



Recommendation ITU-R M.1905
(01/2012)

**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**

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.1905

**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**

(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 operating in the band 1 164-1 215 MHz are presented in this Recommendation. This information is intended for performing analyses of radio-frequency interference impact on RNSS (space-to-Earth) receivers operating in the band 1 164-1 215 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 characteristics of systems and networks in the RNSS and their protection criteria could be different subject to frequency bands and applications;
- d) that there are studies being conducted or planned on the impact to systems and networks in the RNSS from radio sources other than in the RNSS;
- e) that there are a large number of aeronautical and non-aeronautical RNSS applications used or planned for use in the band 1 164-1 215 MHz;
- f) that Recommendation ITU-R M.1787 provides technical descriptions of systems and networks in the RNSS 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;
- g) that Recommendation ITU-R M.1904 provides technical characteristics and protection criteria of receiving space stations operating in the RNSS (space-to-space) in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz;
- h) 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 band 1 164-1 215 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 1 164-1 215 MHz is also allocated on a primary basis to the aeronautical radionavigation service (ARNS) in all three Regions;

c) that No. **5.328A** of the Radio Regulations (RR) states that “stations in the radionavigation-satellite service in the band 1 164-1 215 MHz shall operate in accordance with the provisions of Resolution 609 (WRC-03) and shall not claim protection from stations in the aeronautical radionavigation service in the band 960-1 215 MHz. No. **5.43A** of the RR does not apply. The provisions of No. 21.18 shall apply”;

recommends

1 that the characteristics and protection criteria of receiving earth stations given in Annex 2 should be used in performing analyses of the interference impact on RNSS (space-to Earth) receivers operating in the band 1 164-1 215 MHz from radio sources other than in the RNSS;

2 that a safety margin, as discussed in Annex 1, should be applied for the protection of the safety aspects and applications of the RNSS when performing interference analyses;

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

NOTE 1 – The 6 dB aeronautical safety margin, as discussed in § 3.2 of Annex 1, was developed for a specific aeronautical radionavigation application of the RNSS in the band 1 164-1 215 MHz, and was not intended to be applied to non-aeronautical applications. The level of the safety margin, if any, to be applied to non-aeronautical safety applications of RNSS is to be established on the basis of further study.

Annex 1

Margin for safety applications in the RNSS

1 Introduction

There is a long history within ITU and the International Civil Aviation Organization (ICAO) of reserving a portion of the interference link budget for a margin in order to ensure that the safety aspects of the radionavigation service are protected. These margin values typically lie in the range of 6 to 10 dB, or more. Furthermore, there is ample precedent for a safety margin for radionavigation safety applications in ITU, for example:

“Regardless of the original intentions of radio spectrum planners, there can be no doubt that the pressure on the radio spectrum for additional allocations to the various radio communication services can result in aeronautical protection criteria being effectively regarded as non-aeronautical sharing criteria. As a consequence, a safety service must take considerable precautions to ensure that any radio service sharing the same radio band is constrained sufficiently to leave an adequate margin under all likely circumstances so that the aggregate harmful interference never exceeds the required protection criteria.”¹

Also, Recommendation ITU-R M.1318-1 contains, in its Annex, a model for the evaluation of interference to RNSS receivers from radio sources other than in the RNSS. That model includes the use of a factor called “protection margin (dB)”. Its description states that it is used “to ensure protection as provided by RR. No. 4.10”.

¹ This text appeared in Annex 5 of former Recommendation ITU-R M.1477 (Geneva, 2000).

2 Purpose of safety margin

A safety margin, (which may also be called a public safety factor), is critical for safety-of-life applications in order to account for risk of loss of life due to radio-frequency interference that is real but not quantifiable. To support safety-of-life applications, all interference sources must be accounted for.

3 Aeronautical radionavigation applications of safety margin

3.1 Aeronautical radionavigation safety margin background

The utilization of safety margins in navigation systems is well established. ICAO specifies a safety margin for the microwave landing system (MLS) of 6 dB (Annex 10 to ICAO Convention: International Standards and Recommended practices Aeronautical Telecommunications, Vol. 1 – Radio Navigation Aids (Attachment G, Table G-2)). The instrument landing system (ILS) applies a safety margin of 8 dB (see Recommendation ITU-R SM.1009-1, Appendix 3 to Annex 2). In each case the margin is defined with respect to the navigation system carrier power. That is, to test system performance for these systems, the desired signal power is reduced from the nominal level by the safety margin, then tested to determine whether the system provides the required performance in the presence of interference. In other words, the manufacturer must design the equipment to handle the highest anticipated interference level while receiving a desired signal level lower (by the safety margin) than would be otherwise received.

With global navigation satellite system (GNSS)² this approach is not feasible because received GNSS satellite power is quite low and relatively constrained, and thus GNSS receivers operate over a limited signal dynamic range. For GNSS receivers, the principal received signal quality measure is the $C/N_{0,EFF}$ ratio, the ratio of the recovered carrier power, C , to the effective noise + interference power spectral density, $N_{0,EFF}$. GNSS receivers must be capable of operating near the minimum $C/N_{0,EFF}$ value, a region where important performance parameters, such as detected word error rate or carrier phase error, rise rapidly for small reductions in $C/N_{0,EFF}$ due, for example, to interference.

3.2 Safety margin approach for the GNSS in the band 1 164-1 215 MHz

As with the MLS and ILS, the approach for the GNSS is to define a level of non-aeronautical radio-frequency interference (RFI)³ that the receiver must be able to accept and still meet performance specifications. For the GNSS, the receiver RFI test limit (i.e. the design threshold) exceeds the maximum allowable environmental aggregate interference level by a safety margin. Specifically, if the aggregate continuous interference test limit for GNSS is $J_{agg,max}$ (dBW) and a safety margin, M (dB), is used, then the maximum safe environmental aggregate continuous RFI, $J_{safe,max}$ (dBW) is:

$$J_{safe,max} = J_{agg,max} - M$$

As with the GNSS in the 1 559-1 610 MHz band (see Recommendation ITU-R M.1903, Annex 1), the necessary safety margin, M (dB), is 6 dB.

² GNSS refers to global navigation satellite system, a set of RNSS systems providing aeronautical radionavigation satellite signals as recognized by ICAO.

³ Non-aeronautical interference refers to interference from sources other than the distance measuring equipment (DME), tactical air navigation system (TACAN) and equipment installed on the GNSS receiver-equipped aircraft.

Annex 2

Technical characteristics and protection criteria for receiving earth stations in the RNSS (space-to-Earth) operating in the band 1 164-1 215 MHz

1 Introduction

Several classes of receivers that vary in terms of function and performance are likely to use the RNSS satellite signals in this frequency band. Table 2-1 in this Annex provides characteristics and protection criteria for several types of RNSS receivers including two types that represent air-navigation receivers. One air-navigation receiver type also uses an SBAS⁴ signal transmitted on the same carrier centre frequency as the RNSS signal. Other types listed include high-precision (e.g. surveying), indoor positioning, and general-purpose RNSS receivers. More details of the RNSS and SBAS signals are contained in Recommendation ITU-R M.1787. As the RNSS continues to evolve, RNSS applications using receivers that have more susceptibility to RFI may come into use, requiring this Recommendation to be updated to take them into account.

2 Receiver type and application descriptions

This section describes several types of current and prospective RNSS receivers.

2.1 Air-navigation receiver

The air-navigation category represents several types of RNSS receivers. These receivers represent high integrity airborne receivers for operation in all flight phases and have specific measures to mitigate pulsed interference. Characteristics and protection criteria for two types of RNSS receivers are listed in Table 2-1. Air-navigation receiver No. 1 uses CDMA RNSS and SBAS signals⁵. Interference thresholds for air-navigation receiver No. 1 represent the lowest applicable limits for the set of RNSS and SBAS signals used in that receiver (see Table 2-1, column 1). Air-navigation receiver No. 2 uses FDMA RNSS signals⁶ and operates on several carrier frequencies simultaneously (see Table 2-1, column 2).

Characteristics for the air-navigation receiver No. 2 may also apply to receivers developed for land or maritime applications that are not described in this Annex.

2.2 High-precision receiver

The high-precision category represents RNSS receivers that are used in applications requiring high positioning accuracy (e.g. surveying, scientific, and agricultural applications). High-precision receivers use various techniques (e.g. semi-codeless techniques) to acquire and track RNSS signals

⁴ SBAS refers to the satellite-based augmentation system, a means for providing RNSS regional measurement error correction and integrity data through a GSO satellite signal.

⁵ The phrase “CDMA RNSS and SBAS signals” refers to the use of a technique in which all the RNSS and SBAS satellites transmit on the same carrier frequency but with different modulation codes. Further signal details are contained in Annex 2 (GPS) of Recommendation ITU-R M.1787.

⁶ The phrase “FDMA RNSS signals” refers to a technique in which all the RNSS satellites use the same modulation code but each satellite transmits on a different carrier frequency. Further signal details are contained in Annex 1 (GLONASS) of Recommendation ITU-R M.1787.

in two or three RNSS frequency bands for carrier phase ambiguity resolution, and require protection in all bands used. The characteristics and protection levels for high-precision receivers also apply to RNSS receivers that are designed to operate in specialized RNSS applications (e.g. single-frequency ground networks, and precision navigation).

High-precision RNSS receivers and receivers designed to operate in specialized RNSS applications also can operate in stressed environments (e.g. under foliage). Two receiver types are listed in Table 2-1, column 3; each of which uses a different RNSS satellite signal type (either code division multiple access (CDMA) or frequency division multiple access (FDMA)) and frequency range. The protection criteria and remaining characteristics are the same.

2.3 Indoor positioning receiver

The indoor positioning category represents RNSS receivers intended for indoor use and that typically have a low C/N_0 capability (i.e. very sensitive receivers). Because carrier tracking cannot be used with the low-power signals present in indoor environments, only code tracking is used in this type of receiver. Two receiver types are listed in Table 2-1, column 4; each of which uses a different RNSS satellite signal type (either CDMA, for the E5a⁷ signal, or FDMA), frequency range and pre-correlator filter bandwidth. The protection criteria and remaining characteristics are the same.

2.4 General-purpose receiver

The general-purpose category represents several types of RNSS receivers. These receivers are designed for vehicular navigation, pedestrian navigation, general positioning, etc. Two receiver types are listed in Table 2-1, column 5; each of which uses a different RNSS satellite signal type (either CDMA, for the B2⁸ signal, or FDMA) and frequency range. The protection criteria and remaining characteristics are the same.

3 Pulsed interference

RNSS receivers operating in the frequency band 1 164 to 1 215 MHz are likely to encounter in-band pulsed RFI from ground and airborne stations in the ARNS in addition to in-band continuous interference from RNSS space stations and other continuous sources. For an airborne RNSS receiver, the aggregate pulsed RFI is known to be stronger at higher altitudes where more ARNS ground stations are within the radio horizon. The pulsed RFI intensity decreases to a smaller amount near the ground as the radio horizon decreases.

A different RFI analysis method is needed to account for strong pulsed RFI in the 1 164 to 1 215 MHz band than, for example, the 1 559 to 1 610 MHz band, where pulsed RFI is rather insignificant. Studies by two aviation standards organizations⁹ have identified an analysis method that addresses the combined effect of pulsed and continuous RFI¹⁰. Two variations in the basic method were derived: one for an RNSS air-navigation receiver (with high duty cycle pulsed RFI), and one for more general purpose RNSS receivers (with low duty cycle pulsed RFI).

⁷ Further details of the E5a signal are found in Annex 3 (Galileo) of Recommendation ITU-R M.1787.

⁸ Further details of the B2 signal are found in Annex 7 (COMPASS) of Recommendation ITU-R M.1787.

⁹ RTCA, headquartered in the United States of America, and EUROCAE in Europe.

¹⁰ RTCA SC-159, "Assessment of the Radio Frequency Interference Relevant to the GNSS L5/E5A Frequency Band", RTCA Document No. RTCA/DO-292, Washington, DC, 29 July 2004.

The studies of the two aviation standards organizations have shown that the highest levels of pulsed RFI impacting RNSS air-navigation receivers operating at or above flight level 200 (6 096 m above mean sea level (MSL)) occur in several localized regions around the world. Of those regions, the highest intensity occurs in the European Union (EU) in the vicinity of Frankfurt, Germany at 50.5° N, 9° E and 12 190 m altitude. The next highest spot is in the United States of America near Harrisburg, Pennsylvania, at 40° N, 76° W, and 12 190 m altitude. For those two hot spots, evaluation of the basic pulsed RFI parameters yields values for the blanking percentage between 60 and 65% for receiver signal processing caused by high-level RFI pulses.

Additionally, lower level pulses that are also present contribute an average RFI effect equivalent to a 100 to 150% increase in the RNSS system noise. By comparison, the evaluation near the US hot spot at low altitude (less than 600 m above MSL) shows the high-level pulse blanking percentage drops to about 31% and the low-level pulse average effect drops to a 45% increase in receive system noise. The presence of these relatively large pulse RFI values limits the amount of continuous RFI that the RNSS receiver can tolerate given the satellite signal and receiver technology limitations that determine the maximum interference effect.

Interference thresholds have not been established for receiver operation at altitudes between these two limiting cases (i.e. between 6 096 and 610 m (20 000 and 2 000 feet) above MSL). Pulsed interference parameters are known to be dependent on the number and type of ARNS ground stations within the radio line-of-sight to the RNSS receiver. However, the exact relationship of receiver interference thresholds to altitude in the regions of highest ARNS source concentration requires extensive further study.

Further ITU-R study is required to develop a general method for evaluating pulsed RFI impact on RNSS receivers.

4 RNSS receiver technical characteristics and protection criteria

Table 2-1 lists technical characteristics and protection criteria (maximum aggregate interference thresholds) for several representative RNSS receivers and applications in the 1 164-1 215 MHz band. More RNSS signal information can be found in Recommendation ITU-R M.1787.

Technical characteristics and levels of protection depend on the type of RNSS application. The following RNSS receivers and applications have been included in Table 2-1:

- Air-navigation receivers (2 types) (see § 2.1 and Table 2-1, columns 1 and 2).
- High-precision receivers (2 types) (see § 2.2 and Table 2-1, column 3).
- Indoor positioning receivers (2 types) (see § 2.3 and Table 2-1, column 4).
- General-purpose receivers (2 types) (see § 2.4 and Table 2-1, column 5).

TABLE 2-1

Technical characteristics and protection criteria for RNSS receivers (space-to-Earth) operating in the band 1 164-1 215 MHz

	1	2	3	4	5
Parameter	Air-navigation receiver No. 1	Air-navigation receiver No. 2 (Note 9)	High-precision receivers (Note 12)	Indoor positioning receivers	General-purpose receivers
Signal frequency range (MHz)	1 176.45 ± 12	1 204.704 + 0.423K ± 4.095, where K = -7, ..., +12 (Note 10)	1 176.45 ± 12 1 204.704 + 0.423K ± 4.095, where K = -7, ..., +12	1 176.45 ± 12 1 204.704 + 0.423K ± 4.095, where K = -7, ..., +12	1 207.14 ± 12 1 176.45 ± 12 1 204.704 + 0.423K ± 4.095, where K = -7, ..., +12
Maximum receiver antenna gain in upper hemisphere (dBi)	+3 (circular) (Note 2)	7 (Note 11)	3.0 circular	3	3
Maximum receiver antenna gain in lower hemisphere (dBi)	-5 (linear) (Note 3)	-10	-7 (linear) (elev. ≤ +10°)	-9	-10
RF filter 3 dB bandwidth (MHz)	24.0	17	24.0 or 24.9	24	24
Pre-correlation filter 3 dB bandwidth (MHz)	20.46	17	20.46	20.46 17	20.46
Receiver system noise temperature (K)	727	400	513	330	330
Tracking mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW) (Note 1)	-154.8 (Notes 4, 5)	-143 (Note 13)	-157.4	-193	-150
Acquisition mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW) (Note 1)	-158.7 (Notes 4, 6)	-149 (Note 13)	-157.4	-199	-156

TABLE 2-1 (*end*)**Technical characteristics and protection criteria for RNSS receivers (space-to-Earth) operating in the band 1 164-1 215 MHz**

	1	2	3	4	5
Parameter	Air-navigation receiver No. 1	Air-navigation receiver No. 2 (Note 9)	High-precision receivers (Note 12)	Indoor positioning receivers	General-purpose receivers
Tracking mode threshold power density level of aggregate wideband interference at the passive antenna output (dB(W/MHz)) (Note 1)	-144.8 (Notes 4, 5)	-140 (Note 13)	-147.4	-150	-140
Acquisition mode threshold power density level of aggregate wideband interference at passive antenna output (dB(W/MHz)) (Note 1)	-148.7 (Notes 4, 6)	-146 (Note 13)	-147.4	-156	-146
Receiver input compression level (dBW)	-114 (Note 7)	-80		-100	-100
Receiver survival level (dBW)	0 (Note 8)	-1		-17	-17
Overload recovery time (s)	1×10^{-6}	$(1-30) \times 10^{-6}$	30×10^{-6}	30×10^{-6}	30×10^{-6}

NOTE 1 – Narrow-band continuous interference is considered to have a bandwidth less than 700 Hz. Wideband continuous interference is considered to have a bandwidth greater than 1 MHz. Thresholds for interference bandwidths between 700 Hz and 1 MHz are under study.

NOTE 2 – The maximum upper hemisphere gain applies for an elevation angle of 75° or more with respect to the antenna horizontal plane.

NOTE 3 – The maximum gain value in the lower hemisphere applies at 0° elevation. For elevation angles between 0° and -30°, the maximum gain decreases with elevation angle to -10 dBi at -30° and remains constant at -10 dBi for elevation angles between -30° and -90°.

NOTE 4 – When used in the Recommendation ITU-R M.1318-1 interference evaluation model, the threshold value is inserted in Line (a) and 6 dB (the safety margin, as described in Annex 1) is inserted in Line (b) of the evaluation template.

NOTE 5 – The continuous RFI threshold value applies to airborne receiver operations above 6 096 m (20 000 feet) altitude above MSL. The tracking mode values for airborne operations below 610 m (2 000 feet) altitude above ground level are -143.0 dBW (narrow-band) and -133.0 dB(W/MHz) (wideband).

NOTE 6 – The continuous RFI threshold value applies to airborne receiver operations above 6 096 m (20 000 feet) altitude above MSL. The acquisition mode values for airborne operations below 610 m (2 000 feet) altitude above ground level are -143.1 dBW (narrow-band) and -133.1 dB(W/MHz) (wideband).

NOTE 7 – The input compression level is for power in the 20 MHz pre-correlator bandwidth.

NOTE 8 – The survival level is the peak power level for a pulsed signal with 10% maximum duty factor.

NOTE 9 – Given values represent typical characteristics of receivers. Under certain conditions more rigid values for some parameters could be required (e.g. recovery time after overload, threshold values of aggregate interference, etc.).

NOTE 10 – This receiver type operates on several carrier frequencies simultaneously. The carrier frequencies are defined by f_c (MHz) = 1 204.704 + 0.423*K*, where *K* = –7 to +12 (RNSS signals).

NOTE 11 – Minimum receiver antenna gain at 5 degrees elevation angle is –4.5 dBi.

NOTE 12 – This table column covers characteristics and thresholds for receivers that operate in the band 1 164-1 215 MHz. For characteristics and thresholds for receivers that also acquire and track RNSS signals in the 1 215-1 300 MHz and/or 1 559-1 610 MHz bands, refer also to Recommendations ITU-R M.1902 and/or ITU-R M.1903. The characteristics and protection levels provided in this column also apply to RNSS receivers that are designed to operate in specialized RNSS applications (see § 2.2 high-precision definition above). Pulse response parameters for this receiver type are subject to further study in conjunction with ITU-R work on a general pulsed RFI evaluation method.

NOTE 13 – This threshold should account for all aggregate interference. The threshold value does not include any safety margin. For FDMA signal processing, narrow-band continuous interference is considered to have a bandwidth less than 1 kHz. Wideband continuous interference is considered to have a bandwidth greater than 500 kHz.
