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Report ITU-R SA.2276

(09/2013)

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

SA Series

Space applications and meteorology

International Telecommunication Union

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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 SA.2276

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

(2013)

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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 an aircraft station and an earth station to be 500 km. Since the case of SRS earth station and 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 aircraft station transmissions. The required separation distances are much larger than 500 km. Thus, Table 10 in Annex 7 of ITU RR Appendix **7** needs to be updated to include explicitly a much larger predetermined coordination distance between SRS earth stations and aircraft stations in the 2-GHz band according to the interference results given in this Report.

In this Report, the interferences from 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 an 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 an aircraft station to protect the SRS earth stations supporting manned and unmanned SRS missions.

2 Aircraft station

In this study, aircraft station altitudes are assumed to vary from 4 km to 17 km. Two values of aircraft station e.i.r.p. spectral density are examined:

– Case 1: The aircraft station is assumed to be transmitting at an e.i.r.p. spectral density of –20 dBW/Hz towards the horizon.

– Case 2: The aircraft station is assumed to transmit at the ITU RR No. **21-8** maximum specified e.i.r.p. towards the horizon of 4 dBW/Hz.

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
Wallops (WFF11)	USA	37.95	–75.46
New Norcia	Australia	–31.04	116.19
Perth	Australia	–31.80	115.88
Uchinoura	Japan	31.25	131.08

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

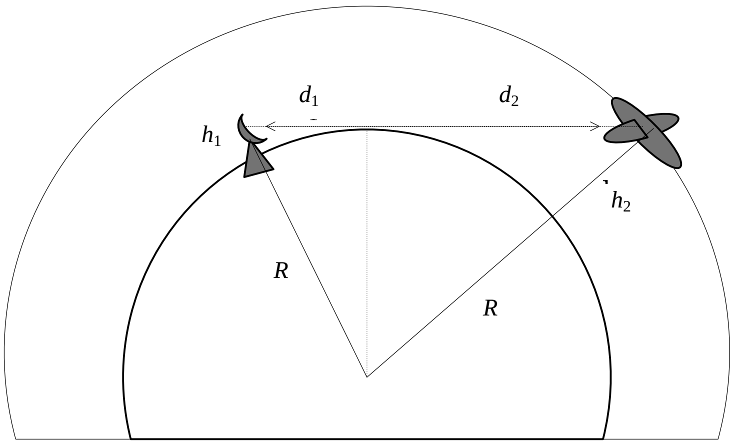
Recommendation ITU-R SA.609 provides protection criteria for the near-Earth SRS earth stations operating in the 2-GHz band. In this Recommendation, low sensitivities of the SRS earth stations are recognized. For the 2-GHz band, to protect the SRS earth stations, Recommendation ITU-R SA.609 established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

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

The RF visibility limit of an 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:

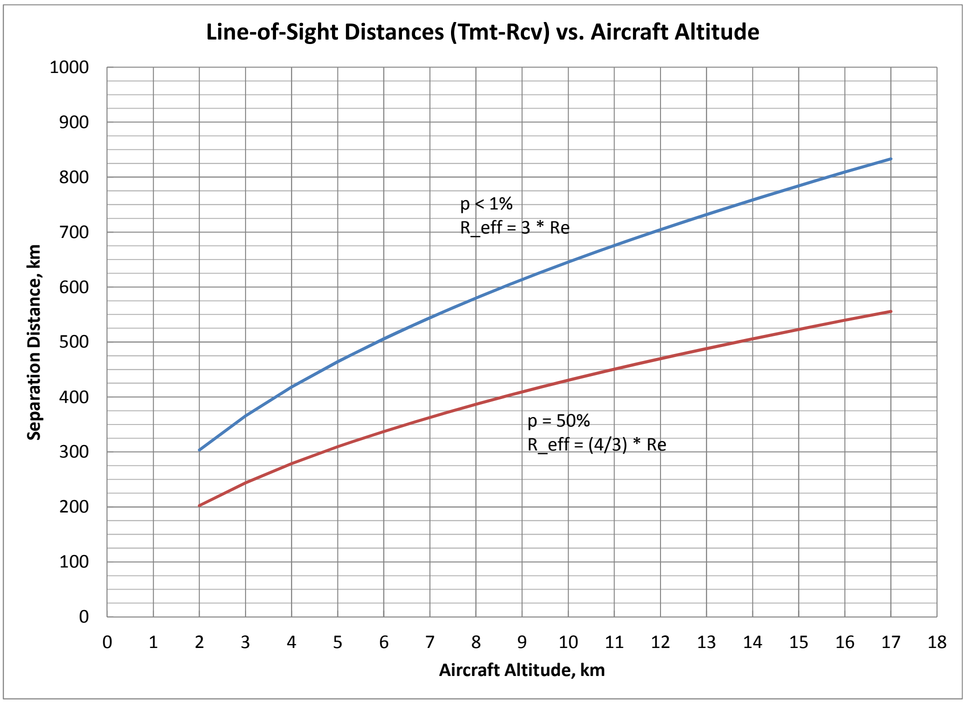
- h_1: SRS antenna centre height
- h_2: aircraft altitude
- R: effective Earth radius
- R_e: radius of Earth
- k: effective Earth radius factor.

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 $k = 4/3$ times the Earth's radius for $p = 50\%$, or $k = 3$ 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 first.

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:

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

The antenna gain 7 dB of the SRS earth station is calculated for the off-boresight angle of 10 degrees. Note that for an aircraft at 500 km away from an SRS earth station, using an aircraft transmitter e.i.r.p. of –20 dBW/Hz, the expected interference will be 27 dB above the protection criterion of the SRS earth station. If the aircraft transmitter emits the maximum allowed e.i.r.p. of 4 dBW/Hz by ITU RR No. **21-8**, the expected interference will be 51 dB above the protection criterion of the SRS earth station, and much larger separation distances will be required to meet the protection criteria of SRS earth stations.

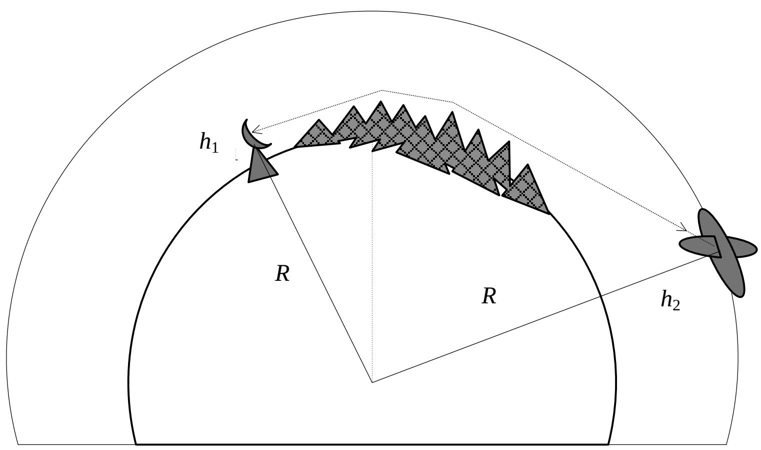
It is clear that an aircraft with radio LoS separation distance of 500 km will cause excessive interference to a receiving SRS earth station. Even for an aircraft at 17 km altitude with RF visibility limit of 830 km, the interference will be 22.6 dB above the protection criteria of the SRS earth station for an aircraft transmit e.i.r.p. density of –20 dBW/Hz. If the aircraft at 17 km altitude has a transmitter e.i.r.p. of 4 dBW/Hz, the exceedence will be 46.6 dB above the SRS protection.

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 interfere 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 a method for predicting basic transmission losses as a result of these effects for aeronautical and satellite services over a range of frequencies encompassing the S-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 –20 dBW/Hz. For this interference power density level (Case 1), it was possible to use IF-77 to determine a separation distance associated with the minimum required propagation losses to ensure that the SRS station protection criteria was met.

For the case where the aircraft station was assumed to transmit with the maximum allowed 4 dBW/Hz e.i.r.p. density (Case 2), it was not always possible to determine the minimum required separation distance using the IF-77 program. For some of these cases, the resulting minimum propagation loss (to protect the SRS earth stations) corresponded to minimum required separation distances in excess of 1 000 km. Propagation loss values for distances much greater than 1 000 km could not be obtained using the IF-77 software. Consequently, an alternative approach for obtaining estimates of propagation losses was employed.

In addition to pointing towards the use of the IF-77 software for calculating propagation losses, Recommendation ITU-R P.528 provides this information directly (in the form transmission loss vs. distance curves and equivalent tabular data).

These curves are presented as a function of several parameters including 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 for use in determining 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 which lies between two values for which the Recommendation does explicitly provides propagation loss amounts.

Unfortunately, since the minimum percent of time value provided in Recommendation ITU-R P.528 is $p = 1\%$, this procedure as given does not support determination of the propagation losses needed for this study. To estimate the propagation loss for the $p = 0.001\%$ and $p = 0.1\%$ values specified in Recommendation ITU-R SA.609, it is necessary to adapt the methods and formulas given to extrapolate propagation loss values at $p = 0.1\%$ and 0.001% based on those given in the Recommendation for $p = 1\%$ and $p = 5\%$. This was accomplished by solving equation 8 in Recommendation ITU-R P.528, Annex 2, § 6, for L_{inf}, and setting L_t and L_{sup} equal to the $p = 1\%$ and $p = 5\%$ propagation loss values given in the Recommendation.

Although this method is a straightforward extension of the Recommendation ITU-R P.528 interpolation methods, its suitability for estimating propagation loss values for very small percent of time values has yet to be verified.

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	10 km is used for coordination contour examples
Transmit e.i.r.p. density towards horizon	–20 4	dBW/Hz dBW/Hz	(Case 1) Used with IF-77 propagation loss values in analyses with all stations (Case 2) Used with extrapolated Recommendation ITU-R P.528 propagation loss values in analysis for Wallops SRS station (Max allowed by ITU RR No. **21.8**)
SRS earth station (rcv)			
Goldstone, Madrid, Canberra			
Minimum tracking angle Antenna diameter Antenna height	10 34 19	degrees m m	
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 can track down to 5 degrees elevation.
Perth			
Minimum tracking angle Antenna diameter Antenna height	10 15 11	degrees m m	Perth can track down to 5 degrees elevation.
Uchinoura			
Minimum tracking angle Antenna diameter Antenna height	5 34 20	degrees m m	
Antenna gain pattern	RR. AP8-10		
Permissible interference level	–216	dBW/Hz	SRS station protection (Recommendation ITU-R SA.609)
Probability of exceedence (*p*)	0.001 0.1	% (manned) % (unmanned)	For trans-horizon interference sources (Recommendation ITU-R SA.609)

The interference PSD received by the SRS earth station from the aircraft station transmitter is given by:

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

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.

6.1 Case 1: Aircraft e.i.r.p. = –20 dBW/Hz

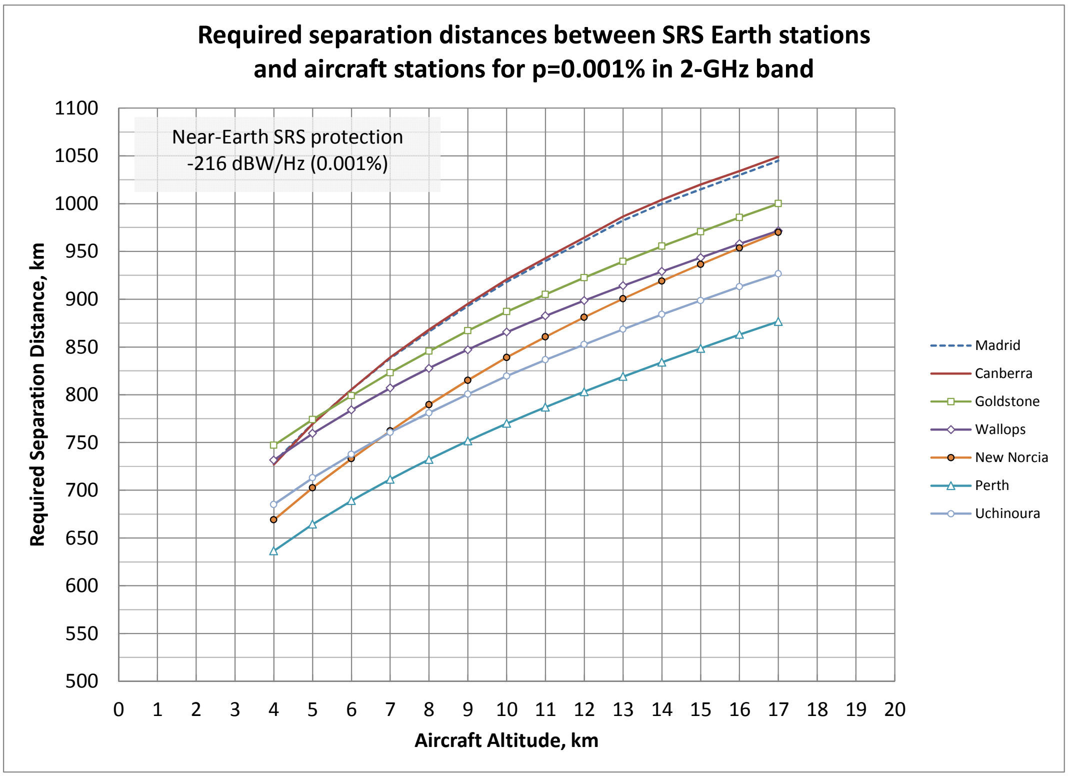
Now using the parameters given in Table 6-1, we can obtain the minimum propagation loss to meet the protection of the SRS earth station. For the case where the aircraft station is transmitting at –20 dBW/Hz towards the horizon, the minimum propagation loss is given as:

$$L_{min} = -20 + 216 + G_r = 196 + G_r \text{ (dB)} \tag{4}$$

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 –20 dBW/Hz case. The results for exceedence probability of $p = 0.001\%$ are shown in Fig. 6.1-1 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 6.1-1

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 –20 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 630 km and 1 050 km away from the SRS earth stations at Goldstone, Wallops, Madrid, Canberra, New Norcia, Perth, and Uchinoura. Note that the required separation distances are about 200-to-300 km greater than the LoS distances for $p < 1\%$.

Figure 6.1-1 also shows that for aircraft stations at an altitude of 10 km and transmitting –20 dBW/Hz e.i.r.p. towards the horizon, the required separation distances need to be as given in Table 6.1-1:

TABLE 6.1-1

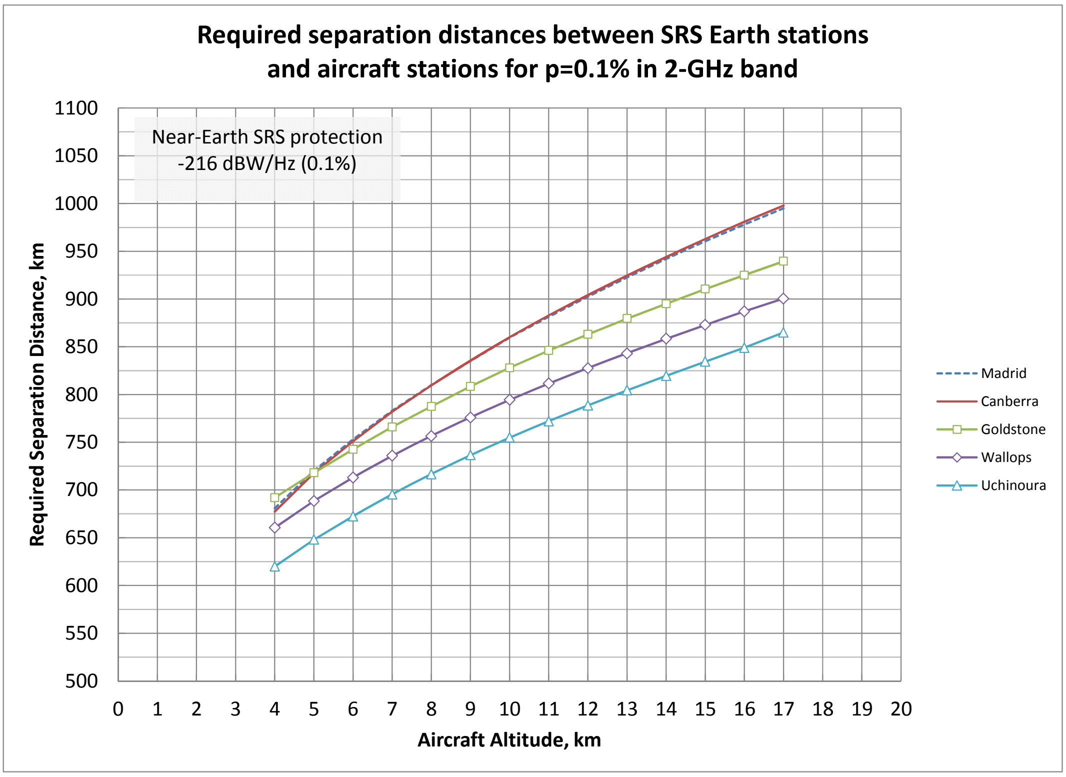
Required separation distances for SRS earth stations supporting manned missions (p = 0.001%) and aircraft station at 10 km altitude transmitting at –20 dBW/Hz e.i.r.p. density (Case 1)

SRS earth station Site, Country	**Required separation distance (km)**
Goldstone, USA	885
Wallops, USA	865
Madrid, Spain	925
Canberra, Australia	925
New Norcia, Australia	840
Perth, Australia	775
Uchinoura, Japan	820

For the interference exceedence probability of p = 0.1% to protect the unmanned SRS missions, the results for the –20 dBW/Hz aircraft station transmit e.i.r.p. case are shown in Fig. 6.1-2 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 6.1-2

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 –20 dBW/Hz



For near-Earth SRS earth stations supporting unmanned SRS mission with exceedence 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 620 km and 1 000 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.

Figure 6.1-2 also shows that for aircraft stations at an altitude of 10 km and transmitting at –20 dBW/Hz towards the horizon, the required separation distances need to be as given in Table 6.1-2.

TABLE 6.1-2

Required separation distances for SRS earth stations supporting unmanned missions (*p* = 0.1%) and aircraft station at 10 km altitude transmitting at –20 dBW/Hz e.i.r.p. density (Case 1)

SRS earth station Site, Country	**Required separation distance (km)**
Goldstone, USA	825
Wallops, USA	800
Madrid, Spain	865
Canberra, Australia	865
Uchinoura, Japan	755

Note that these distances for SRS earth stations supporting unmanned missions (p = 0.1%) are about 60 km less than the distances given for SRS earth stations supporting manned missions (p = 0.001%).

6.2 Case 2: Aircraft e.i.r.p. = 4 dBW/Hz

For the case where the aircraft station is transmitting at 4 dBW/Hz towards the horizon, the minimum propagation loss is given as:

$$L_{min} = 4 + 216 + G_r = 220 + G_r \text{ (dB)} \quad (5)$$

Again, using the minimum propagation loss required for all the azimuthal directions around the Wallops SRS earth station, the separation distances can be determined for the 4 dBW/Hz case. The results for exceedence probability of p = 0.001% and p = 0.1% are shown in Fig. 6.2-1 for the SRS earth stations in Wallops. The results are also documented in Table 6.2-1.

For these results, the extrapolation method using Recommendation ITU-R P.528 provided data was used to determine the propagation losses. The required separation distances are given as a function of the aircraft altitude.

FIGURE 6.2-1

Required separation distance between Wallops SRS earth station and aircraft stations using non-line-of-sight propagation effects for *p* = 0.001% and *p* = 0.1% in 2 GHz band assuming aircraft station transmit e.i.r.p. density of 4 dBW/Hz

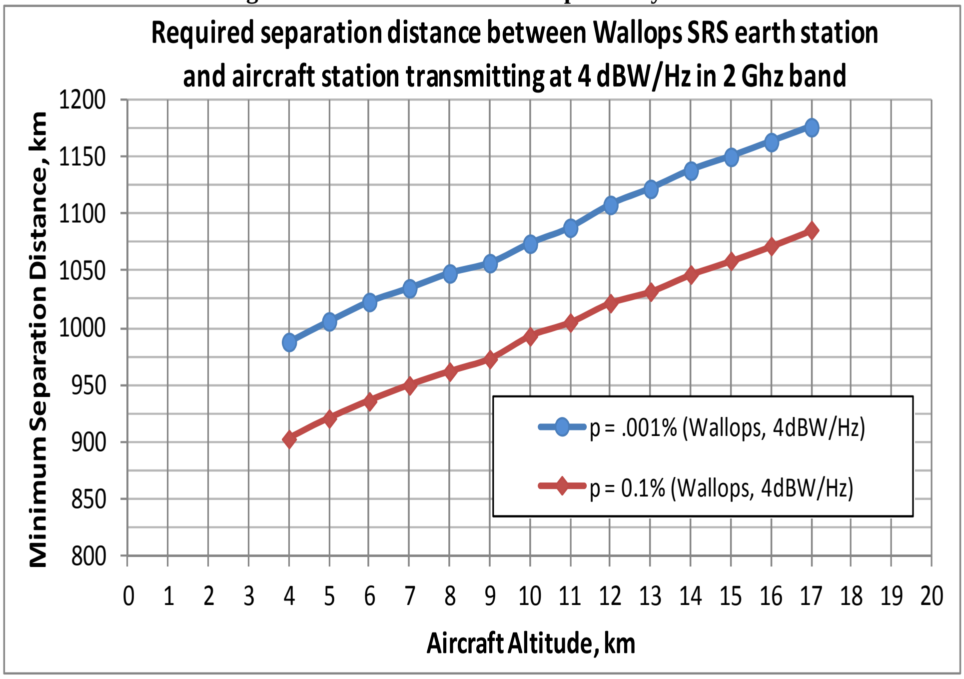


TABLE 6.2-1

Required separation distances between Wallops SRS station and aircraft station transmitting at 4 dBW/Hz e.i.r.p. density (Case 2)

Aircraft altitude (km)	Minimum separation distance, *p* = .001% (km)	Minimum separation distance, *p* = 0.1% (km)
4	988	903
5	1 006	921
6	1 023	936
7	1 035	950
8	1 048	962
9	1 057	973
10	1 074	993
11	1 088	1 005
12	1 108	1 022
13	1 122	1 032
14	1 138	1 047
15	1 150	1 059
16	1 163	1 072
17	1 176	1 086

As seen in these results, when the aircraft station is transmitting at the maximum allowed e.i.r.p. density as given in RR No. **21.8**, protection of the Wallops SRS earth station requires that a separation distance ranging from 988 km to 1 176 km for manned mission support, or 903 km to 1 086 km for unmanned SRS mission support be maintained. Note again that the required separation distances are much larger than the RF visibility limits.

7 Examples of coordination areas around the SRS earth stations for an aircraft station at 10-km altitude transmitting at –20 dBW/Hz towards the horizon (Case 1)

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 for an aircraft flying at 10 km altitude and transmitting at –20 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 –20 dBW/Hz e.i.r.p.

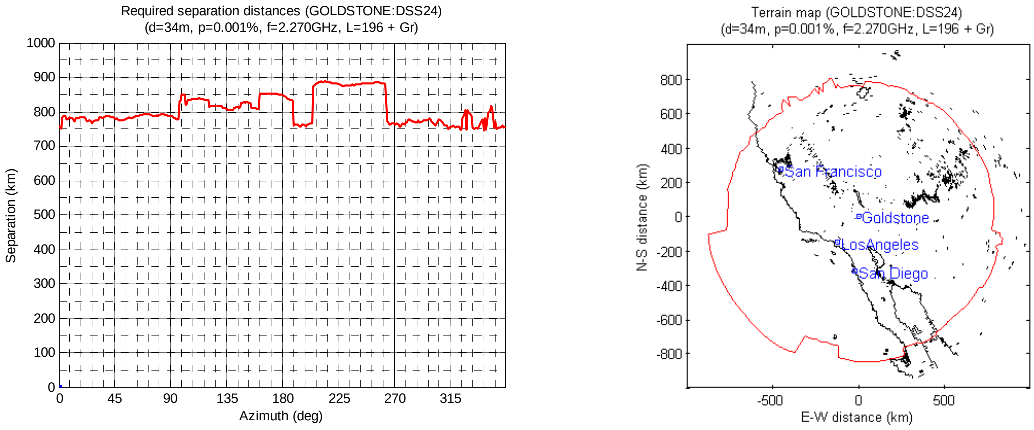


FIGURE 7.1-2

Coordination contour (p = 0.001%) around the receiving Madrid-Spain SRS earth station for the aircraft station transmitting –20 dBW/Hz e.i.r.p.

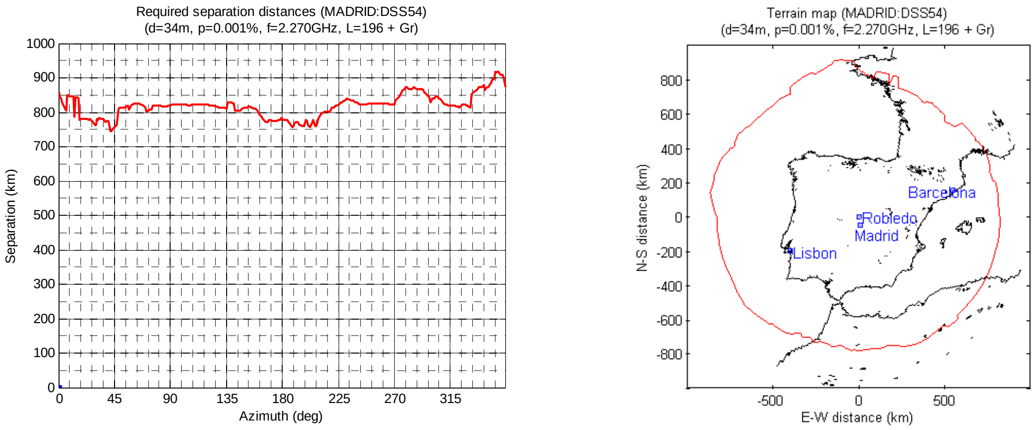


FIGURE 7.1-3

Coordination contour (p = 0.001%) around the receiving Canberra-Australia SRS earth station for the aircraft station transmitting –20 dBW/Hz e.i.r.p.

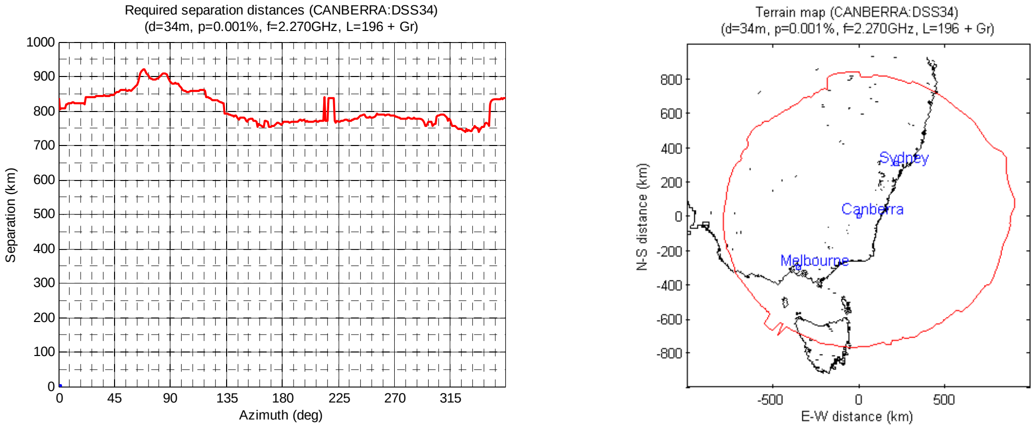


FIGURE 7.1-4

Coordination contour (p = 0.001%) around the receiving Wallops-USA SRS earth station for the aircraft station transmitting –20 dBW/Hz e.i.r.p.

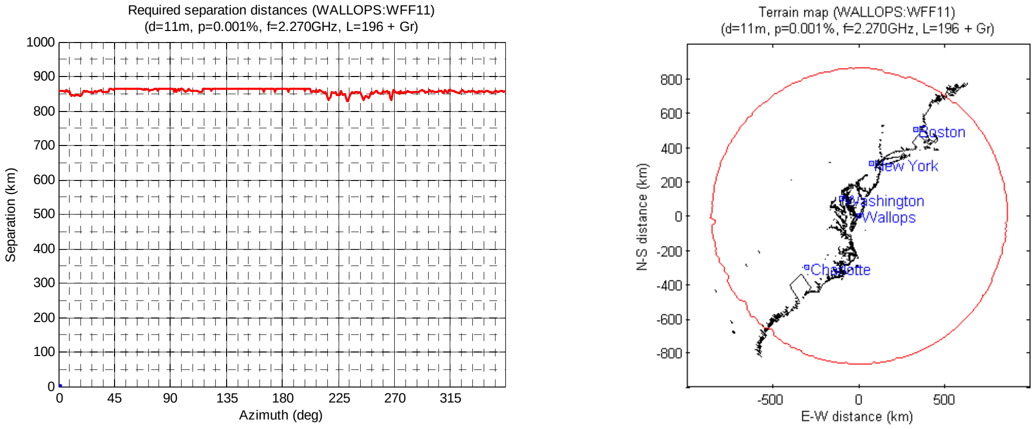


FIGURE 7.1-5

Coordination contour (p = 0.001%) around the receiving New Norcia-Australia SRS earth station for the aircraft station transmitting –20 dBW/Hz e.i.r.p.

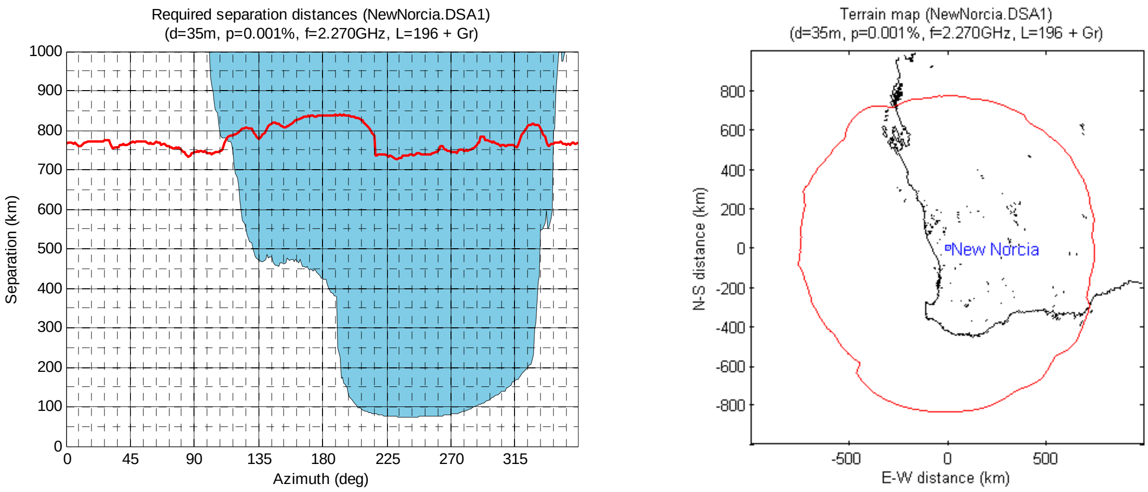


FIGURE 7.1-6

Coordination contour (*p* = 0.001%) around the receiving Perth-Australia SRS earth station for the aircraft station transmitting –20 dBW/Hz e.i.r.p.

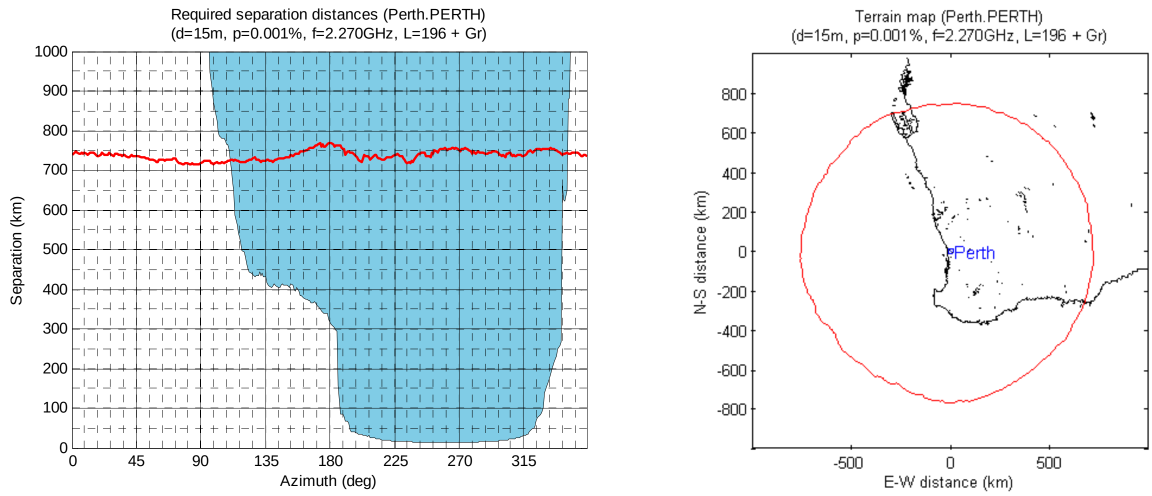
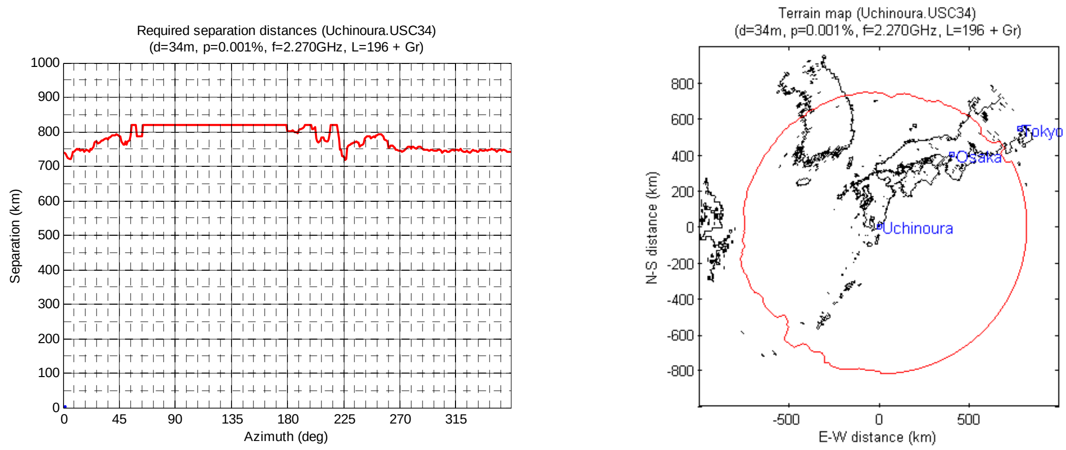


FIGURE 7.1-7

Coordination contour (*p* = 0.001%) around the receiving Uchinoura-Japan SRS earth station for the aircraft station transmitting –20 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 for an aircraft flying at 10 km altitude and transmitting at –20 dBW/Hz e.i.r.p. towards the horizon, to protect the unmanned SRS missions, which have interference exceedence 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 –20 dBW/Hz e.i.r.p.

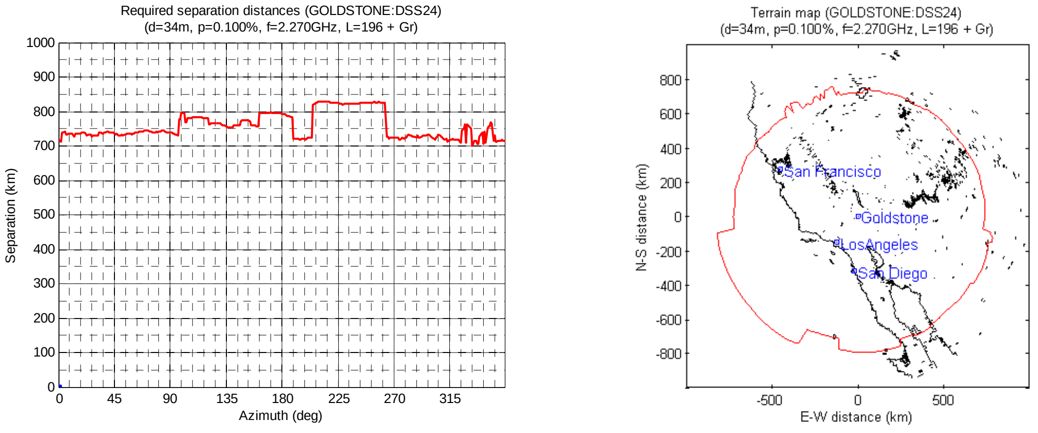


FIGURE 7.2-2

Coordination contour (p = 0.1%) around the receiving Madrid-Spain SRS earth station for the aircraft station transmitting –20 dBW/Hz e.i.r.p.

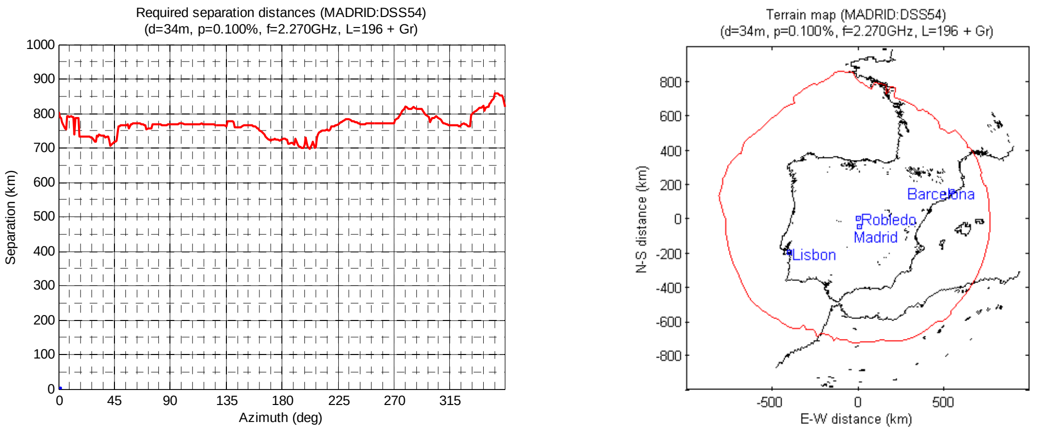


FIGURE 7.2-3

Coordination contour (p = 0.1%) around the receiving Canberra-Australia SRS earth station for the aircraft station transmitting –20 dBW/Hz e.i.r.p.

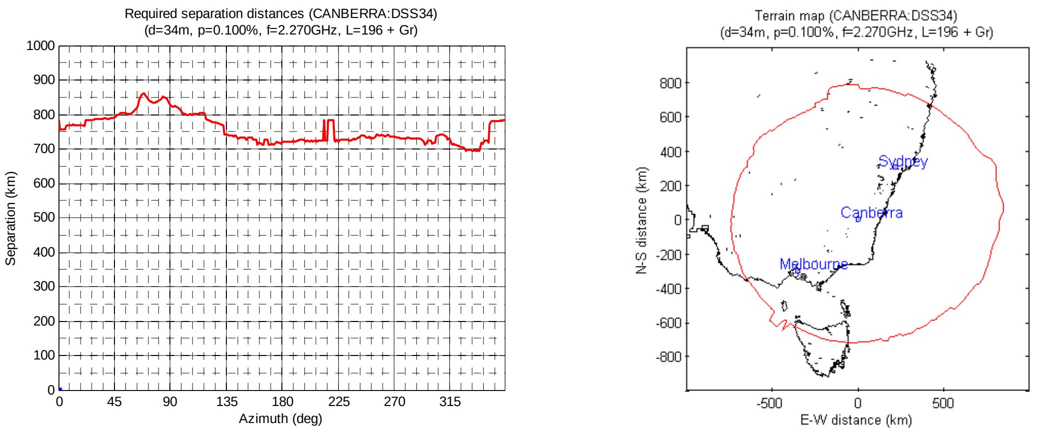


FIGURE 7.2-4

Coordination contour (*p* = 0.1%) around the receiving Wallops-USA SRS earth station for the aircraft station transmitting –20 dBW/Hz e.i.r.p.

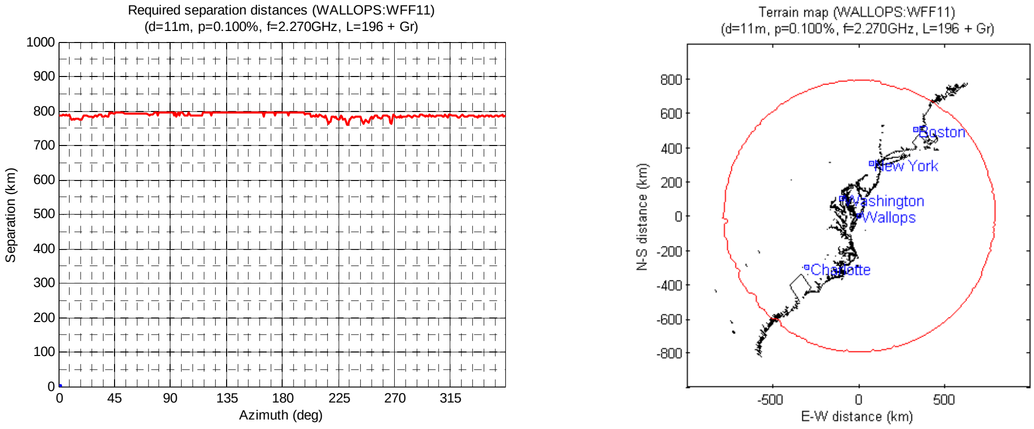
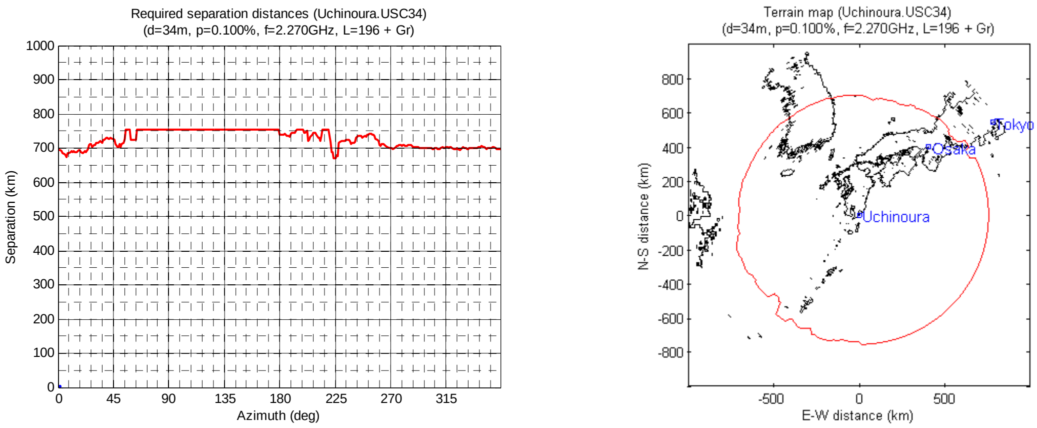


FIGURE 7.2-5

Coordination contour (*p* = 0.1%) around the receiving Uchinoura-Japan SRS earth station for the aircraft station transmitting –20 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 for 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% exceedence probability to support manned near-Earth SRS spacecraft, and 0.1% exceedence probability to support unmanned SRS spacecraft. Figure 8-1 shows the required separation distance between SRS earth station supporting a manned mission and aircraft station as a function of the aircraft altitude for the –20 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 630 km and 1 050 km away from the SRS earth stations at Goldstone, Wallops, Madrid, Canberra, New Norcia, Perth, and Uchinoura, depending on the aircraft altitude. Note also that, in this case, to protect the SRS earth stations, the required separation distances are about 200 to 300 km greater than the RF visibility limits given for $p < 1\%$.

FIGURE 8-1

Required separation distances between SRS earth station (p = 0.001%) and aircraft station transmitting –20 dBW/Hz e.i.r.p. (Case 1) vs aircraft altitude

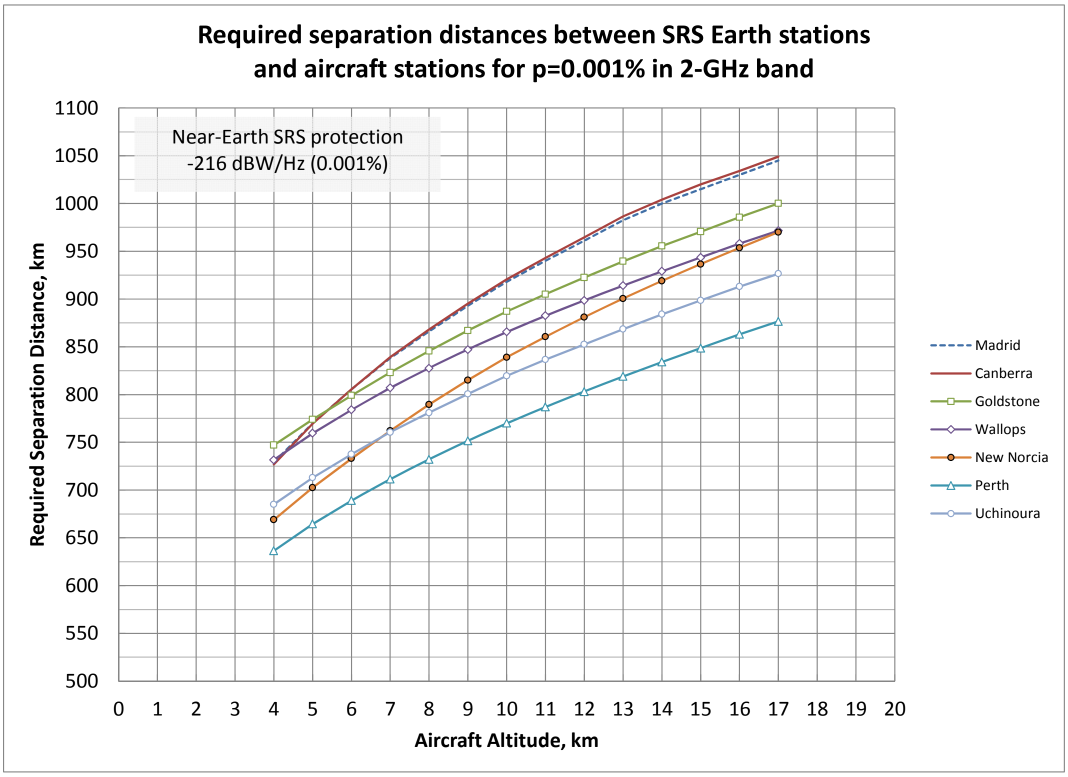


Figure 8-1 also shows that for aircraft stations at an altitude of 10 km which are transmitting with an e.i.r.p. density of –20 dBW/Hz (well below the ITU RR No. **21.8** limit), the required separation distances need to be as given in Table 8-1.

TABLE 8-1

Required separation distances for SRS earth stations supporting manned missions (p = 0.001%) and aircraft station at 10 km altitude transmitting at –20 dBW/Hz e.i.r.p. density (Case 1)

SRS earth station Site, Country	**Required separation distance** **(km)**
Goldstone, USA	885
Wallops, USA	865
Madrid, Spain	925
Canberra, Australia	925
New Norcia, Australia	840
Perth, Australia	775
Uchinoura, Japan	820

Figure 8-2 shows the required separation distances between SRS earth stations, supporting an unmanned SRS mission, and aircraft station as a function of the aircraft altitude for the –20 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 620 km and 1 000 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 –20 dBW/Hz e.i.r.p. (Case 1) vs aircraft altitude

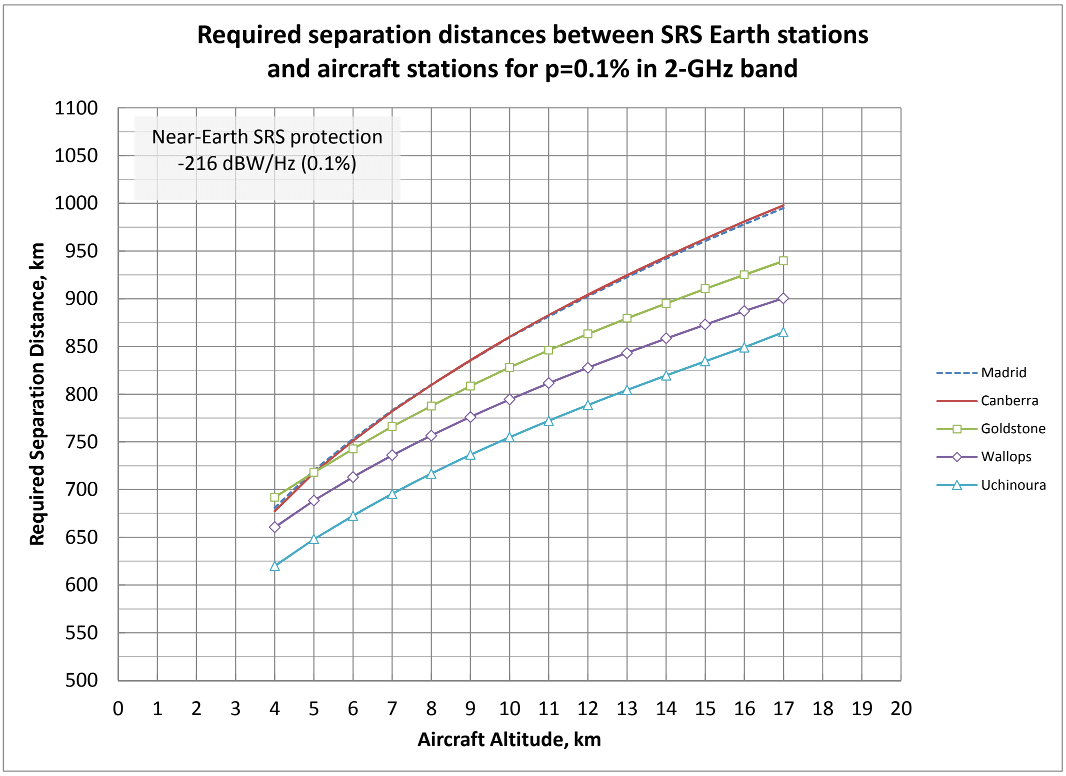


Figure 8-2 also shows that for aircraft stations at an altitude of 10 km and transmitting at –20 dBW/Hz towards the horizon, the required separation distances need to be as given in Table 8-2.

TABLE 8-2

Required separation distances for SRS earth stations supporting unmanned missions (p = 0.1%) and aircraft station at 10 km altitude transmitting at –20 dBW/Hz e.i.r.p. density (Case 1)

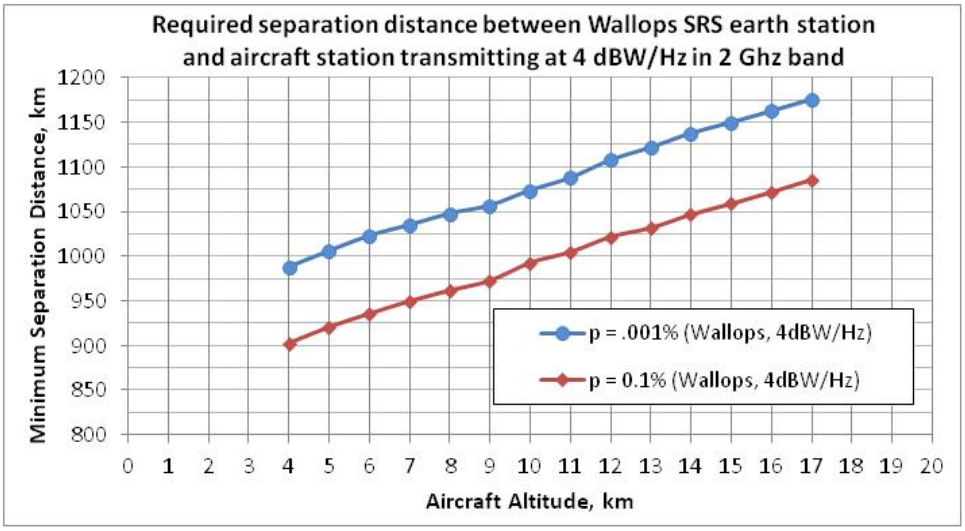
SRS earth station Site, Country	**Required separation distance (km)**
Goldstone, USA	825
Wallops, USA	800
Madrid, Spain	865
Canberra, Australia	865
Uchinoura, Japan	755

Note that these distances for SRS earth stations supporting unmanned missions (p = 0.1%) are about 60 km less than the distances given for SRS earth stations supporting manned missions (p = 0.001%).

Figure 8-3 shows the required separation distances between SRS earth stations, supporting manned and unmanned SRS missions, and an aircraft station transmitting at the maximum allowed 4 dBW/Hz e.i.r.p. density as a function of the aircraft altitude. It shows that, in order to meet the protection of the SRS earth station, the aircraft needs to be between 988 km and 1 176 km away from the Wallops SRS earth stations for the manned mission support case and between 903 km and 1 086 km away for the unmanned SRS mission support scenario. These values are determined using the propagation loss values given in Recommendation ITU-R P.528 and following an extrapolation procedure to estimate propagation loss values for the very low 0.001% exceedance probability given in Recommendation ITU-R SA.609.

FIGURE 8-3

Required separation distances between SRS earth station (p = 0.001% and p = 0.1%) and aircraft station transmitting 4 dBW/Hz (Case 2) vs aircraft altitude



In conclusion, in order to meet the SRS earth station protection criterion for manned and unmanned SRS mission, separation distances greater than 500 km are required between the SRS earth stations and the aircraft stations. Thus, Table 10 in Annex 7 of ITU RR Appendix **7** needs to be updated to include explicitly a much larger predetermined coordination distance between SRS earth stations and aircraft stations in the 2 GHz 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 Appendix **7**, Annex 7) for cases not covered explicitly.