RECOMMENDATION ITU-R S.1341*

# SHARING BETWEEN FEEDER LINKS FOR THE MOBILE-SATELLITE SERVICE AND THE AERONAUTICAL RADIONAVIGATION SERVICE IN THE SPACE-TO-EARTH DIRECTION IN THE BAND 15.4-15.7 GHz AND THE PROTECTION OF THE RADIO ASTRONOMY SERVICE IN THE BAND 15.35-15.4 GHz

(Question ITU-R 242/4)

(1997)

The ITU Radiocommunication Assembly,

*considering*

a) that Resolution 116 (WRC-95) of the World Radiocommunication Conference (Geneva, 1995) calls for studies by the ITU-R of the sharing situation between feeder links (space-to-Earth) for the mobile-satellite service (MSS) and the aeronautical radionavigation service in the band 15.4-15.7 GHz;

b) that the band 15.4-15.7 GHz is allocated to the aeronautical radionavigation service on a primary basis and that No. 953 (S4.10) of the Radio Regulations (RR) applies;

c) that the WRC-95 has added an allocation to the fixed-satellite service in this band for feeder links of non-geostationary (non-GSO) networks in the MSS in the space-to-Earth direction;

d) that the requirements for feeder links (space-to-Earth) of non-GSO satellite systems need to be accommodated in this band;

e) that emissions from satellites can cause harmful interference to stations in the aeronautical radionavigation service;

f) that power flux-density (pfd) limitations have been placed on the emissions from non-geostationary space stations to protect the aeronautical radionavigation service in accordance with No. S5.511A of the RR, which are subject to review by the ITU-R;

g) that the coordination of satellite emissions with aeronautical radionavigation stations is not considered practical;

h) that emissions from aeronautical radionavigation stations propagated along the Earth's surface can cause unacceptable interference to feeder-link earth stations;

j) 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 feeder-link earth stations;

k) that aircraft stations are not permitted to transmit in the band 15.45-15.65 GHz in accordance with No. S5.511B of the RR;

l) that there is fairly extensive use of this band by the aeronautical radionavigation service for airborne, land and ocean based stations;

m) that the technical and operational characteristics of the aeronautical radionavigation stations are reasonable well defined;

n) that the technical and operational characteristics of feeder links are not well defined;

o) that satellite systems in this frequency range usually do not operate with low earth station antenna elevation angles;

p) that studies have been made with respect to § o;

* This Recommendation should be brought to the attention of Radiocommunication Study Groups 7 and 8.

q) that the adjacent band 15.35-15.4 GHz is allocated to the radio astronomy service and other passive services and that protection from harmful interference due to emissions from space stations is needed (see No. S5.511A of the RR);

r) that all emissions are prohibited in the band 15.35-15.4 GHz in accordance with No. S5.340 except those provided for in No. S5.341;

s) that Recommendation ITU-R RA.769 provides threshold levels of detrimental interference for the radio astronomy service,

*recommends*

**1** that feeder links for the MSS should be limited to the band 15.43-15.63 GHz (Note 1);

**2** that provisionally the pfd at the Earth's surface produced by emissions from the feeder links of a space system of non-GSO satellites for all conditions and for all methods of modulation should not exceed the values given in 2.1 under the condition given in § 2.2 (Note 2);

**2.1** in the frequency band 15.43-15.63 GHz, where φ is the angle of arrival (degrees) above the local horizontal plane:

$$
\begin{array}{llll}
-127 & \text{dB(W/m}^2\text{) in 1 MHz} & \text{for} & 0 \le \varphi < 20 \\
-127 + 0.56\,(\varphi - 20)^2 & \text{dB(W/m}^2\text{) in 1 MHz} & \text{for} & 20 \le \varphi < 25 \\
-113 & \text{dB(W/m}^2\text{) in 1 MHz} & \text{for} & 25 \le \varphi < 29 \\
-136.9 + 25 \log(\varphi - 20) & \text{dB(W/m}^2\text{) in 1 MHz} & \text{for} & 29 \le \varphi < 31 \\
-111 & \text{dB(W/m}^2\text{) in 1 MHz} & \text{for} & 31 \le \varphi \le 90
\end{array}
$$

**2.2** that these limits relate to the pfd which would be obtained under assumed free-space propagation conditions;

**3** that with the pfd limits given in *recommends* 2 coordination of satellite emissions with receiving stations in the aeronautical radionavigation service is not required;

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

**5** that the threshold distance for the coordination of emissions from stations in the aeronautical radionavigation service with respect to feeder-link earth stations for the MSS based on an earth station antenna gain in the local horizontal plane of 11.5 dBi are:

– 150 km from the ground segment for aircraft landing system (ALS);

– 600 km from aircraft using general purpose radars;

– 60 km from the aircraft landing surface for radar sensing and measurement systems;

**6** that feeder-link earth stations should limit their operation to angles above the local horizontal plane of at least 5°;

**7** that emissions from the feeder links of a space system of non-GSO satellites for all conditions and all methods of modulation should take into account the threshold levels for the radio astronomy service given in Recommendation ITU-R RA.769 for the band 15.35-15.4 GHz (see Note 3);

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

NOTE 1 – The bandwidth given in *recommends* 1 is smaller than that allocated by WRC-95 for non-GSO MSS feeder links. 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 – The feasibility to design and operate feeder links in the space-to-Earth direction with the provisional pfd limits given in *recommends* 2.1 has not yet been studied. Further, the provisional pfd values given in *recommends* 2.1 should be reviewed to ensure protection to the ARNS.

NOTE 3 – Additional design and operational constraints may be placed on MSS space-to-Earth feeder links in order to take into account the threshold levels for the radio astronomy service given in ITU-R RA.769 per *recommends* 7.

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: <3.5° vertical, inverted cosecant to –31°
  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: ± 1.5°;

– 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):

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

#### 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):

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

### 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 μs

– 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<br>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<br>6.5° vertical

– the vertical pattern is spoiled to achieve at least a 20 dBi gain at 20 degrees 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: ± 35°.

### 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):

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

#### 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):

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

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

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

### 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 μs

– 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 ± 45°

– maximum vertical scan range ± 20°.

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

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

## 3.2 Other characteristics

### 3.2.1 Transmitting

– Peak e.i.r.p.: 70 dBW

– Pulse repetition frequency: 800 Hz

– Pulse duration: 2 μs

– 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: 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

# Protection criteria for the aeronautical radionavigation service and sharing feasibility with feeder links for the MSS (space-to-Earth) in the 15.4-15.7 GHz band and protection of the radio astronomy service in the band 15.35-15.4 GHz (Surface based radars (SBR), used on land and ships for the detecting, location and movement of aircraft and other vehicles on aircraft landing areas)

## 1 Characteristics of aeronautical radionavigation systems

Several systems are identified that operate in this band. These include land and ship based surface detection radars (SBR), ALS, MPR, and RSMS. The antenna patterns of these systems are an important element in determining the pfd as a function of elevation angle. Antenna envelope gain patterns and the other pertinent characteristics are given in Annex 1.

## 2 Analyses

### 2.1 Worst case pfd limits

The general expression for the calculation of a pfd limit for this case is:

$$pfd \leq -217.6 + 10 \log B - 20 \log \lambda - G/T + I/N \qquad \text{dB}(\text{W/m}^2) \text{ in } B \qquad (1)$$

where:

$B$: bandwidth (Hz)

$\lambda$: wave length (m)

$G/T$: antenna gain/noise temperature (dB)

$I/N$: allowable interference/noise (dB)

Since these systems operate in the ARNS and are considered as Safety Service systems, the protection requirements may be more severe than for other services. Assuming an $I/N$ limit of –10 dB, the solution of equation (1) for the SBR parameters given in Annex 1 results in a pfd limit of –146 dB(W/m$^2$) in 1 MHz. Solution of equation (1) for the systems parameters given in Annex 1 results in a pfd limit of –111 dB(W/m$^2$) in 1 MHz for the ALS and RSMS, and –133 dB(W/m$^2$) in 1 MHz for the MPR. These values are based on the maximum antenna gains for these systems.

The pfd limit of –146 dB(W/m$^2$) in 1 MHz implies the use of very large earth station antennas (larger than 15 m diameter) which are not considered practical (see § 2.3). However, the SBRs can be accommodated in the 15.63-15.7 GHz band and this would remove this restriction in a feeder-link band of 15.43-15.63 GHz.

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 imposes no significant pfd restriction, but geographical constraints may apply.

A pfd limit of -133 dB(W/m$^2$) in 1 MHz at low elevation angles of arrival may unduly constrain the implementation of MSS feeder-link earth stations. A pfd of –127 dB(W/m$^2$) in 1 MHz results in earth station antenna diameters that are one-half those imposed by a pfd of –133 dB(W/m$^2$) in 1 MHz. (See 2.3.) Since the MPR uses a narrow beam scanning antenna, interference will occur for short periods of time when its main beam is directed at a satellite. Additionally, normal operation of the MPR need not be considered as a Safety Service. Thus an increase in system noise of up to 40 per cent could be tolerated for short periods of time, which results in a pfd limit of –127 dB(W/m$^2$) in 1 MHz.

## 2.2 pfd limits versus angle of arrival

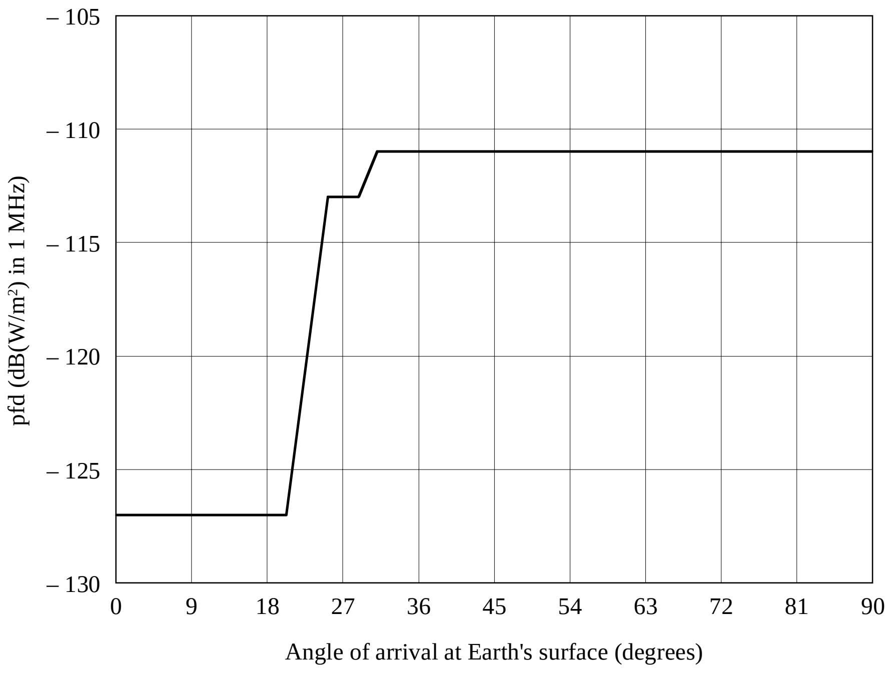
From 2.1 the ALS and MPR would operate in the 15.4-15.7 GHz band including the 15.43-15.63 GHz band shared with feeder links.

Combining the pfd values in 2.1 with the antenna gain functions given in Sections 2 and 3 of Annex 1 results in the pfd limits given below and shown in Fig. 1, where φ is in degrees, i.e.;

$$
pfd \begin{cases}
\leq -127 & \text{dB(W/m}^2\text{) in 1 MHz} \quad \text{for} \quad 0 \leq \varphi < 20 \\
\leq -127 + 0.56\,(\varphi - 20)^2 & \text{dB(W/m}^2\text{) in 1 MHz} \quad \text{for} \quad 20 \leq \varphi < 25 \\
\leq -113 & \text{dB(W/m}^2\text{) in 1 MHz} \quad \text{for} \quad 25 \leq \varphi < 29 \\
\leq -136.9 + 25 \log(\varphi - 20) & \text{dB(W/m}^2\text{) in 1 MHz} \quad \text{for} \quad 29 \leq \varphi < 31 \\
\leq -111 & \text{dB(W/m}^2\text{) in 1 MHz} \quad \text{for} \quad 31 \leq \varphi \leq 90
\end{cases}
$$

FIGURE 1

**Maximum satellite pfd limits (ALS, MPR and RSMS)**

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## 2.3 Impact on feeder-link parameters

Satellite emissions will always occur at low angles of arrival at the surface of the Earth. At low angles the pfd limit is –127 dB(W/m$^2$) in 1 MHz. The diameter of an earth station antenna, $D$, for a given pfd may be computed by:

$$D = \left[(C/N)_t \, (k\, T\, B \,/\, pfd)\,(4M \,/\, \pi\,\eta)\right]^{0.5} \qquad \text{m} \tag{2}$$

where:

- $(C/N)_t$ : threshold carrier-to-noise ratio
- $k$ : Boltsman’s constant
- $T$ : receiving system noise temperature (K)
- $B$ : bandwidth in (Hz) as used in pfd
- $M$ : margin
- $\eta$ : antenna aperture efficiency.

MSS feeder-link earth stations are typically designed to provide link availability of around 99.99%. For operation at elevation angles below 20° (depending on the rain climatic zone of operation) the rain fade margin requirement combined with the requirement to meet the –127 dB(W/m$^2$) in 1 MHz pfd limit may constrain the implementation of MSS feeder-link earth stations in the 15.43-15.63 GHz frequency band.

Assuming a $(C/N)_t$ of 12 dB, a value of $T$ of 24 dB(K), a $\eta$ of 0.6 and values of pfd of –127 dB(W/m$^2$) in 1 MHz, –133 dB(W/m$^2$) in 1 MHz, and –146 dB(W/m$^2$) in 1 MHz in equation (2) results in the following values of $D$:

TABLE 1

| $M$ (dB) | pfd | | |
|---|---|---|---|
| | –127 dB(W/m$^2$) in 1 MHz | –133 dB(W/m$^2$) in 1 MHz | –146 dB(W/m$^2$) in 1 MHz |
| | $D$ (m) | $D$ (m) | $D$ (m) |
| 7 | 1.7 | 3.4 | 15 |
| 10 | 2.4 | 4.8 | 22 |
| 13 | 3.4 | 6.8 | 30.4 |
| 16 | 4.8 | 9.6 | 43 |
| 19 | 6.8 | 13.6 | 61 |
| 22 | 9.6 | 19.2 | 86 |
| 25 | 13.6 | 27.1 | 121 |
| 28 | 19.2 | 38.3 | 171 |

## 2.4 Interference from non-GSO satellites into radio astronomy receivers in the 15.35-15.4 GHz band

Recommendation ITU-R RA.769 provides threshold levels of detrimental interference for the primary radio astronomy service in the band 15.35-15.4 GHz. These levels are –156 dB(W/m$^2$) in 1 MHz and –233 dB(W/m$^2$) in 1 Hz at the surface of the Earth. Assuming that the per Hz value can be extrapolated to one MHz, this would be –173 dB(W/m$^2$) in 1 MHz. A value of –127 dB(W/m$^2$) in 1 MHz applies for angles of arrival up to about 20°, rising to –111 dB(W/m$^2$) in

1 MHz above about 30° in the 15.43-15.63 GHz band. This requires about 46 dB discrimination at 15.4 GHz rising to 62 dB above 30°. A value of 62 dB is achievable with a 6 pole (0.1 dB ripple) filter in 30 MHz with a 50 MHz passband. Operation of space-to-Earth links very near 15.4 GHz does not seem possible. However, if the 15.4-15.43 GHz band is not used by feeder links there would be a 30 MHz guard band in which band pass filters and other means could be employed to protect the radio astronomy service in the 15.35-15.4 GHz band.

The out-of-band emission levels of the feeder links should take into account the needs of the radio astronomy service in the band 15.35-15.4 GHz.

## 3 Summary

The pfd limits given in Section 2.2 are necessary for the protection of the aeronautical radionavigation service from interference from feeder links operating in the space-to-Earth direction in the 15.4-15.7 GHz band.

ANNEX 3

# Coordination distances between feeder-link earth stations in the MSS operating in the space-to-Earth 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 ALS and MPR. The characteristics and analyses necessary to determine coordination threshold distances are given in the following sections.

## 2 Coordination distances

### 2.1 Analyses

The coordination distance, $D_c$, necessary to ensure that potentially unacceptable interference from aeronautical radionavigation stations into feeder-link earth stations in the MSS does not occur, may be computed as shown in the following paragraphs:

$$D_c = D_{fsl} + D_{oth} + D_{as} \qquad \text{km} \tag{3}$$

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 landing surface (applies to ALS and RSMS)

$$D_{fsl} = (2r\, h_1)^{0.5} + (2r\, h_2)^{0.5} \qquad \text{km} \tag{4}$$

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)

$$L_{oth} = E_{eff}/\text{MHz} + 168.6 - L_{fsl} + G(\varphi) - 10 \log T - I/N \qquad \text{dB} \tag{5}$$

where:

$L_{oth}$: over the horizon loss added to $L_{fsl}$ (dB). (This function is shown below and in Fig. 2 which is derived from the 5% functions for 15 GHz in Recommendation ITU-R P.528; i.e., loss exceeded 95% of the time.)

$E_{ef}$/MHz: maximum effective e.i.r.p. density of the ARNS station toward the horizon – (see Annex 2 of Recommendation ITU-R S.1340)

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

$G(\varphi)$: gain of the feeder-link antenna as a function of angle φ above the horizon (dBi)

$T$: noise temperature of earth station (K)

$I/N$: acceptable interference/noise of the feeder-link earth station (dB).

The value of $D_{oth}$ for a value of $L_{oth}$ is determined from the following Table 2:

TABLE 2

| $D_{oth}$ (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 in Table 2 are interpolated by:

$$D_{oth} = D_{ith} + 25\left[(L_{oth} - L_{ith}) / (L_{jth} - L_{ith})\right] \qquad \text{km} \qquad (6)$$

where:

$L_{ith}$: next lower value of $L_{oth}$ in table, from $L_{oth}$ determined by equation (5)

$L_{jth}$: next higher value of $L_{oth}$ in table, from $L_{oth}$ determined by equation (5)

## 2.2 Computed coordination distances

The parameters in the Table 3 are used for determining coordination distances.

If the horizontal plane is in the side lobes of the earth station antenna, then:

$$L_{oth}\ (\text{dB}) = 87.2 - 25 \log \varphi \qquad \text{for the ALS} \qquad (7)$$

$$L_{oth}\ (\text{dB}) = 75.0 - 25 \log \varphi \qquad \text{for the MBR}$$

The side-lobe envelope gain is taken as 29 – 25 log φ in dBi where φ is in degrees.

Using equation (7) for $L_{oth}$ and determining the corresponding distances from equations (6) and (3) results shown in Table 4 for the ALS and MPR. The RSMS distances are within line-of-sight.

TABLE 3

| Parameter | ALS | MBR | RSMS |
|---|---|---|---|
| $h_1$ (km) | 0.01 | 15 | 1.5 |
| $h_2$ (km) | 0.01 | 0.01 | 0.01 |
| $D_{fsl}$ (km) | 26 | 518 | 25[(1)] |
| $D_{as}$ (km) | 0 | 0 | 40 |
| $L_{fsl}$ (dB) | 145 | 171 | NA |
| 10 log $T$ (dB(K)) | 24 | 24 | 24 |
| $I/N$ (dB) | –10 | –10 | –10 |
| $E_{eff}$/MHz (dBW) | 48.2 | 62 | –13.1 |
| $L_{oth}$ (dB) | 69.7 | 57.4 | 0 |
| $D_{oth}$ (km) | 129 | 77 | 0 |
| $D_c$ (km) | 155 | 595 | 65 |

(1) This is based on free space propagation for an angle of arrival at the earth station of 3.2°.

TABLE 4

| Elevation angle φ (degrees) | Coordination distances (km) | | |
|---|---|---|---|
| | ALS | MPR | RSMS |
| 5 | 155 | 595 | 65 |
| 10 | 120 | 578 | 54 |
| 15 | 104 | 569 | 47 |
| 20 | 96 | 565 | |
| 25 | 91 | 562 | |
| 30 | 87 | 560 | |

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 oceans would be enhanced.

## 3 Mitigation factors for reducing the separation distance within the coordination threshold distance

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

– Typically, feeder-link earth stations will have antenna beamwidths of less that 1° and operate at elevation angles of more than 5°. Thus considerable earth station antenna discrimination can be achieved with respect to surface based interfering emissions.

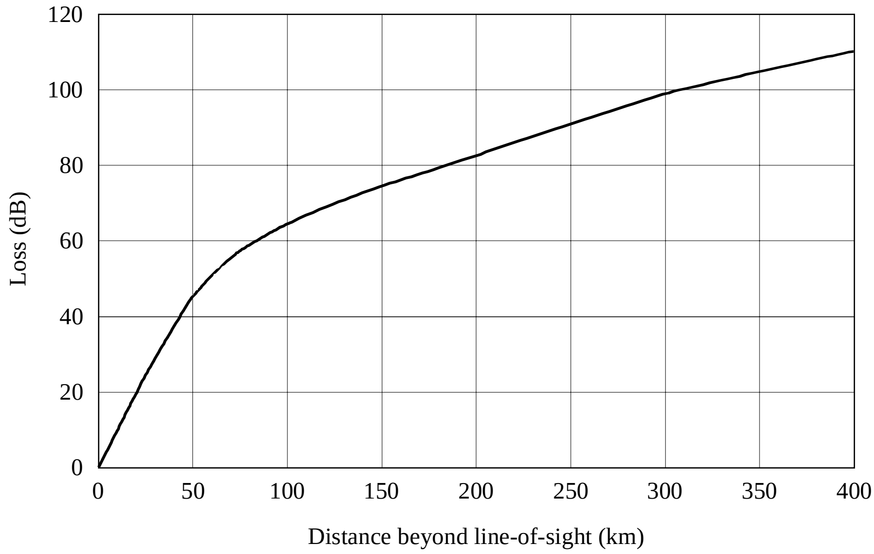
– The surface based aeronautical radionavigation stations may also provide additional antenna discrimination depending on their operations. This is particularly true for the ALS, where the horizontal scan limits do not include the azimuth toward the earth station (see Annex 1).

– Use of an earth mound specifically constructed around the feeder-link earth station antenna(s) to provide additional receiving discrimination for the feeder-link earth 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.

FIGURE 2

**Loss added to free space loss at line-of-sight**

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## 4 Summary

– A method for determining the coordination distances needed for the protection of feeder-link earth stations from interference from aeronautical radionavigation stations in the 15.4-15.7 GHz band is presented in this annex.

– This method can also be used in conjunction with interference mitigation techniques to minimize the separation distances during coordination.

– With an elevation angle constraint of 5° so that only the feeder link earth station antenna side lobes are directed toward the horizon, a coordination distance in the order of 150 km is reasonable for the ALS and 60 km for the RSMS as measured from the landing surface.

– MPRs can operate without coordination at distances greater than 600 km from a feeder-link earth station, (e.g., over ocean areas).