

RECOMMENDATION ITU-R S.1340^{*,**}**Sharing between feeder links for the mobile-satellite service
and the aeronautical radionavigation service in the
Earth-to-space direction in the band 15.4-15.7 GHz**

(Question ITU-R 243/4)

(1997)

The ITU Radiocommunication Assembly,

considering

- a) that Resolution 117 of the World Administrative Radio Conference (Geneva, 1995) (WARC-95) calls for studies by the ITU-R of the sharing situation between feeder links (Earth-to-space) for the mobile-satellite service (MSS) and the aeronautical radionavigation service in the band 15.45-15.65 GHz;
- b) that the band 15.4-15.7 GHz is allocated to the aeronautical radionavigation service on a primary basis and that No. S4.10 of the Radio Regulations (RR) applies;
- c) that the WRC-95 has added an allocation to the fixed-satellite service (FSS) in the band 15.45-15.65 GHz for feeder links of non-geostationary (non-GSO) satellite networks in the MSS in the Earth-to-space direction;
- d) that the requirements for feeder links (Earth-to-space) of non-GSO satellite systems in the MSS need to be accommodated in this band;
- e) that emissions from stations in the aeronautical radionavigation service can cause unacceptable interference to satellites;
- f) that administrations operating stations in the aeronautical radionavigation service are urged to limit the average e.i.r.p. to 42 dBW in order to limit interference to non-GSO satellites; this value is subject to review and study by the ITU-R (see RR No. S5.511C);
- g) that coordination of emissions from aeronautical radionavigation stations with feeder-link space stations is not considered practical;
- h) that emissions from feeder-link earth stations propagated along the Earth's surface can cause harmful interference to aeronautical radionavigation stations;
- j) that certain limitations have been placed on the fixed-satellite service for the protection of the aeronautical radionavigation service in accordance with RR No. S5.511C;
- k) that there is fairly extensive use of this band by the aeronautical radionavigation service for airborne, land and ocean based stations;
- l) that aircraft stations are not permitted to transmit in the band 15.45-16.45 GHz in accordance with RR No. S5.511B;

* This Recommendation should be brought to the attention of Radiocommunication Study Group 8.

** Radiocommunication Study Group 4 made editorial amendments to this Recommendation in 2001 in accordance with Resolution ITU-R 44 (RA-2000).

- m) that the technical and operational characteristics of the aeronautical radionavigation stations are reasonably well known;
- n) that the technical and operational characteristics of feeder links are not well defined;
- o) that methods are needed to determine the coordination and separation distances required between feeder-link earth stations and aeronautical radionavigation stations in order to protect the aeronautical radionavigation stations;
- p) that studies have been made with respect to the preceding *considerings*,

recommends

- 1 that feeder links for the MSS should be limited to the band 15.43-15.63 GHz (see Note 1);
- 2 that the emissions expressed as effective e.i.r.p. (E_{eff}) from aeronautical radionavigation stations should not exceed the following:

- 2.1 for aircraft landing systems and for feeder-link bandwidths greater than 3 MHz:

$$E_{eff} = \begin{cases} 53 & \text{dBW} & \text{for } 0 \leq \varphi < 8 \\ 53 - 0.833 (\varphi - 8) & \text{dBW} & \text{for } 8 \leq \varphi < 14 \\ 48 & \text{dBW} & \text{for } 14 \leq \varphi < 32 \\ 48 - 9 (\varphi - 32) & \text{dBW} & \text{for } 32 \leq \varphi < 34 \\ 30 & \text{dBW} & \text{for } 34 \leq \varphi < 40 \\ 30 - 0.2 (\varphi - 40) & \text{dBW} & \text{for } 40 \leq \varphi \leq 90 \end{cases}$$

- 2.2 for general purpose aircraft radars and for feeder-link bandwidths greater than 1 MHz:

$$E_{eff} = \begin{cases} 62 & \text{dBW} & \text{for } 0 \leq \varphi < 20 \\ 62 - 0.56 (\varphi - 20)^2 & \text{dBW} & \text{for } 20 \leq \varphi < 25 \\ 48 & \text{dBW} & \text{for } 25 \leq \varphi < 29 \\ 71.86 - 25 \log (\varphi - 20) & \text{dBW} & \text{for } 29 \leq \varphi < 68 \\ 29.8 & \text{dBW} & \text{for } 68 \leq \varphi \leq 90 \end{cases}$$

where:

$$E_{eff} = E_p - 15 \log (1 + 5/PW) \quad \text{dBW}$$

E_{eff} : e.i.r.p. which causes the same level of interference to a phase modulated signal as a continuous noise like interferer

E_p : peak pulse e.i.r.p. (dBW) of the aeronautical radionavigation station

PW : pulse duration (μ s) of the aeronautical radionavigation station

φ : angle of elevation (degrees) above the local horizontal plane;

- 3 that feeder links in the Earth-to-space direction should be designed to operate in the interference environment defined in *recommends 2*;
- 4 that with *recommends 2* and *3* coordination of emissions from aeronautical radionavigation stations with satellite receiving stations is not required;

5 that the e.i.r.p. transmitted toward the local horizontal plane by a feeder-link earth station should not exceed 54 dB(W/MHz) (see Note 2);

6 that surface based radars as described in Annex 1 should not operate in the 15.43-15.63 GHz band;

7 that the coordination distances required to protect the aeronautical radionavigation stations from harmful interference from feeder-link earth station emissions are:

- 515 km from the aircraft landing surface for aircraft landing systems (ALS);
- 600 km from aircraft using general purpose radars (MPR);
- 270 km from the aircraft landing for radar sensing and measurement systems;

8 that additional information is contained in Annexes 1, 2 and 3.

NOTE 1 – The frequency band given in *recommends* 1 is slightly different to that allocated by the WRC-95. This difference is recommended to facilitate sharing between the non-GSO MSS feeder links and the aeronautical radionavigation service. *recommends* 1 will be reviewed at a later date in accordance with the outcome of a future WRC.

NOTE 2 – Additional design and operational constraints may be placed on MSS Earth-to-space feeder links in order to take into account the threshold levels for the radio astronomy service given in Recommendation ITU-R RA.769.

ANNEX 1

Aeronautical radionavigation systems in the 15.4-15.7 GHz band

1 Surface based radars (SBR)

The land and ship based SBR are used for the detection, location and movement of aircraft and other vehicles on the surface of airports and other aircraft landing areas.

1.1 Antenna patterns

- Nominal 3 dB beamwidth: <math><3.5^\circ</math> vertical, inverted cosecant to 0.35° horizontal
- Frequency range: 15.65-16.7 GHz
- Polarization: circular
- Typical gain: 43 dBi
- Maximum side-lobe level: 25 dB below peak gain
- Maximum back-lobe level: 35 dB below peak gain
- Vertical tilt range: $\pm 1.5^\circ$
- Maximum horizontal scan range: 360° .

1.1.1 Antenna elevation envelope pattern

Based on measured data and side-lobe level specifications and with the peak gain directed at +1.5°, an elevation envelope gain pattern is defined as follows where φ is the elevation angle (degrees):

$$G(\varphi) = \begin{cases} 43 & \text{dBi} & \text{for } 0 \leq \varphi < 4 \\ 43 - 5(\varphi - 4) & \text{dBi} & \text{for } 4 \leq \varphi < 9 \\ 18 & \text{dBi} & \text{for } 9 \leq \varphi < 16 \\ 43.2 - 21 \log \varphi & \text{dBi} & \text{for } 16 \leq \varphi < 48 \\ 8 & \text{dBi} & \text{for } 48 \leq \varphi \leq 90 \end{cases}$$

1.1.2 Antenna azimuth envelope pattern

Based on measured data and side-lobe level specifications, the azimuth gain pattern is defined as follows where φ is the relative azimuth angle (degrees):

$$G(\varphi) = \begin{cases} 43 - 110 \varphi^2 & \text{dBi} & \text{for } 0 \leq \varphi < 0.4767 \\ 18 & \text{dBi} & \text{for } 4.4767 \leq \varphi < 0.72 \\ 17.07 - 6.5 \log \varphi & \text{dBi} & \text{for } 0.72 \leq \varphi < 48 \\ 8 & \text{dBi} & \text{for } 48 \leq \varphi \leq 180 \end{cases}$$

1.2 Other characteristics

1.2.1 Transmitting

- Peak e.i.r.p.: 86 dBW
- Pulse repetition frequency: 8 192 Hz
- Pulse duration: 0.04 μ s
- Pulse 3.5 dB bandwidth: 25 MHz.

1.2.2 Receiving

- Typical antenna gain: 43 dBi
- Typical noise figure: 6.2-6.9 dB.

2 Aircraft landing systems (ALS)

These ALS are general purpose systems and are used on ships, as portable or permanent land based systems and for shuttle landings. The microwave scanning beam landing system (MSBLS) is one such system. Some of the characteristics vary with the particular applications.

2.1 Surface based station antenna patterns

The antenna patterns are similar for all applications including the MSBLS. The scanning ranges vary with application. The scanning ranges given below cover all applications.

The antenna complement of the ALS consists of an elevation antenna and an azimuth antenna.

The elevation antenna portion of the ALS is used to transmit vertical angle data to the aircraft.

- nominal 3 dB beamwidths: 1.3° vertical
40° horizontal
- frequency range: 15.4-15.7 GHz
- polarization: horizontal and vertical
- typical gain: 28 dBi
- maximum side-lobe level: 17 dB below peak gain in both planes
- maximum vertical scan range: 0 to 30°.

The azimuth antenna portion of the ALS is used to transmit azimuth information to the aircraft.

- nominal 3 dB beamwidths: 2.0° horizontal
6.5° vertical
- the vertical pattern is spoiled to achieve at least a 20 dBi gain at 20° above the horizon
- frequency range: 15.4-15.7 GHz
- polarization: horizontal and vertical
- typical gain: 33 dBi
- maximum side-lobe level: 17 dB below peak gain in both planes
- maximum horizontal scan range: $\pm 35^\circ$.

2.1.1 Combined antenna elevation envelope pattern

A combined vertical envelope gain pattern based on measured data is defined as follows where φ is the elevation angle (degrees):

$$G(\varphi) = \begin{cases} 33 & \text{dBi} & \text{for } 0 \leq \varphi < 8 \\ 33 - 0.833(\varphi - 8) & \text{dBi} & \text{for } 8 \leq \varphi < 14 \\ 28 & \text{dBi} & \text{for } 14 \leq \varphi < 32 \\ 28 - 9(\varphi - 32) & \text{dBi} & \text{for } 32 \leq \varphi < 34 \\ 10 & \text{dBi} & \text{for } 34 \leq \varphi < 40 \\ 10 - 0.2(\varphi - 40) & \text{dBi} & \text{for } 40 \leq \varphi \leq 90 \end{cases}$$

2.1.2 Azimuth antenna patterns

The azimuth envelope pattern of the elevation antenna is defined as follows where φ is the relative azimuth angle (degrees):

$$G(\varphi) = \begin{cases} 28 - 0.0062 \varphi^2 & \text{dBi} & \text{for } 0 \leq \varphi < 70 \\ -2.37 & \text{dBi} & \text{for } 70 \leq \varphi \leq 180 \end{cases}$$

The azimuth envelope pattern of the azimuth antenna is defined as follows where φ is the relative azimuth angle (degrees):

$$G(\varphi) = \begin{cases} 33 - 2\varphi^2 & \text{dBi} & \text{for } 0 \leq \varphi < 3 \\ 15 & \text{dBi} & \text{for } 3 \leq \varphi < 5 \\ 32.5 - 25 \log \varphi & \text{dBi} & \text{for } 5 \leq \varphi < 48 \\ -9.53 & \text{dBi} & \text{for } 48 \leq \varphi \leq 180 \end{cases}$$

2.2 Other characteristics

2.2.1 Transmitting

- Peak e.i.r.p.: 71 dBW
- Pulse repetition frequency: 3 334 Hz
- Pulse duration: 0.333 μ s
- Pulse 3.5 dB bandwidth: 3 MHz.

2.2.2 Receiving

- Typical antenna gain: 8 dBi
- Typical noise figure: 8 dB.

3 Aircraft multipurpose radars (MPR)

The aircraft MPR is a radionavigation, radiolocation and weather radar.

3.1 Antenna patterns

The antenna is a parabola of approximately 0.3 m diameter which is scanned vertically and horizontally with respect to the heading and attitude of the aircraft:

- nominal 3 dB beamwidth: 4.5°
- frequency range: 15.4-15.7 GHz
- polarization: vertical
- typical gain: 30 dBi
- maximum horizontal scan range: $\pm 45^\circ$
- maximum vertical scan range: $\pm 20^\circ$.

The envelope pattern of the antenna is defined as follows where φ is the relative azimuth angle (degrees):

$$G(\varphi) = \begin{cases} 30 & \text{dBi} & \text{for } 0 \leq \varphi < 20 \\ 30 - 0.56(\varphi - 20)^2 & \text{dBi} & \text{for } 20 \leq \varphi < 25 \\ 16 & \text{dBi} & \text{for } 25 \leq \varphi < 29 \\ 39.86 - 25 \log(\varphi - 20) & \text{dBi} & \text{for } 29 \leq \varphi < 68 \\ -2.17 & \text{dBi} & \text{for } 68 \leq \varphi \leq 180 \end{cases}$$

3.2 Other characteristics

3.2.1 Transmitting

- Peak e.i.r.p.: 70 dBW
- Pulse repetition frequency: 800 Hz
- Pulse duration: 2 μ s
- Pulse 3.5 dB bandwidth: 0.5 MHz.

3.2.2 Receiving

- Typical antenna gain: 30 dBi
- Typical noise figure: 8 dB.

4 Radar sensing and measurement system (RSMS)

Measurement techniques using radar technology at 15 GHz are particularly suited to smaller aircraft, including helicopters, offering the benefits of compact, light, equipment with good antenna directivity and more than adequate performance for many operational radionavigation applications which are not practicable at lower frequencies due to propagation or other reasons. For use in a height measurement mode this higher frequency band confers system design benefits, such as lower cross coupling and absence of triangulation effects, which are particularly important for accurate measurement at very low (metric) separations. For some operational applications they present the only viable technical solution.

Systems using these techniques are widely used in certain parts of the world where they make an important contribution to the safety of aircraft operation. Measurement of height and ground clearance is one of the most critical parameters in the operation of aircraft when used to assist the final stages in a landing. High accuracy and interference free operation are vital to success and the enhancement of safety.

RSMS are essentially used in low level operations up to a nominal height of around 1 500 m. An antenna mounting which transmits and receives vertically downwards would be used in the great majority of applications. Power reduction proportional to height above terrain is employed to reduce scatter and other undesirable effects.

4.1 RSMS characteristics

4.1.1 Transmitter

- Frequency range: 15.63-15.65 GHz
- Peak power: 30 dBmW
- Antenna gain: 13 dBi, back lobes <5 dBi
- PRF (pulse repetition frequency): 58 kHz
- Pulse length (max.): 500 ns
- Duty cycle (max.): 3%
- Pulse 3.5 dB bandwidth: 2 MHz.

4.1.2 Receiver

- Antenna gain: 13 dBi, back lobes <5 dBi
- Noise figure: 6 dB.

ANNEX 2

Emission criteria for the aeronautical radionavigation service and sharing feasibility with feed links for the MSS (Earth-to-space) in the 15.4-15.7 GHz band

1 Introduction

A basic method for protecting non-GSO satellites from unacceptable interference is to establish maximum limits on the e.i.r.p. from aeronautical radionavigation stations and minimum e.i.r.p. limits on the emissions from the feeder-link earth stations.

Alternatively, only maximum e.i.r.p. limits on the aeronautical radionavigation stations can be established which define the interference environment in which the feeder links must be able to operate. This alternative appears more attractive in that it is simpler and allows maximum freedom for the design and operation of feeder links. This approach is addressed in the following sections.

Either of these methods is an effective way to eliminate the need for coordination. Coordination is not practical for this case.

2 Characteristics of aeronautical radionavigation systems

Several systems are identified that operate in this band. These include surface based radars (SBR) used on land and ships for the detection, location and movement of aircraft and other vehicles on aircraft landing areas, ALS, MPR and RSMS. The antenna patterns of these systems is an important element in determining the e.i.r.p. as a function of elevation angle. Antenna envelope gain patterns and other pertinent characteristics are given in Annex 1.

3 Analyses

3.1 Pulsed interference into digital carriers

Task Group 4/4 studied the interference from radars into digital carriers. Measurements were made over a wide range of pulse repetition frequencies (PRF), (1-100 kHz) and duty cycles, d , (0.01%-100%) for radar and data rates from 2 Mbit/s to 45 Mbit/s for 3/4 rate forward error correction (FEC) coded QPSK digital carriers operating at a bit error rate (BER) of 1×10^{-6} . An

empirical equation was developed from the measurement data which can be used to relate the peak pulsed radar e.i.r.p., E_p , to an effective e.i.r.p., E_{eff} , i.e., an e.i.r.p. which would cause the same level of interference (see Recommendation ITU-R S.1068). The actual average e.i.r.p., E_{ave} , is equal to the peak e.i.r.p. times the duty cycle. Under these conditions the empirical equation is:

$$E_{eff} = E_p - 15 \log (1 + 0.5(PRF/d)) \quad \text{dBW} \quad (1)$$

where PRF is in kHz and d is in per cent.

Since the pulse width, PW , is equal to (d/PRF) , equation (1) can be expressed as:

$$E_{eff} = E_p - 15 \log (1 + 5/PW) \quad \text{dBW} \quad (2)$$

where PW is in microseconds.

With a $[(\sin x)/x]^2$ power spectral density function the peak power density is approximately 3.5 dB greater than the power density averaged over a $2/PW$ bandwidth. The 3.5 dB bandwidth (BW) (MHz) is approximately $1/PW$. With this, the effective e.i.r.p. density E_{eff}/MHz , for feeder-link carrier bandwidths (BW) (MHz) that are less than $1/PW$ is:

$$E_{eff}/\text{MHz} = E_p - 10 \log (2/PW) + 3.5 - 15 \log (1 + 5/PW) \quad \text{dBW} \quad (3)$$

and for (BW) equal to or greater than $(1/PW)$ the (E_{eff}/MHz) averaged over (BW) is:

$$E_{eff}/\text{MHz} = E_p - 10 \log (2/PW) + 3.5 - 15 \log (1 + 5/PW) - 10 \log [(BW) (PW)] \quad \text{dBW} \quad (4)$$

3.2 Emission limits on aeronautical radionavigation stations

The SBRs can be accommodated in the band 15.63-15.7 GHz. By shifting the 15.45-15.65 GHz band to 15.43-15.63 GHz, interference to feeder links in the Earth-to-space direction does not need to be considered.

The dominant area of operation of the MPR is over the ocean which in most cases will be beyond the coordination distance of feeder-link earth stations, and thus would not require coordination with feeder-link earth stations. Therefore, the operation of the MPR in the 15.4-15.7 GHz band would be permitted even though geographical constraints would apply (see Annex 3). The RSMS currently operates in the 15.4-15.7 GHz band and geographical constraints may also apply.

The parameter values for equations (2), (3) and (4) for the ALS, MPR and RSMS aeronautical radionavigation systems are given in Annex 1 along with the antenna envelope gain functions. With this information the values of E_{eff} can be computed as a function of the elevation angle. The peak e.i.r.p. and PW are limited by equations (2), (3) and (4). The elevation angle, ϕ , is in degrees.

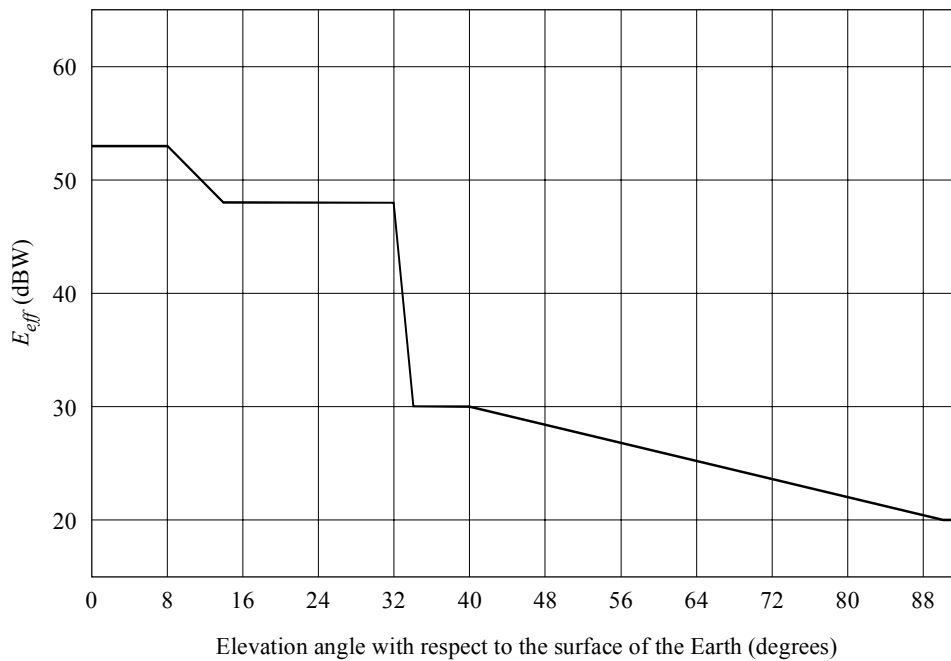
3.2.1 ALS E_{eff} limits

For feeder-link carrier bandwidths greater than 3 MHz:

$$E_{eff} = \begin{cases} 53 & \text{dBW} & \text{for } 0 \leq \varphi < 8 \\ 53 - 0.833(\varphi - 8) & \text{dBW} & \text{for } 8 \leq \varphi < 14 \\ 48 & \text{dBW} & \text{for } 14 \leq \varphi < 32 \\ 48 - 9(\varphi - 32) & \text{dBW} & \text{for } 32 \leq \varphi < 34 \\ 30 & \text{dBW} & \text{for } 34 \leq \varphi < 40 \\ 30 - 0.2(\varphi - 40) & \text{dBW} & \text{for } 40 \leq \varphi \leq 90 \end{cases}$$

This function is shown in Fig. 1.

FIGURE 1
ALS effective e.i.r.p., E_{eff} , limits



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3.2.2 MPR E_{eff} limits

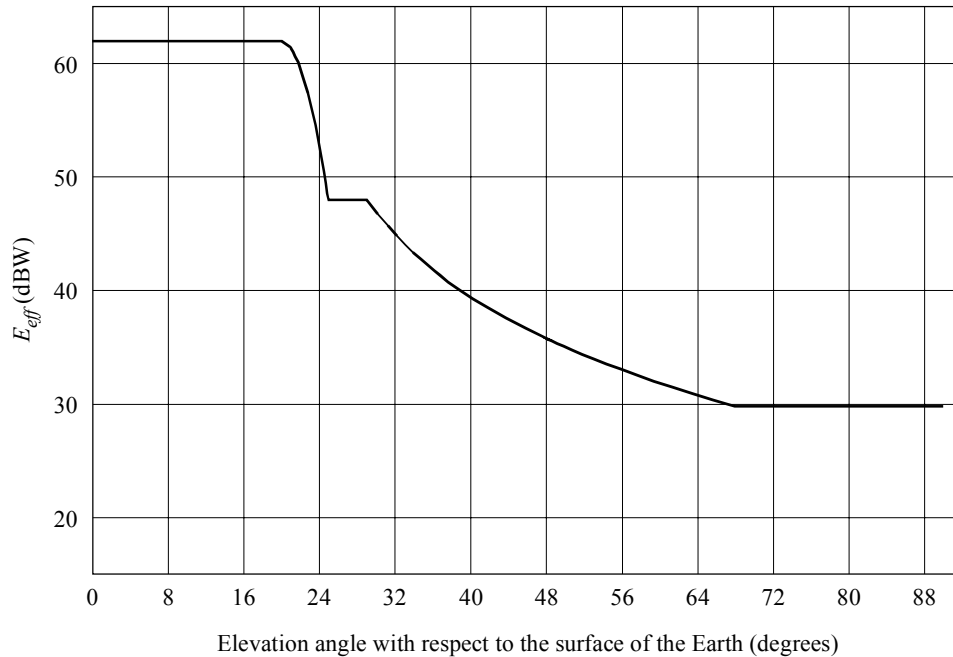
For feeder-link carrier bandwidths greater than 1 MHz:

$$E_{eff} = \begin{cases} 62 & \text{dBW} & \text{for } 0 \leq \varphi < 20 \\ 62 - 0.56(\varphi - 20)^2 & \text{dBW} & \text{for } 20 \leq \varphi < 25 \\ 48 & \text{dBW} & \text{for } 25 \leq \varphi < 29 \\ 71.86 - 25 \log(\varphi - 20) & \text{dBW} & \text{for } 29 \leq \varphi < 68 \\ 29.8 & \text{dBW} & \text{for } 68 \leq \varphi \leq 90 \end{cases}$$

This function is shown in Fig. 2.

The E_{eff} for the RSMS for elevation angles above 0° is -13.1 dBW.

FIGURE 2
MPR effective e.i.r.p., E_{eff} , limits



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3.3 Impact on feeder link up path e.i.r.p.

Protection from up-path interference due to aeronautical radionavigation stations can be achieved by providing adequate up-path e.i.r.p. from the earth station.

For the case of interference to a rate 3/4 FEC QPSK carrier, the carrier-to-interference, C/I , ratio for a 1×10^{-6} BER was about 9 dB for the measurements described in Section 3.1. This C/I is for the condition where interference from other sources is not significant. Since the percentage of time that a radionavigation station is operating and the -3 dB contour of its antenna is in conjunction with a satellite is very low, it is assumed that a C/I of 9 dB can be tolerated for this small percentage of time. For an uncoded QPSK carrier the C/I is about 12 dB.

The up-path e.i.r.p. required to overcome these interference envelopes as a function of the feeder-link carrier bandwidth can be computed by assuming that only one entry of one type will occur at any one time. In general, e.i.r.p. values in the 60 to 70 dBW range may be required.

4 Summary

- The effective e.i.r.p. limits given in § 3.2 are consistent with the operation of currently existing aeronautical radionavigation systems.
- Specifying the maximum interference environment which must be accepted by MSS feeder links allows the feeder-link designers and operators maximum flexibility to meet their service requirements and eliminates any need to specify orbit altitudes, satellite antenna pattern etc., which may be involved in specifying minimum e.i.r.p.s.
- The minimum feeder-link earth station e.i.r.p.s required to operate in the maximum interference environment given in § 3.3 in the Earth-to-space direction are readily achievable.

ANNEX 3

Coordination distances between feeder-link earth stations in the MSS operating in the Earth-to-space direction and stations in the aeronautical radionavigation service in the band 15.4-15.7 GHz

1 Aeronautical radionavigation system characteristics

Several systems are identified that operate in this band. These include aircraft landing systems (ALS) and airborne multipurpose radars (MPR). The characteristics and analyses necessary to determine coordination distances are given in the following section.

2 Coordination distances

2.1 Analyses

The coordination distance, D_c , necessary to ensure protection against interference from feeder-link earth stations in the MSS into stations operating in the aeronautical radionavigation service is computed as shown in the following paragraphs.

$$D_c = D_{fsl} + D_{oth} + D_{as} \quad \text{km} \quad (5)$$

where:

D_{fsl} : total radio line-of-sight distance (km)

D_{oth} : over-the-horizon distance corresponding to the necessary over the horizon loss (km)

D_{as} : distance from aircraft to landing surface (km) (applies to ALS and RSMS)

$$D_{fsl} = (2r h_1)^{0.5} + (2r h_2)^{0.5} \quad \text{km} \quad (6)$$

where:

r : radius of the Earth taken as 4/3 geometric to account for atmospheric refraction (8 500 km)

h_1 : ARNS station height (km)

h_2 : feeder-link earth station height (km)

$$L_{oth} = E_{esd} + 168.6 - L_{fsl} + G/T - I/N \quad \text{dB} \quad (7)$$

where:

L_{oth} : over-the-horizon propagation loss added to L_{fsl} (dB) (this function is shown in below and in Fig. 1 which is derived from the 5% functions for 15 GHz in Recommendation ITU-R P.528; i.e. loss exceeded 95% of the time)

E_{esd} : maximum e.i.r.p. density of the feeder-link earth station toward the horizon (this is taken as 54 dB(W/MHz))

L_{fsl} : free space loss computed for D_{fsl} (dB)

G/T : gain/noise temperature of the ARNS station (dB)

I/N : acceptable interference/noise of the ARNS station (dB).

The values of L_{oth} as a function of D_{oth} are as indicated in Table 1.

TABLE 1

D_{oth} (km)	L_{oth} (dB)	D_{oth} (km)	L_{oth} (dB)	D_{oth} (km)	L_{oth} (dB)
0	0	175	78	350	104
25	24	200	82	375	107
50	45	225	86	400	110
75	57	250	90	425	113
100	64	275	94	450	116
125	69	300	98	475	118
150	74	325	101	500	120

Values of D_{oth} for values of L_{oth} between those given may be extrapolated by:

$$D_{oth} = D_{ith} + 25[(L_{oth} - L_{ith}) / (L_{jth} - L_{ith})] \quad \text{km} \quad (8)$$

where:

L_{ith} : next lower value of L_{oth} in Table 1, from L_{oth} determined by equation (7)

L_{jth} : next higher value of L_{oth} in Table 1, from L_{oth} determined by equation (7).

2.2 Computed coordination distances

Given the equations and computation methods plus some parameter values in § 2.1 and the other necessary parameter values, coordination values are computed as indicated in Table 2:

TABLE 2

Parameter	ALS	MPR	RSMS
h_1 (km)	7.6	15	1.5
h_2 (km)	0.01	0.01	0.01
D_{fst} (km)	372	518	172.7
D_{as} (km)	100	0	40
L_{fst} (dB)	167.7	170.6	160.9
G/T (dB)	-22.7	-2.0	-24.4
I/N (dB)	-10	-10	-10
L_{oth} (dB)	42.2	60	47.3
D_{oth} (km)	46.7	85.7	54.8
D_c (km)	518.7	603.7	267.5

A coordination distance of 600 km can be used for the MPR. The dominant mode of operation of the MPR is over ocean areas, which in most cases will be beyond 600 km of feeder-link earth stations and this would not require coordination. If feeder-link earth stations were located inland the areas of operation over the ocean would be enhanced.

2.3 Reduction of earth station limits

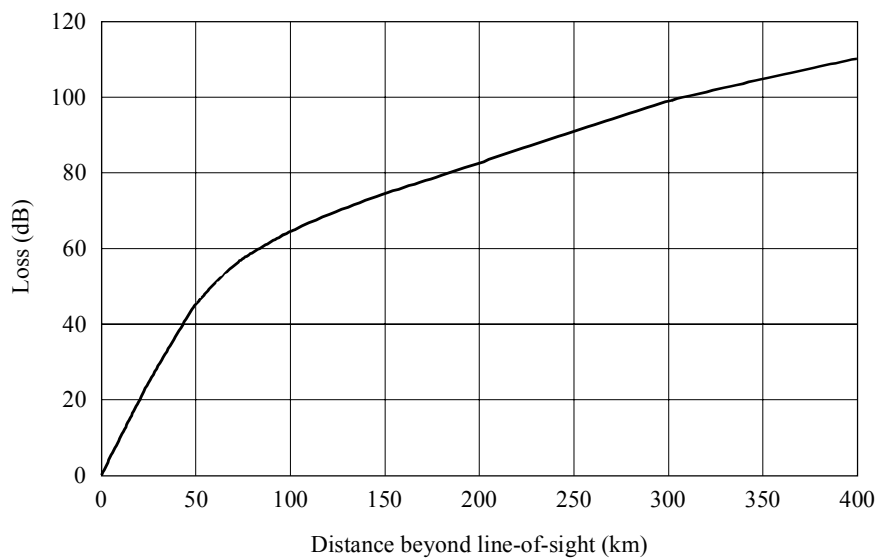
Reducing the maximum e.i.r.p. density limit toward the horizon of the feeder-link earth station should reduce the coordination distance. Using the function in Fig. 3, coordination distances versus E_{esd} are as indicated in Table 3:

TABLE 3

E_{esd} (dB(W/MHz))	ALS (km)	MPR (km)	RSMS (km)
54	519	604	268
44	507	573	254
34	495	561	242
24	485	549	231

It is evident that the coordination distance for the ALS, MPR and RSMS where the distance is largely line-of-sight is not very sensitive to the e.i.r.p. density radiated toward the horizon.

FIGURE 3
Loss added to free space loss at line-of-sight



1340-03

3 Summary

- The maximum emissions from a feeder-link earth station in the local horizontal plane should be limited to 54 dB(W/MHz).
- With this limit a coordination threshold distance of about 515 km is needed to protect ALS stations operating in the aeronautical radionavigation service from unacceptable interference from feeder-link earth station emissions. The distance is about 600 km for the MPR and 270 km for the RSMS.
- The coordination threshold distance for the ALS, MPR and RSMS are not significantly reduced by reducing the maximum allowable emissions from feeder-link earth stations.

The method above can be used in conjunction with other mitigation techniques to minimize the separation distances during coordination.

4 Mitigation factors for reducing the separation distance within the coordination distance

The following considerations should be taken into account where it is necessary for a feeder-link earth station operating in the Earth-to-space direction to be located within the coordination distance:

- Typically, feeder-link earth stations will have antenna beamwidths of less than 1° and operate at elevation angles of more than 5° . This will reduce the e.i.r.p. towards the aeronautical radionavigation station and thus reduce the separation distance.
 - If the horizontal scan limits of the ALS aircraft landing system do not include the azimuth toward the feeder-link earth station, the air space for the aircraft landing system is not in line with the feeder-link earth station which potentially could reduce the separation distance by up to 100 km.
 - Use of an earth mound specifically constructed around the feeder-link earth station antenna(s) to provide additional isolation toward the aeronautical radionavigation station.
 - The geographical location of the feeder-link earth station can be considered to take advantage of natural terrain blocking which will increase the propagation path loss.
 - Any aircraft antenna discrimination that would exist when the aircraft is in the air space of the aircraft landing system and is using the landing system.
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