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| **Radiocommunication Study Groups** |  |
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| Annex 12 to Working Party 5A Chairman’s Report | |
| PRELIMINARY DRAFT NEW REPORT  ITU-R M.[RLAN SHARING 5 725-5 850 MHz] | |
| Sharing and compatibility studies of WAS/RLAN in the 5 725-5 850 MHz frequency range | |

# 1 Introduction

This Report includes the sharing and compatibilities studies of WAS/RLAN in the 5 725‑5 850 MHz frequency range.

It is intended to represent the response to *invites ITU-R* *e)* of Resolution **239 (WRC‑15)** under WRC-19 agenda item 1.16.

# 2 Overall view of allocations in the 5 725-5 850 MHz range

| Allocation to services | | | | Expected studies | |
| --- | --- | --- | --- | --- | --- |
| Region 1 | Region 2 | | Region 3 |
| 5 725-5 830  FIXED-SATELLITE (Earth-to-space)  RADIOLOCATION  Amateur | | 5 725-5 830  RADIOLOCATION  Amateur | | Coexistence between WAS/RLAN and FSS and Radiolocation |
| 5.150 5.451 5.453 5.455 5.456 | | 5.150 5.453 5.455 | |
| 5 830-5 850  FIXED-SATELLITE (Earth-to-space)  RADIOLOCATION  Amateur  Amateur-satellite (space-to-Earth) | | 5 830-5 850  RADIOLOCATION  Amateur  Amateur-satellite (space-to-Earth) | |
| 5.150 5.451 5.453 5.455 5.456 | | 5.150 5.453 5.455 | |

WAS including RLANs already operate in many countries within the 5 725-5 850 MHz frequency range. CITEL Recommendation PCC.II/REC. 11(VI-05) also recommends the use of the 5 725‑5 825 MHz frequency range by WAS including RLANs. Some countries in Region 2 authorize RLAN devices operating at 5 725‑5 850 MHz provide for up to 1 Watt conducted output power, with a maximum power spectral density of 30 dBm in any 500 kHz.

It should also be noted that the 5 725-5 875 MHz frequency band is designated for Industrial, Scientific, and Medical (ISM) applications. Per RR No. **5.150**, “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**.” In addition, RR No. **5.453** includes over 40 countries which have allocated the 5 650‑5 850 MHz frequency range to the fixed and mobile services on a primary basis for which the provisions of Resolution **229 (Rev.WRC-12)** do not apply.

Some countries in Region 1 authorize RLAN devices operating at 5 725‑5 850 MHz on a national basis.

# 3 Assumptions on technical and operational elements for the sharing and compatibility of WAS/RLAN with other services

## 3.1 Technical and operational characteristics of the WAS/RLAN operating in the 5 725- 5 850 MHz ranges

The technical and operational characteristics of the WAS/RLAN operating in the 5 725- 5 850 MHz ranges can be found in Report ITU-R M.[RLAN REQ-PAR]//*[Editor’s note: add a hyperlink to this report]*.

## 3.2 Technical and operational characteristics of the Radiolocation service operating in the 5 725-5 850 MHz

Recommendation ITU-R [M.1638-1](https://www.itu.int/rec/R-REC-M.1638-1-201501-I/en) contains description of 11 radars of the radiolocation service operating in the frequency bands 5 725-5 850 MHz. The technical characteristics and protection criterion are given in Table 3.1. The protection criterion I/N is of minus 6 dB as specified in the Table and it corresponds to section 4 “Protection criteria” of Recommendation ITU-R М.1638-1. These characteristics were used for estimation of thermal noise level, noise power and permissible interference power for the given radars using equations (1)-(3).

TABLE 3.1

Technical characteristics and protection criteria of ground based radars in the radiolocation service   
 operating in frequency bands 5 725-5 850 MHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Radar | Radar 2 | Radar 3 | Radar 4 | Radar 5 | Radar 7 | Radar 12 |
| Location | Ground | Ground | Ground | Ground | Ground, shipborne | Ground, shipborne | |
| Frequency band, MHz | 5 350-5 850 | 5 350-5 850 | 5 400-5 900 | 5 400-5 900 | 5 450-5 825 | 5 400-5 900 | |
| Antenna gain, dB | 54 | 47 | 45.9 | 42 | 30 | 25 | |
| Noise figure, dB | 5 | 5 | 11 | 5 | 10 | 4 | |
| IF bandwidth, MHz | 0.25, 2.4,4.8, | 1.0, 2, 4, | 2.0-8.0 | 8.0 | 1.0, 1.2 | 7.0 | |
| *I/N*, dB | -6 | -6 | -6 | -6 | -6 | -6 | |
| Radar | Radar 13 | Radar 15 | Radar 21 | Radar 22 | Radar 23 |  |
| Location | Ground | Ground | Ground | Ground | Ground |  |
| Frequency band, MHz | 5 450-5 850 | 5 400-5 850 | 5 300-5 750 | 5 400-5 850 | 5 250-5 850 |  |
| Antenna gain, dB | 43 | 42 | 44.5 | 35 | 31.5 |  |
| Noise figure, dB | 3 | 2.3 | 3 | 5 | 13 |  |
| IF bandwidth, MHz | 2.75 | 20 | 0.8 | 4 | 5 |  |
| *I/N*, dB | -6 | -6 | -6 | -6 | -6 |  |

### 3.2.1 Technical characteristics of frequency hopping radars

Frequency Hopping Radar (FH):

This type of radar typically divides its allocated frequency band into channels. The radar then randomly selects a channel from all radar channels for transmission. This random occupation of a channel can occur on a per beam position basis where many pulses on the same channel are transmitted, or on a per pulse basis.

The RLAN device must be agile (flexible) in such a way that the various combinations of frequency hopping and pulse repetition frequencies (PRF) will be taken into account and consequently be detected, even for FH Pulse Doppler radars, with high PRF.

In radars not using a fixed PRF the time between consecutive pulses follows a certain scheme and the radar uses a staggered PRF scheme. Taking into account that different radars implement different schemes to control the PRF, the RLAN DFS mechanism must be agile in the sense that the various staggered modes can be detected.

Frequency Hopping Radars that operate in the 5 GHz band are capable of hopping across the 5 250‑5 850 MHz band. The frequencies will be selected by using a random without replacement algorithm until all frequencies have been used. After the use of all frequencies, the pattern is reset and a new random pattern is generated.

Recommendation [ITU R M.1638-1](http://www.itu.int/rec/R-REC-M.1638/en) is relevant for the required sharing studies between WAS/RLAN and radiodetermination systems under Resolution **239 (WRC-15)**.

## 3.3 Technical and operational characteristics of the Fixed Satellite service operating in the 5 725-5 850 MHz (for Region 1)

In 5 725-5 850 MHz, the Fixed Satellite service (E-s) is allocated in Region 1 only.

Table 3.3

FSS Uplink Parameters (Interfered with)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frequency range | GHz |  |  | 5.725-5.925 |
| CARRIER | Carrier Name |  |  | Carrier #48 |
| Noise bandwidth | MHz |  |  | 4.0-54 |
| SPACE STATION | | | | |
| Peak receive antenna gain | dBi |  |  | 41.6 |
| Antenna receive gain pattern and beamwidth | – |  |  | "Section 1.1 of Annex 1 of Rec. ITU-R S.672-4  LS=-25 Beamwidth:1.5" |
| System receive noise temperature | K |  |  | 400 -500 |

Table 3.4

FSS Uplink Parameters (Interferer)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Frequency range | GHz |  |  | 5.725-5.925 |
| EARTH STATION CARRIER |  |  |  | Carrier #48 |
| Antenna diameter | m |  |  | 13.2 |
| Peak transmit antenna gain | dBi |  |  | 56.4 |
| Peak transmit power spectral density (clear sky) | dBW/Hz |  |  | -28 |
| Antenna gain pattern (ITU Recommendation) | – |  |  | Rec. ITU-R 465-6 |
| Minimum elevation angle of transmit earth station | ° |  |  | 5 |

The protection criteria values provided below assume the use of an *I/N* methodology.

Table 1

Protection Criteria (see Notes 1, 2, 3 and 4)

|  |  |  |
| --- | --- | --- |
| Frequency Ranges | Percentage of time, probability or location for which the *I/N* value could be exceeded (%) | *I/N* Criteria (dB) |
| 5 725-5 925 MHz | 0.0004 | -6 |
| 0.08 | -9 |
| 20 or *I/N* average | -10.5 |

*Note 1:* The noise *N* in the *I/N* criteria as specified above is the system receiver noise (i.e. thermal noise) and is equal to the receiver antenna noise plus the receiver noise referred to the antenna as contained in the technical parameters liaised to WP 5A by WP 4A. Hence studies conducted by WP 5A should only use the values presented above when evaluating the compliance with the protection criteria*.*

*Note 2:* For interference analysis where the degradation is due to atmospheric attenuation, which varies as a function of time, it is appropriate to specify protection criteria based on a percentage of time. However, sharing studies conducted between satellites and RLAN systems under WRC-19 agenda item 1.16 may involve far more complex considerations and calculations, based on additional variables which are not function of time. These studies may include geographical locations in the space domain associated to the RLAN position. As such, the definition of the protection criteria cannot be expressed simply in terms of values against a percentage of time. Therefore, as depicted in Table 1, the percentage is expressed as a percentage of time, location or probability (for example, for Monte Carlo simulations, the percentage can be expressed in terms of a number of snapshots).

*Note 3*: It was concluded that apportionment of the *I/N* protection criteria between services should be done on a case-by-case basis. The protection criteria values given in this document correspond to the total *I/N* contributions present at the satellite or earth station receiver.

*Note 4*: Studies using these short-term protection criteria should be assessed on the basis that these values are put forward by WP 4A to facilitate and complete the work for WRC-19 agenda item 1.16 and these values may evolve in the future based on inputs to the ITU-R. Whilst WP 4A has not completed its work in developing short-term protection criteria, WP 5A should take due account of these short-term protection criteria but should not assume that all FSS/BSS systems will suffer harmful interference if these protection criteria are exceeded.

Studies should use the protection criteria for 20% or *I/N* average for the long term, as well as the 0.08%, as applicable, for the short term to determine whether there is compatibility between the concerned service and the fixed-satellite service. Studies should also be assessed for the criterion associated with 0.0004% in the table above; however, for studies in which results are not available for percentages down to 0.0004%, short term *I/N* values should not exceed the *I/N* value associated with this percentage. The above information on protection criteria should not affect the status of the ongoing studies.

## 3.4 Technical and operational characteristics of the Amateur Radio service operating in 5 650-5 850 MHz in Regions 1 and 3 and in 5 650‑5 925 MHz in Region 2

The secondary allocation to the amateur radio service is 5 650 to 5 850 MHz in Regions 1 and 3 and to 5 650 to 5 925 MHz in Region 2. The reference document for amateur signal characteristics for sharing studies is Rec. ITU-R M.1732-2 (01/2017).

Amateur radio service activities in this frequency range and in particular in 5 760 to 5 765 MHz include terrestrial and Earth-Moon-Earth (EME) communications and weak-signal communications. These activities are typically not channelized and are very sensitive to increases in noise and interference.

### 3.4.1 Amateur systems (Morse, analogue voice and data)

|  |
| --- |
| **Parameter** |
| Necessary bandwidth and emission class designator | 150HA1A 150HJ2A 60H0J2B 250HF1B  2K70J3E 11K0F3E 16K0F3E 20K0F3E |
| Transmitter power (dBW) | 3 to 20 |
| Feeder loss (dB) | 1 to 6 |
| Transmitting antenna gain (dBi) | 10 to 42 |
| Typical e.i.r.p. (dBW) | 1 to 45 |
| Antenna polarization | Horizontal, vertical |
| Receiver Noise Figure (dB) | 0.5 to 1 |

While the foregoing parameters principally characterize amateur radio signals in 5 760 to 5 765 MHz, they may be used anywhere in the allocation.

Receiver bandwidths, as indicated in the emission class designators, range from 150 Hz to 20 kHz

### 3.4.2 Amateur Earth-Moon-Earth (EME) systems

|  |
| --- |
| **Parameter** |
| Necessary bandwidth and emission class designator | 50H0A1A 50H0J2A 1K80F1B  1K50J2D |
| Transmitter power (dBW) | 13 to 20 |
| Feeder loss (dB) | 1 to 4 |
| Transmitting antenna gain (dBi) | 25 to 46 |
| Typical e.i.r.p. (dBW) | 50 to 65 |
| Antenna polarization | Horizontal, vertical, LHCP, RHCP |
| Receiver noise figure (dB) | 1 |

EME systems operating in 5 760 to 5 765 MHz increasingly employ digital “Weak Signal Modes” which are structured for very basic communication with low data rates and narrow bandwidth. The main antenna beam direction can be assumed to be pointing above the horizon; however, the technique is still vulnerable to noise on side lobes.

Receiver bandwidths, as indicated in the emission class designators, range from 50 Hz to 2 kHz.

### 3.4.3 Amateur systems (digital voice, data and multimedia)

Amateur mesh networks, e.g., Broadband HamNet (BBHN) systems, are implemented within the 5 725 to 5 875 MHz range shared with ISM users. However, in 5 760 to 5 765 MHz, narrowband weak signal terrestrial and EME operation is given priority.

|  |
| --- |
| **Parameter** |
| Necessary bandwidth and emission class designator | 2K70G1D 6K00F7D 16K0D1D 150KF1W 10M5G7W |
| Transmitter power (dBW) | 3 to 20 |
| Feeder loss (dB) | 1 to 6 |
| Transmitting antenna gain (dBi) | 10 to 42 |
| Typical e.i.r.p. (dBW) | 1 to 45 |
| Antenna polarization | Horizontal, vertical |
| Receiver noise figure (dB) | 0.5 to 1 |

Receiver bandwidths, as indicated in the emission class designators, range from 2.7 kHz to 10 MHz.

### 3.4.4 Earth-to-space uplinks for amateur satellites

The amateur service allocation in 5 GHz, particularly in 5 760 to 5 765 MHz, is also being considered for uplinks to planned geosynchronous amateur satellites.

|  |
| --- |
| Parameter |
| Necessary bandwidth and class of  emission (emission designator) | 150HA1A 150HJ2A  2K70J3E 2K70J2E 16K0F3E 44K2F1D  88K3F1D 350KF1D 10M0G7W |
| Transmitter power (dBW) | 3 to 20 |
| Feeder loss (dB) | 1 to 10 |
| Transmitting antenna gain (dBi) | 10 to 42 |
| Typical e.i.r.p. (dBW) | 3 to 45 |
| Antenna polarization | Horizontal, vertical, RHCP, LHCP |
| Satellite receiver noise figure (dB) | 1 to 3 |

The receiver bandwidth of an amateur radio satellite is usually as wide as its uplink frequency band unless the transponder is equipped for demodulation and re-modulation. However, the required signal bandwidths, as indicated in the emission class designators, range from 150 Hz to 10 MHz.

**3.5 Technical and operational characteristics of the Amateur Satellite service (space‑to-Earth) operating in 5 830-5 850 MHz**

The secondary allocation to the amateur satellite service is 5 830 to 5 850 MHz. The reference document for amateur signal characteristics for sharing studies is Rec. ITU-R M.1732-2 (01/2017).

### 3.5.1 For Low Earth Orbit (LEO) satellites

|  |
| --- |
| Parameter |
| Necessary bandwidth and emission class designators | 150HA1A 150HJ2A  2K70J3E 2K70J2E 16K0F3E 44K2F1D  88K3F1D 350KF1D  10M0G7W |
| Transmitter power (dBW) | -10 to 10 |
| Transmitting antenna gain (dBi) | 0 to 23 |
| Typical e.i.r.p. (dBW) | 0 to 15 |
| Antenna polarization | Horizontal, vertical, RHCP, LHCP |
| Receiver Noise Figure (dB) | 1 to 7 |

Receiver bandwidths, as indicated in the emission class designators, range from 150 Hz to 10 MHz

### 3.5.2 For High Earth Orbit (HEO) and Geostationary (GEO) satellites

|  |
| --- |
| **Parameter** |
| Necessary bandwidth and emission class designators | 150HA1A 150HJ2A  2K70J3E 2K70J2E 16K0F3E 44K2F1D  88K3F1D 350KF1D  10M0G7W |
| Transmitter power (dBW) | 0 to 20 |
| Transmitting antenna gain (dBi) | 0 to 20 |
| Typical e.i.r.p. (dBW) | 9 to 30 |
| Antenna polarization | Horizontal, vertical, RHCP, LHCP |
| Receiver Noise Figure (dB) | 1 to 7 |

Receiver bandwidths, as indicated in the emission class designators, range from 150 Hz to 10 MHz.

# 4 Sharing studies per service

## 4.1 Sharing and compatibility of Radiolocation with WAS/RLAN in the 5 725‑5 850 MHz

### 4.1.1 Compatibility of WAS/RLAN with ground radars of the radiolocation service in the frequency bands 5 725-5 850 MHz

TABLE 4.x

Additional technical characteristics of ground based radars in the radiolocation service   
operating in frequency bands 5 725-5 850 MHz

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Radar | Radar 2 | Radar 3 | Radar 4 | Radar 5 | Radar 7 | Radar 12 |
| Тn, К | 627 | 627 | 3361 | 627 | 2610 | 438 | |
| Рnoise, add, dBW | -147 | -141 | -130 | -132 | -134 | -134 | |
| Iadd, dBW | -153 | -147 | -136 | -138 | -140 | -140 | |
| Radar | Radar 13 | Radar 15 | Radar 21 | Radar 22 | Radar 23 |  |
| Тn, К | 289 | 202 | 289 | 627 | 5496 |  |
| Рnoise, add, dBW | -140 | -133 | -145 | -135 | -124 |  |
| Iadd, dBW | -146 | -139 | -151 | -141 | -130 |  |

Compatibility evaluation of WAS/RLAN with ground-based radars operating in the considered frequency bands was performed in line with the interference scenario given below.

FIGURE 4.1

Interference scenario for RLS ground-based radar receiver



Interference was estimated using a propagation model described in Recommendation ITU-R [Р.452](https://www.itu.int/rec/R-REC-P.452-16-201507-I/en). This study assumed heights of RLANs transmitters was 14 m, 20 m and 26 m. ITU-R Working Parties 3J, 3K, and 3M recommended the use of Rec. ITU-R P.2108 when modelling transmission loss through buildings.” However, in this study, the propagation loss in walls was considered using the following equation:

, dBW (6)

where:

σ – additional fading, dB.

Fading in walls was assumed as 20 dB. The assumed radar antenna height above the ground level was 20 m. Multi-source interference was taken into account using equation (5).

Table 4.1 presents minimum estimated separation distances based upon the assumptions in this study for protection of ground-based radiodetermination radars from a single-source interference caused by outdoor RLAN transmitters in the frequency bands 5 725-5 850 MHz. Estimations were conducted for two operation modes of RLAN with bandwidth of 20 MHz and 160 MHz. Estimation was also conducted assuming multisource interference caused by three simultaneously operating indoor RLAN transmitters deployed in a single building at the same heights of RLAN.

TABLE 4.1

Separation distances (km) based upon the assumptions in this study protecting ground-based radiolocation radars from outdoor deployed RLANs in the frequency band 5 725-5 850 MHz

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| RLAN bandwidth | 20 MHz | | | | 160 MHz | | | |
| RLAN transmitter height, m | 14 | 20 | 26 | Σ | 14 | 20 | 26 | Σ |
| Radar 2 | 72 | 75 | 77 | 81 | 60 | 63 | 65 | 69 |
| Radar 4 | 52 | 55 | 57 | 60 | 43 | 46 | 48 | 51 |
| Radar 5 | 56 | 59 | 62 | 65 | 47 | 50 | 52 | 55 |
| Radar 7 | 38 | 41 | 43 | 45 | 30 | 34 | 37 | 38 |
| Radar 12 | 40 | 43 | 46 | 49 | 33 | 36 | 38 | 41 |
| Radar 13 | 62 | 65 | 67 | 71 | 51 | 54 | 57 | 60 |
| Radar 15 | 62 | 65 | 68 | 72 | 52 | 55 | 58 | 60 |
| Radar 22 | 49 | 52 | 54 | 57 | 40 | 43 | 46 | 48 |
| Radar 23 | 36 | 39 | 42 | 44 | 29 | 33 | 35 | 37 |

Analysis of the estimation results described in Tables 4.1 shows that the separation distances required for protecting ground radars would be of several dozen km even for RLANs using data transfer channel of 160 MHz. For the Radar operating in the frequency band 5 725-5 850 MHz the protection distance is 65 km. Based on the above the conclusions may be drawn that enlarging RLANs bandwidth to reduce spectral density of interference caused for radars may not be considered as one of the interference mitigation techniques in relation to ground-based radiodetermination radars.

Minimum separation distances required for protection of ground radars from a single-source interference caused by indoor RLAN transmitters in the frequency bands 5 725-5 850 MHz are presented in Tables 4.2. Estimations were conducted for two operation modes of RLAN. Estimation was also conducted assuming multisource interference caused by three simultaneously operating indoor RLAN transmitters deployed in a single building at height of 14 m, 20 m. and 26 m.

TABLE 4.2

Separation distances (km) based upon the assumptions in this study for protecting ground-based radiolocation radars from indoor deployed RLANs in the frequency band 5 725-5 850 MHz

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| RLAN bandwidth | 20 MHz | | | | 160 MHz | | | |
| RLAN transmitter height, m | 14 | 20 | 26 | Σ | 14 | 20 | 26 | Σ |
| Radar 2 | 48 | 51 | 53 | 56 | 39 | 42 | 45 | 47 |
| Radar 4 | 33 | 36 | 39 | 41 | 27 | 30 | 33 | 34 |
| Radar 5 | 36 | 40 | 43 | 44 | 29 | 33 | 36 | 37 |
| Radar 7 | 23 | 26 | 28 | 30 | 14 | 14 | 14 | 21 |
| Radar 12 | 25 | 28 | 31 | 32 | 19 | 20 | 20 | 26 |
| Radar 13 | 40 | 43 | 46 | 48 | 33 | 36 | 39 | 41 |
| Radar 15 | 41 | 44 | 47 | 49 | 33 | 36 | 39 | 41 |
| Radar 22 | 31 | 34 | 37 | 39 | 24 | 28 | 31 | 32 |
| Radar 23 | 23 | 25 | 27 | 29 | 11 | 11 | 11 | 20 |

Analysis of the estimation results described in Tables 4.2 shows that in spite of reducing the level of interference due to fading in the walls using the assumptions in this study the separation distances of several tens km are required for protection of the radar receivers. The results shown in these Tables were gained for the walls with propagation loss of 20 dB rather than the ITU-R P.2108.

According to the results based upon the assumptions in this study, RLAN transmitter signal fading when propagating in walls of buildings may not be considered as an effective stand-alone interference mitigation technique as well as that of enlarging the channel bandwidth. But this may not preclude the possibility of this mitigation technique being used in combination with other techniques to protect the incumbent services.

DFS as a mitigation technique was not considered in the study.

### 4.1.2 Statistical study between WAS-RLAN and frequency hopping radars in the 5 725‑5 850 MHz frequency band

#### 4.1.2.1 Introduction

Under agenda item 1.16 (WRC-19), the frequency bands 5 350‑5 470 MHz and 5 750‑5 850 MHz (among others) are under study to evaluate the possibility of having a MOBILE service allocation associated with a WAS/RLAN identification. These two bands are allocated, inter alia, to the Radio Location Service, and Fast Frequency Hopping radars operate in them.

Allowing WAS/RLAN use under the Mobile allocation in this band will constitute a threat to Fast Frequency Hopping radars operation, specially that the current DFS has not proved yet its ability to properly detect and therefore protect Fast Frequency Hopping radars.

One should note that the DFS operation consists first in detecting a signal on a given frequency, and secondly to identify this signal by saying whether it comes from a radar or not. The detection phase is a critical step in the DFS process; to achieve it properly the DFS should be able to observe enough samples from the radar signal (or enough pulses) that will allow it to continue into the second phase. If the first step fails, the whole DFS is inefficient.

The difficulty to succeed in this task is mainly due to three factors:

– The frequency hopping rate: The radar constantly changes its operating frequency by hoping from one frequency to another;

– The radar rotation: The radar does not transmit its signal on a given/fixed direction, it rotate at given speed either mechanically or electronically;

– The number of pulses per burst: each radar has a signature, which implies a given number of pulses per burst. This number of pulses can be lower than the one “expected/required” by the DFS to properly operate (at maximum 9, in the case of some current standards).

This section mainly deals with the detection step (step 1). A statistical study is conducted in order to assess how far different types of DFS could fulfil the detection step, given different fast frequency hopping radars pattern. Only few modes of Radars 22 and 23, Recommendation ITU-R M.1638-1 are considered.

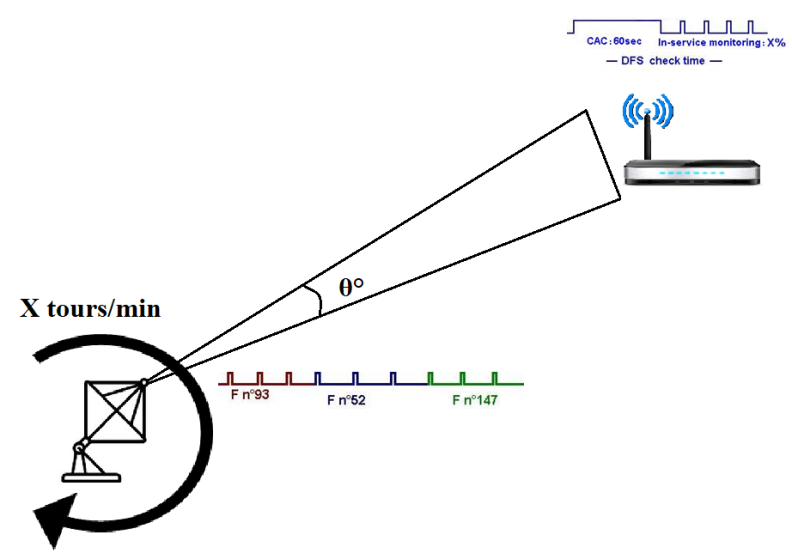
The results of this study, detailed hereafter, demonstrate, in most cases, the difficulties for the DFS to meet the conditions to detect fast frequency hopping radar signal.

#### 4.1.2.2 Simulation parameters and scenario

The simulated scenario is depicted in Figure 1.

Figure 1

Studied scenario, radar at X rotations/min, 3 pulses per burst, frequency hopping pattern,   
and an RLAN on DFS procedure



X rot/min

##### 4.1.2.2.1 Radar characteristics

The radar signal is composed of pulses with a width L (µs), transmitted with a repetition frequency Fr (or a repetition period PRI): Fr = 1/Pri. The radar signal is transmitted on a frequency Fi, and hops on another frequency Fj after P pulses (a burst). Figure 2 illustrates an example where the radar transmits three pulses per burst on the frequency number 93 and then hops to frequency number #52 and finally frequency #147.

Figure 2

Example of a radar hopping pattern

signal radar sauts de F

Radar antenna speed parameter is Nb tr/min and the radar antenna aperture is θ°.

Radar transmits on a number of frequencies equal to Nf, using a hoping pattern among two different drawing methods of frequencies:

– Type M1: random draw (on the Nf possible frequencies at each drawing)

– Type M2: random draw without replacement (on the Nf possible frequencies minus frequencies already used).

When carrying out our simulation we noticed that the results are very close for both modes. Thus, only Mode M1 is retained. We also observed that for high number of hopping frequencies (between 50 and 400 within the same frequency range), changing Nf does not impact the detection probabilities, for this reason results are proposed only for Nf = 200 frequencies.

Numerically speaking the different parameters are replaced by the possible values presented in tables below, which correspond to a possible set for Radar 22 and 23 of Recommendation ITU-R M.1638-1.

In this study, it is considered that PRI and pulse width are constant for each probability calculation (several types of radars use variable pulse width and also variable PRI: these are « staggered » signals; this characteristic have not been integrated in this study.

Table 1

Radar 22 (Recommendation ITU-R M.1638-1) parameters range used in the calculation

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Signal parameters | | | | | Frequency hopping | | |
| Rotation speed | Antenna  Aperture | Pulse Width | Pulse Repetition Interval | Bandwidth | Nb of frequency | Nb of pulses on a frequency | Drawing method |
| Nb (Tr/s) | θ (°) | L (µs) | Pri (ms) | (MHz) | Nf | Np | M |
| 0,5 ; 1 | 2 | 20 | 1 | 5 | 200 | 1 ; 3 ; 6 ; 10 | 1 |

Table 2

Radar 23 (Recommendation ITU-R M.1638-1) parameters range used in the calculation

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Signal parameters | | | | | Frequency hopping | | |
| Rotation speed | Antenna  Aperture | Pulse Width | Pulse Repetition Interval | Bandwidth | Nb of frequency | Nb of pulses on a frequency | Drawing method |
| Nb (Tr/s) | θ (°) | L (µs) | Pri (ms) | (MHz) | Nf | Np | M |
| 0,5 ; 1 | 2 | 6 | 0.2667 | 5 | 200 | 1 ; 3 ; 6 | 1 |

##### 4.1.2.2.2 RLAN DFS characteristics

Recommendation ITU-R M.1652 provides the DFS characteristics. In this study, it is considered that WAS/RLAN use a channel width equal to 20 MHz.

According to ETSI standard DFS has 2 different functioning phases:

– Channel Availability Check time (CAC): when the RLAN is switched “on”, it must at least listen 60 seconds before using the channel.

– In service monitoring: After selection of a channel by RLAN, RLAN transmit on this channel. It transmits and listens during a percentage of time (X%), in the aim to detect potential presence of a new radar.

When a radar signal is received, a given number of pulses can be necessary to decide if it is a radar signal or not. In this study this parameter is noted by N.detect.

Table 3

DFS range parameters used in the studies

|  |  |  |  |
| --- | --- | --- | --- |
| DFS | CAC | Cycle “In service monitoring” | N.Detect |
| Value | 60 s | 300 ms  (this value is not fixed in the standards) | 1 ; 3 ; 6 ; 9 |
| % of listen time | 100% | 20%,30%, 50%, 80% |

In the case of fully loaded RLAN Network the in service monitoring time would be influenced by the CSMA/CA protocol and would be around 70% listening.

##### 4.1.2.2.3 Simulation procedure

A radar signal is considered as “successfully detected” only if N.detect successive radar pulses are acquired by the WAS/RLAN when scanning a specific frequency (in the simulations, a detection takes place as soon as there is a collision in time and in frequency as short as it is). The aim of our simulation is to assess the probability of a successful detection when considering the ranges of parameters defined in table 1 and table 2.

To do so, we generate signals radars with a specific configuration and try to detect N.detect successive pulses on the RLAN side by the DFS, this is done over 50 000 runs (1 iteration correspond to about 1 second). The probability (of a successful detection of N.detect pulses on a given radar rotation is then derived.

Whatever is the duration of the CAC it can be written as a multiple of a given number of radar rotations that we will denote. The detection of at least one event during this period is sufficient to trigger the DFS. Knowing the probability it is possible to derive the probability of a successful detection over experience (meaning during the CAC). This can be achieved considering that the described event follows a binomial distribution, where we are trying to find the probability of i success over experience. This is expressed as follows:

is the binomial coefficient.

Summing this probabilities over (at least one), we get

For example if Nb= 1 rot/s, than the CAC duration is 60 rotations, and thus

.

The simulated algorithm consists in two steps:

– STEP 1: Determine the probability ;

– STEP 2: Deduce the probaility to achive at least one «successful detection» during the CAC or the ‘In service monitoring’ period.

One should note that for example in the ETSI EN301893 (i.e. for fixed frequency radar test signals), DFS detection probability is set to 60% , for the 2 operating phases (CAC and In Service Monitoring), except for meteorological radars where it is set to 99,99%.

#### 4.1.2.3 Simulations results and analysis

According to many possible combinations of the parameters ranges, the results are divided into two sets:

– DFS/RLAN in CAC mode (see Table 4)

– DFS/RLAN In Service Monitoring (see Table 5 to Table 12)

Probabilities are expressed in %. A colour scale is superposed to the results in the table, all probabilities lower than 60% are in red.

Based on the results of the simulations, we observe that generally:

– The radar antenna rotation speed has a big influence on the detection probability;

– The number of pulses per burst that have to be detected N.detect, has also a major impact on the results.

More specifically, for WAS/RLAN in the CAC phase:

– If the DFS is able to deal with a single radar pulse (N.detect=1), probabilities of collision would be quite good (between 95 and 100%) whatever the parameters of the radar signal (PRI, pulse width, number of pulses).

– If the DFS is able to deal with « only » a sequence of 3 pulses, collision probability varies from 2% to 99% depending on the radar parameters.

– If the DFS is able to deal with 6 pulses, probability become extremely low, except in some specific cases and for 9 pulses (corresponding to the possibilities of current DFS), the radar signal will almost never be in position to be detected.

For WAS/RLAN in ‘in service monitoring’, all the studied cases fail to achieve the 60% probability.

The simulation doesn’t take into account DFS being triggered in adjacent WAS/RLAN channels.

#### 4.1.2.4 Conclusion

The present section statistically analysed the probability for a DFS to successfully detect recommendation ITU-R M.1638-1 Radar 22 and 23 in some operational modes. It appeared that this probability depends on many radar signal parameters but also on some DFS parameters. The radar rotation speed and the PRI are the most influencing parameters on the radar side. In CAC mode, if the DFS is able to deal with a single radar pulse, the achieved probabilities appears to be satisfactory, however for a higher number of radar pulses this probability decreases dramatically. For WAS/RLAN in ‘in service monitoring’, all the studied cases fail to achieve the 60% detection probability.

Table 4

RLAN in CAC (100%) – Radar 22 (ITU-R Rec 1638-1), comparison for N.detect = 1, 3, 6 and 9 pulses



Table 5

RLAN ‘In service monitoring’ 3 pulses – Radar 22 in mode M1 200F. Comparison for 20%, 50%   
and 80% of listen time



Table 6

RLAN ‘In service monitoring’ 3 pulses – Radar 23 in mode M1 200F. Comparison for 30%, 50%   
and 80% of listen time



Table 7

RLAN ‘In service monitoring’ 9 pulses – Radar 22 in mode M1 200F, comparison for 20%, 50%  
 and 80% of listen time



Table 8

RLAN ‘In service monitoring’ 9 pulses – Radar 23 in mode M1 200F. Comparison for 30%, 50%   
and 80% of listen time



Table 9

RLAN ‘In service monitoring’ – Radar 22 in mode M1 200F. Comparison for 1, 3, 6   
and 9 pulses



Table 10

RLAN ‘In service monitoring’ – Radar 23 in mode M1 200F. Comparison for 1, 3, 6   
and 9 pulses



Table 11

Radar 22 ‘In Monitoring Service’, mode M1 200F. Comparison between rotation speed   
of the radar antenna



Table 12

Radar 23 ‘In Monitoring Service’, mode M1 200F. Comparison between rotation speed of the radar antenna



## 4.2 Sharing and compatibility of Fixed Satellite Service versus WAS/RLAN in the 5 725-5 850 MHz for Region 1

Note: This study uses more conservative parameters than those provided by WP 4A

The studies outlined below assumed that RLAN deployments were in all of the countries within the satellite footprint. Compatibility studies between RLANs and FSS operating in adjacent band have not been studied.

### 4.2.1 Study 1

CEPT Report 57, published in March 2015, covered a significant amount of work that had been carried out by CEPT.

The general conclusion from CEPT Report 57 was that it was not possible at that time to specify any appropriate mitigation techniques and/or operational compatibility and sharing conditions that would allow WAS/RLANs to be operated in the bands 5 350-5 470 MHz and 5 725-5 925 MHz while ensuring relevant protection of incumbent services in these bands. CEPT Report 57 also concluded that these studies (in particular on additional mitigation techniques) that have not been completed and that any further work undertaken by CEPT could be taken into account when reviewing the results of the WRC-15 under Task (3) of the mandate.

This Report reviews and/or reconfirms the compatibility and sharing conditions developed previously and take account of the results of WRC-15.

Since the publication of CEPT Report 57, CEPT has carried out some additional work on compatibility studies related to RLANs in the 5 725-5 925 MHz band; additional studies on further mitigation techniques are still being investigated both within ETSI and CEPT.

Taking account of the studies shown in CEPT Report 57 and ECC Report 244, a summary of the current status of the various sharing and compatibility studies addressing Sharing and compatibility of Fixed Satellite Service versus WAS/RLAN in the 5 725-5 850 MHz (for Region 1) is presented hereafter:

Further studies since the publication of CEPT Report 57 have focused on the assessment of the interference from RLAN into FSS using a two-step approach:

**Step 1** calculates the maximum number of active, on-tune, RLAN transmitters that can be accommodated by the satellite receiver under consideration (considering the satellite footprint) whilst satisfying the FSS protection criteria.

**Step 2** delivers the number of active, on-tune, RLAN transmitters using a deployment model. The step 2 outputs can be compared with the step 1 values in order to assess the potential for sharing. In theory, if the step 2 values are less than or equal to the step 1 values, then the results suggest that sharing is possible; else if the step 2 values are greater than the step 1 values, sharing is not possible.

As there were a number of options and associated results studied for both steps 1 and 2, it was agreed to perform sensitivity analyses, taking into account ranges of values for some of these factors. Initial calculations and results were presented in ECC Report 244 but although providing some relevant results, it was too early to draw definite conclusions.

Additional studies on the potential for RLAN-FSS sharing were developed.

The wide range of results available reflects the wide range of inputs to the models considered in the studies. Further work would be required on the modelling including on the range of inputs.

As a result, it has not been possible to arrive at a consensus regarding suitable inputs for the modelling, and further studies would be required. Further mitigation techniques may also need to be investigated and studied for their impact on RLAN operations and results of studies. One possible way forward to address some of the uncertainties currently seen in the range of results is to carry out some airborne measurements to compare actual RLAN use with the predicted results from the model for defined geographical areas. An example of how to compare real measurements with the results of the model has been presented during the course of the studies.

Work is still required on the specification of appropriate mitigation techniques and/or operational compatibility and sharing conditions that would allow WAS/RLANs to be operated in the bands while ensuring relevant protection of the Fixed Satellite Services in these bands.

There has been no study on the potential interference from FSS earth stations into RLAN.

Consequently, numerous studies have been conducted by interested Administrations (for example, within CEPT SE 24 and WG FM) to estimate the levels of interference which FSS space receivers in Region 1 could absorb from RLANs without generating a harmful level of interference into FSS space receivers. The general conclusions reached indicate that sharing of WAS/RLAN and FSS space receivers would be very difficult and additional techniques should be developed to mitigate the risk of harmful interference created by the aggregate interfering signals originated by transmitting WAS/RLAN stations. Indeed, the agenda item 1.16 called for studies on suitable mitigation techniques (*resolves b)*).

The following table provides a summary of the conclusions of the studies for three selected representative scenarios (out of the 27 scenarios considered).

| Scenario | Antenna discr.  (dB) | Building  loss (dB) | Band 5 725-5 850 MHz |
| --- | --- | --- | --- |
| “Optimistic” scenario (Case 1 above) | 4 | 17 | FSS protection criteria satisfied for all FSS groups 1, 2 and 4 (margin ranges 1.3 to 12 dB) |
| 4 | 12 | FSS protection criteria satisfied for FSS groups 1 and 2 (margin ranges 2.6 to 9.9 dB). FSS protection criteria exceeded for other FSS group 4 (exceeding of 0.9 dB) |
| 0 | 17 | FSS protection criteria satisfied for FSS groups 1 and 2 (margin ranges 0.8 to 8 dB):  FSS protection criteria  exceeded for other FSS group 4 (exceeding of 2.7 dB) |
| 0 | 12 | FSS protection criteria satisfied for FSS group 1 (margin ranges 5.2 to 5.9 dB). FSS protection criteria exceeded for other FSS groups 2 and 4 (exceeding ranges 1.4 to 4.9 dB) |
| “Medium” scenario (Case 14 above) | 4 | 17 | FSS protection criteria satisfied for FSS group 1 (margin ranges 2.2 to 2.9 dB). FSS protection criteria exceeded for other FSS groups 2 and 4 (exceeding ranges 4.4 to 7.9 dB) |
| 4 | 12 | FSS protection criteria satisfied for FSS group 1 (margin ranges 0 to 0.7 dB). FSS protection criteria exceeded for other FSS groups 2 and 4 (exceeding ranges 6.5 to 10.1 dB) |
| 0 | 17 | FSS protection criteria  exceeded for all FSS groups 1, 2 and 4 (exceeding ranges 1.1 to 11.9 dB) |
| 0 | 12 | FSS protection criteria  exceeded for all FSS groups 1, 2 and 4 (exceeding ranges 3.3 to 14.1 dB) |
| “Pessimistic”  scenario  (Case 27 above) | 4 | 17 | FSS protection criteria exceeded for all FSS groups  1, 2, 3, 4 and 5 (exceeding ranges 4.5 to 15.3 dB) |
| 4 | 12 | FSS protection criteria exceeded for all FSS groups  2, 3, 4 and 5 (exceeding ranges 6.7 to 17.4 dB) |
| 0 | 17 | FSS protection criteria  exceeded for all FSS groups 1,  3, 4 and 5 (exceeding ranges 8.5 to 19.2 dB) |
| 0 | 12 | FSS protection criteria  exceeded for all FSS groups 1,  2, 3, 4 and 5 (exceeding  ranges 10.7 to 21.4 dB) |

The above consideration takes account that all scenarios considered so far by the ECC Report 244 are valid and realistic. Indeed, some previous considerations on the conservativeness of assumptions have not been endorsed by the recent studies of WP 3K/WP 3M and, in particular, these WPs (22‑29 March 2017) concluded that the analysis of the clutter loss and building entry loss models provided in the ITU draft new Recommendations show that:

– Working Party 5A should not use the clutter component of Recommendation ITU‑R P.452.

– The clutter loss model of Recommendation ITU-R P.2108, currently applicable from 10 GHz to 100 GHz, could be extended to the 5 GHz range.

– This clutter model would provide lower values for clutter losses at 5 GHz than those currently assumed in ECC Report 244.

– For the building entry loss model, applicable from 80 MHz to 100 GHz, the average values obtained for the building entry loss at 30 degrees elevation angle is 14 dB at 5.8 GHz and 13.4 dB at 2.4 GHz, which is only a 0.6 dB difference. Some airborne measurements submitted previously to WP 5A showed a difference of 6.1 dB (8.4 dB at 2.4 GHz and 14.5 dB at 5 GHz).

Building entry losses. It was concluded that indoor/outdoor attenuation (currently estimated as 12 and 17 dB) should be considered as very similar at 2.4 GHz and 5 GHz and not a difference of 8,4 dB at 2,4 GHz and 14,5 dB at 5 GHz. Instead, the building losses are actually 13.4 dB at 2.4 GHz and 14.5 dB at 5 GHz, almost no significant difference.

#### 4.2.1.1 Estimation of interference from WAS/RLAN through empirical methods

As a potential way forward to estimate the interference in Region 1 to FSS from WAS/RLAN, an innovative contribution was made available to WP 5A (Doc. [5A/91](http://www.itu.int/md/R15-WP5A-C-0091/en)) suggesting the estimation of interference through an empirical method consisting on airborne measurements. A separate report on measurements on interference created by RLAN using airborne is under elaboration.

A detailed analysis on the set of airborne measurements has been made. In general these airborne measurements are potentially interesting to:

– Achieve a better understanding of the study models before the actual RLAN deployment, with a view to determine the actual interference level observed and compare it with calculated results of studies.

– To measure and control, including on the long term, the aggregate interference into FSS space stations when RLAN deployment is developing.

Preliminary conclusions on the airborne measurements do not allow at this stage characterisation of the interference environment and do not allow quantitative conclusions to be drawn. Additional measurements campaigns from airplanes (including in other geographical areas) would be necessary before being able to draw any conclusions from such measurements.

Furthermore, the following issues should be investigated and clarified on possible future airborne measurements:

– Measurements are made locally at low altitude (few kms) whereas FSS space stations cover wide geographic areas and operate from the GSO orbit in space.

– It is not clear how measurements at 2.4 GHz (for which the reference point is not clear, is it less congested than expected?) can help characterise the interference environment at 5 GHz, especially since measurements at 5 GHz are close to the noise floor.

– Measurements should be made during busy hours.

– It is not clear how space and time dynamics of an airplane is comparable with the case of GSO satellites (which are seen from the Earth as static in the sky).

– These measurements have considered two elevation angles (30 and 90 degrees). It would seem useful to specifically conduct measurements at elevation and azimuths corresponding to the GSO orbit, since the GSO orbit as seen from the Earth is a particular path in the sky, from 0 degree elevation angle at horizon for the most western and eastern azimuths to about 48 degrees elevation angle at south azimuths, from London.

Noting the difficulties to characterize the overall aggregate interference from RLAN into space station receivers of the FSS in a deterministic approach, the empirical methods should ensure the replicability of the results obtained at one frequency range as applicable in another frequency range. Empirical methods are valid scientific approaches to measure realistic scenarios in a facts finding measurement approach, but it is rather scientifically questionable that an empirical approach is used in one frequency range (2.4 GHz) to derive deterministic measurements to be applied in another frequency range (5.8 GHz).The above consideration has been further recently endorsed by results of the WPs 3K/3M making invalid some of the assumptions made regarding clutter/building entry losses.

#### 4.2.1.2 Potential mitigation techniques for WAS/RLAN

As can be checked through the conclusions obtained by various studies conducted so far by CEPT and other Administrations, the only viable mechanism for reaching acceptable sharing conditions between FSS and RLAN in the 5.8 GHz range is through the development, and demonstration of their reliable implementation, of suitable mitigation techniques to be applied by RLAN systems, both in their technical characteristics and their deployment criteria.

Based on the results of Study 1, other RLAN mitigation techniques may be needed in Region 1, such as limitation to indoor only, maximum eirp, elevation angle mask/downward tilt.

The impact of such mitigation techniques on the RLAN deployment and operations (e.g. RLAN e.i.r.p. distribution and the resulting limitations on data rates possible), should be studied.

#### 4.2.1.4 Protection of FSS

Study 1 used Recommendation ITU-R S.1432-1 when looking at the characteristics for FSS protection criterion. To apportion these FSS protection criteria among the potential sources of interference, an apportionment scheme has been used for computing interference from RLANs and has been limited to half of the ΔT/T= 6% criterion i.e. the ΔT/T objective is reduced to a value of 3%. The study assumed an apportionment of 3%. The protection criteria proposed by the ITU-R expert group was different but less stringent than the protection criteria used in this study.

### 4.2.2 Study 2

The protection criteria proposed by the ITU-R expert group was different but less stringent than the protection criteria used in this study.

#### 4.2.2.1 Background and analysis

This analysis is looking to expand on the results of some previous sharing studies carried out in ITU-R and CEPT which are shown in the results of study 1. Those studies use a methodology that makes reference too and analyses the 3 different studies carried out which are:

– Report ITU-R [S.2367](https://www.itu.int/pub/R-REP-S.2367-2015) – *Sharing and compatibility between International Mobile Telecommunication systems and fixed-satellite service networks in the 5 850‑6 425 MHz frequency range*.

– ECC Report 244 – *Compatibility studies related to RLANs in the 5 725-5 925 MHz band* (see Annex 1).

– Annex 25 of the last WP 5A Chairman’s Report – *Use of aggregate RLAN measurements from airborne and terrestrial platforms to support studies under WRC-19 agenda item 1.16.*

When analysing these three studies in order to arrive at a useful range of results we had to make a choice on which study should be used to form the baseline analysis. Both study 1 and this study decided to use the studies contained in ECC Report 244 as the baseline study. Once choosing the baseline study, (which is shown in the results of study 1) we took a 3 step approach to the additional analysis carried out under study 2 which is described below.

– **Step 1:** This step calculates the maximum number of active, on-tune, RLAN transmitters that can be accommodated by the satellite receivers under consideration (considering the satellite footprint) whilst satisfying the FSS protection criteria.

– **Step 2:** This step delivers a sensitivity analysis of the number of active, on-tune, RLAN transmitters using various different assumptions when looking at possible RLAN deployment models. The Step 2 outputs can be compared with the Step 1 values in order to assess the potential for sharing when inputting the different assumptions. In theory, if the Step 2 values are less than or equal to the Step 1 values, then the results suggest that sharing is possible; else if the Step 2 values are greater than the Step 1 values, sharing is not possible.

– **Step 3:** This step delivers a comparison of the overall results from the measurement campaigns with the range of various results that can be seen from Step 2 and looks to see if the range of the results that may be valid for further study could be reduced in order to provide more useful results.

#### 4.2.2.2 Review of SG 3 work

In Study 1 and Study 2 there are two different reviews of the ITU-R SG 3 work on new propagation models for Earth to space paths and how this new work would affect the results in ECC Report 244. From the results of these recent studies we can conclude that the analysis of the clutter loss and building entry loss models provided in the ITU draft new Recommendations show that:

The use of the clutter component of Recommendation ITU-R P.452 in ECC Report 244 should be reviewed.

It is recommended that the clutter loss model of ITU-R P.2108, currently applicable from 10 GHz to 100 GHz, may be extended to the 5 GHz range but work is still ongoing in SG 3.

That a new Recommendation [ITU‑R P.2109](https://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.2109-0-201706-I!!MSW-E.docx) can be consulted when modelling transmission loss through buildings.

The new Recommendation provides a way of estimating building entry losses based on an estimation of the mix of traditional and new buildings used in the studies.

As both the new Recommendation and draft new Report give some room for interpretation the two reviews have interpreted the guidance slightly differently and came up with different results although the values proposed in both contributions for total aggregate BEL at 5.8 GHz fall within the range of values considered in ECC Report 244 (12 and 17 dB).

SG 3 review Study 1

The results of Study 1 assumes 100% of buildings will be of normal construction and concluded that the average values obtained for the building entry loss at 30 degrees elevation angle is 14 dB at 5.8 GHz and 13.4 dB at 2.4 GHz, which is only a 0.6 dB difference between the bands. As a result, this study also concluded that indoor/outdoor attenuation should be considered to be very similar at 2.4 GHz and 5 GHz and not as estimated in previous studies. The methodology in study 1 looking at the analysis of the measurement campaign showed a difference of 6.1 dB (8.4 dB at 2.4 GHz and 14.5 dB at 5 GHz).

SG 3 review Study 2

The results of Study 2 assumes a ratio of 30% thermally efficient buildings to 70% traditional buildings when calculating the BEL and assumes different angles for calculating the BELs for 2.4 GHz (13.4°) and 5.8 GHz (30°) to reflect the different angles between the airborne and satellite platforms being modelled. As a result, this study concluded that the average values obtained for the building entry loss at 30 degrees elevation angle is 15.1 dB at 5.8 GHz and at 13.4 degrees elevation angle 12.9 dB at 2.4 GHz, which is a difference of 2.2 dB between the bands. This is around 4dB less than the difference used previous. Updated studies looking at the effect of using these new figures in the sharing analysis are summarized later in this document.

#### 4.2.2.3 Some thoughts on the possible introduction of LTE LAA or LTE-U into the bands

LAA-LTE is expected to be deployed in the existing 5 GHz bands by operators, mainly in hotspots and enterprise environments. Therefore, in Annex 2 Appendix 2 of this document we have added an analysis using the same methodology used in ECC Report 244 to estimate what the additional deployments of LAA-LTE on top of the existing RLAN deployments would make the results of the sharing studies with FSS look like. From the additional studies that have been made in CEPT for LAA-LTE, when compared to ECC Report 244 the following conclusions became apparent:

– Compatibility of a mix LAA and WiFi market share with FSS. Results are roughly the same as for the case of WiFi only.

Therefore, we believe that we can assume that any impact of adding LAA-LTE use case in 5 GHz bands appears to have minimal effect on the overall results of compatibility and sharing as shown in ECC Report 244.

Any additional analysis being considered further for future overall RLAN vs FSS studies should also consider the effect any new mitigations is likely to affect the possible use of the RLAN extension bands by LAA-LTE technologies.

#### 4.2.2.4 Decisions made regarding assumptions in Step 1

In addition to taking these steps shown above, in order to reduce the range of results from the models further in study 2 we have also looked closely at the assumptions made on some of the technical parameters used in study 1. These choices regarding more suitable assumptions were based on the following principles: evidence based, realistic, justifiable, but still a little conservative. Table 4.5 below shows the choice of assumptions, with the associated evidence and analysis on the updated choices for technical parameters used in the studies.

Table 4.5

Technical parameters to be used in study 2

| Technical Parameters | Choices for technical parameters to be modelled previously | | Choice used in study 2 | Document [4-5-6-7/566](http://www.itu.int/md/R12-JTG4567-C-0566/en) |
| --- | --- | --- | --- | --- |
| % of outdoor usage | 2% | 5% | 2% | An input submitted a paper in the last study cycle Document 4-5-6-7/566 provided an evidence based analysis of the numbers of outdoor Wi-Fi users. It concluded even with very conservative assumptions it was very difficult to reach 2% outdoor use. In addition, WRC-03 studies on Wi‑Fi vs FSS in 5 150‑5 250 MHz bands only took account of studies using 1% outdoor use. **It should be noted that ECC Report 244 only presents results for 5.3% outdoor usage.** This study presents results for 5.3%, 2% and 1%. |
| Building penetration losses | 12 dB | 17  dB | 15.2 dB using SG 3 figures | The different studies contained in Report ITU-R [S.2367](https://www.itu.int/pub/R-REP-S.2367-2015) which looks at IMT vs FSS in 5 850‑6 425 MHz assume a range of 12‑35 dB for building penetration losses, so 17 dB still seems a reasonable assumption based on this agreed ITU‑R Report and the choices given in ECC Report 244. But recently ITU-R Study Group 3 published more up to date studies. |
| Antenna Discrimination/Body loss | 0 dB | 4 dB | 4 dB | In previous ITU-R studies 4 dB was considered realistic in the 5 GHz bands RLAN sharing with EESS and in some IMT studies at lower bands around 2 GHz the body losses from mobile devices was up to 6 dB. |
| Polarisation mismatch | 1.5 dB | 3 dB | 1.5 dB | 3 dB may be overestimating the polarisation losses |
| Clutter losses | Free space model | Free space model + Clutter model based on Rec. ITU-R [P.452](https://www.itu.int/rec/R-REC-P.452-16-201507-I/en) in relation to antenna height distribution | 3.5 dB at 30 deg for FSS | Seems a reasonable assumption to include clutter losses for Urban and Suburban environments. Again, recently ITU-R study group 3 published more up to date studies on the topic of clutter in these scenarios. |

In both Report ITU-R [S.2367](https://www.itu.int/pub/R-REP-S.2367-2015) and ECC Report 244 they used a protection criteria of Δ*T*/*T*= 6% coordination criteria as provided in Recommendation ITU-R [S.1432](https://www.itu.int/rec/R-REC-S.1432/en) for the sharing analysis. There was also further discussion in the ECC Report 244 around how to take account of both geographic and service apportionment. In this study as the 5 725‑5 850 MHz band is only allocated on a primary basis to FSS for ITU-R Region 1 only and as such we believe there is no need to take account for any geographic apportionment. With regards to appropriate service apportionment for this band we believe that the studies should show the results for the full Δ*T*/*T*= 6% for the mobile service as you unlikely to have mobile and fixed services sharing the same channels in a given geographic area due to intra-interference. In addition, the use of the band by fixed services now and into the future looks to be very limited based on current information and projected demand. The appropriate Geographic apportionment is discussed later in this document.

#### 4.2.2.5 Results from study 2 with reference to ECC Report 244 for Step 1 and 2

From the studies shown in ECC Report 244/study 1 (see attached annex 1 for relevant parts of the previous studies) the initial results of the sharing and compatibility analysis carried out for RLAN vs FSS indicate depending on certain assumptions, sharing can be shown to be feasible in a number of cases. Other results show that sharing would be more difficult based on more conservative assumptions for the RLAN parameters considered. The studies in ECC Report 244 contain a sensitivity analysis highlighting 28 cases (Case 1 to Case 28) which show results that range from very conservative figures for RLAN numbers/activity put forward by the satellite industry to not very conservative proposals put forward by the RLAN industry. See below for a summary of the relevant satellites studied in Table 4.6 and Table 4.7 which summarises the range of results from ECC Report 244.

Table 4.6

Sample Satellite Data for the band 5 725-5 850 MHz in Region 1

| Satellite | Sub-satellite longitude | Part of frequency range 5 725-5 875 MHz used | Satellite Maximum Receive Gain Gsat (dBi) | Space Station Receiving System Noise Temperature Tsat (Kelvin) |
| --- | --- | --- | --- | --- |
| A | 5o West | Whole band | 34 | 773 |
| B | 14o West | Whole band | 26.5 | 1200 |
| D | 3o East | Whole band | 34 | 773 |
| F | 53o East | Whole band | 26.5 | 1200 |
| G | 59.5o East | Whole band | 34 | 1200 |

Table 4.7

Summary of FSS analysis in Region 1

| **Scenario** | **Antenna discr. (dB)** | Building loss (dB) | Band 5 725-5 850 MHz |
| --- | --- | --- | --- |
| “Optimistic” scenario (Case 1 above) | 4 | 15.2 dB using SG 3 figures | FSS protection criteria satisfied for all FSS satellites (margin ranges 2.2 to 12 dB) |
| “Medium” scenario (Case 14 above) | 4 | 15.2 dB using SG 3 figures | FSS protection criteria satisfied for FSS satellites B& F (margin of 2.4 dB). FSS protection criteria exceeded for other FSS Cgroups 2 and 4 (exceeding ranges 5 to 7 dB) |
| “Pessimistic” scenario (Case 27 above) | 4 | 15.2 dB using SG 3 figures | FSS protection criteria exceeded for all FSS groups 1, 2, 3, 4 and 5 (exceeding ranges 9.3 to 18.7 dB) |

#### 4.2.2.6 Additional considerations on step 2

In step 2 there are various input assumptions in the stages we go through to come up with the 28 cases that are presented in ECC Report 244 that are summarised in Table 4.7 above. If we look into the choices that come up the ranges and make a choice to remove the cases that we think are unrealistic based on some evidence gathered nationally about future broadband rollout to homes, then we can further reduce the cases that may be considered as relevant. If we consider the values chosen to study as a result of Stages 1 – 3 in step 2 to determine the total number of access points accross Europe there is a choice of 300, 400 or 500 million access points based on no of houses/businesses and public hotspots. Looking at the formula the main bulk (91.8% – 92.5%) of these total calculated numbers are from residential access point numbers in homes. In the initial studies the total number of households in Europe used included a 10% increase on current numbers to give 320 million households. In Study 1 results based on 300 400 and 500 million access points were studied which at the top figure of 500 million looks to have been an unrealistic number of access points because the calculated numbers based on very conservative figures for numbers residential APs were found to be in the range of 300 and 400 million. In order to to reach the 500 million number you would have to account for a massive increase 200% in non-residential access points in order to reach the 500 million number. We also considered some of the figures used in the the formulas used to get to the 300 to 400 million to be excessive (e.g. 90% household penetration in EU) considering that the UK market report[[1]](#footnote-1) for 2015 only had Broadband penetration numbers at 79% of households. Therefore, we think that we can eliminate the 500 million number.

The Table 4.8 below gives some thoughts on the original assumptions used in stages 4 – 7.

Table 4.8

Additional considerations on step 2 stage 4 – 6 choices from ECC Report 244

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Stage no and Parameter title | Choices for parameters to be modelled | | | Choice considered reasonable in the UK | Reasoning for UK Choice |
| Stage 4  Busy Hour Factor | 50% | 62.7% | 70% | 50%, 62.7% | These figures were originally developed for EESS footprints and 70% seems a high figure when you consider the size of the FSS footprints and the time zones involved as well as the numbers of access points that will not be running traffic in the busy hour due to the number of houses that may be empty during business hours, people on holiday, reduction in business use during evening busy hours etc. |
| Stage 5  Apply 5 GHz spectrum factor | 50% | 74% | 97% | 50%, 74% | 97% percent seems extremely unrealistic when you consider there are 3 Wi-Fi bands and 2.4 GHz is the default band for most home users currently. As 200MBit is easily achievable in 2.4 GHz today, not all of the home broadband users will need to move to the 5 GHz band from 2.4 GHz band especially in sub-urban and rural areas where there is no likelihood of spectrum congestion in 2.4 GHz. |
| Stage 6  RF Activity Factor | 3% | 10% | 30% | 3%, 10% | When Wi-FI networks are fully loaded, their highest activity factor is around 30% due to the way the protocol works. In addition, the more congested an area is the more likely there would be more time dedicated to back off from Wi-Fi. Due to all of these factors it is unrealistic to consider that all of the active networks in the busy hour will be fully loaded. Therefore, a conservative figure would be closer to 10 % which seems to be a more realistic figure to model. |

If we were to input these new assumptions into the methodology and studies, then we would end up with a reduced range of cases which are shown below in Table 4.9 and the results shown in Table 4.10.

Table 4.9

|  | Busy hour population | 5 GHz factor | Activity factor | 40 MHz FSS | Multiplier for Stage 4 to 7 |
| --- | --- | --- | --- | --- | --- |
| Case 1 | 50% | 50% | 3% | 12.9% | 0.0010 |
| Case 2 | 50% | 50% | 10% | 12.9% | 0.0032 |
| Case 4 | 50% | 74% | 3% | 12.9% | 0.0014 |
| Case 5 | 50% | 74% | 10% | 12.9% | 0.0048 |
| Case 10 | 62.70% | 50% | 3% | 12.9% | 0.0012 |
| Case 11 | 62.70% | 50% | 10% | 12.9% | 0.0040 |
| Case 13 | 62.70% | 74% | 3% | 12.9% | 0.0018 |
| Case 14 | 62.70% | 74% | 10% | 12.9% | 0.0060 |

Table 4.10

Summary of results of reduced range FSS analysis

|  |  |  |  |
| --- | --- | --- | --- |
| **Scenario** | **Antenna discr. (dB)** | Building loss (dB) | Band 5 725-5 850 MHz |
| “Optimistic” scenario (Case 1) | 4 | 15.2 dB using SG 3 figures | FSS protection criteria satisfied for all Satellites (margin ranges 2.2 to 12 dB) |
| “Medium” scenario (Case 2) | 4 | 15.2 dB using SG 3 figures | FSS protection criteria satisfied for Satellites B & F (margin ranges 5 dB). FSS protection criteria exceeded for other Satellites A, D (exceeding ranges 4.3 dB) & G (exceeding ranges 2.4 dB) |
| “Pessimistic” scenario (Case 14) | 4 | 15.2 dB using SG 3 figures | FSS protection criteria satisfied for Satellites B & F (margin ranges 3.4 dB). FSS protection criteria exceeded for other Satellites A,D (exceeding ranges 6 dB) & G (exceeding ranges 4.1 dB) |

#### 4.2.2.7 Step 3 – Taking into account Wi-Fi Airborne Measurement Campaigns in 2.4 GHz and 5 GHz

The different factors used in step 2 are subject to some uncertainties because of the difficulties involved when deriving values for these factors and in particular when making predictions for future. Due to the lack of evidence being available, there has been a lot of debate on how aggregate interference from a fully mature rollout of WAS/RLAN would look in the future within the 5 GHz band to satellite and airborne platforms. Therefore, it was agreed in CEPT to perform a sensitivity analyses, taking into account ranges of values for some of these factors.

Unfortunately, the introduction of a large range of assumptions into the theoretical models used in steps 1 and 2 has led to a very large range of results that we see in the 27 cases summarized in Table 3 above. This is due largely to the number of variables that has been introduced into the models to be studied, this makes it is difficult to come to any conclusions as the large range of assumptions means predicting an acceptable range of results to make conclusions from is very difficult.

It was recognised that in the 2.4 GHz band there are very mature RLAN deployments and the band is considered to be congested in urban environments. Therefore, the purpose of the measurement campaigns was to try to compare the measurement of the 2.4 GHz band with the models used in ECC Report 244 for the 5 GHz band to see where on the range of the different 28 cases the measurements of the current 2.4 GHz deployments sit. This with some other analysis of the previous studies carried out under study 1 can then be used to reduce the range of results enough to be considered in any final analysis.

The draft working document towards a PDN Report ITU-R [RLAN MEASUREMENTS] also introduces new airborne measurement methods and a proposed methodology for comparing RLAN measurement results in both the 2.4 GHz and 5 GHz bands with the theoretical RLAN aggregate interference modelling used in steps 1 and 2 of the ECC Report defined over a defined geographical area.

When taking into account the measurements and our analysis of the airborne measurement campaign results contained in Annex 1 and 2 of the draft working document towards a PDN Report ITU-R [RLAN MEASUREMENTS] we came to some initial conclusions that the measured figures were somewhere between the "optimistic" scenario (case 1) and "medium" scenario (case 14) that are summarised above in Table 4.10.

Since the initial analysis of the measurement campaign was done as mentioned previously ITU-R Study Group 3 published more up to date studies and guidance for BEL curves and clutter calculations to be used for this band. Therefore, a review of the effect of the SG3 recommendations on the initial results has also been carried out as part of study 2. The readjustment of the results of the measurement campaign had the effect of moving the measured figures away from the more "optimistic" scenario (case 1) and towards the "medium" scenario (case 14).

In this adjustedment to the original studies we can see that the power predicted at the receiver for the airbourne measurements over London was recalculated taking the new SG3 BEL modelling into account and the results are shown below in Table 4.11. The BEL has been revised up to 12.9 dB from 8.4 dB in light of the new evidence from SG 3. The impact, as might be expected, is to reduce the power level predicted at the aircraft. The UK measured a value of -76 dBm / 40 MHz at the aircraft which is still within the range of values predicted by the updated model, but closer to the ”middle” case than previously considered, as shown in Figure 4-2. From these results it can be seen that if 5 GHz were to be as congested as 2.4 GHz band today then the middle cases from ECC Report would be more reflective of a very conservative (fully mature) analysis of 5 GHz RLAN roll out.

Table 4.11

Airborne measurement aggregate power modelling, new values shown in grey

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | 100 mW max. e.i.r.p.  indoor only | | | |
|  | Optimistic | | Middle | |
|  | Value | Log. | Value | Log. |
| STEP 1: Per RLAN Contribution to Aggregate Interference |  |  |  |  |
| RLAN EIRP Distribution (per device avg.) (dBm) | 17.6 | *17.6* | 17.6 | *17.6* |
| Outdoor / Indoor Ratio | 5.3% | *-9.9* | 5.3% | *-9.9* |
| Building Penetration Loss for Indoor RLANs (dB) | -12.9 | -12.9 |
| Activity Factor | 3.0% | *-15.2* | 10.0% | *-10.0* |
| Busy Hour Population | 45.0% | *-3.5* | 56.4% | *-2.5* |
| Band Loading Factor | 3.5% | *-14.6* | 26.0% | *-5.9* |
| Channelisation Factors | 58.3% | *-2.3* | 58.3% | *-2.3* |
| Avg. EIRP Per RLAN, Per 40 MHz Channel (dBm) |  | -31.9 |  | -21.1 |
|  |  |  |  |  |
| **Total agg. power at airborne rx. (dBm / 40 MHz)** |  | **-89.9** |  | **-73.0** |

Figure 4.2

Diagram of update to model



Additionally,as mentioned in the previous paragraph it was recognized that the sensitivity analysis carried out in ECC Report 244 resulted in too many possible cases for the results to be able to provide useful conclusions. In the previous exercise where we further analysed the assumptions used in study 1, we reduced the number of cases to be taken into account to 8 from the original 28. The results of the measurement campaign give us an opportunity to reduce this range further.

Proposal

We discussed shrinking this range towards the value measured by selecting a narrower range of cases. We considered that 1 dB above and 3 dB below that measured might be a good target for the narrowing of the range. We present our proposal in the table below. This is based on using modified versions of the “middle” case which gave -73 dBm / 40 MHz in our previous study:

New pessimistic case

The new pessimistic case is based on the “middle case” considered previously. This has been modified to use an antenna discrimination of -4.0 dB in order to bring the predicted aggregate interference down from -73 dBm / 40 MHz to -75 dBm / 40 MHz which is 1 dB higher than the value measured.

New middle case

This is the same as the new pessimistic case except we have reduced the busy hour population has been reduced from 62.7% to 50%. This has the effect of reducing the aggregate power by another 1 dB when compared with the new pessimistic case, down to ‑76 dBm / 40 MHz.

New optimistic case

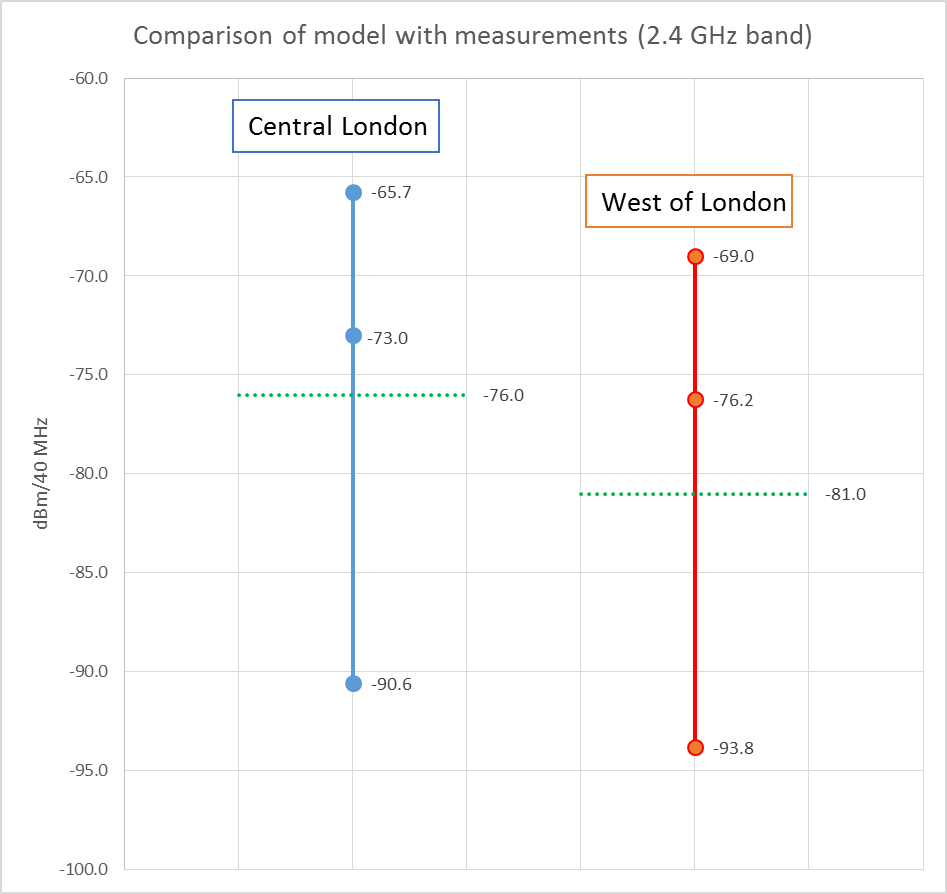
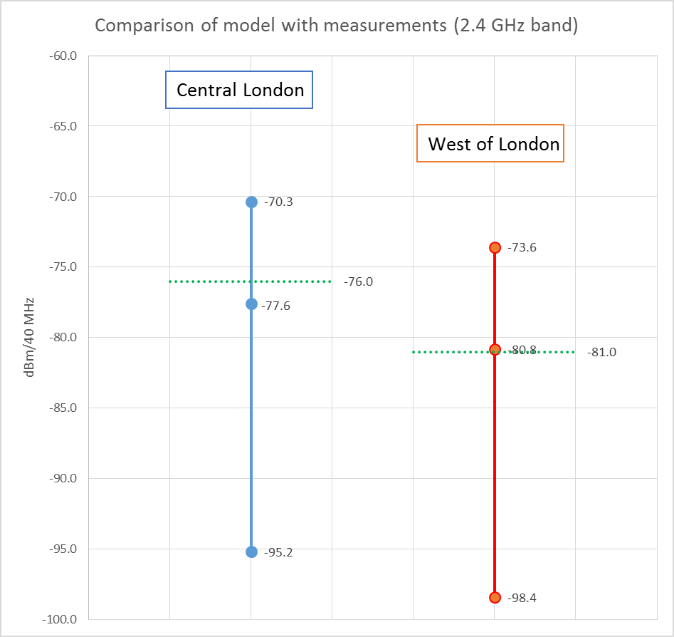
For the new optimistic case, we revise the busy hour population down further, to 25%. This has the effect of reducing the aggregate power by another 3 dB when compared with the new middle case, down to ‑79 dBm / 40 MHz.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | New optimistic | | New middle | | New pessimistic | |
|  | Value | Log. | Value | Log. | Value | LOG. |
| STEP 1: Per RLAN Contribution to Aggregate Interference at 2.4 GHz |  |  |  |  |  |  |
| RLAN EIRP Distribution (per device avg.) (dBm) | 17.6 | *17.6* | 17.6 | *17.6* | 17.6 | *17.6* |
| Outdoor / Indoor Ratio | 5.3% | *-9.9* | 5.3% | *-9.9* | 5.3% | *-9.9* |
| Building Penetration Loss for Indoor RLANs (dB) | -12.9 | -12.9 | -12.9 |
| Activity Factor | 10.0% | *-10.0* | 10.0% | *-10.0* | 10.0% | *-10.0* |
| Busy Hour Population | 25.0% | *-6.0* | 50.0% | *-3.0* | 62.7% | *-2.0* |
| ↑ 10% discount for “shoulder” busy hour | 90% | *-0.5* | 90% | *-0.5* | 90% | *-0.5* |
| Band Loading Factor | 26% | *-5.9* | 26.0% | *-5.9* | 26.0% | *-5.9* |
| Channelisation Factors | 58.3% | *-2.3* | 58.3% | *-2.3* | 58.3% | *-2.3* |
| Antenna Discrimination towards Aircraft (dB) | -4.0 | *-4.0* | -4.0 | *-4.0* | -4.0 | *-4.0* |
| Avg. e.i.r.p. Per RLAN, Per 40 MHz Channel (dBm) |  | -22.1 |  | -18.1 |  | -17.0 |
|  |  |  |  |  |  |  |
| **Total 2.4 GHz agg. power at airborne rx.  (dBm / 40 MHz)** |  | **-79.0** |  | **-76.0** |  | **-75.0** |

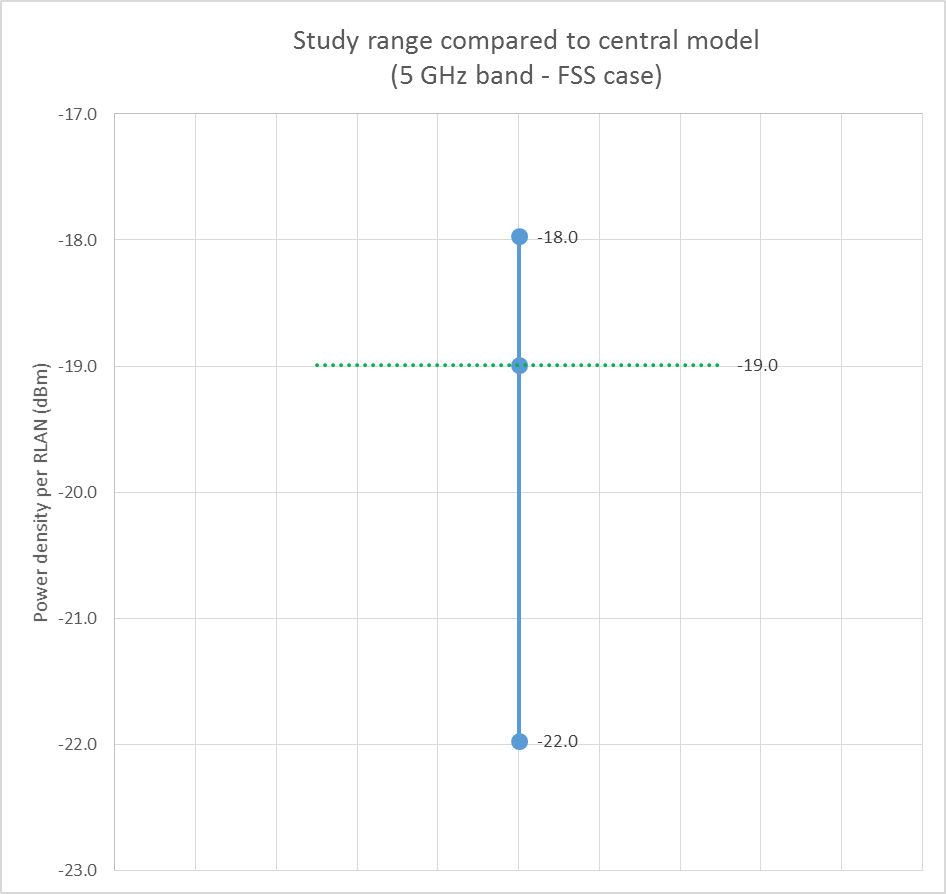
Impact on coexistence at 5.8 GHz

We have updated the 5.8 GHz FSS coexistence model with the values from the new range from the 2.4 GHz airborne measurements models.

The following figures compares, for both 13 (right figure) and 17.6 dBm (left figure) mean eirp, the range of values (min, medium and max) obtained with the model using the figures in the table above for the 2.4 GHz band with the values measured by UK OFCOM in both scenarios, i.e.   
-76 dBm/40 MHz (central London) and -81 dBm/40 MHz (West London).



The following figures compares the corresponding range of study with the central scenario of the model (expressed in average power per RLAN).



The results of the measurement studies as final guide with a reasonable range either side of them and these can be seen in the Table 4.12 shown below.

Table 4.12

Summary of results of reduced range FSS analysis based on 1W max EIRP

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario | Antenna discr. (dB) | Building loss (dB) | Band 5 725-5 850 MHz |
| NEW “Optimistic” scenario  (3 dB below Case 14 Ave power -22 dBm) | 4 | 15.2 dB using SG 3 figures | FSS protection criteria satisfied for Satellites B & F (margin ranges 6.4 dB). FSS protection criteria exceeded for other Satellites A,D (exceeding ranges 3 dB) & G (exceeding ranges 1.1 dB) |
| NEW Base “Medium” scenario  (Case 14 Ave power -19 dBm) | 4 | 15.2 dB using SG 3 figures | FSS protection criteria satisfied for Satellites B & F (margin ranges 3.4 dB). FSS protection criteria exceeded for other Satellites A,D (exceeding ranges 6 dB) & G (exceeding ranges 4.1 dB) |
| NEW “Pessimistic” scenario  (1 dB above Case 14 Ave power -18 dBm) | 4 | 15.2 dB using SG 3 figures | FSS protection criteria satisfied for Satellites B & F (margin ranges 2.4 dB). FSS protection criteria exceeded for other Satellites A,D (exceeding ranges 7 dB) & G (exceeding ranges 5.1 dB) |

#### 4.2.2.8 Review of studies of possible mitigation techniques

The original study results indicated that an uncontrolled large rollout of high power, outdoor access points significantly increase the coexistence risk with FSS in Region 1, therefore, in study 2, some simple mitigation techniques that are easily implemented and controlled have been studied. These simple mitigation techniques are already implemented in other bands that share with satellite services (5 150-5 350 MHz). These mitigation techniques limit the maximum power levels of RLANs to 200 mW EIRP and also limit the outdoor use of the band by RLANs (i.e. no fixed outdoor use). The results can be seen in Table 4.15 shown below. Table 4.13 shows results based on the same parameters and assumptions previously studied but also shows the results for outdoor usage of 1% and 2% which were considered to be more realistic when the mitigation techniques were applied by the CEPT administration.

Table 4.13

FSS / RLAN Sharing scenarios for 5 725-5 850 MHz comparing max EIRPs of 1W with 200 mW indoor



#### 4.2.2.9 Considerations on suitable sharing criteria and apportionment

Regarding suitable sharing criteria to be used and apportionment other factors that need to be taken into account unlike above 5 850 MHz is there is very little current use of the 5 725-5 850 MHz band by FSS in Region 1 and there does not appear to be any plans for a lot of future FSS deployments in the band. This may be because it is an ISM band and is already heavily used for fixed and mobile (including WAS(RLAN)) services in the other Regions. There is also a number of Region 1 countries who have primary mobile and fixed allocation by footnote in this band also. All of these factors look to be making the band unattractive already for future FSS systems, this combined with the limited use of the band currently means the apportionment between the services may need to be rebalanced to take account of the lack of FSS use in the band.

Therefore, in study 2 we look at the bigger picture regarding the methodology used in Recommendation ITU-R [S.1432-1](https://www.itu.int/rec/R-REC-S.1432/en) to derive the sharing criteria for satellite sharing with other services, to take account of the low use of the band by the satellite community, the current situation in Region 1 and the fact that elsewhere in the world in Regions 2 and 3 where there is no satellite allocation.The criterion adopted for the protection of the FSS is that, on any satellite system, the emissions from should not cause an increase of the equivalent temperature greater that x% of the noise temperature of the satellite receiver in clear sky conditions without interference,  
i.e. Δ*T/T*≤ x%.

In the first instance values for x% = x1 + x2 + x3 = 32%, where x1 = 6% for co-primary services, x2 = 1% for non-primary services and x3 = 25% for intra-satellite interference. In the case of the 5 725-5 850 MHz band there is an argument that 25% is too high a figure for a band that is very lightly used by satellites and some of this allowance could be allocated to the other co-primary services.

Regarding geographic and service apportionment the norm would be to use a simply split the % for Δ*T/T* used (e.g. 6%/2 = 3%) for each of these apportionments but in this case, it is unlikely that mobile and fixed services will be in the same place at the same time and it is also unlikely that the busy hours across different tme zones would be synchronised. Therefore, we believe that that using the normal simple way of apportionment would be overly conservative and some allowance for the factors mentioned above should be taken into account when looking at the final apportionment to be agreed.

Examples of the new results if we were to look at a more equal apportionment of the increase allowed in Δ*T/T* can be seen below in Table 4.14.

Table 4.14

FSS / RLAN Sharing scenarios for 5 725-5 850 MHz for new ΔT/T and apportionment values



#### 4.2.2.10 Further Considerations on additional RLAN vs FSS studies

This section looks at studies looking at the effect real satellite footprints, RLAN deployments and interference apportionment. In ECC Report 244 studies looked at using simple approximations for both the apportionment methodology and the Satellite antenna contours to be used when looking at aggregate sharing in the band between RLAN and FSS (E to S). As a result, in ECC Report 244 (which study 1 is based upon) there was a recommendation to carry out further studies looking at the following:

Some studies looking at real satellite antenna profiles and RLAN deployments rather than simple negotiated satellite generic footprints and limited geographical RLAN deployments.

Other possible *I/N* values based on discussions on what should be suitable interference apportionment taking into account the sharing criteria for this particular band which appears underutilized by satellite operators.

In ECC Report 244 for this particular band, the method of apportionment used in combination with the negotiated satellite footprints (rather than real antenna profiles) was considered by some administrations to be a conservative approach, to the studies, below contain some suggestions for additional studies to address these concerns

In studies sent into ITU-R WP 5A previously after the publication of ECC Report 244 there have been some suggested methodologies to look at using generic FSS footprints or actual FSS antenna profiles in combination with the RLAN deployment numbers outside of Europe to take away the need for simple ways of looking at geographic apportionment. In addition, there were new studies that look at the balance between the methodology for the apportionment criteria presented in Recommendation ITU-R S.1432-1 and the amount of actual satellites using the 5 725-5 850 MHz in Region 1.

One contribution submitted during this study cycle proposed a more accurate way of dealing with geographical apportionment in the 5 150‑5 250 MHz bands studies by taking account of the RLAN deployments across the whole of a satellite footprint rather than the simple methodology proposed in ECC Report 244. Although this paper was looking at sharing with MSS feeder links operating in 5 150-5 250 MHz the methodology could be equally used for sharing with FSS in the 5 725‑5 850 MHz. If we use the same assumptions on RLAN activity with the population statistics, BEL and methodology as those used in the French contribution see table xx below, we can calculate the interference from all the RLANs under the generic satellite footprint.

Below are the figures for Europe and Africa.

Table 12

Statistics for the two continents according to the data provided in and to the urban, suburban and rural apportionment used for MSS

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Continent | Number of Inhabitant | Simultaneous active RLAN density per Inhabitant within MSS channel | Total number of active RLAN density per Inhabitant | Urban | Suburban | Rural |
| Europe | 728 619 134 | 0,0022 | 1 602 962 | 802 239 | 431 159 | 369 564 |
| Africa | 812 404 910 | 0,00055 | 446 822 | 225 199 | 103 455 | 118 168 |

The table above shows the number of inhabitant and density figures for MSS footprints. See below in table 13 for the revised results showing the impact that using a simplified methodology for FSS where we just increase the overall population of RLAN APs to reflect the addition of Africa plus using a more balanced approach to the interference apportionment of 10% that could be used in this band to reflect the lack of use by the satellite industry in the 5 725-5 850 MHz band.

TABLE 13



Additional work inputted to CEPT looking at using actual Satellite Antenna profiles.

In documents inputted by Transfinite of behalf of the Wi-Fi Alliance to the CEPT studies there was a proposed methodology with some example results using actual Satellite antenna profiles. The results showed that in some cases the sharing situation could be up to 9 dB better than using real antenna profiles rather than the negotiated satellite footprints. In order to have some confidence in this proposed methodology there would have to be a number of other real satellite antenna profiles studied to see what the range of results would look like.

#### 4.2.2.11 Considerations on the new study results

Both the review carried out of the original inputs from the model used in Study 1 and the measurement campaign indicate that a number of the scenarios that were modelled were unrealistic. Results of both of these studies indicate that figures nearer the middle of the range of cases studies in ECC Report 244 would constitute a conservative analysis of future RLAN use.

In addition, the study results indicate that uncontrolled access to the band for large numbers of high power outdoor access points could significantly increase the potential for interference to occur at some point in the future to FSS. Further studies to further investigate the effect that some simple mitigation techniques would have on the sharing situation like limiting the maximum power levels to 200 mW and limiting the outdoor use of the band (i.e. no fixed outdoor use) have also been carried out.

When looking at the results of study 2 which builds upon the work carried out in Study 1, we can conclude that sharing may be marginal with RLANs at 1W, but when the additional mitigation techniques are implemented sharing is possible between RLAN at 200 mW (no uncontrolled fixed outdoors) and FSS in the 5 725-5 850 MHz band.

In making these conclusions, the following factors were taken into account:

– The bigger picture regarding the conservative methodology used in Recommendation ITU-R S.1432-1 to derive the sharing criteria for satellite sharing with other services;

– The low use of the 5 725-5 850 MHz band by the satellite community;

– As the angle towards the geo – satellites will increase when looking at Africa and elsewhere in Region 1 we would expect this to result in higher BEM losses and lower clutter losses. The effect of these differences was not studied but overall, we would expect there to be additional losses which would enhance sharing.

– The results of previous studies in CEPT shows that there could be a significant difference between results using real antenna profiles and the negotiated satellite footprints used in ECC Report 244 and study 1.

– The current situation elsewhere in the world in regions 2 and 3 where there is no satellite allocation and RLAN use is already established in the band.

– If RLANs were also to get access to the spectrum in 5 925-6 425 MHz in the future, then the aggregate sharing situation would be further enhanced by between 2 to 3 dB.

Table 4.14

FSS / RLAN Sharing scenarios for 5 725-5 850 MHz for new ΔT/T and apportionment values



#### 4.2.2.12 Considerations on studies results so far

Both the review carried out of the original inputs from the model used in ECC Report 244 and the measurement campaign indicate that a number of the scenarios that were modelled in study 1 were unrealistic. Results of both the further analysis of the assumptions used in study 1 and the results of the measurement campaign covered by study 2 indicate that figures nearer the middle of the range of cases studies in ECC Report 244 would constitute a conservative analysis of future RLAN use.

Therefore, it is suggested to use the results of the further analysis using more realistic assumptions and the results of the measurement campaign to come up with a more realistic conservative analysis. The results tacking account of this further analysis and measurement campaign can be seen in Tables 4.11 and 4.12.

In addition, the results of study 2 indicate that large numbers of high power, outdoor access points could significantly increase the coexistence risk with current FSS use in Region 1 so it further investigated the effect that some simple mitigation techniques would have on the sharing situation (based on the fact that the allocation is for mobile stations) like limiting the maximum power levels to 200 mW and limiting the outdoor use of the band (i.e. no fixed outdoor use). The results tacking account of this further analysis and measurement campaign can be seen in Tables 5.13.

Study 2 also looks at some other factors that need to be taken into account regarding suitable sharing criteria to be used and apportionment when looking at FSS use in 5 725-5 850 MHz band. Unlike above 5 850 MHz there is very little current or planned future use of the 5 725-5 850 MHz band by FSS in Region 1. This limited use of the band means the apportionment between the services may need to be rebalanced to take account of the lack of FSS use in the band. The results tacking account of various examples of rebalancing can be seen in Tables 4.14.

Overall, when looking at the results from study 2, we can conclude that sharing is possible between RLAN and FSS in the 5 725-5 850 MHz band especially if further mitigation techniques are implemented.

# 5 Summary of sharing and compatibility studies per service

## 5.1 General considerations

Studies have been conducted with regards to sharing with the radiolocation and the fixed satellite services in Region 1.

Concerning the radiolocation service no new mitigation technique has been proposed in order to allow sharing with studied modes of radars 22 and 23 from Recommendation ITU-R M.1638-1.

## 5.2 Sharing and compatibility results in the 5 725-5 850 MHz band with regards to the radiolocation service

Under the assumptions studied, the separation distances from single-source interference range from several tens km for outdoor RLAN and indoor RLAN as well to ensure protection of ground-based radiolocation radars. Consideration of multi-source interference results in additional increase of the separation distance subject to the RLAN transmitters’ density and the considered Radar operational characteristics.

Analysis of the estimated results show that compatibility of RLAN with Radars operating in this frequency band may bedifficult for some administrations without mitigation techniques of interference caused by RLAN.

Another study based on a statistical approach, demonstrated that the current DFS are not able to detect the studied modes of radar 22 and 23 from Recommendation ITU-R M.1638-1. No new mitigation technique has been proposed in order to solve this problem. Sharing with the radiolocation service is not feasible under those conditions.

## 5.3. Sharing and compatibility results in the 5 725-5 850 MHz band with regards to the FSS

One study has been conducted with a variety of assumptions and interference environment. The initial conclusion was that sharing would be difficult without implementation of mitigation techniques.

Another study showed that by limiting the WAS/ RLANs to indoor only operations and a maximum e.i.r.p. of 200 mW sharing, including associated mitigation techniques, can be achieved between WAS/RLANs and the FSS, operating in Region 1 only, in the 5 725-5 850 MHz frequency band.

annex 1

FSS study 2 relevant sections from ECC Report 244 showing RLAN vs FSS sharing in the 5 725‑5 850 MHz band

Appendix 1 to Annex 1

## A1.1 Basic RLAN characteristics

Table A1-1

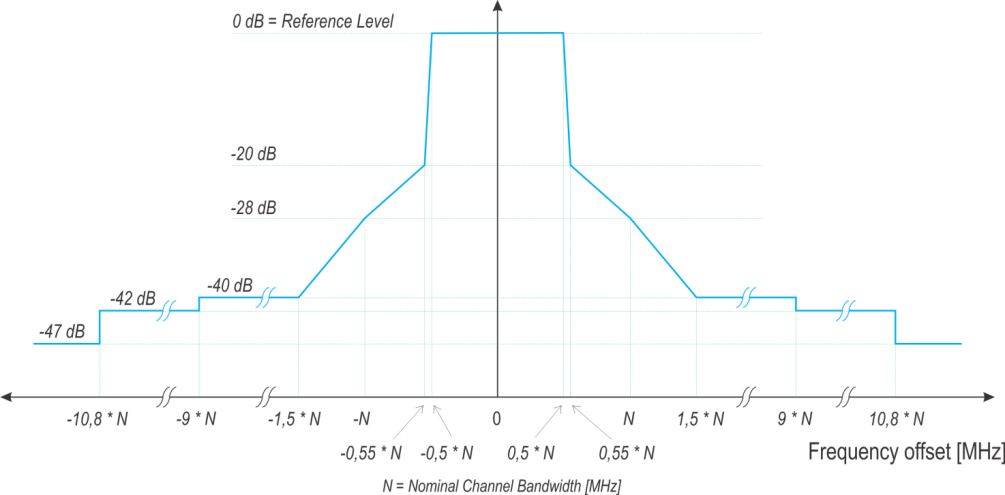
Basic RLAN (Wi-Fi) transmitter characteristics in the band 5 725-5 850 MHz

|  |  |  |  |
| --- | --- | --- | --- |
|  | RLAN 1 Omni-Indoor | RLAN 2  Omni Outdoor | RLAN 3 Directional Outdoor |
| Maximum Transmit Power (e.i.r.p. - dBm) | 23 | 30 | 30 |
| Bandwidth (MHz) | 20/40/80/160 | 20/40/80/160 | 20/40/80/160 |
| Maximum Transmit Power Density (e.i.r.p. - dBm/MHz) | 10/7/4/1 | 10/7/4/1 | 10/7/4/1 |
| Typical AP Antenna Type | Omni (azimuth) See **Error! Reference source not found.** and Type 1 and 2 | Omni (azimuth) See Type 1 and 2 | Directional, See Type 3 and 4 |
| AP Antenna directivity gain (dBi) | 0-6 | 6-7 | 12/18 |

The figure below provides the spectrum mask for RLAN as function of the nominal channel bandwidth, typically 20, 40, 80 or 160 MHz.

Figure A1-1

Spectrum mask for RLAN



The assumed average channel bandwidths distribution of RLAN devices is given in the following table.

Table A1-13

RLAN channel bandwidth distribution

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Channel bandwidth | 20 MHz | 40 MHz | 80 MHz | 160 MHz |
| RLAN Device Percentage | 10 % | 25 % | 50 % | 15 % |

The next table provides RLAN receiver parameters for the purpose of compatibility studies with RLAN as a victim.

Table A1-14

Basic RLAN receiver characteristics in the band 5 725-5 850 MHz

| System parameter | Value | | | |
| --- | --- | --- | --- | --- |
| Bandwidth (MHz) | 20 | 40 | 80 | 160 |
| kTB dBm / bandwidth | -101 | -98 | -95 | -92 |
| Typical Noise figure dB | 4 | | | |
| Noise Power  (dBm / bandwidth) | -97 | -94 | -91 | -88 |
| Typical Sensitivity for MCS0, BPSK  (½ coding rate) (dBm) | -92 | -89 | -86 | -83 |
| C/N for MCS0, BPSK  (½ coding rate) (dB) | 5 | | | |
| I/N (dB) (note 1) | -6 | | | |
| C/I (dB) | 11 for I/N -6 dB; 5 for I/N 0 dB | | | |
| Maximum antenna gain at the RLAN Access Point (dBi) | See **Error! Reference source not found.** | | | |
| Maximum antenna gain at the RLAN user device (dBi) |  | | | |
| Note 1: As per Recommendation ITU-R [M.1739](https://www.itu.int/rec/R-REC-M.1739-0-200603-I/en) ‎0‎0, the *I/N* ratio at the WAS/RLAN receiver should not exceed ‑6 dB, assuring that degradation to a WAS/RLAN receiver’s sensitivity will not exceed approximately 1.0 dB. Whilst it is designed to address interference from multiple sources, this criterion is also considered in this Report for single-entry analysis. | | | | |

### A1.1.1 RLAN antenna pattern

The characteristics in Table A1-5 are representative of an average antenna for all User Equipment within a population of RLAN devices. User Equipment can be defined as mobile or portable devices such as smart phones, tablets, notebooks, wireless scanners etc.

Table A1-15

RLAN User Equipment antenna (mobile/portable device)

|  |  |  |  |
| --- | --- | --- | --- |
| # | Type | Gain (dBi) | Antenna height above ground (m) |
| 1 | Omni-directional Antenna | 1.3 | 1 to 1.5 |
| NOTE: This value is the averaged value obtained from a survey on RLAN UE antennas. For simplicity, this antenna is assumed to be isotropic. | | | |

The antenna pattern in Table A1-3 is considered as a representative average antenna pattern for indoor access points within the RLAN population. The table specifies the gains available at elevation angles; the antenna pattern is omni-directional in azimuth.

Table A1-16

Example of Indoor RLAN Access Point Omni-directional (azimuth) Antenna -   
Elevation Pattern

|  |  |
| --- | --- |
| Elevation angle θ (Degrees) | **Gain (dBi)** |
| 45 < θ ≤ 90 | -4 |
| 35 < θ ≤ 45 | 0 |
| 0 < θ ≤ 35 | 3 |
| –15 < θ ≤ 0 | -1 |
| –30 < θ ≤ –15 | -4 |
| –60 < θ ≤ –30 | -9 |
| –90 < θ ≤ –60 | -8 |

The elevation angles in Table A1-5 are defined from the viewpoint of the RLAN Access Point when mounted to the ceiling. Positive elevation angles are towards the ground and negative elevation angles are towards the sky (typically, the RLAN AP is installed for optimal coverage). The pattern is normalised to 3 dBi gain on boresight.

Table A1-7 sets out the characteristics of RLAN antennas used on fixed indoor or outdoor equipment such as Access Points, Bridges, P2P or P2MP installations. The corresponding antenna patterns are provided in Figure A1-2 to Figure A1-5 below.

Table A1-17

Typical Fixed indoor and outdoor RLAN antenna   
(access points, bridges, P2P and P2MP)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| # | Type | Gain (dBi) | Indoor / Outdoor | Antenna pattern | Antenna Height (m) |
| 1 | Omnidirectional Antenna | 6 | Indoor & Outdoor | Figure A1-2 | 6 to 28,5 |
| 2 | Directional Antenna (sector) | 6 | Indoor & Outdoor | Figure A1-3 |
| 3 | Directional Antenna | 12 | Outdoor | Figure A1-4 |
| 4 | Directional Antenna (sector) | 17 | Outdoor | Figure A1-5 |
| NOTE: The (Highly) directional links are often installed on top of buildings | | | | | |

Figure A1-2

RLAN 6 dBi Omni – Elevation (left) and Azimuth (right) Radiation Patterns

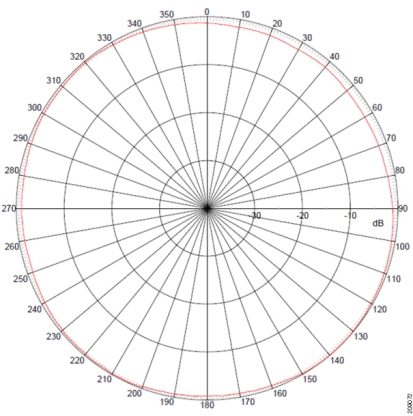
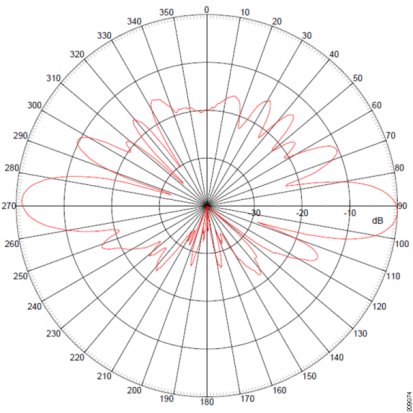


Figure A1-3

RLAN 6 dBi Directional – Elevation (blue) and Azimuth (red) Radiation Patterns

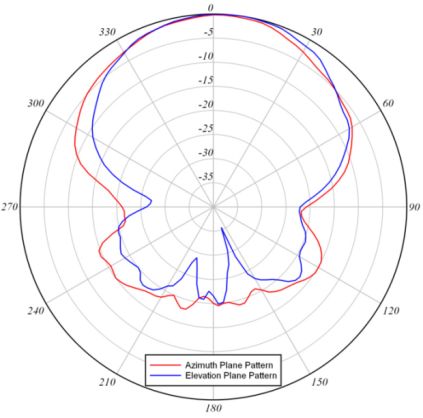


Figure A1-4

RLAN 12 dBi Directional – Elevation (blue) and Azimuth (red) Radiation Patterns

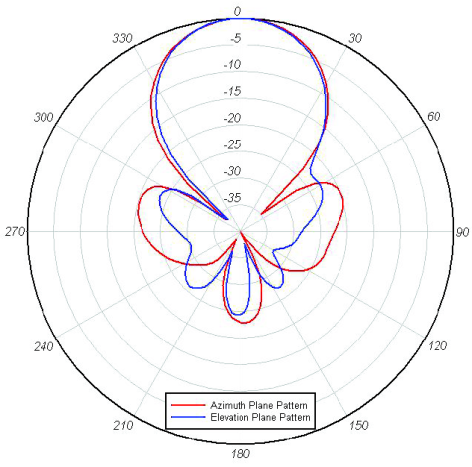
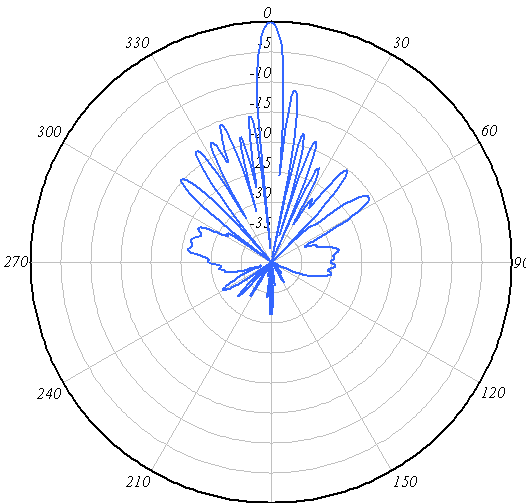
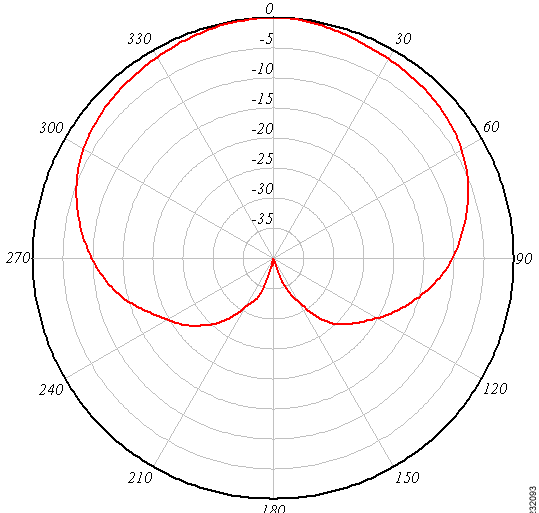


Figure A1-5

RLAN 17 dBi Sector Antenna – Elevation (blue) and Azimuth (red) Radiation Patterns



#### A1.1.1.1 RLAN APs antenna pattern measurements

A measurement campaign (see ‎0) was carried out to measure 7 different RLAN APs operating in the 5 GHz band (3 consumer and 4 enterprise 802.11ac Aps ‎0). This measurement presented the radiation pattern of all access points from 0° to 360° in azimuth and from −90° to +90° in elevation.

RLAN equipment can broadly be categorised in consumer, enterprise, and industrial equipment. The consumer segment is by far the biggest of the three, accounting for more than 85% of unit shipments[[2]](#footnote-2).

In order to obtain representative results it was decided to characterise state-of-the art IEEE 802.11 ac ‎0 consumer and enterprise equipment.

The following IEEE 802.11 ac devices were measured:

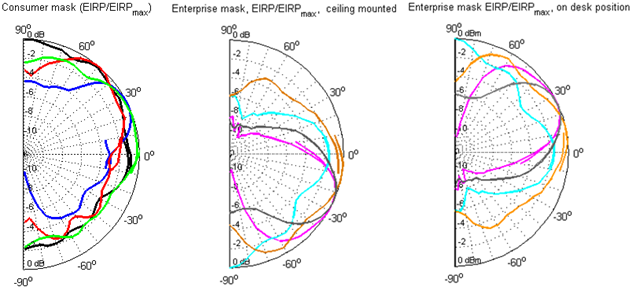
Table A1-18

Measured RLAN APs

|  |  |
| --- | --- |
| Consumer | Enterprise |
| Linksys EA6500 | Ubiquiti UAP-AC |
| Asus RT-AC66U | Aruba APIN0225 |
| Netgear R6300 | Zyxel NWA 1123-AC |
|  | Cisco Aircap 37021-E-K9 |

Figure A1-6

Consumer and Enterprise Antenna patterns



Consumer Access Points measured showed relatively low directivities and similar average e.i.r.p. with respect to elevation angles. In the majority of cases the maximum e.i.r.p. was observed at elevations between 20° and 75°.

Enterprise APs present higher directivities than the consumer ones. Consequently, the emission pattern depends strongly on how the AP is positioned (i.e. ceiling mounted or desk position).

### A1.1.2 RLAN power distribution

Table A1-19

RLAN power distribution

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Tx power e.i.r.p. | 1W (directional) | 1 W (omni) | 200 mW (omni) | 80 mW (omni) | 50 mW (omni) | 25 mW (omni) | all |
| Indoor | 0% | 0% | 18% | 25.6% | 14.2% | 36.9% | 94.7% |
| Outdoor | 0.10% | 0.20% | 0.95% | 1.35% | 0.75% | 1.95% | 5.3% |

The RLAN power distribution presented here leads to a 5.3 % use of outdoor devices. Sensitivity analysis may be performed with other outdoor use ratio to assess the impact of this parameter on the compatibility studies.

### A1.1.3 RLAN deployment and density of active devices

Two options were considered in CEPT Report 57 ‎0‎0 (see section A3.1.7):

Option A: From 0.0008 to 0.008 active devices per 20 MHz channel per inhabitant (based on 3% to 30% activity factor) applied to any population size”.

Option B: 4837 active devices per 20 MHz channel or 9871 active devices per 100 MHz channel per 5.25 million inhabitants as derived from the deployment figures provided in the table below.

Section ‎0 provides a detailed analysis on RLAN deployment and density of active devices used fort the compatibility studies with FSS.

# A1.2 FSS (Earth to space) in the band 5 725-5 850 MHz

### A1.2.1 FSS technical characteristics and deployments

In the 125 MHz portion of the band up to 5 850 MHz, this is a Region 1 allocation only (i.e. only Europe, Africa, and some of the northernmost countries in Asia). FSS deployments use the whole band 5 725-5 850 MHz and it is used by transmitting earth stations in the Earth-to-space direction operating only to satellites in geostationary orbits.

The following table 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) as can be seen by the satellite footprint coverage plots in Annex 6 of ECC Report 068 ‎0.

Table A1-20

Sample Satellite Data for the band 5 725-5 850 MHz

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Satellite | Sub-satellite longitude | Part of Frequency range 5 725-5 875 MHz used | Satellite Maximum Receive Gain Gsat (dBi) | Space Station Receiving System Noise Temperature Tsat (Kelvin) |
| A | 5o West | Whole band | 34 | 773 |
| B | 14o West | Whole band | 26.5 | 1200 |
| D | 3o East | Whole band | 34 | 773 |
| F | 53o East | Whole band | 26.5 | 1200 |
| G | 59.5o East | Whole band | 34 | 1200 |

Typical FSS parameters developed by the ITU are provided in table below.

Table A1-21

Typical FSS parameters in the 6 GHz band

|  |  |
| --- | --- |
| Parameter | Typical value |
| Range of operating frequencies | 5 850-6 700 MHz |
| Antenna diameters (m) | 1.2, 1.8, 2.4, 3.0, 4.5, 8, 16, 32 |
| Antenna reference pattern | Recommendation ITU-R [S.465](https://www.itu.int/rec/R-REC-S.465-6-201001-I/en) |
| Range of emission bandwidths | 40 kHz - 72 MHz |
| Receiving space system figure of merit | +5 ↔ -10 dB/K (The database of Recommendation ITU-R [S.1328](https://www.itu.int/rec/R-REC-S.1328-4-200209-I/en) provides one example with Gsat= 24.8 dBi and Ts= 400 K, corresponding to a G/T of -1.2 dB/K |
| Earth station deployment | All regions, in all locations (rural, semi-urban, 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](https://www.itu.int/rec/R-REC-S.524-9-200604-I/en) |
| Minimum earth station antenna elevation angle, h, (degrees) | 5, 15 and 40 |

### A1.2.2 Protection criteria of FSS systems in the bands 3 400-4 200, 4 500-4 800 and 5 850‑6 700 MHz

The criterion adopted for the protection of the FSS is that, on any satellite system, the RLAN emissions should not cause an increase of the equivalent temperature greater that x% of the noise temperature of the satellite receiver in clear sky conditions without interference, i.e. ΔT/T≤ x%.

In the first instance values for x = 6% (generally applicable for sharing in the case of two co‑primary services, e.g. the FSS and the MS as co-primary services without service apportionment) and x=1% (generally applicable to interference from a non-primary service into FSS, or to interference from several co-primary services, e.g. the MS and FS, into FSS) are utilised.

Apportionment of interference allowance

To apportion these FSS protection criteria among the potential sources of interference, an apportionment scheme has been considered where interference from RLANs is limited to half of the dT/T= 6% criterion i.e. the dT/T objective is reduced to a value of 3%. In addition, geographic apportionment is applied; dependent on the satellite’s coverage, this can have no effect on the dT/T objective or can reduce this to 1.5% or 1%.

# A1.3 Compatibility between RLAN and FSS (Earth to space) in the band 5 725‑5 850 MHz

## A1.3.1 Interference from RLAN into FSS (Earth to space) in the band 5 725‑5 850 MHz

### A1.3.1.1 Methodology

A methodology similar to the one used in ECC Report 206 ‎0 is used for the purpose of sharing and compatibility studies between RLAN and the FSS in the range 5 725-5 850 MHz.

The methodology follows a 2-step approach as outlined below:

– Step 1 is described in section ‎0: This step calculates the maximum number of active, on-tune, RLAN transmitters that can be accommodated by the satellite receiver under consideration (considering the satellite footprint) whilst satisfying the FSS protection criteria described in section ‎3.2.2.

• The criterion adopted for the protection of the FSS is that, on any satellite system, the RLAN emissions should not cause an increase of the equivalent temperature greater that x% of the noise temperature of the satellite receiver in clear sky conditions without interference, i.e. ΔT/T≤ x%. Some initial calculations and results are provided for x=6% (generally applicable for sharing in the case of two co-primary services, e.g. the FSS and the MS as co-primary services without service apportionment) and x=1% (generally applicable to interference from a non-primary service into FSS, or to interference from several co-primary services into FSS such as FS and MS). Further results are presented, taking account of a service and geographic apportionment scheme applied to the dT/T =6% criterion and further modelling considerations.

• Interference apportionment between various potential sources of interference into FSS can be addressed through the choice of the protection criterion. For example, for sharing between FSS and at least two other co-primary services such as FS and MS, the portion of interference allowed to the MS can be derived by apportioning the total x%. See section ‎0 for more elements and analysis on geographic and service apportionment.

• The propagation model is described in section A1.3.1.1.1.3.

– Step 2 is described in section ‎0: This step delivers the number of active, on-tune, RLAN transmitters using a deployment model. The Step 2 outputs can be compared with the Step 1 values in order to assess the potential for sharing. In theory, if the Step 2 values are less than or equal to the Step 1 values, then the results suggest that sharing is possible; else if the Step 2 values are greater than the Step 1 values, sharing is not possible.

#### A1.3.1.1.1 Step 1: Calculations for the maximum number of active RLAN transmitters within the FSS footprint

This section presents the calculations for the maximum number of active on-tune RLANs that can be accommodated by a victim satellite receiver considering a range of protection criteria.

##### A1.3.1.1.1.1 Generic calculations

The following parameters are considered in the calculations:

– RLAN e.i.r.p. distribution and channel bandwidth distribution as provided below.

Table A1-22

RLAN power distribution

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Tx power e.i.r.p. | 1W (directional) | 1 W (omni) | 200 mW (omni) | 80 mW (omni) | 50 mW (omni) | 25 mW (omni) | all |
| indoor | 0% | 0% | 18% | 25.6% | 14.2% | 36.9% | 94.7% |
| outdoor | 0.10% | 0.20% | 0.95% | 1.35% | 0.75% | 1.95% | 5.3% |

Table A1-23

RLAN channel bandwidth distribution and bandwidth correction values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Channel bandwidth | 20 MHz | 40 MHz | 80 MHz | 160 MHz |
| RLAN Device Percentage | 10 % | 25 % | 50 % | 15 % |
| Average bandwidth correction ratio | 0.7 | 0.5 | 0.5 | 0.25 |

– RLAN antenna discrimination towards space: calculations are performed using two values: 0 dBi and 4 dBi.

– Building (indoor to outdoor) attenuation, calculations are performed using two values: 12 dB and 17 dB.

The basic calculation method is illustrated in the table below. Assuming a free space path loss of 199.8 dB, the number of RLAN devices are increased until ΔT/T = 6 % exactly.

Table A1-24

Example calculation for the maximum number of RLANs



Based on this example calculation, Table A1-17 provides some initial results for the maximum number of RLANs that can be accommodated by the satellite receiver whilst satisfying a dT/T of 6%, taking into account two values of antenna discrimination (0 dB and 4 dB) and two values of building loss (12 dB and 17 dB).

Table A1-25

Initial results for Max number of RLANs for dT/T = 6%

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| dT/T = 6% |  |  |  |  |
| Antenna discrimination (dB) | 0 | 4 | 0 | 4 |
| Building loss (dB) | 17 | 17 | 12 | 12 |
| A | 242 000 | 606 000 | 175 000 | 440 000 |
| B | 2 106 000 | 52 90 000 | 1 528 000 | 3 837 000 |
| D | 242 000 | 606 000 | 175 000 | 440 000 |
| F | 2 106 000 | 5 290 000 | 1 528 000 | 3 837 000 |
| G | 375 000 | 941 000 | 272 000 | 683 000 |

##### A1.3.1.1.1.2 Service and geographic apportionment

It should be noted that the case of dT/T of 6% (Table A1-17) does not take account of service and geographic apportionment explicitly. The UK do not think there is a need to include any allowances for either geographic or service apportionment for the 5 725-5 850 MHz band but accept that further studies may be required.

##### A1.3.1.1.1.3 Further modelling considerations

There are other well-established factors that should be taken into account when modelling interference on the Earth to space interference paths and in order to achieve a more realistic model, some further modelling has been performed accounting for clutter loss and polarisation mismatch loss.

Clutter loss

Detailed calculations of the impact of clutter loss on the Earth to space interference path are given in ‎0. They are based on the method for the calculation of clutter loss on interference paths as set out in Recommendation ITU-R [P.452-15](https://www.itu.int/rec/R-REC-P.452-15-201309-S/en).

Depending upon the satellite under consideration, consideration of the clutter loss leads to a percentage increase in the RLAN population in the range 50.34% to 130.16%, as detailed in Table A1‑18 below.

Table A1-26

Impact of clutter loss

|  |  |
| --- | --- |
| Satellite | Increase in the RLAN population when clutter is modelled  (%) |
| A | 51.43 |
| B | 77.58 |
| D | 51.43 |
| E | 78.08 |
| F | 105.98 |
| G | 118.95 |

Polarisation Mismatch Loss

Rationale for values considered for the polarisation mismatch loss and detailed calculations of its impact are given in ‎0. These calculations are based on two values of polarisation mismatch loss, 3 dB and 1.5 dB, applied to those outdoor RLANs that are not exposed to clutter loss.

For all satellites, consideration of polarisation mismatch of 3 dB leads to a percentage increase in the RLAN population of 42% when 12 dB building attenuation is used and 70% when 17 dB building attenuation is used.

When considering a polarisation mismatch loss of 1.5 dB, the increase in the RLAN population is 21% when 12 dB building attenuation is used and 31% when 17 dB building attenuation is used

Maximum number of RLANs after further modelling

Taking into account clutter loss and polarisation mismatch loss, the following Table A1-27 give the maximum number of on-tune, active, RLANs for the bands 5 725-5 850 MHz.

Table A1-27

Maximum number of on-tune RLAN for the 5 725-5 850 MHz band for Step 1   
(apportionment scheme applied)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Band 5 725‑5 850 MHz | With clutter loss and  no polarisation mismatch | | | | With clutter loss and  polarisation mismatch | | | |
| Antenna discrimination (dB) | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 4 |
| Building loss (dB) | 17 | 17 | 12 | 12 | 17 | 17 | 12 | 12 |
| A | 91 615 | 229 416 | 66 251 | 166 573 | 155 746 | 390 008 | 94 076 | 236 534 |
| B | 934 959 | 2 348 496 | 678 356 | 1 703 436 | 1 589 430 | 39 92 442 | 963 265 | 2 418 879 |
| D | 91 615 | 229 416 | 66 251 | 166 573 | 155 746 | 390 008 | 94 076 | 236 534 |
| F | 1 084 485 | 2 724 086 | 786 844 | 1 975 863 | 1 843 624 | 4 630 945 | 1 117 318 | 2 805 726 |
| G | 205 266 | 515 080 | 148 886 | 373 857 | 348 952 | 875 636 | 211 418 | 530 877 |

#### A1.3.1.1.2 Step 2: RLAN deployment model

**Step 1**, described in section ‎0, provides calculations for the maximum number of active on-tune RLANs that can be accommodated by a victim satellite receiver based on a range of FSS protection criteria; initial results and results based on more advanced modelling and the apportionment scheme summarised in Table 1-16 are presented. For Step 1, the RLAN deployment is considered over all European countries/areas.

**Step 2**, presented in this section, aims to develop an RLAN deployment model for Europe with an objective to calculate the number of on-tune RLANs over this area in 2025. In theory, if the value delivered by Step 2 is less than or equal to that obtained in Step 1, this suggests that sharing is feasible.

Although it is obvious that both RLAN Access Points (APs) and terminals present interference potential to incumbent services, this section assumes that APs and terminals are not transmitting simultaneously. The calculation of the number of on-tune RLANs can thus be simplified by calculating the number of on-tune RLAN APs using the following methodology.

This methodology consists of 8 stages:

– Stages 1 to 3 aim at defining the expected total number of RLAN APs over Europe.

– Stages 4 to 7 are considering RLAN operational parameters to derive the expected total number of on-tune, active, RLANs over Europe.

– Stage 8 aims to apply an upper bound on channel re-use.

#### A1.3.1.1.3 Elements related to stages 1 to 3

Stage 1: Define RLAN deployment environments and obtain relevant statistics

The aim is to define RLAN deployment environments and obtain statistics for the set of countries/areas considered (e.g. number of households, number of enterprise establishments).

Stage 2: Assign the statistics obtained in Stage 1 to urban, suburban and rural environments

The aim is to assign the statistics obtained in Stage 1 to urban, suburban and rural environments. This will be more realistic than averaging the RLAN APs over the entire European area. A realistic AP density in urban areas, in particular, allows for a practical investigation of the planning constraints (stage 8).

Stage 3: Apply Market penetration factors in different environments

These factors describe RLAN penetration into the different environments e.g. residential, enterprise and the number of APs per household/enterprise.

Stages 1 to 3 calculations

Detailed statistics and elements related to stages 1 to 3 are provided in ‎0 and ‎0 using a deployment model for the projected 2025 RLAN deployment in the whole of Europe and/or the EU‑28.

Taking into account these elements and the large number of assumptions, it was agreed that some probable scenarios for the situation in 2025 are those defined in Table A1-28 below, based on the following assumptions from **‎0** And ‎0:

– Household “high” scenario with 90% penetration for EU-28 and 85% for the whole of Europe and medium projected growth of 10.4%.

– 2 RLAN APs per household >120 sqm (scenario A, corresponding to 1.22 AP average) or 2 RLAN APs per household >100 sqm (scenario B, corresponding to 1.35 AP average).

– Enterprise “medium” scenario.

– 10 Million non-residential hotspots.

– 5% Add-on to cover all other type of usage, such as transport, industrial, mobile wifi, etc.

Table A1-28

Predictions of number of RLAN APs for 2025



On this basis, it was agreed that taking a value of 400 Million RLAN APs across Europe will provide a representative value to address the following Stages 4 to 7.

However, there is a certain level of uncertainty and, in order to reflect this, it was agreed to consider a range from 300 Million to 500 Million RLAN APs in Europe.

#### A1.3.1.1.4 Elements related to Stages 4 to 7

Stage 4: Apply Busy Hour Factor

This Factor gives the percentage of RLAN APs involved in Busy Hour Activity. A range of values is appropriate.

In Stage 3 an estimate of the actual number of APs is given. Stage 4 applies a factor to the output of Stage 3 to obtain the number and density of APs involved in busy hour in urban, suburban and rural environments.

The deployment model should be worst-case i.e. it should aim to model peak RLAN activity rather than average RLAN activity.

ITU-R work (JTG 4-5-6-7) on RLAN at 5 GHz considered an average value (over the population in urban, suburban and rural areas) of 62.7% for the busy hour factor, assumed to be dominated by the corporate usage.

Some consideration was given to the development of a refined Busy Hour model. While the Busy Hour factor is different for enterprise and residential environments no evidence could be found that this is the case for urban, suburban and rural areas. The fact that the satellite footprint covers different time zones has also been considered. Nevertheless, some further work might be required to refine the busy hour factor model, for instance by taking into account the non-uniform distribution of traffic over the RLAN population.

It was agreed to consider figures of 50%, 62.7% and 70% for the busy hour factor.

Stage 5: Apply 5 GHz Spectrum Factor

This Factor gives the percentage of RLAN activity at 5 GHz (rather than at 2.4 GHz or 60 GHz). This factor is applied in order to obtain the number and density of APs operating at 5GHz in urban, suburban and rural environments during Busy Hour.

It should be noted that there will be RLAN activity at 2.4 GHz and 60 GHz and, since the frequency range under consideration is at 5 GHz only, some RLAN activity during peak periods can be discounted.

A figure of 80% was originally proposed by the RLAN industry based on an optimistic model of corporate Busy Hour where 5 GHz dominates.

In addition, ITU-R work (JTG 4-5-6-7) on RLAN at 5 GHz considered values for the market factor for different environments:

– 80% for urban;

– 80% for suburban, and

– 50% for rural.

These values represent an average figure (over the population in urban, suburban and rural areas) of 74% for the 5 GHz spectrum factor.

Further considerations have led to values of 50% and 97% being exercised. The rationales for these values are described below:

Rationale for a 5 GHz Spectrum Factor of 97%

RLAN has, at this time, 80 MHz of spectrum available in 2.4 GHz and could have potentially 775 MHz of spectrum including the expansion bands in the 5 GHz frequency range. Therefore, considering these two frequency bands but neglecting 60 GHz, about 90% of the spectrum available would be in the 5 GHz range.

Furthermore, the requirement for additional 5 GHz spectrum is mainly based on the need for high throughputs and hence 80 and 160 MHz channels that are only available at 5 GHz, as shown on the RLAN channel bandwidth distribution currently agreed. This distribution depicts a figure of 65% of use of such 80 MHz and 160 MHz bandwidths that cannot be accommodated in the 2.4 GHz band. In addition, the available number of 20 MHz channels is 3 (not overlapping) in the 2.4 GHz band whereas it is 37 in the extended 5 GHz band showing therefore a share of 8% at 2.4 GHz and 92% at 5 GHz for the small channels (20 or 40 MHz), i.e. 35% of the channel use. Taking into account the fact that the other 65% of the channel use (80 and 160 MHz) will only be accommodated at 5 GHz, this gives an overall share of channel use of 3 % (8% × 35%) at 2.4 GHz and 97% (92% × 35% + 65%) at 5 GHz.

Rationale for a 5 GHz Spectrum Factor of 50%

Estimations for the current market deployment of 2.4/5 GHz spectrum were made based upon single (2.4 GHz only) and dual-band (2.4/5 GHz) Wi-Fi products that were shipped (by the overall connectivity market leader) across multiple segments in 2014. By multiplying the “Percentage of single band versus dual band per segment” by the “Percentage of Total products shipped per segment” the percentage of dual-band devices shipped overall was determined.  Based upon the above the percentage of 5 GHz enabled dual band products shipping across all Wi-Fi segments is approximately 57%. This does not take into account any split in spectrum usage for the dual band devices and the 57% value calculated was therefore an overestimation of the 5 GHz spectrum factor as it assumes that all dual band devices are operating in 5 GHz mode only.

Over the coming years although the RLAN industry expects to see a move to an increase in dual‑band devices compared to single band devices it is also expected to see a penetration of up to 50% for 60 GHz devices. It was therefore suggested that a 5 GHz spectrum factor of 50% would be a reasonable estimation for current and longer term.

However, consideration of the 60 GHz band use could have an impact on the total number of APs in Europe as calculated under stage 1 to 3 above and would hence require further study.

It is understood that RLAN usage in the different frequency ranges in 2025 is difficult to predict and it was therefore agreed to consider figures of 50%, 74% and 97% for the 5 GHz spectrum factor.

Stage 6: Apply RF Activity Factor

This Factor gives the percentage of time that a RLAN is transmitting. When applied, this factor provides the number and density of active APs operating at 5 GHz during Busy Hour in urban, suburban and rural environments.

Recommendation ITU-R [M.1651](https://www.itu.int/rec/R-REC-M.1651-0-200306-I/en) sets out a method and example calculations that can be used as inputs to a calculation for the RF activity factor. For example: in the home environment, an RLAN accessing VHiMM for the entire Busy Hour has an individual Activity Factor (related to this VHiMM service only) of 12%.

It is agreed that a range of 3 to 30% is relevant for this factor. Within this range, it is also proposed to consider an activity factor of 10% corresponding to the figure proposed in JTG by the RLAN industry for rural deployment.

Sources: See section ‎0 and CEPT Report 57 ‎0 (see section A3.1.7). This range covers JTG options A and B. The values of 3% and 30%.

Stage 7: Calculate the number of on-tune RLAN APs per 40 MHz

This stage provides the number and density of active, on-tune, APs operating at 5 GHz during Busy Hour, incident to a 40 MHz victim receiver bandwidth sourced from all (urban, suburban and rural) environments.

As described in ECC Report 244 ‎0, this factor depends on the relative positioning of the 40 MHz victim receiver bandwidth on the RLAN channelization scheme, the total number of RLAN channels (for each bandwidth) and the RLAN bandwidth distribution. Stage 7 should be considered together with any bandwidth corrections made during Step 1 (see section ‎8.1.2).

As shown in ECC Report 244 ‎0, there are 2 options to calculate this factor that differ in their outputs (and in where bandwidth correction factors are applied):

– Option 1: delivers the total number of on-tune, active RLANs overlapping in frequency with the 40 MHz FSS receiver. Bandwidth correction factors are considered in Step 1.

– Option 2: delivers the equivalent number of on-tune, active, 40 MHz interferers incident to the 40 MHz FSS receiver. Here the bandwidth correction factor is considered in Step 2.

Outputs from Step 1 are easily adjusted but since the bandwidth correction factor is already considered in Step 1 (see section ‎0), Option 1 is considered the simplest to implement in this study.

This leads to a factor of 12.9% of the total number of RLANs in the 5 GHz range overlapping the 40 MHz FSS receiver bandwidth (see detailed calculations in **Error! Reference source not found.**).

Stages 4 to 7 calculations

The following table provides the aggregate factor from Stages 4 to 7, for the 27 different cases resulting from the range of figures for Stage 4 (busy hour factor, 3 figures), stage 5 (spectrum factor, 3 figures) and stage 6 (activity factor, 3 figures).

Table A1-29

Aggregate factors 4 to 7

|  | Stage 4 | Stage 5 | Stage 6 | Stage 7 | Aggregate |
| --- | --- | --- | --- | --- | --- |
|  | Busy hour population | 5 GHZ factor | Activity factor | 40 MHz FSS | Stage 4 to 7 |
| Case 1 | 50% | 50% | 3% | 12.9% | 0.0010 |
| Case 2 | 50% | 50% | 10% | 12.9% | 0.0032 |
| Case 3 | 50% | 50% | 30% | 12.9% | 0.0097 |
| Case 4 | 50% | 74% | 3% | 12.9% | 0.0014 |
| Case 5 | 50% | 74% | 10% | 12.9% | 0.0048 |
| Case 6 | 50% | 74% | 30% | 12.9% | 0.0143 |
| Case 7 | 50% | 97% | 3% | 12.9% | 0.0019 |
| Case 8 | 50% | 97% | 10% | 12.9% | 0.0063 |
| Case 9 | 50% | 97% | 30% | 12.9% | 0.0188 |
| Case 10 | 62.70% | 50% | 3% | 12.9% | 0.0012 |
| Case 11 | 62.70% | 50% | 10% | 12.9% | 0.0040 |
| Case 12 | 62.70% | 50% | 30% | 12.9% | 0.0121 |
| Case 13 | 62.70% | 74% | 3% | 12.9% | 0.0018 |
| Case 14 | 62.70% | 74% | 10% | 12.9% | 0.0060 |
| Case 15 | 62.70% | 74% | 30% | 12.9% | 0.0179 |
| Case 16 | 62.70% | 97% | 3% | 12.9% | 0.0024 |
| Case 17 | 62.70% | 97% | 10% | 12.9% | 0.0078 |
| Case 18 | 62.70% | 97% | 30% | 12.9% | 0.0235 |
| Case 19 | 70% | 50% | 3% | 12.9% | 0.0014 |
| Case 20 | 70% | 50% | 10% | 12.9% | 0.0045 |
| Case 21 | 70% | 50% | 30% | 12.9% | 0.0135 |
| Case 22 | 70% | 74% | 3% | 12.9% | 0.0020 |
| Case 23 | 70% | 74% | 10% | 12.9% | 0.0067 |
| Case 24 | 70% | 74% | 30% | 12.9% | 0.0200 |
| Case 25 | 70% | 97% | 3% | 12.9% | 0.0026 |
| Case 26 | 70% | 97% | 10% | 12.9% | 0.0088 |
| Case 27 | 70% | 97% | 30% | 12.9% | 0.0263 |

#### A1.3.1.1.5 Overall application of stages 1 to 7

Taking into account the above elements in sections 8.1.3.1 and 8.1.3.2, final results of calculations in this study are summarised in Table A1-30 below.

Table A1-30

Number of on-tune RLAN APs per 40 MHz

|  | Aggregate Stages 4 to 7 (see section 8.1.3.2) | Total number of on-tune RLAN in Europe (for 300 Million APs) | Total number of on-tune RLAN in Europe (for 400 Million APs) | Total number of on-tune RLAN in Europe (for 500 Million APs) |
| --- | --- | --- | --- | --- |
| Case 1 | 0.0010 | 290 118 | 386 824 | 483 530 |
| Case 2 | 0.0032 | 967 061 | 1 289 414 | 1 611 768 |
| Case 3 | 0.0097 | 2 901 182 | 3 868 243 | 4 835 304 |
| Case 4 | 0.0014 | 429 375 | 572 500 | 715 625 |
| Case 5 | 0.0048 | 1 431 250 | 1 908 333 | 2 385 417 |
| Case 6 | 0.0143 | 4 293 750 | 5 725 000 | 7 156 250 |
| Case 7 | 0.0019 | 562 829 | 750 439 | 938 049 |
| Case 8 | 0.0063 | 1 876 098 | 2 501 464 | 3 126 830 |
| Case 9 | 0.0188 | 5 628 294 | 7 504 392 | 9 380 490 |
| Case 10 | 0.0012 | 363 808 | 485 078 | 606 347 |
| Case 11 | 0.0040 | 1 212 694 | 1 616 926 | 2 021 157 |
| Case 12 | 0.0121 | 3 638 083 | 4 850 777 | 6 063 471 |
| Case 13 | 0.0018 | 538 436 | 717 915 | 897394 |
| Case 14 | 0.0060 | 1 794 788 | 2 393 050 | 2991 313 |
| Case 15 | 0.0179 | 5 384 363 | 7 179 150 | 8 973 938 |
| Case 16 | 0.0024 | 705 788 | 941 051 | 1 176 313 |
| Case 17 | 0.0078 | 2 352 627 | 3 136 836 | 3 921 045 |
| Case 18 | 0.0235 | 7 057 881 | 9 410 507 | 11 763 134 |
| Case 19 | 0.0014 | 406 166 | 541 554 | 676 943 |
| Case 20 | 0.0045 | 1 353 885 | 1 805 180 | 2 256 475 |
| Case 21 | 0.0135 | 4 061 655 | 5 415 541 | 6 769 426 |
| Case 22 | 0.0020 | 601 125 | 801 500 | 1 001 875 |
| Case 23 | 0.0067 | 2 003 750 | 2 671 667 | 33 395 83 |
| Case 24 | 0.0200 | 6 011 250 | 8 015 000 | 10 018 750 |
| Case 25 | 0.0026 | 787 961 | 1 050 615 | 1 313 269 |
| Case 26 | 0.0088 | 2 626 537 | 3 502 050 | 4 377 562 |
| Case 27 | 0.0263 | 7 879 611 | 10 506 149 | 13 132 686 |

Comparison of these values with that obtained in Step 1 are provided in ‎0 for the above 27 cases and all satellites, taking into account 400 Million APs.

Compared to these results for 400 Million APs, the case of 300 Million and 500 Million AP can be extrapolated with a factor -1.25 dB and +0.97 dB, respectively, as shown in ECC Report 244 ‎0.

In order to summarise these results, it was agreed to present the results for 3 specific scenarios, as described in the Table A1-31 below:

Table A1-31

Scenarios for FSS summary analysis

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Scenario | Number of AP | Busy hour factor | Spectrum factor | RF activity factor | Total number of on-tune RLAN in Europe |
| “Optimistic” scenario  (Case 1 above) | 300 M | 50 % | 50 % | 3 % | 290 118 |
| “Medium” scenario  (Case 14 above) | 400 M | 62.7 % | 74 % | 10 % | 2 393 050 |
| “Pessimistic” scenario  (Case 27 above) | 500 M | 70 % | 97 % | 30 % | 13 132 686 |

Also, the different FSS satellites have been split in 5 different groups as in Table A1-32, considering similarities in interference potential, taking into account their main characteristics (e.g. max antenna gain, receiving system noise, orbital position, etc.)

Table A1-32

FSS groups for FSS summary analysis

|  |  |  |  |
| --- | --- | --- | --- |
| FSS Group | Satellites | Main characteritics | Remarks |
| FSS Group 1 | B  F | Typical 26.5 dBi antenna gain | Global beams |
| FSS Group 2 | G | Typical 28.5 dBi antenna gain | Global beams  (Satellite G presents a max antenna gain of 34 dBi but a higher system noise and a far east orbital position) |
| FSS Group 4 | A  D | Around 34 dBi antenna gain | Hemispherical beams |

On this basis, the FSS analysis can be summarised as given in Table A1-33 below, based on results taking into account clutter losses and polarisation mismatch with a 3 dB figure. If a figure of 1.5 dB is considered for the polarisation mismatch, the results would be modified by 0.7 dB (for the cases related to 12 dB building loss) and 1.13 dB (for the cases related to 17 dB building loss). For further details, see sections ‎0 and ECC Report 244 ‎0. As an example, the excess interference would be increased by these values.

Table A1-33

Summary of FSS analysis

| Scenario | Antenna discr. (dB) | Building loss (dB) | Band 5 725-5 850 MHz |
| --- | --- | --- | --- |
| “Optimistic” scenario  (Case 1 above) | 4 | 17 | FSS protection criteria satisfied for all FSS groups 1, 2 and 4 (margin ranges 1.3 to 12 dB) |
| 4 | 12 | FSS protection criteria satisfied for FSS groups 1 and 2  (margin ranges 2.6 to 9.9 dB). FSS protection criteria exceeded for other FSS group 4 (exceeding of 0.9 dB) |
| 0 | 17 | FSS protection criteria satisfied for FSS groups 1 and 2 (margin ranges 0.8 to 8 dB):  FSS protection criteria exceeded for other FSS group 4 (exceeding of 2.7 dB) |
| 0 | 12 | FSS protection criteria satisfied for FSS group 1 (margin ranges 5.2 to 5.9 dB). FSS protection criteria exceeded for other FSS groups 2 and 4 (exceeding ranges 1.4 to 4.9 dB) |
| “Medium” scenario  (Case 14 above) | 4 | 17 | FSS protection criteria satisfied for FSS group 1 (margin ranges 2.2 to 2.9 dB). FSS protection criteria exceeded for other FSS groups 2 and 4 (exceeding ranges 4.4 to 7.9 dB) |
| 4 | 12 | FSS protection criteria satisfied for FSS group 1 (margin ranges 0 to 0.7 dB). FSS protection criteria exceeded for other FSS groups 2 and 4 (exceeding ranges 6.5 to 10.1 dB) |
| 0 | 17 | FSS protection criteria exceeded for all FSS groups 1, 2 and 4 (exceeding ranges 1.1 to 11.9 dB) |
| 0 | 12 | FSS protection criteria exceeded for all FSS groups 1, 2 and 4 (exceeding ranges 3.3 to 14.1 dB) |
| “Pessimistic” scenario  (Case 27 above) | 4 | 17 | FSS protection criteria exceeded for all FSS groups 1, 2, 3, 4 and 5 (exceeding ranges 4.5 to 15.3 dB) |
| 4 | 12 | FSS protection criteria exceeded for all FSS groups 1, 2, 3, 4 and 5 (exceeding ranges 6.7 to 17.4 dB) |
| 0 | 17 | FSS protection criteria exceeded for all FSS groups 1, 2, 3, 4 and 5 (exceeding ranges 8.5 to 19.2 dB) |
| 0 | 12 | FSS protection criteria exceeded for all FSS groups 1, 2, 3, 4 and 5 (exceeding ranges 10.7 to 21.4 dB) |

It is important to understand that the potential for RLAN–FSS sharing (Step 2 in particular) is based on some assumptions that may still need further study and, although providing some relevant results, it is at this stage too early to draw any definite conclusions with regard to the potential for RLAN and FSS to share at 5 GHz.

Stage 8: Apply upper bound on channel re-use

The demographic statistics show that in the European Union (EU28) approximately 50% of the population and households (see ‎0, ‎0, ‎0, ‎0, 44 and ‎0) are situated in less than 2% of the total land mass. This stage focusses on applying an upper bound to the number of co-channel RLANs using a practical planning method (i.e. applying a minimum re-use distance between co‑frequency RLANs).

This method uses maximum channel re-use factors for active APs per km2 to derive an upper bound in densely populated areas.

This stage provides an adjustment to the results of Stage 7 by introducing an upper bound on the maximum density per km2 of RLAN APs in highly populated urban areas (e.g. London, UK).

The principle of this Stage 8 is agreed but it is recognised as not being trivial to calculate and quite time consuming. In addition, considering the quite large FSS footprint and since it may only apply to high densely population area, its potential advantage needs to be demonstrated.

At the time where this report was finalised, no studies were provided for Stage 8.

#### A1.3.1.1.6 Summary – analysis of results

The studies have focused on the assessment of the interference from RLAN into FSS and follow a two-step approach:

– **Step 1** is described in section ‎0: This step calculates the maximum number of active, on-tune, RLAN transmitters that can be accommodated by the satellite receiver under consideration (see **Error! Reference source not found.**) (considering the satellite footprint) whilst satisfying the FSS protection criteria described in section ‎3.2.2.

– **Step 2** is described in section ‎0: This step delivers the number of active, on-tune, RLAN transmitters using a deployment model. The Step 2 outputs can be compared with the Step 1 values in order to assess the potential for sharing. In theory, if the Step 2 values are less than or equal to the Step 1 values, then the results suggest that sharing is possible; else if the Step 2 values are greater than the Step 1 values, sharing is not possible.

Concerning step 1, results have been obtained considering 2 different values of building attenuation for indoor use (12 and 17 dB), two values of antenna discrimination (0 and 4 dB), and an approach to service and geographic apportionment of the FSS protection criteria of ΔT/T=6%.

Further modelling takes account of clutter loss and polarisation mismatch loss on the Earth to space interference path.

The different factors used in step 2 are subject to some uncertainties because of the difficulties involved when deriving values for these factors and in particular when making predictions for 2025. Therefore it was agreed to preform sensitivity analyses, taking into account ranges of values for some of these factors.

Calculations and results are presented in this report but, although providing some relevant results, it is at this stage too early to draw definite conclusions.

Conclusions on the potential for RLAN–FSS sharing will be developed in the Part 2 Report, taking into account additional considerations, such as:

– Antenna discrimination for outdoor RLANs.

– Further studies on polarisation mismatch.

– Studies supporting Stage 8 of FSS Step 2 (see section ‎0).

– 5 GHz Spectrum Factor (Stage 5 of FSS Step 2).

– Control / monitoring on the long term aggregate effect of RLAN interference into FSS as RLAN deployment increases and investigation of what can be done in a scenario where the interference threshold is reached.

– Further studies on apportionment of the FSS protection criteria.

#### A1.3.1.1.7 Potential mitigation techniques

Some potential mitigation techniques may need to be considered and their impact on the potential sharing between RLAN and FSS should be assessed. Among others, the following potential mitigation techniques could be addressed:

– RLAN Access Points deployed only indoor;

– Additional power limitation for RLAN.

There is a need for studies on the feasibility and practicability on the potential mitigation techniques.

Appendix 2 to aNNEX 1

Open Issues from ECC Report 244: LAA-LTE

## A2.1 LAA-LTE Characteristics

### A2.1.1 LAA-LTE RF characteristics

This section includes the LAA-LTE RF characteristics, such as transmission power, channel bandwidth, antenna characteristics, etc. which are relevant for the compatibility studies in the band 5 725-5 925 MHz.

#### A2.1.1.1 LAA-LTE transmission power characteristics

The first aspects taken into account are related to the maximum transmit power and in-band emission.

Table A2-34 and Table A2-23 show the basic characteristics of an LAA-LTE transmitter and a user equipment agreed for standardization ‎0 ‎0 . As it can be observed, LAA-LTE will fulfil same requirements as for RLAN characteristics used in ECC Report 244 in terms of conducted and radiated power and power spectral density limits. Also, available channel bandwidths will be aligned with those assumed for RLAN. In LAA-LTE, basic transmission bandwidth per carrier is 20 MHz. Transmissions on bandwidths higher than 20 MHz are done via carrier aggregation.

Table A2-34

Basic LAA-LTE Base station characteristics in the band 5 725-5 925 MHz

| System Parameters | Indoor | | Outdoor | |
| --- | --- | --- | --- | --- |
|  | RLAN | LAA-LTE | RLAN | LAA-LTE |
| Maximum Transmit Power (e.i.r.p. - dBm) | 23 | | 30 | |
| Bandwidth (MHz) | 20/40/80/160 | | 20/40/80/160 | |
| Maximum Transmit Power Density (e.i.r.p. - dBm/MHz) | 10/7/4/1 | | 17/14/11/8 | |
| Typical AP Antenna Type | Omni (azimuth) | Omni-directional (azimuth) | Omni (azimuth) | Omni-directional (azimuth) |
| AP Antenna gain + cable loses (dBi) | 0-6 | 5 | 6-7 | 5 |
| AP Antenna Height (m) | 6-28.5 | 6 | 6-28.5 | 10 |

Table A2-35

Basic LAA-LTE UE characteristics in the band 5 725-5 925 MHz

|  |  |  |
| --- | --- | --- |
| System parameter | Value | |
|  | RLAN | LAA-LTE |
| Maximum Transmit Power (e.i.r.p. - dBm) |  | 23 |
| Bandwidth (MHz) | 20/40/80/160 | |
| kTB (dBm / bandwidth) | -101 | |
| Typical Noise figure (dB) | 4 | 4 |
| Noise Power (dBm / bandwidth) | -97 | -97 |
| I/N (dB)[[3]](#footnote-3) | -6 | |
| Maximum antenna gain (dBi) | 1.3 | 0 |
| Antenna Height (m) | 1-1.5 | 1.5 |

#### A2.1.1.2 LAA-LTE UE power distribution

This section describes the LAA-LTE power distribution. For the case of user equipment (UE), transmit power levels will be allocated following the baseline 3GPP Fractional Power Control (FPC) method which has three components: base-line open loop operating point, dynamic offset part and bandwidth factor. The overall power control equation looks as follows:



Where  is the resulting UE transmit power level,  is the fractional path-loss compensation factor,  is the estimation of actual path-loss between the BS and the UE. The dynamic offset part consists of MCS (Modulation and Coding Scheme) dependent factor,  (TF stands for transmission format) and the explicit power control instruction part. The bandwidth factor is dependent on, which stands for granted bandwidth, in terms of number of granted PRBs.

Figure A2-7

Statistics of UL power levels used by the terminals in the indoor deployment scenario



Figure A2-7 shows the UL transmit power distribution for an indoor deployment scenario, which corresponds to the indoor in-building scenario in 3GPP TR 36.889‎0. In the indoor scenario, two operators deploy 4 small cells each equally spaced and centered in the single-floor building (50m‑by-120m). The distance between two closest nodes from two operators is random. Since the LAA-LTE BS is usually close to the UE in LAA-LTE operations, the terminals transmit in UL using typically low power levels. In this case, the median UE transmit power is less than 0 dBm, for SNRtarget =12 dB.

Figure A2-8 shows the UE transmit power distribution for an outdoor deployment (as specified in 3GPP TR 36.889‎0). In the outdoor scenario, the LAA-LTE cells are in clusters uniformly distributed within the macro geographical area; 4 small cells per operator, uniformly random dropping within the cluster area. As expected, in the outdoor case power levels are higher compared to the indoor case due to higher coupling loss. UL power distribution depends on the specific power control settings, results presented in Figure A2-7 and Figure A2-8 represents a reasonable trade-off in terms of noise raise due to intra system interference and achievable mean throughput. In this case, the median UE transmit power is less than 4 dBm, for SNRtarget =9 dB.

Figure A2-8

Statistics of UL power levels used by the terminals in the outdoor deployment scenario



For the case of LAA-LTE BS, actual transmit power varies according to the cell load variations. Thus, LAA-LTE BS transmits on full power only when the cell is fully loaded according to current specifications (LTE Release 8 BS). It is assumed that on average BS use half of the available power, i.e. an average 50% cell load. Averaged over time BS transmits at half maximum power, i.e. 20 dBm.

Table 3 summarises the LAA-LTE power distribution for both BS and UE, taking into account following assumptions:

– bandwidth distribution as shown in Table 4;

– equal transmission probability between UE and BS (50%/50% share);

– indoor/outdoor ratio of LAA-LTE UEs assuming that 85% and 15% of the traffic is generated indoors and outdoors, respectively;

– at least 9 UEs per LAA-LTE BS; thus, out of the LAA-LTE devices, there will be at least 10% LAA-LTE BS and the rest 90% will be LAA-LTE UEs;

– approximately, one in every six LAA-LTE BS is placed outdoor.

Influence of Wi-Fi deployed nearby LAA-LTE on the power distribution of LAA-LTE remains for further investigation.

Table A2-36

LAA-LTE power distribution considering both LAA BS and UE

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Tx power e.i.r.p. | 1 W | 200 mW | 140 mW | 100 mW | 50 mW | 13 mW | <=1mW | all |
| Indoor, % | 0,00 | 9,55 | 0,96 | 20,58 | 7,96 | 21,50 | 22,95 | 83,50 |
| Outdoor, % | 0,01 | 2,10 | 0,49 | 3,92 | 1,91 | 5,28 | 2,79 | 16,50 |

#### A2.1.1.3 LAA-LTE channel bandwidth characteristics

LAA-LTE can support different channel bandwidths through a carrier aggregation mechanism. It can be observed that IEEE and 3GPP standards are converging in terms of overall spectral efficiency. This is particularly true when the evolution of the 802.11 family with 802.11ax standard is considered. Assuming that LAA-LTE and Wi-Fi will be subject to the same traffic demand by the end users, it is reasonable to expect that very similar channel bandwidth distribution will be required by the two systems.

Based on the above observations, it is expected that Wi-Fi and LAA-LTE will have same channel bandwidth distribution as described in Table A2-37.

Table A2-37

LAA-LTE channel bandwidth distribution and bandwidth correction values

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Channel bandwidth | 20 MHz | 40 MHz | 80 MHz | 160 MHz |
| Device Percentage | 10 % | 25 % | 50 % | 15 % |

#### A2.1.1.4 LAA-LTE antenna pattern

The antenna pattern in Figure A2-9 is considered as representative average antenna pattern for LAA‑LTE omnidirectional antenna which can be employed for indoor and outdoor access points. In a typical deployment, LAA-LTE antenna will be mounted to the ceiling and titled down towards the ground which is beneficial in terms of coverage. Table A2-38 summarize the antenna characteristics for LAA-LTE omni-directional antenna.

Figure A2-9

LAA-LTE Omnidirectional - Elevation (left) and Azimuth (right) Radiation Patterns

|  |  |
| --- | --- |
| C:\Users\jose\Desktop\Image 1.jpg | C:\Users\jose\Desktop\Image 2.jpg |

Table A2-38

Typical Indoor and Outdoor LAA-LTE BS antenna (access point)

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| # | Type | Gain (dBi) | Indoor / Outdoor | Antenna pattern | Typical Antenna Height (m) |
| 1 | Omnidirectional Antenna | 5 | Indoor & Outdoor | Figure 3 | 6   (indoor)  10 (outdoor) |

### A2.1.2 Deployment scenarios of LAA-LTE

LAA-LTE is expected to be deployed by operators, mainly in hotspots and enterprise environments. Therefore deployments of possible LAA-LTE in the residential environment (user deployed) have not been considered in the current studies. These limited assumptions will have to be considered either in an expansion of future technical studies or as a possible regulatory issue to be studied. Operator-deployed means that the actual deployment will be “somewhat planned”, therefore LAA‑LTE will only be used in places where the operator coverage of LAA-LTE is available. Notice that the main target for LAA-LTE is mainly indoor small cells deployments, but outdoor deployment is not precluded as specified in 3GPP TR 36.889 which was developed by vendors and operators.

In the sections below, the potential deployment scenario of LAA-LTE is presented.

#### A2.1.2.1 Indoor scenario

##### A2.1.2.1.1 Enterprise environment

The enterprise deployment is a scenario where the users are in a business environment. So, in essence, this scenario will be a large office space, sport arena, shopping malls, factories, production facilities, etc. In this scenario, usually the locations are covered by wide area LTE network; however, LAA-LTE provides a capacity booster service. For this scenario, the following needs to be considered:

– User distribution/density: there will be dense users in these locations; however the users will be mainly active only in certain parts of the day. Also, in some locations, e.g. sports arena, large number of people will be requiring service only periodically and for a short period of time. In case of large office space or production facilities, there are possibilities that LAA-LTE BS can be LoS to each other. This is beneficial in a sense that, hidden node problem from channel access mechanism is largely removed.

– Usage/activity information: as mentioned earlier, the user density is high at certain times of the day, while there will be no active users in some other times, since the deployment locations for enterprise case only involves activities in certain part of the day.

##### A2.1.2.1.2 Extended indoor coverage

Compared to enterprise deployment, when LAA-LTE is used as capacity booster; for extended indoor coverage, e.g. parking floors or underground places (shops, store houses, etc.), LAA-LTE will be used mainly for providing coverage. In this case, wide area LTE network is sometimes not able to cover the places, thus deployment of LAA-LTE will provide the coverage. In this case, the coverage will be provided when LAA-LTE node will be used in heterogeneous deployment manner. The current understanding is that, extended indoor coverage may include mainly work/public areas. The residential coverage is out of question at this moment.

#### A2.1.2.2 Outdoor Scenario

##### A2.1.2.2.1 Immidiate outdoor scenario

This scenario includes parks, small open area just outside large buildings, enclosed outdoor places inside building areas, etc. This deployment is mainly for boosting the LTE capacity, not necessarily for coverage. Urban city center is one such example. There are few mobile users, however the users can be outdoors, or just inside the buildings. Usually, there are places where there are many people, looking for high data rate services.

##### A2.1.2.2.2 Large open spaces

LAA-LTE will also be deployed in large open spaces with significant number of users, e.g. train stations, or stadium, etc. In this case, the deployment conditions are very similar to the above immediate outdoor scenario; however, the user density at some point of time can be very high.

## A2.2 Compatibility between RLAN/LAA LTE and FSS (Earth to space) in the band 5 725-5 925 MHz

It should be noted that these studies are additional to those presented in ECC Report 244 and take account of both WiFI and LAA-LTE usage in the same band.

### A2.2.1 Step 1: Calculations for the maximum number of active RLAN transmitters within the FSS footprint

This section presents the calculations for the maximum number of active on-tune RLANs that can be accommodated by a victim satellite receiver considering a range of protection criteria‎0.

The following parameters are considered in the calculations:

– Mixed RLAN deployment between Wi-Fi and LAA-LTE:

• For the case of Wi-Fi, power distribution and channel bandwidth distribution as provided in ECC Report 244.

• For the case of LAA-LTE: power distribution and channel bandwidth distribution according section 3.1.

– Antenna discrimination towards space: calculations are performed using two values 0dB and 4 dB for both technologies, i.e. Wi-Fi and LAA-LTE.

– LAA-LTE will be driven by operators and service provider’s deployment, addressing enterprise and hotspot scenarios. Based on JRC prediction for the number of RLAN devices in 2025, the overall percentage of RLANs deployed in an enterprise and hotspot scenario is around 10% compared to 85% of residential usage. As baseline assumption, LAA-LTE will represent 90% of the enterprise sector and 70% of the hotspots. An additional use of 5% is also envisaged (see Table A2-39). On this basis, Step 1 calculations are performed with a share between WiFi and LAA of 91.56 % and 8.44 %, respectively.

– RLAN e.i.r.p. distribution and channel bandwidth distribution as provided in section 1.

– Building (indoor to outdoor) attenuation, calculations are performed using two values: 12 dB and 17 dB.

Table A2-39

Initial results for Max number of RLANs for dT/T = 6%

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **dT/T (%)** | **6% (Table 49)** | | | |
| Antenna discrimination (dB) | 0 | 4 | 0 | 4 |
| Building loss (dB) | 17 | 17 | 12 | 12 |
|  | | | | |
| **Satellite** | | | | |
| A | 235 500 | 588 750 | 173 600 | 434 000 |
| B | 2 056 000 | 5 140 000 | 1 516 000 | 3 790 000 |
| D | 235 500 | 588 750 | 173 600 | 434 000 |
| F | 2 056 000 | 5 140 000 | 1 516 000 | 3 790 000 |
| G | 365 500 | 913 750 | 269 400 | 673 500 |

Maximum number of RLANs after further modelling

Taking into account clutter loss and polarisation mismatch loss and the results given in Table A2‑28 the following Table A2-40 gives the maximum number of on-tune, active, RLANs for the bands 5 725‑5 850 MHz.

Table a2-40

Maximum number of on-tune RLAN for the 5 725-5 850 MHz band for Step 1 (apportionment scheme applied)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Band 5 725-5 850 MHz | With clutter loss and no polarisation mismatch | | | | With clutter loss and polarisation mismatch | | | |
| Antenna discrimination (dB) | 0 | 4 | 0 | 4 | 0 | 4 | 0 | 4 |
| Building loss (dB) | 17 | 17 | 12 | 12 | 17 | 17 | 12 | 12 |
| A | 89 344 | 223 359 | 65 834 | 164 585 | 151 884 | 379 711 | 93 485 | 233 711 |
| B | 914 537 | 2 286 343 | 673 916 | 1 684 790 | 1 554 713 | 3 886 782 | 956 961 | 2 392 402 |
| D | 89 344 | 223 359 | 65 834 | 164 585 | 151 884 | 379 711 | 93 485 | 233 711 |
| F | 1 060 797 | 2 651 993 | 781 694 | 1 954 235 | 18 03 355 | 4 508 387 | 1 110 006 | 2 775 014 |
| G | 200 339 | 500 848 | 147 244 | 368 110 | 340 577 | 851 442 | 209 086 | 522 716 |

### A2.2.2 Step 2: RLAN deployment model

This methodology consists of 8 stages:

– Stages 1 to 3 aim at defining the expected total number of RLAN APs over Europe.

– Stages 4 to 7 are considering RLAN operational parameters to derive the expected total number of on-tune, active, RLANs over Europe.

Since the predictions made by JRC were technology agnostic and based on predictions on the population growth by 2025, for simplicity sake the overall population of RLAN is assumed to be the reference value in the context of this study (noting that a range is exercised), whatever the market penetration is for the different technologies, although new applications offered by LTE LAA would tend to increase the overall number of access points/Base stations. Further studies may be required.

The overall percentage of RLAN deployed in an enterprise and hotspot scenario is around 10% compared to 85% deployed in a residential scenario. An additional use of 5% is also envisaged (see Table A2-41).Three possible scenarios for LAA-LTE and Wi-Fi deployment in 2025:

– LAA-LTE will represent all of the 10% AP deployed in enterprise and hotspot scenarios.

– LAA-LTE will be a completely new addition to the number of RLANs determined based on JRC projections.

– A percentage of RLANs deployed in enterprise and hotspots will be replaced by LAA‑LTE.

As baseline assumption, LAA-LTE will represent 90% of Wi-Fi deployed in enterprise and around 70% of the hotspot deployment; however a sensitivity analysis can be derived. Elements related to stages 1 to 3:

Stage 1: Define RLAN deployment environments and obtain relevant statistics.

Stage 2: Assign the statistics obtained in Stage 1 to urban, suburban and rural environments.

Stage 3: Apply Market penetration factors in different environments.

For elements related to stages 1 to 3, refer to section 8.1.3.1 of ECC Report 244.

Results are reminded in the table below:

Table A2-41

Predictions of number of RLAN APs for 2025



### A2.2.3 Elements related to stages 4 to 7

Stage 4: Apply Busy Hour Factor

The busy hour factor depends on the deployment area and it is not influenced by the RLAN system characteristics. Therefore, the average value of 62.7% considered already in the ITU-R work (JTG 4-5-6-7) on RLAN at 5 GHz and, figures of 50% and 70% for the busy hour factor should also be applicable to LAA-LTE system.

Stage 5: Apply 5 GHz Spectrum Factor

In the context of this report, it is reasonable to investigate spectrum factor values similar to those used in ECC Report 244 (refer to section 8.1.3.2 of ECC Report 244). Further studies may be required.

Stage 6: Apply RF Activity Factor

Given the current LAA-LTE functionalities (listen-before-talk, discontinuous transmissions, DFS, carrier selection and TPC) which are following the regulatory requirements for RLANs operating at 5 GHz, it is expected that LAA-LTE device will have same RF activity levels as other RLANs at 5 GHz. Therefore, the agreed range of 3 to 30% for the RF activity factor should also be applicable to LAA-LTE devices.

Stage 7: Calculate the number of on-tune RLAN APs per 40 MHz

Whatever the technology is, the RLAN have access to the same channels in the 5 GHz band and have the same system bandwidth available. Therefore, the number of RLAN Access points per 40 MHz as discussed in ECC Report 244 applies to LTE-LAA.

Table A2-42

Aggregate factors 4 to 7

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Stage 4 | Stage 5 | Stage 6 | Stage 7 | Aggregate |
|  | Busy hour population | 5 GHZ factor | Activity factor | 40 MHz FSS | Stage 4 to 7 |
| Case 1 | 50% | 50% | 3% | 12.9% | 0.0010 |
| Case 2 | 50% | 50% | 10% | 12.9% | 0.0032 |
| Case 3 | 50% | 50% | 30% | 12.9% | 0.0097 |
| Case 4 | 50% | 74% | 3% | 12.9% | 0.0014 |
| Case 5 | 50% | 74% | 10% | 12.9% | 0.0048 |
| Case 6 | 50% | 74% | 30% | 12.9% | 0.0143 |
| Case 7 | 50% | 97% | 3% | 12.9% | 0.0019 |
| Case 8 | 50% | 97% | 10% | 12.9% | 0.0063 |
| Case 9 | 50% | 97% | 30% | 12.9% | 0.0188 |
| Case 10 | 62.70% | 50% | 3% | 12.9% | 0.0012 |
| Case 11 | 62.70% | 50% | 10% | 12.9% | 0.0040 |
| Case 12 | 62.70% | 50% | 30% | 12.9% | 0.0121 |
| Case 13 | 62.70% | 74% | 3% | 12.9% | 0.0018 |
| Case 14 | 62.70% | 74% | 10% | 12.9% | 0.0060 |
| Case 15 | 62.70% | 74% | 30% | 12.9% | 0.0179 |
| Case 16 | 62.70% | 97% | 3% | 12.9% | 0.0024 |
| Case 17 | 62.70% | 97% | 10% | 12.9% | 0.0078 |
| Case 18 | 62.70% | 97% | 30% | 12.9% | 0.0235 |
| Case 19 | 70% | 50% | 3% | 12.9% | 0.0014 |
| Case 20 | 70% | 50% | 10% | 12.9% | 0.0045 |
| Case 21 | 70% | 50% | 30% | 12.9% | 0.0135 |
| Case 22 | 70% | 74% | 3% | 12.9% | 0.0020 |
| Case 23 | 70% | 74% | 10% | 12.9% | 0.0067 |
| Case 24 | 70% | 74% | 30% | 12.9% | 0.0200 |
| Case 25 | 70% | 97% | 3% | 12.9% | 0.0026 |
| Case 26 | 70% | 97% | 10% | 12.9% | 0.0088 |
| Case 27 | 70% | 97% | 30% | 12.9% | 0.0263 |

Table A2-43

Total number of on-tune RLAN in Europe for low, medium and high scenarios.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Aggregate Stages 4 to 7 (see section 8.1.3.2)** | **Total number of on-tune RLAN in Europe (for 300 Million APs)** | **Total number of on-tune RLAN in Europe (for 400 Million APs)** | **Total number of on-tune RLAN in Europe (for 500 Million APs)** |
| Case 1 | 0.0010 | 290 118 | 386 824 | 483 530 |
| Case 2 | 0.0032 | 967 061 | 1 289 414 | 1 611 768 |
| Case 3 | 0.0097 | 2 901 182 | 3 868 243 | 4 835 304 |
| Case 4 | 0.0014 | 429 375 | 572500 | 715 625 |
| Case 5 | 0.0048 | 1 431 250 | 1 908 333 | 2 385 417 |
| Case 6 | 0.0143 | 4 293 750 | 5 725 000 | 7156 250 |
| Case 7 | 0.0019 | 562 829 | 750 439 | 938 049 |
| Case 8 | 0.0063 | 1 876 098 | 2 501 464 | 3 126 830 |
| Case 9 | 0.0188 | 5 628 294 | 7 504 392 | 9 380 490 |
| Case 10 | 0.0012 | 363 808 | 485 078 | 606 347 |
| Case 11 | 0.0040 | 1 212 694 | 1 616 926 | 2 021 157 |
| Case 12 | 0.0121 | 3 638 083 | 4 850 777 | 6 063 471 |
| Case 13 | 0.0018 | 538 436 | 717 915 | 897 394 |
| Case 14 | 0.0060 | 1 794 788 | 2 393 050 | 2 991 313 |
| Case 15 | 0.0179 | 5 384 363 | 7 179 150 | 8 973 938 |
| Case 16 | 0.0024 | 705 788 | 941 051 | 1 176 313 |
| Case 17 | 0.0078 | 2 352 627 | 3 136 836 | 3 921 045 |
| Case 18 | 0.0235 | 7 057 881 | 9 410 507 | 11 763 134 |
| Case 19 | 0.0014 | 406 166 | 541 554 | 676 943 |
| Case 20 | 0.0045 | 1 353 885 | 1 805 180 | 2 256 475 |
| Case 21 | 0.0135 | 4 061 655 | 5 415 541 | 6 769 426 |
| Case 22 | 0.0020 | 601 125 | 801 500 | 1 001 875 |
| Case 23 | 0.0067 | 2 003 750 | 2 671 667 | 3 339 583 |
| Case 24 | 0.0200 | 6 011 250 | 8 015 000 | 10 018 750 |
| Case 25 | 0.0026 | 787 961 | 1 050 615 | 1 313 269 |
| Case 26 | 0.0088 | 2 626 537 | 3 502 050 | 4 377 562 |
| Case 27 | 0.0263 | 7 879 611 | 10 506 149 | 13 132 686 |

Table A2-44

Scenarios for FSS summary analysis

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Scenario | Number of AP | Busy hour factor | Spectrum factor | RF activity factor | Total number of on-tune RLAN in Europe |
| “Optimistic” scenario  (Case 1 above) | 300 M | 50 % | 50 % | 3 % | 290 118 |
| “Medium” scenario  (Case 14 above) | 400 M | 62.7 % | 74 % | 10 % | 2 393 050 |
| “Pessimistic” scenario  (Case 27 above) | 500 M | 70 % | 97 % | 30 % | 13 132 686 |

Table A2-45

Summary of FSS analysis

|  |  |  |  |
| --- | --- | --- | --- |
| Scenario | Antenna discr. (dB) | Building loss (dB) | Band 5 725-5 850 MHz |
| “Optimistic” scenario  (Case 1 above) | 4 | 17 | FSS protection criteria satisfied for all FSS groups 1, 2 and 4 (margin ranges 1.2 to 11.9 dB) |
| “Medium” scenario  (Case 14 above) | 4 | 17 | FSS protection criteria satisfied for FSS group 1 (margin ranges 3.3 to 4.0 dB)  FSS protection criteria exceeded for other FSS groups 2 and 4 (exceeding ranges 3.2 to 6.8 dB) |
| “Pessimistic” scenario  (Case 27 above) | 4 | 17 | FSS protection criteria exceeded for all FSS groups 1, 2, 3, 4 and 5 (exceeding ranges 2.4 to 13.2 dB) |

# A2.3 Conclusions

Three additional studies have been made with LAA-LTE, compared to ECC Report 244:

– Compatibility of a mix LAA and WiFi market share with FSS. Results are roughly the same as for the case of WiFi only.

Therefore the impact of adding LAA-LTE use case in 5 GHz bands appears to have minimal effect on the overall results of compatibility and sharing as shown in ECC Report 244.

List of References

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[2] ECC Decision (04)08: "Harmonised use of 5 GHz for the implementation of WAS/RLANs"

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[4] ERC Report 67: "Study of the Frequency sharing between HIPERLANs and MSS feeder links in the 5 GHz band"

[5] ERC Report 72: "Compatibility studies related to the possible extension band for HIPERLAN at 5 GHz"

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[7] EC Decision 2005/513/EC complemented by EC Decision 2007/90/EC

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1. Figure 4.35, "Communications Market Report 2015", Ofcom, 04 August 2016, <https://www.ofcom.org.uk/__data/assets/pdf_file/0024/26826/cmr_uk_2016.pdf>. [↑](#footnote-ref-1)
2. 2009 status, based on market reports from IMS Research, ABI Research, iSupply, and Plum Consulting. [↑](#footnote-ref-2)
3. As per Recommendation ITU-R M.1739, the I/N ratio at the WAS/RLAN receiver should not exceed –6 dB, assuring that degradation to a WAS/RLAN receiver’s sensitivity will not exceed approximately 1.0 dB. Whilst it is designed to address interference from multiple sources, this criterion is also considered in this Report for single-entry analysis [↑](#footnote-ref-3)