	0.01404831	0.00154278
-25	-24	0.01195874	0.00130986
-24	-23	0.02158239	0.00235603
-23	-22	0.02056083	0.00217352
-22	-21	0.02458473	0.00262062
-21	-20	0.03858132	0.00418684
-20	-19	0.02855959	0.00293367
-19	-18	0.06371467	0.00570566
-18	-17	0.06705053	0.0064276
-17	-16	0.111014	0.00904571
-16	-15	0.1077672	0.00918228
-15	-14	0.19654109	0.0168179
-14	-13	0.20543486	0.01821015
-13	-12	0.18872367	0.01539904
-12	-11	0.2793397	0.02212217
-11	-10	0.27054511	0.02384912
-10	-9	0.33809155	0.02567581
-9	-8	0.3698307	0.02758767
-8	-7	0.46221837	0.02541564
-7	-6	0.48038512	0.0294976
-6	-5	0.83238209	0.04225504
-5	-4	0.7355522	0.04012876
-4	-3	0.80883973	0.04949071
-3	-2	1.15044156	0.05526345
-2	-1	1.40179092	0.05086398
-1	0	1.33500405	0.04758426
0	1	1.55084857	0.04766939
1	2	1.30196495	0.04985464
2	3	1.83160436	0.05040067

e.i.r.p. min (dBm)	*e.i.r.p.* max (dBm)	Indoor	Outdoor
3	4	2.09710904	0.05570667
4	5	2.81059408	0.05842
5	6	2.83118125	0.06480812
6	7	3.28534234	0.05746542
7	8	3.90450057	0.06243064
8	9	3.76833416	0.05200798
9	10	4.3926062	0.03797855
10	11	5.21149512	0.02997142
11	12	5.86046275	0.02044679
12	13	5.6118004	0.01447723
13	14	6.49606316	0.01293406
14	15	7.13722572	0.01207871
15	16	6.82054414	0.00982737
16	17	7.17380443	0.01108254
17	18	6.6858903	0.00905016
18	19	3.63056019	0.00611646
19	20	2.60460618	0.00431382
20	21	1.54384401	0.00232701
21	22	1.35432962	0.00094313
22	23	1.29622557	0.00047693
23	24	0.01084561	0.00010794
	Total in %	**98.7900261**	**1.2100003**

ANNEX 2: SHARING WITH THE FIXED SERVICE – SITE-GENERAL STUDY A

This study has been performed to assess long-term interference protection and fractional degradation in performance (FDP) of point-to-point Fixed Service (FS) from WAS/RLAN indoor (i.e. low power indoor LPI) as well as from potential outdoor WAS/RLAN (i.e. very low power VLP) portable devices operating with power levels significantly lower than those for indoor uses. The goal is to study feasibility and identify harmonised technical conditions for wireless access systems including radio local area networks in the 6425-7125 MHz band.

The study presented here include parametric inputs, parameters and distributions, which are similar to the one used in ECC Report 302 [1], and ECC Report 316 [2]. Some of the parameters were modified from ECC Report 302 and 316 to be adapted to the upper 6 GHz band.

The study attempts to quantify and qualify the risk of exceeding the long-term interference protection criterion, assessed in terms of I/N threshold, and the fractional degradation in performance using site-general joint and separated location/time Monte Carlo analyses. Some parameters, where relevant, were based on a possible FS deployment in the area “Frankfurt am Main” in Germany. The results of the study are computed taking into account all the possible statistical combination in terms of position, population density, FS height, FS antenna gain from real data set from the German regulator.

A2.1 INTERFERENCE ASSESSMENT FROM WAS/RLAN INTO FS

A2.1.1 Introduction

This section contains the results of a study for long-term interference protection from WAS/RLANs to FS links; fractional degradation in performance is also addressed. It is a Monte Carlo analysis assessing interference from low power indoor (LPI) WAS/RLANs and very low power (VLP) WAS/RLAN portable devices for a site-general scenario using Monte Carlo methodology and considering a population density equivalent to the area of “Frankfurt am Main” in Germany, Hessen state.

A2.1.2 Methodology used

In this Report, the methodology based on I/N = −10 dB not exceeded for more than 20% of time has been used to evaluate the fixed-service long-term protection criterion as in ECC Report 302 [1]. The protection criterion of fractional degradation in performance of 10% for co-primary sharing is also used.

A Monte Carlo simulation was used to generate I/N results. 10 million events were simulated. This simulation aggregates I/N statistics from RLANs dropped randomly at different positions for each event. This high amount of statistics is necessary for Monte Carlo to ensure good compromise between statistical stability and computational speed. For this simulation, SEAMCAT version 5.5.0 was used.

Furthermore, site-general separated location/time Monte Carlo simulations have been performed on 2 cases that exhibited the highest aggregated I/N. 1 million of time-events and 5000 of location-events have been simulated. The separated location/time Monte Carlo simulation is meant to address specifically fixed interferer separately to mobile interferers. In the context of this study, fixed interferers are RLAN access point (AP) and the client RLAN devices are mobile.

A2.2 MONTE CARLO ANALYSIS

A2.2.1 Technical characteristics of FS

The FS technical characteristics were extracted from the German regulators database.

Most of the FS links use 40 MHz bandwidth. The statistics of the antenna height from the German regulator database is so that the 10% of the FS links are below 30 m, 50% are below 45 m and 90% are below 79 m. These values are used for sensitivity analysis.

When the information was not available in the German database, ECC Report 302, table 18 was used instead. The FS technical characteristics are summarised in Table 42.

Table 42: Specific parameters for point-to-point FS systems for the frequency range 6425-7125 MHz

Parameter	Value for this study	Comment
Modulation	64-QAM	From ECC Report 302
Centre frequency (MHz)	6775 (centre of the band)	
Channel spacing and receiver noise bandwidth (MHz)	40	From German regulator database
Feeder/multiplexer loss range (dB)	1.3	From German database between 0 and 7.5 (a value 1.8 between 0 and 6.3 is given in ECC Report 302)
Antenna peak gain (dBi)	45.5 (max) 38.8 (mean) 33.6 (min)	From German regulator database
Antenna pattern	Recommendation ITU-R F.1245 for aggregate interference	From ECC Report 302
Antenna height (m)	10%: 30 50%: 45 90%: 79	Three percentile values selected from the German regulator database
Receiver noise figure (NF) typical (dB)	5	From ECC Report 302 between 4.5 and 5
Receiver noise floor (dBm)	-92.94	-173.97+10log10(BW in Hz) + NF
Antenna uptilt/downtilt	0 deg	From ECC Report 302 and ECC Report 316
Protection requirement (dB)	**Long-term:** I/N = −10 dB not exceeded for more than 20% of time (Recommendation ITU-R F.758 Table 4) **FDP <10%**	
Fade Margin	Min FM 5% percentile: 23 dB Max FM 5% percentile: 40.3 dB FM mode: 29.7 dB	From German regulator database

A2.2.2 Technical characteristics of WAS/RLAN in the band 6425-7215 MHz

A2.2.2.1 WAS/RLAN e.i.r.p. distribution

The *e.i.r.p.* distribution used in this simulation is provided in Annex 1. It is based on the assumptions below.

Table 43: *e.i.r.p.* distributions split between device type and indoor/outdoor type

Device type		Total indoor	Total outdoor	*e.i.r.p.* distribution
LPI	With body loss	21.10 %	0.21 %	200 mW + normalised antenna gain distribution from Table 39
	Without body loss	2.37 %	0.00 %	200 mW + normalised antenna gain distribution from Table 38
VLP	With body loss	9.00 %	1.00 %	25 mW + normalised antenna gain distribution from Table 39
AP (Client)	Without body loss	66.32 %	0.00 %	200 mW + normalised antenna gain distribution from Table 37
Total		98.79 %	1.21 %	

Note that in the SEAMCAT scenario, the interferer is identified for indoor and outdoor. The number of simulated RLANs set for the simulation is therefore 98.8% of the total RLANs for indoor and 1.2% of the total RLANs for outdoor. Therefore, the *e.i.r.p.* distributions need to be normalised to 100% for each of the indoor and outdoor scenario.

Since the SEAMCAT version 5.5.0 is used, it is no longer needed to have a joint *e.i.r.p.* and bandwidth correction factor as an input to the tool (see next section). The *e.i.r.p.* is now set as input to the tool. The normalised *e.i.r.p.* values of Table 41 in Annex 1 are used.

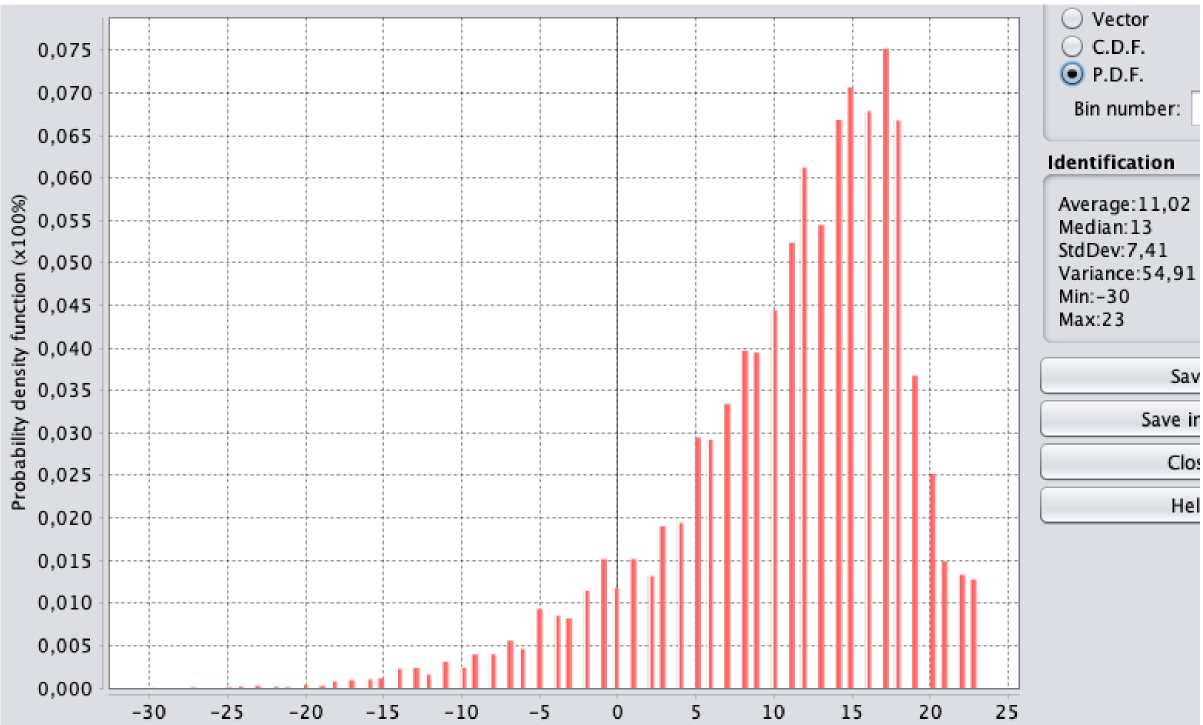


Figure 24: Indoor normalised *e.i.r.p.* probability distribution

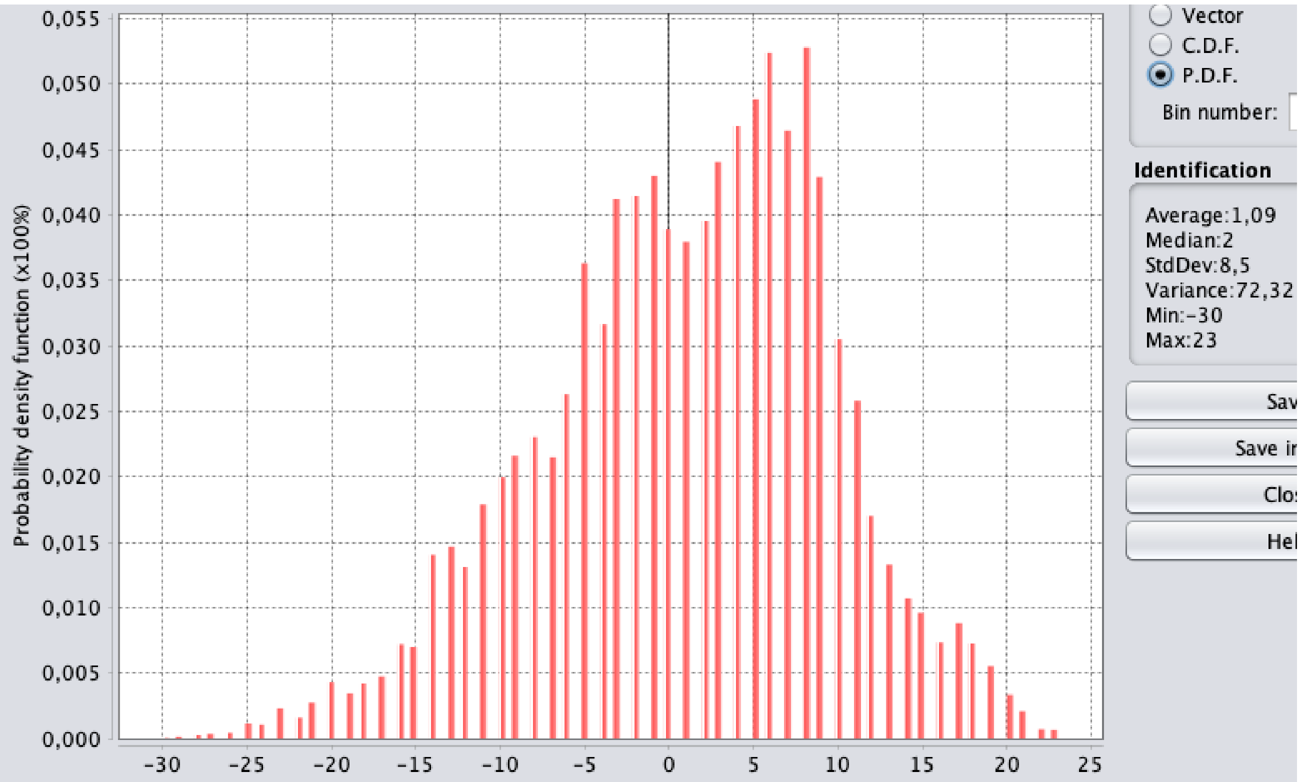


Figure 25: Outdoor normalised *e.i.r.p.* probability distribution

A2.2.2.2 Bandwidth correction factor distribution

The resulting bandwidth correction factor due to the various RLAN bandwidths compared to fixed FS bandwidth of 40 MHz is presented in Table 44.

Table 44: Bandwidth correction factor distribution for a 40 MHz FS

Bandwidth (MHz)	*Correction factor (dB)*	*Probability*
20	0	10%
40	0	5%
80	-3.01	30%
160	-6.02	35%
320	-9.03	20%

The cumulative percentile above is added to the SEAMCAT in the “Additional loss [dB]” distribution fields in the transmitter characteristic of the RLAN (see Figure 26). Since it is a loss as input, the negative values are replaced by positive values.

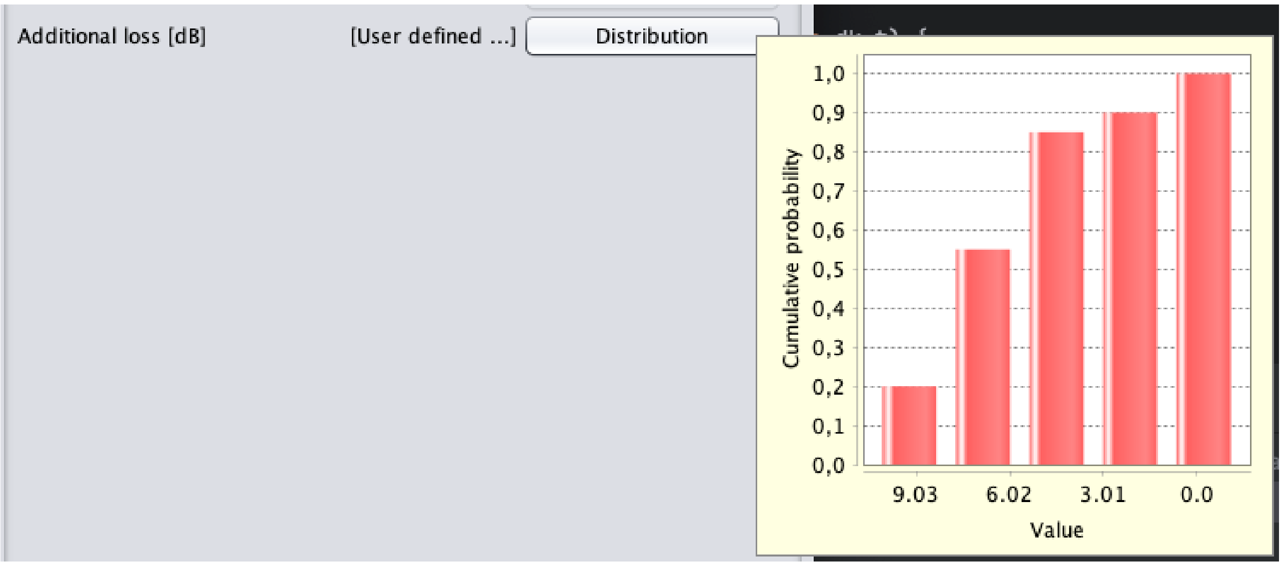


Figure 26: Example of the new "additional loss" field in SEAMCAT 5.5.0 used to configure the correction bandwidth factor

A2.2.2.3 Simulation radius

In order to analyse the long-term FS protection, the aggregated effect of the interferer is the predominant phenomenon. Consequently, in order to encompass the maximum number of interferers, the radio horizon is used to evaluate the size of the simulation radius.

Equation to calculate the distance from an antenna to the horizon or the line of sight, a.k.a. radio horizon, can be found in [12] and it is proportional to the antenna height (in km) above the ground and the mean Earth radius R = 6371 km.

The maximum FS height is 79 m which results in a radio horizon distance at the receiver of d_1=37 km. The maximum possible height of the RLAN is 28 m which results in a radio horizon distance at the transmitter of d_2=22 km. The total radio horizon d of the FS receiving and RLAN transmitting antennas is equivalent to $d=d_1+d_2$=59 km.

A2.2.2.4 WAS/RLAN deployment model and density

In order to evaluate the density of WAS/RLAN devices, FS data from the German regulator's database (not available publicly) were plotted on a map which indicated FS installations in or nearby the city of Frankfurt, Mainz, Bad Kreuznach, etc. which are hilly areas. The Frankfurt area was selected since it has most of the 6 GHz FS links in Germany and used to derive these input parameters.

This need to be considered in the conclusion since the modelling in SEAMCAT assumes flat terrain therefore neglecting any natural protection that terrain relief could provide hence providing conservative results compared to relief specific simulation. However, the results from SEAMCAT modelling approach provide valuable insight to administrations on the effect of potential interference from WAS/RLAN to FS receiver.

For the generic study, a ring like model is used as illustrated in Figure 27. In the centre there is the FS receiver within an urban high dense area, surrounded by a ring assumed as urban environment with lower density, further surrounded by a suburban ring and followed by a rural ring.

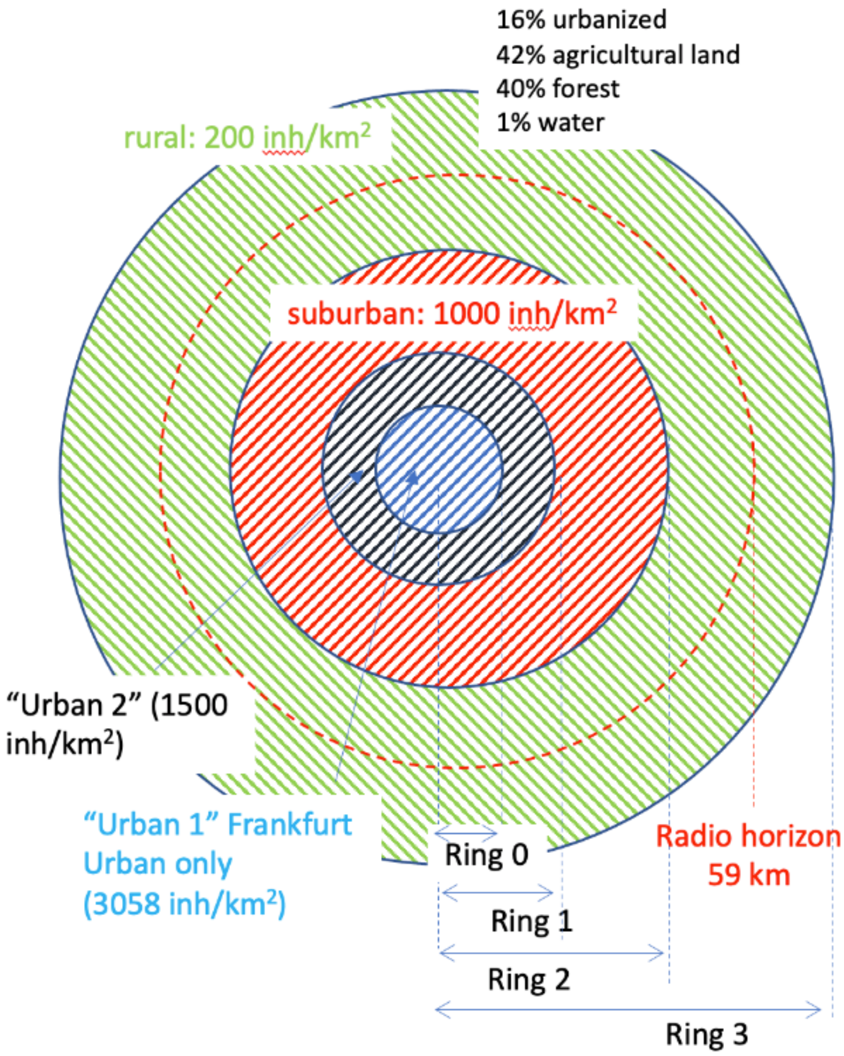


Figure 27: Illustration of the generic ring model simulation derived from the Hessen state area (Frankfurt region) – The FS receiver is in the centre of the simulation area

The radio horizon of 59 km (dotted red circle in Figure 27) is used as the maximum simulation radius.

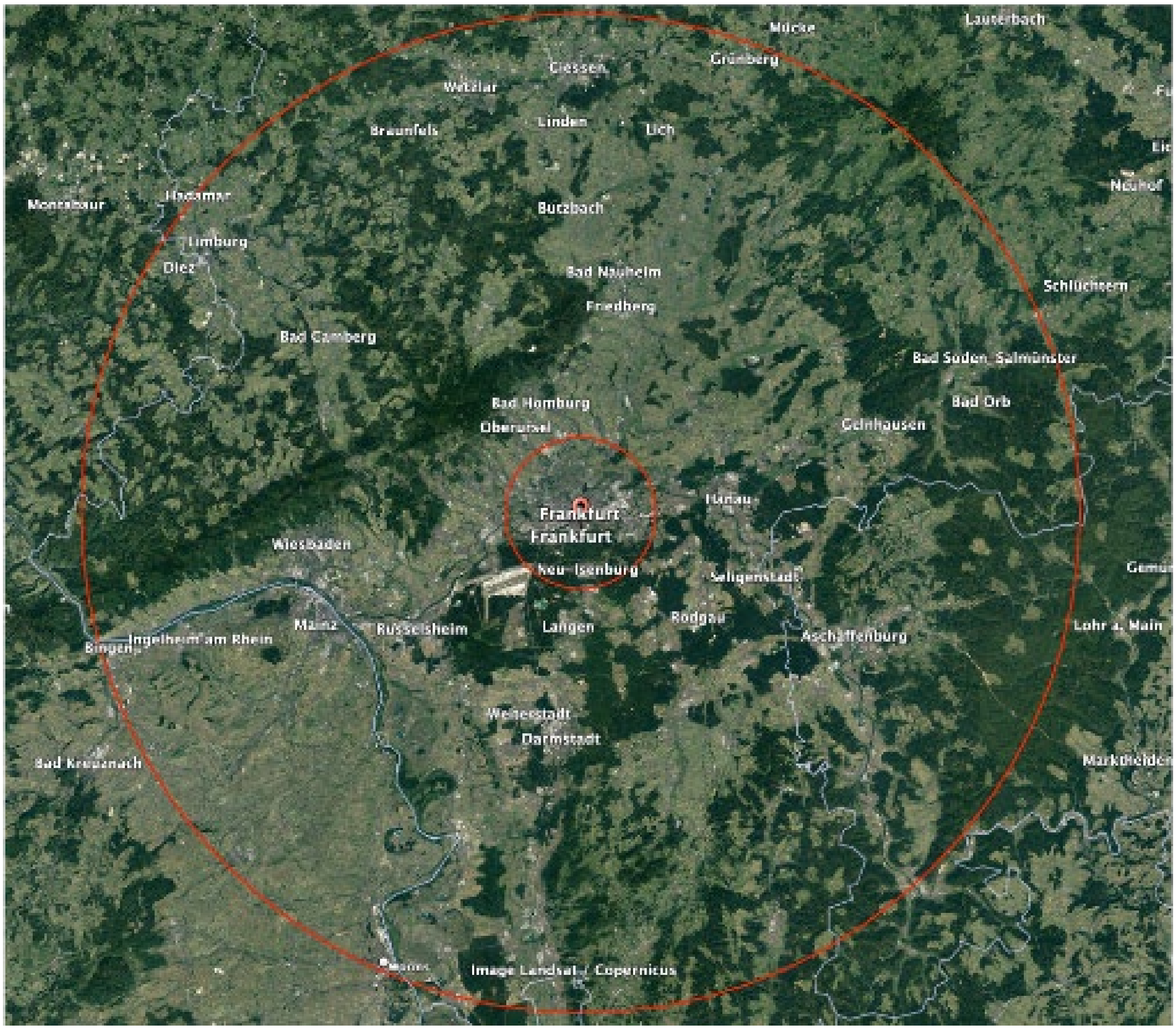


Figure 28: Illustration of the radio horizon (outer circle of 59 km) and the Frankfurt city area (inner circle of 8.89 km)

The city of Frankfurt ("urban 1"), which is the largest city of Hessen State, is considered because of its high density. The Hessen State consists of around 16% urbanised area (i.e. this includes any houses/building, infrastructure which can be in either of the radio urban/suburban/rural model), 42% of agricultural land area, 40% of forest area and 1% of water area.

The city area of Frankfurt is equivalent to 7% of Hessen's urbanised area with 248 km^2 (i.e. radius of 8.89 km) with a high population density of 3058 inhabitants/km^2. Frankfurt is surrounded by large cities like Darmstsdat, Wiesbden, Mainz, etc. consisting of an area of 681 km^2 that can be qualified as urban area with lower density (i.e. 1500 inhabitants/km^2). This is referred as "urban 2" in this Report and counts for 21% of Hessen's urbanised area. It is assumed that the remaining area is split equally between suburban and rural. The suburban population density model is 1000 inhabitants/km^2 and the rural population density model is 200 inhabitants/km^2.

The ratio between populated and non-populated area (in km^2) as well as the resulting total population are summarised in Table 45.

Table 45: Summary of the total population per urbanised area and of the overall Hessen State

(Note 2)	Percentage area in Hessen	ratio of areas	overall percentage	Area (km²) (Note 1)	Population density (inhabitants/km²)	Total population
Urbanised	16.51%					
“Urban 1” (Frankfurt)		7.12%	1.17%	248	3058	758710
“Urban 2” (i.e. Darmstadt,etc.)		21.19%	3.5%	739	1500	1107956
suburban		35.85%	5.92%	1250	1000	1249877
rural		35.85%	5.92%	1250	200	249975
agricultural land	42%		42%	8863	-	
forest	40.1%		40.1%	8481	-	
water	1.4%		1.4%	294	-	

Note 1: The total area is based on a 81.2 km radius, so that the area of Frankfurt is included.

Note 2: Urbanised area is 3315 km², Frankfurt area is 248 km², “urban 2” area is 681 km², agricultural land area is 8859 km², forest area is 8477 km², water area is 294 km².

The proposed model to evaluate the long-term protection criteria will consist of 4 rings.

- Ring 0 is just Frankfurt area (16% · 7%);
- Ring 1 is “urban 2” (i.e. Wiesbaden, Darmstadt, Mainz etc) (16% · 21%) with the water area (because most of the rivers are in these big cities for historical trade reason);
- Ring 2 is the suburban area (16% · 36%) with 50% of the forest area, because middle size cities are separated by forest as shown in Figure 28;
- Ring 3 is the rural area (16% · 36%) complemented with the remaining 50% of the forest area and the agricultural land area.

The simulation radius of the rings and the associated total population is summarised in Table 46.

Table 46: Summary of simulation radius per ring and associated total population per ring

	Radio model	Area (km²)	radius (km)	Total population
Ring 0	“Urban 1“	248	8.88	758710
Ring 1	“Urban 2“+water	1033	20.19	1107956
Ring 2	suburban + 50% forest	5490	46.43	1249877
Ring 3	rural + 50% forest + agricultural	14353	82 (Note 1)	249975

Note 1: Since the radio horizon is 59 km, the last ring needs to be truncated to the radio horizon while keeping the population density. The truncation from 82 to 59 km is equivalent to a surface reduction of 29.02%. Consequently the number of simulated WAS/RLAN devices is reduced by the same percentage.

The total population for each of the four rings is used to calculate the total number of devices that are simultaneously transmitting, according to the WAS/RLAN deployment model described in section 3. This is the same methodology as per ECC Report 302 and ECC Report 316. Three categories of WAS/RLAN deployment were considered as in ECC Report 302: Low, Mid and High deployment.

Later in this Report, ring 0 is referred as "urban 1", ring 1 as "urban 2", ring 2 as "suburban" and ring 3 as "rural" to ease readability.

For the FS system at 40 MHz, a bandwidth overlap factor is adapted to devices operating with 700 MHz of upper 6 GHz and is equivalent to 39.18 %. This value is analytically derived from Monte Carlo simulation.

Table 47: Summary of the WAS/RLAN deployment model in Frankfurt following the methodology as per ECC Report 302

	Low	Mid	High
Wireless devices operating in licence exempt spectrum (remainder operating in licenced spectrum)	90%		
Upper 6 GHz factor	40.75%		
Market Adoption factor (6 GHz capable devices)	25%	32%	50%
Number of devices using 6 GHz	75435		
Busy Hour factor	50%	62.7%	62.7%
RF Activity factor per person (i.e. duty cycle)	1.97%		
Bandwidth overlap factor (as per methodology of ECC Report 302)	23.95 %		

Table 48: Summary of the WAS/RLAN deployment model in the Frankfurt region (High deployment) following the methodology as per ECC Report 302

	Ring 0	Ring 1	Ring 2	Ring 3
Radio model	Urban 1	Urban 2+water	Suburban + 50% forest	Rural + 50% forest + agriculture
Simulation radius (km)	8.88	19.02	45.75	81.60 (Note 2) Radio horizon truncation: 59
Total population	758710	1107956	1249877	249975
Wireless devices operating in licence exempt spectrum	90%	90%	90%	90%
Upper 6 GHz factor	62.70%	62.70%	62.70%	62.70%
Market Adoption factor (6 GHz capable devices)	40.73%	40.73%	40.73%	40.73%
Busy Hour factor	50%	50%	50%	50%
Number of devices using 6 GHz	138979	187197	218625	43725
RF Activity factor per person	1.97%	1.97%	1.97%	1.97%

	Ring 0	Ring 1	Ring 2	Ring 3
Bandwidth overlap factor	23.95%	23.95%	23.95%	23.95%
Equivalent number of instantaneously transmitting WAS/RLANs used in the simulations	412	601	678	136 (Note 2) After radio horizon truncation: 39
Note 2: Since the radio horizon is 59 km, the last ring will need to be truncated to the radio horizon while keeping the population density. The truncation from 82 to 59 km is equivalent to a surface reduction of 29.02%, and an equivalent reduction is applied to the number of simulated WAS/RLAN devices.				

The equivalent number of instantaneously transmitting WAS/RLANs used in the simulations for each of the 4 rings needs to be split between indoor and outdoor usage such as 98.8% are indoor and 1.2% are outdoor.

Table 49 summarises the number of simulated WAS/RLAN devices for a High/Mid/Low deployment. For Urban 1, when the relative antenna height between the FS and the RLAN is small, there is a need to separate the RLAN in an indoor low ring and indoor high ring. The methodology to get these numbers is same as for Table 48 and using Table 47.

Table 49: Number of simulated WAS/RLAN devices for a High/Mid/Low deployment in case the FS height is higher than the max RLAN height

	urban 1				urban 2		suburban		rural	
deployment density	indoor total	indoor low	indoor high	out-door	indoor	out-door	indoor	out-door	indoor	out-door
		78%	RLANs <10.5 m							
High	407	-	-	5	594	7	670	8	38	1
Mid	260	-	-	3	380	5	429	5	24	1
Low	162	-	-	2	237	3	267	3	15	1

Table 50: Number of simulated WAS/RLAN devices for a Mid/Low deployment in case the FS height is similar to the max RLAN height

	urban 1				*urban 2*		*suburban*		*rural*	
deployment density	indoor total	indoor low	indoor high	out-door	indoor	out-door	indoor	out-door	indoor	out-door
		78%	RLANs <10.5 m							
High	407	317	90	5	594	7	670	8	38	1
Mid	260	203	57	3	380	5	429	5	24	1
Low	162	126	36	2	237	3	267	3	15	1

A2.2.2.5 Upper 6 GHz factor

In Germany, and most of the CEPT, the spectrum availability for WAS/RLAN is as follows:

Table 51: Spectrum availability in CEPT

Band designation	Spectrum availability (MHz)
5.15-5.25 GHz	100
5.25-5.35 GHz	100
5.470-5.725 GHz	255
5.725-5.85 GHz	0
5.85-5.925 GHz	0
2.4 GHz	83.5
Lower 6 GHz	480
Total spectrum available	1018.5

The upper 6 GHz factor is the percentage of WAS/RLAN devices utilising the upper 6 GHz frequency band. This is given by the ratio of spectrum available in the upper 6 GHz band to that available across the 6, 5 and 2.4 GHz frequency bands (see table above).

For the studies in the upper 6 GHz, 700 MHz of bandwidth is considered, i.e. 6425-7125 MHz. Hence using the currently available spectrum in CEPT, the upper 6 GHz factor can be calculated as follows:

$$\text{upper 6GHz}_{\text{factor}} = \frac{\text{upper 6 GHz}_{\text{availability}}}{\text{upper 6 GHz} + \text{ lower 6 GHz} + \text{5 GHz} + \text{2.4 GHz}_{\text{availability}}} = \frac{700}{1018.5 + 700} = 40.75\%$$

A2.2.2.6 WAS/RLAN bandwidth and bandwidth overlap factor

From the information given in Germany, most of the FS links operates with 40 MHz bandwidth.

The overlapping factor reflects the number of WAS/RLANs that would fall into the bandwidth of the receiver. The overall envisaged band to WAS/RLAN is 700 MHz. Thus, the receiver is not going to “see” all WAS/RLANs in its observing bandwidth but only a portion of them. This portion needs to be calculated according to WAS/RLAN channelisation. ECC Report 302, annex 2[1] contains the methodology used to derive the BW overlapping factor.

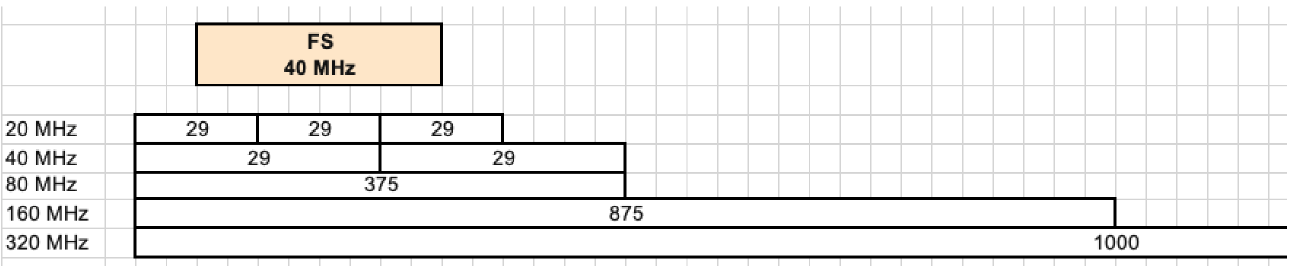


Figure 29: Overlapping WAS/RLAN channels with the 40 MHz FS bandwidth

The value found of 23.95% is used in this simulation.

Table 52: Upper 6 GHz overlap factor for a FS of 40 MHz

	10000	RLANs in example		
RLAN Channnels	#of channels	Percentage of RLAN	Number of RLAN per BW	#of RLANS per channel
20 MHz	35	10%	1000	29
40 MHz	17	5%	500	29
80 MHz	8	30%	3000	375
160 MHz	4	35%	3500	875
320 MHz	2	20%	2000	1000
FS BW = 40 MHz	corresponds to an FS band overlapping (see figure)			
3 channels of 20 MHz				
2 channels of 40 MHz				
1 channel of 80 MHz				
1 channel of 160 MHz				
1 channel of 320 MHz				
This representas a total of (3*29+2*29+1*375+1*875+1*1000)=			2395	
		Bandwidth overlap factor =	**23.95%**	

Table 53: Typical WAS/RLAN system for the frequency range 6425-7125 MHz

Parameter	Value
Centre frequency (MHz)	6775
Antenna peak gain (dBi)	0
Antenna pattern	Omni-directional
Antenna height (m)	See Table 54
Polarisation mismatch (assuming aggregate cases)	3 dB
e.i.r.p.	See Annex 1

A2.2.2.7 WAS/RLAN antenna height distribution and exclusion zone around the FS

The WAS/RLAN heights are used from ECC Report 316. When looking at the full building height Table from ECC Report 316, it is possible to split it per urban/suburban and rural category. Within each category the average height is considered as follows:

- For urban (i.e. “urban 1” and “urban 2”), the WAS/RLAN height is based on the average of categories “>100k”, ”>50k” and “>25k”. The final height for urban is the average height of the three categories. The rationale for using the same height distribution for “urban 1” and “urban 2” is that each ring may cover more than one category of heights as the rings are of the size of tens of kilometres. Looking at the topology of Frankfurt and other “urban” cities in Hessen, Wiesbaden etc., the average building heights are very similar (except for the city centre with towers in Frankfurt);
- For suburban, the WAS/RLAN height is based on the average of the remaining categories “>10k”, “>5k”, “>2.5k” and “<2.5k”. The average height of these categories is also performed to get the height of the suburban model;
- For rural, the WAS/RLAN height is based on the category rural.

Table 54: WAS/RLAN height probabilities from ECC Report 316

Floor	Height (m)	>100k	>50k	>25k	>10k	>5k	>2.5k	<2.5k	Rural	Outdoor (%)
ground	1.5	24.66	35.14	36.95	41.74	49.22	58.08	66.18	71.03	95
1	4.5	20.36	24.74	23.95	25.04	25.97	26.58	26.13	25.43	2
2	7.5	14.05	13.40	12.23	11.34	9.46	6.88	3.80	1.66	2
3	10.5	11.27	9.31	8.75	7.78	6.20	4.25	2.27	1.01	0.5
4	13.5	9.19	6.24	6.13	5.10	3.76	2.27	1.12	0.52	0
5	16.5	7.52	3.78	4.04	2.96	1.80	0.69	0.20	0.13	0
6	19.5	5.56	2.91	3.10	2.30	1.39	0.52	0.14	0.10	0
7	22.5	3.88	2.16	2.29	1.72	1.03	0.37	0.10	0.07	0
8	25.5	2.41	1.50	1.59	1.22	0.72	0.24	0.06	0.04	0
9	28.5	1.10	0.92	0.96	0.78	0.44	0.12	0.02	0.02	0.5

The average height derived from values in Table 54 is shown in Table 55.

Table 55: WAS/RLAN height probabilities for urban, suburban and rural (average based on categories in ECC Report 316)

Floor	Height (m)	urban	suburban	rural	Outdoor (%)
ground	1.5	32.25	53.81	71.03	95
1	4.5	23.02	25.93	25.43	2
2	7.5	13.23	7.87	1.66	2
3	10.5	9.78	5.13	1.01	0.5
4	13.5	7.19	3.06	0.52	0
5	16.5	5.11	1.41	0.13	0
6	19.5	3.86	1.09	0.1	0
7	22.5	2.78	0.81	0.07	0
8	25.5	1.83	0.56	0.04	0
9	28.5	0.99	0.34	0.01	0.5

For all the simulations, an exclusion zone of 20 m is assumed around the FS receiver to prevent unrealistic cases where the WAS/RLAN would be mounted on the FS receiver. This is the same value used in ECC Report 316. The 20 m exclusion zone intends to model that realistically there will be no buildings/constructions at less than 20 m from the FS receiver (a conservative larger distance could be considered), at least in Germany/Europe due to building regulation, electromagnetic exposure regulation, safety regulation, etc. For cases where the FS is mounted on top of a building, it is believed that the building entry loss will be sufficient to prevent any “vertical" interference from RLAN in the building.

For simulation where the FS height is close to the highest WAS/RLAN devices, i.e. where the FS height is 30 m and the highest building is 28.5 m, special care in the modelling is necessary to avoid having WAS/RLAN statistically generated in front of the FS main beam because it is an unrealistic deployment to have a high building in front of the FS Rx. This point was addressed in ECC Report 316. Therefore, WAS/RLANs cannot be simulated within 20 m of the FS and within 200 m if the WAS/RLAN device height is higher than 10.5 m. This is illustrated in Figure 30.

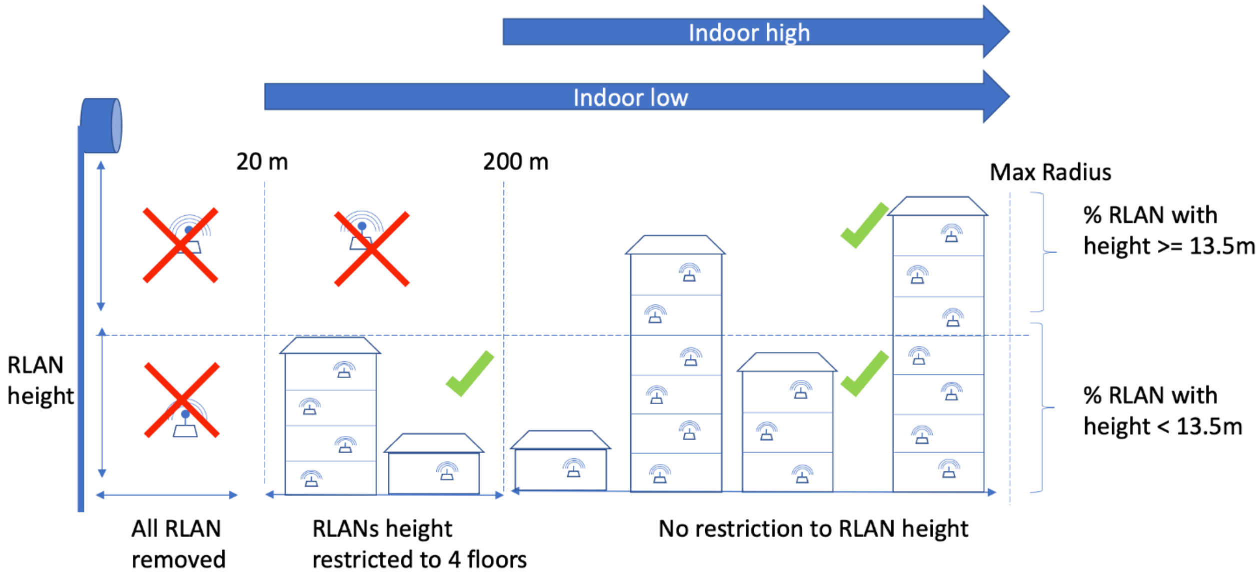


Figure 30: Example of a “WAS/RLAN height and distance removal” algorithm

In order to use the official SEAMCAT version and to avoid post processing data, the following approach is used: WAS/RLAN devices that have a height distribution below and including 10.5 m are distributed uniformly from 20 m to the maximum radius equivalent to the city’s radius (i.e. „indoor low”) and WAS/RLAN devices that have a height distribution higher than 10.5 m are distributed uniformly from 200 m to the largest radius (i.e. „indoor high”). The use of different rings, with different heights, takes into account the Fresnel zone.

In the case of Frankfurt, the largest radius is 8.89 km, this means that the surface of „indoor low” is 248.285 km^2 and the surface of “indoor high” is 248.161 km^2. Note that the difference in the surface area of the two is so small that the difference in the WAS/RLAN devices density is considered negligible. Outdoor devices are excluded from this process because the probability of being in front of the FS is negligible.

For low FS antenna height analysis, the category “urban” is split into two tables as shown below Table 56 (a) and Table 56 (b). According to the category “urban”, about 78% of WAS/RLAN devices are below or equal to 10.5 m and 22% are above.

Table 56: WAS/RLAN indoor height distribution when FS height is below the max height of WAS/RLAN (10.5 m) for urban model

Floor	Height (m)	Probability (%)	Normalised Probability (%)
ground	1.5	32.25	41.20
1	4.5	23.02	29.41
2	7.5	13.23	16.90
3	10.5	9.78	12.49
		78.27	100

(a) WAS/RLAN height for the “indoor low“

Floor	Height (m)	Probability (%)	Normalised Probability (%)
4	13.5	7.19	33.03
5	16.5	5.11	23.50
6	19.5	3.86	17.72
7	22.5	2.78	12.76
8	25.5	1.83	8.43
9	28.5	0.99	4.56
		21.76	100

(b) WAS/RLAN height for the “indoor high”

A2.2.3 Transmission loss calculation

An external propagation model plugin (ePMP) has been used in the study. The WINNER II model [9] has been used up to 1 km, where the first 40 m is upper bounded by free space model [10]. For distances farther than 1 km, Recommendation ITU-R P.2001-4 [19] with clutter loss (Recommendation ITU-R P.2108-0 [8]) is used for urban and suburban. Flat terrain assumption is considered. This is summarised in Table 57 and Table 58.

Table 57: Parameters to the ePMP

Parameters	Value	Unit
Polarisation loss	3	dB
Recommendation ITU-R P.2109 (indoor only) Probability loss	1 to 99	%
Recommendation ITU-R P.2109 (indoor only) Building type	70% traditional 30% thermal efficient	
Free space (Recommendation ITU-R P.525) breakpoint	0.04	km
WINNER II breakpoint	1.0	km
WINNER II model	Urban: C2 Suburban: C1 Rural: D1	-
WINNER II LoS	LoS probability	-
Recommendation ITU-R P.2001-4 Time percentage	0.001 to 100	%

Parameters	Value	Unit
Recommendation ITU-R P.2001-4 Rx/Tx coordinates	Default SEAMCAT value – not relevant as smooth Earth assumption	-
Recommendation ITU-R P.2001-4 Polarization	vertical	
Clutter model	Urban: Recommendation ITU-R P.2108 Suburban: Recommendation ITU-R P.2108 Rural: Recommendation ITU-R P.452-17 (section 4.5.3 and 4.5.4)	
Recommendation ITU-R P.2108 location percentage	0.001 to 100	%
Recommendation ITU-R P.452 clutter model (i.e. Village)	Clutter nominal height = 5 m Clutter nominal distance = 0.07 km	-

Table 58: Propagation models for urban and suburban

Horizontal Distance	Propagation Model	For Indoor only (Building Entry Loss)	Clutter
$0\ \mathrm{m} \leq d < 40\ \mathrm{m}$	Free space	Recommendation ITU-R P.2109 [11] (70% traditional, 30% modern, uniform distribution of probability from 1 to 99%)	not applicable
$40\ \mathrm{m} \leq d < 1000\ \mathrm{m}$	WINNER II model (Urban Macrocell C2 or suburban Macrocell C1)	Recommendation ITU-R P.2109 (70% traditional, 30% modern, uniform distribution of probability from 1 to 99%)	LOS and NLOS ratio probability determination is inherent to the WINNER II model
$d \geq 1000\ \mathrm{m}$	Recommendation ITU-R P.2001-4 (time percentage: uniform distribution from 0.001% to 100%)	Recommendation ITU-R P.2109 (70% traditional, 30% modern, uniform distribution of probability from 1% to 99%)	Recommendation ITU-R P.2108-0 (Location percentage: uniform distribution from 0.001% to 99%)

The SEAMCAT simulation assumes smooth Earth surface which does not consider transmission losses due to terrain profile. Hence the result provided are conservative. To illustrate this, Figure 31 shows the difference in aggregated interference results while applying either smooth Earth or terrain profile. Using DE1 scenario 11 (as example of a set-up) the results of the figure present the effect of taking the terrain profile into account in Recommendation ITU-R P.452 (there is no BEL, no clutter and no polarisation loss simulated, the absolute value has to be noted rather than the relative value). The FS has been placed on a real location in the Frankfurt area. SRTM 1arcsec .bil v3 files were used [14]. The results based on flat terrain assumptions (blue curve) cause more interference compared to when terrain relief (i.e. not flat) is considered.

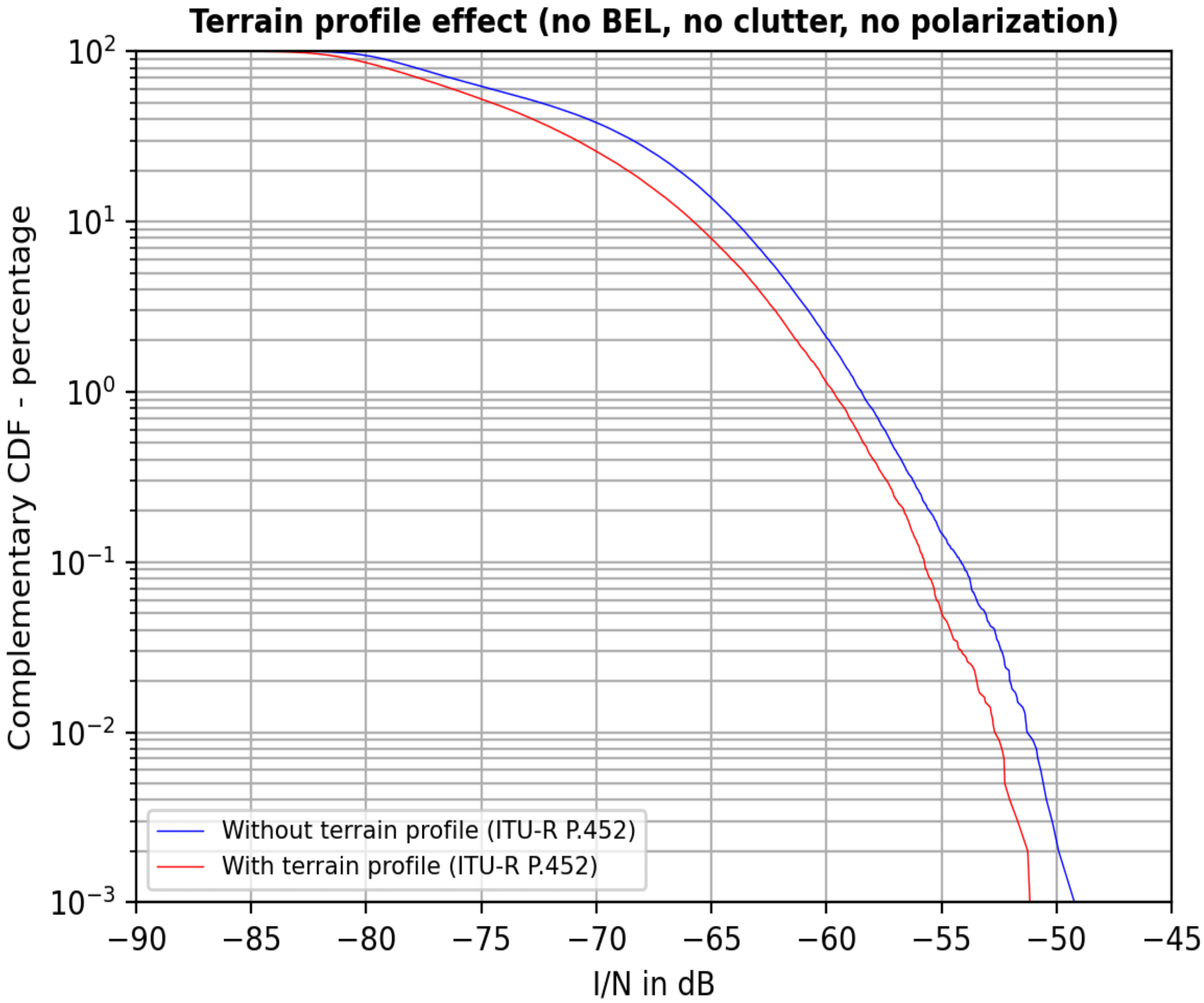


Figure 31: Illustration of the effect of terrain profile (relief) on the interference results

A2.2.4 Simulation results

A2.2.4.1 Simulation scenarios

This study shows the simultaneous impact of indoor and outdoor WAS/RLAN devices on the FS receiver. Figure 32 presents a summary of the DE1 scenarios that have been considered.

filename		city	Antenna gain	deployment density	FS height	FS ant.	urban 1 height (indoor)	urban 2 height (indoor)	suburban height (indoor)	rural height (indoor)	outdoor Height	forest/agricultural land	exclusion zone	
scenario_DE1_	11	Frankfurt	45.5	high	**79 (90%)**	ITU-R F.1245	Hurban	Hurban	Hsuburban	rural	Hout	option 1	20 m	baseline
	12	Frankfurt	33.6	high	79 (90%)	ITU-R F.1245	Hurban	Hurban	Hsuburban	rural	Hout	option 1	20 m	Sensitivity
	13	Frankfurt	45.5	low	79 (90%)	ITU-R F.1245	Hurban	Hurban	Hsuburban	rural	Hout	option 1	20 m	Sensitivity
	14	Frankfurt	45.5	mid	79 (90%)	ITU-R F.1245	Hurban	Hurban	Hsuburban	rural	Hout	option 1	20 m	Sensitivity
	15	Frankfurt	45.5	high	45 (50%)	ITU-R F.1245	Hurban	Hurban	Hsuburban	rural	Hout	option 1	20 m	Sensitivity
	16	Frankfurt	45.5	high	**30 (10%)**	ITU-R F.1245	Hurban_low/high	Hurban_low/high	Hsuburban	rural	Hout	option 1	20 m	Sensitivity
	17	Frankfurt	45.5	low	30 (10%)	ITU-R F.1245	Hurban_low/high	Hurban_low/high	Hsuburban	rural	Hout	option 1	20 m	Sensitivity
	18	Frankfurt	45.5	mid	30 (10%)	ITU-R F.1245	Hurban_low/high	Hurban_low/high	Hsuburban	rural	Hout	option 1	20 m	Sensitivity

Figure 32: Summary of the DE1 simulation scenarios

A2.2.4.2 Results for simultaneous indoor and outdoor operation for realistic case

The overall results, illustrated in Figure 33 and Figure 34, are presented in terms of the complementary cumulative distribution function CCDF of the I/N at the FS receiver to be able to assess the long--term interference criterion and to relate to the results presented in ECC Report 302 and ECC Report 316 for the lower 6 GHz band.

Figure 33 presents the effect of the two different antenna gains of 33.6 dBi and 45.5 dBi respectively. For both antenna gains (i.e. min and max) with the highest FS antenna height, the long-term interference criterion is respected.

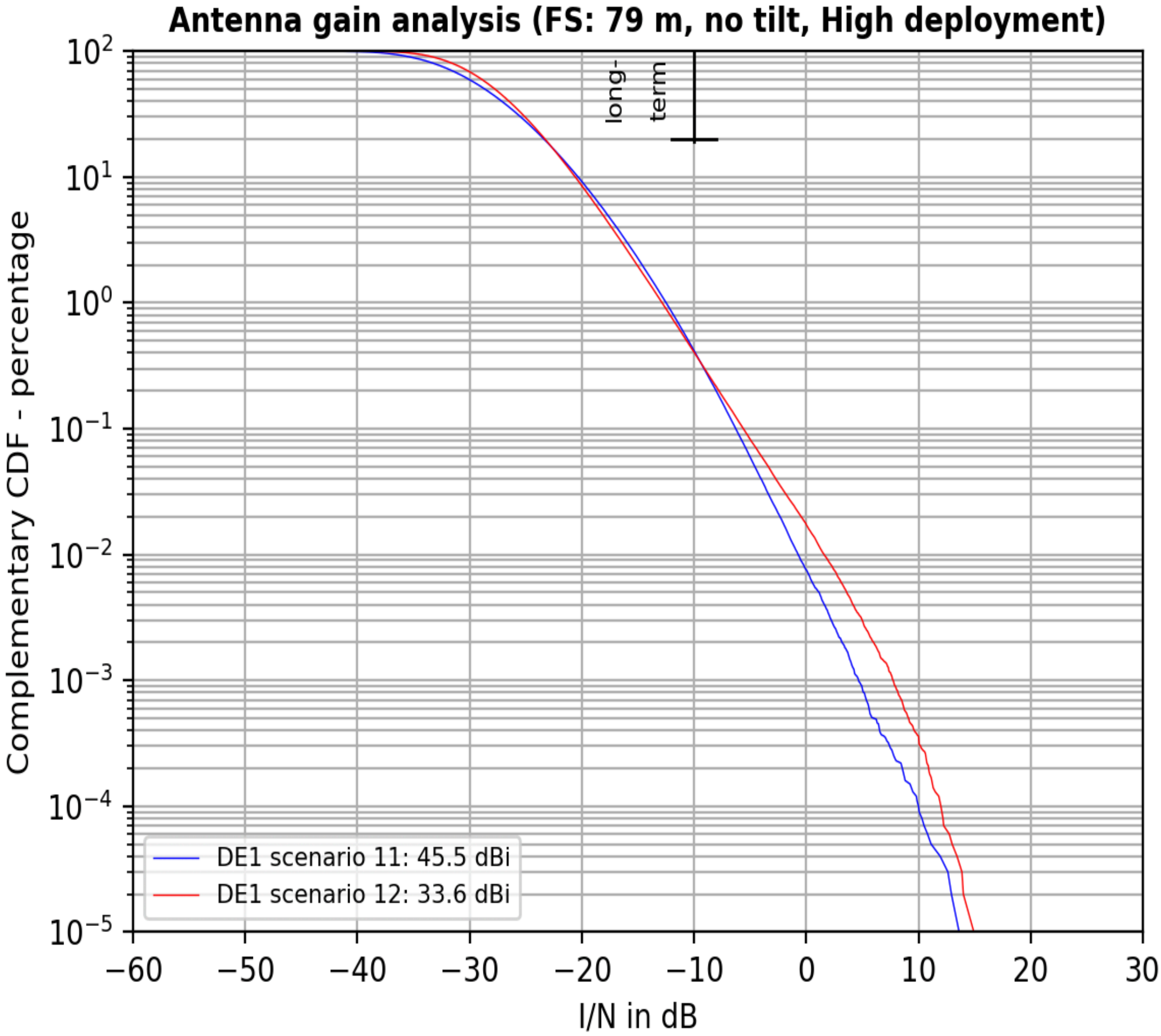


Figure 33: CCDF of I/N results for the highest FS height and with min and max antenna gain

Figure 34 presents a sensitivity analysis for the three WAS/RLAN deployments (i.e. High, Mid and Low) assuming the highest FS antenna height with the maximum antenna gain. For these three deployments, the long-term interference criterion is respected.

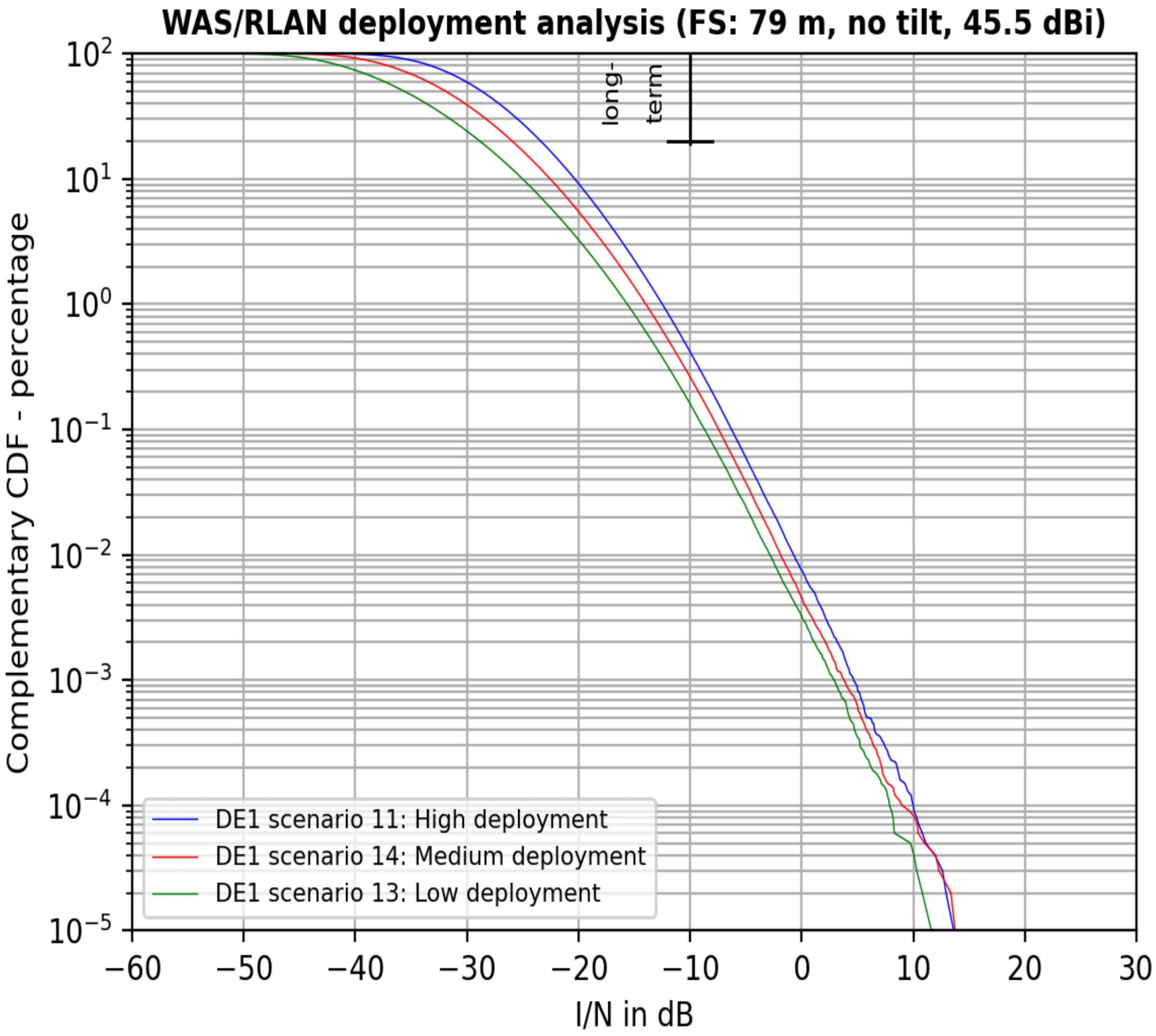


Figure 34: CCDF of I/N results for the for the highest FS heights and max antenna gain for three different deployment categories

A2.2.4.3 Sensitivity analysis results

This section presents more results based on sensitivity analysis. The studied scenarios in this sensitivity analysis do not reflect the actual deployment in Frankfurt because the modelling assumes that the FS Rx is in the centre of the interferer with uniform distribution. In reality, FS receivers in Frankfurt are not in the city centre, but rather at the edge of the city pointing away from the city centre, i.e. most of the high-density interferer are in the back lobe of the FS antenna.

The only aim of this analysis is to show that even with high population density and high building height, sharing is still feasible with FS antenna height as low as 30 m representing 10% of the German FS park. Figure 35 presents a sensitivity analysis for the three WAS/RLAN deployments (i.e. High, Mid and Low) assuming the lowest FS antenna height (i.e. 30 m) with the maximum antenna gain. For these three height deployments, the long-term interference criterion is respected.

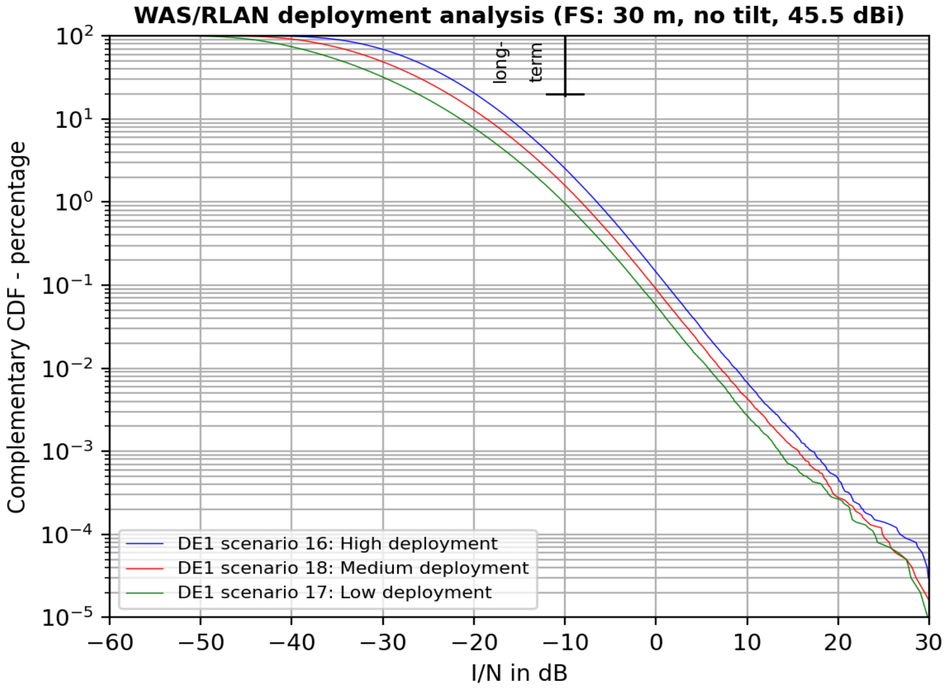


Figure 35:CCDF of I/N results for the for the lowest FS height and max antenna gain for three different deployment categories

Figure 36 presents a sensitivity analysis on the FS antenna height (i.e. 79 m, 45 m and 30 m) assuming the WAS/RLAN High deployment and the maximum FS antenna gain. For these three antenna heights, the long-term interference criterion is respected. It is important to consider both the effect of aggregated interference (typically high FS antenna height) and interference dominated by a single interferer (typically low FS antenna height). Therefore, the low and high antenna FS are important to investigate, the median is not so relevant but provided for convenience.

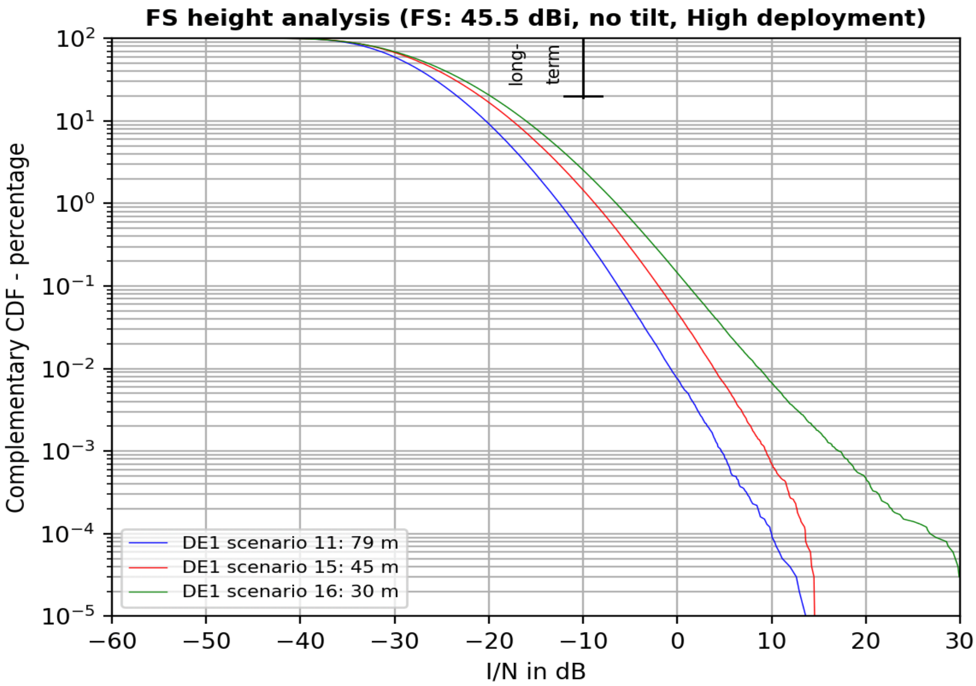


Figure 36: CCDF of I/N results for three FS heights with max FS antenna gain and high WAS/RLAN deployment

A2.3 FDP RESULTS

The I/N results have been post-processed to calculate the Fractional Degradation in Performance (FDP) according to the equations in Annex 10.

The FDP results are presented in Table 60. The calculation considers a generic FS link that does not have ATPC. In Germany the median FS link length is 24.48 km.

For this study, the Fade Margin (FM) and the Net Fade Margin (NFM) values are the ones extracted from the database of the German regulator. The values represent the 5%-ile and 95%-ile of the minimum FM distribution and the mode value (i.e. the most used value). The FM values are within the range of Table 8 and are more specific for Germany and provide a more realistic picture because they come from statistics of real links for different link lengths including 24.48 km. Note that the NFM values are lower than the FM by the ATPC range. The exact coordinates of FS links are not publicly available, therefore for the P_0 calculation in Recommendation ITU-R P.530, a coordinate in the Hessen states was used.

The FDP of Table 60 without ATPC and Table 61 with ATPC is computed with the parameters of Table 59.

Table 59: Input parameters to compute the FDP without ATPC

Parameters	Values
Latitude (Note1)	49.5804
Longitude (Note1)	9.0550
FS Tx height (m)	Scenario dependent {79, 45, 30}
FS Rx height (m)	Scenario dependent {79, 45, 30}
Frequency (MHz)	6685
Receiver noise floor (dBm)	-92.94
FS median link length (km)	24.48
FM minimum (5%-tile and 95%-tile) and mode (dB)	{23, 40.3, 29.7}
NFM minimum (5%-tile and 95%-tile) and mode (dB)	{11, 27.3, 24.9}
Note 1: The latitude and longitude represent a random location within the Hessen state nearby Frankfurt, and do not represent an exact FS location.	

The results from Table 60 indicate that all the FDP values are below 10%.

Table 60: Fractional degradation in performance without ATPC

DE1 Scenarios	FS Antenna gain (dBi)	RLAN deployment density	FS antenna height (m) (with corresponding percentiles)	FS median link length (km)	FDP(%) Min FM 5% percentile: 23 dB	FDP(%) Min FM 95% percentile: 40.3 dB	FDP(%) FM mode: 29.7 dB
11	45.5	High	79 (90%)	24.48	0.44	0.48	0.48
12	33.6	High	79 (90%)	24.48	0.47	0.51	0.5 1
13	45.5	Low	79 (90%)	24.48	0.17	0.19	0.19
14	45.5	Mid	79 (90%)	24.48	0.28	0.31	0.31

DE1 Scenarios	FS Antenna gain (dBi)	RLAN deployment density	FS antenna height (m) (with corresponding percentiles)	FS median link length (km)	FDP(%) Min FM 5% percentile: 23 dB	FDP(%) Min FM 95% percentile: 40.3 dB	FDP(%) FM mode: 29.7 dB
15	45.5	High	45 (50%)	24.48	0.92	1.02	1.02
16	45.5	High	30 (10%)	24.48	2.65	1.88	2.98
17	45.5	Low	30 (10%)	24.48	1.31	0.76	1.2
18	45.5	Mid	30 (10%)	24.48	1.85	1.20	1.75

Table 61: Fractional degradation in performance with ATPC

Scenario	FS Antenna gain (dBi)	RLAN deployment density	FS antenna height (m) (with corresponding percentiles)	FS median link length (km)	FDP(%) Min FM 5% percentile: 11 dB	FDP(%) Max FM 5% percentile: 27.3 dB	FDP(%) FM mode: 24.9 dB
11	45.5	High	79 (90%)	24.48	0.61	0.48	0.44
12	33.6	High	79 (90%)	24.48	0.77	0.51	0.46
13	45.5	Low	79 (90%)	24.48	0.24	0.19	0.17
14	45.5	Mid	79 (90%)	24.48	0.4	0.31	0.28
15	45.5	High	45 (50%)	24.48	1.5	1.01	0.91
16	45.5	High	30 (10%)	24.48	4.18	2.97	2.67
17	45.5	Low	30 (10%)	24.48	1.68	1.38	1.28
18	45.5	Mid	30 (10%)	24.48	2.66	1.85	1.83

A2.4 SEPARATED LOCATION/TIME MONTE CARLO SIMULATION

A2.4.1 Location/Time Methodology

The separated location/time Monte Carlo is meant to address specifically fixed interferers separately from mobile interferers. In the context of this study, fixed interferers are RLAN access point (AP) and the client RLAN devices are mobile.

The transmission of the WAS/RLAN APs depends on the RF activity factor. This factor determines which APs from a pool of APs will be transmitting at a certain time instant. It will cause the active APs to vary with time.

To separate location and time, when an interferer is transmitting, the following interfering budget link equation holds:

$$iRSS_{victim} = Ptx_{intereferer} + Gtx_{intereferer} + GRx_{victim} + BEL_{link} + CL_{link} + PL_{link}$$

where:

- $iRSS_{victim}$ is the received signal at the victim receiver in dB.

- $Ptx_{intereferer}$ is the transmit power from the interferer. Each RLANs will transmit different *e.i.r.p.* (according to a distribution) and will transmit with different bandwidth. It is assumed that for each time instant the AP transmits the same power and uses the same bandwidth;
- $Gtx_{intereferer}$ is the antenna gain from the interfering transmitter. It will vary for each AP. It is modelled as a constant 0 dB value because it is modelled in the *e.i.r.p.* distribution. It is assumed to be a constant value in the time domain;
- GRx_{victim} is the antenna gain from the victim receiver. It will vary for each FS-AP link. It is computed using Recommendation ITU-R F.1245. It is assumed to be a constant value in the time domain;
- BEL_{link} is the building entry loss (BEL) between the AP and the FS. It is computed from Recommendation ITU-R P.2109 and is a statistical model. The BEL is assumed to be constant in the time domain, since the wall structure does not change over time;
- CL_{link} is the clutter loss between the AP and the FS. The CL is computed for urban and suburban environment using Recommendation ITU-R P.2108 and it is a statistical model. For rural environment, the clutter model from Recommendation ITU-R P.452-17 is used and it is not statistical. It is assumed that the clutter environment does not change in the time domain;
- PL_{link} is the propagation loss between the AP and the FS. It will vary with time. It is a combination of three models:
  - For $0 \le d < 40$ m, Recommendation ITU-R P.525 is used. It is not a statistical model;
  - For $40 \le d < 1$ km, WINNER II model is used. It is a statistical model with no time input. It is assumed that the statistical variation is a proxy to time evolution. WINNER II documentation [9], section 3.5, explains nomadic channel conditions where it can be assumed that scatters may move in time with human presence;
  - For $d \ge 1$ km to radio horizon, Recommendation ITU-R P.2001 is used. It is a statistical model with time input.

Reference [9] explains in several instances the impact of moving clusters for nomadic models (section 3.5) “Actually this is quite typical in many cases, like when there are people working in the vicinity of the transceiver. For the nomadic environment it is also typical that an access point and especially user terminals can change place, e.g. in the room and even go out from the room. However, the most important feature to be taken into account in channel modelling is the moving scatterers. […]. In principle, nomadic channels can exist in all the WINNER deployment scenarios, both in indoor and outdoor”.

In addition, it is mentioned that “In indoors the moving objects (called clusters) are assumed to be humans.”

Each WINNER II model has a shadow fading standard deviation that represents the variability of the radio propagation channel which can be time or space dependent. WINNER II model B5 considers that both transceivers are fixed and where the shadow fading standard deviation ranges from 4 to 8 dB depending on LOS and NLOS conditions. For model B5, the variation of the cluster is temporal only.

The channel C2 used as urban modelling in this study, below 1 km, also exhibits shadow fading standard deviation ranging from 4 to 8 dB, therefore it is assumed that the statistical variation will be a proxy to time evolution since the model may contain time and space components.

When a simulation is launched, a total number of RLAN APs is derived from busy hours, 6 GHz factor etc. This is equivalent to find a pool of APs from which some APs will be active and some will not. This pool of RLAN AP is called a morphology pool.

The number of active RLAN APs depends on the AF and will be selected from that morphology. That morphology does not change in time. For each time event, different APs of that morphology will be active. The selection of the fixed RLAN changes for each time instant, while the morphology does not change. For each time instant, an I/N is calculated which leads to a distribution of I/N in the “pseudo” time domain.

For each single morphology, a single value of fractional degradation in performance (FDP) is calculated from a) the I/N distribution and b) the fade distribution that the FS receiver experienced due to either multipath or rain fading. The fade at the FS receiver is computed using Recommendation ITU-R P.530 and is dependent on the link characteristics (coordinates, height, link length, availability/NFM).

To statistically investigate the FDPs in the location domain, several morphologies need to be generated. This will lead to a FDP distribution in a form of a cumulative distribution function (CDF).

This can be written in the following pseudo-code:

```
Calculate the total number of RLANs
Calculate the number of active RLANs
For each location event
        Create a morphology pool by generating the total number of RLANs
        For each pseudo time instant
                For each RLANs
                        Select randomly the number of active RLANs from pool
                        Calculate the aggregated I/N_pseudo time
                End
                Collect the vector I/N_pseudo time event
        End
        Compute the Fade from Recommendation ITU-R P.530
        Compute the FDP_location =function (vector I/N_pseudo time event, Fade)
End
Collect the FDP_location event
Generate the CDF of FDP_location event
```

A2.4.2 Complete simulation and FDP computation

The overall simulation consists of running two sets of simulations:

1. Set of separated location/time Monte Carlo simulation for AP devices only;
2. Set of joint location/time Monte Carlo simulation for client devices only.

The FDP(%) is computed for each morphology-event. The total I/N from which the FDP is derived, consists of the linear summation of the aggregated I/N samples for the AP devices and the aggregated I/N samples for the client devices.

5000 morphology-events and 1 million time-events have been simulated.

Figure 37 depicts the complete simulation process.

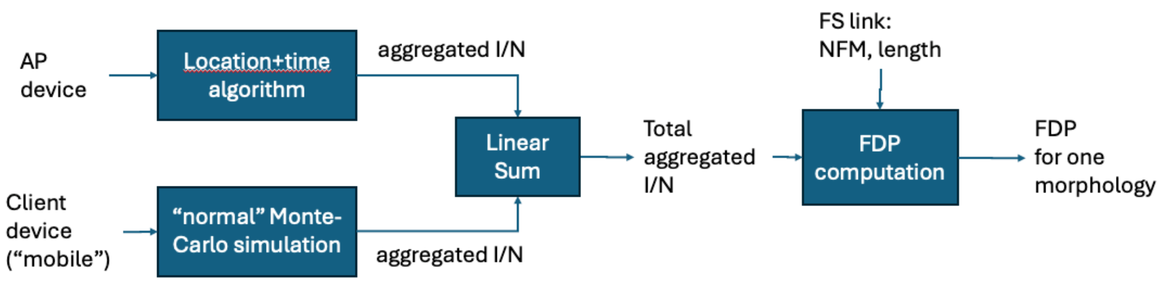


Figure 37: Complete simulation process to derive the FDP(%)

A2.4.3 Simulation assumptions

The activity factor (AF) was measured for both AP and client devices combined. There is no individual AF either for AP or client devices, therefore it is assumed that the AF for the AP and the client is the same.

Compared to joint location/time Monte Carlo simulations, the following assumptions are different:

- The *e.i.r.p.* distributions of the AP and the client have been separated.

- For the High RLAN deployment, the number of AP and client devices to simulate have been separated. Scenario A based on ECC Report 302 is considered in this study.

The rest of the assumptions remains the same as for the joint location/time Monte Carlo simulation.

A2.4.3.1 AP e.i.r.p.

The *e.i.r.p.* of the client and AP are now separated. Table 62 present the *e.i.r.p.* distribution is for AP only.

Table 62: AP *e.i.r.p.* distribution

G_{max} (dB)	AP Probability (%)	G_{max} (dB)	AP Probability (%)	G_{max} (dB)	AP Probability (%)	G_{max} (dB)	AP Probability (%)
-7	0.099406	3	1.2546	13	6.6638	23	1.8621
-6	0.066031	4	1.2434	14	7.8203		
-5	0.20884	5	2.3172	15	8.6798		
-4	0.050212	6	1.9677	16	8.4656		
-3	0.11187	7	2.6282	17	8.8269		
-2	0.36413	8	3.6108	18	8.4427		
-1	0.74216	9	3.6073	19	4.3163		
0	0.64993	10	4.7088	20	3.0841		
1	0.91867	11	5.9779	21	1.8584		
2	0.58648	12	7.0536	22	1.8128		

A2.4.3.2 AP devices deployment

Table 63 presents the assumptions to derive the pool of morphology. A total of 58240 APs constitutes the pool of morphology. For each time-event, a number of active devices (i.e. 58240 ·1.97%) will be selected from this pool of APs.

Table 63: AP High deployment (Scenario A)

	Ring 0	Ring 1	Ring 2	Ring 3
Radio model	“urban 1“	“urban 2“ +water	Suburban + 50% forest	Rural + 50% forest +agriculture
Simulation radius (km)	8.88	19.02	45.75	81.60 (Note 1) After radio horizon truncation: 59
Total population	758710	1107956	1249877	249975
Wireless devices operating in licence exempt spectrum	90%	90%	90%	90%

	Ring 0	Ring 1	Ring 2	Ring 3
Upper 6 GHz factor	62.70%	62.70%	62.70%	62.70%
Market Adoption factor (6 GHz capable devices)	40.73%	40.73%	40.73%	40.73%
Busy Hour factor	50%	50%	50%	50%
AP/client ratio	66.32%	66.32%	66.32%	66.32%
RF Activity factor to get the pool of morphology	100%	100%	100%	100%
Bandwidth overlap factor	23.95%	23.95%	23.95%	23.95%
Equivalent number of AP for the pool of morphology	13856	20234	22826	4565 (Note 1) After radio horizon truncation: 1325
Indoor total pool of AP	13856	20234	22826	1325
Outdoor AP	0	0	0	0
AF for the AP	1.97%	1.97%	1.97%	1.97%
Note 1: Since the radio horizon is 59 km, the last ring will need to be truncated to the radio horizon while keeping the population density. The truncation from 82 km to 59 km is equivalent to a surface reduction of 29.02%, which leads to an equivalent reduction of the number of simulated WAS/RLAN devices by the same percentage.				

A2.4.3.3 Client e.i.r.p.

The client devices *e.i.r.p.* consist of a combination of client without body loss (BL), client with BL, VLP with BL. The AP is removed from the *e.i.r.p.* distribution used in joint location/time Monte Carlo simulation. Figure 38 and Figure 39 present the *e.i.r.p.* distribution for client devices positioned indoor and outdoor respectively.

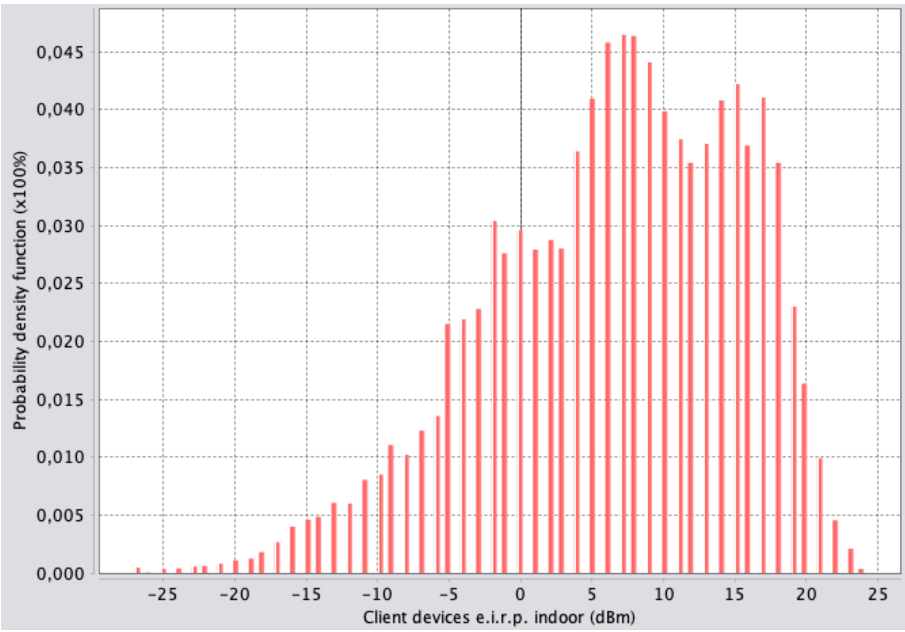


Figure 38: Client *e.i.r.p.* distribution for indoor devices

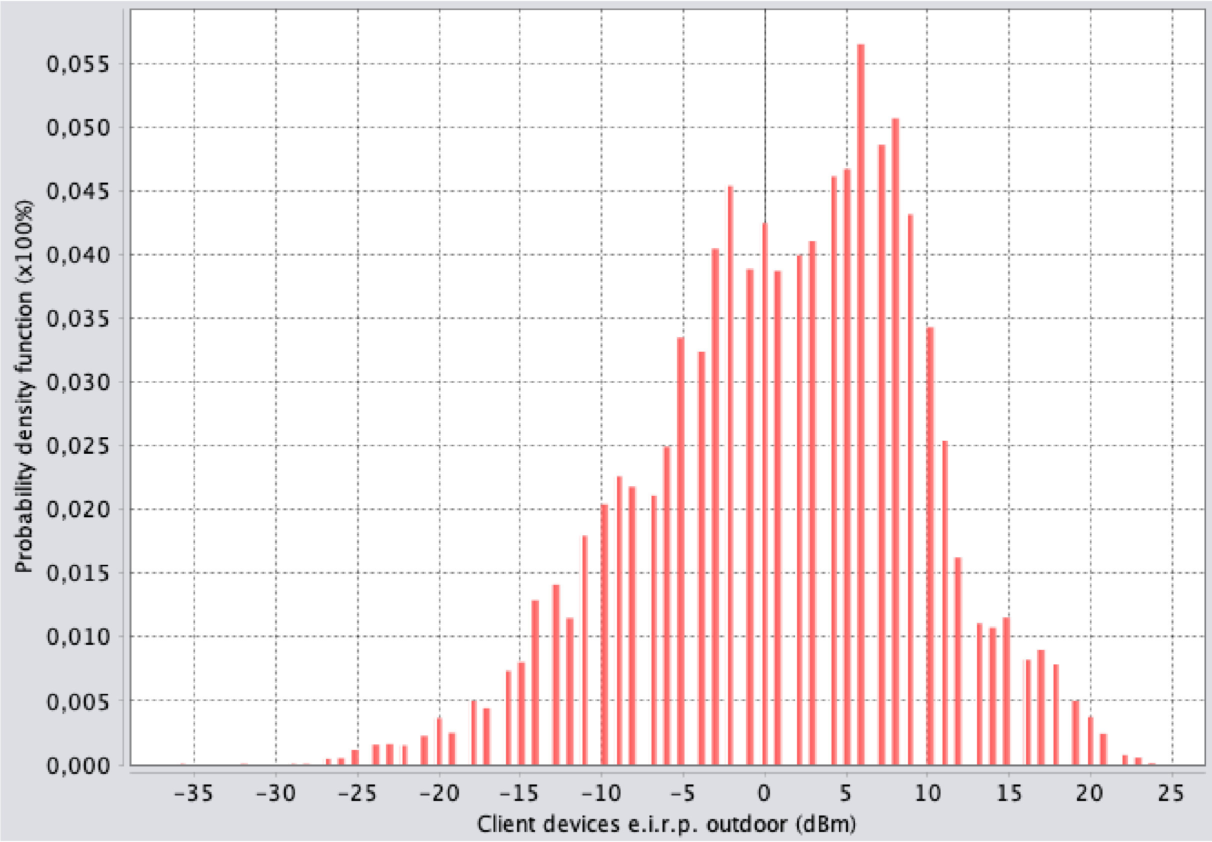


Figure 39: Client *e.i.r.p.* distribution for outdoor devices

A2.4.3.4 Client devices deployment

Table 63 presents the assumptions to derive the pool of morphology. A total of 58240 APs constitutes the pool of morphology. For each time-event, a number of active devices (i.e. 58240 ·1.97%) will be selected from this pool of APs.

Table 64: Client High deployment (Scenario A)

	Ring 0	Ring 1	Ring 2	Ring 3
Radio model	"urban 1"	"urban 2" +water	Suburban + 50% forest	Rural + 50% forest +agriculture
Simulation radius (km)	8.88	19.02	45.75	81.60 (Note 1) After radio horizon truncation: 59
Total population	758710	1107956	1249877	249975
Wireless devices operating in licence exempt spectrum	90%	90%	90%	90%
Upper 6 GHz factor	62.70%	62.70%	62.70%	62.70%

	Ring 0	Ring 1	Ring 2	Ring 3
Market Adoption factor (6 GHz capable devices)	40.73%	40.73%	40.73%	40.73%
Busy Hour factor	50%	50%	50%	50%
AP/client ratio	33.68%	33.68%	33.68%	33.68%
RF Activity factor for client devices	1.97%	1.97%	1.97%	1.97%
Bandwidth overlap factor	23.95%	23.95%	23.95%	23.95%
Equivalent number of instantaneously transmitting client devices	139	202	228	46 (Note 1) After radio horizon truncation: 13
Indoor client devices (98.8%)	137	200	226	13
Outdoor client devices (1.2%)	2	2	3	1
Note 1: Since the radio horizon is 59 km, the last ring will need to be truncated to the radio horizon while keeping the population density. The truncation from 82 km to 59 km is equivalent to a surface reduction of 29.02%, which leads to an equivalent reduction of the number of simulated WAS/RLAN devices by the same percentage.				

A2.4.4 Simulation results

Two DE1 scenarios are investigated: scenario 11 (high FS antenna height) and scenario 16 (low FS antenna height).

A2.4.4.1 I/N Results

Figure 40 presents the CCDF of the I/N results for DE1 scenario 11 (high FS antenna height).

Three sets of curves are shown:

- The first set, consisting of 1 red curve, is the I/N distribution of both the AP and client devices simultaneously modelled using the joint location/time Monte Carlo approach.
- The second set, consisting of 1 green curve, is the I/N distribution of client devices only using the joint location/time Monte Carlo approach.
- The third set, consisting of 5000 blue curves, is the I/N distribution of AP devices only using the separated location/time Monte Carlo approach.

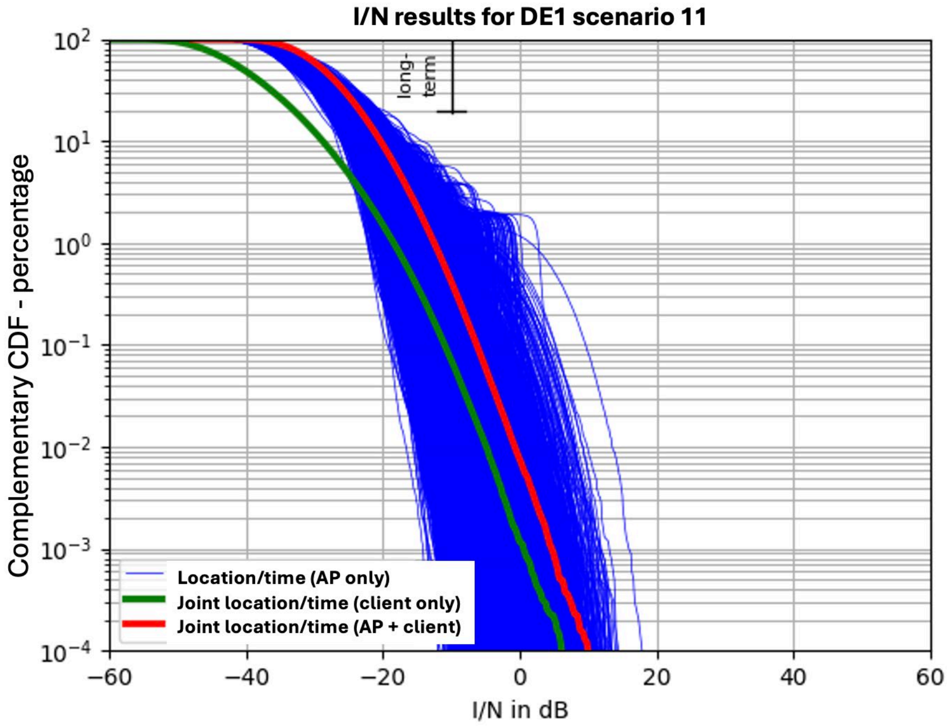


Figure 40: I/N results for DE1 scenario 11 (high FS antenna height) – Scenario A (5000 morphology-events)

Figure 41 presents the CCDF of the I/N results for DE1 scenario 16 (low FS antenna height).

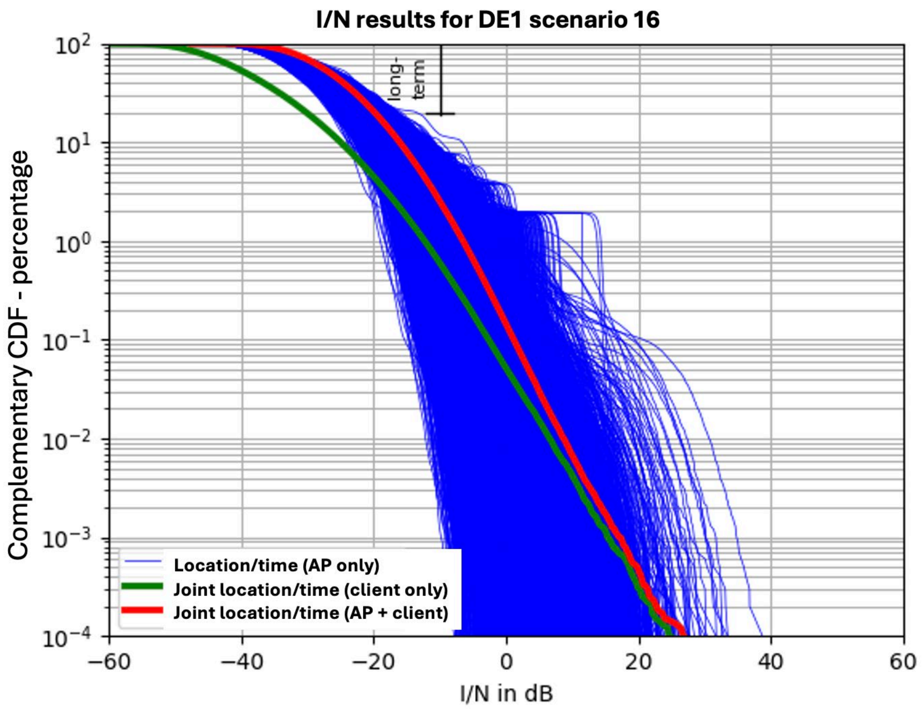


Figure 41: I/N results for DE1 scenario 16 (low FS antenna height) – Scenario A (5000 morphology-events)

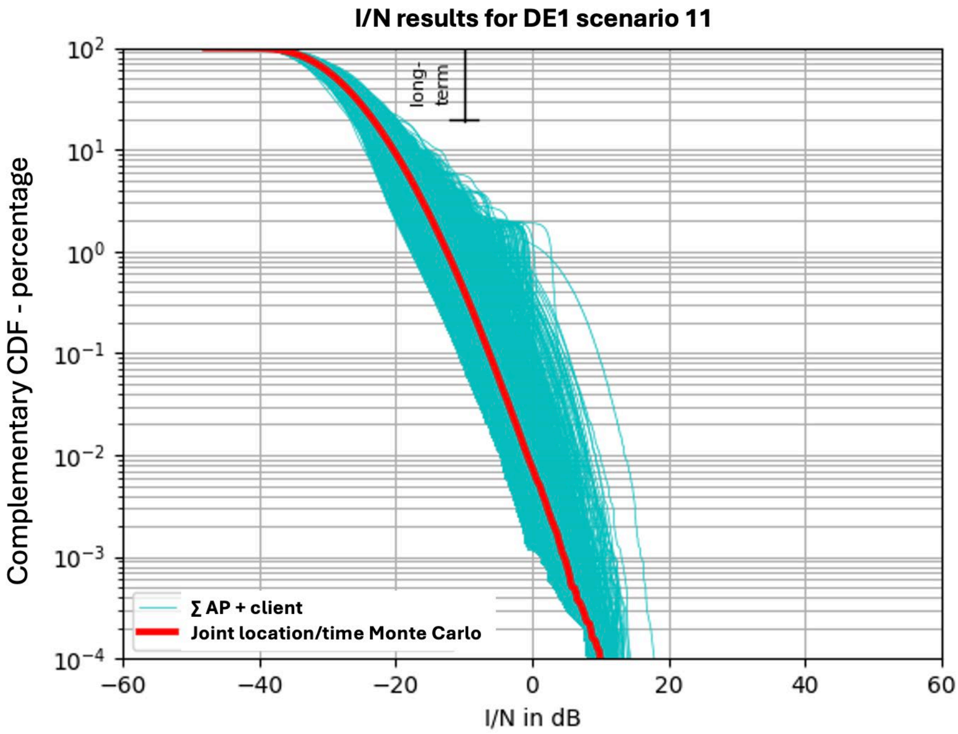


Figure 42: I/N results for joint location/time Monte Carlo and aggregated client and AP (see Figure 37) for DE1 scenario 11 (high FS antenna height) – Scenario A (5000 morphology-events)

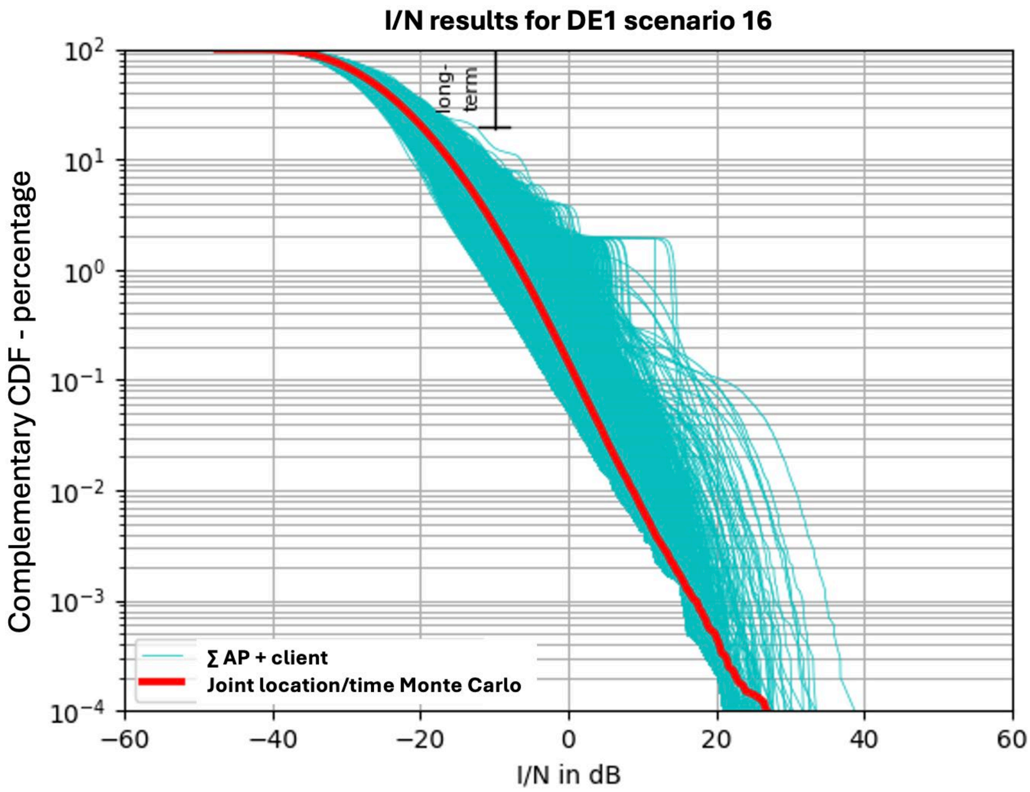


Figure 43: I/N results for joint location/time Monte Carlo and aggregated client and AP (see Figure 37) for DE1 scenario 16 (low FS antenna height) – Scenario A (5000 morphology-events)

The long-term protection criterion (I/N of -10 dB exceeded less than 20% of the time) is respected.

A2.4.4.2 FDP(%) Results

The FDP values are computed with the parameters of Table 65.

Table 65: Input parameters to compute the FDP without ATPC

Parameters	DE1 Scenario 11	DE1 Scenario 16
Latitude (Note1)	49.5804	49.5804
Longitude (Note1)	9.0550	9.0550
FS Tx height (m)	79	30
FS Rx height (m)	79	30
Frequency (MHz)	6685	6685
Receiver noise floor (dBm)	-92.94	-92.94
FS median link length (km)	24.48	24.48
Note 1: The latitude and longitude represent a random location within the Hessen state nearby Frankfurt and do not represent an exact FS location.		

Table 66: FM input parameters to compute the FDP

Parameter	Value
FM minimum value (5%-tile, 95%-tile), and FM mode value (dB)	23, 40.3, 29.7

FDP vs fixed RLAN morphology

Figure 44 presents the FDP(%), for DE1 scenario 11, computed for FM = 23 dB, 29.7 dB and 40.3 dB as a function of the number of fixed RLAN morphologies.

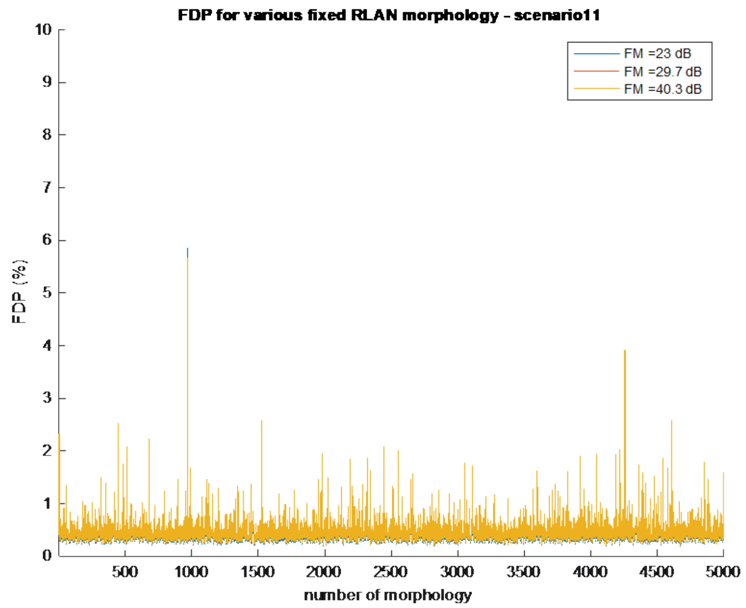


Figure 44: FDP for various fixed RLAN morphologies and different value of fade margins for DE1 scenario 11 (high FS antenna height)

Figure 45 presents the FDP(%), for DE1 scenario 16, computed for the three fade margins.

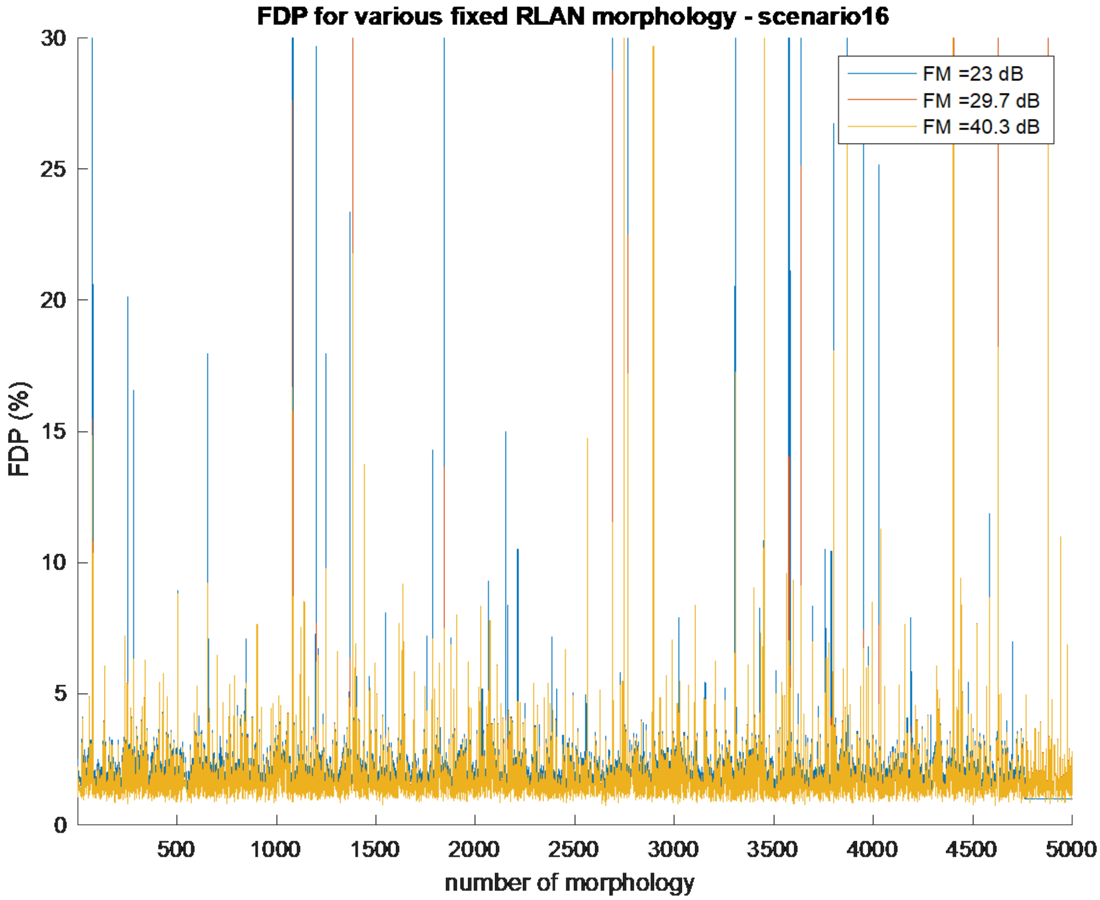


Figure 45: FDP for various fixed RLAN morphologies and different value of fade margins for DE1 scenario 16 (low FS antenna height)

For DE1 scenario 16, in some instances, the FDP can be drastically high compared to the rest of the values which makes the derivation of the PDF and CDF difficult. Therefore, any FDP values higher than 30% is truncated to 30%.

Cumulative distribution function (CDF) of the FDP

Figure 46, for DE1 scenario 11 (high FS), presents the CDF considering FM=23 dB, 29.7 dB and 40.3dB.

The median (i.e. 50%) gives FDP = 0.39% (for FM = 23 dB), FDP = 0.42% (for FM = 29.7 dB) and FDP = 0.42% (for FM = 40.3 dB). When comparing the median values to the FDP(%) calculated based on the joint location/time Monte Carlo as in Table 67, it shows that the FDP(%) results from the two approaches are consistent.

While it would be expected to have a lower FDP for larger FM, for DE1 scenario 11 with low I/N, it is actually the opposite, the FDP is larger by 0.03% for large FM.

The results from Figure 46 (i.e. DE1 scenario 11) shows that for high FS receiver, there is no risk of degradation from RLAN to the FS link because the maximum FDP is 2%.

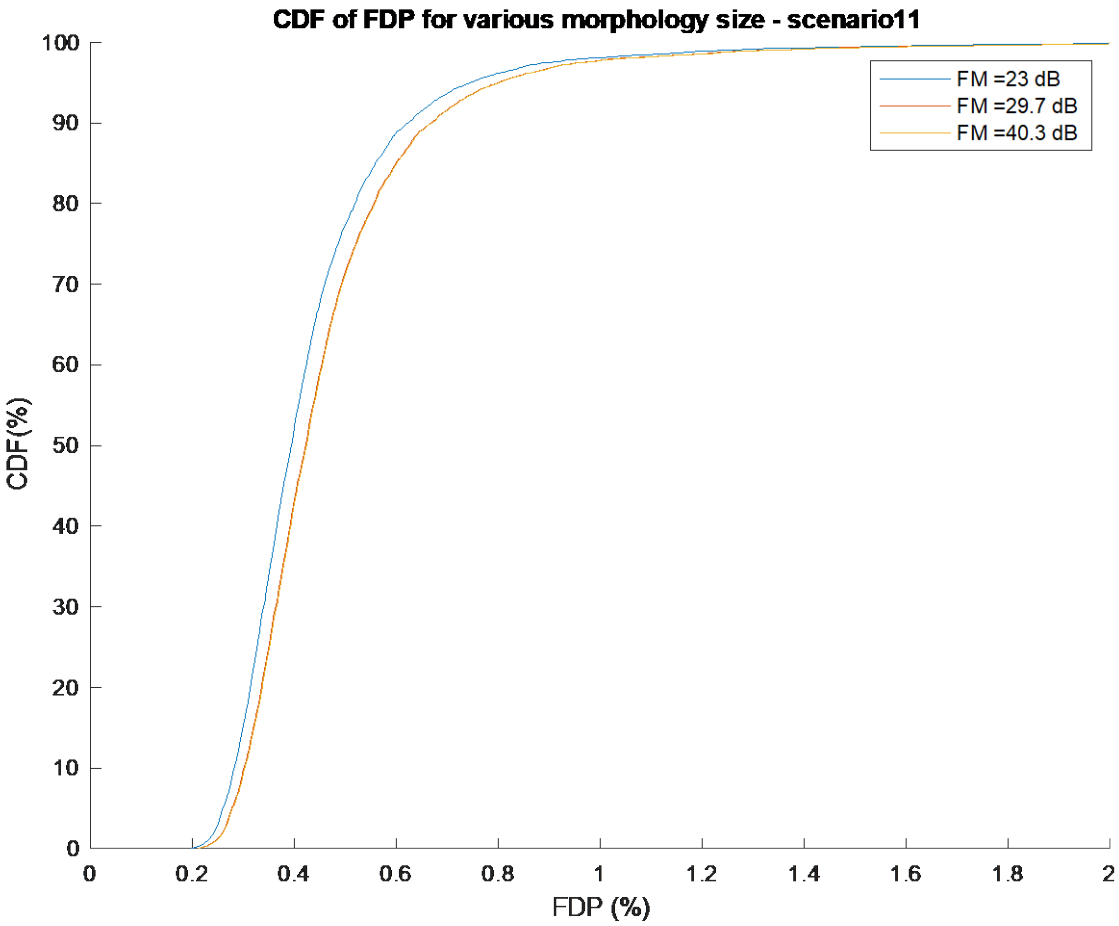


Figure 46: CDF of FDP – DE1 Scenario 11 (high FS antenna height)

Table 67: FDP(%) for DE1 scenario 11 (high FS antenna height- Scenario A) from Monte Carlo analysis

DE 1 Scenario	Antenna gain (dBi)	deployment density	FS height (m) (with corresponding percertiles)	FS median link length (km)	FDP(%) Min FM 5% percentile: 23 dB	FDP(%) FM mode: 29.7 dB	FDP(%) Max FM 95% percentile: 40.3 dB
11 (Scenario A)	45.5	High	79 (90%)	24.48	0.45	0.48	0.48

Figure 47, for DE1 scenario 16 (low FS antenna height), presents the CDF of the FDP(%) and Table 68 summarises the percentage of fixed RLAN morphologies where the FDP does not exceed the 10% FDP criterion.

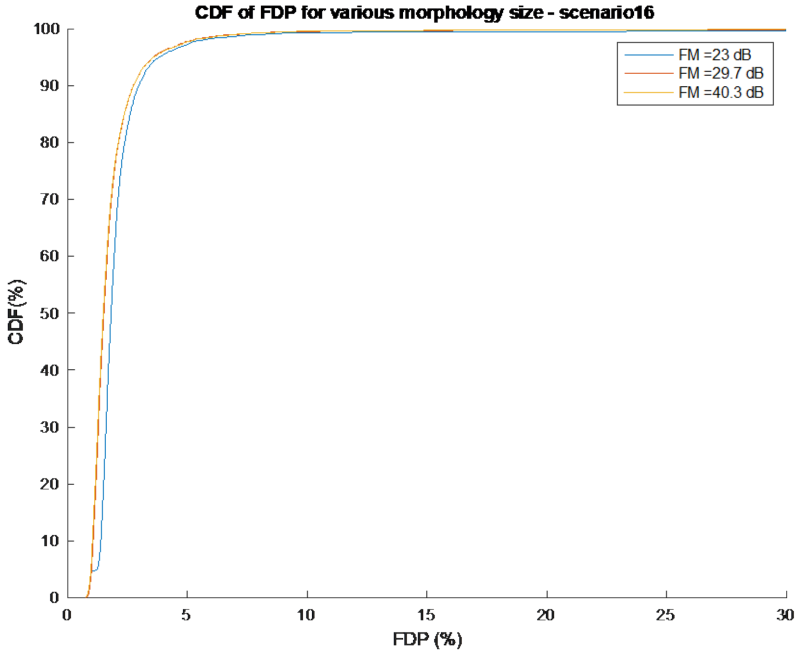


Figure 47: CDF of FDP – DE1 Scenario 16 (low FS antenna height)

DE1 scenario 16 exhibits higher I/N level than DE1 scenario 11. The percentage of fixed RLAN morphologies where the FDP does not exceed the 10% FDP criteria is 99.2% for the minimum of the 5%-ile FM (i.e. 23 dB) and 99.6% for the maximum of the 5%-ile FM (i.e. 40.3 dB). In other words, the results shows that the probability of a FS link being degraded is very low because less than around 0.8% and 0.4% of the fixed RLAN morphologies caused the FDP to exceed 10% for the 5%-ile FM and 95%-ile respectively.

Table 68: Percentage of fixed RLAN morphologies where FDP>10% (DE1 scenario 16)

FM	23 dB	29.7 dB	40.3 dB
Percentile of morphologies below 10%	99.2%	99.5%	99.58%

The median (50%) results for DE1 scenario 16 give an FDP = 1.82% (for FM = 23 dB), FDP = 1.52% (for FM = 29.7 dB) and FDP = 1.49% (for FM = 40.3 dB). These values are lower than for a Monte Carlo approach analysis, as in Table 69, which is because the distribution is not uniform.

As expected, the FDP results are lower for large value of FM.

Table 69: FDP(%) for DE1 scenario 16 (low FS antenna height- Scenario A) from Monte Carlo analysis

DE1 scenario	Antenna gain (dBi)	Deployment density	FS height (m) (with corresponding percentile)	FS median link length (km)	FDP(%) Min FM 5% percentile : 23 dB	FDP (%) FM mode: 29.7 dB	FDP(%) Max FM 95% percentile: 40.3 dB
16 (Scenario A)	45.5	High	30 (10%)	24.48	2.65	2.98	1.88

A2.5 CONCLUSIONS

Site-general joint location/time Monte Carlo simulations have been performed using 10 million events to assess whether the long-criterion and FDP are met when low power WAS/RLAN (LPI) are indoor (with accidental LPI being outdoor) and very low power (VLP) WAS/RLAN are outdoor are both in operation simultaneously.

The studies have considered Frankfurt, which is a large dense German city with surrounding suburban and rural area. The size of the simulation radius[11] is limited by the radio horizon (i.e. 59 km). The studies focused on WAS/RLAN deployment with the highest building height distribution as benchmark, different antenna peak gain (33.6 dBi and 45.5 dBi), different FS antenna heights (i.e. 30 m, 45 and 79 m), and for three different WAS/RLAN density deployment models of Scenario A. SEAMCAT assumes flat terrain surface which does not consider for possible extra losses due to terrain relief. Hence the result provided are conservative.

Results from large number of joint location/time Monte Carlo events show that the long-term protection threshold (-10 dB for less than 20% of the runs) is respected for all the cases even with accidental outdoor LPI. The FDP results are all below 10%. The FDP values obtained for site-general FS link with and without ATPC are all below 10%. In other words, the results show that the probability of a FS link being degraded is very rare.

The joint location/time Monte Carlo simulations carried out used location- and time-based distributions for calculating a percentage of interference. Therefore, results are in terms of location-time percentage and not in terms of time percentage only.

Site-general separated location/time Monte Carlo simulations have investigated DE1 scenario 11 (high FS) and DE1 scenario 16 (low FS) since they have the worst I/N distribution. 5000 different fixed RLAN morphologies representing location-events and 1 million time-events have been considered in this study. These scenarios have been also investigated using the joint location/time Monte Carlo methodology.

The long-term protection criterion of I/N not exceeding -10 dB at 20% of the time is respected.

DE1 scenario 11 with high FS antenna height exhibited much less interference into the FS receiver and the separated location/time Monte Carlo methodology did not detect any exceedance of FDP = 10% which means that there is no risk of degradation from RLAN to the FS link.

DE1 scenario 16 with low FS antenna height exhibits higher interference level. The percentage of fixed RLAN morphologies where the FDP does not exceed the 10% FDP criteria is 99.2% for FM=23 dB, 99.5% for FM=29.7 dB and 99.6% for FM=40.3 dB. In other words, the results shows that the probability of a FS link being degraded is very rare because about less than 0.8% or 0.4% of the fixed RLAN morphology caused the FDP to exceed 10% for the minimum 5%-ile FM and minimum 95%-ile respectively.

The FDP value obtained from joint location/time Monte Carlo and the median value from separated location/time Monte Carlo are similar for all cases.

[11] A large simulation radius, i.e. up to the radio horizon, captures all the aggregated effects from the WAS/RLANs in order to fully account for the long-term interference effect.

ANNEX 3: SHARING WITH THE FIXED SERVICE – SITE-GENERAL STUDY B

This study is similar to analysis of the Frankfurt scenario in Annex 2 but uses an alternative method to assess the potential interference to Fixed Service. Two sets of results are presented with different parametrisation, using different FS antenna patterns and polarisation loss models.

A3.1 SIMULATION PARAMETERS

A3.1.1 RLAN parameters

The RLAN parameters are the same as in section 3, with the following remarks (see Table 70):

Table 70: Parameters for RLAN systems for the frequency range 6425-7125 MHz

Parameter	Value for this study	Remark
RLAN height distribution	Same as in Annex 2 for “Urban” deployment	
Bandwidth overlap factor	23.95%, same as in Annex 2	For 40 MHz FS

A3.1.2 FS parameters

The FS parameters are the same as in section 4, with the following differences and remarks (see Table 71):

Table 71: Parameters for point-to-point FS systems for the frequency range 6425-7125 MHz

Parameter	Value for this study	Remark
Centre frequency (MHz)	6775 (centre of the band)	
Polarisation loss (dB) (Note)	Random polarisation loss	According to ECC Report 302, section 6.3.1 Step 2)
	3	Same as in Annex 2
Antenna peak gain (dBi)	45.5 (max) 33.6 (min)	Same as in Annex 2
Antenna pattern (Note)	Recommendation ITU-R F.699	For single-entry interference
	Recommendation ITU-R F.1245	For aggregate interference
Antenna height (m)	10%: 30 50%: 45 90%: 79	Same as in Annex 2
Receiver noise figure (NF) typical (dB)	5	Same as in Annex 2
Antenna uptilt/downtilt (degrees)	0	Same as in Annex 2
Protection requirement	FDP < 10%	Long-term is not considered
Fade Margin (dB)	5%: 23 50%: 29.7 95%: 40.3	Same as in Annex 2
FS hop lengths (km)	5%: 13 50%: 24.48 95%: 50.78	
Note: The first set of results use Recommendation ITU-R F.699 antenna pattern and random polarisation loss; the second set uses Recommendation ITU-R F.1245 and 3 dB polarisation loss		

The FS link parameters for the purposes of FDP evaluation are as shown in Table 72.

Table 72: FS link parameters for FDP evaluation

Parameter	Value
Longitude (degrees)	9.0283 (centre of Hessen state)
Latitude (degrees)	50.6081 (centre of Hessen state)
Receiver height (m)	30 / 45 / 79
Transmitter height (m)	Same as receiver height
Terrain height (m)	0
Hop distance (km)	13 / 24.48 / 50.78
Fade Margin for non-ATPC links (dB)	23 / 29.7 / 40.3
Net Fade Margin for ATPC links (dB)	10 / 32
ATPC range for ATPC links (dB)	15 / 20

A3.1.3 Scenario and propagation parameters

The scenario is the same as in Annex 2. The simulation radius is limited to 1 km around the FS site. The propagation parameters are shown in Table 73.

Table 73: Propagation models

Horizontal Distance	Propagation Model	For Indoor only (Building Entry Loss)	Clutter
$0\ \text{m} \leq d < 40\ \text{m}$	Free space	Recommendation ITU-R P.2109 [11] (70% traditional, 30% modern, uniform distribution of probability from 1 to 99%)	not applicable
$40\ \text{m} \leq d < 1000\ \text{m}$	WINNER II model (Urban Macrocell C2 or suburban Macrocell C1)	Recommendation ITU-R P.2109 (70% traditional, 30% modern, uniform distribution of probability from 1 to 99%)	LOS and NLOS ratio probability determination is inherent to the WINNER II model

A3.2 SIMULATION DESCRIPTION

The study methodology is as follows:

1. For each Monte Carlo drop, place randomly a single RLAN within 1 km from the FS site using the appropriate RLAN deployment parameters (indoor/outdoor probability, height distribution, *e.i.r.p.* distribution, etc.).
2. Calculate I/N using the propagation parameters, assuming that the RLAN is transmitting at an overlapping frequency with the FS. Hence, the resulting I/N probability distribution function reflects the interference potential resulting from a single RLAN that is overlapping with the FS frequency.
3. Using the FS link parameters (fade margin, availability, ATPC, etc.), calculate the I/N threshold which will exceed 10% FDP for a single RLAN with 1.97% or 2.45% RF activity factor. This can be resolved using the equations in Annex 10 and Annex 11. The probability density function of z (in linear domain) is simply

$z = 10^{\frac{I/N}{10}}$ with a probability of 1.97% or 2.45% (depending on which RF activity factor is used), and zero otherwise.

4. Find from the I/N CDF the probability of exceeding 10% FDP for the given FS link. This is the probability of exceedance, when a single frequency-overlapping RLAN is deployed within 1 km of the FS site in a random location.
5. Use the population density and RLAN density parameters (e.g. market adoption factor, busy hour factor, bandwidth overlap factor, etc.) to determine the number of frequency-overlapping RLANs in the simulation area for each Scenario A and B (low/mid/high) RLAN densities.
6. Calculate the probability of overall 10% FDP exceedance using the number of RLANs according to step 5. This is calculated as $p_N = 1 - (1 - p_1)^N$, where p_1 is the probability according to step 4), and N the total number of frequency-overlapping RLANs according to step 5.

A3.3 SIMULATION RESULTS

A3.3.1 Monte Carlo simulation (step 1)

The purpose of this Monte Carlo simulation is to find out the I/N statistics when a single frequency-overlapping, transmitting RLAN, is randomly deployed within the simulation area (1 km radius around the FS site). The simulation does not take into account the RF activity factor, which is considered later in step 3 of the simulation.

Figure 48 shows the locations of RLANs for a scenario in which the FS height is 45 metres, and the FS antenna gain is 45.5 dBi. Only locations resulting in high I/N in excess of 7 dB are shown. Blue circles are indoor RLANs, and red circles are outdoor RLANs. A total of 10 million locations were simulated, out of which 442 locations exceeded I/N of 7 dB.

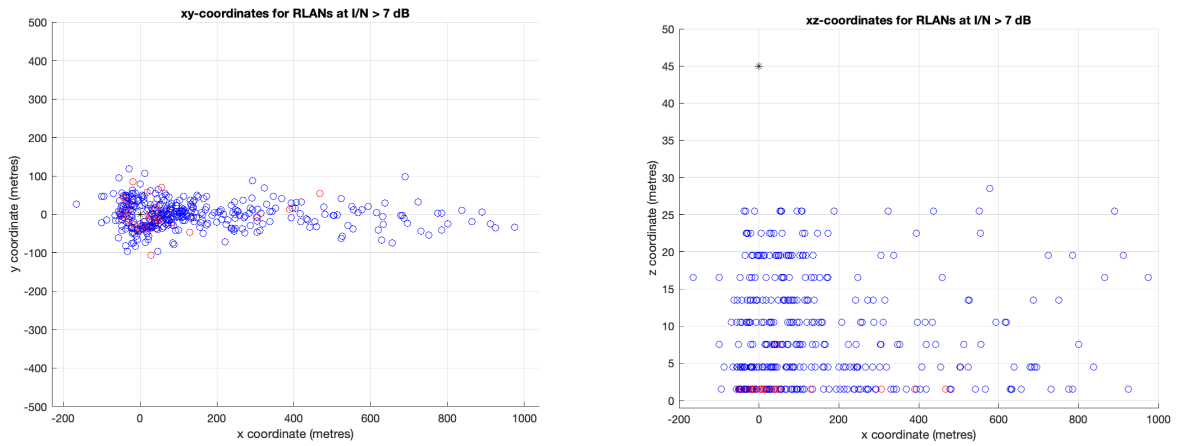


Figure 48: Example RLAN locations for high I/N occurrences (45 m FS antenna height, Recommendation ITU-R F.699 antenna pattern and randomised polarisation loss), *xy* view (left) and *xz* view (right)

A3.3.2 I/N results (step 2)

The following Figure 49 shows the results for all FS heights (30 / 45 / 79 m) and FS antenna gains (36.6 / 45.5 dBi).

Figure 49: I/N resulting from a single RLAN per Monte Carlo drop (left: Recommendation ITU-R F.699 and random polarisation loss; right: Recommendation ITU-R F.1245 and 3 dB polarisation loss)

The results indicate that any RLAN that overlaps with the FS frequency has a non-negligible probability of causing high I/N. This probability is smaller for high FS antennas and high FS antenna gains.

A3.3.3 I/N threshold for Fractional Degradation in Performance > 10% (step 3)

The FDP evaluations require basic FS link parameters for the p_0 (multipath occurrence factor) determination. These were given in Table 72.

As explained in Annex 10, the probability density function of interference z (in linear domain) is $z = 10^{\frac{I/N}{10}}$ with the probability of 1.97% or 2.45% (depending on which RF activity factor is used), and zero otherwise. This makes the calculation of FDP relatively simple.

Three different example links are further evaluated for the non-ATPC case. These examples result in reasonable link availability (>99.995%). The lowest 30 m FS antenna height corresponds to the shortest hop length and lowest fade margin, and the highest 79 m antenna height to the longest hop length and highest fade margin. These are highlighted in Table 74 which also shows the link availability targets and the I/N thresholds for 10% FDP.

Table 74: Link availability and I/N threshold for 10% FDP for single-entry RLAN interferer (assuming 1.97% and 2.45% RF activity factors), for links with no ATPC

FS hop length / antenna height	FM = 23 dB (5%)	FM = 29.7 dB (50%)	FM = 40.3 dB (95%)
13 km (10%) / 30 m	100% – $P_{O,0}$ = 99.998% I/N ≥ 6.7 dB (1.97%) I/N ≥ 5.8 dB (2.45%)	100% – $P_{O,0}$ = 99.999% I/N ≥ 7.3 dB (1.97%) I/N ≥ 6.3 dB (2.45%)	100% – $P_{O,0}$ = 99.9999% I/N ≥ 7.1 dB (1.97%) I/N ≥ 6.1 dB (2.45%)
24.48 km (50%) / 45 m	100% – $P_{O,0}$ = 99.984% I/N ≥ 7.6 dB (1.97%) I/N ≥ 6.7 dB (2.45%)	100% – $P_{O,0}$ = 99.996% I/N ≥ 7.5 dB (1.97%) I/N ≥ 6.5 dB (2.45%)	100% – $P_{O,0}$ = 99.999% I/N ≥ 7.1 dB (1.97%) I/N ≥ 6.1 dB (2.45%)
50.78 km (90%) / 79 m	100% – $P_{O,0}$ = 99.819% I/N ≥ 9.3 dB (1.97%) I/N ≥ 8.1 dB (2.45%)	100% – $P_{O,0}$ = 99.957% I/N ≥ 7.9 dB (1.97%) I/N ≥ 6.8 dB (2.45%)	100% – $P_{O,0}$ = 99.996% I/N ≥ 7.1 dB (1.97%) I/N ≥ 6.1 dB (2.45%)

For ATPC links, no further evaluation is done. For any single-entry RLAN interferer, the 10% FDP condition will be exceeded before the I/N consumes the whole Net Fade Margin, hence the increased outage may be in this specific case calculated using the Fade Margin only (i.e. using the equation for links with no ATPC).

A3.3.4 Probability of exceeding the I/N threshold for single-entry RLAN (step 4)

The I/N thresholds for a single-entry RLAN exceeding the 10% FDP criterion are included in the zoomed-in I/N CCDFs. The corresponding probabilities are shown in Table 75.

Figure 50: Zoom-in of I/N resulting from a single RLAN per Monte Carlo drop, with probabilities of exceeding the I/N thresholds for 10% FDP (left: Recommendation ITU-R F.699 and random polarisation loss; right: Recommendation ITU-R F.1245 and 3 dB polarisation loss)

Table 75: Probability of single RLAN causing exceedance of 10% FDP as a function of RF activity factor

FS antenna height / gain	Recommendation ITU-R F.699, random polarisation loss		Recommendation ITU-R F.1245, 3 dB polarisation loss	
	Scenario A 1.97%	Scenario B 2.45%	Scenario A 1.97%	Scenario B 2.45%
30 m / 36.6 dBi	I/N ≥ 6.7 dB p_1 = 0.037362%	I/N ≥ 5.8 dB p_1 = 0.044399%	I/N ≥ 6.7 dB p_1 = 0.007614%	I/N ≥ 5.8 dB p_1 = 0.009710%
30 m / 45.5 dBi	I/N ≥ 6.7 dB p_1 = 0.011121%	I/N ≥ 5.8 dB p_1 = 0.013702%	I/N ≥ 6.7 dB p_1 = 0.002560%	I/N ≥ 5.8 dB p_1 = 0.003780%
45 m / 36.6 dBi	I/N ≥ 7.5 dB p_1 = 0.018494%	I/N ≥ 6.5 dB p_1 = 0.023790%	I/N ≥ 7.5 dB p_1 = 0.002278%	I/N ≥ 6.5 dB p_1 = 0.002954%
45 m / 45.5 dBi	I/N ≥ 7.5 dB p_1 = 0.003824%	I/N ≥ 6.5 dB p_1 = 0.004971%	I/N ≥ 7.5 dB p_1 = 0.000571%	I/N ≥ 6.5 dB p_1 = 0.000793%
79 m / 36.6 dBi	I/N ≥ 7.1 dB p_1 = 0.006905%	I/N ≥ 6.1 dB p_1 = 0.009563%	I/N ≥ 7.1 dB p_1 = 0.000331%	I/N ≥ 6.1 dB p_1 = 0.000562%
79 m / 45.5 dBi	I/N ≥ 7.1 dB p_1 = 0.001058%	I/N ≥ 6.1 dB p_1 = 0.001489%	I/N ≥ 7.1 dB p_1 = 0.000125%	I/N ≥ 6.1 dB p_1 = 0.000170%

A3.3.5 Number of deployed RLANs (step 5)

Step 4 gave the probability of a single frequency-overlapping RLAN causing interference to FS. To understand the overall interference probability from the overall RLAN deployments, the number of deployed RLANs need to be calculated.

The RLAN deployment model is used for this calculation, as shown in Table 76.

Table 76: Calculation of active frequency-overlapping RLANs

	Scenario A			Scenario B		
	Low	Mid	High	Low	Mid	High
RLAN proxy devices per inhabitant	1	1	1	1	1	1
Licence exempt factor	90%	90%	90%	N/A	N/A	N/A
Busy hour factor	50%	62.7%	62.7%	50%	62.7%	62.7%
Market adoption factor	25%	32%	50%	28%	36%	60%
Upper 6 GHz factor	40.75%	40.75%	40.75%	47.03%	47.03%	47.03%
Bandwidth overlap factor (40 MHz FS)	23.95%	23.95%	23.95%	23.95%	23.95%	23.95%
Active frequency-overlapping RLANs per inhabitant	0.0110	0.0176	0.0275	0.0158	0.0254	0.0424
Population density in Frankfurt area	3058 inhabitants/km^2					
Population within 1 km radius	9607					
Active frequency-overlapping RLANs	105	169	265	151	244	407

A3.3.6 Probability of the overall RLAN deployment exceeding 10% FDP (step 6)

Given the probability of 10% FDP exceedance from a single frequency-overlapping RLAN (p_1), and the total number of frequency-overlapping RLANs (N), the overall 10% FDP exceedance probability can be calculated as $p_N = 1 - (1 - p_1)^N$. This is shown in Table 77 for Recommendation ITU-R F.699 FS antenna pattern and random polarisation loss. For Recommendation ITU-R F.1245 antenna pattern and 3 dB polarisation loss, the results are shown in Table 78.

Table 77: Probability of 10% FDP exceedance due to RLAN deployments (at population density of 3058 inhabitants/km^2) – Recommendation ITU-R F.699 FS antenna pattern and random polarisation loss

	Scenario A			Scenario B		
FS antenna height / antenna gain	Low	Mid	High	Low	Mid	High
30 m / 36.6 dBi	3.85%	6.12%	9.43%	6.49%	10.27%	16.54%
30 m / 45.5 dBi	1.16%	1.86%	2.90%	2.05%	3.29%	5.42%
45 m / 36.6 dBi	1.92%	3.08%	4.78%	3.53%	5.64%	9.23%
45 m / 45.5 dBi	0.40%	0.64%	1.01%	0.75%	1.21%	2.00%
79 m / 36.6 dBi	0.72%	1.16%	1.81%	1.43%	2.31%	3.82%
79 m / 45.5 dBi	0.11%	0.18%	0.28%	0.22%	0.36%	0.60%

Table 78: Probability of 10% FDP exceedance due to RLAN deployments (at population density of 3058 inhabitants/km²) – Recommendation ITU-R F.1245 FS antenna pattern and 3 dB polarisation loss

	Scenario A			Scenario B		
FS antenna height / antenna gain	Low	Mid	High	Low	Mid	High
30 m / 36.6 dBi	0.80%	1.28%	2.00%	1.46%	2.34%	3.88%
30 m / 45.5 dBi	0.27%	0.43%	0.68%	0.57%	0.92%	1.53%
45 m / 36.6 dBi	0.24%	0.38%	0.60%	0.45%	0.72%	1.20%
45 m / 45.5 dBi	0.06%	0.10%	0.15%	0.12%	0.19%	0.32%
79 m / 36.6 dBi	0.03%	0.06%	0.09%	0.08%	0.14%	0.23%
79 m / 45.5 dBi	0.01%	0.02%	0.03%	0.03%	0.04%	0.07%

Using the FS antenna pattern Recommendation ITU-R F.699 and random polarisation loss, the results can be summarised as follows:

- For the low antenna heights, the probability of RLAN deployments causing exceedance of 10% FDP in the Frankfurt area ranges from 1.16% to 16.54% (FM = 23 dB), depending on the RLAN density scenario, and the FS antenna gain;
- For the medium height antennas, the probability ranges from 0.40% to 9.23% (FM = 29.7 dB);
- For the high FS antennas, the probability ranges from 0.11% to 2.77% (FM = 40.3 dB).

Using the FS antenna pattern Recommendation ITU-R F.1245 and 3 dB polarisation loss, the results can be summarised as follows:

- For the low antenna heights, the probability of RLAN deployments causing exceedance of 10% FDP in the Frankfurt area ranges from 0.27% to 3.88% (FM = 23 dB), depending on the RLAN density scenario, and the FS antenna gain;
- For the medium height antennas, the probability ranges from 0.06% to 1.20% (FM = 29.7 dB);
- For the high FS antennas, the probability ranges from 0.01% to 0.23% (FM = 40.3 dB).

There may be potential RLAN interferers beyond the 1 km range within the FS main lobe, which are not considered in this study and could potentially increase the probability of exceedance of 10% FDP.

ANNEX 4: SHARING WITH THE FIXED SERVICE – SITE-GENERAL STUDY C

A4.1 INTRODUCTION

This study uses the separated location/time Monte Carlo method, where the time-dependent and location-dependent random variables are separated and, in each location-iteration, time-dependent random variables are processed to calculate the CDF or PDF of I/N at the FS receiver. Hence, at each location-iteration the protection criterion, long-term and fractional degradational of performance (FDP), are assessed and a statistics of pass and fail values is provided.

This study is site-general where typical FS receiver parameters as depicted in Table 79 have been used. However, geographical position is needed to assess the FDP. Here, the geographical positions of Helsinki, Milan, Barcelona and Paris were selected as it closely represents the population densities used in the simulation.

Sections A4.2 and A4.3 describe the technical parameters used for FS and WAS/RLANs, respectively. Section A4.4 highlights the models employed for simulating signal propagation. Section A4.5 outlines the WAS/RLANs deployment model and simulation methodology. Finally, sections A4.6 and A4.8 present the results and conclusion.

A4.2 TECHNICAL PARAMETERS OF FS

Table 79 provides the FS technical parameters used in this study. More details on the used FS parameters in the simulations can be found in section 4.1.

Table 79: FS technical parameters

Parameter	
Antenna height (m)	30, 40, 79
Centre frequency (MHz)	6775 (centre of the band)
Channel spacing and receiver noise bandwidth (MHz)	40
Feeder/multiplexer loss range (dB)	1.3
Antenna peak gain (dBi)	34 and 46
Antenna pattern	Recommendation ITU-R F.1245 for aggregate interference
Receiver noise figure (NF) typical (dB)	4.5
Receiver noise floor (dBm)	-93.46
Antenna uptilt/downtilt	0 deg
Protection requirement (dB)	Long-term: I/N = −10 dB not exceeded for more than 20% of time FDP <10%
Fade Margin (dB)	Between 24 to 52
ATPC range (dB)	15 and 20

A4.3 TECHNICAL PARAMETERS OF WAS/RLAN

A4.3.1 Indoor/outdoor and *e.i.r.p.* distribution

Table 80 provides the indoor/outdoor and *e.i.r.p.* distributions used in this study.

Table 80: WAS/RLAN indoor/outdoor and *e.i.r.p.* distributions

Device type		Total indoor	Total outdoor	*e.i.r.p.* distribution
LPI Clients	With Body Loss	21.10%	0.21%	200 mW + normalised antenna gain distribution from Table 39
	Without Body Loss	2.37%	0.00%	200 mW + normalised antenna gain distribution from Table 38
VLP	With Body Loss	9.00%	1.00%	25 mW + normalised antenna gain distribution from Table 39
AP (LPI)	Without Body Loss	66.32%	0.00%	200 mW + normalised antenna gain distribution from Table 37
Total		98.79%	1.21%	

The *e.i.r.p.* distribution column in table above presents the PDF for various types of RLAN devices, each of which may have different bandwidths. The distribution of bandwidth used is outlined in Table 81. Considering that the FS receiver analysed in the study operates with a channel bandwidth of 40 MHz, the RLANs *e.i.r.p.* observed at the FS receiver must be adjusted accordingly. The adjustment methodology aligns with the approach used in ECC Report 316 [2].

Table 81: Bandwidth distribution

Channel Bandwidth	20 MHz	40 MHz	80 MHz	160 MHz	320 MHz
WAS/RLAN device percentage	10%	5%	30%	35%	20%

A4.3.2 Antenna heights

Table 82 provides the WAS/RLAN antenna heights used in this study. It should be noted that only the probabilities for urban antenna heights have been taken into consideration.

**Table 82: WAS/RLAN height probabilities
(indoor heights are the average from ECC Report 316 and outdoor height is from ECC Report 302)**

Floor	Height (m)	Urban (%)	Suburban (%)	Rural (%)	Outdoor (%)
ground	1.5	32.25	53.81	71.03	95
1	4.5	23.02	25.93	25.43	2
2	7.5	13.23	7.87	1.66	2
3	10.5	9.78	5.13	1.01	0.5
4	13.5	7.19	3.06	0.52	0
5	16.5	5.11	1.41	0.13	0
6	19.5	3.86	1.09	0.1	0
7	22.5	2.78	0.81	0.07	0
8	25.5	1.83	0.56	0.04	0
9	28.5	0.99	0.34	0.01	0.5

A4.3.2.1 Antenna height condition

To rule out the unrealistic placements of RLANs, a specific condition has been applied to the FS receivers with height of 30 metres or less. Within a 200-metre radius of these FS receivers, only WAS/RLANs with a height of less than or equal to 13.5 m have been placed.

A4.4 SIGNAL PROPAGATION AND ATTENUATION FACTORS

A4.4.1 Propagation models

Table 83 specifies the propagation models and details the corresponding application conditions.

Table 83: Propagation models

Scenario	Propagation Model for RLANs in Urban/Suburban
Distance < 40 m	Free Space Path Loss (FSPL)
40 m ≤ Distance < 1 km	WINNER II LOS/NLOS For WAS/RLAN in Urban, C2 WINNER II is used.
Distance ≥ 1 km	Recommendation ITU-R P.452-17 (0.001 ≤ p ≤ 50, p=time percentage) + P.2108-1 Clutter Loss (1< p <100, p = percentage of locations)

A4.4.2 Building entry loss

The majority of assumed RLANs are located indoor, where the signal from such devices is naturally attenuated by building materials. Therefore, a building entry loss based on Recommendation ITU-R P.2109, using a split ratio of 30:70 for thermally efficient to traditional buildings, have been used.

A4.4.3 Polarisation mismatch

A random polarisation mismatch based on ECC Report 302 has been used.

A4.5 RLAN DEPLOYMENT MODEL AND SIMULATION METHODOLOGY

A4.5.1 RLAN deployment model

This study was performed based on an FS receiver at the centre of a circle of radius 5 km and randomly deploying RLANs around the FS receiver. The deployment of RLANs followed the joint Location/Time Monte Carlo method. The density of RLANs within the circular area has been chosen according to the population densities of major cities in CEPT countries. Therefore, population densities of 3000, 6000, 12000 and 18000 inhabitants per square km have been selected to represent different cities [20]. Specifically, Helsinki, Milan[12], Barcelona and Paris were selected due to their approximate similar population densities in the order mentioned above. Figure 51 shows an example of simulation area with an FS receiver at the centre, and WAS/RLAN devices randomly deployed, with some actively transmitting.

While this study is site-general, a geographical position is needed to assess the FDP. Here, the geographical positions of the cities of Helsinki (Longitude: 24.9354°, Latitude: 60.1695°), Milan (Longitude: 9.18951°, Latitude: 45.46427°), Barcelona (Longitude: 2.2167°, Latitude: 41.3173°) and Paris (Longitude: 2.3522°, Latitude: 48.8566°) were selected as they match the population density used in the simulation. It is worth mentioning that no real links were used and/or there was no information available to confirm if any real FS links similar to the ones studied are deployed in those cities. Section 4.1.2 gives more information about FS deployment in CEPT.

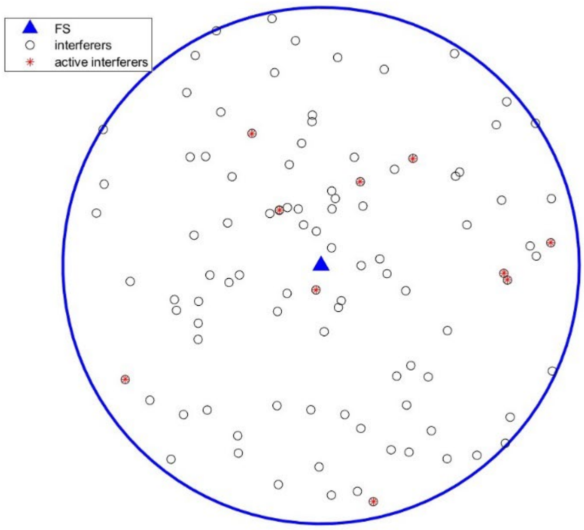


Figure 51: Example of Location/Time Monte Carlo topology

To calculate the total number of WAS/RLAN devices (and active WAS/RLAN devices) within a radius of 5 km, Scenario B was selected. The simulations have been performed for the High values of the Scenario B. Table 6 depicts the RLAN deployment model for the population densities of 3000, 6000, 12000, and 18000 inhabitants per square km in a 5 km circular area.

[12] Although Milan has a population density of 7500 inhabitants per square km, a conservative value of 6000 inhabitants per square km was considered in the analysis.

Table 84: WAS/RLAN deployment model

	Scenario B			
Population density (inhabitants/sq. km)	3000	6000	12000	18000
Simulation area (km)	5			
Population in 5 km circular area	235620	471240	942480	1413700
Wireless devices operating in licence exempt spectrum	100%			
Upper 6 GHz factor	47.03%			
Market Adoption factor (6 GHz capable devices)	28% | 36% | 60%			
Busy Hour factor	50% | 62.7% | 62.7%			
Upper 6 GHz WAS/RLAN devices within the radius of 5 km	15514 | 25012 |41687	31027 | 50025 | 83375	62055 | 100050 | 166750	93082 | 150070 | 250120

Table 84 provided the total number of WAS/RLANs operating in the entire upper 6 GHz. Since the FS link under consideration has a channel bandwidth of 40 MHz with the centre frequency 6.775 GHz by applying a bandwidth overlap factor of 23.95%, the total number of WAS/RLAN overlapping the FS channel bandwidth are derived. By further applying the RF activity factor of 2.45%, the total number of active RLANs are calculated. These are shown in Table 85.

Table 85: WAS/RLAN devices overlapping FS bandwidth of 40 MHz

Upper 6 GHz WAS/RLAN devices within the radius of 5 km	15514 | 25012|41687	31027 | 50025 | 83375	62055 | 100050 | 166750	93082 | 150070 | 250120
BW overlap factor	23.95%			
Upper 6 GHz WAS/RLAN devices within the radius of 5 km overlapping FS	3715 | 5990 | 9984	7431 | 11981 | 19968	14862 | 23962 | 39937	22293 | 35942 | 59904
RF activity factor	2.45%			
Upper 6 GHz simultaneously active WAS/RLAN devices overlapping FS	91 | 147 | 245	182 | 294 | 489	364 | 587 | 978	546 | 881 | 1468

The total number of WAS/RLANs and the active WAS/RLANs as shown in the above table have been used in the simulations.

A4.5.2 Simulation methodology

In the previous sections the FS parameters and RLAN parameters were defined and the number of WAS/RLANs overlapping the FS bandwidth of 40 MHz was calculated. This section explains how all of these variables have been used in the simulations to calculate the I/N for different location topologies.

Overview of simulation flow:

The simulation flow used in the study is outlined as follows:

1 FS link characterisation

Define an FS link with the technical characteristics from Table 82. The position of the FS receiver is set to (0,0).

2 RLAN characterisation

Define RLAN devices according to their types, set technical characteristics to the device types.

3 Initiate the location loop

3.1. Initiate all the location-dependent variables

As per the simulation radius, calculate the total number of RLANs overlapping FS bandwidth. Starting from 20 m distance from the FS receiver, randomly deploy RLANs. For each of the dropped RLAN, calculate FS antenna gain, propagation loss depending upon the distance from FS receiver (WINNER II assuming only location variability, Recommendation ITU-R P.452 is a function of time), clutter-loss, BEL and polarisation loss.

3.2. Initiate time loop

3.2.1. Initiate all the time dependent variables

3.2.2. Out of all the deployed RLANs in step 3.1., randomly activate the RLANs according to the RF activity factor. Calculate the propagation loss (Recommendation ITU-R P.452), if applicable

3.3. End time loop

3.4. Collect the I/N values obtained over the time loop.

3.5. Assess the protection criteria based on the obtained I/N statistics which corresponds for the current location iteration.

3.5.1. Form the CDF/PDF of the I/N values obtained and verify against the long-term protection criterion

3.5.2. Calculate the FDP value (The outage due to fading at the FS receiver is computed using Recommendation ITU-R P.530.

4 End location loop.

5 Gather statistics of how many of the location iterations have passed/failed the protection criteria from all the tested location iterations.

To obtain sufficient statistical accuracy, 3000 location iterations were performed, with 100000 time-iterations conducted for each location iteration. Section A4.7 provides the statistical rationale behind this choice.

It is to be noted that all the WAS/RLAN devices considered in the study have been assumed to be stationary. This assumption is straight forward for the access points and parts of the clients such TVs, gaming consoles, wireless speakers, virtual assistants, etc., since they are always stationary. On the other hand, mobile clients would connect to the same access points from within the same vicinity around the access point. Therefore, it is reasonable to assume this limited mobility is perceived as stationary at the FS Rx.

A4.6 RESULTS

The results were expressed in terms of percentage of location morphologies exceeding the protection criteria, defined later on as exceedance rate.

Each spatial iteration was validated against the long-term protection criterion of I/N=-10 dB (not exceeded for more than 20% of time) and the fractional degradation in performance (FDP) (not exceeding 10%). The calculation for the results of long-term protection criterion is straightforward: each I/N vector derived from the spatial iteration was compared against the criterion. If the 20% of the I/N vector values were less than -10 dB, then result is a pass, otherwise, it is a fail. Figure 52 shows the I/N vectors plot from the 3000 location iterations for the case with population density=18000, FS gain = 34 dBi and FS height = 30 m.

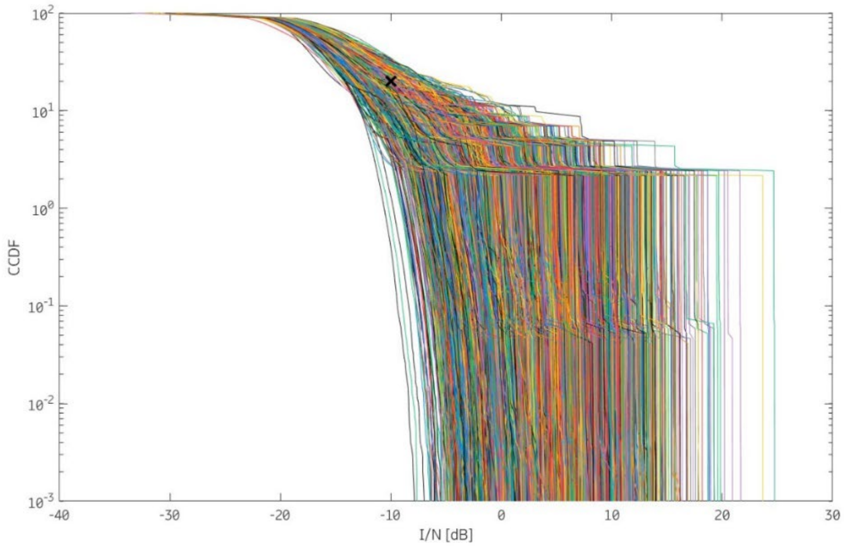


Figure 52: CCDF (%) plot of I/N values derived from 3000 location-iterations, case: population density = 18000, FS height = 30 m, FS gain = 34 dBi

For the FDP, I/N vectors have been further processed. The methodology and other technical characteristics to estimate the FDP are explained Annex 10 and Annex 11. Both, FDP calculations with automatic transmit power control (ATPC) and without ATPC have been explained.

The simulations were performed for the four sets of cases each for the population densities of 3000, 6000, 12000 and 18000. These cases are as follows:

- FS gain: 34 dBi, FS height: 30 m;
- FS gain: 46 dBi, FS height: 30 m;
- FS gain: 46 dBi, FS height: 40 m;
- FS gain: 46 dBi, FS height: 79 m.

Three types of typical link lengths were considered based on the FS heights. A short-haul link of length 20 km was chosen for an FS height of 30 m, while medium and long-haul links of length 32 km and 50 km were chosen for FS heights of 40 m and 79 m, respectively. Table 86 shows the coordinates, link lengths, fade margin for the chosen cases.

Table 86: Characteristics of the links chosen in the study

Population density (inhabitants per km^2), City name	Latitude, Longitude	FS Gain (dB)	FS Height (m)	Link Length (km)	Fade Margin (dB)
3000, Helsinki	60.1695, 24.9354	34	30	20	32
		46	30	20	32
		46	40	32	40
		46	79	50	48
6000, Milan	45.46427, 9.18951	34	30	20	32.4
		46	30	20	32.4
		46	40	32	41.2
		46	79	50	45
12000, Barcelona	41.3173, 2.2167	34	30	20	35
		46	30	20	35
		46	40	32	43
		46	79	50	51
18000, Paris	48.8566, 2.3522	34	30	20	30
		46	30	20	30
		46	40	32	37
		46	79	50	45

Note that for the shortest link of 20 km, 2 antennas values were chosen, 34 dBi and 46 dBi, as a sensitivity analysis. In order to have the possibility to make a one-to-one comparison, all other parameters were left the same, including the link length and fade margin, although the system gain increases by at least 12 dB with the 46 dBi antennas. However, it could be assumed that the FS link with the 46 dBi antenna and higher system gain is operating at a higher capacity, i.e. higher modulation format requiring a higher signal-to-noise ratio, therefore the fade margin remains the same even at the same link length.

Table 87 shows the combined results for both the interference criteria, long-term and FDP without ATPC. Further analysis assessing the effect of ATPC (using 15 dB and 20 dB) showed no difference between the cases with and without ATPC for the links under consideration.

Table 87: Long-term protection criterion and FDP results

Link	Radius (km)	Population Density (inhabitants per square kilometre)	FS Gain (dBi)	FS Height (m)	Link Length (km)	Exceedance rate for Long-Term Protection Criterion	Exceedance rate for FDP
1,1	5	3000	34	30	20	0%	3.5%
1,2	5	3000	46	30	20	0%	1.5%
1,3	5	3000	46	40	32	0%	0.6%
1,4	5	3000	46	79	50	0%	0%

Link	Radius (km)	Population Density (inhabitants per square kilometre)	FS Gain (dBi)	FS Height (m)	Link Length (km)	Exceedance rate for Long-Term Protection Criterion	Exceedance rate for FDP
2,1	5	6000	34	30	20	0%	7.17%
2,2	5	6000	46	30	20	0%	7.17%
2,3	5	6000	46	40	32	0%	1.63%
2,4	5	6000	46	79	50	0%	0.3%
3,1	5	12000	34	30	20	1.53%	18.47%
3,2	5	12000	46	30	20	2.67%	10.5%
3,3	5	12000	46	40	32	0.3%	4.3%
3,4	5	12000	46	79	50	0%	0.2%
4,1	5	18000	34	30	20	23.57%	34.80%
4,2	5	18000	46	30	20	30.63%	21.97%
4,3	5	18000	46	40	32	5%	11.17%
4,4	5	18000	46	79	50	0%	0.93%

The CDF-plots for the four sets of cases with population densities of 6000 and 18000 inhabitants per square km are shown in Figure 53 and Figure 54. The figures indicate that the FDP exceedance increases with the population density, as the number of interferers rises. Additionally, in the areas with higher population density, even the 79 metres FS links are susceptible to interference.

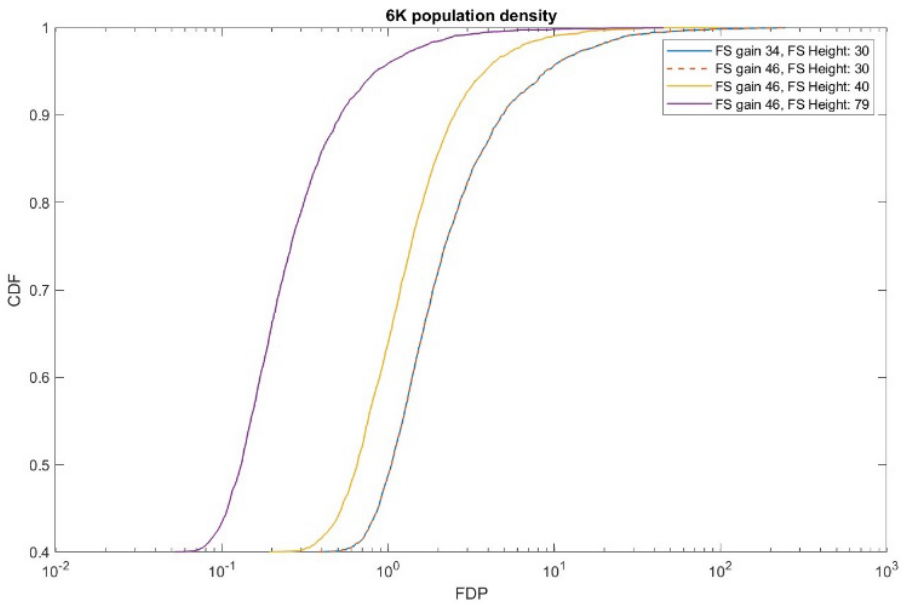


Figure 53: CDF plot for the FDP (%) without ATPC for a population density of 6000 inhabitants per square km

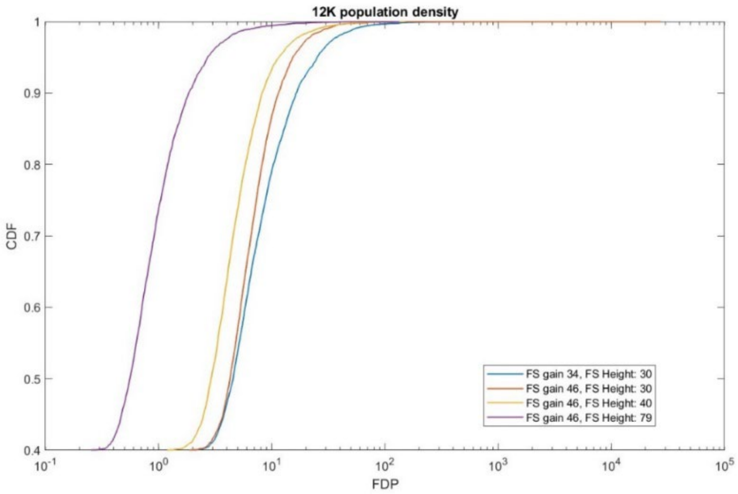


Figure 54: CDF plot for the FDP (%) without ATPC for a population density of 18000 inhabitants per square km

A4.7 STATISTICAL VALIDATION OF NUMBER OF ITERATIONS

To validate the required number of time-iterations and space-iterations for the study, a statistical analysis was conducted. Initially, the length of I/N vector, representing the number of time iterations for a given number of space-iterations, was varied. Variable checkpoints were set at 100, 1000, 10000, 100000 and 1000000, and the FDP values derived from the I/N vector at these checkpoints were examined. The analysis revealed that the FDP values start converging around 100000 iterations. Therefore, a number of 100000 time-iterations was chosen.

Figure 55 shows the convergence of FDP values at 100000 time-iterations.

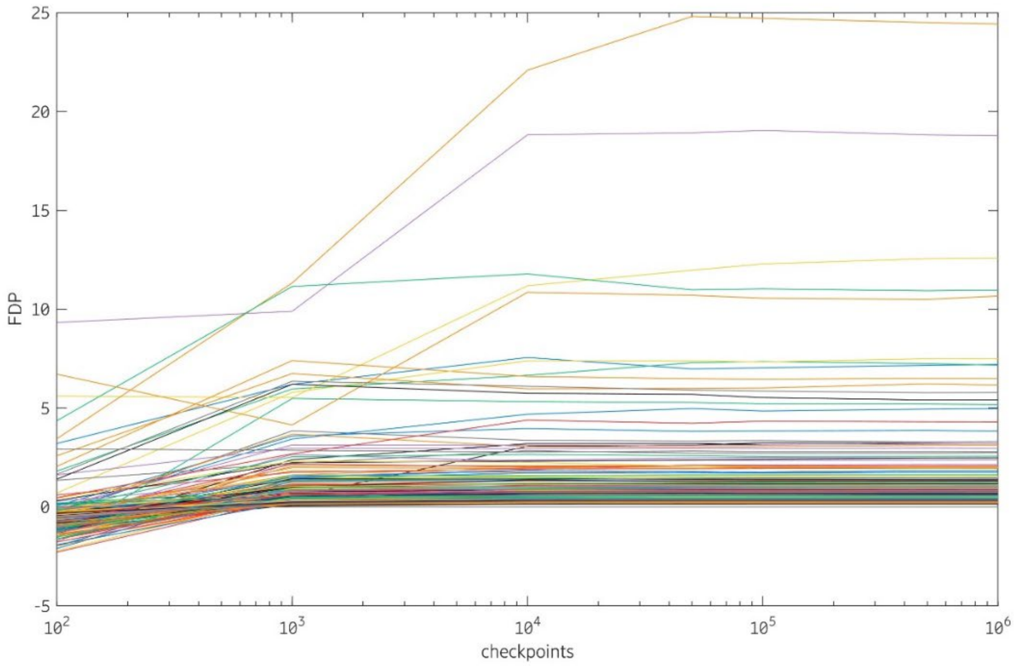


Figure 55: FDP values (in %) for the varying checkpoints of time-iterations for population density=3000 inhabitants per square km

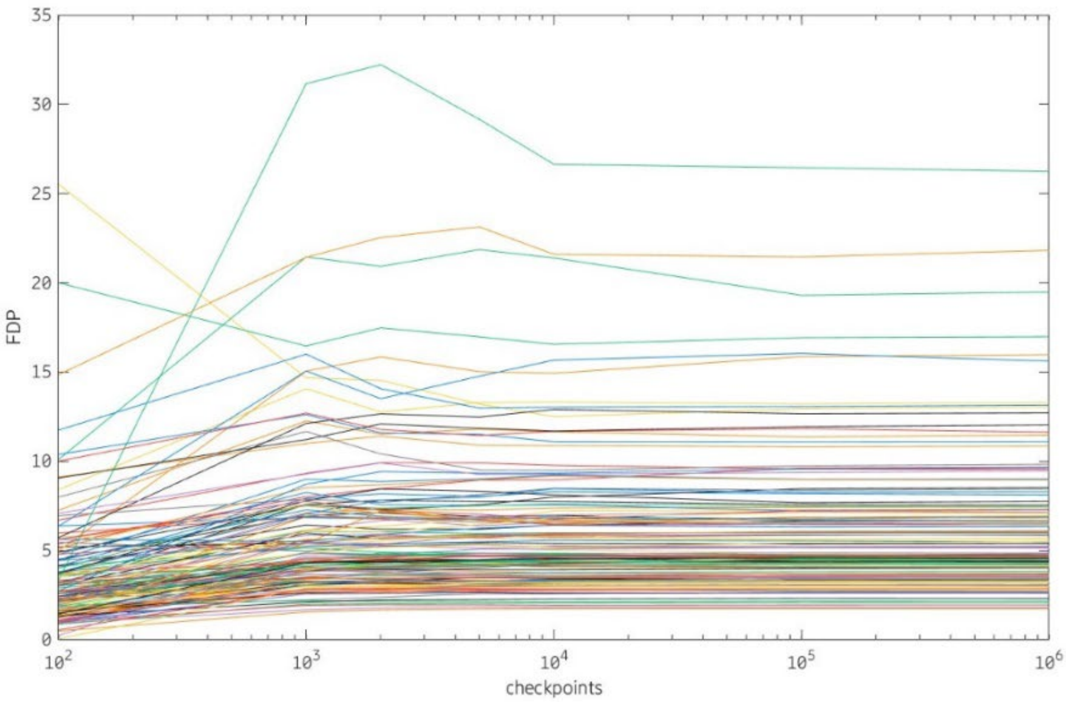


Figure 56: FDP values (in %) for the varying checkpoints of time-iterations for population density=18000 inhabitants per square km

A similar approach was adopted for the location iterations as well. Checkpoints were set at 500, 1500, 2500 and 3000 location iterations. It can be seen that beyond 500 iterations the CDF curve starts converging. Thus, 3000 location iterations were set to have statistical stability.

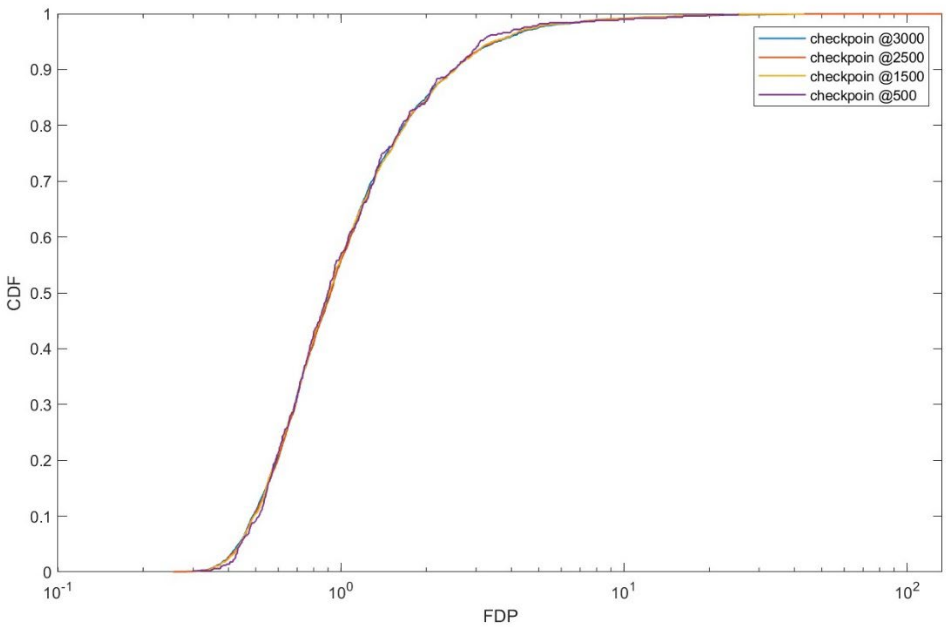


Figure 57: CDF plot the FDP (%) for the varying checkpoints of location iterations

A4.8 CONCLUSION

This study utilises the separated location/time Monte Carlo method to assess the long-term protection criterion and FDP at the FS receiver resulting from the deployment of WAS/RLAN devices in a circular area with a radius of 5 km. The number of interfering WAS/RLAN devices around an FS receiver were derived using High parametric values from Scenario B. Four different population densities of 3000, 6000, 12000, 18000 inhabitants per square km were used. Three different FS antenna heights were considered, 30 m, 40 m, and 79 m, coupled with three link lengths 20 km, 32 km, and 50 km, respectively. An FS antenna sensitivity analysis was done by comparing results for 34 dBi and 46 dBi antennas for the shortest link of 20 km. The medium and long link were studied with 46 dBi antennas. The study includes results with and without ATPC.

The results show that higher population densities result in a higher exceedance rate of the two protection criteria. The exceedance rate for the long-term protection criterion ranges from 0% to 30.63% and for the FDP ranges from 0% to 34.80% (for a range of FM values between 30 dB and 51 dB). Under the considered combinations of the different parameters, it can be further recognised that for FS receivers with lower antenna gains (hence higher sidelobes) and/or lower antenna heights, the exceedance rate is more likely to be increased. The exceedance rates for the studied FS links utilising ATPC are similar to the ones without ATPC.

ANNEX 5: SHARING WITH THE FIXED SERVICE – SITE-GENERAL STUDY D

This study uses a Monte Carlo approach to analyse the interference caused by WAS/RLAN systems operating in the 6425-7125 MHz frequency range on the Fixed Service (FS).

The scenario considers a deployment where the FS receiver is located in the centre of a city with a high density of population (about 5400 inhabitants/km^2) distributed in a large area (about 600 km^2).

A customised simulator based on the source code of SEAMCAT was used to assess the WAS/RLAN impact on both the long-term and the fractional degradation in performance (FDP) protection criteria of FS links.

A5.1 FS PARAMETERS

Since this is a site-general study, the generic FS characteristics from Table 8 have been considered where the effect of the antenna peak gain, antenna height, and fade margin were investigated based on the values in Table 88.

Table 88: FS technical parameters

Parameter	Value
Modulation	64-QAM
Centre frequency (MHz)	6775 (centre of the band)
Channel spacing and receiver noise bandwidth (MHz)	40
Feeder/multiplexer loss range (dB)	1.3
Antenna peak gain (dBi)	34, 40, 46
Antenna pattern	Recommendation ITU-R F.1245 for aggregate interference
Antenna height (m)	40, 75
Receiver noise figure (NF) typical (dB)	4.5
Receiver noise floor (dBm)	-93
Fade margin (FM) (dB)	from 13 to 45
ATPC	None
Protection requirement	Long-term: I/N = −10 dB not exceeded for more than 20% of time (Recommendation ITU-R F.758, Table 4) Fractional Degradation in Performance (FDP) not exceeding 10%.

A5.2 WAS/RLAN PARAMETERS

Both Low Power Indoor (LPI) and Very Low Power (VLP) WAS/RLAN are considered, with a maximum *e.i.r.p.* of 23 dBm and 14 dBm, respectively.

LPI devices are a mixed of WAS/RLAN access points (APs) and clients. For LPI clients, body loss may or may not be considered, whereas for VLP devices, body loss is always applied.

The *e.i.r.p.* distributions of indoor and outdoor WAS/RLAN devices are given in Table 41 of Annex 1.The WAS/RLAN bandwidth distribution is given in Table 4. Since, the instantaneously transmitting WAS/RLANs have varying bandwidths, the *e.i.r.p.* seen by an FS receiver with a fixed bandwidth of 40 MHz would need to be adjusted consequently. The following reduction factor is added to the transmitted *e.i.r.p.* based on the previous bandwidth distribution and FS receiver bandwidth.

Table 89: *e.i.r.p.* reduction factor for WAS/RLAN overlapping a 40 MHz FS in upper 6 GHz

WAS/RLAN Bandwidth (MHz)	Reduction Factor (dB) vs a 40 MHz FS link	Distribution
20	0	10%
40	0	5%
80	3.01	30%
160	6.021	35%
320	9.031	20%

In the customised simulator, this *e.i.r.p.* reduction factor is added as a distribution in the transmitter tab for the WAS/RLAN system according to the previous weights.

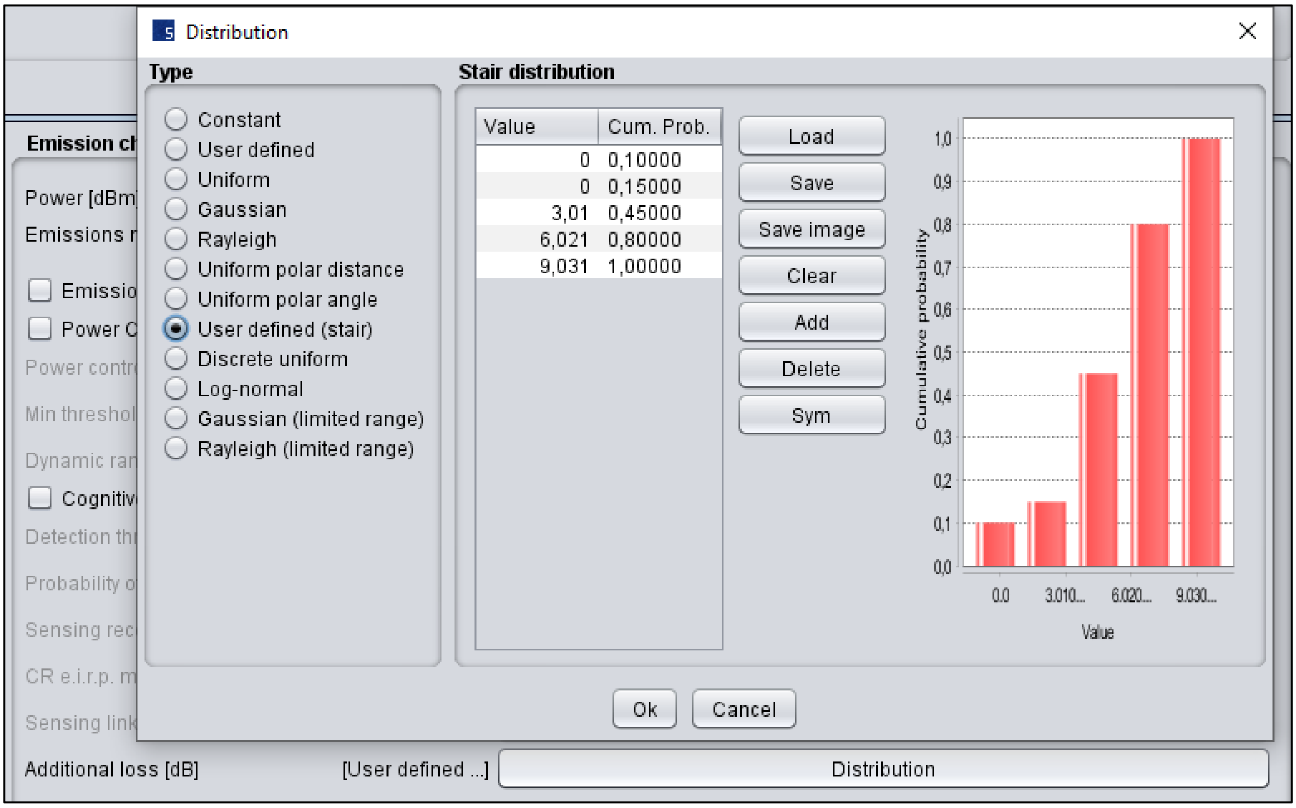


Figure 58: Bandwidth reduction factor implementation

For WAS/RLAN antenna height, the averaged distributions given in Table 3 have been considered.

A5.3 METHODOLOGY

A Monte Carlo approach is used in this study to assess the impact of WAS/RLAN deployment in the 6425-7125 MHz band toward an FS link. A customised simulator based on the source code of SEAMCAT was used.

Based on the scenario, a given number of WAS/RLANs is dropped indoor and outdoor. The I/N statistics at the FS receiver link are gathered to assess both the long-term protection criterion (I/N = −10 dB not exceeded for more than 20% of time) and the fractional degradation in performance criterion (FDP below 10%).

A5.3.1 Propagation model

For this study, the following propagation model was considered for the interfering link between a WAS/RLAN transmitter and an FS receiver.

Table 90: Propagation model for WAS/RLAN (incl. clutter loss) for urban scenario

Distance	Propagation Model
Distance < 40 m	Free Space Path Loss (FSPL)
40 m ≤ Distance < 1 km	WINNER II C2 LOS/NLOS
Distance ≥ 1 km	Recommendation ITU-R P.452-17 + Recommendation ITU-R P.2108 Clutter loss

A5.3.2 Clutter loss

Recommendation ITU-R P.2108 clutter loss is added to all WAS/RLANs deployed 1 km away from the FS receiver link in the urban environment.

SEAMCAT v5.5.0 source code was modified to allow Recommendation ITU-R P.2108 clutter loss to be combined with building entry loss for WAS/RLAN transmitters located indoor[13].

A5.3.3 Building entry loss

Building entry loss from Recommendation ITU-R P.2109 has been used for WAS/RLANs located indoors (70% traditional, 30% modern, uniform distribution of probability from 1% to 99%).

A5.3.4 Fresnel exclusion zone

It is common practice for FS link deployment to avoid any obstacles in the first (n = 1) Fresnel zone. As such, it makes sense to avoid dropping WAS/RLAN devices in this area (or exclusion zone) during a Monte Carlo simulation. SEAMCAT v5.5.0 source code was modified to be able to consider the n^{th} Fresnel zone and avoid dropping RLAN in it.

A 3D-ellipsoid (semi-axis length a, b, b) was used to model the n^{th} Fresnel zone between the FS transmitter and the FS receiver. The 3D-position of any WAS/RLAN device is re-drawn until it is outside the Fresnel zone. A fixed height offset (h_{offset}) is added to the WAS/RLAN height to capture the ceiling of the room where an WAS/RLAN device would be dropped since this ceiling should of course not lie in the Fresnel zone.

[13] Note that the latest SEAMCAT version under development at the time of this study, namely SEAMCAT v5.5.1-Alpha3, allows the clutter loss to be used for a system independently of its indoor/outdoor status.

Figure 59 depicts the Fresnel exclusion zone implementation.

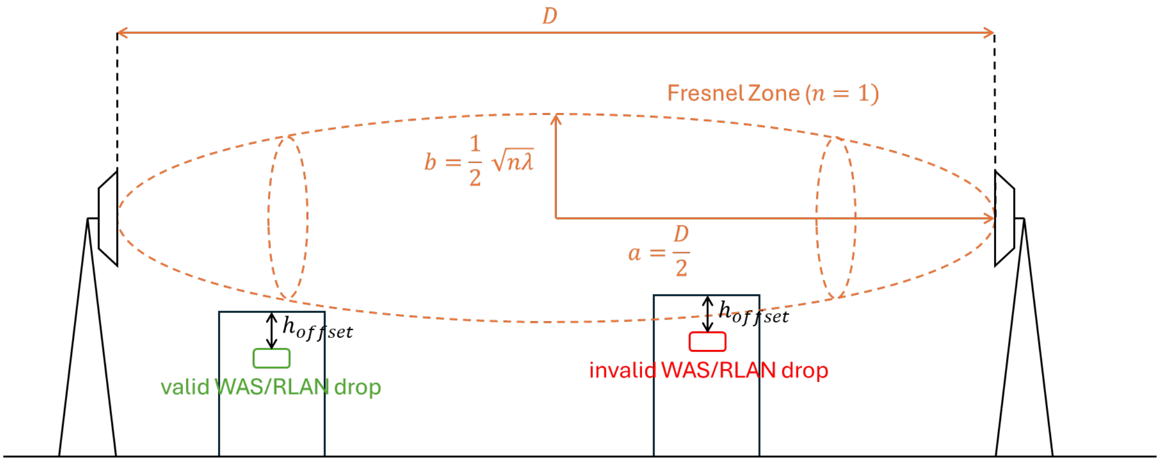


Figure 59: Fresnel exclusion zone definition

Figure 60 shows the drop of 10000 interferers around an FS link of 20 km of length for various Fresnel exclusion zone configurations (*n* = 1 and 5000 and 30000) as a simple sanity check ((x, y) view, the Fresnel zone is modelled in (x, y, z) 3D-space). The values *n* = 5000 and 30000 are non-realistic values but are used to make the Fresnel zones visible in the figures.

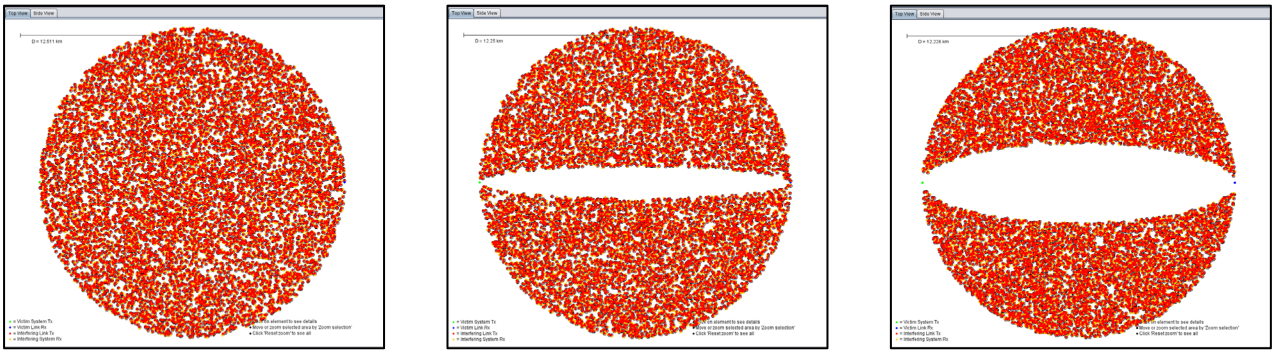


Figure 60: Sanity check of the Fresnel exclusion zone implementation for a 20 km FS link operating at 6775 MHz for *n* = 1, 5000, 30000 leading to *b* = 14.87 m (Fresnel zone not visible), 1.05 km, 2.57 km, respectively

For this study, the first Fresnel zone (*n* = 1) and a height offset (h_{offset}) of 1.5 m have been considered.

A5.4 SIMULATION RESULTS

A5.4.1 FS and WAS/RLAN deployment model

A population density of about 5400 inhabitants/km^2 was considered, dropped uniformly inside a circular area of 13.89 km radius modelling a dense city centre and leading to about 3.3 million inhabitants living in this area (around 606 km^2). Such density is among one of the highest in the CEPT countries. An FS link of 20 km was considered with its receiver located in the centre of this WAS/RLAN circular drop zone as shown in Figure 61.

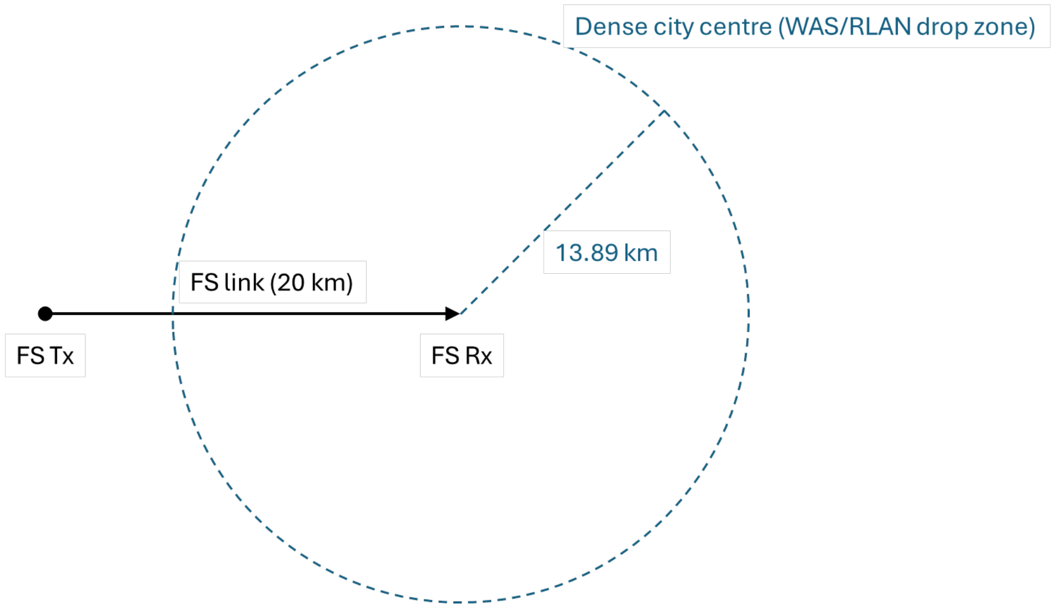


Figure 61: Dense city model area (WAS/RLAN drop zone)

Due to the high population density selected, only the urban environment was assumed for the propagation model.

Table 91 gives the total number of instantaneously transmitting (indoor and outdoor) WAS/RLAN devices assuming the Scenario A parameters considering the “High” assumptions in terms of market adoption.

Table 91: RLAN deployment model based on Scenario A (High)

Parameters	Urban Area
Simulation radius (km)	13.89
Total population	3277451
Market Adoption factor (6 GHz capable devices)	50.00%
Busy Hour factor	62.70%
Wireless devices operating in licence exempt spectrum	90.00%
Upper 6 GHz factor	40.75%
Number of Upper 6 GHz transmissions	376828.62
RF Activity factor	1.97%
Bandwidth overlapping factor	23.95%
Number of instantaneously transmitting WAS/RLANs	1779
Number of instantaneously transmitting WAS/RLANs indoor	**1757**
Number of instantaneously transmitting WAS/RLANs outdoor	**22**

No WAS/RLANs were dropped within a 20-metre radius from the FS receiver which represent a reasonable assumption. Figure 62 shows the result of 10 cumulative drops of (1757 + 22) WAS/RLANs in the Monte Carlo simulator.

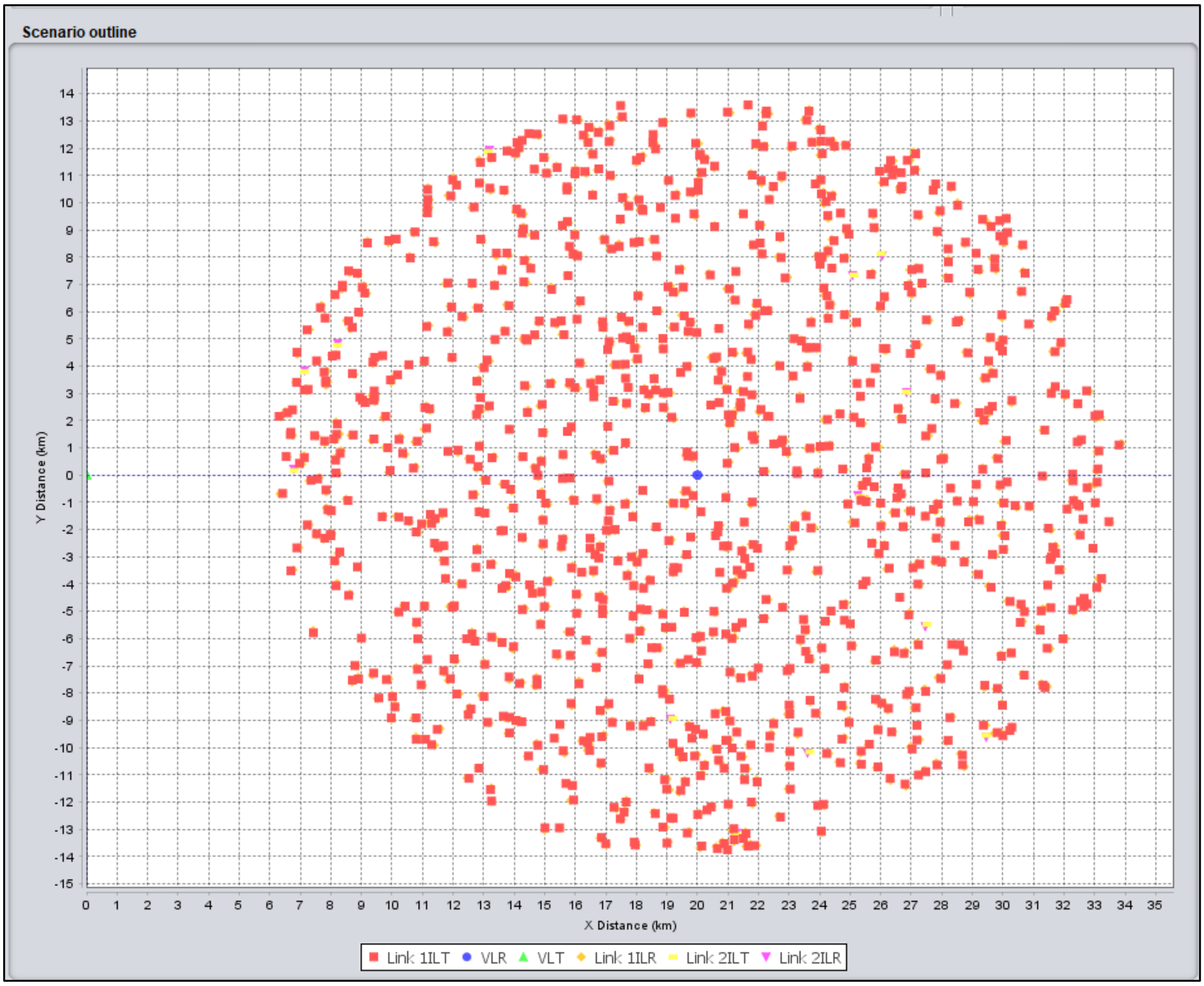


Figure 62: WAS/RLAN (cumulative) drop example (10 events)

As this site-general study does not consider real FS link, several FS parameters were investigated to assess the interference of a WAS/RLAN deployment. For each parameter investigated, I/N statistics were collected using 5 million events from the Monte Carlo simulations.

A5.4.2 Effect of the FS antenna gain

To assess the effect of the FS antenna gain in such deployment scenario, three different peak values were selected for the FS antenna gain: 34, 40 and 46 dBi.

No polarisation mismatch was assumed between the WAS/RLAN transmitter antenna and the FS receiver antenna.

Figure 63 shows the complementary cumulative distribution function (CCDF) of the I/N at the FS receiver for various peak antenna gains. All curves are below the long-term protection criterion (I/N not exceeding -10 dB for more than 20% of the time).

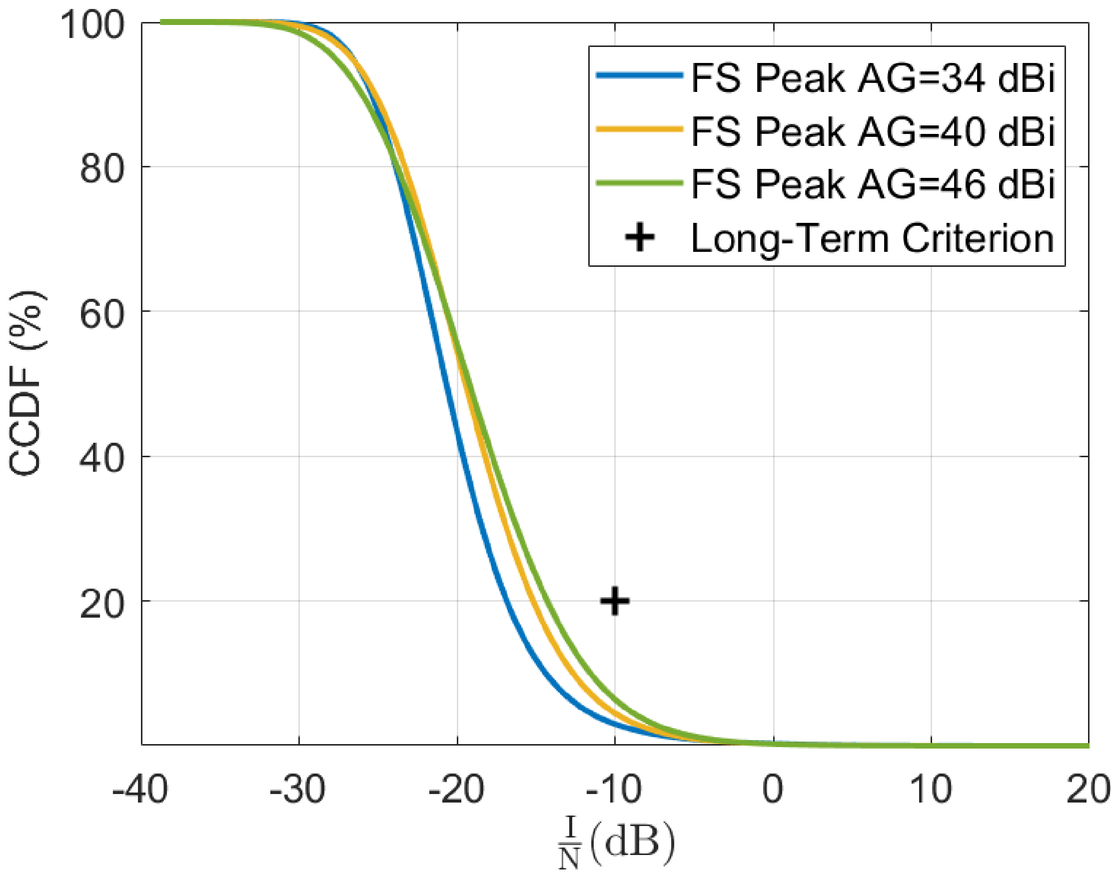


Figure 63: CCDF of I/N for different FS receiver antenna gains (no polarisation mismatch)

While this study is site-general, a geographical position is needed to assess the FDP. Here, the geographical position of the city of Madrid (Longitude: -3.70261°, Latitude: 40.4165°) was selected as it matches the population density used in the simulation. It is worth mentioning that no real links were used and/or there was no information available to confirm if any real FS links similar to the ones studied are deployed in this city. Section 4.1.2 gives more information about FS deployment in CEPT.

Without the knowledge of a real FS link characteristics, the FDP for various Fade Margin (FM) was assessed as shown in Figure 64.

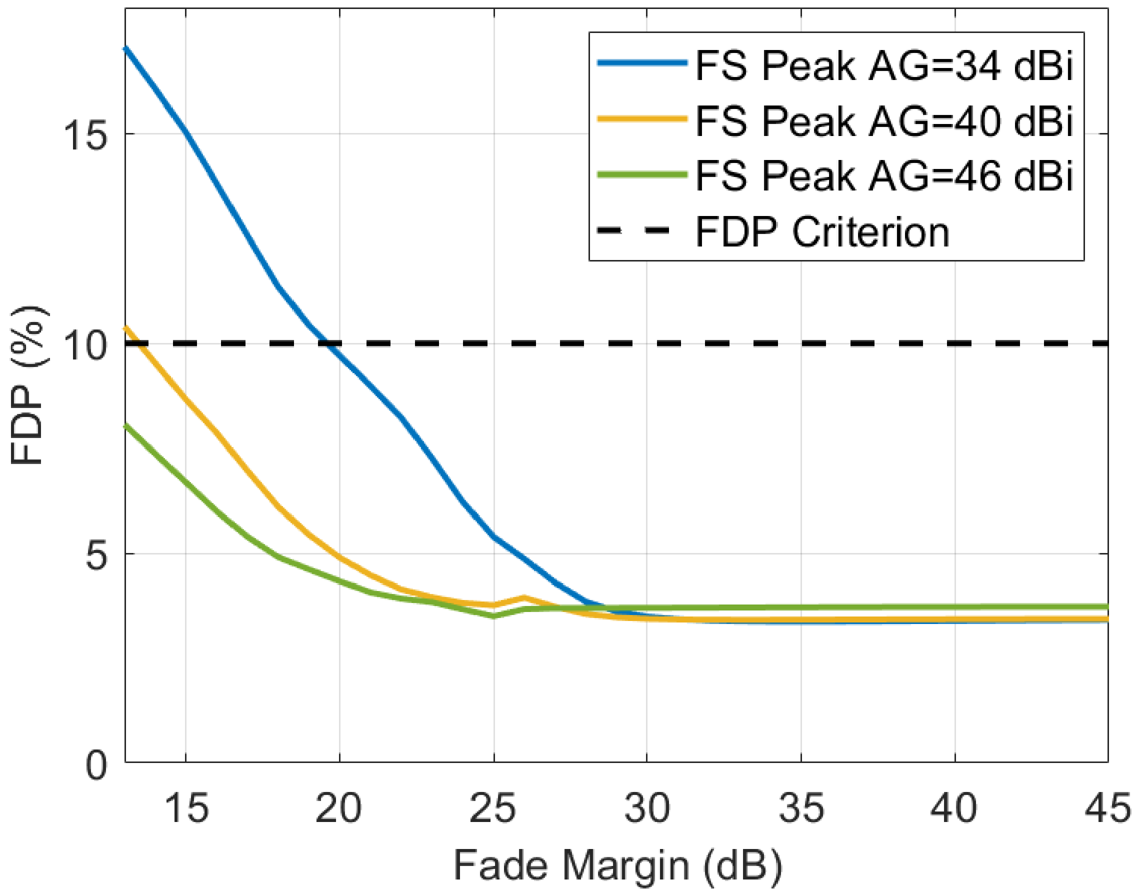


Figure 64: FDP vs FM for different FS receiver antenna gains (no polarisation mismatch)

It can be observed that the FDP criterion is most of the time respected for all FMs, except when the FM is quite low and mainly for low peak antenna gain (34 dBi) as shown by the blue curve.

A5.4.3 Effect of the polarisation mismatch

Assuming a polarisation mismatch of 3 dB between the WAS/RLAN transmitter and the FS receiver is equivalent to removing 3 dB to the I/N samples previously obtained.

On the long-term protection criterion, the CCDF of Figure 63 will be shifted by 3 dB to the left. Since even without polarisation mismatch, the long-term protection criterion was already respected, there is no need to plot the CCDF with polarisation mismatch.

On the FDP criterion, the computation needs to be redone and is given in Figure 65.

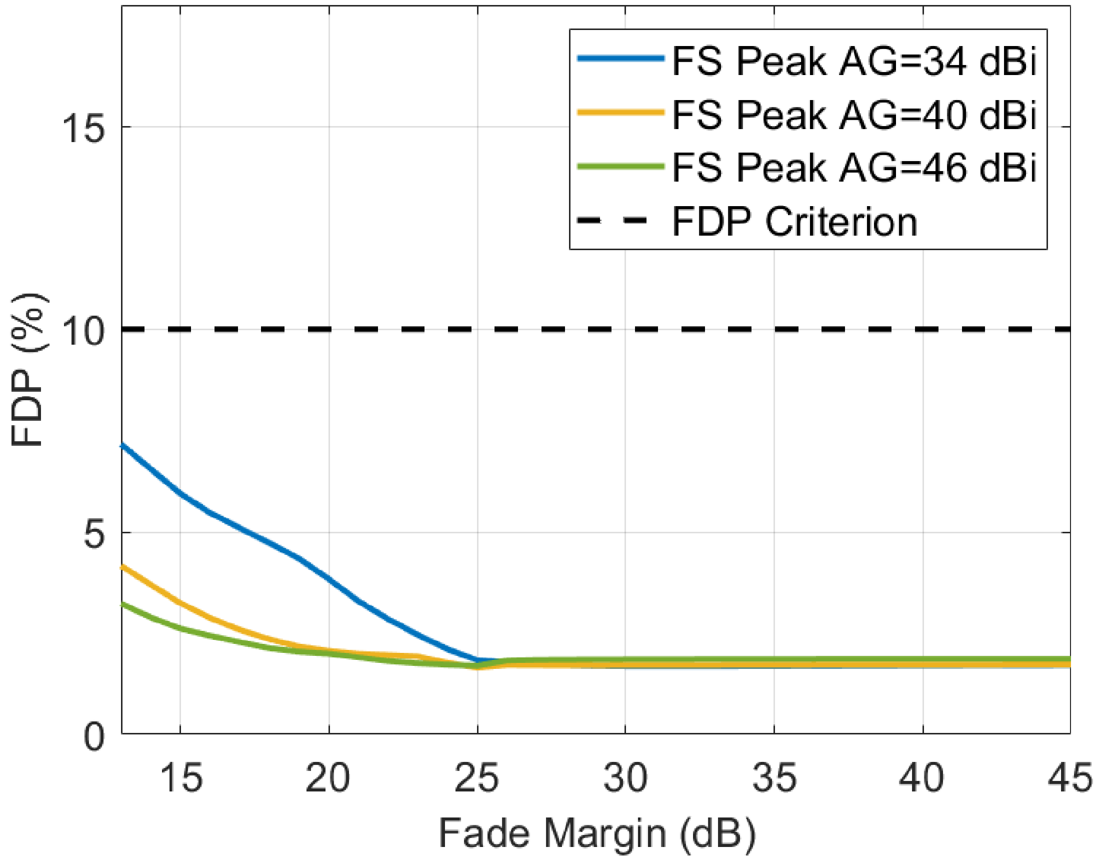


Figure 65: FDP vs FM for different FS receiver antenna gains (with polarisation mismatch)

All FDP values are below 6% for a large variety of FM values and for all antenna gains. Therefore, the 10% FDP criterion is respected on all those configurations when polarisation mismatch is assumed.

A5.4.4 Effect of the FS antenna height

The protection criteria when an FS antenna height of 75 m is used instead of 40 m was also investigated. A peak antenna gain of 46 dBi was assumed with a polarisation mismatch of 3 dB. Long-term protection criterion and FDP vs FM comparison are given in Figure 66 and Figure 67, respectively.

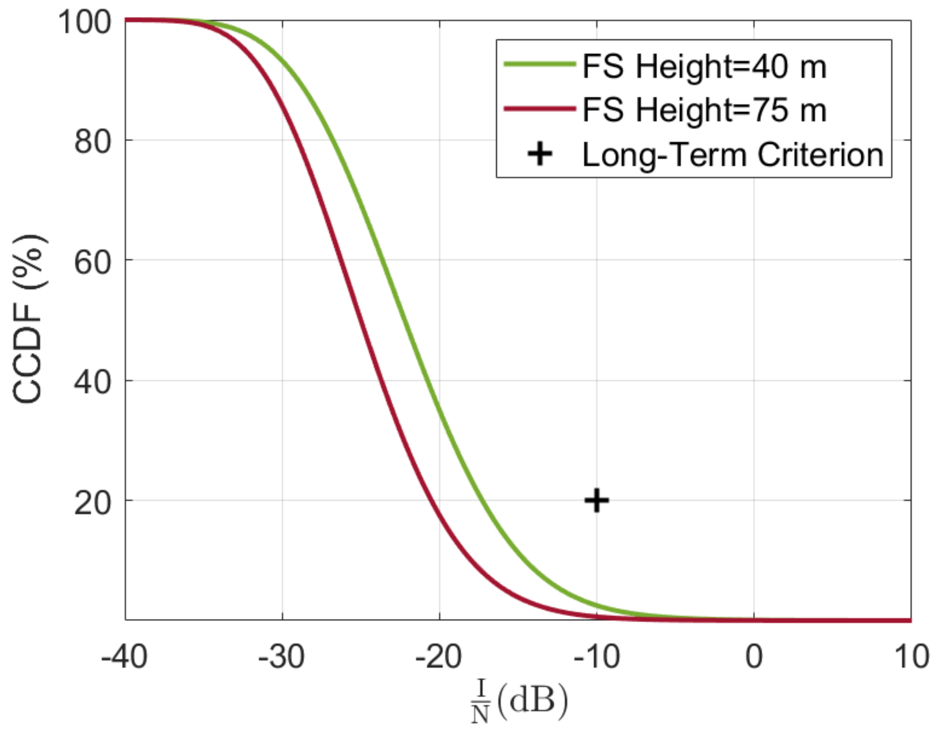


Figure 66: CCDF of I/N for different FS receiver heights

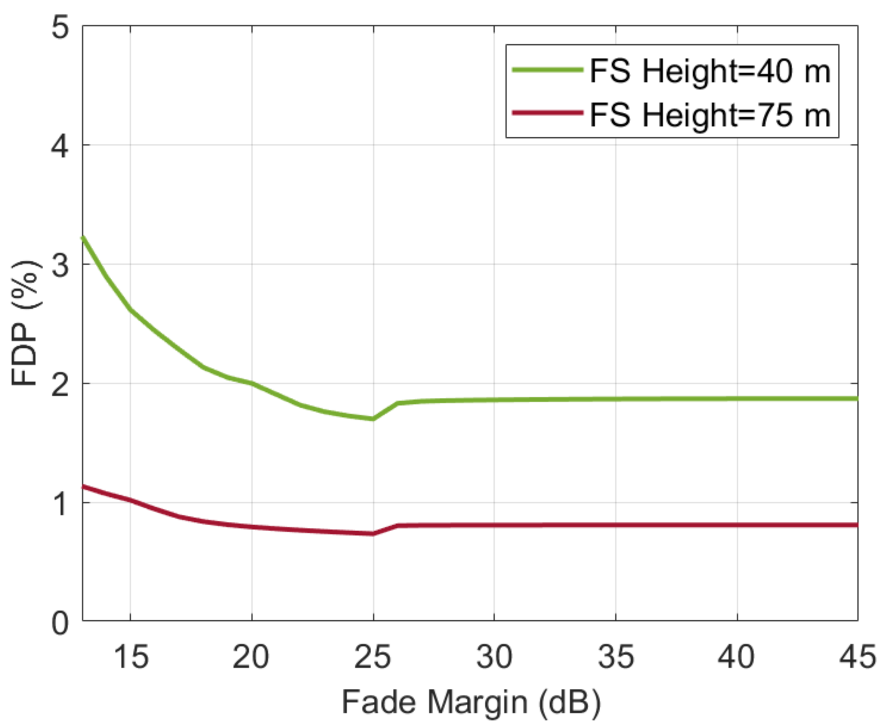


Figure 67: FDP vs FM for different FS receiver heights

As expected, both long-term and FDP criteria are respected for both FS antenna heights.

A5.4.5 Effect of the FS antenna tilt

In all previous simulations, the FS transmitter was assumed to be perfectly aligned with the receiver when pointing in the horizontal direction (antenna elevation of 0° from FS Tx to FS Rx).

To analyse the effect of the FS antenna tilt (or elevation) over the aggregated received interference in case of misalignment, a random uniform distribution of the antenna tilt (-2°≤ antenna tilt ≤ 2°) was assumed while keeping the receiver gain unchanged (46 dBi). The FS heights of 40 metres are kept for both Tx and Rx, thus the Fresnel exclusion zone was also unchanged. A polarisation mismatch of 3 dB was assumed.

In Figure 68 and Figure 69, it can be observed that both FS protection criteria are respected. Having an antenna receiver pointing upwards for some events has the effect to reduce the long-term protection criterion exceedance, as fewer WAS/RLANs would be within the main beam on average (Figure 68). On the other hand, the FDP is increased for fade margin up to 34 dB with uniform tilt (Figure 69) which could be explained by the fact that when the FS receiver is pointing downwards in some events, it has a higher chance to get a WAS/RLAN in its main beam at a closest distance. More investigations per event could be carried out, but misalignment of the Tx/Rx antenna elevation of an FS link is not a typical situation.

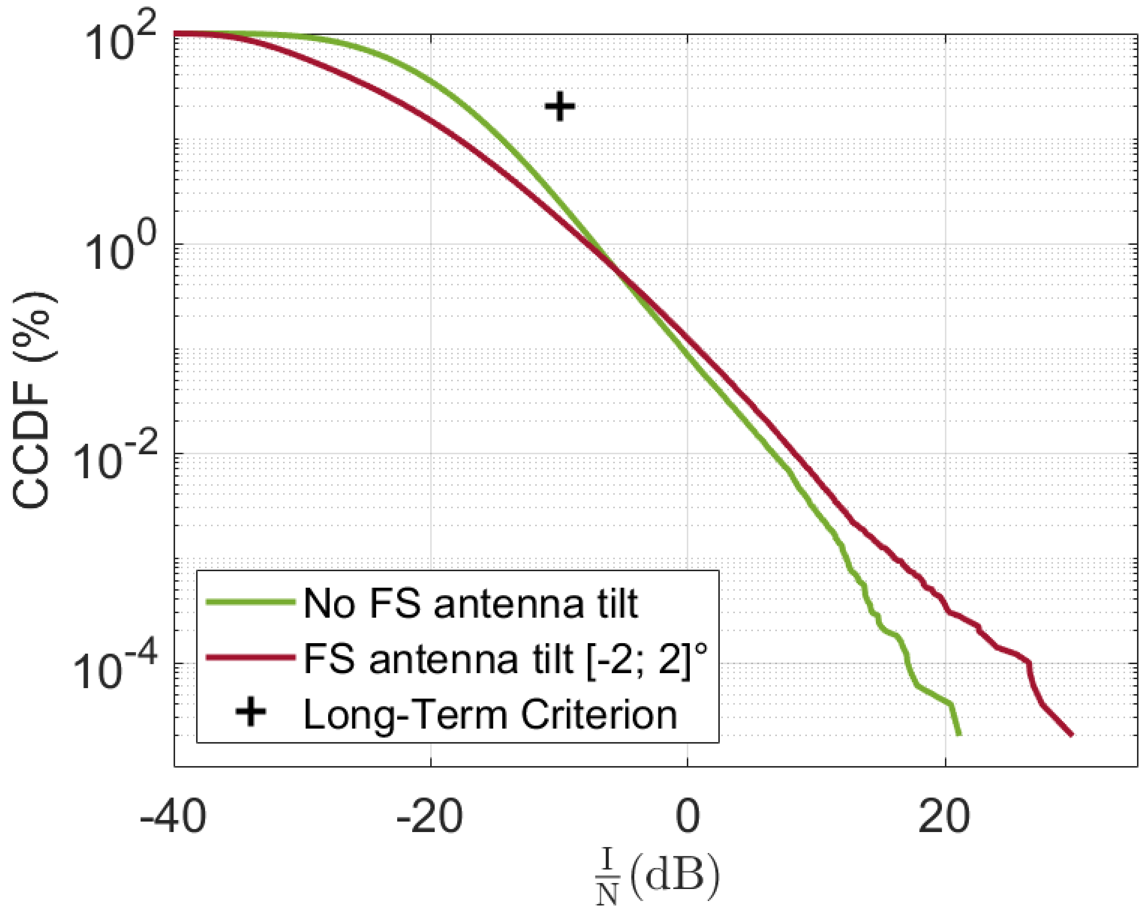


Figure 68: CCDF of I/N for different FS antenna tilt (constant vs uniform)

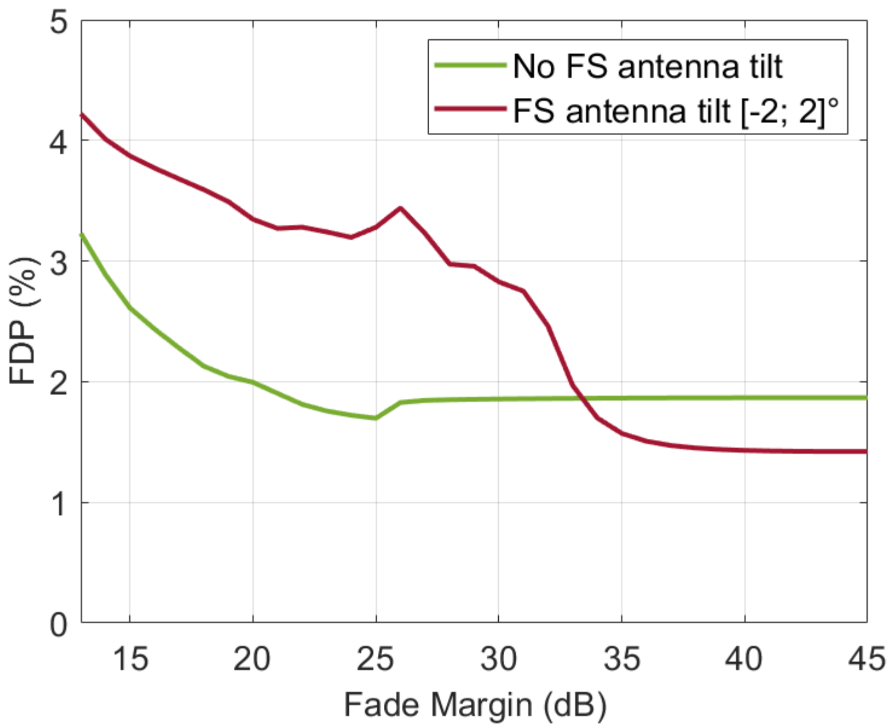


Figure 69: FDP vs FM for different FS antenna tilt distribution (constant vs uniform)

A5.5 SENSITIVITY ANALYSIS

While Scenario A (based on ECC Report 302) represents the baseline of this study with the “High” assumptions already capturing an optimistic upper 6 GHz adoption by the market, it could be interesting to see the results of the even more optimistic set of parameters from Scenario B with “High” assumptions for the market adoption.

A5.5.1 FS and WAS/RLAN deployment model

Table 92 gives the number of simultaneous indoor and outdoor transmitting WAS/RLAN to drop per event for Scenario B.

Table 92: RLAN deployment model based on Scenario B (High)

Parameters	Urban Area
Simulation radius (km)	13.89
Total population	3277451
Market Adoption factor (6 GHz capable devices)	60.00%
Busy Hour factor	62.70%
Wireless devices operating in licence exempt spectrum	100.00%
Upper 6 GHz factor	47.00%
Number of Upper 6 GHz transmissions	579499.22
RF Activity factor	2.45%

Parameters	Urban Area
Bandwidth overlapping factor	23.95%
Number of instantaneously transmitting WAS/RLANs	3402
Number of instantaneously transmitting WAS/RLANs indoor	**3360**
Number of instantaneously transmitting WAS/RLANs outdoor	**42**

The same baseline for the FS configured with 20 km length and a Tx/Rx height of 40 metres was kept with a polarisation mismatch of 3 dB between the FS receiver and WAS/RLAN transmitters.

Both extreme values of the FS peak antenna gain, namely 34 and 46 dBi, were investigated.

Each Monte Carlo simulation was run for 5 million events for each configuration.

A5.5.2 Protection criteria

Figure 70 shows the CCDF of I/N at the FS receiver side when comparing Scenario A and Scenario B. In all scenarios and FS configurations, the long-term protection criterion is respected.

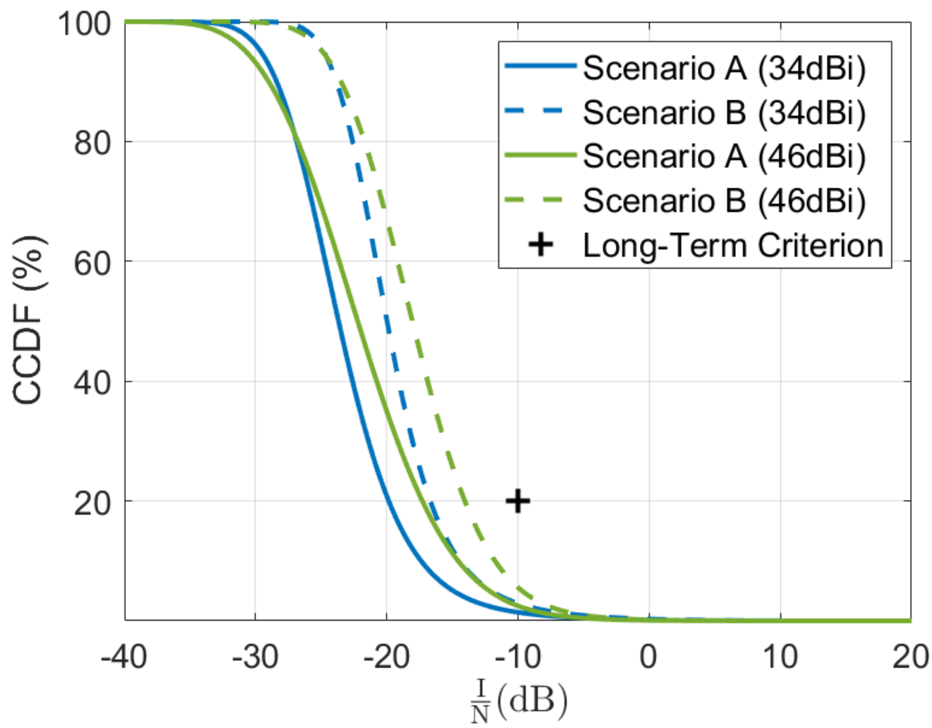


Figure 70: CCDF of I/N Scenario A and Scenario B

The FDP criterion is respected for an FS peak antenna gain of 46 dBi for all FM considered in Scenario B as shown in Figure 71. For an FS peak antenna gain of 34 dBi, the FDP exceeds the 10 % threshold only for low FM (below 16 dB), otherwise the criterion is respected. For a dense city as the one studied (about 5400 inhabitants/km^2), the choice of a low FM (15 dB) seems unlikely to be coupled with a low antenna gain (34 dBi).

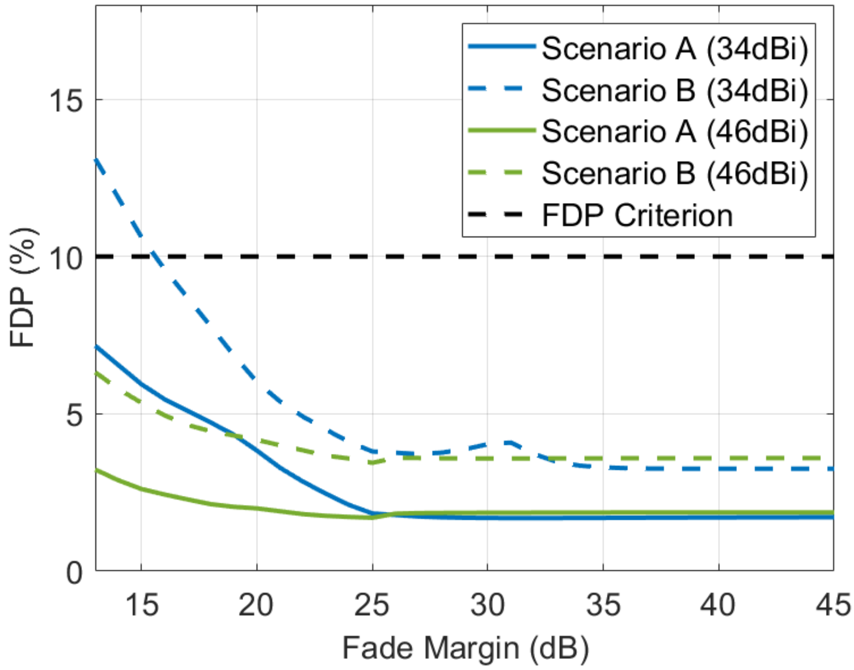


Figure 71: FDP vs FM: Scenario A and Scenario B

A5.6 LOCATION AND TIME ANALYSIS

A5.6.1 Methodology

Previous Monte Carlo simulations assumed a new drop of active-only WAS/RLAN per event, creating each time a new topology. A separated location/time approach can be used to assess the FDP protection criteria. In general, this approach consists in dropping all WAS/RLAN overlapping with the FS (one topology), and only considers the active ones per event. Such Monte Carlo simulation will give the I/N statistics for a given topology (time), while several topologies could be randomly simulated (location).

For a given topology, only the location of the indoor WAS/RLAN devices was set to be fixed in this study, while the location of the outdoor WAS/RLAN would change per event as they represent mobile devices which would naturally be moving over time. Active indoor WAS/RLAN per event are randomly selected based on the RF activity factor percentage.

The general simulation methodology used for one topology is as follows:

1 Randomly drop fixed indoor WAS/RLAN around the FS receiver (location dependent)

- 1.1. For each fixed indoor WAS/RLAN:
  - 1.1.1. Compute the WAS/RLAN *e.i.r.p.* (incl. potential body loss)
  - 1.1.2. Compute the clutter loss
  - 1.1.3. Compute the building entry loss

2 For each time-event (time dependent)

- 2.1. For each fixed indoor WAS/RLAN, select if it is active based on the RF activity factor
  - 2.2.1. For each active fixed indoor WAS/RLAN:
    - Compute the bandwidth reduction factor
    - Compute the propagation model

2.2. Randomly drop (active) outdoor WAS/RLAN around the FS receiver

2.2.2. For each active outdoor WAS/RLAN:

- Compute the WAS/RLAN *e.i.r.p.* (incl. potential body loss);
- Compute the clutter loss;
- Compute the bandwidth reduction factor;
- Compute the propagation model.

2.3. Compute the I/N value for this time-event due to all active WAS/RLAN

3 Process I/N values obtained for this topology (FDP computation)

This methodology is then repeated to get several topologies (and I/N statistics).

Note that building entry loss and WAS/RLAN *e.i.r.p.* (incl. potential body loss) of all indoor WAS/RLAN were considered fixed for a given topology. This approach is conservative as only LPI WAS/RLAN access points are fixed by nature while indoor WAS/RLAN clients may move around, thus exhibiting different building entry loss and transmit power towards the FS receiver over time.

A5.6.2 FS and WAS/RLAN deployment model

This separated location/ time simulation is computationally expensive as two loops are involved: one outer loop for the topology (location) and one inner loop for the active WAS/RLAN selected (time). Thus, a limited simulation radius (5 km instead of 13.89 km) was selected for the WAS/RLAN drop zone to assess the FDP criterion (and not the long-term protection criterion).

Under this approach and assumptions, the WAS/RLAN deployment model for Scenario A and Scenario B are given by Table 93. For Scenario A, this model leads to 11556 fixed indoor WAS/RLAN being dropped per topology, with 228 active indoor WAS/RLAN (among those 11556) on average and exactly 3 outdoor WAS/RLAN being considered per time-event.

Table 93: RLAN deployment model based on "High" assumption for location and time simulation

Parameters	Scenario A	Scenario B
Simulation radius (km)	5	
Total population	424770	
Market Adoption factor (6 GHz capable devices)	50.00%	60%
Busy Hour factor	62.70%	
Wireless devices operating in licence exempt spectrum	90.00%	100%
Upper 6 GHz factor	40.75%	47%
Number of Upper 6 GHz transmissions	48838.41	75105.28
Bandwidth overlapping factor	23.95%	
Number of WAS/RLANs	11696.80	17987.72
Number of WAS/RLANs indoor (fixed)	**11556**	**17771**
RF Activity factor	1.97%	2.45%
Average number of instantaneously transmitting WAS/RLANs indoor	228	436
Number of instantaneously transmitting WAS/RLANs outdoor	**3**	**6**

For the FS parameter, an antenna height of 40 m and a peak antenna gain of 46 dBi were assumed. A polarisation mismatch of 3 dB was also considered.

A customised simulator based on the source code of SEAMCAT 5.5.1-Alpha3 was used to run the separated location/time simulations described above. Fresnel exclusion zone implementation was also included into this code. This version allows some variables (including the interferer positions) to be fixed after the first event, meaning that each instance can simulate one topology. Figure 72 to Figure 74 show how the location dependent parameters can be fixed.

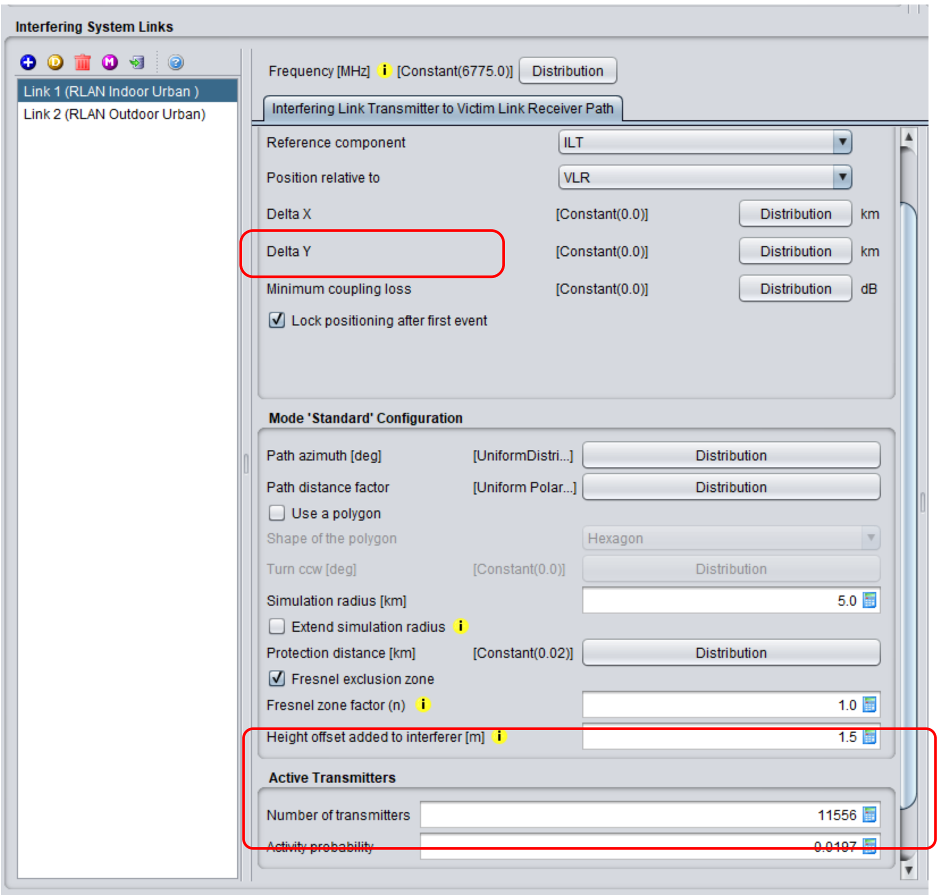


Figure 72: Indoor WAS/RLAN position locked after first event and active probability configuration

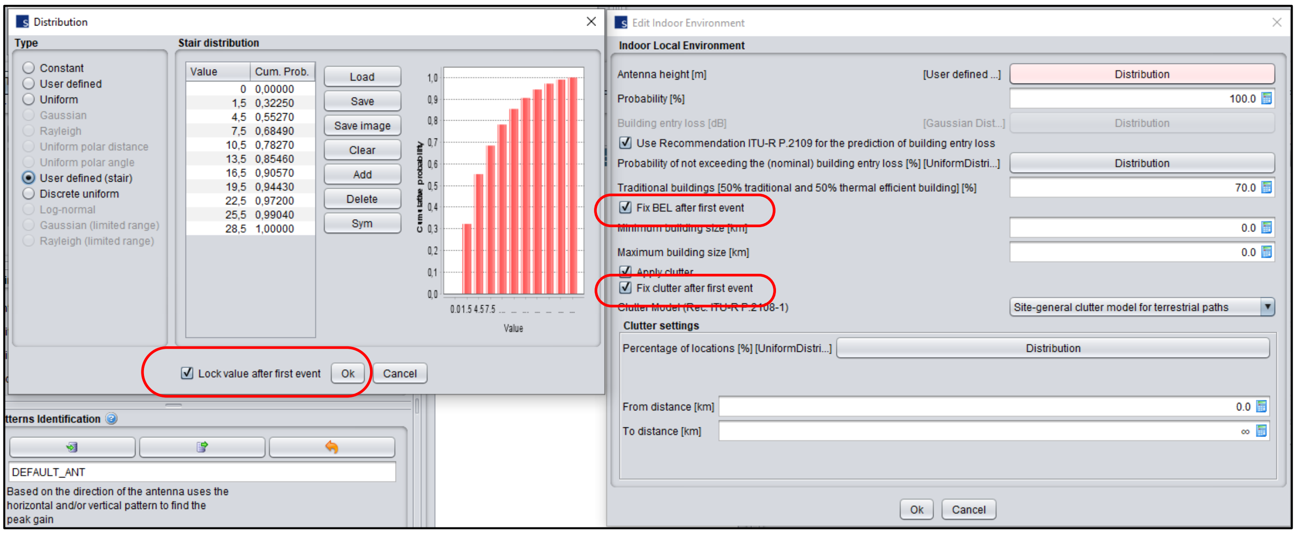


Figure 73: Indoor WAS/RLAN height, clutter loss and building entry loss locked after first event

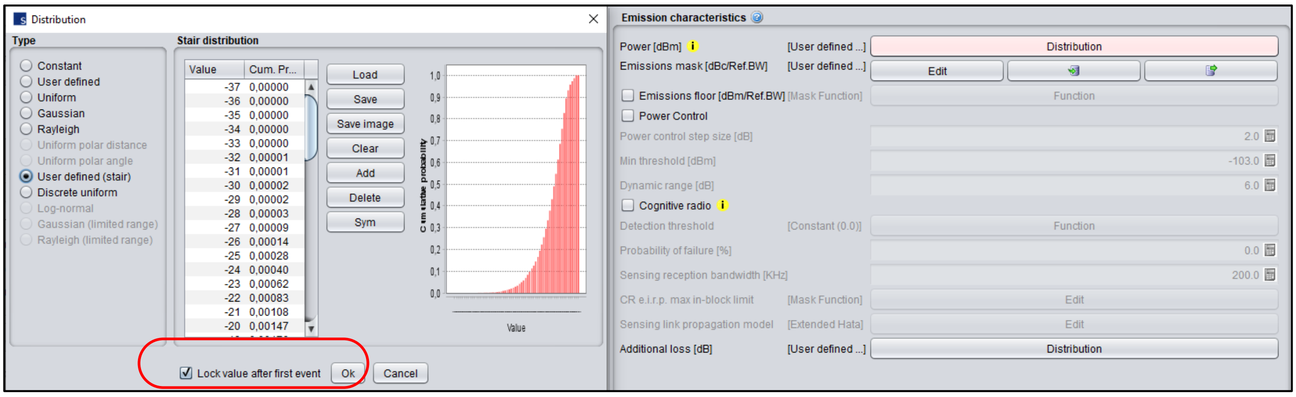


Figure 74: Indoor WAS/RLAN *e.i.r.p.* locked after first event

A filter was added to the event result panel to be able to display only the active interferers per event, displaying the results in a more user-friendly manner, as shown in Figure 75.

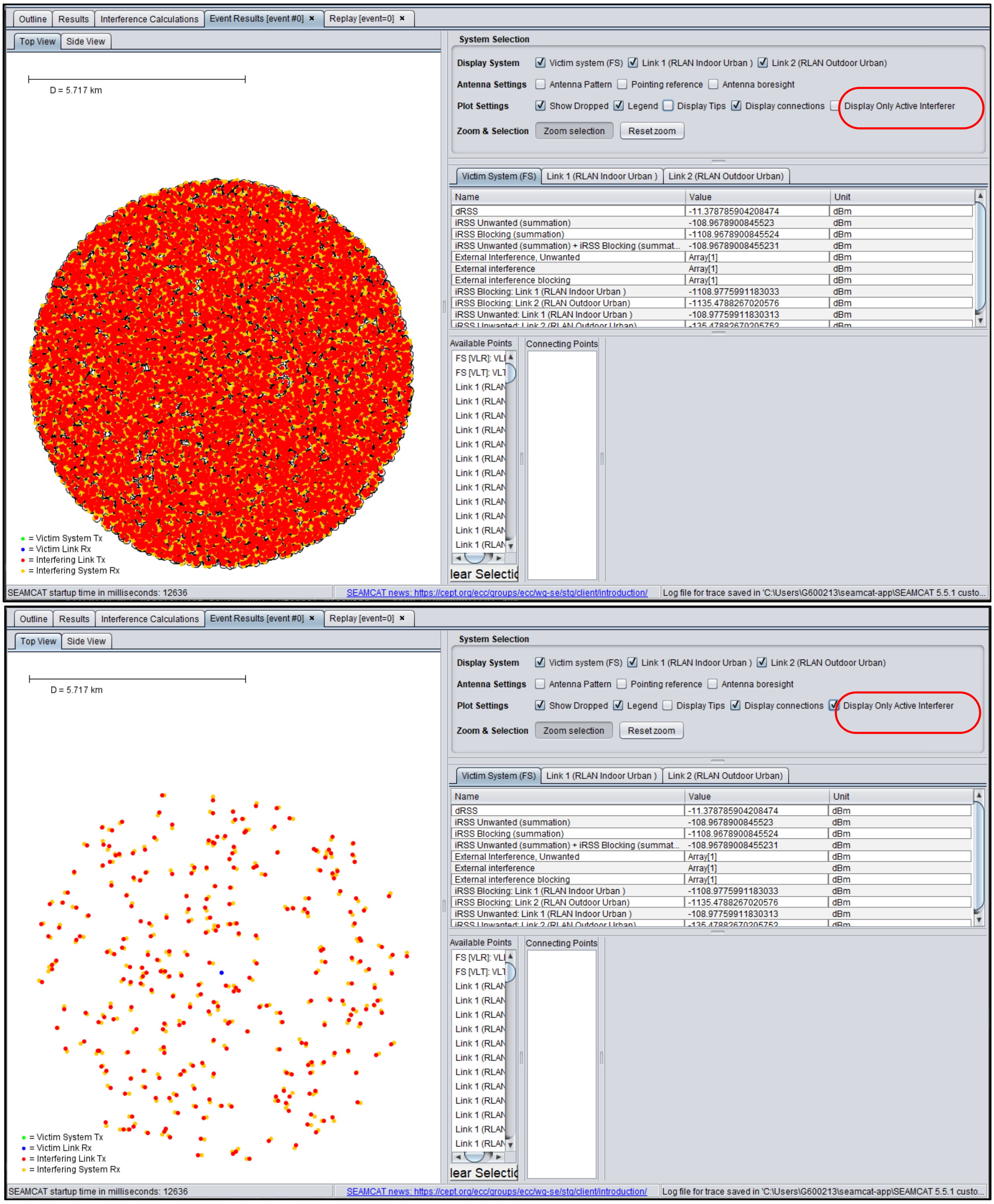


Figure 75: Filtering option to display only active interferer: off vs on

For this study, 200 topologies were simulated for both scenarios, each topology consisting of 100000 time-events, leading to 20 million events (four times the number of events more than for the previous simulations).

A5.6.3 FDP protection criterion

Figure 76 shows the CCDF of I/N for all simulated topologies for Scenario A. The I/N values serve as the input for the FDP assessment.

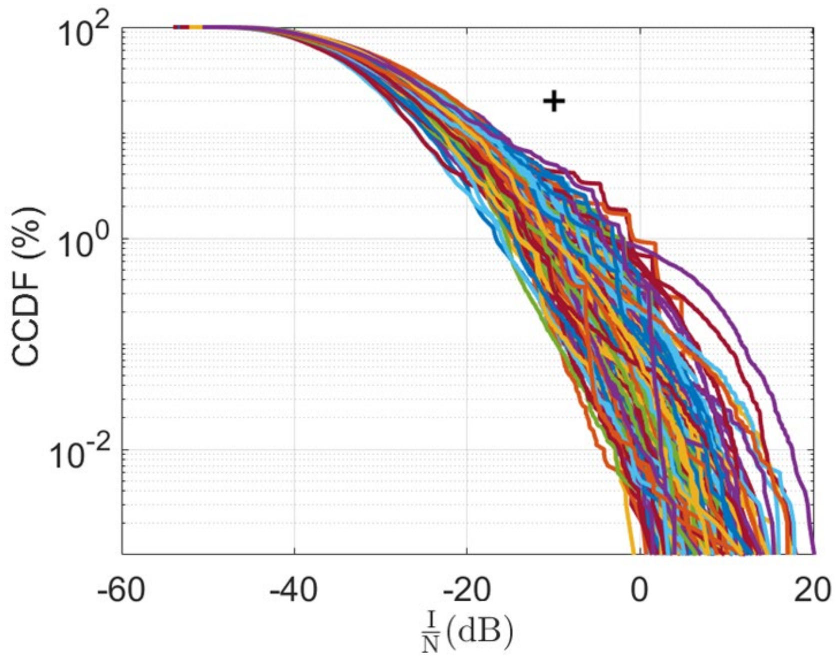


Figure 76: CCDF (%) of I/N for all simulated topologies (location and time framework for Scenario A)

Figure 77 shows the FDP evolution for various FM for each topology for Scenario A. Among the 200 topologies simulated, only around 3% of them may exhibit an FDP exceeding 10% for low FM (below 20 dB). In particular, two topologies seem to cause a high FDP (topology #67 and topology #147) and would require an FM of at least 23 dB and 18 dB to be below the 10% protection criteria, respectively.

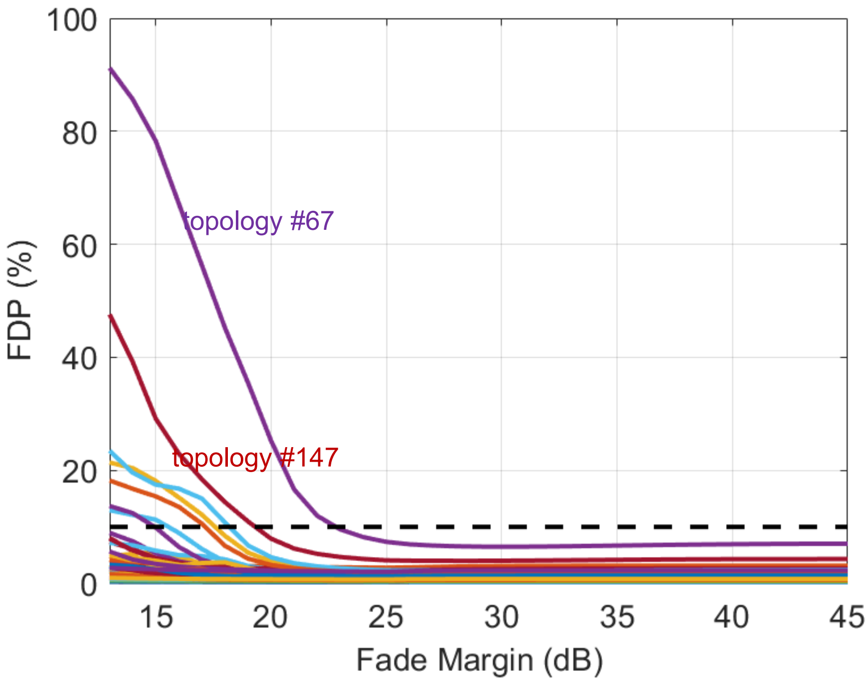


Figure 77: FDP vs FM for all simulated topologies (location and time framework for Scenario A)

It is possible to check the I/N values per time event for the "worst-case" topology #67 as shown in Figure 78.

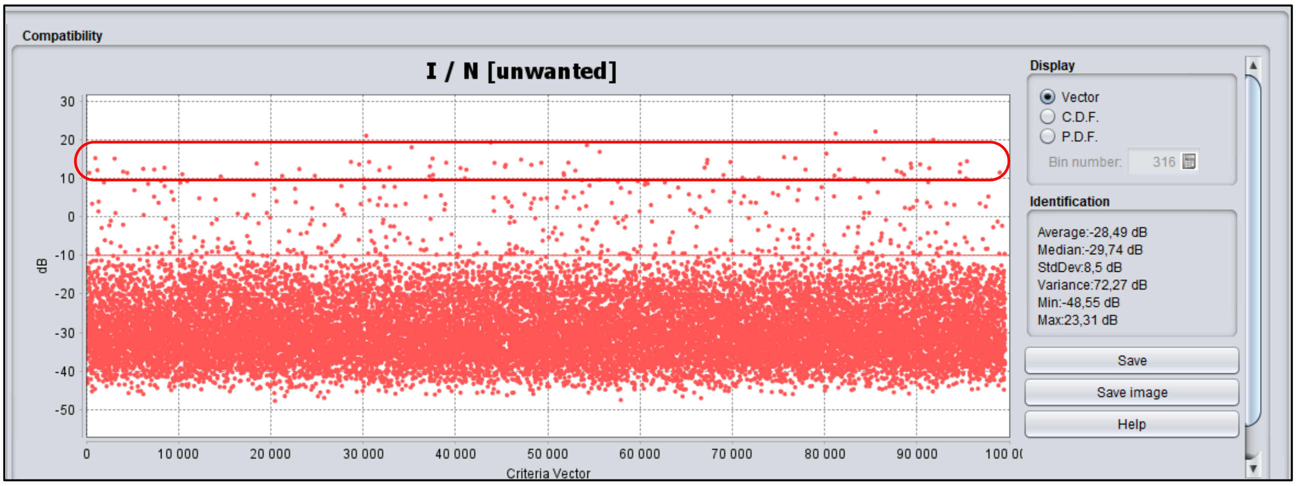


Figure 78: I/N samples for the topology#67

As it can be observed, some of the time-events have high I/N values (e.g. event 30165, 53669, 81014, 85332, 91223, 91599)[14]. When looking only at the active interferers in the result panel for those events, the same WAS/RLAN close to the FS receiver is active as shown by Figure 79.

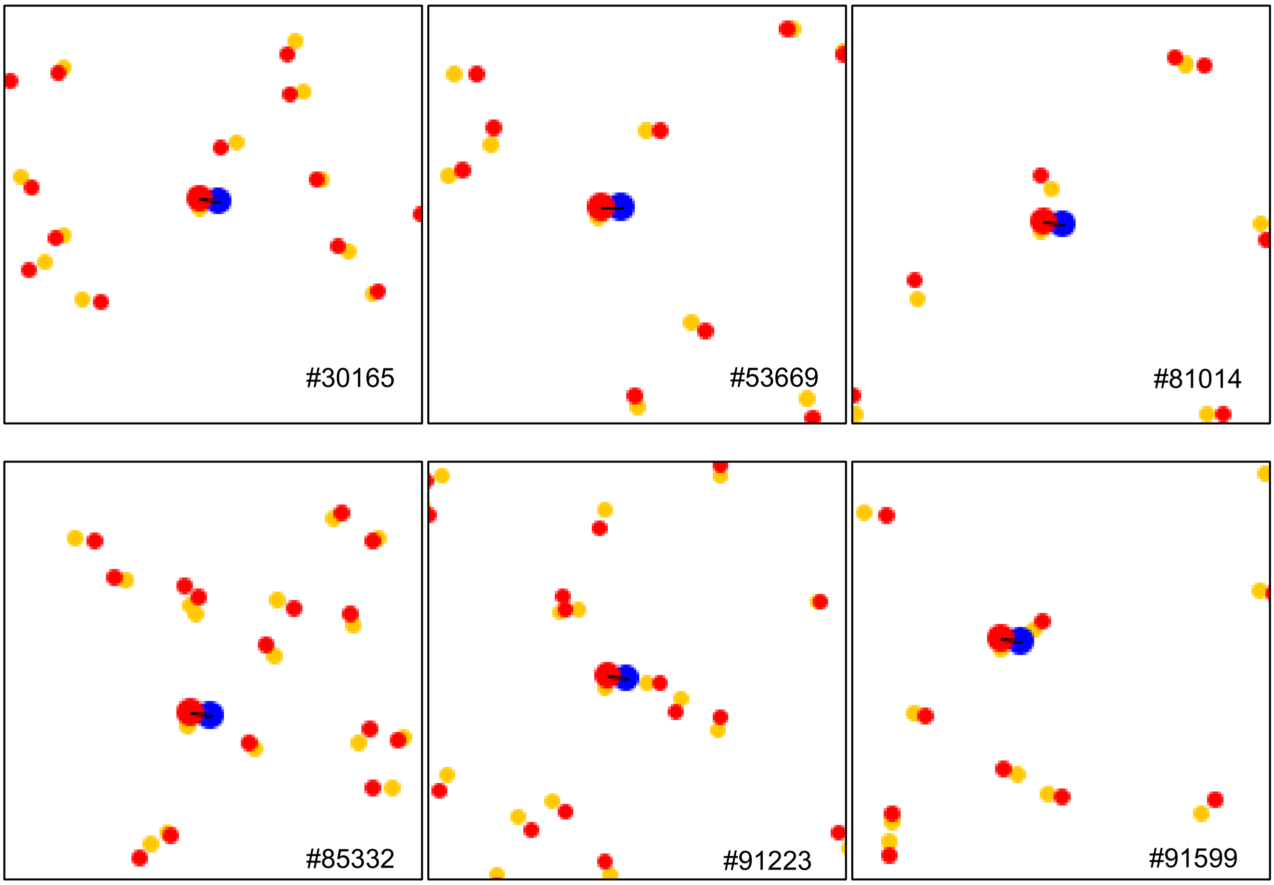


Figure 79: Active WAS/RLAN causing high I/N value event in topology #67

To confirm that this WAS/RLAN is the cause of the high I/N, a deep-dive analysis of topology #67 was done where all events leading to an I/N greater than or equal to 19 dB (without polarisation mismatch) have been

[14] I/N values displayed here are without the 3 dB of polarisation mismatch as this effect was added in a post processing stage.

investigated. As shown by Table 94, it confirmed they are all caused by the same interferer ("ILT 9159") whose characteristics against the FS receiver is given in Figure 80.

Table 94: Time-events leading to an I/N ≥ 19 dB for topology #67 (Scenario A) and identification of the main interferer

Time-event with I/N ≥ 19 dB	Main interferer	iRSS Main interferer (dBm)	iRSS All interferers (dBm)
172	ILT 9159	-74.094966	-74.094777
6876	ILT 9159	-72.556346	-72.555702
13505	ILT 9159	-71.125116	-71.125107
14682	ILT 9159	-72.415401	-72.415232
16030	ILT 9159	-73.70948	-73.709464
16542	ILT 9159	-74.078284	-74.072261
22306	ILT 9159	-73.426427	-73.426223
30165	ILT 9159	-72.034928	-72.034922
43652	ILT 9159	-73.78058	-73.777484
52373	ILT 9159	-72.861414	-72.860483
53669	ILT 9159	-70.36466	-70.364656
54062	ILT 9159	-74.454642	-74.454537
57168	ILT 9159	-72.916321	-72.915333
69927	ILT 9159	-72.740034	-72.739554
72356	ILT 9159	-74.451398	-74.451396
76805	ILT 9159	-73.41686	-73.41685
81014	ILT 9159	-71.453301	-71.453099
83433	ILT 9159	-74.308748	-74.308709
85332	ILT 9159	-70.930912	-70.930908
91223	ILT 9159	-70.190173	-70.189754
91599	ILT 9159	-73.083699	-73.082631

Name	Value	Unit
Link Details		
Frequency	6775.0	MHz
Distance	0.089	km
Tx-Rx azimuth (global)	354.172	degree
Tx-Rx elevation (global)	7.369	degree
TX power	20.0	dBm
Path loss	94.004	dB
Effective path loss	90.19	dB
ILT Power in VLR Bandwidth	20.0	dBm
Minimum coupling loss	0,000E+00	dB
iRSS Unwanted	-70.19	dBm
iRSS Blocking	-1070.19	dBm
Tx Values (Link 1 (RLAN Indoor Urban) [ILT]: ILT 9159)		
Position	(19.912, 0.009)	(km,km)
Antenna height	28.5	m
Terrain height	0,000E+00	m
Antenna Azimuth angle	94.667	degree
Antenna Azimuth pointing (global)	259.505	degree
Azimuth boresight (global)	259.505	degree
Antenna Elevation angle	7.369	degree
Antenna Elevation pointing (global)	0,000E+00	degree
Elevation boresight (global)	0,000E+00	degree
Gain	0,000E+00	dBi
Building entry loss	10.868	dB
Additional loss	0,000E+00	dB
Rx Values (FS [VLR]: VLR)		
Position	(20.0, 0.0)	(km,km)
Antenna height	40.0	m
Terrain height	0,000E+00	m
Antenna Azimuth angle	354.172	degree
Antenna Azimuth pointing (global)	180.0	degree
Azimuth boresight (global)	180.0	degree
Antenna Elevation angle	-7.369	degree
Antenna Elevation pointing (global)	0,000E+00	degree
Elevation boresight (global)	0,000E+00	degree
Gain	5.114	dBi
Additional loss	1.3	dB

Figure 80: Parameter of the WAS/RLAN causing high I/N occurrences in topology #67 (Scenario A) for time-event #91223

This WAS/RLAN was dropped almost in the line of sight of the FS receiver, at an 89 m distance, with a height of 28.5 m, a transmit power of 20 dBm seen by the FS receiver and with a relatively low building entry loss (around 10 dB).

Of the 100000 time-events of topology #67 investigated, 177 time-events were dominated by this WAS/RLAN interferer and presented an I/N greater than 13 dB (without polarisation mismatch). If those time-events were to be removed, the FDP of this topology would look like the one given in Figure 81 and would be below the 10% criterion for all FM, validating the fact the FDP exceedance is only due to one WAS/RLAN.

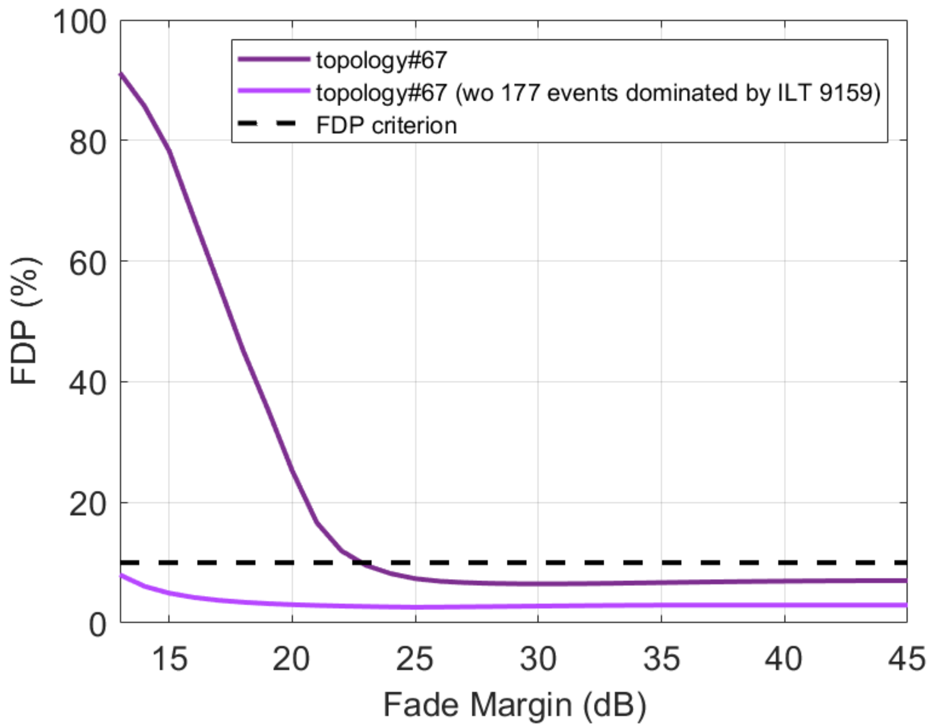


Figure 81: FDP vs FM for topology#67 with and without the I/N samples greater than 13 dB dominated by the main interferer

The same analysis was made for topology #147 as shown in Table 95 and Figure 82 leading to an equivalent conclusion: a single WAS/RLAN is responsible for the high I/N values and was dropped almost in the line of sight of the FS receiver, at an 129 m distance, with a height of 7.5 m, a transmit power of 22 dBm seen by the FS receiver and a low building entry loss (around 3.3 dB). As there are few occurrences of high I/N in this topology, it is logic to find that its FDP curve is lower than the worst-case topology #67.

Table 95: Time-events leading to an I/N ≥ 19 dB for topology #147 (Scenario A) and identification of the main interferer

Time-event with I/N ≥ 19 dB	Main interferer	iRSS Main interferer (dBm)	iRSS All interferers (dBm)
6286	ILT 3347	-72.48542	-72.485407
36206	ILT 3347	-73.220988	-73.220959
81584	ILT 3347	-73.852841	-73.852829
91832	ILT 3347	-73.723745	-73.723662
94201	ILT 3347	-71.200353	-71.20035

Name	Value	Unit
Link Details		
Frequency	6775.0	MHz
Distance	0.129	km
Tx-Rx azimuth (global)	349.936	degree
Tx-Rx elevation (global)	14.133	degree
TX power	22.0	dBm
Path loss	90.38	dB
Effective path loss	93.2	dB
ILT Power in VLR Bandwidth	22.0	dBm
Minimum coupling loss	0,000E+00	dB
iRSS Unwanted	-71.2	dBm
iRSS Blocking	-1071.2	dBm
Tx Values (Link 1 (RLAN Indoor Urban) [ILT]: ILT 3347)		
Position	(19.873, 0.023)	(km,km)
Antenna height	7.5	m
Terrain height	0,000E+00	m
Antenna Azimuth angle	242.741	degree
Antenna Azimuth pointing (global)	107.194	degree
Azimuth boresight (global)	107.194	degree
Antenna Elevation angle	14.133	degree
Antenna Elevation pointing (global)	0,000E+00	degree
Elevation boresight (global)	0,000E+00	degree
Gain	0,000E+00	dBi
Building entry loss	3.396	dB
Additional loss	0,000E+00	dB
Rx Values (FS [VLR]: VLR)		
Position	(20.0, 0.0)	(km,km)
Antenna height	40.0	m
Terrain height	0,000E+00	m
Antenna Azimuth angle	349.936	degree
Antenna Azimuth pointing (global)	180.0	degree
Azimuth boresight (global)	180.0	degree
Antenna Elevation angle	-14.133	degree
Antenna Elevation pointing (global)	0,000E+00	degree
Elevation boresight (global)	0,000E+00	degree
Gain	-1.52	dBi
Additional loss	1.3	dB

Figure 82: Parameter of the WAS/RLAN causing high I/N occurrences in topology #147 (Scenario A) for time-event #94201

Similar investigations were also carried out for the other FDP outlier curves (i.e. the ones above 10% for a low FM margin) and the same trend could be observed: a WAS/RLAN in close vicinity of the FS receiver (in the main beam), with a (relative) high height compared to the FS receiver height, with a high transmit power seen by the FS receiver, and with a low building entry loss may cause the FDP criteria to be exceeded when the FS fade margin is low.

The likelihood of having all those conditions being fulfilled in real world is highly site-specific. This site-general simulation shows that the vast majority of the simulated topologies fulfilled the FDP criteria for all the FM values investigated and that only few occurrences (around 3%) would cause interference when the FM of the FS link is low.

A5.6.4 Sensitivity analysis

Simulations using Scenario B parameters with ”High” deployment assumptions were also carried out as a sensitivity analysis as those hypotheses capture an optimistic 6 GHz WAS/RLAN market penetration. I/N distribution and FDP vs FM for each topology are given in Figure 83 and Figure 84, respectively.

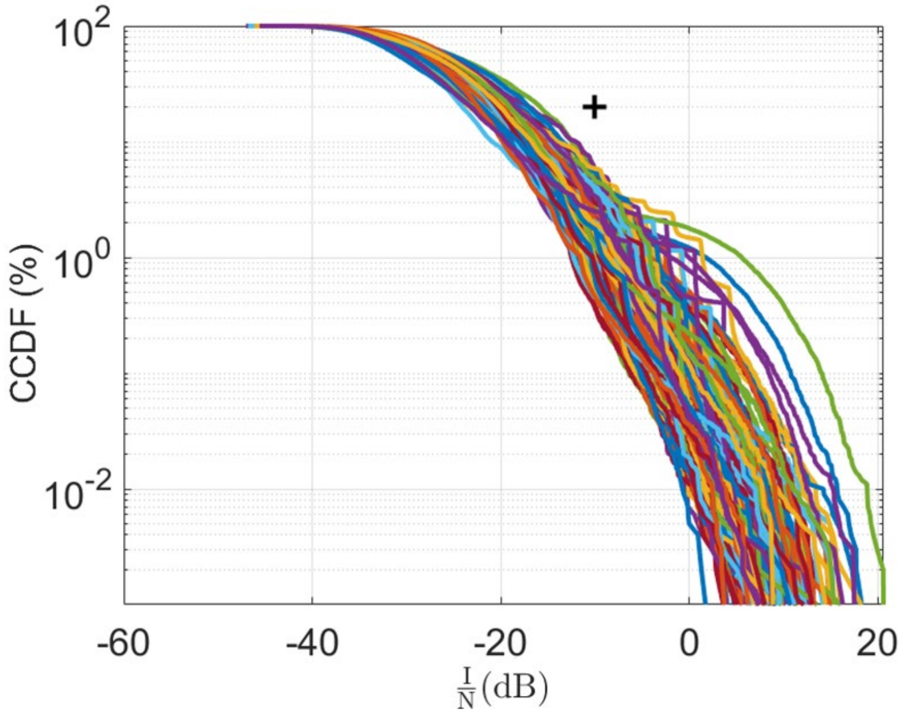


Figure 83: CCDF (%) of I/N for all simulated topologies (separated location/time approach for Scenario B)

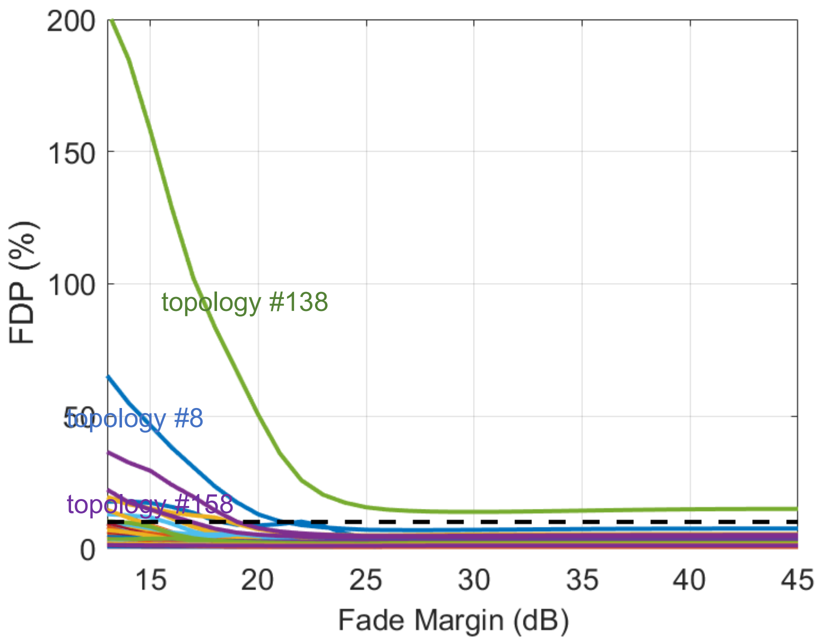


Figure 84: FDP vs FM for all simulated topologies (separated location/time approach for Scenario B)

Around 5.5 % of the topologies exceeds the FDP criteria for the lowest FM value investigated (13 dB), while 0.5% of the topologies exceeds it even for the highest FM value (45 dB). Among the simulated topologies, three have particularly high FDP compared to the others. Topology #8 and topology #158 require an FM above 20 dB and 18 dB to be below the FDP criterion of 10%, respectively. Only topology #138 cannot meet the FDP criterion for any of the FM values tested.

The same deep-dive analysis was done for those three topologies, where time-events caused I/N to be greater or equal to 19 dB (without polarisation mismatch). As shown in Table 96 to Table 98, only one WAS/RLAN is causing those high I/N values.

Table 96: Time-events leading to an I/N ≥ 19 dB for topology #138 (Scenario B) and identification of the main interferer

Time-event with I/N ≥ 19 dB	Main interferer	iRSS Main interferer (dBm)	iRSS All interferers (dBm)
2170	ILT 7015	-74.123109	-74.1225
4848	ILT 7015	-70.574434	-70.573136
6461	ILT 7015	-73.471988	-73.471851
10065	ILT 7015	-73.591974	-73.59189
13476	ILT 7015	-74.081817	-74.076354
18357	ILT 7015	-72.219718	-72.219706
18453	ILT 7015	-69.295387	-69.295367
18785	ILT 7015	-71.634446	-71.634429
24870	ILT 7015	-74.338587	-74.338068
26246	ILT 7015	-73.022191	-73.020691
27254	ILT 7015	-72.471788	-72.471621
28453	ILT 7015	-71.57213	-71.571621
29148	ILT 7015	-71.651491	-71.651339
30814	ILT 7015	-73.557966	-73.557857
32622	ILT 7015	-73.509838	-73.509821
35362	ILT 7015	-70.968297	-70.968287
40229	ILT 7015	-71.544513	-71.544192
44267	ILT 7015	-74.460352	-74.460224
50442	ILT 7015	-74.18652	-74.186461
59641	ILT 7015	-71.333426	-71.333178
65468	ILT 7015	-69.902093	-69.901718
67523	ILT 7015	-74.403181	-74.401076
68940	ILT 7015	-74.108831	-74.108045
70947	ILT 7015	-73.254591	-73.254527

Time-event with I/N ≥ 19 dB	Main interferer	iRSS Main interferer (dBm)	iRSS All interferers (dBm)
72370	ILT 7015	-74.345204	-74.344815
75419	ILT 7015	-73.272503	-73.27248
76260	ILT 7015	-73.160425	-73.160404
77999	ILT 7015	-73.736206	-73.73603
78011	ILT 7015	-74.442601	-74.440924
79042	ILT 7015	-74.371651	-74.370166
83314	ILT 7015	-74.08218	-74.081889
83662	ILT 7015	-72.826973	-72.826727
88790	ILT 7015	-71.216251	-71.216227
91929	ILT 7015	-74.190897	-74.190741
95018	ILT 7015	-69.91603	-69.91582
95482	ILT 7015	-73.890881	-73.890865
95650	ILT 7015	-71.645118	-71.644955

Table 97: Time-events leading to an I/N ≥ 19 dB for topology #8 (Scenario B) and identification of the main interferer

Time-event with I/N ≥ 19 dB	Main interferer	iRSS Main interferer (dBm)	iRSS All interferers (dBm)
24364	ILT 3635	-73.562798	-73.561814
31928	ILT 3635	-74.130109	-74.128896
72664	ILT 3635	-72.206834	-72.206452
74352	ILT 3635	-72.778137	-72.778096
77990	ILT 3635	-71.068928	-71.068763
85757	ILT 3635	-72.802313	-72.802286
86047	ILT 3635	-73.676257	-73.676178
96889	ILT 3635	-73.328832	-73.328658
24364	ILT 3635	-73.562798	-73.561814

Table 98: Time-events leading to I/N ≥ 19 dB for Topology #158 (Scenario B) and identification of the main interferer

Time-event with I/N ≥ 19 dB	Main interferer	iRSS Main interferer (dBm)	iRSS All interferers (dBm)
10281	ILT 16989	-74.438332	-74.436015
45037	ILT 16989	-73.151331	-73.15113
45582	ILT 16989	-72.999254	-72.999204
62565	ILT 16989	-73.078505	-73.075099
72348	ILT 16989	-72.011902	-72.011867

For the worst case topology #138, the highest interfering WAS/RLAN, whose characteristics are given in in Figure 85, was dropped at 44 metres from the FS receiver, with a height of 25.5 metres, with a high transmit power of 22 dBm seen by the FS receiver and with a very low building entry loss of 3.4 dB. This configuration explains why the FDP criterion cannot be met for this topology for any of the FM values. Note that in those simulations the building entry loss was kept constant for all indoor WAS/RLAN over time, while in practice only the LPI access points will be fixed, as WAS/RLAN clients are more likely to move around, thus having different building entry loss.

The analysis of the other interferer link (Figure 86 and Figure 87) shows the same general characteristics for a WAS/RLAN to affect an FS link as observed previously: a WAS/RLAN in close vicinity, and with a (relative) high height, and with a high transmit power as seen by the FS receiver, and with a low building entry loss may cause the FDP criterion to be exceeded when the FS fade margin is low.

The likelihood of having all those conditions occurring in real world is highly site-specific. This site-general simulation shows that, even in this sensitivity study for Scenario B, the vast majority of the simulated topologies were respecting the FDP criteria for all FM investigated and that only few occurrences (percentage in the single digit) would not respect it for low FM.

Name	Value	Unit
Link Details		
Frequency	6775.0	MHz
Distance	0.044	km
Tx-Rx azimuth (global)	99.776	degree
Tx-Rx elevation (global)	18.149	degree
TX power	22.0	dBm
Path loss	77.42	dB
Effective path loss	91.295	dB
ILT Power in VLR Bandwidth	22.0	dBm
Minimum coupling loss	0,000E+00	dB
iRSS Unwanted	-69.295	dBm
iRSS Blocking	-1069.295	dBm
Tx Values (Link 1 (RLAN Indoor Urban) [ILT]: ILT 7015)		
Position	(20.008, -0.044)	(km,km)
Antenna height	25.5	m
Terrain height	0,000E+00	m
Antenna Azimuth angle	98.336	degree
Antenna Azimuth pointing (global)	1.44	degree
Azimuth boresight (global)	1.44	degree
Antenna Elevation angle	18.149	degree
Antenna Elevation pointing (global)	0,000E+00	degree
Elevation boresight (global)	0,000E+00	degree
Gain	0,000E+00	dBi
Building entry loss	3.414	dB
Additional loss	0,000E+00	dB
Rx Values (FS [VLR]: VLR)		
Position	(20.0, 0.0)	(km,km)
Antenna height	40.0	m
Terrain height	0,000E+00	m
Antenna Azimuth angle	99.776	degree
Antenna Azimuth pointing (global)	180.0	degree
Azimuth boresight (global)	180.0	degree
Antenna Elevation angle	-18.149	degree
Antenna Elevation pointing (global)	0,000E+00	degree
Elevation boresight (global)	0,000E+00	degree
Gain	-12.575	dBi
Additional loss	1.3	dB

Figure 85: Parameter of the WAS/RLAN causing high I/N occurrences in topology #138 (Scenario B) for time-event #18453

Name	Value	Unit
Link Details		
Frequency	6775.0	MHz
Distance	0.057	km
Tx-Rx azimuth (global)	12.441	degree
Tx-Rx elevation (global)	17.055	degree
TX power	16.0	dBm
Path loss	82.138	dB
Effective path loss	87.069	dB
ILT Power in VLR Bandwidth	16.0	dBm
Minimum coupling loss	0,000E+00	dB
iRSS Unwanted	-71.069	dBm
iRSS Blocking	-1071.069	dBm
Tx Values (Link 1 (RLAN Indoor Urban) [ILT]: ILT 3635)		
Position	(19.944, -0.012)	(km,km)
Antenna height	22.5	m
Terrain height	0,000E+00	m
Antenna Azimuth angle	208.273	degree
Antenna Azimuth pointing (global)	164.168	degree
Azimuth boresight (global)	164.168	degree
Antenna Elevation angle	17.055	degree
Antenna Elevation pointing (global)	0,000E+00	degree
Elevation boresight (global)	0,000E+00	degree
Gain	0,000E+00	dBi
Building entry loss	5.842	dB
Additional loss	0,000E+00	dB
Rx Values (FS [VLR]: VLR)		
Position	(20.0, 0.0)	(km,km)
Antenna height	40.0	m
Terrain height	0,000E+00	m
Antenna Azimuth angle	12.441	degree
Antenna Azimuth pointing (global)	180.0	degree
Azimuth boresight (global)	180.0	degree
Antenna Elevation angle	-17.055	degree
Antenna Elevation pointing (global)	0,000E+00	degree
Elevation boresight (global)	0,000E+00	degree
Gain	-3.631	dBi
Additional loss	1.3	dB

Figure 86: Parameter of the WAS/RLAN causing high I/N occurrences in topology #8 (Scenario B) for time-event #77990

Name	Value	Unit
Link Details		
Frequency	6775.0	MHz
Distance	0.099	km
Tx-Rx azimuth (global)	2.618	degree
Tx-Rx elevation (global)	10.065	degree
TX power	15.0	dBm
Path loss	89.715	dB
Effective path loss	87.012	dB
ILT Power in VLR Bandwidth	15.0	dBm
Minimum coupling loss	0,000E+00	dB
iRSS Unwanted	-72.012	dBm
iRSS Blocking	-1072.012	dBm
Tx Values (Link 1 (RLAN Indoor Urban) [ILT]: ILT 16989)		
Position	(19.902, -0.005)	(km,km)
Antenna height	22.5	m
Terrain height	0,000E+00	m
Antenna Azimuth angle	192.216	degree
Antenna Azimuth pointing (global)	170.403	degree
Azimuth boresight (global)	170.403	degree
Antenna Elevation angle	10.065	degree
Antenna Elevation pointing (global)	0,000E+00	degree
Elevation boresight (global)	0,000E+00	degree
Gain	0,000E+00	dBi
Building entry loss	6.695	dB
Additional loss	0,000E+00	dB
Rx Values (FS [VLR]: VLR)		
Position	(20.0, 0.0)	(km,km)
Antenna height	40.0	m
Terrain height	0,000E+00	m
Antenna Azimuth angle	2.618	degree
Antenna Azimuth pointing (global)	180.0	degree
Azimuth boresight (global)	180.0	degree
Antenna Elevation angle	-10.065	degree
Antenna Elevation pointing (global)	0,000E+00	degree
Elevation boresight (global)	0,000E+00	degree
Gain	4.003	dBi
Additional loss	1.3	dB

Figure 87: Parameter of the WAS/RLAN causing high I/N occurrences in topology #158 (Scenario B) for time-event #72348

A5.7 CONCLUSION

This site-general study involves an FS link receiver deployed in the middle of a simulation zone where population density is about 5400 inhabitants/km^2. This value is among the highest that can be found in CEPT countries.

Several assumptions were investigated and in almost all cases, WAS/RLAN respect both long-term and FDP criteria (assuming the first Fresnel zone being cleared). It is only when assuming the highest deployment of Scenario B (high market adoption of the WAS/RLAN in the upper 6 GHz) coupled with a low FS fade margin and a low FS peak antenna gain that the FDP criterion could be exceeded by few percent, while in the very vast majority of the studied cases, the FDP is well below the 10% threshold resulting in a feasible FS link operation in presence of WAS/RLAN.

A location and time analysis showed that topologies having a combination of many factors where a WAS/RLAN was in close vicinity of the FS receiver (main beam), and with a (relative) high height compared to the FS receiver height, and with a high transmit power seen by the FS receiver, and with a low building entry loss may cause the FDP criteria to be exceeded when the FS fade margin is low. This site general study of a densely populated city centre showed that the likelihood of exceeding the FDP criterion is highly dependent upon having all those conditions being fulfilled and is low even for a link with a limited fade margin (3% for Scenario A and 5.5% for Scenario B for fade margin of 13 dB) and is highly site-specific.

ANNEX 6: SHARING WITH THE FIXED SERVICE – SITE-SPECIFIC STUDY

A6.1 BACKGROUND

This analysis presents WAS/RLAN sharing studies with the point-to-point Fixed Service (FS) in the "Upper 6 GHz band" (i.e. 6425-7125 MHz). This analysis extends the sharing and compatibility studies performed in ECC Reports 302 and 316 between WAS/RLAN systems and existing incumbent systems in 5925-6425 MHz to the Upper 6 GHz band.

The studies attempt to quantify and qualify the risk of exceeding the long-term and Fractional Degradation in Performance (FDP) protection criteria.

Section A6.2 presents the WAS/RLAN assumption used in this study, which aligns with the agreed parameters. This includes the parametric inputs, parameters and distributions, which are detailed in ECC Report 302 and 316, taking into account models of year 2030 for WAS/RLAN deployments and an additional consideration for WAS/RLAN antenna height distribution.

Section A6.3 presents the FS sharing study methodology and results. This study follows the methodology from ECC Report 302's "Study B Monte Carlo analysis" using representative FS links from: the UK, France, Lithuania and the Czech Republic.

A6.2 TECHNICAL CHARACTERISTICS OF WAS/RLAN IN THE UPPER 6 GHZ FREQUENCY RANGE

The WAS/RLANs were modelled as follows.

A6.2.1 Transmitter Radiated Power

The *e.i.r.p.* distribution was derived using the agreed normalised antenna gain distribution and the mix of WAS/RLAN devices, according to Table 40. The resulting overall distribution is summarised in Table 41 for indoor and outdoor WAS/RLANs.

A6.2.2 WAS/RLAN antenna heights

A6.2.2.1 Links situated in Czech Republic, Lithuania and France

For the links situated in the Czech Republic, Lithuania and France , the WAS/RLAN heights distribution is the one from ECC Report 316 and ECC Report 302.

- The indoor WAS/RLAN heights are set based on the indoor height distribution from ECC Report 316 Table 18 (in Annex 3). This is shown in Table 99 where the distribution from ECC Report 316 (per household size) is converted to Urban and Suburban, by assuming cities with more than 25000 households are Urban and the remaining cities are Suburban. ECC Report 316 already provided the height distribution for Rural which is used here as is.
- For the outdoor WAS/RLANs, the outdoor height distribution from ECC Report 302 Table 10 is used,
- The overall WAS/RLAN height distribution is replicated in Table 99.

A6.2.2.2 FS receivers situated in the UK

This analysis considered seven links extracted from the UK fixed links database. For six of the links studied, both ends of the link were in the UK territory, while for one of the links studied, the receiver end was in the French territory (see section A6.3.1).

For the six FS receivers in the UK, the indoor and outdoor WAS/RLAN heights are assigned as follows:

- Within approximately 2 km of each FS receiver, the indoor WAS/RLANs are dropped within the buildings per the UK building database [39] (see Figure 88) and outdoor WAS/RLANs are dropped outside of the buildings. Per the simulated region, building heights varied from 1 floor (1.5 m) to 33 floors (97.5 m). Furthermore, 5% of all outdoor RLANs continue to be dropped over the buildings, which could represent outdoor usage on balconies, roofs, etc. As such, for these indoor and outdoor WAS/RLANs, the height is set based on the height of the building it is dropped on, where the RLAN height is selected randomly between 1.5 m and the building height in steps of 3 m with equal probability. The height of the remaining outdoor WAS/RLANs is set to 1.5 m;

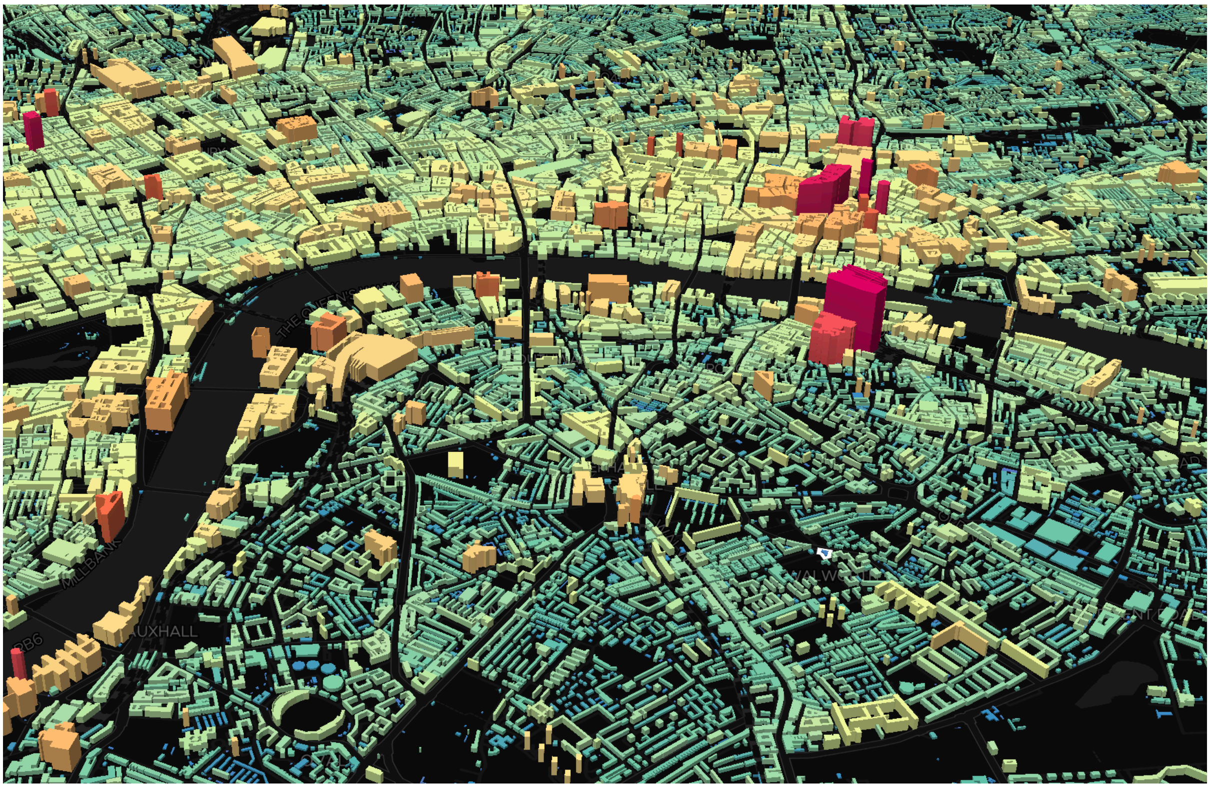


Figure 88: Example of buildings height in 3D near London area

- For the indoor WAS/RLANs greater than 2 km distance of any of the six FS receivers located in the UK, the indoor height distribution derived from the UK building database over the simulation region is used (see Table 99). Similarly, for the remaining outdoor WAS/RLANs, the outdoor height distribution from ECC Report 302, table 10 is used, as replicated in Table 99.

Table 99: WAS/RLAN indoor height distribution derived from the UK building database

Building Story	**Height (m)**	Urban Indoor	Suburban Indoor	Rural Indoor
1	1.5	68.06%	81.13%	99.99953%
2	4.5	29.65%	18.13%	0.00033%
3	7.5	1.82%	0.64%	0.00014%
4	10.5	0.32%	0.06%	0%
5	13.5	0.09%	0.02%	0%
6	16.5	0.03%	0.01%	0%
7	19.5	0.01%	0.003%	0%
8	22.5	0.006%	0.002%	0%

Building Story	Height (m)	Urban Indoor	Suburban Indoor	Rural Indoor
9	25.5	0.003%	0.001%	0%
10	28.5	0.017%	0.005%	0%
Total		100%	100%	100%

For the one FS receiver in France (FS ID 5 in Table 104), the indoor and outdoor WAS/RLAN heights are assigned as per Table 3 above.

A6.2.3 Operating frequency

Figure 89 shows the WAS/RLAN channel set from IEEE 802.11be D5.0 [47] given in Table 100, starting at 6425 MHz.

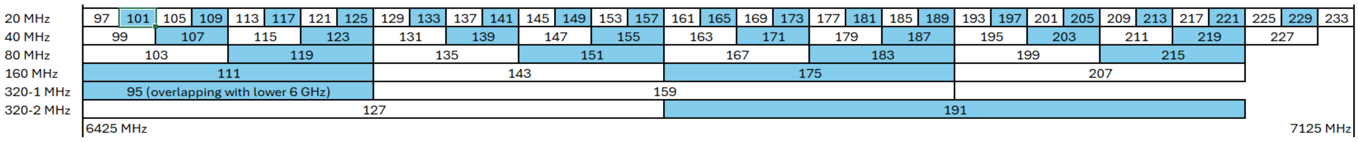


Figure 89: WAS/RLAN channel plan in the Upper 6 GHz Band (IEEE 802.11be D5.0 [47])

Table 100: Channel set

Channel Bandwidth	# of channels	Channel set
20 MHz	35	97, 101, 105, 109, 113, 117, 121, 125, 129, 133, 137, 141, 145, 149, 153, 157, 161, 165, 169, 173, 177, 181, 185, 189, 193, 197, 201, 205, 209, 213, 217, 221, 225, 229, 233
40 MHz	17	99, 107, 115, 123, 131, 139, 147, 155, 163, 171, 179, 187, 195, 203, 211, 219, 227
80 MHz	8	103, 119, 135, 151, 167, 183, 199, 215
160 MHz	4	111, 143, 175, 207
320 MHz	2	95 (overlapping with lower 6 GHz), 159, 127, 191

A6.2.4 Bandwidth

The bandwidth distribution is per Table 101 below, where 320 MHz bandwidth has been introduced to the distributions used in ECC Report 302.

Table 101: Bandwidth distribution

Channel Bandwidth	20 MHz	40 MHz	80 MHz	160 MHz	320 MHz
WAS/RLAN device percentage	10%	5%	30%	35%	20%

A6.2.5 Number of Instantaneously transmitting devices

Table 102 and Table 103 summarise the WAS/RLAN deployment model and specify the total number of instantaneously transmitting devices within the CEPT countries during the busy hours. The UN projected population of CEPT in 2030 including 'all ages' and 'ages 10 to 90 years old' are considered as indicated in Table 102 and Table 103 respectively. Each table includes parametric inputs (Low, Mid and High) for the busy hour factor and the market adoption factor. Therefore, Low, Mid and High values of instantaneously transmitting devices are given for each scenario.

Two sets of simulations are run, one assuming a population of 'all ages' and another sensitivity analysis assuming a population of 'ages 10 to 90'.

In each simulation iteration, the instantaneously transmitting devices are dropped in proportion to the population density based on the 30 arcsecond Gridded Population of the Word database along with a few other considerations, such as indoor and outdoor WAS/RLAN placement over buildings within 2 km of any FS receiver in the UK and no WAS/RLAN placement over water, as detailed in section A6.3.3.

Table 102: Summary of the WAS/RLAN deployment model (all ages)

	Low	Mid	High
Total UN projected Population of CEPT 2030 (all ages)	688 447 000		
Wireless devices operating in licence exempt spectrum (remainder operating in licensed spectrum)	90%		
Busy Hour Factor	50%	62.70%	62.70%
Upper 6 GHz Factor (Upper 6 GHz / (Upper 6 GHz + 5 GHz + 2.4 GHz)) (%)	40.75%		
Market Adoption Factor (6 GHz capable devices)	25%	32%	50%
RF Activity Factor Per Person	1.97%		
Instantaneously Transmitting Devices	621752	997986	1559353

Table 103: Summary of the WAS/RLAN sensitivity analysis deployment model (ages 10 to 90 years old)

	Low	Mid	High
Total UN projected Population of CEPT 2030 (ages 10 to 90 year old)	609 503 000		
Wireless devices operating in licence exempt spectrum (remainder operating in licensed spectrum)	90%		
Busy Hour Factor	50%	62.70%	62.70%
6 GHz Factor (Upper 6 GHz / (Upper 6 GHz + 5 GHz + 2.4 GHz)) (%)	40.75%		
Market Adoption Factor (6 GHz capable devices)	25%	32%	50%
RF Activity Factor Per Person	1.97%		
Instantaneously Transmitting Devices	550455	883547	1380542

A6.2.6 Assignment of populations to urban, suburban and rural environments

As in ECC Report 302, the total population of CEPT has been assigned to urban, suburban and rural environments as follows:

- Urban: 50%;
- Suburban: 27%;
- Rural 23%.

A6.2.7 Indoor vs Outdoor

The WAS/RLANs indoor/outdoor ratio is assumed to be:

- Indoor: 98.79%;
- Outdoor: 1.21%.

As in ECC Report 302, for indoor WAS/RLAN usage, Recommendation ITU-R P.2109 building entry loss is applied assuming 70% traditional buildings, and 30% thermally efficient buildings. The simulation samples the Recommendation ITU-R P.2109 distribution uniformly between 1% and 99% as it is the range of probability where the model has been validated against empirical data.

A6.3 FS SHARING METHODOLOGY

A6.3.1 FS Parameters

Using the latest administration database[15], fixed service links in the Upper 6 GHz band were extracted. Next, in order to select a few representative links to do the study for, the following was done:

- When the receiver antenna gains were available, links with a receiver antenna gain of less than 34.4 dBi were removed to match the lowest gain analysed in the UK's 2020 study [44];
- Choose the links that were either selected in the UK's 2020 study or had similar topology (e.g. both transmitter and receiver being in urban area, high antenna gains) as those selected in the UK's 2020 study.

For Czech Republic's and French links only the second criterion from above applied (i.e. receiver in densely populated areas).This resulted in a number of links with the link parameters in Table 104-Table 107 that were used in the I/N calculations.

Table 104: UK FS link transmitter and receiver locations and parameters

FS ID	Licence Number	FS Tx Latitude Longitude	FS Rx Latitude Longitude	Centre Frequency (MHz)	Bandwidth (MHz)	FS Tx AGL Height (m)	FS Rx AGL Height (m)	FS Rx Peak Antenna Gain (dBi)	FS Rx Feeder Loss (dB)
1	1218912/3	50° 50' 35.63372" N 1° 4' 8.52762" W	50° 40' 36.39525'' N 1° 22' 13.3606" W	6685	60	23	55	39.7	8.8

15 Ofcom database was downloaded from https://www.ofcom.org.uk/spectrum/information/spectrum-information-system-sis/spectrum-information-portal on 17-April-2023 Republic, the data were consulted in cooperation with Czech Telecommunication Office, which operates internal database of frequency assignment, on June 2024. For France, the following link was used https://carte-fh.lafibre.info/ on June 2024. For Lithuania, data was consulted on May 2023 in cooperation with the administration.

FS ID	Licence Number	FS Tx Latitude Longitude	FS Rx Latitude Longitude	Centre Frequency (MHz)	Bandwidth (MHz)	FS Tx AGL Height (m)	FS Rx AGL Height (m)	FS Rx Peak Antenna Gain (dBi)	FS Rx Feeder Loss (dB)
2	1218912/3	50° 40' 36.39525" N 1° 22' 13.3606" W	50° 50' 35.63372" N 1° 4' 8.52762" W	7025	60	55	23	39.7	2.2
3	1118962/1	51° 35' 9.57852" N 0° 28' 30.33169" E	51° 32' 5.82649" N 0° 0' 23.8075" W	6460	30	20	138	35	0.5
4	1118962/1	51° 32' 5.82649" N 0° 0' 23.8075" W	51° 35' 9.57852" N 0° 28' 30.33169" E	6800	30	138	20	35	0.5
5	1266190/1	51° 20' 28.50676" N 1° 23' 27.51076" E	51° 2' 30.98892" N 2° 16' 40.40006" E	6800	40	77	85	39.5	0.38
6	1041404/1	51° 27' 5.75597" N 0° 2' 57.0038" E	51° 29' 21.02343" N 0° 17' 50.03528" W	6610	30	32	70	39.6	0.5
7	1041404/1	51° 29' 21.02343" N 0° 17' 50.03528" W	51° 27' 5.75597" N 0° 2' 57.0038" E	6950	30	70	32	39.6	0.5

Table 105: France FS link transmitter and receiver locations and parameters[16]

FS ID	FS Tx Latitude Longitude	FS Rx Latitude Longitude	FS Tx AGL Height (m)	FS Rx AGL Height (m)	FS Rx Peak Antenna Gain (dBi)
1	48.80502° N 2.533139° E	48.885513° N 2.422432° E	96	103	34.77
2	48.885513° N 2.422432° E	48.80502° N 2.533139° E	103	96	34.77
3	49.029807° N 2.753452° E	48.916162° N 2.415722° E	41.7	45.5	42.38
4	45.747017° N 4.97979° E	45.764023° N 4.822339° E	77	43	39.88
5	45.764023° N 4.822339° E	45.747017° N 4.97979° E	43	77	34.77
6	48.288174° N -1.959124° E	48.108287° N -1.672523° E	56	55	36.36

Table 106: Lithuania FS link transmitter and receiver locations and parameters

FS ID	FS Tx Latitude Longitude	FS Rx Latitude Longitude	Centre Frequency (MHz)	Bandwidth (MHz)	FS Tx AGL Height (m)	FS Rx AGL Height (m)	FS Rx Peak Antenna Gain (dBi)
1	55° 54' 28.05" N 24° 20' 09.41" E	55° 44' 04.1" N 24° 21' 30" E	6480	56	50	46	35
2	55° 32' 32.63" N 24° 04' 31.23" E	55° 44' 04.1" N 24° 21' 30" E	6480	56	60	44	35
3	56° 08' 32.17" N 23° 12' 36.32" E	55° 56' 05.3" N 23° 19' 00.2" E	6460	40	70	29.5	35
4	55° 59' 25.13" N 23° 38' 41.82" E	55° 56' 05.3" N 23° 19' 00.2" E	6460	40	72	29.5	35
5	55° 22' 03.8" N 25° 47' 59.5" E	55° 20' 16.52" N	6840	40	45	46	35

[16] The RX part is supposed to be the part situated in the most populated area as a worst-case study

FS ID	FS Tx Latitude Longitude	FS Rx Latitude Longitude	Centre Frequency (MHz)	Bandwidth (MHz)	FS Tx AGL Height (m)	FS Rx AGL Height (m)	FS Rx Peak Antenna Gain (dBi)
		26° 10' 33.06" E					
6	54° 45' 49.9" N 25° 22' 21.9" E	54° 43' 46.2" N 25° 14' 47.3" E	6480	56	40	54	32.8
7	54° 31' 11.4" N 25° 19' 21.2" E	54° 39' 39.5" N 25° 16' 47.1" E	6480	56	55	40	32.8

Table 107: Czech Republic FS link transmitter and receiver locations and parameters

FS ID	FS Tx Latitude Longitude	FS Rx Latitude Longitude	Bandwidth (MHz)	FS Tx AGL Height (m)	FS Rx AGL Height (m)
1	49.82277778° 13.67027778°	50.08° 14.37583333°	40	30	52
2	49.19888889° 16.57972222°	49.20083° 17.12138889°	40	17	30
3	49.86111° 18.21444444°	49.62778° 18.62722222°	40	52	33
4	48.86722° 14.28138889°	48.99917° 14.48138889°	40	44	37
5	49.46194° 12.91583333°	49.7775° 13.35361111°	40	25	22
6	50.38806° 14.93111111°	50.05583° 14.37944444°	80	12	117

Notes:

- For all FS Rx antennas in the simulation, Recommendation ITU-R F.1245 is used for the antenna pattern.
- For the French FS:
  - In the absence of the FS links' centre frequency and channel bandwidth, centre frequency is set to the middle of the Upper 6 GHz band (i.e. 6775 MHz) and the channel bandwidth is set to 40 MHz for all the 6 FS links;
  - Furthermore, the FS Rx peak antenna gains (G_{max}) are derived from the FS Rx antenna diameter (D) in the national database and frequency of 6775 MHz ($\lambda = 0.044\ meters$) per Recommendation ITU-R F.1245 using the following formula:

$$G_{max} \approx 20\log_{10}\left(\frac{D}{\lambda}\right) + 7.7$$

- For the Czech Republic FS, in the absence of FS receiver antenna peak gain in the Czech Republic database, the mode value of 38 dBi from ECC Report 302, table 18 (adopted from Recommendations ITU-R F.758) on FS link characteristics in the Upper 6 GHz band is chosen;
- For France, Lithuania and the Czech Republic, in the absence of data related to the FS noise figure, a generic value of 4.5 dB was selected using the minimum value from ECC Report 302, table 18 which is

from Recommendation ITU-R F.758. Also, in the absence of feeder loss value, the generic value of 1.3 dB was used based on Table 8.

A6.3.2 Propagation models

Table 108 summarises the propagation models used for the FS simulation, as per ECC Report 302.

Table 108: Summary of propagation models for FS study

Scenario	Propagation Model for RLANs in Urban/Suburban	Propagation Model for RLANs in Rural
Distance < 40 m	Free Space Path Loss (FSPL)	
40 m ≤ Distance < 1 km	WINNER II LOS/NLOS For WAS/RLAN in Urban and Suburban, C2 and C1 WINNER II models are used respectively.	Recommendation ITU-R P.452-17 (3 arcsecond SRTM terrain database [14]) + Recommendation ITU-R P.452-17 Clutter Loss (if the distance and angle conditions are met) Recommendation ITU-R P.452-17 Clutter Loss Category: ▪ Deciduous Tree, Mixed-Tree Forest or Coniferous Tree if the European Environment Agency's Corine Land Cover (CLC)[17] indicates as such ▪ Else, Village Center Clutter
Distance ≥ 1 km	Recommendation ITU-R P.452-17 (3arcsecond SRTM terrain database) + Recommendation ITU-R P.2108-0 Clutter Loss	

As discussed in Report 302, WINNER II LOS probabilities are implemented using the following pseudocode:

1 Place each WAS/RLAN on Earth randomly according to population density
2 For each WAS/RLAN, calculate the distance to the FS: d
3 For each WAS/RLAN, calculate probability of LOS, p_{LOS}, which is a function of distance d and the environment (WAS/RLAN can be in Urban, Suburban or Rural environment)
4 For each WAS/RLAN, generate a random number r = rand(1) with a uniform distribution over the interval [0, 1]
    if r < p_{LOS}: calculate transmission loss using LOS equation
    else: calculate transmission loss using NLOS equation
5 repeat for all FSs

For WAS/RLANs above 10 m, the probability of a WINNER II LOS path is set to one, as it was done in ECC Report 302.

A6.3.3 Methodology

The studies in this Report are based on Monte Carlo simulation methodology similar to Study B in ECC Report 302, where the interference distribution to each FS receiver is derived.

The Monte Carlo study was carried out on FS links (as identified in section A6.3.1) to determine the aggregate I/N at each FS receive location.

This interference environment was modelled for each WAS/RLAN deployment iteration by randomly distributing active WAS/RLANs using the probability distribution for population density and building database

[17] Used the latest version of this database as of May 2023, U2018_CLC2012_V2020_20u1.tif.

(for UK only) and other relevant parameters such as centre frequency, bandwidth, *e.i.r.p.* and height. Each WAS/RLAN deployment iteration was assumed to be independent.

Five million independent WAS/RLAN deployments were simulated for each FS station to derive statistics to determine whether:

- The FS long-term protection criterion of I/N = -10 dB not being exceeded for more than 20% of the time due to the operation of WAS/RLANs was met (per Recommendation ITU-R F.758);
- The FS FDP criterion of less than 10% due to the operation of WAS/RLANs was met.

For the fixed links, the I/N is aggregated over all co-channel WAS/RLANs within 150 km of the FS receiver.

A6.3.4 Step by step simulation methodology

Interference from WAS/RLAN deployments into FS receivers is analysed using a Monte Carlo simulation. The simulation has the following structure:

1 Define RLAN drop methodology
  1.1. The RLAN drop methodology utilises Gridded Population of the World (GPW)[18] data as well as building database (for UK only) in the vicinity of FS receivers to set random RLAN locations (longitude, latitude, and height) in each iteration of the Monte Carlo simulation. The RLAN drop methodology is a key component in the simulation and is described in detail below.

2 Data setup:
  2.1. Put the FS Transmitters (Tx) and FS Receivers (Rx) link information into a database;
  2.2. Set up the RLAN drop probability distributions as described in the detailed description of RLAN Drop Methodology below.

3 Monte Carlo iterations:
  3.1. Generate a random layout of WAS/RLANs using the device population probability distribution;
  3.2. Generate the transmission loss, clutter loss, and building loss values between each WAS/RLAN and FS Rx in accordance with the propagation modelling set out in section A6.3.2;
  3.3. Using the FS Rx antenna pattern, feeder loss, bandwidth and noise figure, compute the aggregate WAS/RLAN I/N at each FS Rx.

4 Iterate:
  4.1. Repeat step 2 for the total specified number of iterations. Record I/N values for each FS Rx on each iteration and write results to a file.

5 Use the recorded aggregate I/N values to create the I/N Complementary Cumulative Distribution Function (CCDF).

Steps 1, 2 and 3 above are further elaborated below.

Step 1 Define RLAN Drop Methodology:

The procedure for determining the distribution for RLAN position (longitude, latitude, height) is as follows.

1 World population raster data with a resolution of 30 arcsec which is about 900 metres is read.

2 Regions are classified as Urban/Suburban/Rural based on the population density thresholds. Population density thresholds are calculated so that the percentages of Urban/Suburban/Rural population over the simulation region matches the target values of 50% Urban, 27% Suburban, 23% Rural (per A6.2.6).

3 Each 30 arcsec x 30 arcsec grid region in the simulation region is assigned a probability equal to the population in that grid region divided by the total population in the simulation region. In this way, all 30 arcsec x 30 arcsec regions in the simulation region have a discrete probability distribution and the sum of all these probabilities is 1.

4 A random 30 arcsec x 30 arcsec grid region is selected using the discrete distribution derived in step 4 above. The corresponding ENVIRONMENT_TYPE (Urban/Suburban/Rural) is determined.

5 The RLAN is considered to be Outdoor/Indoor using the discrete distribution:

[18] gpw_v4_population_density_rev11_2020_30_sec.tif is used.

Prob(Indoor) = 0.9879

Prob(Outdoor) =0.0121

The RLAN height is then determined by using the corresponding distribution for Indoor/Outdoor with the corresponding ENVIRONMENT_TYPE (per Table 3). The RLAN longitude/latitude coordinates are determined by selecting a position uniformly distributed over the 30 arcsec x 30 arcsec grid region.

For the UK study, as mentioned above, in the first 2 km radius region around the FS receiver, the real building database is read. Note that the building database contains building height for each sample point with a resolution of about 1 metre. Thus, any RLANs dropped in the first 2 km, is assigned to a real position and height. The following applies:

- If the grid region selected in Step 5 is covered by the building database, a sub-grid of building database with (1/30) arcsec resolution over the 30 arcsec x 30 arcsec region is considered. Note that this sub-grid contains 900x900 = 810000 points. Each of these points is classified as to whether or not there is a building at that location using the building database. Of these 810000 points, the total number where there is a building is counted. Let NB = number of points where there is a building, NN = number of points where there is no building. Note that NB + NN = 810000.
- Probabilities for Indoor/Outdoor/OutdoorBldg are defined as

  PIN = Prob(Indoor) = 0.9879

  POUT = Prob(Outdoor) = 0.0121 · 0.95 = 0.011495

  POUTBLDG = Prob(OutdoorBldg) = 0.0121 · 0.05 = 0.000605
- Each of the 810000 points is assigned a probability. Points for which there is no building are assigned a probability POUT/NN. Points for which there is a building are assigned a probability (PIN+POUTBLDG) · h/SH, where h is the building height at the point, and SH is the sum of building heights over all points where there is a building.
- A single point is selected using the distribution defined in the previous step. If the point has no building, it is considered to be Outdoor and assigned a height of 1.5 metres (per section A6.2.2). If the point has a building, it is considered to be either Indoor with probability PIN/(PIN+POUTBLDG) or Outdoor with probability POUTBLDG/(PIN+POUTBLDG). The height is then selected randomly between 1.5 m and the building height in steps of 3 m with equal probability.

Step 2 Data Setup:

The data setup portion of the simulation encompasses reading FS data into the simulation, defining corresponding Recommendation ITU-R F.1245 antenna patterns for each FS receiver, defining *e.i.r.p.* distributions used for RLAN devices, specifying parameters for transmission loss models, as well as other link budget parameters.

Gridded population of the world (GPW) data is utilised and contains population density values on a 30 arcsecond grid in longitude and latitude coordinates as described in the previous step. In addition, a polygon encompassing all the CEPT countries is utilised which defines the simulation region.

Step 3 Monte Carlo iterations:

For each iteration, a random layout of active WAS/RLAN devices generates one WAS/RLAN at a time, using the methodology described in Step 1) above.

Each WAS/RLAN is assigned a random bandwidth using a discrete probability distribution, as in Table 101, and a random centre frequency by selecting a channel for the corresponding bandwidth, as shown in Table 100. The centre frequency is generated by considering all possible centre frequencies for the selected bandwidth and using a uniform distribution.

For each FS in the simulation, interference from all WAS/RLANs is computed and aggregated. If the distance from a WAS/RLAN to the FS Rx is larger than 150 km, the WAS/RLAN is assumed to contribute no interference to the FS Rx.

Next, the FS Tx and FS Rx locations are used with the WAS/RLAN position to determine if the WAS/RLAN is inside the FS link's first Fresnel zone. If the WAS/RLAN is, in fact, inside the FS's first Fresnel zone, it is ignored in the interference calculation. This is assumed to be an unlikely interference path and a poor FS link design since the FS link does not have first Fresnel zone clearance.

The WAS/RLAN bandwidth and centre frequency, along with the FS Rx bandwidth and centre frequency, are used to compute the fraction of the WAS/RLAN bandwidth that overlaps with the FX Rx bandwidth. If there is no overlap, the WAS/RLAN is ignored in the interference calculation.

To visualise the impact of those factors and the placement of WAS/RLANs within 150 km of FS, section A6.4.1 below provides more detail.

In the implementation of Recommendation ITU-R P.452-17, time percentages (p) between 0% and 100% are generated randomly, and time percentages greater than 50% are set to 50%. A random building entry loss is computed using Recommendation ITU-R P.2109-0 and the building type and elevation angle from the WAS/RLAN to the FS Rx. Random transmission loss and clutter loss values are generated using the specified transmission loss/clutter loss simulation models in section A6.3.2.

A fixed polarisation loss value of 3 dB is applied.

The FS Rx antenna angle off boresight in the direction of the WAS/RLAN is calculated considering the location of the FS Rx, FS Tx and the WAS/RLAN Location. This angle and the gain vs angle off boresight equations in Recommendation ITU-R F.1245 are then used to interpolate the FS Rx antenna gain in the direction of the WAS/RLAN.

The interference power at the FS Rx is computed by appropriately summing WAS/RLAN *e.i.r.p.*, building entry loss, transmission loss, clutter loss, polarisation loss, FS Rx gain in the direction of each WAS/RLAN, FS Rx feeder loss and spectral overlap loss. This interference is aggregated over all WAS/RLANs for each FS Rx in the simulation. The aggregate I/N is the ratio of the aggregate interference power and the receiver noise power. The receiver noise power is calculated, for each FS receiver, using the following equation:

$$N\ (\mathrm{dBW}) = 10\log_{10}(k\,T_0\,B) + NF$$

where:

- N = FS Rx noise power at receiver input (dBW);
- k = Boltzmann's constant = $1.3806488 \cdot 10^{-23}$ (J/K);
- T_0 = 290 K;
- B = FS Rx Bandwidth (Hz);
- NF = FS Rx Noise Figure.

For the UK FS, a Noise Figure = 5 dB is selected in order to achieve close agreement with the Noise levels specified by Ofcom (UK) for planning purposes [18]. In the absence of data for the other administrations, a noise figure of 4.5 dB is used as mentioned in section A6.3.1

The resulting aggregate I/N (dB) is calculated as below:

$$\frac{I}{N}(dB) = 10\log_{10}\left(\sum_{i=1}^{N} 10^{(e.i.r.p_i + G_{\mathrm{FS},i} - L_{\mathrm{b},i} - L_{\mathrm{BEL},i} - L_{\mathrm{pol}} - L_{\mathrm{spectraloverlap},i})/10}\right) - N$$

Where:

- $e.i.r.p._i$ is the *e.i.r.p.* of the i^{th} RLAN in dBW;
- $G_{\mathrm{FS},i}$ represents the Fixed Service station gain towards the i^{th} RLAN in dBi;
- $L_{\mathrm{b},i}$ is the pathloss and clutter loss between the i^{th} RLAN and the FS Rx in dB;
- $L_{\mathrm{BEL},i}$ is the building entry loss in dB (for indoor devices);
- L_{pol} is the polarisation loss of 3 dB;
- $L_{\mathrm{spectraloverlap},i}$ is the spectral overlap loss in dB.

A6.4 FS ANALYSIS RESULTS

A6.4.1 WAS/RLAN deployment model

To visualise the Monte Carlo methodology in the placement of WAS/RLANs within 150 km of an FS receiver, as detailed in section A6.3.3, a single iteration of the Monte Carlo simulation was run considering one link for each administration.

Table 109 shows how the parameters outlined in section A6.2.5 were implemented with respect to this simulation, applied for UK FS 4.

Table 109: Number of active WAS/RLAN devices simulated in a single iteration of UK FS 4 for 'all ages' scenario

Study Population	Instantaneously transmitting devices	Instantaneously transmitting devices in 150 km radius	Instantaneously transmitting devices overlapping FS frequency in 150 km radius
688447000	1559353	56981	4635

Figure 90 shows the location of FS 4 (green dot) on the map to the east of London. It also shows the density of instantaneously transmitting devices that have frequency overlap with FS 4.

Within a 150 km radius of FS 4, 56981 WAS/RLAN devices are expected to be active every instant in time; 4635 of them overlap with the FS's bandwidth of 30 MHz. The city centre has the highest density of blue dots. Each blue dot represents an active WAS/RLAN device falling into the FS band. The blue and red dots represent the indoor and outdoor WAS/RLANs in Figure 90 respectively.

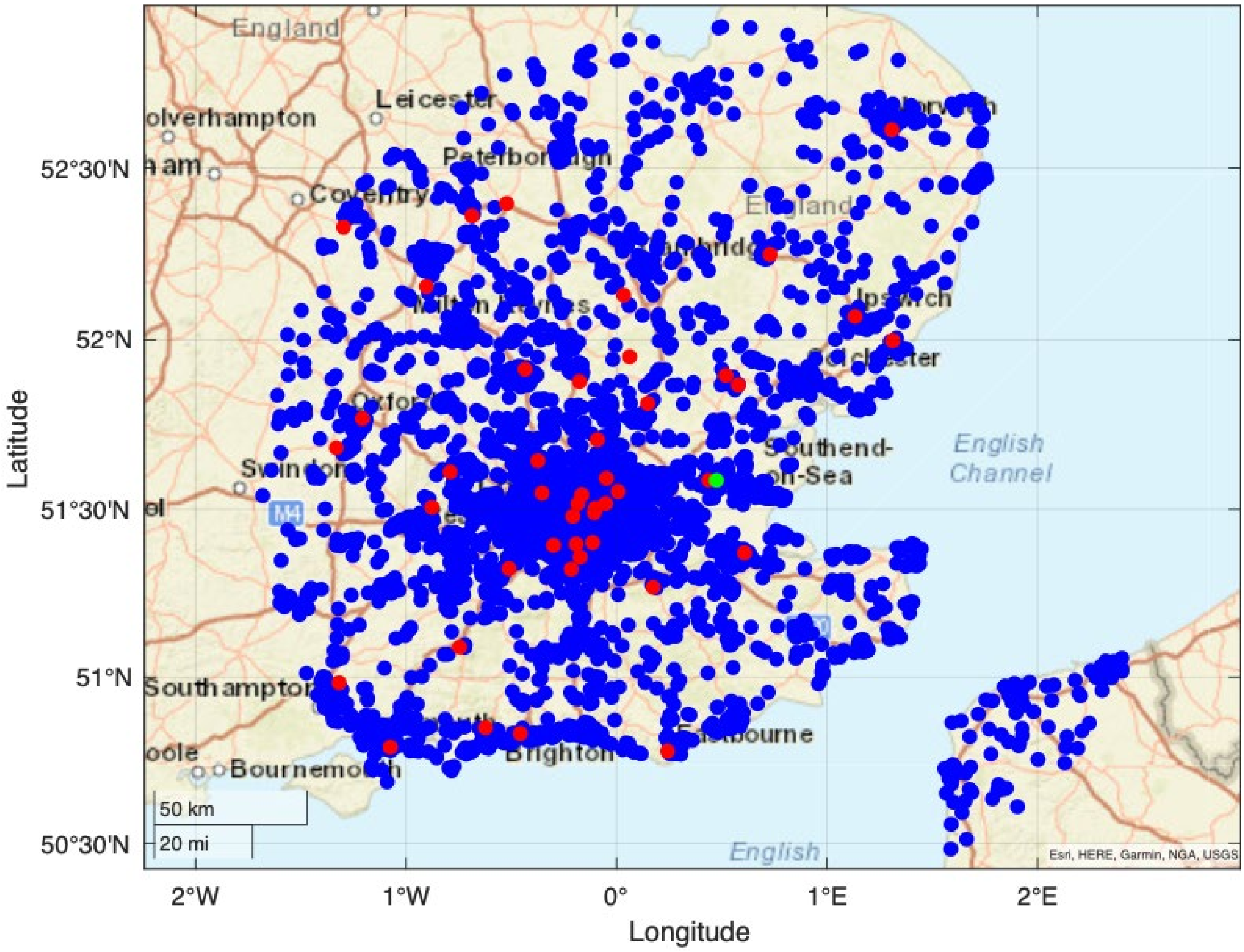


Figure 90: Example of simultaneously transmitting WAS/RLANs with frequency overlap in a 150 km radius from UK FS 4 receiver (one simulation iteration)

Figure 91 shows the location of FS 1 (green dot) on the map to the northeast of Paris. It also shows the density of instantaneously transmitting devices that have frequency overlap with FS 1.

Within a 150 km radius of FS 1, 39717 WAS/RLAN devices are expected to be active every instant in time; 9425 of them overlap with the FS's bandwidth of 40 MHz. The city centre has the highest density of blue dots. Each blue dot represents an active WAS/RLAN device falling into the FS band. The blue and red dots represent the indoor and outdoor WAS/RLANs in Figure 90 respectively.

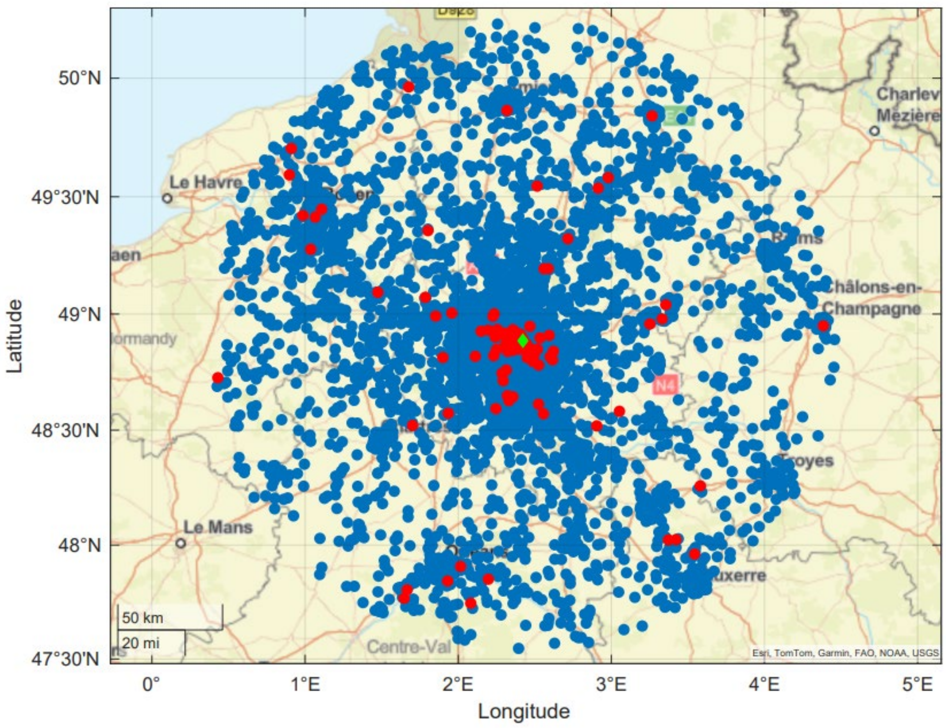


Figure 91: Example of simultaneously transmitting WAS/RLANs with frequency overlap in a 150 km radius from France FS 1 receiver (one simulation iteration)

Figure 92 shows the location of FS 6 (green dot) on the map to the north of Vilnius. It also shows the density of instantaneously transmitting devices that have frequency overlap with FS 6.

Within a 150 km radius of FS 6, 4231 WAS/RLAN devices are expected to be active every instant in time; 1196 of them overlap with the FS's bandwidth of 56 MHz. The city centre has the highest density of blue dots. Each blue dot represents an active WAS/RLAN device falling into the FS band. The blue and red dots represent the indoor and outdoor WAS/RLANs in Figure 90 respectively.

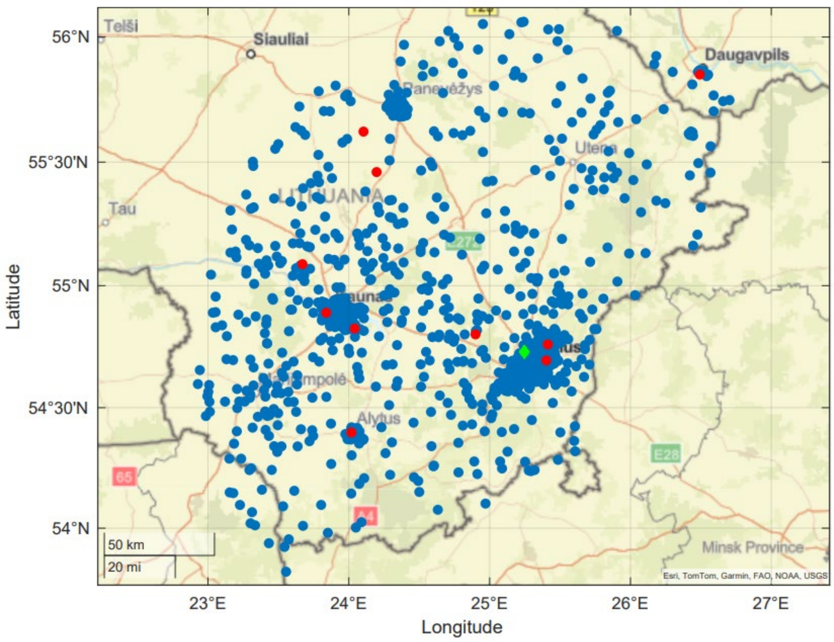


Figure 92: Example of simultaneously transmitting WAS/RLANs with frequency overlap in a 150 km radius from Lithuania FS 6 receiver (one simulation iteration)

Figure 93 shows the location of FS 6 (green dot) on the map to the west of Prague. It also shows the density of instantaneously transmitting devices that have frequency overlap with FS 6.

Within a 150 km radius of FS 6, 21083 WAS/RLAN devices are expected to be active every instant in time; 5914 of them overlap with the FS's bandwidth of 80 MHz. The city centre has the highest density of blue dots. Each blue dot represents an active WAS/RLAN device falling into the FS band. The blue and red dots represent the indoor and outdoor WAS/RLANs in Figure 90 respectively. It has to be noted that no RLANs are deployed in the neighbouring country outside CEPT.

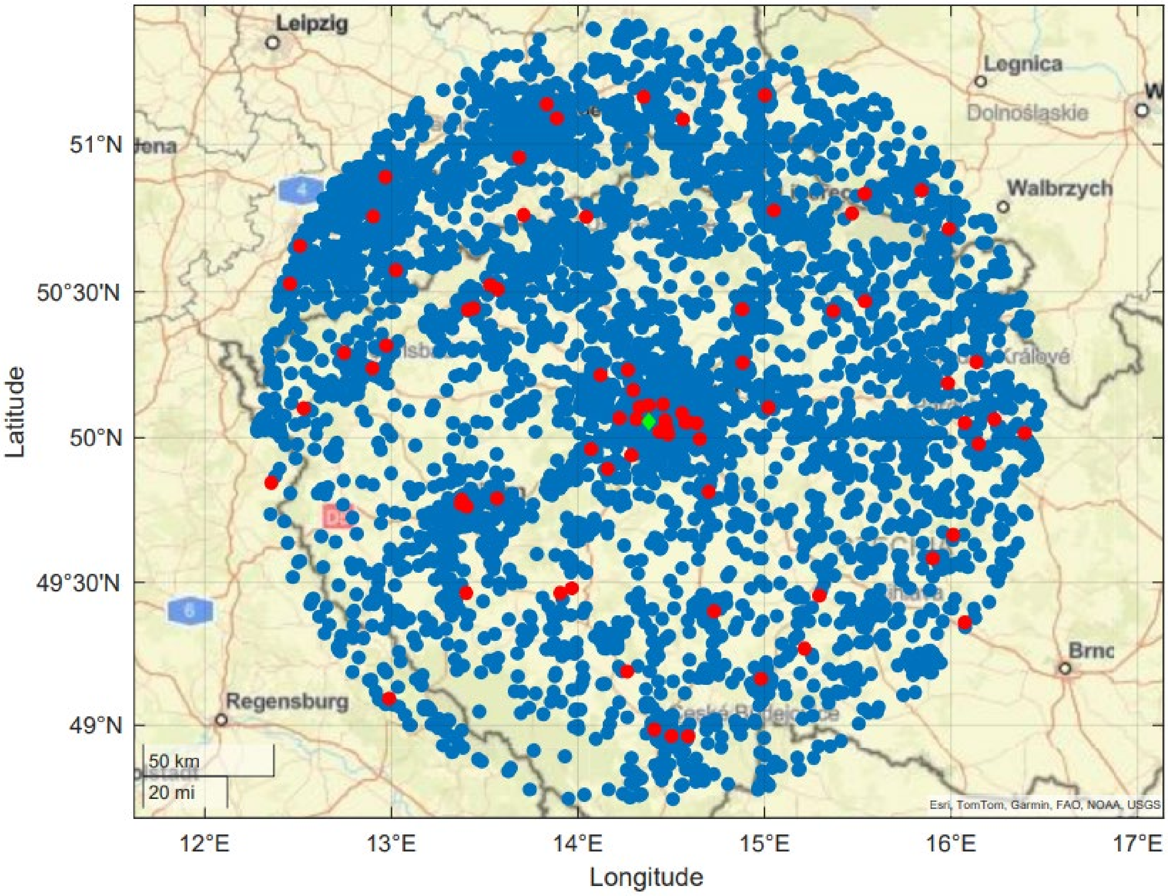


Figure 93: Example of simultaneously transmitting WAS/RLANs with frequency overlap in a 150 km radius from Czech Republic FS 6 receiver (one simulation iteration)

A6.4.2 Long-term Protection Criterion

For each of the administrations, five million iterations of a Monte Carlo simulation were performed to determine the aggregate I/N at each of the FS receive locations. For each iteration, the active WAS/RLANs were deployed randomly in accordance with section A6.2. Two separate runs were done: one using the "High" parameters from Table 102, based on CEPT region 'all-ages' population of 688 447 000, and another using the "High" parameters from Table 103, based on CEPT region 'ages 10 to 90' population of 609 503 000. Together, for each run, these iterations represent 35 000 000 different WAS/RLAN-to-FS interference morphologies in the United Kingdom and Lithuania and 30 000 000 different morphologies in the Czech Republic and France. Each iteration of the simulation models the set of simultaneously transmitting devices in the WAS/RLAN network.

Figure 94 shows the percentage of 5000000 iterations for each of the 7 FS receivers located in the UK where the I/N from all WAS/RLANs (indoor + outdoor) exceeded the I/N level on the x-axis for the 'all ages'. The results indicate that all FS met the long-term protection criterion.

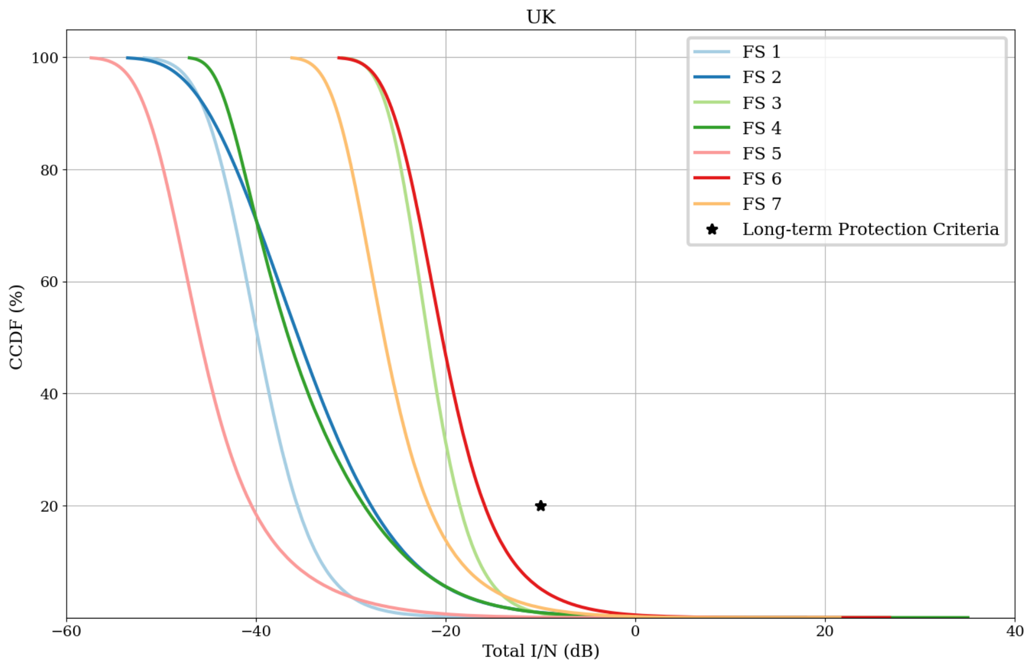


Figure 94: Complementary CDF of total I/N for the ‘all ages’, UK links

Figure 95 shows the percentage of 5000000 iterations for each of the 6 FS receivers located in France where the I/N from all WAS/RLANs (indoor + outdoor) exceeded the I/N level on the x-axis for the ‘all ages’. The results indicate that all FS met the long-term protection criterion.

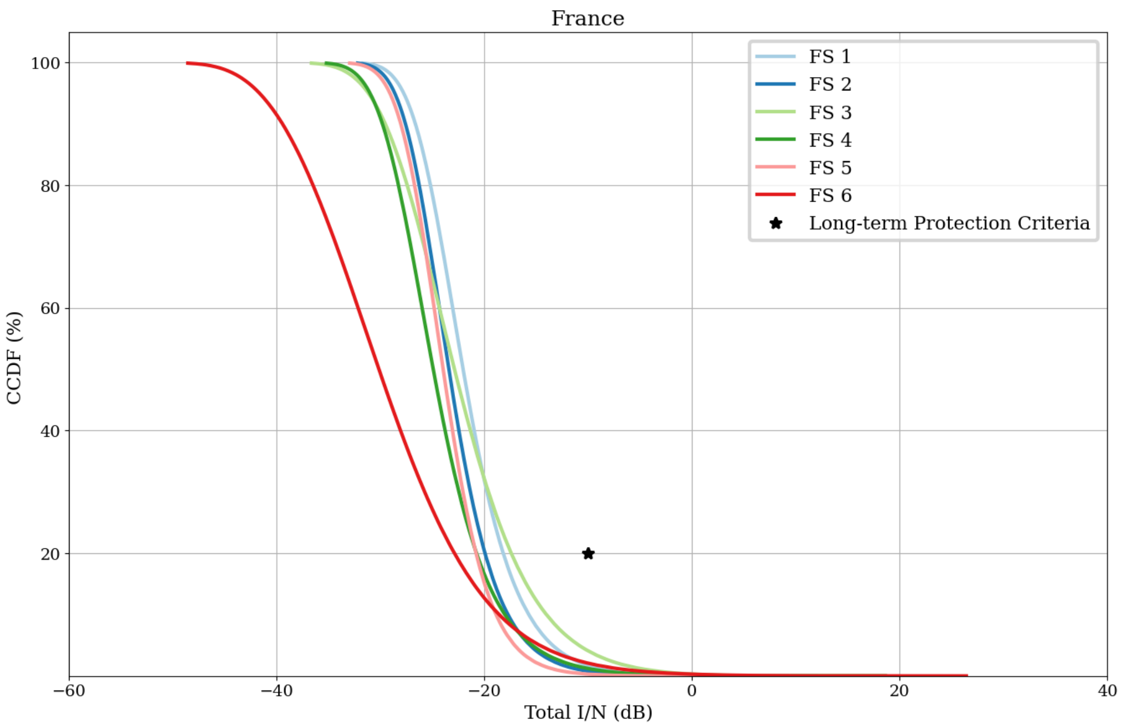


Figure 95: Complementary CDF of total I/N for the ‘all ages’, France links

Figure 96 shows the percentage of 5000000 iterations for each of the 7 FS receivers, situated in Lithuania, where the I/N from all WAS/RLANs (indoor + outdoor) exceeded the I/N level on the x-axis for the ´all ages’. The results indicate that all FS met the long-term protection criterion.

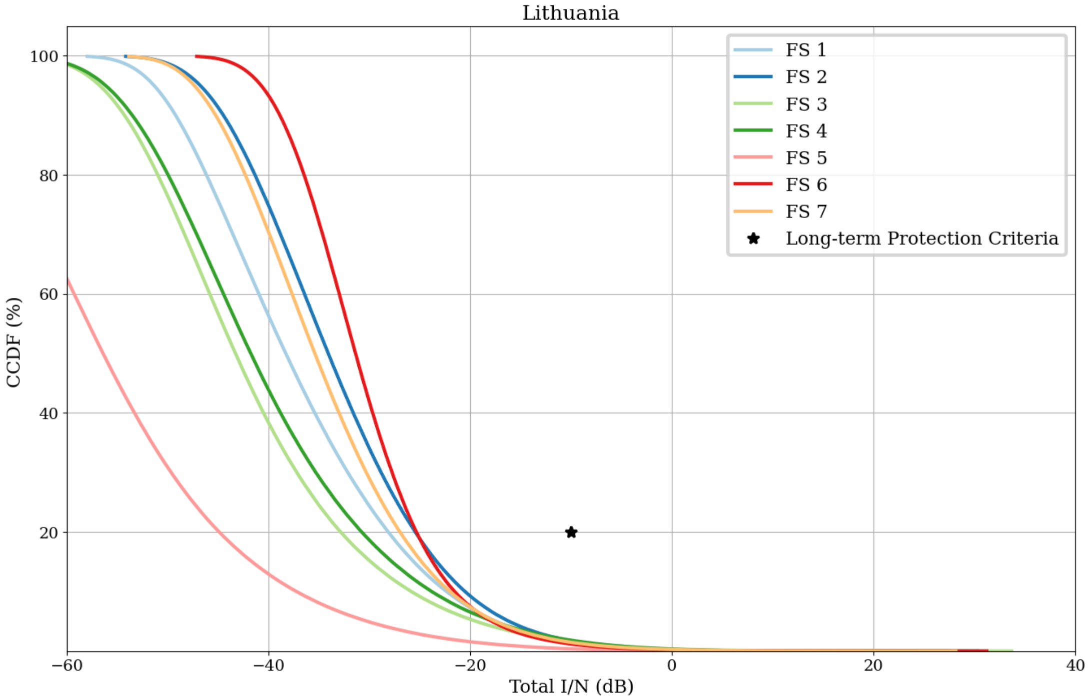


Figure 96: Complementary CDF of total I/N for the ‘all ages’ Lithuania links

Figure 97 shows the percentage of 5000000 iterations for each of the 6 FS receivers, situated in the Czech Republic, where the I/N from all WAS/RLANs (indoor + outdoor) exceeded the I/N level on the x-axis for the ‘all ages’. The results indicate that all FS met the long-term protection criterion.

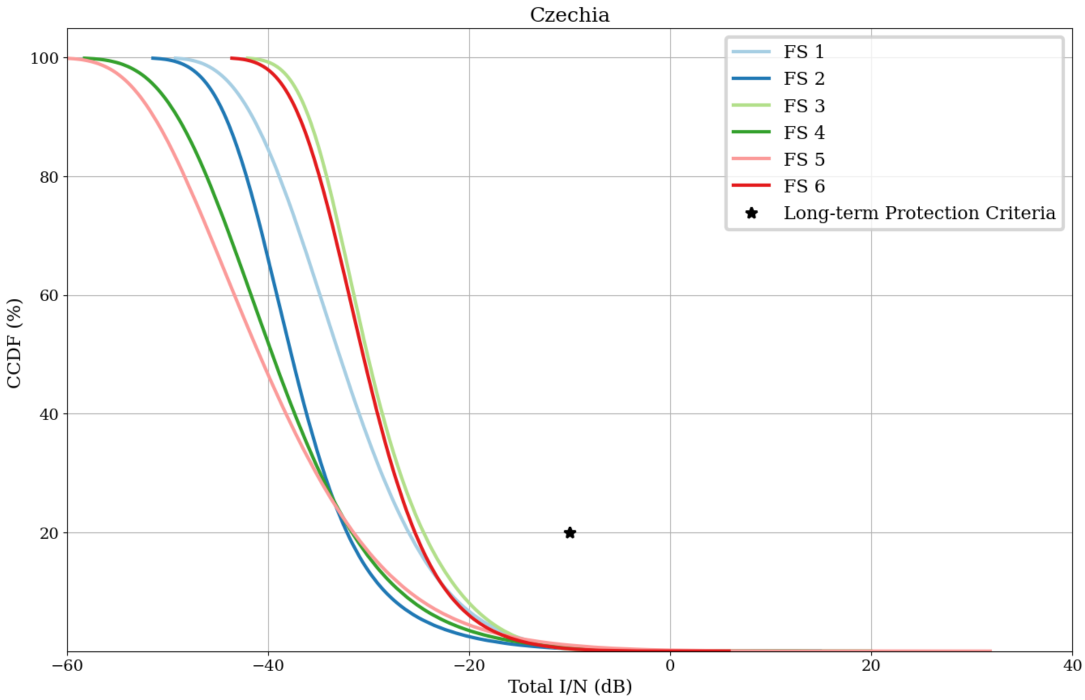


Figure 97: Complementary CDF of total I/N for the ‘all ages’ scenario, Czech Republic links

A6.4.3 FDP Protection Criterion

Table 110 shows the FDP values for each of the FS studied in the UK, using the I/N distribution from the 5 million iterations (as shown in Figure 94), the links' actual fade margins (from the UK database) and the fade distributions from Recommendation ITU-R P.530, for the 'all ages' scenario. The tables show the total FDP values, where,

$$\mathrm{FDP_{total}} = \mathrm{FDP_{long-term}} + \mathrm{FDP_{short-term}} \cdot$$

As indicated, for the 'all ages,' FDP ranges from 0.02% (FS ID 1) to 6.66% (FS ID 4).

As it can be observed, all the studied links meet the 10% FDP criterion and thus, no impact on the FS operation is to be expected.

Table 110: FDP from 5 million iterations, for the UK links

FS ID	Actual Fade Margin (dB)	$\mathrm{FDP_{total}}$ (all ages)
1	15	0.02%
2	15	1.09%
3	15	1.70%
4	15	6.66%
5	24.25	0.03%
6	28.90	4.43%
7	29.27	1.30%

Table 111 show the FDP values for each of the FS links studied in France using the I/N distribution from the 5 million iterations (as shown in Figure 95), the links' fade margins (calculated using Recommendation ITU-R P.530 using the link data from the French database and assuming 99.99%[19] availability) and the fade distributions from Recommendation ITU-R P.530, for the 'all ages' . The tables show the total FDP values.

As indicated, for the 'all ages,' total FDP ranges from 0.66% (FS ID 5) to 2.82% (FS ID 3).

As it can be observed, all the studied links meet the 10% FDP criterion and thus, no impact on the FS operation is to be expected.

[19] The 99.99% availability was chosen to get the links' Fade Margins within France's minimum and maximum fade margins with this band.

Table 111: FDP from 5 million iterations, for the French links

FS ID	Fade Margin (dB)	FDP (all ages)
1	24.13	1.68%
2	23.98	1.08%
3	39.53	2.82%
4	25.44	0.72%
5	26.27	0.66%
6	36.09	2.44%

Table 112 shows the FDP values for each of the FS studied in Lithuania, using the I/N distribution from the 5 million iterations (as shown in Figure 96), the links' fade margins (calculated using Recommendation ITU-R P.530 using the link data from the Lithuania database and assuming 99.999% availability) and the fade distributions from Recommendation ITU-R P.530, for the 'all ages'. The tables show the total FDP values.

As indicated, for the 'all ages,' total FDP ranges from 0.23% (FS ID 5) to 4.52% (FS ID 7).

As it can be observed, all the studied links meet the 10% FDP criterion and thus, no impact on the FS operation is to be expected.

Table 112: FDP from 5 million iterations, for the Lithuania links

FS ID	Actual Fade Margin (dB)	FDP (all ages)
1	34.1	1.10%
2	38.8	1.63%
3	34.8	4.07%
4	32.7	1.93%
5	38.3	0.23%
6	39.7	1.55%
7	29.4	4.52%

Table 113 show the FDP values for each of the FS studied in the Czech Republic, using the I/N distribution from the 5 million iterations (as shown in Figure 97), the links' fade margins (calculated using Recommendation ITU-R P.530 using the link data from the Czech Republic database and assuming 99.999% availability) and the fade distributions from Recommendation ITU-R P.530, for the 'all ages' . The high fade margins for some of the links are due to those FS links being very long (e.g. 40 to 58 km). The tables show the total FDP values.

As indicated, for the 'all ages,' total FDP ranges from 0.24% (FS ID 2) to 1.39% (FS ID 5).

As it can be observed, all the studied links meet the 10% FDP criterion and thus, no impact on the FS operation is to be expected.

Table 113: FDP results, for the Czech Republic links

FS ID	Actual Fade Margin (dB)	FDP (all ages)
1	41.84	0.39%
2	40.24	0.24%
3	39.88	0.32%
4	25.89	0.34%
5	44.01	1.39%
6	36.61	0.28%

A6.4.4 Sensitivity analysis

A sensitivity analysis was assessed by considering only the population portion aged between 10 and 90 years, but did not show significant impact on the results.

A6.4.5 Summary of the sharing study between WAS/RLAN and FS

This analysis considered a site-specific study covering some real links selected in the UK, France, Lithuania and the Czech Republic. The links were selected in densely populated surrounding areas. This study has shown with over 5 million Monte Carlo simulation runs that all the links met the long-term protection criterion of -10 dB I/N not to be exceeded more than 20% of the runs. Furthermore, when analysing the Fractional degradation in performance, it also appeared that all the links exhibited an FDP below the 10% threshold criterion. In summary, all the links met both long-term and FDP criteria.

ANNEX 7: SHARING WITH THE FIXED-SATELLITE SERVICE (EARTH-TO-SPACE)

A7.1 BACKGROUND

This analysis presents RLAN sharing studies with Fixed-Satellite Service (FSS) uplinks (Earth-to-space) in the "Upper 6 GHz band" (i.e. 6425-7125 MHz). This analysis extends the sharing and compatibility studies performed in ECC Report 302 between WAS/RLAN systems and existing incumbent systems in 5925-6425 MHz to the upper 6 GHz band.

The studies attempt to quantify and qualify the risk of exceeding the I/N protection criteria. It has to be noted that studies in ECC Report 302 have already shown that WAS/RLAN in the lower 6 GHz band fulfil the protection criterion of FSS uplink (UL) with large margins.

A7.2 TECHNICAL CHARACTERISTICS OF WAS/RLAN IN THE UPPER 6 GHZ FREQUENCY RANGE

The WAS/RLANs were modelled as follows.

A7.2.1 Transmitter Radiated Power

The *e.i.r.p.* distribution was derived using the agreed normalised antenna gain distribution and mixed according to Table 36. The resulting overall distribution is summarised in Table 41 for indoor and outdoor WAS/RLANs.

A7.2.2 WAS/RLAN antenna heights

The WAS/RLANs indoor height distribution from Table 3 is used in this study.

A7.2.3 Operating frequency

The WAS/RLAN channel set from IEEE 802.11be D5.0 [47] given in Table 5, starting at 6425 MHz was used in the simulation.

A7.2.4 Bandwidth

The bandwidth distribution is per Table 4.

A7.2.5 Number of instantaneously transmitting devices

Table 114 and Table 115 summarise the WAS/RLAN deployment model and specifies the total number of instantaneously transmitting devices within the CEPT countries during the busy hour for Scenario A. The UN projected population of CEPT in 2030 including 'all ages' and 'ages 10 to 90 years old' are considered as indicated in Table 114 and Table 115 respectively. Each table includes parametric inputs (Low, Mid and High) for the busy hour factor and the market adoption factor. Therefore, Low, Mid and High values of instantaneously transmitting devices are given for each scenario.

Two sets of simulations are run, one assuming population of 'all ages' and another assuming population of 'ages 10 to 90.'

In each simulation iteration, the instantaneously transmitting devices are dropped in proportion to the population density based on the 30 arcsecond Gridded Population of the World database [26].

Table 114: Summary of the WAS/RLAN deployment model (all ages) – Scenario A

	Low	Mid	High
Total UN projected Population of CEPT 2030 (all ages)	688 447 000		
Wireless devices operating in licence exempt spectrum (remainder operating in licensed spectrum)	90%		
Busy Hour Factor	50%	62.70%	62.70%
Upper 6 GHz Factor (Upper 6 GHz / (Upper 6 GHz + 5 GHz + 2.4 GHz)) (%)	40.75%		
Market Adoption Factor (6 GHz capable devices)	25%	32%	50%
RF Activity Factor Per Person	1.97%		
Instantaneously Transmitting Devices	621752	997986	559353

Table 115: Summary of the WAS/RLAN deployment model (ages 10 to 90 years old) – Scenario A

	Low	Mid	High
Total UN projected Population of CEPT 2030 (ages 10 to 90 years old)	609 503 000		
Wireless devices operating in licence exempt spectrum (remainder operating in licensed spectrum)	90%		
Busy Hour Factor	50%	62.70%	62.70%
Upper 6 GHz Factor (Upper 6 GHz / (Upper 6 GHz + 5 GHz + 2.4 GHz)) (%)	40.75%		
Market Adoption Factor (6 GHz capable devices)	25%	32%	50%
RF Activity Factor Per Person	1.97%		
Instantaneously Transmitting Devices	550455	883547	1380542

For the FSS simulations, the following total population projections in 2030 for 'all ages' and 'ages 10 to 90 years old', for each region, have been used in generating WAS/RLAN deployments:

1 Europe (including CEPT states), Total population: 736 574 215 [20] (all ages), 662 870 567 (ages 10-90);
2 Africa, Total population: 1 710 666 359 (all ages), 1 264 013 906 (ages 10-90);
3 Americas and the Caribbean, Total population: 1 090 881 324 (all ages), 950 453 476 (ages 10-90);
4 Asia, Total population: 4 958 807 420 (all ages), 4 299 116 829 (ages 10-90);
5 Oceania, Total population: 49 212 010 (all ages), 41 989 007 (ages 10-90).

Using the total populations per above and same assumptions as Table 114 and Table 115 for the Scenario A (High), Table 116 and Table 117 show the number of instantaneously transmitting WAS/RLAN devices that are simulated in each region within the satellite footprint using population of 'all ages' and 'ages 10 to 90 years old' respectively. In addition, the number of active WAS/RLAN devices in Africa, Asia and Oceania is divided

[20] This figure includes the population of additional countries in Europe that not in CEPT, resulting in a higher population than CEPT alone in Table 117.

by factor of 4 to reflect the delay in maturity of WAS/RLANs deployment at 6 GHz. Finally, for Asia, Americas and Oceania, the number of active WAS/RLAN devices reflect the values over Americas up to 62.5° West longitude, and Asia/Oceania up to 146° East longitude to exclude regions outside the satellites' view.

Table 116: Summary of the WAS/RLAN deployment model for FSS study - Scenario A (High) using population of all ages

Continent	2030 population	Number of instantaneously transmitting WAS/RLAN devices
Europe	736 574 215	1 668 362
Africa	1 710 666 359	968 678
Asia	4 958 807 420	2 807 663
Americas and the Caribbeans	1 090 881 324	601 078
Oceania	49 212 010	14 016

Table 117: Summary of the WAS/RLAN deployment model for FSS study – Scenario A (High) using population of ages 10 to 90 years old

Continent	2030 population	Number of instantaneously transmitting WAS/RLAN devices
Europe	662 870 567	1 501 421
Africa	1 264 013 906	715 757
Asia	4 299 116 829	2 434 148
Americas and the Caribbeans	950 453 476	523 702
Oceania	41 989 007	11 959

A7.2.6 Assignment of populations to urban, suburban and rural environments

As in ECC Report 302, the total population of each of the following regions: CEPT, Africa, Asia, Americas and the Caribbeans and Oceania, have been assigned to urban, suburban and rural environments as follows:

- Urban: 50%;
- Suburban: 27%;
- Rural 23%.

A7.2.7 Indoor vs. Outdoor

The WAS/RLANs indoor/outdoor ratio is assumed to be:

- Indoor: 98.79%;
- Outdoor: 1.21%.

As in ECC Report 302, for indoor WAS/RLAN usage, Recommendation ITU-R P.2109 building entry loss is applied assuming 70% traditional building and 30% thermally-efficient building. The simulation samples the Recommendation ITU-R P.2109 distribution uniformly between 1% to 99% as it is the range of probability where the model has been validated against empirical data.

A7.3 FSS UL SHARING METHODOLOGY

In this Report, the methodology from ECC Report 302's Study A is used, where the aggregate I/N into a number of satellite uplink beams is calculated using the WAS/RLAN deployment described in section A7.2 and a few representative satellite Figure-of-Merit G/T contours cited in section A7.3.1.

A7.3.1 FSS UL satellite receiver parameters

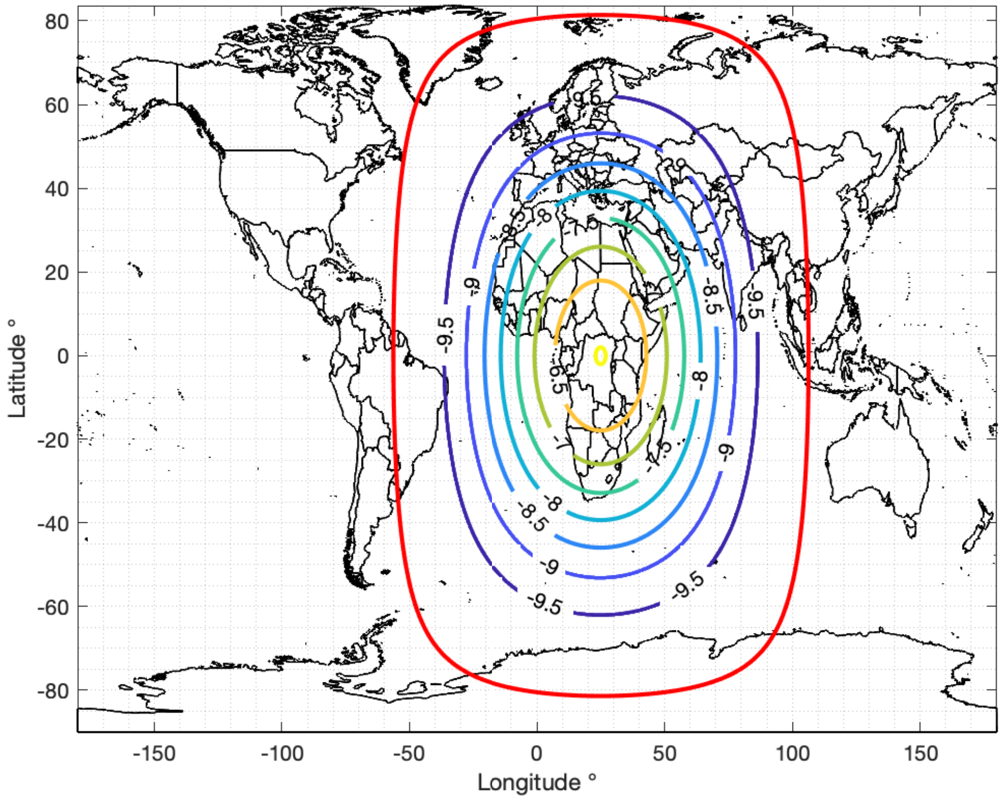
Table 118 shows the representative FSS beams that were studied which include a Global Beam, a Regional Beam and two Spot Beams and a Zone Beam.

Satellites receiver parameters are provided per 1 MHz, thus the analysis has been applied to a one MHz satellite channel in the middle of the Upper 6 GHz Band, from 6774 MHz to 6775 MHz. The results will be the same across any other 1-MHz satellite channel within the Upper 6 GHz band.

Table 118: Representative FSS beams

Satellite Beam	Satellite Longitude	Satellite Pointing Direction	G/T Contour Model	Peak G/T (dB/K)
Global Beam	25° E	Nadir	Recommendation ITU-R S.672-4 *recommends* 1 Beamwidth (2 x ψ_0) = 15° Gain max (G_{max}) = 22 dBi	-5.99 (T = 630 K)
Regional Beam	64° E	52.622286° N 2.150199° W	Recommendation ITU-R S.672-4 ANNEX 1's Section 2.4.1-b Beamwidth (2 x ψ_0) = 6° Equivalent Peak Gain (G_{ep}) = 28 dBi	-1.12 (T = 400 K)
Spot Beam	64° E	52.622286° N 2.150199° W	Recommendation ITU-R S.672-4 *recommends* 1 (circular beam) Beamwidth (2 x ψ_b)= 0.8° L_N = -25 Peak Gain (G_m) = 38 dBi	11.98 (T = 400 K)
Spot Beam 2	64° E	52.622286° N 2.150199° W	Recommendation ITU-R S.672-4 ANNEX 1's Section 1.1 Beamwidth (2 x ψ_0)= 2.6° L_s = -25 Peak Gain (G_m) = 36.4 dBi	10.38 (T = 400 K)
Zone Beam	64° E	53.273313° N 6.229937° W	Recommendation ITU-R S.672-4 *recommends* 1 (circular beam) Beamwidth (2 x ψ_b)= 4.6° L_N = -25 Peak Gain (G_m) = 32 dBi	5.98 (T = 400 K)

Figure 98 through Figure 102 show the G/T contours of the Global Beam, Regional Beam, Spot Beams 1 and 2, and the Zone Beam, generated according to the data of Table 118.



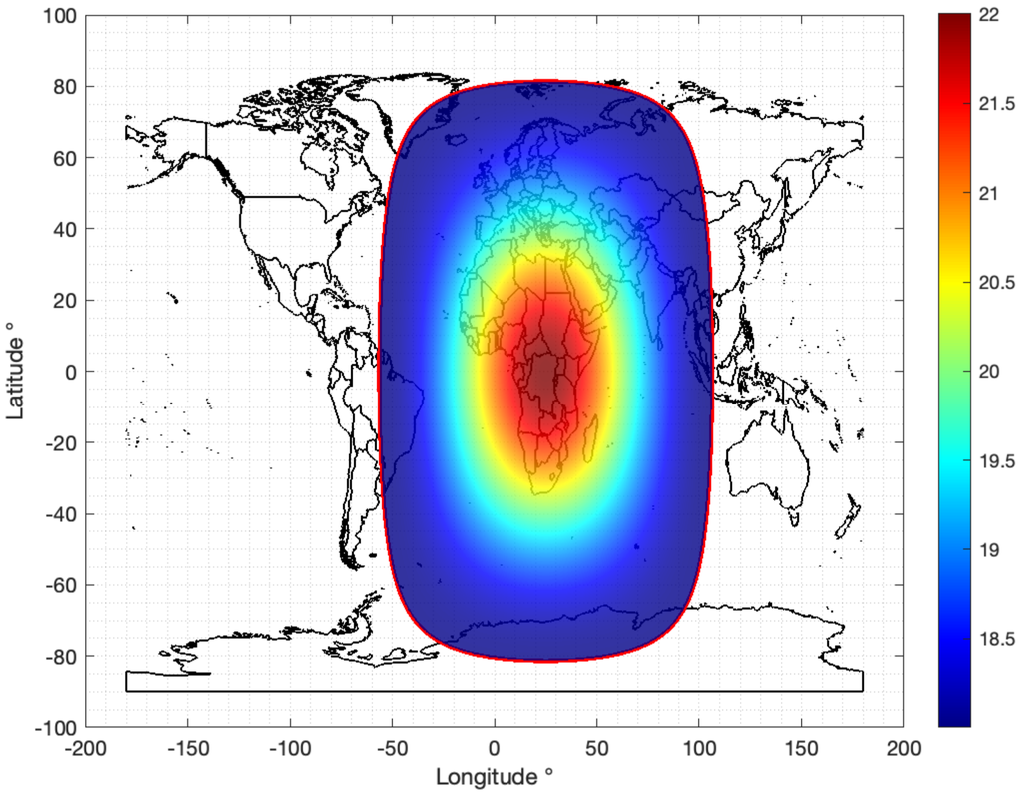


Figure 98: Global Beam (at 25° E) G/T contour (top) and antenna receiver gain contour (bottom). Red curve is the zero-degree elevation visibility limit

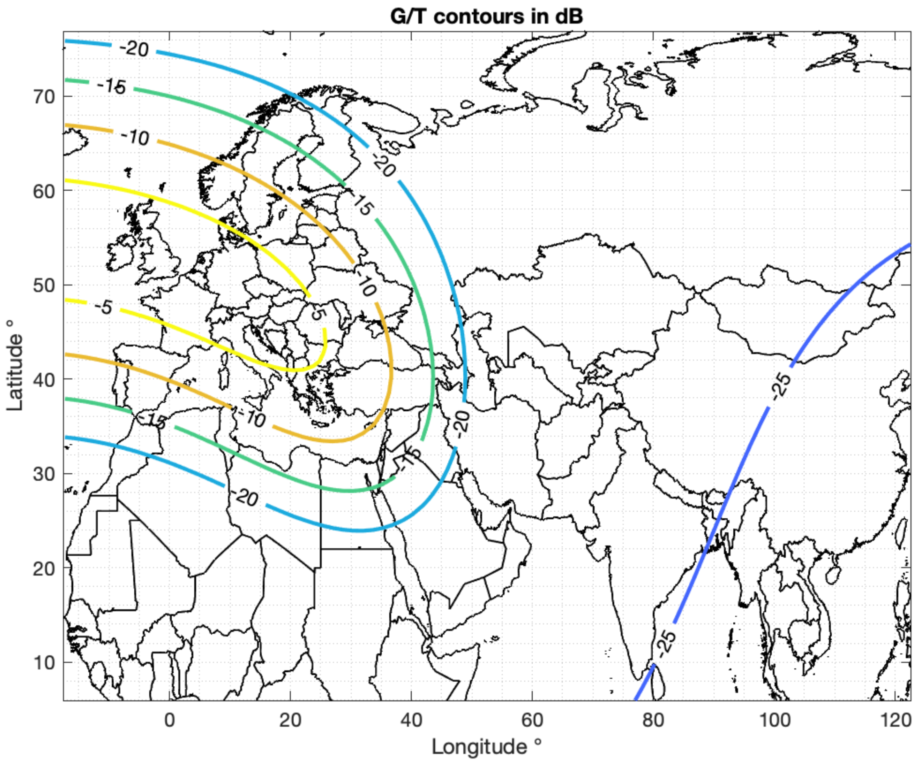


Figure 99: Regional Beam (at 64° E) G/T contour

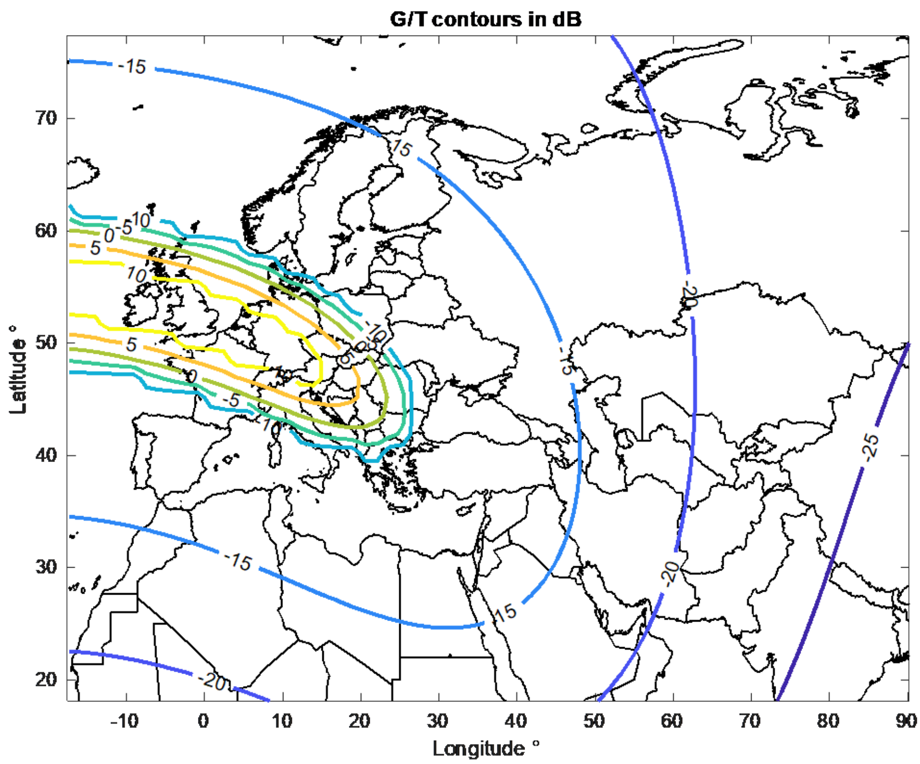


Figure 100: Spot Beam (at 64° E) G/T contour

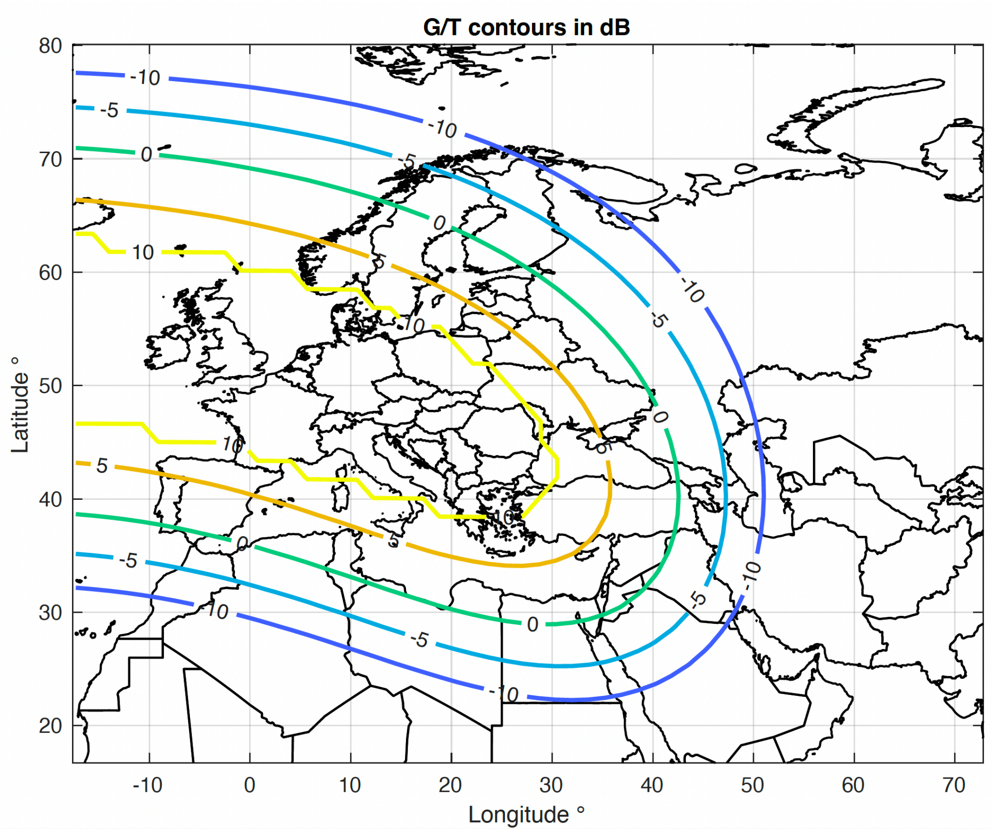


Figure 101: Spot Beam 2 (at 64° E) G/T contour

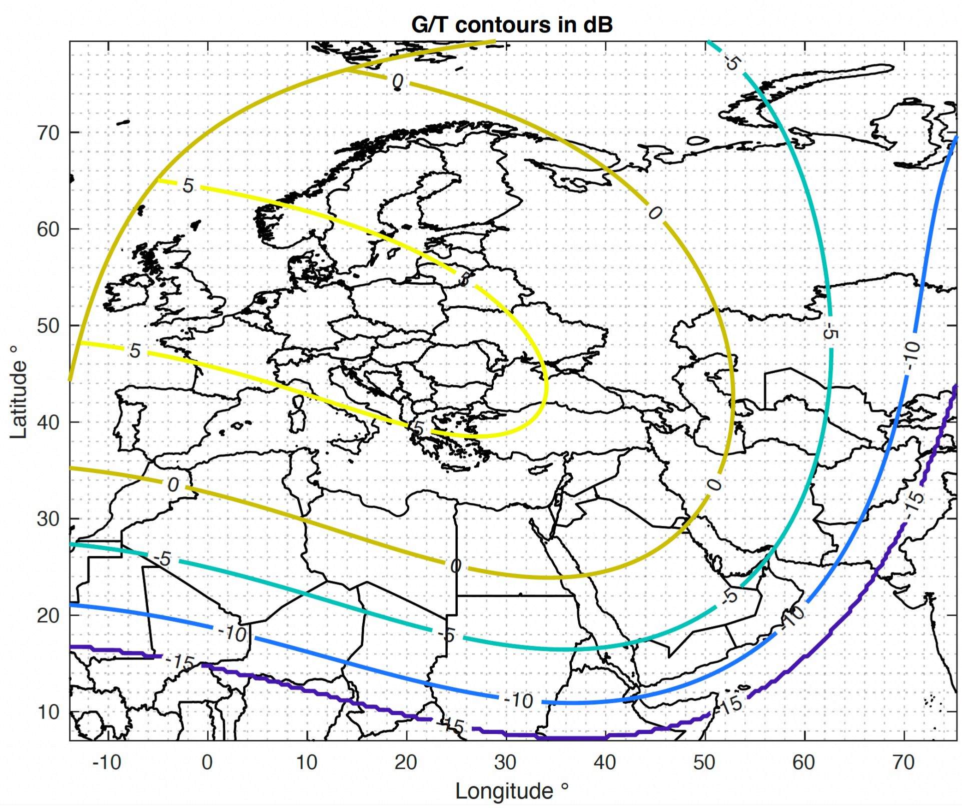


Figure 102: Zone Beam (at 64° E) G/T contour

A7.3.2 FSS Uplink protection criterion

The FSS protection criterion, that is based on an I/N methodology, is the same as the one used in ECC Report 302, section 4.2.2 set to I/N=-10.5 dB.

A7.3.3 Propagation models

The same propagation models as in ECC Report 302, section 5.2.2 (repeated below) are used.

All WAS/RLANs having the satellite in view with an elevation angle higher than 0° are taken into account in the computation of the aggregate interference. Figure 103 shows WAS/RLANs that are in the view of the satellite with the Global beam, which were considered in the interference calculation. WAS/RLANs for which the satellite is not in view are considered to contribute no interference. The transmission loss is computed using free space transmission loss, per Recommendation ITU-R P.619-3 [41], from the WAS/RLAN position to the satellite orbital slot. Atmospheric loss, which is small, was ignored in this calculation.

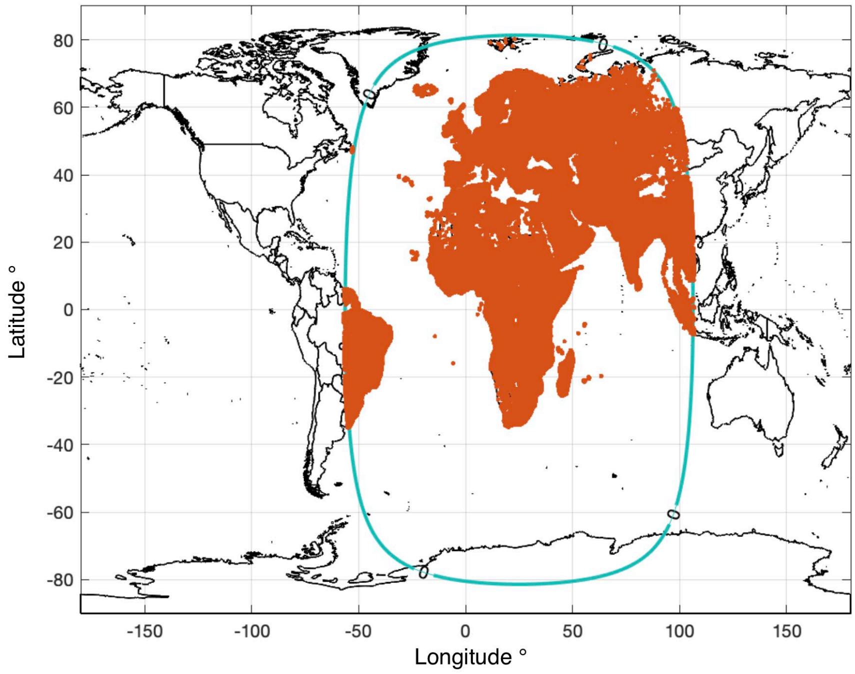


Figure 103: WAS/RLANs considered in the global beam example

Next, for suburban and urban propagation areas, local end-point clutter is added using Recommendation ITU-R P.2108-0, Section 5.3 (for Earth-to-space paths) over the model's full percentage of locations from 0% to 100%.

For conservativeness, no clutter is assumed for rural WAS/RLANs even though the WAS/RLANs at low elevation angle towards the satellite would most likely incur clutter loss from trees and/or buildings.

Finally, for indoor WAS/RLAN usage, Recommendation ITU-R P.2109 building entry loss is used for computing indoor-to-outdoor interference path propagation losses, over the probability range from 1% to 99%.

A7.3.4 Methodology

The study follows the methodology from ECC Report 302, study A in section 7.1.1.

Interference from WAS/RLAN deployments into FSS satellite receiver is simulated using a Monte Carlo simulation of the WAS/RLAN deployment generated from the various probability distributions given in Section A6.2.

The simulation is performed according to the following steps:

1 Data setup
   1.2. Define the simulation region and create a database of population density at points within the simulation region;
   1.3. Transform population data over the simulation region to active WAS/RLAN device population probability distribution over the simulation region;
   1.4. Specify the orbital slot of the FSS satellite receiver and the G/T values over the simulation region;
   1.5. Specify the FSS satellite channel to simulate.

2 Monte Carlo iteration
   2.2. Generate a random layout of WAS/RLANs using the device population probability distribution;
   2.3. Generate the clutter loss, building entry loss, and transmission loss values between each WAS/RLAN and FSS satellite receiver in accordance with the propagation modelling set out in section A7.3.2;
   2.4. Compute the aggregate interference from all co-channel WAS/RLANs into the FSS satellite receiver for the simulated FSS channel.

3 Iterate
   3.2. Record I/N values for the FSS channel on each iteration and write the results to a file.

4 Plot the CDF of the recorded I/N values.

Steps 1 and 2 above are further elaborated below.

Step 1: Data Setup

Gridded population of the world (GPW) data is used and contains population density values on a 30 arcsecond grid in longitude and latitude coordinates. Polygons defining regions for Europe, Africa, Asia, Americas (and the Caribbeans) and Oceania are also considered. Their union defines the simulation region.

Each grid point from the GPW data file that is in one of the region polygons is classified as being urban, suburban or rural depending on the population density value for the grid point and threshold values that are inputs to the simulation. Note that each region polygon has its own set of population threshold values.

The GPW data file is used to produce the active WAS/RLAN device population probability distribution over the simulation region. The first step is to convert population density values into population values for each grid point by multiplying the population density by the area of the 30 arcsec x 30 arcsec region centred at the grid point. These population values are then summed for each of the regions: Europe, Africa, Americas, Asia and Oceania.

Let P_{EU}, P_{AF}, P_{AM}, P_{AS}, and P_{OC} be the populations of Europe, Africa, Americas, Asia and Oceania, respectively. Let N_{EU}, N_{AF}, N_{AM}, N_{AS}, and N_{OC} be the number of active WAS/RLAN devices in Europe, Africa, Americas, Asia and Oceania, respectively. These values are inputs to the simulation. For each grid point, the population value is converted to the average WAS/RLAN device count by multiplying by (N_{EU}/P_{EU}), (N_{AF}/P_{AF}), (N_{AM}/P_{AM}), (N_{AS}/P_{AS}) or (N_{OC}/P_{OC}) depending on whether the grid point is in Europe, Africa, Americas, Asia or Oceania. This is then converted into a large discrete probability distribution function where each grid point is assigned a probability equal to the average WAS/RLAN device count at that grid point divided by the total WAS/RLAN device count.

A random WAS/RLAN position is produced by generating a random grid point using this discrete probability distribution, then selecting a location uniformly distributed over the 30 arcsec x 30 arcsec region centred at the grid point. The values of G/T over the simulation region are specified in a matrix generated from Recommendation ITU-R S.672-4. Each row/line of the matrix specifies LON/LAT and the G/T value at the corresponding LON/LAT position. Bi-linear interpolation is used to compute G/T for LON/LAT points between the grid points specified in the matrix.

Step 2: Monte Carlo Iterations

For each iteration, a random layout of active WAS/RLAN devices is generated. Each WAS/RLAN device is assigned a random longitude/latitude position using the device population probability distribution described above. Each WAS/RLAN device is also assigned a random height, *e.i.r.p.* (Table 2). Building types are outdoor (meaning no building attenuation), indoor-traditional or indoor thermally efficient (respecting a 30% thermally efficient / 70% traditional distribution).

Each WAS/RLAN is assigned a random bandwidth using a discrete probability distribution as in Table 101 and a random centre frequency as in Figure 89. The centre frequency is generated by considering all possible centre frequencies for the selected bandwidth and using a uniform distribution.

WAS/RLANs for which the satellite is not in view are considered to contribute no interference to the satellite and are thus ignored in the interference calculation.

For the 1 MHz FSS channel in the simulation, interference from all WAS/RLANs for which the satellite is in view is computed and aggregated. The WAS/RLAN bandwidth and centre frequency along with the FSS channel bandwidth and centre frequency are used to compute the fraction of the WAS/RLAN bandwidth that overlaps with the FSS channel. If there is no overlap, the WAS/RLAN contributes no interference to the FSS channel.

In addition, a random building entry loss is computed using Recommendation ITU-R P.2109-0 using the building type and elevation angle from the WAS/RLAN to the FSS satellite receiver orbital slot. Note that for outdoor WAS/RLANs, the building entry loss is 0 dB.

Random path clutter values are generated per Recommendation ITU-R P.2108-0 for urban and suburban WAS/RLANs (as described in section A7.3.2). No clutter is assumed for rural WAS/RLANs.

The transmission loss is computed using free space transmission loss model (FSPL), per Recommendation ITU-R P.619-3, from the WAS/RLAN position to the FSS satellite orbital slot. Note that additional signal attenuations from atmospheric gases and beam-spreading are not included.

Polarisation loss of 3 dB is added.

The FSS satellite Figure-of-Merit (G/T) is computed at the WAS/RLAN position as described above. The I/N contribution for a single WAS/RLAN into an FSS channel is computed by:

$$\frac{I}{N} = e.i.r.p. - L_{\mathrm{BEL}} - PL - L_{\mathrm{p}} - L_{\mathrm{c}} - L_{\mathrm{s}} + \frac{G}{T} - 10\log_{10}(kB)$$

Where:

- $e.i.r.p.$ = WAS/RLAN *e.i.r.p.* (dBW);
- L_{BEL} = Building Entry Loss (dB);
- PL = Free Space Path Loss (dB);
- L_{p} = Polarisation Loss = 3 (dB);
- L_{c} = Clutter Loss (dB);
- L_{s} = Spectral Overlap Loss (dB);
- $\frac{G}{T}$ = Satellite receiver Figure-of-Merit (dB/K);
- k = Boltzmann's constant = 1.3806488 x 10-23 (J/K);
- B = FSS channel bandwidth = 1 000 000 (Hz).

The I/N is aggregated over all WAS/RLANs for the 1 MHz FSS channel in the simulation.

A7.3.5 FSS (Earth-to-space) Simulation Results

From 100 Monte Carlo simulation iterations, the CDF of the aggregate I/N over all indoor and outdoor WAS/RLANs within the satellite's view to the 1 MHz FSS channel is generated for each of the 5 FSS beams. Figure 104 and Figure 105 show the CDFs for the 5 beams for the two simulated scenarios, population of 'all ages' and 'ages 10 to 90 years old,' respectively. The vertical shape of the CDF curves indicates that there is minimal variability over the 100 iterations meaning that more iterations are not needed.

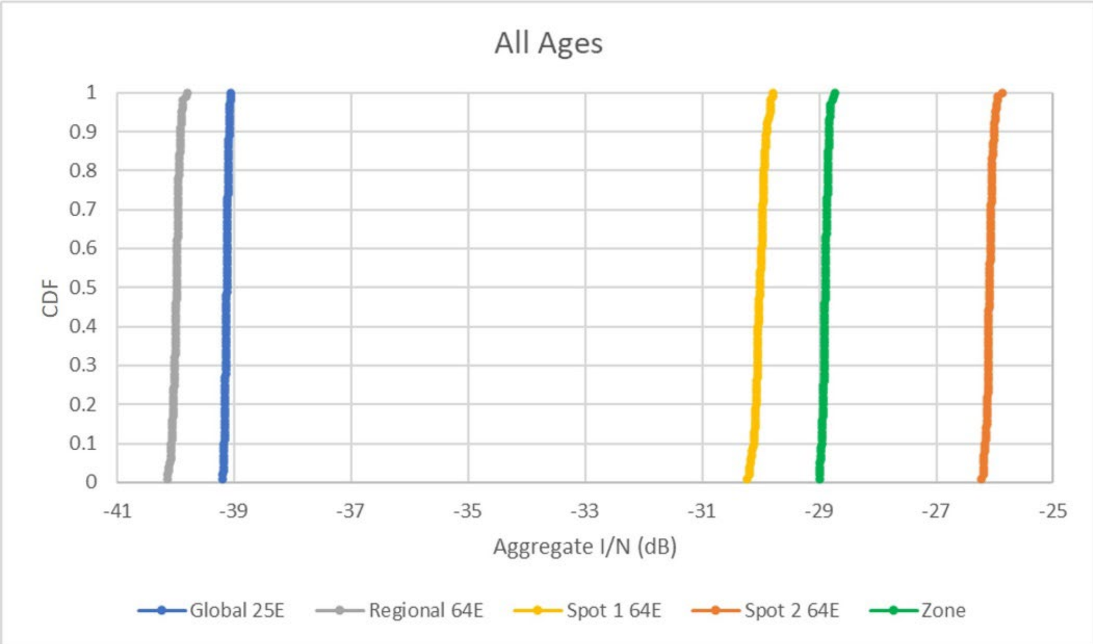


Figure 104: CDF of aggregate I/N for the 5 FSS beams (all ages)

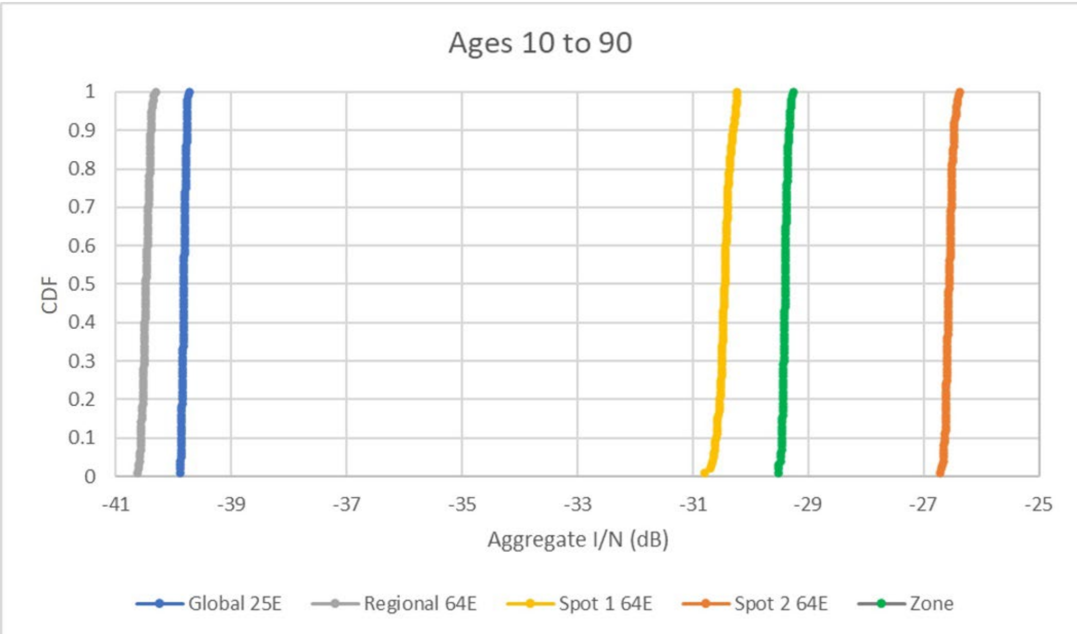


Figure 105: CDF of aggregate I/N for the 5 FSS beams (all ages 10 to 90)

Table 119 and Table 120 show the results of the FSS Monte Carlo simulations over 100 iterations for the 5 FSS beams considering the population for 'all ages' and 'ages 10 to 90' respectively. The minimum and maximum I/N levels correspond to the I/N levels that aggregated interference from all the indoor and outdoor co-channel RLANs in the view of the satellite. The Monte Carlo simulations demonstrate I/N values that are well below the protection criteria of FSS uplink. The highest I/N simulated of -25.86 dB (Spot Beam 2 in Table 119) results in a 15.36 dB margin against the -10.5 dB protection criterion.

As indicated, the delta between the minimum and maximum aggregate I/N values is at most 0.56 dB, indicating the stability of results from 100 simulation iterations. Furthermore, the maximum aggregate I/N values for 'all ages' is 0.44 to 0.67 dB higher than the maximum aggregate I/N values for 'ages 10 to 90.'

Table 119: FSS Simulation Results (all ages)

Satellite Beam	Satellite Longitude	Peak G/T (dB/K)	Min I/N (over 100 iterations) (dB)	Max I/N (over 100 iterations) (dB)	Max I/N – Min I/N (dB) (over 100 iterations)
Global Beam	25° E	-5.99 (T = 630 K)	-39.19	-39.06	0.13
Regional Beam	64° E	1.98 (T = 400 K)	-40.14	-39.81	0.33
Spot Beam 1	64° E	11.98 (T = 400 K)	-30.23	-29.79	0.44
Spot Beam 2	64° E	10.38 (T = 400 K)	-26.24	-25.86	0.37
Zone Beam	64° E	5.98 (T = 400 K)	-29.00	-28.73	0.27

Table 120: FSS Simulation Results (ages 10 to 90)

Satellite Beam	Satellite Longitude	Peak G/T (dB/K)	Min I/N (over 100 iterations) (dB)	Max I/N (over 100 iterations) (dB)	Max I/N – Min I/N (dB) (over 100 iterations)
Global Beam	25° E	-5.99 (T = 630 K)	-39.88	-39.72	0.16
Regional Beam	64° E	1.98 (T = 400 K)	-40.62	-40.30	0.32
Spot Beam 1	64° E	11.98 (T = 400 K)	-30.80	-30.23	0.56
Spot Beam 2	64° E	10.38 (T = 400 K)	-26.72	-26.38	0.34
Zone Beam	64° E	5.98 (T = 400 K)	-29.51	-29.25	0.26

A7.3.6 Summary of the sharing study between WAS/RLAN and FSS (Earth-to-space)

Simulations show that in all cases studied under WAS/RLAN assumptions for the Scenario A (High) in the Upper 6 GHz Band, the I/N for all satellites is more than 15.36 dB below the -10.5 dB threshold. It can be concluded that deployment of WAS/RLANs will not impact the operation of the FSS uplinks in the 6425-7125 MHz band. This confirms the results already obtained in the lower 6 GHz band.

ANNEX 8: SHARING WITH THE FIXED-SATELLITE SERVICE (SPACE-TO-EARTH)

A8.1 INTRODUCTION

The frequency band 6700-7075 MHz is allocated to the FSS globally (space-to-Earth) for feeder links for non-geostationary satellite systems of the mobile-satellite service (MSS). The use of this band by feeder links for non-geostationary satellite systems in the mobile-satellite service is not subject to No. **22.2** as per footnote RR No. **5.458B**.

There are currently a limited number of earth stations (space-to-Earth) in the bands 6725-7025 MHz, 7025-7075 MHz, operating with LEO and MEO satellites.

The band 6700-7075 MHz is considered for a MEO satellite system with coverage over Europe that will have up to 20 gateway earth stations and is also considered for the European Secure Space Connectivity System (ESSCS) project which is planned as an initiative of the European Union (EU) towards a third EU space pillar after Galileo and Copernicus. The 6700-7075 MHz FSS (space-to-Earth) allocation ruled by No. **5.458B** is a particularly good candidate, paired with the 5091-5250 MHz FSS (Earth-to-space) allocation, noting that the other similar feeder link allocation in 19.3-19.7 GHz/29.1-29.5 GHz will soon become congested with the deployment of “mega-constellations” in addition to existing systems.

Due to the foreseen satellite usage described above, the total number of receiving Earth stations using the 6700-7075 MHz feeder link allocation will increase but will remain limited in Europe.

In this section, site-specific Monte Carlo simulations are presented, using real ground station positions, population data matrix with 1 km^2 resolution and SRTM terrain data with 90 m resolution [14]. Real building positions and height are considered where available.

A8.2 SYSTEMS CHARACTERISTICS AND ELEMENTS OF METHODOLOGY

A8.2.1 FSS DL characteristics

The studied constellation is the HIBLEO-X constellation from Globalstar. It is defined by the following Walker Delta parameters 52: 48/8/7.5 as shown in Figure 106.

This study considered only the communication mode with tracking elevation higher than 10°, the acquisition mode with tracking elevations down to 5° was not yet considered and may be covered in future studies.

In the analysis for sharing between WAS/RLAN and Fixed-Satellite Service in this Report, the FSS protection criterion used is I/N = -10.5 dB not to be exceeded for more than 20% of time.

Other protection criteria for FSS are currently being discussed in ITU-R at the time of writing this Report.

The HIBLEO-X constellation was simulated over a minimum period of 4 days, with a step of 10 seconds. This period is considered to be sufficient to model actual system operation. The 10 second time step corresponds to approximately 0.6 degrees that is consistent with gateway antenna characteristics.

For the sake of example, Figure 107 depicts the number of visible satellites (with an elevation angle greater than 10°) during the simulation period. It can be observed that most of the time, the ground station will be in communication with 4 satellites simultaneously. Taking into account that, for diversity reasons, a ground station location includes most of the time three to four antennas, all elevations representing links with the different satellites are recorded at each time step and considered for the simulations.

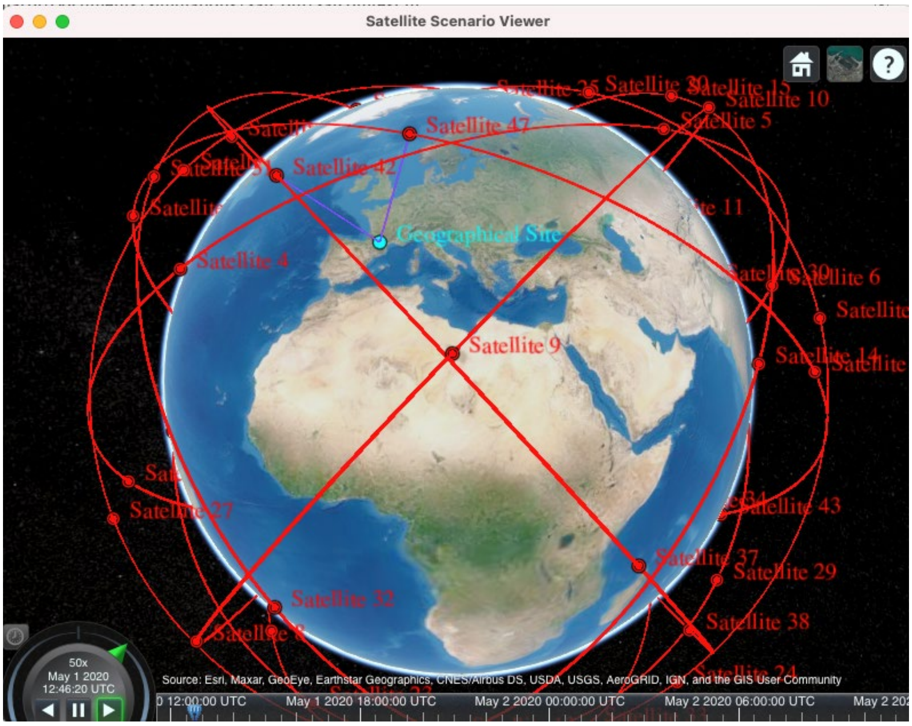


Figure 106: Studied HIBLEO-X constellation

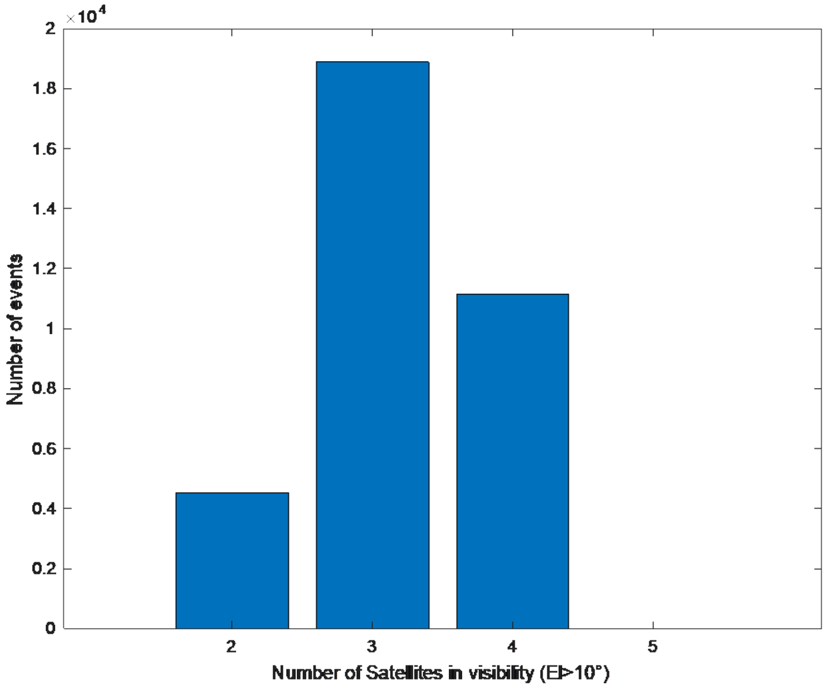


Figure 107: Number of simultaneously visible satellites with elevation > 10°, from the ground station situated in Aussaguel, France

Considering the visible satellites above 10° elevations, the stored elevations of those satellites are shown in a bi-variate histogram in Figure 108. One can observe that for azimuths between –50° to 50°, the satellites are seen at high elevations, this will have a significant impact on the simulation results as these azimuths represents the heading to the closest urban area which is Toulouse. Thus, the Toulouse area, for example, will be visible to the ground station at side lobes only.

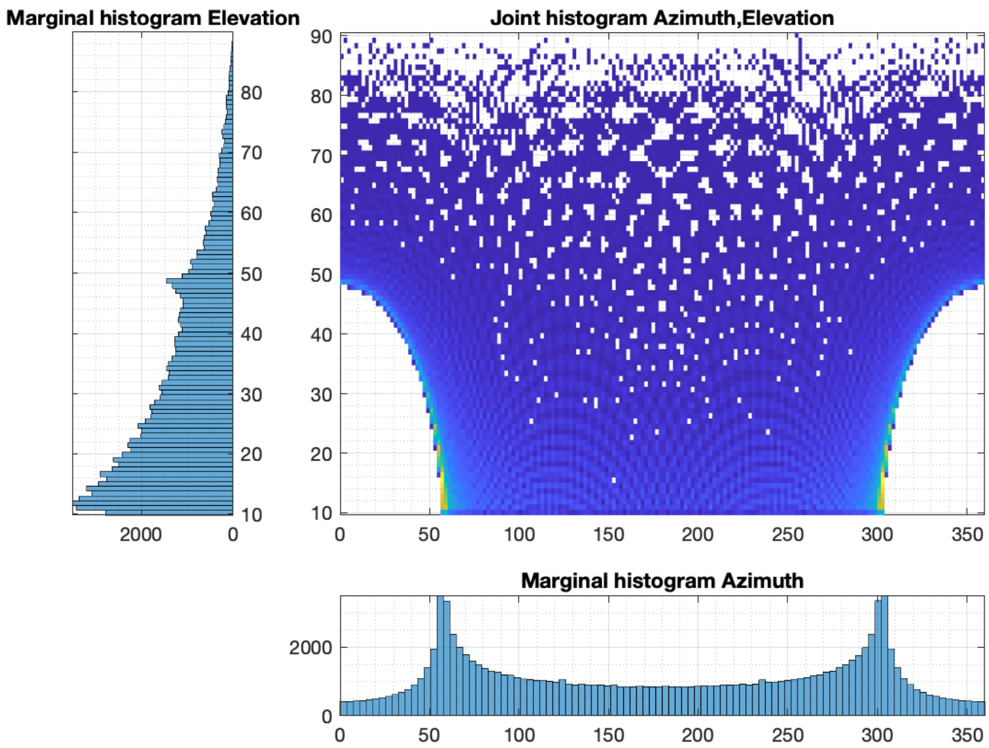


Figure 108: Marginal and joint histograms of elevation and azimuth, all satellites in visibility above 10° elevation, from Aussaguel station

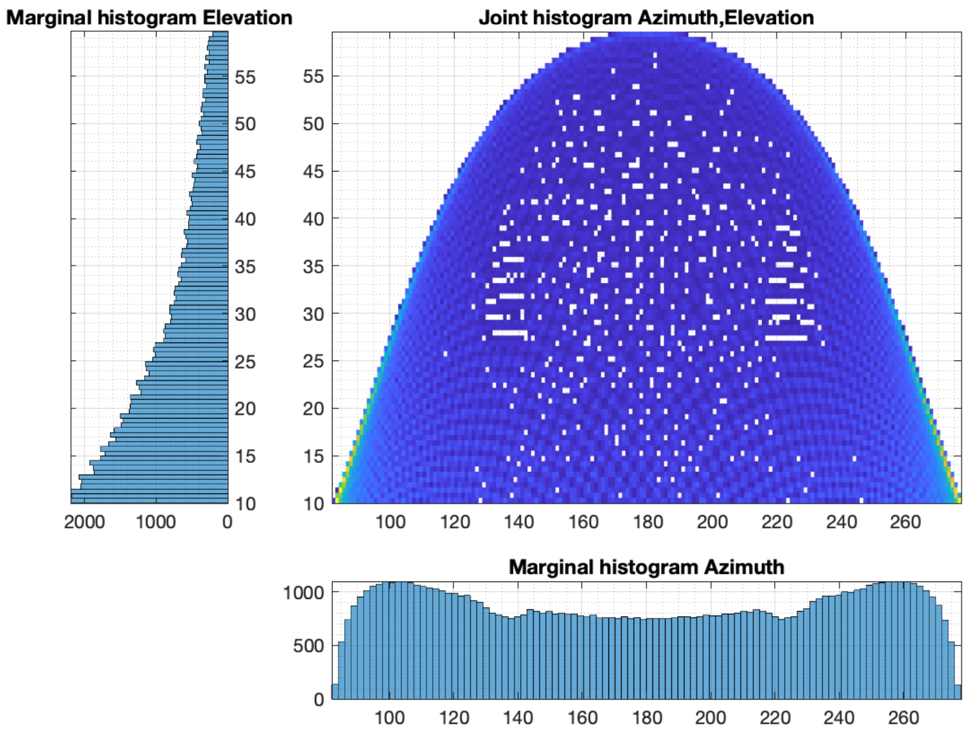


Figure 109: Marginal and joint histograms of elevation and azimuth, all satellites in visibility above 10° elevation, from Estonia station

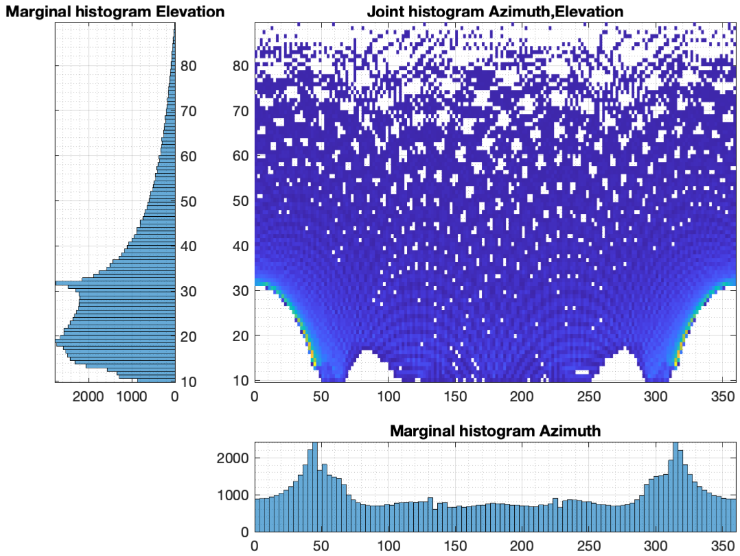


Figure 110: Marginal and joint histograms of elevation and azimuth, all satellites in visibility above 10° elevation, from Greece station

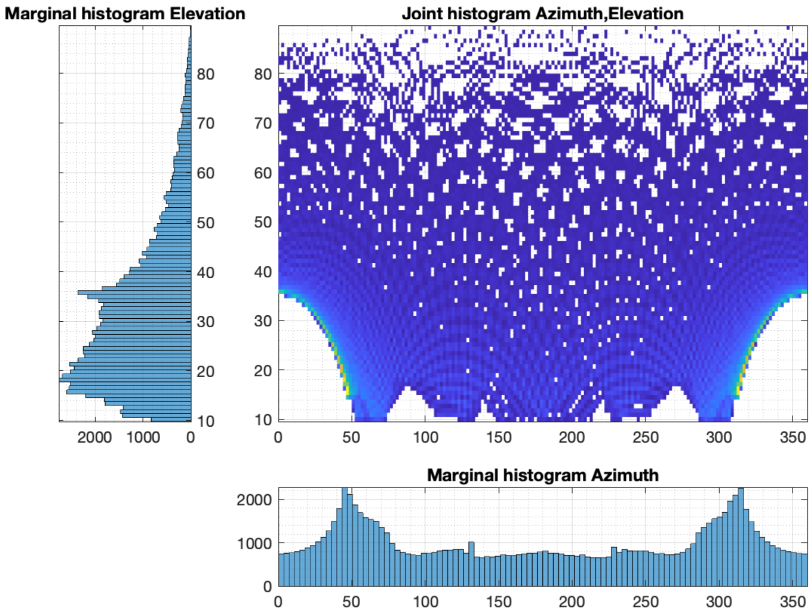


Figure 111: Marginal and joint histograms of elevation and azimuth, all satellites in visibility above 10° elevation, from Spain station

A8.2.2 WAS/RLAN characteristics

The WAS/RLAN *e.i.r.p.* distribution is the one depicted in Table 41 mixed according to the indoor/outdoor/device class of Table 40.

The WAS/RLAN heights distribution is according to Table 3.

The WAS/RLAN bandwidth distribution is according to Table 4.

The methodology used in ECC Report 302, annex 2 [1] is used to deduce the portion of RLANs falling into a channel of 1.23 MHz, resulting into an overlapping factor of 23.08%.

The combination of the different parameters results in the WAS/RLAN density Table 121 for Scenario A.

Table 121: WAS/RLAN active devices falling into one FSS DL channel of 1.23 MHz width, for Scenario A

	Low	Mid	High
Wireless devices operating in licence exempt spectrum (remainder operating in licensed spectrum)	90%		
Busy Hour Factor	50%	62.70%	62.70%
Upper 6 GHz Factor (Upper 6 GHz / (Upper 6 GHz + 5 GHz + 2.4 GHz)) (%)	40.75%		
Market Adoption Factor (6 GHz capable devices)	25%	32%	50%
RF Activity Factor Per Person	1.97%		
BW overlapping factor (1.23 MHz)	23.08%		
RLAN active per person	0.000208	0.0003346	0.000523

Only the High case scenario was studied.

A8.2.3 Simulation area, population density and urban/suburban/rural classification

Four ground stations were chosen for this study in Greece, Spain, Estonia, and France. Each ground station has its own specificities in terms of surrounding terrain relief but also population density. The simulation area considered, ensured a latitude/longitude rectangle covering a 40 km radius circle (see Figure 112).

Looking at the geographical location of the ground stations some exclusion zones were applied where no indoor RLAN would be active in accordance with the built-up area around the station. This exclusion zone varies from one ground station to another, as follows

- Greece: 500 m;
- Spain: 320 m;
- Estonia: 350 m;
- France: deployment according to real buildings positions (see A8.2.6).

The simulations were based on a population density with 30 arc second resolution (1 km at equator) extrapolated to 2030 downloaded from the [15].

The pixels were categorised into urban, suburban and rural based on the population density and according to the following apportionment:

- Urban: 50%;
- Suburban: 27%;
- Rural 23%.

An example of the resulting apportionment is shown in Figure 112, for the ground station situated in France, it can clearly be observed that the results match the nature of the neighbourhood.

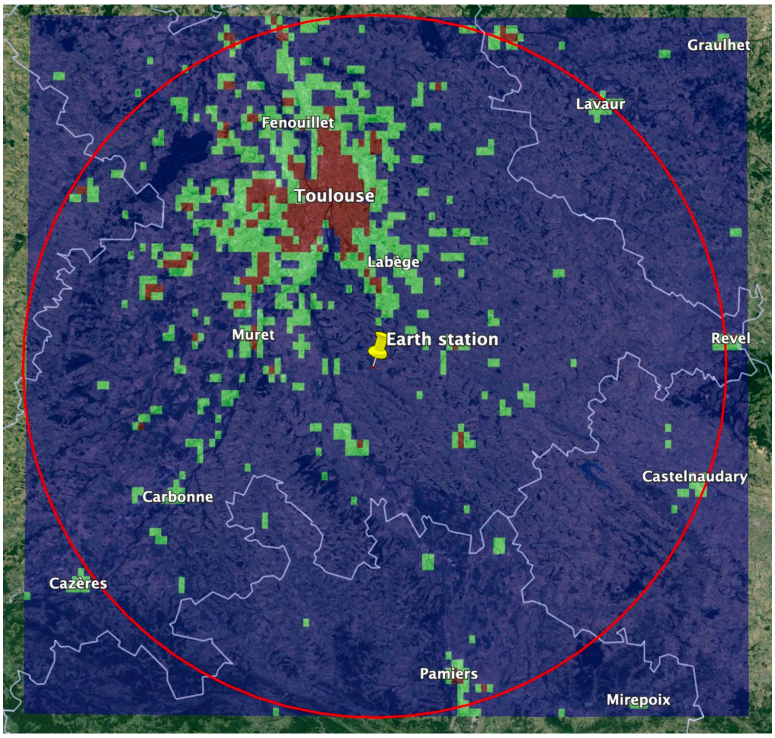


Figure 112: Urban (red), suburban (green), and rural (blue) apportionment of the population density pixels resulting from 50%, 27%, 23% distribution. Red circle represents 40 km distance.

An example of RLAN scattering when using Table 121 is plotted below. The blue dots represent rural RLANs, green ones are suburban RLANs and red ones are urban RLANs.

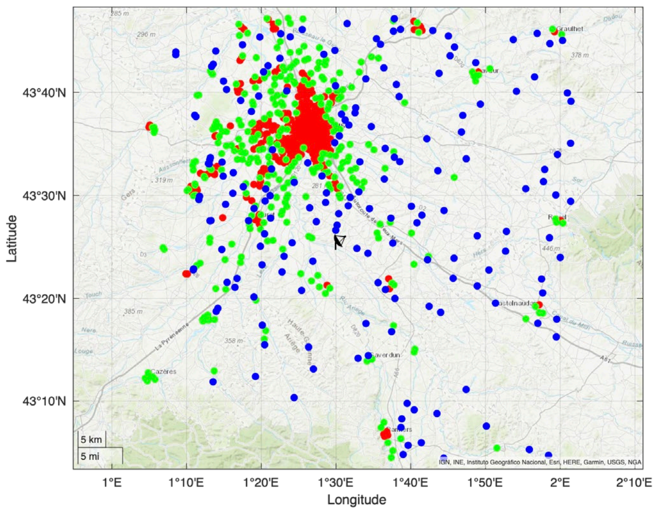


Figure 113: Example of urban (red), suburban (green), and rural (blue) RLANs random scattering based on population density and numbers from Table 121.

A8.2.4 Propagation scenario

The following propagation scenario was used in the simulations:

Table 122: Propagation model used in the simulation

Horizontal Distance	Propagation Model	For Indoor only	Clutter
$0\ \text{m} \leq d < 40\ \text{m}$	Free space	Recommendation ITU-R P.2109 (70% traditional, 30% modern, uniform distribution of probability from 1 to 99%)	not applicable
$40\ \text{m} \leq d < 1000\ \text{m}$	WINNER II model	Recommendation ITU-R P.2109 (70% traditional, 30% modern, uniform distribution of probability from 1 to 99%)	LOS and NLOS ratio probability determination is inherent to the WINNER II model
$d \geq 1000\ \text{m}$	Recommendation ITU-R P.2001-4 (time percentage: uniform distribution 0% to 100%) Using SRTM data 90 m resolution Or Recommendation ITU-R P.452-17 (time percentage: uniform distribution 0% to 100% truncated at 50% max) Using SRTM data 90 m resolution	Recommendation ITU-R P.2109 (70% traditional, 30% modern, uniform distribution of probability from 1% to 99%)	For urban and sub-urban: Recommendation ITU-R P.2108-1 (Location percentage: uniform distribution) For Rural: Use the Recommendation ITU-R P.452-17 clutter model (high crop fields, sparse houses at both ends)

A8.2.5 Monte Carlo simulation algorithm

1 Fix the ground station location and the satellite constellation parameters;

2 Simulate the constellation, and store the azimuth and elevation of visible satellites above a given elevation (>10°) for a sufficient period of time

3 Determine the simulation area around the ground station (40 km in this case)

4 Start a loop over stored satellite positions and for each position, using the bearing of the ground station (elevation, azimuth), perform the following inner-steps

4.1. Deduce the number of active RLANs according to the population density of the pixel and the number of active RLANs per person (see Table 121). This number of active RLANs is generated according to a Binomial distribution with parameters N=pixel population count (rounded to nearest integer) and probability of success p=number of active RLAN per person. Once done, scatter these active RLANs inside the pixel, and store if the RLAN is urban, suburban or rural.

4.2. Using the different distributions allocate to each RLAN, an *e.i.r.p.*, a height and indoor/outdoor operation.

4.3. Using the ground station bearing and RLAN position (latitude, longitude, height) compute the ground station gain towards each RLAN

4.4. Compute the aggregate I/N at the ground station according to the following equation, where G_r represents the ground station gain towards RLAN(i), L_b the pathloss according to Recommendation ITU-R P.2001-4 or Recommendation ITU-R P.452-17, L_c the clutter loss, L_{bel} the building entry loss if it applies (indoor devices), pol is the polarisation mismatch fixed to 3 dB, and BW_{factor} is the bandwidth correction factor

$$\frac{I}{N}(dB) = 10\log_{10}\left(\sum_{i=1}^{N} 10^{EIRP(i)+G_r(i)-L_b(i)-L_c(i)-L_{bel}(i)-pol-BW_{factor}}\right) - N$$

4.5. Store the I/N values and repeat all sub-steps 4 for the decided time period.

5 Generate Complementary Cumulative Distribution Function (CCDF), using the stored I/N values.

A8.2.6 Specific case of the ground station in France

For the French ground station, the RLANs inside the first 8 km around the ground station are picked only in positions where a building exists. To do so, the French building data base BD TOPO [31] was used. This also allows to drop RLAN with a realistic height, since the database contains the building height as well. Note that for simplicity reason the RLANs are only dropped in the centre of each building and not in random positions in the premises. Given the random nature of building entry loss and clutter loss, this shall not have any impact on the simulation results.

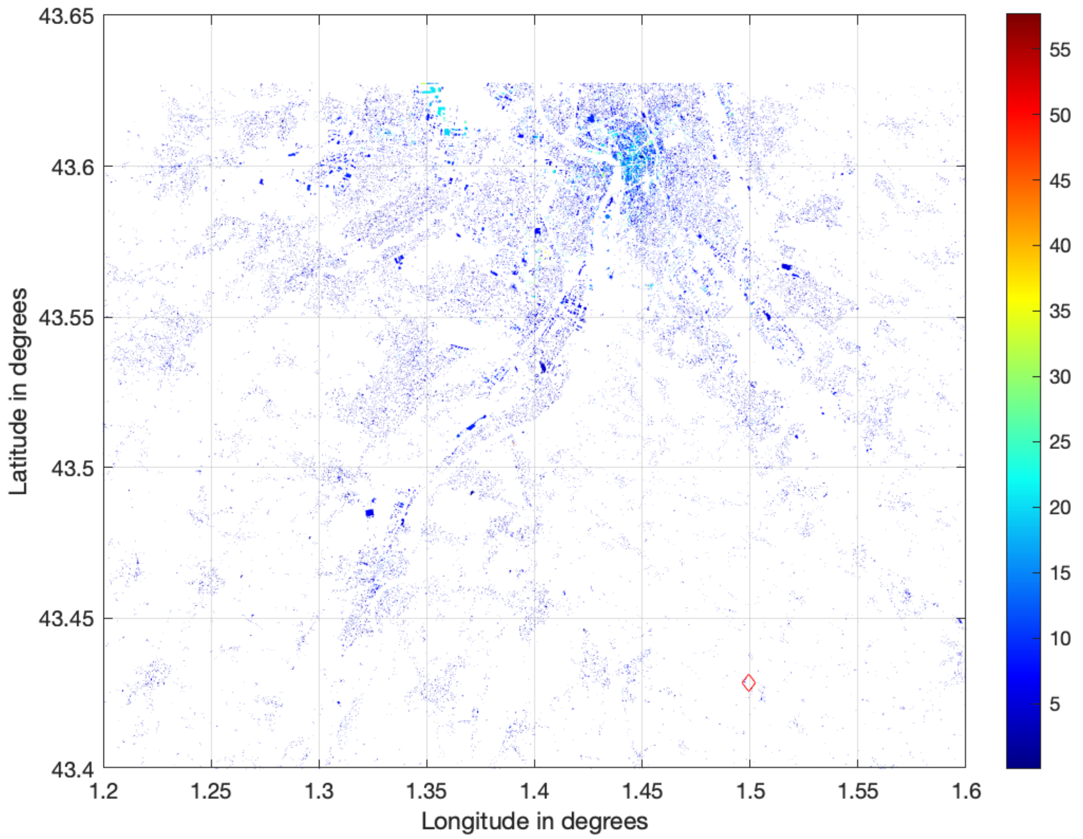


Figure 114: Buildings positions and height around the ground station, the red diamond is the ground station's position

A8.3 SIMULATION RESULTS

As already stated, four real ground station locations in Europe were studied. It has to be noted that all studied ground stations are located in rural areas with very low surrounding population densities.

The obtained CCDF of I/N observations over 20 days of simulations for Greece, Spain and Estonia and 8 days for France are shown in Figure 115. It can be observed that the protection criterion is never exceeded for all stations with a large margin. The results also show that there is no difference between using Recommendation ITU-R P.2001-4 with a percentage of time ranging uniformly between 0 and 100% or using Recommendation ITU-R P.452-17 with a percentage of time ranging uniformly between 0 and 100% but truncated at 50%.

A8.4 CONCLUSION

Monte Carlo sharing studies were conducted between WAS/RLAN and FSS DL ground stations over four ground stations in Europe, under Scenario A (High). The studies for the ground stations in Spain, Greece and Estonia were conducted under the assumption of exclusion zones set to 325 m, 500 m and 350 m as observed on the maps. The station in France was studied with real building data. Studies have shown that all stations respected the protection criterion of I/N=-10.5 dB not to be exceeded for more than 20% of the time.

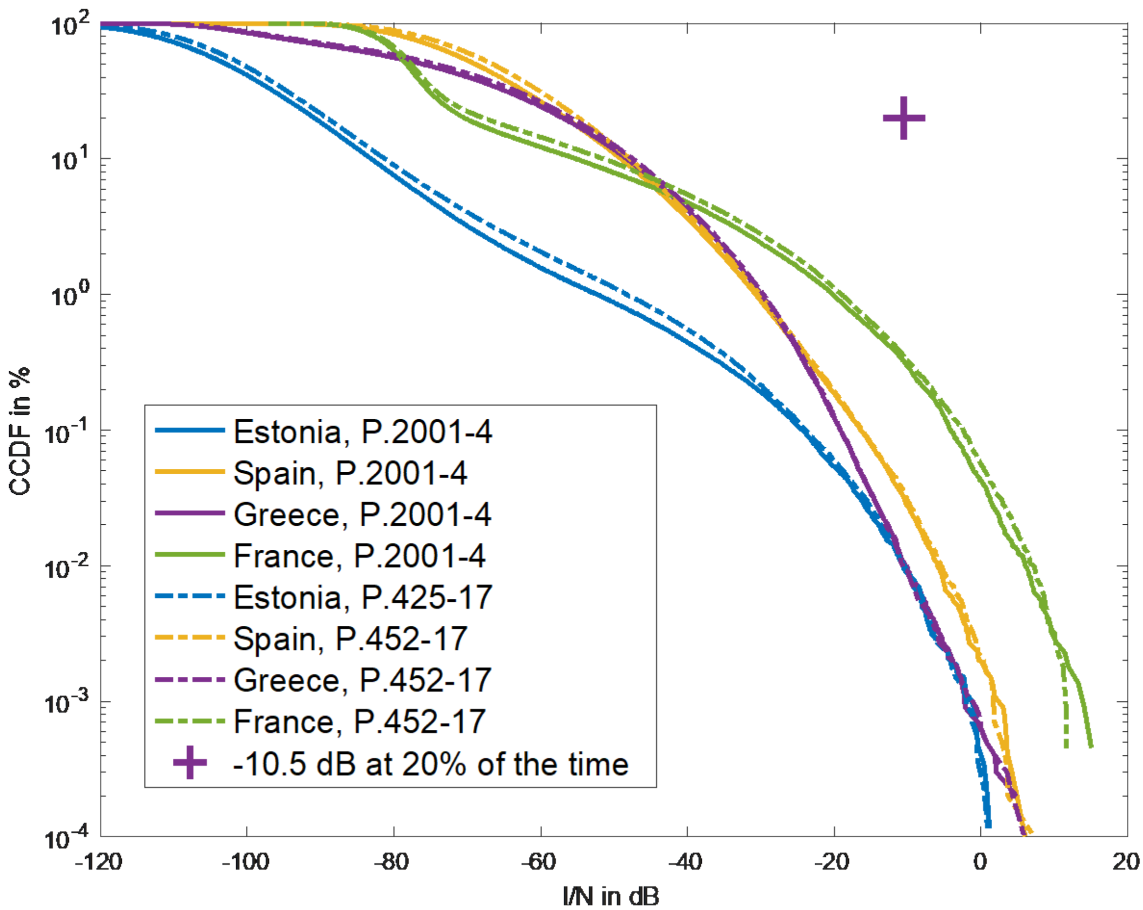


Figure 115: Obtained CCDF of observed aggregated I/N

ANNEX 9: SHARING WITH RADIO ASTRONOMY

A9.1 USE OF THE BAND BY RAS

Observations of the methanol (CH_3OH) maser[21] line in the RR **5.149** band 6 650.0−6 675.2 MHz, are important to radio astronomers around the world. In Europe, there are a many radio telescopes, which are equipped with state-of-the-art receivers to perform measurements of this spectral line with a substantial percentage of the total observing time. According to footnote RR **5.149** of the Radio Regulations, administrations are urged to take all practicable steps to protect the RAS from harmful interference in the band 6 650.0−6 675.2 MHz.

With RR No. **5.149**, the ITU-R recognised the importance of methanol observations in the 6.6 GHz band. Since then, the methanol line has become very important for the observation of star formation in its earliest stages. In fact, its detection and study in the inner parts of star forming regions is the principal way for astronomers to investigate stellar genesis. Since its comparatively recent discovery in star-forming regions, and in conjunction with observations of the spectral line arising from the water molecule at ~22 GHz, methanol observations are the primary means for astronomers to detect and then follow this process of star formation, as these regions are opaque to other (e.g. optical) spectral lines. Methanol is also one of the few compounds that produce strong masers, which allows detection over cosmic distances, e.g. in the core of active galaxies orbiting super-massive black holes, and thus providing insights into black hole physics and the high-energy processes in their vicinity The VLBI (Very Long Baseline Interferometry) Networks are important, consisting of a large number of CEPT RAS stations. VLBI observations of methanol masers are also needed in high-precision astrometry studies, which e.g. allow the determination of the spiral structure of the Milky Way with very high accuracy and provide an independent probe of the value of the Hubble constant.

A9.2 OUTLINE OF THE STUDY

As the target frequency range of WAS/RLAN devices in the upper 6-GHz band (6425−7125 MHz) is much larger than the frequency interval used by the RAS (6650.0−6675.2 MHz), both, sharing (co-channel) and compatibility (adjacent channel) scenarios have been considered. However, as the results of the study in this Annex shows, even in the sharing scenario, the required separation distances are relatively low, such that compatibility calculations are not strictly necessary for practical purposes.

WAS/RLAN will be deployed in large numbers such that single-entry calculations do not seem well-suited to assess the co-existence conditions with respect to the RAS. Therefore, this study focuses on the aggregation scenario, where a certain number of devices is deployed in the vicinity of a RAS station. For realistic results, the actual population density and land-cover types (which are relevant not only for clutter losses, but also for the deployment numbers and typical transmitter heights) have to be considered. Such datasets are available with high quality and sufficient spatial resolution for all European RAS sites. Therefore, only site-specific scenarios with respect to the RAS are studied in this Report.

In aggregation simulations, a number of WAS/RLAN devices is sampled randomly into a simulated area around a specific RAS site, according to the actual population density and with a range of transmitter heights above ground, reflecting the probability of devices on different floors of buildings. A certain fraction of the devices will be outdoors, but the majority is assumed to be operated indoors. The specific distribution functions for all these parameters were introduced in section 3. In the next step, the individual path propagation losses between transmitters and the RAS receiver are calculated. All received powers are aggregated (summed up) and compared with the permitted threshold levels (assuming a typical observing time of 2000 s; see Recommendation ITU-R RA.769-2 [12]). To assess the typical statistical uncertainty of the simulation, the simulation is repeated 2000 times, which makes it possible to study the posterior distribution (ensemble results) and is also important to measure the expected data loss percentage to the RAS observations.

[21] Microwave Amplification by Stimulated Emission of Radiation: The maser is based on the principle of stimulated emission. When atoms or molecules have been induced into an excited energy state, they can amplify radiation at a frequency particular to the atoms or molecule used as the masing medium (similar to what occurs in the lasing medium in a laser). In radio astronomy, cosmic masers are widely observed in OH, H_2O, SiO, CH_3OH and others.

The calculations in this study have been performed with the free open-source software package for spectrum management compatibility studies for Python, pycraf[22], which is developed by the Committee on Radio Astronomy Frequencies of the European Science Foundation (ESF-CRAF) in collaboration with the Square Kilometre Array Observatory (SKAO).

A9.3 TECHNICAL PARAMETERS, DEPLOYMENT SCENARIOS AND PROPAGATION

A9.3.1 RAS receiver parameters

Protection criteria for RAS are defined in Recommendation ITU-R RA.769-2 [12] and are shown in Table 123. In the 6.65 GHz band, RAS is primarily performing the so-called spectroscopy and VLBI observations. Associated threshold levels are listed in Recommendation ITU-R RA.769-2, tables 2 and 3. As the band is primarily used for spectroscopic observations, the spectroscopy limits of Recommendation ITU-R RA.769-2 are used. For convenience, the limits are also included in Table 123 with other relevant parameters. A list of relevant CEPT RAS stations is included in Table 124.

Table 123: Radio astronomy technical parameters

System Parameter	Value	Remarks
Integration time	2000 s	
Side lobe gain, G_r	0 dBi	According to Recommendation ITU-R RA.769-2, only side lobe receptions need to be considered
Threshold interference level Spectral power, $P_{lim,v}$ Spectral pfd, $S_{lim,v}$	 -176 dB (mW/MHz) -228 dB (W/m^2/Hz)	For spectroscopic observations: interpolated from Recommendation ITU-R RA.769-2 [12] Table 2
Antenna height, h_{rt}	Height of focal point	The average receiving feed's height above ground of the particular telescope is to be used.

Table 124: List of CEPT countries with RAS stations operating in the frequency band 6650−6675 MHz

RAS station	Country	Geographic longitude	Geographic latitude
Effelsberg	Germany	06° 53′ 01.0″	50° 31′ 29.4″
Wettzell		12° 52′ 38″	49° 08′ 42″
Medicina	Italy	11° 38′ 49″	44° 31′ 15″
Noto		14° 59′ 20″	36° 52′ 33″
Sardinia		09° 14′ 42″	39° 29′ 34″
Irbene	Latvia	21° 51′ 18″	57° 33′ 13″
Westerbork	Netherlands	06° 36′ 15″	52° 55′ 01″
Yebes	Spain	–03° 05′ 13″	40° 31′ 28.8″
Onsala	Sweden	11° 55′ 04″	57° 23′ 35″
Bleien	Switzerland	08° 06′ 43.3″	47° 20′ 23.7″

[22] https://pypi.org/project/pycraf/

RAS station	Country	Geographic longitude	Geographic latitude
Jodrell Bank	UK	–02° 18′ 26″	53° 14′ 10″
Pickmere		–02° 26′ 42″	53° 17′ 20″
Darnhall		–02° 32′ 09″	53° 09′ 24″
Knockin		–02° 59′ 49″	52° 47′ 26″
Defford		–02° 08′ 39″	52° 06′ 03″
Cambridge		00° 02′ 14″	52° 10′ 01″
Goonhilly (Note 1)		–05° 11′ 00″	50° 03′ 02″
Chilbolton (Note 1)		–01° 26′ 19″	51° 08′ 42″
Note 1: Planned operations			

A9.3.2 WAS/RLAN transmitter parameters

Transmitted power levels of the WAS/RLAN devices in this Report vary significantly and therefore, for an aggregation scenario a distribution of output powers is assumed according to Table 2 (in section 3). This lists several deployment types (e.g. indoor and outdoor with various power levels and different antenna gain distribution functions). Furthermore, different channel bandwidths can be used by the devices, according to Table 4. In Section A9.4.2 there is more details about how these parameters are handled in the calculations.

A9.3.3 Propagation model, clutter loss, and building entry loss

For the aggregated interference scenarios studied in the following, the propagation model specified in Recommendation ITU-R P.452-18 [6] is applied. In this propagation model, a time-percentage parameter exists, which needs to be distributed randomly. As the Recommendation ITU-R P.452 model is defined for time percentages up to 50%, all sampled values higher than 50% are set to 50%. This will impact the posterior distribution of received powers, but this is not an issue for the RAS compatibility studies as one is only interested in the highest 2% of the distribution (2% is the maximum data loss that RAS has to accept according to Recommendation ITU-R RA.1513-2 [13]) and higher time percentage parameters are associated with higher propagation losses.

In addition to the basic transmission loss, clutter loss and building entry loss (BEL) must be considered, as appropriate. Recommendation ITU-R P.2108-1 [8] is taken into account, which provides a statistical clutter model. One important condition for Recommendation ITU-R P.2108 is that transmitters are installed below the typical heights of the clutter (i.e. below the roof-tops of housings). This would certainly be the case for all indoor RLAN devices and also for the majority of outdoor devices. Recommendation ITU-R P.2108 is only applicable to urban and suburban areas. RAS stations, however, are usually situated in remote areas to avoid as much as possible artificial radio signals. The latest version (18) of Recommendation ITU-R P.452 proposes a different approach, in which clutter along the full propagation path is taken into account and not only for the path endpoints. In the following, the clutter loss is thus treated according to Recommendation ITU-R P.452-18. This works by using bare terrain height data (so-called digital terrain models, DTM) and adding the effective clutter height to every point on the path, except at the position of the transmitter and receiver. This will be further explained below.

Most of the RLAN devices in the aggregation simulations are indoors and thus subject to building entry loss. This is determined according to Recommendation ITU-R P.2109-1 [11]. A probability parameter is used in Recommendation ITU-R P.2109, which represents the probability that the resulting BEL is not exceeded. Unlike for the time-percent parameter of Recommendation ITU-R P.452, the approach of this study was to randomly vary that probability for all devices and time steps in each simulation run.

A9.4 AGGREGATION SIMULATIONS

In the following, the aggregation simulations are described in detail. The calculations have been performed for four different RAS stations, which are a good proxy for a range of environmental conditions:

- The *Effelsberg 100-m telescope* is situated in a valley in the German Eifel mountains, a sparsely populated area. However, at distances of about 30 and 40 kilometres, there are the major cities of Bonn and Cologne;
- The *Jodrell Bank Observatory (JBO)* is located in a relatively densely populated area close to Manchester (UK) on rather flat terrain;
- The *Sardinia Radio Telescope (SRT)* is on an elevated location in southern Sardinia, not far from the capital Cagliari in a mountainous area. Compared to the other sites under study, it has the lowest population count in the simulated area;
- The *Westerbork Synthesis Radio Telescope (WSRT)* is situated on very flat land in the Netherlands, surrounded by many villages in relatively open terrain and several larger urban centres and cities at some distance.

A9.4.1 GIS datasets

For European RAS stations, high-quality Geographic Information System (GIS) datasets are available, which make it possible to feed the relevant ITU-R models with actual data based on the environment around the sites. In the following, the datasets used for the aggregation simulation are briefly described.

A9.4.1.1 Land-cover data for determination of clutter zones and vertical device deployment

Corine Land Cover (CLC) data[23] were queried to obtain the clutter zone types for each position in the simulated map. The definition of clutter "classes" in CLC has a finer granularity than the clutter zones in model Recommendation ITU-R P.452, so a conversion was performed[24]. Based on the clutter zones, queried from CLC an effective clutter height can be determined, which is required for the Recommendation ITU-R P.452-18 model along each step of the height profile for the propagation loss calculations (see Recommendation ITU-R P.452-18, Table 3). The map of clutter zones is displayed in Figure 116. The clutter zone types are also used in the following to assign each transmitter location on the map to either of the rural, suburban and urban classes, which is relevant for the transmitter height distributions. For that matter, the Recommendation ITU-R P.452 "Sparse", "Deciduous Trees" and "Coniferous Trees" clutter classes are assigned to Rural zones, the "Suburban" and "Industrial Zone" clutter classes are assigned to Suburban and "Urban" is assigned to Urban.

---

[23] Corine Land Cover (CLC), https://www.copernicus.eu/

[24] See pycraf manual: https://bwinkel.github.io/pycraf/latest/pathprof/index.html#conversion-between-landcover-classes-and-p-452-clutter-types

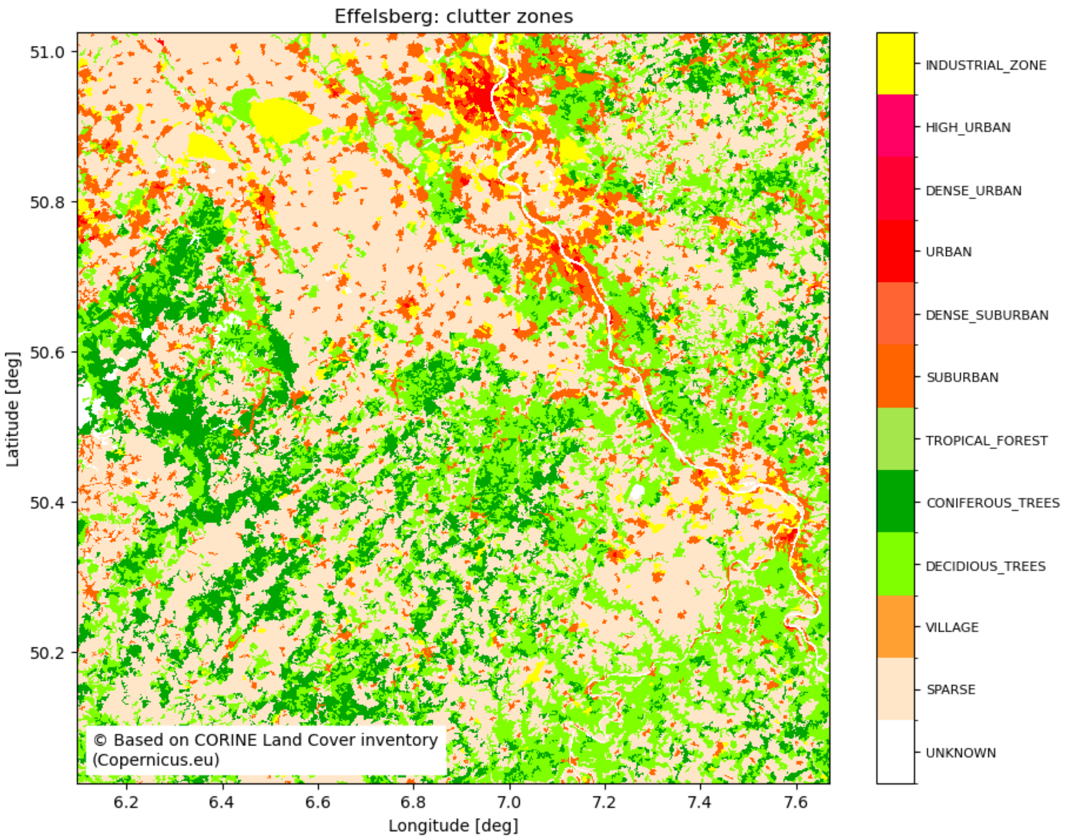


Figure 116: Clutter zone types based on Corine Land Cover data

A9.4.1.2 Terrain heights for propagation calculations

In order to use the propagation loss model specified in Recommendation ITU-R P.452-18, terrain height information is needed. In the past, NASA/SRTM data [14] was often utilised, but this is actually providing a digital surface model (DSM) rather than the required DTM. For most European sites, newer and more accurate Lidar-based terrain height maps are available (often as both DTM and DSM). The sources of these vary from region to region[25]. Figure 117 displays the terrain height map for the Effelsberg observatory, as an example. The simulated area is 1 deg^2 (about 110 km × 110 km) in this case. It will turn out that for the other RAS sites, the required separation distances are larger than for the Effelsberg site, making larger simulation box sizes necessary (see Table 125).

[25] Sources for the different RAS stations used in this Report, based on a compilation provided by Sonny (https://sonny.4lima.de/) under CC BY 4.0:

- Effelsberg, DEU: Land Nordrhein-Westfalen (2017), DTM 1 Meter & Landesamt für Vermessung und Geobasisinformation Rhineland-Palatinate: DTM 25 Meter (DGM25) ; License: Datenlizenz Deutschland Namensnennung 2.0
- WSRT, NL: Actueel Hoogtebestand Nederland (AHN2): DTM 5 Meter
- SRT, IT: Regione Autonoma della Sardegna, Sardegna Geoportale: DTM 1 m and DTM 10 m
- JBO, UK, Environment Agency: LiDAR Composite DTM 10 m, Open Government Licence

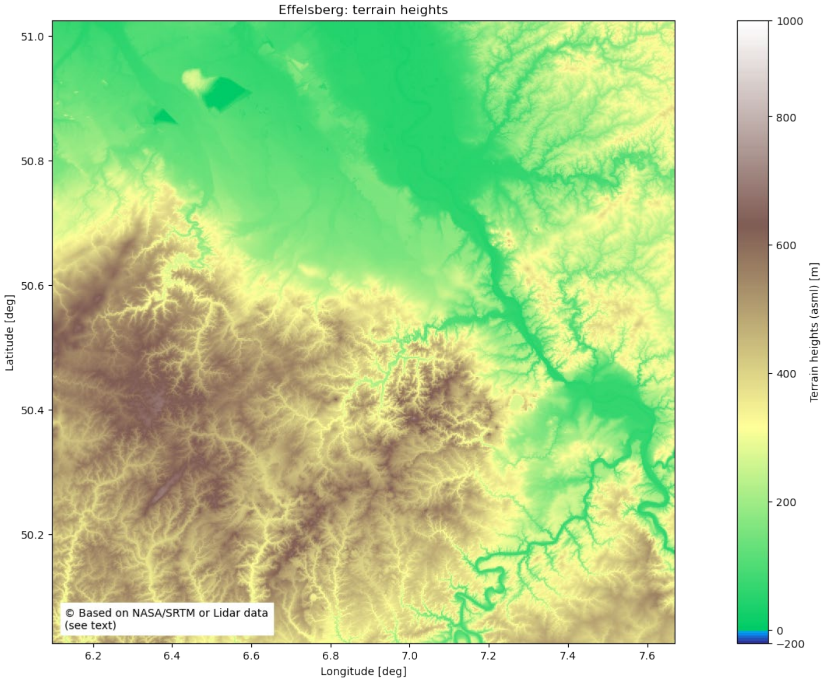


Figure 117: Terrain height map based on Lidar data for the Effelsberg observatory

Based on the terrain height map and assuming a certain WAS/RLAN transmitter height (above ground), transmission losses to the RAS station can be calculated using the propagation model based on Recommendation ITU-R P.452-18; see Figure 118. For the purpose of visualisation, in Figure 118 a time percentage parameter of 2% was chosen, but as explained above, the simulations use random values. In the simulations, transmitters can be situated at different (discrete) heights according to the building floor where they are installed (compare Table 125). For each of these heights, an associated attenuation map is determined and stored in memory to allow fast look-up in the simulation.

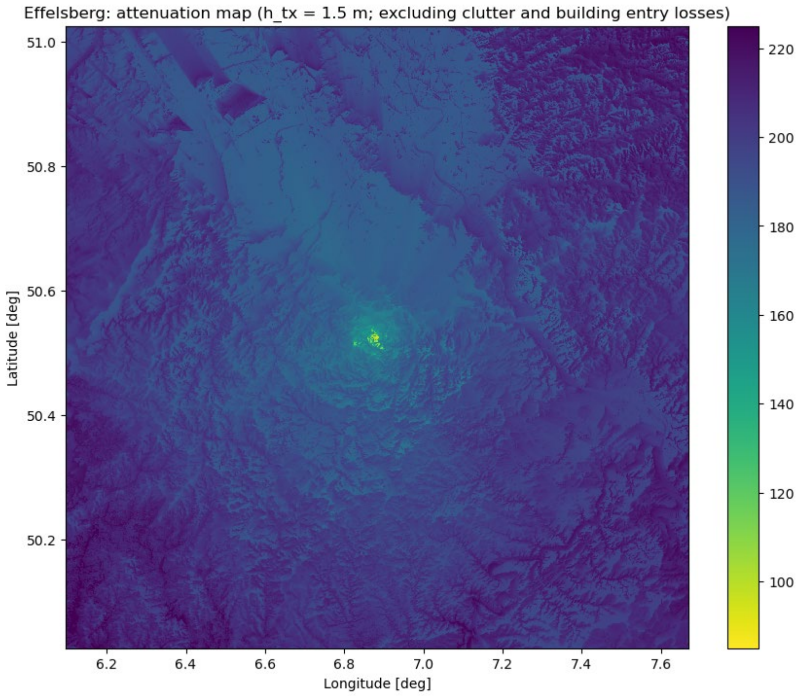


Figure 118: Transmission loss (dB) for the area around the Effelsberg observatory, assuming 1.5 m transmitter heights (above ground)

A9.4.1.3 Population density for spatial device deployment

Population density maps can be used to control the spatial deployment of devices in the simulation. It is assumed that population density is a good proxy for the typical number of WAS/RLAN devices in a given grid cell (at least on average): people use such networks when they are at work or at home, but also in shopping malls and restaurants. While the population density data is usually tied to the home addresses of people, it is assumed here that the spatial distributions of the other activities resemble the former.

A world-wide map of population density is provided by the European Commission Joint Research Centre (JRC) in the form of a "Global Human Settlement population grid" (GHS) data set [15], which is available for several years, including forecasts for 2030 (used here). A visualisation is shown in Figure 119 for the example of the Effelsberg RAS station.

Based on the population density map, a population map can be derived (which is better suited for random sampling of devices) by multiplying the density with the area of each grid cell. This is almost a scaled version of the density map, but as the grid cell area is somewhat inhomogeneous owing to the curvature of the Earth, there is a slight difference. Using a method called the "inverse sampling technique" (see A9.6, random samples of longitude and latitude, pairs can now be generated, which adhere to the population distribution function. For this, the total number of active devices in the target area has to be provided. This will be explained further below.

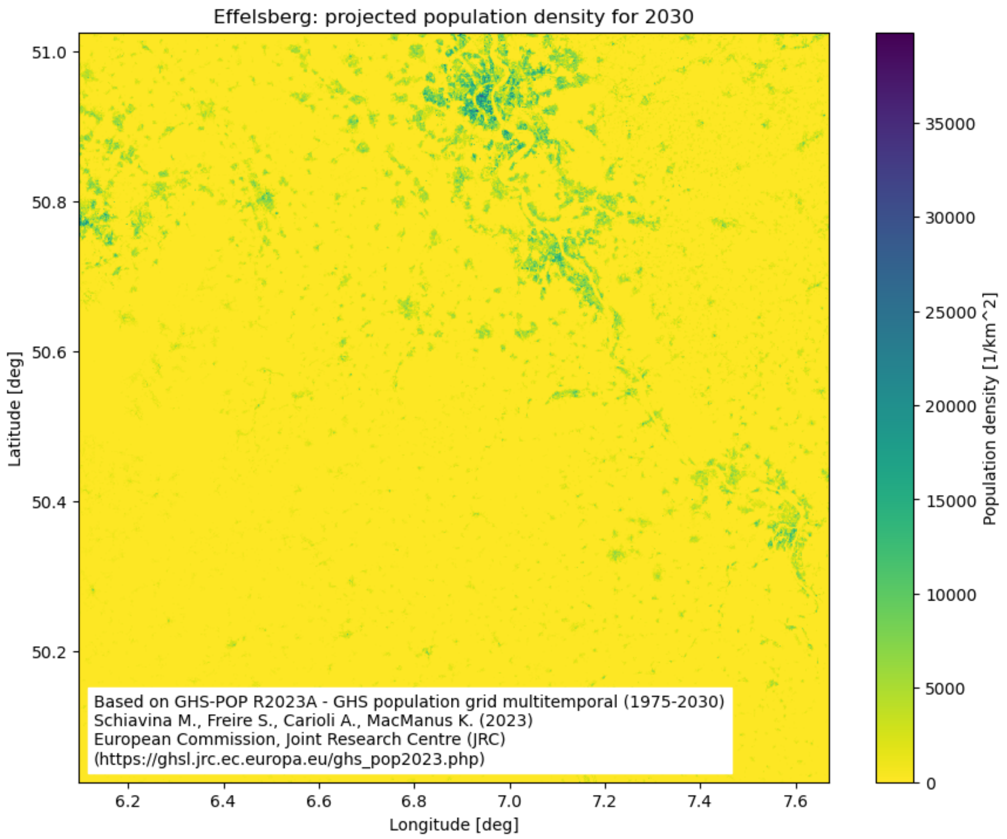


Figure 119: Population density around the Effelsberg observatory

A9.4.2 Device deployment

As discussed in Section A9.2, the population (density) map is used for the spatial deployment in the simulation, i.e. the location sampling of devices. For this, it is necessary to know how many active transmitters are in the simulated box. Based on various assumptions, a *deployment factor* can be inferred; see Section 3.2. It depends on the estimated market adoption factor, the fraction of devices in the 6 GHz band (compared to all bands), busy hours, etc. Multiplying all percentages the effective factor is computed. When this is multiplied with the population counted in the simulated area, the total number of active devices is obtained. However, not all active devices use an RLAN channel that overlaps with the RAS band, such that the relevant number of devices is further reduced (this is further explained below). Table 7 shows various usage scenarios (Scenarios A and B, each with Low, Mid and High traffic). In Table 125, the resulting number of active devices in the simulation box area is compiled.

Table 125: Total population number (2030) and instantaneously transmitting WAS/RLANs in the simulated area

RAS Station	Simulation box size	Total population (in Million inhabitants)	Instantaneously transmitting WAS/RLANs (RLAN channel overlapping RAS channel)					
			Scenario A			Scenario B		
			Low	Mid	High	Low	Mid	High
Effelsberg	1°×1°	4.78	766	1233	1964	1337	2248	3616
Jodrell Bank	3°×3°	29.96	4788	7605	11752	8466	13758	22923
SRT	2°×2°	1.00	159	258	423	292	479	784
WSRT	3°×3°	29.03	4608	7693	11479	8345	13247	21886

Once the locations of the devices have been randomly chosen, they have to be assigned to one of the four different transmitter "types" (i.e. maximum *e.i.r.p.*) for both, indoor and outdoor (see Table 2). Whether a device is indoor or outdoor will influence the assignment of BEL. Likewise, the maximum *e.i.r.p.* and the antenna gain distributions are used to sample a random actual *e.i.r.p.* for each device. According to Table 4, there are different likelihoods for certain channel bandwidths. The transmit power per channel is, however, independent on the channel bandwidth, i.e. the spectral power (W per Hz) is lower for larger bandwidths. For convenience, the *e.i.r.p.* values are converted to spectral *e.i.r.p.* by dividing the numbers by (the randomly chosen) channel bandwidths for each device.

Then, the likelihood that the active RLAN channel is overlapping with any of the spectral channels in the RAS band needs to be determined. Assuming equal spacing of the various channel bandwidths from the lowest frequency 6425 MHz, one can derive that two 20, 40, and 80 MHz channels overlap the RAS band (6650 - 6675.2 MHz), but only one channels each for 160 and 320 MHz[26]. However, as the spectroscopy limits in Recommendation ITU-R RA.769-2 (their table 2) are for narrowband spectral channels within the RAS frequency range. Only a single RLAN channel of a given width can overlap a RAS spectral channel at any time. This results in the following likelihoods: 20 MHz: 1/36=0.0278, 40 MHz: 1/18=0.0556, 80 MHz: 1/9=0.1111, 160 MHz: 1/5=0.2, 320 MHz: 1/3=0.3333. Together with the bandwidth distribution (Table 4), the total likelihood to have any RLAN channel overlap any spectral channel in the RAS band is thus 17.55% (the numbers of active devices in Table 125 already account for this). As the transmitted powers were converted to spectral powers previously, no additional bandwidth correction is required. Consequently, the RAS spectral power limits are used later for assessing the exceedance of the threshold.

To determine the associated received spectral powers at the RAS station, the path propagation loss and the building entry loss need to be determined for each active device. The path propagation losses depend on the antenna installation heights, the locations of the transmitters and the Recommendation ITU-R P.452 time percentage parameter. The latter was randomised, but the same value was assigned to every device in the map in each simulation run. This is considered more realistic as the radio propagation conditions are not expected to vary a lot in a relatively small area for a certain time (of course, at different observing times, variation will occur). Tests were conducted where every device was assigned a random value even within a simulation run, but the result did not significantly differ from the first approach. The distribution of antenna heights is provided in Table 3. The effective clutter losses depend on the clutter zone types along the propagation path (compare Figure 116). Most radio telescopes are either much higher than surrounding clutter

[26] 20 MHz: 6645–6665 MHz, 6665–6685 MHz; 40 MHz: 6625–6665 MHz, 6665–6705 MHz; 80 MHz: 6585–6665 MHz, 6665–6745 MHz; 160 MHz: 6585–6745 MHz; 320 MHz: 6425–6745 MHz

or are in open terrain. An exception is the Westerbork observatory (with relatively small dish sizes), which is surrounded by coniferous trees.

The building entry losses according to Recommendation ITU-R P.2109-1 depend on the (propagation) path elevation angle. Therefore, the Recommendation ITU-R P.452 procedures are used to calculate that angle and a random probability is assigned to each device required by the Recommendation ITU-R P.2109 algorithm. Recommendation ITU-R P.2109 also makes a distinction between thermally efficient buildings (higher BEL) and traditional buildings. Based on ECC Report 302 (section 5.4) it is assumed that 30% of the buildings are thermally efficient and 70% are traditional.

In the following, a few example figures are provided, which visualise some of the above quantities for one of the simulation runs (Effelsberg telescope, all Scenario A (High)). In all figures, only the active devices with an RF channel that overlaps the RAS band are shown. Figure 120 has the sampled antenna installation heights (i.e. building floor heights). The majority of transmitters is located on the ground or first floor (1.5 and 4.5 m height, respectively). The spatial distribution follows the population density map. In Figure 121, the effective spectral *e.i.r.p.* levels (i.e. already including antenna gain distributions) are contained. The assigned building entry losses are displayed in Figure 122. BEL peaks at about 15–20 dB; see Figure 123. (outdoor devices have 0 dB BEL.)

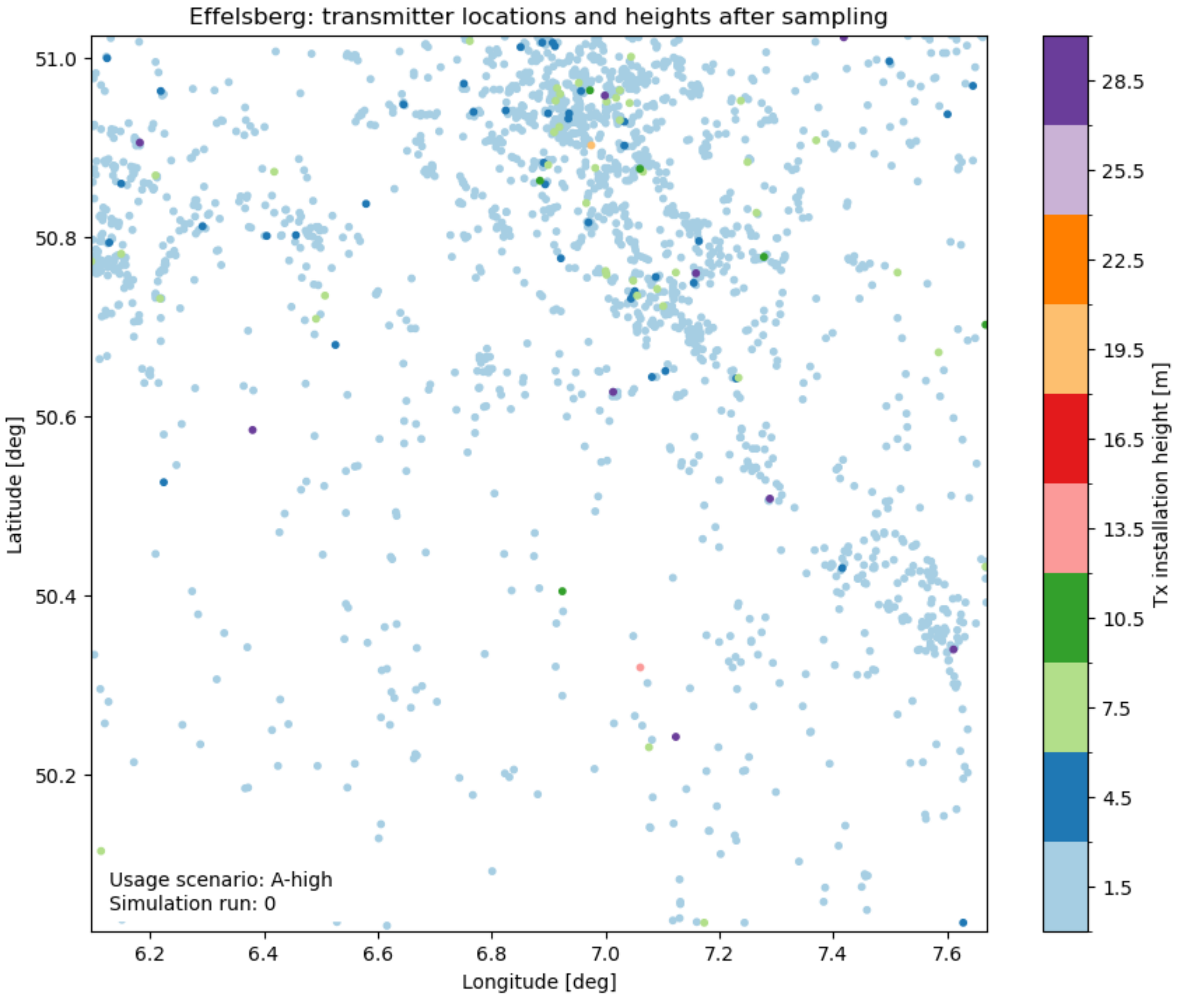


Figure 120: Example outcome of location and height sampling in the simulations

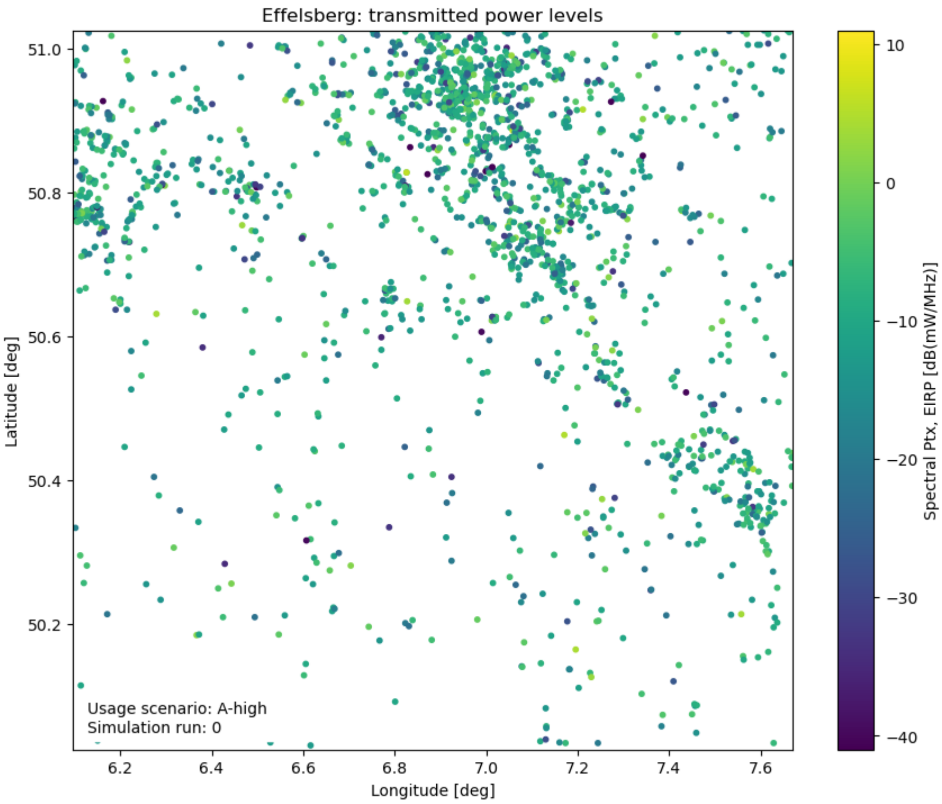


Figure 121: Assigned effective spectral *e.i.r.p.* values for the devices in Figure 120

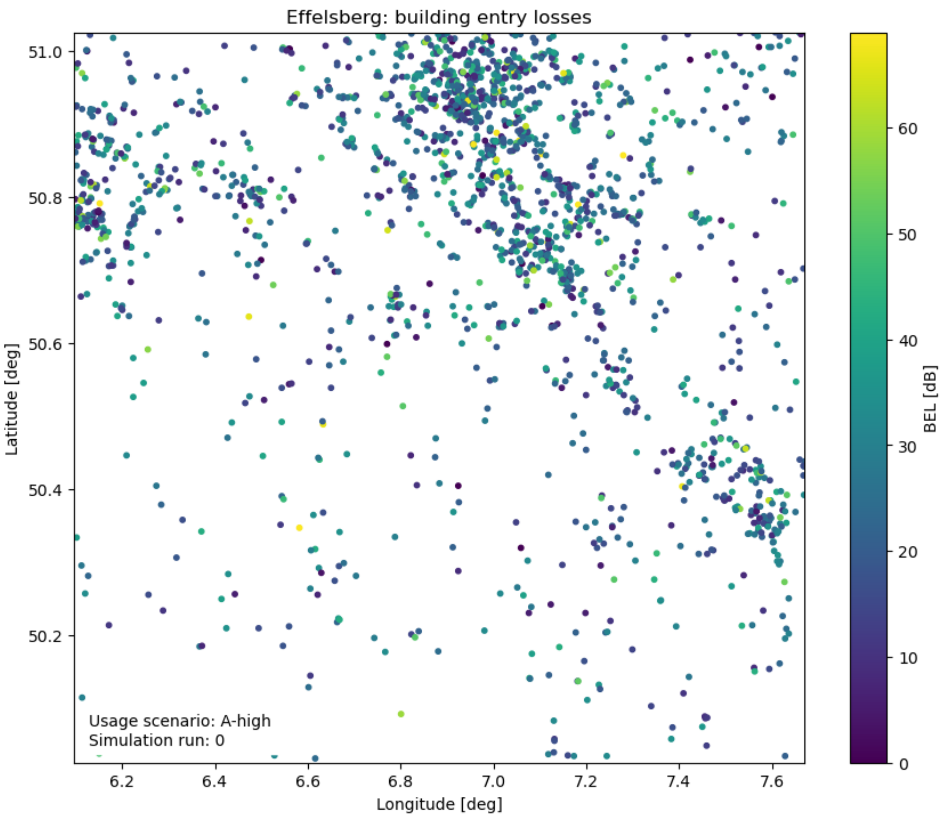


Figure 122: Assigned building entry losses for the devices in Figure 120

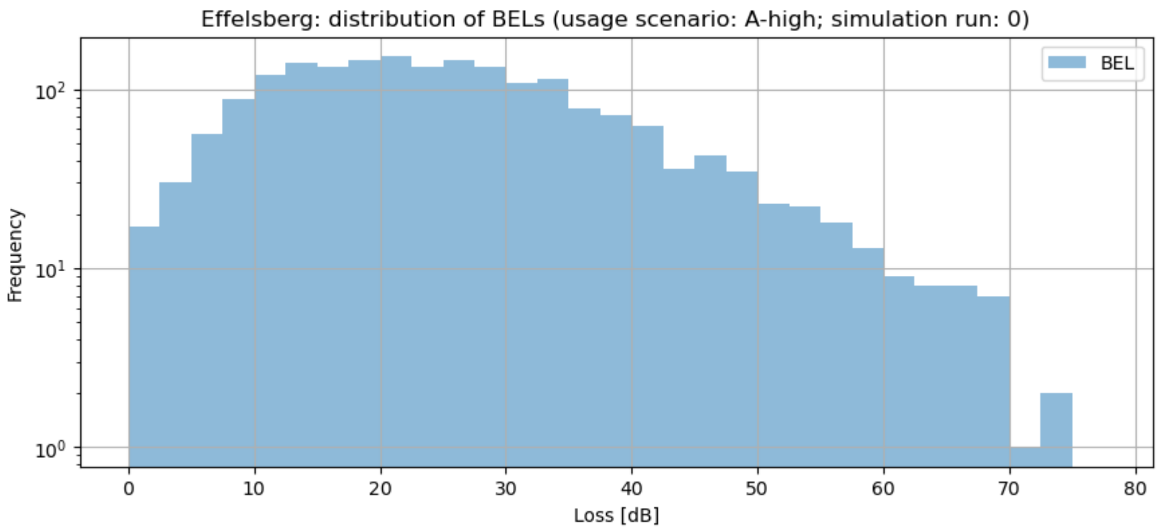


Figure 123: Histogram of the BEL values (shown in Figure 122)

A9.4.3 Total received spectral power at RAS station

Subtracting the propagation, clutter and building entry losses from the transmitted spectral power (in logarithmic units), the received spectral power from each device at the RAS receiving system is obtained. The individual contributions are displayed in Figure 124 (locations) and Figure 125 (histogram). The vertical green line in Figure 125 indicates the aggregated received spectral power (i.e. linear sum of all individual contributions), the vertical red line indicates the RAS threshold level provided by Recommendation ITU-R RA.769-2. In the example simulation run, shown in Figure 125, the aggregated power would be well below the threshold. However, there may also be simulation runs, where the aggregated power exceeds the threshold. This can happen if there are one or more transmitting devices close to the RAS station (in particular if outdoors). The simulation is repeated 1000 times to analyse the typical statistical scatter of the results.

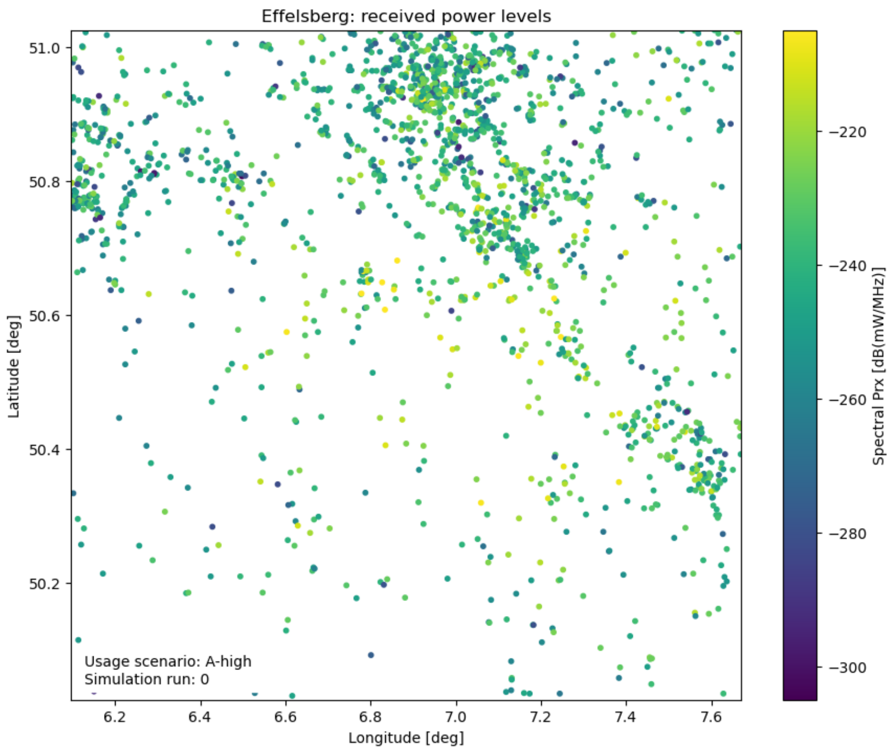


Figure 124: Received spectral power from active devices in Figure 120

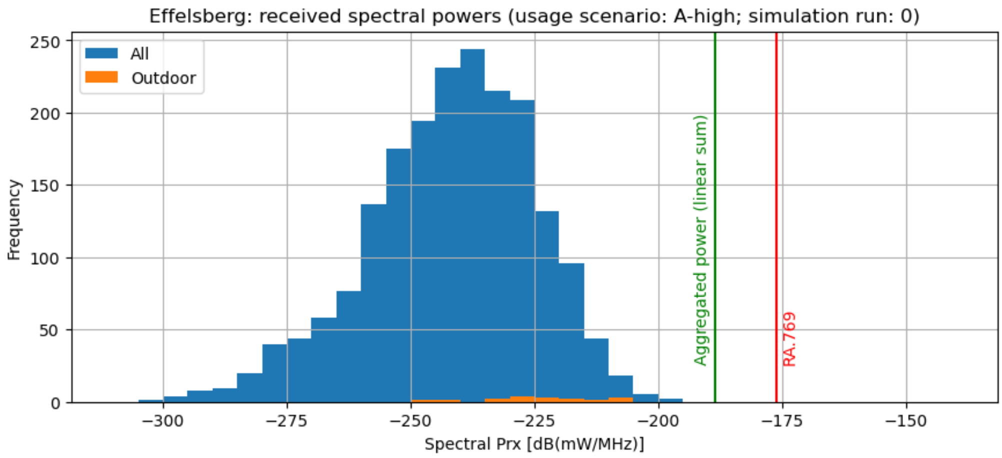


Figure 125: Distribution of received spectral powers (shown in Figure 124)

A9.4.4 Required exclusion zone sizes

As a fraction of simulation runs may yield aggregated spectral powers which exceed the RAS limits, an analysis was carried out on which minimal separation distance would be required for co-existence in the 6650.0−6675.2 MHz band. For this, a hypothetical exclusion zone with growing radius was applied, i.e. all devices within the exclusion zone radius are not considered when computing the aggregated power; see Figure 126. The grey curves show the resulting aggregated power for each individual simulation run as a function of increasing exclusion radius. The black solid line is the median of the individual results. The median, however, is not the required quantity here. According to Recommendation ITU-R RA.1513-2 [13], RAS has to accept a maximum data loss of 2%. Therefore, the intersection of the 98% percentile curve (the dashed black line) with the Recommendation ITU-R RA.769 threshold (horizontal red solid line) indicates the minimum required exclusion zone radius. The figure also contains the results for the case where indoor-only devices are considered, which may be useful for comparison (cyan-coloured curves). This shows that the total aggregated spectral power is dominated by outdoor installations. For comparison, Figure 127 shows the outcome of the simulations for “Low” usage scenario. The difference in exclusion radii between Low and High traffic scenarios is not very large.

For completeness, the results for the Jodrell Bank Observatory, SRT and WSRT in the Scenario “A-High” are also shown in Figure 128, Figure 129 and Figure 130.

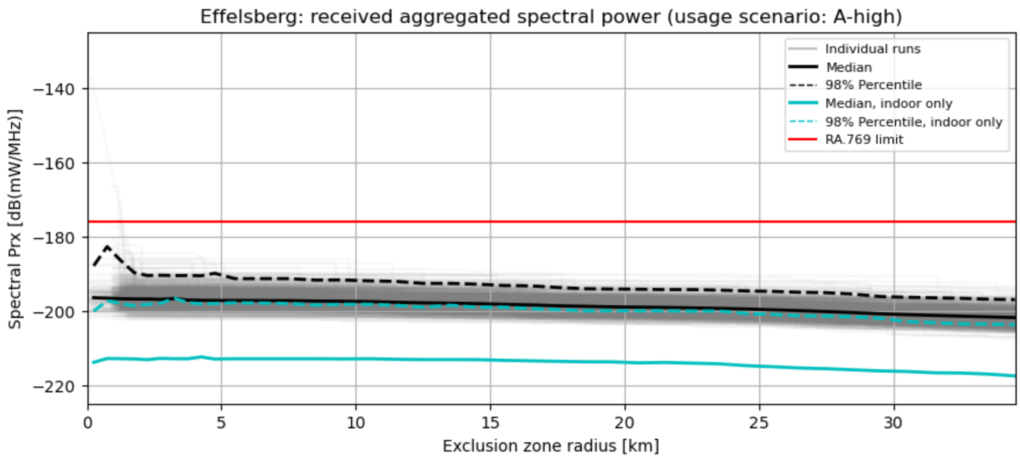


Figure 126: Aggregated received spectral powers from all simulation runs as a function of exclusion zone size. Result is shown for the High usage Scenario A

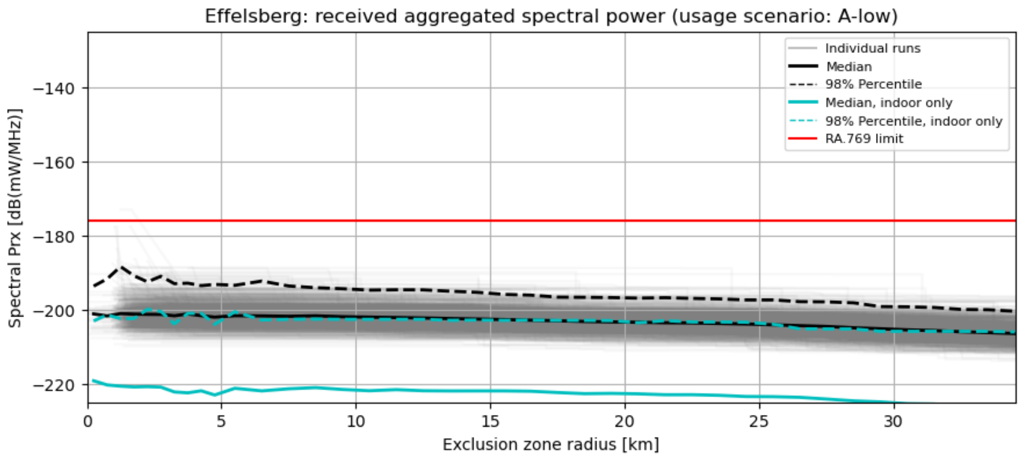


Figure 127: As Figure 126 but for Low usage Scenario A

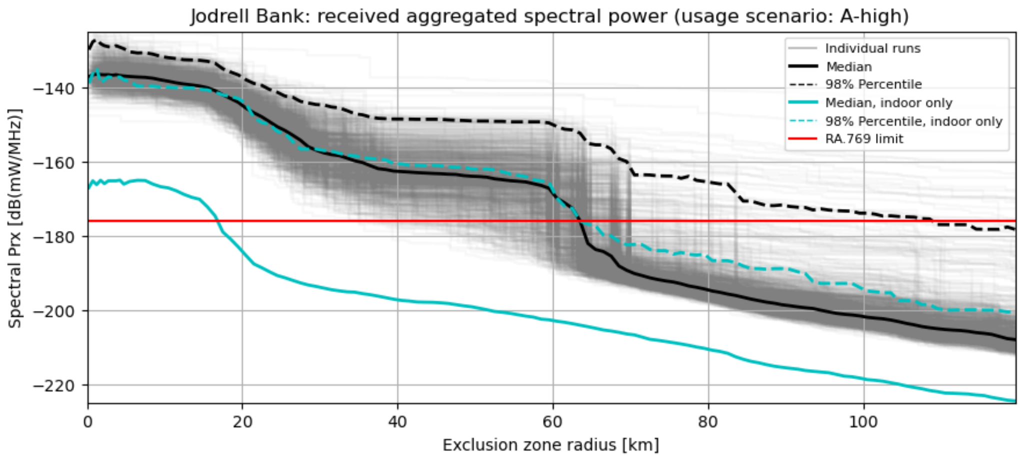


Figure 128: As Figure 126 but for Jodrell Bank Observatory (UK)

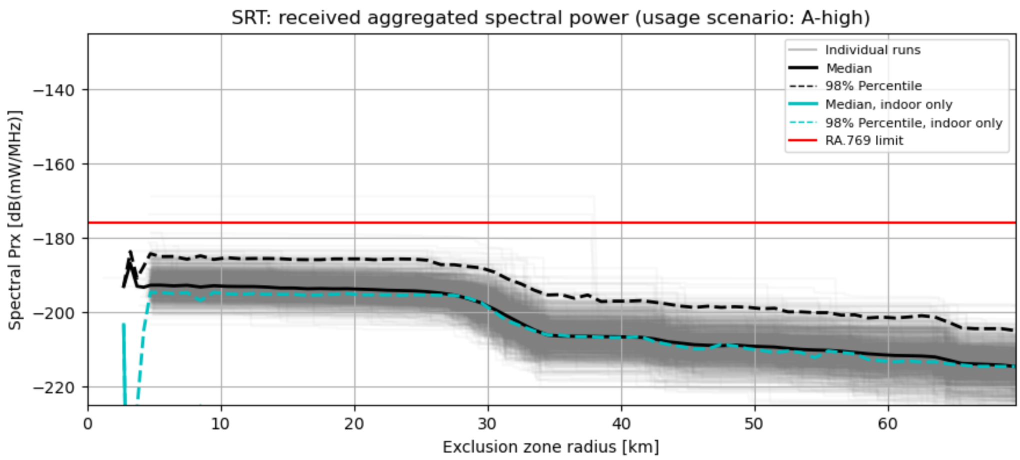


Figure 129: As Figure 126 but for Sardinia Radio Telescope (Italy)

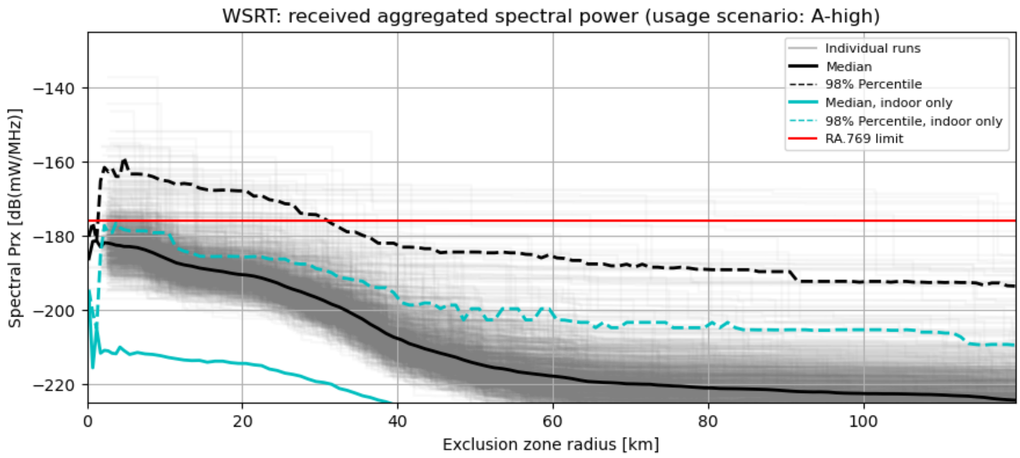


Figure 130: As Figure 126 but for WSRT (NL)

A9.5 SUMMARY

The results for Effelsberg, as displayed in Figure 126 and Figure 127, show that even a very small coordination zone would suffice to fully protect the RAS operations in the 6650.0−6675.2 MHz band. For Jodrell Bank and WSRT the required radii are relatively large.

All results are compiled in Table 126 and Table 127.

Table 126: Required exclusion zone radii in kilometres for all RAS stations and deployment scenarios

RAS Station	Scenario A			Scenario B		
	Low	Mid	High	Low	Mid	High
Effelsberg 100-m	<1	<1	<1	<1	<1	<1
Jodrell Bank Observatory	84.5	84.5	108.5	97.5	110.5	118.5
Sardinia Radio Telescope	<1	<1	<1	<1	<1	2.8
Westerbork	26.5	24.5	30.5	25.5	33.5	36.5

Table 127: As Table 126 but restricted to indoor devices

RAS Station	Scenario A			Scenario B		
	Low	Mid	High	Low	Mid	High
Effelsberg 100-m	<1	<1	<1	<1	<1	<1
Jodrell Bank Observatory	60.5	60.5	63.5	60.5	63.5	69.5
Sardinia Radio Telescope	<1	<1	<1	<1	<1	<1
Westerbork	2.2	<1	<1	4.2	8.5	10.5

A9.6 INVERSE SAMPLING TECHNIQUE

To sample random numbers adhering to a given probability distribution, the "inverse sampling" technique can be used. Here the discrete version is explained, which works with any discrete probability distribution, $\rho(x)$, and can also be used to approximate continuous cases. Figure 131 outlines the principle of the method. Mathematically, the inverse CDF, F^{-1}, is determined and random numbers from the uniform distribution are fed into it:

$$x_n \sim F^{-1}(y_n), \quad \text{with } y_n \sim U(0,1) \text{ and } F(x) = \int_0^x \rho(x')dx'.$$

For discrete distributions or numerical approximations, the integral is replaced with the sum, in which case $F(x)$ becomes the cumulative sum of $\rho(x)$. Taking the inverse is then a search operation in the CDF curve, i.e. finding the piece of the curve having the required y_n-value, which gives the associated x_n.

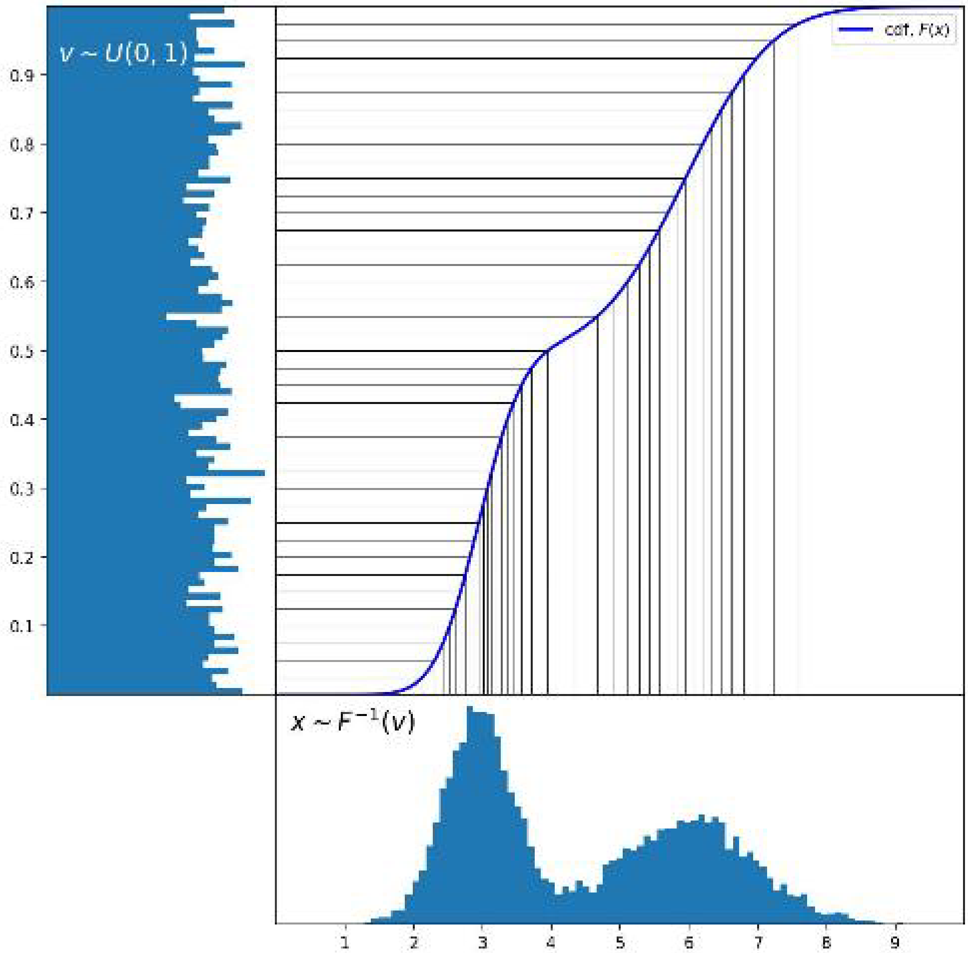


Figure 131: The inverse sampling technique can be used to generate random numbers adhering to a given target probability distribution by using the inverse CDF (or an approximation of it) and utilising uniformly distributed random samples

ANNEX 10: FRACTIONAL DEGRADATION IN PERFORMANCE DERIVATION ASSUMING FS LINK WITH NO ATPC

1 As described in Recommendation ITU-R F.1108 [38] the Fractional Degradation in Performance (FDP) is given by

$$\text{FDP} = \frac{P_{\text{O},i} - P_{\text{O},0}}{P_{\text{O},0}} = \frac{P_{\text{O},i}}{P_{\text{O},0}} - 1 \quad (1)$$

where:

- $P_{0,0} = \text{Prob}(f \geq \text{FM})$ is the probability of outage due to fading only
- $\text{Prob}(f \geq \text{FM}) = \int_{\text{FM}}^{+\infty} \text{pdf}_f(f)\, df$
- f is the fade in dB
- $\text{pdf}_f(f)$ is the fade probability density function based on, e.g. Recommendation ITU-R P.530, and its support is from $+\infty$ to $-\infty$.
- FM is the Fading Margin in dB estimated based on Recommendation ITU-R P.530 according to the Performance Objectives (EPO) parameters
- $P_{0,i}$ is the probability of outage from fading and interference and is given by the joint probability in equation (2). This is written in a format that was derived in Recommendation ITU-R F.1108

$$P_{0,i} = \int_0^{+\infty} \text{pdf}_z(z) \cdot \text{Prob}(f \geq \text{FM} - 10\log_{10}(1+z))\, dz \quad (2)$$

where:

- $z = \frac{i}{n}$, and $\frac{i}{n}$ is the numerical interference to noise ratio in linear scale
- $\text{pdf}_z(z)$ is the probability density function of the interference to noise ratio distribution and its support is from 0 to $+\infty$.

2 The FDP equation can be divided into two components, a short-term and long-term:

$$\text{FDP} = \text{FDP}_{\text{ST}} + \text{FDP}_{\text{LT}} = \frac{P_{\text{O},i_{\text{ST}}} - P_{\text{O},0}}{P_{\text{O},0}} + \frac{P_{\text{O},i_{\text{LT}}} - P_{\text{O},0}}{P_{\text{O},0}} \quad (3)$$

where:

FDP_{ST} is the short-term fractional degradation in performance. It occurs when the interference degradation exceeds the FM. This is referred to as short-term degradation because high levels of interference occur with low probability.

$$\text{FDP}_{\text{ST}} = \frac{P_{\text{O},i_{\text{ST}}}}{P_{\text{O},0}} - 1 = \frac{P_{\text{O},i_{\text{ST}}} - P_{\text{O},0}}{P_{\text{O},0}} \quad (4)$$

FDP_{LT} is the long-term fractional degradation in performance. It occurs when the interference degradation is less than the FM, but the combination of fading and interference exceed the FM. It is referred to as long-term because low levels of interference occur with higher probability.

$$\text{FDP}_{\text{LT}} = \frac{P_{\text{O},i_{\text{LT}}}}{P_{\text{O},0}} - 1 = \frac{P_{\text{O},i_{\text{LT}}} - P_{\text{O},0}}{P_{\text{O},0}} \quad (5)$$

$P_{O,i_{\text{ST}}}$ is the joint probability of outage from fading and interference when the interference degradation is greater or equal than the FM (or $z \geq \left(\frac{i}{n}\right)_{\text{ST}}$ and $\left(\frac{i}{n}\right)_{\text{ST}} = 10^{\frac{\text{FM}}{10}} - 1$) and is given by:

$$P_{\text{O},i_{\text{ST}}} = \int_{(i/n)_{\text{ST}}}^{+\infty} \text{pdf}_z(z) \cdot \text{Prob}\big(f \geq \text{FM} - 10\log_{10}(1+z)\big)\, dz + (1-\gamma) \cdot P_{\text{O},0} \quad (6)$$

Where $(i/n)_{\text{ST}} = \text{FM}$ (Fade Margin)

The joint probability of fading and interference is considered to account also for upfading events when an interference degradation higher than the fade margin is needed to produce outage.

Where $\gamma = \text{Prob}\ (z \geq (i/n)_{\text{ST}})$ is a normalisation term and is added so that the FDP equation can retain the format defined in Recommendation ITU-R F.1108.

$P_{0,i_{\text{LT}}}$ is the joint probability of outage from fading and interference when the interference degradation is less than the FM (or $z < \left(\frac{i}{n}\right)_{\text{ST}}$) and is given by:

$$P_{\mathrm{O},i_{LT}} = \int_0^{(i/n)_{\mathrm{ST}}} \mathrm{pdf}_z(z) \cdot \mathrm{Prob}\big(f \geq \mathrm{FM} - 10\log_{10}(1+z)\big)\,\mathrm{d}z + \gamma \cdot P_{\mathrm{O},0} \tag{7}$$

Where $(i/n)_{\mathrm{ST}} = \mathrm{FM}$ (Fade Margin)

Note that both equations (6) and (7) take into account both upfading and downfading events by considering both positive and negative fading in the distribution of the fade f.

3 The FDP % should not exceed 10% (co-primary service) or 1% (non-co-primary service).

ANNEX 11: FRACTIONAL DEGRADATION IN PERFORMANCE DERIVATION ASSUMING FS LINK WITH ATPC

1 When the FS link uses power control, the probability of outage $P_{O,i\,\mathrm{ATPC}}$ from fading and interference calculation needs to be divided into two parts: when the fading is below the Automatic Transmit Power Control (ATPC) range and when it is above it.

When the fade f is below the ATPC range, the margin is kept constant to the Net Fade Margin (NFM), therefore outage occurs when the degradation due interference is larger than NFM. This probability becomes $\mathrm{Prob}(f \leq \mathrm{ATPC\ Range}) \cdot \mathrm{Prob}(10\log_{10}(1+z) \geq \mathrm{NFM})$.

When the fade f is above the ATPC range, outage occurs when the degradation due interference is larger than the fade margin (FM). This probability becomes $\int_{\mathrm{ATPC\ range}}^{+\infty} \mathrm{pdf}_f(f) \cdot \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{FM} - f)\,\mathrm{d}f$.

The probability of outage with ATPC is

$$P_{O,i} = \int_{-\infty}^{+\infty} \mathrm{pdf}_f(f) \cdot \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{NFM} + \mathrm{ATPC}(f) - f)\,\mathrm{d}f \tag{A}$$

And

$$\mathrm{ATPC}(f) = \begin{cases} f & \text{if } f \leq \mathrm{ATPC\ Range} \\ \mathrm{ATPC\ Range} & \text{otherwise} \end{cases} \tag{B}$$

Therefore, combining (A) and (B), (A) can be rewritten as

$$P_{O,i} = \int_{-\infty}^{\mathrm{ATPC\ Range}} \mathrm{pdf}_f(f) \cdot \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{NFM} + f - f)\,\mathrm{d}f + \int_{\mathrm{ATPC\ Range}}^{+\infty} \mathrm{pdf}_f(f) \cdot \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{NFM} + \mathrm{ATPC\ Range} - f)\,\mathrm{d}f$$

$$= \int_{-\infty}^{\mathrm{ATPC\ Range}} \mathrm{pdf}_f(f) \cdot \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{NFM})\,\mathrm{d}f + \int_{\mathrm{ATPC\ Range}}^{+\infty} \mathrm{pdf}_f(f) \cdot \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{FM} - f)\,\mathrm{d}f$$

$$= \int_{-\infty}^{\mathrm{ATPC\ Range}} \mathrm{pdf}_f(f) \cdot \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{NFM})\mathrm{d}f + \int_{\mathrm{ATPC\ Range}}^{+\infty} \mathrm{pdf}_f(f) \cdot \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{FM} - f)\,\mathrm{d}f$$

Combining the two parts above, the probability of outage becomes

$$P_{O,i\,\mathrm{ATPC}} = \mathrm{Prob}(f \leq \mathrm{ATPC\ Range}) \cdot \mathrm{Prob}(10\log_{10}(1+z) \geq \mathrm{NFM}) + \int_{\mathrm{ATPC\ range}}^{+\infty} \mathrm{pdf}_f(f) \cdot \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{FM} - f)\,\mathrm{d}f \tag{8}$$

Eq. (8) takes into account both upfading and downfading events by considering both positive and negative fading in the distribution of the fade f.

The double integral in the second term in eq. (8) can be rewritten by swapping the integrals as $\int_{\mathrm{ATPC\ range}}^{+\infty} \mathrm{pdf}_f(f) \cdot \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{FM} - f)\,\mathrm{d}f =$

$$\int_0^{+\infty} \mathrm{pdf}_z(z) \cdot \; \mathrm{Prob}\big(f > \max(\mathrm{ATPC\,range},\; \mathrm{FM} - 10\log_{10}(1+z))\big)\,\mathrm{d}z \qquad (9)$$

2 In order to the separate between short-term and long-term interference, the integral in z in eq. (9) can be split as

$$\int_0^{+\infty} \mathrm{pdf}_z(z) \cdot \mathrm{Prob}(f > \max(\mathrm{ATPC\,range},\; \mathrm{FM} - 10\log_{10}\,(1+z))\,\mathrm{d}z =$$

$$\int_0^{(i/n)_{\mathrm{ST}}} \mathrm{pdf}_z(z) \cdot \mathrm{Prob}\big(f > \max(\mathrm{ATPC\,range},\; \mathrm{FM} - 10\log_{10}(1+z))\big)\,\mathrm{d}z + \int_{(i/n)_{\mathrm{ST}}}^{+\infty} \mathrm{pdf}_z(z) \cdot \mathrm{Prob}\big(f > \max(\mathrm{ATPC\,range},\; \mathrm{FM} - 10\log_{10}(1+z))\big)\,\mathrm{d}z \qquad (10)$$

where $\left(\frac{i}{n}\right)_{\mathrm{ST}} = 10^{\frac{\mathrm{NFM}}{10}} - 1$ is the threshold when the degradation due to interference is greater or equal to the NFM.

Eq. (10) can be further simplified as

$$\int_0^{(i/n)_{\mathrm{ST}}} \mathrm{pdf}_z(z) \cdot \mathrm{Prob}\big(f > \max(\mathrm{ATPC\,range},\; \mathrm{FM} - 10\log_{10}\,(1+z))\big)\,\mathrm{d}z + \int_{(i/n)_{\mathrm{ST}}}^{+\infty} \mathrm{pdf}_z(z) \cdot \mathrm{Prob}\big(f > \max(\mathrm{ATPC\,range},\; \mathrm{FM} - 10\log_{10}(1+z))\big)\,\mathrm{d}z =$$

$$\int_0^{(i/n)_{\mathrm{ST}}} \mathrm{pdf}_z(z) \cdot \mathrm{Prob}(f > \; \mathrm{FM} - 10\log_{10}(1+z))\,\mathrm{d}z + \int_{(i/n)_{\mathrm{ST}}}^{+\infty} \mathrm{pdf}_z(z) \cdot \mathrm{Prob}(f > \mathrm{ATPC\,range})\,\mathrm{d}z = \qquad (11)$$

$$\int_0^{(i/n)_{\mathrm{ST}}} \mathrm{pdf}_z(z) \cdot \mathrm{Prob}(f > \mathrm{FM} - 10\log_{10}(1+z))\mathrm{d}z + \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{NFM}) \cdot \mathrm{Prob}(f > \mathrm{ATPC\,range}) \qquad (12)$$

where the identity $\mathrm{ATPC\,range} = \mathrm{FM} - 10\log_{10}(1 + (i/n)_{\mathrm{ST}})$ was used in Eq. (11) and $\int_{(i/n)_{\mathrm{ST}}}^{+\infty} \mathrm{pdf}_z(z)\,\mathrm{d}z = \mathrm{Prob}(10 \cdot \log_{10}(1+z) > \mathrm{NFM})$ in Eq. (12).

Finally, the probability of outage due to long-term interference is the first term of Eq. (12)

$$P_{\mathrm{O},i\,\mathrm{ATPC_{LT}}} = \int_0^{(i/n)_{\mathrm{ST}}} \mathrm{pdf}_z(z) \cdot \mathrm{Prob}\big(f > \; \mathrm{FM} - 10\log_{10}(1+z)\big)\,\mathrm{d}z + \gamma \cdot P_{\mathrm{O},0} \qquad (13)$$

which is the same as the probability of outage due to long-term interference without ATPC defined in Eq. (7). The probability of outage due to short-term interference the sum of the first term in Eq. (8) and the second term in Eq. (12)

Where $(i/n)_{\mathrm{ST}} = \mathrm{FM}$ (Fade Margin)

$$P_{\mathrm{O},i\,\mathrm{ATPC_{ST}}} = \mathrm{Prob}(f \le \mathrm{ATPC\ Range}) \cdot \mathrm{Prob}(10\log_{10}(1+z) \ge \mathrm{NFM}) + \mathrm{Prob}(10\log_{10}(1+z) > \mathrm{NFM}) \cdot \mathrm{Prob}(f > \mathrm{ATPC\ range}) + (1-\gamma) \cdot P_{\mathrm{O},0} = \mathrm{Prob}(10\log_{10}(1+z) \ge \mathrm{NFM}) + (1-\gamma) \cdot P_{\mathrm{O},0} \qquad (14)$$

Where $\gamma = \mathrm{Prob}\,(z \ge (i/n)_{\mathrm{ST}})$ is a normalization term and is added so that the FDP equations can retain the format defined in Recommendation ITU-R F.1108.

Where $(i/n)_{\mathrm{ST}} = \mathrm{FM}$ (Fade Margin)

3 The FDP equation is then defined as:

$$\mathrm{FDP} = \mathrm{FDP_{LT}} + \mathrm{FDP_{ST}} = \frac{P_{\mathrm{O},i_{\mathrm{LT}}} - P_{\mathrm{O},0}}{P_{\mathrm{O},0}} + \frac{P_{\mathrm{O},i_{\mathrm{ST}}} - P_{\mathrm{O},0}}{P_{\mathrm{O},0}} \qquad (15)$$

where:

- $\mathrm{FDP_{ST}}$ is the short-term fractional degradation in performance. It occurs when the degradation due to interference exceeds the NFM. This is referred to as short-term degradation because high levels of interference occur with low probability.
- $\mathrm{FDP_{ST}} = \frac{P_{0,i_{\mathrm{ST}}}}{P_{0,0}} - 1 = \frac{P_{0,i_{\mathrm{ST}}} - P_{0,0}}{P_{0,0}}$ (16)
- $\mathrm{FDP_{LT}}$ is the long-term fractional degradation in performance. It occurs when the degradation due to interference is less than the NFM. It is referred to as long-term because low levels of interference occur with higher probability.
- $\mathrm{FDP_{LT}} = \frac{P_{0,i_{\mathrm{LT}}}}{P_{0,0}} - 1 = \frac{P_{0,i_{\mathrm{LT}}} - P_{0,0}}{P_{0,0}}$ (17)
- $P_{0,i_{\mathrm{LT}}}$ and $P_{0,i_{\mathrm{ST}}}$ are the probability of outage from long-term and short-term interference degradation defined in Eqs. (13) and (14), respectively.

4 The FDP % should not exceed 10% (co-primary service) or 1% (non-co-primary service).

ANNEX 12: INVESTIGATIONS ON THE RF ACTIVITY FACTOR AS A SUPPORT OF SCENARIO B: VIDEO SIMULATION CAMPAIGN

A12.1 INTRODUCTION

This annex describes a simulation of a video streaming of an up to 4K video, using rate adaptative methods over various channel conditions over a network of two IEEE 802.11ax devices (a single client and a single access point).

This simulation is combined with a distribution of RSSIs between -81 and -62 dBm, with the median value at -75 dBm, in order to get a statistical distribution of the radiofrequency activity factor (RF AF).

A12.2 SIMULATION SETUP

A discrete-event simulator (ns-3, see https://www.nsnam.org) is used to simulate:

- an IEEE 802.11ax network;
- using two spatial streams (MIMO);
- and composed of one WAS/RLAN client device and one access point (AP).

It is setup to run in real-time and to propagate real network traffic to and from outside the simulator.

A12.2.1 Streaming platform

The streaming platform consists of a HyperText Transfer Protocol (HTTP) server serving Moving Picture Experts Group - Dynamic Adaptive Streaming over HTTP (MPEG-DASH) segments.

The video stream considered is a 4K 30fps rendering of “Big Buck Bunny”, compressed with h.264 and h.265.Resolutions of 3840x2160 pixels all the way down to 320x180 pixels are served by the HTTP server, depending on the channel conditions.

For h.264, for the highest resolution (4K), the size of the sum of MPEG-DASH segments (audio and video) amount to 7513,6 MBits, for a video duration of 634 s, that is, a mean bitrate of 11.9 MBits/s.

For h.265, for the highest resolution (4K), the size of the sum of MPEG-DASH segments (audio and video) amount to 2295.2 MBits, for a video duration of 634 s, that is, a mean bitrate of 3.6 MBits/s.

A12.3 REPRODUCTION OF RESULTS IN ECC REPORT 302

A12.3.1 Simulation setup

In order for the simulation to model the same measurement setup used in ECC Report 302, annex 7 [1], the following settings were used as input to the simulator, and only applies to this Annex:

- an IEEE 802.11ac network;
- operating on channel 42 (carrier frequency: 5210 MHz);
- with an occupied bandwidth of 80 MHz;
- using one spatial stream (SISO);
- and composed of one client device and one AP.

A12.3.2 Results

In the technical work leading to the RF AF value of ECC Report 302 (see Annex 7 in particular) the results of a test procedure involving transmitting 10s 3Mbps TCP flow three times spaced by 2 second intervals, using propagation conditions allowing for the higher MCS to be selected (MCS 9), were provided and are included in Figure 132 (left). The results of simulations using the same procedure are depicted in in Figure 132 (right). Comparing these results, a similar pattern of instantaneous AF was observed. Furthermore, the simulations result in an AF of 2% to be compared to the measured 2.33% and 2.23%. This difference is comparable to AF variations between different RLAN equipment as measured during the writing of ECC Report 302 (between 1.21% and 2.32%).

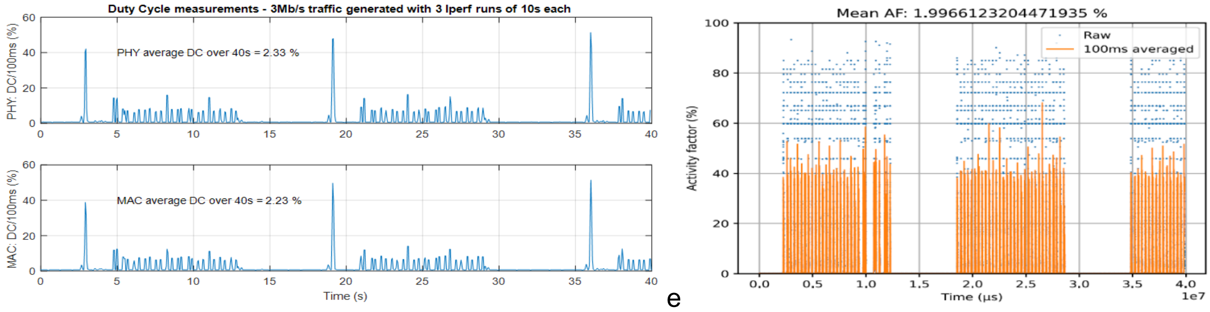


Figure 132: Left: instantaneous RF AF from measurements used for ECC Report 302. Right: Instantaneous simulated RF AF

A12.3.3 Comparison with IEEE 802.11ax RF AF

IEEE 802.11ax had slightly worst RF AF than IEEE 802.11ac when looking at a transmission to a single client. This was mainly because the IEEE 802.11ax PHY preamble is longer than IEEE 802.11ac to aid in coordination with multiple clients.

A12.4 EVOLUTION OF RF AF WITH BANDWIDTH AND SNR

Simulating and plotting RF AF in Figure 133 for different bandwidth or SNR reveals that it does not scale linearly with either quantity, and that, for the flux used here (that is a 3 Mbps TCP transmission) there is diminishing returns as the SNR or bandwidth gets higher.

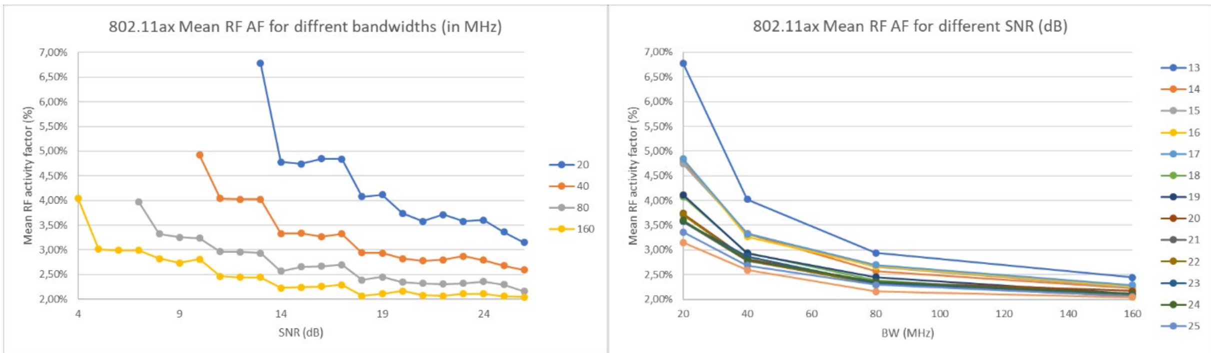


Figure 133: RF AF of 802.11ax as a function of SNR and bandwidth, assuming an AWGN channel, 2 spatial steams and a 3 Mbps TCP flux

A12.5 DERIVATION OF RF AF FOR A 4K VIDEO STREAM

A12.5.1 Distribution of RF AF parametrised on codec and received power

Only results with an RLAN bandwidth of 80 MHz were generated[27]. Figure 134 gives the 100 ms-sampled distributions of RF AF as produced by the access point (LPI, transmitting the video stream) and the client device (receiving the video stream) for received power between -81 and -62 dBm.

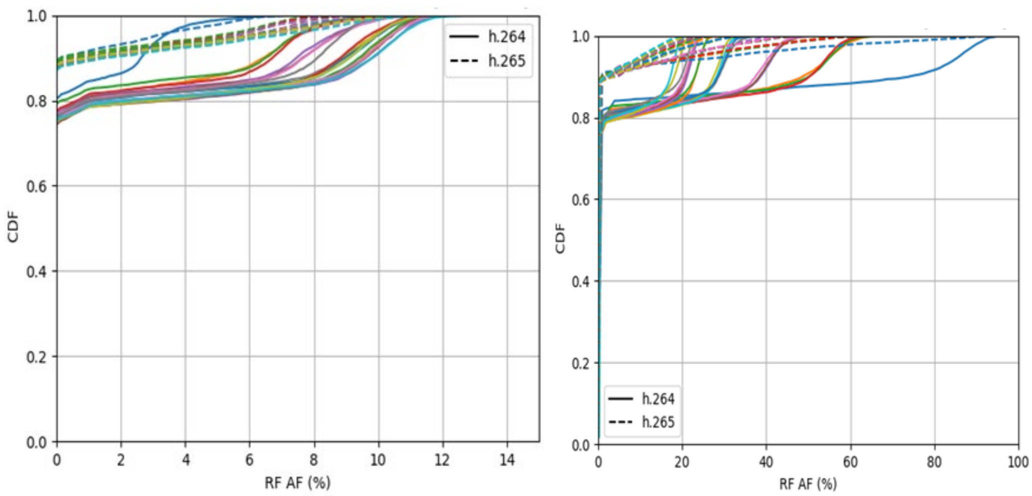


Figure 134: RF AF distribution for client device (left) and AP (right) for a bandwidth of 80 MHz and power received within −81 and −62 dBm

A12.5.2 Received level distribution based on indoor propagation

The received level distribution is based on the site-general office model of Recommendation ITU-R P.1238-11 [42], AP *e.i.r.p.* distributions and antenna pattern/body loss joint measurements on client devices contributed for deriving the *e.i.r.p.* distributions of Annex 1. The office model of Recommendation ITU-R P.1238-11 has been chosen as no residential model is available in this Recommendation for this frequency band. Figure 135 illustrates the composite propagation model, and Figure 136 shows how it behaves when distances are distributed in a 100 m² square (that would be representative of a typical house surface in Europe).

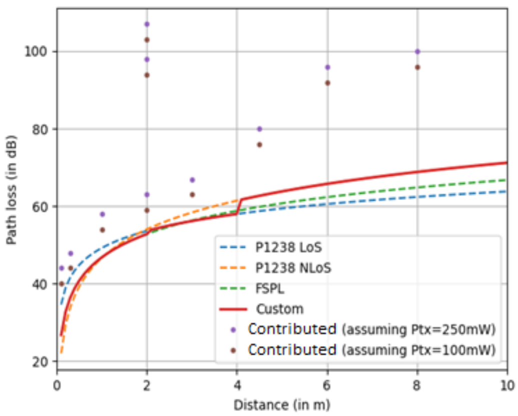


Figure 135: Median transmission loss model used in this study, as a combination of FSPL, and site-general office model of Recommendation ITU-R P.1238-11

[27] According to Table 4, the average bandwidth in this Report is 148 MHz, which means this simulation of 80 MHz channels considers an occupied bandwidth of only 54% of the average.

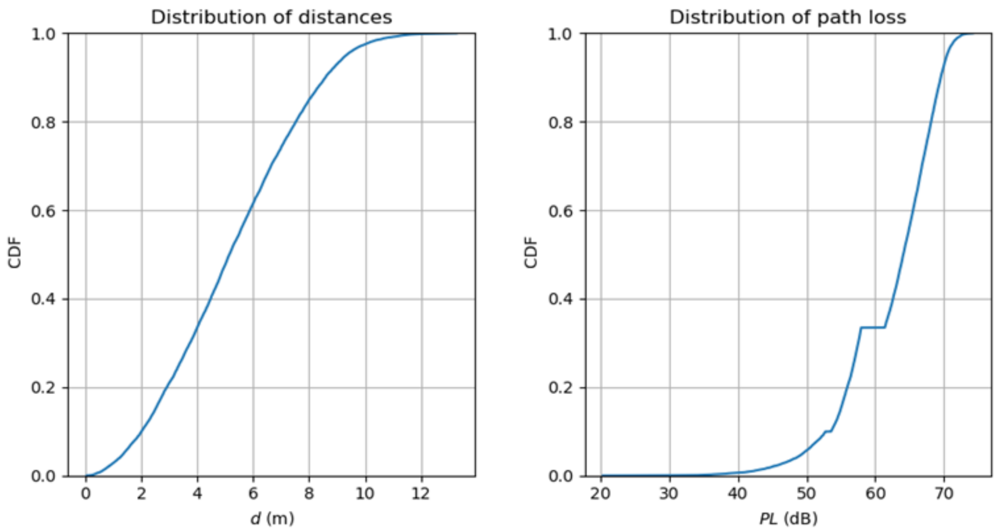


Figure 136: Monte Carlo generated ECDF of distance $d(\omega)$ and associated empirical CDF of transmission loss $PL(\omega)$

A12.5.2.1 Description of the received level model

Received levels for client device and AP are computed as:

$$P_{\text{Rx, client}} = e.i.r.p._{\text{AP}} + (G_{\text{client}} + BL) - PL$$

$$P_{\text{Rx, AP}} = (e.i.r.p. + BL)_{\text{client}} + G_{\text{AP}} - PL$$

Where distributions of *e.i.r.p.* for AP, of *e.i.r.p.* plus body loss for client device, as well as distributions of antenna gains for AP, and antenna gains plus body loss for client device can be found in Annex 1. The CDF of $P_{\text{Rx, client}}$ and $P_{\text{Rx, AP}}$ are given in Figure 137[28].

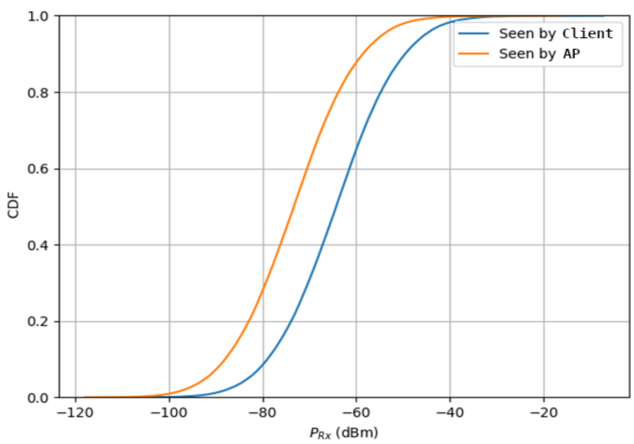


Figure 137: CDF of received levels as seen by client device and AP devices

[28] Data on residential RSSI measurements demonstrate that the median RSSI is in the range of -51 to -63 dBm in 2.4 GHz and 5 GHz frequency bands [45] and [46].

A12.5.3 Monte Carlo sampling of input parameters

Distributions of RF AF obtained by simulation are parametrised on three random variables:

- Received power, denoted $P_{\mathrm{rx}}(\omega)$;
- Codec (h.264 or h.265), denoted codec(ω);
- Type of device: AP or client device;
- Bandwidth, denoted BW. Bandwidth could be distributed, a fixed value of 80 MHz was used.

For the codec, the probability of using h.264 was set as twice the probability of using h.265. Although h.264 (and other codecs of this generation) will eventually fade out of the market in favour of newer codecs like h.265, at that time, the video industry will also have moved on more demanding content (60 FPS , HDR are already being deployed on popular platforms and Recommendation ITU-T H.266 [43] mentions 7620×4320 picture resolution and bit depth of 10 bits in its introduction). Thus, $\mathbb{P}\{\text{codec}(\omega) \text{ is h.264}\} = \frac{2}{3}$ and $\mathbb{P}\{\text{codec}(\omega) \text{ is h.265}\} = \frac{1}{3}$, which means that the expected value of the video is $\frac{2}{3} \times 11.9 + \frac{1}{3} \times 3.6 = 9.1$ Mbps[29].

Distribution of RF AF can then be estimated via Monte Carlo sampling:

$$RFAF_{\text{client}}(\omega) = RFAF_{\text{client}}\left(P_{\text{rx,AP}}(\omega), \text{codec}(\omega), \text{BW}\right)$$

$$RFAF_{\text{AP}}(\omega) = RFAF_{\text{AP}}\left(P_{\text{rx,client}}(\omega), \text{codec}(\omega), \text{BW}\right)$$

Note that the RF AF transmitted by client device depends on the quality of the signal received by the AP, and vice-versa.

Due to a configuration error of the simulation campaign, only RF AF with an RLAN bandwidth of 80 MHz were generated, as shown in Figure 138.

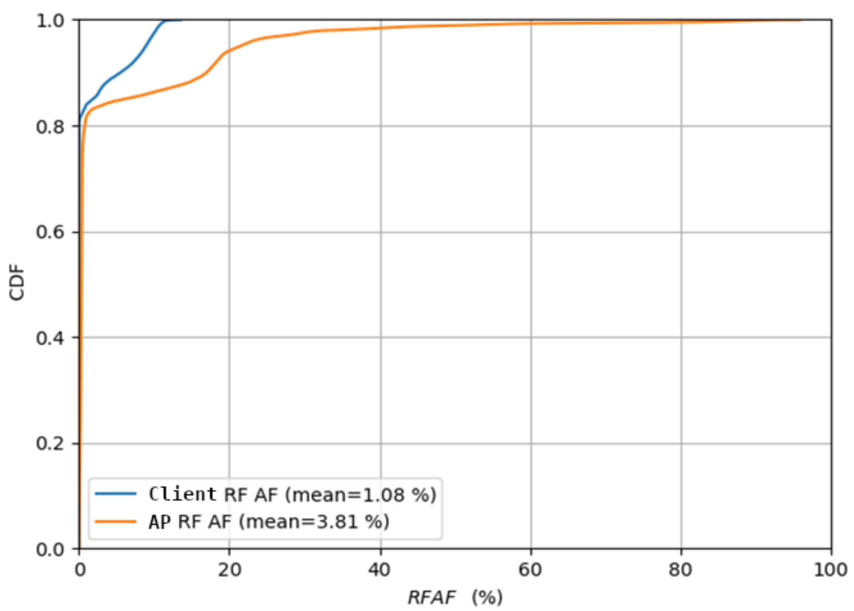


Figure 138: Overall distribution RF AF distribution for client device and AP

29 This average data rate is more than two times what was considered for average busy hour traffic for ECC Report 302.

A12.6 RESULTS

In the last section, a network composed of two IEEE 802.11ax RLAN devices, using 2 spatial stream MIMO and 80 MHz of bandwidth, was simulated, with:

- a client device, whose transmission power is limited to VLP levels, acting as a video client;
- an AP, whose transmission power is limited to LPI levels, acting as an adaptative streaming video server.

It is worth noting that:

- Manual inspection of the simulations revealed that, in nearly all cases, the simulated propagation was good enough to transmit the full 4K resolution (both in h.264 and h.265). Meaning that the client barely ever asked for lower resolutions;
- While several bandwidth values could not be simulated in time for the RF AF campaign, initial investigations showed that, for the bitrate considered here, there is diminishing returns to go from 80 MHz to 160 MHz in terms of RF AF, due to incompressible RLAN headers and other signalling.

It is worth noting that ns-3 uses a packet loss probability based on an AWGN channel hypothesis, while actual indoor channel is frequency selective, leading to higher packet error rates than in the AWGN case (even though OFDM, as used in IEEE 802.11, simplifies channel equalisation). Furthermore, actual WAS/RLAN networks typically operate in a star configuration where several clients are connected to an AP. Even when these clients are not active, they do generate some traffic that increases the number of collisions on the channel, which increase the number of retransmissions (and with more retransmissions comes even more chances of collisions).

Computing the sample mean of RF AF gives 3.8% for AP and 1.1% for client device for the transmission of an audio and video flux with 9.1 Mbps as expected value of the bitrate, over an 80 MHz channel. The mean of these two quantities (2.45%) was retained for the RF AF of Scenario B.

ANNEX 13: LIST OF REFERENCES

[1] ECC Report 302: “Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) in the frequency band 5925-6425 MHz", approved May 2019

[2] ECC Report 316: "Sharing studies assessing short-term interference from Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) into Fixed Service in the frequency band 5925-6425 MHz", May 2020

[3] ERC Report 025: “The European table of frequency allocations and applications in the frequency range 8.3 kHz to 3000 GHz”, approved 1994, latest amended January 2025

[4] Recommendation ITU-R F.758: "System parameters and considerations in the development of criteria for sharing or compatibility between digital fixed wireless systems in the fixed service and systems in other services and other sources of interference"

[5] Recommendation ITU-R F.1245: "Mathematical model of average and related radiation patterns for point-to-point fixed wireless system antennas for use in interference assessment in the frequency range from 1 GHz to 86 GHz"

[6] Recommendation ITU-R P.452: "Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz"

[7] Recommendation ITU-R SF.1650-1: "The minimum distance from the baseline beyond which in-motion earth stations located on board vessels would not cause unacceptable interference to the terrestrial service in the bands 5 925-6 425 MHz and 14-14.5 GHz"

[8] Recommendation ITU-R P.2108: "Prediction of Clutter Loss"

[9] P. Kyösti, J. Meinilä, L. Hentilä, X. Zhao, T. Jämsä, C. Schneider, M. Narandzić, M. Milojević, A. Hong, J. Ylitalo, V.-M. Holappa, M. Alatossava, R. Bultitude, Y. d. Jong and T. Rautiainen, "IST-4-027756 WINNER II D1.1.2 V1.2, WINNER II Channel Models, Part I: Channel Models," 2008. Available here

[10] Recommendation ITU-R P.525: “Calculation of free-space attenuation”

[11] Recommendation ITU-R P.2109: “Prediction of building entry loss”

[12] Recommendation ITU-R RA.769: “Protection criteria used for radio astronomical measurements”

[13] Recommendation ITU-R RA.1513: “Levels of data loss to radio astronomy observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the radio astronomy service on a primary basis”

[14] T. G. Farr, P. A. Rosen, E. Caro, R. Crippen, R. Duren, S. Hensley, M. Kobrick, M. Paller, E. Rodriguez, L. Roth, D. Seal, S. Shaffer, J. Shimada, J. Umland, M. Werner, M. Oskin, D. Burbank and D. Alsdorf, “The Shuttle Radar Topography Mission:” Reviews of Geophysics, Vol. 45, 2007

[15] M. Schiavina, S. Freire, A. Carioli, K. MacManus: GHS-POP R2023A – GHS population grid multitemporal (1975-2030); European Commission, Joint Research Centre (JRC), 2023. Available here

[16] Radio horizon calculator. Available here

[17] http://www.citypopulation.de/en/spain/cities/madrid/

[18] OfW 446, Technical Frequency Assignment Criteria for Fixed Point-to-Point Radio Services with Digital Modulation, Ofcom, July 2018, Version 12

[19] Recommendation ITU-R P.2001-4: “A general purpose wide-range terrestrial propagation model in the frequency range 30 MHz to 50 GHz”

[20] https://www.citypopulation.de/

[21] “FCC Opens 6 GHz Band to Wi-Fi and Other Unlicensed Uses”, Federal Communication Commission, April 24, 2020. Available here

[22] “FCC Permits Very Low Power Device Operations in 6 GHz Band”, Federal Communication Commission, November 1, 2023. Available here

[23] ECC Report 173: “Fixed Service in Europe Current use and future trends post 2022”, approved June 2023

[24] United Nations, Department of Economic and Social Affairs, Population Division (2024). World Population Prospects 2024: Release note. Available here

[25] Center for International Earth Science Information Network - CIESIN - Columbia University. 2005. Gridded Population of the World, Version 3 (GPWv3): Administrative Unit Center Points with Population Estimates. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). Available here

[26] Center for International Earth Science Information Network - CIESIN - Columbia University. 2016. Gridded Population of the World, Version 4 (GPWv4): Administrative Unit Center Points with Population Estimates. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). Available here

[27] European Environment Agency (EEA), CORINE Land Cover 2018 (vector/raster 100 m), Europe, 6-yearly. Available here

[28] Dynamic Spectrum Alliance, "How do Europeans Connect to the Internet", 2022. Available here

[29] European Commission Joint Research Centre, 'Busy Hour Factor Considerations', August 2015. Available here

[30] ABI research, Wireless Connectivity Technology Segmentation and Addressable Markets, 2021

[31] BD TOPO: "La modélisation 2D et 3D du territoire et de ses infrastructures sur l'ensemble du territoire français". Available here

[32] https://www.infas360.de/

[33] Recommendation ITU-R F.699 "Reference radiation patterns for fixed wireless system antennas for use in coordination studies and interference assessment in the frequency range from 100 MHz to 86 GHz"

[34] ECC Decision (20)01: "On the harmonised use of the frequency band 5945-6425 MHz for Wireless Access Systems including Radio Local Area Networks (WAS/RLAN)", approved November 2020, latest amended November 2024

[35] Recommendation ITU-R F.1108: "Determination of the criteria to protect fixed service receivers from the emissions of space stations operating in non-geostationary orbits in shared frequency bands"

[36] Recommendation ITU-R S.672-4: " Satellite antenna radiation pattern for use as a design objective in the fixed-satellite service employing geostationary satellites"

[37] Recommendation ITU-R P.1411-12: "Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz"

[38] Recommendation ITU-R P.530: "Propagation data and prediction methods required for the design of terrestrial line-of-sight systems"

[39] Building Heights in Great Britain from Emu Analytics (emu-analytics.net), 05/25/2023

[40] ETSI TR 103 524 V1.1: "System Reference document (SRdoc); Wireless access systems including radio local area networks (WAS/RLANs) in the band 5 925 MHz to 6 725 MHz"

[41] Recommendation ITU-R P.619: "Propagation data required for the evaluation of interference between stations in space and those on the surface of the Earth"

[42] Recommendation ITU-R 1238: "Propagation data and prediction methods for the planning of indoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 450 GHz"

[43] Recommendation ITU-T H.266: "Versatile video coding"

[44] Ofcom UK: "Improving spectrum access for Wi-Fi - Spectrum use in the 5 GHz and 6 GHz bands". Available here

[45] Characterizing home networks with HomeNet Profiler, September 2011. Available here

[46] Analyzing the Signal Strength of 2,946 Clients Operating in 446 WiFi Networks, September 2, 2020. Available here

[47] "IEEE Draft Standard for Information technology--Telecommunications and information exchange between systems Local and metropolitan area networks--Specific requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment: Enhancements for Extremely High Throughput (EHT)," in IEEE P802.11be/D5.0, November 2023. Available here

[48] ECC Report 355: "Measurement-based compatibility studies assessing interference from Very Low Power (VLP) Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) operating in 5945-6425 MHz to Communication Based Train Control (CBTC) systems operating in 5915-5935 MHz", approved May 2024