|  |  |
| --- | --- |
| **US Radiocommunications Sector**  **Fact Sheet** | |
| **Working Party:** ITU-R WP 5B | **Document No:** USWP5B29-10 |
| **Reference:** M.1730, M.2170 | **Date:** 08 June 2022 |
| **Document Title:** Working document towards a Preliminary Draft New Report “Compatibility analysis and results for radiolocation systems operating in the 15.4 to 17.3 GHz band and other incumbent services as well as with the radio astronomy service operating in the adjacent band 15.35-15.40 GHz” | |
| **Author(s)/Contributors(s):**  Andrew Meadows  Air Force  Dominic Nguyen  eSimplicity for AFSMO  Loulit Legesse Tefera  eSimplicity for AFSMO | Phone : 334-467-4720  E-mail : [andrew.meadows.1@us.af.mil](mailto:andrew.meadows.1@us.af.mil)  Phone : 703-606-7394  E-mail : [dominic.nguyen@esimplicity.com](mailto:dominic.nguyen@esimplicity.com)  Phone : 240-863-2334  E-mail : [loulit.tefera@esimplicity.com](https://esimplicitycom.sharepoint.com/tc/Shared%20Documents/AFSMO%20-%20DSAT/WRC-23/ITU-R%20Working%20Parties/WP5B/6th%20Meeting%20-%20July%202022/US%20Prep/AFSMO%20Contribution/2170/loulit.tefera@esimplicity.com) |
| **Purpose/Objective:** This contribution proposes a Working document towards a Preliminary Draft New Report “Compatibility analysis and results for radiolocation systems operating in the 15.4 to 17.3 GHz band and other incumbent services as well as with the radio astronomy service operating in the adjacent band 15.35-15.40 GHz”. | |
| **Abstract:** ITU-R Report M.2170-0 contains the sharing studies between radiolocation and other incumbent services in the frequency bands between 15.4 and 17.3 GHz. This Recommendation was approved in 2009. During the November 2021 meeting, France raised concern on the new power of System 6. This contribution provides sharing studies between radiolocation, which has a new power, and other incumbent services in the frequency bands between 15.4 and 17.3 GHz. Furthermore, a sharing study is done for the updated radiolocation system 6 and RAS in the 15.35 to 15.40 GHz range. | |
| **Fact Sheet preparer:** Dominic Nguyen and Loulit Legesse Tefera | |

|  |  |
| --- | --- |
| **Radiocommunication Study Groups** | Logo  Description automatically generated |
|  |  |
|  |  |
| Source: Document 5B/  Subject: WRC-23 agenda item 1.10 | **Document 5B/XX** |
| **XX July 2022** |
| **English only** |

|  |  |  |
| --- | --- | --- |
| |  | | --- | |  | | **United States of America**  Compatibility analysis and results for radiolocation systems operating in the 15.4 to 17.3 GHz band and other incumbent services as well as with the radio astronomy service operating in the adjacent band 15.35-15.40 GHz |  Introduction The United States of America would like to conduct compatibility analyses between radiolocation and other incumbent services in the frequency band 15.4-17.3 GHz as well as with the adjacent Radio Astronomy service in the 15.35 to 15.40 GHz range.  Attachment: Revisions are presented for consideration. |

ATTACHMENT

Compatibility analysis and results for radiolocation systems operating  
in the 15.4 to 17.3 GHz band and aircraft landing system operating in the  
15.4-15.7 GHz band as well as the radio astronomy service operating  
in the adjacent band 15.35-15.40 GHz, FSS systems  
and aeronautical radionavigation systems

(202X)

# 1 Introduction

Prior compatibility analyses between radiolocation and the automatic landing systems, aeronautical radionavigation systems, and fixed satellite services in the frequency band 15.4 to 15.7 GHz, as well as the radio astronomy services operating in the adjacent bands 15.35 to 15.4 GHz, showed that sharing was feasible. In preparation for WRC-23, the radiolocation parameters were revised. This document shows the compatibility analysis between the radiolocation system with the updated parameters and the other incumbent services in the frequency bands 15.4 to 15.7 GHz as well as the radio astronomy services operating in the adjacent bands 15.35 to 15.4 GHz.

# 2 Systems characteristics

The following section contains the radiolocation technical characteristics that will be used in the compatibility analyses.

## 2.1 Radiolocation System Characteristics

A Preliminary Draft Revision of Recommendation ITU-R M.1730-1 contains technical characteristics and protection criteria for radiolocation radars in the band 15.4-17.3 GHz band. The band 15.4-17.3 GHz is already allocated to the radiolocation service on a primary basis. The radiolocation System‑6 is used in the compatibility analysis for this Report and the characteristics are shown in Table 1.

TABLE 1

Radiolocation systems characteristic in the 15.4-17.3 GHz band

| Characteristics | System‑6 |
| --- | --- |
| Function | Search, track and ground-mapping  (multi-function) |
| Platform type | Airborne (300 - 13 700 m) |
| Tuning range (GHz) | 15.4-17.3 |
| Modulation | Linear FM chirp |
| Transmit peak power (W) | 500, 2k, 10k |
| Pulse width (μs) | 0.05-50 |
| Pulse rise/fall time (ns) | 5-100 |
| Pulse repetition rate (pps) | 200-20 000 |
| Maximum duty cycle | Up to 0.2(1) |
| Output device | Travelling wave tube |
| Antenna pattern type | Pencil (ITU-R M.1851 cosine square distribution) |
| Antenna type | Phased array |
| Antenna polarization | Linear |
| Antenna gain (dBi) | 35 |
| Antenna elevation beamwidth (degrees) | 3.2 |
| Antenna azimuthal beamwidth (degrees) | 3.2 |
| Antenna horizontal scan rate | 1-30°/s |
| Antenna horizontal scan type (continuous, random, sector, etc.) | ±45° (electronic) |
| Antenna vertical scan rate | 1, 5°/s |
| Antenna vertical scan type | +5° to −45° (electronic) |
| Antenna 1st side-lobe level | 3.5 dBi at 5.2° |
| Antenna height | Aircraft altitude |
| Receiver IF −3 dB bandwidths (MHz) | 25 |
| Receiver noise figure (dB) | 5 |
| Minimum discernible signal (dBm) | −100 |
| Chirp bandwidth (MHz) | < 1 900 (2) |
| Transmitter RF emission bandwidth (MHz):  −3 dB  −20 dB | 1 850 1 854 |
| 1. Sharing studies will be conducted using multiple duty cycles from low duty cycles such as 0.01 to high duty cycles up to 0.2. 2. Sharing studies will focus on chirp bandwidths greater than 1 600 MHz. | |

# 3 Compatibility analysis/methodology

## 3.1 Aircraft Landing Systems (ALS) Characteristics

The technical characteristics of ALS systems that operate in the 15.4-15.7 GHz band can be found in a working document towards a preliminary draft new Recommendations ITU-R M.[15.4-15.7\_GHZ\_ARNS]. This section provides an overview and characteristics of an ALS system that operates in the 15.4-15.7 GHz band which is implemented by some administrations.

Some ARNS systems are installed in unmanned aircraft (UA) or on the ground to detect non-cooperative aircraft as a surveillance system contributing to the UA detect and avoid (DAA) system. These radars are used for collision avoidance on-board UA and can be used as a part of the integration of unmanned aircraft system (UAS). Some ARNS systems are used for landing.

Table 2 lists the technical characteristics of the ALS transmitter and receiver used in the analysis.

TABLE 2

Aircraft landing systems characteristics in the 15.4-15.7 GHz band

|  |  |  |
| --- | --- | --- |
| Characteristics | Aircraft landing system | |
| Function | Transmitter | Receiver |
| Platform type | Located at the landing site/ship | Airborne platform |
| Tuning range (GHz) | 15.4-15.7 | |
| Modulation | Pulse | N/A(1) |
| Transmit peak power (W) | 2 500 |
| Pulse width (μs) | 0.3 |
| Pulse rise/fall time (ns) | 25-50/25-200 |
| Pulse repetition rate (pps) | 15 000 |
| Maximum duty cycle | 0.05 |
| Antenna pattern type | Parabolic reflector | Horn |
| Antenna gain (dBi) | Azimuth 32 – Elevation 26 | 6 |
| Antenna elevation beamwidth (degrees) | 1.3 horizontal 6 vertical | 36 |
| Antenna azimuthal beamwidth (degrees) | 40 horizontal  2 vertical | 70 |
| Antenna horizontal scan type | Sector | Fixed |
| Antenna vertical scan type | Sector | Fixed |
| Antenna 1st side-lobe level | At least 17 dB below peak | At least 17 dB below peak |
| Antenna height (m) | Land: 10  Ship: 15-24 | 2 000 (maximum height) |
| Receiver IF −3 dB bandwidths (MHz) | N/A | 12 |
| Receiver noise figure (dB) | N/A | 11.5 |
| Minimum discernable signal (MDS) (dBm) | N/A | −72 |

(1) Not applicable.

## 3.2 ALS Compatibility Methodology and Assumptions

For this analysis, the interference to noise ratio (I/N) will be calculated, as shown in subsequent paragraphs, to assess compatibility between radiolocation systems operating in the 15.4-17.3 GHz band and a typical ALS system that operates in the 15.4-15.7 GHz band.

The initial step in assessing compatibility is the determination of the noise power which is given by:

*N =* –204 dBW + 10 log(*BIF* (Hz)) + *NF* (1)

where:

*BIF*: receiver IF bandwidth (Hz);

*NF* : receiver noise figure (dB).

The following equation can be used to determine if interference to the aircraft ALS receiver from System‑6 transmissions is likely to occur and what separation distance is required to eliminate the interference:

*I* = *PTx* + *GTx* + *GRx* – *LTrans* – *FDR* (2)

where:

*I* : interference, peak power of the radar pulses at the receiver (dBW)

*PTx*: peak power of the interfering system (dBW)

*GTx* : antenna gain of the interfering transmitter in the direction of the victim receiver (dBi)

*GRx* : antenna gain of the victim receiver in the direction of the interfering transmitter (dBi)

*LTrans* : transmission loss between transmitting and receiving antennas (dB) using Recommendation ITU-R P.528-5 depending on the analysis type.

*FDRIF* : frequency-dependent rejection produced by the receiver IF selectivity curve on an unwanted transmitter emission spectra (dB).

Since the radars will operate on a co-frequency basis, only the on-tune rejection (OTR) is considered. OTR for non‑coherent chirped pulsed signals is given by Recommendation M.1461-2:

*OTR* = 10 log (*BC* / (*BR*2 *T*)) for BC / (BR2 T) > 1 (3)

Otherwise OTR = 0

where:

*BR*: receiver bandwidth (MHz)

BC: transmitter chirped bandwidth during the pulse width, T (MHz)

T: chirped pulse width (s).

The ALS receiver protection criterion as described in the working document towards a preliminary draft new Recommendations ITU-R M.[15.4-15.7\_GHZ\_ARNS] is:

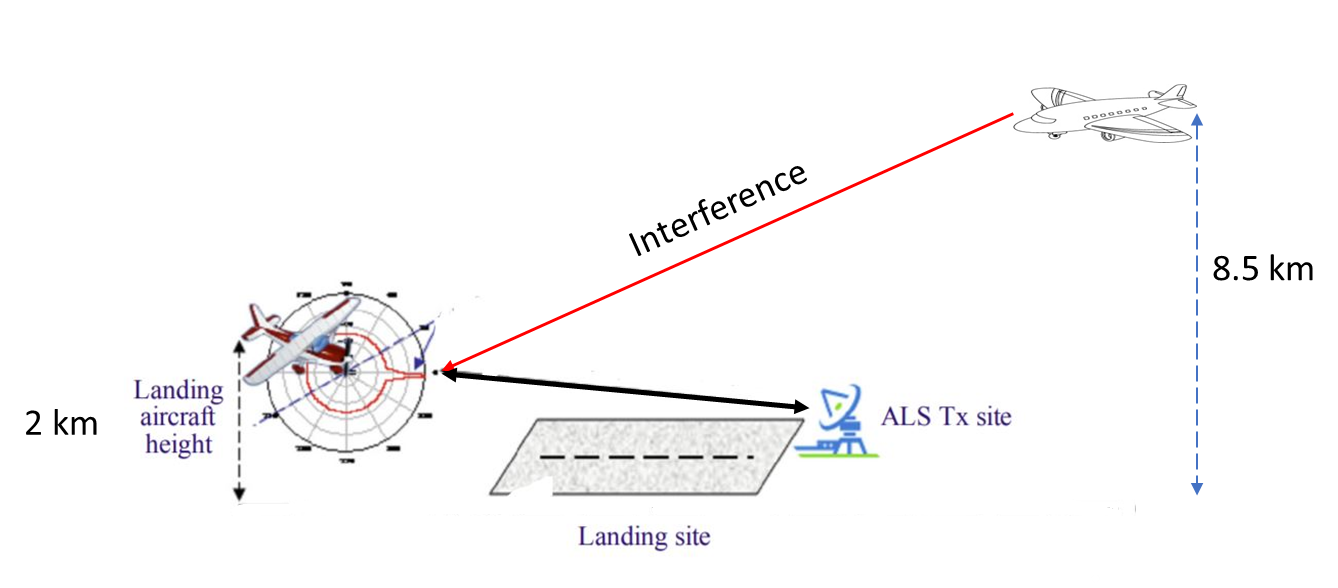
I/N [−6/-10] dB (4)

### 3.2.1 Compatibility Analysis Scenario

One compatibility analysis scenario is shown in Figure 1.

Figure 1

Compatibility analysis scenario



### 3.2.2 Analysis Assumptions

The analysis assumptions:

1. Propagation loss using Recommendation ITU-R P.528-5 – A propagation prediction method for aeronautical mobile and radionavigation services using the VHF, UHF, and SHF bands. The time percentage of 5% is used.
2. The altitude of radiolocation is at 8500 m above the Earth’s surface and the ALS is at 2000 m above the Earth’s surface.
3. The center frequency of radiolocation is 16.35 GHz. The center frequency of the ALS is 15.55 GHz.
4. The ALS receiver system is randomized at a 100 km radius of an ALS transmitter system. The radiolocation aircraft is randomized within a 100 km radius of an ALS receiver system.
5. The antenna pattern for a transmitting radiolocation can be modeled using Recommendation ITU-R M.1851 cosine square pattern. The antenna pattern for the ALS receiver is the horn antenna pattern.
6. The pointing angle of the radiolocation transmitting antenna is randomized ±45° horizontally, and +5° to −45° vertically.
7. The ALS receiver is pointing toward the ALS transmitter.
8. The polarization loss value is 3 dB.
9. The analysis was performed with 1 million sampling points with the protection criteria is I/N of -6 dB.
10. Based on Recommendation ITU-R M.1372-1, the situations that are normally of concern are limited to:
    1. radar side lobe/back lobe to radar side lobe/back lobe,
    2. radar main beam to radar side lobe/back lobe, and
    3. radar side lobe/back lobe to radar main beam.

### 3.3 Compatibility Analysis and Assessment of Results

Figure 2 below provides the Cumulative Distribution Functions (CDFs) of I/N values for the compatibility analysis between radiolocation and ALS. Figure 3 below provides the separation distance that are required to protect the ALS.

Figure 2

CDF Plot of I/N values for the compatibility analysis between radiolocation and ALS

Chart, line chart

Description automatically generated

FIGURE 3

**Separation distance between radiolocation and ALS**

Chart, line chart

Description automatically generated

Based on Figure 5, the radiolocation system will not cause harmful interference to aircraft landing systems when a separation distance of 100 km is maintained by the radiolocation system.

# 4 Radio Astronomy Service (RAS)

## 4.1 Radio Astronomy Service Systems Characteristics

RAS is a service with a primary status in the band 15.35-15.4 GHz in the RR Nos. 5.340 and 5.511. During an observation, a radio astronomy telescope points towards a celestial radio source at a specific right ascension and declination corresponding with a specific azimuth and elevation at a given moment in time, and the pointing direction of the telescope is continuously adjusted to allow the system to continuously point towards its respective target. Table 3 below is an extract from the WP 7D Reply Liaison Statement to WP 5B (doc. [5B/120](https://www.itu.int/md/R19-WP5B-C-0120/en)) that shows major radio astronomy stations installed in various countries of the world, together with their location, height above mean sea level, and antenna diameter.

TABLE 3

**Typical radio telescopes for compatibility studies**

| **Administration** | **Name** | **N. Latitude** | **E. Longitude** | **Height AMSL (m)** | **Diameter (m)** |
| --- | --- | --- | --- | --- | --- |
| Germany | Effelsberg | 50° 31' 29" | 06° 53' 03" | 369 | 100 |
| South Africa | MeerKAT | −30° 43′ 16" | 21° 24' 40" | 1 054 | 64 × 13.5 m |
| USA | Green Bank Telescope | 38° 25' 59" | −79° 50' 23" | 250 | 100 |
| USA | Jansky VLA | 33° 58' 22" to 34° 14' 56" | −107° 24' 40" to  −107° 48' 22" | 2 000 | 27 × 25 m |
| Australia | Parkes | −33º 00' 00" | 148º 15' 44" | 372 | 64 |
| China | Tianma | 31° 05′ 13" | 121° 09′ 48" | 5 | 65 |
| Japan | Nobeyama | 35º 56' 40" | 138º 28' 21" | 1 350 | 45 |
| France | Plateau de Bure | 44º 38' 02" | 05° 55' 28.5" | 2 250 | 12 × 15 m |

The peak gain of the antennas used in the radio astronomy stations presented in Table 4 below.

TABLE 4

**Peak gain and -3dB beamwidth of Radio Astronomy antennas in the frequency band 15.35-15.4 GHz**

| **Administration** | **Name** | **(m)** | **(dBi)** | **(deg)** |
| --- | --- | --- | --- | --- |
| Germany | Effelsberg | 100 | 82.6 | 0.0068 |
| South Africa | MeerKAT | 64 × 13.5 m | 84 |
| USA | Green Bank Telescope | 100 | 82.6 |
| USA | Jansky VLA | 27 × 25 m | 84 | 0.0106 |
| Australia | Parkes | 64 | 78.7 |
| China | Tianma | 65 | 78.8 | 0.0104 |
| Japan | Nobeyama | 45 | 75.6 | 0.0150 |
| France | Plateau de Bure | 12 × 15 m | 84 |

## 4.2 RAS Compatibility Methodology and Assumptions

The protection criteria given in Recommendation ITU-R RA.769-2 assumes that the interferer is in the antenna far field of a radio telescope, and that it is received in the side lobe of the RAS antenna pattern, at a level of 0 dBi at relative angles greater than 19° from the antenna boresight (see also Recommendation ITU-R SA.509-3). It should also be noted that a radio telescope typically uses an antenna with a very high gain, a typical maximum of 84 dBi as shown in Table 5 above and as stated in Recommendation ITU-R RA.1631-0.

The sensitivity levels given in Recommendation ITU-R RA.769-2 employ values for the bandwidth and integration time for which these other factors usually are insignificant. These values are shown in Table 5.

TABLE 5

RAS protection criteria

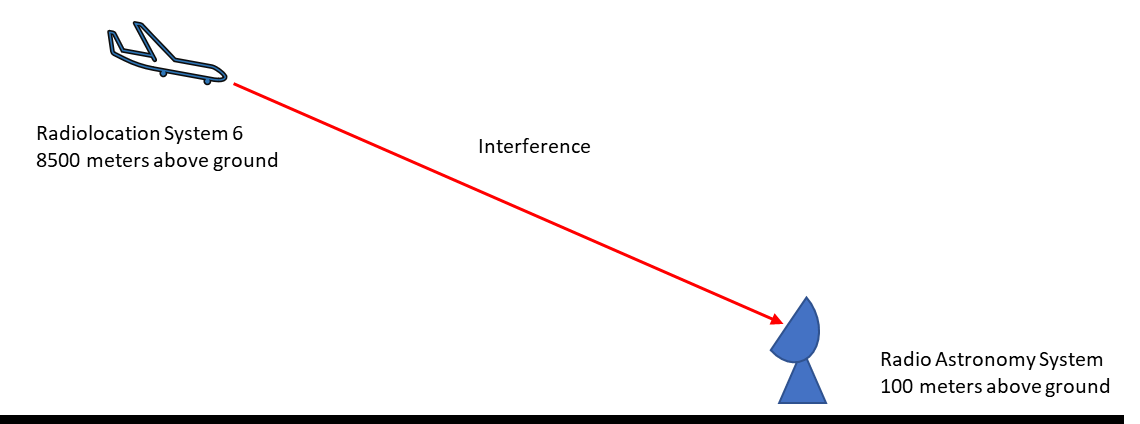
|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | System sensitivity (noise fluctuations) | | Threshold interference levels | | |
| Temperature (K) | Power spectral density (W/Hz) | Input power | Power flux-density (W/m2) | Spectral power flux-density (W/(m2 ⋅ Hz)) |
| Single dish | 0.095 m | −269 dB | −202 dBW/50 MHz | −156 dB | −233 dB |

## 4.2.1 Compatibility Analysis Scenario

One compatibility analysis scenario is shown in Figure 4.

Figure 4

Compatibility analysis scenario



## 4.2.2 Analysis Assumptions

For this compatibility study the following assumptions are made:

1. Propagation loss using Recommendation ITU-R P.528-5 – A propagation prediction method for aeronautical mobile and radionavigation services using the VHF, UHF, and SHF bands. The time percentage of 5% is used.
2. The altitude of radiolocation is at 8.5 km above the Earth’s surface. The altitude of the RAS is at 100 m above the Earth’s surface.
3. The centre frequency of radiolocation is 16.35 GHz. The centre frequency of the RAS is 15.375 GHz.
4. The FDR value between radiolocation and RAS receiver is 70 dB.
5. The radiolocation aircraft is randomized within a 100 km radius of the RAS system.
6. The antenna pattern for a transmitting aircraft can be modelled using Recommendation ITU-R M.1851 cosine square pattern. The antenna for the RAS system is based on Recommendation ITU-R SA.509-3.
7. The pointing angle of the radiolocation transmitting antenna is randomized ±45° horizontally, and +5° to −45° vertically.
8. The pointing angle of the RAS receiver antenna is randomized between 0° to 360° horizontally, and 0 to +90° vertically.
9. The polarization loss value is 3 dB.
10. The analysis was performed with 1 million sampling points with the protection criteria of Interference level does not exceed -202 dBW/50 MHz for less than 2% of the time.

## 4.3.1 Compatibility Analysis and Assessment of the Results

Figure 5 below provides the CDFs of I/N values for the compatibility analysis between radiolocation and RAS.

Figure 5

CDF Plot of I/N values for the compatibility analysis between radiolocation and RAS

Chart, line chart

Description automatically generated

Based on Figure 5, the radiolocation system will not cause harmful interference to radio astronomy services since the interference level of -202 dBW/50MHz is exceeded for less than 2% of the time.

# 5 Fixed-Satellite Service (FSS)

## 5.1 FSS (Earth-to-Space) Systems Characteristics

Typical characteristics of an NGSO satellite using the frequency band 15.43 – 15.63 GHz to receive signals from an Earth station are provided in Table 6 below.

TABLE 6

**Typical characteristics of FSS NGSO satellite**

**in the frequency band 15.43-15.63 GHz**

| **Characteristic** | **Notation** | **Unit** | **Value** |
| --- | --- | --- | --- |
| Platform type | - | | NGSO satellite |
| Altitude above ground level | - | km | 400 to 2,000**(1)** |
| Centre frequency | - | GHz | 15.53 |
| Carrier bandwidth | - | MHz | 200 |
| Beam characteristics | - | | Single circular beam |
| Antenna pointing | Any point at the surface of the Earth, within the footprint of the satellite**(2)** |
| Noise bandwidth |  | MHz | 1 |
| System receiver noise temperature |  | K | 600 |
| Notes:  **(1)** This is the range of values for a Low Earth Orbit (LEO) satellite.  **(2)** The footprint is assumed to be all points at the surface of the Earth that are visible from the satellite. | | | |

The antenna installed on-board the satellite is typically a parabolic reflector whose characteristics are provided in Table 7 below.

TABLE 7

**Characteristics of the FSS antenna**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Characteristic** | **Notation** | **Unit** | **Value** | | |
| Carrier | - | | 1 | 2 | 3 |
| Diameter |  | m | 1.2 | 1.8 | 2.4 |
| -3 dB bandwidth |  | deg | 1.3 | 0.75 | 0.56 |
| Aperture efficiency (note 1) |  |  | 0.6 | | |
| Operating frequency (GHz) |  | GHz | 15.53 | | |
| Peak gain (dBi) (note 2) |  | dBi | 43.6 | 47.1 | 49.6 |
| Major axis/Minor axis for the radiated beam (note 3) | - | | 1 | | |
| Near-in-side-lobe level relative to the peak gain (dB) | -25 | | |
| Far side-lobe level (dB) |  | dB | 0 | | |
| Notes:  **(1)** Typical aperture efficiency values for a parabolic antenna range from 0.55 to 0.7.  **(2)** The peak gain of a parabolic antenna is related to its diameter according to the formula (33) below.  **(3)** This ratio equals 1 because the beam is supposed circular. | | | | | |

Recommendation ITU-R S.672-4 provides a typical radiation pattern for parabolic dish antennas installed on-board GSO satellites. By extension, it is assumed usable for NGSO satellites.

## 5.2 FSS Compatibility Methodology and Assumptions

For this analysis, the *I*/*N* ratio will be calculated to assess compatibility between radiolocation systems operating in the 15.4-17.3 GHz band and the FSS system operating in the 15.43-15.63 GHz band.

[The initial step in assessing compatibility is the determination of the noise power, at the satellite and earth station receivers, which is given by:

 (5)

where:

*BIF* : receiver IF bandwidth (MHz)

*Te* : receiver noise temperature (K)

*To* : 290°.

The protection criteria for this study are I/N = -6 dB for 99.4% and 0 dB for 99.98% as suggested by WP 4A in liaison statement [5B/378](https://www.itu.int/md/R19-WP5B-C-0378/en).

## 5.2.1 Compatibility Analysis Scenarios

Depictions of the potential interference scenarios used in this analysis are shown in Figures 6 and 7. Figure 6 shows the dynamic scenario of a circular orbiting satellite, Figure 7 shows the static scenario where main beam antenna coupling occurs between the satellite and System‑6.

Figure 6

Scenario configuration for LEO-E elliptical orbit



Figure 7

Scenario for satellites



## 5.2.2 Analysis Assumptions

The analysis assumptions are:

1. Transmission loss is calculated using Recommendation ITU-R P.525-4 – Free Space loss, and ITU-R P.676-12 – Attenuation by atmospheric gases and related effects.
2. The altitude of radiolocation is at 8.5 km above the Earth’s surface. The altitude of the non-GSO FSS system is 400 km above the Earth’s surface.
3. The center frequency of radiolocation is 16.35 GHz. The center frequency of the FSS system is 15.53 GHz.
4. The FDR value between radiolocation and FSS receiver is 60 dB.
5. The FSS system is in flight in a circular orbit with 0 degree inclination.
6. The antenna pattern for a transmitting aircraft can be modeled using Recommendation ITU-R M.1851 cosine square pattern. The antenna pattern for the non-GSO FSS is given in Recommendation ITU-R S.672-4.
7. The pointing angle of the radiolocation transmitting antenna is randomized ±45° horizontally, and +5° to −45° vertically.
8. The FSS receiver is pointing toward the Earth’s station, which has an altitude of 10 m.
9. The polarization loss value is 3 dB.
10. The analysis was performed with 1 million sampling points with the protection criteria I/N of 0 dB for 99.98% and -6 dB for 99.4% of points.

## 5.3 Compatibility Analysis and Assessment of Results

The following sections contain the resulting CDF plots of the analysis. The FSS interference threshold lines are drawn for reference.

Figure 8 below provides the CDFs of I/N values for the compatibility analysis between radiolocation and FSS.

Figure 8

CDF Plot of I/N values for the compatibility analysis between radiolocation and FSS

Chart, line chart

Description automatically generated

Based on Figure 8, the radiolocation system will not cause harmful interference to fixed satellite services since the I/N value are much smaller than -6 dB, the FSS protection criteria.

# 6 Summary of Studies Results

The results of the analysis in this Report show that based on the operational scenarios and assumptions, the radiolocation systems with updated parameters operating in the 15.4-17.3 GHz band is compatible with the RAS systems and FSS systems. For ARNS systems, if the separation distances identified in this report is maintained by the radiolocation system, then the protection criteria is not exceeded and sharing is feasible.