Electronic Communications Committee

CPG-15 PTD

CPG-15 PTD #6

Luxembourg, 28 April – 2 May 2014

Date issued: 22 April 2014

Source: France

Subject: **Update of the compatibility study between RLAN 5 GHz and EESS (active) in the band 5350-5470 MHz**

Password protection required? (Y/N) N

Summary:

During the last JTG 4-5-6-7 (February 2014), udaptes have been made on the RLAN parameters. These updates are mainly related to the RLAN densities (D1 proposed by US & D2 – low & high - proposed by FRANCE) and three different antenna patterns (A1 by France, A2 by US and A3 by UK).

This document presents an update of the French document submitted to the last JTG (document 4-5-6-7/424) taking into account the last version of RLAN parameters agreed in JTG and proposes comparison of results according to the parameters chosen.

The EIRP mask proposed at last JTG by the US as a possible mitigation technique is also investigated.

Proposal:

It is proposed that CPG/PTD takes account of this document in its outcomes on sharing between RLANs and other services to reaffirm the JTG conclusion that sharing between RLAN and EESS (active) is not feasible without mitigation techniques.

It is also proposed that CPG/PTD considers this document to conclude that the EIRP Mask proposed by the US is not efficient to ensure protection of the EESS (active) systems.

Background:

Document 4-5-6-7/424 (France) on "*sharing studies between RLAN and EESS (active) systems in the band 5350-5470 MHz*"

Document 4-5-6-7/495 (US) on "*sharing studies between RLAN and EESS (active) systems in the band 5350-5470 MHz*"

France

SHARING STUDIES BETWEEN RLAN AND EESS (ACTIVE) SYSTEMS IN THE BAND 5350-5470 MHZ

1 Introduction

World Radiocommunication Conference 205 (WRC-15) agenda item 1.1 considers "additional spectrum allocations to the mobile service on a primary basis and identification of additional frequency bands for International Mobile Telecommunications (IMT) and related regulatory provisions, to facilitate the development of terrestrial mobile broadband applications, in accordance with Resolution **233 (WRC-12)**.

The band 5 350-5 470 MHz is under consideration in JTG 4-5-6-7 for a potential allocation to Mobile service and a subsequent potential identification for RLAN systems. Such allocation/identification are subject to compatibility and sharing studies that are required with incumbent services and in particular with the EESS (active) allocated in both the 5 350-5 460 MHz and 5 460-5 470 MHz bands.

Following-up the compatibility studies presented by France at previous JTG 4-5-6-7 meeting (documents 4-5-6-7/335 and 424) as well as RLAN parameters agreed at previous JTG meeting (document 4-5-6-7/584 - Annex 2 – Appendix 2A), the present document provides updated sharing studies between the EESS (active) and RLAN in the band 5 350-5 470 MHz, by using the more realistic scenario, taking into account, the aggregated power of RLAN devices in EESS receiver in dynamic simulations.

This document also addresses and analyses the US proposal to consider an EIRP mask as a mitigation factor.

2 Methodology

The methodology used below consists in determining, in a dynamic analysis, the Cumulative Distribution Function (CDF) of interferences arising from the aggregated power of RLAN systems in the EESS receiver. These interferences (I) may be written in the following form:

$$I = 10\log\left(\sum_{n=1}^{n=N} 10^{\left[Pt_n + Gt_n + Gr_n - Loss_n - A_n\right]/10}\right) \quad \text{(dB)} \qquad (1)$$

Where:

Pt_n: Power level (dBm) in the reference bandwidth at the input of the antenna of a transmitting RLAN.

A_n: Additional attenuation of the RLAN of index n due to the location of the equipment (indoor or outdoor). This factor depends of the distribution of location.

Gt_n: RLAN gain (dBi).

Gr_n: Relative antenna gain (dBi) of the EESS receiver in the direction of the RLAN of index n.

$Loss_n$: Calculated losses in a free space assumption between the RLAN of index n and the EESS receiver.

Then, the final Cumulative Distribution Function (CDF) is built with several positions of EESS satellite around Earth. For each position, the aggregated power is calculated following the equation

(1). At the end, each value of interference is well known for each EESS position and the CDF is assessed by counting the number of each identical interference value on the global positions.

3 Earth Exploration Satellite Service (EESS) Characteristics

The EESS (active) sensors performance and interference criteria are given in Recommendation **ITU-R RS.1166-4** and have been further confirmed by WP7C in its Liaison Statements to JTG (see documents 4-5-6-7/123 and 248).

The band 5 350-5 470 MHz is expected to be used only by SAR and altimeters and the relevant interference criteria are given in Table 2. Even if RLANs could be mobile by nature, their very high density implies that the interference will be systematic. The relevant percentage of time is therefore 99%.

For Sentinel-1, the antenna pattern is derived from the information provided in the liaison statement from 7C to the JTG (**R12-JTG4567-C-0123**), as illustrated in the Figure 1.

TABLE 1

Technical characteristics of SAR, CSAR and SRAL inboard of respectively Radarsat Next Generation, Sentinel-1 and 3. Values extracted from the R12-JTG4567-C-0123

Parameter	Radarsat Next Generation (RNG)	Sentinel-1 CSAR	Sentinel-3 SRAL
Sensor type	SAR	SAR	ALTIMETER
Orbital altitude (km)	586.9-615.2	693	800
Orbital inclination (degrees)	97.74	98.18	98.65
RF centre frequency (MHz)	5 405	5 405	5 410
Peak radiated power (W) at antenna input	1 990	4140	32
Polarization	HH, VV, HV,VH	V and H	Linear
Antenna type	Phase array	Phase array	Parabolic reflector 1.2m
Antenna gain (dBi)	40-45	43.5 to 45.1	34.5
Antenna pattern	Define in LS from 7C	See Figure 1	Based on F.699
Antenna orientation (degrees from nadir)	33^0 (right-looking)	20 to 47	0 (altimeter)
Receiver noise figure (dB)	6 (system)	3.2	3.8
Pulse/Receiver bandwidth (MHz)	14-300	Up to 100 MHz	320
Noise power (dBW)	–128 to –114	-121	-115
Service area	Global	Global	Global
Footprint (km^2)	225 (avg)	From 80 to 400 km	48.4 km (diameter)

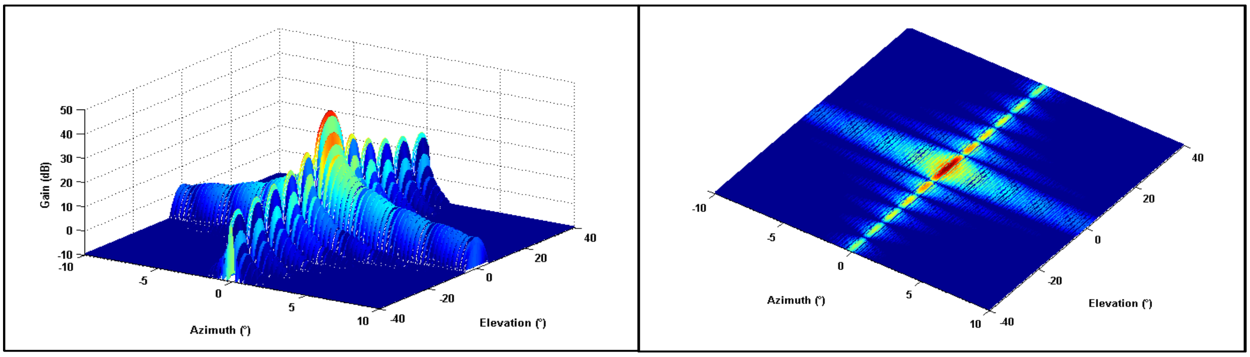


Figure 1: Antenna gain representation of EESS satellite (Sentinel-1). 3D representation (left) and projection on a plan (right)

TABLE 2
Interference criteria given by ITU-R RS.1166-4

Sensor type	Interference criteria		Data availability criteria (%)	
	Performance degradation	*I/N* (dB)	Systematic	Random
Synthetic aperture radar	10% degradation of standard deviation of pixel power	–6	99	95
Altimeter	4% degradation in height noise	–3	99	95

Based on the elements from Tables 1 and 2, the interference criterion for EESS systems become -117 dBm/MHz (-127dBW/100MHz) for Sentinel-1 and -114dBm/MHz for Sentinel-3 (-124dBW/100MHz).

4 RLAN Characteristics

Last JTG considered the issue of RLAN parameters and found an agreement on a number of parameters whereas 2 parameters are still with options remaining (RLAN vertical antenna pattern and the number of active RLAN).

France supports these agreements made in JTG (document 4-5-6-7/584 - Annex 2 – Appendix 2A) on various parameters and has therefore used them in the studies presented in the present document.

<u>Eirp distribution (agreed in JTG):</u>

TABLE 3
RLAN eirp distribution

RLAN EIRP Level	200 mW (Omni-Directional)	80 mW (Omni-Directional)	50 mW (Omni-Directional)	25 mW (Omni-Directional)
RLAN Device Percentage	19%	27%	15%	39%

<u>Indoor/outdoor ratio (agreed in JTG):</u>

RLAN devices are assumed to be indoors only, based on the requirement to help facilitate coexistence. However, for the purposes of sharing studies, 5% of the devices should be modelled without building attenuation.

Such agreement accounts for potential accidental RLAN outdoor usage recognising that for such mass-market and unlicensed equipment, it is impossible to control the only indoor RLAN limitation.

Channel bandwidth (agreed in JTG):

TABLE 4
RLAN channel bandwidths distribution

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

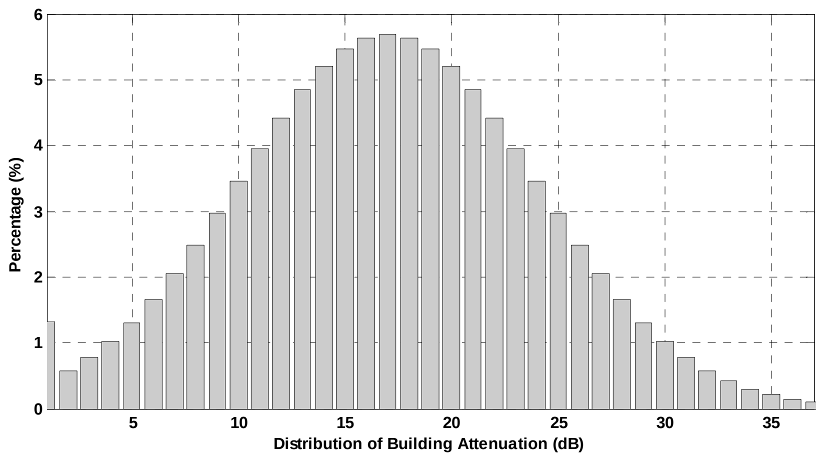
Note: this RLAN bandwidth distribution has been used to assess the necessary Bandwidth factor to be applied to RLAN overlapping the EESS (active) bandwidth (100 MHz). Such assessment leads to the following distribution in Table 5:

TABLE 5
RLAN Bandwidth Factor attenuation

BF Attenuation (dB)	0	2	3	6
Percentage (100%)	48.33%	15%	11.67%	25%

Building attenuation (agreed in JTG):

Gaussian distribution with a 17 dB mean and a 7 dB standard deviation (truncated at 1 dB), as depicted below:



Propagation model (agreed in JTG):

Recommendation ITU-R P.619 + angular clutter loss model from Recommendation ITU-R P.452 (as revised – see Document 3/52(Rev.1)) + building attenuation as described above.

Antenna gain/discrimination (optional in JTG):

Concerning the antenna discrimination in elevation, France supports the JTG Option A1, a pattern omnidirectional in elevation, hence representing a 0 dBi antenna gain.

It can be noted that, although most calculation have been performed with Option A1, some calculations have also been made with both Option A3 (4 dB discrimination) and Option A2 (antenna pattern with 12 dB discrimination) in the parametric studies (§ 5.5 and 5.6).

<u>RLAN device density (optional in JTG):</u>

France considers that the density of simultaneous Active RLAN (AR) by person/inhabitant (AR/inh) should be used as a factor of merit. This value could be represented by the multiplication of RLAN density per person with the activity factor.

As described in detail in document 4-5-6-7/430, France proposes to consider a density of 0.004 to 0.04 active RLAN per inhabitant in the 100 MHz band of the Sentinel-1 sensor (i.e. JTG Option D2).

Taking into account the French population (around 66 Million inhabitants), this hence represents from 264 000 to 2 640 000 active RLANs deployed in France.

One should note that JTG option D1 considers a number of 9871 active RLAN over a population of 5 250 000 inhabitants, hence representing a density of around 0.0019 active RLAN per inhabitant. This density has been used for some parametric calculation in §5.6.

5 Determination of the EESS interference CDF

5.1. General Simulation methodology

The result of CDF is built on several assumptions:

1. The simulations are provided considering the deployment of RLAN on a territory. The coverage of the EESS sensor is assumed to correspond to the satellite positions for which the sensors is pointing to or close to territory (see Figures 2 & 4 below for details).
2. The EESS satellite used for simulation is based on the characteristic of Sentinel-1
3. RLAN distribution follows the density of population per km^2 for each mentioned country and the density of RLAN by population (AR/inh).
4. RLANs characteristics (EIRP, Bandwidth factor...) follow the distributions presented in Tables 3 & 5.
5. During the deployment of RLAN on the French territory, 95% of the totals RLAN are considered to be indoor (5% outdoor).
6. For each position in time of Sentinel-1, the angle between each RLAN and the satellite is calculated and subsequently the EESS gain in the direction of the RLAN location. Then, for each satellite position in time and space, the aggregated power in the EESS receiver can be assessed by Equation (1). Finally the CDF of aggregated power in the EESS receiver is constructed with all positions of the satellite in time and space (the work area as described on Figure 2 & 3).

5.2. Results of simulation over France during a period of 15 days.

As shown on Figure 2, the satellite work area is wider than French territory (also covering south of UK, Belgium, south of Netherland, Switzerland …). Since the RLAN deployment used in the simulation is limited to French, this means that the results of interference on the EESS receiver are underestimated.

The total numbers of RLAN are distributed according to the population in France (66 million distributed in France). The simulations were performed with RLAN densities of 0.004 (Option D2 low) & 0.04 (Option D2 high) (i.e. around 264 000, 2 640 000 Active RLANs – See figure 2) in order to respect the assumptions of Active RLANs density proposed by France.

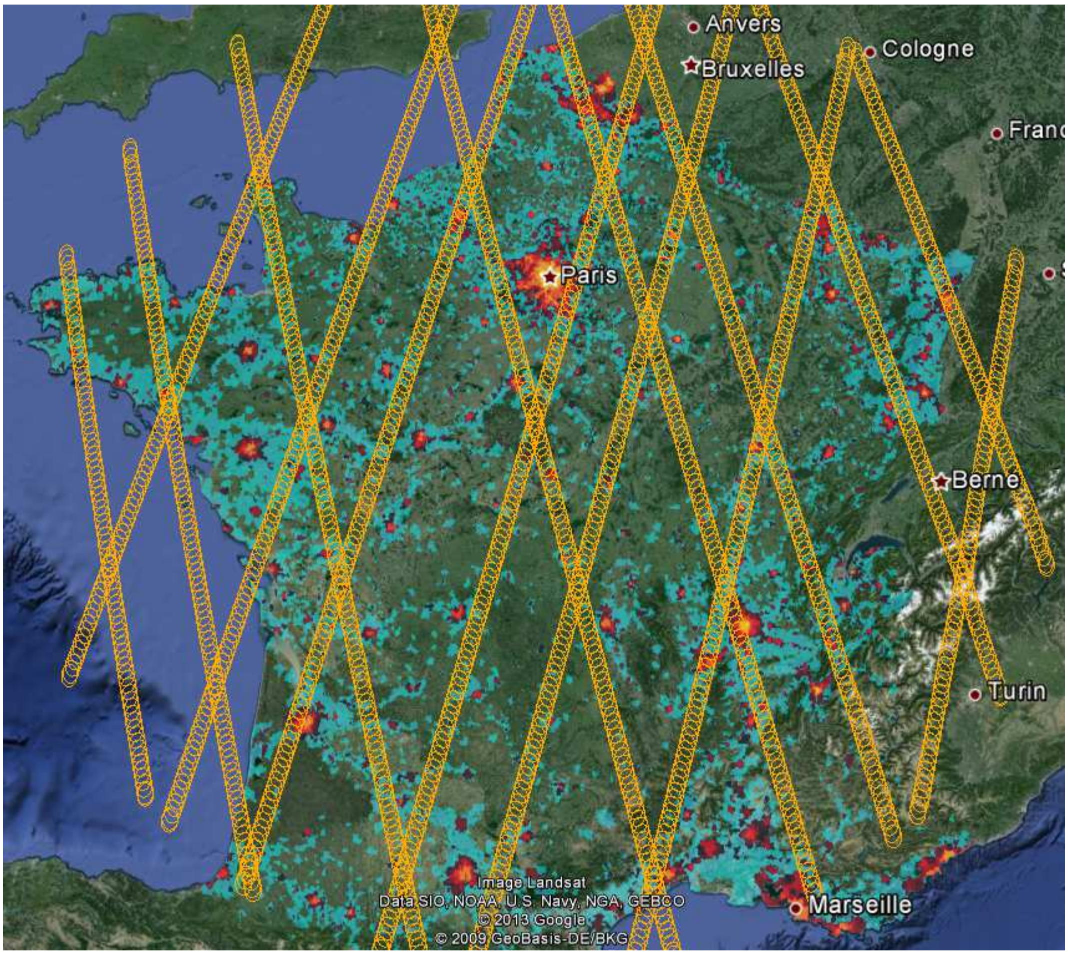


Figure 2: Active RLAN deployment (blue and red surface in the case of 0.04 AR/inh (Around 2 640 000 ARs) and only red surface in the case of 0.004 AR/inh (Around 264 000 ARs)) and satellite positions (orange circle) during 15 days

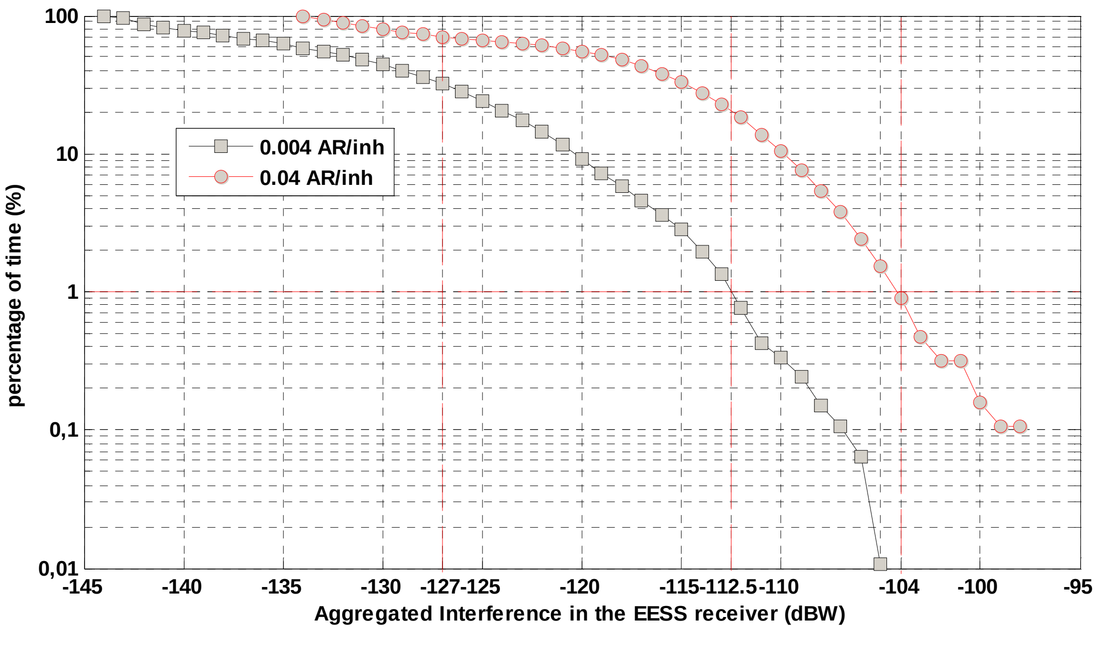


Figure 3: simulation results of CDF for 0.004 & 0.04 AR/inh (D2-low and D2-high) deployed in FRANCE

The simulation results on Figure 3 clearly show that the EESS protection criterion is exceeded by:

- 14.5 dB for 0.004 (option D2 low) active RLAN per inhabitant in France (around 264 000 active RLANs)
- 23 dB for 0.04 (option D2 high) active RLAN per inhabitants (around 2 640 000 active RLANs)

As expected, Figure 4 shows too, that the aggregated interference of 0.04 AR/inh is approximately 10 times greater than the case of 0.004 AR/inh (actually 8.5 dB at 1%). This difference could be easily explained by the fact that the RLAN distribution considering density population is not really homothetic (increase of Active RLAN ratio implies rise of RLANs deployment zone – see figure 2).

5.3. Results of simulation over UK + Ireland during a period of 15 days.

As shown on Figure 4, the satellite work area is wider than UK and Ireland (also covering a wide part of sea area).

In this study, the simulation methodology described in section 5.1 is applied. The total population considered is around 59 million for UK and 3.9 million for Ireland, which means a total number of 251 000 Active RLAN (236 000 for UK and 15 600 for Ireland) in the case of 0.004 AR/inh (D2-low).

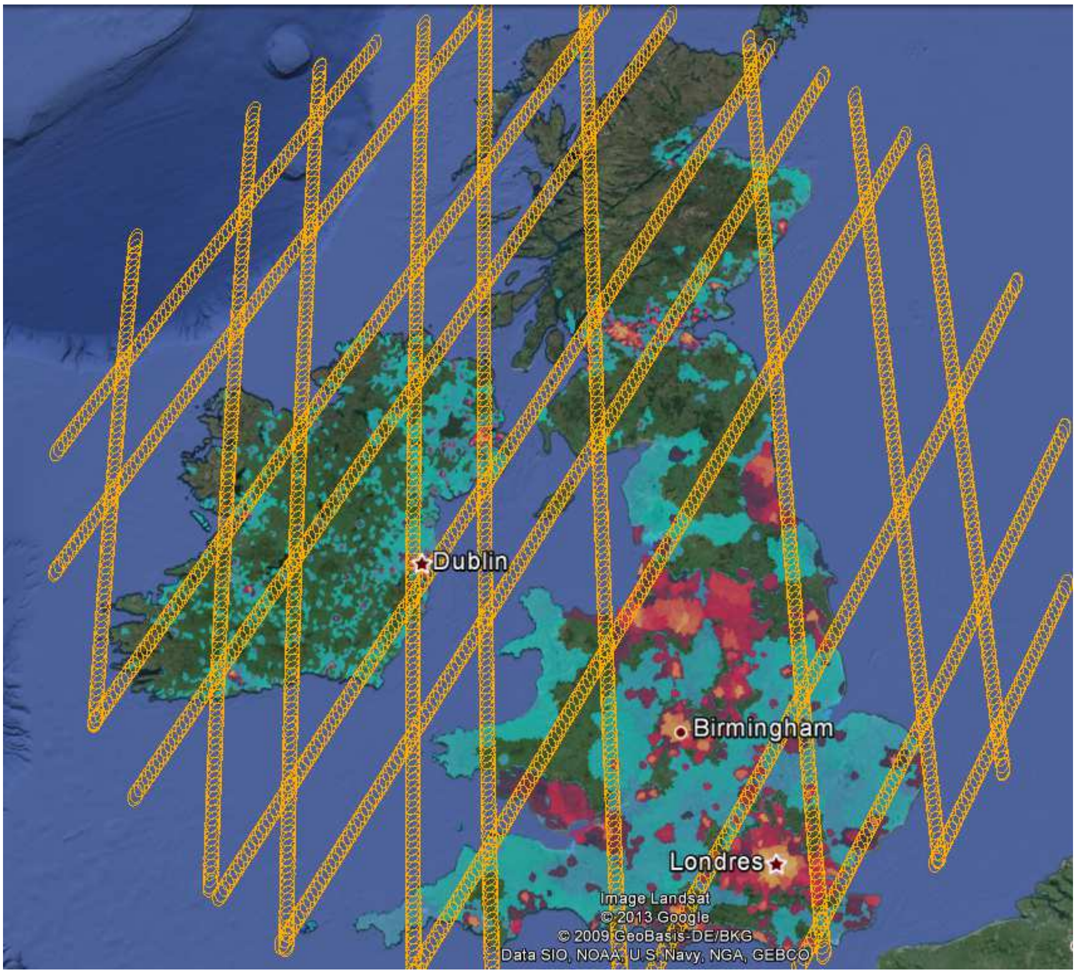


Figure 4: Active RLAN deployment (blue and red surface in the case of 0.04 AR/inh (Around 2 400 000 ARs for UK and 160 000 for Ireland) and only red surface in the case of 0.004 AR/inh (Around 240 000 ARs for UK and 16 000 for Ireland)) and satellite positions (orange circle) during 15 days

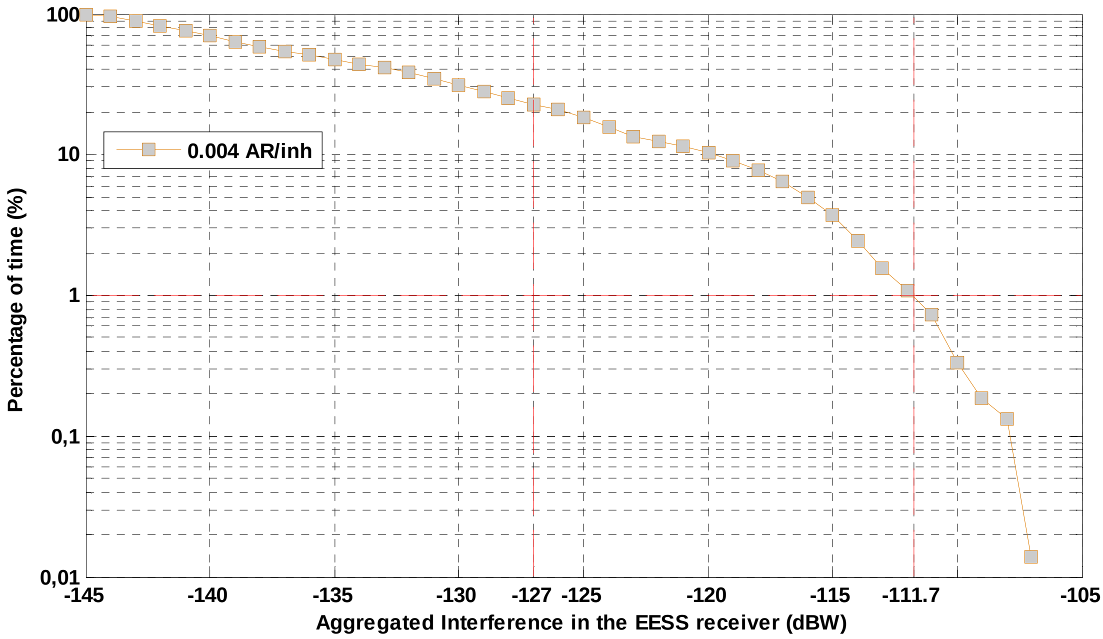


Figure 5: simulation results of CDF for 0.004 AR/inh (D2-low) deployed in UK + Ireland

The simulation results presented in Figure 5 clearly show that the EESS protection criterion is exceeded by 15.3 dB for 0.004 active RLAN per inhabitant in UK + Ireland (around 251 000 active RLANs – red surface on Figure 4 for RLAN deployment).

5.4 Results of simulation over London

In this study, the simulation methodology described in section 5.1 is applied but limited to a portion of orbit corresponding to measurements over London. The total number of active RLAN in 100 MHz is deployed following a density of 0.004 AR/inh – D2 Low - (36 000 for London City) and the total measurement area is roughly of 9600 km² (80 km x 120 km).

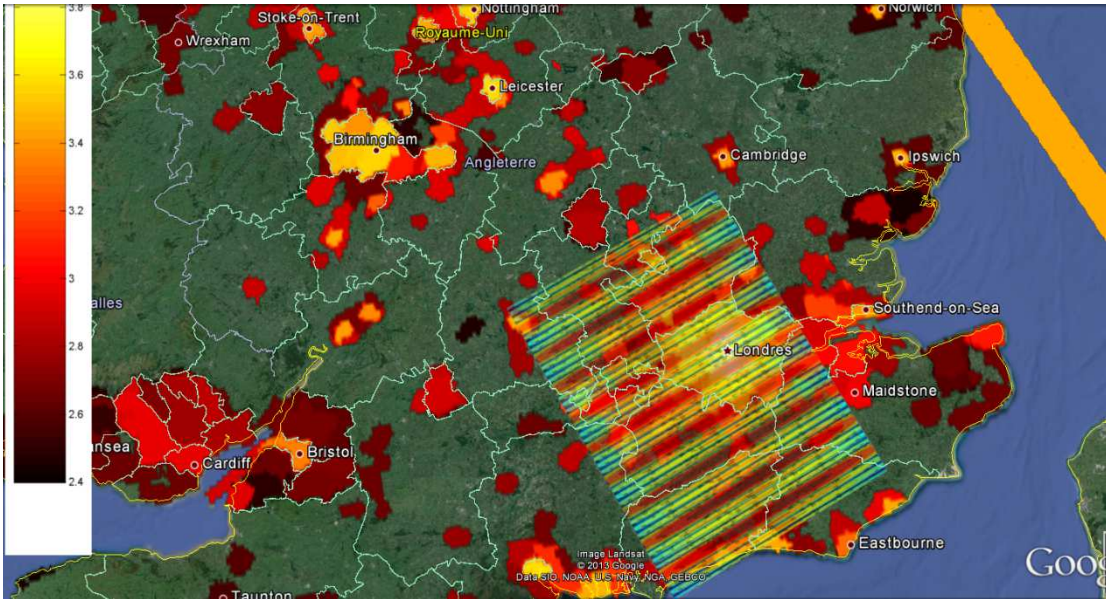


Figure 6: Active RLAN deployment for 0.004 AR/inh, satellite positions (orange line) and antenna footprint (every 2 seconds)

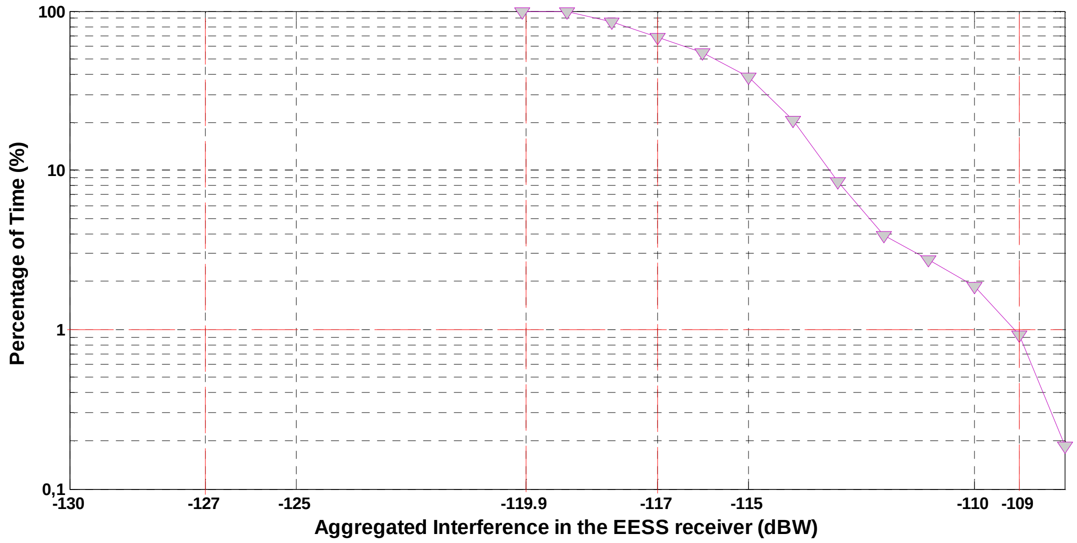


Figure 7: simulation results of CDF for 0.004 AR/inh (D2-low) for one passage of the satellite over great London

The simulation results presented in Figure 6 clearly show that the EESS protection criterion is exceeded by 18 dB for 0.004 active RLAN per inhabitant over great London.

5.5. Parametric studies for antenna options

The present section investigates the parametric impact of the JTG options related to the antenna discrimination A1 (France) and A3 (UK).

The methodology used for the simulation is the same to the one described in section 5.1 and results obtained in section 5.2 (Option A1 – Omnidirectional antenna for RLAN) for the French territory are compared with similar simulations performed with option A3 (generic additional attenuation of 4dB).

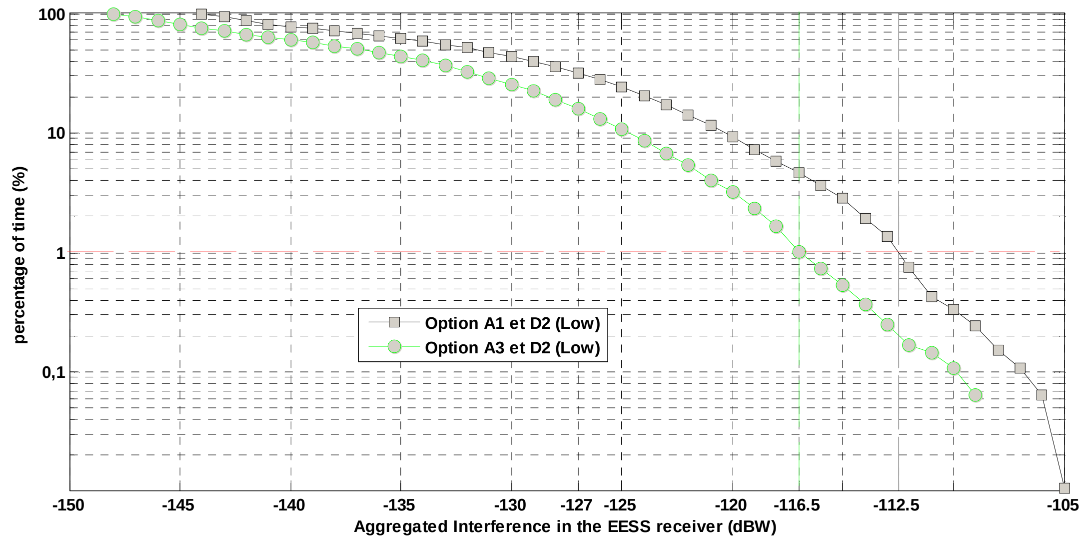


Figure 8: Comparison between each antenna option (A1 & A3) for French territory. Simulations are performed with 0.004 AR/inh (D2 Low).

The simulation results of Figure 6 clearly show that the EESS protection criterion is exceeded by:

- 14.5 dB by using Option A1 assumptions
- 10.5 dB by using Option A3 assumptions (difference of 4 dB with Option A1)

Simulation results are coherent with homothetic transformation. So this result could be applied to every kind of simulations in order to compare Option A1 and A3 (see Table 7 in conclusion).

5.6. Parametric studies for EIRP Mask proposed by US

At last JTG, the US proposed(in document 4-5-6-7/495) to develop an EIRP mask as a mitigation technique to ensure protection of EESS, under the assumption that with options A2 (Antenna gain) and D1 (RLAN density), their simulations results show that the EESS (active) protection criteria is only exceeded by 0.92 dB (for Sentinel-1).

On this basis, the following mask has been proposed by associating the antenna pattern as in JTG Option A2 with the maximum RLAN EIRP 23 dBm.

TABLE 6
EIRP Mask (US proposal in 4-5-6-7/495)

Elevation Angle θ (Degrees)	Antenna gain (pattern from option A2) (dBi)	Maximum Allowable e.i.r.p. Toward Elevation Angle (dBm)	Maximum Allowable e.i.r.p. Toward Elevation Angle (mW)
45 < θ ≤ 90	-4	=23-3+(-4) = 16	40
35 < θ ≤ 45	0	=23-3+(0) = 20	100
0 < θ ≤ 35	3	23	200
–15 < θ ≤ 0	-1	=23-3+(-1) = 19	80
–30 < θ ≤ –15	-4	=23-3+(-4) = 16	40
–60 < θ ≤ –30	-9	=23-3+(-9) = 11	13
–90 < θ ≤ –60	-8	=23-3+(-8) = 12	16

Simulations have been performed over London (consistently with section 5.4 above) considering this EIRP mask and JTG option D1 and the corresponding results are presented in Figure 9.

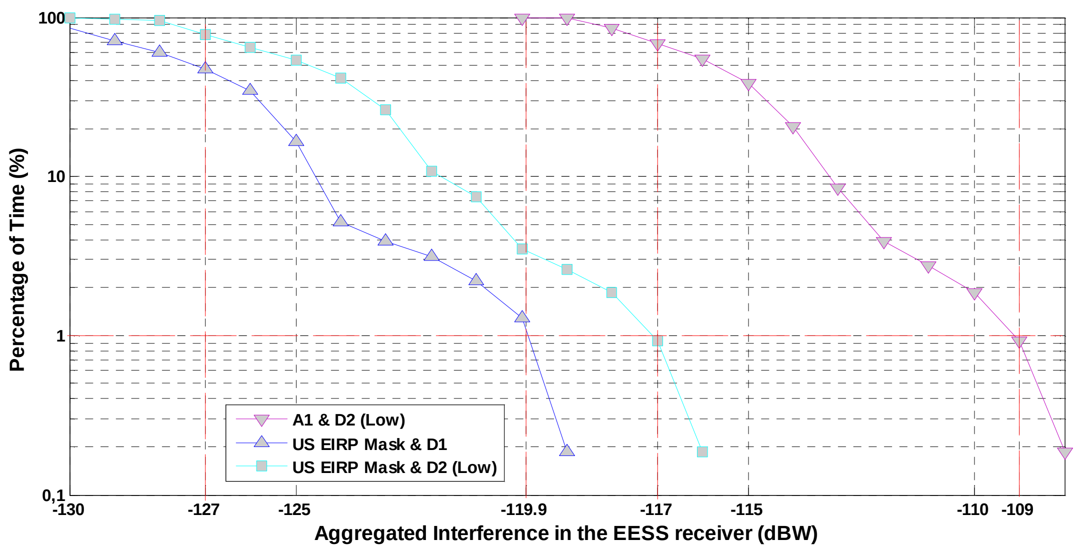


Figure 9: Comparison between simulations with the US EIRP Mask and two RLAN densities (D1 & D2) over London area.

As expected, the result of the simulations considering the US EIRP mask and the JTG density option D2 (Low) is 8 dB below the result of the simulation performed with Options A1 and D2. This difference can be easily explained by the difference of 4 dB on the maximum eirp (19 dBm average on the one hand and 23 dBm maximum on the other hand) and the difference in antenna discrimination which is between 11 and 12 dB.

In addition, result of the simulation performed with US EIRP mask and JTG density option D1 are 2.9 dB dB below the result of the simulation made with US EIRP mask and JTG density option D2. This difference is directly linked to the density factor between D2 (0.004AR/inh) and D1 (0.0019AR/inh) closed to 50% (3dB).

These results clearly show that the EIRP mask proposed by the US as a mitigation technique is not efficient to ensure protection of the EESS (active) systems whatever RLAN density is chosen, either Option D1 for which the criteria is exceeded by 7.1 dB, or Option D2 for which the excess is of 10 dB.

6 Conclusion

The dynamic studies presented in this document indicate that, under all scenarios and options agreed in JTG, an RLAN deployment in the frequency band 5350-5470 MHz would create unacceptable interference to the EESS (active) and in particular to the CSAR sensor on board the Sentinel 1 satellite.

Indeed, when considering RLAN densities of 0.004 to 0.04 RLAN per inhabitant over different territories, these simulations lead to exceeding the EESS (active) protection criteria by large figures as summarized in the following Table 7.

TABLE 7
Summarised results of simulations – Difference with protection criteria

		Density of Active RLAN (AR/inh)	
Country	Antenna Option	D2 Low (0.004)	D2 High (0.04)
FRANCE	A1	+14.5 dB	+23 dB
	A3	+10.5 dB	+11.5 dB*
UK + Ireland	A1	+15.3 dB	+23.8 dB*
	A3	+11.3 dB*	+19.8 dB*
London	A1	+18 dB	+26.5 dB*
	A3	+14 dB*	+22.5 dB*

Note on Table 6: * Extrapolated values with results of simulation performed in section 5.2.

In addition, it has been shown that that the EIRP mask proposed by the US as a mitigation technique is inefficient to protect the EESS (active), presenting an exceeding of the protection criteria of **7.1 dB** (Figure 9) even though this mask is based on the minimum RLAN density (JTG Option D1). By using the low density proposed by France (D2 Low), the EESS criteria is exceeded by **10 dB** (Figure 9)

This study:

- confirms that sharing the band 5350-5470 MHz between RLAN and EESS (active) is not feasible with a significant negative margin,

- and shows that the EIRP mask proposed by the US to mitigate this RLAN interference is largely inefficient in that respect .