CEPT ECC
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Sharing and compatibility studies related to Wireless Access Systems including Radio Local Area Networks (WAS/RLAN) up to 4 W e.i.r.p. in the frequency band 5945-6425 MHz

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0 EXECUTIVE SUMMARY

This Report describes technical methodologies which could be used to enable indoor and outdoor operation of Wireless Access Systems including Radio Local Area Networks (WAS/RLANs) in the 5945-6425 MHz frequency band, at transmit power levels of up to 4 W *e.i.r.p.*, i.e. beyond what is permitted under ECC Decision (20)01 [10]. This is referred to as Higher Power (HP) in this Report.

This Report assumes the technical protection requirements of incumbent services will be fulfilled by a Dynamic Spectrum Access Coordination Function (DSACF) accessible by the HP WAS/RLAN device. Upon interaction with the DSACF-system, the HP WAS/RLAN device would be provided with a list of available frequencies and associated maximum power levels (further referred to as “Channel-Power List” in this Report) that are available for use at its specific location. In terms of implementation, calculation and/or definition of the restriction zones could either be done within the DSACF system or outside of the DSACF system (in which case information such as the Channel-Power List would be derived from pre-computed maps, possibly provided by administrations).

Studies have been carried out regarding the following incumbents: Fixed Service (FS), Fixed-Satellite Service (FSS) in band and Radio Astronomy Service (RAS), Urban rail Communication Based Train Control (CBTC), and Road Intelligent Transport Systems (ITS) in adjacent band.

Since restriction zones cannot be applied to FSS (Earth-to-space), Road ITS and UWB, protection of these systems is provided by other technical means.

For FSS (Earth-to-space), some of the studies from ECC Report 302 [1] have been updated to take account of additional deployment of up to 4W HP WAS/RLAN. The impact of any added discrimination towards a satellite provided by for example directional antennas and/or beamforming applied to the HP WAS/RLAN devices, and/or an *e.i.r.p.* limitation above a certain elevation angle have not been studied. The additional impact could be the subject for further work, as appropriate.

For Road ITS, an out-of-band emission limit of -27 dBm/MHz below 5925 MHz is proposed.

For UWB, studies can be found in ECC Report 302 [1].

For all other services and applications, different methods, modelling the DSACF behaviour in terms of communicating a Channel-Power List to HP WAS/RLAN, were proposed along with associated studies. Most studies assumed that DSACF would compute Channel-Power Lists based on free-space path loss link budget calculations. The studies also assumed that in its calculation of Channel-Power List, DSACF only considered omnidirectional HP WAS/RLAN antenna patterns.

The main technical findings of the Report are summarised in the Table 1. A set of technical elements required to enable DSACF was also identified and can be found in section 6.

Table 1: HP WAS/RLAN Compatibility

Incumbent Service	Results of studies on Outdoor & Indoor HP WAS/RLAN (5945-6425 MHz)
FS (In-band)	Unmitigated HP WAS/RLAN operation can cause interference to FS, mainly depending on their respective location. The characteristics of an FS receiver such as antenna pattern and gain, height and pointing direction, determine the areas or zones where an HP WAS/RLAN would be restricted in the frequency channels and/or power it could use.
FSS (E-s) (In-band)	Interference protection criteria were met for the mid scenario of WAS/RLAN deployment (see Table 6) with significant margin for all satellite even under conservative assumptions for device usage and power increase. Although an up to 3 dB decrease in the I/N margin was noted for three of the four satellites studied, compared to ECC Report 302 [1], due to an increased number of LPI and VLP WAS/RLAN, and the additional deployments of the HP WAS/RLAN. Based on these analyses, the DSACF systems would not need to apply any further mitigation for FSS. The impact of antenna discrimination, beam forming and *e.i.r.p.* limitations for certain elevation angles of HP WAS/RLAN were not considered in these studies.
RAS (Adjacent band)	RAS requires protection from HP WAS/RLAN located nearby. Example restriction zones and/or restricted *e.i.r.p.* limits were studied that could be applied through a DSACF system in order to protect the RAS receivers from harmful interference from HP WAS/RLAN located nearby.
Urban rail ITS/CBTC (Adjacent band)	Urban Rail ITS (CBTC) requires protection through a DSACF system from HP WAS/RLAN outdoor and indoor use. For outdoor HP WAS/RLAN Out-Of-Band Emissions (OOBE) limits below 5935 MHz ranging from -27 dBm/MHz to -9 dBm/MHz, a separation distance ranging from 10 m to 80 m from the CBTC track, and from 18 m to 150 m from CBTC APs was calculated. In order to simplify the calculation within the DSACF or pre-calculated to ensure compatibility, a single OOBE level of HP WAS/RLAN such as -22 dBm/MHz could be applied to HP WAS/RLAN. The studies assumed that OOBE is the dominating factor in the interference calculation. If this hypothesis no longer holds (i.e. OOBE is low enough), then blocking of the CBTC receiver would need to be considered.
Road ITS (Adjacent band)	ECC Report 302 [1] studied the adjacent band compatibility between WAS/RLAN and Road ITS. Since Road ITS, in contrast to urban rail ITS, is not restricted to well defined areas, it cannot be protected by the DSACF. Consequently, a generic unwanted emissions limit below 5925 MHz would be required to ensure the protection of road ITS. Based on the studies in ECC Report 302 [1] and considering that an unwanted emissions limit of -27 dBm/MHz below 5925 MHz is implemented in some part of the world, such a value is deemed sufficient to protect road ITS operation from HP WAS/RLAN systems operating above 5945 MHz.
Road Tolling (Adjacent band)	Road tolling systems operate in the band 5795 to 5815 MHz while band allocation for HP WAS/RLAN systems starts at 5945 MHz. Compatibility studies were not carried out due to the fact that the operation band of the road tolling systems is 130 MHz from the band edge of the HP WAS/RLAN. If administrations considered that the road rolling systems need to be taken into account then Road tolling data with geo locations could provide the necessary data for a DSACF.
UWB systems (in the range 6-8.5 GHz)	ECC Report 302 [1] studied compatibility between WAS/RLAN and UWB systems.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
AFC	Automated Frequency Coordination
AP	Access Point
ASECAP	Association Européenne des Concessionnaires d'Autoroutes et d'Ouvarages à Péage (European Association of Operators of Toll Road Infrastructures)
ATPC	Automatic Transmit Power Control
BEL	Building Entry Loss
BW	Bandwidth
CBTC	Communication Based Train Control
CEPT	Conférence européenne des administrations des postes et télécommunications (European Conference of Postal and Telecommunications Administrations)
C/I	Carrier to interferer ratio
DEM	Digital elevation model
DSACF	Dynamic Spectrum Access Coordination Function
DSSS	Direct Sequence Spread Spectrum
ECA	European Common Allocation
ECC	Electronic Communications Committee
EFIS	ECO Frequency Information System
e.i.r.p.	Equivalent Isotropically Radiated Power
EPO	Error Performance Objective
EU	European Union
FDP	Fractional Degradation in Performance
FM	Fade Margin
FS	Fixed Service
FSS	Fixed-Satellite Service
FWA	Fixed Wireless Access
HP	Higher Power
I/N	Interference-to-Noise ratio
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of things
ITM	Irregular Terrain Model
ITS	Intelligent Transport System
ITU	International Telecommunications Union
LPI	Low Power Indoor
M2M	Machine-to-machine

Abbreviation	Explanation
MIMO	Multiple Input Multiple Output
NFM	Net Fade Margin
OBU	On-Board Units
OOBE	Out-of-Band-Emission
Pfd	Power flux density
PSD	Power Spectral Density
QAM	Quadrature Amplitude Modulation
RAS	Radio Astronomy Service
RLAN	Radio Local Area Network
RSU	Roadside Units
RX	Receiver
TDMA	Time division multiple access
TTT	Transport and Traffic Telematics
TU	Train unit
TX	Transmitter
WAS	Wireless Access Systems
WINNER II	World Initiative New Radio phase II

1 INTRODUCTION

This Report studies technical conditions to enable the possible implementation of a dynamic spectrum access coordination function for Wireless Access Systems including Radio Local Area Networks (WAS/RLANs) in the 5945-6425 MHz frequency band, beyond what is permitted under ECC Decision (20)01 [10]. This encompasses the possible use of WAS/RLAN equipment in a range of transmit power levels up to 4 W *e.i.r.p.* and considered the protection requirements of incumbent services in the 5945-6425 MHz and adjacent frequency bands.

Hereinafter in this Report WAS/RLAN with a transmit power of up to 4 W *e.i.r.p.* is referred to as Higher Power (HP) WAS/RLAN, as the maximum permissible power in ECC Decision (20)01 in the 5945-6425 MHz frequency band for devices without DSACF is 200 mW, for Low Power Indoor (LPI) WAS/RLAN.

The working assumption of this Report is that the technical protection requirements of incumbent services is contained within a Dynamic Spectrum Access Coordination Function (DSACF) that each HP WAS/RLAN device[1] consult before transmission. The DSACF is presumed to provide available frequencies/channels and the associated maximum power levels that are available for use at the specific location of each HP WAS/RLAN device (Channel-Power list).

In this Report, possible implementations of DSACF were modelled via different methods, and the protection of incumbents subsequently analysed. The incumbents considered in-band were the Fixed Service (FS) and Fixed-Satellite Service (FSS) (see section 4.1) and in the adjacent bands, Radio Astronomy Service (RAS), Communications Based Train Control (CBTC) and Road Intelligent Transport Systems (ITS) (see section 5.3.4).

A separate analysis was carried out to consider the additional aggregate effects of HP WAS/RLAN on FSS uplink.

ECC Report 302 [1], ECC Report 316 [19] and ECC Report 364 [35] were used as background material for the studies to determine appropriate technical protection criteria for in-band and adjacent services for potential use of HP WAS/RLAN.

[1] Client devices may use a proxy device and be coordinated by an individual AP. In centrally managed networks such as an enterprise WAS/RLAN, communication with the DSACF may be performed by the central management entity that knows the location of HP WAS/RLAN APs.

2 CONCEPT OF DSACF

ECC Decision (20)01 [10] allows WAS/RLAN to operate in the frequency band 5945-6425 MHz under Low Power Indoor (LPI, 200 mW *e.i.r.p.*) and Very Low Power (VLP, 25 mW *e.i.r.p.*) conditions, which are the limits on transmit power intended to ensure compatibility with incumbent services in the band.

There is a growing interest for operating WAS/RLAN indoors and outdoors at transmit power levels higher than that of LPI to enable new use cases such as enterprise and campus networks, smart-city infrastructure, and other applications. To enable HP WAS/RLAN operation it is necessary to determine which technical conditions, that would allow coexistence with incumbent services.

Unrestricted HP WAS/RLAN deployments could, in certain situations, give rise to harmful interference to these incumbent services. DSACF is envisaged as a dynamic mechanism designed to enable the operation of HP WAS/RLAN systems while protecting incumbent users.

The main function of DSACF is to prevent harmful interference from HP WAS/RLAN APs to incumbents. In order to achieve that, it would ensure that HP WAS/RLAN APs operate only on frequencies, and at power levels that protect incumbent services.

The protection of incumbent users is achieved through:

- **Incumbent Database**: DSACF systems make a reference to a regularly updated comprehensive database of all registered incumbent receivers that need to be protected, and their associated technical characteristics, or alternatively, a pre-calculated Channel-Power List specifying the maximum permitted power for each geographical location and other information as required;
- HP **WAS/RLAN AP Registration**: Before an HP WAS/RLAN AP can transmit, its geographic location (potentially including altitude), and other relevant technical parameters must be communicated to the DSACF system;
- **Interference Calculation**: The technical characteristics of the HP WAS/RLAN AP and incumbents are used to carry out interference calculations, considering the propagation characteristics between the actual HP WAS/RLAN AP location and all nearby incumbent receivers (and their respective characteristics). These calculations may take into account various parameters such as terrain, antenna patterns, and atmospheric conditions. The calculations could be done on demand within the DSACF system or pre-calculated outside of DSACF;
- **Channel-Power List**: The DSACF system determines the maximum *e.i.r.p.* for each frequency/channel and communicates this to the HP WAS/RLAN AP. This is either based on the calculation and results of the interference calculations for each potentially affected incumbent receiver, or the DSACF could access a pre-calculated look-up table specifying the permitted channels and associated maximum transmit power for each geographical location;
- **Regular Communication**: HP WAS/RLAN APs periodically communicate with the DSACF system to re-validate their Channel-Power List. This ensures that any changes in incumbent operations or the environment are accounted for. If a device with an expired Channel-Power List fails to communicate with the DSACF, it ceases to transmit after a defined amount of time.

The detailed technical parameters of the above are addressed in section 6.

In effect, the DSACF enforces reduced power in certain geographic locations so that the HP WAS/RLAN does not cause harmful interference to incumbents. Figure 1 illustrates different HP power levels on a specific channel depending on location with two HP WAS/RLAN locations is shown, one of which is unrestricted (i.e. up to 4 W *e.i.r.p.* is allowed) and another is power constrained.

Similar systems have already been standardised and implemented in other regions (e.g. "Automated Frequency Coordination (AFC)" systems in the United States and Canada [52][53]).

Figure 1 illustrates the DSACF concept using the example of HP WAS/RLAN APs intending to operate in the presence of an FS link. Each colour indicates a range of permissible HP WAS/RLAN transmit power levels within an area. Depending on the location of the HP WAS/RLAN AP, different transmit power levels would be permitted. The red colour indicates that HP WAS/RLAN transmission will not be permitted in these areas, the other colours correspond to restricted transmit powers. As determined by the DSACF, the AP on the left is

subject to transmit power constraints while the AP on the right may transmit at up to the maximum power level of 4 W (36 dBm) *e.i.r.p.*

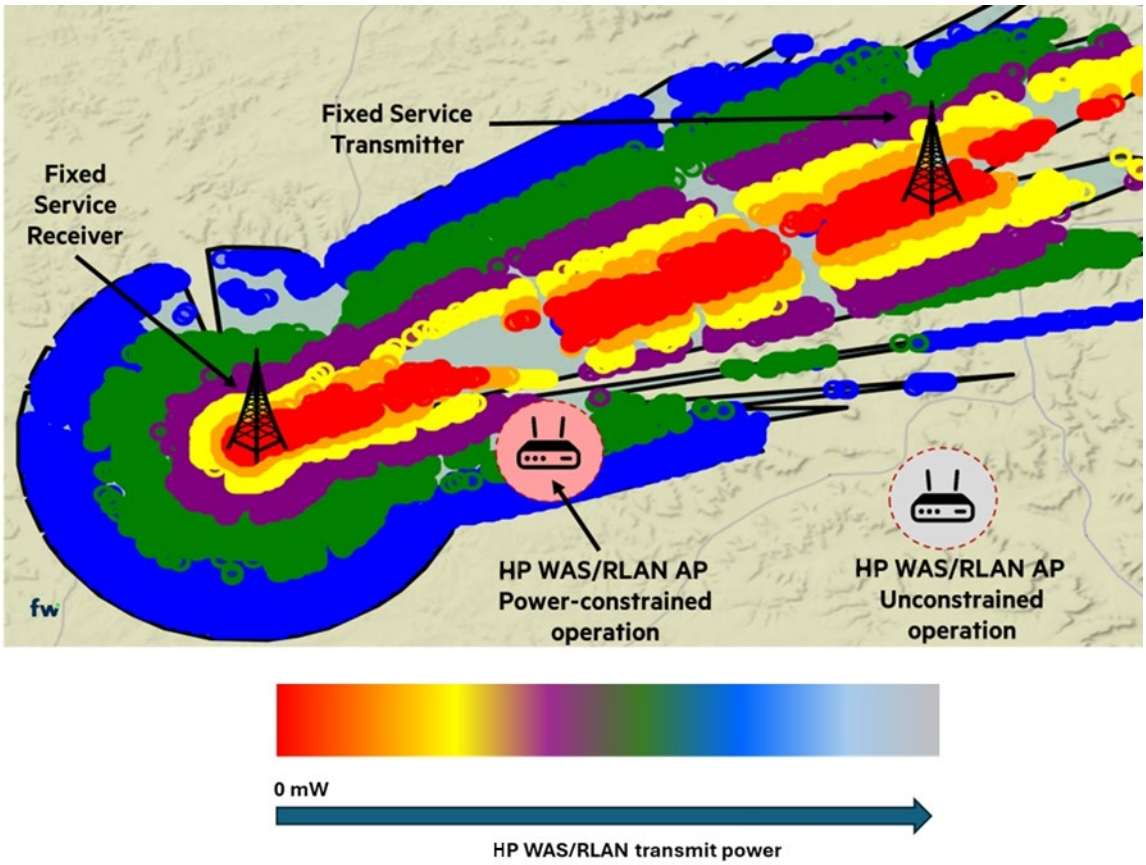


Figure 1: Example of location dependent HP WAS/RLAN power levels for a specific channel

Figure 2 shows an example from USA and Canada of the permissible HP WAS/RLAN transmit power levels in different WAS/RLAN channels that were determined by an AFC system similar to DSACF. While in some channels, up to the maximum transmit power may be used, power restrictions apply in other channels.

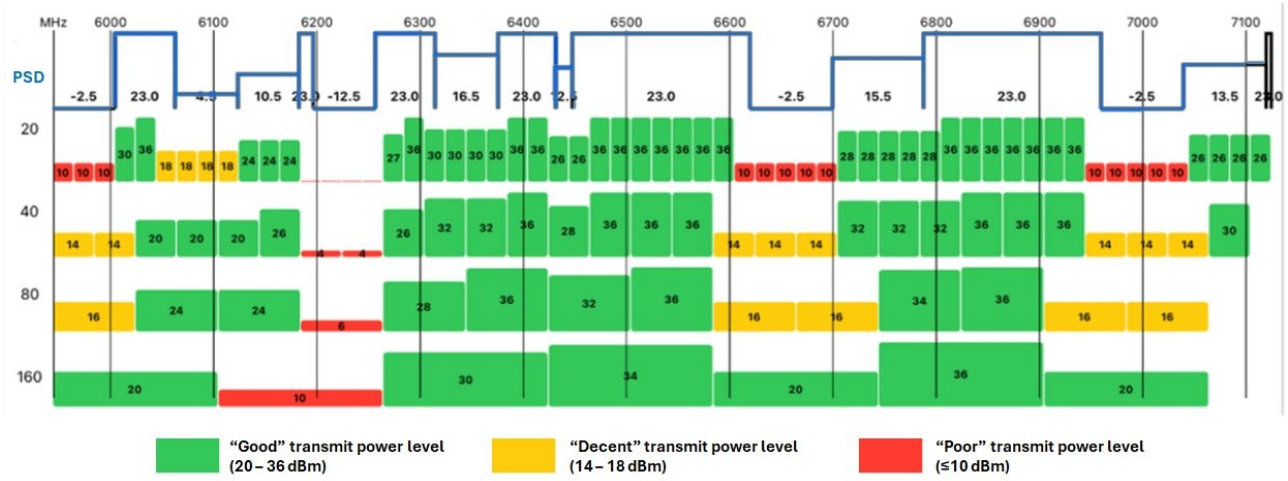


Figure 2: Example from USA, Canada etc. of channels and maximum transmit power levels determined to be available for HP WAS/RLAN operation at a specific location in the presence of FS links

3 ALLOCATIONS AND APPLICATIONS

3.1 ALLOCATIONS IN 5925-6425 MHZ AND ADJACENT BANDS

An extract of the European Common Allocation (ECA) for 5925-6425 MHz and the adjacent bands can be found in Annex 1.

3.2 USE CASES FOR HP WAS/RLAN

HP WAS/RLAN in combination with a DSACF is intended to operate at higher power levels than LPI WAS/RLAN, enabling extended range and improved performance for indoor networking and the ability to provide coverage for outdoor environments.

The use cases comprise indoor and outdoor installations in urban, suburban, and rural areas and can cover areas/ranges from hundreds of square metres to several kilometres (outdoors). Typical possible use cases include:

1 WAS/RLAN in enterprise and large venues including office buildings, conference centres, shopping malls, airports, concert halls, stadiums, outdoor event venues, universities, camping, and hospital campuses.

2 Industrial IoT and smart manufacturing including factory automation, robotics, machine-to-machine (M2M) communication, industrial sensors, predictive maintenance and smart agriculture.

3 Smart cities and public WAS/RLAN Networks including municipal WAS/RLAN for public spaces (parks, transportation hubs, downtown zones), intelligent traffic systems, surveillance cameras, smart lighting.

4 Broadband Fixed Wireless Access (BFWA) in rural and suburban environment.

5 Point-to-point and mesh wireless backhaul for small cells in enterprise, manufacturing plants, logistics centres, construction sites.

6 WAS/RLAN access for residential users (limited number of installations).

4 TECHNICAL CHARACTERISTICS AND DEPLOYMENT MODEL OF HP WAS/RLAN

4.1 TECHNICAL CHARACTERISTICS

4.1.1 Power levels

WAS/RLAN devices could have different maximum power levels, depending on the application:

- Indoor/outdoor Very Low Power (VLP): up to 25 mW *e.i.r.p.*;
- Low Power Indoor (LPI): up to 200 mW *e.i.r.p.*;
- Indoor/outdoor Higher Power (HP) being considered in this Report: up to 4 W e.i.r.p, enabled by DSACF.

Two different *e.i.r.p.* distribution models were used in the studies, as explained in section 4.1.1.1 and 4.1.1.2.

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.

4.1.1.1 Weighted average e.i.r.p.

Table 2 is equivalent to ECC Report 302, table 21 [1] except the change of maximum power level from 1000 mW to 4000 mW.

Table 2: Percentage of *e.i.r.p.* HP WAS/RLAN including body loss

e.i.r.p. (mW)	4000	250	100	50	13	1	40	20	5	Total
indoor (%)	0.71%	9.16%	4.39%	13.75%	40.00%	5.67%	1.82%	12.03%	12.47%	100%
outdoor (%)	3.24%	4.24%	4.38%	14.10%	20.97%	3.08%	3.46%	22.85%	23.68%	100%

4.1.1.2 Peak Internet busy hour scenario

The peak Internet busy hour and associated use cases and simulations are based on 1% outdoor VLPs and 99% of LPI, as per ECC Report 364 [35], with some modifications, taking into account the potential use of indoor and outdoor HP use up to 4 Watts, also taking account of some accidental LPI client outdoor usage.

The normalised antenna gain distributions for WAS/RLANs used are given in ECC Report 364, annex 1. Those tables depict a maximum antenna gain normalised to 0 dBi.

To obtain the *e.i.r.p.* distributions, ECC Report 364, tables 37, 38 and 39 from Annex 1 are used together with one indoor/outdoor distribution. This scenario uses the distribution from Table 2 for sharing studies with incumbents. A detailed derivation of the distribution is available in ECC Report 364, annex 1, where the overall distribution can be found in ECC Report 364, table 40.

Table 3 is equivalent to ECC Report 364, table 2 [35] except that LPI WAS/RLAN is replaced with HP WAS/RLAN.

Table 3: WAS/RLAN indoor/outdoor and *e.i.r.p.* distributions during peak internet busy hour

Device type		Total indoor	Total outdoor	*e.i.r.p.* distribution
LPI/HP Clients	With Body Loss	21.10%	0.21%	200 mW or up to 4 W (with DSACF) + normalised antenna gain distribution from ECC Report 364, table 39
	Without Body Loss	2.37%	0.00%	200 mW or up to 4 W (with DSACF) + normalised antenna gain distribution from ECC Report 364, table 38
VLP	With Body Loss	9.00%	1.00%	25 mW + normalised antenna gain distribution from ECC Report 364, table 39
AP (LPI/HP)	Without Body Loss	66.32%	0.00%	200 mW or up to 4 W (with DSACF) + normalised antenna gain distribution from ECC Report 364, table 37
Total		98.79%	1.21%	

4.1.2 Out-of-band emission levels

For some studies considering adjacent band services and applications, the out-of-band emission (OOBE) in line with the transmit spectral power mask of LPI WAS/RLAN as illustrated in Figure 3 was applied for HP WAS/RLAN except when more stringent OOBE levels were used for these studies below 5935 MHz.

This Report does not define a specific OOBE mask for HP WAS/RLAN. The different studies have taken account of different assumptions, some based on:

- the mask illustrated in Figure 3;
- ETSI EN 303 687 v1.1.1, table 4 [26] ("Transmitter unwanted emissions in the out-of-band domain");
- parametric values.

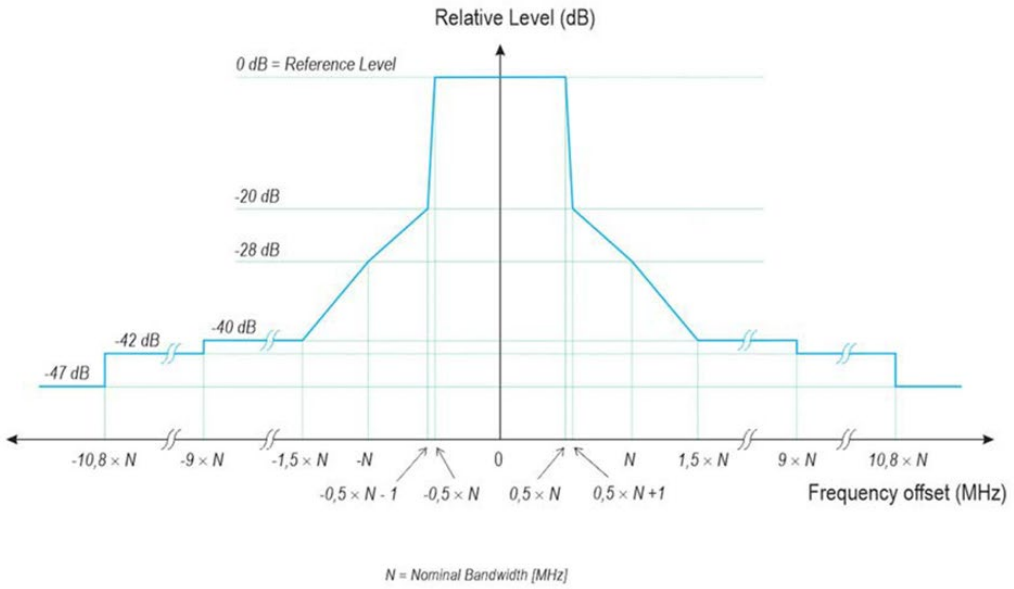


Figure 3: Emission mask from ETSI EN 303 687[26] for LPI WAS/RLAN

Further details on the specific OOBE used are presented in the studies, it should be noted that ERC Recommendation 74-01 [49] on spurious emission limits were also assumed to apply where it is applicable.

4.1.3 Antenna heights

In a DSACF system an HP WAS/RLAN will report its actual location in three-dimensional space.

For compatibility studies on single entry interference, the studies used selected values for antenna height, as indicated in the respective studies.

For compatibility studies on aggregate interference, it was assumed that typical antenna heights follow a distribution rather than a fixed value. Typical antenna heights depend on the region (urban, suburban and rural) where users are located.

Two separate antenna height distributions were used for outdoor and indoor, respectively. The indoor antenna height distribution was taken from ECC Report 316 [19]. The outdoor antenna height distribution was taken from ECC Report 302, section 3.1.2 [1]. Given that distributions are needed according to the urban, suburban and rural categories and not according to the number of households/buildings per city, a simplified indoor height distribution based on ECC Report 316 is given in Table 4. The rural distribution was given as standalone in ECC Report 316.

Table 4: Antenna height distribution

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

4.1.4 Channel bandwidth

Figure 4 shows the WAS/RLAN channel set defined by IEEE 802.11 (from IEEE 802.11be D5.0 [36]) for the 5945-6425 MHz band.

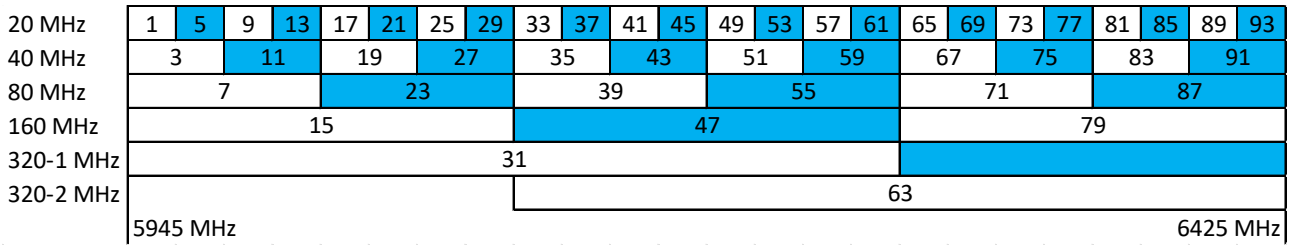


Figure 4: WAS/RLAN channel plan in the 5925-6425 MHz frequency band (IEEE 802.11be D5.0 [36])

For compatibility studies on aggregate interference, it was assumed that channel bandwidths follow the distribution given in Table 5 which was taken from ECC Report 364.

For compatibility studies on single entry interference, the studies used selected values for channel bandwidth, as indicated in the respective studies.

Table 5: Channel bandwidth distribution

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

4.2 DEPLOYMENT MODEL

The deployment model described in this section was assumed for the aggregate interference study for FS.

4.2.1 Peak Internet busy hour scenario

The peak Internet busy hour scenario for VLP and LPI WAS/RLAN, shown in Table 6, is given in ECC Report 364 [35]. HP WAS/RLAN deployments are expected to be significantly lower than those given in Table 6.

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 6:

$$N_{\text{Active RLAN}} = N_{\text{pop}} \cdot F_{\text{licence exempt}} \cdot F_{\text{6GHz}} \cdot F_{\text{Market adoption}} \cdot F_{\text{Busy hour}} \cdot F_{\text{RF AF}}$$

More information on these factors, including definitions and how they were derived, can be found in ECC Report 364, section 3.2.1 [35].

Table 6: 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%		
6 GHz factor (F_{6GHz})	47.15%			64.87%		
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 WAS/RLAN deployment model factors	0.10%	0.17%	0.26%	0.22%	0.36%	0.60%

4.2.2 Fixed Wireless Access scenario

Fixed Wireless Access (FWA) systems typically use directional antennas. Considering that the maximum transmit power for HP WAS/RLAN is expressed in terms of *e.i.r.p.*, a directional antenna does not cause more interference than an omni-directional antenna with the same *e.i.r.p.* Therefore, the peak Internet busy hour scenario covers the FWA scenarios.

5 TECHNICAL STUDIES

5.1 FIXED SERVICE (IN-BAND)

5.1.1 Description of incumbent

Fixed Service (FS) are radio links between fixed points, typically for point-to-point or point-to-multipoint communication. These links are widely used for applications such as backhaul for mobile networks, broadcasting support feeding radio and digital terrestrial TV stations, infrastructure and Enterprise connectivity.

5.1.1.1 Technical parameters

Table 7: Typical Fixed Service parameters

Parameter/model	
Antenna height	10, 25, 40, 55 m
Antenna gain	38.1-45 dBi (for 64 QAM FS) 38.7-46.6 dBi (for 128 QAM FS)
Link length	Between 10 and 80 km
Feeder loss	2.5-5.6 dB (for 64 QAM FS) 1.1-3 dB (for 128 QAM FS)
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 [13] for single-entry interference Recommendation ITU-R F.1245 [15] for aggregate interference
Receiver noise figure	4 and 5 dB

5.1.1.2 Protection criterion

The long-term protection criterion with a value of I/N=-10 dB (see Recommendation ITU-R F.758, table 5 [14]) that should not be exceeded for more than 20% of time.

The evaluation of the Fractional Degradation in Performance (FDP) as given in ECC Report 367 [45] should not exceed 10% of the total Error Performance Objectives (EPO).

5.1.2 Methods of protection studied

5.1.2.1 Method 1: Restriction zones

The calculation of separation distance indicates the restriction zone/area where a DSACF would apply *e.i.r.p.* limitation per channel to the HP WAS/RLAN device, therefore the MCL calculation below would be carried out for each HP WAS/RLAN channel.

It is assumed that an FS station is the victim receiver (Rx) and an HP WAS/RLAN 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 separation distance (d, in m) is found as the lowest value satisfying the following MCL equation together with the parameters in Table 7:

$$\mathrm{EIRP}_{\mathrm{WAS\ RLAN}} - L_{\mathrm{FSPL}}(d) - L_{\mathrm{Clutter}} - L_{\mathrm{BEL}} + G_{\mathrm{Rx}} + 10 \cdot \log_{10}\left(\frac{B_{\mathrm{Rx}}}{B_{\mathrm{Tx}}}\right) \leq 10 \cdot \log_{10}(kT_0B) + NF_N + \left.\frac{I}{N}\right|_{\mathrm{th}}$$

where:

- $\mathrm{EIRP}_{\mathrm{WAS\ RLAN}}$ is the radiated power (*e.i.r.p.*) of the WAS/RLAN transmitter, in dBm;
- $L_{\mathrm{FSPL}}(d)$ is the free space path loss attenuation t at distance d, in dB;
- L_{Clutter} is the attenuation caused by obstacles in the path of transmission (see details below), in dB;
- L_{BEL} is the attenuation caused by walls when the WAS/RLAN transmitter is located inside a building, in dB;
- G_{Rx} is the antenna gain of the FS receiver in direction of the WAS/RLAN transmitter, in dBi;
- NF_N is the noise figure of the FS receiver, in dB;
- $\left.\frac{I}{N}\right|_{\mathrm{th}}$ is the protection criterion (interference-to-noise ratio = $(I - N)$), in dB;
- $B_{\mathrm{Tx}}$is the transmitter bandwidth, in MHz;
- $B_{\mathrm{Rx}}$is the receiver bandwidth, in MHz.

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

- Free space path loss (FSPL) model is used for the distances from 0 m to 55 m;
- From 55 m to 1000 m, Recommendation ITU-R P.1411-12 model [46] is used as line of sight (LOS);
- From 1000 m, the Recommendation ITU-R P.452-17 [47] is used as a non-line of sight (NLOS) case. The clutter loss model, described in Recommendation ITU-R P.2108-1 [48], is used for distances greater than 1000 m.

This method needs the following inputs:

- Position (3D) of FS antennas;
- Radiation patterns (3D) (or model associated with relevant parameters) of FS antennas;
- Orientation (azimuth, elevation) of FS antennas;
- Centre frequency and receiving bandwidth of the FS receiver;
- Noise Figure of the FS receiver.

5.1.2.2 Method 2: Limitation of maximum e.i.r.p.

In this method, HP WAS/RLAN devices in a given channel are assigned a maximum *e.i.r.p.* based on computing a simple FSPL-based link budget to each FS station visible to the HP WAS/RLAN (radio horizon). It can be formally described as follows.

$$\mathrm{EIRP}_{\mathrm{DSACF}}(f_{c,}, B) = \max\left\{\mathrm{EIRP}_{\mathrm{min}}; \min\left\{\mathrm{EIRP}_{\mathrm{max}}; \min_{i\in[0;N_{\mathrm{FS}}]}\left\{\mathrm{EIRP}_{\mathrm{DSACF,i}}(f_{c,}, B)\right\}\right\}\right\}$$

$$\mathrm{EIRP}_{\mathrm{DSACF,i}}(f_{c,}, B) = \left.\frac{I}{N}\right|_{\mathrm{th}} - G_{\mathrm{FS},i} + L_{\mathrm{FSPL},i} - L_{\mathrm{ovl}}(f_{c,\mathrm{FS},i}, B_{\mathrm{FS},i}, f_c, B) + N(B_{\mathrm{FS},i}, \mathrm{NF}_i)$$

with:

- $L_{\mathrm{ovl}}(f_{c,\mathrm{FS},i}, B_{\mathrm{FS},i}, f_c, B)$ is the part of the WAS/RLAN spectrum emission mask (in dB) that falls within the FS receiver band;
- the noise level at the FS receiver given (in dBm) by: $N(B_{\mathrm{FS},i}, \mathrm{NF}_i) = 10.\log_{10}(k.T_0.B_{\mathrm{FS},i}) + \mathrm{NF}_i + 30$

where:

- $\mathrm{EIRP}_{\mathrm{DSACF}}(f_c, B)$ (in dBm) is the maximum e.i.r.p assigned to the WAS/RLAN station for the channel defined by the center frequency f_c (in Hz) and bandwidth B (in Hz);
- N_{FS} is the number of FS stations visible to the WAS/RLAN (based on radio horizon);
- $f_{c,\mathrm{FS},i}$ (in Hz) is the center frequency of the ith FS receiver;
- $B_{\mathrm{FS},i}$ (in Hz) is the bandwidth of the ith FS receiver;
- NF_i (in dB) is the noise figure of the ith FS receiver;
- $T_0 = 290$ K is the reference noise-equivalent temperature;
- k (J/K) is the Boltzmann constant;
- NF_i (dB) is the noise figure of the ith FS receiver;
- $\mathrm{EIRP}_{\mathrm{min}}$ (in dBm) is the e.i.r.p limit that would apply to the device in absence of DSACF (that is: 200 mW for LPI and 25 mW for VLP);
- $\mathrm{EIRP}_{\mathrm{max}}$ (in dBm) is the maximum e.i.r.p limit that can be granted by DSACF (that is: 4W);
- $\left.\frac{I}{N}\right|_{\mathrm{th}}$ (in dB) is the I/N threshold (set to -10 dB, same value as the FS protection criterion (see section 5.1.1.2);
- $G_{\mathrm{FS},i}$ (in dBi) is the antenna gain of the i'th FS antenna in the direction of the WAS/RLAN device;
- $L_{\mathrm{FSPL},i}$ (in dB) is the free-space path loss between the ith FS antenna position and the WAS/RLAN device position.

This method needs the following inputs:

- Position (3D) of the WAS/RLAN device;
- Position (3D) of FS antennas;
- Spectrum emission mask of the WAS/RLAN device;
- Radiation patterns (3D) (or model associated with relevant parameters) of FS antennas;
- Orientation (azimuth, elevation) of FS antennas;
- Centre frequency and receiving bandwidth of the FS receiver;
- Noise Figure of the FS receiver.

5.1.3 Outcome of studies

5.1.3.1 Study A relative to Method 1: Example of restriction zones

Methodology

In the following, calculations were done for an area around an FS receiver 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, assuming that the HP WAS/RLAN antennas are omni-directional and using Recommendation ITU-R F.699 [13] for FS.

The resulting diagrams in Figure 5, Figure 6, Figure 7 and 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 (N_{limit}). 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 WAS/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.

Results

This study aims at illustrating restriction zones resulting from the computation of separation distances using method 1, for some sets of input parameters.

MCL calculations have been done assuming smooth Earth in the calculation area. The WAS/RLAN heights are 5 m and 7.5 m for outdoor use cases. For indoor use cases are the WAS/RLAN heights of 1.5 m and 7.5 m. The weighted average of the WAS/RLAN height distribution in Urban case is 7.5 m. The resulting plots illustrate the horizontal plane giving an indication from which position the WAS/RLAN transmitter is introducing an interference level equal to the amount of the power thresholds (N_{limit}).

In the following, the outdoor/indoor urban cases with constant FS receiving bandwidth of 40 MHz and variable WAS/RLAN transmit bandwidth from 40 MHz to 320 MHz are studied to account for different bandwidth overlap factors (although the spectrum emission mask of the WAS/RLAN is not taken into account). 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 [18]) 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 [48]). The clutter loss is 32.5 dB.

For this study, the FS parameters of Table 8 were used.

Table 8: FS parameters for study A relative to method 1

Parameter	Value	Comment / Reference
RLAN power (*e.i.r.p.*)	36 dBm (HP outdoor) 36 dBm (HP indoor)	
RLAN bandwidths	40 MHz - 320 MHz	Table 5
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 [1] / Table 4
FS Antenna Pattern	Recommendation ITU-R F.699 [13] (single-entry interference)	Table 7 (ECC Report 302, table 18 [1])
FS Antenna height	30 m, 40 m, 75 m	Table 7
FS Antenna gain	46 dBi	Table 7
FS Receiver Noise Figure	4.5 dB	Table 7
FS Feeder loss	1.3 dB	Table 7
FS bandwidth	40 MHz	Table 7
FS Protection criterion: I/N	-10 dB	Long-term: not exceeded for more than 20% of time ECC Report 302 [1], ECC Report 316 [19]
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)
Probability (p) of building entry loss (L_{BEL})	50%	Recommendation ITU-R P.2109-2 [18] (ECC Report 302, section 6.2 [1])
Time percentage (p)	20%	Recommendation ITU-R P.452-17 [47] (ECC Report 302 [1]) Recommendation ITU-R P.1411-12 (ECC Report 302 [1])
Parameter	Value	Comment / Reference

The results in the outdoor/indoor use cases show that the restriction zones become smaller as the HP WAS/RLAN bandwidths increase. This can be clearly seen in the peak radius results. The reason for this is the decreasing spectral power density of the HP WAS/RLAN with increasing bandwidth.

The circle radius (minimum distances) is independent of FS heights. The height of the FS receiver has a decisive influence on the peak radius separation distances.

Table 9: Results for 4 W *e.i.r.p.* outdoor use cases, urban/suburban scenario with HP WAS/RLAN heights of 5 m / 7.5 m

HP WAS/RLAN Bandwidths	FS Heights	Distances Peak radius (Maximum distances)	Distances Circle radius (Minimum distances)
40 MHz	30 m	32.2 km / 35.0 km	1.0 km / 1.1 km
40 MHz	40 m	35.4 km / 38.1 km	1.1 km / 1.1 km
40 MHz	75 m	43.7 km / 46.1 km	1.0 km / 1.1 km
320 MHz	30 m	25.8 km / 28.1 km	1.1 km / 1.0 km
320 MHz	40 m	28.7 km / 31.0 km	1.0 km / 1.1 km
320 MHz	75 m	36.5 km / 39.1 km	1.0 km / 1.0 km

Table 10: Results for 4 W *e.i.r.p.* indoor use cases, urban/suburban scenario with HP WAS/RLAN heights of 1.5 m / 7.5 m

HP WAS/RLAN Bandwidths	FS Heights	Distances Peak radius (Maximum distances)	Distances Circle radius (Minimum distances)
40 MHz	30 m	14.0 km / 21.4 km	1.0 km / 1.0 km
40 MHz	40 m	16.0 km / 21.2 km	1.1 km / 1.0 km
40 MHz	75 m	19.6 km / 19.5 km	1.0 km / 1.0 km
320 MHz	30 m	6.3 km / 6.7 km	0.4 km / 0.4 km
320 MHz	40 m	1.0 km / 5.9 km	0.4 km / 0.4 km
320 MHz	75 m	1.0 km /1.0 km	0.4 km / 0.4 km

Figure 5, Figure 6, Figure 7 and Figure 8 show the restriction zones around an FS receiver using this calculation method.

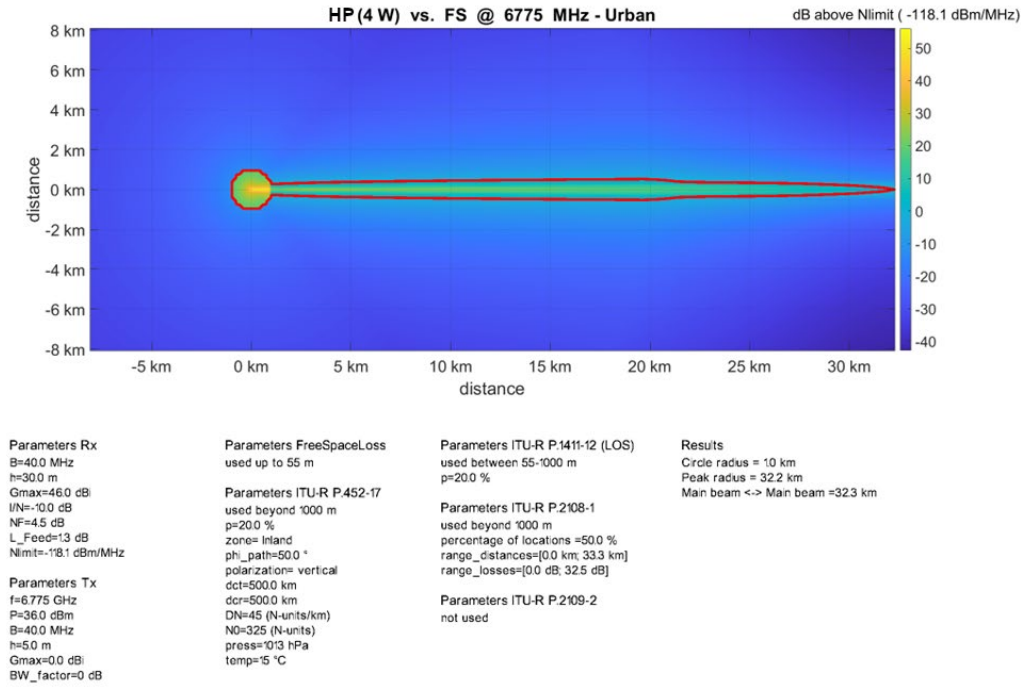


Figure 5: Example Outdoor use case with HP WAS/RLAN antenna height 5 m

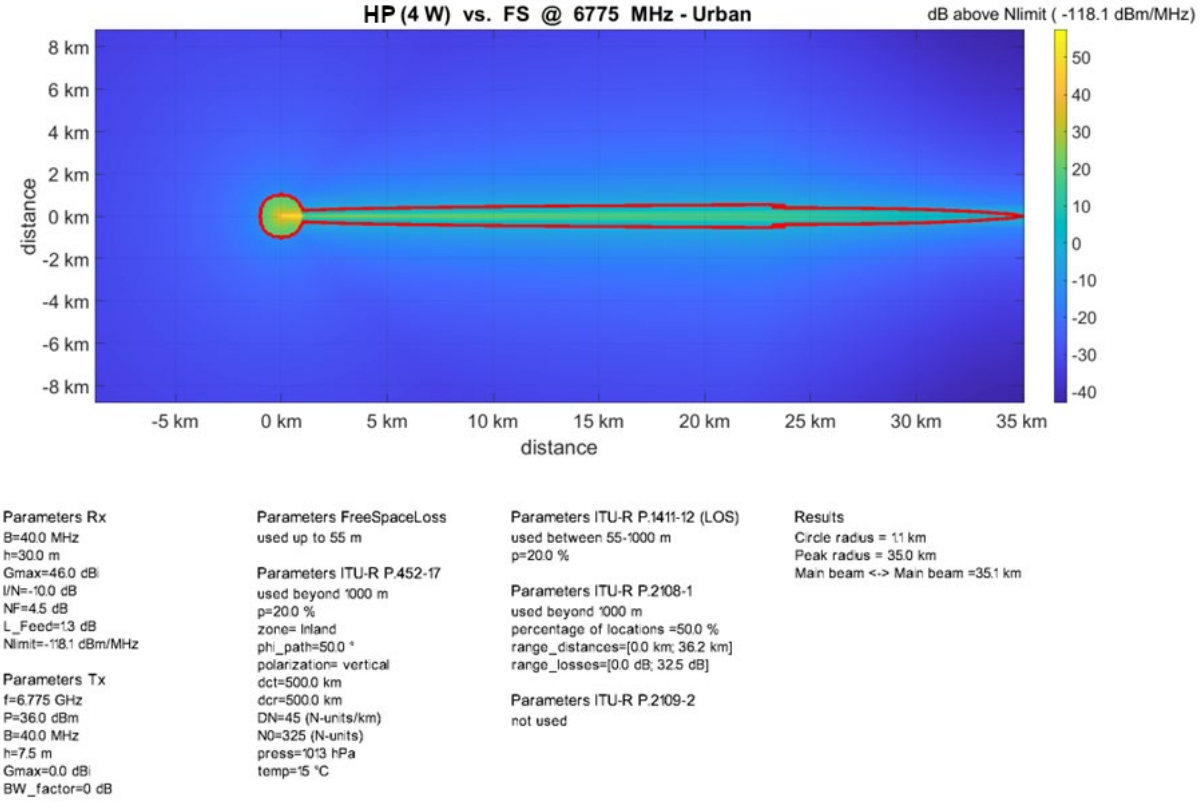


Figure 6: Example Outdoor use case with HP WAS/RLAN antenna height 7.5 m

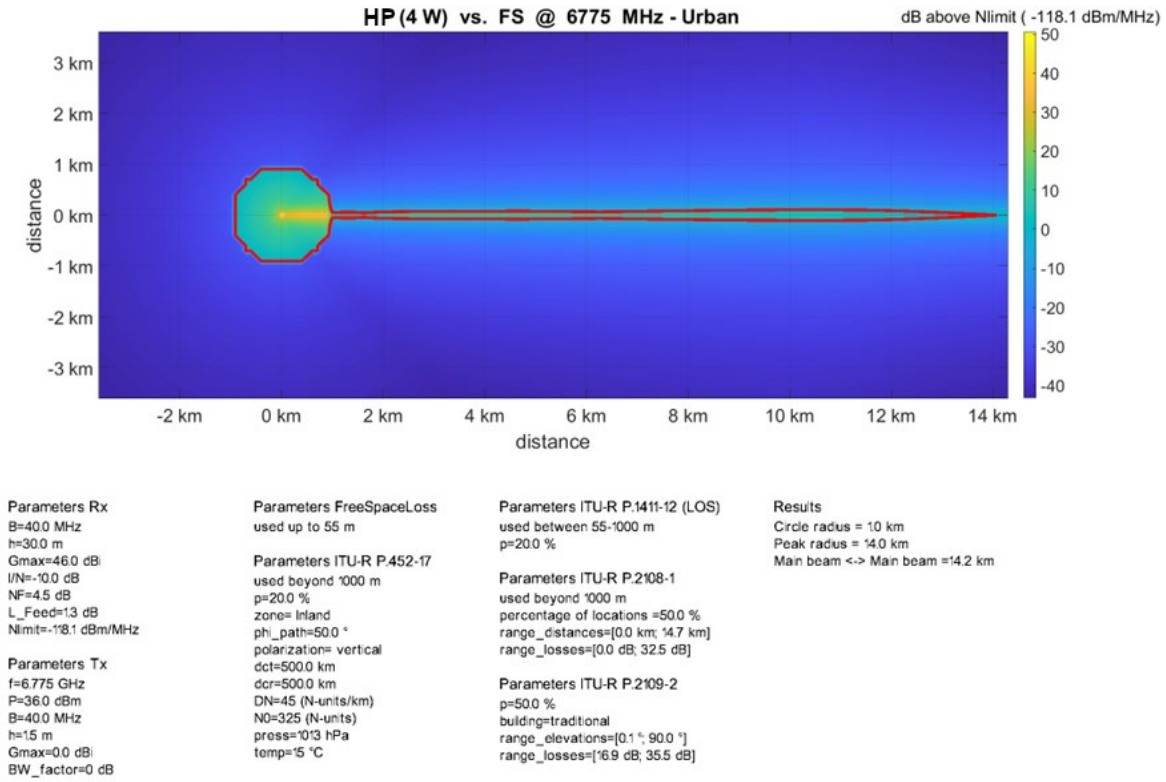


Figure 7: Example Indoor use case with HP WAS/RLAN antenna height 1.5 m

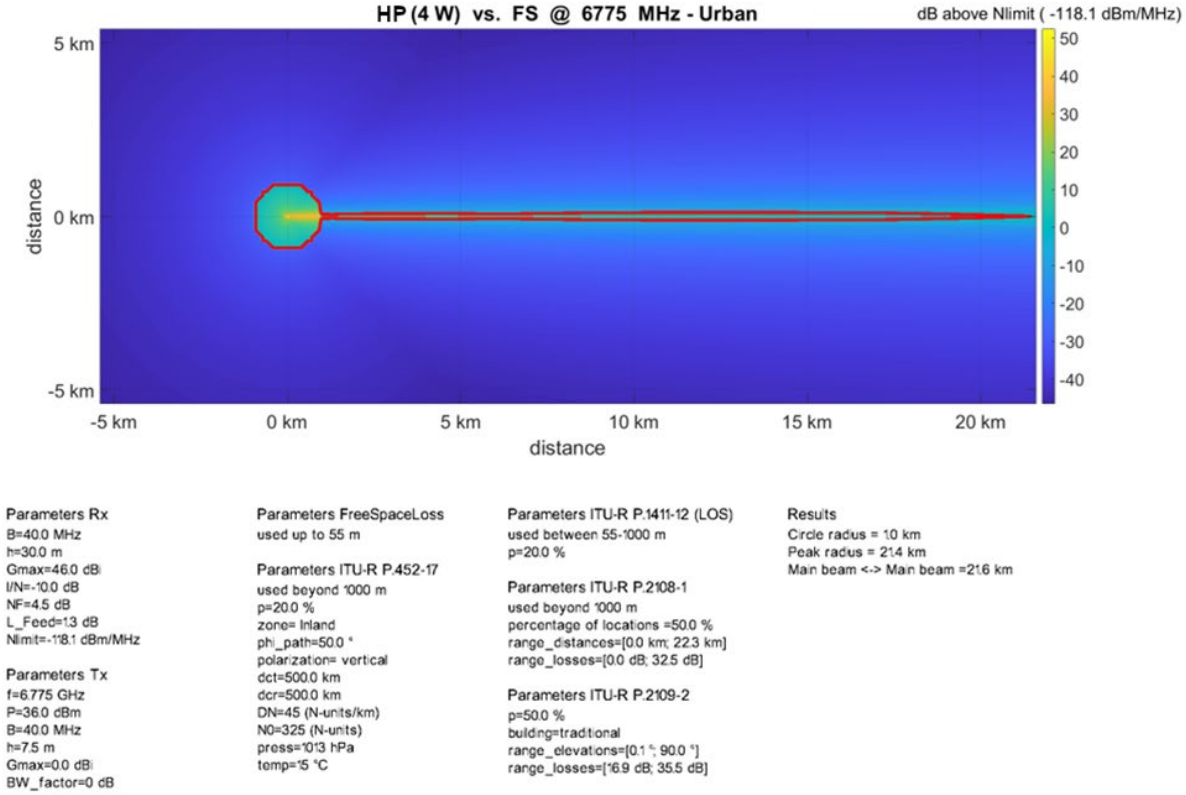


Figure 8: Example Indoor use case with HP WAS/RLAN antenna height 7.5 m

5.1.3.2 Study B relative to Method 1: Example of restriction zones

Figure 9, Figure 10, Figure 11 and Figure 12 illustrate the geographical distribution of *e.i.r.p.* around an FS station close to Poitiers (France), when using method 1, for four maximum WAS/RLAN *e.i.r.p.* (25 mW, 200 mW, 1 W and 4 W) and under various WAS/RLAN channels. The associated calculations did not consider clutter loss nor BEL.

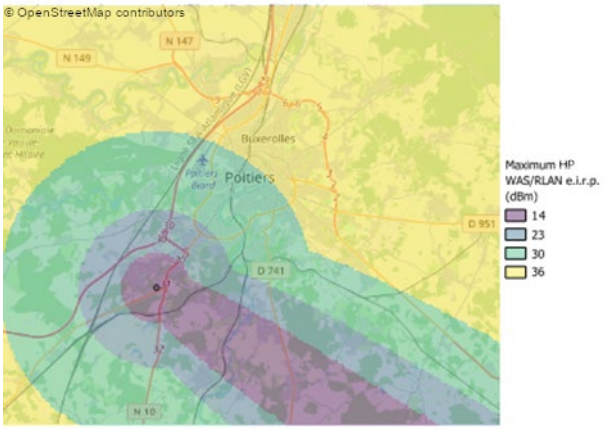


Figure 9: Example of *e.i.r.p.* limitation (WAS/RLAN bandwidth of 40 MHz, in-band channel)

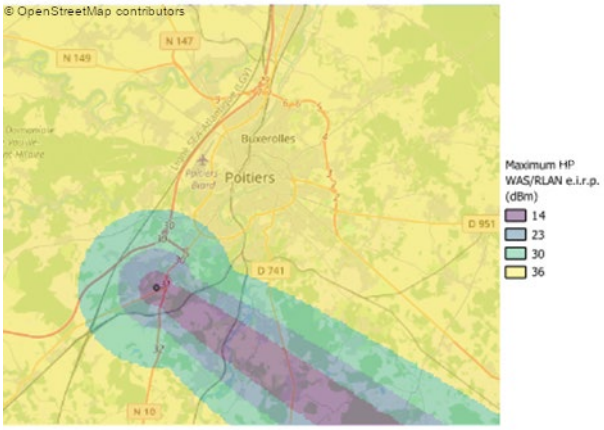


Figure 10: Example of *e.i.r.p.* limitation (WAS/RLAN bandwidth of 160 MHz, in-band channel)

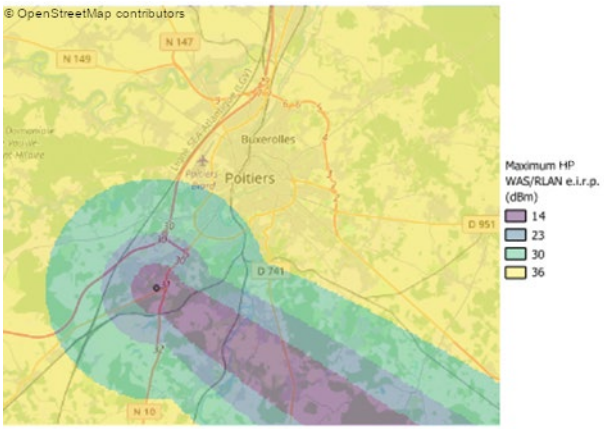


Figure 11: Example of *e.i.r.p.* limitation (WAS/RLAN bandwidth of 40 MHz, adjacent channel)

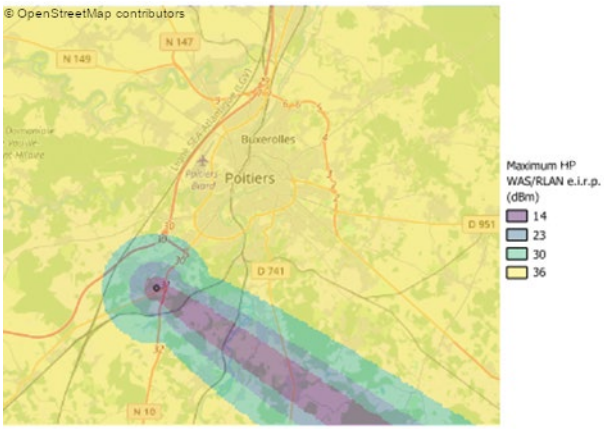


Figure 12: Example of *e.i.r.p.* limitation (WAS/RLAN bandwidth of 160 MHz, adjacent channel)

5.1.3.3 Study A relative to Method 2: Monte-Carlo simulation

This study investigates the impact of a deployments of HP WAS/RLAN, enabled by DSACF, on stations of the FS operating in-band. To this extent, a sensibility analysis is performed, which assumed that all active LPIs in the simulation zone will request higher power (see Table 3). It is assumed that no VLP will be capable of higher power.

The study is site-specific: it uses data from FS deployments in France [40], June 2024 edition), coupled with IGN BD TOPO building database ([41], last version as of May 2024), IGN RGE ALTI digital terrain model ([42], December 2021 edition) and GHS-POP population density map ([43] 2023 edition, projected to year 2025).

The FS deployment database lacks three important elements: the elevation of each FS station, the length of the link (used to compute the FDP), and the fade margin (idem). In order to figure out the elevation and length of the link, the database is processed in order to find the most likely pairs of FS stations. This is done by constructing a loss function considering the FS antenna in the azimuthal plane using Rec. ITU-R F.699, as well as the Fresnel clearance of each candidate link (using terrain data). Once a pair of FS stations has been resolved to a link, it is then possible to compute the elevation of each FS station, as well as the link distance.

Deployment density of WAS/RLAN follows scenario B high (worst case). The simulation implements a separate time/location Monte-Carlo approach where each Monte-Carlo run consists of several time-steps. The FS protection criterion (I/N < -10 dB less than 20% of the time, or FDP less than 10%) is evaluated time-wise, leading to a percentage of Monte-Carlo run were the criterion is respected.

For each Monte-Carlo run, an FS station is selected from the database, and its centre frequency is uniformly distributed within the 5945-6425 MHz band (minus 20 MHz at the edges). All WAS/RLAN active during the busy hour are distributed within the simulation area (i.e. location, centre frequency, bandwidth, etc. is randomly drawn), and pairs are formed (with max distance of 3m for VLP pairs, and 50m for Client/AP pairs). This pairing aims at modelling that APs do the DSACF request (based on its location), and the maximum *e.i.r.p.* that gets assigned to it also applies to its clients.

Outdoor WAS/RLAN are deployed outside at 1.5 m of altitude. Indoor WAS/RLAN are deployed in buildings identified as residential in the database and, given a constant population density, the WAS/RLAN density of a particular building is given by its area multiplied by the number of floors[2]. Within a building, the position of WAS/RLAN devices is uniformly distributed within the 3D shape.

Each Monte-Carlo run consist of 1000 time snapshots, for which a random subset of deployed WAS/RLAN are transmitting, based on RF activity factor and depending on weather the device is an AP, a client or a VLP (see Table 3).

At each time-step, the following variable are resampled: the actively transmitting WAS/RLAN (out of the one deployed for the Monte-Carlo run considered), the *e.i.r.p.* of body-worn devices and polarisation loss of body worn devices. Path loss computation uses the model of Recommendation ITU-R P.452-17 [47], with the time percentage fixed at 50%, reference temperature and pressures from Recommendation ITU-R P.835 [51] and clutter maps from CORINE Land Cover [44]).

Building entry loss (BEL) model is from Recommendation ITU-R P.2109 [19]. BEL is distributed once per Monte-Carlo run for non-body-worn devices, and once per time-step for body-worn devices (i.e. body-worn devices are supposed to be mobile).

The spectrum emission mask of WAS/RLAN is considered in the simulation but, due to lack of available characteristics, FS receivers are assumed to have perfect blocking.

To reduce the runtime, simulation zones are taken as footprint proportional to the FS antenna diagram horizontal cut, with a maximum distance at boresight of 11.7 km (see Figure 13).

[2] BD TOPO contains fields for building height and number of floors. When the former is not available, it is estimated from the latter as 1 floor for all heights <5m, and h/2.5 (rounded to the previous integer) for all other heights. When the latter is not available, it is estimated from the former as h=2.5*n_floors. When none are available, the height is set to 2.5m and the number of floors to 1.

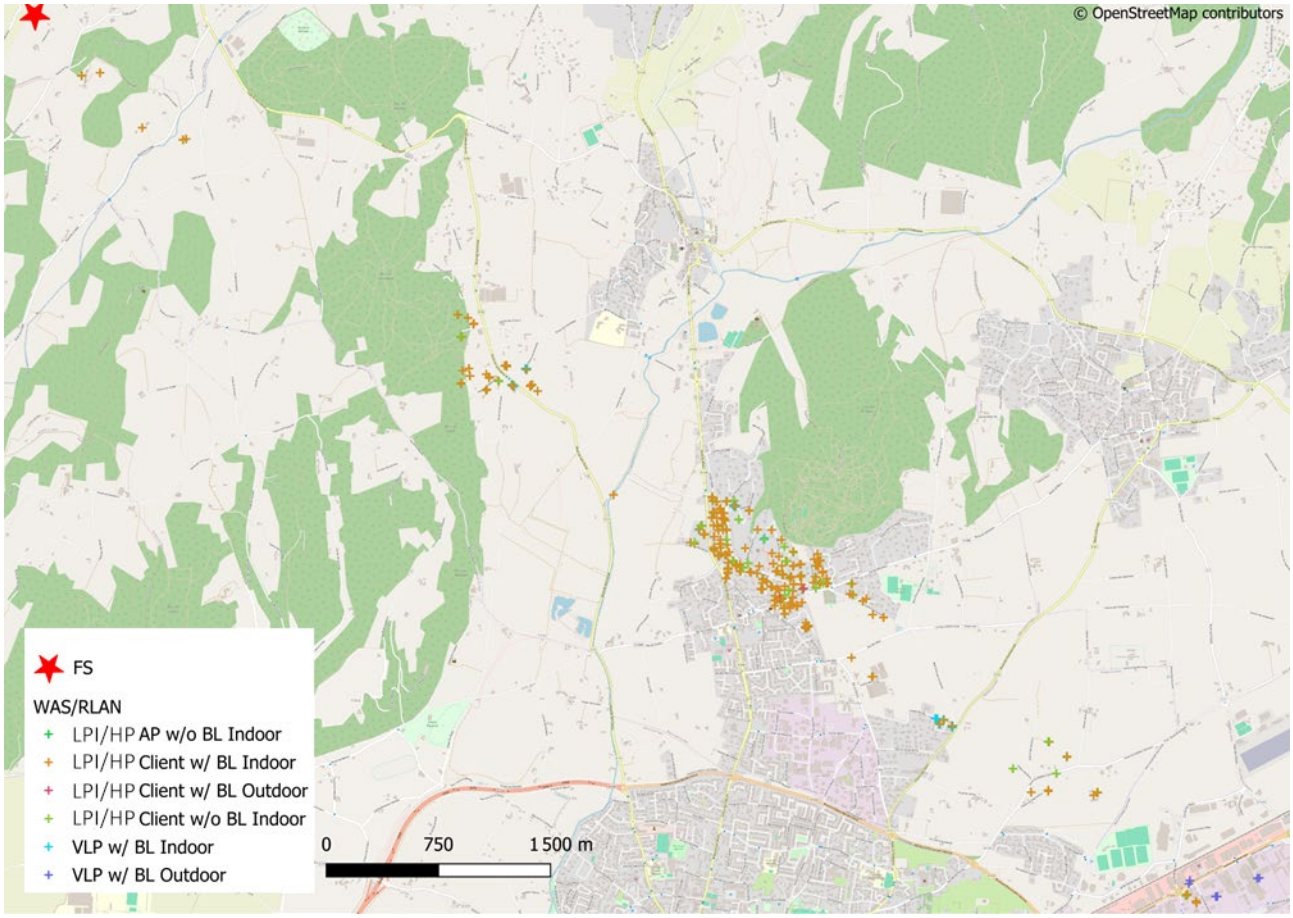


Figure 13: Example of deployment

Figure 14 and Figure 15 present the distribution of FDP, and I/N criterion compliance, respectively. As fade margin is not present in the FS database used, simulations with the three values of 13, 22 and 31 dB are performed and presented. Both figures show that DSACF method 2 allows for negligible degradation with respect to a VLP/LPI only deployment. Finally, Figure 16 shows that DSACF method 2 allows more that 50% of the WAS/RLAN in the simulation zone to have an *e.i.r.p.* higher than 250 mW, with more that 30% at an *e.i.r.p.* of 4 W.

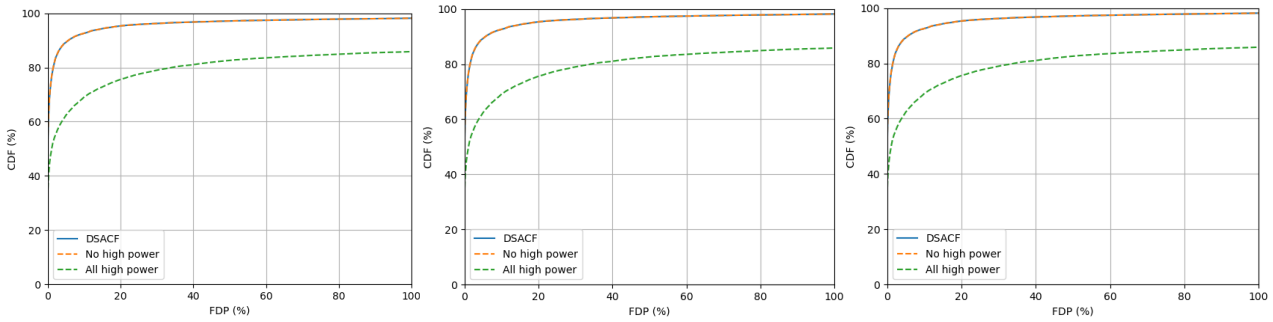


Figure 14: Distribution of FDP with DSACF method 2, with fade margin of 13 (left), 22 (middle) and 31 (right) dB

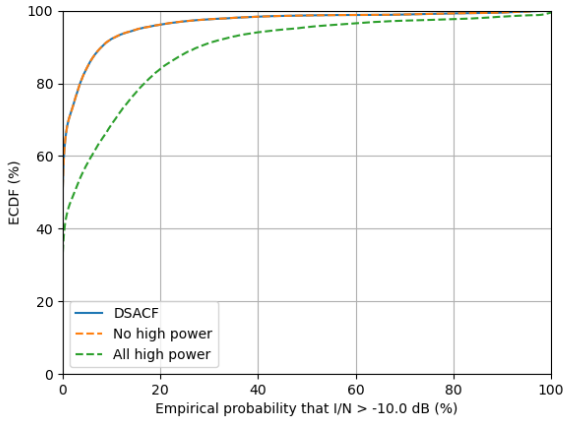


Figure 15: Distribution of I/N criterion exceedance with DSACF method 2

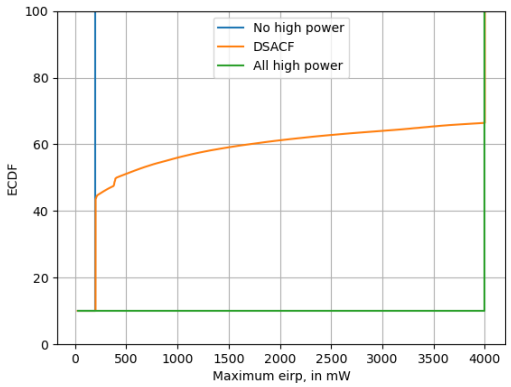


Figure 16: Assigned *e.i.r.p.* using DSACF method 2

5.1.3.4 Study B relative to Method 2: Example of spatial distribution of WAS/RLAN e.i.r.p.

Figure 17, Figure 18, Figure 19 and Figure 20 illustrate the geographical distribution of higher e.i.r.p around the FS station close to Poitiers (France), when using method 2, under various WAS/RLAN configurations.

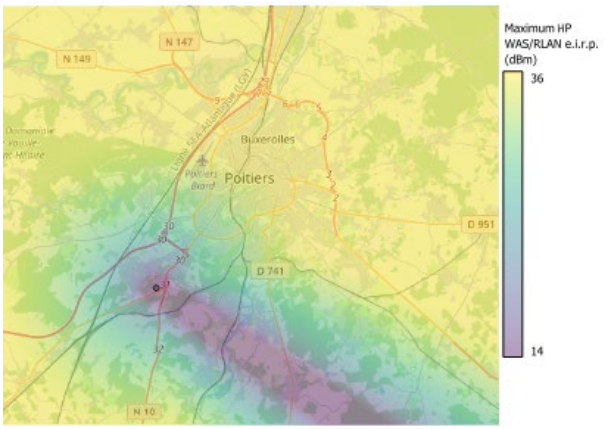


Figure 17: Example of *e.i.r.p.* limitation (WAS/RLAN bandwidth of 40 MHz, in-band channel)

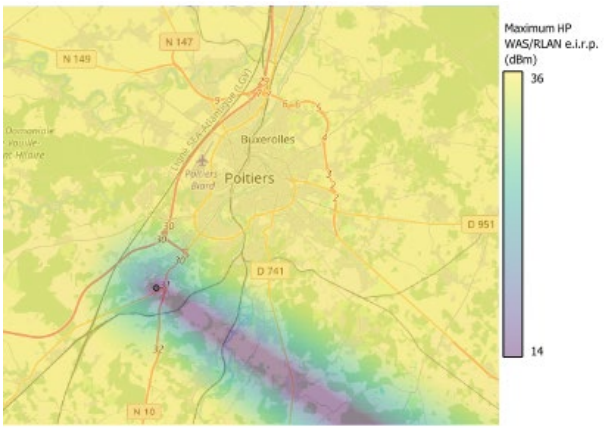


Figure 18: Example of *e.i.r.p.* limitation (WAS/RLAN bandwidth of 160 MHz, in-band channel)

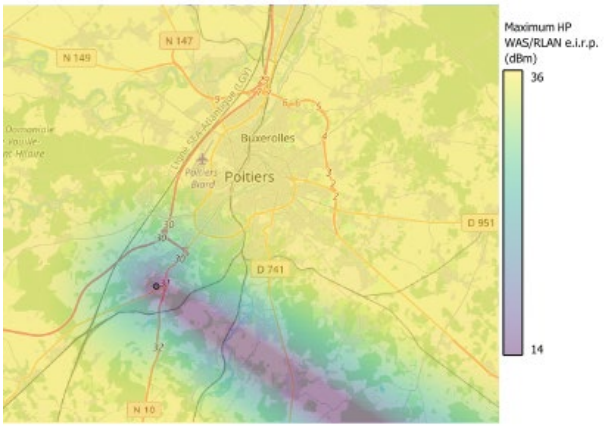


Figure 19: Example of *e.i.r.p.* limitation (WAS/RLAN bandwidth of 40 MHz, adjacent channel)

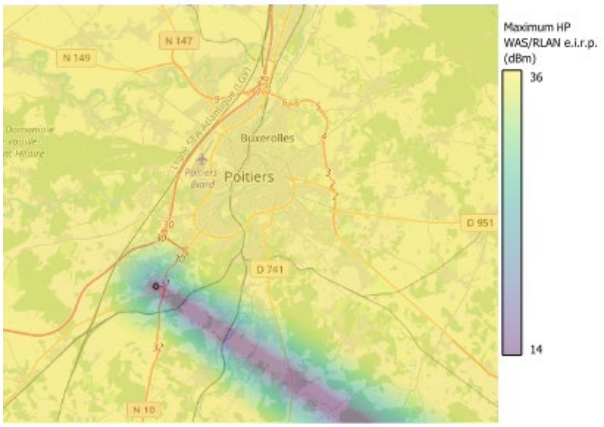


Figure 20: Example of *e.i.r.p.* limitation (WAS/RLAN bandwidth of 160 MHz, adjacent channel)

5.1.4 Summary of studies

These studies show that unmitigated HP WAS/RLAN operation can cause interference to FS mainly depending on their respective location. The characteristics of an FS receiver such as antenna pattern and gain, height and pointing direction, determine the areas or zones where an HP WAS/RLAN would be restricted in the available frequency channels and or power it could use.

5.2 FIXED-SATELLITE SERVICE (EARTH-TO-SPACE, IN-BAND)

5.2.1 Description of incumbent

5.2.1.1 Technical parameters

FSS deployments can be found in 5925-6425 MHz where Earth stations in the Earth-to-space uplink direction operate only to satellites in geostationary orbits. Typical parameters can be found in Table 11. Additional information on these parameters can be found in ECC Report 302, section 4.2 [1].

In these frequency bands, the satellite receiver beams cover very large areas of the Earth (using global, hemispherical, zonal or regional beams).

Table 11: Typical FSS Transmitter (Earth Station) parameters in the frequency range 5945-6425 MHz

Parameter	Typical value
Range of operating frequencies (MHz)	5945-6425
Antenna diameters (m)	1.2, 1.8, 2.4, 3.0, 4.5, 8, 16 and 32
Antenna reference pattern	Recommendation ITU-R S.465 [37]
Range of emission bandwidths (MHz)	0.040-72
Earth station deployment	All regions, in all locations (rural, suburban and urban)
Earth station *e.i.r.p.* density towards the horizon	In accordance with RR No. **21.8** and Recommendation ITU-R S.524-9 [38]
Minimum earth station antenna elevation angle (degrees)	5

5.2.1.2 Protection criterion

Any interference scenario in the Earth-to-space direction is considered on a time invariant basis and the protection criteria to be applied should be based on an I/N value of -10.5 dB, where N refers to the thermal noise, in line with Recommendation ITU-R S.1432-1 [39]. This value does not include apportionment, if any, of the allowable interference into FSS between other (than FSS) co-primary services, apportionment has to be considered on a case-by-case basis.

5.2.1.3 Deployment parameters

Table 12 provides details of the selection of satellites that have been taken as representative of those requiring protection in the visible portion of the geostationary orbit from Europe. In these frequency bands, the satellite beams cover very large areas of the Earth (using global, hemispherical, zonal or regional beams).

It should be understood as representative characteristics to conduct sharing studies independently of the lifetime of the particular satellites being analysed. Indeed, even if a particular satellite reaches the end of its lifetime, it will be replaced for an equivalent satellite that allows continuing providing FSS in the relevant service area. It should be noted that the band 5925-6425 MHz is extensively used by FSS networks worldwide and that currently about 180 satellites are in orbit using this band.

Table 12: FSS satellite parameters

Satellite	Sub-satellite longitude	Maximum Receive Gain (dBi)	Receiving Thermal Noise Temperature (K)	Figure of merit (dB/K) (using thermal noise)	Receiving System Noise Temperature (K)	Figure of merit (dB/K) (using system noise)
A	5º West	20.3	595	-7.44		
B	14º West	26.5	1200			
C	31.5º West	32.8	700			
D	3º East	22.9	316	-2.09		
E	27.5º West	34.2	565.76	6.67	832	5.00
F	53º East	26.5	1200			
I	359º East	28.67	340.68	3.35	501	1.67
J	40.5º West	22	190	-0.8		
K	22º West	28.2	190	5.4		
L	20º West	31.8	250	7.8		
M	50.5º East	32.4	250	8.4		
N	57º East	27.9	190	5.1		
O	5º East	32.5	700			
P	47.5º West	20	190	-2.8		
Q	37.5º West	30.5	190	7.7		
R	60º East	37.29	201.28	14.25	296	12.58
R'	5º East	37.29	201.28	14.25	296	12.58
T	34.5º West	39.90	224.4	16.39	330	14.71
U	8º West	27.2	428	0.88		
V	10º East	24.2	412	-1.94		
W	66º East	27.86	357	2.33	525	0.66
Y	45º West	31.04	298.52	6.29	439	4.62
Z	72º East	28.33	252.96	4.30	372	2.62

5.2.2 Methods of protection studied

Since there is no obvious way to protect space stations with a DSACF mechanism (typical geographical means like separation distances are not relevant), this Report will focus on quantifying the impact of enabling HP WAS/RLAN on large scales.

5.2.3 Outcome of studies

5.2.3.1 Study A

ECC Report 302 [1] studied impact of WAS/RLAN devices with transmit power higher than the 200 mW LPI power level, i.e. for indoor/outdoor cases, respectively, 9.15%/ 4.24% of devices with transmit power equal to

250 mW and 0.71%/3.24% of devices with transmit power equal to 1 W. The results showed that protection criteria are met except for the sensitivity analysis for the high scenario where 5% outdoor WAS/RLAN devices were considered. This sensitivity analysis confirms the importance of the WAS/RLAN deployment assumptions on the results of the simulation and highlights the need to control the distribution of the devices by demonstrating how increased outdoor devices, especially with higher power, will lead to exceedance of the FSS protection criteria.

Using ECC Report 302 [1] as baseline, analysis for 4 satellites is performed considering the impact of HP WAS/RLAN. Analysis parameters are updated to reflect the change in potential number of devices due to population increase from 2025 to 2030 and transmit power levels up to 4 W for indoor and outdoor HP WAS/RLAN devices operating under the control of DSACF (see Table 2).

For population, an assumed 5% increase for all studied continents/regions is applied. The number of devices impacting the satellites are also increased proportional to the population increase. HP WAS/RLAN devices were considered by assuming all 1 W-devices considered in ECC Report 302 [1] are operating at the maximum allowed 4 W power level. This simplification results in a conservative model. The percentage of outdoor devices is kept at 2% for these studies.

Table 13, Table 14, Table 15 and Table 16 show aggregate link budgets for 4 of the satellites (IS-33e, SES 50.5E Zone, SES 57E Hemispheric and SES 37.5W Hemispheric).

The average Building Entry Loss, Clutter Loss, Free Space Path Loss and G/Ts are the averages over the values used by the Monte Carlo simulation in ECC Report 302 [1] amongst all the WAS/RLANs within the corresponding region.

Table 13: IS-33e (at 60° East), Beam C4A, link budget for the mid WAS/RLAN scenario

Parameter	Unit	Europe	Africa
Number of Med. Active WAS/RLANs		1 382 886	633 278
Number of Active WAS/RLANs contributing to I/N		1 380 640	634 327
Avg. *e.i.r.p.* per WAS/RLAN			
Indoor Traditional Building (70%)	mW	49.1	49.1
Indoor Thermally Efficient Building (30%)	mW	21.0	21.0
Outdoor (2%)	mW	3.2	3.2
Total	mW	73.38	73.38
Aggregate Avg. *e.i.r.p.* (all WAS/RLANs)			
Indoor Traditional Building (70%)	mW	67 794 011	31 147 571
Indoor Thermally Efficient Building (30%)	mW	29 054 576	13 348 959
Outdoor (2%)	mW	4 460 154	2 049 192
Total	mW	101 308 741	46 545 723
Satellite Noise Bandwidth	MHz	36	36
Total WAS/RLAN Band	MHz	480	480
Bandwidth Correction		0.075	0.075
Aggregate Avg. *e.i.r.p.* (Bandwidth correction)			
Indoor Traditional Building (70%)	mW	5 084 551	2 336 068

Parameter	Unit	Europe	Africa
Indoor Thermally Efficient Building (30%)	mW	2 179 093	1 001 172
Outdoor (2%)	mW	334 512	153 689
Total	mW	7 598 156	3 490 929
Aggregate Avg. *e.i.r.p.* (Bandwidth correction)			
Indoor Traditional Building (70%)	dBW	37.06	33.68
Indoor Thermally Efficient Building (30%)	dBW	33.38	30.01
Outdoor (2%)	dBW	25.24	21.87
Total	dBW	38.81	35.43
Avg. Building Loss (Indoor WAS/RLAN only) (simulation)			
Traditional Building (power avg.)	dB	-12.93	-14.92
Thermally Efficient Building (power avg.)	dB	-20.82	-21.88
Avg. Free Space Path Loss (simulation)	dB	-200.20	-199.84
Polarisation Loss	dB	-3	-3
Avg. Clutter Loss (power avg.) (simulation)	dB	-3.77	-1.88
Aggregate Interference at satellite			
Indoor Traditional Building	dBW	-182.84	-185.95
Indoor Thermally Efficient Building	dBW	-194.40	-196.58
Outdoor	dBW	-181.72	-182.84
Total	dBW	-179.11	-180.99
Satellite Receiver Antenna Peak G/T (not used)	dB/K	14.185	14.185
Satellite Receiver Antenna Avg. G/T simulation)	dB/K	10.55	-4.24
Boltzmann's Constant	dBW/K/Hz	-228.60	-228.60
Satellite Noise Bandwidth	MHz	36.0	36.0
Aggregate Avg. I/N			
Indoor Traditional Building	dB	-19.25	-37.15
Indoor Thermally Efficient Building	dB	-30.81	-47.78
Outdoor	dB	-18.14	-34.05
Total	dB	-15.52	-32.19

Table 14: SES Satellite at 50.5° East Zone Beam link budget for the mid WAS/RLAN scenario

Parameter	Unit	Europe	Africa
Number of Med. Active WAS/RLANs		1 382 886	633 278
Number of Active WAS/RLANs contributing to I/N		1 380 640	634 327
Avg. *e.i.r.p.* per WAS/RLAN			
Indoor Traditional Building (70%)	mW	49.1	49.1
Indoor Thermally Efficient Building (30%)	mW	21.0	21.0
Outdoor (2%)	mW	3.2	3.2
Total	mW	73.38	73.38
Aggregate Avg. *e.i.r.p.* (all WAS/RLANs)			
Indoor Traditional Building (70%)	mW	67 794 011	31 147 571
Indoor Thermally Efficient Building (30%)	mW	29 054 576	13 348 959
Outdoor (2%)	mW	4 460 154	2 049 192
Total	mW	101 308 741	46 545 723
Satellite Noise Bandwidth	MHz	36	36
Total WAS/RLAN Band	MHz	480	480
Bandwidth Correction		0.075	0.075
Aggregate Avg. *e.i.r.p.* (Bandwidth correction)			
Indoor Traditional Building (70%)	mW	5 084 551	2 336 068
Indoor Thermally Efficient Building (30%)	mW	2 179 093	1 001 172
Outdoor (2%)	mW	334 512	153 689
Total	mW	7 598 156	3 490 929
Aggregate Avg. *e.i.r.p.* (Bandwidth correction)			
Indoor Traditional Building (70%)	dBW	37.06	33.68
Indoor Thermally Efficient Building (30%)	dBW	33.38	30.01
Outdoor (2%)	dBW	25.24	21.87
Total	dBW	38.81	35.43
Avg. Building Loss (Indoor WAS/RLAN only) (simulation)			
Traditional Building (power avg.)	dB	-13.45	-16.09
Thermally Efficient Building (power avg.)	dB	-21.03	-22.46
Avg. Free Space Path Loss (simulation)	dB	-200.10	-199.69
Polarisation Loss	dB	-3	-3
Avg. Clutter Loss (power avg.) (simulation)	dB	-3.23	-1.29

Parameter	Unit	Europe	Africa
Aggregate Interference at Satellite			
Indoor Traditional Building	dBW	-182.71	-186.39
Indoor Thermally Efficient Building	dBW	-193.97	-196.44
Outdoor	dBW	-181.08	-182.11
Total	dBW	-178.68	-180.62
Satellite Receiver Antenna Peak G/T (not used)	dB/K	8.4	8.4
Satellite Receiver Antenna Avg. G/T (simulation)	dB/K	5.15	-9.57
Boltzmann's Constant	dBW/K/Hz	-228.60	-228.60
Satellite Noise Bandwidth	MHz	36.0	36.0
Aggregate Avg. I/N			
Indoor Traditional Building	dB	-24.52	-42.91
Indoor Thermally Efficient Building	dB	-35.79	-52.97
Outdoor	dB	-22.90	-38.64
Total	dB	-20.49	-37.15

Table 15: SES Satellite at 57° East Hemispheric Beam link budget for the mid WAS/RLAN scenario

Parameter	Unit	Europe	Africa	Middle East
Number of Med. Active WAS/RLANs		1 382 886	633 278	178 464
Number of Active WAS/RLANs contributing to I/N		1 380 640	634 327	178 697
Avg. *e.i.r.p.* per WAS/RLAN				
Indoor Traditional Building (70%)	mW	49.1	49.1	49.1
Indoor Thermally Efficient Building (30%)	mW	21.0	21.0	21.0
Outdoor (2%)	mW	3.2	3.2	3.2
Total	mW	73.38	73.38	73.38
Aggregate Avg. *e.i.r.p.* (all WAS/RLANs)				
Indoor Traditional Building (70%)	mW	67 794 011	31 147 571	8 774 638
Indoor Thermally Efficient Building (30%)	mW	29 054 576	13 348 959	3 760 559
Outdoor (2%)	mW	4 460 154	2 049 192	577 282
Total	mW	101 308 741	46 545 723	13 112 478
Satellite Noise Bandwidth	MHz	36	36	36
Total WAS/RLAN Band	MHz	480	480	480
Bandwidth Correction		0.075	0.075	0.075

Parameter	Unit	Europe	Africa	Middle East
Aggregate Avg. *e.i.r.p.* (Bandwidth correction)				
Indoor Traditional Building (70%)	mW	5 084 551	2 336 068	658 098
Indoor Thermally Efficient Building (30%)	mW	2 179 093	1 001 172	282 042
Outdoor (2%)	mW	334 512	153 689	43 296
Total	mW	7 598 156	3 490 929	983 436
Aggregate Avg. *e.i.r.p.* (Bandwidth correction)				
Indoor Traditional Building (70%)	dBW	37.06	33.68	28.18
Indoor Thermally Efficient Building (30%)	dBW	33.38	30.01	24.50
Outdoor (2%)	dBW	25.24	21.87	16.36
Total	dBW	38.81	35.43	29.93
Avg. Building Loss (Indoor WAS/RLAN only) (simulation)				
Traditional Building (power avg.)	dB	-13.10	-15.29	-16.66
Thermally Efficient Building (power avg.)	dB	-20.89	-22.06	-22.58
Avg. Free Space Path Loss (simulation)	dB	-200.16	-199.79	-199.63
Polarisation Loss	dB	-3	-3	-3
Avg. Clutter Loss (power avg.) (simulation)	dB	-3.59	-1.67	-1.11
Aggregate Interference at Satellite				
Indoor Traditional Building	dBW	-182.79	-186.07	-192.22
Indoor Thermally Efficient Building	dBW	-194.26	-196.51	-201.81
Outdoor	dBW	-181.51	-182.59	-187.38
Total	dBW	-178.96	-180.86	-186.03
Satellite Receiver Antenna Peak G/T (not used)	dB/K	5.1	5.1	5.1
Satellite Receiver Antenna Avg. G/T (simulation)	dB/K	2.05	2.94	1.23
Boltzmann's Constant	dBW/K/Hz	-228.60	-228.60	-228.60
Satellite Noise Bandwidth	MHz	36.0	36.0	36.0
Aggregate Avg. I/N				
Indoor Traditional Building	dB	-27.70	-30.09	-37.95
Indoor Thermally Efficient Building	dB	-39.17	-40.54	-47.54
Outdoor	dB	-26.42	-26.61	-33.10
Total	dB	-23.87	-24.88	-31.76

Table 16: SES Satellite at 37.5° West Hemispheric Beam link budget for the mid WAS/RLAN scenario

Parameter	Unit	Europe	Africa	Middle East
Number of Med. Active WAS/RLANs		701 972	321 461	90 591
Number of Active WAS/RLANs contributing to I/N		659 798	311 940	44 504
Avg. *e.i.r.p.* per WAS/RLAN				
Indoor Traditional Building (70%)	mW	49.1	49.1	49.1
Indoor Thermally Efficient Building (30%)	mW	21.0	21.0	21.0
Outdoor (2%)	mW		3.2	3.2
Total	mW	73.38	73.38	73.38
Aggregate Avg. *e.i.r.p.* (all WAS/RLANs)				
Indoor Traditional Building (70%)	mW	32 398 268	15 317 291	2 185 314
Indoor Thermally Efficient Building (30%)	mW	13 884 972	6 564 553	936 563
Outdoor (2%)	mW	2 131 475	1 007 721	143 771
Total	mW	48 414 715	22 889 565	3 265 648
Satellite Noise Bandwidth	MHz	36	36	36
Total WAS/RLAN Band	MHz	480	480	480
Bandwidth Correction		0.075	0.075	0.075
Aggregate Avg. *e.i.r.p.* (Bandwidth correction)				
Indoor Traditional Building (70%)	mW	2 429 870	1 148 797	163 899
Indoor Thermally Efficient Building (30%)	mW	1 041 373	492 341	70 242
Outdoor (2%)	mW	159 861	75 579	10 783
Total	mW	3 631 104	1 716 717	244 924
Aggregate Avg. *e.i.r.p.* (Bandwidth correction)				
Indoor Traditional Building (70%)	dBW	33.86	30.60	22.15
Indoor Thermally Efficient Building (30%)	dBW	30.18	26.92	18.47
Outdoor (2%)	dBW	22.04	18.78	10.33
Total	dBW	35.60	32.35	23.89
Avg. Building Loss (Indoor WAS/RLAN only) (simulation)				
Traditional Building (power avg.)	dB	-12.40	-13.27	-11.57
Thermally Efficient Building (power avg.)	dB	-20.59	-21.01	-20.26
Avg. Free Space Path Loss (simulation)	dB	-200.31	-200.12	-200.51
Polarisation Loss	dB	-3	-3	-3

Parameter	Unit	Europe	Africa	Middle East
Avg. Clutter Loss (power avg.) (simulation)	dB	-4.71	-3.19	-9.09
Aggregate Interference at Satellite				
Indoor Traditional Building	dBW	-186.56	-188.97	-202.02
Indoor Thermally Efficient Building	dBW	-198.44	-200.39	-214.39
Outdoor	dBW	-185.98	-187.52	-202.27
Total	dBW	-183.12	-185.04	-199.01
Satellite Receiver Antenna Peak G/T (not used)	dB/K	7.7	7.7	7.7
Satellite Receiver Antenna Avg. G/T (simulation)	dB/K	2.90	4.45	1.09
Boltzmann's Constant	dBW/K/Hz	-228.60	-228.60	-228.60
Satellite Noise Bandwidth	MHz	36.0	36.0	36.0
Aggregate Avg. I/N				
Indoor Traditional Building	dB	-30.62	-31.48	-47.90
Indoor Thermally Efficient Building	dB	-42.50	-42.90	-60.27
Outdoor	dB	-30.04	-30.03	-48.15
Total	dB	-27.18	-27.55	-44.88

Aggregate link budget analysis presented in this section shows that interference protection criteria are met for the mid WAS/RLAN deployment scenario with significant margin for all satellite, even under the conservative device usage and power increase assumptions applied.

In this section, summary of results for all four satellites for low, mid, and high WAS/RLAN deployment scenarios are presented.

Table 17, Table 18, Table 19 and Table 20 show the aggregate average I/N in decibel for low and high WAS/RLAN deployment scenarios. Even in the case of conservative high scenario, protection criteria are met.

Table 17: Aggregate average I/N (dB) for IS-33e (at 60° East), Beam C4A, in different scenarios

Scenario	Europe	Africa
Low	-17.58	-34.25
Mid	-15.52	-32.19
High	-13.58	-30.25

Table 18: Aggregate average I/N (dB) for SES Satellite at 50.5° East, Zone Beam, in different scenarios

Scenario	Europe	Africa
Low	-22.55	-39.21

Scenario	Europe	Africa
Mid	-20.49	-37.15
High	-18.55	-35.21

Table 19: Aggregate average I/N (dB) for SES Satellite at 57° East, Hemispheric Beam, in different scenarios

Scenario	Europe	Africa	Middle East
Low	-25.93	-26.94	-33.82
Mid	-23.87	-24.88	-31.76
High	-21.93	-22.94	-29.82

Table 20: Aggregate average I/N (dB) for SES Satellite at 37.5° West, Hemispheric Beam, in different scenarios

Scenario	Europe	Africa	Middle East
Low	-29.24	-29.61	-46.94
Mid	-27.18	-27.55	-44.88
High	-25.24	-25.61	-42.94

5.2.4 Summary of studies

These studies show that interference protection criteria is met for the mid WAS/RLAN deployment scenario with significant margin for all satellite even under the conservative device usage and power increase assumptions applied.

Based on the above analysis the DSACF systems would not need to apply any further mitigation for FSS.

The impact of the antenna discrimination, beam forming and *e.i.r.p.* limitations for certain elevation angles of HP WAS/RLAN were not considered in these studies.

5.3 RADIO ASTRONOMY SERVICE (ADJACENT BAND)

5.3.1 Description of incumbent

The frequency band 6650-6675.2 MHz is one of the bands listed in footnote No. **5.149** of the Radio Regulations. In those bands, “administrations are urged to take all practicable steps to protect the radio astronomy service from harmful Interference”.

There are 17 radio astronomy stations operating in 7 CEPT countries in the 6650−6675.2 MHz band as listed in the Table 21.

Table 21: List of CEPT countries with RAS stations operating in the frequency band 6650−6675.2 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″
Torun	Poland	18° 33′ 50.6″	53° 05′ 43.7″
Yebes	Spain	–03° 05′ 13″	40° 31′ 28.8″
Onsala	Sweden	11° 55′ 04″	57° 23′ 35″
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*		–01° 26′ 19″	51° 08′ 42″
Note 1: Planned operations			

RAS stations operate out of HP WAS/RLAN operating band, as a result, HP WAS/RLANs transmit power will be significantly attenuated by their emission mask. Table 24 shows the maximum power spectral density (in dBm/MHz) by transmission of HP WAS/RLAN devices at the upper edge of the 5945–6425 MHz band at maximum power of 36 dBm total power. Emission mask is derived using ETSI 6 GHz specification [26]. While most devices will have lower emissions than the ETSI specification, the highest possible emission into the RAS band will be -21.875 dBm/MHz. This calculation does not take into account antenna mismatches, polarisation losses, and body losses.

5.3.1.1 Protection criterion

Recommendation ITU-R RA.769 [23] provides threshold levels of interference detrimental to radio astronomy, for continuum and spectral line observations. The threshold applicable to the frequency band 6650-6675.2 MHz are not given in that Recommendation but can be extrapolated with the methodology given in Report ITU-R RA.2131 [24].

The protection criterion is specified in Recommendation ITU-R RA.1513 [25]: the data loss of all observations with an integration time of 2000 s should remain below 2%. Further details are given in Table 22.

Table 22: 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.

5.3.2 Methods of protection studied

5.3.2.1 Method 1: Restriction zones

The separation distance (d, in m) is found as the lowest value satisfying the following MCL equation together with the parameters in Table 22:

$$\mathrm{EIRP}_{\mathrm{WAS\ RLAN}} - 10.\log_{10}(B) - L_{OOB}(f_{RAS}, f_c, B) - L_{FSPL}(d) + 10.\log_{10}(F_{AF}) \leq PSD_{th}$$

where:

- $\mathrm{EIRP}_{\mathrm{WAS\ RLAN}}$ is the radiated power (*e.i.r.p.*) of the WAS/RLAN transmitter, in dBm.
- $L_{\mathrm{FSPL}}(d)$ is the free space path loss attenuation t at distance d, in dB;
- $L_{OOB}(f_{RAS}, f_c, B)$ is the OoB attenuation of the WAS/RLAN at $f_{RAS} = 6650$ MHz, for a WAS/RLAN channel defined by the center frequency f_c (in Hz) and bandwidth B (in Hz)(see Figure 3 and Table 23);
- PSD_{th} =-176 dB (mW/MHz) is the protection criterion of RAS (see Table 22);
- F_{AF} is the assumed mean activity factor of WAS/RLAN (between 1.97% and 2.45% in ECC Report 364).

Table 23: WAS/RLAN attenuation at RAS band edge.

WAS/RLAN channel bandwidth B (MHz)	WAS/RLAN channel center frequency f_c (MHz)	Attenuation at RAS band edge $L_{OOB}(f_c, B)$ (dB)
20	5935-6415	-47.0
40	5945-6205	-47.0
40	6225-6285	-42.0
40	6305-6405	-40.0
80	5965-6385	-40.0
160	6005-6345	-40.0
320	6085	-40.0
320	6265	-32.9

This method needs the following inputs:

- Position (2D) of the WAS/RLAN device;
- Position (2D) of Radio Astronomy stations.

5.3.2.2 *Method 2: Limitation of maximum e.i.r.p.*

In this method, HP WAS/RLAN devices in a given channel are assigned a maximum ***e.i.r.p.*** based on computing a simple FSPL-based link budget to each RAS station visible to the HP WAS/RLAN (radio horizon). It can be formally described as follows:

$$\mathrm{EIRP_{DSACF}}(f_{c,}, B) = \max\left\{\mathrm{EIRP_{min}}; \min\left\{\mathrm{EIRP_{max}}; \min_{i\in[0;N_{\mathrm{RAS}}]}\left\{\mathrm{EIRP_{DSACF,i}}(f_{c,}, B)\right\}\right\}\right\}$$

$$\mathrm{EIRP_{DSACF,i}}(f_{c,}, B) = PSD_{th} + 10.\log_{10}(B) + L_{OOB}(f_{RAS}, f_c, B) + L_{FSPL}(d) - 10.\log_{10}(F_{AF})$$

where:

- $\mathrm{EIRP_{DSACF}}(f_{c,}, B)$ (in dBm) is the maximum e.i.r.p assigned to the WAS/RLAN station for the channel defined by the center frequency f_c (in Hz) and bandwidth B (in Hz).
- $L_{\mathrm{FSPL}}(d)$ is the free space path loss attenuation t at distance d, in dB;
- $L_{OOB}(f_{RAS}, f_c, B)$ is the OoB attenuation of the WAS/RLAN at $f_{RAS} = 6675.2$ MHz, for a WAS/RLAN channel defined by the center frequency f_c (in Hz) and bandwidth B (in Hz) (see Figure 3 and Table 23);
- PSD_{th} =-176 dB (mW/MHz) is the protection criterion of RAS (see Table 22);
- F_{AF} is the assumed mean activity factor of WAS/RLAN (between 1.97% and 2.45% in ECC Report 364).

This method needs the following inputs:

- Position (2D) of the WAS/RLAN device.
- Position (2D) of Radio Astronomy stations.

5.3.3 Outcome of studies

5.3.3.1 *Study A relative to Method 1: Example of restriction zones*

This study used the maximum emission into the RAS band that is expected to be -21.875 dBm/MHz. The level is taken from Table 24 which contains the proposed levels of OOBE into the RAS band from HP WAS/RLAN devices. Noting that for the 20/40/80 MHz channels that it would have to meet the -30dBm/MHz level mandated at the edge of the spurious domain. These levels are assumed for the case where the WAS/RLANs are operating with full 36 dBm transmit power at the top channel edge of their operating frequency range in the lower 6 GHz band (i.e., up to 6425 MHz). This is the closest frequency that WAS/RLAN could operate adjacent to RAS. It is expected that most enterprise networks will be using a variety of maximum power levels up to 36 dBm and channel widths of 80 MHz or lower to provide frequency re-use patterns depending upon the interference environment, coverage needed and density of users being supplied.

Table 24: Power Spectral Density OOBE of WAS/RLAN in the RAS frequency ranges

BW (MHz)	Inband PSD (dBm/MHz)	IEEE Channel Number (uppermost channel)	Centre Frequency	Frequency Offset (RAS Lower Edge - RLAN fc)	ETSI Mask Level @ RAS (dBr) ETSI EN 303 687 [26]	PSD @ RAS (dBm/MHz)
20	23	93	6415	235	-47	-24
40	20	91	6405	245	-40	-20
80	17	87	6385	265	-40	-23
160	14	79	6345	305	-40	-26
320	11	63	6265	385	-32.875	-21.875

In this very simple and worst-case analysis, the free space path loss model is used without any additional losses (clutter, body, terrain etc.). Assuming a WAS/RLAN PSD level of -21.875 dBm/MHz in the RAS bands, the resulting protection area size is 182 km. Following ITU-R RA.1031-3, and assuming each RLAN has an activity factor of 2%, we can get 17 dB reduction over the 2000 seconds integration time. This reduces the protection area size to 25 km using free space path loss. Using Winner 2 rural macro NLOS model, the protection area radius is reduced to 1.3 km (applying urban models would result in even smaller areas).

It is to be noted that RAS sites are outside urban centres in Europe and away from cities.

Figure 21 and Figure 22 illustrate the geographical distribution of *e.i.r.p.* around an RAS station close to Effelsberg (Germany), when using method 1, for four maximum WAS/RLAN *e.i.r.p.* (25 mW, 200 mW, 1 W and 4 W) and under various WAS/RLAN channels. The associated calculations did not consider clutter loss nor BEL.

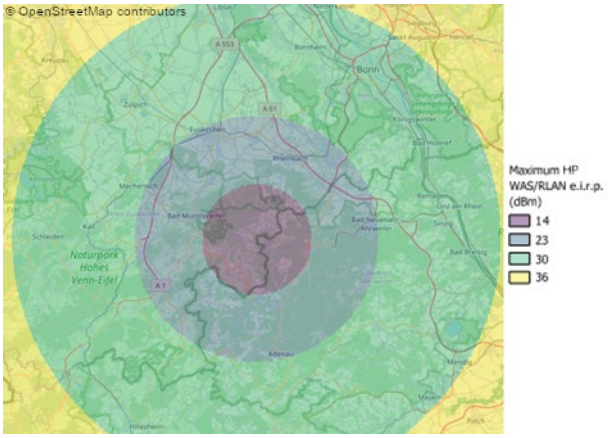


Figure 21: Example of *e.i.r.p.* limitation (40 MHz WAS/RLAN channel centred at 6405 MHz)

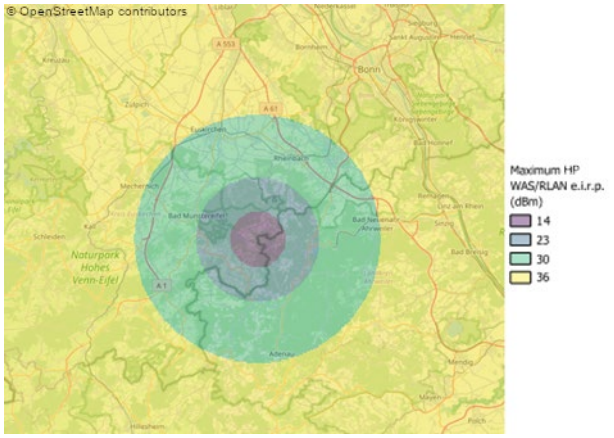


Figure 22: Example of *e.i.r.p.* limitation (160 MHz WAS/RLAN channel centred at 6345 MHz)

5.3.3.2 Study A relative to Method 2: Example of spatial distribution of WAS/RLAN e.i.r.p.

Figure 23 and Figure 24 illustrate the geographical distribution of *e.i.r.p.* around an RAS station close to Effelsberg (Germany), when using method 2, for four maximum WAS/RLAN *e.i.r.p.* (25 mW, 200 mW, 1 W and 4 W) and under various WAS/RLAN channels. The associated calculations did not consider clutter loss nor BEL.

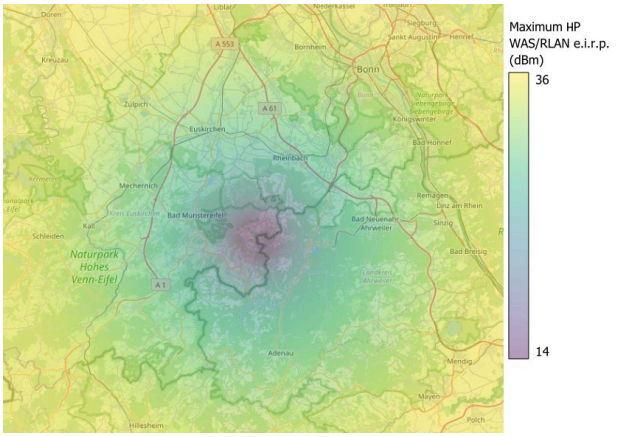


Figure 23: Example of *e.i.r.p.* limitation (40 MHz WAS/RLAN channel centred at 6405 MHz)

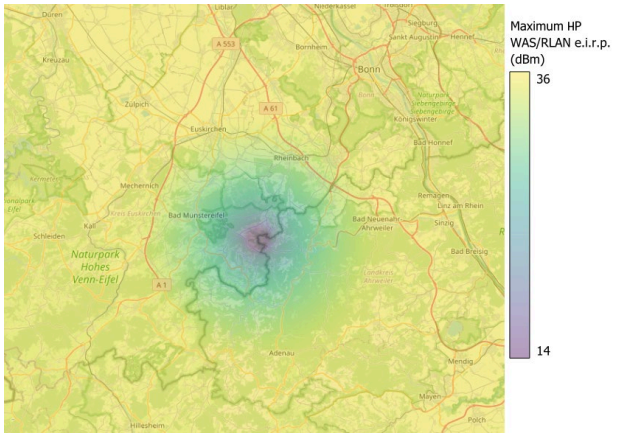


Figure 24: Example of *e.i.r.p.* limitation (160 MHz WAS/RLAN channel centred at 6345 MHz)

5.3.4 Summary of studies

These studies show that RAS requires protection from HP WAS/RLAN located nearby. Restriction zones and/or restricted *e.i.r.p.* were calculated that could be applied through a DSACF system that would protect the RAS receivers from harmful interference from HP WAS/RLAN located nearby.

5.4 URBAN RAIL ITS / CBTC (ADJACENT BAND)

5.4.1 Description of incumbent

ITS encompass Road ITS and Urban Rail ITS. Urban Rail ITS means urban or suburban railway lines segregated from road and pedestrian traffic. Urban Rail ITS is used for CBTC. CBTC systems are used in some metropolitan cities in Europe (5915-5935 MHz) with deployments engaged or planned in at least 11 countries, in accordance with ECC Decision (08)01. In addition, some existing systems are deployed in Denmark (5925-5975 MHz) and Spain (5905-5925 MHz).

ECC Report 302 [1] and CEPT Report 75 studied the coexistence between WAS/RLAN operating above 5945 MHz and CBTC operating below 5935 MHz. ECC Decision (20)01 [10] harmonises the use of WAS/RLAN in the 5945-6425 MHz band, for VLP portable use and for LPI fixed use.

Noting that ETSI has published the technical specification TS 103 745 for shared use of the band 5915-5925 MHz by both Urban Rail and Road ITS. The solution consists of a map server, containing geographic regions of Restricted Modes of Operations (RMOs) (see an illustrative map in Figure 25 as an example).

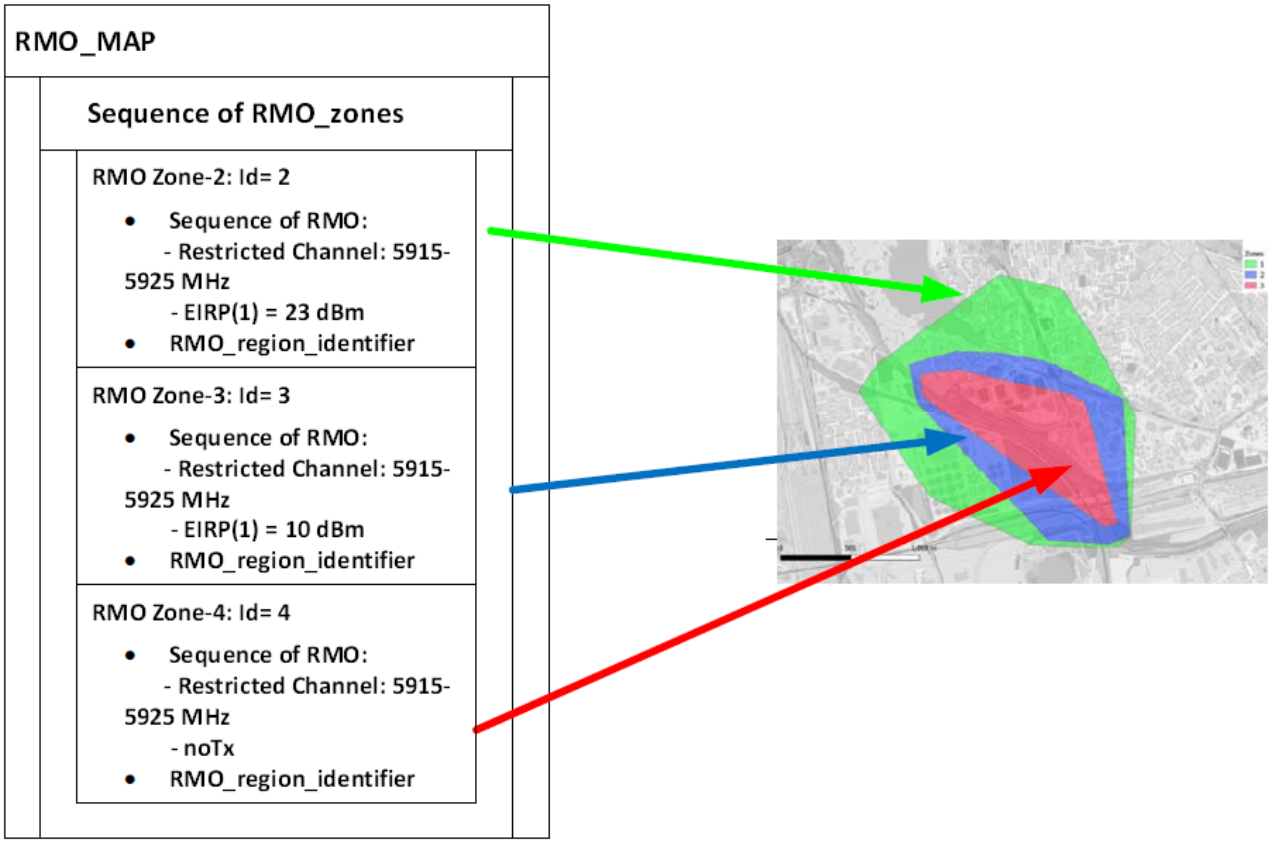


Figure 25: Illustrative map including three RMO zones, with their respective restrictions

The system is designed to enable existing and new urban rail lines to be protected, with limited updates.

A similar system could support the protection of urban rail systems against adjacent band interference from HP WAS/RLANs.

Polygons surrounding the outdoor tracks could represent areas where the power of HP WAS/RLAN devices would be restricted in order to protect CBTC systems. The system could be interfaced with DSACF system(s).

5.4.1.1 Technical parameters

Parameters can be found in Table 25, Table 26 and Table 27 They were extracted from IEEE based characteristics of the CBTC system studied in ECC Report 302 [1] and ECC Report 355 [7].

CBTC Access Points (AP) are installed near rail tracks with known locations. Train Units (TU) are installed at each end of an urban rail train.

Table 25: CBTC radio parameters

Parameter	CBTC AP	CBTC TU
Frequency band	5915-5935 MHz	
Technology	based on IEEE 802.11	
Channel bandwidth	5 MHz	
Protection ratio C/I	9 dB	9 dB
Noise floor	-97 dBm	-97 dBm
Sensitivity	-88 dBm	-88 dBm

Table 26: CBTC receivers

Parameter	CBTC AP	CBTC TU
Antenna gain (main lobe)	18 dBi	14 dBi
Side lobe discrimination (90° azimuth)	15 dB	18 dB
Hardware loss	9 dB	6 dB

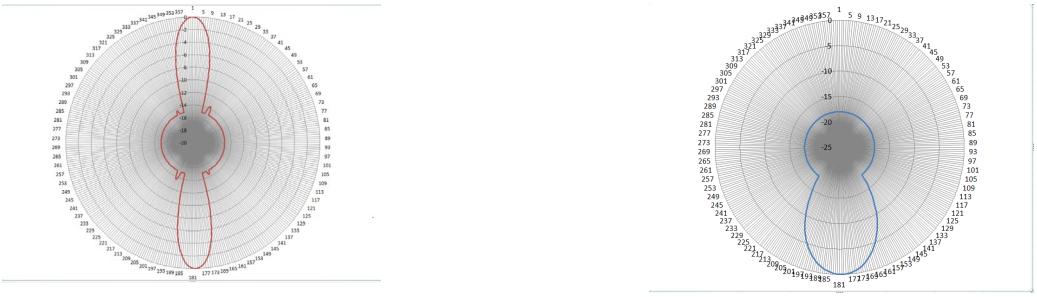


Figure 26: Typical antenna patterns
Left: CBTC Access Point, Right: CBTC Train Unit

Table 27: Antenna modelling

Parameter	CBTC AP	CBTC TU
Antenna gain (main lobe)	18 dBi	14 dBi
Main lobe 3 dB Horizontal beamwidth	15 degrees	30 degrees
Model for main lobe discrimination	$12\left(\frac{azimuth}{beamwidth}\right)^2$	$12\left(\frac{azimuth}{beamwidth}\right)^2$
Side lobe model	15 dB between 16.7 and 90 degrees	18 dB between 37 and 90 degrees

5.4.1.3 Protection criteria

Table 28: Protection criteria

Parameter	CBTC AP	CBTC TU
Criteria	2 dB desensitization	3 dB desensitization
I/N	-2.3 dB	0 dB

5.4.2 Methods of protection studied

5.4.2.1 Method 1: Restriction zones based on fixed distance

This method fixes a given separation distance to CBTC tracks and CBTC APs.

This method needs the following inputs:

- Position (2D) of the WAS/RLAN device.
- Position (2D) of CBTC APs and tracks.
- Map of CBTC railways.

5.4.2.2 Method 2: Restriction zones based on link budget

Separation distances for CBTC APs and TUs are computed using the same equation, but with different values of the gain of the CBTC to the HP WAS/RLAN (due to different antennas and different orientations). They are found as the lowest value of d (in m) satisfying the following MCL equation:

$$\mathrm{EIRP}_{\mathrm{WAS\ RLAN}} - L_{\mathrm{FSPL}}(d) + G_{\mathrm{Rx}} - L_{OOB}(f_c, B) \leq P_N + \left.\frac{I}{N}\right|_{\mathrm{th}}$$

Where:

- $\mathrm{EIRP}_{\mathrm{WAS\ RLAN}}$ is the radiated power (*e.i.r.p.*) of the WAS/RLAN transmitter, in dBm;
- $L_{\mathrm{FSPL}}(d)$ is the free space path loss attenuation t at distance d, in dB;
- $L_{OOB}(f_c, B)$ is the OoB attenuation of the WAS/RLAN in the CBTC channel, for a WAS/RLAN channel defined by the center frequency f_c (in Hz) and bandwidth B (in Hz) (see Figure 3 and Table 29);
- G_{Rx} is the antenna gain of the CBTC (AP or TU) receiver in direction of the WAS/RLAN transmitter, in dBi (see Figure 9 and Table 27);
- P_N (dBm) is the noise floor of the CBTC receiver (see Table 25).
- $\left.\frac{I}{N}\right|_{\mathrm{th}}$ (in dB) is the I/N threshold (see Table 28).

Table 29: WAS/RLAN OoB attenuation in the CBTC band

WAS/RLAN channel bandwidth B (MHz)	WAS/RLAN channel centre frequency f_c (MHz)	Attenuation in CBTC band $L_{OOB}(f_c, B)$ (dB)
20	5935	-6.0
20	5955	-36.7
20	5975-6095	-46.0
20	6115-6135	-48.0

WAS/RLAN channel bandwidth B (MHz)	WAS/RLAN channel centre frequency f_c (MHz)	Attenuation in CBTC band $L_{OOB}(f_c, B)$ (dB)
20	6155-6415	-53.0
40	5945	-9.0
40	5965	-34.0
40	5985	-44.4
40	6005-6285	-49.0
40	6305-6345	-51.0
40	6365	-53.3
40	6385-6405	-56.0
80	5965	-12.0
80	5985	-34.5
80	6045	-49.8
80	6065-6385	-52.0
160	6005	-15.1
160	6025	-36.3
160	6165	-53.9
160	6185-6345	-55.1
320	6085	-18.1
320	6265	-47.0

This method needs the following inputs:

- Position (2D) of the WAS/RLAN device;
- Position (2D) of CBTC APs and tracks;
- Antenna diagram and antenna heights of CBTC Aps;
- Orientation of CBTC Access Point antenna;
- Antenna diagram of CBTC Train Units.

5.4.2.3 Method 3: Limitation of maximum e.i.r.p.

In this method, HP WAS/RLAN devices in a given channel are assigned a maximum *e.i.r.p.* based on computing a simple FSPL-based link budget to CBTC track and CBTC AP locations. It can be formally described as follows:

$$\mathrm{EIRP}_{\mathrm{DSACF}}(f_c, B) = \max\{\mathrm{EIRP}_{\mathrm{min}}; \min\{\mathrm{EIRP}_{\mathrm{max}}; \mathrm{EIRP}_{\mathrm{DSACF,CBTC\ AP}}(f_c, B)\ ; \mathrm{EIRP}_{\mathrm{DSACF,CBTC\ tracks}}(f_c, B)\}\}$$

$$\mathrm{EIRP}_{\mathrm{DSACF,CBTC\ AP}}(f_c, B) = \min_{i \in [0; N_{\mathrm{CBTC\ AP}}]} \{\mathrm{EIRP}_{\mathrm{DSACF,CBTC\ AP,i}}(f_c, B)\}$$

$$\mathrm{EIRP}_{\mathrm{DSACF,CBTC\ tracks}}(f_c, B) = \min_{i \in [0; N_{\mathrm{CBTC\ tracks}}]} \{\mathrm{EIRP}_{\mathrm{DSACF,CBTC\ tracks,i}}(f_c, B)\}$$

Where, for the latter, it is assumed that CBTC tracks are discretised into $N_{\text{CBTC tracks}}$ points (locations). The WAS/RLAN *e.i.r.p.* due to the ith CBTC AP in visibility (radio horizon or 93 km[3]) is computed as:

$$\text{EIRP}_{\text{DSACF,CBTC AP,i}}(f_c, B) = P_{N,AP} + \frac{I}{N}\Big|_{\text{th,AP}} + L_{\text{FSPL}}(d_{AP,i}) - G_{\text{Rx,AP,i}} + L_{OOB}(f_c, B)$$

The WAS/RLAN *e.i.r.p.* due to the ith CBTC track in visibility (radio horizon or 45 km[4]) is computed as:

$$\text{EIRP}_{\text{DSACF,CBTC AP,i}}(f_c, B) = P_{N,TU} + \frac{I}{N}\Big|_{\text{th,TU}} + L_{\text{FSPL}}(d_{track,i}) - G_{\text{Rx,TU,i}} + L_{OOB}(f_c, B)$$

where:

- $\text{EIRP}_{\text{DSACF}}(f_c, B)$ (in dBm) is the maximum e.i.r.p assigned to the WAS/RLAN station for the channel defined by the center frequency f_c (in Hz) and bandwidth B (in Hz);
- $N_{\text{CBTC AP}}$ is the number of CBTC APs visible to the WAS/RLAN (based on radio horizon or 93 km);
- $N_{\text{CBTC tracks}}$ is the number of discretised track points visible to the WAS/RLAN (based on radio horizon or 45 km);
- $P_{N,AP}$ and $P_{N,TU}$ are the noise floor of CBTC APs and TUs, respectively (see Table 25);
- $\frac{I}{N}\Big|_{\text{th,AP}}$ and $\frac{I}{N}\Big|_{\text{th,TU}}$ (in dB) is the I/N threshold of CBTC APs and TUs, respectively (see Table 28);
- $G_{\text{Rx,AP,i}}$ (in dBi) is the antenna gain of the ith AP antenna in the direction of the WAS/RLAN device (see Figure 26 and Table 27);
- $G_{\text{Rx,TU,i}}$ (in dBi) is the antenna gain of the ith TU antenna in the direction of the WAS/RLAN device (see Figure 26 and Table 28);
- $L_{OOB}(f_c, B)$ is the OoB attenuation of the WAS/RLAN in the CBTC channel, for a WAS/RLAN channel defined by the center frequency f_c (in Hz) and bandwidth B (in Hz) (see Figure 3 and Table 29);
- $L_{\text{FSPL}}(d)$ (in dB) is the free-space path loss at distance d;
- $d_{AP,i}$ and $d_{track,i}$ (in m) is the distance between the WAS/RLAN device and the ith CBTC AP and ith CBTC track point in visibility, respectively.

Note that, for the calculation of $G_{\text{Rx,TU,i}}$, the train unit antenna is supposed to be aligned with the tracks.

This method needs the following inputs:

- Position (2D) of the WAS/RLAN device;
- Position (2D) of CBTC APs and tracks;
- Antenna diagram and antenna heights of CBTC APs;
- Orientation of CBTC Access Point antenna;
- Antenna diagram of CBTC Train Units.

5.4.2.4 Combined method to determine restriction zones for the protection of urban rail

The aim of this method is to determine the maximum power of HP WAS/RLAN device ensuring the protection of urban rail system from both HP WAS/RLAN wanted and unwanted emissions. A necessary input to this method is a specified maximum unwanted emission level of HP WAS/RLAN devices in the band used by urban rail ITS.

This method consists of the following steps:

- definition of the maximum acceptable interference power for the Urban Rail ITS to be protected;
- computation of propagation loss maps from APs and tracks' locations;
- computation of maximum HP WAS/RLAN *e.i.r.p.* maps, based on the previous steps and on the unwanted emission of the HP WAS/RLAN devices.

[3] Worst case separation distance to AP.

[4] Worst case separation distance to TU.

This method needs the following inputs:

- Maximum acceptable interference power at the CBTC antenna port;
- Position (2D) of CBTC APs and tracks;
- Antenna diagram and antenna heights of CBTC APs;
- Orientation of CBTC AP antennas;
- Antenna diagram of CBTC Train Units;
- Position (2D) and height of the WAS/RLAN device;
- HP WAS/RLAN unwanted emission limit.

5.4.3 Outcome of studies

5.4.3.1 Study A relative to Method 1

Three sets of interferer parameters are considered: LPI (for reference), HP WAS/RLAN indoor, HP WAS/RLAN outdoor.

The following parameters or variables are considered:

Table 30: WAS/RLAN interferer assumptions

Parameter	LPI indoor only	HP indoor	HP outdoor
e.i.r.p.	23 dBm	36 dBm	36 dBm
OOBE < 5935 MHz	-22 dBm/MHz	-9 dBm/MHz (Note 1)	-9 dBm/MHz (Note 1)
Building Entry Loss (BEL)	17 dB	17 dB	0 dB
Position relative to CBTC victim, line axis	X	X	X
Position relative to CBTC victim, perpendicular to the line axis (distance to the line)	Y	Y	Y
Difference in height	Z = 0	Z= 0	Z= 0
Propagation	Free Space loss	Free space loss	Free space loss
Note 1: corresponds to a similar mask as for LPI (max e.i.r.p. density – 32 dB)			

Figure 27 shows that there exist realistic configurations where a WAS/RLAN interferer, whether indoor or outdoor, could be very close to the line (2.5 to 5 m). It can also be in unobstructed line of sight over a large portion of the line.



Figure 27: Examples of outdoor urban rail environment

For a given level of WAS/RLAN OOBE, there is a risk of interference when the WAS/RLAN is inside a 2D contour around the CBTC victim (or 3D surface if the difference in height is considered). The contour depends

on the CBTC antenna pattern (as shown in Figure 28) and on propagation conditions in the direction of the victim. In the case of the CBTC Train Unit, the contour is dynamically moving along the line.

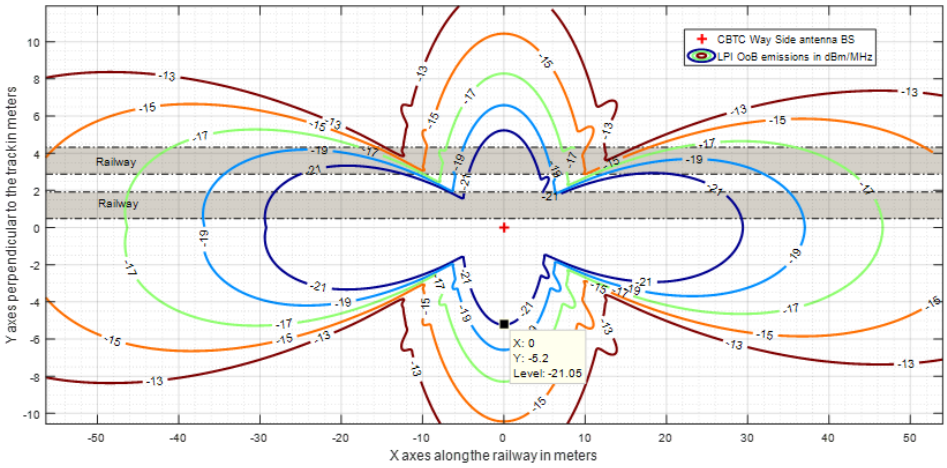


Figure 28: Example of contours (LPI coexistence with CBTC AP)

In what follows specific points in the contour (in the side lobe and in the main lobe) are considered to obtain an insight of the corresponding distance to tracks where the I/N criteria might no longer be met.

Table 31 computes the interference between an LPI / HP WAS/RLAN and a CBTC AP.

Table 31: WAS/RLAN versus CBTC AP

Parameters	Unit	LPI	HP indoor	HP outdoor	HP outdoor	Calculation
WAS/RLAN geometry/victim						
X (In the rail axis)	m	0	0	0	180	
Y (Distance to track)	m	5	21	150	50	y, set to match OOBE
WAS/RLAN - CBTC distance	m	5	21	150	187	distance
Azimuth (TX -> RX)	degrees	90.0	90.0	90.0	15.5	a
CBTC radio parameters						
Frequency	MHz	5935	5935	5935	5935	
C/I	dB	9	9	9	9	
Noise floor	dBm	-97	-97	-97	-97	b
Sensitivity	dBm	-88	-88	-88	-88	
Desensitization		2	2	2	2	
INR		-2.3	-2.3	-2.3	-2.3	c
Feeder and other loss	dB	9.0	9.0	9.0	9.0	d
Gain	dBi	18.0	18.0	18.0	18.0	e

Parameters	Unit	LPI	HP indoor	HP outdoor	HP outdoor	Calculation
Main Lobe 3 dB Beamwidth Horizontal	degrees	15.0	15.0	15.0	15.0	pattern
Calculations						
Victim Main or Side lobe	SL/ML	SL	SL	SL	ML	
TX Horizontal discrimination	dB	15.0	15.0	15.0	12.9	f, pattern
Free Space Loss	dB	61.8	74.3	91.4	93.3	FSL
Building entry loss	dB	17.0	17.0	0.0	0.0	g
Coupling loss	dB	84.8	97.3	97.4	97.2	h FSL+d+f+g-e
Max OOBE	dBm/5 MHz	-14.5	-2.0	-1.9	-2.1	b+c-h
Max OOBE	dBm/MHz	-21.5	-9.0	-8.9	-9.1	
Separation distance from the track	m	5	21	150	50	y (summary)

A distance to track of 150 m between an HP WAS/RLAN operating outdoor and the outdoor rail track would be needed to ensure the protection of CBTC AP side lobe. The CBTC AP can also be impacted through its main lobe by a distant WAS/RLAN (50 m away from the track).

In dense urban/suburban environment, interference can arise from the first line of buildings along the urban rail line even with indoor operation of the HP WAS/RLAN (if within 21 m to tracks).

Table 32 computes the interference between an HP WAS/RLAN and a CBTC TU.

Table 32: HP WAS/RLAN versus CBTC TU

Parameter	Unit	HP indoor	HP indoor	HP outdoor	HP outdoor	Calculation
HP WAS/RLAN geometry/victim						
X (In the rail axis)	m	0	15	0	150	
Y (Distance to track)	m	10	10	70	80	y, set to match OOBE
WAS/RLAN geometry/victim	m	10	14	70	170	distance
Azimuth (TX -> RX)	degrees	90.0	33.7	90.0	28.1	a
CBTC radio parameters						

Parameter	Unit	HP indoor	HP indoor	HP outdoor	HP outdoor	Calculation
Frequency	MHz	5935	5935	5935	5935	
C/I	dB	9	9	9	9	
Noise floor	dBm	-97	-97	-97	-97	b
Sensitivity	dBm	-88	-88	-88	-88	
Desensitization		3	3	3	3	
INR		0	0	0	0	c
Feeder and other loss	dB	6.0	6.0	6.0	6.0	d
Gain	dBi	14.0	14.0	14.0	14.0	e
Main Lobe 3 dB Beamwidth Horizontal	degrees	30	30.0	30.0	30.0	pattern
Calculations						
Victim Main or Side lobe	SL/ML	SL	ML	SL	ML	
TX Horizontal discrimination	dB	18.0	15.1	18.0	10.5	f, pattern
Free Space Loss	dB	67.9	70.8	84.8	92.5	FSL
Building entry loss	dB	17.0	17.0	0.0	0.0	g
Coupling loss	dB	94.9	94.9	94.8	95.0	h FSL+d+f+g-e
Max OOBE	dBm/5MHz	-2.1	-2.1	-2.2	-2.0	b+c-h
Max OOBE	dBm/MHz	-9.1	-9.1	-9.2	-9.0	
Separation distance from the track	m	10	10	70	80	y (summary)

A distance to tracks of 70-80 m between an HP WAS/RLAN operating outdoor and the outdoor rail track would be needed to ensure the protection of CBTC TUs. Constraints from the main and side lobe are similar.

In dense urban/suburban environment, interference can arise from the first line of buildings along the urban rail line even with indoor operation of the HP WAS/RLAN (if within 10 m of the track).

The study results suggest that compatibility of HP WAS/RLAN with CBTC in the 5915-5935 MHz may not be feasible without an exclusion zone around the CBTC outdoor line. The exclusion zone can be defined considering the maximum level of OOBE below 5935 MHz, the local CBTC characteristics (technology, modulation, antenna patterns, location of access points) and the environment along the line (obstacles).

Conclusion based on separation distances with -9 dBm/MHz WAS/RLAN OOBE limits

In this method, WAS/RLAN devices in 5945-6425 MHz are granted HP power levels if:

- their distance to any CBTC railway is higher than 80m;
- and their distance to any CBTC APs is higher than 150m.

5.4.3.2 Study B relative to Method 1

This study complements Study A relative to method 1 by investigating the impact of several OOBE limits on the separation distances, for HP WAS/RLAN operating outdoor or indoor, as shown in Table 1. The separation distances are derived from Study A by scaling with the appropriate factors: i.e. a reduction of 6 dB in OOBE limits reduces the separation distance by a factor of 2, and indoor case is deducted from outdoor case by considering a 17 dB BEL (reducing the required separation distance by a factor of approximately 7).

The chosen OOBE range (from -27 dBm/MHz to -9 dBm/MHz) was assumed to encompass OOBE limits which could be achieved at 5935 MHz.

Table 33: Separation distances due to WAS/RLAN OOBE

WAS/RLAN OOBE @5935 MHz	Outdoor HP Separation distance to CBTC track	Outdoor HP Separation distance to CBTC AP	Indoor HP Separation distance to CBTC track	Indoor HP Separation distance to CBTC AP	Comment
-9dBm/MHz	80 m	150 m	10 m	21 m	Study A case
-15 dBm/MHz	40 m	75 m	6 m	11 m	
-22 dBm/MHz	18 m	34 m	2.5 m	5 m	LPI OOBE limit (Note 1)
-27 dBm/MHz	10 m	18 m	1.5 m	2.5 m	Same level as HP OOBE limit @5925 MHz in the USA
Note 1: LPI are restricted to indoor use only					

For all OOBE limits studied, the separation distance between the HP WAS/RLAN and the CBTC AP and track is higher than 10-20 m to protect CBTC from outdoor HP WAS/RLAN.

To prevent interference in proximity of the CBTC track, a restriction zone controlled by the DSACF seems necessary to avoid potential interference arising from HP WAS/RLAN.

This study assumes that OOBE is the dominating factor in the interference calculation. If this hypothesis no longer holds (i.e. OOBE is low enough), then blocking of the CBTC receiver would need to be considered.

5.4.3.3 Study A and B relative to Method 1: Example of restriction zones

The following figures illustrate the restriction zone along an urban rail line, for 2 levels of OOBE, -9 dBm/MHz (study A) and -22 dBm/MHz (study B). Those figures are only indicative and contours are approximate. CBTC base stations are where the stars are depicted. Red dots show the limits of the restriction zone for outdoor HP WAS/RLAN operation and green dots the limits for indoor operation (for OOBE of -9 dBm/MHz).

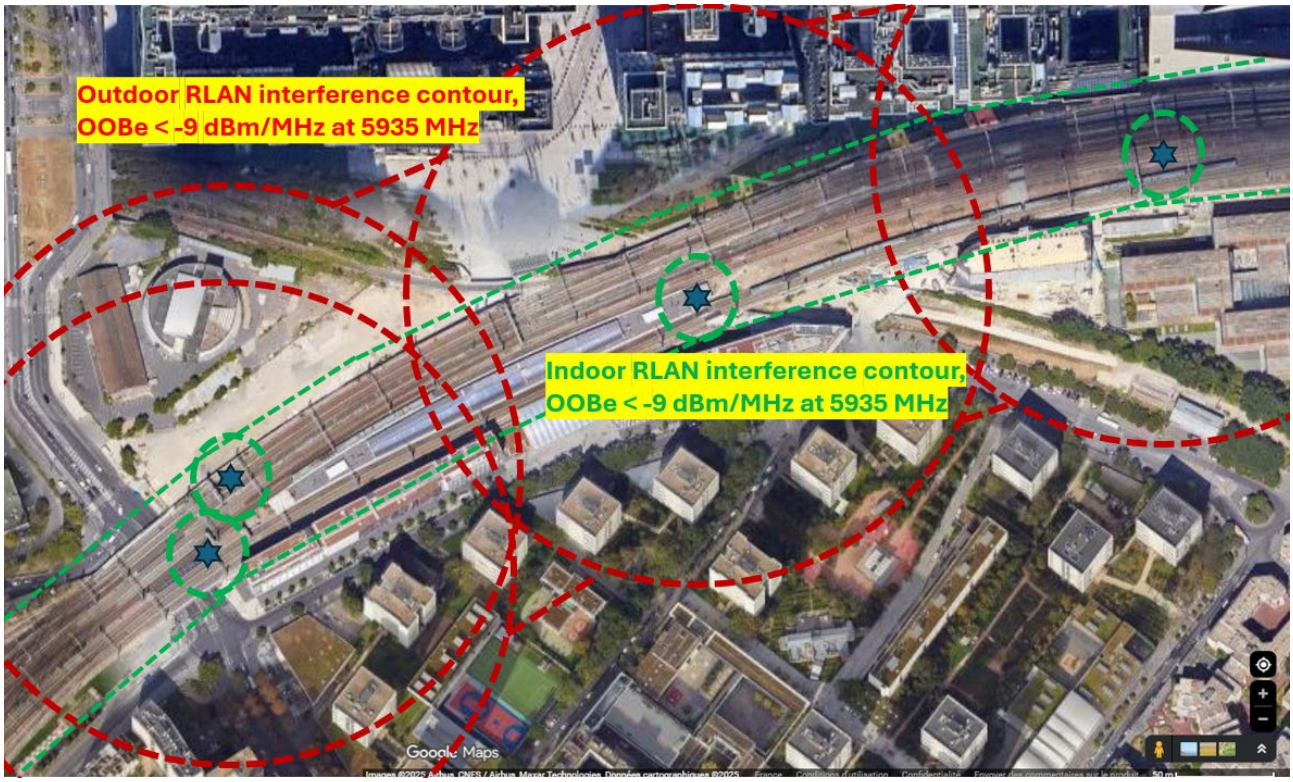


Figure 29: Study A, example of outdoor and indoor restriction zones for OOBE@5935 MHz = -9 dBm/MHz (side lobe distances)

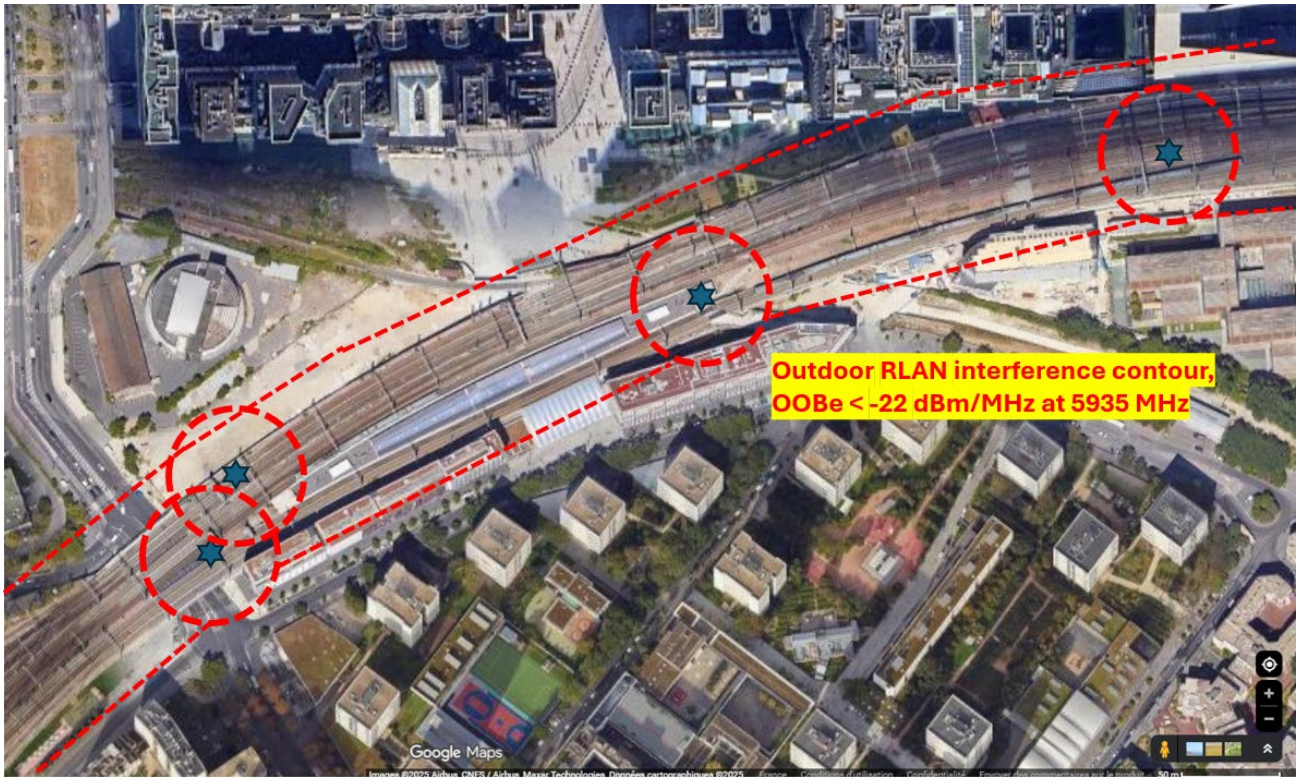


Figure 30: Study B example of outdoor restriction zones for OOBE@5935 MHz = -22 dBm/MHz (side lobe distances)

5.4.3.4 Study C relative to Method 1: CBTC blocking

This study investigates, for a specific case, the main dimensions of a zone where an HP WAS/RLAN wanted emission would impact a CBTC receiver, i.e. an overloading effect. This specific case does not intend to derive "generic dimensions" applicable to any CBTC receiver and HP WAS/RLAN transmitter configuration. It merely aims at demonstrating that the overloading effect should be considered to ensure the coexistence between Urban Rail and HP WAS/RLANs, and that the protection could be applied through an DSACF system.

In this study, it was assumed that an Urban Rail ITS receiver would be over the threshold if the interfering HP WAS/RLAN emission at its antenna port exceeds a value of, for example, -45 dBm/20 MHz. Using this example, Table 34 derives the corresponding free space loss distances for CBTC AP and TU and for both for main lobe and side lobe coupling configurations, where the gain and losses from Table 26 are used. An HP WAS/RLAN maximum power of 36 dBm/20 MHz is assumed.

Table 34: FSPL distance between HP WAS/RLAN and Urban Rail receiver to avoid interference from HP WAS/RLAN wanted emissions

	FSPL distance (m)	
	CBTC AP	CBTC TU
Main lobe	127	113
Side lobe	23	15

From these results it can be inferred that the interference from the wanted HP WAS/RLAN emission onto CBTC receivers could be harmful over a range of a few tens of meters. The extent of such zones appears reasonably manageable through localised restrictions. In addition, it can be observed from Table 35 that these distances are comparable but shorter than the distances required for OOBE of -22 dBm/MHz. This suggests that, for this OOBE level, the unwanted emissions will be the predominating factor of the coexistence.

Table 35: Comparison of FSPL distance between HP WAS/RLAN and Urban Rail receiver to avoid interference from either blocking or unwanted emissions

	CBTC AP	CBTC TU
Side lobe separation distance due to blocking.	23m	15m
Side lobe separation distance due to OOBE -22 dBm/MHz.	34m	18m

5.4.4 Summary of studies

For outdoor HP WAS/RLAN OOBE limits below 5935 MHz ranging from -27 dBm/MHz to -9 dBm/MHz, the separation distance range from 10 m to 80 m from the CBTC track and 18 to 150 m from CBTC APs. A single level of a HP WAS/RLAN such as -22 dBm/MHz could be applied to HP WAS/RLAN as this could simplify the calculation within the DSACF or pre-calculated to ensure compatibility.

The studies assume that OOBE is the dominating factor in the interference calculation. If this hypothesis no longer holds (i.e. OOBE is low enough), then blocking of the CBTC receiver would need to be considered.

The studies show that Urban Rail ITS (CBTC) would require protection through a DSACF system from HP WAS/RLAN outdoor and indoor use.

5.5 OTHER INCUMBENTS (ADJACENT BAND)

5.5.1 Road ITS

Intelligent Transport Systems (ITS) encompass Road ITS and Urban Rail ITS. Road ITS includes any kind of ground-based transportation systems, e.g. cars, trucks, bicycles, motor bicycles, tramways, pedestrians, constructions equipment, agricultural equipment, etc. Road ITS operate up to 5925 MHz while use of the band for HP WAS/RLAN systems is considered above 5945 MHz. Hence, there is at least 20 MHz guard band between these two systems.

ECC Report 302 [1] studied the adjacent band compatibility between WAS/RLAN and Road ITS. Since Road ITS, in contrast to urban rail ITS, is not restricted to well defined areas, it cannot be protected by the DSACF. Consequently, a generic unwanted emissions limit below 5925 MHz is required to ensure the protection of road ITS. Based on the studies in ECC Report 302 [1] and considering that an unwanted emissions limit of -27 dBm/MHz below 5925 MHz is implemented in some part of the world, such a value is deemed sufficient to protect road ITS operation from HP WAS/RLAN systems above 5945 MHz.

5.5.2 Road Tolling

Road tolling systems operate in the band 5795 to 5815 MHz while band allocation for HP WAS/RLAN systems starts at 5945 MHz. Compatibility studies were not carried out due to the fact that the operation band of the road tolling systems is 130 MHz from the band edge of the HP WAS/RLAN. If administrations considered that the road rolling systems need to be taken into account then Road tolling data with geo locations could provide the necessary data for a DSACF.

It could be noted that a data base related to road tolling already exist as a results of the work carried out in the context of the coexistence between road ITS and road tolling in ECC Report 277 [4].

5.5.3 UWB

Ultra-Wide Band (UWB) systems operate in the frequency range 6-8.5 GHz. Compatibility studies were not carried as there were already done in ECC Report 302 [1].

6 ELEMENTS TO ENABLE DSACF

6.1 TECHNICAL ELEMENTS

This section identifies a common set of technical elements that supports, from a spectrum engineering perspective, operation of DSACF systems. The DSACF system provides Channel-Power Lists either computed or derived from the lookup table independently for each WAS/RLAN request.

For the specific implementation of each specific DSACF system, the technical elements below would be elaborated in more detail.

Information to be provided about the HP WAS/RLAN device:

- Geographical location (in 3D);
- Confidence level of geographical location.

6.1.1 DSACF with internal calculation

Information available within the DSACF system (not expected to be updated regularly):

- Information on HP WAS/RLAN system
  - OOBE mask (for adjacent);
- List of incumbent systems to be protected;
- Information on each incumbent system;
  - Protection criterion (including possible restriction zones and/or country borders);
  - Blocking mask (for adjacent);
  - Method of protection (see section 5);
  - Relevant propagation model;
- Terrain and clutter.

Regularly updated information about incumbents made available within the DSACF system:

- Information on each incumbent receiver
  - Application type;
  - Frequency and bandwidth;
  - Location (in 3D);
  - Antenna diagram.

Information returned by the DSACF to be used by the HP WAS/RLAN device includes a Channel-Power List (list of available WAS/RLAN channels and associated *e.i.r.p.* limits, see section 2).

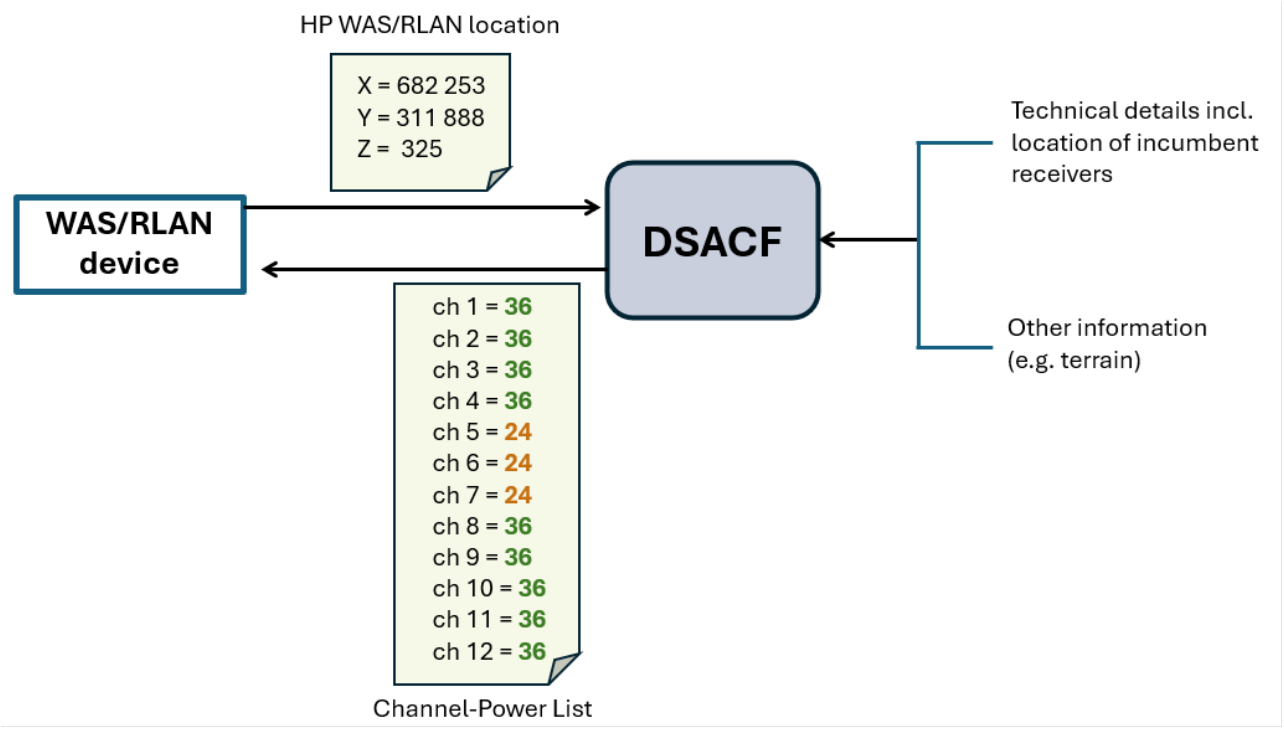


Figure 31: Example of how the DSACF system interacts with an HP WAS/RLAN device, using an internally calculated Channel-Power List

6.1.2 DSACF with external calculation

In this approach, all interference protection calculations are performed in advance, possibly by an administration, and the DSACF itself performs lookups in a dataset which includes maximum *e.i.r.p.* levels for every channel and every geographical position.

This implementation of DSACF consists of two functional stages:

- Pre-generated protection dataset. This stage generates a geographic dataset containing permitted channel and corresponding maximum *e.i.r.p.* values for each defined geographic area "tile" and, where relevant, altitude layer;
- DSACF operation builds and sends the Channel-Power List to the HP WAS/RLAN device based on the information in the pre-generated protection dataset.

This functional separation allows a direct control (e.g. by an administration) of the protection dataset (for example verification, handling of confidential data, etc.). The DSACF acts as a simple lookup engine with minimal internal logic.

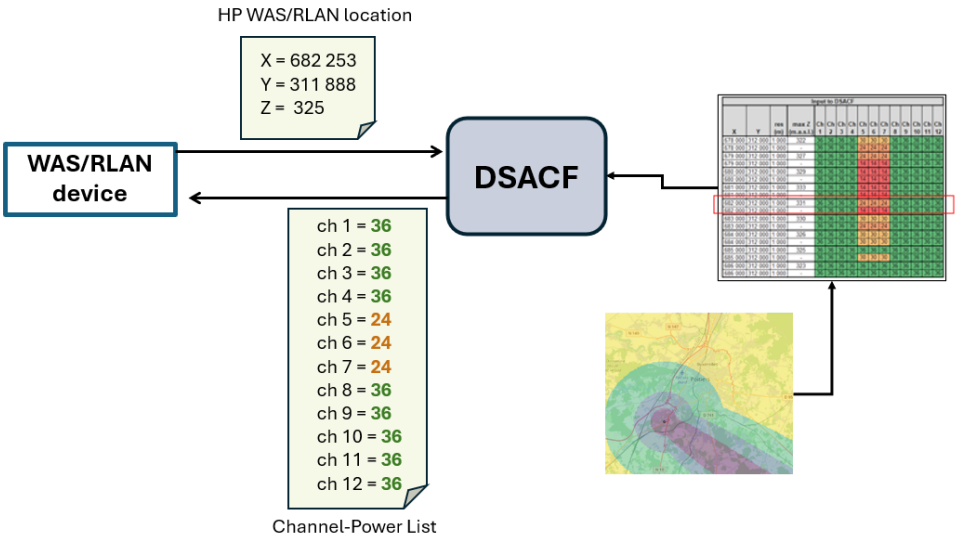


Figure 32: Example of how the DSACF system interacts with an HP WAS/RLAN device, using a pre-generated protection dataset in a lookup-table format

The HP WAS/RLAN device provides its 3D location, and the DSACF returns a response message which includes the Channel-Power List. If no tile-layer match is available, a predefined default value applies. The protection data consists of a geographic dataset (including, where relevant, altitude layers) that defines the maximum *e.i.r.p.* for HP WAS/RLAN devices for each channel.

6.2 NON-TECHNICAL ELEMENTS

Some non-technical elements that may also be relevant to identify in order to enable transmission by HP WAS/RLAN were considered out of scope of this Report:

- Registration/device identifier to be provided by the HP WAS/RLAN;
- A recording of Channel-Power List responses to each HP WAS/RLAN;
- Cyber security considerations;
- Maintenance and operational responsibilities of a DSACF;
- Cross-border coordination;
- Standardisation of interface between HP WAS/RLAN and DSACF;
- Standardisation of HP WAS/RLAN OOBE levels;
- Standardisation of interface for inputs on incumbent data (including lookup geographical data) for DSACF;
- Validity time of the Channel-Power List and allowed location deviation;
- HP WAS/RLAN request rules (e.g. information when to do next request).

These elements may be considered elsewhere when considering regulatory or standardisation matters.

7 CONCLUSIONS

The main findings of this Report are presented in the Executive summary (Section 0).

ANNEX 1: EXTRACT OF THE EUROPEAN COMMON ALLOCATION TABLE

Table 36 contain an extract of the ECA Table for the frequency band 5925-6700 MHz.

Table 37 and Table 38 contain an extract of the ECA Table for the adjacent frequency bands 5850-5925 MHz and 6700-7075 MHz respectively.

Table 36: European Common Allocation Table for the frequency band 5925-6700 MHz [11]

RR Region 1 Allocations and Footnotes applicable to CEPT	European Common Allocations and ECA Footnotes	Applications	ECC/ERC harmonisation measure	Standard	Notes
FIXED 5.457 FIXED-SATELLITE (EARTH-TO-SPACE) 5.457A 5.457B MOBILE 5.457C 5.457E 5.149 5.440 5.458	FIXED FIXED-SATELLITE (EARTH-TO-SPACE) (5.457A) MOBILE (5.457E) Earth exploration-satellite (passive) 5.149 5.440 5.458	ESV	ECC/DEC/(05)09	EN 301 447	Within the band 5925-6425 MHz
		FSS Earth stations			
		Fixed	ECC/REC/(14)06 ERC/REC 14-01 ERC/REC 14-02	EN 302 217	Point-to-point
		ITS	ECC/DEC/(08)01 ERC/REC 70-03		Urban rail systems only 5925–5935 MHz. Safety related applications within the band 5875-5935 MHz.
		LPR	ECC/DEC/(11)02 ERC/REC 70-03	EN 302 729	
		Passive sensors (satellite)			For sea surface temperature, sea surface wind speed and soil moisture measurements
		RLAN	ECC/DEC/(20)01	EN 303 687	Within the band 5945-6425 MHz
		Radio astronomy			Spectral line observations (e.g. methanol line), VLBI
		TLPR	ERC/REC 70-03	EN 302 372	
		UWB applications	ECC/DEC/(06)04 ECC/DEC/(07)01 ECC/DEC/(12)03 ERC/REC 70-03	EN 302 065	Generic UWB as well as UWB on-board aircraft regulation within the band 6.0-8.5 GHz
		VSAT		EN 301 443	

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

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

RR Region 1 Allocations and Footnotes applicable to CEPT	European Common Allocations and ECA Footnotes	Applications	ECC/ERC harmonisation measure	Standard	Notes
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. 5.457 In Australia, Burkina Faso, Cote d'Ivoire, Mali and Nigeria, the allocation to the fixed service in the bands 6 440-6 520 MHz (HAPS-to-ground direction) and 6 560-6 640 MHz (ground-to-HAPS direction) may also be used by gateway links for high-altitude platform stations (HAPS) within the territory of these countries. Such use is limited to operation in HAPS gateway links and shall not cause harmful interference to, and shall not claim protection from, existing services, and shall be in compliance with Resolution 150 (WRC 12). Existing services shall not be constrained in future development by HAPS gateway links. The use of HAPS gateway links in these bands requires explicit agreement with other administrations whose territories are located within 1 000 kilometres from the border of an administration intending to use the HAPS gateway links. (WRC 12) 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) 5.457B In the frequency bands 5 925-6 425 MHz and 14-14.5 GHz, earth stations located on board vessels may operate with the characteristics and under the conditions contained in Resolution 902 (Rev.WRC-23) in Algeria, Saudi Arabia, Bahrain, Comoros, Djibouti, Egypt, United Arab Emirates, Jordan, Kuwait, Libya, Morocco, Mauritania, Oman, Qatar, the Syrian Arab Republic, Sudan, Tunisia and Yemen, in the maritime mobile-satellite service on a secondary basis. Such use shall be in accordance with Resolution 902 (Rev.WRC-23). (WRC-23) 5.457C In Region 2 (except Brazil, Cuba, French overseas departments and communities, Guatemala, Mexico, Paraguay, Uruguay and Venezuela), the frequency band 5 925-6 700 MHz may be used for aeronautical mobile telemetry for flight testing by aircraft stations (see No. 1.83). Such use shall be in accordance with Resolution 416 (WRC-07) and shall not cause harmful interference to, or claim protection from, the fixed-satellite and fixed services. Any such use does not preclude the use of this frequency band by other mobile service applications or by other services to which this frequency band is allocated on a co-primary basis and does not establish priority in the Radio Regulations. (WRC-15) 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.					

Table 37: European Common Allocation Table for the frequency band 5850-5925 MHz [11]

RR Region 1 Allocation and footnotes applicable to CEPT	European Common Allocation and ECA Footnotes	Applications	ECC/ERC harmonisation measure	Standard	Notes
FIXED FIXED-SATELLITE (EARTH-TO-SPACE) MOBILE 5.150	FIXED FIXED-SATELLITE (EARTH-TO-SPACE) MOBILE 5.150	BFWA	ECC/REC/(06)04	EN 302 502	Within the band 5725-5875 MHz
		ISM			Within the band 5725-5875 MHz
		ITS	ECC/DEC/(08)01 ECC/REC/(08)01 ERC/REC 70-03	EN 302 571	Safety related applications within the band 5875-5935 MHz. Non-Safety applications within the band 5855-5875 MHz.
		MBR	ECC/REC/(17)03	EN 303 276	Within 5852-5872 MHz and 5880-5900 MHz
		Non-specific SRDs	ERC/REC 70-03	EN 300 440	Within the band 5725-5875 MHz
		TLPR	ERC/REC 70-03	EN 302 372	
		VSAT		EN 301 443	
		WIA	ERC/REC 70-03	EN 303 258	Within the band 5725-5875

5.150 The following bands:

13 553-13 567 kHz (centre frequency 13 560 kHz),
26 957-27 283 kHz (centre frequency 27 120 kHz),
40.66-40.70 MHz (centre frequency 40.68 MHz),
902-928 MHz in Region 2 (centre frequency 915 MHz),
2 400-2 500 MHz (centre frequency 2 450 MHz),
5 725-5 875 MHz (centre frequency 5 800 MHz), and
24-24.25 GHz (centre frequency 24.125 GHz)

are also designated for industrial, scientific and medical (ISM) applications. Radiocommunication services operating within these bands must accept harmful interference which may be caused by these applications. ISM equipment operating in these bands is subject to the provisions of No. 15.13.

Table 38: European Common Allocation Table for the frequency band 6700-7075 MHz [11]

RR Region 1 Allocation and footnotes applicable to CEPT	European Common Allocation and ECA Footnotes	Applications	ECC/ERC harmonisation measure	Standard	Notes
FIXED FIXED-SATELLITE (EARTH-TO-SPACE) (SPACE-TO-EARTH)(5.441) MOBILE(5.457E) 5.458 5.458A 5.458B	FIXED FIXED-SATELLITE (EARTH-TO-SPACE) (SPACE-TO-EARTH)(5.441) MOBILE(5.457E) Earth exploration-satellite (passive) 5.458 5.458A 5.458B	Feeder links			
		Fixed	ECC/REC/(14)06 ERC/REC 14-02	EN 302 217	Point-to-point
		LPR	ECC/DEC/(11)02 ERC/REC 70-03	EN 302 729	
		Passive sensors (satellite)			For sea surface temperature, sea surface wind speed and soil moisture measurements
		TLPR	ERC/REC 70-03	EN 302 372	
		UWB applications	ECC/DEC/(06)04 ECC/DEC/(07)01 ECC/DEC/(12)03 ERC/REC 70-03	EN 302 065	Generic UWB as well as on-board aircraft regulation within the band 6.0-8.5 GHz
		VSAT		EN 301 443	
		Video PMSE	ERC/REC 25-10	EN 302 064	Cordless Cameras; Portable video links; Mobile video links; Temporary point-to-point video link within 7-8.5 GHz.

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)

5.457E: 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.

ANNEX 2: 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 244: “Compatibility studies related to RLANs in 5 725-5 925 MHz”, approved January 2016

[3] Recommendation ITU-R P.525-5 (11/2024): “Calculation of free-space attenuation”

[4] ECC Report 277: “Use of SRD applications in cars in the band 5 725-5 875 MHz”, approved April 2018

[5] CEPT Report 075: “Report from CEPT to the European Commission in response to the Mandate

“to study feasibility and identify harmonised technical conditions for Wireless Access Systems including Radio Local Area Networks in the 5925-6425 MHz band for the provision of wireless broadband services”

Report B: Harmonised technical parameters for WAS/RLANs operating on a coexistence basis with appropriate mitigation techniques and/or operational compatibility/coexistence conditions, operating on the basis of a general authorisation”, approved November 2020

[6] Dynamic Spectrum Alliance, “Automated Frequency Coordination Report – An established tool for modern spectrum management”

[7] 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

[8] FCC, “Report & Order FCC 20-51”, April 2020

[9] WinnForum, “TS-1014”

[10] 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, amended November 2024

[11] ERC Report 025: “The European table of frequency allocations and applications in the frequency range 8.3 kHz to 3000 GHz (ECA table)”)”, approved June 1994, latest amended November 2025

[12] ECC Report 173: “Fixed Service in Europe Current use and future trends post 2022”, approved March 2012, latest amended June 2023

[13] Recommendation ITU-R F.699-8 (01/2018): “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”

[14] Recommendation ITU-R F.758-8 (02/2025): “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”

[15] Recommendation ITU-R F.1245-3 (01/2019): “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”

[16] Recommendation ITU-R P.452-18 (10/2023): “Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 100 MHz”

[17] Recommendation ITU-R P.617-5 (08/2019): “Propagation prediction techniques and data required for the design of trans-horizon radio-relay systems”

[18] Recommendation ITU-R P.2109-2 (08/2023): “Prediction of building entry loss”

[19] 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” , approved May 2020

[20] 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"

[21] 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

[22] Recommendation ITU-R RA.769: “Protection criteria used for radio astronomical measurements”

[23] Report ITU-R RA.2131: “Supplementary information on the detrimental threshold levels of interference to radio astronomy observations in Recommendation ITU-R RA.769”

[24] 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”

[25] ETSI EN 303 687: “6 GHz WAS/RLAN; Harmonised Standard for access to radio spectrum”

[26] https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem

[27] https://land.copernicus.eu/en/products/corine-land-cover

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[29] Recommendation ITU-R P. 527 “Electrical characteristics of the surface of the Earth”

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