

Recommendation ITU-R M.1787-5

(07/2024)

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

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

Foreword

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Series	Title
BO	Satellite delivery
BR	Recording for production, archival and play-out; film for television
BS	Broadcasting service (sound)
BT	Broadcasting service (television)
F	Fixed service
M	Mobile, radiodetermination, amateur and related satellite services
P	Radiowave propagation
RA	Radio astronomy
RS	Remote sensing systems
S	Fixed-satellite service
SA	Space applications and meteorology
SF	Frequency sharing and coordination between fixed-satellite and fixed service systems
SM	Spectrum management
SNG	Satellite news gathering
TF	Time signals and frequency standards emissions
V	Vocabulary and related subjects

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.1787-5

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

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

(2009-2012-2014-2018-2022-2024)

Scope

The information on orbital parameters, navigation signals and technical characteristics of systems and networks in the radionavigation-satellite service (RNSS) (space-to-Earth, space-to-space) operating in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz are presented in this Recommendation. This information is intended for use in the assessment of the interference impact between systems and networks in the RNSS and with other services and systems.

Keywords

RNSS, orbital parameters, navigation signals, technical characteristics.

Abbreviations/Glossary

ABAS	Aircraft-based augmentation system
ECEF	Earth-centred, Earth-fixed
GBAS	Ground-based augmentation system
GMS	Ground monitoring station
GTRF	Galileo terrestrial reference frame
GUS	Ground uplink station
HA	High accuracy
ITRS	International terrestrial reference frame
MCS	Master control station
MRS	Monitor and ranging station
NCS	Network communication subsystem
OS	Open service
PNT	Positioning, navigation and timing
PRN	Pseudo-random noise
PRS	Public regulated service
PSD	Power spectral density
SA	Standard accuracy
SBAS	Satellite-based augmentation system
SiS	Signal-in-space
SPS	Standard positioning service
WAAS	Wide area augmentation system

Related ITU-R Recommendations and Reports

- Recommendation ITU-R M.1318 – 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.1831 – A coordination methodology for RNSS inter-system interference estimation
- Recommendation ITU-R M.1901 – 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 – 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 – 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.1904 – 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 – 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.2030 – 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
- Report ITU-R M.766 – Feasibility of frequency sharing between the GPS and other services
- Report ITU-R M.2458 – Radionavigation-satellite service applications in the 1 164-1 215 MHz, 1 215-1 300 MHz, and 1 559-1 610 MHz frequency bands

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 several operating and planned systems and networks in the RNSS;
- c) that any properly equipped earth station may receive navigation information from systems and networks in the RNSS on a worldwide basis,

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);
- b) 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;
- c) that use of the RNSS in the band 1 215-1 300 MHz is subject to RR No. **5.329**;
- d) that under RR No. **5.328B** systems and networks in the RNSS intending to use the bands 1 164-1 215 MHz, 1 215-1 300 MHz, 1 559-1 610 MHz and 5 010-5 030 MHz for which complete coordination or notification information, as appropriate, is received by the Radiocommunication

Bureau after 1 January 2005 are subject to the application of the provisions of RR Nos. **9.12**, **9.12A** and **9.13**;

- e) that under RR No. **9.7**, stations in satellite networks in the RNSS using the GSO are subject to coordination with other such satellite networks;
- f) that Recommendations ITU-R M.1905, ITU-R M.1902, ITU-R M.1903 and ITU-R M.1904 provide technical and operational characteristics of, and protection criteria for, receiving stations in the RNSS (space-to-Earth and space-to-space) 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.1318 provides an evaluation model for continuous interference from 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, 1 559-1 610 MHz and 5 010-5 030 MHz bands;
- h) that Recommendation ITU-R M.2030 provides 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;
- i) 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;
- j) that Report ITU-R M.766 contains information that is relevant to RNSS operations in the band 1 215-1 300 MHz;
- k) that Recommendation ITU-R M.1831 provides a methodology for RNSS intersystem interference estimation to be used in coordination between systems and networks in the RNSS;
- l) that Report ITU-R M.2458 provides further information on the current and planned RNSS applications in the frequency bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz, including additional RNSS applications not addressed in the M-Series Recommendations,

recommends

1 that, in the bands 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz, the characteristics of transmitting space stations and system descriptions of Annexes 1 to 14 should be considered:

1.1 in determination of methodology and criteria for mutual coordination of systems and networks in the RNSS;

1.2 in assessing the interference impact between systems and networks in the RNSS (space-to-Earth and space-to-space) and systems in other services, taking into account the status of RNSS with respect to these other services;

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

NOTE – In the Annexes of this Recommendation, the term ‘signal frequency range’ refers to the frequency range of the RNSS signal of interest (for CDMA systems: Carrier frequency $\pm$ Half the signal bandwidth (unless otherwise noted); for FDMA systems: Base frequency + (Channel number * Channel spacing) $\pm$ Half the signal bandwidth). Channel number range should also be given for FDMA systems. The signal frequency range is expressed in MHz.

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Annex 1

Technical description of system and characteristics of transmitting space stations of the GLONASS global navigation satellite system

1 Introduction

The GLONASS system consists of 24 satellites equally spaced in three orbital planes with eight satellites in each plane. The orbit inclination angle is 64.8 degrees. Each satellite transmits navigation signals in three frequency bands: L1 (1.6 GHz), L2 (1.2 GHz) and L3 (1.1 GHz). The satellites transmit two types of signals: with frequency division multiple access and code division multiple access. Signals with frequency division multiple access are differentiated by carrier frequency; the same carrier frequency may be used by antipodal satellites located in the same plane. Navigation signals are modulated with a continuous bit stream (which contains information about the satellite ephemeris and time), and also a pseudo-random code for pseudo-range measurements. Signals with code division multiple access have the same carrier frequency and are differentiated by code. These signals are modulated by structured binary sequence that contains coded data about ephemerides and time. A user receiving signals from four or more satellites is able to determine the three location coordinates and the three velocity vector constituents with high accuracy. Navigational determinations are possible when on or near the Earth's surface.

1.1 Frequency requirements

The frequency requirements for the GLONASS system were based upon ionosphere transparency, radio link budget, simplicity of user antennas, multipath suppression, equipment cost and Radio Regulations (RR) provisions.

1.1.1 Signals with frequency division multiple access

The carrier frequencies of navigation signals with frequency division multiple access vary by an integer multiple of 0.5625 MHz in the L1 band, by 0.4375 MHz in the L2 band and by 0.423 MHz in the L3 band.

Since 2006 new satellites in the GLONASS system use 14 to 20 carrier frequencies in different bands. In the L1 band carrier frequencies 1 598.0625 MHz (lowest) to 1 605.3750 MHz (highest) are used, in the L2 band carrier frequencies from 1 242.9375 MHz (lowest) to 1 248.6250 MHz (highest) are used and in the L3 band carrier frequencies from 1 201.7430 MHz (lowest) to 1 209.7800 MHz (highest) are used. Nominal values of carrier frequencies of radionavigation signals used in the GLONASS system are given in Table 1.

TABLE 1

Nominal values of carrier frequencies of radionavigation signals in the GLONASS system

K (No. of carrier frequency)	FKL1 (MHz)	FKL2 (MHz)	FKL3 (MHz)
12	—	—	1 209.7800
11	—	—	1 209.3570
10	—	—	1 208.9340
09	—	—	1 208.5110
08	—	—	1 208.0880
07	—	—	1 207.6650
06	1 605.3750	1 248.6250	1 207.2420
05	1 604.8125	1 248.1875	1 206.8190
04	1 604.2500	1 247.7500	1 206.3960
03	1 603.6875	1 247.3125	1 205.9730
02	1 603.1250	1 246.8750	1 205.5500
01	1 602.5625	1 246.4375	1 205.1270
00	1 602.0000	1 246.0000	1 204.7040
−01	1 601.4375	1 245.5625	1 204.2810
−02	1 600.8750	1 245.1250	1 203.8580
−03	1 600.3125	1 244.6875	1 203.4350
−04	1 599.7500	1 244.2500	1 203.0120
−05	1 599.1875	1 243.8125	1 202.5890
−06	1 598.6250	1 243.3750	1 202.1660
−07	1 598.0625	1 242.9375	1 201.7430

Two phase-shift keying (by 180 degrees of the phase) navigation signals shifted in phase by 90 degrees (in quadrature) are transmitted at each carrier frequency. They are a standard accuracy (SA) signal and a high accuracy (HA) one.

1.1.2 Signals with code division multiple access

The carrier frequencies of GLONASS navigation signals with code division multiple access are 1 600.995 MHz 1 248.06 MHz and 1 202,025 MHz in the L1, L2 and L3 bands, respectively.

The signal with code division multiple access in L1 band includes four components. These components are formed by BPSK(1), BOC (1,1) and BOC (5,2.5) modulations.

The signal with code division multiple access in L2 band includes four components. These components are formed by BPSK(1), BOC (1,1) and BOC (5,2.5) modulations.

The signal with code division multiple access in L3 band includes two components. These components are formed by BPSK(10) modulation.

2 System overview

The GLONASS system provides navigation data and accurate time signals for terrestrial, maritime, air and space users.

The system operates on the principle of passive trilateration. The GLONASS system user equipment measures the pseudo-ranges and radial pseudo-velocities from all visible satellites and receives information about the satellites' ephemeris and clock parameters. On the basis of these data, the three coordinates of the user's location and the three velocity vector constituents are calculated and user clock and frequency correction are made. Coordinate system PE-90 is used by GLONASS system.

3 System description

The GLONASS system consists of three major segments: the space segment, the control segment and the user segment.

3.1 Space segment

The GLONASS system is comprised of 24 satellites located in three orbital planes with eight satellites in each plane. The planes are separated from each other by 120-degree longitude. The orbit inclination angle is 64.8 degrees. The satellites are equally spaced by 45 degrees in a plane by argument of latitude. Their rotation period is 11 h 15 min. The height of the orbit is 19 100 km.

3.2 Control segment

The control segment consists of the system control centre and a monitoring station network. The monitoring stations measure the satellite's orbital parameters and clock shift relative to the main system clock. These data are transmitted to the system control centre. The centre calculates the ephemerides and clock correction parameters and then uploads messages to the satellites through the monitor stations on a daily basis.

3.3 User segment

The user segment consists of a great number of user terminals of different types. The user terminal consists of an antenna, a receiver, a processor and an input/output device. This equipment may be combined with other navigation devices to increase navigation accuracy and reliability. Such a combination can be especially useful for highly dynamic platforms.

4 Navigation signal structure

4.1 Signals with frequency division multiple access

The SA signal structure is the same for both the L1 and L2 bands and different in the L3 band. It is a pseudo-random sequence which is Modulo-2 added to a continuous digital data stream transmitted with a 50 bit/s (L1, L2) and 125 bit/s (L3) rate. The pseudo-random sequence has a chip rate of 0.511 MHz (for L1, L2) and of 4.095 MHz (for L3) and its period is 1 ms.

In the L1, L2 and L3 bands, the HA signal is also a pseudo-random sequence Modulo-2 added to a continuous data stream. The pseudo-random sequence chip rate is 5.11 MHz in the L1 and L2 bands and it is 4.095 MHz in the L3 band.

Digital data include information about the satellite's ephemerides, clock time and other useful information.

4.2 Signals with code division multiple access

In L1 band two signals with code division multiple access emitted at a single carrier frequency 1 600.995 MHz at different quadrature with 90 degrees shift. Each signal consists of two components

with a time-division multiplexing. The data transfer speed is 125 bit/s and it is identical for two signals.

In L2 band two signals with code division multiple access emitted at a single carrier frequency 1 248.06 MHz at different quadrature with 90 degrees shift. Each signal consists of two components with a time-division multiplexing. The data transfer speed in two signals is 125 bit/s and 250 bit/s respectively.

In L3 band signal with code division multiple access emitted at frequency 1 202.025 MHz and includes two phase-shift keying signals of equal power, that are shifted in phase by 90 degrees. The data transfer speed in signal is 100 bit/s.

5 Signal power and spectra

5.1 Signals with frequency division multiple access

Transmitted signals are elliptically right-hand polarized with an ellipticity factor no worse than 0.7 for L1, L2 and L3 bands. The minimum guaranteed power of a signal at the input of a receiver (assumes a 0 dBi gain antenna) is specified as –161 dBW (–131 dBm) for both SA and HA signals in the L1, L2 and L3 bands.

Three classes of emissions are used in the GLONASS system: 8M19G7X, 1M02G7X, 10M2G7X. Characteristics of these signals are given in Table 2.

TABLE 2

Characteristics of GLONASS signals with frequency division multiple access

Frequency range	Emission class	Tx bandwidth (MHz)	Maximum peak power of emission (dBW)	Maximum spectral power density (dB(W/Hz))	Antenna gain (dB)
L1	10M2G7X	10.2	15	–52	11
	1M02G7X	1.02	15	–42	
L2	10M2G7X	10.2	14	–53	10
	1M02G7X	1.02	14	–43	
L3 ⁽¹⁾	8M19G7X	8.2	15	–52.1	12
	8M19G7X	8.2	15	–52.1	

⁽¹⁾ Two GLONASS L3 signals are shifted relative to each other by 90 degrees (in quadrature).

The power spectrum envelope of the navigation signal is described by the function $(\sin x/x)^2$, where:

$$x = \pi(f - f_c)/f_t$$

in which:

f : frequency considered

f_c : carrier frequency of the signal

f_t : chip rate of the signal.

The main lobe of the spectrum forms the signal's operational spectrum. It occupies a bandwidth equal to $2f_t$. The lobes have a width equal to f_t .

5.2 Signals with code division multiple access

The GLONASS system uses four classes of emission: 2M05G7X, 4M10G7X, 15M4G7X, 20M5G7XCC. The characteristics of these signals are shown in Table 3.

TABLE 3
Characteristics of GLONASS signals with code division multiple access

Frequency range	Emission class	Tx bandwidth (MHz)	Maximum peak power of emission (dBW)	Maximum spectral power density (dB(W/Hz))	Antenna gain (dB)
L1	2M05G7X	2.05	15.6	−44.1	14
	4M10G7X	4.1	15.6	−46.7	
	15M4G7X	15.4	15.6	−51.3	
	15M4G7X	15.4	15.6	−51.3	
L2	2M05G7X	2.05	14	−45.6	12.5
	4M10G7X	4.1	14	−48.2	
	15M4G7X	15.4	14	−52.8	
	15M4G7X	15.4	14	−52.8	
L3	20M5G7XCC	20.5	13	−56.6	12.4
	20M5G7XCC	20.5	13	−56.6	

Annex 2

Technical description and characteristics of the Navstar Global Positioning System (GPS)

1 Introduction

Current information on the Navstar Global Positioning System (GPS) is available at no charge at URL <http://www.gps.gov>. Information on the GPS operating in the 1 164-1 215 MHz, 1 215-1 300 MHz and 1 559-1 610 MHz bands is documented in the latest version of GPS interface specification documents IS-GPS-200, IS-GPS-705, and IS-GPS-800 with their latest revision notices¹. Information on the functional data transfer interface between the GPS Control Segment (CS) and the GPS user and user-support communities is documented in the latest version of GPS interface control documents ICD-GPS-240 and ICD-GPS-870 with their latest revision notices. The levels of Standard Positioning Service (SPS) are defined in terms of broadcast signal parameters and GPS constellation design. Additional information on the levels of Signal in Space (SIS) performance

¹ IS-GPS-200, IS-GPS-705, IS-GPS-800, ICD-GPS-240, and ICD-GPS-870 can be found at <https://www.gps.gov/technical/icwg/>

provided by the USG to the SPS user community is documented in the latest version of the GPS SPS Performance Standard document with its latest revision notice².

The baseline GPS satellite constellation nominally consists of a minimum of 24 operational satellites in six 55 degrees inclined equally spaced orbital planes. GPS satellites circle the Earth every 12 hours emitting continuous navigation signals. The system provides accurate position determination in three dimensions and timing anywhere on or near the surface of the Earth.

1.1 GPS frequency requirements

The frequency requirements for the GPS system are based upon an assessment of user accuracy requirements, space-to-Earth propagation delay resolution, multipath suppression, and equipment cost and configurations. Three channels are centred at 1575.42 MHz (GPS L1), 1227.6 MHz (GPS L2) and 1176.45 MHz (GPS L5).

The L1, L2 and L5 channels consist of space-based positioning, navigation, and timing (PNT) signals delivered free of direct user fees for peaceful civil, commercial, and scientific uses worldwide. Receivers can be designed to process one or several signals depending on the specific application, user requirements and/or targeted market. GPS signals provide the necessary frequency diversity and wide bandwidth for increased range and timing accuracy, improved multipath suppression, and SIS redundancy.

2 System overview

GPS is a continuous space-based, all-weather radio system for PNT service which provides extremely accurate three-dimensional position and velocity information together with a precise common time reference to suitably equipped users anywhere on or near the surface of the Earth.

The system operates on the principle of passive trilateration. The GPS user equipment first measures the pseudo-ranges to four satellites, computes their positions, and synchronizes its clock to GPS by the use of the received ephemeris and clock correction parameters. (The measurements are termed 'pseudo' because they are made by an imprecise user clock and contain fixed bias terms due to the user clock offsets from GPS time.) It then determines the three-dimensional user position in a Cartesian Earth-centred, Earth-fixed (ECEF) World Geodetic System 1984 (WGS-84) coordinate system, and the user clock offset from GPS time by essentially calculating the simultaneous solution of four range equations.

Similarly, the three-dimensional user velocity and user clock-rate offset can be estimated by solving four range rate equations given the pseudo-range rate measurements to four satellites.

3 System segments

The system consists of three major segments: the space segment, the control segment and the user segment. The principal function of each segment is as follows.

3.1 Space segment

The space segment comprises the GPS satellites, which function as 'celestial' reference points, emitting precisely time-encoded navigation signals from space. The operational constellation consists of a minimum of 24 satellites in 12-hour orbits with a semi-major axis of about 26 600 km. The

² GPS Standard Positioning Service Performance Standard document can be found at <https://www.gps.gov/technical/ps/>

satellites are placed in six orbital planes inclined 55 degrees relative to the equatorial plane, and the orbital planes are equally spaced about the equator at a 60-degree separation. There are typically a minimum of four satellites per plane.

The satellite is a three-axis stabilized vehicle. The major elements of its principal navigation payload are the atomic frequency standard that generates the stable time base for the satellite, the mission computer that receives the uploaded navigation data (NAV) from the Control Segment, the Navigation Baseband subsystem that generates the pseudorandom noise (PRN) ranging codes and adds the NAV message data to the PRN ranging codes, and the L-Band subsystem that modulates the resulting binary sequences onto the L1 (1575.42 MHz), L2 (1227.6 MHz), and L5 (1176.45 MHz) carriers which are then broadcast by the helix array antenna.

3.2 Control segment

The Control Segment (CS) is comprised of four major subsystems: a Master Control Station (MCS), an Alternate Master Control Station (AMCS), a network of four ground antennas (GA), and a network of globally distributed monitor stations (MS). The MCS is responsible for all aspects of constellation command and control.

3.3 User segment

The user segment is the ensemble of all user sets and their support equipment. A user set typically consists of an antenna, receiver front end, processor, input/output devices, and a power supply. A set acquires and tracks the navigation signal from four or more satellites in view, measures their propagation times and Doppler frequency shifts, converts them to pseudo-ranges and pseudo-range rates, solves for three-dimensional position and velocity, and sets the GPS time. (GPS time is different than UTC time, but the difference is less than a second and the GPS signals carry the information for conversion between the two. Also, GPS time is continuous whereas UTC time has leap seconds.) User equipment ranges from relatively simple, light-weight receivers to sophisticated receivers which are integrated with other navigation sensors or systems for accurate performance in highly dynamic environments.

4 GPS signal structure

The GPS navigational signal transmitted from the satellites consists of three modulated carriers: L1 at centre frequency of 1 575.42 MHz ($154 f_0$), L2 at centre frequency of 1 227.6 MHz ($120 f_0$), and L5 at centre frequency of 1 176.45 MHz ($115 f_0$), where $f_0 = 10.23$ MHz. f_0 is the output of the on-board atomic frequency standard to which all signals generated are coherently related. In the text below, the signals on each GPS carrier frequency are listed (and those with more than one component are further described) and a short description of RF and signal-processing parameters is given.

On the L1 carrier, GPS transmits four signals. The signals include C/A, P(Y), L1C and M which are described in § 6.1 below.

On the L2 carrier, GPS transmits three signals. The signals include L2C or C/A (rarely), P(Y) and M which are described in § 6.2 below.

On the L5 carrier, GPS transmits a single signal, denoted L5. The L5 signal has two components transmitted in phase quadrature which are described in § 6.3 below.

Tables 4, 5 and 6 list values for the key parameters of the GPS L1, L2 and L5 signal transmissions, respectively. These parameters include the following RF characteristics: Signal frequency range; 3 dB bandwidth of the satellite RF transmit filter; signal modulation method; and minimum received power level at the output of a reference receiver antenna located on the Earth's surface.

Also included in the tables are digital signal processing parameters including the PRN code chipping rate and the navigation message data bit and data symbol rates. Furthermore, for each carrier frequency, the satellite transmit antenna parameters of polarization and maximum ellipticity are provided.

The functions of the ranging codes (also referred to as PRN codes) are twofold:

- they provide good multiple access properties among different satellites, since all satellites transmit on the same carrier frequencies and are differentiated from one another only by the unique PRN codes they use; and
- their correlation properties allow precision measurement of time of arrival and rejection of multipath and interference signals.

The values provided in Tables 4, 5 and 6 are those recommended for use in initial assessments of RF compatibility with the GPS.

5 Signal power and spectra

The GPS satellites employ a shaped-beam antenna that radiates near-uniform power to receivers near the Earth's surface. The signals transmitted on the L1, L2 and L5 carriers are right-hand circularly polarized with the worst-case ellipticity shown in Tables 4, 5 and 6 for the angular range of $\pm 13.8^\circ$ from nadir.

6 GPS transmission parameters

The characteristics of the GPS signal transmissions are provided below.

In addition to phase-shift keying (PSK) modulations, GPS employs binary offset carrier (BOC) modulations. $BOC(m,n)$ denotes a binary offset carrier modulation with a square-wave frequency of $m \times 1.023$ (MHz) and code chipping rate of $n \times 1.023$ (Mchip/s). For sine-phased BOC modulated GPS signals, a normalized power spectral density given by:

$$BOC_{m,n}(f) = f_c \left[\frac{\sin\left(\frac{\pi f}{f_c}\right) \tan\left(\frac{\pi f}{2f_s}\right)}{\pi f} \right]^2$$

where:

f : frequency (Hz)

f_c : chipping rate; i.e. $n \times 1.023$ Mchip/s

f_s : square-wave frequency; i.e. $m \times 1.023$ MHz.

6.1 GPS L1 transmission parameters

GPS operates four signals in the 1 559-1 610 MHz RNSS band. The signals include C/A, L1C, P(Y) and M. The C/A signal uses a BPSK-R(1) modulation, and the P(Y) signal uses a BPSK-R(10) modulation, where the BPSK-R(n) denotes a binary phase-shift keying rectangular (BPSK-R) modulation with a chipping rate of $n \times 1.023$ (Mchip/s). The M signal uses a BOC(10,5) modulation. The L1C signal consists of two components. One component, denoted L1C_D, is modulated by a data message; and the other, denoted L1C_P, is dataless (i.e. a pilot signal only), and the two components use different PRN codes. (The dataless component improves RNSS acquisition and tracking performance.) P(Y) and both L1C components are transmitted in phase, while C/A is transmitted in quadrature to those signals and the signal carrier lags by 90 degrees. The key parameters of the GPS L1 transmissions are presented in Table 4.