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| U.S. Radiocommunications SectorFact Sheet |
| **Working Party:** ITU-R WP 5B | **Document No:** USWP5B27-15 First Draft |
| **Ref:** ITU-R 5B/355-E Annex 24 | **Date:** 15th September 2021 |
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| **Document Title:** Working document towards a preliminary draft new Recommendation Itu-r m.[cnpc\_char\_5GHz] - **Characteristics and protection criteria of terrestrial and satellite unmanned aircraft system control and non-payload communications links operating in the aeronautical mobile (route) service and aeronautical mobile satellite (R) service in the band 5 030-5 091 MHz** |

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| **Purpose/Objective:** The purpose of this contribution is to propose an update to the terrestrial characteristics based on a recent update to the RTCA MOPS DO-362A that standardizes and defines this CNPC Link. |
| **Abstract:** This contribution contains characteristics and protection criteria for terrestrial and satellite based systems that can be used for remote control of unmanned aircraft. |

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| **Radiocommunication Study Groups** |  |
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| Source: Document 5B/355 Annex 24Subject: New Recommendation ITU-R M.[CNPC\_CHAR\_5GHz] | **Document XXX** |
| **XXX 2021** |
| **English only** |
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| Working document towards a preliminary draft new Recommendation Itu-r m.[cnpc\_char\_5GHz] |
| **Characteristics and protection criteria of terrestrial and satellite unmanned aircraft system control and non-payload communications links operating in the aeronautical mobile (route) service and aeronautical mobile satellite (R) service in the band 5 030-5 091 MHz** |

**Scope**

This Recommendation specifies the characteristics of terrestrial air-ground links operating in the aeronautical mobile (route) service (AM(R)S) in the frequency band 5 030-5 091 MHz. The technical and operational characteristics should be used in analysing compatibility between unmanned aircraft systems (UAS) control and non-payload communication (CNPC) links operating in the AM(R)S and other services.

**Keywords**

5 030-5 091 MHz

**Abbreviations/Glossary**

AM(R)S: Aeronautical mobile (route) service

ARS: Airborne radio system

ATC: Air traffic control

BLoS: Beyond line of sight

C2: Command and control

CNPC: Control and non-payload communication

CS: Control station

GRS: Ground radio system

ICAO: International Civil Aviation Organization

LoS: Line of sight

S&A: Sense and avoid

UA: Unmanned aircraft

UACS: Unmanned aircraft control station

UAS: Unmanned aircraft system

**Related ITU Recommendations, Reports**

*Recommendations*

*Reports*

ITU-R [M.2205](https://www.itu.int/pub/R-REP-M.2205-2010) Results of studies of the AM(R)S allocation in the band 960-1 164 MHz and of the AMS(R)S allocation in the band 5 030-5 091 MHz to support control and non-payload communications links for unmanned aircraft systems

The ITU Radiocommunication Assembly,

*considering*

*a)* that the frequency band 5 030-5 091 MHz is allocated to the aeronautical mobile (route) service (AM(R)S) for unmanned aircraft control and non-payload communications links to support the safe operation of unmanned aircraft;

*b)* that the frequency band 5 030-5 091 MHz is also allocated to the aeronautical radionavigation service to the globally standardized microwave landing system;

*c)* that the frequency band 5 030-5 091 MHz is also allocated to the aeronautical mobile-satellite (route) service for long distance communications,

*[Chairman’s note: these seem more like recognizing’s than considering’s, and I don’t believe they are allocated for specific purposes]*

*recognizing*

*a)* that use of the frequency band 5 030-5 091 MHz by the aeronautical mobile (R) service is limited to internationally standardized aeronautical systems;

*b)* that from RR No. **5.444**, in the frequency band 5 030-5 091 MHz, the requirements of microwave landing system have priority over other uses of this frequency band,

*recommends*

that the technical and operational characteristics of the unmanned aircraft control and non-payload communications links operating in the AM(R)S described in the Annex should be considered representative of AM(R)S systems operating in the frequency band 5 030-5 091 MHz and used in studies of compatibility with systems in other services.

Annex

**1 Introduction and scope**

The Characteristics of unmanned aircraft systems (UAS) and spectrum requirements must support their safe operation in non-segregated airspace. There is a strong and growing demand for the use of UAS (also known as remote pilot aircraft within the International Civil Aviation Organization (ICAO)) in civil applications. These UAS flights will share airspace with passenger carrying aircraft so their operation needs to be managed to safely allow the introduction of this new paradigm in aviation.

The control and non-payload communications (CNPC) link system consists of the CNPC ground radio system (GRS) Link (fixed, or mobile) and the CNPC airborne radio system (ARS) Link. Each link consists of the transceiver radio, the antenna(s), and the associated cabling.

Figure

**Command and non-payload communications link system components**

CNPC LINK SYSTEM

CNPC GROUND RADIO SYSTEM

CNPC AIRBORNE RADIO SYSTEM

In non-segregated airspace a link between air traffic control and the unmanned aircraft control station (UACS) via the unmanned aircraft (UA), called air traffic control (ATC) relay, will be required to relay ATC and air-to-air communications received and transmitted by the UA.

For communicating with ATC, the UA uses the same equipment as a manned aircraft. This report only considers the downlink bringing the ATC information from the UA to the UACS and the uplink from the UACS to the UA allowing the UACS to communicate with ATC.

As these communications are critical for a safe management of the controlled airspaces, especially in terminal approach areas with high density of aircraft, future ICAO standards are obviously mandatory for these kinds of communications.

Command and control is the typical link between the UACS and the UA. The following two ways of communications are:

*– The uplink*:To send telecommands to the aircraft for flight and navigation equipment control.

*– The downlink*: To send telemetry (e.g. flight status) from the UA to the UACS. It is anticipated that in some flight conditions or in specific airspaces it could be necessary to downlink video streams.

In areas under the responsibility of the aeronautical authorities, the command-and-control communications will have to be compliant with ICAO standards. Nevertheless, in the periods where the UA will follow a full autonomous flight, the up and down links could have very low data rates.

A UA designed to fly in controlled airspace must be able to operate in both high- and low-density airspace. The air traffic control system would not necessarily be able to restrict UA to low density airspace only. Therefore, it is recommended that larger UA be equipped with a terrestrial link capability wherever possible, and a UA may use a geo-stationary satellite link in low density sectors and also probably in high density sectors where the total number of UA in that sector is low.

The impact of latency on UAS command and control systems is a prime factor when considering the safety of operations. Latency will be of the utmost importance when establishing a safety case for the operation of UA, particularly in non-segregated airspace. Current air traffic management relies heavily on voice communications although information via data links is being progressively implemented.

The potential types of information exchanges over the command and control (C2) link system are:

The UA control – To support the remote pilot's activity to fly the UA, power plant status information from the aircraft back to the remote pilot is essential on a frequent basis relative to the dynamics of the UA.

The Avionics – Avionics systems send information (e.g. flight guidance system, flight management system, ATC communication, detect and avoid, weather radar, status reporting system) over the C2 Link System from the UA to the control station (CS).

The Payload **–** Payload communications are not allowed to be carried in the C2 link system. In some cases, the C2 link system and payload communications information may be carried over a common link.

One aspect of the management of safe UAS operations is the management of the interference received by the control and non-payload communications (CNPC) receivers that link the UA and the CS, either line of sight (LoS) or beyond line of sight (BLoS). Additionally, since the frequency band is shared with other aeronautical systems (like microwave landing system under RR No. **5.444**), the interference caused by the UAS must also be managed to ensure that the levels of safety are appropriately maintained.

To enable this interference analysis to be undertaken the characteristics and protection criteria for these terrestrial and satellite CNPC links operating in the AM(R)S and aeronautical mobile satellite (route) service allocations under RR Nos. **5.443C** and **5.443D** are proposed. This working document contains those characteristics and protection criteria based on systems that are being developed for international standardization by ICAO and which will eventually be included within Annex 10, Volume VI, of their Standards and Recommended Practices.

**1.1 Definitions**

**Control and non-payload communications:** The radio links, used to exchange information between the UA and UACS, that ensure safe, reliable, and effective UA flight operation. The functions of CNPC can be related to different types of information such as: telecommand messages, non-payload telemetry data, support for navigation aids, air traffic control voice relay, air traffic services data relay, target track data, airborne weather radar downlink data, non-payload video downlink data.

**Command and non-payload communication link system:** The combination of airborne and ground UAS radios and antennas that support the data and information exchanges between the UA and the Pilot Station for the purposes of managing and controlling the flight and operation of the UA.

**Command and non-payload communication link system airborne radio:** The CNPC radio that is part of the CNPC link airborne radio system (ARS).

**Command and non-payload communication link airborne radio system:** The system that resides on the UA to transmit and receive control and communication data to and from the CNPC link GRS. The ARS consists of the CNPC link system airborne radio, one or more airborne antennas, and all associated cabling.

**Command and non-payload communication link system ground radio:** The CNPC radio that is part of the CNPC link GRS.

**Command and non-payload communication link ground radio system:** The system that resides on the ground to transmit and receive control and communication data to and from the CNPC link airborne radio system. The GRS consists of the CNPC link system ground radio, one or more antennas, and all associated cabling.

**Unmanned aircraft:** Designates all types of aircraft remotely controlled.

**Unmanned aircraft control station:** Facilities from which a UA is controlled remotely.

**Handover operations:** is the transfer:

– of a direct (LoS) RF communication from one dedicated UACS to another (LoS) dedicated UACS;

– of a direct (LoS) to an indirect (BLoS) RF communication link or *vice versa*.

**Pilot Station:** The equipment used to maintain control, communicate, guide, or otherwise manage an UA.

**Radio line-of-sight:** is defined as the direct radio line of sight radiocommunication between the UA and UACS.

**Sense and avoid:** Sense and avoid (S&A) corresponds to the piloting principle “see and avoid” used in all air space volumes where the pilot is responsible for ensuring separation from nearby aircraft, terrain and obstacles.

**Unmanned aircraft system:** Consists of the following subsystems:

– Unmanned aircraft subsystem (i.e. the aircraft itself);

– Unmanned aircraft control station subsystem;

– ATC communications subsystem (not necessarily relayed through the UA);

– Sense and avoid (S&A) subsystem;

– Payload subsystem (e.g. video camera …).

**2 Characteristics of command and non-payload communication links at 5 GHz**

**2.1 Unmanned aircraft and control station line-of-sight link characteristics**

TABLE 1

**Transmission and reception characteristics for the control and non-payload communication link system**

|  | **Units** | **Airborne** | **Ground** |
| --- | --- | --- | --- |
| Frequency of operation | MHz | 5 030 to 5 091 | 5 030 to 5 091 |
| User data rates | kbps | 7.04 to 34.8 | 7.04 to 34.8 |
| Duplexing |  | Time Division Duplex (TDD) | Time Division Duplex (TDD) |
| Transmit/receive duration up from control station down from the UA | msec | 23 Up plus 1.3 Guard23 Down plus 2.7 Guard | 23 Up plus 1.3 Guard23 Down plus 2.7 Guard |
| Modulation |  | GMSK or QPSK | GMSK or QPSK |
| Modulation symbol rates | ksps | GMSK: 34.5, 69, 103.5 and 138 QPSK: 20 and 80:including error correction/detection, guard times and synchronization overhead | GSMK: 34.5, 69, and 103.5QPSK: 20 and 80:including 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 block size transmitted per 50 ms TDD frame | bits | GMSK: 352, 800, 1280 and 1728QPSK @ 20 ksps: 200 and 360QSPK @ 80 ksps: 1032 and 1744 | GMSK: 352, 800, 1280 and 1728QPSK @ 20 ksps: 200 and 360QSPK @ 80 ksps: 1032 and 1744 |
| User data rates | kbps | GMSK Tx: 7.04, 16.0, 25.6 and 34.56GSMK Rx: 7.04, 16.0 and 25.6QPSK Tx/Rx @ 20 ksps: 20.64 and 34.88;Includes TDD duty cycle overhead | GMSK Rx: 7.04, 16.0, 25.6 and 34.56GSMK Tx: 7.04, 16.0 and 25.6QPSK Tx/Rx @ 20 ksps: 20.64 and 34.88;Includes 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 | 22.5 |
| 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 (MSL)Typical 8 000 | 2 to 50Typical 10 |
| Service range | km | 550Typical 200 | 550Typical 200 |
| Transmitter conducted power | dBm | 40 | 40 |
| Transmitter in band emission limits | dBc/kHz | −96 at 2 MHz offsetSee Table 3 | −96 at 2 MHz offsetSee Table 3 |
| Receiver noise figure | dB | 7 | 7 |
| Receiver sensitivity | dBm | GMSK: -118, -115 and -113QPSK @ 20 ksps: -120.5 and -118QSPK @ 80 ksps: -114.5 and -112 | GMSK: -118, -115 and -113QPSK @ 20 ksps: -120.5 and -118QSPK @ 80 ksps: -114.5 and -112 |
| 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 *I/N* \* | dB | [TBD (see *editor’s note*)] | [TBD (see *editor’s note*)] |
| \**[Editor’s note: ICAO is invited to provide the technical performance criteria contained in its official documentation on this topic.]* |

TABLE 2

**Control station elevation antenna pattern
Pattern is constant in azimuth**

|  |  |
| --- | --- |
| **Elevation degrees** | **Gain dBi** |
| 0.5 | 21.5 |
| 1.5 | 22.0 |
| 2.5 | 22.5 |
| 3.5 | 22.0 |
| 7 | 19.5 |
| 11.5 | 16.5 |
| 16 | 14.0 |
| 32 | 9.0 |
| 64 | 4.0 |
| >75 | 3.0 |

TABLE 3

**Transmitter in band emission limits**

|  |  |
| --- | --- |
| **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 out of band emission limits**

|  |
| --- |
| **Maximum command and non-payload communication link system power spectral density** |
| **Airborne**  | **Ground**  |
| TBD | TBD |

*[Editor’s note: It is envisioned that the proposed Recommendation will eventually include the out of band emission characteristics of AM(R)S transmissions into adjacent bands 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

**Command and non-payload communication link system receiver selectivity/blocking limits**

|  |  |
| --- | --- |
| **Airborne** | **Ground** |
| TBD | TBD |

**2.2 Unmanned aircraft and control station link characteristics beyond line-of-sight**

It is to be noted that:

– feeder links between the UACS and the satellite are assumed to be in the frequency band 5 030-5 091 MHz, but may also be accommodated in other frequency bands;

– a QPSK 1/2 DVB-RCS type waveform is considered;

– the availability (link availability from the ground earth station to the UA and from the UA to the ground earth station) considered in this example is 99.99%;

– the link budgets are performed for UA and UACS located in Western Europe, corresponding to the worst case in terms of sharing with MLS (according to ICAO database used in Report ITU-R M.2205). On other areas more favourable from a sharing point of view, additional margin is available;

– the path loss includes the degradation due to atmospheric effects. The multipath and scintillation effects are included in the 3 dB link budget margin. Such a value is consistent with the margins needed for multipath and scintillation in the propagation channel of the 1.5/1.6 GHz aeronautical band;

– the link budget is carried out considering rain loss on the satellite – UA link, this representing the worst case compared to the UACS – Satellite link.

The feeder link is assumed to be in the frequency band 5 030-5 091 MHz, this case being the most restrictive one. A QPSK 1/2 DVB-RCS type waveform is considered. The availability (link availability from the ground earth station to the UA and from the UA to the ground earth station) that is considered is 99.99%.

TABLE 6

**Aeronautical mobile satellite (route) service return link budget**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **System** |  |  | **Repeater** |  |
| Availability (%) | 99.99% |   | Repeater gain (dB) | 110.5 |
| Satellite longitude (degrees) | –2.8 |   | Tx feeder loss (dB) | 1.0 |
| Conditions | Rain UL |   | Amplifier BO (OBO) (dB) | 3.5 |
| Modulation | QPSK 1/2 |   | Amplifier NPR (dB) | 17.0 |
| Useful bit rate per carrier (kbps) | 44.0 |   | *C*/*IM*0 degradation (dB/Hz) | 67.2 |
| Duplex ratio | 0.5 |   |   |  |
| Symbol rate per carrier (kbauds) | 103.5 |   | **Satellite Tx antenna** |  |
| Minimum bandwidth per carrier (kHz) | 139.8 |   | Tx antenna diameter (m) | 6.0 |
|   |  |   | Tx e.i.r.p. per carrier (dBW) | 14.1 |
| **Aircraft Earth stations** |  |   | Max Tx e.i.r.p. per carrier (dBW) | 17.1 |
| Frequency (MHz) | 5 000 |   | Downlink *C*/*I* inter-spots (dB) | 17.0 |
| Elevation (degrees) | 39.5 |   | Downlink *C*/*I*0 inter-spots (dB/Hz) | 67.2 |
| Carrier HPA power (W) | 20.0 |   |   |  |
| Antenna gain (dBi) | 3.0 |   | **Downlink propagation** |  |
| Tx loss (dB) | 2.0 |   | Total path loss (dB) | 198.0 |
| Power control uncertainty (dB) | 0.5 |   |   |  |
| Tx e.i.r.p. per carrier (dBW) | 13.5 |   | **Ground Earth station** |  |
|   |  |   | Downlink frequency (MHz) | 5 000 |
| **Uplink propagation** |  |   | Elevation (deg) | 39.5 |
| Total path loss (dB) | 198.5 |   | Antenna diameter (m) | 3.8 |
|   |  |   | *G*/*T* (dB/K) | 18.8 |
| **Satellite Rx antenna** |  |   | Downlink *C*/*N*0 (dB/Hz) | 63.5 |
| Rx antenna diameter (m) | 6.0 |   |   |  |
| Rx antenna gain (dBi) | 45.1 |   | **Demodulation** |  |
| Rx feeder loss (dB) | 0.5 |   | MLS degradation (dB) | 1.0 |
| Satellite *G*/*T* (dB/°K) | 18.7 |   | Total *C*/(*N*0+*IM*0+*I*0) (dB/Hz) | 57.0 |
| Uplink *C*/*N*0 (dB/Hz) | 62.4 |   | Total *C*/(*N*+*IM*+*I*) (dB) | 6.8 |
| Uplink *C*/*I*0 inter-spots (dB/Hz) | 67.2 |   | Required *C*/(*N*0+*IM*0+*I*0) (dB/Hz) | 54.0 |
| Uplink *C*/*I* inter-spots (dB) | 17.0 |   | Required *C*/(*N*+*IM*+*I*) (dB) | 3.8 |
|   |  |   | Margin (dB) | 3.0 |

TABLE 7

**Aeronautical mobile satellite (route) service forward link budget**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **System** |  |  | **Repeater** |  |
| Availability (%) | 99.99% |   | Repeater gain (dB) | 104.5 |
| Satellite longitude (degrees) | –2.8 |   | Tx feeder loss (dB) | 1.0 |
| Conditions | Rain DL |   | Amplifier BO (OBO) (dB) | 4.0 |
| Modulation | QPSK ½ |   | Amplifier NPR (dB) | 17.0 |
| Useful bit rate per carrier (kbps) | 7.0 |   | *C*/*IM*0 degradation (dB/Hz) | 59.2 |
| Duplex ratio | 0.5 |   |   |  |
| Symbol rate per carrier (kbauds) | 16.5 |   | **Satellite Tx antenna** |  |
| Minimum bandwidth per carrier (kHz) | 22.2 |   | Tx antenna diameter (m) | 6.0 |
|   |  |   | Tx e.i.r.p. per carrier (dBW) | 44.7 |
| **Ground Earth station** |  |   | Max Tx e.i.r.p. per carrier (dBW) | 47.7 |
| Frequency (MHz) | 5.000 |   | Downlink *C*/*I* inter-spots (dB) | 17.0 |
| Elevation (degrees) | 39.5 |   | Downlink *C*/*I*0 inter-spots (dB/Hz) | 59.2 |
| Number of carriers | 20 |   |   |  |
| HPA power (W) | 100.0 |   | **Downlink propagation** |  |
| Antenna diameter (m) | 3.8 |   | Total path loss (dB) | 198.5 |
| Antenna gain (dBi) | 44.1 |   |   |  |
| Tx loss (dB) | 1.0 |   | **Aircraft Earth station** |  |
| Power control uncertainty (dB) | 0.5 |   | Downlink frequency (MHz) | 5.000 |
| Tx e.i.r.p. per carrier (dBW) | 49.6 |   | Elevation (deg) | 39.5 |
|   |  |   | *G*/*T* (dB/K0 | –23.0 |
| **Uplink propagation** |  |   | Downlink *C*/*N*0 (dB/Hz) | 51.9 |
| Total path loss (dB) | 198.0 |   | Downlink *C*/*N* (dB) | 9.7 |
|   |  |   |   |  |
| **Satellite Rx antenna** |  |   | **Demodulation** |  |
| Rx antenna diameter (m) | 6.0 |   | MLS degradation (dB) | 1.0 |
| Rx antenna gain (dBi) | 45.1 |   | Total *C*/(*N*0+*IM*0+*I*0) (dB/Hz) | 49.0 |
| Rx feeder loss (dB) | 0.5 |   | Total *C*/(*N*+*IM*+*I*) (dB) | 6.8 |
| Satellite *G*/*T* (dB/K) | 18.7 |   | Required *C*/(*N*0+*IM*0+*I*0) (dB/Hz) | 46.0 |
| Uplink *C*/*N*0 (dB/Hz) | 98.9 |   | Required *C*/(*N*+*IM*+*I*) (dB) | 3.8 |
| Uplink *C*/*I*0 inter-spots (dB/Hz) | 59.2 |   | Margin (dB) | 3.0 |
| Uplink *C*/*I* inter-spots (dB) | 17.0 |   |   |  |

*[Editor’s note: The previous table was quoted from Report ITU-R M.2233 (Annex 3 § 6) Comparison should be made with other reports dealing with the same topic, in order to identify and complete missing parameters. Satellite antenna diameters should be checked as well for consistency.]*