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| **Radiocommunication Study Groups** |  |
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| Annex 9 to Working Party 5B Chairman’s Report |
| WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEWREPORT ITU-R M.[FOD\_EESS\_SHARE] |
| Sharing and compatibility studies between earth exploration satellite service sensors and foreign object debris detection systemin the frequency range 92‑100 GHz |

# 1 Introduction

The range resolution of a radar is dependent on the pulse repetition frequency or the bandwidth of radar signals. To achieve a range resolution of less than a few cm, radar bandwidths in the order of GHz are required. Since the band 92-100 GHz is allocated for radiolocation services on a primary basis, the bandwidth of 8 GHz can provide the high range resolution around 2 cm. The study on foreign object debris (FOD) detection systems to utilize such broad bandwidth for airport safety operation is currently conducted by WP 5B and the technical and operational characteristics will be provided by Report ITU-R M.[FOD 92-100 GHZ]. However, FOD detection systems should be deployed to protect a number of incumbent services operating in the band 92-100 GHz and the adjacent bands.

The 94.0-94.1 GHz band is allocated to the Earth exploration satellite service (EESS) (active) on a primary basis for spaceborne active sensors, such as cloud profile radars (CPRs). Herein are presented technical characteristics of two typical EESS (active) cloud profile radar systems operating in the frequency band 94.0-94.1 GHz and technical characteristics for typical FOD detection systems proposed for the frequency range 92-100 GHz. Performance criteria and interference criteria for active spaceborne cloud profile radar operating in the 94.0-94.1 GHz frequency band are provided. Preliminary calculations are made of the attenuation required of the FOD detection systems in-band emission levels in order for those emissions to be below the EESS (active) interference protection criteria level of the most susceptible CPR.

The 86-92 GHz band is allocated to EESS (passive) on a primary basis for EESS (passive) spaceborne passive sensors, such as radiometers. Herein are presented technical characteristics of one typical EESS (passive) radiometer system operating in the frequency band 86-92 GHz and technical characteristics for typical FOD detection systems proposed for the frequency range 92‑100 GHz. Performance criteria and interference criteria for passive spaceborne radiometers operating in the 86-92 GHz frequency band are provided. Preliminary calculations are made of the attenuation required of the FOD detection systems out-of-band (OOB) emission levels in order for those emissions to be below the EESS (passive) interference protection criteria level of the most susceptible radiometer.

# 2 Foreign object debris detection system characteristics

Information on 94 GHz band FOD detection systems is provided in section 2 of the Working document toward a preliminary draft new Report ITU-R M.[FOD 92-100 GHz], “Technical and operational characteristics of the FOD detection system operating in the frequency range 92-100 GHz”. The characteristics of the FOD detection systems are summarized in the Table 1 and the spectrum mask and antenna radiation pattern are shown in Figures 2 and 3. The measured data at 92 GHz, 94 GHz, 96 GHz, 98 GHz and 100 GHz is provided by the following table.



Table 1

Technical and operational characteristics of foreign object debris detection system
operating in the frequency range 92-100 GHz

| Parameters | Units | Values |
| --- | --- | --- |
| Frequency range  | GHz | 92….100 |
| Channel plan |  | See Figure 1 |
| Chanele bandwidth | GHz | 0.58…..7.98 |
| Output power  | mW | 200 |
| Spectrum envelope | - | See Figure 2 |
| Sweep frequency | kHz  | 1.250 |
| Antenna type | - | Cassegrain |
| Antenna gain | dBi | 42 |
| Antenna pattern | - | See Figure 3Recommendation ITU-R M.1851 |
| Antenna height | m | 6....8 |
| Full width at half maximum | degrees | Elevation: 1.0, Azimuth: 1.0 |
| Antenna rotation speed  | rpm | 15 |
| Detection distance | m | 200 |
| Antenna elevation angle | degrees | −1.8 |
| Radiated rotation angle | degrees | ±60 |
| Radar cross section  | dB/m2 | -20 |
| Range resolution  | cm | 3…..50 |
| Emission bandwidth (–3 dB) | MHz | 1 (see Figure 2 (b)) |
| Emission bandwidth (–20 dB) | MHz | 3.5 (see Figure 2 (b)) |
| Adjacent channel leakage ratio | dBc | < −70 |
| Receiver noise figure | dB | 10 |
| Maximum number of FOD radars per 4-km runway |  | 48 (see Figure 5) |
| *I/N* protection criteria | dB | [−6 or −10] |

FIGURE 1

Channel plan for foreign object debris detection system operating in the frequency range 92-100 GHz



Figure 2

Measure spectrum of foreign object debris detection system

(a) Spectrum envelope of FWCW signal in the frequency band 92-97 GHz



(b) Adjacent channel leakage ratio at an offset frequency of 10 MHz



Figure 3

Antenna radiation pattern of 42 dBi at 96-GHz



# 3 Technical characteristics of incumbent services

## 3.1 Earth exploration satellite service (active) spaceborne cloud profile radars

Technical characteristics of CPRs in the frequency band of 94.0-94.1 GHz are provided in “Recommendation ITU-R RS.2105 – *Typical technical and operational characteristics of Earth exploration-satellite service (active) systems using allocations between 432 MHz and 238 GHz*”. The technical characteristics for two CPR systems CPR-L1 and CPR-L2 are presented below in Table 2.

Table 2

Characteristics of Earth exploration satellite service (active) missions in the frequency band 94-94.1 GHz

| Parameter | Units | CPR-L1 | CPR-L2 |
| --- | --- | --- | --- |
| Sensor type |  | Cloud Profiling Radar | Cloud Profiling Radar |
| Type of orbit |  | Sun synchronous orbit | Sun synchronous orbit |
| Altitude | km | 705 | 393 |
| Inclination | degrees | 98.2 | 97 |
| Ascending Node LST |  | 13:30 | 10:30[[1]](#footnote-1) |
| Repeat period, days |  | 16 | 25 |
| Antenna type |  | Parabolic reflector to Offset cassegrain antenna | Parabolic reflector |
| Antenna diameter |  | 1.85-2.5 m | 2.5 m |
| Antenna (transmit & receive) peak gain | dBi | 63.1-65.2 | 65.2 |
| Polarization |  | linear | LHC, RHC |
| Incidence angle at Earth | degrees | 0 | 0 |
| Azimuth scan rate | rpm | 0 | 0 |
| Antenna beam look angle | degrees | 0 | 0 |
| Antenna beam azimuth angle | degrees | 0 | 0 |
| Antenna elevation. beamwidth | degrees | 0.12 | 0.095 |
| Antenna azimuth. beamwidth | degrees | 0.12 | 0.095 |
| Beamwidth | degrees | 0.095-0.108 | 0.095 |
| RF center frequency | MHz | 94.050 | 94.050 |
| RF bandwidth | MHz | 0.36 | 7 |
| Transmit peak power | W | 1 000 | 1 430 |
| Transmit Average power | W | 21.31 | 28.8 |
| Pulsewidth,  | μsec | 3.33 | 3.3 |
| Pulse Repetition Frequency (PRF),  | Hz | 4 300 | 6 100-7 500 |
| Chirp rate  | MHz/μsec | N/A[[2]](#footnote-2) | 2.1 |
| Transmit duty cycle  | % | 1.33 | 2.01 |
| Minimum sensitivity  | dBZ | –30 to –35 | –30 to –35 |
| Horizontal resolution |  | 0.7-1.9 km | 800 m |
| Vertical resolution |  | 250-500 m | 500 m |
| Doppler range |  | ±10 m/s | –10 ~ +10 m/s |
| Doppler accuracy |  | 1 m/s | 1 m/s |
| System noise figure | dB | 7 | 7 |

## 3.2 Earth exploration satellite service (passive) spaceborne radiometers

Technical characteristics of spaceborne radiometers in the frequency band of 86-92 GHz are provided in “Recommendation ITU-R RS.1861 – *“Typical technical and operational characteristics of Earth exploration-satellite service (passive) systems using allocations between 1.4 and 275 GHz”*. The technical characteristics for one spaceborne radiometer system L8 is presented below in Table 3.

Table 3

Characteristics of Earth exploration satellite service (passive) missions in the frequency band 86-92 GHz

| Parameter | Units | L8 |
| --- | --- | --- |
| Sensor type |  | Conical scan radiometer |
| Type of orbit |  | SSO |
| Altitude | km | 700 |
| Inclination | degrees | 98.2 |
| Repeat period |  | 16 |
| Antenna type |  | Parabolic reflector antenna |
| Antenna diameter |  | 2.0 m |
| Antenna (receive) peak gain | dBi | 62.4 |
| Polarization |  | Linear H,V |
| Incidence angle at Earth | degrees | 55 |
| Azimuth scan rate | rpm | 40 |
| Antenna beam look angle | degrees | 47.5 |
| Antenna beam azimuth angle | degrees | 0 to 360 |
| Antenna elevevation beamwidth | degrees | 0.15 |
| Antenna azimuth beamwidth | degrees | 0.15 |
| Beamwidth | degrees | 0.15 |
| RF centre frequency | GHz | 89.0 |
| RF bandwidth | MHz | 3000 |
| Horizontal resolution |  | 2.9 km |
| Vertical resolution |  | 5.1 km |

# 4 Performance criteria of Earth exploration satellite service (active) and Earth exploration satellite service (passive)

Performance requirements for spaceborne active sensors in the EESS (active) are provided by Recommendation ITU-R RS.1166-4 “Performance and interference criteria for active spaceborne sensors”. The performance criteria for the EESS (active) cloud profile radars specifies measurements of a minimum reflectivity of –30 dBz ±10%, *I/N* no greater than –10 dB and random data availability criteria of at least 99.8%.

Performance requirements for spaceborne passive sensors in the EESS (passive) are provided by Recommendation ITU-R RS.2017 – *“Performance and interference criteria for satellite passive remote sensing”*. The performance criteria for the EESS (passive) radiometers specifies a temperature differential, Δ*Te* of 0.05 K and data availability criteria of at least 99.99%.

# 5 Interference criteria

## 5.1 Earth exploration satellite service (active) and Earth exploration satellite service (passive)

Interference requirements for spaceborne active sensors in the EESS (active) are given in preliminary draft revision of Recommendation ITU-R RS.1166-4 “Performance and interference criteria for active spaceborne sensors” (Annex 2 of [7C/344](https://www.itu.int/md/R15-WP7C-C-0344/en)). The interference threshold criteria for the EESS (active) CPR in the 94.0‑94.1 GHz frequency band is –155 dBW over 300 kHz. The availability criteria is 99%.

*[Chairman’s note: The reference to Doc. 7C/344 will need to have been removed in the final document.]*

Interference requirements for spaceborne passive sensors in the EESS (passive) are given in Recommendation ITU-R RS.2017 – *“Performance and interference criteria for satellite passive remote sensing”*. The interference threshold criteria for the EESS (passive) radiometer in the 86‑92 GHz frequency band is –169 dBW with a percentage of area or time permissible interference level may be exceeded of 0.01%.

## 5.2 foreign object debris detection system

# 6 Deployment scenarios of foreign object debris detection system

Figure 4 shows the location of major airports in Japan where FOD detection systems may be implemented in the future. The number of FOD implemented in runway is estimated by using Figure 5. The important parameter of the deployment scenario is the separation distance of FOD radars which is 200 m. If the runway length is 4,000 m, the number of FOD radars becomes 48, as shown in Figure 5. FOD radars are deployed at each side of runway. Table 4 summarizes the estimated number of FOD radars which will be implemented in major airports. Those number of FOS radars should be taken into account when interference from FOD radars is studied

Figure 4

Foreign object debris detection systems planned to operate in the airports



Figure 5

Basic concept of implementation of foreign object debris radars in 4-km runway



TABLE 4

Estimated number of foreign object debris radars in each airport

|  |  |  |  |
| --- | --- | --- | --- |
| Airport | No. of runway | Runway length (m) | Estimated number of FOD radars |
| CTS1 | 2 | 3 000, 3 000 | 68 |
| FUK2 | 1 | 2 800 | 17 |
| HND3 | 4 | 2 500, 2 500, 3 000, 3 360 | 120 |
| ITM4 | 2 | 1 828, 3 000 | 52 |
| KIX5 | 2 | 3 500, 4 000 | 84 |
| KOJ6 | 1 | 3 000 | 32 |
| NGO7 | 1 | 3 500 | 36 |
| NRT8 | 2 | 2 500, 4 000 | 74 |
| OKA9 | 1 | 3 000 | 32 |
| 1 New Chitose Airport, 2 Fukuoka Airport, 3 Tokyo International Airport (Hneda), 4 Osaka International Airport - Itami Airport, 5 Kansai International Airport, 6 Kagoshima Airport, 7 Chubu Centrair International Airport, 8 Narita International Airport, 9 Naha Airport |

# 7 Sharing and compatibility studies

## 7.1 In-Band emissions of foreign object debris detection systems into Earth exploration satellite service (active)

FOD detection systems are proposed to operate in the 92-100 GHz frequency band. The 94.0‑94.1 GHz band which is allocated to the EESS (active) CPR would be in-band with the FOD detection band 92-100 GHz. The maximum in-band emissions occur when the FOD FMCW signal spectrum is positioned over the spectrum of the EESS (active) band.

## 7.2 Compatibility studies for Earth exploration-satellite service (active)

The study results are included in Annex 1. Section A1 contains the static analysis and section A2 contains the dynamic analysis.

## 7.3 Out-of-Band emissions of foreign object debris detection systems into Earth exploration satellite service (passive)

FOD detection systems are proposed to operate in the 92-100 GHz frequency band. The 86-92 GHz band which is allocated to the EESS (passive) spaceborne radiometer would be OOB with respect to the FOD detection band 92-100 GHz. The maximum OOB emissions occur when the FOD FMCW signal spectrum is positioned near the spectrum edge of the EESS (passive) band just above 92 GHz.

## 7.4 Compatibility studies for Earth exploration-satellite service (passive)

The study results are included in Annex 2. Section A1 contains the static analysis and section A2 contains the dynamic analysis.

Annex 1

Interference analysis for Earth exploration satellite service (active)

*[No change]*

ANNEX 2

Interference analysis for Earth exploration satellite service (passive)

*[No change]*

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1. Descending. [↑](#footnote-ref-1)
2. The sensor uses an unmodulated pulse. [↑](#footnote-ref-2)