International Telecommunication Union

ITU-R

Radiocommunication Sector of ITU

Recommendation ITU-R M.1584
(07/2002)

Methodology for computation of separation distances between earth stations of the radionavigation-satellite service (Earth-to-space) and radars of the radiolocation service and the aeronautical radionavigation service in the frequency band 1 300-1 350 MHz

M Series

Mobile, radiodetermination, amateur and related satellite services

International Telecommunication Union

Foreword

The role of the Radiocommunication Sector is to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including satellite services, and carry out studies without limit of frequency range on the basis of which Recommendations are adopted.

The regulatory and policy functions of the Radiocommunication Sector are performed by World and Regional Radiocommunication Conferences and Radiocommunication Assemblies supported by Study Groups.

Policy on Intellectual Property Right (IPR)

ITU-R policy on IPR is described in the Common Patent Policy for ITU-T/ITU-R/ISO/IEC referenced in Annex 1 of Resolution ITU-R 1. Forms to be used for the submission of patent statements and licensing declarations by patent holders are available from http://www.itu.int/ITU-R/go/patents/en where the Guidelines for Implementation of the Common Patent Policy for ITU-T/ITU-R/ISO/IEC and the ITU-R patent information database can also be found.

Series of ITU-R Recommendations

(Also available online at http://www.itu.int/publ/R-REC/en)

Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	**Mobile, radiodetermination, amateur and related satellite services**
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

Note*: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

Electronic Publication
Geneva, 2011

RECOMMENDATION ITU-R M.1584*, **

Methodology for computation of separation distances between earth stations of the radionavigation-satellite service (Earth-to-space) and radars of the radiolocation service and the aeronautical radionavigation service in the frequency band 1 300-1 350 MHz

(2002)

Scope

This Recommendation outlines the methodology for computation of separation distances between earth stations of the radionavigation-satellite service (Earth-to-space) and radars of the radiolocation service and the aeronautical radionavigation service in the frequency band 1 300-1 350 MHz. These methodologies are to be taken into account, when selecting the location of RNSS uplink earth stations in the range 1 300-1 350 MHz, in order to compute separation distance between RNSS uplink stations and radiolocation and aeronautical radionavigation radar systems.

The ITU Radiocommunication Assembly,

considering

a) that the band 1 300-1 350 MHz is allocated on a primary basis to the aeronautical radionavigation service (ARNS) for use by ground-based radar systems;

b) that the World Radiocommunication Conference (Istanbul, 2000) (WRC-2000) has added a primary allocation to the radionavigation-satellite service (RNSS) (Earth-to-space) in the 1 300-1 350 MHz band;

c) that WRC-2000 has raised the status of the radiolocation service from secondary to primary in the 1 300-1 350 MHz band;

d) that the allocation to the radiolocation service is used by terrestrial as well as airborne radar systems;

e) that there is a potential for interference between uplink stations in the RNSS and radar systems of the ARNS and radiolocation service;

f) that radar systems of the ARNS and radiolocation service can be protected with the implementation of adequate separation distances;

g) that Appendix 7 of the Radio Regulations (RR) shall be used to determine the affected administrations for the coordination of specific RNSS earth stations in the Earth-to-space direction under RR No. 9.17,

---

* Radiocommunication Study Group 8 made editorial amendments to this Recommendation in 2004 in accordance with Resolution ITU-R 44.

** Radiocommunication Study Group 5 made editorial amendments to this Recommendation in November 2010.

recognizing

a) that WRC-2000 added RR No. 5.337A stating the use of the band 1300-1350 MHz by earth stations in the RNSS and by stations in the radiolocation service shall not cause harmful interference to, nor constrain the operation and development of, the ARNS;

b) that operational and practical difficulties exist in complying with and maintaining the separation distance between RNSS uplink stations and airborne radars, thus possibly adversely affecting the mission capabilities of the airborne radars;

c) that, for the examples used in Annexes 1 and 2, in order for RNSS earth stations to properly protect ground and airborne radiodetermination stations, it is necessary to provide an attenuation of 50 dB for elevation angles of 10° or less,

noting

a) that the application of the methodology for the example in Annex 1 results in computed separation distances ranging from 50-325 km between RNSS earth stations and radars in the radionavigation service;

b) that the application of the methodology for the example in Annex 2 without a choke ring results in computed separation distances up to the radio horizon of the airborne radars,

recommends

1 that the methodologies in Annexes 1 and 2 be taken into account, when selecting the location of RNSS uplink earth stations in the range 1 300-1 350 MHz, in order to compute separation distance between RNSS uplink stations and radiolocation and aeronautical radionavigation radar systems;

2 that administrations continue to study the compatibility issues between RNSS earth station transmitters and airborne radiolocation radars and provide these studies to ITU-R.

NOTE 1 – Administrations should continue to study the compatibility issues between RNSS satellite receivers and radars in the radionavigation and radiolocation services and provide these studies to ITU-R.

Annex 1

Methodology for computation of separation distances between earth stations of the RNSS (Earth-to-space) and terrestrial radars of the radiolocation service and the ARNS in the frequency band 1300-1350 MHz

1 Introduction

New radionavigation-satellite systems will use the band 1300-1350 MHz for the transmission by uplink stations of information such as navigation, synchronization or integrity data, to a constellation of medium Earth orbiting (MEO) satellites.

This study provides an analysis of the interference created by uplink stations into receiving terrestrial radar.

It results from the study that a separation distance permits to avoid excess interference into terrestrial radar.

2 Systems characteristics

2.1 Radiolocation and aeronautical radionavigation radars

The radar parameters used in this Recommendation are those given in Recommendation ITU-R M.1463 – Characteristics of and protection criteria for radars operating in the radiodetermination service in the frequency band 1 215-1 400 MHz, covering radars of the radiolocation service and ARNS.

In order to calculate radar perturbation thresholds, the following formula and a –6 dB protection criteria (I/N) as given in Recommendation ITU-R M.1463 have been used:

$$P_{threshold} \text{ (dBm)} = 10 \log (K\, T_0\, FB) + 24$$

TABLE 1

Radar-receiving parameters

	Bandwidth (MHz)	**Reception antenna gain (dBi)**	**Perturbation threshold (dBm)**
System 1	0.780	33.5	–119.1
System 2	0.690	38.9	–119.6
System 3	4.4 and 6.4	38.2	–108.8 and –107.2
System 4	1.2	32.5	–115.7
Wind profile radars	2.5	33.5	–114.5

2.2 Typical RNSS radio uplink stations

– Transmitted power: ≤ 57.1 dBm

– Antenna type: omnidirectional with a physical isolation for low elevation (typically 50 dB attenuation with a choke-ring (see Appendix 2 to Annex 1 for the description of a choke ring))

– Orientation: zenith

– Maximum gain: ≤3 dBi

– Gain: ≤1 dBi for elevation angles less than 10°

– Modulation: spread spectrum (1.023 and 10.23 Mchip/s)

– Polarization: left-hand circular polarization

– Height: 2 m

– Network: less than 20 uplink stations regularly spaced around the world. Each uplink station transmits on the same frequency to a constellation of MEO satellites.

The total power is used to transmit two signals, one spread with a 1.023 Mchip/s code and the other spread with a 10.23 Mchip/s code. While the 10.23 Mchip/s code signal has a power of 53 dBm, the 1.023 Mchip/s has a power of 55 dBm. As a worst-case illustration and for the purpose of this study, frequency of the uplink stations is taken as the same as the radar. However, the impact of a frequency shift is studied.

3 Interference of RNSS uplink stations into radar

3.1 Compatibility study

In order to assess the separation distance necessary to protect radar reception, the propagation loss, L (dB), is calculated as:

$$L = P_t + G_t - A_t - FL_t + G_r - FL_r + R_b - D_{pol} - P_{threshold}$$
$$= P_{interfering} - P_{threshold} \quad (1)$$

where:

- P_t: transmitting interfering power (dBm)
- G_t: transmitting interfering gain (dBi) in the radar direction
- A_t: physical isolation at low elevation (due to choke ring) (dB)
- FL_t: transmitting feeder losses (dB)
- $P_{threshold}$: perturbation threshold (dBm)
- G_r: reception gain (dBi)
- FL_r: reception feeder losses (dB)
- R_b: rejection factor (dB)
- D_{pol}: polarization coupling factor (dB).

The rejection factor R_b represents the amount of the RNSS emission total power which is filtered by the radar receiver. Thus, it takes into account the radar receiver bandwidth, the frequency offset between the radar and the RNSS uplink emission central frequencies and the RNSS signal normalized power spectral density (NPSD). For a square binary phase-shift keying modulation (expected for RNSS):

$$R_b = \int_{(B_r)} NPSD(f)\,\mathrm{d}f$$

$$= \int_{f_{0R}-B_r/2}^{f_{0R}+B_r/2} \frac{1}{fc} \cdot \sin c^2 \left(\frac{(f - f_{0T})}{fc} \right) \cdot \mathrm{d}f \quad (2)$$

$$= \int_{f_{0R}-f_{0T}-B_r/2}^{f_{0R}-f_{0T}+B_r/2} \frac{1}{fc} \cdot \sin c^2 \left(\frac{f}{fc} \right) \cdot \mathrm{d}f$$

where:

- B_r: reception bandwidth.

It is to be noticed that the slow code (code rate = 1.023 Mchip/s) is also a short code (1 023 chips). Consequently, the spectrum of the corresponding signal has 1 kHz line components. Some of these line components have a power level greater than the (sinc x)^2 values, but the average of lines keeps approximately a (sinc x)^2 shape. Taking into account that the reception bandwidth is large with respect to the 1 kHz intervals, a great number of line components are averaged and equation (2) is adequate to compute R_b.

Following the determination of L, one can evaluate the corresponding separation distance. This is done through Recommendation ITU-R P.452 – Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above about 0.7 GHz, as well as Recommendation ITU-R P.526 – Propagation by diffraction. The method proposed in Recommendation ITU-R P.452, Table 5, has been used in order to derive the overall prediction taking into account the path type (line-of-sight, line-of-sight with sub-path diffraction or trans-horizon).

In Table 2 are given the main hypotheses that have been taken into account in the application of the above Recommendations:

TABLE 2

Main hypotheses for protection distances calculations

Model	Parameter	Value	Comment
Tropospheric scatter	Path centre sea-level refractivity: N_0	360	Compromise among all the continents' worst values
Ducting/layer reflection	Over-sea surface duct coupling corrections for the interfering and the interfered-with stations (A_{ct}, A_{cr})	0 dB	It is assumed that the distance from each terminal to the coast along the great-circle interference-path is more than 5 km
	Terrain roughness parameter, that is the maximum height of the terrain above the smooth Earth surface (h_m)	< 10 m	We assume that the Earth's surface is smooth
Additional clutter losses	Additional losses due to local ground clutters such as buildings, vegetation, … (A_{ht}, A_{hr})	0 dB	We assume the worst case that there are no local ground obstacles between the interfering and the interfered-with stations
All	Refractive index lapse rate over the first 1 km of the atmosphere (ΔN)	80	Worst-case value
All	Required time percentage for which the calculated basic transmission loss is not exceeded: p	1%	
All	Median effective Earth radius factor (K_{50})	2.0389	Obtained with $\Delta N = 80$

3.2 Calculation of separation distance beyond which protection is assured (protection distance)

Equation (1) is applied for all radars given in Recommendation ITU-R M.1463, for both worst-case co-frequency operations and for 3 MHz frequency off-set operation between the centre frequency of the radar and the RNSS emission. In Appendix 1 of this Annex are given the tables with the required loss calculations in order to protect each type of radar.

The methodology in Recommendation ITU-R P.452, as mentioned in § 3.1, is applied in order to calculate the protection distances from the required loss. In Figs. 1 and 2 are given some examples of the results in terms of protection distances for several heights (above mean sea-level) of the interfering station and the interfered-with radars and for two worst-case required losses (see Appendix 1 of this Annex):

– 161.1 dB, which is the worst case (Radar 2) with co-frequency operation of the radar and the RNSS station;

– 149.7 dB, which is the worst case (Radar 3, receiving bandwidth of 6.4 MHz) with a 3 MHz offset between the central frequencies of the radar and the RNSS emission.

For understanding Figs. 1 and 2:

– *h* (m, amsl) Rx (receiver) is the height (m) above mean sea level of the interfered-with radar;

– *h* (m, amsl) Tx (transmitter) is the height (m) above mean sea level of the transmitting uplink RNSS station.

FIGURE 1

Radar protection distances for a required loss of 161.1 dB

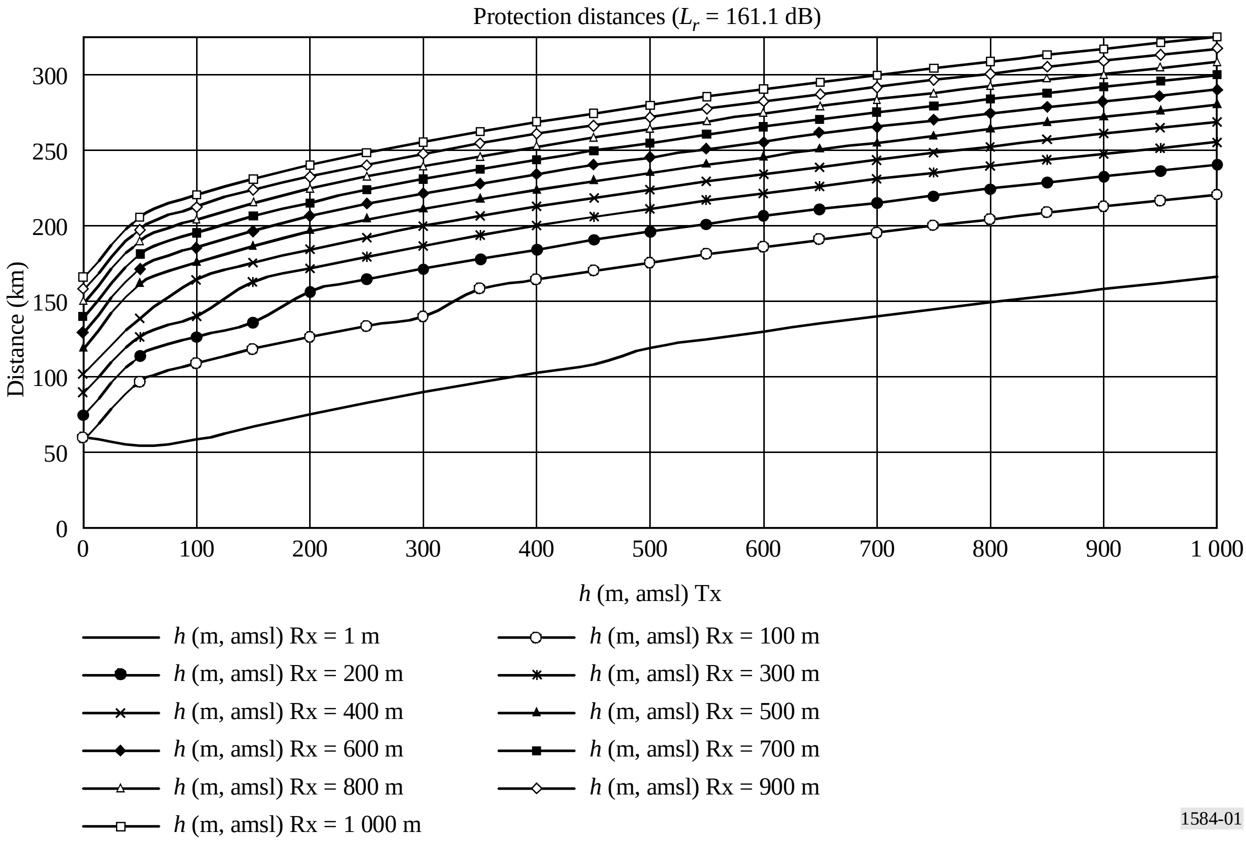
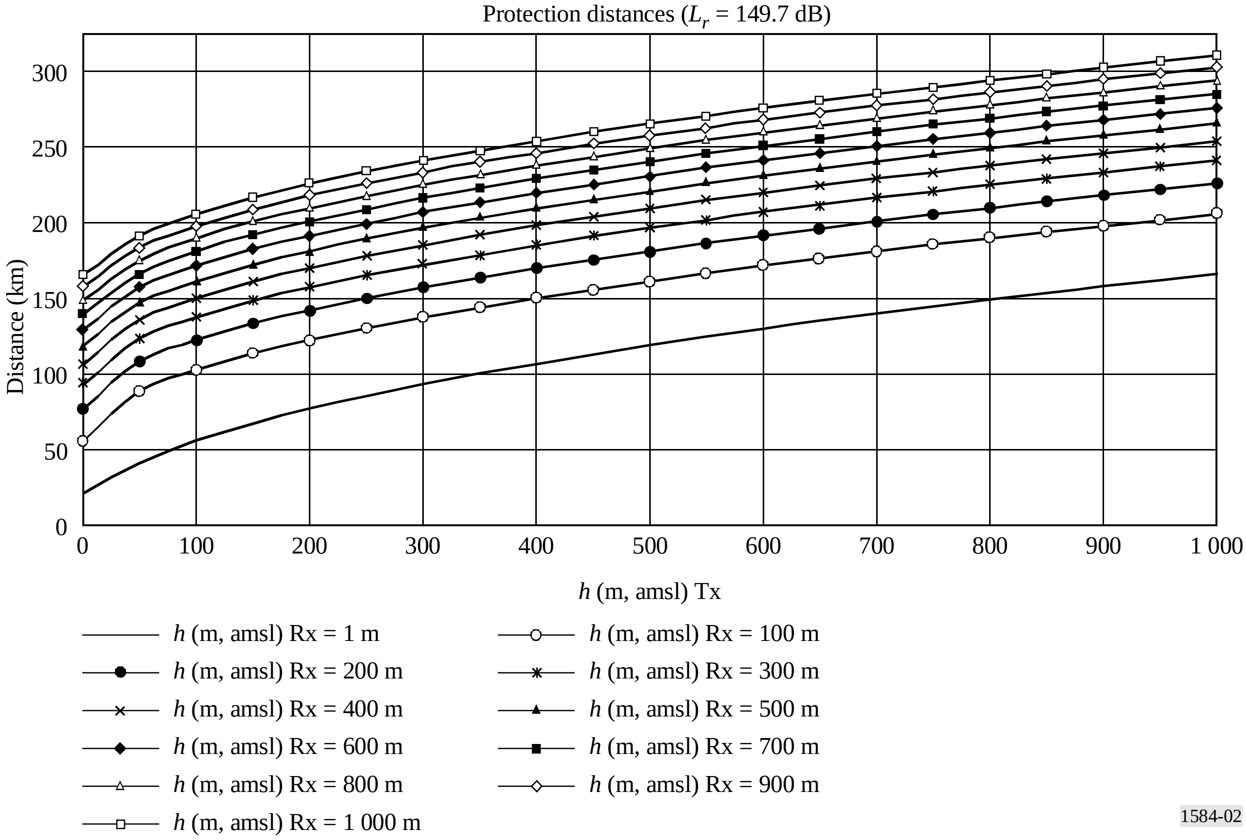


FIGURE 2

Radar protection distances for a required loss of 149.7 dB



3.3 Conclusions

The results in the section before show the radar protection distances for several interfered-with radars and the interfering RNSS uplink stations heights, from 1 m to 1 000 m above mean sea-level. These distances go from 50 km to 325 km, depending on RNSS uplink stations and radar system heights. For different parameters (radar receiving parameters, RNSS earth station transmitting parameters, antenna heights, etc.), the methodology contained in this Annex should be applied to calculate the required protection distance. Also, in the section above it has been assumed that there are no local obstacles between the interfering RNSS stations and the interfered-with radars. The choice of an adequate location (i.e. a naturally protected zone) could allow for a closer radar protection distance, and could be studied on a case-by-case basis taking into account the specific path profile.

Appendix 1
to Annex 1

System 1
Required loss between radar and uplink stations

	Surface-based radar typical values (frequency-offset = 0 MHz)			Surface-based radar typical values (frequency-offset = 3 MHz)		
	Code 10.23 Mchip/s	**Code 1.023 Mchip/s**	**Addition of powers from both codes**	**Code 10.23 Mchip/s**	**Code 1.023 Mchip/s**	**Addition of powers from both codes**
P_t	53.0	55.0		53.0	55.0	
A_t	–50.00	–50.00		–50.00	–50.00	
G_t	0.0	0.0		0.0	0.0	
FL_t	0.0	0.0		0.0	0.0	
G_r	33.5	33.5		33.5	33.5	
FL_r	0.5	0.5		0.5	0.5	
R_b	–11.2	–1.8		–12.4	–24.4	
D_{pol}	0.0	0.0		0.0	0.0	
$P_{interfering}$	24.8	36.2	36.5	23.6	13.6	24
$P_{threshold}$	–119.1	–119.1	–119.1	–119.1	–119.1	–119.1
Required loss (dB)	143.9	155.2	155.5	142.6	132.7	143.0

System 2
Required loss between radar and uplink stations

	Surface-based radar typical values (frequency-offset = 0 MHz)			Surface-based radar typical values (frequency-offset = 3 MHz)		
	Code 10.23 Mchip/s	**Code 1.023 Mchip/s**	**Addition of powers from both codes**	**Code 10.23 Mchip/s**	**Code 1.023 Mchip/s**	**Addition of powers from both codes**
P_t	53.0	55.0		53.0	55.0	
A_t	–50.00	–50.00		–50.00	–50.00	
G_t	0.0	0.0		0.0	0.0	
FL_t	0.0	0.0		0.0	0.0	
G_r	38.9	38.9		38.9	38.9	
FL_r	0.5	0.5		0.5	0.5	
R_b	–11.7	–2.2		–13	–25.6	
D_{pol}	0.0	0.0		0.0	0.0	
$P_{interfering}$	29.7	41.2	41.5	28.4	17.8	28.8
$P_{threshold}$	–119.6	–119.6	–119.6	–119.6	–119.6	–119.6
Required loss (dB)	149.3	160.8	161.1	148	137.4	148.4

System 3

Required loss between radar and uplink stations

	Surface-based radar typical values Rx Bw = 4.4 MHz (worst case) (frequency-offset = 0 MHz)			Surface-based radar typical values Rx Bw = 6.4 MHz (worst case) (frequency-offset = 3 MHz)		
	Code 10.23 Mchip/s	**Code 1.023 Mchip/s**	**Addition of powers from both codes**	**Code 10.23 Mchip/s**	**Code 1.023 Mchip/s**	**Addition of powers from both codes**
P_t	53.0	55.0		53.0	55.0	
A_t	–50.00	–50.00		–50.00	–50.00	
G_t	0.0	0.0		0.0	0.0	
FL_t	0.0	0.0		0.0	0.0	
G_r	38.2	38.2		38.2	38.2	
FL_r	0.5	0.5		0.5	0.5	
R_b	–3.9	–0.2		–3.6	–1.7	
D_{pol}	0.0	0.0		0.0	0.0	
$P_{interfering}$	36.8	42.5	43.5	37.1	41	42.5
$P_{threshold}$	–108.8	–108.8	–108.8	–107.2	–107.2	–107.2
Required loss (dB)	145.7	151.3	152.4	144.4	148.3	149.7

Rx Bw: receiver bandwidth.

System 4

Required loss between radar and uplink stations

	Surface-based radar typical values (frequency-offset = 0 MHz)			Surface-based radar typical values (frequency-offset = 3 MHz)		
	Code 10.23 Mchip/s	**Code 1.023 Mchip/s**	**Addition of powers from both codes**	**Code 10.23 Mchip/s**	**Code 1.023 Mchip/s**	**Addition of powers from both codes**
P_t	53.0	55.0		53.0	55.0	
A_t	–50.00	–50.00		–50.00	–50.00	
G_t	0.0	0.0		0.0	0.0	
FL_t	0.0	0.0		0.0	0.0	
G_r	32.5	32.5		32.5	32.5	
FL_r	0.5	0.5		0.5	0.5	
R_b	–9.3	–0.8		–10.6	–20.7	
D_{pol}	0.0	0.0		0.0	0.0	
$P_{interfering}$	25.7	36.2	36.6	24.4	16.3	25
$P_{threshold}$	–115.7	–115.7	–115.7	–115.7	–115.7	–115.7
Required loss (dB)	141.4	151.9	152.3	140.1	132	140.7

Wind profile radars
Required loss between radar and uplink stations

	Surface-based radar typical values (frequency-offset = 0 MHz)			Surface-based radar typical values (frequency-offset = 3 MHz)		
	Code 10.23 Mchip/s	**Code 1.023 Mchip/s**	**Addition of powers from both codes**	**Code 10.23 Mchip/s**	**Code 1.023 Mchip/s**	**Addition of powers from both codes**
P_t	53.0	55.0		53.0	55.0	
A_t	–50.00	–50.00		–50.00	–50.00	
G_t	0.0	0.0		0.0	0.0	
FL_t	0.0	0.0		0.0	0.0	
G_r	33.5	33.5		33.5	33.5	
FL_r	0.5	0.5		0.5	0.5	
R_b	–6.2	–0.4		–7.4	–18.3	
D_{pol}	0.0	0.0		0.0	0.0	
$P_{interfering}$	29.8	37.6	38.3	28.6	19.7	29.1
$P_{threshold}$	–114.5	–114.5	–114.5	–114.5	–114.5	–114.5
Required loss (dB)	144.3	152.1	152.7	143.1	134.2	143.6

Appendix 2
to Annex 1

Description of a choke ring antenna design providing high attenuation at low elevation, for RNSS uplinks in the 1 300-1 350 MHz bandwidth

1 Introduction, purpose of the choke ring

Earth-to-space uplinks can be used for RNSS purposes, with MEO satellites for instance. The power transmitted in this band would be typically around 57 dBm. The ground antennas will be pointed toward zenith. These antennas are supposed to be omnidirectional, with a gain of –1 dB for an elevation angle α_0 of 10°, without the help of a choke ring. In order to properly protect radar links, it is necessary to have a choke ring providing an attenuation of 50 dB for the 10° elevation.

2 Description of the choke ring

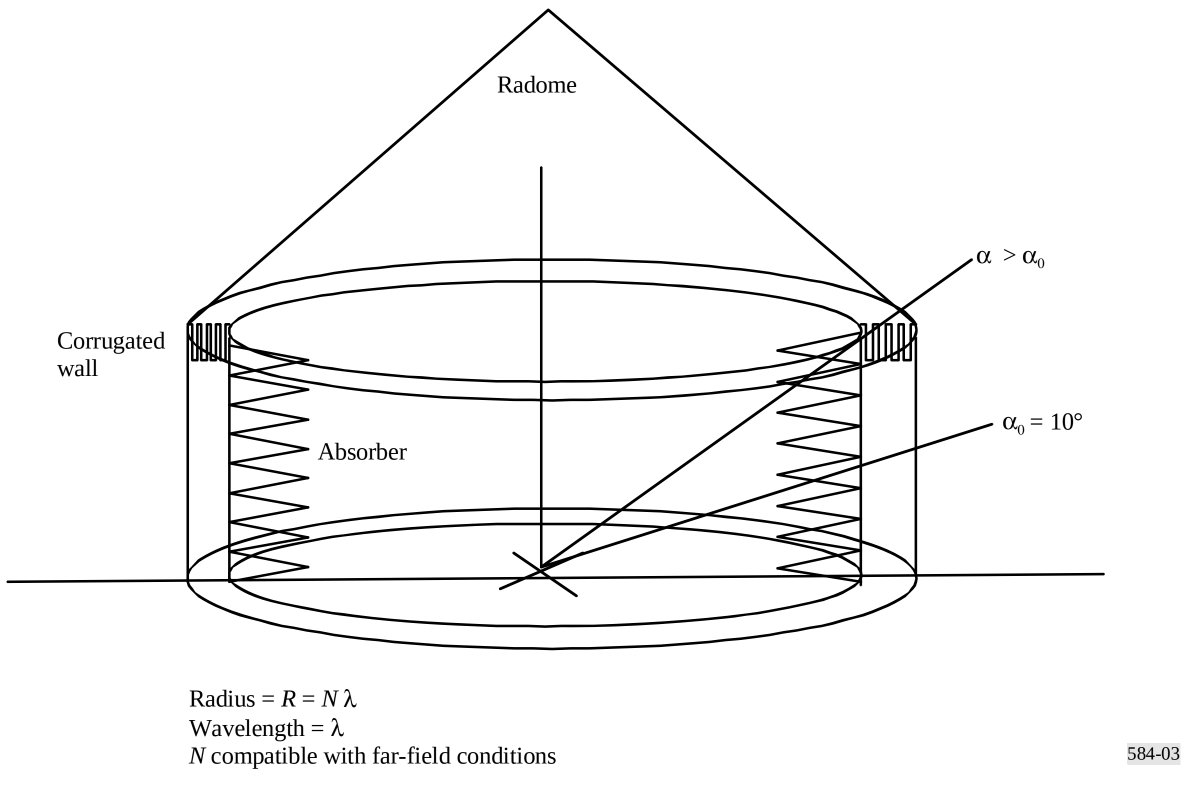
A choke ring is made of one or several cylindrical elements placed around the radiating element of an antenna. They are used classically for global positioning system (GPS) reception antennas, in order to mitigate multipath and attenuate the antenna gain at low elevations. The diameter of these choke rings is limited to about 20 to 50 cm in the case of GPS reception. This diameter corresponds to 1 or 2 wavelengths of the GPS signal. The choke ring operates here in the near-field area, and, as such, has limited attenuation performances.

For the purpose of the mentioned RNSS uplinks, the attenuation at low elevation shall be increased. This can be done with a choke ring cylinder having a large diameter, compared to the wavelength of the transmitted signal, as shown in Fig. 3. In such a case, the choke ring operates in the far-field area, and can be considered as a real physical mask. The necessary diameter is a few metres (about 5 m in the considered example). The elevation angle α of the choke ring seen from the antenna phase centre is close to about 25°. A cylindrical wall centred on the radiating element of the antenna makes the choke ring. (The height of the wall is about 1 m in the considered example.) The material of the wall is preferably absorbing, but simple concrete could also be used. The inside of the wall is covered with absorber. This absorber can be made of large pyramids, for instance. Commercial absorbers providing an attenuation of about 50 dB in L band are available, and compatible with the radiated power without inflammation risk due to the radiated power. The edge of the wall is designed to limit diffraction: a ridged or corrugated wall can be used, for instance, and an extra absorber can be put on the top of the wall if necessary. The overall structure is covered by a radiotransparent radome. This structure allows therefore an attenuation better than 50 dB for a 10° elevation angle, taking only into account the effects of the absorber and the corrugation. A second choke ring could be even added if a significant performance improvement were necessary.

Moreover, it can be noted that some meteorological radars also use transmitting and receiving antenna elements inside separated walls covered by absorbers. This concept is also called tunnel antenna. It allows an isolation of about 100 dB between both antennas, for an elevation angle below 5°.

FIGURE 3

Illustration of choke ring



Annex 2

Methodology for computation of separation distances between earth stations of the RNSS (Earth-to-space) and airborne radars of the radiolocation service in the frequency band 1 300-1 350 MHz

1 Introduction

This Annex provides an analysis of the interference created by uplink stations into receiving airborne radars.

2 System characteristics

2.1 Airborne radiolocation radars

The systems listed in Table 3 are representative systems of airborne radars that are operational or planned for the 1 300-1 350 MHz band.

2.1.1 System A

System A is an airborne, non-coherent, side-looking radar used for ocean surveillance. The radar will be carried on aircraft with an operation altitude of 15 500 to 25 500 ft (approximately 4.7-7.7 km) in over-water operations at ranges of 50 to 500 nm (approximately 92.6-926 km) from shore.

2.1.2 System B

System B is a multichannel airborne radar measurement system with operations at altitudes not to exceed 10 000 ft (approximately 3 km).

2.1.3 System C

System C is an airborne radar that has two operator-electable, frequency-diverse pairs. The diverse frequencies have 15 MHz separation. In one mode, all four frequencies are used to eliminate second-time-around echoes. The radar is carried on a tethered balloon which is moored at an altitude of 10 000 to 15 000 ft (approximately 3-4.5 km).

2.1.4 System D

System D is an airborne radar that is normally operated above 30 000 ft (approximately 9.1 km) (typically 30 000-40 000 ft, i.e. approximately 9.1-12.2 km).

TABLE 3

Airborne radiolocation technical characteristics

Parameter	System A	System B	System C	System D
Frequency range (MHz)	1 300-1 350	1 215-1 350	1 215-1 400	1 215-1 400
Output power (kW)	15	19.2	8.4	27
Emission BW (MHz)	19	1	3	6, 12
Modulation	Pulsed linear FM	Linear FM spread spectrum	Pulse w/linear FM chirp	–
Pulse rate (pps)	55	250	369	300-1 000
Pulse width (μs)	28	50	260.4	5-50
Rise time	0.04 μs	250 ns	0.1 μs	–
Fall time	0.04 μs	20 ns	0.1 μs	–
Antenna gain (dBi)	20/22	27	35	33
Antenna heights (ft)	25 500 (approx. 7.7 km)	10 000 (approx. 3 km)	15 000 (approx. 4.7 km)	40 000 (approx. 12.2 km)
Protection criteria (*I*/*N*) (dB)	–6	–6	–6	–
Noise figure (dB)	4	4	3.87	5
Reflector size	4' × 2.5' and 2' × 9' (approx. 1.2 × 0.76 and 0.61 × 2.7 m)	4' × 4' (approx. 1.2 × 1.2 m)	3 m	–
Beam type	Phased array	Phased array	Parabolic	Pencil
Beamwidth	39° (azimuth) or 12° (azimuth) 13° (elevation)	5.20° (azimuth) 10.45° (elevation)	(1)	3.5°
Scan	(2)	(3)	360° horizontal	360° azimuth ±60° elevation
Revolutions per minute	Fixed	2	5	5
IF bandwidth (–3 dB) (MHz)	14	9	20	–

(1) Horizontal – first major side lobe 13.5 dBi at 2.7°, vertical –3.5°, 3 dB spoiled.

(2) There are two possible antennas for this radar, both of which are mounted at a right angle to the flight track. The first antenna has a beamwidth, off boresight shape of 60 × 21° of azimuth with an elevation of 14 × 27° elevation off boresight. The second antenna has a beamwidth off boresight shape of 36 × 14° of azimuth with an elevation of 14 × 27° elevation off boresight.

(3) The array is an active aperture capable of scanning ±60° in the azimuth plane. Since the array, when mounted on the aircraft, will not rotate, there will be a 240° region around the rear of the array which is naturally blanked at all times. The main beam can be pointed in any sector of a 120° region (±60° from array boresight) in front of the array.

3 Interference of RNSS uplink stations into airborne radars

Considering the airborne radar characteristics given in § 2 of this Annex, we can derive the required loss (dB) in order to protect these airborne radars from RNSS uplink stations beacons. These required loss values have been obtained with equation (1) in § 3.1 of Annex 1 and they are given in Appendix 1 to Annex 2.

3.1 Results

Taking into account the maximum height (supposed to be amsl) of each kind of airborne radar, we have computed the required distance between the border of the area where the airborne radars are in operation, and the uplink RNSS stations using the free space loss propagation model (which is the worst case). For all the calculations we have assumed that the height (amsl) of the transmitting RNSS earth station is 1 000 m.

TABLE 4

Free space separation distances (including choke ring on RNSS antenna) for airborne radar versus RNSS uplink station (zero frequency offset)

System A			**System B**			**System C**			**System D**		
10.23 Mchip/s	1.023 Mchip/s	Addition of powers from both codes	10.23 Mchip/s	1.023 Mchip/s	Addition of powers from both codes	10.23 Mchip/s	1.023 Mchip/s	Addition of powers from both codes	10.23 Mchip/s	1.023 Mchip/s	Addition of powers from both codes
P_L (dB) 128.4	P_L (dB) 131.0	P_L (dB) 132.9	P_L (dB) 134.5	P_L (dB) 137.8	P_L (dB) 139.5	P_L (dB) 140.2	P_L (dB) 142.6	P_L (dB) 144.5	P_L (dB) 140.0	P_L (dB) 144.5	P_L (dB) 145.8
Distance (km) **47.1**	Distance (km) 63.5	Distance (km) 79.0	Distance (km) 95.0	Distance (km) 138.9	Distance (km) 169.0	Distance (km) 183.1	Distance (km) 241.4	Distance (km) 300.5	Distance (km) 179.9	Distance (km) 302.0	Distance (km) **350.8**

If the choke ring attenuation of 50 dB is included in the computation, then the minimum separation required is 47 km (System A, 10.23 Mchip/s). The maximum required separation distance is 351 km (System D, addition of powers from both codes).

If the choke ring attenuation is not included in the computation, then the minimum separation required is determined by the radio horizon of the airborne radar.

3.2 Conclusions

From these examples, the methodology described herein, assuming an uplink gain of –1 dBi at elevation angles below 10° and the use of a choke ring providing an additional attenuation of 50 dB, results in a separation protection distance of 349 km for the airborne radar (Radar D) having the worst-case parameters. For different parameters (radar receiving parameters, RNSS earth station transmitting parameters, absence of choke ring, etc.) other distances will be obtained. If the choke ring were not used in the example, the distances would become prohibitive for airborne radars.

In addition, it should be noted that other mitigation techniques such as the frequency planning shall reduce the level of interference into airborne radars.

Appendix 1
to Annex 2

System A
Required loss between A type airborne radars and uplink stations

	Airborne radar typical values (frequency-offset = 0 MHz)			Airborne radar typical values (frequency-offset = 3 MHz)		
	Code 10.23 Mchip/s	**Code 1.023 Mchip/s**	**Addition of powers from both codes**	**Code 10.23 Mchip/s**	**Code 1.023 Mchip/s**	**Addition of powers from both codes**
P_t	53.0	55.0		53.0	55.0	
A_t	–50.00	–50.00		–50.00	–50.00	
G_t	0.0	0.0		0.0	0.0	
FL_t	0.0	0.0		0.0	0.0	
G_r	22	22		22	22	
FL_r	0.5	0.5		0.5	0.5	
R_b	–0.6	–0.1		–1.1	–0.1	
D_{pol}	0.0	0.0		0.0	0.0	
$P_{interfering}$	23.9	26.4	28.4	23.4	26.4	28.2
$P_{threshold}$	–104.5	–104.5	–104.5	–104.5	–104.5	–104.5
Required loss (dB)	128.4	131	132.9	128	130.9	132.7

System B
Required loss between B type airborne radars and uplink stations

	Airborne radar typical values (frequency-offset = 0 MHz)			Airborne radar typical values (frequency-offset = 3 MHz)		
	Code 10.23 Mchip/s	**Code 1.023 Mchip/s**	**Addition of powers from both codes**	**Code 10.23 Mchip/s**	**Code 1.023 Mchip/s**	**Addition of powers from both codes**
P_t	53.0	55.0		53.0	55.0	
A_t	–50.00	–50.00		–50.00	–50.00	
G_t	0.0	0.0		0.0	0.0	
FL_t	0.0	0.0		0.0	0.0	
G_r	27	27		27	27	
FL_r	0.5	0.5		0.5	0.5	
R_b	–1.4	–0.1		–2.3	–0.2	
D_{pol}	0.0	0.0		0.0	0.0	
$P_{interfering}$	28.1	31.4	33.1	27.2	31.3	32.7
$P_{threshold}$	–106.4	–106.4	–106.4	–106.4	–106.4	–106.4
Required loss (dB)	134.5	137.8	139.5	133.6	137.7	139.2

System C

Required loss between C type airborne radars and uplink stations

	Airborne radar typical values (frequency-offset = 0 MHz)			**Airborne radar typical values (frequency-offset = 3 MHz)**		
	Code 10.23 Mchip/s	**Code 1.023 Mchip/s**	**Addition of powers from both codes**	**Code 10.23 Mchip/s**	**Code 1.023 Mchip/s**	**Addition of powers from both codes**
P_t	53.0	55.0		53.0	55.0	
A_t	–50.00	–50.00		–50.00	–50.00	
G_t	0.0	0.0		0.0	0.0	
FL_t	0.0	0.0		0.0	0.0	
G_r	35	35		35	35	
FL_r	0.5	0.5		0.5	0.5	
R_b	–0.4	0		–0.5	0	
D_{pol}	0.0	0.0		0.0	0.0	
$P_{interfering}$	37.1	39.5	41.4	37	39.5	41.4
$P_{threshold}$	–103.1	–103.1	–103.1	–103.1	–103.1	–103.1
Required loss (dB)	140.2	142.6	144.5	140.1	142.5	144.5

System D

Required loss between D type airborne radars and uplink stations

	Airborne radar typical values Rx Bw = 6 MHz (worst case) (frequency-offset = 0 MHz)			**Airborne radar typical values Rx Bw = 6 MHz (worst case) (frequency-offset = 3 MHz)**		
	Code 10.23 Mchip/s	**Code 1.023 Mchip/s**	**Addition of powers from both codes**	**Code 10.23 Mchip/s**	**Code 1.023 Mchip/s**	**Addition of powers from both codes**
P_t	53.0	55.0		53.0	55.0	
A_t	–50.00	–50.00		–50.00	–50.00	
G_t	0.0	0.0		0.0	0.0	
FL_t	0.0	0.0		0.0	0.0	
G_r	33	33		33	33	
FL_r	0.5	0.5		0.5	0.5	
R_b	–2.7	–0.1		–3.8	–3.1	
D_{pol}	0.0	0.0		0.0	0.0	
$P_{interfering}$	32.8	37.4	38.7	31.7	34.4	36.3
$P_{threshold}$	–107.2	–107.2	–107.2	–107.2	–107.2	–107.2
Required loss (dB)	140.0	144.5	145.8	138.9	141.6	143.5