International Telecommunication Union

# ITU-R

Radiocommunication Sector of ITU

**Recommendation ITU-R M.1904-1**
**(09/2019)**

# Characteristics, performance requirements and protection criteria for receiving stations of the radionavigation-satellite service (space-to-space) operating in the frequency bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 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.*

*Electronic Publication*
Geneva, 2019

# RECOMMENDATION ITU-R M.1904-1

## Characteristics, performance requirements and protection criteria for receiving stations of the radionavigation-satellite service (space-to-space) operating in the frequency bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz

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

(2012-2019)

**Scope**

The characteristics and protection criteria for radionavigation-satellite service (RNSS) spaceborne receivers are presented in this Recommendation. This information is intended for performing analyses of radio-frequency interference impact on RNSS receivers operating space-to-space in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz from emissions of non-RNSS sources.

**Keywords**

RNSS, protection criteria, radiofrequency interference impact

**Abbreviations/Glossary**

| | |
|---|---|
| AWGN | Additive white Gaussian noise |
| PDC | Pulse duty cycle |
| PNT | Position, navigation and timing |
| PRF | Pulse repetition frequency |
| RHCP | Right-hand circular polarization |
| SQPN | Staggered quadrature pseudo-random noise |
| SQPSK | Staggered quadrature phase-shift keying |
| SSC | Spectral separation coefficient |

**Related ITU Recommendations, Reports**

| | |
|---|---|
| Recommendation ITU-R M.1318-1 | Evaluation model for continuous interference from radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz and 5 010-5 030 MHz bands |
| Recommendation ITU-R M.1787-3 | Description of systems and networks in the radionavigation-satellite service (space-to-Earth and space-to-space) and technical characteristics of transmitting space stations operating in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz |
| Recommendation ITU-R M.1901-2 | Guidance on ITU-R Recommendations related to systems and networks in the radionavigation-satellite service operating in the frequency bands 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz, 5 000-5 010 MHz and 5 010-5 030 MHz |
| Recommendation ITU-R M.1902-1 | Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) operating in the band 1 215-1 300 MHz |

| | |
|---|---|
| Recommendation ITU-R M.1903-1 | Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) and receivers in the aeronautical radionavigation service operating in the band 1 559-1 610 MHz |
| Recommendation ITU-R M.1905-1 | Characteristics and protection criteria for receiving earth stations in the radionavigation-satellite service (space-to-Earth) operating in the band 1 164-1 215 MHz |
| Recommendation ITU-R M.1906-1 | Characteristics and protection criteria of receiving space stations and characteristics of transmitting earth stations in the radionavigation-satellite service (Earth-to-space) operating in the band 5 000-5 010 MHz |
| Recommendation ITU-R M.2030-0 | Evaluation method for pulsed interference from relevant radio sources other than in the radionavigation-satellite service to the radionavigation-satellite service systems and networks operating in the 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz frequency bands |
| Recommendation ITU-R M.2031-1 | 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 |

The ITU Radiocommunication Assembly,

*considering*

*a)* that spaceborne receivers of the RNSS, making use of existing or planned RNSS transmissions in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz, are already in operation or are planned for operation on spacecraft by various satellite networks and systems;

*b)* that RNSS downlink emissions in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz can also be used for space-to-space applications (e.g. spacecraft positioning), without using additional spectrum resources,

*noting*

*a)* that Recommendation ITU-R M.1787 provides information on signal characteristics of RNSS systems and networks, and Recommendations ITU-R M.1905, ITU-R M.1902 and ITU-R M.1903 provide information on technical and performance characteristics of RNSS receivers for RNSS systems and networks;

*b)* that Recommendation ITU-R M.1901 provides guidance on this and other ITU-R Recommendations related to systems and networks in the RNSS operating in the frequency bands 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz, 5 000-5 010 MHz and 5 010-5 030 MHz,

*recognizing*

*a)* that the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz are allocated on a primary basis to RNSS (space-to-Earth) (space-to-space) in all three Regions;

*b)* that under Radio Regulations No. **5.329A**, "use of systems in the radionavigation-satellite service (space-to-space) operating in the bands 1 215-1 300 MHz and 1 559-1 610 MHz is not intended to provide safety service applications, and shall not impose any additional constraints on other systems or services operating in accordance with the Table";

*c)* that the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz are also allocated on a primary basis to other services in all three Regions, *recommends*

**1** that the RNSS receiver characteristics and protection criteria given in Annexes 1, 2 and 3 should be used in performing analyses of radio-frequency interference to spaceborne RNSS receivers operating (space-to-space) in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz from non-RNSS sources;

**2** that the aggregate interference power thresholds given in the Annexes may be used in interference calculations for radionavigation receivers on board satellites;

**3** that the requirements given in Annexes 1, 2 and 3 together with other characteristics of the RNSS systems may be used in interference calculations for spaceborne RNSS receivers at higher altitudes;

**4** that in cases where the aggregate interference power thresholds given in the Annexes are exceeded, the requirements given in Annexes 1, 2 and 3 together with other characteristics of the RNSS systems may be used in interference calculations for spaceborne RNSS receivers;

**5** that the following Note should be considered as part of this Recommendation.

NOTE − This Recommendation is not intended to be used to form the basis for future modifications to maximum unwanted emission levels for the band 1 559-1 610 MHz that are stated in the Annexes to Recommendations ITU-R M.1343-1 and ITU-R M.1480 for MSS MESs. The maximum unwanted emission levels for the band 1 559-1 610 MHz stated in Recommendations ITU-R M.1343-1 and ITU-R M.1480 have been developed pursuant to a specific interference scenario, and are not intended to be applied to any service other than MSS MESs operating in the 1-3 GHz range without further study.

# Annex 1

## GLONASS spaceborne receiver characteristics

Table 1 provides characteristics of spaceborne RNSS receivers for use with the GLONASS system.

TABLE 1

**GLONASS spaceborne receiver characteristics**

| **Parameter** | **Value** | |
|---|---|---|
| **Signals** | **FDMA** | **CDMA** |
| Carrier frequencies (MHz) | (1998-2005)(1)<br>$F$ = 1 602 + 0.5625 $K$<br>where<br>$K$ = −7, …, 13<br>$F$ = 1 246 + 0.4375 $K$<br>where<br>$K$ = −7, …, 13<br>(After 2005)<br>$F$ = 1 602 + 0.5625 $K$<br>where<br>$K$ = −7, …, 6<br>$F$ = 1 246 + 0.4375 $K$<br>where<br>$K$ = −7, …, 6<br>$F$ = 1 204.704 + 0.423 $K$<br>where<br>$K$ = −7, …, 12 | $F$ = 1 600.995<br>$F$ = 1 248.06<br>$F$ = 1 202.025 |
| Pseudo-random noise (PRN) code chip rate (Mcps) | 5.11 (HA L1 signals and HA L2 signals)<br>0.511 (SA L1 signals and SA L2 signals)<br>4.095 (HA L3 and SA L3 signals) | 1.023 (L1, L2)<br>10 * 1.023 (L3) |
| Navigation data bit rate (bps) | 50 (L1 and L2 signals)<br>125 (L3 signals) | 125 (L1 signals)<br>125 and 250 (L2 signals)<br>100 (L3 signals) |
| Maximum allowable bit error rate | $1 \times 10^{-5}$ | $1 \times 10^{-5}$ |
| Signal modulation method | BPSK | For L1 and L2 signals:<br>BPSK(1), BOC(1,1), BOC(5,2.5)<br>For L3 signal: bi-phase manipulation (BPSK(10)) |
| Polarization | Right-hand circular polarization (RHCP) | |
| Ellipticity (dB) | –1.55 | –1.55 |
| Minimum received power level (dBW) | –170 | –170 |
| Minimum receiver antenna gain (2) (dBi) at corresponding elevation angle (degrees) | –6 (L1, L2, L3 signals) at 5 degrees | –6 (L1, L2, L3 signals) for 5 degrees |

TABLE 1 *(end)*

| Parameter | Value | |
|---|---|---|
| **Signals** | **FDMA** | **CDMA** |
| Maximum receiver antenna gain in upper hemisphere (dBi) | 3 | 3 (L1)<br>1 (L2 and L3) |
| Maximum receiver antenna gain in lower hemisphere (dBi) | 0 | 0 |
| RF filter 3 dB bandwidth (MHz) | 60 (L1 signals)<br>30 (L2 signals)<br>17 (L3 signals) | 30 (L1 signals)<br>30 (L2 signals)<br>30 (L3 signals) |
| Pre-correlation filter 3 dB bandwidth (MHz) | 22 (L1 signals)<br>20 (L2 signals)<br>17 (L3 signals) | 25 (L1 signals)<br>25 (L2 signals)<br>25 (L3 signals) |
| Receiver system noise temperature (2) (K) | 100-670 | |
| **Thresholds for continuous interference** | | |
| Threshold power level of aggregate narrow-band interference at the output of a passive antenna in tracking mode (dBW) (3) | –149 | |
| Threshold power level of aggregate narrow-band interference at the output of a passive antenna in acquisition mode (dBW) (3) | –155 | |
| Threshold power density level of aggregate wideband interference at the output of a passive antenna in tracking mode (dBW/MHz) (3) | –140 | |
| Threshold power density level of aggregate wideband interference at the output of a passive antenna in acquisition mode (dBW/MHz) (3) | –146 | |
| **Thresholds for pulsed interference** (see Note 4) | | |
| Receiver input saturation level (4) (dBW) | –80 | |
| Receiver survival level (4) (dBW) | –1 | |
| Overload recovery time (4) (s) | $1 \times 10^{-3}$ | |

HA = high accuracy.

SA = standard accuracy.

(1) GLONASS receivers manufactured before 2006 can operate with navigation signals having carrier frequency numbers (K) –7 to +13.

(2) Different spacecraft receivers may have values which differ from these typical values.

(3) The threshold should account for all non-RNSS aggregate interference. The threshold value does not include a safety margin of 6 dB.

(4) The values in these rows are to be used for assessment of interference from pulsed sources in conjunction with the methodology given in Recommendation ITU-R M.2030. Pulsed interference is used here to mean interference which consists of bursts of transmission followed by periods of non-transmission. Compatibility with RNSS is a function of the burst power and duration, and the transmission duty cycle.

# Annex 2

## Navstar Global Positioning System spaceborne receiver characteristics

The receiver characteristics provided below are for the purposes of analyses of interference to the RNSS by radio sources other than the RNSS systems and are not to be considered technical requirements, specifications or standards. Current information on Global Positioning System (GPS) operating in the 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz bands is documented in Recommendation ITU-R M.1787.

Table 2 provides characteristics of spaceborne receivers for use with the GPS system. It should be noted that since the technical requirements and operational environment for spaceborne RNSS receivers differs from that for terrestrial receivers, their characteristics may be different. For example, signal acquisition may be more difficult for a spaceborne receiver in low-Earth orbit due to larger Doppler frequency shifts and shorter RNSS satellite time-in-view durations.

TABLE 2

**GPS spaceborne receiver characteristics[1]**

| Parameter | Parameter (value) |
|---|---|
| Signal frequency range (MHz) | 1 575.42 ± 15.345 (GPS L1 signal),<br>1 227.6 ± 15.345 (GPS L2 signal),<br>1 176.45 ± 12 (GPS L5 signal) |
| Maximum receiver antenna gain in upper hemisphere (dBi) | 7.0 (antenna pointed in zenith direction from low-Earth orbit (LEO))<br>(with respect to RHCP signal) |
| Maximum receiver antenna gain in lower hemisphere (dBi) | –10.0 (antenna pointed in zenith direction from LEO)<br>(with respect to RHCP signal) |
| RF filter 3 dB bandwidth (MHz) | 24.0 |
| Precorrelation filter 3 dB bandwidth (MHz) | 20.46 |
| Receiver system noise temperature (K) | 111.0 (1) |
| **Thresholds for continuous interference** | |
| Tracking mode threshold power level of aggregate narrow-band interference at the output of a passive antenna (dBW) | –164.0 (L1 signal) (2)<br>–157.0 (L2 signal) (3)<br>–154.0 (L5 signal) (4)<br>(interfering bandwidth < 1 MHz)<br>(these values apply primarily to space-based interference sources) |
| Acquisition mode threshold power level of aggregate narrow-band interference at the output of a passive antenna (dBW) | –164.0 (L1 signal) (2)<br>–163.0 (L2 signal) (5)<br>–154.0 (L5 signal) (4)<br>(interfering bandwidth < 1 MHz)<br>(these values apply primarily to space-based interference sources) |

1 Further information on GPS signal characteristics in these bands is contained in Recommendation ITU-R M.1787.

TABLE 2 *(end)*

| Parameter | Parameter (value) |
|---|---|
| Tracking mode threshold power density level of aggregate wideband interference at the output of a passive antenna (dB(W/MHz)) | –154.0 (6)<br>(interfering bandwidth ≥ 1 MHz) |
| Acquisition mode threshold power density level of aggregate wideband interference at the output of a passive antenna (dB(W/MHz)) | –154.0 (6)<br>(interfering bandwidth ≥ 1 MHz) |
| **Thresholds for pulsed interference** (see **(8)**) | |
| Receiver input saturation level (dBW) (8) | –56.0 |
| Receiver survival level (dBW) (7) (8) | –15.0 |
| Overload recovery time (s) (8) | $10^{-6}$ |

(1) This noise temperature is based on an existing space receiver used for cm-level spacecraft precision orbit determination. The receiver has a low noise amplifier with 0.8 dB noise figure, zenith pointed 7 dBi antenna with 10 K antenna noise temperature, and 0.5 dB cable loss. The thermal noise floor is thus $N_0$ = 10log($kT_{sys}$) = –208 dB(W/Hz) = –148 dB(W/MHz) where $k$ is the Boltzmann constant.

(2) This threshold value applies only to the L1 CA-code receiver channel and for continuous narrow-band interference signal bandwidth less than 700 Hz. For bandwidths between 700 Hz and 1 MHz, the threshold increases as follows (see Fig. 2-1 in Recommendation ITU-R M.1903); (1) for interference bandwidth $B_I$ from 700 Hz to 10 kHz, the threshold increases linearly with log($B_I$) ($B_I$ in kHz) from –164 dBW at $B_I$ = 0.7 kHz to –157 dBW at $B_I$ = 10 kHz; (2) for 10 kHz ≤ $B_I$ ≤ 100 kHz, the threshold increases linearly with the log($B_I$) ($B_I$ in kHz) from –157 dBW at $B_I$ = 10 kHz to –154 dBW at $B_I$ = 100 kHz; (3) for 100 kHz ≤ $B_I$ ≤ 1 000 kHz, the threshold is –154 dBW.

(3) This value is based on the L2C signal consisting of a 511.5 kcps moderate-length code (L2C-M) with 20 ms code period time-multiplexed with another 511.5 kcps long code (L2C-L) with 1 500 ms code period to produce a total chipping rate of 1.023 Mcps. Thresholds for interference bandwidths between 1 kHz to 1 MHz for L2C are undefined and may require further study.

(4) This threshold is due to the spectral line nature of the L5 pilot signal which can result in up to 10 dB less interference rejection capability than that calculated assuming a non-periodic 10.23 Mcps random code with a continuous power spectrum (i.e. under the random code assumption, the threshold would be −144 dBW). Thresholds for interference bandwidths between 700 Hz and 1 MHz are under study.

(5) This value is based on direct acquisition of the L2C signal using L2C-M. Thresholds for interference bandwidths between 1 kHz to 1 MHz for L2C are undefined and may require further study.

(6) This threshold is based on an $I/N$ ratio of –6 dB with respect to the thermal noise floor ($N_0$ = –148 dB(W/MHz)). Equivalently, this interference will result in a 1 dB increase in the thermal noise floor. The noise floor increase may be greater than 1 dB in the 1 215-1 300 MHz and 1 164-1 215 MHz bands due to potential pulsed radio-frequency interference (RFI) (e.g. from spaceborne synthetic aperture radars and/or ARNS transmitters). The effect of pulsed RFI on receiver performance will depend on a variety of factors including received pulse power (peak/average), pulse duration, and pulse duty cycle as well as specific receiver parameters such as front-end saturation level, saturation recovery time, automatic gain control saturation level and time constant (if multi-bit A/D is used), and type of A/D converter and quantization threshold levels. Further ITU-R study is required to develop a method for evaluating pulsed RFI impact on RNSS receivers. See also Recommendation ITU-R M.2030 for "an evaluation method for pulsed interference from relevant radio sources other than in the RNSS to the RNSS systems and networks operating in the 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz bands".

(7) These survival levels are the peak power level for a pulsed signal with a 10% maximum duty cycle.

(8) The values in these rows are to be used for assessment of interference from pulsed sources in conjunction with the methodology given in Recommendation ITU-R M.2030. Pulsed interference is used here to mean interference which consists of bursts of transmission followed by periods of non-transmission. Compatibility with RNSS is a function of the burst power and duration, and the transmission duty cycle.

# Annex 3

## Galileo spaceborne receiver characteristics

Table 3 provides characteristics of spaceborne RNSS receivers for use with the Galileo system.

TABLE 3

**Galileo spaceborne receiver characteristics**

| **Parameter** | **Parameter value** | | | | | |
|---|---|---|---|---|---|---|
| | **E5a** | **E5b** | **E6 CS** | **E6 PRS** | **E OS** | **E PRS** |
| Signal frequency range (MHz) | 1 176.45 ± 12 | 1 207.14 ± 12 | 1 278.75 ± 20.5 | | 1 575.42 ± 16 | |
| PRN code chip rate (Mcps) | 10.023 | | 5.115 | | 1.023 | 2.5575 |
| Navigation data bit/symbol rates (bps/sps) | 25 bps/ 50 sps | 125 bps/ 250 sps | 500 bps/ 1 000 sps | classified | 125 bps/ 250 sps | classified |
| Maximum allowable bit error rate | $2 \times 10^{-7}$ | | | | | |
| Signal modulation method (1) | AltBOC (15.10) | | BPSK (5) | BOC (10,5) | MBOC | BOC (15,2.5) |
| Polarization | RHCP | | | | | |
| Minimum received power level (dBW) | –160 | | | | | |
| Maximum receiver antenna gain in upper hemisphere (dBi) | 7.0 (LEO satellite)<br>14 (GSO satellite) | | | | | |
| Maximum receiver antenna gain in lower hemisphere (dBi) | –10.0 (LEO satellite)<br>–15 (GSO satellite) | | | | | |
| RF filter 3 dB bandwidth (MHz) | 51.15 | | 30.69 | | 4 (basic) to 24 (science use) | 32 |
| Pre-correlation filter 3 dB bandwidth (MHz) | 24 | | 30.69 | | 4 (basic) to 24 (science use) | 32 |
| Receiver system noise temperature (K) | 75 | | | | | |

TABLE 3 *(end)*

| Parameter | Parameter value |
|---|---|
| **Thresholds for continuous interference** | |
| Tracking mode threshold power level of aggregate narrow-band interference at the output of a passive antenna (dBW) (2) | –142.0 |
| Acquisition mode threshold power level of aggregate narrow-band interference at the output of a passive antenna (dBW) (2) | –135.0 |
| Tracking mode threshold power density level of aggregate wideband interference at the output of a passive antenna (dBW/MHz) (2) | –142.0 |
| Acquisition mode threshold power density level of aggregate wideband interference at the output of a passive antenna (dBW/MHz) (2) | –135.0 |
| **Thresholds for pulsed interference (3)** | |
| Receiver input saturation level (dBW) (3) | –50 |
| Receiver survival level (dBW) (3) | –10 |
| Overload recovery time (s) (3) | $10^{-6}$ |

(1) For Galileo RNSS parameters, BPSK-R(*n*) denotes a binary phase shift keying modulation using rectangular chips with a chipping rate of $n \times 1.023$ (Mcps). BOC (*m*, *n*) denotes a binary offset carrier modulation with a carrier frequency offset of $m \times 1.023$ (MHz) and chipping rate of $n \times 1.023$ (Mcps). MBOC denotes a multiplexed binary offset carrier modulation such that the power spectrum density $G_{MBOC}$ of the MBOC signal at a given frequency, *f*, equates: $G_{MBOC}(f) = 10/11\ G_{BOC(1,1)}(f) + 1/11\ G_{BOC(6,1)}(f)$.

(2) A continuous narrow-band interference signal is considered to have a bandwidth less than 700 Hz. A continuous wideband interference signal is considered to have a bandwidth greater than 1 MHz.

(3) The values in these rows are to be used for assessment of interference from pulsed sources in conjunction with the methodology given in Recommendation ITU-R M.2030. Pulsed interference is used here to mean interference which consists of bursts of transmission followed by periods of non-transmission. Compatibility with RNSS is a function of the burst power and duration, and the transmission duty cycle.