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| U.S. Radiocommunications Sector  Fact Sheet | |
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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 provide updates to the characteristics of terrestrial air-ground UAS CNPC links to enable any future sharing studies to use the correct values of the parameters of the characteristics of these systems. | |
| **Abstract:** This contribution will provide values of a range of RF parameters associated with the CNPC links that operate in the AM(R)S allocation under No. 5.443C. The performance of these links has a direct relationship to the safe operation of these unmanned aircraft. Consequently, it is important to ensure their operation is correctly considered in any sharing and interference analysis that may be carried out in the future. | |

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| **Radiocommunication Study Groups** |  |
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| United Sates of America | |
| 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 | |

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

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

(202X)

**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

ARS: Airborne radio system

ATC: Air traffic control

BLoS: Beyond line of sight

CNPC: Control and non-payload communication

GRS: Ground radio system

ICAO: International Civil Aviation Organization

LoS: Line of sight

UA: Unmanned aircraft

UACS: Unmanned aircraft control station

UAS: Unmanned aircraft system

**Related ITU Recommendations, Reports**

*Recommendations*

*Reports*

ITU-R [M.2171](https://www.itu.int/pub/R-REP-M.2171-2009) Characteristics of unmanned aircraft systems and spectrum requirements to support their safe operation in non-segregated airspace

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 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,

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 (RPA) 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 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 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 C2 Link System are:

The UA Control - To support the remote pilot's activity to aviate 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 (FMS), ATC Communication, DAA, Weather Radar, Status Reporting System) over the C2 Link System from the UA to the 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 Unmanned Aircraft (UA) and the Control Station (CS), either line of sight (LOS) or beyond line of sight (BLOS). Additionally, since the frequency band is shared with other Route Service systems (like MLS 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 AMS(R)S allocations under 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

***Unmanned Aircraft (UA)*:** Designates all types of aircraft remotely controlled.

***Unmanned Aircraft Control Station (UACS)*:** Facilities from which a UA is controlled remotely.

***Control and non-payload communications (CNPC)*:** 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. ***Sense and avoid (S&A)*:** 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 (UAS)*:** Consists of the following subsystems:

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

– Unmanned aircraft control station (UACS) subsystem;

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

– Sense and avoid (S&A) subsystem;

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

***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.

***CNPC 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.

**CNPC Link Airborne Radio System (ARS):** The system that resides on the UA to transmit and receive control and communication data to and from the CNPC Link Ground Radio System. The ARS consists of the CNPC Link System Airborne Radio, one or more airborne antennas, and all associated cabling.

**CNPC Link System Airborne Radio:** The CNPC radio that is part of the CNPC Link Airborne Radio System (ARS).

**CNPC Link Ground Radio System (GRS):** 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.

**CNPC Link System Ground Radio:** The CNPC radio that is part of the CNPC Link Ground Radio System (GRS).

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

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

# 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 Guard  23 Down plus 2.7 Guard | 23 Up plus 1.3 Guard  23 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 103.5  QPSK: 20 and 80:  including error correction/detection, guard times and synchronization overhead |
| Forward Error Correction |  | GMSK: Rate 5/8 Turbo Conv. Code  QPSK: Rate 5/9 and Rate 1/3 TCC | GMSK: Rate 5/8 Turbo Conv. Code  QPSK: 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 1728  QPSK @ 20 ksps: 200 and 360  QSPK @ 80 ksps: 1032 and 1744 | GMSK: 352, 800, 1280 and 1728  QPSK @ 20 ksps: 200 and 360  QSPK @ 80 ksps: 1032 and 1744 |
| User Data Rates | kbps | GMSK Tx: 7.04, 16.0, 25.6 and 34.56  GSMK Rx: 7.04, 16.0 and 34.56  QPSK Tx/Rx @ 20 ksps: 20.64 and 34.88;  Includes TDD duty cycle overhead | GMSK Tx: 7.04, 16.0, 25.6 and 34.56  GSMK Rx: 7.04, 16.0 and 34.56  QPSK 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 | 3 | 22.5 |
| Cable loss | dB | 2 | 3 |
| Antenna pattern |  | Constant Azimuth  Constant Elevation | Constant Azimuth  Tailored in Elevation  See Table 2 |
| Antenna polarization |  | Vertical with aircraft flying straight and level | Vertical |
| Maximum antenna height | m | 22 860 (MSL)  Typical 8 000 | 2 to 50  Typical 10 |
| Service range | km | 550  Typical 200 | 550  Typical 200 |
| Transmitter conducted power | dBm | 40 | 40 |
| Transmitter in band emission limits | dBc/kHz | −96 at 2 MHz offset  See Table 3 | −96 at 2 MHz offset  See Table 3 |
| Receiver noise figure | dB | 7 | 7 |
| Receiver Sensibility | dBm | GMSK: -118, -115 and -113  QPSK @ 20 ksps: -120.5 and -118  QSPK @ 80 ksps: -114.5 and -112 | GMSK: -118, -115 and -113  QPSK @ 20 ksps: -120.5 and -118  QSPK @ 80 ksps: -114.5 and -112 |
| Receiver in band rejection – except the operating channel | dB | One channel separation: 23  Two channel Separation: 43  Three channel separation: 57  2 MHz or more separation: 63 | One channel separation: 23  Two channel Separation: 43  Three channel separation: 57  2 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 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%.

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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.]*