Radiocommunication Study Groups

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France

SHARING STUDY BETWEEN RADIOLOCATION AND IMT-2020 BASE STATION WITHIN 31 800-33 400 MHz

1 Introduction

WRC-19 agenda item 1.13 is considering additional spectrum allocation to mobile service and identification of additional frequency bands for IMT including the frequency band 31.8-33.4 GHz. TG 5/1 is taking on-board sharing studies in relation to this agenda item. France proposed a preliminary sharing study on IMT-2020 BS interference onto the radionavigation system in the band 31.8-33.4 GHz at last TG 5/1 meeting dealing with single entry interference scenario.

This contribution provides a sharing analysis between IMT-2020 systems and radionavigation systems in the band 31.8-33.4 GHz on a cumulative effect of interference basis.

2 Allocation information in the 31.8-33.4 GHz frequency range

The allocation of the inter-satellite service is provided in the following table extracted from the Radio Regulations:

TABLE 1

Frequencies allocation in Regions 1, 2 and 3 in 31 800-33 400 MHz-27.5 GHz

31.8-32	FIXED 5.547A RADIONAVIGATION SPACE RESEARCH (deep space) (space-to-Earth) 5.547 5.547B 5.548
32-32.3	FIXED 5.547A RADIONAVIGATION SPACE RESEARCH (deep space) (space-to-Earth) 5.547 5.547C 5.548
32.3-33	FIXED 5.547A INTER-SATELLITE RADIONAVIGATION 5.547 5.547D 5.548
33-33.4	FIXED 5.547A RADIONAVIGATION 5.547 5.547E

3 Technical characteristics

3.1 Technical and operational characteristics of IMT-2020 base-stations operating in the 25.25-27.5 GHz frequency range

3.1.1 Technical characteristics of IMT-2020 base station (BS)

Table 2 provides the parameters related to BS and UE:

TABLE 2

BS parameters

Parameter	**Unit**	**BS**
Antenna array configuration N_H x N_V	N/A	8x8
Single element output power	dBm/200 MHz	10
Maximum element gain	dBi	5
Conducted power[1]	dBm/200 MHz	28
Maximum composite antenna Gain	dBi	23
Array Ohmic losses	dB	3
Maximum e.i.r.p.	dBm/200 MHz	48
H/V[2] radiating element spacing	N/A	λ/2
Antenna height (above ground level)	m	6 (suburban hotspot , urban) 15 (suburban **open space** hotspot)

[1] Without ohmic losses

[2] Horizontal/Vertical

H/V[2] 3dB Beamwidth	°	65 for both
Am and SLA	dB	30 for both
Mechanical downtilt	°	10 (suburban hotspot , urban) 15 suburban **open space** hotspot)

Moreover, as indicated in the previous TG 5/1 Chairman's Report (Doc. 5-1/92, Annex 1 Section 11), sensitivity studies can be performed on the BS e.i.r.p. values in order to evaluate the impact on the results of the sharing analysis. Reminding that the baseline study assumes 48 dBm e.i.r.p, one optional scenario *up to 5 dB higher antenna element power* is carried out in this document.

3.1.2 Operational characteristics of IMT-2020 base stations

3.1.2.1 Discussion on the calculation of the AAS gain

Considering the response of Working Party 5D (Document 5-1/101), for the purpose of sharing study, the *total radiated power (TRP)* of an IMT-2020 system can be understood as the summation inputs from the power amplifiers into each antenna element minus the losses within the AAS. Moreover Document 5-1/137 indicates the need to introduce a normalization factor to the calculation of the antenna directivity in each direction (using the formula in 3GPP TR 37.840 Table 5.4.4.2-3 and Rec. ITU-R M.2101 Table 4) in order to ensure that the total array directivity is equal to 0 dB.

Recalling the 3GPP expression for the composite array radiation pattern (TR 37.840):

$$\breve{G}_{dB}(\theta,\varphi) = A_{E\,dB}(\theta,\varphi) + 10\log_{10}\left\{1+\rho\left[\left|\sum_{m=1}^{N_H}\sum_{n=1}^{N_V} w_{m,n}v_{m,n}\right|^2 - 1\right]\right\}$$

This actual array gain that has to be performed in any sharing studies should be normalised as follows:

$$D(\theta,\varphi,\varphi scan, etilt) = \frac{\breve{G}(\theta,\varphi)}{\frac{1}{4\pi}\int_0^{2\pi}\int_0^{\pi}\breve{G}(\theta,\varphi)\sin(\theta)\,d\theta d\varphi} \quad ,$$

to ensure that TRP $= P_{Tx}$ where P_{Tx} is the conducted power input to the array system. Consequently, this contribution accounts this normalization factor in the computation of the IMT-2020 systems antenna gain, i.e. BS and UE.

Finally, it has to be noted that the same document indicates that 3GPP RAN4 also confirmed that this normalization factor is correct.

3.1.2.2 BS deployment

The number of BS (N_{BS}) transmitting simultaneously within a land area of surface *S* is derived using the following formula:

$$N_{BS} = S \times BS_{AF} \times BS_{NLF} \times R_b \times (R_{aSU} \times (D_{BS_{SUO}} + D_{BS_{SU}}) + R_{aU} \times D_{BS_U})$$

With

BS_{AF}	the BS TDD activity factor (80%[3])
BS_{NLF}	the BS network loading factor (20%[3])
Ra	the ratio of hotspot areas to areas of cities/built areas/districts (3% for suburban (R_{aSU}) and 7% for urban (R_{aU})[3]);
Rb	the ratio built areas to total area of region in study (5%[3])
D_{BSsuo}	BS density in the outdoor suburban open space (0 or 1 BS/km^2) [3]
D_{BSsu}	BS density in the outdoor suburban hotspot (10 BS/km^2) [3]
D_{BSU}	BS density in the outdoor urban hotspot (30 BS/km^2) [3]

The following analysis considers D_{BSsuo} =1.

3.1.2.3 Discussion on the BS deployment

Finally, the computation of the BS and UE antenna gains requires the statistic of beam pointing orientation, i.e. electrical tilt and phi-scan angles because AAS are subject to time varying beam directions. Based on the TG 5/1 Chairman's Report (see Document 5-1/92, Annex 1, Section 12), it's also possible to perform the distribution of BS antenna beam pointing orientation angles (in e-tilt, φ-scan) towards UEs over the cell area by computing:

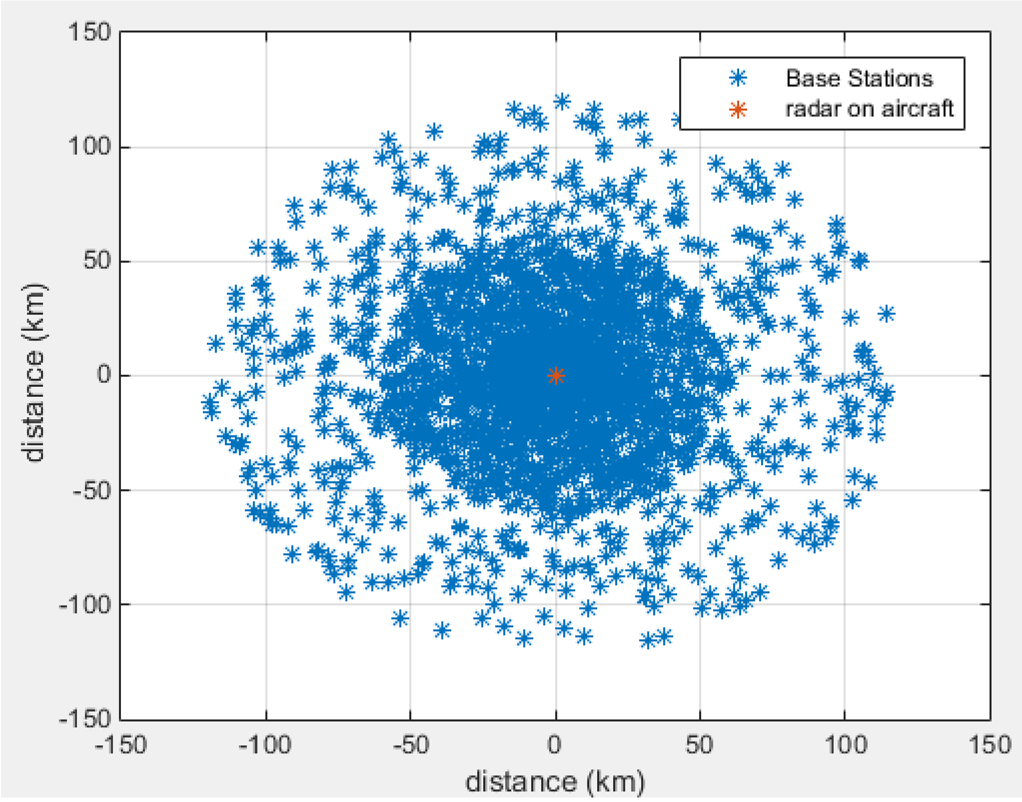
- the azimuth between UE and BS following a normal distribution N(0°, 30°) with cutting off at ±60° angular sector. This angular sector contains 95% of the normally-distributed values resulting in 2.5% of the remaining tail-end values on either side ;
- the distance (BS,UE) following
  - Rayleigh distribution with $\sigma = 32$ when UEs are connected to BS antenna height=6m above the ground,
  - Log-normal distribution with $\mu = 3.9$, $\sigma = 0.42$ when UEs are connected to BS antenna height=15m above the ground.

The area of interest defines the zone where BSs (as interferers) are deployed in the vicinity of the aeronautical radar. Figure 1 depicts the geometry of the simulation surface by considering a ring centred at the victim (radar) receiver location on which BSs are positioned in a heterogeneous way, i.e. non uniform with distance(radar, BS)∈ [0;120] (in km).

[3] See Document 5-1/36.

FIGURE 1

An example of simultaneously transmitting BSSs deployment



Each BS antenna panel can be oriented in different way following that's why uniform distribution of the BS antenna panel orientation is taken as an assumption in this study. As described in Rec ITU-R M.2101 (see Figure 10), the 0° azimuth reference direction is taken as the vertical line.

The amount of BSs spread within the area is derived following the mathematical formula:

$$\mathrm{NbBSs} = \mathrm{BS\ density} \times \mathrm{R_a} \times \mathrm{R_b} \times \mathrm{TDD\ Factor} \times \mathrm{Network\ load}$$

Where

- R_a(%) refers to the ratio of hotspot areas to areas of cities/built areas/districts
- R_b(%) relates to the ratio of built areas to total area of region in study.
- BS TDD Factor (%) corresponds to the DL activity factor
- Network load (%) refers to the percentage of BSs transmitting at full power
- BS density provides the number of BSs per km^2.

As indicated in the Chairman's Report of the previous TG 5/1 meeting, another approach has been discussed, where for some sharing/compatibility scenarios related to specific geographical areas, it could be necessary to have a better assessment of the spatial distribution of the number of BS/UE (based on the application of Ra and Rb factors provided by WP 5D) over this area. For such a specific geographical area of study, it is possible to redistribute the BSs into more populated areas based on the population density information, but without changing the overall number of BSs provided by WP 5D.

Moreover, the same document stated that even when alternative (different than provided by WP 5D) approaches are used for a specific study, it is required to provide the results of such a study also using Ra and Rb values, provided by WP 5D, for the purpose of comparison and validation. Furthermore, the application of aforementioned alternative approaches need to be accompanied with a clear description of the way how they are applied and how the BSs distribution across built-up areas is derived alongside with the references to geographical databases used.

Consequently, in order to allow for comparison and understanding of the impact of the spatial distribution on the sharing/compatibility studies, it is proposed to apply both approaches i.e. directly using Ra and Rb parameters provided by WP 5D and the following one based on redistribution of BSs based on population statistics:

– Calculate the total number of BSs based on Ra and Rb values provided by WP 5D after excluding known large non-built-up areas (e.g. oceans, deserts, icy areas like North/South poles);
– While keeping the total number of BSs identical, and in proportion to the density of population available within the area of study S, redistribute the number of BSs across the built-up areas within S.

Table 2 provides the resulting (rounded) number of BSs simultaneously transmitting within the area of study, e.g. centred around one airport in the suburbs of Paris (Orly) (for 120 km radius) based on both approach:

TABLE 2

Distribution of BSs in an area around Paris-Orly (120 km radius)

Approach	Nb hotspots BSs	Nb open area BSs
Ra and Rb (WP 5D)	109	11
Redistribution of BSs based on population density database	2 448	31

One could notice that the combination of regions adjacent to the Region Ile-de-France and Ile-de-France results in a significantly more populated area compared to the remaining area from France. This then explains why there is a big difference in the obtained number of BSs when based on the population or with *Ra* and *Rb*. Since the area comprises different regions of France (numbered 75, 77, 78, 91, 92, 93, 94 and 95), it’s possible to extract the inhabitants density each one so that an overall inhabitants density is achieved within S.

3.1.2.4 BS antenna pointing

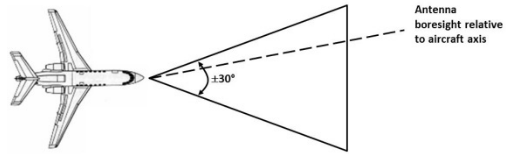
In order to account the time varying nature of the BS beam pointing antenna, the distribution of the electrical tilt and phi-scan of the BS antenna (for both 6 m and 15 m antenna heights) was performed following the procedure described in the TG 5/1 Chairman's report (see Document 5-1/92, Annex 1 Section 12).

3.2 Technical and operational characteristics of radionavigation system operating in the 31 800-33 400 MHz frequency range

3.2.1 Technical characteristics of radionavigation system

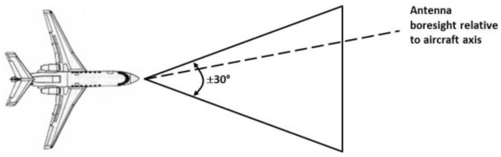
The characteristics of this radar system are extracted from Recommendation ITU-R M.1466 below:

Parameter	Units	Radar No. 3
Type		Aircraft
Altitude	m	Maximum: from 300 to ground Nominal: from 150 to ground
Center frequency	GHz	Adjustable from 31.8 to 33.4 GHz
Chirp RF emission bandwidth	MHz	From 20 to 500 Nominal: 200
Pulse repetition frequency	pps	500 (FM cycle repetition frequency)
Receiver IF bandwidth (–3 dB)	MHz	60

Parameter	Units	Radar No. 3
Receiver noise figure	dB	6
Input power threshold receiver overload	dBm	-40
Antenna type		linear array
Maximum antenna gain	dBi	30
Overall antenna coverage	°	Elevation θ_r: –30 to +5 azimuth φ_r: –30 to +30 

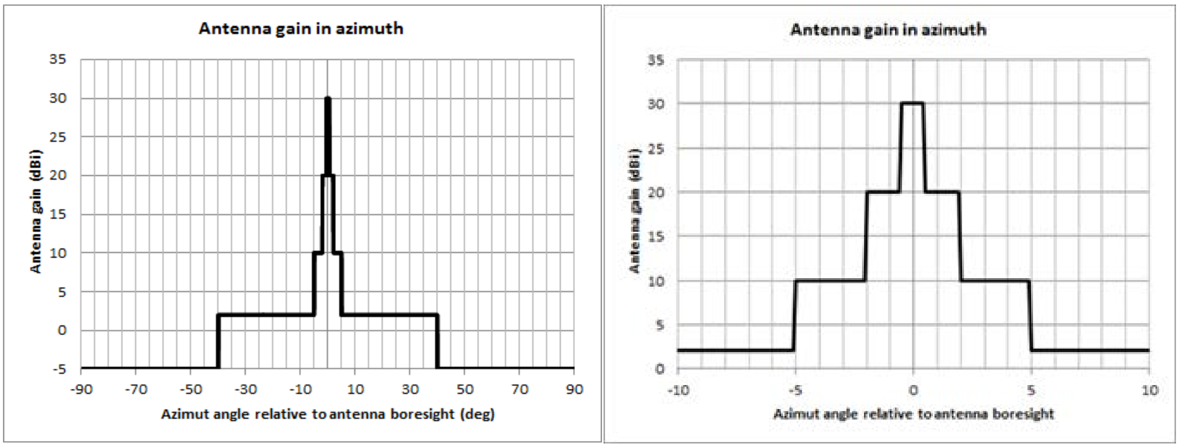
Which is the characteristic of the radar element radiation pattern?

The antenna is composed of a linear antenna array. All elements are combined to form a beam within an angular (azimuth) sector, as depicted below:

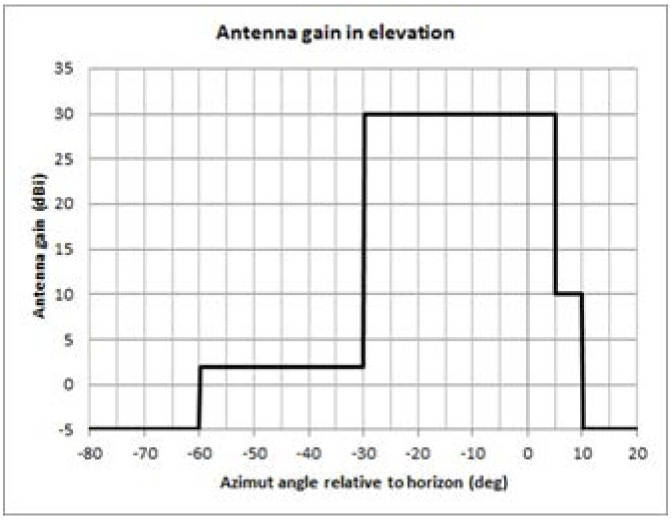


Which is the characteristic of the radar composite radiation pattern?

Note that this azimuthal overall coverage is not instantaneous. The instantaneous radiation pattern within the azimuth plan is the following:



The corresponding radiation pattern in elevation is the following:



These figures corroborate that the azimuth and elevation 3 dB beamwidths are:

θ_{3dB}=1°, α_{3dB}=35°, knowing that peak antenna gain is G_{peak}=30 dB.

Radar 3 operating in the frequency band 31.8-33.4 GHz is considered in this study.

3.2.2 Protection criterion of radionavigation system

Recommendation Rec ITU-R M.1466 specifies the protection criteria for radionavigation systems to be equal to I/N = -6 dB. As no percentage of time of exceedance is associated to the protection criterion, in the Recommendation, but since this application relates to safety of life application, a percentage of exceedance of 0.1% is assumed in this analysis.

3.2.3 Radar operation

The radar is embedded over an aircraft for a radionavigation purpose and more precisely to provide an enhanced flight vision system. Consequently, the antenna of the radar system (above the ground) is located at the same altitude as the aircraft operates, i.e. at 300 m in this document. The rotating nature of the radar antenna in azimuth is also accounted for in the current study, that’s why a random (e.g. uniform) distribution of radar main beam orientation in the azimuthal plane is performed. Moreover, during the landing procedure, the approach path taken by the aircraft (generally 3°) as well as the incidence angle (above the horizon) have to be taken into account. However, it has to be noticed that these angles are already covered in the radar antenna elevation diagram, i.e. that the off-axis angle describing the radiation pattern is defined with respect to the any angular gap between the position of the aircraft in the approach path with an incidence angle. The current preliminary analysis therefore assumes no vertical orientation angle of the radar antenna with respect to aircraft.

3.3 Propagation assumptions

Considered phenomena involved in the losses of the link budget between the GSO satellite and the IMT-2020 systems (BSs and UEs) are of different natures:

– the free space loss (using Rec. ITU-R P.525),

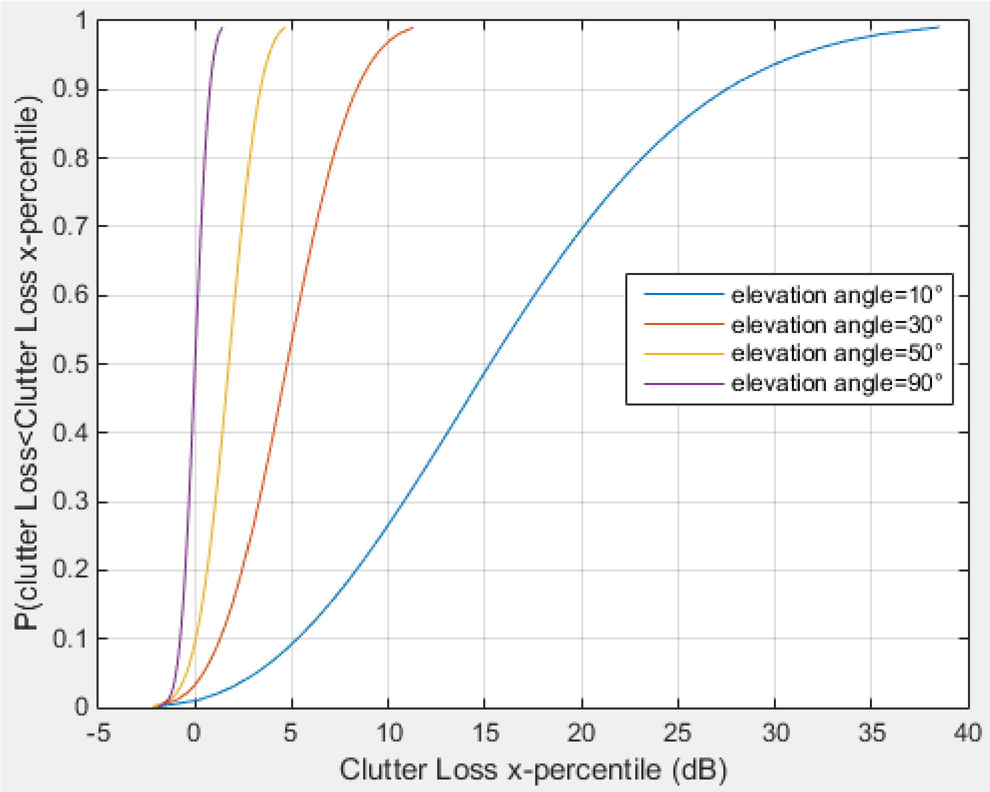
– losses due to atmospheric gases using Rec. ITU-R P.676-11 Annex 2 (slant paths),

– losses due to polarization: as outlined by the TG 5/1 Chairman’s Report (Document 5-1/92, Annex 1, Section 9), aggregate studies should be *completed using both of the values of 0 dB and 3 dB for polarization discrimination*. Indeed, in case of cumulative effect of interference, coupling loss involves different range of antenna gain values (main lobe, side lobes...) which makes the calculation of the discrimination in polarization necessary to account random elliptic polarization of the incident radio wave with respect of the receiving antenna. As analysed in Document 5-1/104, -3 dB (i.e. a loss of 3 dB) is assumed in this study,

– losses due to clutter for BSs located at 6 m above the ground, for earth-aeronautical when the terrestrial environment is urban or suburban. Note that the BSs at 15 m are not subject to a shielding effect. Rec ITU-R P.2108 was used to compute such losses in the simulation (see Section 3.3). The following Figure 2 provides the cumulative density function (cdf) of the clutter losses for different elevation boresight angles (above the ground) of the BS with respect to the aircraft:

FIGURE 2

cdf of clutter loss not exceeded for 31.8-33.4GHz band



– losses due to spherical-Earth diffraction (using Rec ITU-R P.526-13 or a part of Section 4.2 of Rec ITU-R P.452-16) only accounted for trans-horizon distances (noting that the median value of effective Earth radius is computed to do so).

4 Technical analysis

4.1 BS Aggregated interference calculation

The cumulative effect of interference signal coming from BSs located in land area requires performing the calculation of the single radio link budget between one interfering BS_i (i=1..BS) and the victim (radar) receiver:

$P_{R,i}$(dBm/MHz)=P_{BS}(dBm)+G_{BS}(dBi)-PL(dB)-ClutterLoss(dB)-LossAtmosphericGases-PolarizationLoss(dB)+G_{radar}(dBi)

Where

– $P_{R,i}$ the power at the radar receiver, coming from BSi
– P_{BS} refers to the conducted power
– G_{BS} is the BS transmitting antenna gain towards the radar
– G_{radar} is the radar receiving antenna gain in the direction of BSi.

For that reason, Monte-Carlo simulations are performed over the IMT-2020 mobile network and the radar within the area of simulation to calculate the aggregated interference with caused by the BSs in order to derive a reliable statistic, e.g. cdf of the experienced aggregated interference over noise level, i.e. I_{agg}/N. Let's denote *j* the index of the random sampling.

The aggregated interference is then achieved in the following way:

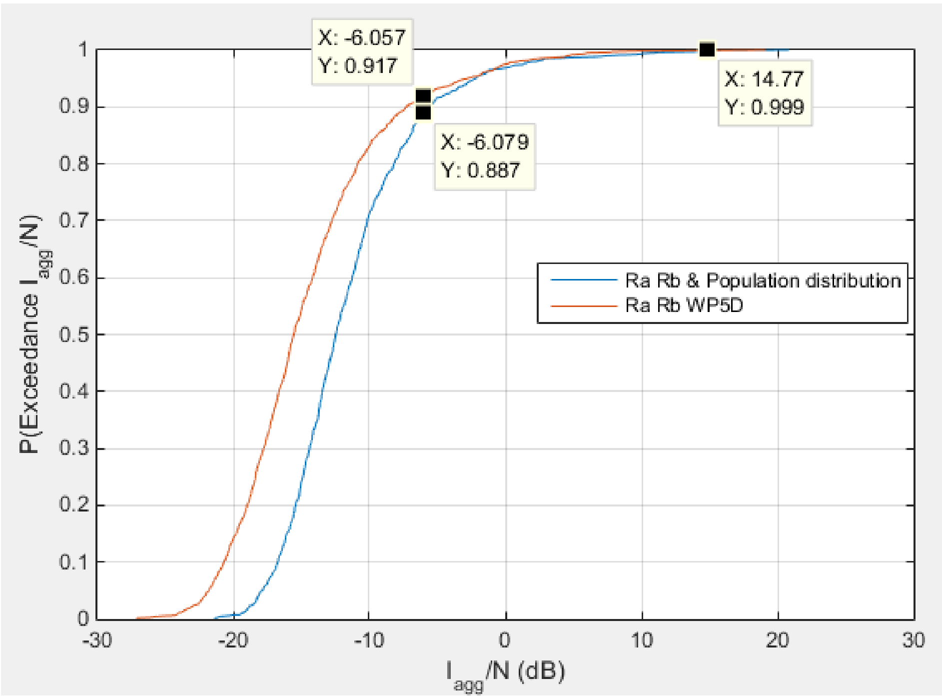
$$\text{Iagg}\left(\frac{\text{dBm}}{\text{MHz}}\right) = 10\log_{10}\left(\sum_{\substack{1\le i\le \text{NbBSs},\\ 1\le j\le \text{NbEvents}}} 10^{\frac{P_{R,ij}}{10}}\right).$$

4.2 Aggregated effect analysis

As described in previous sections, the aggregated interference coming from BSs was assessed on two different BSs deployment scenarios. The cdf (i.e. $P(X\le x_0)$) is depicted in ordinate while x-axis provides associated I/N values for a TRP=2 dBm/MHz (equivalent to conducted power=28 dBm/200 MHz before 3 dB ohmic loss).

FIGURE 3

Distribution of I/N received at radar on aircraft (altitude=300 m)



These results suggest several comments:

– the probability of exceeding I/N is higher for all cases of calculation of number of BSs (>11% blue curve for *Ra, Rb* combined with population distribution, >8% red curve for *Ra and Rb* assumptions provided by WP 5D (>8%) since the approach based on the population information leads to significant increase of number of BSs located within the area of study.

– they were obtained with a 120 km radius area of simulation around a given airport. For other airports and other simulation radius, the distribution of I/N would change,

– in order to meet the maximum probability of exceedance of the protection criterion (0.1%), an additional 20 dB margin would be required at any case. Moreover, when considering sensitivity analysis with 5 dB higher BS e.i.r.p. (as described in TG 5/1 Chairman's Report Document 5-1/92, Annex 1), the margin would increase to 25 dB,

– the effect of UEs interference was not accounted for in the statistical study, suggesting that the cumulative effect of BSs and UE would result in a worst sharing conditions.

5 Summary and analysis of the results of studies

In the previous TG 5/1 meeting, a study (Document 5-1/69) dealing with one single-entry worst case scenario indicated some issues with co-channel sharing between a single IMT-2020 BS and a radar on an aircraft.

In this document, a sharing analysis with the aggregated effect of BSs interference was proposed, confirming similar previous results, i.e. that the probability of exceeding the interference level of the radar is high (>11%) compared to the one considered for the ESV application, as a safety of life operation (0.1%).

Based on these results, it can then be concluded that the sharing between IMT-2020 systems and radionavigation within 31.8-33.4 GHz is not possible/feasible.

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