RECOMMENDATION ITU-R M.1800

Protection of the fixed, mobile and radiolocation services from MSS feeder links that may operate in the bands 1 390-1 392 MHz (Earth-to-space) and 1 430-1 432 MHz (space-to-Earth)*

(2007)

Scope

This Recommendation provides protection requirements for ground-based receivers of the radiolocation service with respect to MSS feeder links (Earth-to-space) that may operate in the band 1 390-1 392 MHz as well as protection requirements for the fixed and the aeronautical mobile service with respect to MSS feeder links (space-to-Earth) that may operate in the band 1 430-1 432 MHz.

The ITU Radiocommunication Assembly,

considering

a) that WRC-03 made a provisional allocation on a secondary basis to the FSS for MSS feeder links through RR No. 5.339A in the bands 1 390-1 392 (Earth-to-space) and 1 430-1 432 MHz (space-to-Earth);

b) that these allocations are limited to use by feeder links for non-geostationary-satellite networks in the mobile-satellite service with service links below 1 GHz, and Resolution 745 (WRC-03) applies;

c) that Resolution 745 (WRC-03) calls for studies, tests and demonstrations to validate the studies on operational and technical means to facilitate sharing around 1.4 GHz between existing and currently planned services and FSS feeder links for use by non-GSO satellite systems in the MSS with service links operating below 1 GHz;

d) that the band 1 427-1 452 MHz is allocated to the fixed service (FS) and the mobile service (MS) on a primary basis in all Regions;

e) that this band is used, amongst others, by low-capacity digital FS links with channel bandwidths as low as 25 kHz;

f) that the band 1 429-1 535 MHz is also allocated to the aeronautical mobile service (AMS) on a primary basis exclusively for the purposes of aeronautical telemetry within the national territory of countries identified in RR (Radio Regulations) No. 5.342;

g) that the protection criteria and typical system characteristics of aeronautical telemetry in the band 1 429-1 535 MHz fully comply with the protection criteria and system characteristics presented in Recommendation ITU-R M.1459 for the band 1 452-1 525 MHz;

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* This Recommendation was jointly prepared by Radiocommunication Study Groups 8 and 9 and any future revision will also be undertaken jointly.

h) that the band 1 350-1 400 MHz is allocated to the radiolocation service on a primary basis in all Regions;

j) that studies have shown that large separation distances would be required for the protection of ground-based radiolocation systems as shown in Annex 2;

k) that Recommendation ITU-R M.1184 provides technical characteristics of mobile-satellite systems in frequency bands below 3 GHz for use in developing criteria for sharing between the MSS and other services,

noting

a) that studies have shown that sharing would not be feasible with ship-borne and transportable radiolocation systems;

b) that studies have shown that sharing would not be feasible with aeronautical radiolocation systems;

c) that the pfd limit recommended for protection of the FS is also adequate for the protection of transportable radio-relay systems which are operated under the MS by some administrations,

recommends

1 that, in order to protect FS receivers in the band 1 427-1 452 MHz, MSS feeder links operating in the band 1 430-1 432 MHz (space-to-Earth) should not exceed a pfd value of −164 dBW/m^2 in any 4 kHz in the band 1 427-1 452 MHz (see Annex 1);

2 that, in order to protect AMS receivers in the band 1 429-1 535 MHz, MSS feeder links operating in the band 1 430-1 432 MHz (space-to-Earth) should not exceed the following pfd values at any aeronautical mobile receiving station in any 4 kHz in the band 1 429-1 535 MHz:

-181	dB(W/m^2)	$0 \leq \alpha \leq 4$
$-193 + 20 \log \alpha$	dB(W/m^2)	$4 < \alpha \leq 20$
$-213.3 + 35.6 \log \alpha$	dB(W/m^2)	$20 < \alpha \leq 60$
-150	dB(W/m^2)	$60 < \alpha \leq 90$

where:

α: angle of arrival (in degrees above the horizon plane).

3 that the methodology in Annex 2 be taken into account when selecting the location of FSS earth stations in the range 1 390-1 392 MHz, in order to compute separation distances between FSS stations and ground-based radiolocation systems.

Annex 1

Protection of the fixed service in the band 1 430-1 432 MHz

1 Derivation of a pfd mask for the protection of FS receivers in the 1.4 GHz band

Simulations were conducted to assess the interference generated by one single representative non-GSO MSS constellation with a given pfd limit in a fixed service receiver located on the Earth.

Simulation results are expressed in terms of fractional degradation in performance (FDP), described in Recommendation ITU-R F.1108, for azimuths 0 to 180° with a step of 1°.

This FDP is then compared to a criterion. If this criterion is exceeded, the pfd limit is tightened, and the simulation is run again until the criterion is respected.

2 MSS system characteristics

Several MSS system descriptions of the "little LEO" type can be found in Recommendation ITU-R M.1184. Table 1 shows the MSS systems and relevant characteristics extracted from this Recommendation. In line with recent developments and studies within the relevant ITU-R working parties, the number of satellites for the "Q" constellation was reduced from five satellites per plane to four, and the total number of satellites from 32 to 26. The inclination angles were increased from 51° to 66°.

TABLE 1

Parameters of several non-GSO MSS networks

System	L	M			P	Q		S
Number of satellites	48	48			6	26 (32)		6
Altitude (km)	950	825		775	893	1 000		692, 667
Inclination (degrees)	50	45	0	70, 108	99	66 (51)	83	98.04
Orbit planes	8	3	1	2	2	6	2	2
Satellite/plane	6	8			3	4 (5)	1	3
Right ascension of ascending node (degrees)	0, 45, 90, 135, 180, 225, 270, 315	0, 120, 240	0	0, 180	9.8	0, 60, 120, 180, 240, 300	0, 90	143.5, 53.5
Channel bandwidth for gateway downlinks (kHz)	60	50			855	175/45		300
Polarization (Tx wave)	RHCP				LHCP	RHCP		RHCP

3 FS station characteristics and protection criterion

Table 2 hereafter lists the characteristics of point-to-multipoint links from Recommendation ITU-R F.758.

TABLE 2

Point-to-multipoint system characteristics

Frequency band (GHz)	1.427-1.452/1.492-1.517				
Modulation	O-QPSK				
Capacity	60 × 64 kbit/s				
Channel spacing (MHz)	3.5				
	Central station/repeater			Out station	
Antenna gain (maximum) (dBi)	13	16	31	23.5	17
Feeder/multiplexer loss (dB)	4.4			2.5	
Antenna type	Omni	Sectoral 180°	Dish (3 m)	Dish (1.2 m)	Panel
Receiver IF bandwidth (MHz)	3.5			3.5	
Receiver thermal noise (dBW)	–134			–134	

The FS receiver corresponding to the worst case is a directional central station with a maximum antenna gain of 31 dBi, a feeder/multiplexer loss of 4.4 dB, a bandwidth of 3.5 MHz and a 4.5 dB noise figure. A worst-case elevation angle of 5° is also considered.

Recommendation ITU-R F.1245 was used to model the antenna pattern of the directional central station.

According to Recommendation ITU-R F.1094, the maximum allowable performance degradation should be divided into 89% for the fixed service, 10% for sharing with primary services, and 1% for all other sources of interference, including secondary services and unwanted emissions. In this case, the FDP must therefore stay below the value of 1%, at least on average overall azimuth pointing angles.

4 Simulation results

Table 3 gives the results obtained for the MSS constellations given in Table 1. The pfd value taken in the simulation is given in row 3, which leads to the FDP values given in rows 4, 5 and 6. Figures 1 and 2 give as an example more details on the FDP values obtained for system Q.

TABLE 3

Simulation results for several non-GSO MSS networks

System	Q	L	M	P	S
Number of satellites	26	48	48	6	6
Altitude (km)	1 000	950	800	900	700
Pfd to comply with an FDP of 1% (dBW/m^2 in 4 kHz)	–163	**–164**	**–164**	–156	–155
FDP min. (%)	0.27	0.05	0.40	0.15	0.15
FDP avg. (%)	0.85	0.95	0.86	0.83	0.86
FDP max. (%)	3.08	4.61	2.39	1.80	1.72

FIGURE 1

FDP for all FS pointing azimuths for MSS system Q

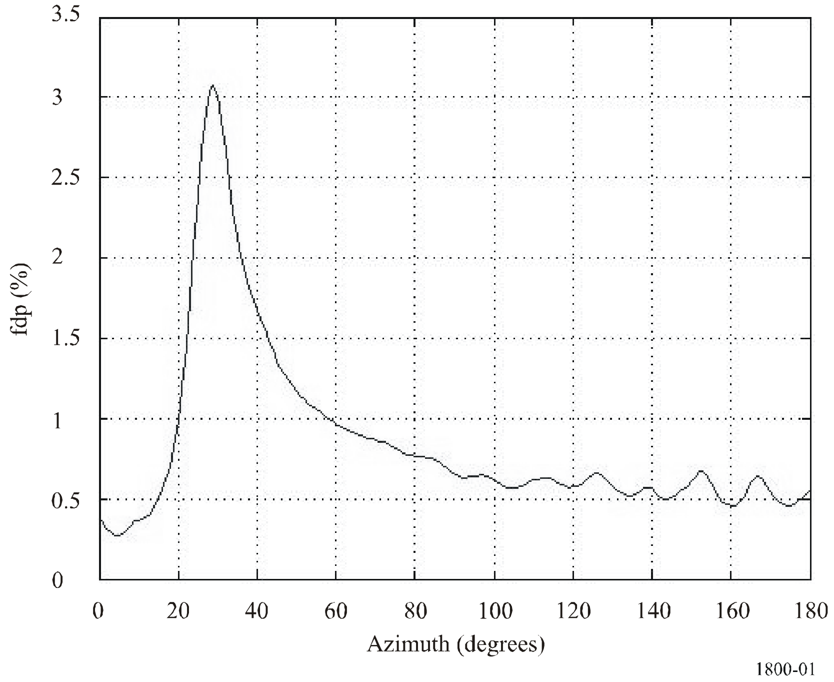
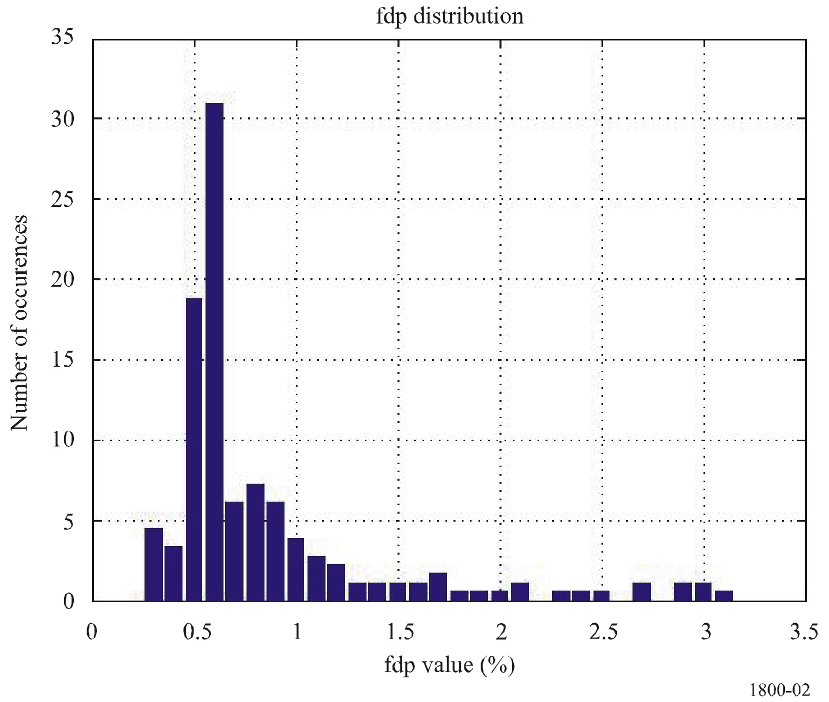


FIGURE 2

FDP distribution for all FS pointing azimuths for MSS system Q



Annex 2

Protection of ground-based radiolocation receivers operating in the band 1 390-1 392 MHz

1 Technical characteristics of radiolocation receivers

Radiolocation receiver characteristics used in this study have been obtained from Recommendation ITU-R M.1463. This Recommendation describes four different systems in the band of 1 215-1 400 MHz.

The radars operating in the 1215-1400 MHz band use a variety of modulation schemes including continuous wave (CW) pulses, frequency modulated (chirped) pulses and phase coded pulses. Cross-field, linear beam and solid state output devices are used in the final stages of the transmitters. Typical receiver bandwidths of radars operating in the 1 215-1 400 MHz band range from 0.5 to 6.4 MHz.

2 Protection criteria

The desensitizing effect on radiolocation radars from other emissions of a CW or noise-like type modulation is predictably related to its intensity. In any azimuth sectors in which such interference arrives, its power spectral-density can, to within a reasonable approximation, simply be added to the power spectral-density of the radar receiver thermal noise. If power spectral-density of radar-receiver noise in the absence of interference is denoted by N_0 and that of noise-like interference by I_0, the resultant effective noise power spectral-density becomes simply $I_0 + N_0$. An increase of about 1 dB would constitute significant degradation, equivalent to a detection-range reduction of about 6%. Such an increase corresponds to an $(I + N)/N$ ratio of 1.26, or an I/N ratio of about −6 dB (see *recommends* 3 of Recommendation ITU-R M.1463). This represents the aggregate effect of multiple interferers, when present; the tolerable I/N ratio for an individual interferer depends on the number of interferers and their geometry, and needs to be assessed in the course of analysis of a given scenario. If CW interference were received from most azimuth directions, a lower I/N ratio would need to be maintained.

3 Technical characteristics of MSS feeder-link earth stations

The MSS Earth-to-space feeder-link characteristics used for this study are described in Table 4. Feeder-link characteristics are based on Annex 2 of Recommendation ITU-R M.1184. The pattern shown in Fig. 3 illustrates the gain envelope of the MSS earth station antenna. This pattern is taken from Appendix 8, Annex III of the Radio Regulations. Gain values are obtained considering a ratio between the antenna diameter and the wavelength of $D/\lambda \leq 100$.

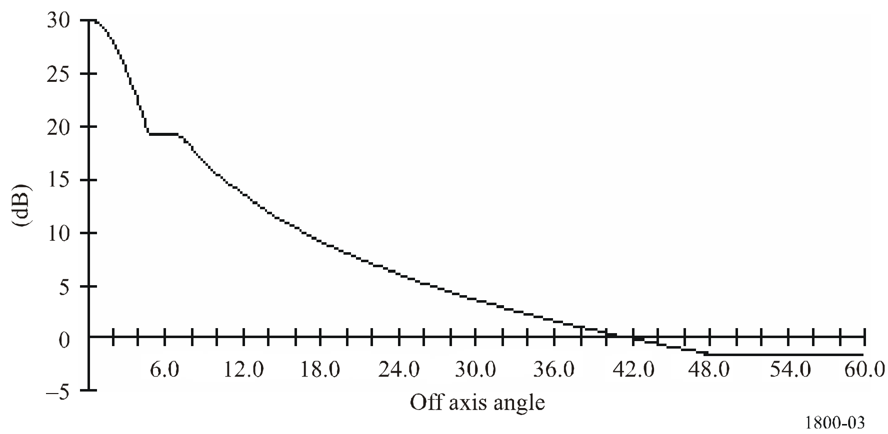
TABLE 4

Earth-to-space feeder-link characteristics

Parameter	Value
Number of earth stations	60
Earth station locations	Distributed throughout the world
Transmit antenna peak gain	30 dBi
3 dB beamwidth	5°
Gain floor	–1.5 dBi
Antenna pattern	RR Appendix 8, Annex III
Antenna polarization	Right hand circular
Antenna pointing	Tracks nearest satellite at elevations between 5° and 90°
Transmit power	10 W per 100 kHz

FIGURE 3

MSS earth station receive and transmit antenna pattern



4 Study considerations and assumptions

This study assumes a receiver reference bandwidth of 100 kHz.

A transmitting MSS feeder uplink station may cause interference to a receiving ground-based radiolocation system if the separation distance between these systems is not sufficient. This distance is a function of several parameters.

The following assumptions have been made in this study:

– 8 m of effective antenna height over ground for the MSS stations.

– 10 m of effective antenna height over ground for the radar station.

– For the MSS feeder uplink station antenna, it has been assumed that the antenna is pointing in the direction of the radiolocation receiver with a minimum transmission elevation angle of 5°.

– Radio climatic zone A2, propagation over land, has been considered. Propagation paths over the sea will require higher separation distances.

– Calculations are based on a latitude of 45°.

– Regarding percentage of time that such a level may be exceeded, 0.1% is considered appropriate. Assuming pointing of the radar antenna main lobe towards the MSS earth station, it is considered that any interference received by the radar receiver will be seen as a target and therefore can be considered as harmful interference.

5 Permissible interference power level for radar systems

The first step is to determine the permissible interference power level that radar systems can afford without losses in their performance. This procedure is described in Recommendation ITU-R M.1461-1.

Equation (1) allows to determine the interference power level at which the radar receiver performance starts to degrade, I_T.

$$I_T = I/N + N \tag{1}$$

where:

I/N: interference-to-noise ratio at the detector input necessary to maintain acceptable performance criteria, equal to –6 dB in this case

N: receiver inherent noise level (dBW)

$N = -144 \text{ dBW} + 10 \log B \text{ (MHz)} + NF$

where:

B: receiver bandwidth (MHz)

NF: receiver noise figure (dB).

Assuming an interference-to-noise ratio 6 dB below its threshold level and a receiver reference bandwidth of 100 kHz, the results for the four radar systems are shown in Table 5.

TABLE 5

Permissible interference power level for radar systems

Radar system (Recommendation ITU-R M.1463)	**1**	**2**	**3**	**4**
Noise factor *NF* (dB)	2	2	4.7	3.5
Noise level *N* (dBW/100 kHz)	–152	–152	–149.3	–150.5
Permissible interference I_T (dBW/100 kHz)	–158	–158	155.3	–156.5

6 Computation of the separation distance

Interference to a radiolocation receiver may arise through a range of propagation mechanisms whose individual dominance depends on climate, radio frequency, time percentage, distance and path topography. The required separation distance is to a major extent a function of the actual transmitter and receiver antenna gains.

In addition to the free space loss, interfering signals are attenuated by path obstacles and diffraction due to the Earth's curvature. Besides direct paths and propagation by diffraction, there exist additional propagation mechanisms, such as troposcatter and layer refraction (ducting), which can cause interference to the radiolocation receivers.

The procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above about 0.7 GHz is considered in Recommendation ITU-R P.452. The underlying mathematical models are quite complex and can only be addressed at high level in this Recommendation.

The key equation for the required basic transmission loss is given by:

$$L_b(p) = P_t + G_t + G_r - I_T\,(p) \qquad \text{(dB)} \qquad (2)$$

where:

- p: maximum percentage of time for which the permissible interference power may be exceeded
- $L_b(p)$: minimum required loss (dB) for p% of the time; this value must be exceeded by the predicted path loss for all but p% of the time. This is the basic transmission loss taken as the reference level (0 dB) in the plots of Figs. 5 to 8
- P_t: maximum available transmitting power level (dBW) in the reference bandwidth at the terminals of the antenna of a transmitting earth station
- $I_T\,(p)$: permissible interference power of an interfering emission (dBW) in the reference bandwidth to be exceeded for no more than p% of the time at the receiving station that may be subject to interference, where the interfering emission originates from a single source
- G_t: gain (dB relative to isotropic), for a transmitting earth station, this is the antenna gain towards the physical horizon on a given azimuth
- G_r: gain (dB relative to isotropic) of the antenna of the receiving station that may be subject to interference.

It has been assumed that all of the MSS links operate on the same frequency and are within the radar bandwidth. All simulations were performed at a frequency of 1 392 MHz and used transmit power levels of 10 W associated with a 100 kHz channel bandwidth.

7 Selected scenarios

Seven different scenarios have been considered for this study. These cases have been selected to represent typical situations of radar stations and MSS feeder-link stations with one obstacle in between at 10 km of the MSS feeder-link station, as shown in Fig. 4.

Case 1: represents an unfavourable case with the radar pointing horizontally at 0° elevation and an obstacle height of 100 m.

Case 2: shows a typical scenario with the radar pointing at 2° of elevation above the horizon and an obstacle height of 300 m.

Case 3: represents a favorable case with the radar pointing at 4° of elevation and an obstacle height of 850 m.

Case 4: is for a radar system pointing at 2° of elevation and an obstacle height of 100 m.

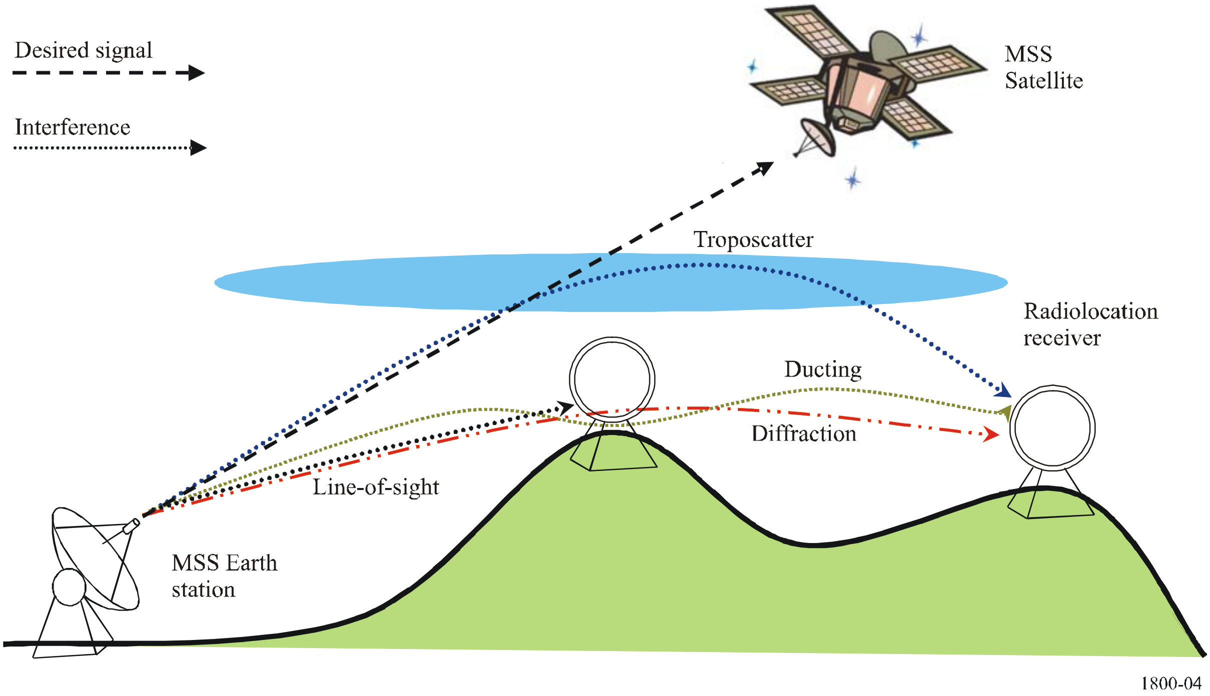
Case 5: is for a radar system pointing at 2° of elevation and an obstacle height of 850 m.

Case 6: is for a radar system pointing at 0° of elevation and an obstacle height of 300 m.

Case 7: is for a radar system pointing at 4° of elevation and an obstacle height of 300 m.

FIGURE 4

Interference configuration between a transmitting MSS feeder uplink station and a radiolocation receiver



8 Results

The next figures show the different separation distances obtained for cases 1 to 7 respectively for the four different radiolocation systems considered. Under each figure a table with the main characteristics and numerical distances expressed in km is shown. The transmission loss computed from the contributions of the different propagation mechanisms is plotted against the separation distance between the MSS earth station and the radiolocation station. The level 0 dB is the transmission loss relative to L_p as computed from equation (2) for the four different types of radiolocation systems.

FIGURE 5

Results for radar system 1

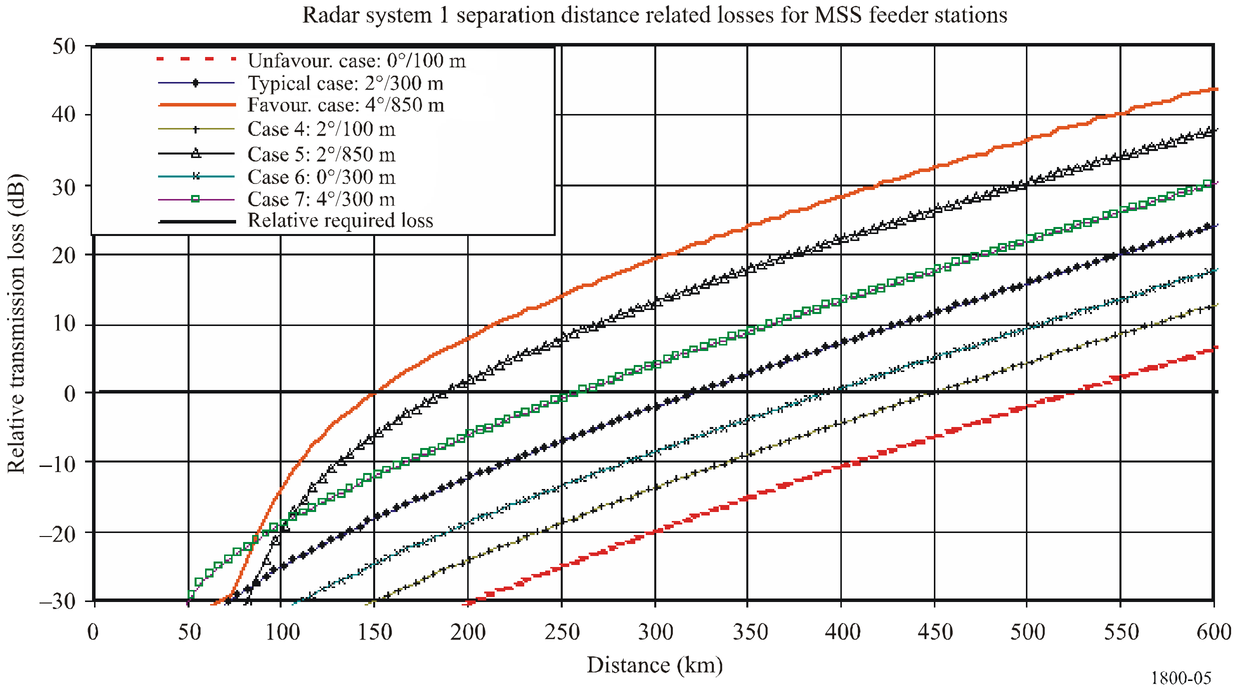


TABLE 6

System 1 main data

	Unfavourable case	Typical case	Favourable case	Case 4	Case 5	Case 6	Case 7
Radio frequency (GHz)	1.392	1.392	1.392	1.392	1.392	1.392	1.392
Permissible interference level for radar station (dB(W/100 kHz))	–158.0	–158.0	–158.0	–158.0	–158.0	–158.0	–158.0
Radar antenna off-pointing angle to MSS station (degrees)	0.0	2.0	4.0	2.0	2.0	0.0	4.0
Radar elevation antenna gain towards MSS station (dBi)	33.5	27.1	21.0	27.1	27.1	33.5	21.0
Radar antenna centre point above terrain level (m)	10.0	10.0	10.0	10.0	10.0	10.0	10.0
MSS station max. EIRP density towards horizon (dB(W/100 kHz))	30.8	30.8	30.8	30.8	30.8	30.8	30.8
MSS effective antenna height above terrain level (m)	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Height of nearest obstacle above terrain level (m)	100.0	300.0	850.0	100.0	850.0	300.0	300.0
Distance to nearest obstacle along the Earth's surface (km)	10	10	10	10	10	10	10
Required basic transmission loss (dB)	222.3	215.9	209.8	215.9	215.9	222.3	209.8
Required separation distance (km)	527.0	327.0	152.0	452.0	192.0	397.0	262.0

FIGURE 6

Results for radar system 2

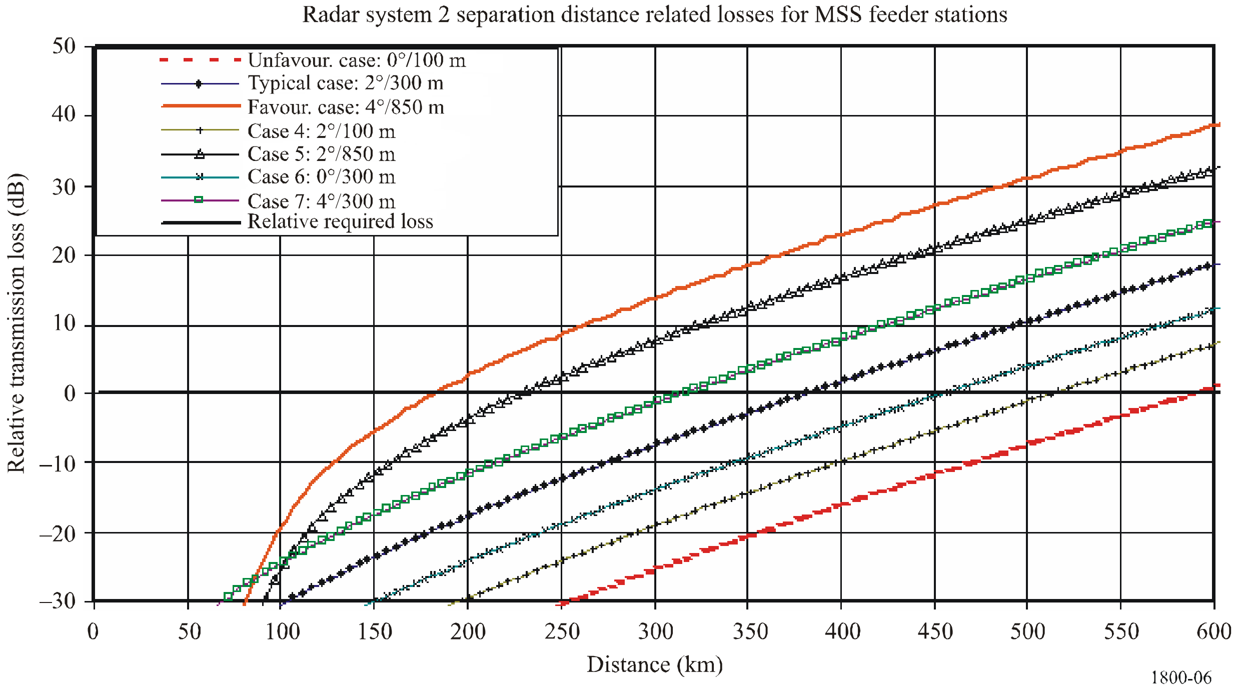


TABLE 7

System 2 main data

	Unfavourable case	Typical case	Favourable case	Case 4	Case 5	Case 6	Case 7
Radio frequency (GHz)	1.392	1.392	1.392	1.392	1.392	1.392	1.392
Permissible interference level for radar station (dB(W/100 kHz))	–158.0	–158.0	–158.0	–158.0	–158.0	–158.0	–158.0
Radar antenna off-pointing angle to MSS station (degrees)	0.0	2.0	4.0	2.0	2.0	0.0	4.0
Radar elevation antenna gain towards MSS station (dBi)	38.9	32.5	26.4	32.5	32.5	38.9	26.4
Radar antenna centre point above terrain level (m)	10.0	10.0	10.0	10.0	10.0	10.0	10.0
MSS station max. EIRP density towards horizon (dB(W/100 kHz))	30.8	30.8	30.8	30.8	30.8	30.8	30.8
MSS effective antenna height above terrain level (m)	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Height of nearest obstacle above terrain level (m)	100.0	300.0	850.0	100.0	850.0	300.0	300.0
Distance to nearest obstacle along the Earth's surface (km)	10	10	10	10	10	10	10
Required basic transmission loss (dB)	227.7	221.3	215.2	221.3	221.3	227.7	215.2
Required separation distance (km)	592.0	382.0	187.0	517.0	232.0	457.0	317.0

FIGURE 7

Results for radar system 3

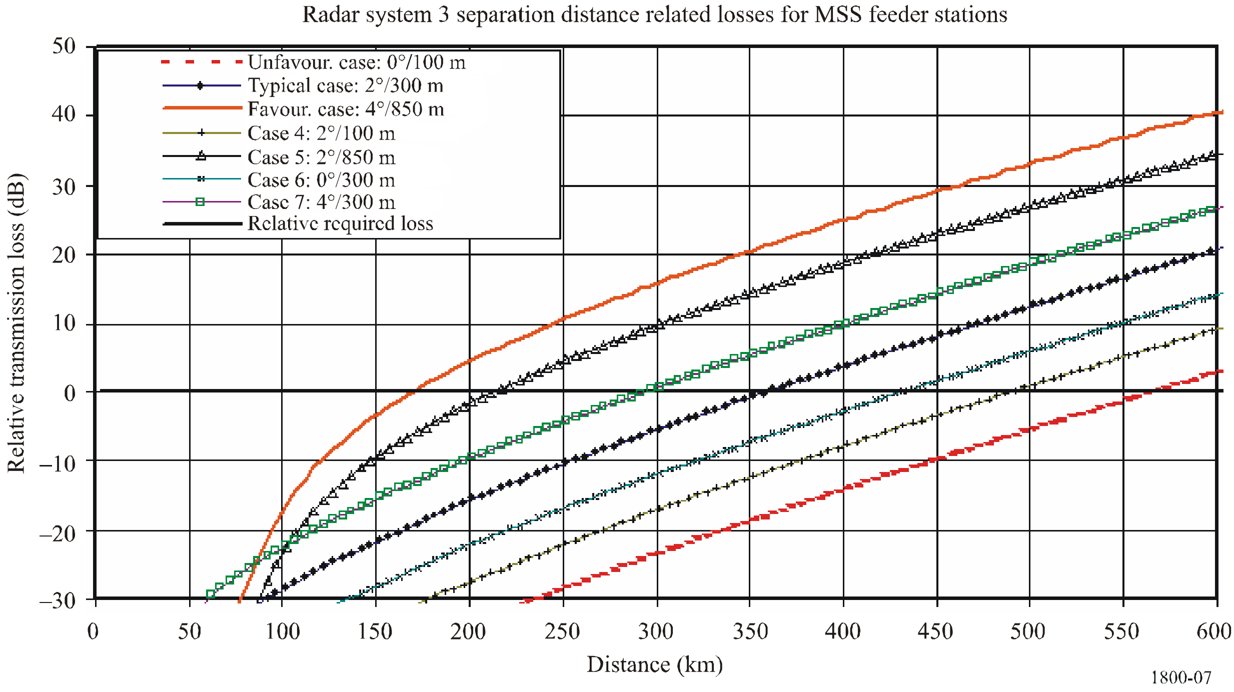


TABLE 8

System 3 main data

	Unfavourable case	Typical case	Favourable case	Case 4	Case 5	Case 6	Case 7
Radio frequency (GHz)	1.392	1.392	1.392	1.392	1.392	1.392	1.392
Permissible interference level for radar station (dB(W/100 kHz))	–155.3	–155.3	–155.3	–155.3	–155.3	–155.3	–155.3
Radar antenna off-pointing angle to MSS station (degrees)	0.0	2.0	4.0	2.0	2.0	0.0	4.0
Radar elevation antenna gain towards MSS station (dBi)	38.2	31.8	25.7	31.8	31.8	38.2	25.7
Radar antenna centre point above terrain level (m)	10.0	10.0	10.0	10.0	10.0	10.0	10.0
MSS station max. EIRP density towards horizon (dB(W/100 kHz))	30.8	30.8	30.8	30.8	30.8	30.8	30.8
MSS effective antenna height above terrain level (m)	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Height of nearest obstacle above terrain level (m)	100.0	300.0	850.0	100.0	850.0	300.0	300.0
Distance to nearest obstacle along the Earth's surface (km)	10	10	10	10	10	10	10
Required basic transmission loss (dB)	225.7	219.3	213.2	219.3	219.3	225.7	213.2
Required separation distance (km)	567.0	362.0	172.0	492.0	217.0	432.0	297.0

FIGURE 8

Results for radar system 4

Radar system 4 separation distance related losses for MSS feeder stations

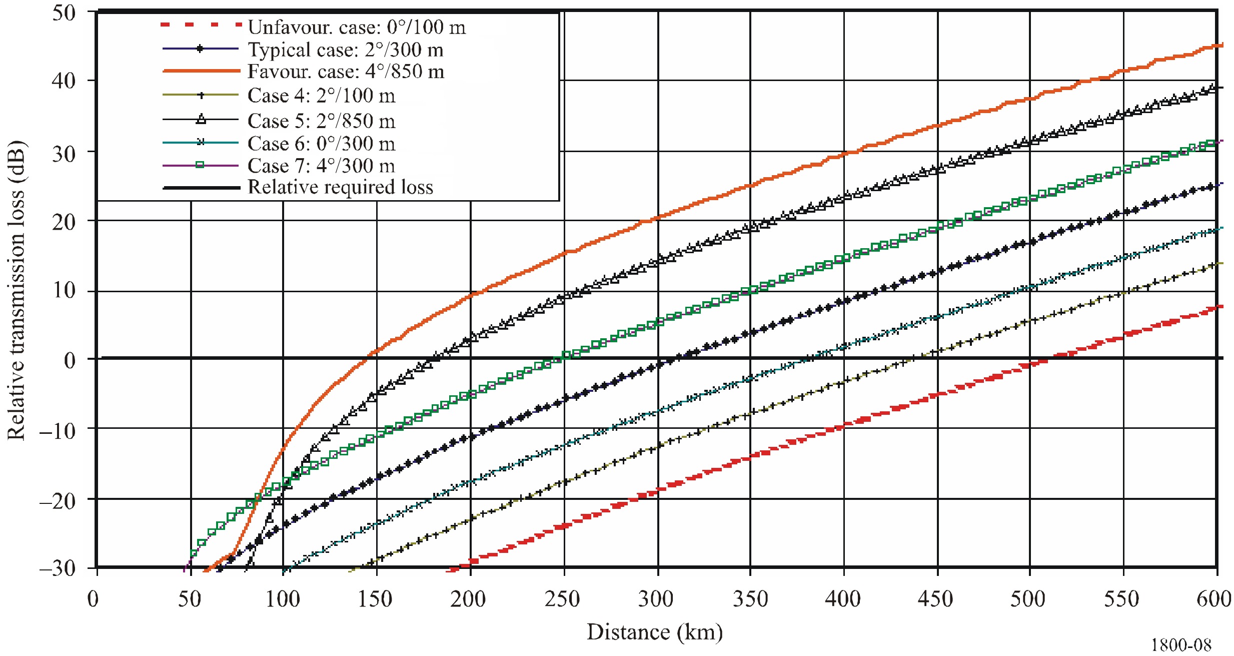


TABLE 9

System 4 main data

	Unfavourable case	Typical case	Favourable case	Case 4	Case 5	Case 6	Case 7
Radio frequency (GHz)	1.392	1.392	1.392	1.392	1.392	1.392	1.392
Permissible interference level for radar station (dB(W/100 kHz))	–156.5	–156.5	–156.5	–156.5	–156.5	–156.5	–156.5
Radar antenna off-pointing angle to MSS station (degrees)	0.0	2.0	4.0	2.0	2.0	0.0	4.0
Radar elevation antenna gain towards MSS station (dBi)	32.5	26.1	20.0	26.1	26.1	32.5	20.0
Radar antenna centre point above terrain level (m)	10.0	10.0	10.0	10.0	10.0	10.0	10.0
MSS station max. EIRP density towards horizon (dB(W/100 kHz))	30.8	30.8	30.8	30.8	30.8	30.8	30.8
MSS effective antenna height above terrain level (m)	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Height of nearest obstacle above terrain level (m)	100.0	300.0	850.0	100.0	850.0	300.0	300.0
Distance to nearest obstacle along the Earth’s surface (km)	10	10	10	10	10	10	10
Required basic transmission loss (dB)	221.2	214.8	208.7	214.8	214.8	221.2	208.7
Required separation distance (km)	512.0	312.0	147.0	437.0	182.0	382.0	252.0

9 Conclusions

A number of cases have been analyzed in this study to determine the minimum distance between a radar earth station and a MSS feeder-link station in the frequency band 1 390-1 392 MHz, in order to avoid harmful interference.

The results obtained show that the separation distances to protect ground-based radiolocation receivers operating around 1.4 GHz from interferences of MSS feeder-link stations vary between 150 and 600 km, depending on the cases considered. Propagation paths over large bodies of water are likely to require higher distances.