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| **Document Title:** **WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ITU-R M.[RNSS\_AM(R)S\_5GHZ\_SHARING]** – Sharing and compatibility study between RNSS and AM(R)S systems operating in the 5 000 to 5 150MHz Frequency Band |

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| **Purpose/Objective:** The purpose of this contribution is a sharing and compatibility study between the RNSS operating in the 5 010 – 5 030 MHz frequency band and the AM(R)S service supporting Unmanned Aircraft Systems operating in the 5 030 to 5 091 MHz frequency band. This study is aimed at finalizing the e.i.r.p. density limit that is currently provisional in RR No. 5.443C |
| **Abstract:** This initial contribution provides an outline for the study and the characteristics of the two systems. |

Changes from the second draft are shown in MS Word Markup

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| WORKING DOCUMENT TOWARDS A preliminary draft new RePORT Itu-r m.[RNSS\_AM(R)S\_5GHz\_SHARING] |
| **Sharing and compatibility study between RNSS and AM(R)S systems operating in the 5 010 to 5 091 MHz Frequency Band** |

**Introduction**

At WRC-2012 it was agreed, under No. 5.443C, that the frequency band 5 030-5 091MHz could be used by the aeronautical mobile (R) service limited to internationally standardized aeronautical systems. Industry, international standards development organizations and ICAO have been working since then to develop the technology and standards necessary to use that allocation. Consequently, it is now possible to provide characteristics and protection criteria for such systems for use in any future sharing studies within ITU-R.

**Proposal**

The United States of America proposes to assist in answering the above need by providing characteristics as Attachment 1 for such Control and Non-Payload Communications (CNPC) links operating in the AM(R)S allocation under No. 5443C and used in air-ground applications between Unmanned Aircraft (UA) and their Control Station (CS) where the Remote Pilot (RP) is located.

Attachment 2 provides the characteristics of the Galileo Positioning System, and the Global Positioning System, the two most widely used GNSS constellation in Region 2 of the RNSS services operating in the 5 010 – 5 030 MHz frequency band as found in ITU-R M.2031-1.

Attachment 3 provides an outline for conducting the sharing and compatibility study of the two systems detailing the various cases and the processes.

**Attachments**: 3

ATTACHMENT 1

**UAS CNPC Characteristics**

# Introduction and scope

As recommended, UAS CNPC Characteristics are taken from PDNR ITU-R M.[AM(R)S\_AMS(R)S\_CHAR\_5GHZ] - Characteristics and Protection Criteria of Terrestrial and Satellite Unmanned Aircraft System Control and Non-Payload Communications Links operating in the Aeronautical Mobile (R) Service and Aeronautical Mobile Satellite (R) Service in the band 5 030-5 091 MHz.

[Figure 1]

Example command and non-payload communications link system components



#  Unmanned aircraft and control station characteristics for terrestrial control and non-payload communication link

The terrestrial component uses an airborne radio system (ARS) on the UA to communicate with a ground radio system (GRS) that connects to the UACS.

TABLE 1

Transmission and reception characteristics for the terrestrial control
and non-payload communication link System 1

| Terrestrial command and non-payload communication System 1 |
| --- |
|  | Units | UA ARS | GRS |
| Frequency of operation | MHz | 5 030 to 5 091 | 5 030 to 5 091 |
| Duplexing |  | Time division duplex (TDD) | TDD |
| Transmit/receive duration  | msec | 60 Receive + 2.5 guard time65 Transmit + 2.5 guard time | 60 Transmit + 2.5 guard time65 Receive + 2.5 guard time |
| Modulation |  | GMSK or QPSK | GMSK or QPSK |
| Modulation symbol rates | ksps | GMSK: TBDincluding error correction/detection, guard times and synchronization overhead | GSMK: TBDincluding error correction/detection, guard times and synchronization overhead |
| Forward error correction |  | GMSK: Rate 5/8 Turbo Conv.CodeQPSK: Rate 5/9 and Rate 1/3 TCC | GMSK: Rate 5/8 Turbo Conv. CodeQPSK: Rate 5/9 and Rate 1/3 TCC |
| Error detection |  | 32-bit CRC | 32-bit CRC |
| Baseband Input/Output Signal |  | User Data | User Data |
| User Data Bit Rates | kbps | GMSK: TBDQPSK: TBDIncludes TDD duty cycle overhead | GMSK: TBDQPSK: TBDIncludes TDD duty cycle overhead |
| Occupied bandwidth, C | kHz | Variable per application with a maximum of 250 | Variable per application with a maximum of 250 |
| Antenna gain | dBi | 2 | Maximum 20 |
| Cable loss | dB | 2 | 1 |
| Antenna pattern  |  | Constant azimuthConstant elevation | Constant azimuthTailored in elevationSee Table 2 |
| Antenna polarization |  | Vertical with aircraft flying straight and level | Vertical |
| Maximum antenna height | m | 22 860 (mean sea level)Typical 6 000 | 2 to 50Typical 10 |
| Service range | km | 550Typical 80 | 550Typical 80 |
| Transmitter conducted power | dBm | 40 | 40 |
| Transmitter in band emission limits | dBc/1 MHz | −66 at 2 MHz offsetSee Table 3 | −66 at 2 MHz offsetSee Table 3 |
| Receiver noise figure | dB | 7 | 7 |
| Receiver sensitivity | dBm | GMSK: TBDQPSK: TBD | GMSK: TBDQPSK: TBD |
| Receiver in band rejection – except the operating channel | dB | One channel separation: 23Two channel separation: 43Three channel separation: 572 MHz or more separation: 63 | One channel separation: 23Two channel separation: 43Three channel separation: 572 MHz or more separation: 63 |
| Protection criteria (aggregate) I/N | dB | –6 | –6 |

TABLE 2

GRS elevation antenna pattern envelope is constant in azimuth for System 1 with 20 dBi antenna with
elevation 3 dB beamwidth equal to 9° and azimuth 3 dB beamwidth equal to 32°

|  |
| --- |
| System 1 |
| Elevation degrees | Gain dBi |
| 0.5 | 19.0 |
| 1.5 | 19.5 |
| 2.5 | 20.0 |
| 3.5 | 19.5 |
| 7 | 17.0 |
| 11.5 | 14.0 |
| 16 | 11.5 |
| 32 | 6.5 |
| 64 | 1.5 |
| >75 | 0.5 |

Note: The GRS uses a sectorized or steerable in azimuth beam antenna, with the fixed elevation pattern given in Table 2.

*[Editor’s note: All the gains indicated for the antenna pattern in Table 2.1 are positive, which is questionable.]*

TABLE 3

Transmitter out of band emission limits in the 5 030-5 091 MHz frequency band for system 1

|  |
| --- |
| System 1 |
| Offset from carrier frequency | dBc/kHz |
| Channel width ÷ 2 | −54 |
| 1.5 × channel width | −74 |
| 500 kHz | −90 |
| 2 000 kHz | −96 |

TABLE 4

Transmitter spurious emission limits

|  |  |
| --- | --- |
|  | Maximum command and non-payload communication link system power spectral density in the spurious domain |
|  | UA ARS | GRS |
| System 1 | *TBD* | *TBD* |

[Editor’s note: It is envisioned that the proposed Recommendation will eventually include the spurious emission characteristics of AM(R)S transmissions into adjacent allocations including those below 5 030 MHz that would be necessary for sharing studies to resolve the provisional nature of the ‑75 dBW/MHz protection value in RR No. **5.443C**.]

TABLE 5

Terrestrial System 1 Example link budget

|  |  |  |
| --- | --- | --- |
| Link Budget Element | GRS to UA | UA to GRS |
| Maximum Slant Range  | 80 km | 80 km |
| Typical UA Altitude (AGL) at Slant Range | 6,000 m | 6,000 m |
| GRS to UA LOS Path Elevation Angle | 3.0 deg | 3.0 deg |
| Transmitter Antenna Gain at Path Elevation Angle | 19.75 dBi | 2 dBi |
| EIRP (10W transmitter conducted power, plus Antenna Gain minus cable loss) | 58.75 dBm | 41.0 dBm |
| Free Space Loss at Slant Range at 5 091 MHz | 144.7 dB | 144.7 dB |
| Multipath Fading plus Airframe Obstruction for 99.8% Availability | 13.0 dB | 13.0 dB |
| Receiver Antenna Gain at Path Elevation Angle | 2 dBi | 19.75 dBi |
| Received Signal Level, C (including cable loss) | −98.0 dBm | −98.0 dBm |
| Total On Channel Interference Power Density from other CNPC Systems  | −138.3 dBm/kHz | −129.0 dBm/kHz |
| Receiver Noise Power for 7dB Noise Figure in 500 kHz Noise Bandwidth | −140.0 dBm/kHz | −140.0 dBm/kHz |
| Total On Channel Interference Power Density from other non-CNPC Systems at -6dB Aggregate I/N Protection Criteria | −146.0 dBm/kHz | −146.0 dBm/kHz |
| Combined On Channel Interference and Noise Power Density | −135.6 dBm/kHz | −128.6dBm/kHz |
| ICAO 6dB Aeronautical Safety Margin added to Combined On Channel Interference and Noise Power Density, Io + No | −129.6 dBm/kHz | −122.6 dBm/kHz |
| Maximum Modulation Symbol Rate, Rs | 170 kHz | 170 kHz |
| Es/No including 3 dB implementation Loss, for required BER assuming GMSK with rate 5/8 Turbo Convolutional Code for FEC | 2.3 dB | 2.3 dB |
| Required Cmin/(Io + No), equals Es/No plus 10 x Log Rs | 24.6 dBm-kHz | 24.6 dBm-kHz |
| Available C/(Io + No) | 31.6 dBm-kHz | 24.6 dBm-kHz |
| Excess Link Margin @ Maximum Modulation Symbol Rate | 7.0 dB | 0.0 dB |

ATTACHMENT 2

**RNSS Characteristics**

# Introduction and scope

As recommended by WP 4C (5B/312), RNSS characteristics and protection criteria are taken from Recommendation ITU-R M.2031-1 - Characteristics and protection criteria of receiving earth stations and characteristics of transmitting space stations in the radionavigation-satellite service (space-to-Earth) operating in the band 5 010-5 030 MHz.

These characteristics and protection criteria should be used in performing analyses of radio frequency interference impact on systems and networks in the RNSS (space-to-Earth) operating in the band 5 010-5 030 MHz from the Control and Non-Payload Communications (CNPC) links operating in the AM(R)S allocation under No. 5443C.

TABLE 1-1

Service link characteristics and protection criteria for receiving earth stations
operating in the band 5 010-5 030 MHz

| Parameter | Galileo | GPS |
| --- | --- | --- |
| Signal frequency range (MHz) |  |  |
| Maximum receiver antenna gain (dBi) |  |  |
| RF filter 3 dB bandwidth (MHz) |  |  |
| Pre-correlation filter 3 dB bandwidth (MHz) |  |  |
| Receiver system noise temperature (K) |  |  |
| Tracking mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW) | –157.1 | −154.6  |
| Acquisition mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW) | –160.1 | −157.6  |
| Tracking mode threshold power density level of aggregate wideband interference at the passive antenna output (dB(W/MHz)) | –147.1 | −144.6  |
| Acquisition mode threshold power density level of aggregate wideband interference at the passive antenna output (dB(W/MHz))  | –150.1 | −147.6  |

TABLE 1-2

Feeder link characteristics for receiving earth stations
operating in the band 5 010-5 030 MHz

**Characteristics of receiving feeder-link earth stations
operating in the band 5 010-5 030 MHz**

| **Parameter** | **GPS** | **QZSS** |
| --- | --- | --- |
| Antenna diameter (m) |  |  |
| Polarization |  |  |
| Antenna pattern |  |  |
| Theoretical antenna gain (dBi) |  |  |
| Antenna efficiency loss (dB) |  |  |
| Maximum receive antenna gain (dBi) |  |  |
| Receiver system noise temperature (K) |  |  |
| Minimum elevation (degrees) |  |  |

**Feeder downlink transmissions in the band 5 010-5 030 MHz**

| **Parameter** | **GPS** | **QZSS** |
| --- | --- | --- |
| Signal frequency range (MHz) (Note 1) |  |  |
| Encoded bit rate (bit/s) |  |  |
| Signal modulation method |  |  |
| Polarization |  |  |
| Ellipticity (dB) |  |  |
| Transmit e.i.r.p. (dBW) |  |  |
| NOTE 1 – Carrier frequency of the RNSS signal of interest ± half the signal bandwidth. |  |

**Feeder Link Protection Criteria**

|  |  |  |
| --- | --- | --- |
| **Parameter** | **GPS** | **QZSS** |
| Aggregate interfering power not to exceed Δ T\_sys (percentage) | 6% | 6% |

[Editor’s note: Draft Liaison Statement to WP5B indicates WP4C initiating an update/revision to ITU-R M.2031-1.]

ATTACHMENT 3

**Outline for conducting the sharing and compatibility study of the two systems**

# 1 Introduction and scope

At WRC-2012 it was agreed, under No. 5.443C, that the frequency band 5 030-5 091MHz could be used by the aeronautical mobile (R) service limited to internationally standardized aeronautical systems.

No. 5.443C states that “Unwanted emissions from the aeronautical mobile (R) service in the frequency band 5030-5091 MHz shall be limited to protect RNSS system downlinks in the adjacent 5010-5030 MHz band. Until such time that an appropriate value is established in a relevant ITU-R Recommendation, the e.i.r.p. density limit of −75 dBW/MHz in the frequency band 5010-5030 MHz for any AM(R)S station unwanted emission should be used. (WRC-12)”

It is the intention of this study to investigate the e.i.r.p. density limit that needs to be applied to the emissions of UAS CNPC (whose characteristics are provided in Attachment 1) in order to protect the RNSS whose characteristics and protection criteria are provided in Attachment 2 and in so doing enable the provisional nature of the current e.i.r.p. density limit to be resolved.

**1.1 RNSS and UAS CNPC Frequency Allocation**

The frequency arrangement is shown below. The RNSS systems operating in the 5 010-5 030 MHz frequency band which is adjacent to the CNPC frequency band, are to be protected.

Figure 1

Frequency Placement of RNSS, CNPC and AM(R)S operating in the 5 000-5 150 MHz frequency band



NOTE 1: Compatibility studies among UAS CNPC systems are currently being conducted mainly by aeronautical standardization bodies and are outside the scope of this shared-use study.

NOTE 2: RNSS (UL) in the 5 000-5 010 MHz frequency range is out of scope as there is sufficient frequency separation.

[Editor's Note: There is an AM(R)S system operating at 5 010-5 030 MHz and 5 091-5 150 MHz called AeroMACS. However, its operational status is still under investigation and will be addressed in a future WP 5B meeting.]

# 2 Terrestrial CNPC Link Compatibility studies with RNSS

In this section, the terrestrial control and non-payload communication link consists of a single ground radio system, or a network of multiple ground radio systems in a CNPC link with a single or multiple UAs. A sharing study will be conducted to protect the following RNSS services: service links which provide the end-user services, and the feeder links which support control and maintenance of the RNSS satellite constellation. This study will focus on protecting the downlink portion (space-to-earth) of the RNSS services, which is allocated in the band adjacent to the CNPC frequencies as seen in the previous section.

The sharing study intends to provide insights for resolving the provisional nature of the current e.i.r.p. density limit of −75 dBW/MHz of terrestrial CNPC link unwanted emissions to adequately protect RNSS services operating in the adjacent frequency band of 5010-5030 MHz. The overall RF environment consists of multiple GRS stations in a network providing CNPC links to multiple UAs in a specific area where other multiple ground and airborne mobile vehicles utilize RNSS end-user services. A single fixed ground RNSS feeder station also exists in the specific area of the RF environment involved in feeder link services with an RNSS satellite. Figure 2 depicts the overall RF environment of the sharing study.

FIGURE 2

Example System Diagram of the CNPC link transmissions and downlink portions of the RNSS Services

 

The study is broken down into the following cases below:

### Case A.1: Potential interference from GRS stations to mobile station RNSS end-users (ground and airborne)

Figure 3 shows a single instance of one GRS station potentially affecting RNSS services to a mobile ground RNSS user, and an airborne RNSS user. The analysis will further extend this case to multiple GRS stations in a network.

FIGURE 3



### Case A.2: Potential interference from GRS to fixed station RNSS feeder space-to-Earth link.

Figure 4 shows a single instance of one GRS station potentially affecting a single fixed ground RNSS feeder station.

FIGURE 4



### Case A.3: Potential interference from the UA to mobile station RNSS users (ground and airborne)

Figure 5 shows a single UA station potentially affecting RNSS services to a single mobile ground RNSS user, and an airborne RNSS user. The analysis will further extend this case to multiple UA stations flying in the vicinity of these mobile RNSS users.

FIGURE 5



### Case A.4: Potential interference from UA to fixed station RNSS feeder space-to-Earth link

Figure 6 shows a single UA station potentially affecting a single fixed ground RNSS feeder station.

FIGURE 6



*[Editor’s Note: The geographical and situational environmental scenarios to use in each of these cases are still being developed.]*

In each of these cases, the protection criteria in Attachment 2 will be used to assess adequate protection to RNSS services.

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