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Recommendation ITU-R M.1903-1

(09/2019)

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

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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[1] operating in the band 1 559-1 610 MHz

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

(2012-2019)

Scope

Characteristics and protection criteria for radionavigation-satellite service (RNSS) receiving earth stations and certain aeronautical radionavigation service (ARNS) receiving stations operating in the band 1 559-1 610 MHz are presented in this Recommendation. This information is intended for performing analyses of radio frequency interference impact on RNSS (space-to-Earth) and ARNS receivers operating in the band 1 559-1 610 MHz from radio sources other than in the RNSS.

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

[1] See Note 3.

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.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
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 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 any properly equipped earth station may receive navigation information from systems and networks in the RNSS on a worldwide basis;

c) that there are various operating and planned systems and networks in the RNSS;

d) that there is an essential need to protect systems and networks operating in the RNSS in the band 1 559-1 610 MHz;

e) that RNSS safety services exist, and that the use of these services will expand in the future;

f) that the International Civil Aviation Organization (ICAO) has developed standards for the global navigation satellite system (GNSS), whose elements include systems and networks in the RNSS;

g) that the International Maritime Organization (IMO) requires ships to equip with RNSS for navigation in narrow waterways and for docking;

h) that there are a large number of aeronautical and non-aeronautical RNSS applications that use or plan to use the 1 559-1 610 MHz band;

i) 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;

j) 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;

k) 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 1 559-1 610 MHz is allocated on a primary basis to the RNSS (space-to-Earth) (space-to-space) and ARNS in all three Regions;

b) that there are a number of receivers of RNSS signals used in safety service applications that process these signals in different ways, as described in Annex 2;

c) that there are a number of different existing and planned augmentations of systems and networks in the RNSS which support safety services,

noting

that Recommendation ITU-R M.1343 defines the essential technical requirements of mobile earth stations (MESs) for global non-GSO MSS systems in the bands 1-3 GHz,

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) and certain ARNS receivers as referred to in Note 3 operating in the band 1 559-1 610 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 and ARNS, when performing interference analyses;

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

NOTE 1 – 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, and ITU-R SM.1757 for UWB. 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. Levels given in Recommendation ITU-R SM.1757 are specific to ultra-wideband technology.

NOTE 2 – The 6 dB aeronautical radionavigation safety margin, as discussed in § 3 of Annex 1, was developed for a specific aeronautical radionavigation application of the RNSS and ARNS in the band 1 559-1 610 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.

NOTE 3 – In limited cases described in Annex 2, some types of receivers operate with terrestrial transmitters that transmit, using the co-primary ARNS allocation, an RNSS-like radionavigation signal intended for reception by aircraft station receivers that also receive RNSS (space-to-Earth) signals.

Annex 1

Margin for safety applications in the RNSS

1 Introduction

There is a long history within ITU and 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-R, 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."[2]

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."

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.

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[2] This text appeared in Annex 5 of Recommendation ITU-R M.1477 (Geneva, 2000), among other places.

That is, to test system performance for these systems, the desired signal power is reduced from the nominal level by the safety margin, and 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 GNSS[3] this approach is not possible, because reducing the carrier power by 6 dB or more below the designed power could result in satellites being dropped in the tracking algorithm of the receiver. This is because the received GNSS satellite power is relatively limited, and thus GNSS receivers operate over a small 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, $N_{0,EFF} = N_0 + I_0$. 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 for the GNSS in the band 1 559-1 610 MHz

As with the MLS and ILS, the approach for the GNSS is to define a level of non-aeronautical radio-frequency interference[4] (RFI) 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:

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

For the GNSS in the 1 559-1 610 MHz band, the necessary safety margin, M (dB), is 6 dB.

A safety margin of 5.6 dB was used in the development of the −70 dB(W/MHz) emission limit adopted in Recommendation ITU-R M.1343-1. However, for general application this margin is adjusted slightly to 6 dB, which brings it into the range of safety service margins which have been adopted by ITU-R for other safety applications, as indicated in § 3.1 above.

For example, a Category I precision approach SBAS Type 1 air navigation receiver (see Table 2 of Annex 2) operating in the 1 575.42 ± 12 MHz band is designed and tested to withstand a wideband aggregate interference threshold level of −140.5 dB(W/MHz) in the signal tracking mode. Applying the 6 dB safety margin, as indicated in the equation above, to the aggregate threshold results in the safe level of allowable received interference of −146.5 dB(W/MHz).

An aeronautical safety margin of at least 6 dB is required to protect the GNSS safety applications. Additional margins may be required, depending on:

– the effects of the statistics on all parameters used in interference analyses unless the worst-case conditions are assumed; and

– RFI sources that are not specifically included in the interference analysis but that may have a potential to contribute to the interference of GNSS.

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[3] GNSS refers to Global Navigation Satellite System, a set of RNSS systems providing aeronautical radionavigation satellite signals as recognized by ICAO.

[4] Non-aeronautical interference refers to interference from sources other than aeronautical equipment installed on the GNSS receiver-equipped aircraft.

3.3 Aeronautical radionavigation interference risk allocation and compliance

3.3.1 Interference risk allocation

Interference analyses employed for communication networks which are based on service unavailability are not applicable for safety-of-life services, because an outage for such a service is not acceptable if it is in excess of a rate of 1×10^{-6}/h (see below). In addition, they do not address the effects on spurious emissions, of aging or malfunctioning equipment, and unit-to-unit performance variations. Also, there is the temptation to discount the impact of interference sources that do not routinely occur. However, the aeronautical community attempts to quantify the risks associated with events that could cause outages or misleading information, even those which may be considered very unlikely.

Aeronautical equipment must be designed to handle very rare events on the assumption that they will indeed occur. Given the millions of flight hours flown by civil aircraft each year, the probability of a very rare (1×10^{-6}/h) event occurring somewhere during the year is a virtual certainty. It is important to recognize that the risk created by interference must be assessed when conducting interference analyses.

The ICAO standards for GNSS satellite-based augmentation system (SBAS) and ground-based augmentation system (GBAS) airborne receivers require the annunciation of a navigation alert when the RFI receiver susceptibility level is exceeded. The GNSS risk analysis allocates a 1×10^{-5} per approach loss of continuity for non-GNSS interference for Category I approaches. The intent of the continuity requirement is to limit the RFI events to one in 100 000 approaches. During precision approaches the 6 dB aeronautical safety margin may be consumed by variations in the GNSS $C/N_{0,EFF}$, as indicated in § 3.1. Therefore any increase in the aggregate non-aeronautical interference above the −146.5 dB(W/MHz) limit (from the example used in § 3.2) would cause a loss of continuity event at the GNSS receiver. Precedence for this interpretation is the ITU-R margin definition given for ILS in § 3.1. As stated there, the RFI is evaluated at minimum $C/N_{0,EFF}$ conditions at selected spatial points in the ILS coverage volume. In other words, no credit is assigned the interfering signal because of the existence of the safety margin.

3.3.2 Compliance considerations

Any proposal to share an ARNS/RNSS band must include consideration of the failure modes of the proposed service. The proposal must identify any faults that might present a threat to the native safety service and describe how such modes would be detected. It must also discuss how users of the safety service will be notified and analyse the time-to-alarm of such notification. The proposal must also describe how the salient features of any relevant failure will be archived for later analysis. Such faults would include excursions in the radiated in-band or out-of-band power. They would also include deviations in the radiated spectrum – narrow-band versus wideband, for example.

Such a proposal must also detail how the specified safety margin would be maintained through all relevant operational scenarios. These analyses would include path loss calculations from the proposed service to all users of the safety service. These analyses would need to consider all likely proximities of the proposed service to aircraft, ships and land emergency users of the safety service.

They would also need to reasonably consider the possible multiplicity of interference sources. The proposal must also consider the likely proximity of the proposed service to fixed radio assets used by the safety service.

Finally, the proposal would need to consider the impact on recent or planned additions to the safety service.

3.4 Conclusions

1 The 6 dB GNSS safety margin results in substantially less than 6 dB $C/N_{0,EFF}$ margin. This lower $C/N_{0,EFF}$ value is less than the safety margins for other ICAO defined navigation systems, but within the range of margins accepted within ITU-R for safety services.

2 The safety assessment by the radionavigation services requires that the probability of a non-aeronautical RFI source exceeding its protection limit should be less than one in 100 000 Category I approaches. This loss-of-continuity risk is not included in the GNSS safety margin.

3 The allowable level of non-aeronautical interference is a fixed number, and represents the aggregate interference from all known sources. If new services are established, their emissions must be restricted in order not to exceed the allowable aggregate level.

Annex 2

Technical characteristics and protection criteria for receiving earth stations in the RNSS (space-to-Earth) operating in the band 1 559-1 610 MHz

1 Introduction

This Annex is intended to provide a description of some RNSS receiver applications, a brief description of RNSS signals in the 1 559-1 610 MHz band, and RNSS receiver protection levels. More detailed information on RNSS signals used by these receivers is given in Recommendation ITU-R M.1787. Section 2 provides descriptions of RNSS applications. Sections 3 and 4 describe the use of maximum received aggregate interference power thresholds for RNSS receiver protection and list the technical characteristics and protection criteria. The protection levels given there are intended, in general, to address continuous and pulsed[5] non-RNSS interference sources.

Threshold values for the maximum received aggregate interference power from radio sources other than in the RNSS are provided in Table 2. For narrow-band interference, a received power value is used together with an upper limit on interference bandwidth. For wideband interference, a received power spectral density is used together with a lower limit on interference bandwidth. The thresholds are for the aggregate interference at the output of the receiving antenna.

2 RNSS applications

Several RNSS receiver types for particular applications are described in this Annex. There are a few aeronautical receiver types for which the requirements are relatively well developed. At this time certain non-aviation applications are known to be relatively more susceptible to interference. This is due primarily to excess path loss (i.e. weak received signal) in some cases, or to additional signal processing loss (e.g. in semi-codeless processing) in other cases. As the RNSS continues to evolve,

[5] 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.

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.

2.1 Aeronautical RNSS receivers

2.1.1 SBAS Category I precision approach receiver

A SBAS is a means for providing RNSS regional measurement error correction and integrity data through a GSO satellite signal.

Type 1

This aeronautical receiver type is an airborne navigation receiver designed to provide an ICAO Category I precision approach. It must meet the requirements of an SBAS specification. It tracks both RNSS L1 C/A and SBAS L1 CDMA signals[6]. SBAS L1 signals have codes similar to L1 C/A transmitted at the same centre frequency (1 575.42 MHz). Characteristics of this type of receiver are specified in Table 2, column 1.

Type 2

This aeronautical receiver type is also an airborne navigation receiver designed to provide an ICAO Category I precision approach.

However, this receiver type operates with RNSS and SBAS FDMA signals[7] on several carrier frequencies simultaneously. It tracks both RNSS and SBAS signals, which may be on different carrier frequencies. Characteristics of this type of receiver are specified in Table 2, column 2.

2.1.2 GBAS Category II/III precision approach receiver

Type 1

This aeronautical receiver type is an airborne navigation receiver designed to provide an ICAO Category II/III precision approach. It must track RNSS (L1 C/A) satellite signals and VHF band GBAS datalink signals. This receiver receives CDMA signals. Characteristics of this type of receiver are specified in Table 2, column 3.

Type 2

This aeronautical receiver type is also an airborne navigation receiver designed to provide an ICAO Category II/III precision approach. This receiver type operates with FDMA RNSS signals on several carrier frequencies simultaneously. It must track RNSS satellites and VHF band GBAS datalink signals. Also, this receiver may operate with information from terrestrial ARNS transmitters that transmit radionavigation signals similar to RNSS (space-to-Earth) signals to aircraft stations. Characteristics of this type of receiver are specified in Table 2, column 4.

2.1.3 SBAS ground reference receiver

This aeronautical receiver type is a ground-based reference receiver which is used in SBAS ground network operations to determine ionospheric delays and RNSS signal integrity. This receiver uses a

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[6] The term “CDMA” refers to the use of a code-division multiple access modulation technique in which all the RNSS and/or SBAS satellites transmit on the same carrier frequency but with different modulation codes. Further signal details are contained in Annex 1 (GLONASS) and Annex 2 (GPS) of Recommendation ITU-R M.1787.

[7] The term “FDMA” refers to a frequency-division multiple access modulation 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.

semi-codeless technique that exploits a unique feature enabled by the particular RNSS signal architecture whereby the L1 and L2 P(Y) code signals are tracked, aided by the knowledge of a dynamic carrier phase obtained from L1 C/A[8] code and carrier tracking, and the knowledge of the average encryption clocking rate. This cross-correlation technique provides the capability to measure the signal delay at L2, thus making it possible to determine the signal delay variations due to the ionosphere. The cross-correlation scheme is made possible in part by the fact that the L1 and L2 P(Y) signals have identical codes. This receiver must also acquire and track SBAS satellite signals at the same frequency as the L1 C/A carrier. Semi-codeless receivers are more sensitive to interference because they operate without benefit of knowing the Y code[9]. SBAS ground receivers serve critical roles such as integrity monitoring of RNSS signals at SBAS ground stations in known fixed locations. Hence appropriate protection to ensure continuous uninterrupted access to RNSS signals should exist for such receivers; such as, but not limited to, physical buffer zones. Characteristics of this type of receiver are specified in Table 2, column 5.

SBAS ground reference receivers serve critical roles, such as integrity monitoring of RNSS systems, at SBAS ground stations in known fixed locations. Hence appropriate protection to ensure continuous uninterrupted access to RNSS signals exists for these receivers; such as, but not limited to, physical buffer zones.

2.1.4 Air-navigation precision approach receiver

This receiver type is an air-navigation receiver designed to provide a precision approach. This receiver type can use both CDMA and FDMA RNSS signals and can operate on several carrier frequencies simultaneously. Characteristics of this type of receiver are specified in Table 2, column 6.

Characteristics for the air-navigation receivers may also apply to receivers developed for land and maritime applications that are not described in this Annex.

2.2 High-precision receivers

The high-precision category represents receivers designed to provide one to two centimetre-level positioning accuracy in real-time in a dynamic mode, using a dual-frequency technique or triple frequency signals and also SBAS networks. Their characteristics are similar to those of the aeronautical semi-codeless SBAS ground reference receivers described above, but in some applications may be more sensitive than these aeronautical applications since these high-precision receivers operate in stressed environments, such as under foliage. High-precision receivers and systems are used in applications requiring high positioning accuracy, such as agriculture, construction, mining, natural resource management, science and surveying.

High-precision RNSS receivers use a semi-codeless technique whereby two or three RNSS signals with different carriers are acquired and tracked (e.g. L1 and L2 P(Y) signals), aided by the knowledge of dynamic carrier phase obtained from code tracking of one of the signals (e.g. L1 C/A). These receivers require protection in all RNSS bands used. Two basic methods are used: 1) the RNSS signals in the different bands are cross-correlated, or 2) the RNSS signals are actually independently tracked. There are also variations to these methods, or combinations of the two methods. In any case, the purpose is to provide an estimate of the ionospheric delay, or an independent set of carrier phase measurements, that support rapid removal of wavelength ambiguities. This process provides

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[8] The L1 C/A and L1 P(Y) signals are in the 1 559-1 610 MHz RNSS frequency band while L2 P(Y) signals are in the 1 215-1 300 MHz RNSS band. Further details for these signals are found in Annex 2 (GPS) of Recommendation ITU-R M.1787.

[9] The Y code is a modified and encrypted P code, having the same chipping rate and modulation characteristics as that of the P code.

improved position accuracy, even when the receiver is in motion. The cross-correlation scheme is made possible if the signals have identical, nearly synchronized codes. The signals on one carrier frequency are phase-shifted and delayed by the ionosphere relative to signals on another carrier frequency from the same satellite. However, when signals have identical code and carrier Doppler, the ability to aid the semi-codeless tracking using very narrow-band tracking loops may exist.

Newer versions of these receivers may also track the L2C[10] signal if available from a particular satellite, in which case they may not operate in a semi-codeless mode for that satellite. However, since these receivers would be operating in a ground network in conjunction with semi-codeless receivers, and in conjunction with semi-codeless tracking of satellite signals without L2C, their sensitivity to interference is the same as semi-codeless sensitivity to interference.

Multiband receivers may also be used in commercial-grade networks. In such applications the RNSS signals may be processed by semi-codeless methods to determine the ionospheric delay in the signals. This information is used by the network to improve accuracy over a large region.

The multiband commercial ground network receivers are generally more sensitive to interference than the aeronautical semi-codeless receivers described in § 2.1 above, even though they may also track the L2C signal from individual satellites. They generally are designed to operate in a dynamic environment and do not generally utilize a precise frequency reference. The interference thresholds stated below for high-precision RNSS receivers in Table 2 are also applicable to commercial-grade semi-codeless receivers.

Note that the relevant tracking thresholds for these semi-codeless receivers (see “High-precision” column in Table 2) are based on the most sensitive of the tracked signals. For example, in some multiband applications involving receivers operating in the 1 559-1 610 MHz band, the most sensitive signal may be in the 1 215-1 300 MHz band, in which case the relevant protection criteria are provided in Recommendation ITU-R M.1902.

Three receiver types are listed in Table 2, column 11; each of which uses a different RNSS satellite signal type (either CDMA, for the L1 P(Y) and C/A signals; or for GLONASS signals, CDMA and/or FDMA), frequency range and filter bandwidths. The protection criteria and remaining characteristics are the same.

2.3 Assisted RNSS (A-RNSS) receivers

A-RNSS refers to commercial-grade handheld and assisted RNSS receivers. This class of receivers operate within “stressed” environments, such as under heavy foliage, indoors or in urban canyons. They are sometimes “cell-phone assisted”, since aiding information (Doppler, timing, navigation data) is provided in real-time to enable RNSS signal acquisition and tracking through significant attenuation (such as building walls). Because of heavy foliage or wall attenuation, it is not appropriate to define standard RNSS received signal levels. Thus, interference power thresholds cannot be defined relative to received signal levels.

Therefore, the accepted approach is to define the aggregate interference power density threshold at a level that will not raise the total noise floor by more than 1 dB above the environmental noise floor. Here, that environmental noise floor is that of an indoor environment (−144 dBW/MHz), which translates to a receiver noise power density of −141 dBW/MHz for a receiver with a 3 dB noise figure, resulting in an aggregate wideband interference power density threshold of –146.9 dBW/MHz, at the output of a 0 dBi circularly polarized passive antenna. In the case of aggregate narrow-band interference (see Fig. 1), the interference power threshold is then –156.9 dBW. Since these receivers

[10] Further details of the L2C signal are found in Annex 2 (GPS) of Recommendation ITU-R M.1787.

are generally assisted, the thresholds for acquisition and tracking are identical. Characteristics of this type of receiver are specified in Table 2, column 7.

2.4 General-purpose receivers

The general-purpose category represents several types of RNSS receivers. These receivers are designed for vehicular navigation, pedestrian navigation, general positioning, etc. Three receiver types are listed in Table 2 column 8 and one type in column 9. The three general-purpose No. 1 types in column 8 use different signal types (either CDMA, for the L1 C/A signal; or for GLONASS signals, CDMA and/or FDMA), frequency range and pre-correlator bandwidth. The protection criteria and remaining characteristics are the same. The general-purpose No. 2 receiver (column 9) uses CDMA signals (B1-C)[11] and has different characteristics and protection criteria than general-purpose No. 1.

2.5 Indoor positioning

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. Three receiver types are listed in Table 2, column 10; each of which uses a different RNSS satellite signal type (either CDMA, or for GLONASS signals, CDMA and/or FDMA), frequency range and pre-correlator filter bandwidth.

3 RNSS continuous interference thresholds for non-RNSS radio sources

In the following descriptions, received power levels at the antenna output refer to the power levels that account for the maximum antenna gain in the direction of the interference sources. An example of the RNSS specification of relative aggregate interference levels versus interference source bandwidth for receivers using the L1 C/A signal is shown in Fig. 1. The interference levels in Fig. 1 are normalized relative to the 1.0 MHz interference bandwidth tracking mode threshold power level specified for certain L1 C/A receiver types in Table 2 (as indicated by Note 1).

The acquisition mode curve in Fig. 1 applies to the SBAS and GBAS Type 1 receivers. The acquisition curve for A-RNSS and high-precision receivers is identical to the Fig. 1 tracking mode curve. Bandwidth breakpoints and relative level values for the curves in Fig. 1 are given in Table 1.

[11] Further details of the B1-C signal are found in Annex 7 (COMPASS) of Recommendation ITU-R M.1787.

FIGURE 1

Relative continuous interference power thresholds for some receiver types using the L1 C/A signal

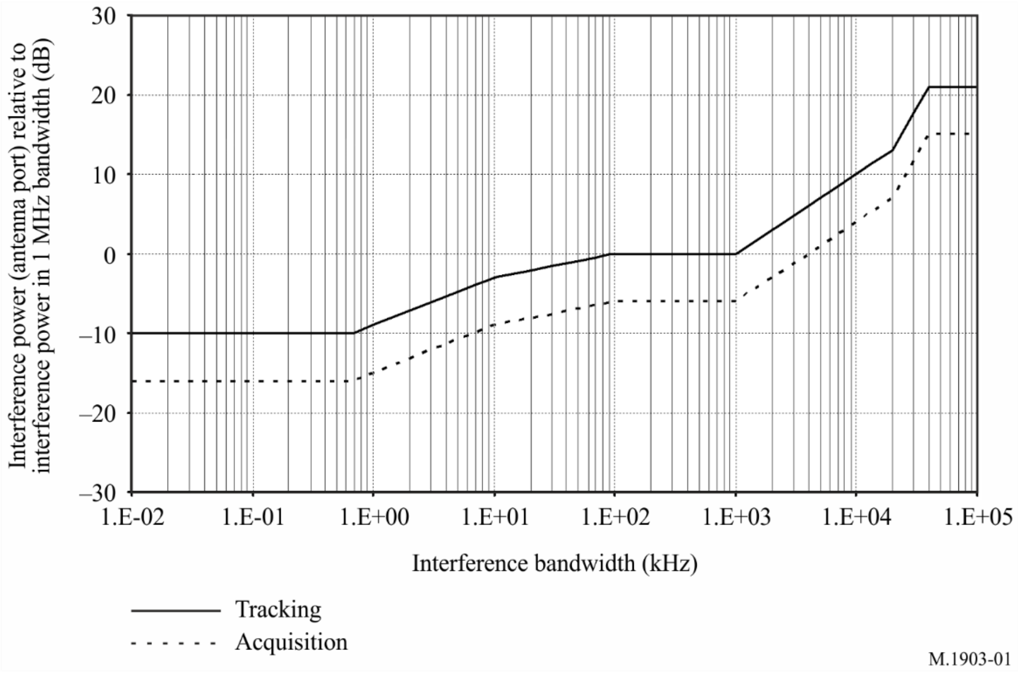


TABLE 1

Relative continuous interference power thresholds for some receiver types using the L1 C/A signal

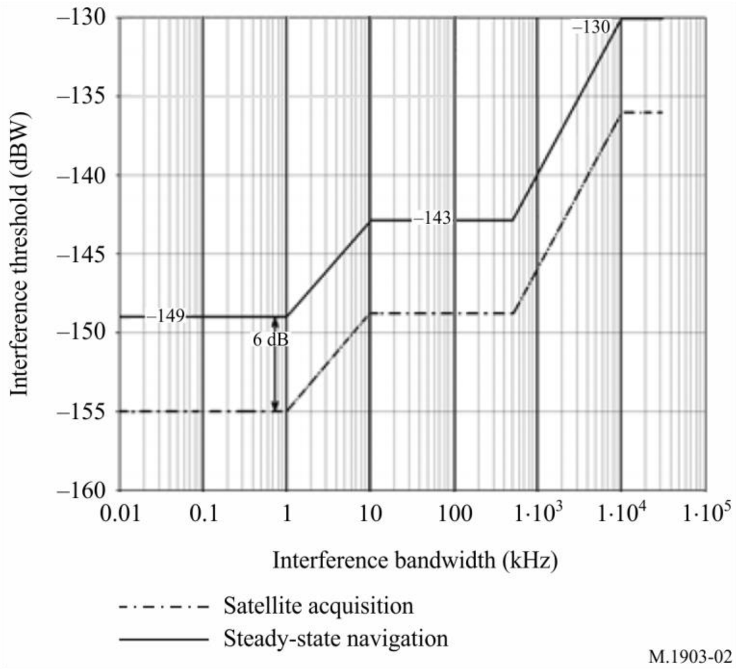
Bandwidth	Relative interference level
$0 \leq BW_I \leq 700$ Hz	−10 dB
700 Hz < $BW_I \leq$ 10 kHz	Linearly increasing from −10 dB to −3 dB
10 kHz < $BW_I \leq$ 100 kHz	Linearly increasing from –3 dB to 0 dB
100 kHz < $BW_I \leq$ 1 MHz	0 dB
1 MHz < $BW_I \leq$ 20 MHz	Linearly increasing from 0 to 13 dB (1)
20 MHz < $BW_I \leq$ 30 MHz	Linearly increasing from 13 to 19.4 dB (1)
30 MHz < $BW_I \leq$ 40 MHz	Linearly increasing from 19.4 to 21 dB (1)
40 MHz < BW_I	21 dB*

(1) For interference bandwidths greater than 1 MHz, the interference power spectral density shall not exceed the pertinent wideband threshold listed in Table 2 over the frequency range 1 575.42 ± 10 MHz.

Figure 2 illustrates the case of air-navigation receivers that track FDMA RNSS signals and provides associated interference threshold levels versus interference source bandwidth. It should be noted that the threshold values indicated in Fig. 2 do not take into account a safety margin (about 6 dB) that is normally applied by ICAO in relevant standards.

FIGURE 2

Threshold values of interference for FDMA receivers



4 RNSS receiver technical characteristics and protection criteria

Table 2 lists technical characteristics and protection criteria (maximum aggregate interference thresholds) for several representative RNSS applications in the 1 559-1 610 MHz band. More RNSS signal information is available in Recommendation ITU-R M.1787. The applicability and application of safety margins to RNSS receiver protection is given in Annex 1.

Table 2 proposes different levels of protection depending on the RNSS receiver type or application. The following different receivers and applications have been included in the table:

– SBAS Category I receiver (2 types) and GBAS Category II/III receiver (2 types) (see §§ 2.1.1 and 2.1.2 above, and Table 2, columns 1 through 4 below).

– SBAS ground reference receiver (see § 2.1.3 above and Table 2, column 5).

– Air-navigation precision approach receiver (see § 2.1.4 above and Table 2, column 6).

– High-precision (3 types) (see § 2.2 above and Table 2, column 11).

– A-RNSS (see § 2.3 above and Table 2, column 7).

– General-purpose No. 1 (3 types) (see § 2.4 above and Table 2, column 8).

– General-purpose No. 2 (see § 2.4 above and Table 2, column 9).

– Indoor positioning (3 types) (see § 2.5 above and Table 2, column 10).

TABLE 2

Technical characteristics and protection criteria for RNSS receivers (space-to-Earth) operating in the 1 559-1 610 MHz band

	1	**2**	**3**	**4**	**5**	**6**		**7**	**8**			**9**	**10**			**11**		
Application (see § 4) Parameter	**SBAS Category I Type 1**	**SBAS Category I Type 2**	**GBAS Category I I/ III Type 1**	**GBAS Category II/III Type 2**	**SBAS ground reference receiver***	**Air-navigation precision approach receiver**		**A-RNSS**	**General-purpose No. 1**			**General-purpose No. 2**	**Indoor positioning**			**High-precision* (Note 11)**		
Signal frequency range (MHz)	1 575.42 ± 15.345	1 602 + 0.5625*K* ± 5.11, where *K* = −7, …, +6 and 1 602 + 0.5625*N* ± 0.511, where *N* = +7, …, +12 (Note 12)	1 575.42 ± 15.345	1 602 + 0.5625*K* ± 5.11, where *K* = −7, …, +6 and 1 602 + 0.5625*N* ± 0.511, where *N* = −12, …, −8 (Note 15)	1 575.42 ± 15.345	1 602 + 0.5625*K* ± 5.11, where *K* = −7, …, +6 (Note 17)	1600.995 ± 7.7	1 575.42 ± 15.345	1 575.42 ± 12	1 602 + 0.5625*K* ± 5.11, where *K* = −7, …, +6	1600.995 ± 7.7	1 561.098 ± 2.046 1 589.742 ± 2.046	1 575.42 ± 12	1 602 + 0.5625*K* ± 5.11, where *K* = −7, …, +6	1600.995 ± 7.7	1 575.42 ± 15.345	1 602 +0.5625*K* ± 5.11, where *K* = −7, …, +6	1600.995 ± 7.7
Maximum receiver antenna gain in upper hemisphere (dBi)	+3.0 (circular) (Note 5)	+7 (circular) (Note 13)	+3.0 (circular) (Note 5)	+7 (circular) (Notes 13 and 16)	−2.0 (circular) (Note 6)	+7 (circular) (Note 13)		0.0	6			3	6			+3.0		
Maximum receiver antenna gain in lower hemisphere (dBi)	−5.0 (linear) (Note 7)	−10 (circular)	−5.0 (linear) (Note 8)	−10 (circular)	−9.0 (circular) (Note 6)	−10 (circular)		0.0	6 (Note 18)			−10	6 (Note 18)			−5.0 (Note 10)		
RF filter 3 dB bandwidth (MHz)	24.0	30	24.0	30	24.0	30		30.69	32		30	4.196	32		30	30.69 or 32		30
Pre-correlation filter 3 dB bandwidth (MHz)	20.46	22	20.46	22	20.46	22	25	20.46	2	22	25	4.096	2	22	25	20.46	22	25
Receiver system noise temperature (K)	513	400	513	400	513	400		513	645			330	645			513		

TABLE 2 (*continued*)

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	
Application (see § 4) Parameter	**SBAS Category I Type 1**	**SBAS Category I Type 2**	**GBAS Category I I/ III Type 1**	**GBAS Category II/III Type 2**	**SBAS ground reference receiver***	**Air-navigation precision approach receiver**	**A-RNSS**	**General-purpose No. 1**	**General-purpose No. 2**	**Indoor positioning**	**High-precision* (Note 11)**	
Thresholds for continuous interference												
Tracking mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW)	−150.5 (Notes 1 and 2)	−149 (Notes 3 and 14)	−150.5 (Notes 1 and 2)	−149 (Notes 3 and 14)	−160.0 (Note 9)	−149 (Notes 3 and 14)	−156.9 (Note 2)	−152 (Note 2, CDMA) (Note 3, FDMA and CDMA (carrier frequency 1 600.995 MHz))	−150 (Note 4)	−184 (Note 2, CDMA) (Note 3, FDMA and CDMA (carrier frequency 1 600.995 MHz))	−157.4 (Note 2)	−157.4 (Note 3)
Acquisition mode threshold power level of aggregate narrow-band interference at the passive antenna output (dBW)	−156.5 (Notes 1 and 2)	−155 (Notes 3 and 14)	−156.5 (Notes 1 and 2)	−155 (Notes 3 and 14)	−157.4 (Note 9)	−155 (Notes 3 and 14)	−156.9 (Note 2)	−158 (Note 2, CDMA) (Note 3, FDMA and CDMA (carrier frequency 1 600.995 MHz))	−156 (Note 4)	−190 (Note 2, CDMA) (Note 3, FDMA and CDMA (carrier frequency 1 600.995 MHz))	−157.4 (Note 2)	−157.4 (Note 3)
Tracking mode threshold power density level of aggregate wideband interference at the passive antenna output (dB(W/MHz))	−140.5 (Notes 1 and 2)	−140 (Notes 3 and 14)	−140.5 (Notes 1 and 2)	−140 (Notes 3 and 14)	−146.0 (Note 9)	−140 (Notes 3 and 14)	−146.9 (Note 2)	−136 (Note 2, CDMA) (Note 3, FDMA and CDMA (carrier frequency 1 600.995 MHz))	−140 (Note 4)	−142 (Note 2, CDMA) (Note 3, FDMA and CDMA (carrier frequency 1 600.995 MHz))	−147.4 (Note 2)	−147.4 (Note 3)

TABLE 2 (*end*)

	1	2	3	4	5	6	7	8	9	10	11	
Application (see § 4) Parameter	**SBAS Category I Type 1**	**SBAS Category I Type 2**	**GBAS Category I I/ III Type 1**	**GBAS Category II/III Type 2**	**SBAS ground reference receiver***	**Air-navigation precision approach receiver**	**A-RNSS**	**General-purpose No. 1**	**General-purpose No. 2**	**Indoor positioning**	**High-precision* (Note 11)**	
Acquisition mode threshold power density level of aggregate wideband interference at the passive antenna output (dB(W/MHz))	−146.5 (Notes 1 and 2)	−146 (Notes 3 and 14)	−146.5 (Notes 1 and 2)	−146 (Notes 3 and 14)	−147.4 (Note 9)	−146 (Notes 3 and 14)	−146.9 (Note 2)	−142 (Note 2, CDMA) (Note 3, FDMA and CDMA (carrier frequency 1 600.995 MHz))	−146 (Note 4)	−148 (Note 2, CDMA) (Note 3, FDMA and CDMA (carrier frequency 1 600.995 MHz))	−147.4 (Note 2)	−147.4 (Note 3)
Thresholds for pulsed interference (*see Note 22*)												
Receiver input saturation level (dBW) (Note 19) (Note 22)	−135 (Note 20)	−80	−135 (Note 20)	−80	−135 (Note 20)	−80		−70	−70	−100	−120	
Receiver survival level (dBW) (Note 22)	−10 (Note 21)	−1	−10 (Note 21)	−1	−10 (Note 21)	−1		−20	−20	−17	−20	
Overload recovery time (s) (Note 22)	25.0×10^{-6}	$(1 \text{ to } 5) \times 10^{-6}$	25.0×10^{-6}	$(1 \text{ to } 5) \times 10^{-6}$	25.0×10^{-6}	$(1 \text{ to } 5) \times 10^{-6}$		30×10^{-6}	30×10^{-6}	30×10^{-6}	$(1 \text{ to } 30) \times 10^{-6}$	

Notes du Table 2:

* These table columns cover characteristics and thresholds for receivers that operate in the band 1 559-1 610 MHz. (CDMA receivers of this type operate with the signals described in Annex 2 to Recommendation ITU-R M.1787.) For characteristics and thresholds for receivers that also acquire and track RNSS signals in the 1 215-1 300 MHz and/or 1 164-1 215 MHz bands, refer also to Recommendations ITU-R M.1903 and/or ITU-R M.1905.

NOTE 1– 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 2 – 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 provided in § 3 (see Fig. 1 and Table 1). These values are for L1 C/A code and not intended for use in environments with significant pulsed interference.

NOTE 3 – For FDMA and CDMA (carrier frequency 1 600.995 MHz) 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. Thresholds for interference bandwidths between 1 kHz and 500 kHz are provided in Figure 2.

NOTE 4 – 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.

NOTE 5 – The maximum upper hemisphere receiver RHCP antenna gain applies for an elevation angle of 75° or more with respect to the antenna horizontal plane.

NOTE 6 – The listed maximum upper hemisphere gain value applies for 30° elevation (maximum expected RFI arrival angle). The listed maximum lower hemisphere gain value applies for 5° elevation.

NOTE 7 – The listed maximum gain value applies for 0° elevation. For elevation angles between 0° and −30° the maximum gain decreases to −10 dBi and remains constant at −10 dBi for elevation angles between −30° and −90°.

NOTE 8 – The listed maximum lower hemisphere gain value applies for 0° elevation. For elevation angles between 0° and −30° the maximum gain decreases to −10 dBi and remains constant at −10 dBi for angles between −30° and −45°. For elevation angles between −45° and −90° the maximum gain limit is −13 dBi.

NOTE 9 – The tracking values apply to the L1 SBAS signal. Tracking thresholds are based upon FAA Specification FAA-E-2892B, Modification No. 0012. The acquisition values apply to the L1 C/A signal with an I/N of −6 dB. Continuous interference bandwidth limits for narrow-band and wideband thresholds are 700 Hz (max.) and 1 MHz (min.), respectively. Thresholds for interference bandwidths between these limits are not specified and may require further study.

NOTE 10 – The listed maximum lower hemisphere gain value applies for angles of less than +10° elevation.

NOTE 11 – The characteristics and protection levels provided in this column also apply to RNSS receivers that are designed to operate in specialized RNSS applications (e.g. single-frequency ground networks, and precision navigation). (See § 2.2 high-precision definition above.) Parameters regarding response to pulsed interference for this receiver type are subject to further study in conjunction with ITU-R work on a general pulsed RFI evaluation method.

NOTE 12 – This receiver type operates on several carrier frequencies simultaneously. The carrier frequencies are defined by f_c (MHz) = 1 602 + 0.5625K, where K = −7, ..., +6 (RNSS signals) and f_c (MHz) = 1 602 + 0.5625N, where N = +7, ..., +12 (SBAS signals).

NOTE 13 – Minimum receiver antenna gain at 5 degrees elevation angle is −5.5 dBic.

NOTE 14 – This threshold should account for all aggregate interference. The threshold value does not include any safety margin.

NOTE 15 – This receiver type operates on several carrier frequencies simultaneously. The carrier frequencies are defined by f_c (MHz) = 1 602 + 0.5625K, K = −7, ..., +6 (RNSS signals) and f_c (MHz) = 1 602 + 0.5625N, where N = −12, ..., −8 (ARNS signals).

NOTE 16 – Minimum receiver antenna gain at 5 degrees elevation angle is −21 dBi (ARNS signals).

NOTE 17 – This receiver type operates on several carrier frequencies simultaneously. The carrier frequencies are defined by f_c (MHz) = 1 602 + 0.5625K, where K = −7 to +6. Navigation receivers manufactured before 2006 can operate with navigation signals having carrier frequency numbers (K) −7 to +12.

NOTE 18 – 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.

NOTE 19 – Except where otherwise specified, for receivers operating at carrier frequency 1 575.42 MHz, the receiver input saturation level applies over the corresponding RF filter 3-dB bandwidth in Row 4 of this table, provided the receiver RF filter 3-dB bandwidth does not extend beyond the band 1 559-1 610 MHz. For other carrier frequencies the corresponding RF bandwidth for the receiver input saturation level is currently under study.

NOTE 20 – These receiver input saturation levels are for power in a 1 MHz bandwidth.

NOTE 21 – These survival levels are the peak power level for a pulsed signal with a 10% maximum duty cycle.

NOTE 22 – 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.