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(05/2015)

Protection of SRS earth stations from transmitting mobile (aircraft) stations in the 2 200-2 290 MHz band

SA Series

Space applications and meteorology

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REPORT ITU-R SA.2276-1

Protection of SRS earth stations from transmitting mobile (aircraft) stations in the 2 200-2 290 MHz band

(2013-2015)

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1 Introduction

Appendix **7** of the ITU Radio Regulations (RR) covers the methods to determine the coordination area around an earth station in the frequency bands between 100 MHz and 105 GHz. Annex 7 of ITU RR Appendix **7** gives system parameters for determination of the coordination area around an earth station. In addition, Table 10 in Annex 7 of ITU RR Appendix **7** gives predetermined coordination distances in sharing situations involving services allocated with equal rights. The predetermined coordination distances are given for several cases of earth stations and ground stations in several frequency bands. In addition, for the cases not covered explicitly, the last row of this table specifies the predetermined coordination distance between a mobile (aircraft) station and an earth station to be 500 km. Since the case of SRS earth station and mobile (aircraft) station is not covered explicitly, the predetermined coordination distance of 500 km applies. However, previous studies and the studies given in this Report show that 500 km is not enough to protect the SRS earth stations from interference caused by mobile (aircraft) station transmissions. The required separation distances are much larger than 500 km. Thus, Table 10 in Annex 7 of ITU RR (2012) Appendix **7** needs to be updated to include explicitly a much larger predetermined coordination distance between SRS earth stations and mobile (aircraft) stations in the 2-GHz band according to the interference results given in this Report.

In this Report, the interferences from mobile (aircraft) stations to SRS earth stations are studied taking into account the tropospheric scatter, diffraction, and ducting mechanism for non-line-of-sight interference. As expected, the separation distance based on the radio line-of-sight (LoS) between an SRS earth station and a mobile (aircraft) station is not enough to protect the SRS earth station from excessive interference. This Report provides the results for the required separation distance between an SRS earth station and a mobile (aircraft) station to protect the SRS earth stations supporting manned and unmanned SRS missions.

2 Mobile (aircraft) station

In this study, mobile (aircraft) station altitudes are assumed to vary from 4 km to 17 km. The mobile (aircraft) station is assumed to be transmitting at an e.i.r.p. spectral density of –50 dBW/Hz towards the horizon.

3 Near-Earth SRS earth stations

There are many near-Earth SRS earth stations in several countries, and this number is expected to increase in the future. In this Report, we have used the SRS earth stations located at Goldstone and Wallops in USA, Madrid in Spain, Canberra, New Norcia, and Perth in Australia, and Uchinoura in Japan as examples of SRS earth stations supporting near-Earth SRS missions. The latitude and longitude of these stations are shown below in Table 3-1. It is expected that similar results would be applicable for the other near-Earth SRS stations not covered in this study.

TABLE 3-1

SRS earth station locations

Station name	Country	Latitude (degrees)	Longitude (degrees)
Goldstone (DSS24)	USA	35.43	–116.89
Madrid (DSS54)	Spain	40.43	–4.25
Canberra (DSS34)	Australia	–35.40	148.98

TABLE 3-1 *(end)*

Station name	Country	Latitude (degrees)	Longitude (degrees)
Wallops (WFF11)	USA	37.95	–75.46
New Norcia (DSA1)	Australia	–31.04	116.19
Perth	Australia	–31.80	115.88
Uchinoura (USC34)	Japan	31.25	131.08

The parameters of the SRS earth stations used in this study are summarized in § 6, Table 6-1.

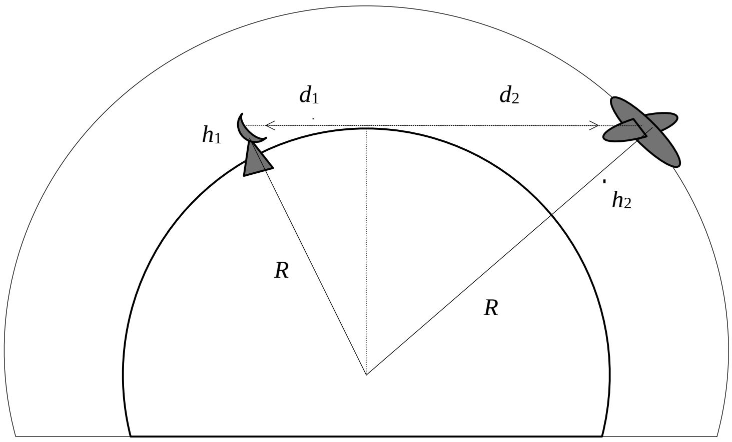
The protection criteria of the SRS earth stations are given in Recommendation ITU-R SA.609 for the near-Earth SRS earth stations operating in the 2-GHz band. In this Recommendation, high sensitivities of the SRS earth stations are recognized. For the 2-GHz band, to protect the SRS earth stations, Recommendation ITU-R SA.609 established a power spectral density (PSD) of –216 dBW/Hz. Interference received by the SRS earth station from any source is calculated using an exceedance probability of 0.001% for manned SRS missions and 0.1% for unmanned SRS missions.

4 Interference between mobile (aircraft) station and SRS earth station using RF visibility limits

The RF visibility limit of a mobile (aircraft) station is defined as the separation distance at which the aircraft is just on the horizon as shown in Fig. 4-1.

FIGURE 4-1

RF visibility limit between aircraft station and SRS earth station



The RF visibility limit, which defines the radio LoS distance between an earth station and an aircraft, is calculated using the smooth-earth model as follows:

$$d_1 + d_2 = \sqrt{(R+h_1)^2 - R^2} + \sqrt{(R+h_2)^2 - R^2}$$
$$R = k^* R_e \quad (1)$$

where:

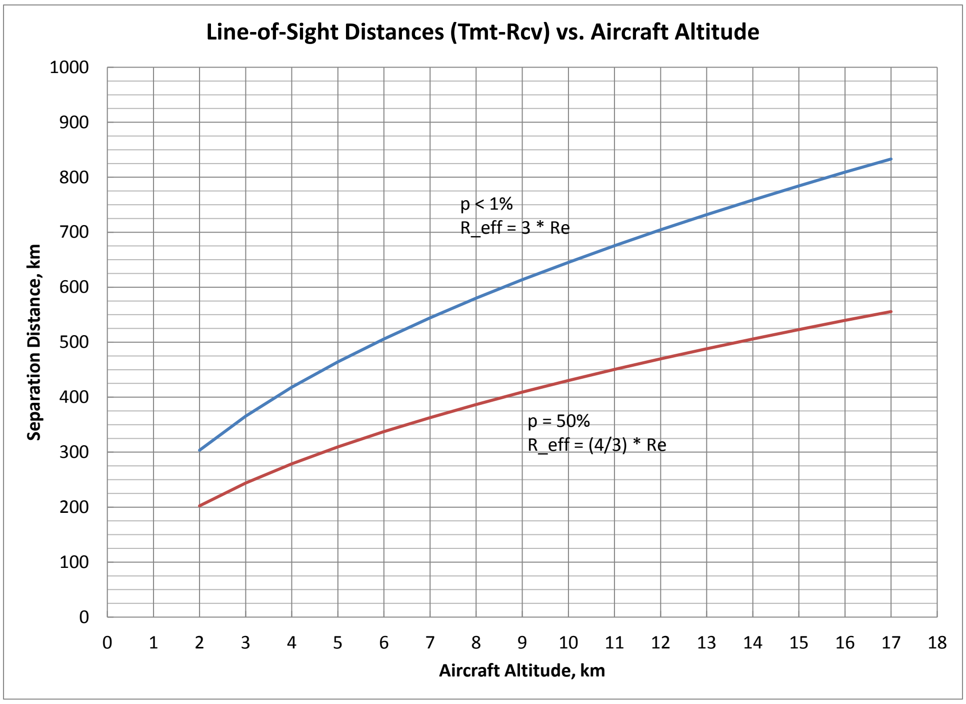
- h_1: SRS antenna centre height
- h_2: aircraft altitude
- R: effective Earth radius
- R_e: radius of Earth
- k: effective Earth radius factor.

Note that, to account for the bending of the RF waves due to the variation of the refractive index of the atmosphere, the calculation above uses the effective Earth radius, which is about 4/3 times the Earth's radius for p = 50%, or 3 times the Earth's radius for p < 1% (Recommendations ITU-R P.834 and ITU-R P.452).

Figure 4-2 gives the radio LoS distances between an aircraft at different altitudes and an SRS earth station with 19-m antenna height, for effective Earth radii corresponding to k = 4/3 and k = 3. The figure shows that the radio LoS distances vary from 200 km to 550 km for k = 4/3, and vary from 300 km to 830 km for k = 3.

FIGURE 4-2

LoS distances between aircraft station and SRS earth station using RF visibility limits (k = 4/3 and k = 3)



When the aircraft is just at the RF visibility limit as seen from the SRS earth station antenna, there is a potential interference from the aircraft station transmissions to the SRS earth station receiver. Below, the case for 500 km radio LoS separation is analysed.

For the 2 GHz band, using the protection criterion ($P_{r,0}$) of the SRS earth station, antenna gain (G_r) of the SRS earth station towards the aircraft station, and the space loss (L) for a LoS separation distance of 500 km, we obtain the maximum transmit e.i.r.p. of the aircraft station as:

$$EIRP_{t,max,500km} = P_{r,0} + L - G_r = -216 + 154 - 7 = -47 \text{ dBW/Hz} \quad (2)$$

The antenna gain 7 dB of the SRS earth station is calculated for an off-boresight angle of 10 degrees and 153.5 dB is the free space loss for 500 km separation and 2.27 GHz frequency. Note that for an aircraft at 500 km away from an SRS earth station, using an aircraft transmitter e.i.r.p. of –50 dBW/Hz, the expected interference will be 19.5 dB above the protection criterion of the SRS earth station for SRS antenna gain of 7 dB. Thus, separation distances larger than 500 km will be required to meet the protection criteria of SRS earth stations. In addition, if the interference is received closer to the SRS antenna boresight, the exceedance will be greater. For example, for 6-degree off-boresight angle, the antenna gain will be 12.5 dB and interference will be 25 dB above the SRS protection criterion; for 2-degree off-boresight angle, the antenna gain will be 24.5 dB and the excess interference will be 37 dB.

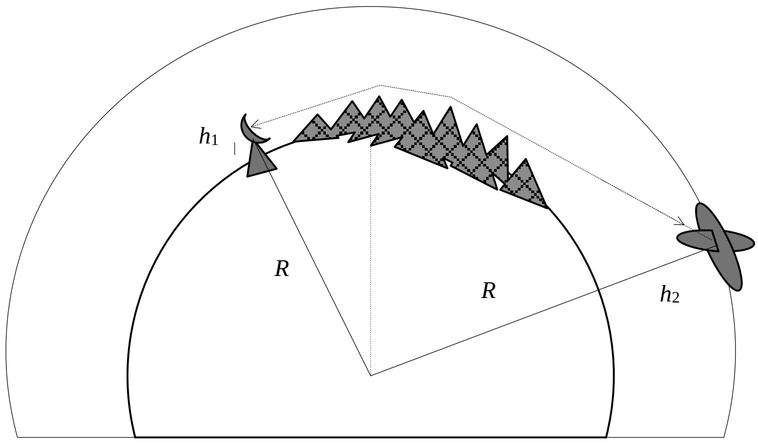
It is clear that an aircraft with radio LoS separation distance of 500 km will cause excessive interference to a receiving SRS earth station. Even for an aircraft at 17 km altitude with RF visibility limit of 830 km and 7 dB SRS antenna gain, the space loss would be 157.9 dB and the interference will still be 15.1 dB above the protection criteria of the SRS earth station for an aircraft transmit e.i.r.p. density of –50 dBW/Hz.

5 Interference between aircraft station and the SRS earth station using terrain and atmospheric propagation effects

Figure 5-1 shows the case when the aircraft is below the RF visibility limit. In this case, it can still cause interference to receiving SRS earth stations.

FIGURE 5-1

Interference between aircraft station and SRS earth station using terrain and atmospheric propagation effects



Here, the interference signal reaches the SRS earth station through the troposcattering, diffraction, and ducting mechanism of the atmosphere and the earth terrain. Recommendation ITU-R P.528 provides methods for predicting basic transmission losses using models of the above mechanisms for aeronautical and satellite services over a range of frequencies encompassing the 2 GHz-band.

In this study, these non-line-of-sight propagation losses are calculated in order to determine the required separation distances to meet the SRS earth station protection criteria.

As recommended in Recommendation ITU-R P.528, the IF-77 program was used to calculate the expected non-line-of-sight propagation losses taking into account the troposcattering, diffraction, and ducting mechanism of atmosphere and local horizon heights and distances for the case where the aircraft station is assumed to be transmitting an e.i.r.p. density of –50 dBW/Hz. For this transmit e.i.r.p. spectral density, IF-77 program is used to obtain propagation loss maps around SRS earth stations, which are then used to determine separation distances associated with the minimum required propagation losses to ensure that the SRS station protection criteria was met.

In addition to citing the use of the IF-77 software for calculating propagation losses, Recommendation ITU-R P.528 provides the propagation losses directly by set of curves and equivalent tabular data. These curves are parameterized by earth station antenna height, aircraft station antenna height, frequency, and percent of time exceeded. Each curve and table provided in the Recommendation corresponds to a set of specific values for these parameters, and several values for each parameter are used in the Recommendation.

Recommendation ITU-R P.528 also provides a detailed procedure and set of formulas to determine the propagation loss for specific parameter values for which curves are not provided. These procedures involve the use of interpolation to determine the loss associated with a parameter value that lies between two values for which the Recommendation does explicitly provide propagation loss amounts.

6 Interference from aircraft station to SRS earth station in the 2 GHz band using IF-77

The parameters used for the aircraft transmitter interference to the SRS earth station are given in Table 6-1.

TABLE 6-1

Parameters used for aircraft transmitter interference to SRS earth station

Parameter	Value		Note
Aircraft station (tmt)			
Frequency	2.27	GHz	
Aircraft altitude	4-17	km	Coordination contours are shown for 17 km aircraft altitude
Transmit e.i.r.p. density towards horizon	–50	dBW/Hz	Used with IF-77 propagation loss values in analyses with all stations
SRS earth station (rcv)			
Goldstone, Madrid, Canberra			
Minimum tracking angle Antenna diameter Antenna height	10 34 19	degrees m m	Goldstone, Madrid and Canberra stations can track down to 6 degrees elevation.
Wallops			
Minimum tracking angle Antenna diameter Antenna height	5 11.3 15	degrees m m	
New Norcia			
Minimum tracking angle Antenna diameter Antenna height	10 35 21	degrees m m	New Norcia station can track down to 5 degrees elevation.

TABLE 6-1 (*end*)

Parameter	Value		Note
Perth			
Minimum tracking angle Antenna diameter Antenna height	10 15 11	degrees m m	Perth station can track down to 5 degrees elevation.
Uchinoura			
Minimum tracking angle Antenna diameter Antenna height	10 34 20	degrees m m	Uchinoura station can track down to 5 degrees elevation.
Antenna gain pattern	RR. AP8-10		
Permissible interference level	–216	dBW/Hz	SRS station protection (Recommendation ITU-R SA.609)
Probability of exceedance (p)	0.001 0.1	% (manned) % (unmanned)	For trans-horizon interference sources (Recommendation ITU-R SA.609)

The interference p.s.d. received by the SRS earth station from the mobile (aircraft) station transmitter is given by:

$$L_{min} = EIRP_t - P_{r,0} + G_r \text{ (dBW/Hz)} \quad (3)$$

where:

$EIRP_t$: maximum e.i.r.p. spectral density transmitted by the aircraft station towards the SRS earth station

L_{min}: minimum propagation loss required between the transmitter and the receiver

G_r: off-boresight gain of the receive antenna of the SRS earth station.

Note that the off-boresight gain (G_r) of the receive SRS earth station antenna depends on the horizon elevation and the minimum tracking angle of the SRS earth station antenna, which can vary considerably depending on the terrain elevation around the SRS earth station.

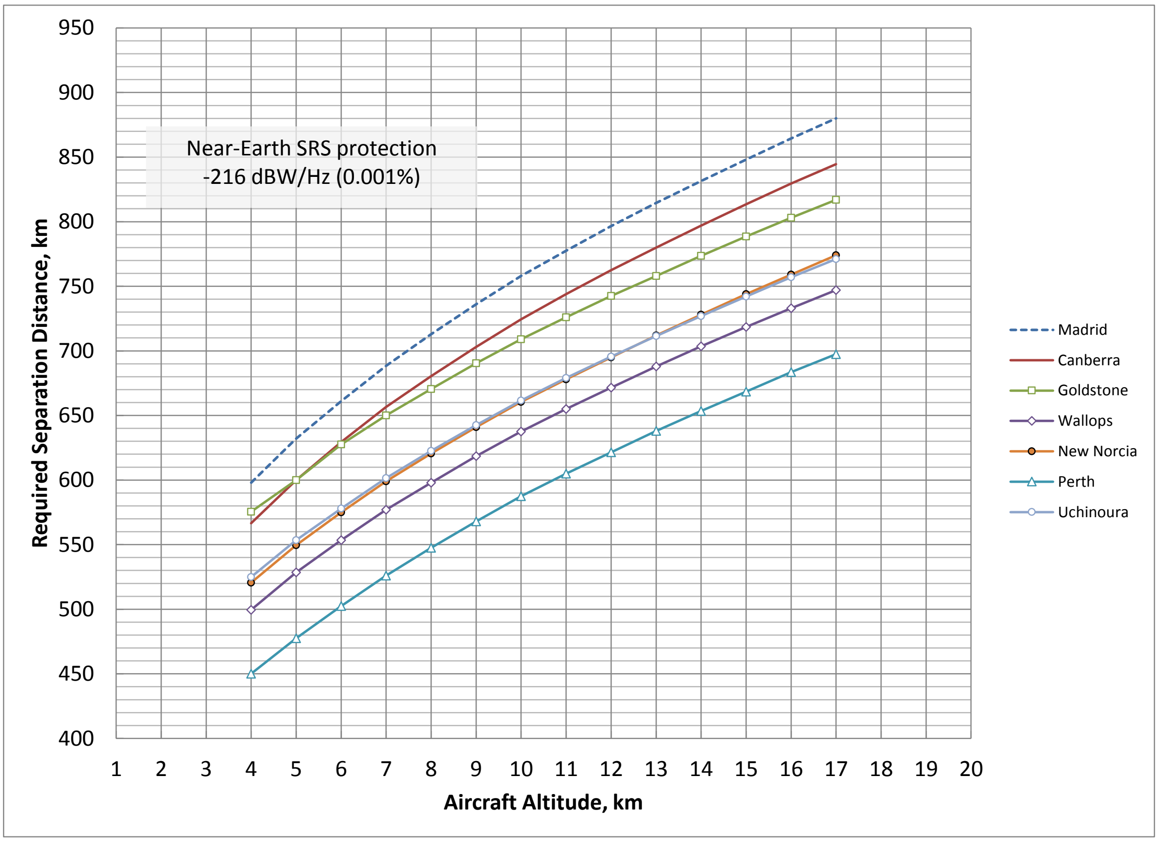
Now using the parameters given in Table 6-1, we can obtain the minimum propagation loss to meet the protection of the SRS earth station. For the case where the aircraft station is transmitting at –50 dBW/Hz towards the horizon, the minimum propagation loss is given as:

$$L_{min} = -50 + 216 + G_r = 166 + G_r \text{ (dB)} \quad (4)$$

Now using the minimum propagation loss required for all the azimuthal directions around the SRS earth stations, the separation distances can be determined for the –50 dBW/Hz e.i.r.p. of aircraft transmitters. The results for exceedance probability of p = 0.001% are shown in Fig. 6-1 for the SRS earth stations at Goldstone and Wallops in USA, Madrid in Spain, Canberra, New Norcia, and Perth in Australia, and Uchinoura in Japan. In calculating the propagation losses, IF-77 program is used, which takes into account the troposcatter, diffraction, and ducting mechanism. The required separation distances are given as a function of the aircraft altitude.

FIGURE 6-1

Required separation distance between SRS earth stations and aircraft stations using non-line-of-sight propagation effects for *p* = 0.001% in 2 GHz band assuming aircraft station transmit e.i.r.p. density of –50 dBW/Hz



The results indicate that, in order to meet the protection of the SRS earth station supporting manned SRS mission, depending on the aircraft altitude, the aircraft needs to be between 450 km and 880 km away from the SRS earth stations at Goldstone, Wallops, Madrid, Canberra, New Norcia, Perth, and Uchinoura. Table 6-2 below gives the required separation distances for aircraft stations at an altitude of 17 km and transmitting –50 dBW/Hz e.i.r.p. towards the horizon, which can also be read from Fig. 6-1 above:

TABLE 6-2

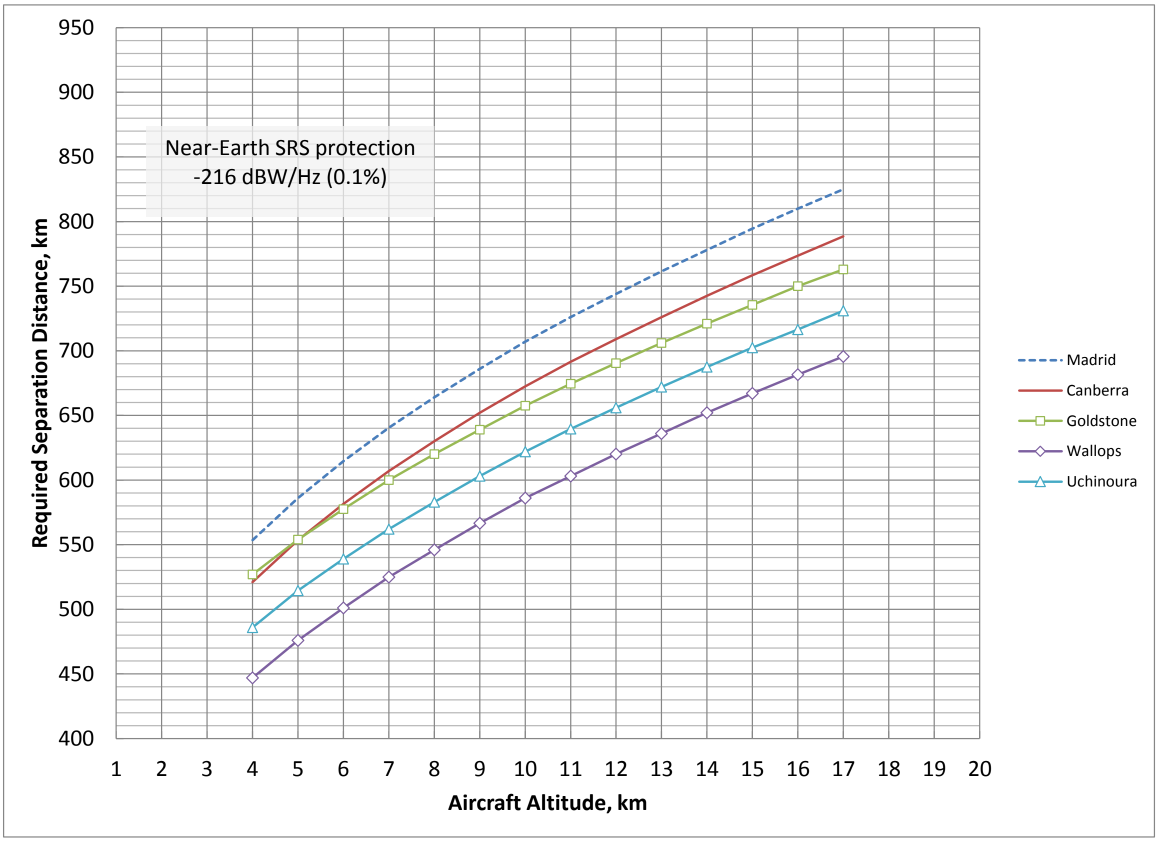
Required separation distances for SRS earth stations supporting manned missions (*p* = 0.001%) and aircraft station at 17 km altitude transmitting at –50 dBW/Hz e.i.r.p. density

SRS earth station Site, Country	Required separation distance (km)
Goldstone, USA	817
Wallops, USA	747
Madrid, Spain	880
Canberra, Australia	845
New Norcia, Australia	774
Perth, Australia	698
Uchinoura, Japan	771

For the interference exceedance probability of p = 0.1% to protect the unmanned SRS missions, the results for the –50 dBW/Hz aircraft station transmit e.i.r.p. case are shown in Fig. 6-2 for the SRS earth stations in Goldstone, Wallops, Madrid, Canberra, and Uchinoura. The required separation distances are given as a function of the aircraft altitude.

FIGURE 6-2

Required separation distance between SRS earth stations and aircraft stations using non-line-of-sight propagation effects for p = 0.1% in the 2 GHz band assuming aircraft station transmit e.i.r.p. density of –50 dBW/Hz



For near-Earth SRS earth stations supporting unmanned SRS mission with exceedance probability of p = 0.1%, the results indicate that, in order to meet the protection of the SRS earth station, depending on the aircraft altitude, the aircraft needs to be between 450 km and 825 km away from the SRS earth station at Goldstone, Wallops, Madrid, Canberra, and Uchinoura. Note again that the required separation distances are larger than the RF visibility limits.

Table 6-3 below gives the required separation distances for aircraft stations at an altitude of 17 km and transmitting at –50 dBW/Hz towards the horizon, which are also shown in Fig. 6-2 above.

TABLE 6-3

Required separation distances for SRS earth stations supporting unmanned missions (*p* = 0.1%) and aircraft station at 17 km altitude transmitting at –50 dBW/Hz e.i.r.p. density

SRS earth station Site, Country	Required separation distance (km)
Goldstone, USA	763
Wallops, USA	696
Madrid, Spain	825
Canberra, Australia	789
Uchinoura, Japan	731

Note that these distances for SRS earth stations supporting unmanned missions (*p* = 0.1%) are about 50 km less than the distances given for SRS earth stations supporting manned missions (*p* = 0.001%).

7 Examples of coordination areas around the SRS earth stations for an aircraft station at 17-km altitude transmitting at –50 dBW/Hz towards the horizon

7.1 Example coordination contours for manned SRS missions (*p* = 0.001%)

Figures 7.1-1 through 7.1-7 below give the coordination areas around the SRS earth stations at Goldstone and Wallops in USA, Madrid in Spain, Canberra, New Norcia, and Perth in Australia, and Uchinoura in Japan. These coordination areas are for an aircraft flying at 17 km altitude and transmitting at –50 dBW/Hz e.i.r.p. so as to protect the manned SRS missions, which have an interference exceedance probability of *p* = 0.001%.

FIGURE 7.1-1

Coordination contour (*p* = 0.001%) around the receiving Goldstone-USA SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.

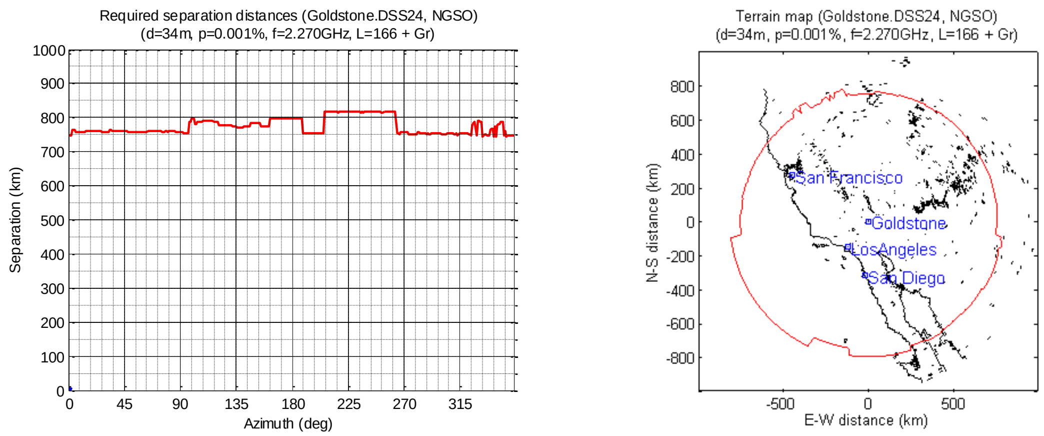


FIGURE 7.1-2

Coordination contour (p = 0.001%) around the receiving Madrid-Spain SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.

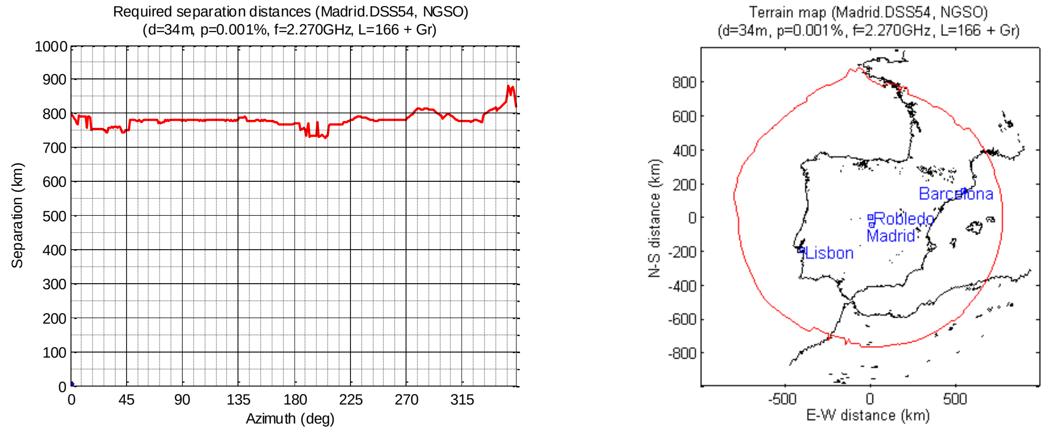


FIGURE 7.1-3

Coordination contour (p = 0.001%) around the receiving Canberra-Australia SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.

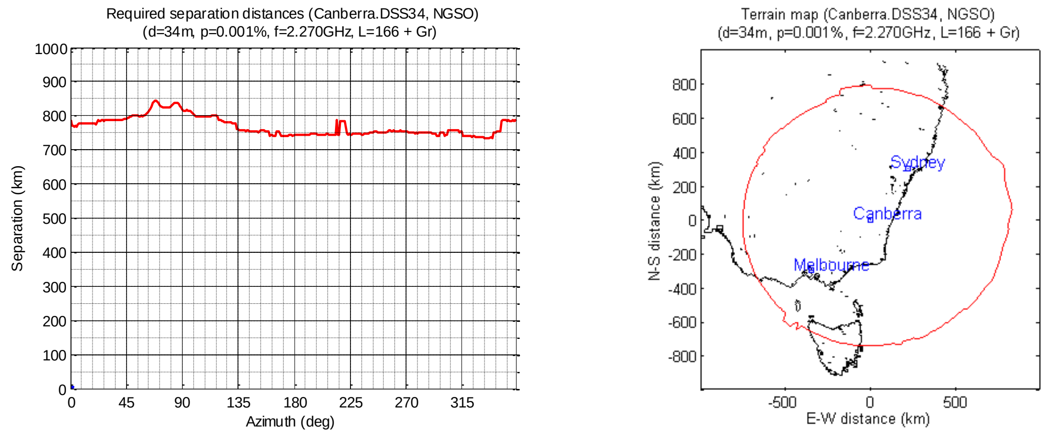


FIGURE 7.1-4

Coordination contour (p = 0.001%) around the receiving Wallops-USA SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.

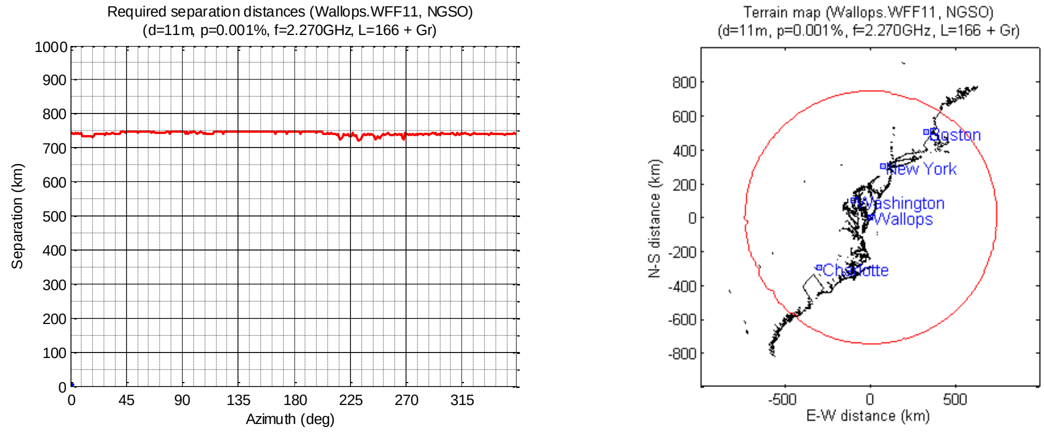


FIGURE 7.1-5

Coordination contour (p = 0.001%) around the receiving New Norcia-Australia SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.

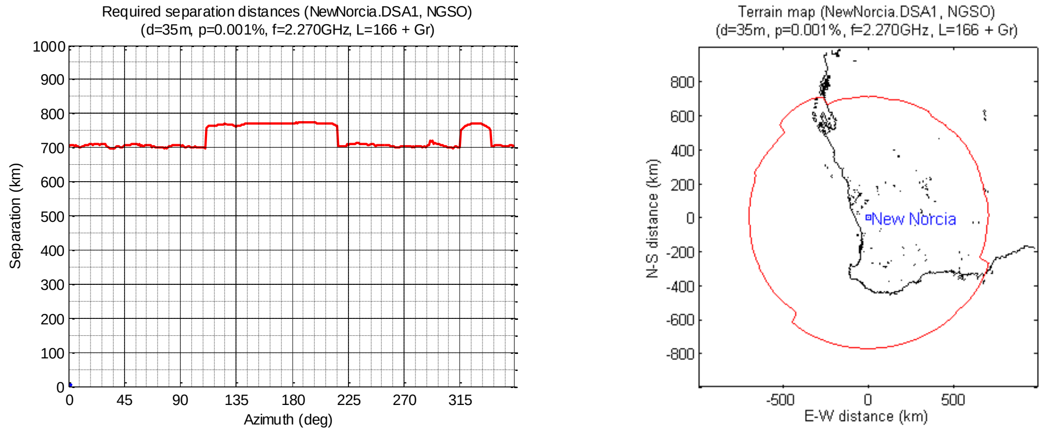


FIGURE 7.1-6

Coordination contour (p = 0.001%) around the receiving Perth-Australia SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.

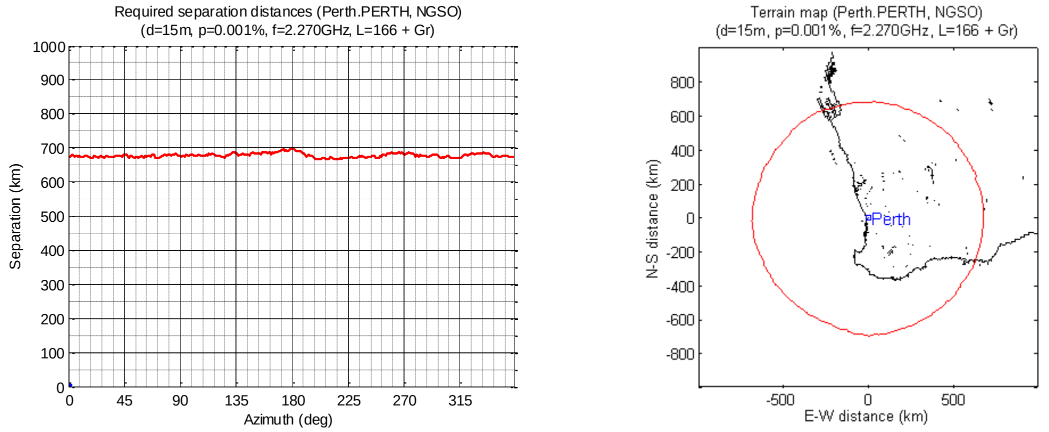
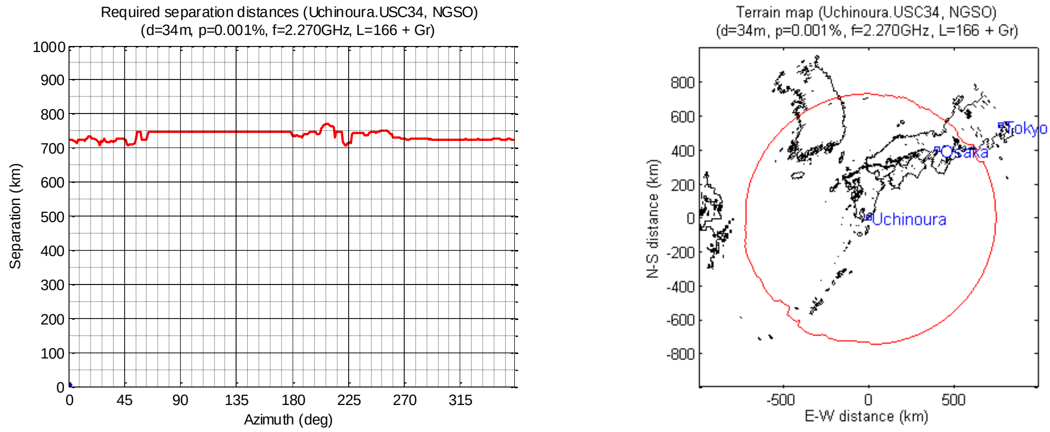


FIGURE 7.1-7

Coordination contour (p = 0.001%) around the receiving Uchinoura-Japan SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.



7.2 Example coordination contours for unmanned SRS missions (p = 0.1%)

Figures 7.2-1 through 7.2-5 give the coordination areas around the SRS earth stations in Goldstone-USA, Madrid-Spain, Canberra-Australia, Wallops-USA, and Uchinoura-Japan. These coordination areas are for an aircraft flying at 17 km altitude and transmitting at –50 dBW/Hz e.i.r.p. towards the horizon, to protect the unmanned SRS missions, which have interference exceedance probability of 0.1%.

FIGURE 7.2-1

Coordination contour (p = 0.1%) around the receiving Goldstone-USA SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.

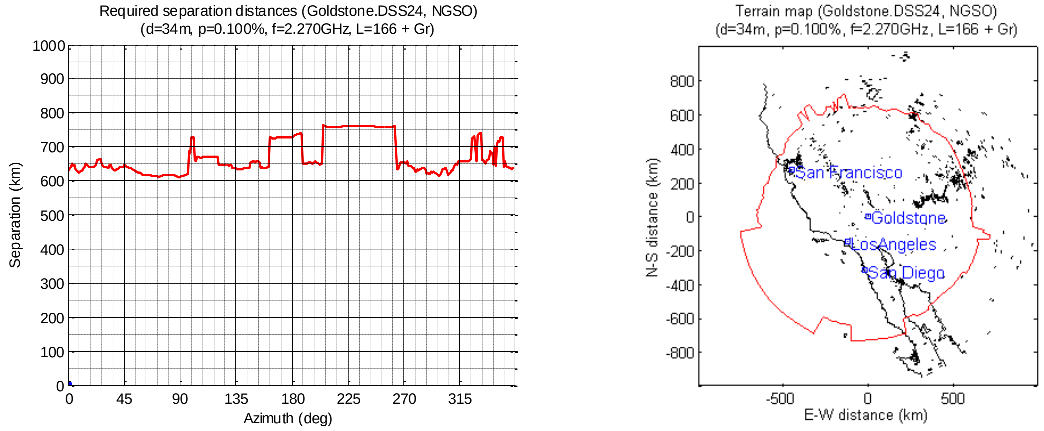


FIGURE 7.2-2

Coordination contour (p = 0.1%) around the receiving Madrid-Spain SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.

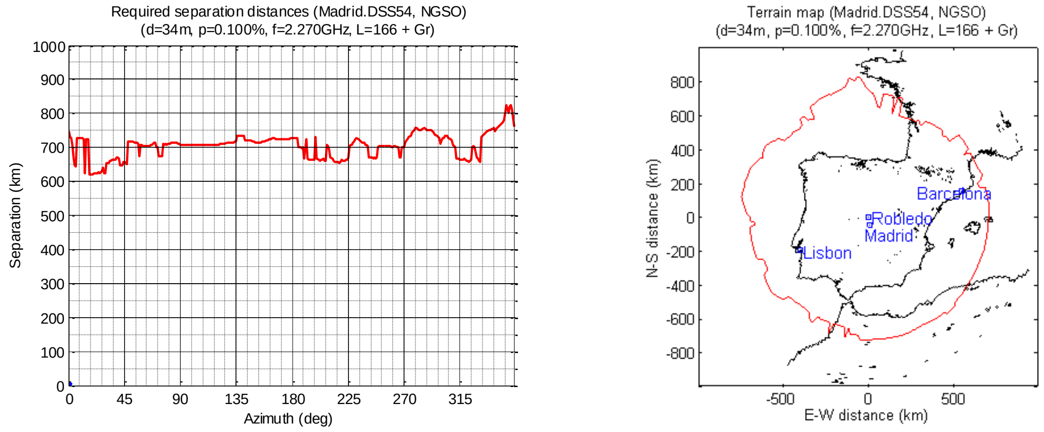


FIGURE 7.2-3

Coordination contour (p = 0.1%) around the receiving Canberra-Australia SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.

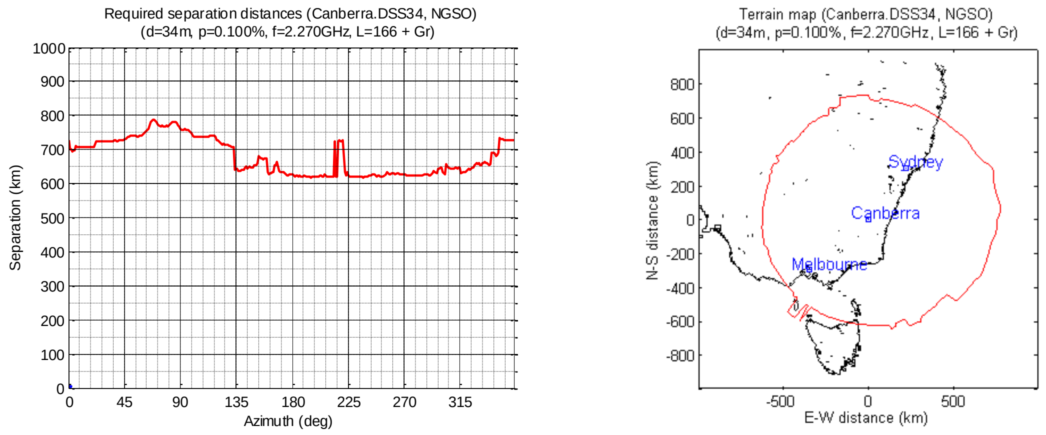


FIGURE 7.2-4

Coordination contour (p = 0.1%) around the receiving Wallops-USA SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.

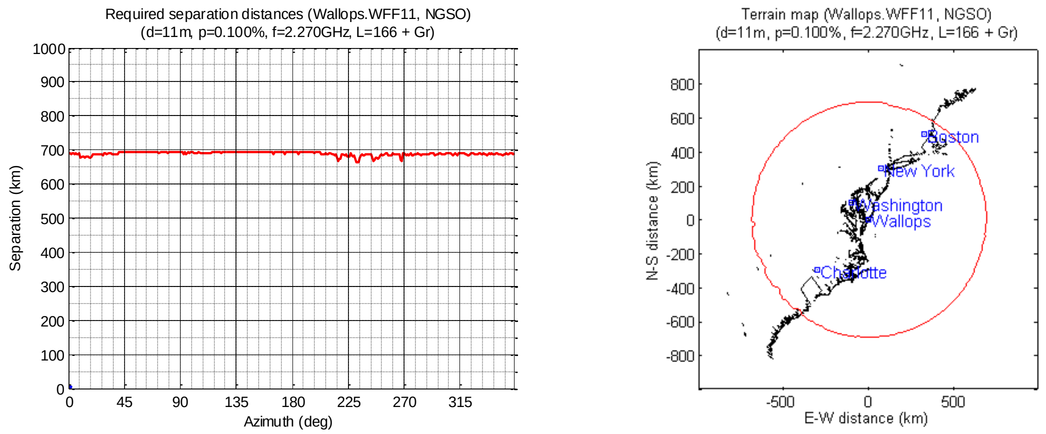
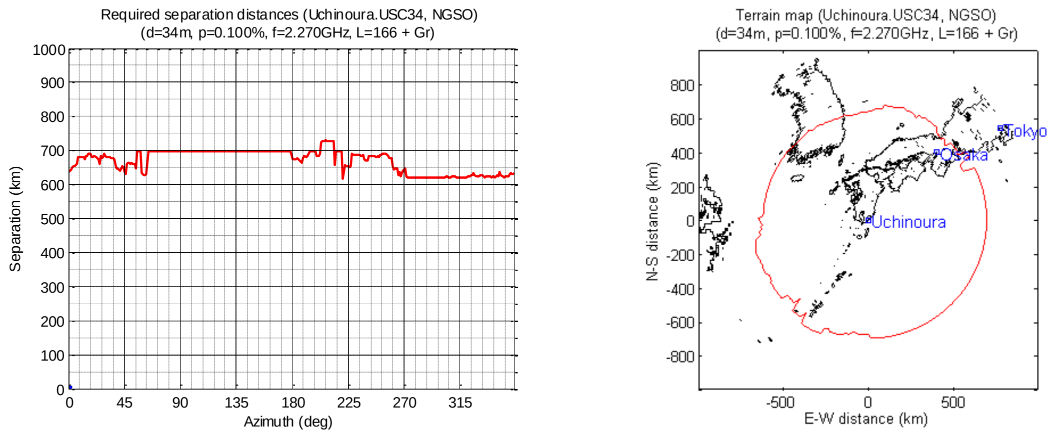


FIGURE 7.2-5

Coordination contour (p = 0.1%) around the receiving Uchinoura-Japan SRS earth station for the aircraft station transmitting –50 dBW/Hz e.i.r.p.



8 Conclusion

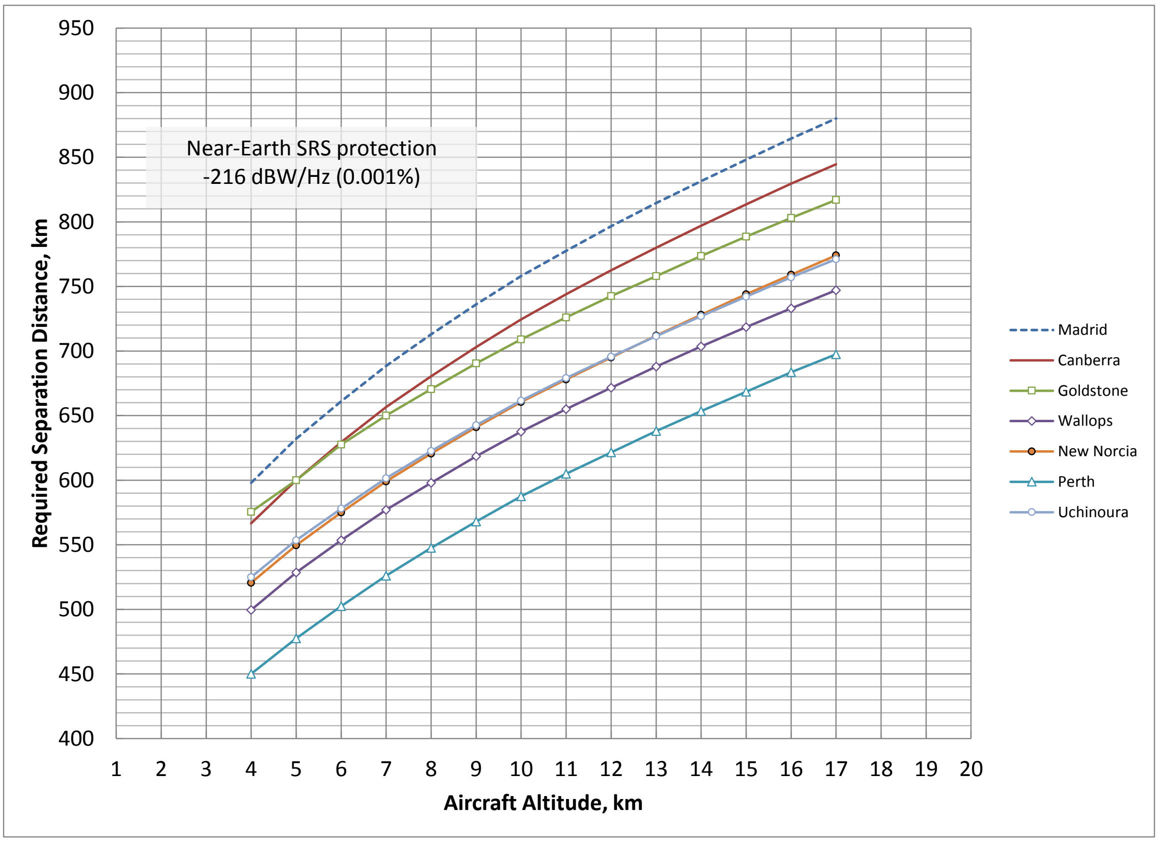
This Report has presented the results of a study for the interference received by the SRS earth stations from the aircraft stations in the 2-GHz band. The study considered the protection of manned and unmanned SRS missions. It shows that aircraft stations beyond the radio LoS of an SRS earth station can cause interference to the SRS earth station. It gives the required separation distances around the SRS earth stations, such that the non-line-of-sight interferences from the aircraft stations meet the protection criterion of the SRS earth stations.

The separation distances are derived using the IF-77 program recommended in Recommendation ITU-R P.528, and the SRS earth station protection level specified in the Recommendation ITU-R SA.609. The SRS earth station protection is specified as a threshold spectral density of –216 dBW/Hz with 0.001% exceedance probability to support manned near-Earth SRS spacecraft, and 0.1% exceedance probability to support unmanned SRS spacecraft.

Figure 8-1 below shows the required separation distance between SRS earth station supporting a manned mission (p = 0.001%) and aircraft station as a function of the aircraft altitude for the –50 dBW/Hz transmit e.i.r.p. density case. It shows that, in order to meet the protection of the SRS earth station, the aircraft needs to be between 450 km and 880 km away from the SRS earth stations at Goldstone, Wallops, Madrid, Canberra, New Norcia, Perth, and Uchinoura, depending on the aircraft altitude.

FIGURE 8-1

Required separation distances between SRS earth station (p = 0.001%) and aircraft station transmitting –50 dBW/Hz e.i.r.p. vs aircraft altitude



For aircraft stations at an altitude of 17 km, with transmit e.i.r.p. density of –50 dBW/Hz, the required separation distances are given in Table 8-1 as shown in Fig. 8-1.

TABLE 8-1

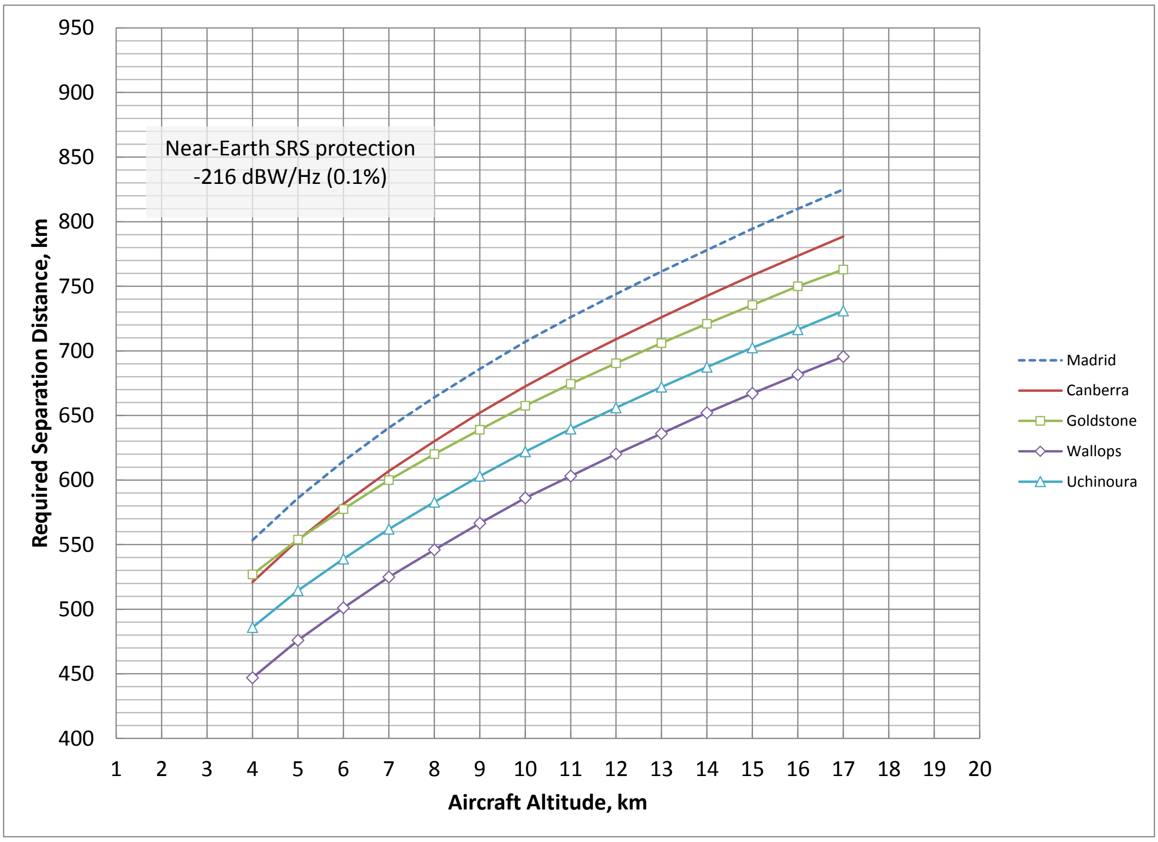
Required separation distances for SRS earth stations supporting manned missions (*p* = 0.001%) and aircraft station at 17 km altitude transmitting at –50 dBW/Hz e.i.r.p. density

SRS earth station Site, Country	Required separation distance (km)
Goldstone, USA	817
Wallops, USA	747
Madrid, Spain	880
Canberra, Australia	845
New Norcia, Australia	774
Perth, Australia	698
Uchinoura, Japan	771

Figure 8-2 below shows the required separation distances between SRS earth stations, supporting an unmanned SRS mission (p = 0.1%), and aircraft station as a function of the aircraft altitude for the –50 dBW/Hz transmit e.i.r.p. density case. It shows that, in order to meet the protection of the SRS earth station, the aircraft needs to be between 450 km and 825 km away from the SRS earth stations at Goldstone, Wallops, Madrid, Canberra, and Uchinoura, depending on the aircraft altitude. Note that, again, to protect the SRS earth stations, the required separation distances are greater than the RF visibility limits given for $p < 1\%$.

FIGURE 8-2

Required separation distances between SRS earth station (*p* = 0.1%) and aircraft station transmitting –50 dBW/Hz e.i.r.p. vs aircraft altitude



For aircraft stations at an altitude of 17 km and transmitting at –50 dBW/Hz e.i.r.p. spectral density towards the horizon, the required separation distances are given in Table 8-2 as shown in Fig. 8-2.

TABLE 8-2

Required separation distances for SRS earth stations supporting unmanned missions (*p* = 0.1%) and aircraft station at 17 km altitude transmitting at –50 dBW/Hz e.i.r.p. density

SRS earth station Site, Country	Required separation distance (km)
Goldstone, USA	763
Wallops, USA	696
Madrid, Spain	825
Canberra, Australia	789
Uchinoura, Japan	731

Note that these distances for SRS earth stations supporting unmanned missions (*p* = 0.1%) are about 50 km less than the distances given for SRS earth stations supporting manned missions (*p* = 0.001%).

In conclusion, in order to meet the SRS earth station protection criterion for manned and unmanned SRS mission, separation distances greater than default 500 km as indicated in the current version of RR Appendix **7** are required between the SRS earth stations and the aircraft stations. Thus, Table 10 in Annex 7 of ITU RR (2012) Appendix **7** needs to be updated to include explicitly a predetermined coordination distance of 880 km between SRS earth stations and aircraft stations in the 2 200-2 290 MHz band, according to the results of this study. This will avoid using erroneously the 500 km predetermined coordination distance between the SRS earth stations and aircraft stations as specified in the last row of Table 10 (ITU RR (2012) Appendix **7**, Annex 7) for cases not covered explicitly.