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| **Document Title:** **PRELIMINARY DRAFT NEW RECOMMENDATION 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 |

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| **Purpose/Objective:** The purpose of this contribution is to propose an update to the terrestrial and satellite characteristics based on a recent update to the RTCA MOPS DO-362A and EUROCAE MOPS ED-265 that standardize and define 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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| **United Sates of America** |
| preliminary draft new Recommendation 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 (route) service and aeronautical mobile satellite (R) Service in the band 5 030-5 091 MHz** |

**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 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**: 1

ATTACHMENT

PRELIMINARY DRAFT NEW RECOMMENDATION 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 (route) service and aeronautical**

**mobile satellite (R) Service in the band 5 030-5 091 MHz**

**Scope**

This Recommendation specifies the characteristics of control and non-payload communications (CNPC) links, carrying command and control (C2) information, operating in the aeronautical mobile (R) service (AM(R)S) and aeronautical mobile-satellite (R) service (AMS(R)S) in the frequency band 5 030-5 091 MHz in order to be used in analysing compatibility between unmanned aircraft systems (UAS) CNPC operating in the AM(R)S and AMS(R)S and other services.

**Keywords**

Unmanned aircraft systems

**Abbreviations/Glossary**

AM(R)S Aeronautical mobile (route) service

AMS(R)S Aeronautical mobile-satellite (route) service

ARRS Airborne radio relay system

ARS Airborne radio system

BGRS Beyond line-of-sight ground radio system

C2 Command and control

CNPC Control and non-payload communication

CRC Cyclic redundancy check

DVB-RCS Digital video broadcasting - return channel via satellite

FDMA Frequency division multiple access

GMSK Gaussian minimum shift keying

GRS Ground radio system

ICAO International Civil Aviation Organization

QPSK Quadrature phase shift keying

RPA Remotely piloted aircraft

RPAS Remotely piloted aircraft system

RR Radio Regulation

TCC Turbo code comparison

TDD Time division duplex

UA Unmanned aircraft

UACS Unmanned aircraft control station

UAS Unmanned aircraft system

**Related ITU Reports**

*Reports*

[ITU-R M.2205](https://www.itu.int/pub/R-REP-M.2205) 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

[ITU-R M.2233](https://www.itu.int/pub/R-REP-M.2233) Examples of technical characteristics for unmanned aircraft control and non-payload communications links

[ITU-R M.2171](https://www.itu.int/pub/R-REP-M.2171) Characteristics of unmanned aircraft systems and spectrum requirements to support their safe operation in non-segregated airspace

The ITU Radiocommunication Assembly,

*considering*

*a)* that …

*recognizing*

*a)* that the frequency band 5 030-5 091 MHz is allocated to both the aeronautical mobile (route) service (AM(R)S) and the aeronautical mobile-satellite (route) service (AMS(R)S) and are planned to be used for unmanned aircraft (UA) control and non-payload communication (CNPC) command and control (C2) links to support the safe operation of UA;

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

*c)* that some internationally standardized microwave landing systems operate in this band in accordance with Radio Regulations (RR) No. **5.444**;

*d)* 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;

*e)* that use of the frequency band 5 030-5 091 MHz by the AM(R)S and AMS(R)S is limited to internationally standardized aeronautical systems in accordance respectively with RR No. **5.443C** and RR No. **5.443D**.

*recommends*

1 that the technical and operational characteristics of the UA CNPC links for C2 operating in the AM(R)S and AMS(R)S described in the Annex should be considered representative of AM(R)S and AMS(R)S systems operating in the frequency band 5 030-5 091 MHz and should be used in studies of compatibility with systems operating under an allocation to another service;

2 that an aggregate interference protection criterion *I/N* for terrestrial system unmanned aircraft system (UAS) CNPC receiving stations of −6 dB[[1]](#footnote-1) should be used.

Annex

**1 Introduction and scope**

The characteristics and protection criteria of UAS CNPC C2 links and their spectrum requirements must support the safe operation of unmanned aircraft (UA) in non-segregated airspace. There is a strong and growing demand for the use of UAS (also known as remotely piloted aircraft systems (RPAS) within the international civil aviation organization (ICAO)) in civil applications. These UA 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.

As these communications are critical for a safe management of the airspaces, future ICAO standards are obviously mandatory for these kinds of communications.

The CNPC C2 Link between the unmanned aircraft control station (UACS) and the UA support the following two ways of communication:

*– The forward link*:Link from the UACS to the unmanned aircraft for flight and navigation equipment control.

*– The return link*: Link from the UA to the UACS. It is anticipated that in some flight conditions or in specific airspaces it may be necessary to downlink video streams.

The potential types of C2 information exchanges carried over the CNPC C2 link system are:

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

The UA avionics – Avionics systems send information (e.g. flight guidance system, flight management system, air traffic control communication, detect and avoid, weather radar, status reporting system) over the CNPC C2 link system from the UA to the UACS.

One aspect of the management of safe UAS operations is the management of the interference received by the receivers that link the UA and the UA CS. To enable this interference analysis to be undertaken the characteristics and protection criteria are proposed for these links operating in the AM(R)S and AMS(R)S allocations where RR Nos. **5.443C** and **5.443D** apply. This recommendation contains those characteristics and protection criteria based on systems which are currently under development and that will have to comply with the international standardization being developed by ICAO.

The CNPC C2 link consists of air-to-ground links that can be used simultaneously or independently, as required, to provide operational coverage and performance. CNCP C2 Link systems include a terrestrial based component, a high-altitude relay-based component and a satellite-based component.

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. The high-altitude relay component uses a similar ARS on the UA, [which communicates via the airborne radio relay system (ARRS)] to a beyond line-of-sight ground radio system (BGRS) on the ground that connects to the UACS. The satellite component uses an airborne earth station on the UA to communicate with a ground earth station (via the geostationary satellite) that connects to the UACS.

[Figure 1

**Example command and non-payload communications link system components]**



*[Editor’s note: Concerns were raised with respect to the Airborne radio relay system in the figure above. According to the explanations given by ICAO, the relay system is under consideration by ICAO for standardization. It is not clear if the standardization will be completed before the adoption of this recommendation]*

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

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

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 ~~18~~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.

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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 |

**[2.2 Unmanned aircraft and ground radio station characteristics for control and non-payload communication link via high altitude relay platform**

Command and non-payload communications link can also be used via high altitude relay platform. Such high-altitude relay system consists of:

a) A BGRS on the ground, with user data and link management interfaces to the host ground system.

b) An airborne relay radio system (ARRS) with user data and link management interfaces hosted on the airborne relay RPA.

c) An ARS with user data and link management interfaces hosted on the RPA.

This high-altitude relay system based C2 link system (“system 3” in this document) utilizes the frequency band 5 030–5 091 MHz to provide two-way communication between a beyond line-of-sight GRS (BGRS) and RPA flying at lower altitude via an airborne relay RPA. By using radios on the airborne relay-RPA as a relay point, C2 Link for other RPA can be extensively transmitted without deploying many radios stations on the ground.

The ARRS relays the C2 link between the ARSs and a BGRS within the coverage area of the system. As shown in Figure XX the ARRS simultaneously forms multiple beams (using one or more antennas) for the User Links between the ARRS and ARS and for the Feeder Link between the ARRS and BGRS.

Figure XX

**Overview of the high-altitude relay system**



The feeder link can be used as a C2 link for the airborne relay-RPA equipped with the ARRS. The airborne relay-RPA can also be controlled by another C2 link system. Communication protocols of a forward link of the User Link and a reverse link of the feeder link are both the same as those of a link from the GRS to the RPA which is an uplink of the terrestrial system. Likewise, the communication protocols of a reverse link of the user link and a forward link of the feeder link are both the same as those of a link from the RPA to the GRS which is a downlink of the terrestrial system. Therefore, the ARRS of the high-altitude relay system can be viewed as equivalent to the terrestrial system GRS, but in the sky. The ARS for the Terrestrial system can be connected to the ARRS of the high-altitude relay system without any particular modification.]

[TABLE XX

**Transmission and reception characteristics of the Feeder link for the BGRS and the ARRS**

|  | **Units** | **BGRS** | **ARRS** |
| --- | --- | --- | --- |
| 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 | GMSK |
| Modulation symbol rates | ksps | 5 300 (max) | 5 300 (max) |
| Occupied bandwidth, C | kHz | 5 600 (max) | 5 600 (max) |
| Antenna gain | dBi | 22.5 | 18.7 |
| Cable loss | dB | 1 | 2 |
| Antenna pattern  |  | less than 15 degree for the wider of elevation direction and azimuth direction (3 dB bandwidth) | less than 45 degree(3 dB bandwidth) |
| Maximum antenna height | m | 2 to 50Typical 10 | Approximately between60,000ft to 65,000ft |
| Service range | km | 77.6 | 74 |
| Transmitter conducted power | dBm | 30 (max) | 30 (max) |
| Transmitter in band emission limits | dBc/kHz | See Table XX(See Table 3, when C is 250kHz) | See Table XX(See Table 3, when C is 250kHz) |
| Receiver noise figure | dB | 7 | 7 |
| Receiver sensitivity | dBm | ‒111~‒96 | ‒111~‒96 |
| Receiver in band rejection – except the operating channel | dB | TBD | TBD |
| Protection criteria (aggregate) *I/N* | dB | TBD | TBD |

TABLE XX

**Transmission and reception characteristics of the User link for the ARRS and the ARSs**

|  | **Units** | **ARSs** | **ARRS** |
| --- | --- | --- | --- |
| 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 block size transmitted per TDD frame | bits | GMSK: TBDQPSK @ TBDQSPK @ TBS | GMSK: TBDQPSK @ TBDQSPK @ TBD |
| 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 | 18.7 |
| 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 8 000 | Approximately between60,000ft to 65,000ft |
| Service range | km | 74 | 74 |
| Transmitter conducted power | dBm | 40 | 30 |
| 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: TBDQPSK @ TBDQSPK @ TBD | GMSK: TBDQPSK @ TBDQSPK @ 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 |

*[Editor’s note: The high-altitude relay system is a system that is compatible with the system described in paragraph 2.1 and most of the communication characteristics of the user link are the same. The specific aspects of communication between the ARRS and UA ARS flying at high altitudes are highlighted in yellow.]*

TABLE XX

**Transmitter out of band emission limits in the 5 050-5 091 MHz frequency band
for the BGRS and ARRS (Feeder link)**

|  |  |
| --- | --- |
| **Offset from carrier frequency** | **dBc/kHz** |
| Channel width ÷ 2 | −54 |
| Channel width ×1.1 | −90 |
| Channel width ×1.5 | −96 |

*[Editor’s note: during discussion in July 2023 and May 2024 meetings of WP 5B, some administration(s) raised a concern that compatibility studies of the high altitude relay system had not been performed in ITU-R during the study cycle in preparation of WRC-12. In order to respond to the concern, it was agreed that detailed technical specifications of the high-altitude relay system and the result of the compatibility study will be provided at a future meeting. Further clarifications and information are welcome to address this concern.]*

**2.3 Unmanned aircraft and control station characteristics for control and non-payload communication link via satellite**

**2.3.1 Control and non-payload communication via geostationary orbiting satellite systems**

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 digital video broadcasting - return channel via satellite (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 microwave landing system (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.

TABLE 6

**Aeronautical mobile-satellite (route) service return link budget for GSO C2 Link system**

| **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 for GSO C2 Link system**

| **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 |  |   |  |

The previous table was quoted from Report ITU-R M.2233 (Annex 3 § 6).

**2.3.2 Control and non-payload communication via low Earth orbiting non-geostationary satellite orbiting systems**

This section describes the link between the satellite and the aircraft.

TABLE 8

**Example of aircraft earth station characteristics for one NGSO use case**

| **Parameters** | **Units** | **Values** |
| --- | --- | --- |
| Altitude | km | 0-20 |
| Frequency range | MHz | 5 030-5 091 |
| Overall Tx necessary bandwidth | MHz | 15 |
| Minimum Tx e.i.r.p. density | dBW/Hz | −37.9 |
| Minimum Tx e.i.r.p. | dBW | 13.5 |
| Tx loss | dB | 2 |
| Tx bandwidth per carrier | kHz | From 20 to 140 |
| OoB emissions | dBm | ITU-R SM.1541-7 |
| Max antenna gain\*\* | dBi | 3 |
| Type antenna gain | / | Omni |
| Overall Rx bandwidth\* | MHz | 15 |
| Minimum Rx bandwidth carrier | kHz | 22 |
| Protection criteria (aggregated interference): *I/N\*\*\** | dB | –6 |
| Rx blocking | dBm | TBD |
| \* Assumptions of 4 color reuse of the 61 MHz total available bandwidth\*\* steerable antenna could be considered later on\*\*\* does not include the 6 dB safety margin |

TABLE 9

**Example of space station characteristics for one NGSO use case**

| **Parameters** | **Units** | **Values** |
| --- | --- | --- |
| Altitude | km | 1200 |
| Frequency range | MHz | 5 030-5 091 |
| Overall Tx necessary bandwidth | MHz | 15 |
| Minimum Tx e.i.r.p. density at 30° elevation | dBW/Hz | −24.4 |
| Minimum Tx e.i.r.p at 30° elevation | dBW | 19 |
| Minimum Tx bandwidth per carrier | kHz | 22 |
| OoB emissions | dBm | ITU-R SM.1541-7 |
| Max antenna gain | dBi | 15 |
| Type antenna gain | / | ITU-R S.1528 |
| Overall Rx bandwidth\* | MHz | 15 |
| Rx bandwidth carrier | kHz | From 20 to 140 |
| Protection criteria (aggregated interference): I/N\*\* | dB | −6 |
| Rx blocking | dBm | TBD |
| \* Assumptions of 4 color reuse of the 61 MHz total available bandwidth\*\* does not include safety margin |

*[Editor’s note: Further discussion on protection criteria is expected for Table 9.]*

1. Safety margin is not included in the protection criteria. [↑](#footnote-ref-1)