



**Recommendation ITU-R M.2031**  
(12/2012)

**Characteristics and protection criteria of  
receiving earth stations and characteristics  
of transmitting space stations of the  
radionavigation-satellite service  
(space-to-Earth) operating in  
the band 5 010-5 030 MHz**

**M Series**  
**Mobile, radiodetermination, amateur  
and related satellite services**

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*Note: This ITU-R Recommendation was approved in English under the procedure detailed in Resolution ITU-R 1.*

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RECOMMENDATION ITU-R M.2031<sup>1</sup>**Characteristics and protection criteria of receiving earth stations and characteristics of transmitting space stations of the radionavigation-satellite service (space-to-Earth) operating in the band 5 010-5 030 MHz**

(Questions ITU-R 217-2/4 and ITU-R 288/4)

(2012)

**Scope**

Characteristics and protection criteria for radionavigation-satellite service (RNSS) receiving earth stations and characteristics of RNSS transmitting space stations planned or operating in the band 5 010-5 030 MHz are presented in this Recommendation. This information is intended for performing sharing and compatibility 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 radio sources other than in the RNSS.

The ITU Radiocommunication Assembly,

*considering*

- a) that systems and networks in the radionavigation-satellite service (RNSS) provide worldwide accurate information for many positioning, navigation and timing applications, including safety aspects for some frequency bands and under certain circumstances and applications;
- b) that there are various operating and planned systems and networks in the RNSS;
- c) that studies are being conducted on the impact to RNSS networks and systems from other radio sources;
- d) that Recommendation ITU-R M.1901 provides guidance on ITU-R Recommendations related to systems and networks in the RNSS,

*recognizing*

- a) that the band 5 010-5 030 MHz is allocated on a primary basis to the RNSS (space-to-Earth and space-to-space) in all three Regions;
- b) that the band 5 010-5 030 MHz is also allocated on a primary basis to the aeronautical radionavigation service (ARNS) in all three Regions;
- c) that the band 5 010-5 030 MHz is also allocated on a primary basis to the aeronautical mobile-satellite (route) service (AMS(R)S) in all three Regions subject to RR No. 9.21;
- d) that, under RR No. 5.328B, “the use of the bands 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz and 5 010-5 030 MHz by systems and networks in the RNSS for which complete coordination or notification information, as appropriate, is received by the Radiocommunication Bureau after 1 January 2005 is subject to the application of the provisions of RR Nos. 9.12, 9.12A and 9.13 ...”, and studies to determine additional methodologies and criteria to facilitate such coordination are being planned;

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<sup>1</sup> This Recommendation should be brought to the attention of ITU-R Study Group 5 and the International Civil Aviation Organization (ICAO).

e) that RR No. 5.443B and Resolution 741 (Rev.WRC-12) provide aggregate power flux-density limits on space stations in the RNSS to prevent harmful interference to the radio astronomy service (RAS) operating in the band 4 990-5 000 MHz;

f) that RR No. 5.443B provides aggregate power flux-density limits on space stations in the RNSS to prevent harmful interference to the microwave landing system which operates in the ARNS above 5 030 MHz,

*recommends*

1 that the characteristics and protection criteria of receiving earth stations and the characteristics of transmitting space stations given in Annexes 1, 2 and 3 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 radio sources other than in the RNSS;

2 that the allowance for interference to service links of systems and networks in the RNSS (space-to-Earth) in Annexes 1 and 2 operating in the band 5 010-5 030 MHz from all radio sources other than in the RNSS, not exceed the interference threshold values given in Tables 1-1 and 2-4.

## Annex 1

### Typical technical characteristics and protection criteria for Galileo receiving earth stations operating in the band 5 010-5 030 MHz

#### 1 Introduction

The Galileo Positioning System service link provides information used to determine position, navigation and timing (PNT) by suitably equipped navigation receivers. This Annex focuses on the Galileo Positioning System service link receiving characteristics and does not address transmitting space stations of the same network. It is anticipated that this Annex will be updated in a future revision of this Recommendation once the transmitting space station characteristics are available.

#### 2 Galileo service link characteristics

The Galileo PNT service provides downlinks in the 5 010-5 030 MHz band for the PNT requirements of mobile users (land, maritime, aeronautical).

Galileo PNT offers two services: one with global coverage and one that makes use of spot beams, providing higher  $C/N_0$  in specific areas. To provide high ranging accuracies and positioning performances, wideband signal transmissions are essential. Similar to the RNSS signal transmissions in L-band, the transmissions in C-band are implemented as spread spectrum signals with multiplexed signal components.

Compared to the sharing conditions in the RNSS allocations between 1 164 MHz and 1 610 MHz, the band 5 010-5 030 MHz offers significantly lower levels of potential interference that renders it attractive for safety critical and similar elevated service applications.

The derived receiver protection criteria are given in Table 1-1 below, using the downlink conditions for a global coverage beam. The different signal components are multiplexed using constant envelope modulations. Full service quality, as required by market demands, has to be achieved for all elevation angles above 5°.

The service link assumes to provide PNT services to mobile RNSS receivers from satellites visible above 5° elevation using hemispherical coverage antennas with a gain of –5 dBi. The gain for the assumed typical receive antenna varies from –5 dBi to +4 dBi for elevation angles between 5° and 90°.

### 3 RNSS receiver protection criteria

The aggregate interference threshold levels in Table 1-1 are calculated for interference of continuous transmissions only, assumed as white noise.

The values of the aggregate narrow-band interference threshold levels in Table 1-1 are tentative. As outlined in Recommendation ITU-R M.1831, while there is an appropriate method to model continuous external wideband interference scenarios, additional methods need to be defined for narrow-band and pulsed interference and at this time there is no Recommendation that handles narrow-band interference.

To provide PNT information, RNSS receivers apply several critical steps in the RF reception and processing of spread-spectrum signals. These process steps are signal (carrier and phase) acquisition, carrier and phase tracking, code and sub-carrier tracking and decoding of the navigation message.

The protection of the performances for the aforementioned receiver processes require therefore special attention as it is not only the degrading of the  $C/N_0$  due to interferences simplified as white noise, but also the spectral shape of these interferences that could harmfully degrade the receiver performance. In other words, coloured noise can degrade the receiver performance even in the case of a presumably harmless  $C/N_0$  degradation based on an inappropriate additive white Gaussian noise (AWGN) interference model.

Coloured noise also has an influence on the implementation of early-late decorrelators, which are an essential element in the RNSS receiver process.

Recommendation ITU-R M.1831 describes the calculation process for coordination between RNSS systems taking the spectral signal characteristics into account by applying a Spectral Separation Coefficient (SSC).

Similarly to continuous interferences, the  $C/N_0$  degradations computed with pulsed interferences and considering the white noise assumption are not representative of the real effects onto the receiver performances. Additionally to the continuous interferences new parameters, as the peak power, the pulse duty cycle (PDC) and the pulse repetition frequency (PRF) need to be taken into account for an adequate evaluation of receiver performance degradations. Closed-form expressions can consider these additional parameters, but the limits of modelling become apparent if non-linear effects on the receiver front-end have to be taken into account.

In the case of pulsed interference, the time required to transit from a saturated receiver front-end during the pulse to a steady state, where linear equations are valid, highly depends on receiver implementations. During the time period of the pulse duration added to the previous recovery time, the samples provided to the correlator are useless for tracking or data-demodulation.

The higher the number of pulses per coherent integration interval, the larger will be the degradation for a fixed PDC, due to accumulated effects of the recovery times. The pulse duration has to be only a small portion of the coherent integration period. In general, any time period showing strongly degraded samples caused by the saturation of the receiver front-end due to high power pulses, that are greater than or equal to a tenth of the receiver's coherent integration time (usually about 1 ms), could harmfully degrade the integration process. In order to avoid repetition of the aforementioned effects it is necessary to have the PRF non-proportional to the symbol rate of the RNSS signals or any fraction of it.

Mitigation strategies to protect the receiver against pulsed interference are considered to be left with receiver designers and manufacturers as a competitive asset rather than a limiting constraint imposed by Radio Regulations.

TABLE 1-1

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

<b>Parameter</b>	<b>RNSS parameter description</b>
Signal frequency range (MHz)	5 010-5 030
Maximum receiver antenna gain (dBi)	4
RF filter 3 dB bandwidth (MHz)	20
Pre-correlation filter 3 dB bandwidth (MHz)	20
Receiver system noise temperature (K)	530
Tracking mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW)	-157.1
Acquisition mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW)	-160.1
Tracking mode threshold power density level of aggregate wideband interference at the passive antenna output (dB(W/MHz))	-147.1
Acquisition mode threshold power density level of aggregate wideband interference at the passive antenna output (dB(W/MHz))	-150.1

## Annex 2

### **Technical characteristics and protection criteria of receiving earth stations and characteristics of transmitting space stations in the Global Positioning System (GPS) operating space-to-Earth in the band 5 010-5 030 MHz**

#### **1 Introduction**

The Global Positioning System (GPS) uplink and downlink feeder-links will provide communications for system and satellite monitoring, commanding and control; updates of orbit ephemerides; and clock synchronization. The minimum operational elevation angle for GPS feeder-link operations is 5 degrees resulting in a maximum path length of 25 252 km. GPS service links will provide information used to determine PNT by suitably equipped navigation receivers.

#### **2 GPS feeder downlink characteristics**

GPS plans estimate the operational bandwidth of the feeder downlink to be 6.6 MHz, with an encoded data rate of 6.6 Mbit/s. The space station's feeder downlink antenna is specified to be a centre-fed circular parabolic dish. However, due to the simultaneous use of the 5 000-5 010 MHz Earth-to-space band for feeder uplinks and the adjacent 5 010-5 030 MHz space-to-Earth band for service links and feeder downlinks, appropriate design features are necessary to avoid potential

interference. Implementation of transmit filters with very sharp cut-offs in both the satellites and earth stations are an important element of this. Transmit filtering will be implemented for all GPS transmit signals and spurious transmissions are intended to be –60 dB from the peak.

Table 2-1 provides characteristics for GPS receiving feeder-link earth stations operating in the band 5 010-5 030 MHz. Although parameters are derived from and consistent with GPS specifications, these values are still subject to change. Table 2-2 provides characteristics of the corresponding GPS space station feeder-link transmissions.

In countries where RNSS feeder downlink earth stations are deployed, national arrangements are likely to be required within national borders, by administrations wishing to also deploy terrestrial systems in these bands. If an administration wishes to ensure the protection of the receiving RNSS feeder downlink earth station located in its territory from the transmitting terrestrial station located in the adjacent countries, specific earth stations located at the edge of the territory should be registered to the ITU through the coordination and notification procedure under the provisions of RR Articles 9 and 11. If preliminary studies show that the aggregate interference in the receiver bandwidth of the feeder link, from all radio sources of primary services in the band other than in the RNSS, exceeds 6% of the RNSS feeder link receiver system noise temperature, referred to the output terminals of the receiving antenna, further studies should be performed to determine the potential for inter-system compatibility.

TABLE 2-1  
**Characteristics of GPS receiving feeder-link earth stations  
operating in the band 5 010-5 030 MHz**

Parameter	Parameter value
Antenna diameter (m)	5.00
Polarization	RHCP
Antenna pattern	Centre-fed circular parabolic dish
Theoretical antenna gain (dBi)	48.39
Antenna efficiency loss (dB)	1.50
Maximum receive antenna gain (dBi)	46.63
Receiver system noise temperature (K)	140
Minimum elevation (degrees)	5.0

TABLE 2-2  
**GPS feeder downlink transmissions in the band 5 010-5 030 MHz**

Parameter	Parameter value
Signal frequency range (MHz) (Note 1)	$5\ 013.63 \pm 3.3$
Encoded bit rate (bit/s)	6 600 000
Signal modulation method	Filtered QPSK
Polarization	Right-hand circular (RHCP)
Ellipticity (dB)	1.5 maximum
Transmit e.i.r.p. (dBW)	34.6

NOTE 1 – Carrier frequency of the RNSS signal of interest  $\pm$  half the signal bandwidth.

### 3 GPS PNT service link characteristics and protection criteria

GPS PNT service downlinks for the 5 010-5 030 MHz band can be developed under current satellite technologies. A simple link budget calculation can show that it is well within current satellite technology to provide RNSS PNT services to RNSS users employing assumed antennas with an idealized uniform 3 dBi gain over hemispherical coverage.

A downlink signal modulation, which meets 5 GHz service link requirements, is filtered staggered quadrature phase-shift-key (SQPSK) with a 10 Mbit/s pseudorandom spreading code (SQPSK(10)). The SQPSK signal could have a dataless component, to aid signal acquisition, in quadrature with a data component. The filtering would provide protection for services in other bands, while the filtered SQPSK(10) still provides good characteristics for PNT and transmit power and signal generation. The signal would be circularly polarized, but whether right- or left-handed is a design choice that could depend on the polarization of other signals in the band; viz., RNSS feeder links.

The key parameters of the GPS 5-GHz service link transmissions are presented in Table 2-3. While the service link parameters presented in this section are derived from and consistent with GPS specifications, these values are still subject to change.

TABLE 2-3

**GPS service link transmissions in the band 5 010-5 030 MHz**

<b>Parameter</b>	<b>Parameter value</b>
Signal frequency range (MHz)	5 019.861 ± 9.86
PRN code chip rate (Mchip/s)	10.23
Navigation data bitrate (bit/s)	50 to 50 000
Signal modulation method	Filtered SQPSK(10)
Polarization	Circular
Ellipticity (dB)	1.5 maximum
Minimum received power level at the output of the reference antenna (dBW)	-171.6

It is anticipated that receivers in the 5 010-5 030 MHz band will react to interference in a manner analogous to RNSS receivers using modernized PRN codes of PNT signals; e.g. GPS L1C, L2C, and L5, operating in the 1 164-1 300 MHz and 1 559-1 610 MHz bands, and studies for compatibility and sharing with non-RNSS services are expected to proceed along similar lines.

The aggregate interference threshold levels in Table 2-4 are intended for continuously transmitting interference only. Although parameters are derived from and consistent with GPS specifications, these values are still subject to change.



TABLE 2-4

**Service link characteristics and protection criteria of GPS receiving user ground stations for operation in the band 5 010-5 030 MHz**

Parameter	Parameter value
Signal frequency range (MHz)	5 019.861 ± 9.86
Maximum receiver antenna gain in upper hemisphere (dBi)	3
Maximum receiver antenna gain in lower hemisphere (dBi)	3 (see Note 2)
Receiver RF filter 3 dB bandwidth (MHz)	20
Receiver pre-correlation 3 dB bandwidth (MHz)	20
Receiver system noise temperature (K)	500
Tracking mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW)	-154.6 (see Note 1)
Acquisition mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW)	-157.6 (see Note 1)
Tracking mode threshold power density level of aggregate wideband interference at the passive antenna output (dB(W/MHz))	-144.6 (see Note 1)
Acquisition mode threshold power density level of aggregate wideband interference at the passive antenna output (dB(W/MHz))	-147.6 (see Note 1)

NOTE 1 – Narrow-band continuous interference is considered to have a bandwidth of less than 700 Hz in the 5 010-5 030 MHz band. Wideband continuous interference is considered to have greater than 1 MHz bandwidth in the 5 010-5 030 MHz band. Threshold power levels for interference bandwidths between 700 Hz to 1 MHz are derived by log-linear interpolation between the narrow-band power limit in a 700 Hz bandwidth and the wideband power density limit in a 1 MHz bandwidth.

NOTE 2 – Because the antenna in some RNSS receiver applications could potentially be pointed in almost any direction, the maximum antenna gain in the lower hemisphere could (under worst-case conditions) be equal to that for the upper hemisphere.

Compared to similar systems implemented at 1.5 GHz, RNSS systems developed for the 5 GHz band would experience as much as 10 dB increased free-space path loss, as well as increased water vapour, rainfall and foliage attenuation. Also, the technology for 5 GHz is currently more expensive than for other RNSS bands.

Offsetting these drawbacks, there are some benefits to a 5 GHz implementation. The primary benefit is that the shorter wavelength makes use of higher gain antennas and antenna arrays possible within a given antenna footprint. In fact, since the wavelength is about 30% of other RNSS bands, the diameter, physical aperture, and weight of antennas with the same gain patterns as a similar antenna in the 1.5 GHz range is reduced by roughly factors of 0.3,  $(0.3)^2 = 0.09$ , and  $(0.3)^3 = 0.027$ , respectively. This may lend itself to applications for which size and weight are strong system constraints for both user equipment and satellite payloads. This, in turn, may enable the use of adaptive antennas with the capability to increase received signal power or put nulls on RFI sources or both. Such capabilities are useful since unwanted emissions from other services could interfere with RNSS signals at short range. Such antennas however may not be suitable for all applications. In addition, since such an antenna consists of a number of antenna elements, receiver front-ends and beam-forming/steering electronics, the receiver architecture becomes complex.

Another benefit to a 5 GHz implementation is the potential for improved position and timing accuracy. This is due to the reduced variability in ionospheric propagation delay.

As noted in § 2 above, no studies have concluded on how 5 GHz service links would work in the presence of RNSS feeder downlinks. Further study could include such techniques as orthogonal circular polarizations, modulations with low cross-correlation properties, and incorporating more link margin for RFI from feeder downlinks. Also, the compatibility of simultaneous feeder downlink and service link signals from different RNSS systems needs to be considered.

Protection criteria for the service link signals need to be further developed as RNSS system designs mature. Those protection criteria should take into account the RNSS features necessary to ensure the receiver can operate in its intended environment, including any signal bandwidth and filtering constraints to ensure compatibility with radio astronomy. In addition, if the RNSS link will be fielded in an airport environment, it should be designed to tolerate unwanted emissions from the ICAO standard microwave landing system (MLS) operating in the adjacent band. More 5 GHz RNSS receiver details will become available after initial system designs are completed.

### **Annex 3**

## **Technical characteristics and protection criteria of receiving earth stations and characteristics of transmitting space stations in the Quasi-Zenith Satellite System (QZSS) operating in the band 5 010-5 030 MHz**

### **1 Introduction**

The Quasi-Zenith Satellite System (QZSS) uplink and downlink feeder links provide communications for system and satellite monitoring, command, control, and navigation message upload. The QZSS control stations are located in the Asia-Pacific Region.

### **2 QZSS characteristics**

Characteristics of QZSS feeder-link receiving earth stations operating in the band 5 010-5 030 MHz are provided in Table 3-1. Characteristics of QZSS feeder-link transmitting space stations operating in the band 5 010-5 030 MHz are provided in Table 3-2.

In order to avoid self-interference, a filtering technique will be implemented in QZSS satellites. Furthermore, only the lower portion of the 5 000-5 010 MHz uplink frequency band and the upper portion of the 5 010-5 030 MHz downlink frequency band are used.

The QZSS feeder downlink in the 5 010-5 030 MHz band includes telemetry and ranging functions.

For evaluation of potential interference into the QZSS telemetry link, the characteristics in Tables 3-1 and 3-2 should be used.

For evaluation of the ranging link, the characteristics and protection criteria should be exchanged in bilateral discussions as is the usual practice for satellite inter-system frequency coordination. This is because proper assessment of any interference impact into the QZSS ranging link requires an overall  $C/N_0$  evaluation taking into account the uplink and downlink segments. (It is not possible to evaluate the QZSS ranging link performance based only on interference to the downlink.)

TABLE 3-1

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

Parameter	Parameter value
Antenna pattern	Rec. ITU-R S.465-5
Maximum antenna gain (dBi)	49.0
Necessary bandwidth (kHz)	400
Noise temperature (K)	150

NOTE 1 – Tables 3-1 and 3-2 only contain the characteristics of the QZSS telemetry link. The paragraph preceding Table 3-1 should be referenced regarding the characteristics and protection criteria of the QZSS ranging link.

NOTE 2 – The characteristics in Table 3-1 can be used to perform the preliminary studies mentioned in the paragraph following Table 3-1.

In countries where RNSS feeder downlink earth stations are deployed, national arrangements are likely to be required within national borders, by administrations wishing to also deploy terrestrial systems in these bands. If an administration wishes to ensure the protection of the receiving RNSS feeder downlink earth station located in its territory from the transmitting terrestrial station located in the adjacent countries, specific earth stations located at the edge of the territory should be registered to the ITU through the coordination and notification procedure under the provisions of RR Articles 9 and 11. If preliminary studies show that the aggregate interference in the receiver bandwidth of the feeder link, from all radio sources of primary services in the band other than in the RNSS, exceeds 6% of the RNSS feeder-link receiver system noise temperature, referred to the output terminals of the receiving antenna, further studies should be performed to determine the potential for inter-system compatibility.

TABLE 3-2

**Characteristics of QZSS feeder-link transmitting space stations  
operating in the band 5 010-5 030 MHz**

Parameter	Parameter value
Antenna pattern	Global beam
Polarization	RHCP
Transmit e.i.r.p. range (dBW)	9.8 to 23.3
Modulation	PCM-PSK/PM