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Coordination between space research service (deep space) stations operating in the band 7 145-7 190 MHz and IMT stations operating in the band 6 425-7 125 MHz

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***Note**: This ITU-R Report was approved in English by the Study Group under the procedure detailed in Resolution ITU-R 1.*

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REPORT ITU-R M.2561-0

Coordination between space research service (deep space) stations operating in the band 7 145-7 190 MHz and IMT stations operating in the band 6 425-7 125 MHz

(2025)

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List of acronyms and abbreviations

BS Base station

IMT International Mobile Telecommunications systems

MCL Minimum coupling loss

SRS Space research service

UE User equipment

WRC World Radiocommunication Conference

1 Introduction

The World Radiocommunication Conference 2023 (WRC-23), held on 20 November – 15 December 2023, identified IMT in the frequency ranges of 6 425-7 125 MHz in accordance with Resolution **220 (WRC-23)**.

Space research service (SRS) earth stations may operate with high power transmissions to track a non-GSO spacecraft in deep space and SRS earth stations operating in the 7 145-7 190 MHz have the potential to cause interference to IMT receivers operating in the 6 425-7 125 MHz.

Resolution **220 (WRC-23)** *invites the ITU Radiocommunication Sector* 7 "to update existing ITU-R Recommendations/Reports or develop new ITU-R Recommendations/Reports, as appropriate, to provide information and assistance to the administrations concerned on possible coordination of SRS (deep space) stations operating in the band 7 145-7 190 MHz with IMT stations operating in the frequency band 6 425-7 125 MHz".

The purpose of this Report is to provide a generic methodology that may be used for calculating coordination areas. The coordination areas will differ from one SRS site to another (due to the specificity of SRS characteristics and the surrounding terrain where IMT base stations may be deployed). Additional Annexes to the Report provide example implementations of the generic methodology for calculations of the coordination areas for specific sites. It is noted that, where appropriate, alternative methodology may be used to calculate coordination areas on a case-by-case basis, taking into account all relevant information available.

2 Generic methodology

The generic methodology for calculating a coordination area around an SRS earth station is set out in the following steps:

Step 1: Determine the parameters for both IMT base stations and the SRS earth station and propagation loss for terrestrial paths, as shown in § 3. This is on a site-specific basis where the specific details of the SRS earth station and the terrain in the evaluation area should be used. The evaluation area should be set large enough to cover the entire coordination area to be determined.

Step 2: Calculate the interference, I, (from the parameters determined in Step 1) for each point on a sufficiently tight grid in the evaluation area. The interference I of a transmitting SRS earth station to a receiving IMT base station is calculated by evaluating the unwanted emissions transmit power and antenna gain of an SRS transmit earth station towards an IMT base station as shown in § 4.

Step 3: Compare the calculated interference for each grid point in the evaluation area with the maximum interference level acceptable for an IMT base station as shown in § 5.

Step 4: Determine the coordination area based on the comparison of maximum interference level acceptable for an IMT base station for each grid point.

3 Determination of the parameters

3.1 Parameters of SRS earth station

If available, calculation of coordination areas should use characteristics for the specific SRS earth station in question. Otherwise, an example of SRS transmitter characteristics which can be found in Recommendation ITU-R SA.1014 (see Table 1) can be used for a general analysis.

TABLE 1

SRS (deep space) earth station transmitter characteristics

Parameter	Value	
Transmit frequency (MHz)	7 145-7 190	
Transmitter power (dBW)	43	49
Attenuation for unwanted emissions (dBc)	60 (in 4 kHz reference bandwidth, see RR Appendix **3**)	
Unwanted power spectral density at 7 125 MHz (dB(W/Hz))	−53	−47
Antenna diameter (m)	70	
Peak transmit antenna gain (dBi)	72	
Antenna gain pattern	Rec. ITU-R SA.509	
Antenna height (above ground level) (m)	39	
Minimum elevation angle of transmit earth station (degrees)	10	

3.2 Parameters of IMT base station

If available, the calculations should take into account the specific characteristics of IMT base stations deployed/to be deployed in the evaluation area. Otherwise, example technical characteristics of IMT systems for operation in the band 6 425-7 125 MHz may be used for a general analysis as in Table 2.

TABLE 2

Parameters of IMT base stations

Parameter	Macro suburban	Macro urban
Antenna array configuration $N_H \times N_V$ (N/A)	8 × 16	8 × 16
Maximum element gain (dBi)	6.4	5.5
Maximum composite antenna gain (dBi)	27.5	26.6
H/V radiating element spacing (N/A)	0.5 of wavelength or H, 0.7 of wavelength for V	0.5 of wavelength for H, 0.5 of wavelength for V
Antenna height (above ground level) (m)	20	18
H/V 3 dB beamwidth (degree)	90º for H 65º for V	90º for H 90º for V
H/V front-to-back ration (dB)	30 for both	30 for both
Mechanical down tilt (degree)	6	10
Thermal noise (dBW/Hz)	−204	−204
Noise figure (dB)	6	6
Antenna polarization (degree)	Linear ±45	Linear ±45
Base station vertical coverage range (degree)	90-100	90-120
Sectorization	3 sectors	3 sectors
Protection criterion (dB)	$I/N = -6$ dB	$I/N = -6$ dB

The IMT base station antenna gain is described in Recommendation ITU-R M.2101, § 5. In case specific information is not available, an assumption that can be used for the pointing of the base stations’ antennas is to have the horizontal direction towards the SRS earth station and the vertical direction towards the cell edge.

3.3 Propagation loss

The signal propagating from the SRS earth station to the IMT base station is subject to the following propagation losses/attenuations:

– free space loss;

– diffraction loss due to the surrounding terrain;

– clutter loss;

– polarization loss.

3.3.1 Basic propagation loss for terrestrial paths

For each grid point in the evaluation area, the propagation loss should be determined using an appropriate propagation model such as the one contained in Recommendation ITU-R P.452 or Recommendation ITU-R P.2001. Recommendations ITU-R P.452 and ITU-R P.2001 are basic models for terrestrial paths, including free space loss and diffraction loss.

It is well known that the topography around an SRS site has a significant impact on the general interference situation. Diffraction by terrain is one of the most effective mitigation measures. So, the terrain should be incorporated in any coordination efforts, as it usually makes the required coordination area much smaller. Recommendations ITU-R P.452 and ITU-R P.2001 provide information and procedures to account for multiple aspects of terrain loss, including knife-edge diffraction effects and spherical-Earth impacts.

Some SRS gateway earth stations may have natural or artificial site shielding, where the SRS earth station is located behind a building. This needs to be considered on a case-by-case basis and the appropriate loss compensation figure needs to be determined.

3.3.2 Clutter loss

Recommendations ITU-R P.2108 and ITU-R P.452-18 provide models to calculate the clutter loss.

Recommendation ITU-R P.2108, section 3.2 (terrestrial paths) provides a statistical clutter loss model. The model could be applied for urban and suburban environments provided terminal heights are well below the clutter heights along the propagation paths.

Recommendation ITU-R P.452-18 provides procedures for deriving diffraction loss using radio path profile with path-specific data for terrain (bare-earth) and path specific clutter (ground cover) categories along the path. Therefore, usage of Recommendation ITU-R P.452-18 with actual clutter profiles along the path, where available, could also be considered for calculating clutter loss as an alternative to the use of the statistical clutter loss model in Recommendation ITU-R P.2108.

Recommendation ITU-R P.452-18 also includes a methodology based on representative clutter height given in this Recommendation which could be considered as an alternative to models above.

3.3.3 Polarization loss

The polarization loss will be specific to the loss caused by the polarization mismatch. Because the base station has linear polarization and the SRS earth station has circular polarization, polarization loss should be considered.

4 Interference calculation

To determine if an SRS earth station could interfere with IMT base stations in the surrounding area, the following methodology can be used. A coordination area should be calculated around the SRS earth, and for IMT base stations that would fall within such a coordination area, more detailed calculations need to be carried out. If there is a risk for interference, mitigation methods need to be assessed.

The interference level for each grid point in the evaluation area is calculated, using the following equation:

$$I_{IMT} = EIRP_{SRS}(\theta_{SRS}) - L_{basic} - L_{clutter} - L_{PL} + G_{IMT}(\theta_{IMT}) \quad \text{dB}$$

where:

I_{IMT}: interference level at IMT base station

$EIRP_{SRS}(\theta_{SRS})$: SRS transmit earth station off-axis e.i.r.p. density at the radio horizon elevation angle (for diffraction path) or above it (tropospheric scatter path) θ_{SRS} and in the azimuth direction of the receive IMT base station in dBW/Hz in the IMT receiving band

L_{basic}: basic propagation loss in dB including losses due to terrain and site shielding

$L_{clutter}$: clutter loss, in dB

L_{PL}: polarization losses, in dB

$G_{IMT}(\theta_{IMT})$: IMT base station receive antenna gain at the radio horizon elevation angle (for diffraction path) or above it (tropospheric scatter path) θ_{IMT} in the azimuth direction of the SRS transmit earth station in dBi.

5 Maximum interference level acceptable for an IMT base station

Assuming the protection criterion for IMT BS is $I/N = -6$ dB, the maximum interference level can be evaluated as follows:

Maximum interference level = IMT receiver noise floor −6 dB

= Thermal noise + Noise figure −6 dB

= −204 dB(W/Hz) + 6 dB −6 dB

= −204 dB(W/Hz).

NOTE – This is based on a noise temperature of 290 K and a noise figure of 6 dB.

6 Summary

This Report provides a possible methodology that may be used for calculating coordination areas between space research service (deep space) stations operating in the band 7 145-7 190 MHz and IMT stations operating in the band 6 425-7 125 MHz. It is noted that, where appropriate, alternative methodologies may be used to calculate coordination areas on a case-by-case basis, taking into account all relevant information available. Annexes to this Report provide example implementations of the calculation methodology for some SRS stations.

Annex 1

Example of coordination area calculations

This study presents an example of calculations of the coordination area around SRS earth stations using the method defined in this Report.

1 Technical and operational characteristics of SRS transmitters

Generic information on SRS (deep space) transmitter characteristics can be found in Recommendation ITU-R SA.1014. Table 3 sets out the SRS earth station transmitter characteristics used in this study.

In order to assess the impact from SRS unwanted emissions on IMT BS receivers operating below 7 125 MHz, the level of attenuations provided in Radio Regulations (RR) Appendix **3** (60 dBc in a 4 kHz reference bandwidth) has been assumed for SRS earth station transmitters.

TABLE 3

SRS (deep space) earth station transmitter characteristics operating in the frequency band 7 145-7 190 MHz

SRS characteristic	Description/Value	
Transmitter power (kW)	20	80
Attenuation for unwanted emissions (dBc)	60 (in 4 kHz reference bandwidth, see RR Appendix **3**)	

TABLE 3 *(end)*

SRS characteristic	Description/Value	
Resulting unwanted power spectral density at 7 125 MHz (dB(W/Hz))	−53	−47
Transmitter antenna minimum elevation angle (degree)	10	
Antenna diameter (m)	35	
Transmitter maximum antenna gain (dBi)	66	
Transmitter antenna radiation pattern	Rec. ITU-R SA.509	
Transmitting earth station antenna radiation centre height above ground level (m)	21	

In this study, the following specific locations are considered for the SRS Earth stations:

– Cebreros (Spain): 40°N27'10", 4°W22'03'';

– Malargue (Argentina): 35°S46'34'', 69°W23'53'';

– New Norcia (Australia): 31°S02'54'', 116°E11'30''.

2 Technical and operational characteristics of IMT systems

The IMT receiver characteristics and antenna parameters used in this study are given in Table 2 (see column labelled "Macro suburban").

The IMT base station antenna gain is described in Recommendation ITU-R M.2101.

3 Methodology, assumptions and propagation models used in the study

The interference level at the IMT base station from SRS is calculated, using the approach described in § 4 of the main body of this Report.

The IMT BS antenna is assumed pointing in azimuth towards the SRS station and the SRS antenna is at 10 degrees elevation.

Polarization loss is assumed to be 3 dB.

Recommendation ITU-R P.452 is used to generate the propagation losses around the SRS earth stations. Since SRS Earth stations are located in rural areas, it is also assumed that IMT Base stations are deployed in rural areas, and therefore, no additional clutter loss is considered around IMT Base stations.

Concerning the probability of exceedance in the application of Recommendation ITU-R P.452, a value of p = 50% is assumed for the three Earth stations considered in this study. In addition, for the case of the Cebreros Earth station, a sensitivity analysis is provided with the following values: p = 0.1%, 1% and 50%.

The terrain heights around the specific SRS earth stations are generated from the SRTM digital elevation database in order to calculate site-specific interference.

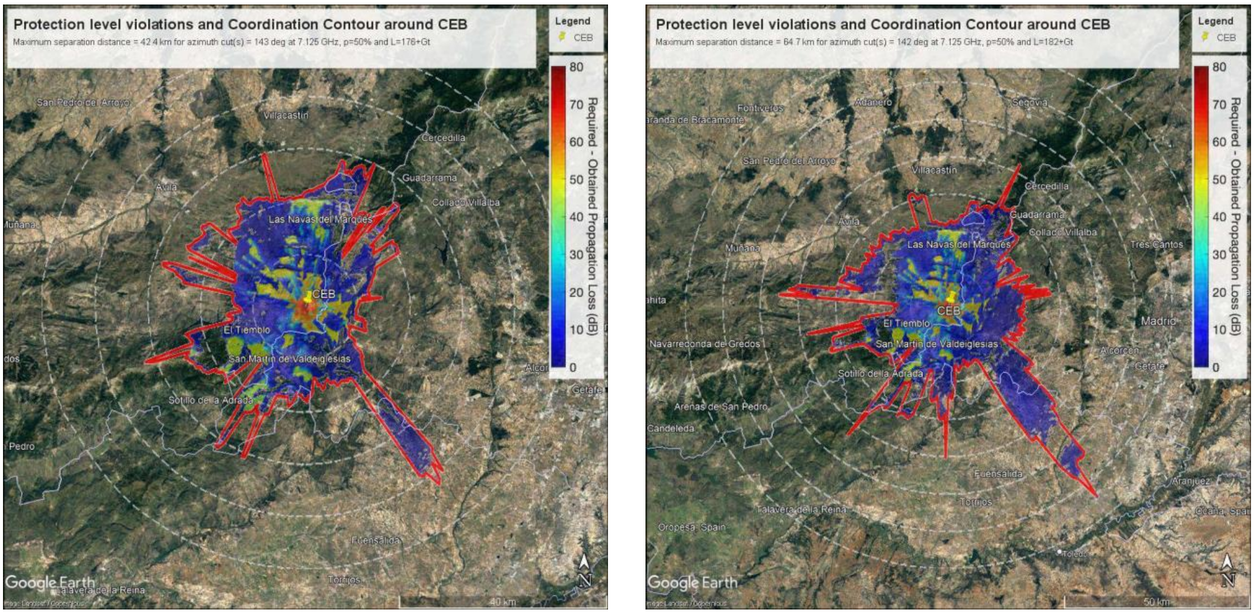
4 Study results

4.1 Impact from the SRS Earth station (Cebreros) into IMT BS receivers at 7 125 MHz

Figure 1 displays the coordination area in order to protect IMT receivers at 7 125 MHz from unwanted emissions of the SRS (deep space) earth station located in Cebreros (Spain), assuming the value of 50% for the probability of exceedance in the application of Recommendation ITU-R P.452. The coordination area is generated for both 20 kW and 80 kW SRS transmitters.

FIGURE 1

Coordination area for the protection of IMT from Cebreros SRS earth station (*p* = 50%)



SRS transmit power (20 kW) SRS transmit power (80 kW)

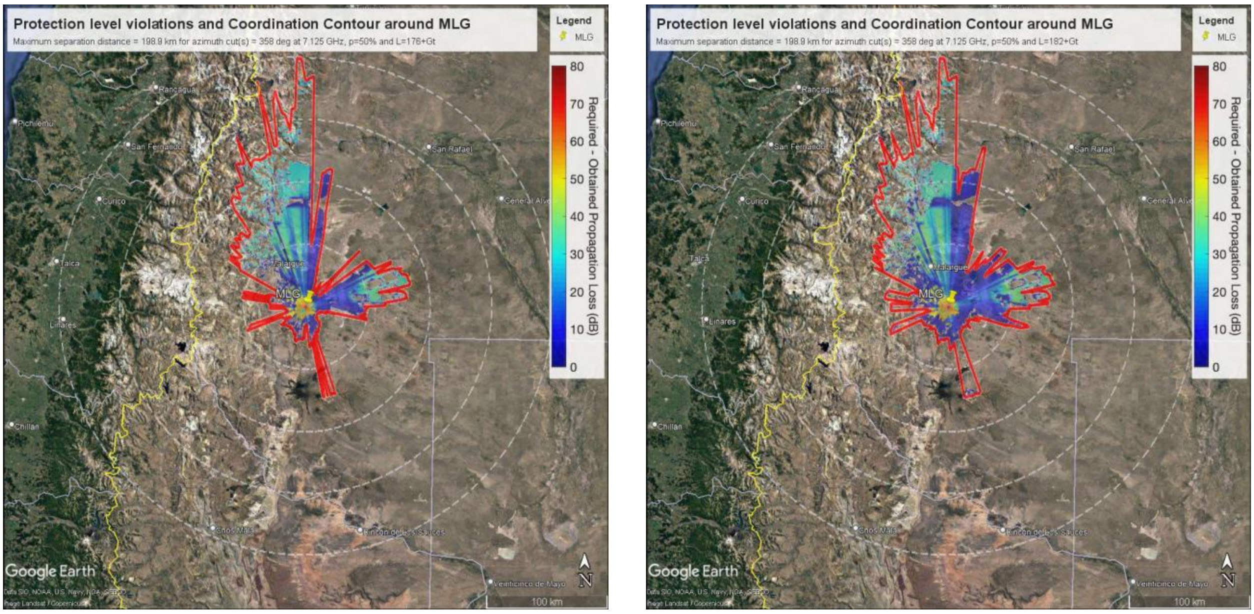
The maximum coordination distance for the Cebreros station associated with a 50% probability is 42 km for a 20 kW SRS transmitter and is 65 km in the case of an 80 kW SRS transmitter.

4.2 Impact from the SRS Earth station (Malargue) into IMT BS receivers at 7 125 MHz

Figure 2 displays the coordination area in order to protect IMT receivers at 7 125 MHz from unwanted emissions of the SRS (deep space) earth station located in Malargue (Argentina), assuming the value of 50% for the probability of exceedance in the application of Recommendation ITU-R P.452. The coordination area is generated for both 20 kW and 80 kW SRS transmitters.

FIGURE 2

Coordination area for the protection of IMT from Malargue SRS earth station (p = 50%)



SRS transmit power (20 kW) SRS transmit power (80 kW)

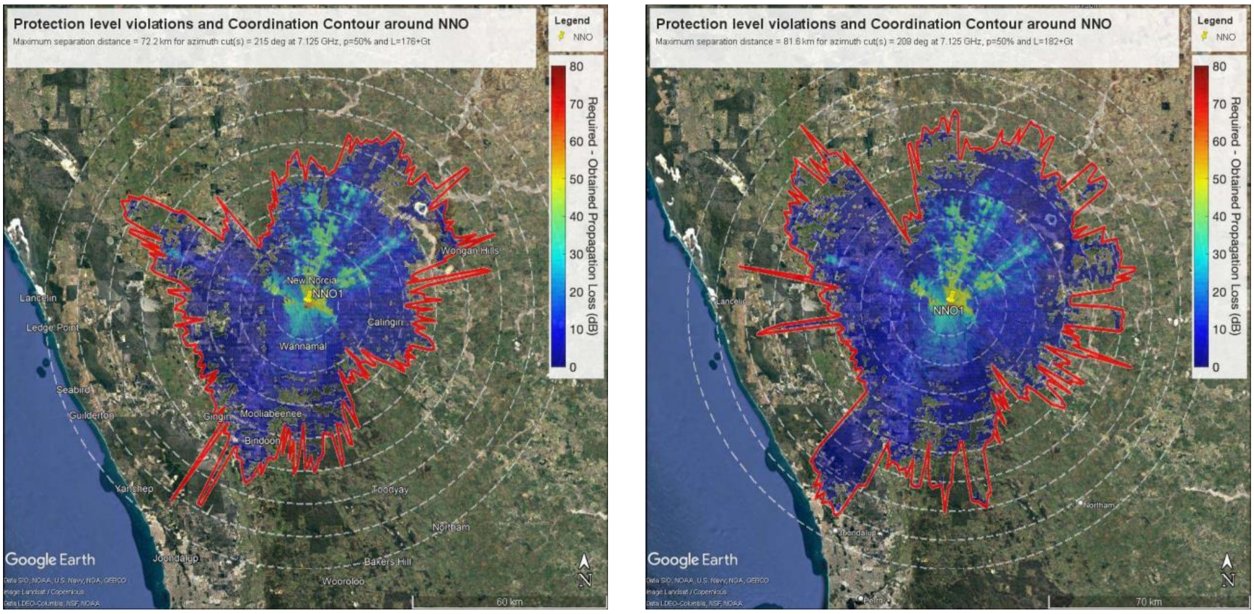
The maximum coordination distance for the Malargue station associated with a 50% probability is 199 km.

4.3 Impact from the SRS earth station (New Norcia) into IMT BS receivers at 7 125 MHz

Figure 3 displays the coordination area in order to protect IMT receivers at 7 125 MHz from unwanted emissions of the SRS (deep space) earth station located in New Norcia (Australia), assuming the value of 50% for the probability of exceedance in the application of Recommendation ITU-R P.452. The coordination area is generated for both 20 kW and 80 kW SRS transmitters.

FIGURE 3

Coordination area for the protection of IMT from New Norcia SRS earth station (*p* = 50%)



SRS transmit power (20 kW) SRS transmit power (80 kW)

The maximum coordination distance for the New Norcia station associated with a 50% probability is 72 km for a 20 kW SRS transmitter and is 82 km in the case of an 80 kW SRS transmitter.

4.4 Sensitivity analysis

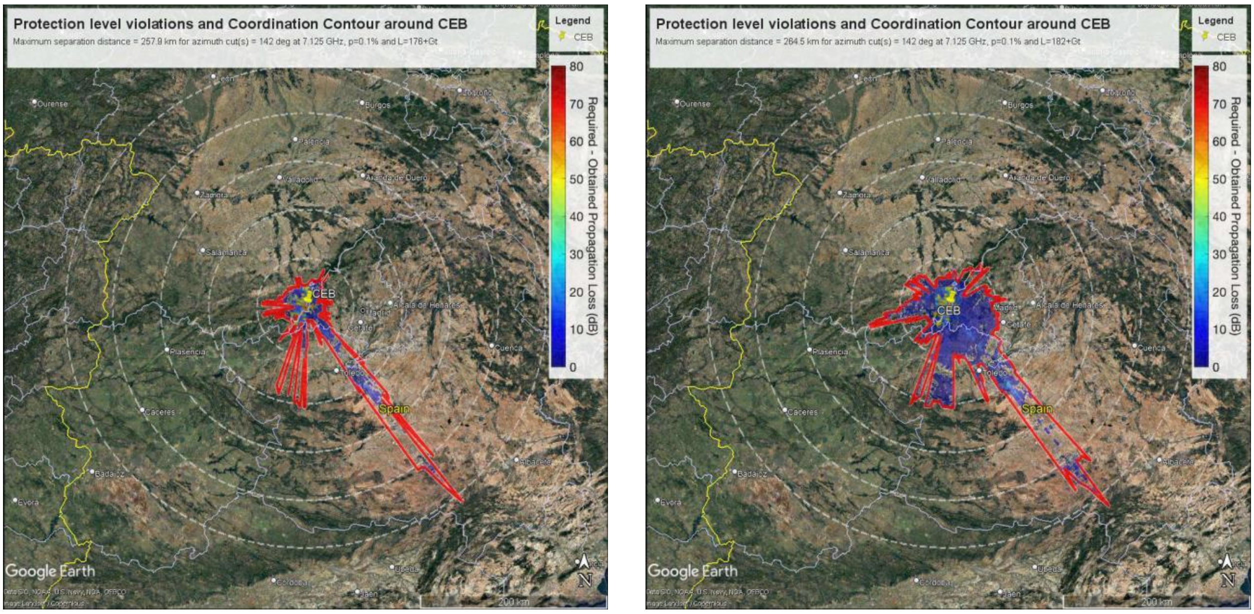
In the case of the Cebreros Earth station, this subsection provides the coordination area for different values of the probability p of exceedance in the application of Recommendation ITU-R P.452.

Section 4.1 provides the coordination area for *p* = 50%.

Figures 4 and 5 display the coordination area around the Cebreros Earth station for *p* = 0.1% and 1% respectively.

FIGURE 4

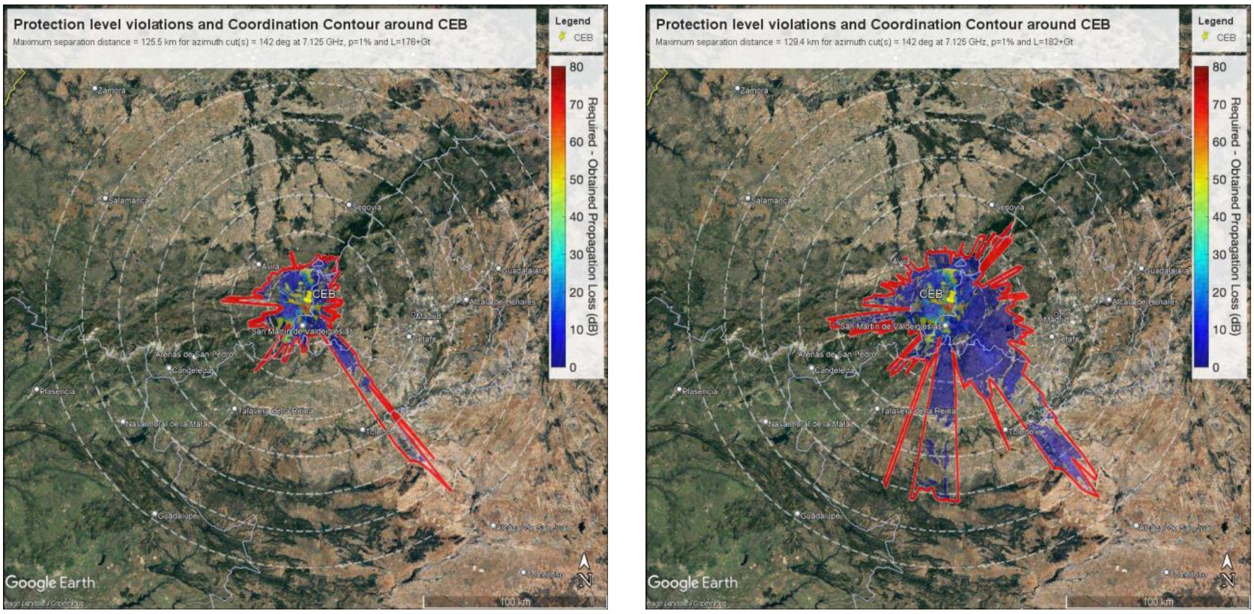
Coordination area for the protection of IMT from Cebreros SRS earth station ($p = 0.1\%$)



SRS transmit power (20 kW) SRS transmit power (80 kW)

FIGURE 5

Coordination distances for the protection of IMT from Cebreros SRS earth station ($p = 1\%$)



SRS transmit power (20 kW) SRS transmit power (80 kW)

The maximum coordination distances for the various probability values p are summarised in Table 4.

TABLE 4

Maximum coordination distances for the SRS earth station in Cebreros

	SRS transmit power (20 kW)	SRS transmit power (80 kW)
Probability of exceedance 0.1%	258 km	265 km
Probability of exceedance 1%	125 km	129 km
Probability of exceedance 50%	42 km	65 km

5 Summary

The study results show that the extent of the coordination area might range from tens of kilometres up to a few hundreds of kilometres, depending upon the considered case, without consideration of additional clutter around the IMT base station.

This study assumes an unwanted emissions attenuation of 60 dBc (in a 4 kHz reference bandwidth) for the SRS transmitters, in accordance with RR Appendix **3**. It is envisaged that SRS earth stations actually deployed may offer better performance for the unwanted emissions attenuation, consequently leading to lower coordination distances.

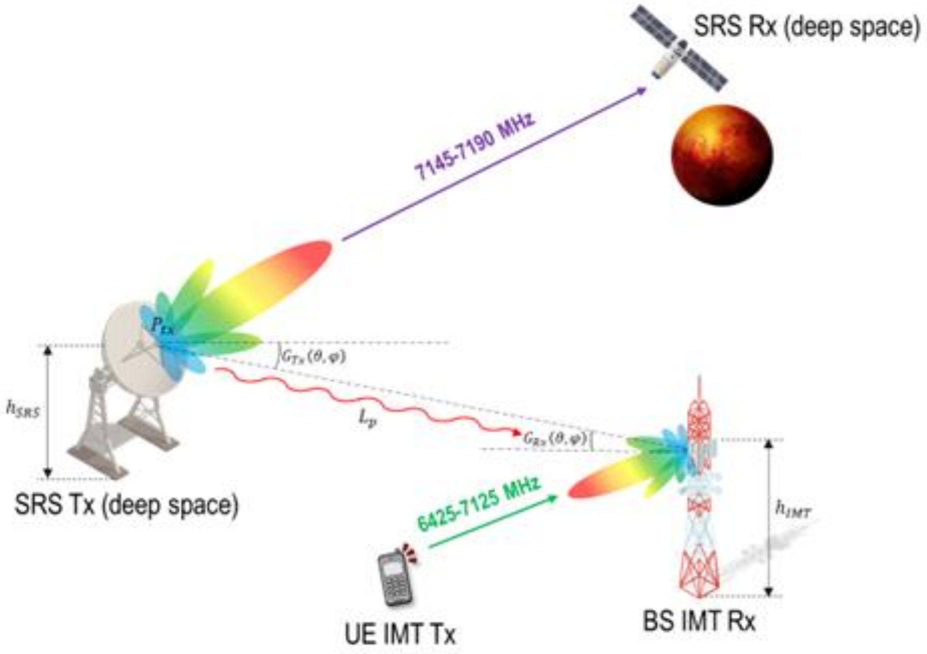
Annex 2

Example of coordination area calculations

Given the high-power levels of space research Earth stations, which communicate with deep space objects, out-of-band interference to IMT base stations is possible. Figure 6 illustrates a typical interference scenario where SRS operating in the 7 145-7 190 MHz frequency band interferes with IMT operating in the 6 425-7 125 MHz frequency band.

FIGURE 6

Interference scenario from SRS ES (deep space) to IMT BS



1 Parameters of the interfering SRS

Six Earth station examples were specifically chosen for this purpose: Cebreros (40.4528°N, 4.3678°W), Madrid (40.426°N, 4.254°W), Malargue (35.7758°S, 69.3983°W), New Norcia (31.0483°S, 116.191°E), and Canberra (35.399°S, 148.982°E), Ussuriisk (44.0159°N, 131.7571°E), Kalyazin (57.2519°N, 37.9843°E). The parameters used in these studies for these stations, summarized in Table 5, were assumed for further analysis.

TABLE 5

SRS (deep space) earth station transmitter characteristics

Parameter	Value
Transmitter power (dBW)	49
Attenuation for unwanted emissions (dBc)	60 in 4 kHz reference bandwidth
Unwanted power spectral density at 7 125 MHz (dB(W/Hz))	−47
Antenna diameter (m)	70
Peak transmit antenna gain (dBi)	72
Antenna gain pattern	Rec. ITU-R SA.509
Antenna height (above ground level)	39 m for SRS stations Cebreros, Madrid, Malargue, New Norcia, Canberra 46 m for SRS stations Ussuriisk, Kalyazin
Minimum elevation angle of transmit earth station (degree)	10

2 Parameters of IMT base stations

The study focuses on IMT base stations deployed in suburban and rural areas, as they are likely to experience the highest levels of interference. This is due to factors such as greater antenna height, higher mechanical downtilt, lower clutter probability, and increased antenna gains. IMT parameters used in the study are given in Table 2 (see column labelled "Macro suburban").

3 Assumptions and propagation models used in the study

In the calculations, it is assumed that the azimuth of each IMT base station is aligned with the direction of the SRS station. Polarization loss is assumed to be 3 dB. The study uses SRTM terrain to calculate site-specific interference.

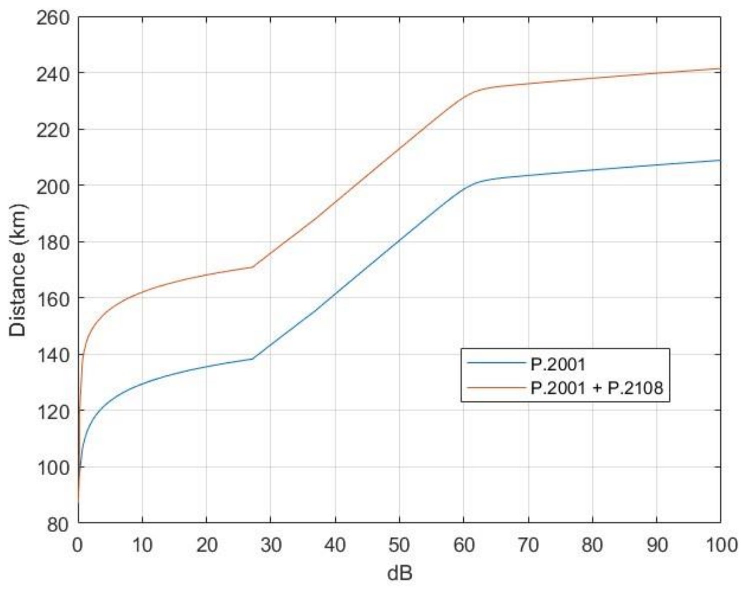
Two types of calculations were performed: one with clutter applied to the IMT base stations and one without. While the probability of clutter presence is generally high, calculating the contours without clutter helps estimate the worst-case scenario.

Propagation losses were calculated using the model based on Recommendation ITU-R P.2001, which describes a radio-wave propagation method for terrestrial paths. This Recommendation is applicable across a wide range of frequencies, distances, and percentage times, and it predicts both fading and signal level enhancements. It is particularly suitable for Monte-Carlo simulations, where a random percentage of time is used for each interfering base station. Given that this percentage generally averages out, a 50% value was applied in the simulations.

Clutter losses were calculated using the propagation model based on Recommendation ITU-R P.2108, considering 50% of locations. Figure 7 illustrates the propagation losses according to Recommendation ITU-R P.2001 for 50% of the time without clutter (blue curve) and with clutter losses accounted for (orange curve).

FIGURE 7

Propagation losses of Recommendation ITU-R P.2001 with 50% percentage of time with and without clutter losses



The interference level from SRS station to the IMT station may be expressed with the following equation:

$$I = P_{tx} + G_{tx}(\theta, \varphi) + G_{rx}(\theta, \varphi) - L_{2001} - L_{clutter} - L_{pol}$$

where:

P_{tx}:	output power of the SRS in dBW
$G_{tx}(\theta, \varphi)$:	antenna gain of the SRS towards the IMT station in dBi
$G_{rx}(\theta, \varphi)$:	antenna gain of the IMT station towards the SRS station in dBi
L_{2001}:	propagation losses based on Recommendation ITU-R P.2001
$L_{clutter}$:	clutter losses based on Recommendation ITU-R P.2108 in dB
L_{pol}:	polarization difference losses in dB.

4 Results

Figures 8 to 14 show the coordination areas for the scenario without clutter (red contours) and scenario with clutter applied to the receiving IMT station (blue contours).

FIGURE 8

Coordination area around Cebreros SRS earth station (p = 50%)

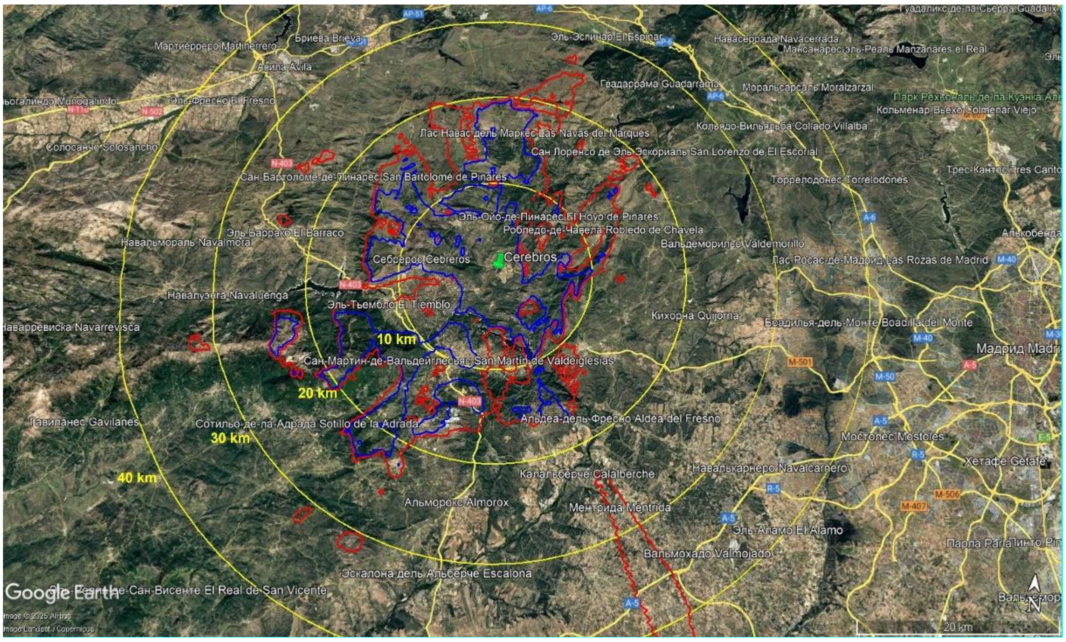


FIGURE 9

Coordination area around Madrid SRS earth station (p = 50%)

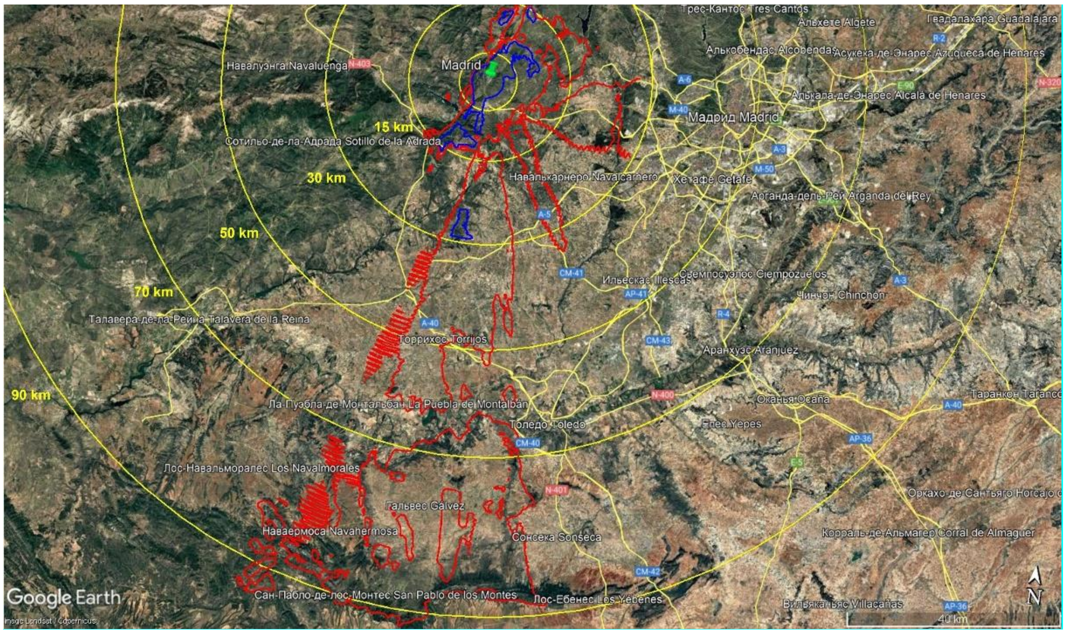


FIGURE 10

Coordination area around Malargue SRS earth station (p = 50%)

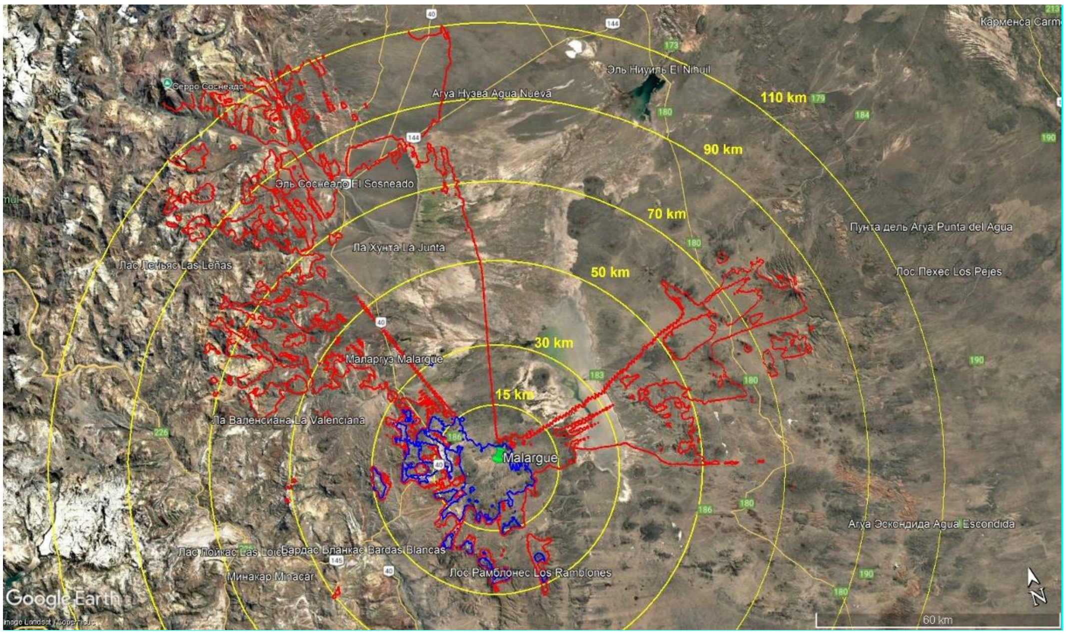


FIGURE 11

Coordination area around New Norcia SRS earth station (p = 50%)

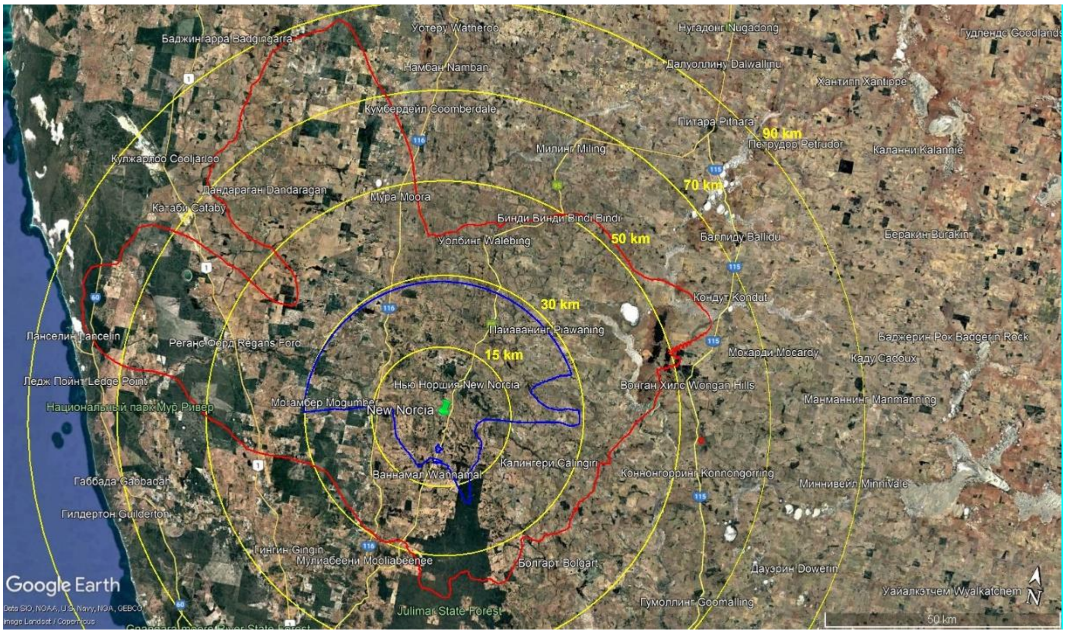


FIGURE 12

Coordination area around Canberra SRS earth station (p = 50%)

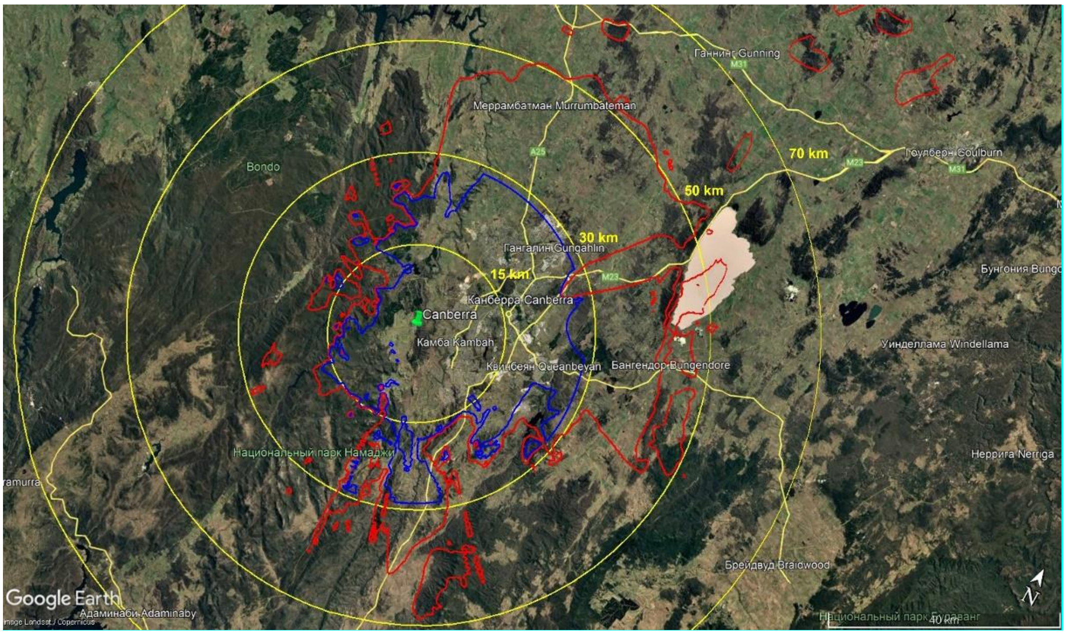


FIGURE 13

Coordination area around Ussuriisk SRS earth station ($p = 50\%$)

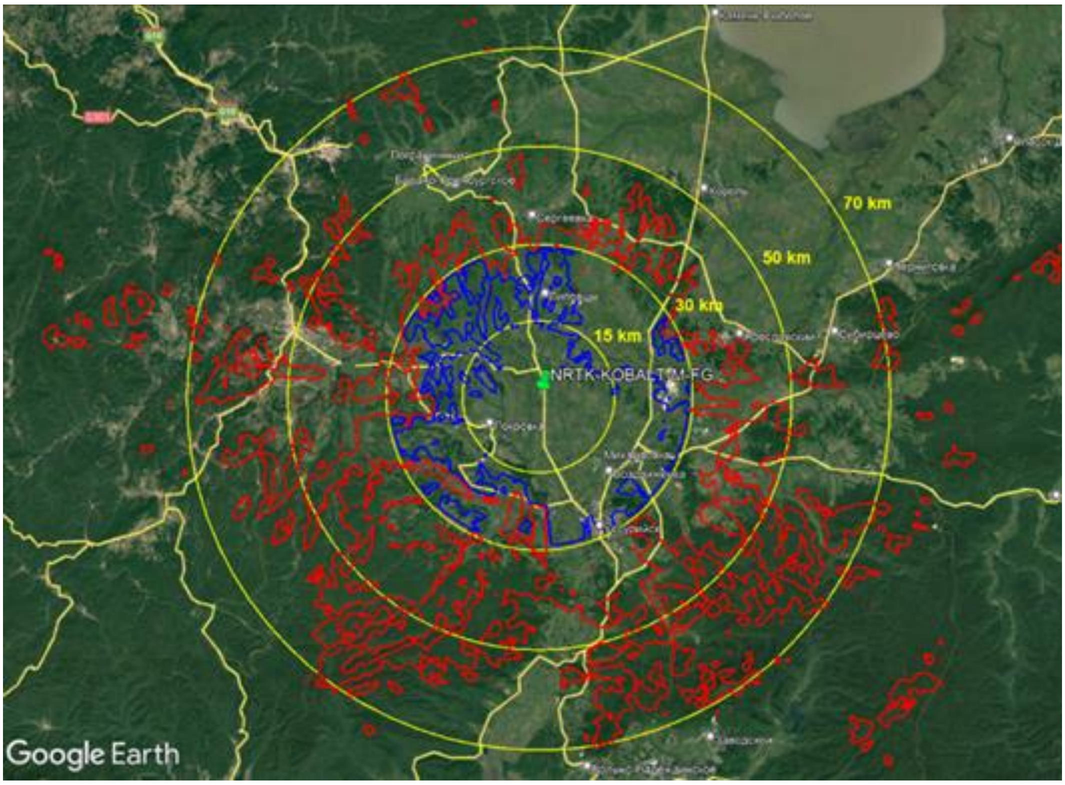
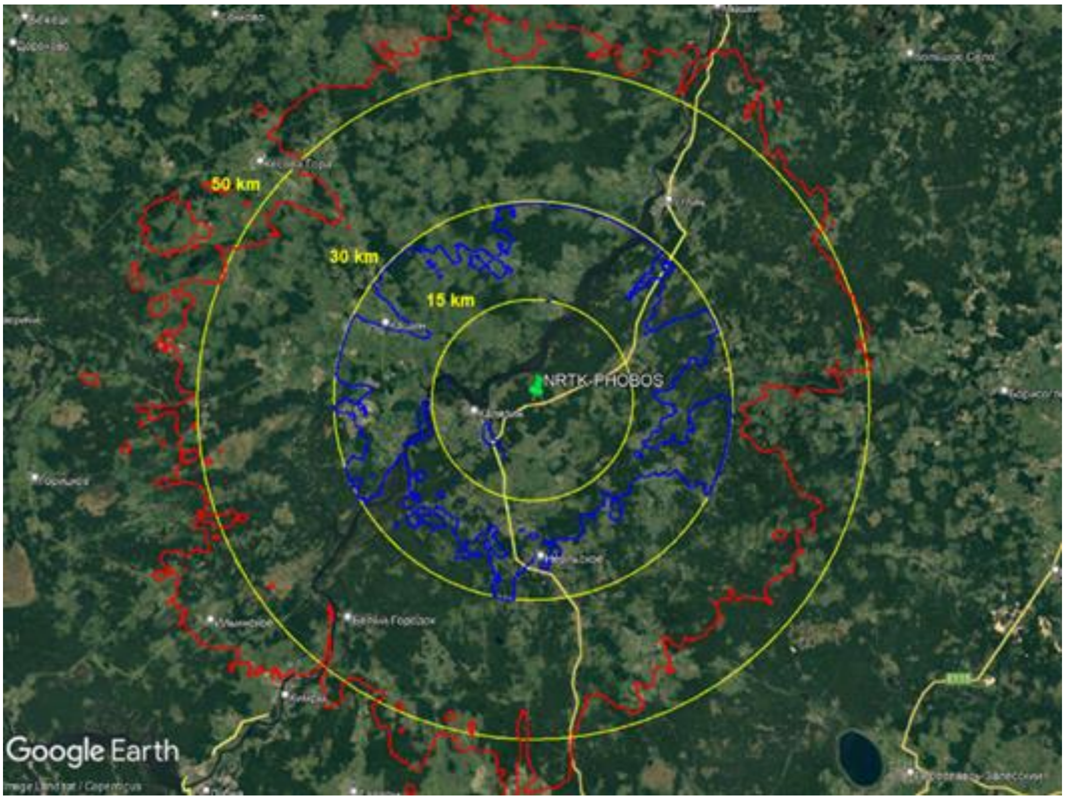


FIGURE 14

Coordination area around Kalyazin SRS earth station ($p = 50\%$)



The Figures above indicate that, in the presence of clutter, the required coordination distances for all six SRS stations range from 5 to 30 km. However, in the absence of clutter, the coordination distances become highly dependent on the specific site and range from 20 to 110 km.

Annex 3

Example of coordination distance calculations

This Annex presents an example for calculating the coordination area around the SRS earth station using the Minimum Coupling Loss (MCL) analysis method defined in this Report.

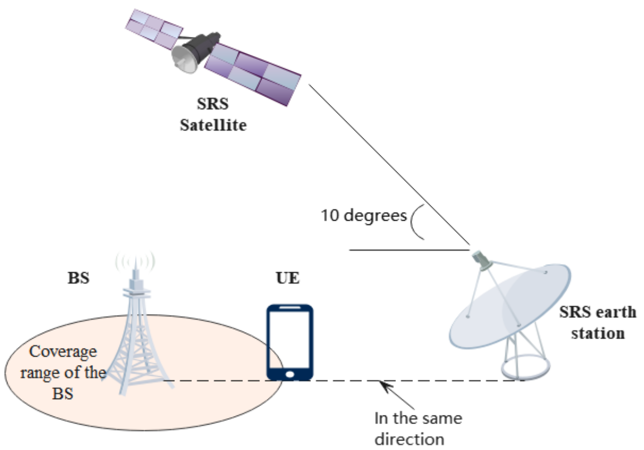
1 Parameters of SRS earth station

The example set of SRS transmitter characteristics used in this study are given in Table 1. The location of SRS earth station in this study is assumed Cebreros, Spain with latitude of 40°27' N and longitude of 4°22' W.

The antenna gain of SRS earth station in direction of the IMT base station is calculated based on Recommendation ITU-R SA.509. For evaluation of the worst-case scenario, the SRS satellite is assumed located at the same horizontal direction from SRS earth station to IMT base station and the elevation angle of SRS earth station is minimum elevation angle of transmit earth station, which means the azimuth angle from SRS earth station to IMT base station is the same as the azimuth angle from SRS earth station to SRS satellite, which is illustrated as in Fig. 15.

FIGURE 15

Locations of IMT BS, UE, SRS earth station and SRS satellite



2 Parameters of IMT base stations

This study considers IMT BSs in suburban as baseline considering it is one of the typical deployment scenarios and are more likely to be affected by the transmission of the SRS earth station. The technical parameters of macro suburban IMT BS used in this study are given in Table 2 (see column labelled "Macro suburban").

The antenna gain of IMT base station in direction of the SRS earth station is calculated based on Recommendation ITU-R M.2101 and antenna beam of IMT base station points to the UE. For evaluation of the worst-case scenario, the UE is assumed located at the same horizontal direction from IMT base station to SRS earth station and at the edge of a cell, which means the azimuth angle from IMT base station to UE is the same as the angle from IMT base station to SRS earth station, as shown in Fig. 15.

Assuming SRS earth station is located in the rural area, IMT BS in rural area would be affected. However, the rural deployment is not typical deployment scenario for 6 425-7 125 MHz, so the results relevant to the IMT BS deployed in rural area is presented merely as sensitivity analysis in this study. Technical parameters of rural IMT BS are assumed as the same as those for suburban IMT BS in this study.

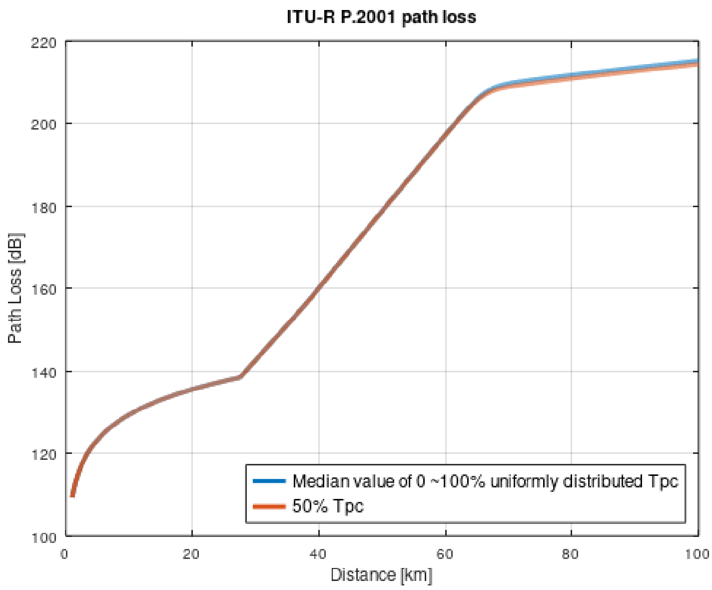
3 Propagation model

3.1 Basic propagation loss for terrestrial paths

Recommendation ITU-R P.2001 is used to calculate the propagation loss in this study. This Recommendation provides a calculation for basic transmission loss across the 0-100% full distribution of time percentages, defined as the percentage (T_{pc}) of an average year for which a given loss value is not exceeded for frequencies between 30 MHz and 50 GHz. This study considers MCL analysis method, so only a fixed time percentage configuration can be used. In this study, 50% time percentage is considered which matches the median value of 0~100% uniformly distributed time percentage (see Fig. 16). Antenna gains for IMT BS and SRS earth station are calculated based on maximum antenna gain that can be achieved, but there is a very low probability that this worst-case scenario occurs. Therefore, 50% time percentage is a more accurate and reasonable assumption than other fixed values for MCL considering long-term interference.

FIGURE 16

Recommendation ITU-R P.2001 model propagation loss



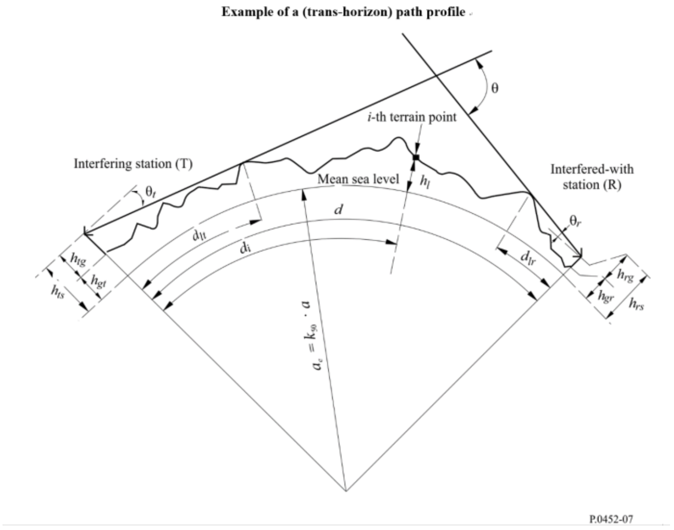
The terrain profile around the assumed SRS station is considered in this study. The terrain profile is generated using the SRTM database that is sampled with azimuth step of 1 degree and a distance of 45 m. Recommendation ITU-R P.2001 provides procedures to calculate basic transmission loss L_b

attenuated by the terrain profile. In order to get the signal level from the interferer station that reaches the victim station, antenna gains of the interferer Tx and victim Rx stations, i.e. G_t and G_r, need to be added on top of basic transmission loss L_b. The determination of G_t and G_r is independent of basis transmission loss and is not defined in Recommendation ITU-R P.2001.

In this study, G_t is SRS earth station antenna gain at the θ_{srs} off-axis angle. Two cases are considered in this study to determine θ_{srs}. One is based on flat earth assumption and θ_{srs} is assumed as equal to SRS minimum elevation angle. The other is considering of the terrain profile, θ_{srs} is horizontal elevation angle θ_t as described in Fig. 17 minus SRS minimum elevation angle. The calculation method of θ_{IMT} off-axis angle is the same to θ_{srs}.

FIGURE 17

Example of a trans-horizon path profile



Parameter	Description
θ_t	For a transhorizon path, horizon elevation angle above local horizontal (mrad), measured from the interfering antenna. For a LoS path this should be the elevation angle toward the interfered-with antenna
θ_r	For a transhorizon path, horizon elevation angle above local horizontal (mrad), measured from the interfered-with antenna. For a LoS path this should be the elevation angle toward the interfering antenna

3.2 Clutter loss

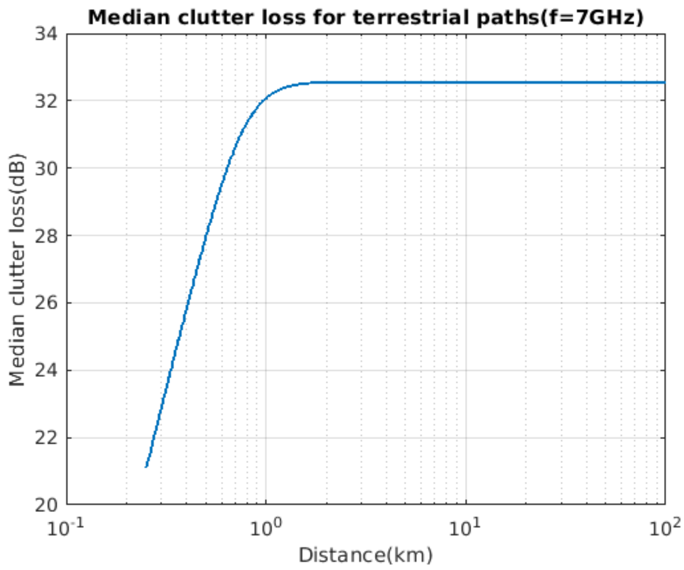
For the prediction of clutter loss, § 3.2 of Recommendation ITU-R P.2108 should be employed if the IMT is deployed in suburban or urban areas. In order to define propagation conditions, line-of-sight (LOS) or non-line-of-sight (NLOS) concept is used in order to decide whether clutter loss should be applied. There are a number of LoS/NLoS models in ITU-R and 3GPP, e.g. Report ITU-R M.2412, 3GPP TR38.901 and WINNER2, demonstrating that for transmitter and receiver heights up to 20 m, there is a very high probability of NLoS condition at distances beyond 1.5 km. For IMT BS deployed in suburban area, clutter loss is applied to IMT base station side for the reason explained above. Clutter loss is not applied to the SRS earth station side.

The location percentage is set to 50%. This percentage is considered because it matches the median value of 0~100% uniformly distribution, and it is an accurate assumption for MCL considering long-term interference. Figure 18 shows the median value of clutter loss for 7 GHz based on the Recommendation ITU-R P.2108. When the distance exceeds 2 km, the median clutter loss is a constant value with 32.6 dB.

The sensitivity study assuming IMT BS deployed in rural area, no clutter loss is assumed for IMT BS side.

FIGURE 18

Median clutter loss of Recommendation ITU-R P.2108



3.3 Polarization loss

The antenna of IMT base station is linear polarization and that of SRS earth station is circular polarization, so the polarization loss with 3 dB should be considered.

3.4 Propagation modelling summary

TABLE 6

Propagation modelling summary

	Parameters
Basic propagation loss	Recommendation ITU-R P.2001 model
	Consider terrain loss
Clutter loss model	Recommendation ITU-R P.2108 clutter model is applied to IMT BS deployed in suburban For sensitivity analysis assuming IMT BS deployed in rural, clutter loss model is not applied
Polarization loss	3 dB

4 Interference calculation

The interference level from SRS needs to be calculated, using the following equation:

$$I_{IMT} = EIRP_{SRS}(\theta_{SRS}) - L_{basic} - L_{clutter} - L_{PL} + G_{IMT}(\theta_{IMT}) \qquad \text{dB}$$

where:

I_{IMT}: interference level at IMT base station

$EIRP_{SRS}(\theta_{SRS})$: SRS transmit earth station off-axis e.i.r.p. density in the direction of the receive IMT base station in dBW/Hz

L_{basic}: basic propagation loss in dB, including losses due to terrain

$L_{clutter}$: clutter loss in dB

L_{PL}: polarization losses in dB

$G_{IMT}(\theta_{IMT})$: IMT base station receive antenna gain in direction of the SRS transmit earth station in dBi.

Assuming the protection criteria of IMT base station is $I/N = -6$ dB, the maximum interference level acceptable for an IMT base station is $I = -204$ dB(W/Hz).

The calculated interference for each pixel is compared with the maximum interference level acceptable for an IMT base station. The coordination distance is derived for each direction of SRS earth station. Then the coordination area around SRS earth station can be drawn.

5 Results

Figures 19 to 22 show the minimum distance for each azimuthal angle for which the IMT protection criterion is met around SRS earth station in Cebreros, Spain for different IMT deployment cases. Beyond this distance, there might be isolated area or location that also exceeds the protection criterion due to the real terrain.

The maximum distances among all the azimuthal angles for which the IMT protection criterion is met around SRS earth station in Cebreros, Spain for different IMT deployment cases are also provided below.

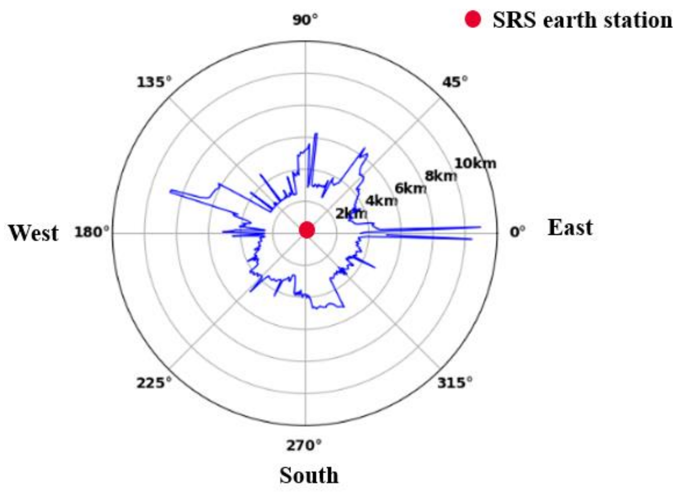
Assuming the G_t, G_r based on flat earth as explained in § 3.1

The minimum distance for each azimuthal angle for which the IMT protection criterion is met around SRS earth station in Cebreros, Spain with IMT BS deployed in suburban area, is calculated and shown as in Fig. 19. The largest ones among the minimum distances for all azimuthal angles are 11.0 km (43 dBW) and 12.6 km (49 dBW), respectively. The 6 dB difference in Tx power results in 1 km difference in maximum coordination distance, because the real terrain is considered that introduces non-line-of-sight propagation condition with much higher attenuations along a relative short distance.

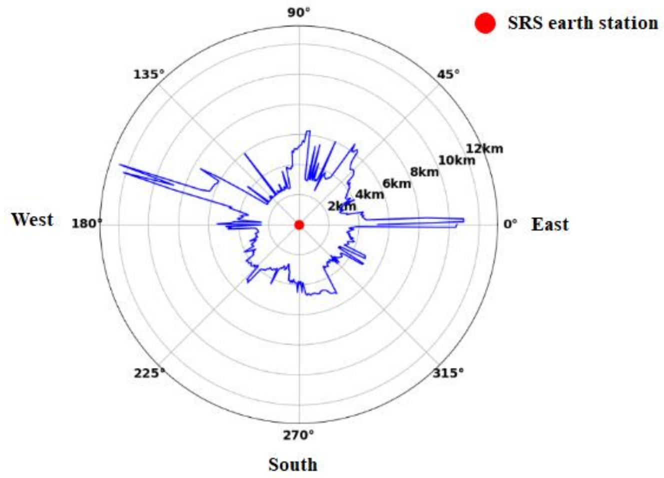
The maximum distances among all the azimuthal angles for which the IMT protection criterion is met around SRS earth station in Cebreros, Spain are 29.3 km (43 dBW) and 32.9 km (49 dBW).

FIGURE 19

Minimum distance for each azimuthal angle for which the IMT protection criterion is met (IMT BS deployed in suburban area)



(a) Tx power of earth station = 43 dBW



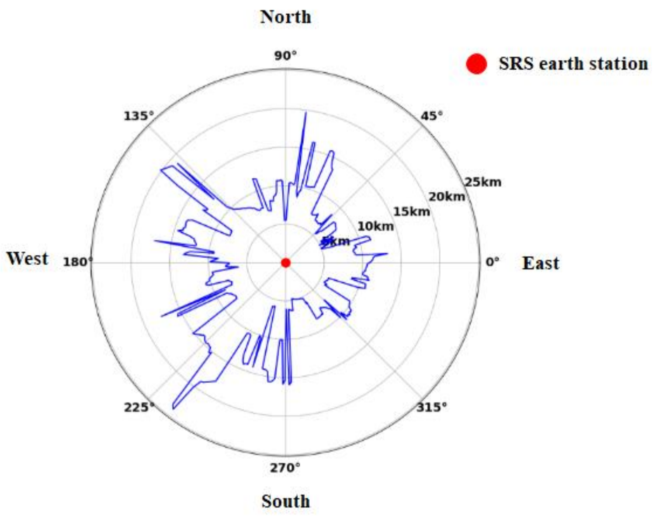
(b) Tx power of earth station = 49 dBW

For sensitivity analysis assuming IMT BS deployed in rural, the minimum distance for each azimuthal angle for which the IMT protection criterion is met around SRS earth station, is shown in Fig. 20. And the largest ones among the minimum distances for all azimuthal angles are 24.0 km (43 dBW) and 25.2 km (49 dBW), respectively.

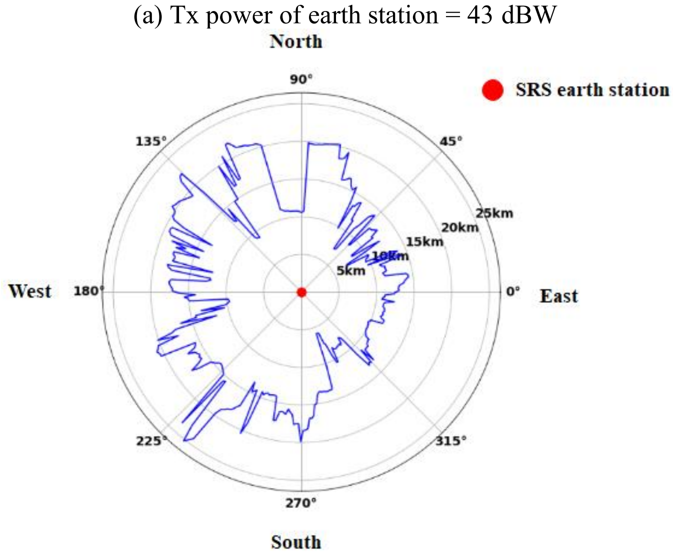
The maximum distances among all the azimuthal angles for which the IMT protection criterion is met around SRS earth station in Cebreros, Spain are 59.9 km (43 dBW) and 71 km (49 dBW).

FIGURE 20

Minimum distance for each azimuthal angle for which the IMT protection criterion is met (IMT BS deployed in rural area, sensitivity analysis)



(a) Tx power of earth station = 43 dBW



(b) Tx power of earth station = 49 dBW

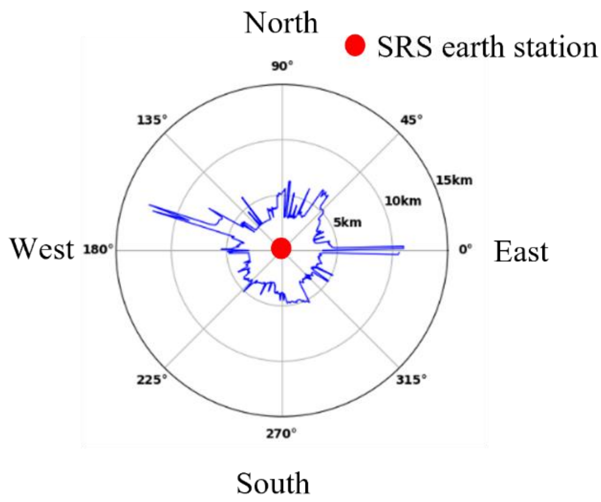
Assuming the G_t and G_r taking into the terrain profile as explained in § 3.1

The minimum distance for each azimuthal angle for which the IMT protection criterion is met around SRS earth station in Cebreros, Spain with IMT BS deployed in suburban area and in rural area are drawn as in Fig. 21. The largest ones among the minimum distances for all azimuthal angles are 12.6 km (43 dBW) and 12.7 km (49 dBW), respectively.

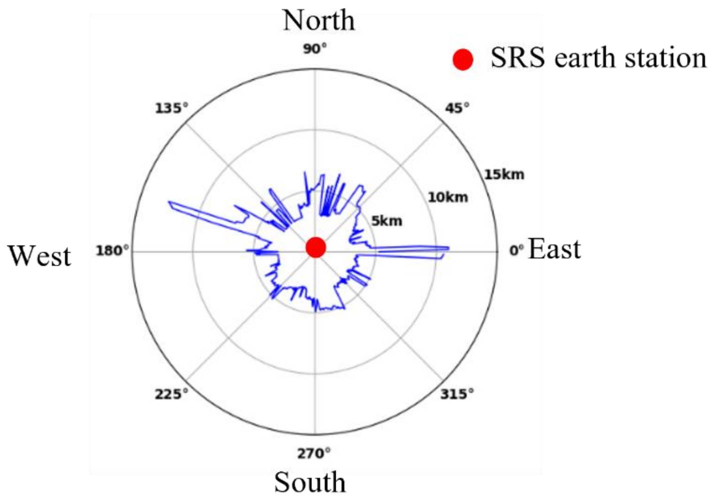
The maximum distances among all the azimuthal angles for which the IMT protection criterion is met around SRS earth station in Cebreros, Spain are 29.3 km (43 dBW) and 32.9 km (49 dBW).

FIGURE 21

Minimum distance for each azimuthal angle for which the IMT protection criterion is met (IMT BS deployed in suburban area)



(a) Tx power of earth station = 43 dBW



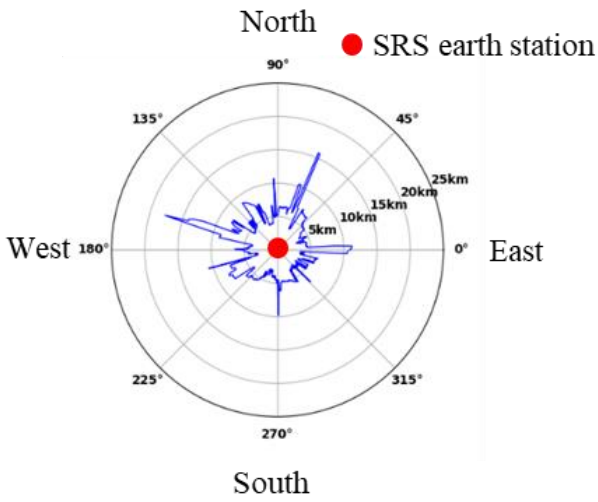
(b) Tx power of earth station = 49 dBW

For sensitivity analysis assuming IMT BS deployed in rural, the minimum distance for each azimuthal angle for which the IMT protection criterion is met around SRS earth station, is shown in Fig. 22. And the largest ones among the minimum distances for all azimuthal angles are 17.7 km (43 dBW) and 24 km (49 dBW), respectively.

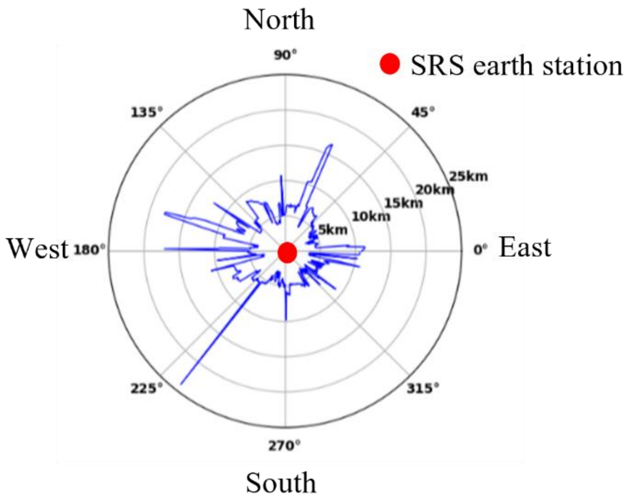
The maximum distances among all the azimuthal angles for which the IMT protection criterion is met around SRS earth station in Cebreros, Spain are 59.9 km (43 dBW) and 71 km (49 dBW).

FIGURE 22

Minimum distance for each azimuthal angle for which the IMT protection criterion is met (IMT BS deployed in rural area, sensitivity analysis)



(a) Tx power of earth station = 43 dBW



(b) Tx power of earth station = 49 dBW

Annex 4

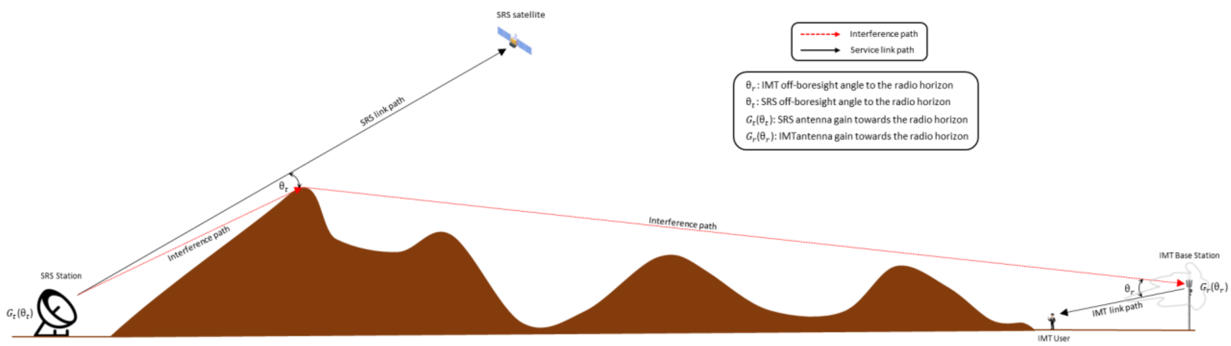
Example of coordination area calculations

1 Introduction

Earth stations of the space research service (SRS) operate in the 7 145-7 190 MHz band with high power uplink transmissions to communicate with spacecraft, which have the potential to cause interference to IMT receivers operating in the 6 425-7 125 MHz band. Figure 23 shows the interference scenario between transmitting SRS earth stations and receiving IMT base stations.

FIGURE 23

Interference scenario between SRS earth station and IMT base station



This Annex provides the coordination distances required between IMT base stations and two deep space stations, one in Canberra (Australia) and the other in Madrid (Spain).

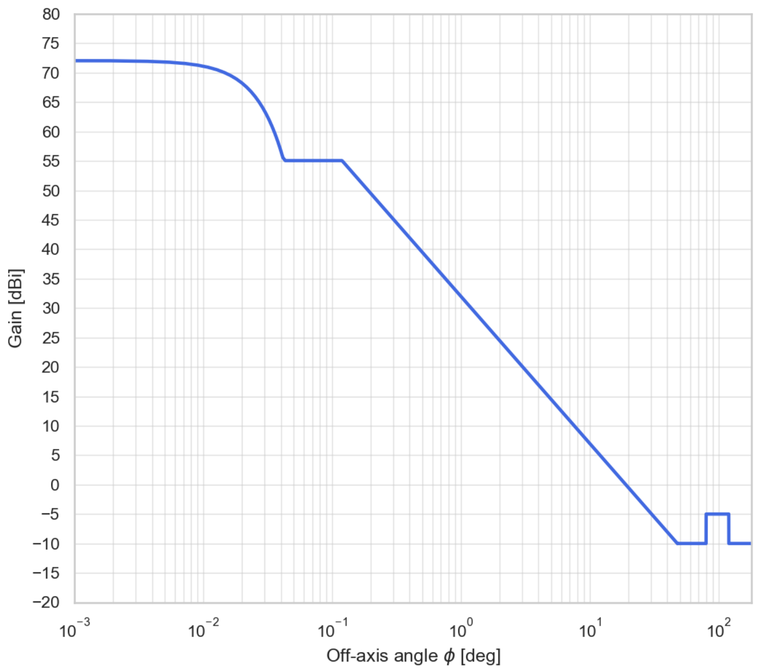
2 SRS (deep space) earth station transmitter parameters

The transmitter parameters for the SRS (deep space) earth stations are given Table 1 with Transmitter power 49 dBW. The SRS antenna polarization is circular.

The SRS transmit e.i.r.p. towards the IMT base station will depend on the transmitter PSD, the elevation angle of the physical horizon around the SRS earth station, and the SRS antenna gain pattern. The gain pattern for the 70 m diameter SRS antenna is given in Fig. 24 as specified in Recommendation ITU-R SA.509.

FIGURE 24

Gain pattern for the 70-m SRS antenna at 7 125 MHz



3 IMT base station receiver parameters

This study assumes that the IMT base stations are located in suburban areas. The technical parameters for the IMT base stations used in this study are given in Table 2 (see column labelled "Macro suburban").

The IMT base station vertical antenna pattern for Advanced Antenna System (AAS) is presented in Fig. 26 using the model from Recommendation ITU-R M.2101, considering the mechanical downtilt of 6°. In this study, the IMT base station antenna is assumed to have a vertically steerable beam directed toward the user equipment (UE). All possible UE positions along the same azimuthal direction as the SRS antenna pointing are considered. Furthermore, the maximum upward electronic beam steering is limited to 91.76°, corresponding to the UE position at the cell edge, while the downward beam steering limit is set to 100°, in accordance with IMT characteristics. Figure 25 presents the scenario and the elevation angle calculation for a user located at the edge of the cell, assuming flat terrain within the suburban cell area. Figure 26 illustrates the vertical antenna pattern of the AAS, using eight simulation samples and considering the specified beam steering constraints.

FIGURE 25

Elevation Angle of the IMT UE at the Edge of the Cell

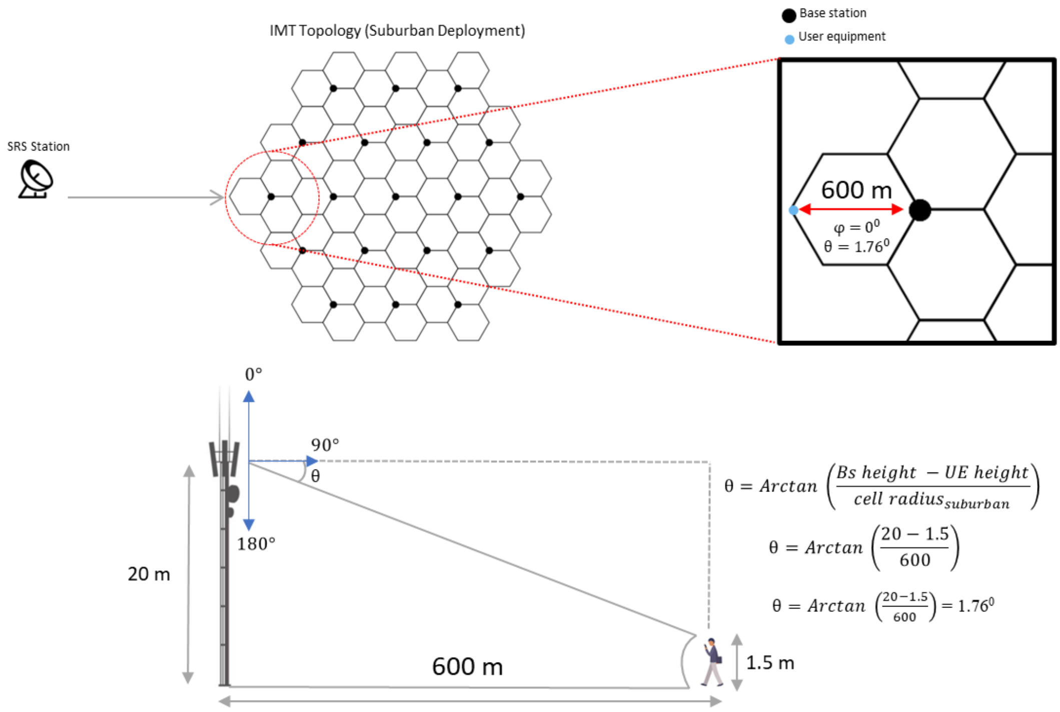
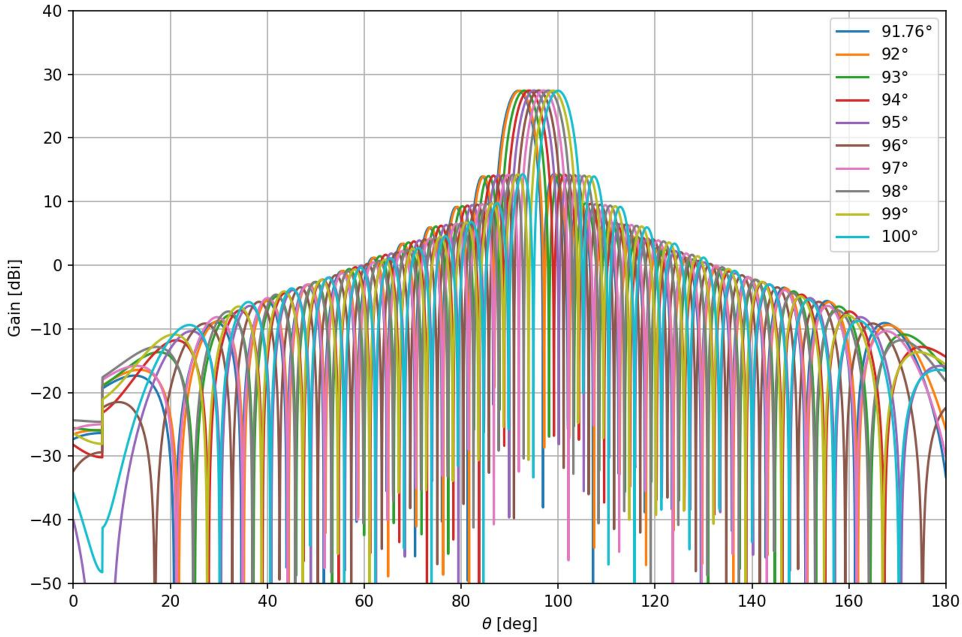


FIGURE 26

IMT AAS vertical antenna pattern at 7 125 MHz



4 Terrestrial propagation model

The propagation losses are determined using the propagation model given in Recommendation ITU-R P.452 as recommended by the WPs 3M/3K. This model includes losses due to several propagation mechanisms such as free-space, atmosphere, tropospheric scatter, diffraction, ducting, site shielding and clutter.

This loss model requires an input probability parameter, p, and calculates a predicted propagation loss value, L, such that the $Prob\{ loss <= L \} = p$. Thus, the calculated interference power received by the IMT receiver will exceed the protection criteria with probability p. A value of p = 20% was considered in this study, similar to the percentage used for the long-term protection criterion for some other terrestrial services (e.g. Recommendation ITU-R F.758). Other values, such as p = 50%, can also be used.

The terrain height profiles around the SRS earth stations are generated using the Shuttle Radar Topography Mission (SRTM) 1-arc-second global data.

5 Clutter loss

This study considered results for two different scenarios for clutter loss: the first based on actual terrain data as represented by the SRTM dataset without additional statistical endpoint clutter loss from Recommendation ITU-R P.2108, and the second based on SRTM terrain with the addition of Recommendation ITU-R P.2108 (§ 3.2) statistical median clutter loss using p = 50%. These two cases are considered in this study because the SRTM terrain data incorporates measurements of the clutter height, but can significantly underestimate the clutter height particularly in areas of vegetation and dense foliage. However, the use of SRTM terrain data with path specific clutter in addition to P.2108 clutter loss can also significantly overestimate the loss.

6 Polarization loss

This study assumes a polarization loss factor of 3 dB.

7 Interference calculation

The interference-to-noise ratio (*I/N*) of the IMT receiver is calculated as given below:

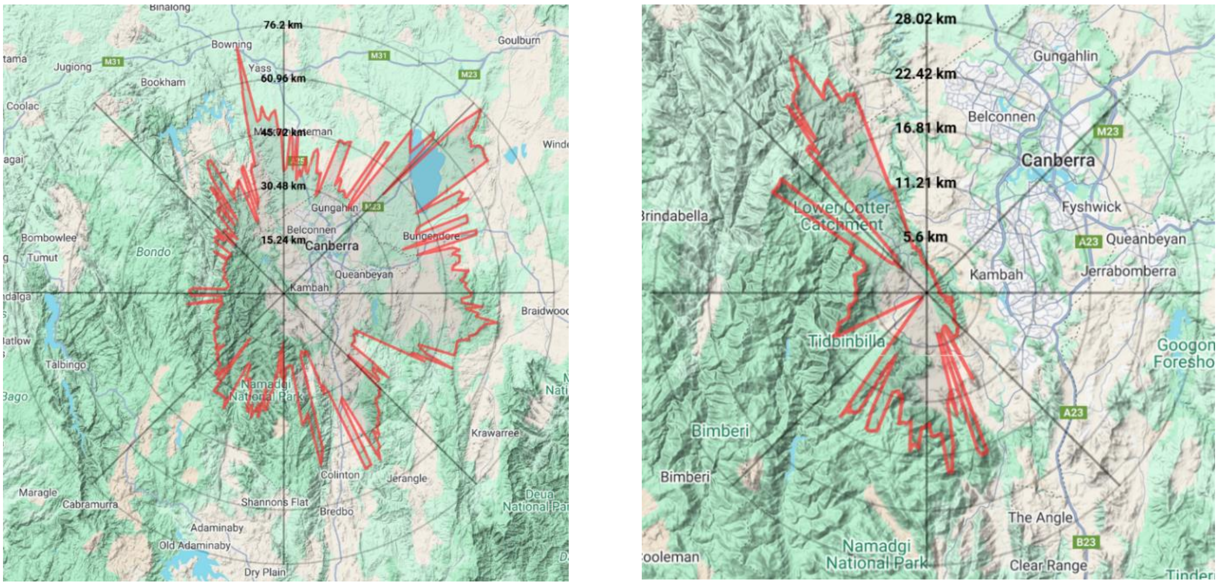
$$I/N\ (\mathrm{dB}) = P_t + G_t(\theta) + G_r(\theta) - L(d,p) - N_{rcv}$$

which needs to be less than the IMT receiver protection level of −6 dB. $G_t(\theta)$ is the SRS earth station antenna gain in dB towards the physical horizon, with θ representing the off-boresight angle, $G_r(\theta)$ is the IMT antenna gain in dB towards the physical horizon, with θ also representing the off-boresight angle, and N_{rcv} is the IMT receiver thermal noise.

8 Coordination areas around SRS (deep space) earth stations

FIGURE 27

Canberra (Recommendation ITU-R P.452-18 (*p* = 20%))

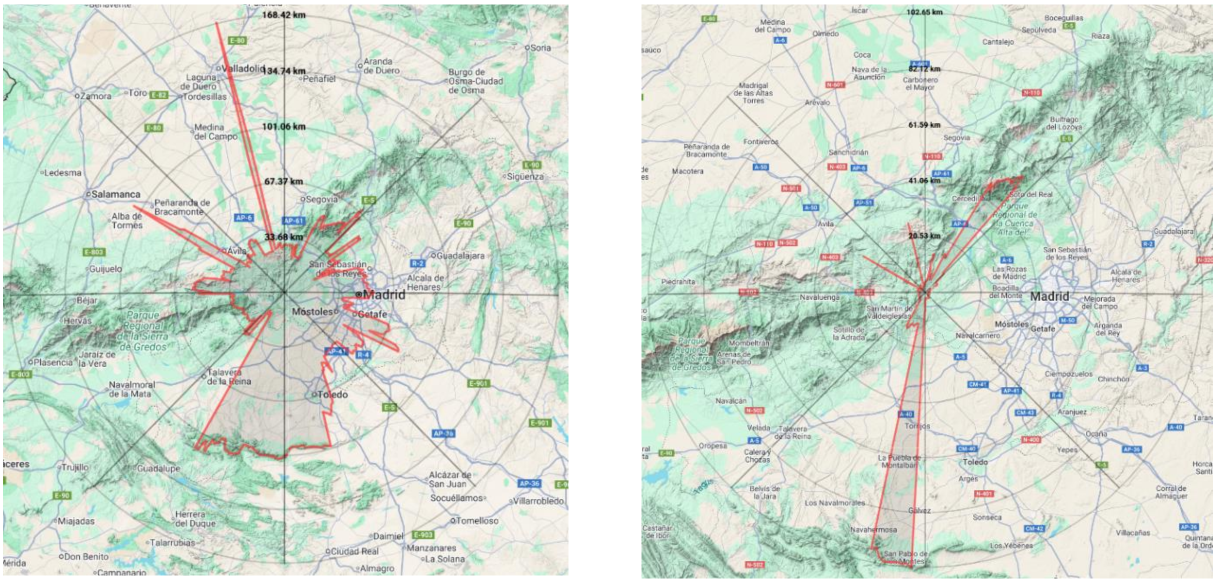


Rec. ITU-R P.452 with SRTM terrain

Rec. ITU-R P.452 with SRTM terrain +
Rec. ITU-R P.2108 median endpoint clutter loss

FIGURE 28

Madrid (Recommendation ITU-R P.452-18 (*p* = 20%))



Rec. ITU-R P.452 with SRTM terrain

Rec. ITU-R P.452 with SRTM terrain + Rec. ITU-R P.2108 median endpoint clutter loss

The maximum coordination distances between the IMT base station and SRS (deep space) Earth stations in Canberra and Madrid, which are azimuth-dependent, are 76.2 km and 168.4 km, respectively, using SRTM terrain data without additional Recommendation ITU-R P.2108 median endpoint clutter loss. In a scenario where Recommendation ITU-R P.2108 median terrestrial clutter loss is added, these distances reduce to 28.0 km and 102.7 km for Canberra and Madrid, respectively. These distance ranges correspond to a time percentage (*p*) of 20%, as specified in Recommendation ITU-R P.452-18.

9 Summary

This study addresses the identification of the required coordination distances between IMT base stations operating within the 6 425-7 125 MHz frequency range and SRS (deep space) Earth stations in the 7 145-7 190 MHz frequency range, with a focus on potential coordination in Canberra and Madrid. The maximum required coordination distances, which are azimuth-dependent, are 76.2 km and 168.4 km for Canberra and Madrid, respectively, using SRTM terrain data without additional Recommendation ITU-R P.2108 median endpoint clutter loss. In scenarios where Recommendation ITU-R P.2108 median terrestrial clutter loss is added, these distances reduce to 28.0 km and 102.7 km, respectively. These distances correspond to a time percentage (*p*) of 20%, as defined in ecommendation ITU-R P.452-18.

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