ECC Recommendation (19)01

Technical toolkit to support the introduction of 5G while ensuring, in a proportionate way, the use of existing and planned EESS/SRS receiving earth stations in the 26 GHz band and the possibility for future deployment of these earth stations

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INTRODUCTION

Compatibility between IMT-2020 and Space Research Service/Earth Exploration-Satellite Service (SRS/EESS) earth stations operating in the frequency band 25.5-27 GHz can be achieved by appropariate coordination zone.

Coordination zones within radius of a few km for EESS earth stations and of a few tens of km for SRS earth stations (less numerous and more remote) have been calculated. The exact coordination zone shape will have to be calculated on a case-by-case, mainly depending on the terrain profile around the specific earth station considered and the type of station.

There is a need to define a recommendation describing the methodology to be used by an administration when calculating these coordination zones. Although this process presents some similarity with the process described in Appendix 7 of the Radio Regulations [1] to define coordination between FS systems and SRS/EESS earth stations, this methodology is more complex, since it is not a static worst case analysis, but a dynamic Time Variable Gain (TVG) analysis.

Given the differences in protection criteria and earth station antenna operations among SRS, Non-Geostationary Satellite Orbit (NGSO) EESS and GSO EESS, three slightly different methodologies are described in three separate annexes. In particular, with regard to SRS, the spacecraft trajectory is highly variable and therefore, in order to cover all cases, the antenna movement is not taken into consideration; this leads to slightly higher distances. An additional Annex 4 provides a methodology to address the deployment of IMT-2020 base stations within the coordination zone of EESS earth stations.

ECC RECOMMENDATION 19(01) OF 8 MARCH 2019 ON A TECHNICAL TOOLKIT TO SUPPORT THE INTRODUCTION OF 5G WHILE ENSURING, IN A PROPORTIONATE WAY, THE USE OF EXISTING AND PLANNED EESS/SRS RECEIVING EARTH STATIONS IN THE 26 GHZ BAND AND THE POSSIBILITY FOR FUTURE DEPLOYMENT OF THESE EARTH STATIONS

"The European Conference of Postal and Telecommunications Administrations,

considering

a) that a methodology is needed to calculate the coordination zones around EESS and SRS earth stations for compatibility with IMT-2020 systems deployed in the frequency band 25.5-27 GHz;

b) that only a consistent application of methodologies in line with those contained in this recommendation by all administrations would ensure a proper coordination between IMT-2020 and EESS and SRS earth stations;

c) that the resulting coordination zones will differ for all earth station cases that will be analysed, due to the specificity of the terrain surrounding each of these earth stations;

recommends

1. that the methodology described in Annex 1 be used to calculate the coordination zone around SRS earth stations operating in the frequency band 25.5-27 GHz;

2. that the methodology described in Annex 2 be used to calculate the coordination zone around NGSO EESS earth stations operating in the frequency band 25.5-27 GHz;

3. that the methodology described in Annex 3 be used to calculate the coordination zone around GSO EESS earth stations operating in the frequency band 25.5-27 GHz;

4. that, when deploying an IMT-2020 base station inside the coordination zone determined by recommends 2 and 3, administrations should ensure that a minimum propagation loss (Lb) given in Table 1 is available between the base station and the EESS earth station."

Table 1: Required propagation losses (Lb) to ensure protection of EESS earth stations

Type	Azimuth (°)	GSO Lb (dB)	NGSO Lb (dB)
Hotspot (25 dBm TRP in 200 MHz, 64 antenna elements)	0	$137.5+(G_{hor}+6)$	142
	10		
	20		
	30		
	40	$136+(G^{hor}+6)$	140
	50	$135+(G_{hor}+6)$	139
	60	$133+(G_{hor}+6)$	137
	70	$130+(G_{hor}+6)$	134
	80	$124+(G_{hor}+6)$	128
	90	$119+(G_{hor}+6)$	123

Note 1: Those propagation losses have been derived using the methodology in Annex 4. The corresponding required separation distance should be computed using a relevant propagation model and considering the terrain, buildings, or clutter available on the path between the base station and the earth station considered.

Note 2: for TRP higher than 25 dBm/200 MHz, the minimum attenuation should be increased correspondingly. The BS gain is based on 8x8 antenna with a maximum gain of 23 dBi.

Note 3: G_{hor} is the EESS antenna gain in the direction of the horizon.

Note 4: The Lb values have been determined for the NGSO case assuming an EESS gain in the direction of

Type	Azimuth (°)	GSO Lb (dB)	NGSO Lb (dB)
the horizon of 15 dBi. Should the EESS antenna gain towards the horizon be higher, the required propagation loss has to be increased accordingly.			

Note:

Please check the Office documentation database https://www.ecodocdb.dk for the up to date position on the implementation of this and other ECC Recommendations.

ANNEX 1: METHODOLOGY FOR CALCULATING THE COORDINATION ZONE AROUND SRS EARTH STATIONS

A1.1 INTRODUCTION

Although it is recognised that the SRS earth station is most of the time tracking a NGSO spacecraft, and hence, its gain towards the horizon varies with time, the trajectory of SRS spacecraft varies considerably from one mission to the other. All types of missions can be envisaged for SRS (near Earth), ranging from Low Earth Orbits (LEO) to missions around one of the Lagrange points, and including Geostationary Satellite Orbits (GSO), Highly Elliptical Orbits (HEO) or Lunar missions. Similarly, SRS (deep space) missions generally target planets in the ecliptic plane, but can stay for an extended period in near earth orbits, or depart from the ecliptic plane when chasing comets, asteroids or other bodies.

To ensure that the methodology defined here will cover all types of SRS missions, the SRS earth station antenna is assumed to be pointing towards the azimuth of the IMT-2020 station, at its minimum elevation angle.

The zone area which is determined through this methodology can be relatively large given the sensitivity of SRS earth stations, and the impossibility to consider a specific trajectory or orbit for the spacecraft. Hence, such zones should be considered as coordination zones where IMT-2020 can still be deployed, after agreement is obtained with the SRS operator.

The methodology used is the Time Variable Gain (TVG) methodology given in RR Appendix 7 [1]. This methodology would give results like a Monte Carlo analysis, but is much faster and more efficient. In order to validate it, a comparison with results given by a Monte Carlo analysis has been performed for some of the points of the contour, using Recommendation ITU-R M.2101 [2], showing that when a BS was deployed just outside of the contour, the SRS protection criterion was met, and when a BS was deployed just inside the contour, the SRS protection criterion was exceeded.

Given that the user equipment will operate either indoor or in heavy clutter, the methodology focusses on the IMT-2020 base station. Since studies have shown that there is little aggregate effect from several base stations and user equipment near the earth station, the methodology only considers a single base IMT-2020 base station. When considering the aggregation of multiple BS, distances are not expected to increase as long as BS antenna panels are not concurrently pointing towards the ES in azimuth.

A1.2 TVG STANDARD METHODOLOGY

The required minimum propagation loss is then given by EQ 1.

$$L_{req}(p_v) = P_t + G_t(p_n) + G_r - I(p) \qquad \text{(EQ 1)}$$

Where:

- P_t is the total transmitting power level (dBW) in the reference bandwidth of a transmitting IMT-2020 base station;
- $I(p)$ is the protection threshold (dBW) in the reference bandwidth to be exceeded for no more than p% of the time at the input of the antenna of the receiving SRS earth station that may be subject to interference;
- $G_t(p_n)$ is the gain towards the horizon of the transmitting antenna (dBi) that is exceeded for p_n% of the time on the azimuth under consideration;
- G_r is the gain towards the physical horizon for a given azimuth (dBi) of the victim SRS earth station antenna;
- (p_v) is the minimum required propagation loss (dB) for p_v% of the time; this loss must be exceeded by the propagation path loss for all possible p_v% values retrieved from the considered gain complementary cumulative distribution function. p_v is the time percentage that approximates the

convolution between the variable horizon gain and the propagation mode path loss and is given by EQ 2.

$$p_v = \begin{cases} 100\ p / p_n & \text{for } p_n \geq 2\ p \\ 50 & \text{for } p_n < 2\ p \end{cases} \quad \% \qquad \text{(EQ 2)}$$

The limitation to 50% comes from the propagation model used, Recommendation ITU-R P.452 [3], which is limited to percentages of time up to 50%.

A1.3 DETERMINATION OF THE IMT-2020 BASE STATION TOTAL POWER

The IMT-2020 base station total power is given by EQ 3.

$$P_t = P_e + 10\log(N) - L_O - 30 + 10\log\left(\frac{B_{ref}}{B_{IMT}}\right) \qquad \text{(EQ 3)}$$

Where:

- P_e (dBm) is the power per antenna element;
- N is the number of antenna elements;
- L_O (dB) is the ohmic losses;
- B_{ref} is the reference bandwidth of the SRS protection criterion (MHz);
- B_{IMT} is the reference bandwidth of the IMT base station (MHz).

As an example, an urban or suburban hotspot 8x8 elements antenna at 26 GHz with an input power of 10 dBm/200 MHz per element and a 3 dB ohmic loss would have a total power of -28 dBW/MHz.

A1.4 DETERMINATION OF THE DISTRIBUTION OF THE IMT-2020 BS ANTENNA GAIN TOWARDS THE HORIZON

The base station antenna panel is assumed pointing towards the SRS earth station in azimuth. The distribution of antenna gain towards the horizon is determined from the distribution of electric azimuth angles φ_{escan} and electrical tilt angles θ_{etilt}, as well as the mechanical tilt θ_{mtilt}. Those distributions themselves are given by the distributions of azimuths and distances of the user equipment as seen from the base station, using the BS and UE antenna heights.

In this ECC Recommendation, the mechanical tilt makes reference to the horizontal plane. As the antenna panel is always oriented towards the ground this value is negative. The electrical tilt is defined with reference to the angle perpendicular to the antenna panel where a negative value refers to an electrical down-tilt.

The following distribution has been derived for a suburban hotspot base station at 6 m height with a -10° antenna mechanical tilt, and user equipment at 1.5m height. In this case, the azimuth beam pointing φ_{escan} can be simplified to a normal distribution $\mathcal{N}(\mu, \sigma^2)$ with zero mean $\mu = 0°$ and $\sigma = 30°$, capped at -60° and +60°. The φ_{escan} distribution is shown in Figure 1.

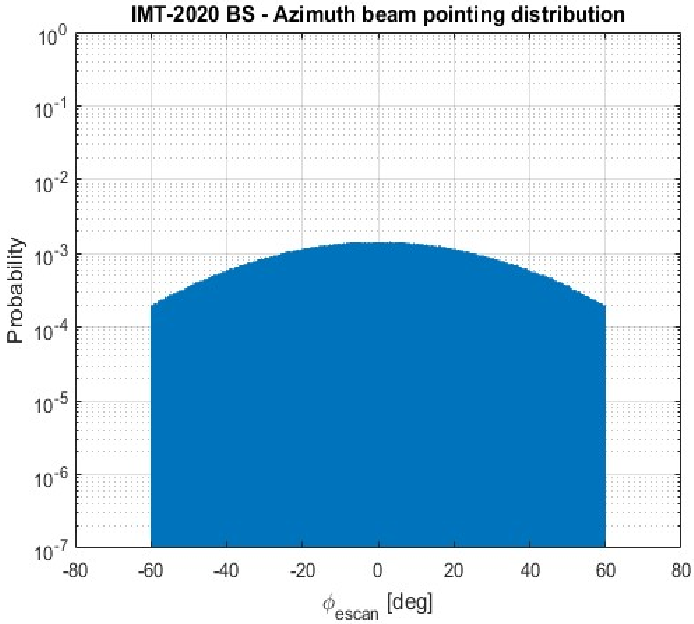

Figure 1: IMT-2020 5G BS (Suburban hotspot) – Azimuth beam pointing distribution

The elevation tilt $\theta_{\mathrm{tiltTOT}} = \theta_{\mathrm{etilt}} + \theta_{\mathrm{mtilt}}$ (see Figure 2) distribution has to be retrieved from the Rayleigh distribution ($\sigma = 32\mathrm{m}$) of the distance between BS and UE.

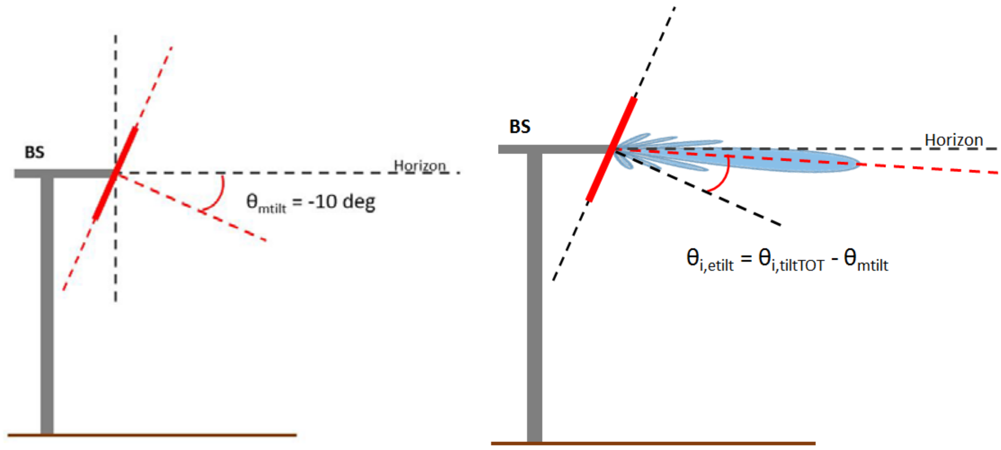

Figure 2: IMT-2020 5G BS (Suburban hotspot) – Definition of total tilt

The UE distance and $\theta_{\mathrm{tilt\,TOT}}$ PDFs are shown in Figure 3 and Figure 4, respectively.

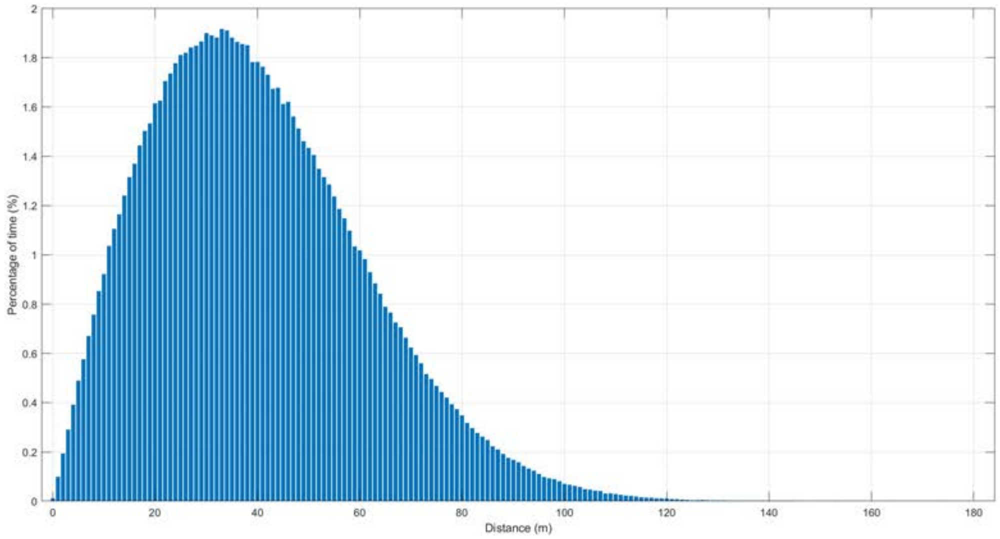

Figure 3: IMT-2020 5G BS (Suburban hotspot) – UE distance from BS PDF

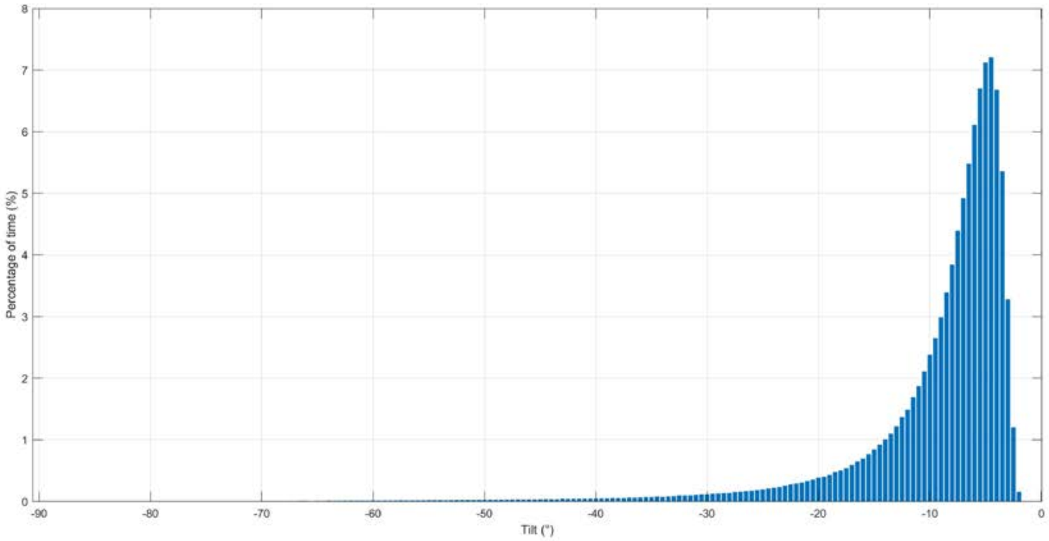

Figure 4: IMT-2020 5G BS (Suburban hotspot) – Total elevation tilt PDF

From these distributions, it is possible to determine the antenna gain distribution towards the victim earth station, using the antenna pattern from Recommendation ITU-R M.2101 [2]. The pattern for an 8x8 antenna with a 65° element aperture with an antenna gain of 5 dBi and a front to back lobe ratio of 30 dB is given in Figure 5. The Recommendation ITU-R M.2101 antenna radiation pattern has been capped at -30 dB (which is the minimum value of the single element radiation pattern of the array).

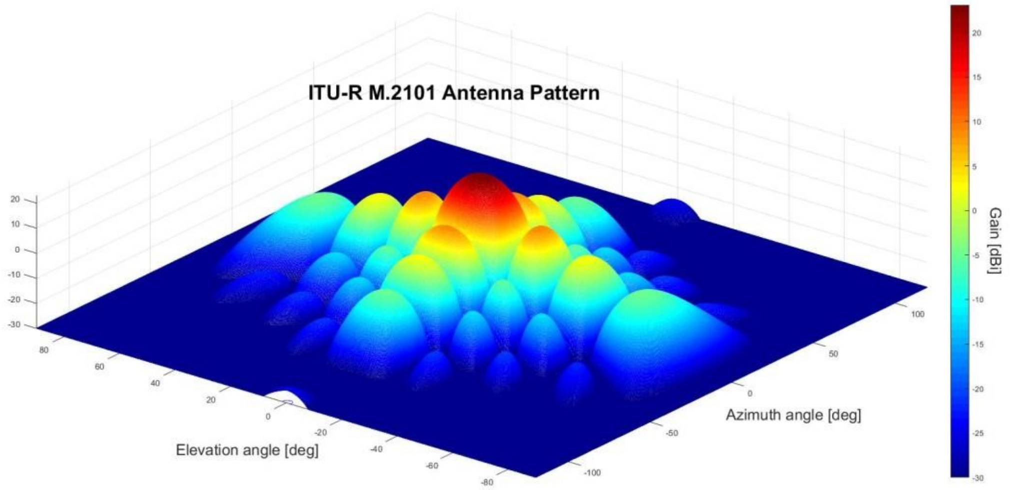

Figure 5: IMT-2020 5G BS (Suburban hotspot) – BS antenna pattern at 0° electrical tilt

The distribution has been computed assuming a flat terrain, i.e. horizon 0 deg. This is a worst-case assumption given that higher horizon angles would provide lower antenna gain values (the antenna is pointing towards ground). It is given in Figure 6 for 26 GHz. The gain on the X-axis is G_t, and the percentage on the Y-axis is p_n, as described in (EQ 1).

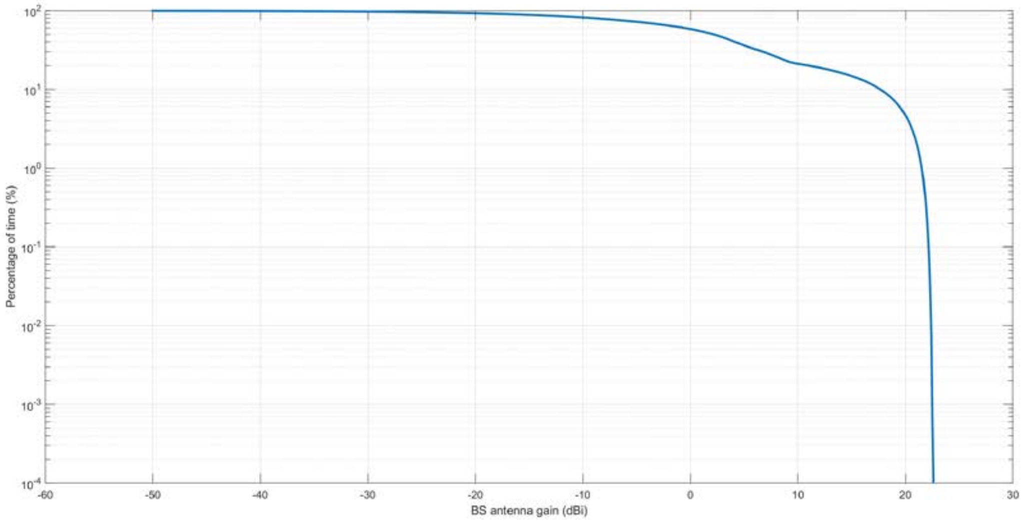

Figure 6: Gain toward the horizon CCDF (IMT-2020 5G BS Suburban hotspot, 24.25-33.40 GHz)

A1.5 DETERMINATION OF THE SRS ANTENNA GAIN GR TOWARDS THE HORIZON

The SRS antenna gain towards the horizon is determined using the minimum pointing elevation angle for the azimuth considered and the relevant antenna pattern.

The minimum elevation angle for SRS (near-Earth) in the bands 25.5-27 GHz is either 5°, or 1° above the horizon when the horizon elevation is higher than 4°.

As an example, Figure 7 gives the horizon profile for the NASA SRS earth station in Robledo (Spain). The elevation angle around 75° azimuth and above 250° is higher than 4°, hence the minimum elevation angle is 1° above this horizon. Elsewhere, the relevant value would be 5°.

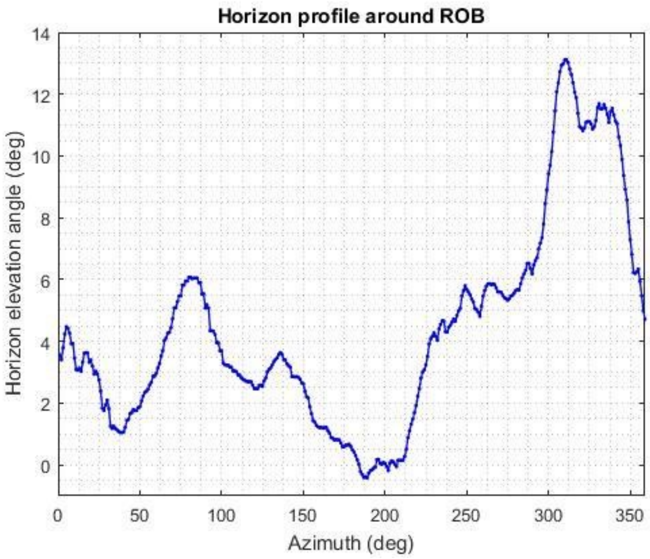

Figure 7: Horizon profile around Robledo

It should be noted that Recommendation ITU-R P.452 [3] computes the elevation angle for all the points of the terrain model between the transmitter and the receiver, and then determines the maximum elevation value as seen from the transmitter side and from the receiver side. In this case, the value extracted from Recommendation ITU-R P.452 for the receiver side for all the azimuths would directly permit to generate the horizon profile depicted in Figure 7.

Recommendation ITU-R SA.509 [10] can be used for the antenna pattern in the 25.5-27 GHz band. Alternatively, the antenna patterns contained in RR Appendices 7 or 8 [1] could also be considered.

Figure 8 provides an example of SRS antenna gain Gr as function of the azimuth around the NASA SRS earth station in Robledo (Spain).

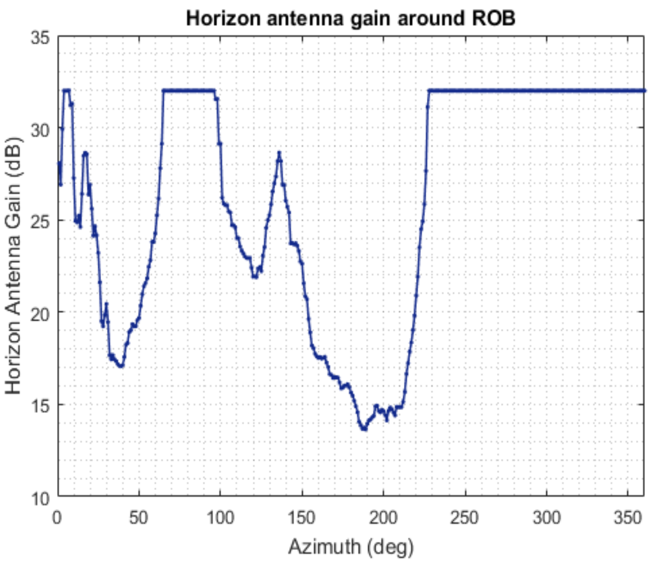

Figure 8: NASA SRS earth station antenna gain towards the horizon around Robledo

A1.6 DETERMINATION OF THE SRS PROTECTION THRESHOLD AND REFERENCE BANDWIDTH

The SRS protection threshold I is given in Recommendation ITU-R SA.609 [4] for SRS (Near-Earth) below 30 GHz, as -156 dBW in a reference bandwidth B_{ref} of 1 MHz. The associated percentage of time p

is either 0.1% for unmanned missions or 0.001% for manned missions. Since most of SRS earth stations can support both manned and unmanned missions, the value of 0.001% should be used.

Those criteria do not include any apportionment that could be envisaged on a case-by-case basis.

A1.7 DETERMINATION OF THE REQUIRED PROPAGATION LOSS AND ASSOCIATED PERCENTAGE OF TIME

For each azimuth around the SRS earth station, and each percentage of time p_n determined in section A1.4, the required propagation loss L_{req} and associated percentage of time p_v should be determined using equations (1) and (2) respectively.

A1.8 DETERMINATION OF THE COORDINATION CONTOUR

For each of the azimuth around the SRS earth station, each of the distances from the SRS earth station location, and each of the percentages of time p_v determined in section A1.7, the propagation loss should be determined using an appropriate propagation model such as the one contained in Recommendation ITU-R P.452-16 [3], considering the terrain elevation surrounding the earth station.

The terrain elevation model can be the 1-arcsec resolution terrain profile data of the Shuttle Radar Topography Mission (SRTM), however more detailed terrain models, including build area models, may be used. The terrain profiles can be sampled with an azimuth step of 1° around the earth station of interest and a distance step of 25 m. The losses can then be computed around the station with an azimuth step of 1 degree and a distance step of 100 m.

For each azimuth and percentage of time p_v, the separation distance required is then the maximum distance at which the propagation loss calculated is just below the required propagation loss $L_{req}(p_v)$. The coordination distance to be retained for the azimuth angle considered is the maximum distance obtained for all values of p_v.

The following Figure 9 provides as an example the coordination contour obtained around the ESA station in Cebreros (Spain) for an 8x8 suburban hotspot base station at 26 GHz.

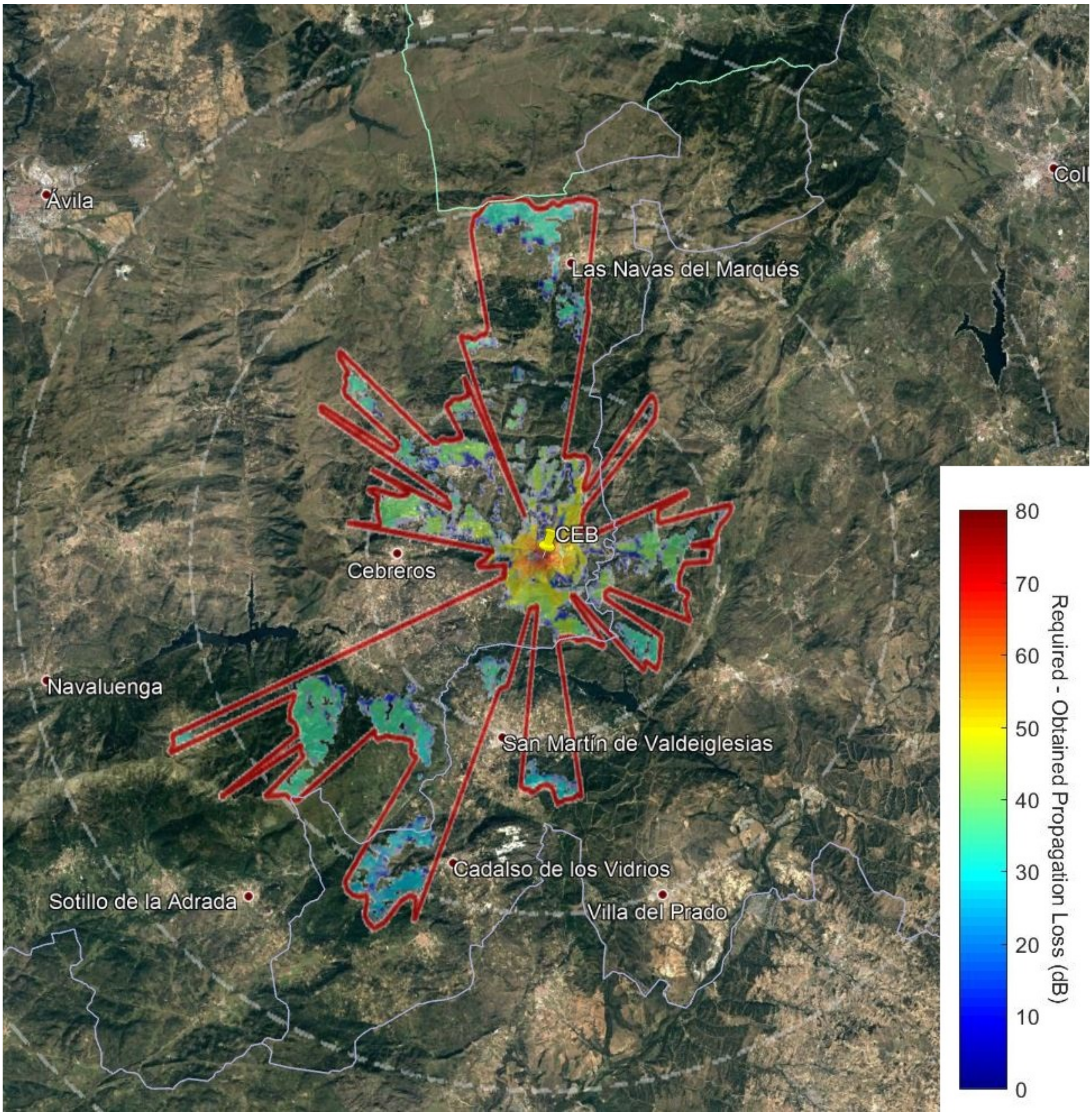

Figure 9: Google Earth view of coordination contour and protection level exceedance around Cebreros

ANNEX 2: METHODOLOGY FOR CALCULATING THE COORDINATION ZONE AROUND NGSO EESS EARTH STATIONS IN THE BAND 25.5-27 GHZ

A2.1 INTRODUCTION

Most of NGSO EESS satellites using this frequency band will be LEO satellites on polar orbits. Other types of orbits can also be used with different inclinations, however it is not expected that this would change the results obtained when using this methodology with a particular satellite on an 800 km sun synchronous orbit, as proposed in Section A2.5.

The methodology used is based on the Time Variable Gain (TVG) methodology given in RR Appendix 7 [1]. However, since both the transmitter and receiver antenna gains are varying, a convolution has to be made between the distributions of those gains and hence, the methodology has to be slightly revised. Here again, the methodology has been validated through additional Monte Carlo simulation for some of the contour points.

Given that the user equipment will operate either indoor or in heavy clutter, the methodology focusses on the IMT-2020 base station. Since studies have shown that there is little aggregate effect from several base stations and user equipment near the earth station, the methodology only considered a single IMT-2020 base station. When considering the aggregate, distances are not expected to increase as long as BS antenna panels are not concurrently pointing towards the ES in azimuth.

A2.2 TVG MODIFIED METHODOLOGY

A modified version of the Time Variable Gain (TVG) methodology given in RR Appendix 7 [1] has been used to approximate the convolution of the distributions of the transmitter antenna gain (base station tracking the UE), the receiver antenna gain (the EESS earth station tracking an EESS satellite on a typical polar orbit), and the propagation model. (EQ 1) can be rewritten as follows:

$$(p_v) = P_t + G_\mathrm{t}(p_t) + G_r(p_r) - I(p) - Lc = P_t + G_{tot}(p_n) - I(p) - Lc \qquad \text{(EQ 3)}$$

Where:

- P_t is the total transmitting power level (dBW) in the reference bandwidth of a transmitting IMT-2020 base station;
- $I(p)$ is the protection threshold (dBW) in the reference bandwidth to be exceeded for no more than p% of the time at the input of the antenna of the receiving SRS earth station that may be subject to interference;
- $G_t(p_\mathrm{t})$ is the gain towards the horizon of the transmitting antenna (dBi) that is exceeded for p_t% of the time on the azimuth under consideration;
- $G_r(p_r)$ is the gain towards the physical horizon for a given azimuth (dBi) of the victim SRS earth station antenna that is exceeded for p_r% of the time on the azimuth under consideration;
- $G_{tot}(p_n) = G_t(p_t) + G_r(p_r)$ is given by the convolution between the transmitting gain distribution $G_t(p_t)$ and the victim Earth station distribution $G_r(p_r)$;
- Lc is the clutter loss (dB) applicable to the IMT-2020 base station specific environment, if any;
- (p_v) is the minimum required propagation loss (dB) for p_v% of the time; this loss must be exceeded by the propagation path loss for all possible p_v% values retrieved from the considered gain complementary cumulative distribution function. p_v is the time percentage that approximates the convolution between the variable horizon gain and the propagation mode path loss and is given by EQ 2.

A2.3 DETERMINATION OF THE IMT-2020 BASE STATION TOTAL POWER

Same as section A1.3.

A2.4 DETERMINATION OF THE DISTRIBUTION OF THE IMT-2020 BS ANTENNA GAIN TOWARDS THE HORIZON

Same as section A1.4.

A2.5 DETERMINATION OF THE EESS ANTENNA GAIN GR TOWARDS THE HORIZON

To determine the EESS earth station antenna gain towards the horizon for each azimuth, it is necessary to run a simulation whereby an EESS satellite orbit is propagated over a given period.

EESS satellites are generally using sun-synchronous orbits, with altitudes between 400 and 1400 km, a typical value being 800 km. For a worst case 400 km altitude, the orbit inclination would be 97°. Figure 10 provides a view of such orbit.

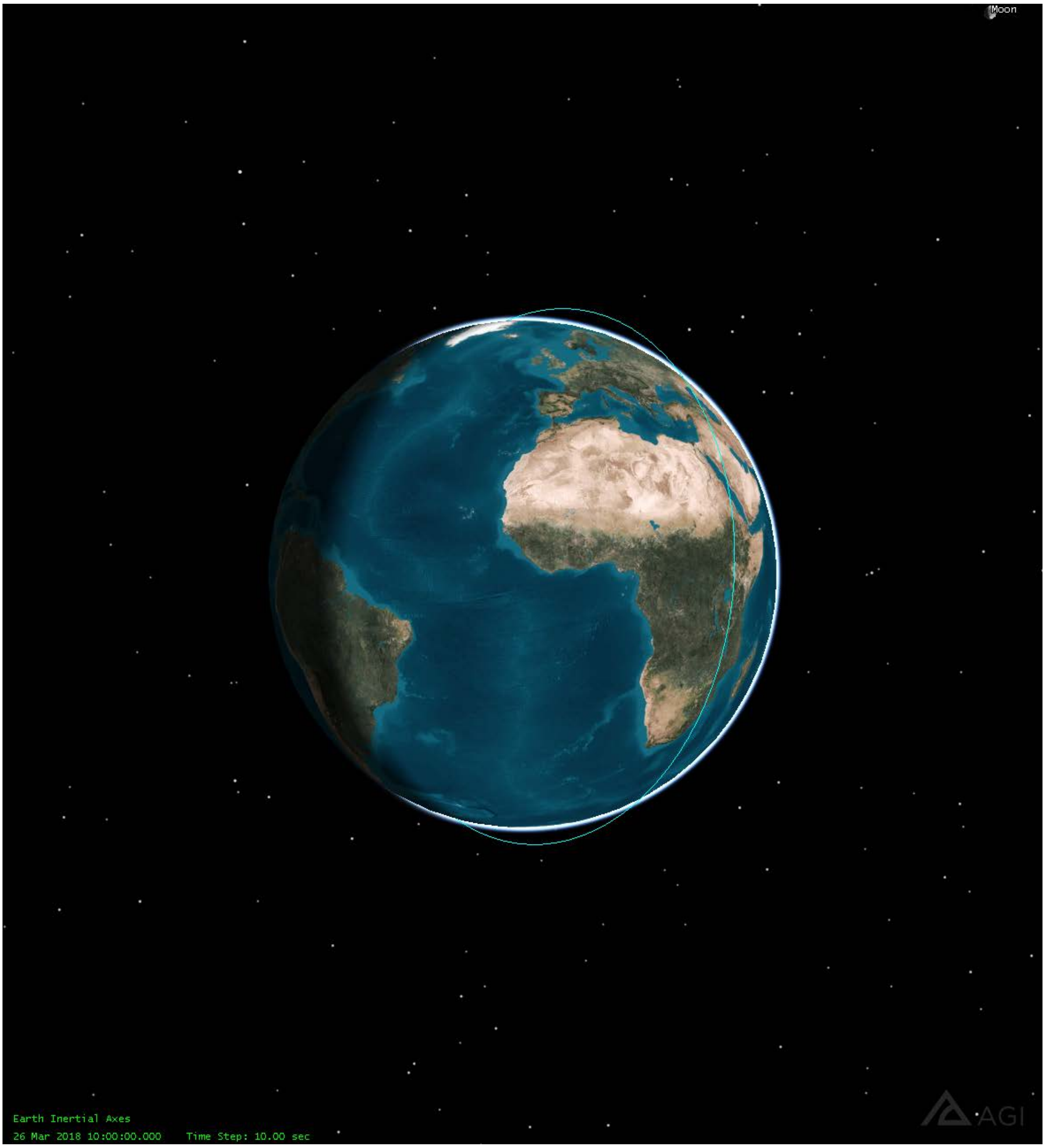

Figure 10: EESS satellite orbit

It is then necessary to determine the visibilities of such satellite from the EESS earth station considered. The satellite is visible as soon as its elevation angle as seen from the earth station is over 5°. Figure 11 provides as an example a view of the portions of orbits that are visible from Kiruna (Sweden) over 5° elevation over a 11 days period.

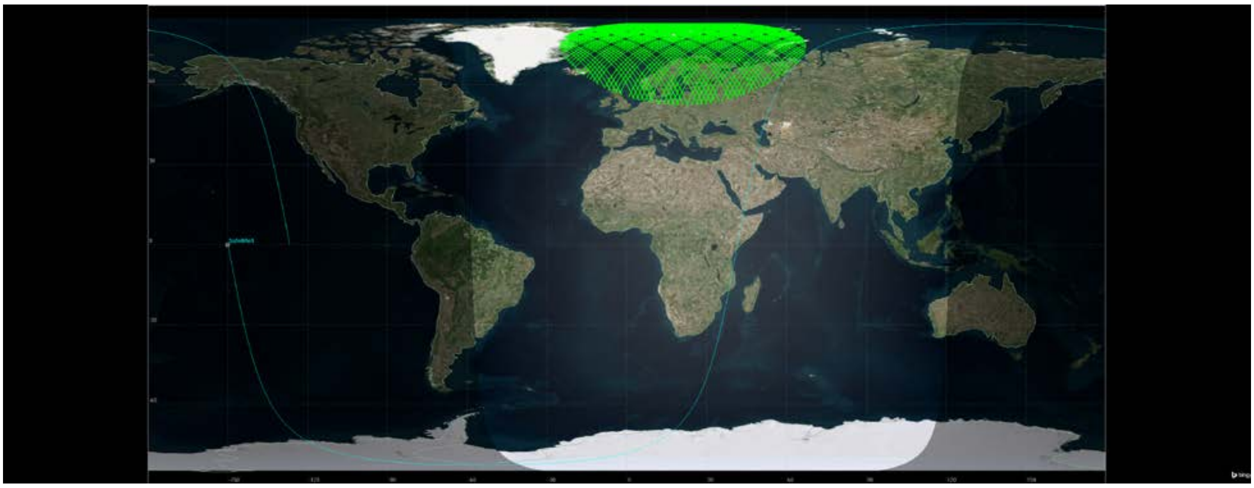

Figure 11: Visibility of the EESS satellite from a given earth station

For each of the time steps where the satellite is in visibility, and each azimuth around the earth station, it is then necessary to determine the offset angle between the vector earth station-satellite, and the horizon direction for the azimuth considered. This offset angle can then be used to determine the antenna gain towards the horizon, using antenna patterns such as RR Appendix 7 or Appendix 8 [1]. The cumulative distribution function of the antenna gain can then be extracted for each azimuth, as shown in Figure 12 for Kiruna, and an antenna following AP8 with a 70.7 dBi maximum antenna gain.

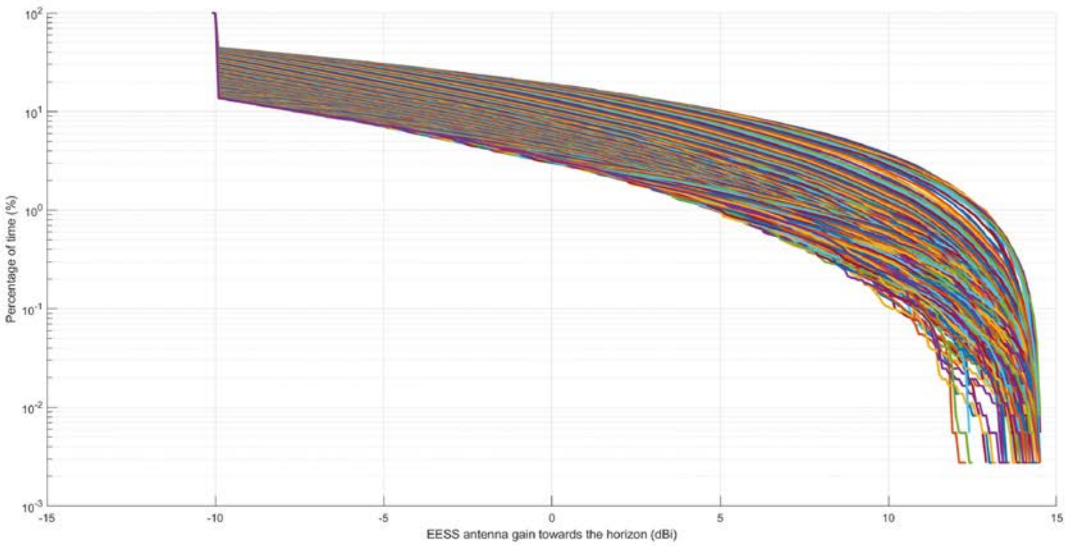

Figure 12: EESS Antenna gain towards the horizon

This cdf provides on the X-axis the value of G_r and on the Y-axis the value of p_r used in equation 3, for each azimuth.

A2.6 DETERMINATION OF THE CONVOLUTION G_{TOT} OF BOTH ANTENNA GAINS TOWARDS THE HORIZON

When both distributions of base station gain towards the horizon and EESS gain towards the horizon are available, the next step is to convolve them. This can be done directly for each azimuth, or using this alternative approach:

- Generate N random base station antenna gain values G_t following the distribution $G_t(p_t)$ obtained in section A1.4;
- Generate N random EESS earth station antenna gain values Gr following the distribution $G_r(p_r)$obtained in section A2.5;
- Sum the two random numbers obtained $G_{tot}=G_t+G_r$;
- Generate the cdf of $G_{tot.}$

This has been done as an example for the EESS earth station in Kiruna, for all azimuth around the earth station, in Figure 13.

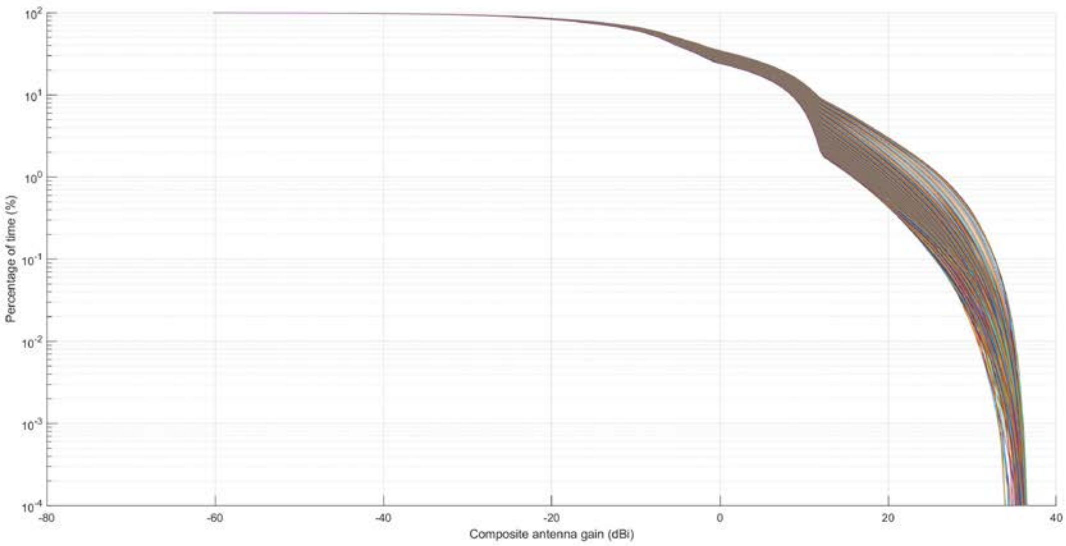

Figure 13: Composite gain G_{tot}

A2.7 DETERMINATION OF THE EESS PROTECTION THRESHOLD AND REFERENCE BANDWIDTH

The EESS sharing threshold I is given in Recommendation ITU-R SA.1027 [6]. This Recommendation proposes two criteria, one long-term and one short-term. Monte Carlo analyses have shown that when the short-term criterion was met, the long-term was also met. In addition, applying this methodology with the long-term criterion and a percentage of time of 20% would largely overestimate the separation distances required to ensure protection to EESS earth stations.

The sharing criterion to be used is therefore the short-term criterion, given as -116 dBW in a reference bandwidth B_{ref} of 10 MHz. The associated percentage of time p is 0.005%.

A2.8 DETERMINATION OF THE REQUIRED PROPAGATION LOSS AND ASSOCIATED PERCENTAGE OF TIME

Same as section A1.7.

A2.9 DETERMINATION OF THE COORDINATION ZONE CONTOUR

For each of the azimuth around the EESS earth station, each of the distances from the EESS earth station location, and each of the percentages of time p_v determined in section A1.8, the propagation loss should be determined using an appropriate propagation model such as the one contained in Recommendation ITU-R P.452-16 [3], considering the terrain elevation surrounding the earth station.

The terrain elevation model can be the 1-arcsec resolution terrain profile data of the Shuttle Radar Topography Mission (SRTM), however more detailed terrain models, including build area models, may be used. The terrain profiles can be sampled with an azimuth step of 1°around the earth station of interest and a distance step of 25 m. The losses can then be computed around the station with an azimuth step of 1 degree and a distance step of 100 m.

For each azimuth and percentage of time p_v, the separation distance required is then the maximum distance at which the propagation loss calculated is just below the required propagation loss $L_{req}(p_v)$. The separation distance to be retained for the azimuth angle considered is the maximum distance obtained for all values of p_v.

The following Figure 14 provides as an example the coordination zone contour obtained around the ESA station in Kiruna (Sweden) for an 8x8 suburban hotspot base station at 26 GHz.

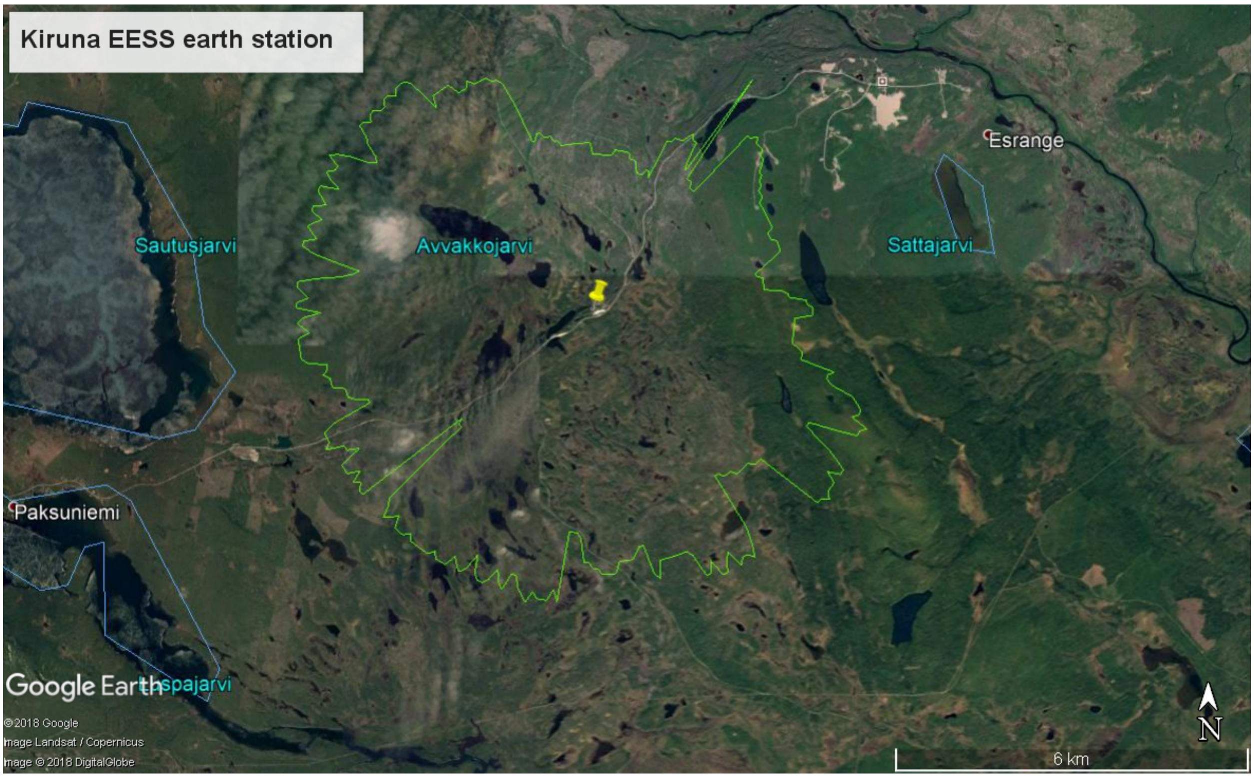

Figure 14: Google Earth view of coordination zone contour around Kiruna

ANNEX 3: METHODOLOGY FOR CALCULATING THE COORDINATION ZONE AROUND GSO EESS EARTH STATIONS IN THE BAND 25.25-27.5 GHZ

A3.1 INTRODUCTION

This methodology would apply to EESS satellites performing observations from the GSO orbit such as meteorological satellites, in the band 25.5-27 GHz.

In this case, the EESS earth station is tracking a given GSO satellite and hence its antenna is not moving. The TVG methodology given in RR Appendix 7 [1] can therefore be applied as such. This methodology would give results similar to a Monte Carlo analysis, but is much faster and more efficient. Here again, the methodology has been validated through additional Monte Carlo simulation for some of the contour points.

Given that the user equipment will operate either indoor or in heavy clutter, the methodology focusses on the IMT-2020 base station. Since studies have shown that there is little aggregate effect from several base stations and user equipment near the earth station, the methodology only considered a single base IMT-2020 base station. When considering the aggregate, distances are not expected to increase as long as BS antenna panels are not concurrently pointing towards the ES in azimuth.

A3.2 TVG STANDARD METHODOLOGY

See section A1.2.

A3.3 DETERMINATION OF THE IMT-2020 BASE STATION TOTAL POWER

See section A1.3.

A3.4 DETERMINATION OF THE DISTRIBUTION OF THE IMT-2020 BS ANTENNA GAIN TOWARDS THE HORIZON

See section A1.4.

A3.5 DETERMINATION OF THE EESS ANTENNA GAIN G_R TOWARDS THE HORIZON

In this case, the GSO satellite is fixed at a given longitude on the GSO arc, at round 36000 km altitude. It is therefore easy to determine only once the vector going from the EESS earth station towards the EESS satellite. The offset angle between this vector and the horizon direction for each azimuth can also be determined only once, whereas for a NGSO satellite it had to be determined for each time step.

This offset angle allows to determine the antenna gain of the EESS earth station towards the horizon for the azimuth considered. Normally, it should be at its maximum value in the azimuth corresponding to the azimuth where the GSO satellite is.

A3.6 DETERMINATION OF THE EESS PROTECTION THRESHOLD AND REFERENCE BANDWIDTH

The short-term EESS sharing threshold I is given in Recommendation ITU-R SA.1161 [5], as -133 dBW in a reference bandwidth B_{ref} of 10 MHz. The associated percentage of time p is 0.1%.

A3.7 DETERMINATION OF THE REQUIRED PROPAGATION LOSS AND ASSOCIATED PERCENTAGE OF TIME

See section A1.7.

A3.8 DETERMINATION OF THE COORDINATION ZONE CONTOUR

For each of the azimuth around the EESS earth station, each of the distances from the EESS earth station location, and each of the percentages of time p_v determined in section A1.7, the propagation loss should be determined using an appropriate propagation model such as the one contained in Recommendation ITU-R P.452-16 [3], considering the terrain elevation surrounding the earth station.

The terrain elevation model can be the 1-arcsec resolution terrain profile data of the Shuttle Radar Topography Mission (SRTM), however more detailed terrain models, including build area models, may be used. The terrain profiles can be sampled with an azimuth step of 1° around the earth station of interest and a distance step of 25 m. The losses can then be computed around the station with an azimuth step of 1 degree and a distance step of 100 m.

For each azimuth and percentage of time pv, the separation distance required is then the maximum distance at which the propagation loss calculated is just below the required propagation loss L_{req}(pv). The separation distance to be retained for the azimuth angle considered is the maximum distance obtained for all values of p_v.

The following Figure 15 provides as an example the coordination zone contour obtained around the EUMETSAT earth station in Leuk (Switzerland) for a 8x8 suburban hotspot base station at 26 GHz.

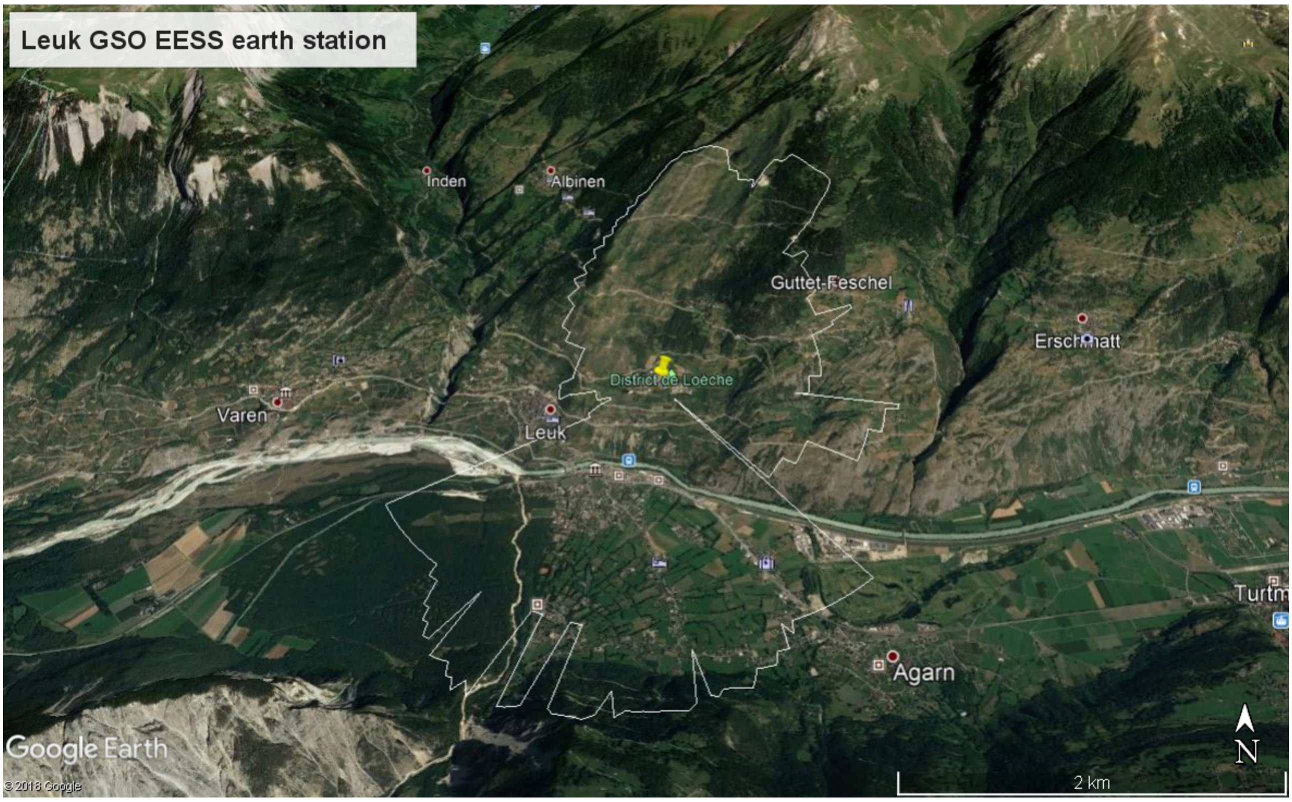

Figure 15: Google Earth view of the coordination zone contour around Leuk

ANNEX 4: METHODOLOGY TO ENSURE THE PROTECTION OF EESS EARTH STATIONS INSIDE THE COORDINATION ZONE

A4.1 INTRODUCTION

The purpose of the annex is to describe one methodology to ensure the protection of EESS earth stations (GSO or/and NGSO) from IMT-2020 when the IMT base station is within the coordination area. Outside this coordination area, no calculation is necessary and the deployment of IMT-2020 could be made without particular constraint. However, in the coordination area, IMT-2020 could be deployed but some precautions have to be taken.

Studies have shown that, in the case of EESS protection (GSO or NGSO), the generic TVG (made without terrain profile), provides distances which can most of the time be approximated as follows:

- For GSO earth station, to distance calculated with the maximum gain of BS towards horizon and a percentage of 50% in the model described by Recommendation ITU-R P.452 [3];
- For NGSO earth station, to distance calculated with the maximum composite gain (G_{tot} – sum of EESS and BS gain) and a percentage of 50% in the model described by Recommendation ITU-R P.452.

The distance found by the TVG is also dependent of the emitted power. The studies show that the previous conclusion is totally relevant for the e.i.r.p described by WP5D as 48dBm/200 MHz for a 8x8 antenna (25 dBm/200 MHz of power considering 3dB of ohmic losses and 23 dBi of maximum gain) and could be extended until an e.i.r.p of 70 dBm/200 MHz.

Some other studies, on EESS earth station, developed in ITU-R have shown that meeting short term criteria (-133 dBW/10 MHz for 0.1% (GSO case) and -116 dBW/10 MHz for 0.005% (NGSO) also implies meeting the long term criteria. So, for EESS earth station, the studies could only focus on this criterion.

For the case of an EESS Earth station, the coordination distance is, most of the time, limited to line of sight (LOS). In other words the distance is often close to or below the radio horizon. Under this condition, the calculated losses provided by Recommendation ITU-R P.452 (50% and LOS conditions) are based on free space losses and diffraction.

A4.2 PROPAGATION LOSSES

Under LOS condition, as described by Recommendation ITU-R P.452 [3], the ducting and troposcatter effects do not play a role and the minimum losses are given by free space and diffraction. Free space loss increases with distance and diffractions are linked to the presence of physical obstacles on the propagation path, as well as diffraction by round Earth. The diffraction losses increase with the number and the height of the obstacles.

In an urban environment, with hotspots at 6m, the diffraction by buildings, i.e. clutter contribution, could be very important. As an example, the curves provided by Recommendation ITU-R P.2108 [7] provide diffraction losses between 13 and 45 dB in the first 500m. For this distance, the average value is close to 19 dB. This value is arbitrary and will be used as example in calculation. The used of real terrain profile with building level is however more accurate. Figure 16 provides an example of the building level that could be used in simulation.

Figure 16: Example of Building Levels in the centre of the City of Toulouse

A4.3 AGREGATE EFFECT IN THE EESS EARTH STATION FROM SEVERAL IMT- 2020 BS

The aggregated effect of several base stations can be significant when their emissions are of the same magnitude of power to the EESS receiver. To obtain this condition in a LOS situation, considering the previous assumption of calculation (max gain, 50%), the BSs need to have the maximum gain towards the earth station with almost the same losses on each propagation paths. Hence a small margin on the EESS protection criteria to account for this aggregation effect could be used.

A4.4 EARTH STATION POINTING ON GEOSTATIONARY ARC

A4.4.1 General rules

As mentioned in the previous section (A4.1), the separation distance in the coordination area between an earth station pointing towards a GSO satellite and an IMT-2020 base station could be defined considering:

1. The maximum gain of the earth station towards the horizon (G_{rmax})
2. The maximum gain of the BS towards the horizon (G_{tmax})
3. The IMT-2020 power (or TRP with 3dB of ohmic losses) converted in the EESS protection criteria reference bandwidth (10 MHz) (P_t)
4. The short term criterion of the EESS earth station : -133 dBW/10 MHz (C_r)
5. A margin for aggregation (A)
6. A percentage of time of 50% in Recommendation ITU-R P.452 [3] (note: for simplification, Recommendation ITU-R P.525 [8] (free space) and Recommendation ITU-R P.526 [9] (diffraction) could be used).
7. A relevant terrain profile between the earth station and the BS. This terrain profile has to be as precise as possible by including building/clutter level.

In a real deployment, the separation distance could be difficult to use. In this situation, in order to define the position of the BS in regards of the EESS earth station, the best way to proceed is to define the necessary losses based on the assumptions above. The losses could be calculated as follow:

$$\mathrm{L} = P_t + G_{tmax} + G_{rmax} - C_r + A \quad \text{(EQ 4)}$$

A4.4.2 Minimum attenuation towards the EESS station

The study explores the possibility to use he discrimination angle between the mechanical azimuth of BS and the azimuth where the EESS earth station is as a factor of compatibility improvement. The following figure provides the cumulative distribution of the BS antenna gain (hotspot at 6m) towards the horizon for different BS panel physical azimuth angle. The figure was built considering the distribution of electrical tilt (see Section A1.4) and a mechanical tilt of -10°. Due to the UE distribution in azimuth (between -60 and 60°) and distance, the figure shows that a maximum gain between 22.5 to 20 dBi could be found towards the horizon for azimuth values between 0 to 50°. After this value, the maximum gain towards horizon decreases considerably and become less than 5dBi when the BS is perpendicular to the receiver.

These results show that the position of BS with regards to the EESS earth station could considerably improve the compatibility between both services. Table 1 provides the necessary losses considering the distribution of gain presented in Figure 17 and equation (4) from section A4.4.1. The maximum TRP of the BS is taken as 25dBm/200 MHz. Considering the reference bandwidth of EESS protection criteria (see section A1.3), the emitted power represents -18 dBW/(10 MHz). For higher TRP the minimum attenuation would increase correspondingly. For antenna with lower or higher number of elements the minimum attenuation would need to be recalculated.

The EESS earth station could point towards different positions on the geostationary arc, but the calculation shows that the gain towards horizon (G_r) could only vary from -6 to -10 dBi, at least in most European countries below a given latitude. In order to ensure the protection of the earth station, a value of -6 dB is chosen.

Table 2 shows that, if an average clutter loss value of 19 dB is used the separation distance between IMT-2020 and EESS earth station could become less than 1 km if the BS points in direction of the earth station and less than 100 m if the BS is perpendicular to the earth station.

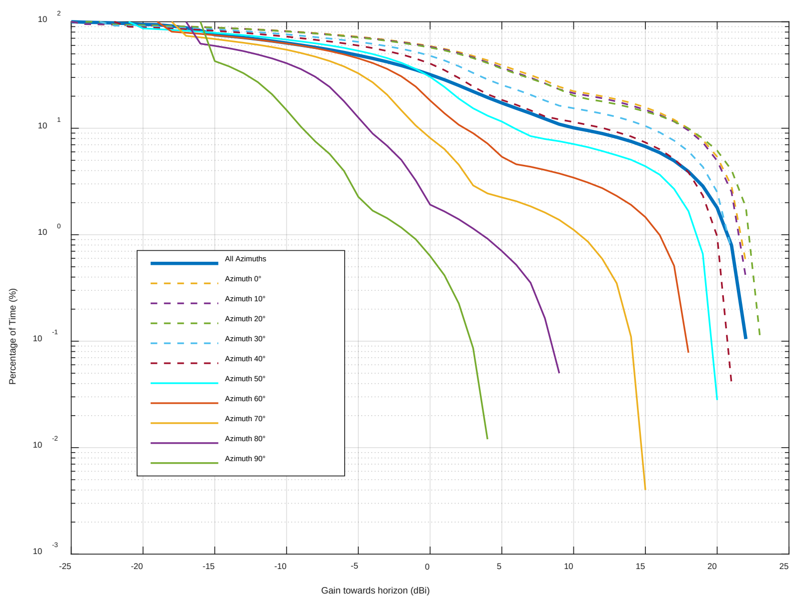

Figure 17: CDF of BS gain toward horizon for different azimuths

Table 2: Evaluation of necessary losses

<table>
<tr><th>Type</th><th>Azimuth (°)</th><th>Pt (dBW /10MHz)</th><th>Gt (dBi)</th><th>Gr (dBi)</th><th>Cr (dBW /10MHz)</th><th>Aggr. effect (dB)</th><th>Lb (dB)</th><th>FS distance (km)</th><th>FS+CLUTTER distance (km) (1)</th></tr>
<tr><td rowspan="10">Hotspot</td><td>0</td><td rowspan="4">-18</td><td rowspan="4">22.5</td><td rowspan="4">-6</td><td rowspan="4">-133</td><td rowspan="4">6</td><td rowspan="4">137.5</td><td rowspan="4">6.6</td><td rowspan="4">0.8</td></tr>
<tr><td>10</td></tr>
<tr><td>20</td></tr>
<tr><td>30</td></tr>
<tr><td>40</td><td>-18</td><td>21</td><td>-6</td><td>-133</td><td>6</td><td>136</td><td>5.8</td><td>0.65</td></tr>
<tr><td>50</td><td>-18</td><td>20</td><td>-6</td><td>-133</td><td>6</td><td>135</td><td>5.2</td><td>0.58</td></tr>
<tr><td>60</td><td>-18</td><td>18</td><td>-6</td><td>-133</td><td>6</td><td>133</td><td>4.1</td><td>0.47</td></tr>
<tr><td>70</td><td>-18</td><td>15</td><td>-6</td><td>-133</td><td>6</td><td>130</td><td>3</td><td>0.33</td></tr>
<tr><td>80</td><td>-18</td><td>9</td><td>-6</td><td>-133</td><td>6</td><td>124</td><td>1.5</td><td>0 .17</td></tr>
<tr><td>90</td><td>-18</td><td>4</td><td>-6</td><td>-133</td><td>6</td><td>119</td><td>0.8</td><td><0.1</td></tr>
<tr><td colspan="10">(1) the distance are evaluated considering an average clutter value of 19 dB (average value of distribution provided by P.2108 [7]for a distance of 500m)</td></tr>
</table>

A4.5 EARTH STATION TRACKING A NON-GEOSTATIONARY SATELLITE

A4.5.1 General rules

As shown in section (A4.1), the separation distance in the coordination area between an earth station pointing towards a NGSO satellite and an IMT-2020 base station could be defined considering:

1. The maximum composite gain (associated gain of BS and earth station) towards horizon (G_{cmax})
2. The IMT-2020 power (or TRP with 3dB of ohmic losses) converted in the EESS protection criteria reference bandwidth (10 MHz) (P_t)
3. The short term criteria of the NGSO EESS earth station : -116 dBW/10 MHz (C_r)
4. A fixed value of Aggregation (A)
5. A percentage of time of 50% in Recommendation ITU-R P.452 [3] that could be often simplified by the associated use of Recommendation ITU-R P.525 [8] (free space) and Recommendation ITU-R P.526 [9] (diffraction).
6. A relevant terrain profile between the earth station and the BS. This terrain profile has to be as precise as possible including building/clutter level.

In real deployment, the separation distance could be difficult to use. In this situation, in order to define the position of the BS in regards of the EESS earth station, the best way to proceed is to define the necessary losses based on the assumptions above. The losses could be calculated as follows:

$$\mathrm{L} = P_t + G_{cmax} - C_r + A \qquad \text{(EQ 5)}$$

A4.5.2 Practical Case

Similarly to the previous section, the study focuses on the possibility to use the discrimination angle between mechanical axes of BS and EESS earth station as a factor of compatibility improvement. Figure 18 provides the cumulative distribution of the composite gain (association of the BS gain and EESS gain) towards the horizon for different azimuth angles. Due to the angle limitation of BS electrical tilt from -60 to 60°, the maximum composite gain is between 35 and 37.5 dBi for discrimination angle between 0 to 50° and decreases for angles above.

Table 2 provides the necessary losses considering the distribution of gain presented in Figure 16 and equation (EQ 4) from section A4.5.2. In this example, the maximum power of the BS is taken as described by ITU-R WP5D (25 dBm/(200 MHz)). Considering the reference bandwidth of EESS protection criteria (see section A1.3), the emitted power represents -18 dBW/(10 MHz).

The EESS earth station tracks a non-geostationary satellite at 800 km of altitude in polar orbit. The minimum elevation angle is taken as 5°. For this elevation, the maximum antenna gain towards horizon, using RR appendix 8 is closed to 15 dBi.

Table 3 shows that, if an average value of clutter loss of 19 dB is used the separation distance between IMT-2020 and the EESS earth station could become less than 1.3 km if the BS points in direction of the earth station and less than 140 m if the BS is perpendicular to the earth station.

Figure 19 provides the map of losses in a city where the EESS earth station could be deployed in France. This figure shows that the maximum distance in the city, where no building is present, is close to 3 km to obtain 142 dB of losses. When buildings are present in the path, the distance can decrease to a few hundred meters. However, care has to be taken far away (around 5 km) from the station on height elevation position (hills, mountains…) as shown in the North East and South West directions of the station. Figure 16 shows that the diffraction losses due to the presence of buildings on the propagation path would ensure the EESS earth station protection without imposing undue constraint to IMT-2020.

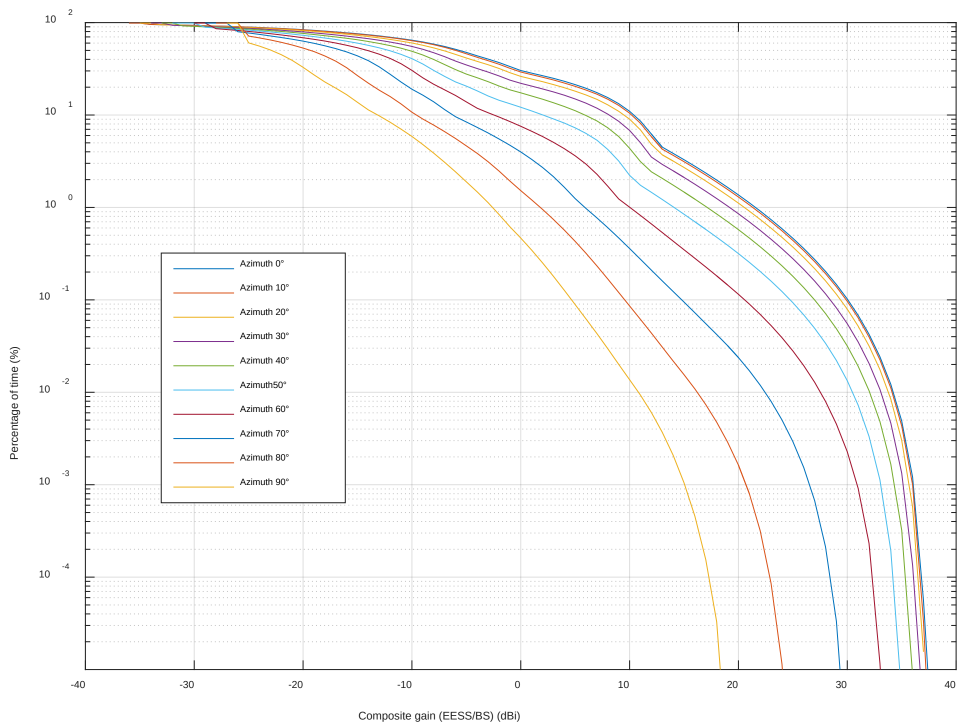

Figure 18: CDF of Composite gain toward horizon for different azimuth

Table 3: Evaluation of necessary losses

Type	Azimuth (°)	Pt (dBW /10MHz)	Gc (dBi)	Cr (dBW /10MHz)	Aggr. effect (dB)	Lb (dB)	FS distance (km)	FS+CLUTTER distance (km) (1)
Hotspot	0	-18	38	-116	6	142	11.6	1.3
	10							
	20							
	30							
	40	-18	36	-116	6	140	9.2	1.03
	50	-18	35	-116	6	139	8.3	0.92
	60	-18	33	-116	6	137	6.6	0.73
	70	-18	30	-116	6	134	4.6	0.52
	80	-18	24	-116	6	128	2.3	0.26
	90	-18	19	-116	6	123	1.3	0.14

(1) the distance are evaluated considering an average clutter value of 19 dB (average value of distribution provided by P.2108 for a distance of 500m)

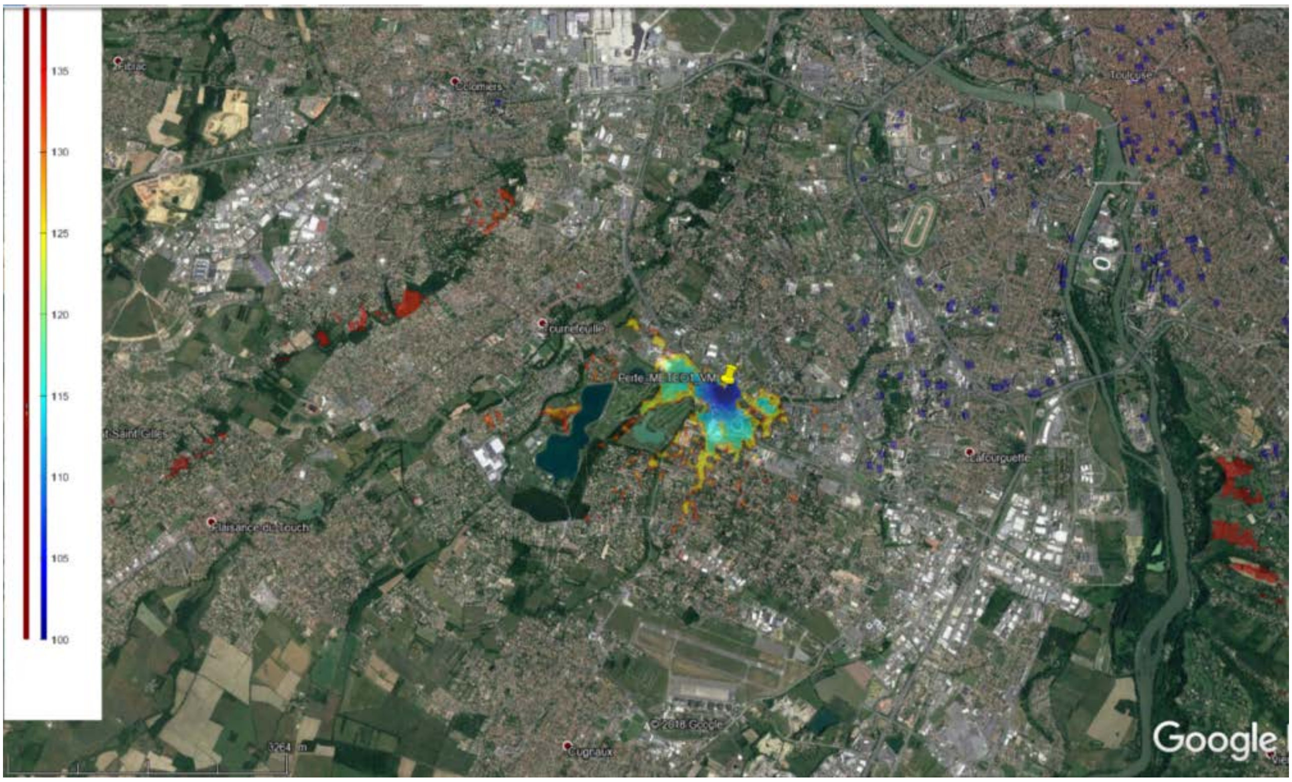

Figure 19: Loss Map of the city of Toulouse using Recommendation ITU-R P.452-14 [3] (50%) and real terrain profile associated with building model

ANNEX 5: LIST OF REFERENCES

[1] ITU Radio Regulations Edition of 2016
[2] Recommendation ITU-R M.2101-0: "Modelling and simulation of IMT networks and systems for use in sharing and compatibility studies"
[3] Recommendation ITU-R P.452: "Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz"
[4] Recommendation ITU-R SA.609-2: "Protection criteria for radiocommunication links for manned and unmanned near-Earth research satellites"
[5] Recommendation ITU-R SA.1161-2: "Sharing and coordination criteria for data dissemination and direct data readout systems in the Earth exploration-satellite and meteorological-satellite services using satellites in geostationary orbit"
[6] Recommendation ITU-R SA.1027-5: "Sharing criteria for space-to-Earth data transmission systems in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit"
[7] Recommendation ITU-R P.2108-0: "Prediction of Clutter Loss"
[8] Recommendation ITU-R P.525-3: "Calculation of free-space attenuation"
[9] Recommendation ITU-R P.526-14: "Propagation by diffraction"
[10] Recommendation ITU-R SA.509-3: "Space research earth station and radio astronomy reference antenna radiation pattern for use in interference calculations, including coordination procedures, for frequencies less than 30 GHz"