Radiocommunication Study Groups

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France

COMPATIBILITY STUDY BETWEEN THE POTENTIAL NEW MS ALLOCATION AROUND THE 1 400-1 427 MHz PASSIVE BAND AND THE RADIO ASTRONOMY SERVICE – UPDATE WITH AGGREGATED POWER

1 Introduction

WRC-15 agenda item 1.1 deals with the consideration of additional spectrum requirement for the mobile service (MS) and more specifically for International Mobile Telecommunication and other terrestrial mobile broadband application IMT systems in accordance with Resolution **233 (WRC-12)**.

France has proposed the two bands 1 375-1 400 MHz and 1 427-1 452 MHz for studies under agenda item 1.1 (2x25 MHz, FDD).

The adjacent band 1 400-1 427 MHz is allocated on a primary basis to passive services such as earth exploration satellite and radio astronomy, and systems under these services are highly susceptible to interference from unwanted emissions of active services. It is therefore necessary to address the relevant protection of these services from mobile service unwanted emissions.

The methodology applied in this study consists in determining the separation distance a between a radio astronomy station and an IMT base station (BS), which will depend on the characteristics of the BS as well as the radio astronomy (RA) receiver sensitivity.

In this statistical study, **the mobile user Terminal (TS) case is not included**. In fact, the separation distance between an RAS station and a BS determines intrinsically the separation distance between an RAS receiver and a TS.

2 Employed methodology

The methodology consists in determining, in a statistical analysis, the necessary separation distance between an RAS station and IMT equipment, taking into account the interference due to the aggregated power of a base station in the radio astronomy receiver. These interferences (I) may be written in the following form:

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

Where:

Pt_n: Power level (dBm) in the reference bandwidth at the input of the antenna of a transmitting base station (BS) of the mobile service.

Gt_n: Base station or terminal gain (dBi).

Gr_n: Relative antenna gain (dBi) of the radio astronomy receiver in the direction of the mobile system of index n.

$Loss_n$: Calculated losses with Recommendation ITU-R P.452-14 between the mobile system of index n and the radio astronomy receiver.

The aggregated power is calculated following equation (1), considering each position, gain and power of the BS. The losses are assessed for each propagation path between the BS and the RAS receiver.

3 Mobile service characteristics

The characteristics of mobile service (base stations and terminals) are presented in Attachment 1 of the Annex 8 to Joint Task Group 4-5-6-7 Chairman’s Report (Document 4-5-6-7/242). This document deals with the considerations of the frequency bands 1 375-1 400 MHz and 1 427-1 452 MHz for the mobile service and with the compatibility between this service and the EESS in an adjacent band (1 400-1 427 MHz). All the parameters for IMT in Tables 1 and 2 below are taken directly from the JTG study (section 2.2). In the base station (BS) case, it has been considered that each base station will include 3 sectors of 120°. However, it has also been assumed that, on average, emissions from one sector will always be blocked. Therefore, only 2 sectors per base station have been considered with the following parameter. Considering terminal stations (TS), it has been assumed that, on average, one terminal station will always be transmitting within each of the 2 sectors. These studies suggest that, under a static assumption, to ensure protection of EESS (passive) systems, OoB limits close to –80 dBW/27 MHz (-64 dBm/MHz) are required for base stations.

TABLE 1

Mobile service characteristics – Base station with two sectors

Antenna Gain	17 dBi
Antenna Pattern	Recommendation ITU-R F.1336
Antenna Elevation	-6° (down tilt)
Average Activity Factor	50%
Height	45m (macro-cells)

Table 3 is extracted from Table C of Document 4-5-6-7/236, providing the average cell radius of base station (macro and micro cells) as function of base station location.

This study assumes that each location type is represented by a frame of population density (PS) (expressed as inhabitants per square kilometer) as:

- Urban : PS >10^3 inh/km²
- Suburban : 10^3 inh/km² <PS <100 inh/km²

- Rural : 100 inh/km^2<PS < 1 inh/km²
- Deserted: PS < 1 inh/km². For a deserted location, cell deployment is assumed to be insignificant.

TABLE 2

Mobile service base station deployment

	Macro rural	**Macro suburban**	**Macro urban**	**Small cell outdoor / Micro urban**	**Small cell indoor / Indoor urban**
Cell radius / Deployment density (for bands between 1 and 2 GHz)	> 3 km (typical figure to be used in sharing studies 5 km)	0.5-3 km (typical figure to be used in sharing studies 1 km)	0.25-1 km (typical figure to be used in sharing studies 0.5 km)	1-3 per urban macro cell <1 per suburban macro site	depending on indoor coverage/ capacity demand
Cell radius / Deployment density (for bands between 2 and 3 GHz)	> 2 km (typical figure to be used in sharing studies 4 km)	0.4-2.5 km (typical figure to be used in sharing studies 0.8 km)	0 0.8 km (typical figure to be used in sharing studies 0.4 km)	1-3 per urban macro cell <1 per suburban macro site	depending on indoor coverage/ capacity demand

Document 4-5-6-7/236 states that the distance between each BS is three times greater than the cell radius. Therefore in this study, the deployment takes into account distances between each BS equal to:

- 1.5 km in macro urban case
- 3 km in macro suburban case
- >10 km in macro rural case

4 Radio astronomy service characteristics

The band 1 400-1 427 MHz is used more intensely than any other, in all ITU-R Regions, for radio astronomy observations. The band is used for studies of the so-called 21 cm spectral line of cosmic neutral hydrogen and for broadband continuum observations. The band is fundamental to our understanding of e.g. the origin and evolution of structures in the Universe, and of the galaxies within them (see also Document 4-5-6-7/175). In addition, this band is fully protected by RR footnote **5.340** (“all emissions are prohibited”).

Any evolution of the use of bands adjacent to 1 400-1 427 MHz requires careful coexistence studies to ensure that this band remains as fully operational for passive services as it is today.

Table 5 provides the technical characteristics of this band in the case of two kinds of observation: continuum and spectral line. These values are taken from Recommendation ITU-R RA.769-2. In order to fully protect radio astronomy observations, the protection criteria of continuum observation will be used, i.e., an interference threshold level of -189 dBm/MHz. This criterion has to be respected during at least 98% of the time (interference can occur for a maximum of 2% of the time – see Recommendation ITU-R RA.1513)

TABLE 3

Technical characteristics of the passive band 1 400-1 427 MHz for continuum observations (CO - dark grey) and spectral line observations (SLO - grey)

Obs. Type	Centre Frequency (MHz)	Assumed Bandwidth (MHz)	Minimum Noise Temperature (K)	Receiver Noise Temp. (K)	Temp. (mK)	Power Spectral Density dB(W/Hz)	Input Power (dBW/dBm)	Power Flux Density (dB(W/m^2))
CO	1413.5	27	12	10	0.095	-269	-205/-175	-180
SLO	1420	0.02	12	10	3.48	-253	-220/-190	-196

Notes to Table 3:

- For spectral line measurements, the input power corresponds to -220 dBW or -190 dBm in 20 kHz, or -173 dBm/MHz.
- For continuum measurements, the input power corresponds to -205 dBW or -175 dBm in 27 MHz, or -189 dBm/MHz.

In accordance with Recommendation ITU-R RA.769-2, the antenna gains of all radio astronomy stations will be assumed to be 0 dBi corresponding to a semi-omnidirectional antenna (half the space above the ground/horizon). Most of the radio astronomy receivers listed in Table 4 have a height of 15 to 20 meters. In order to evaluate the coordination (or exclusion) distance around radio astronomy stations, only two kinds of stations combined with two kinds of population density are used (as mentioned in Table 4): Stations among low and high configurations of terrain relief, surrounded by low or high population densities.

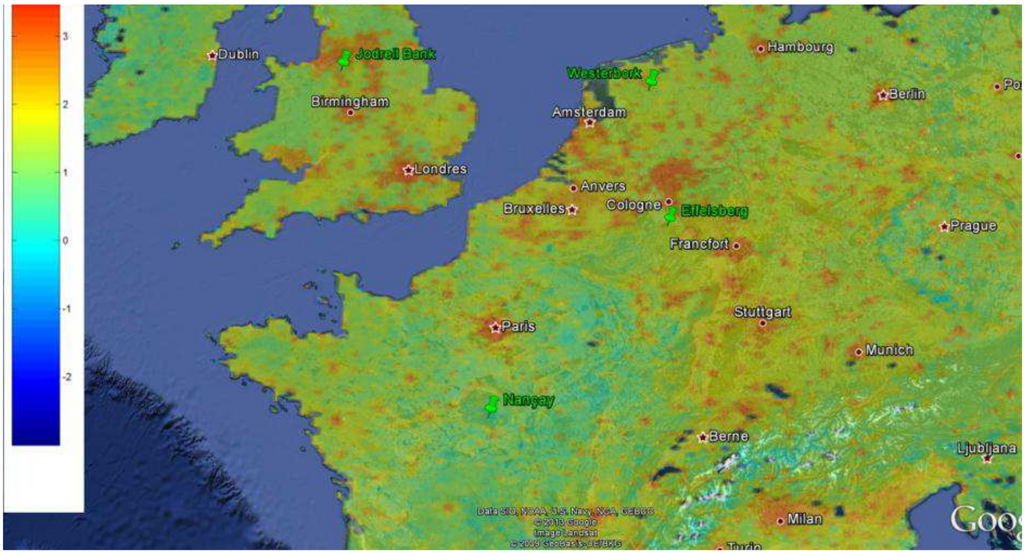
TABLE 4

List of radio astronomy site observing in the band 1 420-1 427 MHz, used in this study

Site	Dimensions (m)	Minimum elevation (°)	Country	GPS location (longitude, latitude)	Relief / population density around
Nançay	Flat mirror (200×40) Spherical Mirror (300×35)	3.6	France	02°12’00” 47°23’00”	Flat / Low
Effelsberg	100	7	Germany	06°53’00” 50°31’32”	Medium / Low
Jodrell Bank	76	2	UK	-02°18’26” 53°14’10”	Flat / High
Westerbork	14×25	0	Netherlands	06°36’01” 57°13’22”	Flat / Medium
MeerKAT	64×13.5	x	South Africa	21°24’39.6” -30°43’15.6”	High/Deserted

FIGURE 1

Representation of population density around four of the RAS stations listed in Table 4 (Jodrell Bank, Nançay, Effelsberg and Westerbork). In the legend, the logarithm of the population density (in inhabitants/km^2) is shown



5 Determination of the coordination distance in a statistic assumption

Terminal locations are directly linked to BS positions. In this study, the separation distance is therefore only calculated for BS.

The result of study is based on several assumptions:

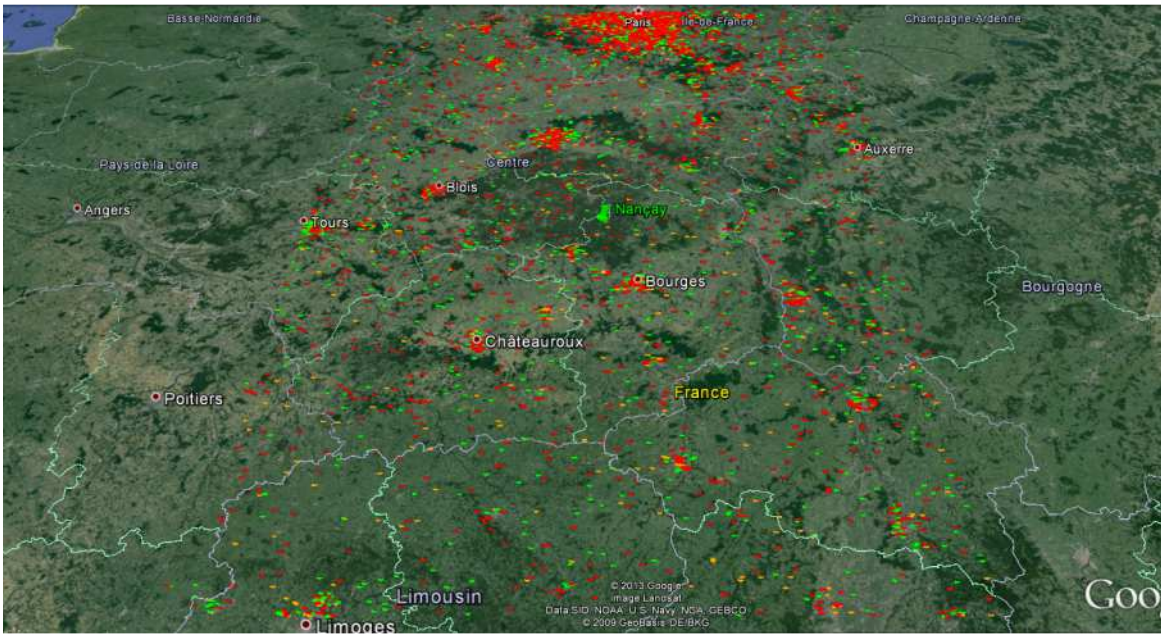
1. The simulations are made considering the BS deployment around the radio astronomy receiver. This deployment is directly linked to the population density per km^2 and the macro cells radius per location (rural, urban…) described in the Table 3 (between 1 to 3 GHz).
2. The distribution considers random positions of BS. For each BS, only one sector is assumed to point in the direction of the RAS station. The elevation between the transmitter and the RAS receiver is calculated taking into account the tilt angle of the BS. For a BS, there is a probability of 33% that the sector in the direction of the RAS station is turned off (in which case the BS is considered to have no contribution to the aggregated power). This assumption is linked to the fact that on average, emissions from one sector will always be blocked. After the deployment, 50% of the remaining sectors are considered randomly turned off (to take into account the factor activity – 50% - by assuming that measurements are made by the RAS receiver 100% of the time).
3. The BS OoB emission level is assumed to be -64 dBm/MHz (i.e., the OoB level necessary to respect the EESS (passive) protection in the band 1 400-1 427 MHz).
4. The losses between each BS and the RAS receiver are calculated using Recommendation ITU-R P.452-14. In this loss calculation **urban clutter is not used**

5.1 Study of Nançay – Low population density and low relief

Taking into account the deployment rules (Table 3) and the population density of Figure 1, the total number of deployed BS near Nançay is close to 2500. Considering the switch off ratio and the sector discriminations, the number of active sectors is around 880 within an area of 1.5 degree in latitude and (330 km) and 1.5 degree in longitude (210 km) around the RAS station (see Figure 2 below) (or about 67 000 km^2). On average, the study considers 1.3 BS per 100 km^2 pointing in the direction of Nançay.

FIGURE 2

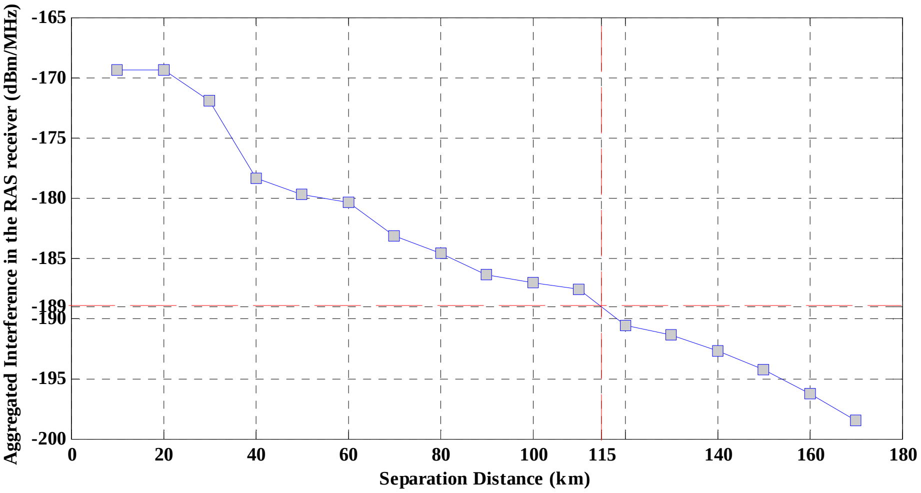
Representation of the random BS deployment for the case of Nançay. Each point indicates a BS position. Red points correspond to BS with a 50% turn off. Orange points are BS which do not emit in the direction of the RAS station. Green points are BS which turned on and present at least one sector in the direction of the RAS station



For an OoB level of -64 dBm/MHz, and 450 working base stations, the separation distance between the RAS receiver and the first BS has to be about 115 km (see Figure 3) in the case of flat terrain profile and low population density.

FIGURE 3

Representation of the aggregated interference in the station of Nançay



5.2 Study of Effelsberg – High population density and high relief

Taking into account Table 3 and the population density of Figure 1, the total number of BS deployed near Effelsberg is close to 8000. Considering the switch off ratio and the sector discrimination, the final number of actives sectors is around 2600 within an area of 1.5 degree in latitude (330 km) and 1.5 degree in longitude (210 km) around the RAS station (see Figure 4 below) (or about 67 000 km^2). On average, the study considers 4 BS per 100 km^2 pointing in the direction of Effelsberg.

FIGURE 4

Representation of the random BS deployment for the case of Effelsberg. Each point indicates a BS position. Red Points correspond to BS with a 50 % turn off. Orange points are BS which do not emit in the direction of the RAS station. Green points are BS which turned on and present at least one sector in the direction of the RAS station

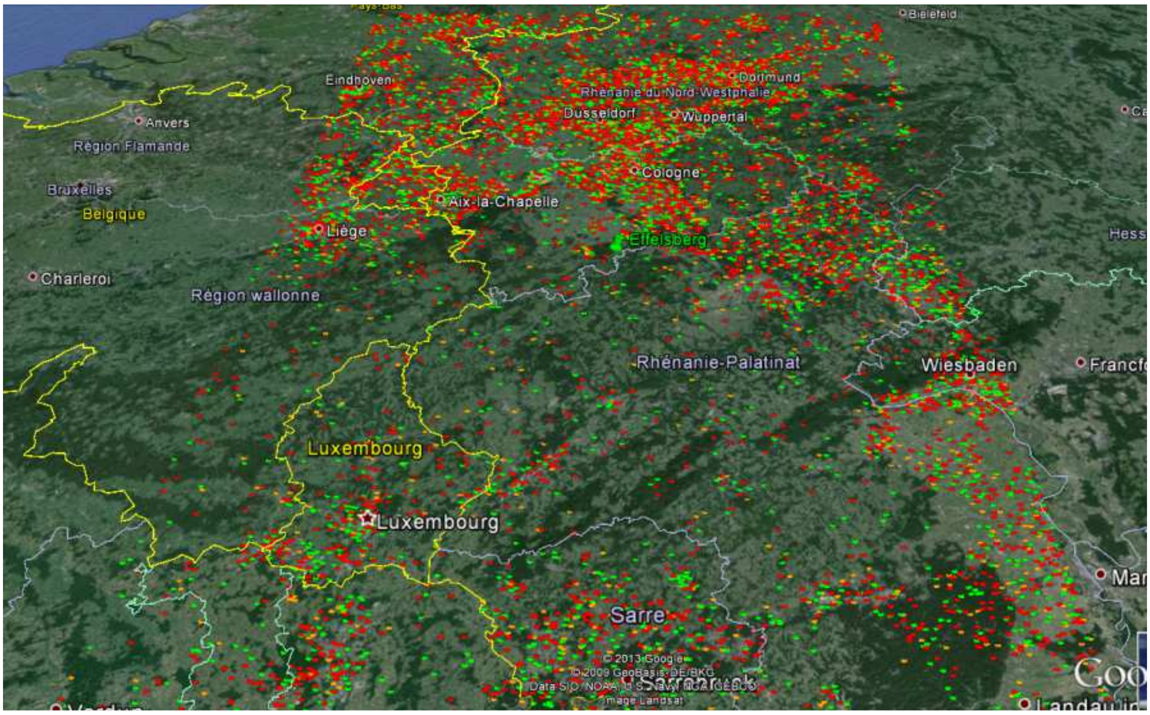


FIGURE 5

Representation of the aggregated interference in the station of Effelsberg

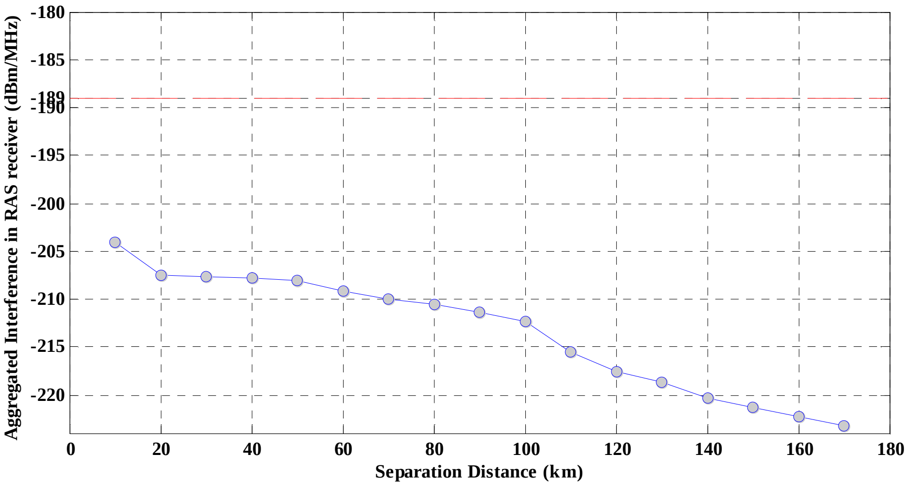


Figure 5 shows that the separation distance between RAS receiver and the first BS have to be inferior of 10 km. In fact, the case of Effelsberg is particular. The station is enclosed between medium terrain profiles (hills /valley) and this configuration ensures to the RAS receiver a really good protection to interference coming from BS on the top.

5.3 Study of Jodrell Bank and Westerbork – High / Medium population density and low relief

Taking into account Table 3 and the population density of Figure 1, the total numbers of BS deployed respectively near Jodrell Bank and Westerbork are close to 6000 and 4400. Considering the switch off ratio and the sector discrimination, the final number of active sectors is respectively around 2000 and 1600 within an area of 1.5 degree in latitude (320 km) and 1.5 degree in longitude (215 km) around each RAS station (see Figures 6 and 7 below) (or about 67 000 km^2). On average, the study considers 3 BS per 100 km^2 for Jodrell Bank and 2.4 BS per 100 km^2 for Westerbork.

FIGURE 6

Representation of the random BS deployment for the case of Jodrell Bank. Each point indicates a BS position. Red Points correspond to BS with a 50% turn off. Orange points are BS which do not emit in the direction of the RAS station. Green points are BS which turned on and present at least one sector in the direction of the RAS station

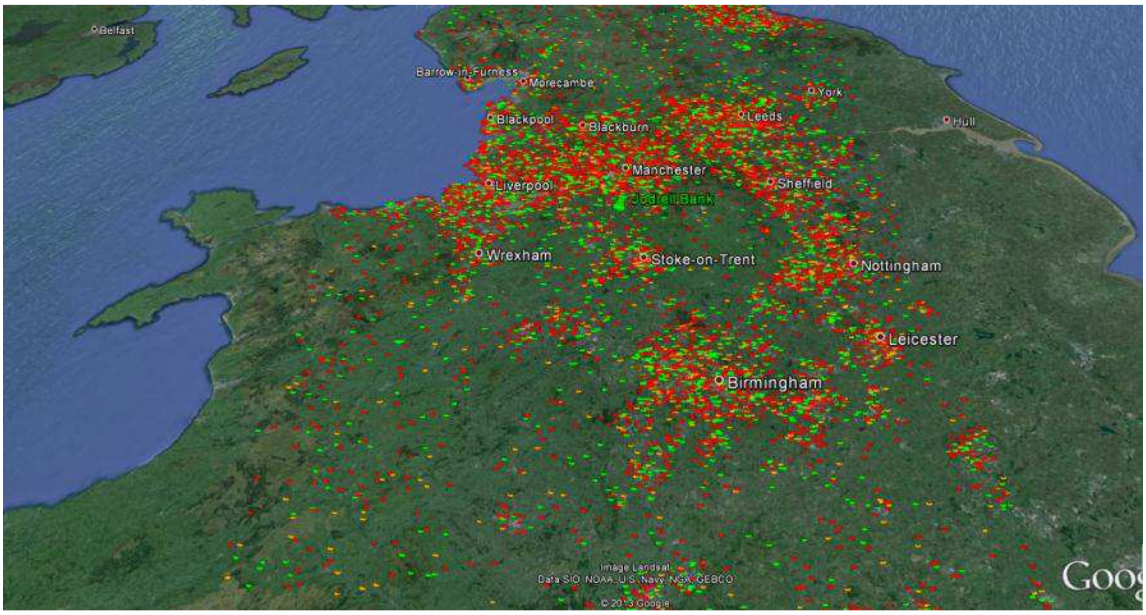


FIGURE 7

Representation of the random BS deployment for the case of Westerbork. Each point indicates a BS position. Red Points correspond to BS with a 50% turn off. Orange points are BS which do not emit in the direction of the RAS station. Green points are BS which turned on and present at least one sector in the direction of the RAS station

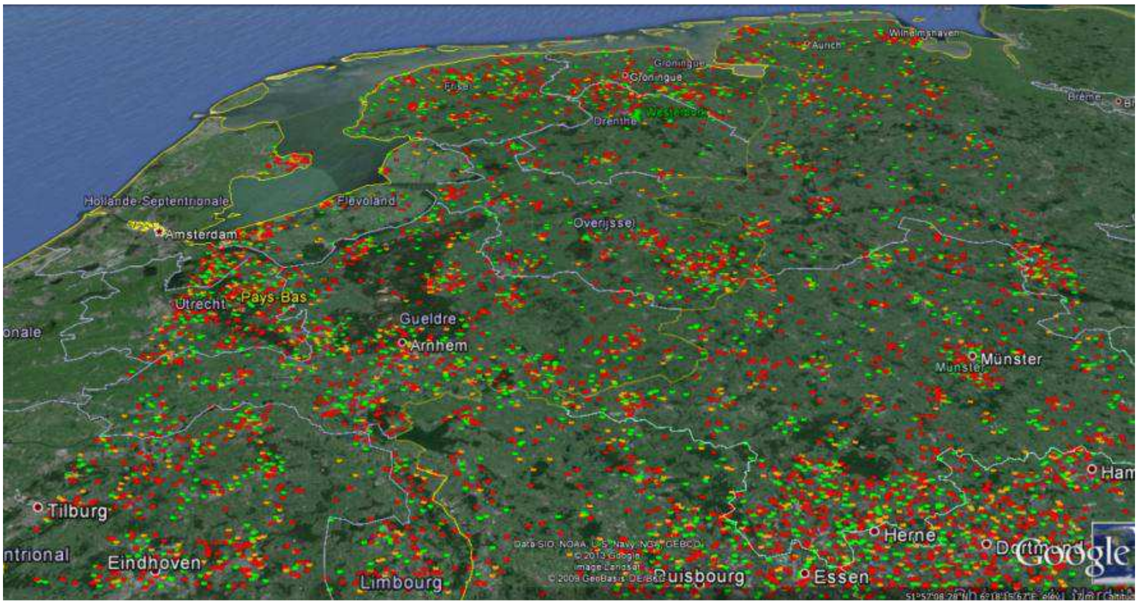
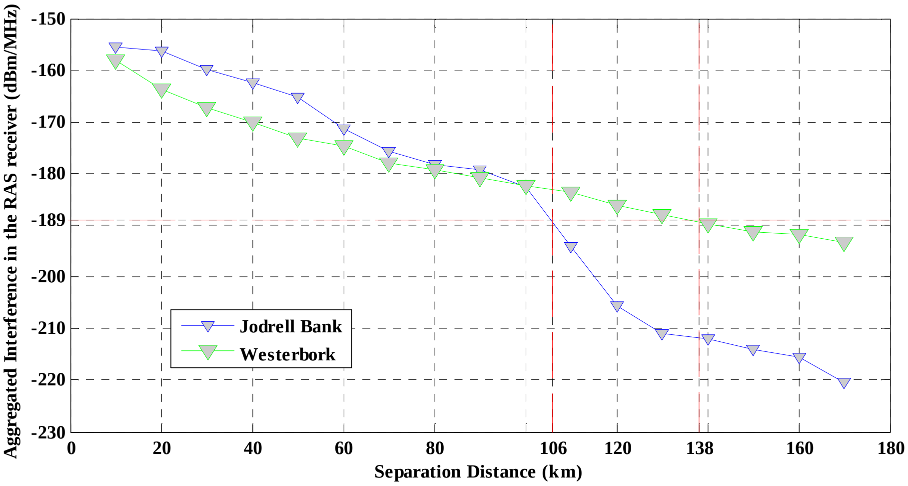


FIGURE 8

Representation of the aggregated interference in the station of Jodrell Bank



For an OoB level of -64 dBm/MHz, and 2000 working base stations (Jodrell Bank), the separation distance between the RAS receiver and the first BS has to be about 106 km (see Figure 8). In the case of 1600 working base stations (Westerbork), the distance becomes equal to 138 km.

By comparison with Nançay (flat terrain assumption), it can be noted that the difference of the aggregated interference in the RAS receiver is around 14 dB between Nançay and Jodrell Bank in the case of zero separation distance. This value is directly linked to the proximity of high density population areas near Jodrell Bank (combination of the two factors). Finally, the required separation distances for the two stations are quite similar, because for each separation distance, a large number of BS near Jodrell Bank are erased (in fact at 100 km, there are no BS in the biggest cities in UK – Manchester, Liverpool, Nottingham, and Birmingham)

5.4 Study of MeerKAT – Deserted location and high relief

The total number of BS deployed near MeerKAT is close to 36. Considering the switch off ratio and the sector discrimination, the final number of used BS is 13 within an area of 1.5 degree in latitude (320 km) and 1.5 degree in longitude (215 km) around the RAS station.

FIGURE 9

Representation of the random BS deployment for the case of MeerKAT. Each point indicates a BS position. Red Points correspond to BS with a 50% turn off. Orange points are BS which do not emit in the direction of the RAS station. Green points are BS which turned on and present at least one sector in the direction of the RAS station

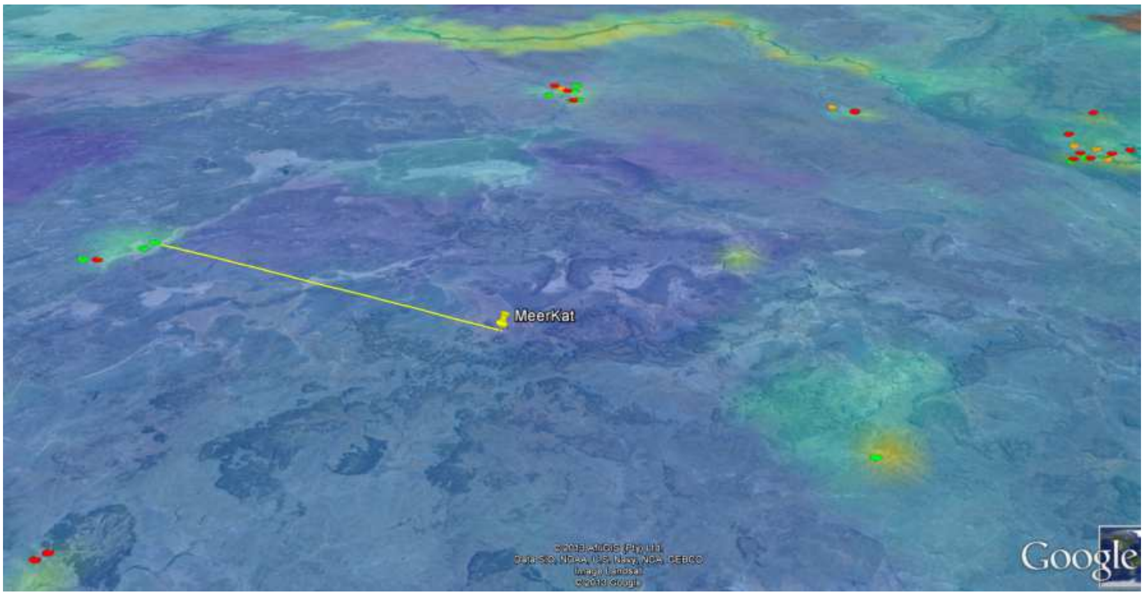


FIGURE 10

Representation of the aggregated interference in the station of Meerkat

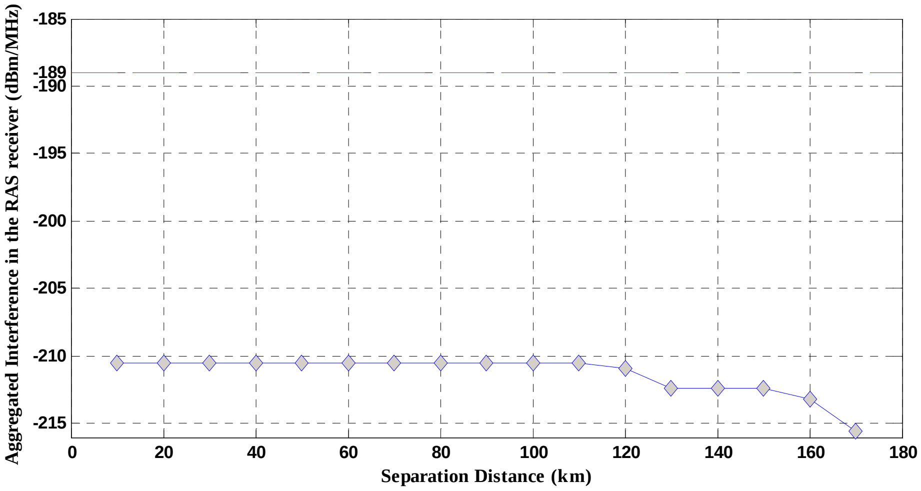


Figure 10 does not yield a separation distance (with the distribution used) necessary to protect the RAS receiver. A look at the BS distribution displayed in Figure 9 shows clearly that the first functional base station is at distance of around 100 km (yellow line in Figure 9). For such a large distance, the aggregated power in the receiver is not affected by the aggregated OoB emissions from the more remote BS.

6 Conclusions

Table 5 summarizes the results (for both kinds of IMT equipment, BS and TS) of the calculated separation distances necessary to protect a radio astronomy receiver. The BS OoB power level used in this study is -64 dBm/MHz (i.e., the level necessary to ensure the protection of the EESS in the passive band 1 400-1 427 MHz). The antenna gain depends of the reception angle and the BS tilt. Moreover the results summarized in Table 5 are dependent on the time-variability of the population density.

In the case of station surrounded by a high density population, the use of the urban clutter in a real condition of deployment could decrease the separation distance.

TABLE 5

Summary of statistic simulation results using Recommendation ITU-R P.452-12 for base station

Terrain relief	Population Density	Approximated coordination distance (km) (Min-Max)
Low (h<100m)	Low	115
	High	106 – 138
Medium & High (100m<h)	Deserted	Not necessary (in this configuration)
	High	<10

This study shows clearly that the compatibility between IMT out of band emission and radio astronomy observations protection, around 1 400-1 427 MHz, could be achieved within each country by setting appropriate coordination distances (Table 5) or/and limits of unwanted emission levels at the radioastronomy site, considering the actual equipment deployment.

In the case of calculated small, or even zero, separation distances of a few kilometers (5 to 10 km) around the RAS station have to be used as an exclusion zone in order to eliminate TS from the proximity of the RAS station, taking into account the low probability of connections between TS and BS through particular propagation paths.