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Contents

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Satellite Earth Stations and Systems (SES).

The present document is part 3 of a multi-part deliverable covering GNSS-based Location Systems (GBLS), as identified below:

Part 1: Functional requirements;

Part 2: Reference Architecture;

Part 3: Performance requirements;

Part 4: Requirements for location data exchange protocols;

Part 5: Performance test specification.

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

The increasing proliferation of location-based services is based on several trends in user applications and devices; these include notably the widespread adoption of multi-functional smart-phones etc., and the wider adoption of tracking devices (e.g. in transport). This need for new and innovative location-based services is generating a need for increasingly complex location systems. These systems are designed to deliver location-related information for one or more location targets to user applications.

The wide spectrum of technical features identified in ETSI TR 103 183 [i.1] calls for a new and broader concept for location systems, taking into account hybrid solutions in which GNSS technologies are complemented with other technology sensors to improve robustness and the performance.

1 Scope

The present document addresses performance requirements for GNSS-based Location Systems (GBLSs) that combine Global Navigation Satellite Systems (GNSS - e.g. Galileo™) and other navigation technologies with telecommunication networks for delivery of location-based services.

The present document defines Performance Features applicable to GBLS and specifies the conditions and requirements for these Performance Features.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long-term validity.

The following referenced documents are necessary for the application of the present document.

[1] European GNSS (Galileo™) Open Service (Issue 1.1): "Signal In Space Interface Control Document".

[2] IS-GPS-200 (March 7, 2006): "Revision D, Navstar GPS Space Segment/Navigation User Interfaces".

[3] IS-GPS-705 (September 22, 2005): "Navstar GPS Space Segment/User Segment L5 Interfaces".

[4] IS-GPS-800 (September 4, 2008): "Navstar GPS Space Segment/User Segment L1C Interfaces".

[5] "Global Navigation Satellite System GLONASS Interface Control Document", Version 5, 2002.

[6] BDS-SIS-ICD-B1I-2.0 (December 2013): "BeiDou Navigation Satellite System Signal In Space Interface Control Document Open Service Signal (Version 2.0)".

[7] ETSI TS 103 246-1: "Satellite Earth Stations and Systems (SES); GNSS based location systems; Part 1: Functional requirements".

[8] ETSI TS 103 246-2: "Satellite Earth Stations and Systems (SES); GNSS based location systems; Part 2: Reference Architecture".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long-term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 103 183: "Satellite Earth Stations and Systems (SES); Global Navigation Satellite Systems (GNSS) based applications and standardisation needs".

[i.2] IEEE 802.11™: "Wireless Local Area Networks".

[i.3] IEEE 802.15™: "Wireless Personal Area Network".

[i.4] IEEE 802.15.1™ (for Bluetooth).

[i.5] IEEE 802.15.4a™ (for low rate WPAN).

[i.6] ETSI TS 145 001: "Digital cellular telecommunications system (Phase 2+); Physical layer on the radio path; General description (3GPP TS 45.001)".

[i.7] ETSI TS 125 104: "Universal Mobile Telecommunications System (UMTS); Base Station (BS) radio transmission and reception (FDD) (3GPP TS 25.104)".

[i.8] ETSI TS 136 171: "LTE; Evolved Universal Terrestrial Radio Access (E-UTRA); Requirements for Support of Assisted Global Navigation Satellite System (A-GNSS) (3GPP TS 36.171)".

[i.9] R. Grover Brown and Gerald Y. Chin: "GPS RAIM: Calculation of Threshold and Protection Radius Using Chi-Square Methods - A Geometric Approach", Global Positioning System: Inst. Navigat., Volume V, pages 155-179, 1997.

[i.10] Juan Blanch et al.: "An Optimized Multiple Hypothesis RAIM Algorithm for Vertical Guidance", Proceedings of ION GNSS 2007, Fort Worth (TX) September 2007.

[i.11] Miguel Azaola et al.: "Isotropy-Based Protection Levels: a Novel Method for Autonomous Protection Level Computation with Minimum Assumptions", NAVITEC 2008, Noordwijk (The Netherlands), December 2008.

[i.12] Clark, B., Bevly, D.: "FDE Implementations for a Low-Cost GPS/INS Module", 22nd International Meeting of the Satellite Division of The Institute of Navigation, Savannah, GA, September 22-25, 2009.

[i.13] Walter, T., Enge, P., Blanch, J. and Pervan, B.: "Worldwide Vertical Guidance of Aircraft Based on Modernised GPS and New Integrity Augmentations", Proceedings of the IEEE Volume 96, Number 12, December 2008.

[i.14] Gratton, L., Joerger, M., Pervan, B: "Carrier Phase Relative RAIM Algorithms and Protection Level Derivation", Journal of Navigation Volume 63, Number 2, April 2010.

[i.15] Lee, Y: "Optimization of Position Domain Relative RAIM", ION GNSS 21st International Technical Meeting of the Satellite Division, Savannah, GA, September 16-19, 2008.

[i.16] M. Spangenberg PhD Thesis: "Safe navigation for vehicles", Ecole doctorale Mathématiques, Informatique et Télécommunications de Toulouse, Laboratoire de Télécommunications Spatiales et Aéronautiques (TéSA), June 2009.

[i.17] J.L. Farrell: "Full integrity testing for GPS/INS", Journal of the institute of navigation Volume 53, Number 1, Spring 2006, USA.

[i.18] Clark, B., Bevly, D.: "FDE Implementations for a Low-Cost GPS/INS Module", 22nd International Meeting of the Satellite Division of The Institute of Navigation, Savannah, GA, September 22-25, 2009.

[i.19] DO-316: "Minimum Operational Performance Standards for Global Positioning System/Aircraft Base Augmentation System".

3 Definitions and abbreviations

3.1 Definitions

For the purposes of the present document the following terms and definitions apply:

almanac: information transmitted by a GNSS satellite consisting of coarse orbit and status information for each satellite in the constellation, an Ionospheric model, and information to relate GPS derived time to Coordinated Universal Time (UTC)

architecture: abstract representation of a communications system, in this case representing functional elements of the system and associated logical interfaces

assistance: use of position data available from a telecommunications network to enable a GNSS receiver to acquire and calculate position (A-GNSS) under adverse satellite reception conditions

availability: measures percentage of time when a location system is able to provide the required location-related data

class A, B, C: classes categorize the performance level of the GBLS for a given performance feature

NOTE: In all cases Class A is the highest performance class and C is the lowest.

continuity: likelihood that the navigation signal-in-space supports accuracy and integrity requirements for duration of intended operation

NOTE: Continuity aids a user to start an operation during a given exposure period without an interruption of this operation and assuming that the service was available at beginning of the operation. Related to the Continuity concept, a Loss of Continuity occurs when the user is forced to abort an operation during a specified time interval after it has begun (the system predicts service was available at start of operation).

continuity risk: probability of detected but unscheduled navigation interruption after initiation of an operation

electromagnetic interference: any source of RF transmission that is within the frequency band used by a communication link, and that degrades the performance of this link

NOTE: Jamming is a particular case of electromagnetic interference.

Horizontal Dilution Of Precision (HDOP): measure of position determination accuracy that is a function of the geometrical layout of the satellites used for the fix, relative to the receiver antenna

integrity: measure of the trust in the accuracy of the location-related data provided by the location system

NOTE: Integrity is expressed through the computation of a protection level. The Integrity function includes the ability of the location system to provide timely and valid warnings to users when the system does not fulfil the condition for intended operation. Specifically, a location system is required to deliver a warning (an alert) of any malfunction (as a result of a set alert limit being exceeded) to users within a given period of time (time-to-alert). Related to the Integrity concept, a Loss of Integrity event occurs when an unsafe condition occurs without annunciation for a time longer than the time-to-alert limit.

integrity risk: risk that a positioning error is greater than a protection level per independent sample of time

jamming: deliberate transmission of interference to disrupt processing of wanted signals (which in this case are GNSS or telecommunications signals)

NOTE: Spoofing is considered to be a deceptive form of jamming.

latency: time elapsed between the event triggering the determination of the location-related data for (a) location target(s) (i.e. location request from external client, external or internal event triggering location reporting), and the availability of the location-related data at the user interface

localization: process of determining the position or location of a location target

location: 3-dimensional position or location

location-based application: application that is able to deliver a location-based service to one or several users

location-based service: service built on the processing of the Location-related data associated with one or several location targets

location-related data: set of data associated with a given location target, containing at least one or several of the following time-tagged information elements: location target position, location target motion indicators (velocity and acceleration), and Quality of Service indicators (estimates of the position accuracy, reliability or authenticity)

NOTE: This data is the main output of a Location system.

location system: system responsible for providing to a location based application the Location-related data of one or several location targets

location target: physical entity on whose position the location system builds the location-related data

NOTE: This entity may be mobile or stationary.

Observed Time Difference Of Arrival (OTDOA): time interval observed between the reception of downlink signals from two different cells (in a cellular telecoms system). If a signal from cell 1 is received at the moment t_1, and a signal from cell 2 is received at the moment t_2, the OTDOA is $t_2 - t_1$

performance feature: set of performance requirements for a given location-related data category produced by the GBLS

position: 3-dimensional position or location

positioning: process of determining the position or location of a location target

privacy: function of a location system that aims at ensuring that the location target user private information (identity, bank accounts, etc.) and its location-related data cannot be accessed by a non-authorized third party

Protection Level (PL): upper bound to the positioning error such that the probability: $P(\varepsilon > \mathrm{PL}) < I_{risk}$, where I_{risk} is the integrity risk and ε is the position error

NOTE: The *protection level* is provided by the location system, and with the integrity risk, is one of the two sub-features of the *integrity* system.

Pseudo-Random Noise Code (PRN): unique binary code (or sequence) transmitted by a GNSS satellite to allow a receiver to determine the travel time of the radio signal from satellite to receiver

Quality of Service (QoS): set of indicators that can accompany the location target's position/motion information and is intended to reflect the quality of the information provided by the location system

NOTE: QoS indicators can be an accuracy estimate, a protection level statistic, integrity risk, and authenticity flag.

security: function of a *location system* that aims at ensuring that the *location-related data* is safeguarded against unapproved disclosure or usage inside or outside the *location system*, and that it is also provided in a secure and reliable manner that ensures it is neither lost nor corrupted

spoofing: transmission of signals intended to deceive location processing into reporting false *location target* data e.g. meaconing

time-to-alert: time from when an unsafe integrity condition occurs to when an alerting message reaches the user

vertical axis: axis locally defined for the *location target*, collinear to the zenith/nadir axis

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

3GPP	3rd Generation Partnership Project
A-GNSS	Assisted GNSS
AL	Alarm Limit
EGNOS	European Geostationary Navigation Overlay System
EMI	Electro-Magnetic Interference
E-UTRA	Evolved - UMTS Terrestrial Radio Access

FFS	For Further Study
FM	Frequency Modulation
GBLS	GNSS-based Location System
GEO	Geostationary Earth Orbit
GIC	GNSS Integrity Channel
GLONASS	Global Navigation Satellite System (Russian based system)
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSM	Global System for Mobile communications
HDOP	Horizontal Dilution of Precision
HPE	Horizontal Positioning Error
HPL	Horizontal Protection Level
INS	Inertial Navigation Sensor
ITS	Intelligent Transport Systems
LoS	Line of Sight
LTE	Long-Term Evolution
n/a	Not Applicable
OS	Open Service
OTDOA	Observed Time Difference of Arrival
PL	Protection Level
PRN	Pseudo-Random Noise code
PVT	Position, Velocity and Time
QoS	Quality of Service
RAIM	Receiver Autonomous Integrity Monitoring
RF	Radio Frequency
SF	Scale Factor
TBD	To Be Defined
TSP	Total Spoofing Power
TTFF	Time-To-Tirst-Fix
UMTS	Universal Mobile Telecommunications System
UMTS	Universal Mobile Telecommunications System
UTRA	UMTS Terrestrial Radio Access
Wi-Fi	Wireless Fidelity
WPAN	Wireless Personal Area Network

4 Overview of GNSS-based Location System Performance Features and Classes

4.1 GNSS-based Location System (GBLS)

The present document defines the performance requirements applicable to GNSS-based Location System (GBLS) location-related data.

GBLS Functional Requirements and Reference Architecture in ETSI TS 103 246-1 [7] and ETSI TS 103 246-2 [8] shall apply. A GBLS intends to provide one or more users with location-related data associated with one or more location targets. Figure 1 is an extract of ETSI TS 103 246-2 [8] and depicts the GBLS Architecture (level 2).

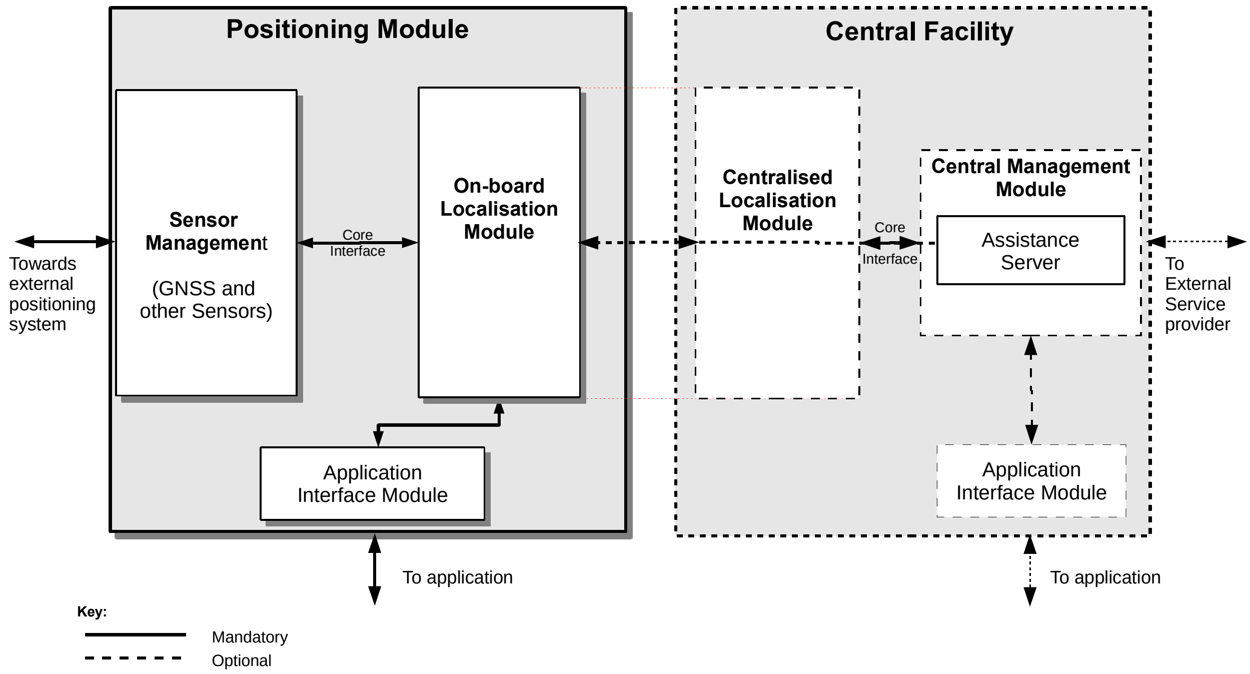


Figure 1: GNSS-based Location System (GBLS) Architecture

4.2 Performance Features

Location-related data delivered by a GNSS-based Location System is required to meet a number of performance requirements, derived from GBLS Functional requirements ETSI TS 103 246-1 [7]. These performance requirements are grouped in categories called Performance Features.

A detailed definition of each Performance Feature with its attributes and metrics is given in clause 5. Table 1 lists the Performance Features included in this technical specification and other additional features identified but left for further study (FFS):

Table 1: GBLS Performance Features

Performance Feature	Corresponding clause
Horizontal Position Accuracy	5.2
Vertical Position Accuracy	5.3
GNSS Time Accuracy	5.4
Time-To-First-Fix	5.5
Position Authenticity	5.6
Robustness to Interference	5.7
GNSS Sensitivity	5.8
Position Integrity (Protection Level)	5.9
Availability of Required Accuracy (probability that PVT data is provided with a certain level of accuracy)	*FFS*
EMI Localization Accuracy (error of location measurement of an interfering signal)	*FFS*
GNSS-Denied Accuracy (error in PVT data when there is a loss of GNSS signal reception)	*FFS*
Position Integrity (Time-to-Alert) (the time from occurrence of an unsafe integrity condition to the issue of an alerting message)	*FFS*
Position Integrity (Time-to-Recover-from-Alert) (the time from cancellation of an unsafe integrity condition to removal of an alerting message)	*FFS*
Accuracy of speed and acceleration (horizontal and vertical)	*FFS*

4.3 Class of Performance requirements

Associated with each Performance feature, a set of Performance requirements is defined for one or several use cases.

Three Classes of performance (A, B and C) are defined in order to categorize the performance level of the GBLS for a given Performance feature. In all cases Class A is the highest performance class and C is the lowest. The classes' contents in term of performance requirements are driven by the different implementations of the reference architecture ETSI TS 103 246-1 [7].

Performance features shall be considered independently of each other and for a given GBLS not all Performance features shall be necessarily addressed. The choice of applicable Performance features is left to users in accordance with the requirements of their targeted applications. The GBLS class of performance shall be established for each chosen performance feature and may not be the same for all of them.

For each Performance feature one or several use cases with different operational environments for each use case are considered, with corresponding metric measurements for Performance classes A, B and C. A Performance feature associated to a given use case and a given operational environment shall be considered independent to another combination. The choice of one or several use cases as well as the choice of operating environments with their corresponding Performance class is left to users in accordance with the requirement of their targeted applications. However, the compliance to a given Performance class (A, B or C) requires all metrics of the table to be met. The compliance to a Performance class does not require conformance to all use cases and all associated operational environments for that particular Performance feature.

Table 2 provides an example of selection of Performance Class for a specific GBLS application for Performance features, with different combinations of use cases with operational conditions and Performance classes.

Table 2: Example of selection of Performance Class for a specific GBLS application

Performance Features (defined in clause 5)	Use cases (defined in annex A)	Operational Environments (defined in annex A)	Selected Performance Class
Horizontal Accuracy	Static Location Target	Open Area	Class A
		Urban Area	Class B
	Moving Location Target	Urban Area	Class B
		Asymmetric Area	Class C
Vertical Accuracy	Static Location Target	Open Area	Class B
GNSS Time Accuracy	Performance Feature not considered for this specific application		
Time-to-first-fix	Static Location Target	Open Area Urban Area	Class C
Position Authenticity	Static Location target Interference (spoofing) scenario	Open Area	Class A
	Moving Location Target Interference (spoofing) scenario		Class B
Robustness to Interference	Moving Location Target 20 MHz deviation with J#2	Open Area	Class B
	Moving Location Target 10 MHz deviation with J#1		Class C
GNSS Sensitivity	Performance Feature not considered for this specific application		
Position Integrity & Protection Level	Moving Location Target	Urban Area	Class C

4.4 Use cases associated to Performance Features

For a Performance Feature, several use cases are defined, with associated performance requirements. A use case describes the applicable conditions and scenarios to be used for measuring the performance metrics. It sets the operational environment of the GBLS system, the location target motion, type of signals, etc. All these operating conditions are defined in clause A. The ranges of environments and receiver types have been chosen as the most representative of those commonly encountered today. Clause 5 defines the requirements for each feature in terms of an associated set of performance metrics (i.e. measurement parameters).

5 Performance Requirements

5.1 General

The following clauses define the performance requirements for each of the Performance features listed in clause 4. Considering given operating conditions, to comply with a Class of performance, the tested GBLS performances shall be equal to or better than the performance requirements of the corresponding column of the table.

In all cases the applicable GNSS and other signals are defined in clause A.2, unless otherwise specified.

The performance features are defined in each case for a range of operating conditions, where applicable, including:

- Location target operational environments (see clause A.3):
  - Open area
  - Urban
  - Asymmetric area
- Location target motion types (see clause A.4 and A.5):
  - Moving
  - Static
- GBLS types (Class A, B, C)
- Clear signal (non-interfered) or signal interference conditions (see clause A.6)
- Authenticity threat scenario and parameters (see clause A.7)
- Integrity threat scenario and parameters (see clause A.8)

5.2 Horizontal Position Accuracy

5.2.1 Definition

The Horizontal Position Accuracy is the difference (error) between the position of the location target reported by the GBLS and its true position projected onto the horizontal plane, at a given time (i.e. with a given timestamp).

The requirements for this feature can range from relaxed constraints for personal navigation applications, to more stringent ones for liability-critical applications, such as road charging, dangerous cargo tracking, etc.

5.2.2 Metrics

The metric used to characterize Horizontal Position Accuracy is the Horizontal Position Error over a specified time interval in terms of its:

- Mean value
- Standard deviation
- 50^{th}, 67^{th}, 95^{th} and 99^{th} percentiles distribution

These metrics are defined as follows:

- Let p be the true position of the location target.
- Let $\{p_i^*\}_{i \in [1,N]}$ be the position estimates collected over a specified time interval (N samples), projected on the local horizontal plane containing the location target true position.
- $\{\varepsilon\}_i$ is the positioning error vector, defined as $\{\varepsilon\}_i = p - \{p^*\}_i$. Note that this vector is contained in the local horizontal plane.
- The mean value is defined as:

$$m = \|E[\varepsilon]\|$$

- The standard deviation is defined as:

$$\sigma = \sqrt{E[\|\varepsilon - E[\varepsilon]\|^2]}$$

- The percentiles, noted σ_x (i.e. respectively σ_{67} σ_{95} σ_{99}) is defined as the smallest error verifying:

$$P(\|\varepsilon\| > \sigma_x) < \left(1 - \frac{x}{100}\right)$$

In addition to the above, when the use case considers a moving location target, the following metrics apply:

- the along-track error is the projection of the position error on the axis tangential to the location target trajectory, determined at the location target true position at the time the position was sampled by the GBLS;
- the cross-track error is the projection of the position error on the axis orthogonal to the location target trajectory, determined at the location target true position at the time the position was sampled by the GBLS.

Both of these errors are characterized by their mean value, and the 67^{th}, 95^{th} and 99^{th} percentiles values.

Figure 2 illustrates these errors.

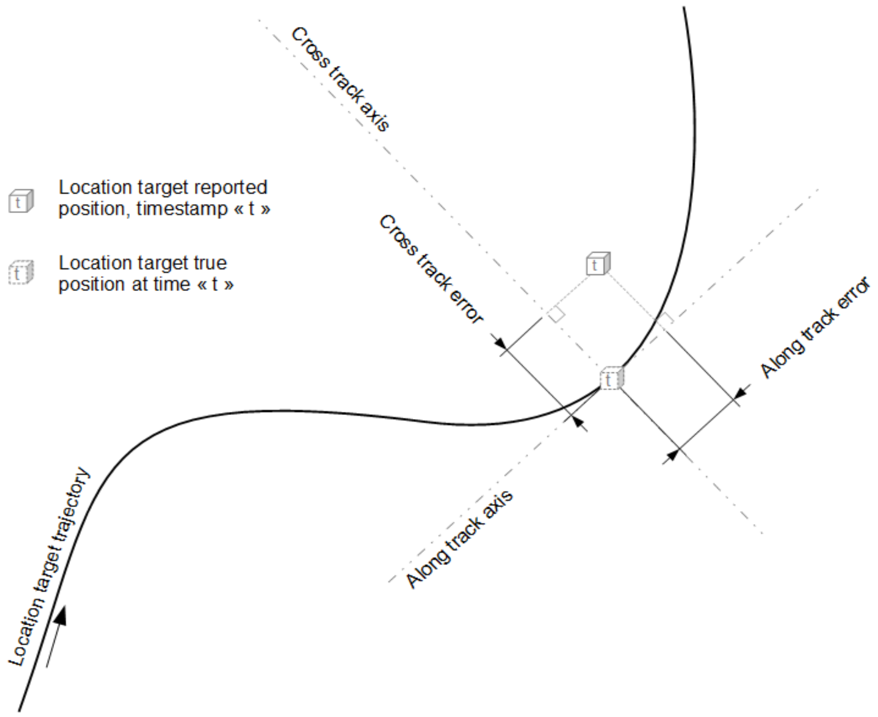


Figure 2: Definition of Cross-Track and Along-Track Position Errors

5.2.3 Performance requirements

5.2.3.1 Use case: Moving Location Target

5.2.3.1.1 Operational environment: Open area

The performance requirements are specified in table 3. The location target follows the trajectory defined in clause A.4.

Table 3: Performance requirements for Horizontal Position Accuracy, Moving location target, Open area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean error	0,2	[tbd]	8,4
Standard deviation	0,2	[tbd]	5,2
50th percentile	0,2	[tbd]	6,7
67th percentile	0,3	[tbd]	8,8
95th percentile	0,4	[tbd]	22,1
99th percentile	0,5	[tbd]	23,8
Mean cross track error	0,1	[tbd]	4,8
Cross track error - 67th percentile	0,1	[tbd]	5,8
Cross track error - 95th percentile	0,2	[tbd]	16,5
Cross track error - 99th percentile	0,3	[tbd]	20
Mean along track error	0,2	[tbd]	5,4
Along track error - 67th percentile	0,3	[tbd]	6,4
Along track error - 95th percentile	0,4	[tbd]	21,9
Along track error - 99th percentile	0,5	[tbd]	22,4

5.2.3.1.2 Operational environment: Urban area

The performance requirements are specified in table 4. The location target follows the trajectory defined in clause A.4.

Table 4: Performance requirements for Horizontal Position Accuracy, Moving location target, Urban area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean value	1,6	24,2	40,8
Standard deviation	1,7	17,2	17,2
50th percentile	0,5	20,9	42,1
67th percentile	0,8	29,2	52,5
95th percentile	9,3	49,9	75,3
99th percentile	19,0	62,9	98,7
Cross track error - Mean value	1,0	15,2	26,9
Cross track error - 67th percentile	0,6	18,8	37,9
Cross track error - 95th percentile	3,7	42,6	59,0
Cross track error - 99th percentile	13,8	51,4	66,9
Along track error - Mean value	1,1	15,4	21,9
Along track error - 67th percentile	0,5	19,2	25,6
Along track error - 95th percentile	6,2	44,3	68,3
Along track error - 99th percentile	14,6	56,3	90,4

5.2.3.1.3 Operational environment: Asymmetric area

The performance requirements are specified in table 5. The location target follows the trajectory defined in clause A.4.

Table 5: Performance requirements for Horizontal Position Accuracy, Moving location target, Asymmetric area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean value	0,5	12,1	31,7
Standard deviation	0,5	5,0	19,8
50th percentile	0,4	9,1	36,5
67th percentile	0,5	13,6	45,4
95th percentile	1,0	38,0	79,0
99th percentile	1,2	54,9	99,5
Cross track error - Mean value	0,3	10,2	15,3
Cross track error - 67th percentile	0,4	11,4	19,3
Cross track error - 95th percentile	0,8	32,4	59,0
Cross track error - 99th percentile	1,1	50,4	77,3
Along track error - Mean value	0,3	5,1	21,4
Along track error - 67th percentile	0,3	5,6	33,6
Along track error - 95th percentile	0,6	18,3	68,1
Along track error - 99th percentile	0,9	28,3	92,0

5.2.3.2 Use case: Static Location Target

5.2.3.2.1 Operational environment: Open area

The performance requirements are specified in table 6.

Table 6: Performance requirements for Horizontal Position Accuracy, Static location target, Open area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean value	0,3	1,2	2,4
Standard deviation	0,2	0,5	1,1
50th percentile	0,2	0,5	0,7
67th percentile	0,4	0,7	1,3
95th percentile	0,5	1,1	3,8
99th percentile	0,5	2,2	8,5

5.2.3.2.2 Operational environment: Urban area

The performance requirements are specified in table 7.

Table 7: Performance requirements for Horizontal Position Accuracy, Static location target, Urban area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean value	6,1	12,5	22,1
Standard deviation	5,3	10,2	12,1
50th percentile	6,5	12,4	21,3
67th percentile	7,5	14,5	36,8
95th percentile	11,1	25,5	52,5
99th percentile	13,2	35,6	65,2

5.2.3.2.3 Operational environment: Asymmetric area

The performance requirements are specified in table 8.

Table 8: Performance requirements for Horizontal Position Accuracy, Static location target, Asymmetric area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean value	13,2	27,6	36,7
Standard deviation	6,1	15,6	25,4
50th percentile	12,1	21,5	34,5
67th percentile	14,6	29,6	44,6
95th percentile	19,7	45,3	77,1
99th percentile	34,8	63,6	99,6

5.3 Vertical Position Accuracy

5.3.1 Definition

The Vertical Position Accuracy is the difference (error) between the position of the location target reported by the GBLS and its true position projected onto the vertical plane, at a given time (i.e. with a given timestamp).

This feature applies when vertical guidance is required, for instance to allow position coordinates provided to an emergency indoor caller to result in an "actionable location" for emergency response, especially in urban environments.

5.3.2 Metrics

The metrics are defined in the same way as for Horizontal Position Accuracy in clause 5.2.2, with "horizontal position" replaced by "vertical position".

5.3.3 Performance requirements

5.3.3.1 Use case: Moving Location Target

5.3.3.1.1 Operational environment: Open area

The performance requirements are specified in table 9. The location target follows the trajectory defined in clause A.4.

Table 9: Performance requirements for Vertical Position Accuracy, Moving location target, Open area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean value	0,3	2,1	5,4
Standard deviation	0,3	1,6	5,1
50th percentile	0,3	2,3	5,9
67th percentile	0,3	3,5	6,5
95th percentile	0,4	6,9	10,2
99th percentile	0,7	9,6	16,5

5.3.3.1.2 Operational environment: Urban area

The performance requirements are specified in table 10. The location target follows the trajectory defined in clause A.4.

Table 10: Performance requirements for Vertical Position Accuracy, Moving location target, Urban area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean value	1,2	5,6	20,1
Standard deviation	0,6	5,4	9,8
50th percentile	1,0	6,5	18,7
67th percentile	1,6	8,9	26,2
95th percentile	2,9	13,2	35,2
99th percentile	3,9	17,5	81,4

5.3.3.1.3 Operational environment: Asymmetric area

The performance requirements are specified in table 11. The location target follows the trajectory defined in clause A.4.

Table 11: Performance requirements for Vertical Position Accuracy, Moving location target, Asymmetric area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean value	2,3	11,2	35,6
Standard deviation	1,3	9,6	30,2
50th percentile	2,9	13,2	30,6
67th percentile	3,4	16,5	41,3
95th percentile	4,5	19,5	69,3
99th percentile	5,7	28,5	102,1

5.3.3.2 Use case: Static Location Target

5.3.3.2.1 Operational environment: Open area

The performance requirements are specified in table 12.

Table 12: Performance requirements for Vertical position accuracy, Static location target, Open area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean value	0,5	1,2	5,4
Standard deviation	0,3	0,8	5,1
50th percentile	0,3	2,1	5,6
67th percentile	0,5	2,9	6,9
95th percentile	0,8	4,6	8,4
99th percentile	1,5	6,5	10,2

5.3.3.2.2 Operational environment: Urban area

The performance requirements are specified in table 13.

Table 13: Performance requirements for Vertical Position Accuracy, Static location target, Urban area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean value	3,1	6,3	20,1
Standard deviation	3,2	5,2	21,0
50th percentile	2,9	6,4	25,2
67th percentile	4,5	8,2	34,5
95th percentile	7,1	14,5	42,1
99th percentile	7,8	18,9	64,9

5.3.3.2.3 Operational environment: Asymmetric area

The performance requirements are specified in table 14.

Table 14: Performance requirements for Vertical Position Accuracy, Static location target, Asymmetric area

Metric	Max position error (m)		
	Class A	Class B	Class C
Mean value	8,1	17,5	40,1
Standard deviation	7,4	18,8	42,8
50th percentile	8,1	16,1	41,7
67th percentile	10,1	22,4	55,4
95th percentile	13,2	31	69,1
99th percentile	15,7	34,5	80,1

5.4 GNSS Time Accuracy

5.4.1 Definition

GNSS Time Accuracy is the difference between the true GNSS time (reference time of the GNSS system) and the time computed by the GBLS System.

For example, applications requiring synchronization of assets distributed across wide geographical areas can use GNSS time as a reference.

5.4.2 Performance requirements

5.4.2.1 Use case: Moving Location Target

5.4.2.1.1 Operational environment: Open area

The performance requirements are specified in table 15. The location target follows the trajectory defined in clause A.4.

Table 15: Performance requirements for GNSS Time Accuracy, Moving location target, Open area

Metric	Maximum time error (ns)		
	Class A	Class B	Class C
Mean value	6	37	93
95th percentile	13	97	163

5.4.2.1.2 Operational environment: Urban area

The performance requirements are specified in table 16. The location target follows the trajectory defined in clause A.4.

Table 16: Performance requirements for GNSS Time Accuracy, Moving location target, Urban area

Metric	Maximum time error (ns)		
	Class A	Class B	Class C
Mean value	76	317	627
95th percentile	130	483	1 180

5.4.2.1.3 Operational environment: Asymmetric area

The performance requirements are specified in table 17. The location target follows the trajectory defined in clause A.4.

Table 17: Performance requirements for GNSS Time Accuracy, Moving location target, Asymmetric area

Metric	Maximum time error (ns)		
	Class A	Class B	Class C
Mean value	76	403	873
95th percentile	193	880	1 720

5.4.2.2 Use case: Static Location Target

5.4.2.2.1 Operational environment: Open area

The performance requirements are specified in table 18.

Table 18: Performance requirements for GNSS Time Accuracy, Static location target, Open area

Metric	Maximum time error (ns)		
	Class A	Class B	Class C
Mean value	6	17	70
95th percentile	17	50	117

5.4.2.2.2 Operational environment: Urban area

The performance requirements are specified in table 19.

Table 19: Performance requirements for GNSS Time Accuracy, Static location target, Urban area

Metric	Maximum time error (ns)		
	Class A	Class B	Class C
Mean value	216	260	520
95th percentile	440	483	927

5.4.2.2.3 Operational environment: Asymmetric area

The performance requirements are specified in table 20.

Table 20: Performance requirements for GNSS Time Accuracy, Static location target, Asymmetric area

Metric	Maximum time error (ns)		
	Class A	Class B	Class C
Mean value	403	517	670
95th percentile	653	850	1 557

5.5 Time-to-First-Fix (TTFF)

5.5.1 Definition

TTFF is the time taken by the GBLS to provide location-related data, starting either from the reception of a request, or from another triggering event (for instance for periodic or geo-dependent reporting).

The TTFF is defined for a cold-start condition, defined as the GNSS receiver having:

- no prior information;
- inaccurate estimates of its position, velocity and time; or
- inaccurate positions of any of the GNSS satellites.

In this case, the receiver will systematically search for all possible satellites.

Depending on GBLS capability, the GBLS positioning module can acquire **assistance data** (provided by the central facility for instance ETSI TS 103 246-2 [8]) to reduce the TTFF. Assistance data contains information on time and GNSS ephemeris, etc.

5.5.2 GBLS starting conditions

The following start conditions as defined in table 24 are used for the definition of performance requirements:

- **Assisted cold-start with fine time assistance.** At the start point, the GBLS is provided with assistance data, which may include estimates of, its position, velocity, and information on, or position knowledge of, relevant GNSS satellites. It also includes a good estimate of current time to the microsecond level of accuracy. This allows the GBLS to make an accelerated fix.
- **Assisted cold-start with coarse time assistance.** At the start point, the GBLS is provided with necessary assistance data, which may include estimates of its position, velocity, and information on, or position knowledge of, relevant GNSS satellites. It also includes an estimate of current time to the second level of accuracy. This allows the GBLS to make an accelerated fix.
- **Cold-start without assistance**.

NOTE 1: Cold-start only is considered because it offers discrimination between system configurations.

The starting conditions are detailed in table 21:

Table 21: Description of starting conditions

<table>
<tr><th>Assisted Condition</th><th>Max time error at GNSS sensor start</th><th>Max Position error at GNSS sensor start</th><th>GNSS Satellites Ephemeris</th><th>Precise Time of Week</th></tr>
<tr><td>Assisted cold-start with fine time assistance</td><td>±10 µs
(retrieved from assistance data)</td><td rowspan="2">Retrieved from assistance data:
Horizontal: ±3 km
Altitude: ±500 m</td><td rowspan="2">Retrieved from assistance data</td><td>From assistance data</td></tr>
<tr><td>Assisted cold-start with coarse time assistance</td><td>±2 s
(retrieved from assistance data)</td><td>Decoded from satellite data, or calculated as additional state of the navigation</td></tr>
<tr><td>Cold-start without assistance</td><td>None</td><td>Not known</td><td>Decoded from satellite data</td><td>Decoded from satellite data</td></tr>
</table>

Max time error: the time difference between the GNSS time provided in assistance data and the real GNSS time.

Max Position error: the difference between the estimated position of the receiver provided by the assistance server and the real position of the receiver.

GNSS Satellites Ephemeris: the current fine orbital parameters of GNSS satellites that should be visible from the position of the receiver and provided in assistance data.

GNSS Time of the Week: the time stamp broadcast by GNSS satellites in their navigation message and provided in assistance data.

NOTE 2: Assistance data allows the GBLS to restrict its search area for satellites signals and data in order to expedite the elaboration of a first position fix.

5.5.3 Performance requirements

5.5.3.1 Use case: Moving Location Target

5.5.3.1.1 Operational environment: Open area

The performance requirements are specified in table 22. The location target follows the trajectory defined in clause A.4.

In all cases the requirements are dependent on achieving a maximum 95th percentile horizontal and vertical (if applicable) positioning error of 100 m.

Table 22: Performance requirements for TTFF, Moving location target, Open area

Metric	TTFF [s]		
	Class A	**Class B**	**Class C**
Mean value	1,55	2,5	29,8
Standard deviation	0,12	0,4	4,9
67th percentile	1,56	2,7	30,2
95th percentile	1,62	3,3	36,9
99th percentile	2,21	3,8	38,8

5.5.3.1.2 Operational environment: Urban area

The performance requirements are specified in tables 23 and 24. The location target follows the trajectory defined in clause A.4.

In all cases the requirements are dependent on achieving a maximum 95th percentile horizontal and vertical (if applicable) positioning error of 100 m.

Table 23: Performance requirements for TTFF, Moving location target, Urban area.

Metric	TTFF [s]		
	Class A	**Class B**	**Class C**
Mean value	1,47	4,4	56,0
Standard deviation	0,16	1,4	7,9
67th percentile	1,46	4,6	59,0
95th percentile	1,78	7,2	68,3
99th percentile	2,30	8,5	87,6

Table 24: Performance requirements for TTFF, Moving location target, with interference (Medium level: -9 dB), Urban area

Metric	TTFF [s]		
	Class A	**Class B**	**Class C**
Mean value	3,8	21,0	59,6
Standard deviation	1,4	7,7	9,8
67th percentile	2,3	12,7	60,4
95th percentile	5,3	29,3	73,8
99th percentile	12,1	66,9	87,6

5.5.3.1.3 Operational environment: Asymmetric area

The performance requirements are specified in tables 25 and 26. The location target follows the trajectory defined in clause A.4.

In all cases the requirements are dependent on achieving a maximum 95th percentile horizontal and vertical (if applicable) positioning error of 100 m.

Table 25: Performance requirements for TTFF, Moving location target, Asymmetric area

Metric	TTFF [s]		
	Class A	Class B	Class C
Mean value	1,50	5,4	n/a (see note)
Standard deviation	0,54	2,1	n/a (see note)
67th percentile	1,43	5,3	n/a (see note)
95th percentile	1,95	9,7	n/a (see note)
99th percentile	4,78	15,1	n/a (see note)
NOTE: Class C receivers do not have a requirement to achieve a position fix in the asymmetric area scenario.			

Table 26: Performance requirements for TTFF, Moving location target with interference (Medium level: - 9 dB), Asymmetric area

Metric	TTFF [s]		
	Class A	Class B	Class C
Mean value	10,49	21,0	n/a (see note)
Standard deviation	6,59	7,7	n/a (see note)
67th percentile	13,42	12,7	n/a (see note)
95th percentile	21,50	29,3	n/a (see note)
99th percentile	27,25	66,9	n/a (see note)
NOTE: Class C receivers do not have a requirement to achieve a position fix in the asymmetric area scenario.			

5.5.3.2 Use case: Static Location Target

5.5.3.2.1 Operational environment: Open area

The performance requirements are specified in table 27. In all cases the requirements are dependent on achieving a maximum 95th percentile horizontal and vertical (if applicable) positioning error of 100 m.

Table 27: Performance requirements for TTFF, Static location target, Open area

Metric	TTFF[s]		
	Class A	Class B	Class C
Mean value	1,55	2,5	29,8
Standard deviation	0,12	0,4	4,9
67th percentile	1,56	2,7	30,2
95th percentile	1,62	3,3	36,9
99th percentile	2,21	3,8	38,8

5.5.3.2.2 Operational environment: Urban area

The performance requirements are specified in table 28. In all cases the requirements are dependent on achieving a maximum 95th percentile horizontal and vertical (if applicable) positioning error of 100 m.

Table 28: Performance requirements for TTFF, Static location target, Urban area

Metric (as per clause 4.2)	TTFF[s]		
	Class A	Class B	Class C
Mean value	1,44	3,51	56,0
Standard deviation	0,39	0,88	7,9
67th percentile	1,36	3,81	59,0
95th percentile	1,91	5,36	68,3
99th percentile	3,32	5,87	87,6

5.5.3.2.3 Operational environment: Asymmetric area

The performance requirements are specified in table 29. In all cases the requirements are dependent on achieving a maximum 95th percentile horizontal and vertical (if applicable) positioning error of 100 m.

Table 29: Performance requirements for TTFF, Static location target, Asymmetric area

Metric	TTFF[s]		
	Class A	Class B	Class C
Mean value	1,98	5,4	n/a (see note)
Standard deviation	1,73	2,1	n/a (see note)
67th percentile	1,37	5,3	n/a (see note)
95th percentile	7,35	9,7	n/a (see note)
99th percentile	9,14	15,1	n/a (see note)
NOTE: Class C receivers do not have a requirement to achieve a position fix in the asymmetric area scenario.			

5.6 Position Authenticity

5.6.1 Definition

Position Authenticity gives a level of assurance that the data for a location target has been derived from real signals relating to the location target.

GBLS authenticates the estimated positions by means of specific algorithms that detect, and possibly mitigate, the presence of structured RF interference (i.e. RF spoofing, see ETSI TS 103 246-1 [7]).

The position authenticity performance is defined by the ability of the GBLS to provide authentic positioning data (i.e.: positioning data computed through the processing of true GNSS signals) and to promptly detect spoofing attempts (i.e.: detection of false GNSS signals intentionally transmitted to deceive the GBLS).

5.6.2 Metrics

The Position Authenticity performance is defined in terms of:

- Probability of false alarm (P_{FA}): the probability that the GBLS falsely detects spoofed GNSS signals when there is no RF spoofing attack (clear scenario).
- Probability of detection (P_D): the probability that the GBLS detects spoofed GNSS signals during an RF spoofing attack; (interference scenario).

5.6.3 Performance requirements

5.6.3.1 Specific conditions and interference threat scenarios

The interference threat scenarios for position authenticity are defined in clause A.7.

These scenarios represent a typical spoofing attack against the GBLS. The scenarios can be easily replicated in a controlled environment and was used to derive the performance requirements given below.

The applicable operational environment is the Open Sky Plot (see clause A.3), either in clear or interference scenarios.

Two use cases are considered:

- Case 1: moving location target defined in clause A.5.
- Case 2: static location target.

Latency condition: the latency to provide authenticity shall not exceed 5 seconds.

5.6.3.2 Use case: Moving Location Target

5.6.3.2.1 Operational environment: Open area

The P_{FA} shall meet the levels specified in table 30:

Table 30: Performance requirements for P_{FA}, Moving location target, Open area

Maximum False Alarm probability (%)		
Class A	**Class B**	**Class C**
0,20	1,0	10

5.6.3.2.2 Operational environment: Interference (Spoofing) Scenario

The P_D shall meet the following requirements:

Table 31: Performance requirements for P_D, Moving location target, Spoofing scenario

Interference scenario (clause A.7)	Maximum Total Spoofing Power [dBW]	Maximum Error	Minimum P_D (%)		
			Class A	**Class B**	**Class C**
M-1	-143,5	$0,55 \cdot 10^{-6}$ s	85	75	68
	-142,5	$0,66 \cdot 10^{-6}$ s	92	85	80
	-141,5	$0,75 \cdot 10^{-6}$ s	98	95	90
M-2	-147,5	170 m	85	75	68
	-146,5	200 m	92	85	80
	-145,5	228 m	98	95	90
M-3	-147,5	57 m	85	75	68
	-146,5	70 m	92	85	80
	-145,5	78 m	98	95	90

5.6.3.3 Use case: Static Location Target

5.6.3.3.1 Operational environment: Open area

The P_{FA} shall meet the levels specified in table 32.

Table 32: Performance requirements for P_{FA} Requirement, Static location target, Open area

Maximum False Alarm probability (%)		
Class A	**Class B**	**Class C**
0,05	0,20	1,0

5.6.3.3.2 Operational environment: Interference (Spoofing) scenarios

The P_D shall meet the following requirements:

Table 33: Performance requirements for P_D, Static location target, Spoofing scenario

Interference scenario (clause A.7)	Maximum Total Spoofing Power (dBW)	Maximum Error	Minimum P_D (%)		
			Class A	Class B	Class C
S-1	-156,09	$0{,}48 \cdot 10^{-6}$ s	90	75	63
	-154,46	$0{,}58 \cdot 10^{-6}$ s	95	90	85
	-153,5	$0{,}68 \cdot 10^{-6}$ s	98	97	95
S-2	-156,09	145 m	90	75	63
	-154,46	175 m	95	90	85
	-153,5	205 m	98	97	95
S-3	-156,09	40 m	90	75	63
	-154,46	48 m	95	90	85
	-153,5	56 m	98	97	95

5.7 Robustness to Interference

5.7.1 Definition

GBLSs might be required to operate in RF environments subject to interference, in particular in the GNSS frequency bands.

Robustness to interference characterizes the ability of the receiver to operate under interference conditions and maintain an appropriate level of performance in terms of PVT degradation.

Robustness to Interference is the PVT degradation caused by interference sources and is defined in terms of:

- increase of the horizontal position error;
- decrease of availability of the position fix.

5.7.2 Metrics

The performance parameters which characterize the robustness to interference are the following:

- position fix accuracy (horizontal) with degradation under interference conditions;
- position fix availability as a function either of the jammer distance or the jamming-to-GNSS signal power ratio (J/S).

The robustness to interference is characterized by the maximum tolerable J/S, which is defined as that providing a position fix availability greater than 90 % with a maximum horizontal error of 100 m. The horizontal position error statistics provided are based on position fixes satisfying the condition of a maximum horizontal error of 100 m.

5.7.3 Performances requirements

5.7.3.1 Specific conditions and operational environment

The operational environment applicable to Robustness to Interference Performance Feature is the Open Area type, defined in clause A.3. The location target follows the trajectory defined in clause A.4. The jammers to be used are J#1 and J#2, defined in clause A.6.

5.7.3.2 Use case 1: 20 MHz FM deviation

The performance requirements are specified in tables 34 and 35.

Table 34: Performance requirements for Robustness to Interference with J#1

Metric	Performance requirement		
	Class A	Class B	Class C
maximum J/S (dB)	89,0	83,0	77,0
minimum Jammer distance (m)	28,0	45,1	64,5
Maximum Horizontal Position Error [m]			
Mean value	64,0	64,0	64,0
Standard deviation	15,7	15,7	15,7
67th percentile	61,7	61,7	61,7
95th percentile	96,2	96,2	96,2
99th percentile	99,6	99,7	99,6

Table 35: Performance requirements for Position fix accuracy (Horizontal) with degradation under interference conditions with J#1

J/S [dB]			Maximum Horizontal Position Error [m]				
Class A	Class B	Class C	Mean value	67th percentile	95th percentile	99th percentile	Standard deviation
< 85	< 78	< 72	46,7	47,6	50,1	51,4	1,9
85	79	73	52,6	54,6	59,1	60,0	3,6
86	80	74	52,5	52,1	63,5	66,8	4,5
87	81	75	55,2	55,9	61,9	66,5	3,1
88	82	76	52,7	54,4	74,2	76,5	8,4
89	83	77	64,1	61,8	96,2	99,7	15,7

- J/S (dB) figures characterize the interference power applied to the GBLS and are expressed in term of Jamming to Signal Ratio. The applicable J/S values are sorted by Class of GBLS (A, B, C) and increasing from the top to the bottom of the table.
- Maximum Horizontal Position Error (m) values characterize the GBLS maximum Horizontal accuracy error that can be tolerated when applying the corresponding J/S to the GBLS. As set in clause 5.7.2, the maximum tolerable error is 100 m whatever is the applied J/S.
- The performance Class of a GBLS is then determined by the interference power it tolerates for a given Horizontal accuracy error and not directly by the error resulting from the interference power. A Class A GBLS being more resistant to interference than a GBLS Class B or C, it tolerates higher J/S than those tolerated by Class B and C.

5.7.3.3 Use case 2: 10 MHz FM deviation

The performance requirements are specified in tables 36 and 37.

Table 36: Performance requirements for Robustness to Interference with J#2

Metric	Performance requirement		
	Class A	Class B	Class C
maximum J/S (dB)	70	64	58
minimum Jammer distance (m)	68	87	105
Maximum Horizontal Position Error [m]			
Mean value	52,6	52,6	52,6
Standard deviation	12,8	12,8	12,8
67th percentile	49,9	49,9	49,9
95th percentile	87,6	87,6	87,6
99th percentile	94,2	94,2	94,2

Table 37: Performance requirements for Position fix accuracy (Horizontal) with degradation under interference conditions with J#2

J/S [dB]			Maximum Horizontal Position Error [m]				
Class A	Class B	Class C	Mean value	67th percentile	95th percentile	99th percentile	Standard deviation
< 67	< 61	< 55	44,2	44,3	46,5	46,7	1,1
67	61	55	48,6	45,1	65,3	69,6	6,4
68	62	56	49,2	49,0	65,9	78,6	6,4
69	63	57	50,1	50,3	79,7	93,8	11,3
70	64	58	52,6	49,9	87,6	94,2	12,8

- J/S (dB) figures characterize the interference power applied to the GBLS and are expressed in term of Jamming to Signal Ratio. The applicable J/S values are sorted by Class of GBLS (A, B, C) and increasing from the top to the bottom of the table.
- Maximum Horizontal Position Error (m) values characterize the GBLS maximum Horizontal accuracy error that can be tolerated when applying the corresponding J/S to the GBLS. As set in clause 5.7.2, the maximum tolerable error is 100 m whatever is the applied J/S.
- The performance Class of a GBLS is then determined by the interference power it tolerates for a given Horizontal accuracy error and not directly by the error resulting from the interference power. A Class A GBLS being more resistant to interference than a GBLS Class B or C, it tolerates higher J/S than those tolerated by Class B and C.

5.8 GNSS Sensitivity

5.8.1 Definition

GNSS Sensitivity is defined in terms of the maximum masking (attenuation) values tolerated by the GBLS while still allowing the provision of the required location-related data. It is respectively specified for Tracking and Acquisition.

GNSS sensitivity is typically applicable for GBLSs operating in urban or indoor environments, when GNSS signals can be significantly attenuated.

5.8.2 Metrics

The Tracking Sensitivity is defined as the maximum attenuation (dB) which allows the receiver to provide a position fix.

The Acquisition Sensitivity is defined as the maximum attenuation (dB) which allows the receiver to have a first position fix within a given time.

5.8.3 Performance requirements

5.8.3.1 Operational scenario and specific masking conditions

The Location target follows the trajectory defined in clause A.4.

Two different environment types are used: Open area and Asymmetric area with specific masking conditions. The Sky Attenuation Conditions described in clause A.3.2 are used with attenuation values to compute the position fix delivered by the location-related data:

- Open sky masking condition: x_1 variable, x_2 set to 100 dB (table 39)
- Asymmetric visibility masking condition: x_1 set to 0 dB, x_2 set to 100 dB, x_3 variable (table 40)

GNSS Time assistance is provided for both environments. GNSS Time assistance is provided through assistance data and gives an estimation of the GNSS Time and other information to fasten the computation of a position fix. Two types of assistance are usually defined, fine time assistance and coarse time assistance (detailed in table 21).

Table 38 summarizes the applicable operational conditions for the Performance Feature GNSS Sensitivity:

Table 38: Specific conditions applicable to GNSS Sensitivity

Use case	Operational environment type	Location target Scenario	Masking parameters x1, x2 and x3 from clause A.3.2	Assistance data
Use case 1	Open area (clause A.3)	Moving Scenario (clause A.4)	Variable, see table 39	Fine-time assistance
Use case 2	Asymmetric area (clause A.3)	Moving Scenario (clause A.4)	Variable, see table 40	Coarse-time assistance

5.8.3.2 Use case 1: Open area and fine time assistance

The performance requirements are specified in tables 39 and 40. For all tables performance requirements are met if the receiver is able to provide a position fix with a horizontal position error and probability as defined above in clause 5.8.2.

Table 39: Performance requirements for GNSS Sensitivity, Open area and fine time assistance

Operational condition: Signal Power Attenuation [dB] (x1 and x2 defined in clause A.3.2)			Tracking/ Acquisition Sensitivity	Metrics	Performance requirements		
Class A	Class B	Class C			Class A	Class B	Class C
x1 = 33 x2 = 100	x1 = 28 x2 = 100	x1 = 18 x2 = 100	Tracking sensitivity	Horizontal position error with a probability greater than 90 %	< 100 m	< 100 m	< 100 m
x1 = 32 x2 = 100	x1 = 20 x2 = 100	x1 = 16 x2 = 100	Acquisition sensitivity	Horizontal position error with a probability greater than 90 %	< 100 m	< 100 m	< 100 m
				Time of the first position fix	< 300 s	< 300 s	< 300 s

5.8.3.3 Use case 2: Asymmetric area and coarse time assistance

The performance requirements are specified in table 40.

Table 40: Performance requirements for GNSS Sensitivity, Asymmetric area and coarse time assistance

Operational condition: Signal Power Attenuation [dB] (x1,x2 and x3 defined in clause A.3.2)			Tracking/ Acquisition Sensitivity	Metrics	Performance requirements		
Class A	Class B	Class C			Class A	Class B	Class C
x1 = 0 x2 = 100 x3 = 33	x1 = 0 x2 = 100 x3 = 28	x1 = 0 x2 = 100 x3 = 18	Tracking sensitivity	Horizontal position error with a probability greater than 90 %	< 100 m	< 100 m	< 100 m
x1 = 0 x2 = 100 x3 = 32	x1 = 0 x2 = 100 x3 = 20	x1 = 0 x2 = 100 x3 = 16	Acquisition sensitivity	Horizontal position error with a probability greater than 90 %	< 100 m	< 100 m	< 100 m
				Time of the first position fix	< 300 s	< 300 s	< 300 s

5.9 Position Integrity (Protection Level)

5.9.1 Definition

Position Integrity is the ability of the GBLS to measure the trust that can be placed in the accuracy of the location target position. It is relevant to Safety- and Liability-Critical applications (e.g. critical navigation, billing) where undetected large position errors can generate legal or economic consequences.

It is expressed through the computation of a protection level associated to a predetermined integrity risk (as a function of the type of end-user application) see [i.19]. Concerning in particular Liability-Critical applications, the ultimate purpose of an integrity solution is to provide the user with a horizontal protection level (HPL) which:

- guarantees horizontal position error (HPE) bounding up to the required integrity risk (e.g. 10^{-5} per independent sample);

- maximizes availability, e.g. the percentage of time that protection levels exist and remain below a pre-determined value (the alert limit).

In terms of integrity algorithms, they can be based on Receiver Autonomous Integrity Monitoring (RAIM), on ground monitoring approach with a GNSS integrity channel (GIC, e.g. EGNOS) or a combination of them. The operational context of users for Liability-Critical applications is assumed to be suitable for Multiple Failure & Multiple Constellation RAIM integrity algorithms with or without using GIC.

The integrity performance is defined by:

- The Position Integrity, expressed in terms of Protection Level expressed in metres at 95 percentile.
- The Integrity Risk, expressed as the probability that the position accuracy exceeds the position protection level.

NOTE: The integrity algorithms considered to define GBLS classes are based on usage of RAIM plus INS plus potential GIC for GPS, Galileo™ and GLONASS constellations. A number of algorithms have been assessed: see [i.9] to [i.18].

5.9.2 Operational conditions

The Operational environments defined in clause A.3 are applicable. For the Urban Area attenuation conditions, additional environmental features including Integrity Threats as defined in clause A.8 are applicable.

The location target follows the trajectory defined in clause A.4. The integrity risk is set to 10^{-5} per independent sample of time.

5.9.3 Use case: Moving Location Target

The performance requirements are specified in table 41.

Table 41: Performance requirements for Position integrity: Protection levels

Environment	Horizontal Protection Level (in metres at 95 percentile)		
	Class A	Class B	Class C
Open Area	1	10	18
Urban Area	10	30	110

NOTE: The integrity risk to be taken into account is defined above in clause 5.9.2.

Annex A (Normative): Applicable Conditions and Scenarios

A.1 General

This clause defines the conditions applicable to the definition of the performance requirements given in clause 5. These conditions concern:

- the external systems with which the GBLS interacts;
- the operational environments;
- the moving location target scenario;
- the interference scenarios.

A.2 External Location Systems Parameters

A.2.1 GNSS system parameters

GNSS systems applicable to the performance specifications are shown below including:

- the constellation geometry to be used;
- signal parameters to be used, in particular the signal modulation parameters, and the minimum received power on ground in nominal conditions.

Table A.1: GNSS Constellations parameters

GNSS system	System/User interface description	HDOP range
GALILEO OS	[1]	1,6 to 2,5
GPS L1C/A	[2]	1,6 to 2,5
GPS L5 (see note)	[3]	1,6 to 2,5
GPS L1C (see note)	[4]	1,6 to 2,5
GLONASS	[5]	1,6 to 2,5
Beidou	[6]	1,6 to 2,5
NOTE: Single frequency use only is considered at present.		

A.2.2 Wireless systems parameters

The GBLS may employ other telecommunications networks for positioning with the following interfaces:

- Wi-Fi: IEEE 802.11™ [i.2].
- Wireless Personal Area Network (short range wireless): IEEE 802.15™ [i.3].
  - Bluetooth: IEEE 802.15.1™ [i.4].
  - WPAN: IEEE 802.15.4a™ [i.5].
- Cellular:
  - GSM: ETSI TS 145 001 (3GPP TS 45.001) [i.6].
  - UTRA: ETSI TS 125 104 (3GPP TS 25.104) [i.7].
  - E-UTRA: ETSI TS 136 171 (3GPP TS 36.171) [i.8].

A.3 Operational Environments

A.3.1 Operational Environments definition

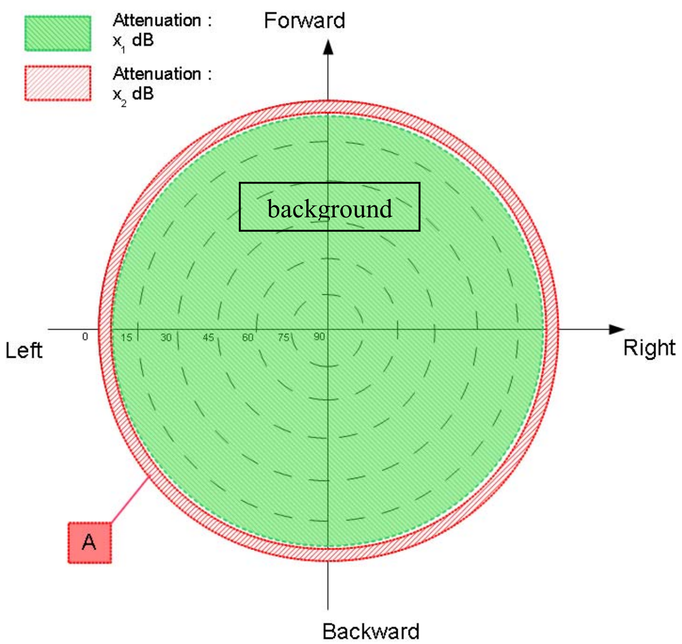
Each Operational Environment defined in table A.2 includes the associated conditions indicated, which are further defined in the clauses below.

Table A.2: Operational Environments and Associated Conditions

Operational environment type (see note 2)	Associated Conditions					
	Sky attenuation conditions (clause A.3.2)	Track trajectory (see note 4) (clause A.4)	Multipath Level (clause A.3.3)	Interference Level (dBW/Hz) (see note 3)	Magnetic conditions (see note 1) (clause A.3.4)	Telecommunica-tions beacon distribution (see note 1) (clause A.3.5)
Open Area	Open sky	Outdoor	None	None	Nominal	Sparse outdoor
Urban Area	Urban Canyon	Outdoor	Yes	-195	Degraded	Dense outdoor
Asymmetric Area	Asymmetric visibility	Indoor	Yes	-195	Degraded	Dense indoor
NOTE 1: These conditions apply if the GBLS system implements the related sensor. NOTE 2: For all these environments, the antenna gain is assumed to be 0 dBi. NOTE 3: Interference is defined as the external noise power density at the antenna. NOTE 4: When the moving location target with the track trajectory scenario is used.						

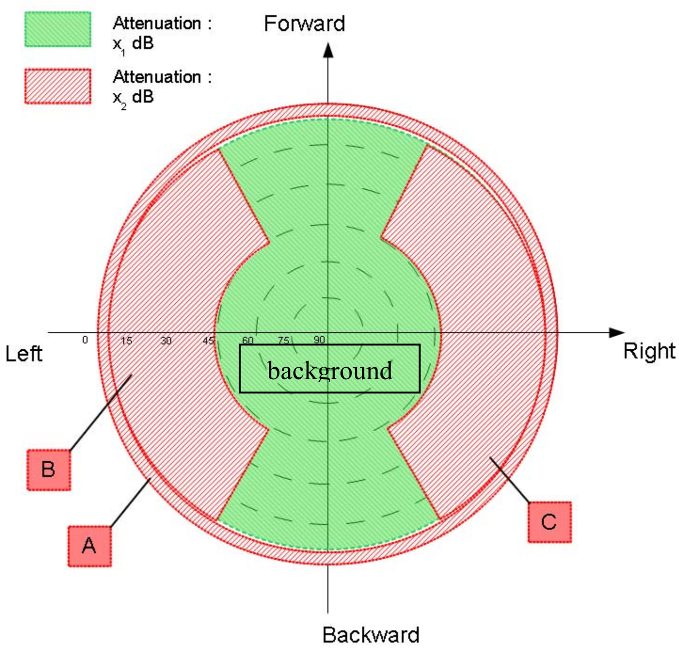
A.3.2 Sky Attenuation Conditions

The sky plots below define the solid angles (defined by elevation and azimuth angles) associated with a given attenuation in the hemisphere of the sky above the GNSS receiver.



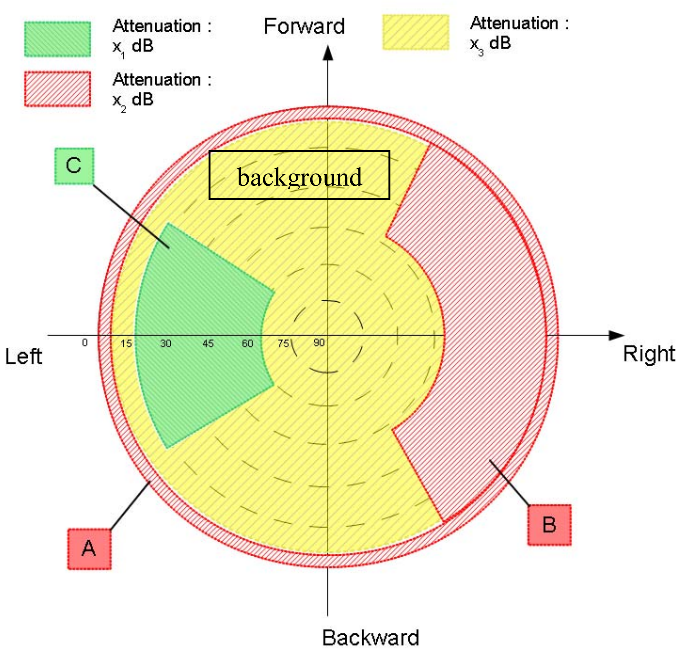
Zone	Elevation range (deg)	Azimuth range (deg)	Attenuation (dB)
A	0 to 5	0 to 360	x_2 = 100
Back-ground	Angles out of Zone A		x_1 = 0

Figure A.1: Open Sky plot



Zone	Elevation range (deg)	Azimuth range (deg)	Attenu-ation (dB)
A	0 to 5	0 to 360	$x_2 = 100$
B	5 to 60	210 to 330	$x_2 = 100$
C	5 to 60	30 to 150	$x_2 = 100$
Back-ground	Angles out of Zones A, B, C		$x_1 = 0$

Figure A.2: Urban canyon plot.



Zone	Elevation range (deg)	Azimuth range (deg)	Attenu-ation (dB)
A	0 to 5	0 to 360	$x_2 = 100$
B	5 to 60	30 to 150	$x_2 = 100$
C	10 to 60	230 to 310	$x_1 = 0$
Back-ground	Angles out of Zones A, B, C		$X_3 = 15$

Figure A.3: Asymmetric visibility plot

A.3.3 Multipath Level

Multipath is applied to signals of satellites whose Line of Sight has an elevation lower than 30 degrees. A single tap reflection model is used. Characteristics of the reflected signal (or multi-path) with respect to the direct signal are given below.

The Carrier and Code Doppler frequencies of direct and multi-path for GNSS signal are defined in table A.3.

Table A.3: Multi-path model components

Initial relative Delay [m]	Carrier Doppler frequency of tap [Hz]	Code Doppler frequency of tap [Hz]	Relative mean Power [dB]
0	Fd	Fd / N	0
X	Fd - 0,1	(Fd - 0,1) /N	Y

NOTE 1: Discrete Doppler frequency is used for each tap.

NOTE 2: The above model and values are based on those of ETSI TS 125 104 [i.7].

X, Y and N depend on the GNSS signal type. In addition, Y depends on the intensity of multi-path faced in the operational environments. N is the ratio between the transmitted carrier frequency of the signals and the transmitted chip rate.

The initial carrier phase difference between taps shall be randomly selected between 0 and 2π. The initial value shall have uniform random distribution.

Table A.4 defines the parameters values.

Table A.4: Multi-path model parameters

System	Signals	X [m]	Y [dB]
Galileo™	E1	125	-4,5
	E5a	15	-6
	E5b	15	-6
GPS/Modernized GPS	L1 C/A	150	-6
	L1C	125	-4,5
	L2C	150	-6
	L5	15	-6
GLONASS	G1	275	-12,5
	G2	275	-12,5

Table A.5: Ratio between Carrier Frequency and Chip Rate

System	Signals	N
Galileo	E1	1 540
	E5a	115
	E5b	118
GPS/Modernized GPS	L1 C/A	1 540
	L1C	1 540
	L2C	1 200
	L5	115
GLONASS	G1	3 135,03 + k · 1,10
	G2	2 438,36 + k · 0,86
NOTE: Parameter "k" above is the GLONASS frequency channel number.		

A.3.4 Magnetic Conditions

A.3.4.1 Output model

The heading output model of the sensor accounts for common magnetometers compass errors, and is given below.

$$Heading^{out} = (1 + SF) \times Heading^{true} + I_{mag} + b_{mag} + n_{mag}$$

Where:

- SF the scale factor;
- I_{mag} the EMI and magnetic materials interference term;
- b_{mag} the sensor offset; and
- n_{mag} a zero mean Gaussian noise term.

The bias is modelled by a Gauss Markov process:

$$b_{mag}(t+1) = b_{mag}(t) \times (1 - 1/T_{mag}) + w_{mag}$$

Where:

- T_{mag} being the bias correlation time; and
- w_{mag} the zero mean Gaussian bias noise term.

A.3.4.2 Perturbation level

Two perturbation levels are applied: nominal and degraded. Table A.6 shows the output model parameters values:

Table A.6: Magnetometers output model parameters

Parameters	Perturbation level	
	nominal	degraded
I_{mag}	0,1°	2°
n_{mag} (standard deviation)	0,05°	0,1°
SF	0,005	0,01
b_{mag} (offset)	0,1°	0,3°
T_{mag}	3 000 s	3 000 s
W_{mag} (standard deviation)	0,001°	0,001°

A.3.5 Telecommunications Beacons

Table A.7 defines the beacon density and type of telecommunications systems considered in the scenarios of table A.2.

Table A.7: Telecommunications beacon scenarios components

Type of telecommunications system	Sparse outdoor scenario	Dense outdoor scenario	Dense indoor scenario
Cellular	Yes (sparse distribution)	Yes (dense distribution)	Yes (dense distribution)
Wi-Fi	No	Yes	Yes
Bluetooth	No	No	Yes

The beacon distribution characteristics are provided for each type of beacon in the following clauses.

NOTE: Skyplots defined for GNSS environments are not accounted for in Telecommunications beacon scenarios: attenuations considered are not applied to the beacon signals; the concept of elevation angle is ignored (all beacons are assumed to be seen at low elevation angles by the user), and signal attenuation (contribution to the Telecommunications range error) will be mainly driven by the distance from user to beacon and the associated RF losses.

Table A.8 provides the characteristics of the sparse and dense distributions applicable for the different telecommunications system type.

Table A.8: Telecommunications beacon distributions characteristics

Telecommunications Type	Distribution type	Density Number of beacon per km²
Cellular	sparse	9,37E-3
Cellular	dense	0,53
Wi-Fi	dense	2 660
Bluetooth	dense	2 660

A.4 Moving Location Target Scenario - Track trajectory

The definition below defines the reference trajectory for a Track moving scenario for the location target.

Figure A.4 defines the reference trajectory, and is in the horizontal plane with the reference point at the origin (0,0,0). The reference point may be anywhere on the Earth's surface. The track is traversed in clock-wise direction.

Two sets of parameters are defined, one for indoor and one for outdoor scenarios.

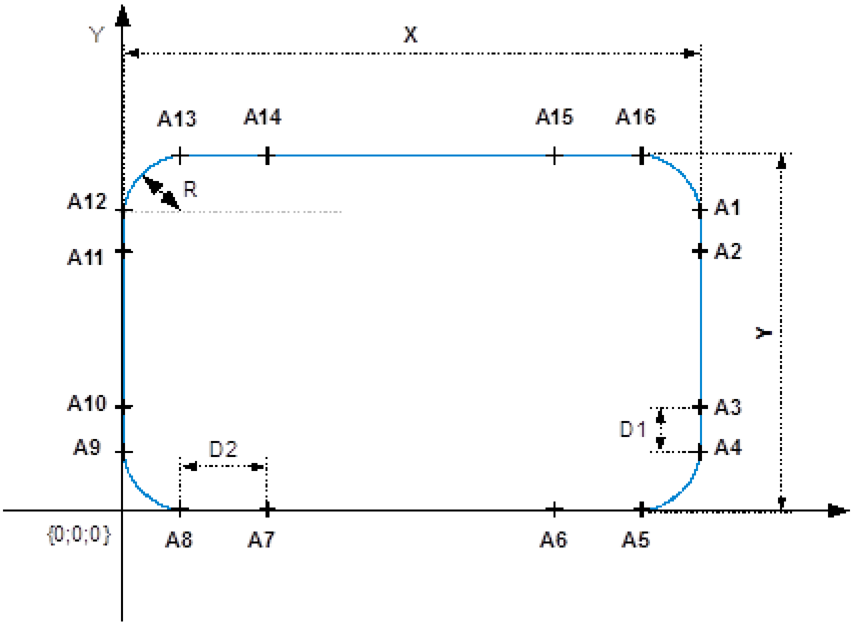


Figure A.4: Location target trajectory

Table A.9: Trajectory parameters

Parameter	Value (m) - outdoor	Value (m) - indoor
X	1 440	45,6
Y	940	37,6
R	20	1
NOTE: The above outdoor values are based on those of ETSI TS 125 104 [i.7].		

Figure A.5 provides the location target speed profile, when travelling along the trajectory above.

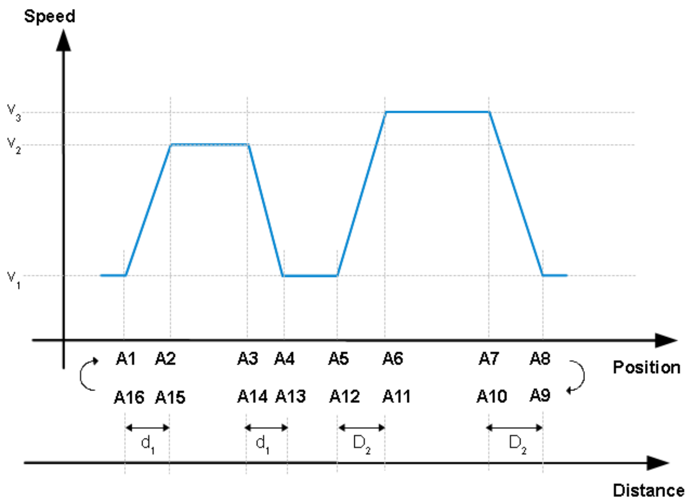


Figure A.5:Location target speed profile

The trajectory parameters for each Performance Feature are:

Table A.10: Location target trajectory parameters

Trajectory parameter	Value for outdoor trajectory	Value for indoor trajectory
v_1	25 km/h	1 km/h
v_2	100 km/h	4 km/h
v_3	100 km/h	4 km/h
d_1	250 m	10 m
D_2	250 m	10 m

A.5 Moving Location Target Scenario - Straight line trajectory

The definition below defines the reference trajectory for a Straight line moving scenario for the location target.

The trajectory is in the horizontal plane with the starting point anywhere on the Earth's surface. The location target moves on a straight trajectory at a uniform speed of 50 km/h.

A.6 Interference source definition

Table A.11 specifies the jamming signals used as interference sources scenarios in clause 5.7. The definition of the jammer is based on the interference models of some PPDs (Personal Privacy Devices) as described in literature.

Table A.11: Interference source definition

Class	Centre Frequency (MHz)	-3 dB Bandwidth (MHz)	Sweep time (µs)	Peak (dBm)
J#1: Chirp signal with one saw-tooth function	1 575,42	20	20	-9,6
J#2: Chirp signal with one saw-tooth function	1 575,42	10	20	-9,6

The jammer power accounts for the free space propagation losses defined in figure A.6 and the initial jammer power from table A.11. The relative Doppler is negligible compared to the frequency range of the jammer.

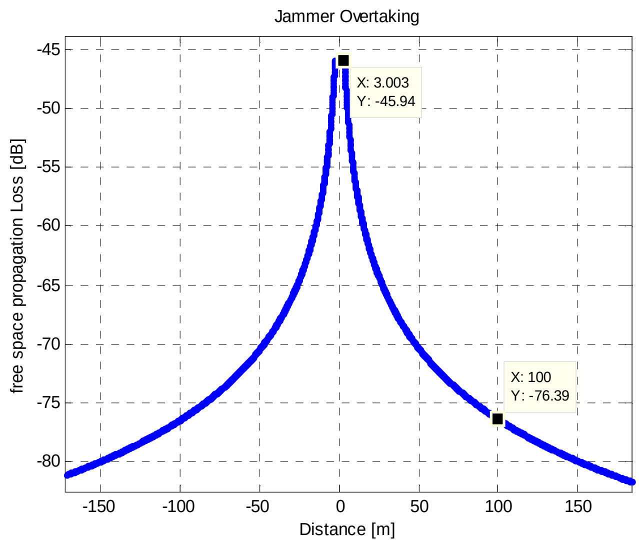


Figure A.6: Free space propagation loss with respect to the jammer distance

A.7 Authenticity Threat Scenarios

A.7.1 Scenarios description

Clause A.7 defines the threat scenarios for the definition of the Authenticity performance requirements.

All the threat scenarios define spoofing attempts to the GNSS sensor of the GBLS. Such spoofing attempts broadcast intentional RF interference, with a structure similar to authentic GNSS signals, in order to deceive the GNSS sensor into erroneously estimating pseudo-ranges and computing false PVT solutions.

The threat scenarios are defined below. The following pre-conditions apply to these scenarios:

- location-related data of the location target are available;
- all tracked GNSS signals are authentic.

A.7.2 Moving Location Targets

The error is modelled as a ramp function with slope equal to *b*. Such a ramp function starts at the same instant of the threat.

Table A.12: Threat scenario for moving location targets

Scenario identifier	Number of spoofed PRNs	Total Spoofing Power range (dBW)	Misleading information category	error slope b value range
M-1	All (see note 1)	-144,5 to -140,5	Estimated Time	2 to 20 ns/s (see note 2)
M-2	4	-148,5 to -144,5	Pseudorange measurement	3,5 to 6,5 m/s
M-3	4	-148,5 to -144,5	Estimated Position	1 to 7,5 m/s (see note 2)
NOTE 1: The number of spoofed PRNs is equal to the number of the satellites in view. NOTE 2: The model value ranges for the estimated time and position assume HDOP compliance with table A.1.				

A.7.3 Static Location Targets

The error is modelled as a ramp function with slope equal to *b*. Such a ramp function starts at the same instant of the threat.

Table A.13: Threat scenario for static location target

Scenario identifier	Number of spoofed PRNs	Total Spoofing Power range (dBW)	Misleading information category	error model b value range
S-1	All (see note 1)	-158,5 to -153,5	Estimated Time	2 to 20 ns/s (see note 2)
S-2	1	-158,5 to -153,5	Pseudorange measurement	3,5 to 6,5 m/s
S-3	1	-158,5 to -153,5	Estimated Position	1 to 7,5 m/s (see note 2)
NOTE 1: The number of spoofed PRNs is equal to the number of the satellites in view.				
NOTE 2: The model value ranges for the estimated time and position assume HDOP compliance with table A.1.				

A.7.4 Scenario parameters

A.7.4.1 Attack classification

Shadowed spoofing is defined for the GBLS. In this method, the counterfeit GNSS signals are generated and radiated towards the GNSS sensor in a way that the correlation peak associated to the counterfeit signal rises in the shadow of the correlation peak of real signal. Varying the relative delay between the authentic and counterfeit spreading codes and increasing the power of the counterfeit GNSS signals, the GNSS sensor is forced to lose the tracking of the authentic spreading code and synchronizes its local code with the counterfeit spreading code. Therefore, it means that GNSS constellation geometry, current GNSS time, and GNSS sensor position are known by the spoofing source in order to estimate the authentic code delay and Doppler frequency at the location target GNSS sensor. The counterfeit signal is a false copy of that actually in view at the moment of the attack.

Figure A.7 illustrates this concept on the correlation domain, where the correlation peaks associated to authentic signals are green, correlation peaks due to counterfeit signals are in purple and the composite correlation peaks are in blue.

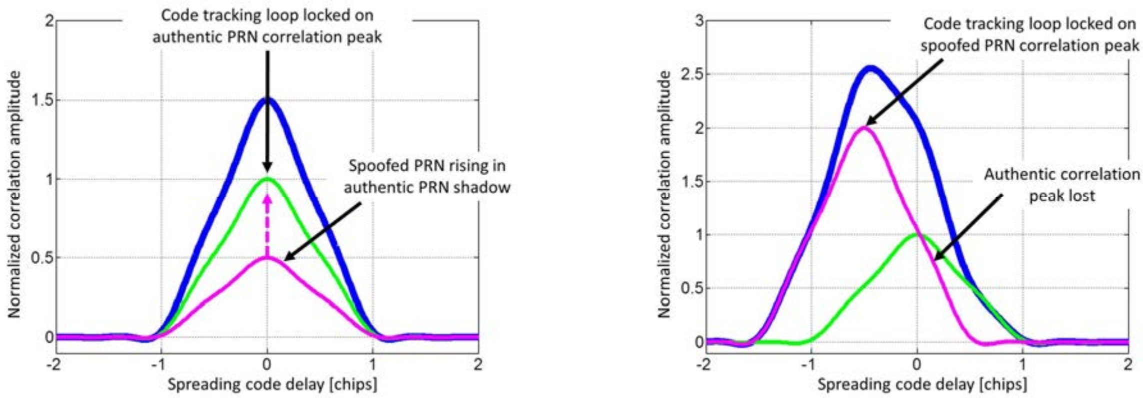


Figure A.7: Effects of shadowed spoofing on correlation functions

A.7.4.2 Total spoofing power

The total spoofing power (TSP) is the signal power of the sum of counterfeit GNSS signals received at the GNSS sensor antenna, which is assumed isotropic so that all signals are weighted equally.

It is defined as:

$$TSP = \sum_{i=1}^{N_{spoof}} P_i^s \quad \text{[dBW]}$$

where P_i^s is the power of the i^th^ counterfeit signal generated by the spoofing device.

The TSP is variable for each scenario, and used to define the authenticity performance.

A.7.4.3 Misleading information categories

The spoofing attacks can cause the following types of misleading information at GNSS sensor:

- erroneous pseudorange measurement;
- erroneous time estimates;
- erroneous estimates of the position (for both static of moving scenario).

For each type of misleading information, the error is modelled as a ramp function with slope equal to *b*. Such a ramp function starts at the same instant of the threat. Table A.14 defines the units of the error and slope with respect to the type of misleading information.

Table A.14: Misleading information model parameters

Misleading information	Error unit	Slope b unit
pseudorange measurement	m	m/s
time estimates	s	s/s
position estimates (see note)	m	m/s
NOTE: The position error is measured on the across-track axis.		

The slope of the error model is variable for each scenario, and is used to define the GBLS authenticity performance.

A.8 Integrity Threat Scenarios

A.8.1 Integrity Threat definition

An Integrity Threat is the occurrence of a condition able to compromise the system integrity. Integrity is compromised under low observability conditions. Such conditions occur when the measurements errors are combined in such a way as to produce an appreciable error in the position and at the same time leave a small residual.

The integrity threat scenarios are defined as:

- Non-LoS (Line of Sight) tracking;
- Pseudo-range Ramp errors.

These threat scenarios are defined further below.

A.8.2 Non-LoS tracking

Non-LoS tracking events are modelled with an empirical statistical model that describes the Non-LoS effect on pseudo-ranges and Doppler errors when the GBLS is located in an urban environment. The effect and the duration of Non-LoS tracking are determined by:

- the selection of the satellites affected by Non-LoS (depending on the masking area of the urban environment and the conditional probability of the satellite being affected by Non-LoS conditions, given that the satellite is occulted);
- the duration of the Non-LoS condition (modelled as an exponential distribution);
- pseudo-range error and Doppler errors modelled as due to single reflections.

A.8.3 Pseudo-range Ramp errors

The threat is modelled through the generation of pseudo-range ramp errors per satellite with:

- 1 hour duration; and
- resulting in a horizontal position error growing by 5 m every 60 seconds.

This ramp error is generated every 4 hours for 1 hour (3 hours simulation nominal, and 1 hour simulating this threat conditions). The pseudo-range ramp error is generated by projecting a horizontal vector growing linearly from 0 to 300 meters over 1 hour into the Line of Sight of the affected satellites, which may be just a subset of those being tracked. The resulting error is on top of the other errors due to the nominal conditions of the urban environment except for Non-LoS.

Annex B (informative): Bibliography

- ETSI TS 103 246-4: "Satellite Earth Stations and Systems (SES); GNSS based location systems Part 4: Requirements for location data exchange protocols".
- ETSI TS 103 246-5: "Satellite Earth Stations and Systems (SES); GNSS based location systems Part 5: Performance Test specification".
- ETSI TS 125 171: "Universal Mobile Telecommunications System (UMTS); Requirements for support of Assisted Global Positioning System (A-GPS); Frequency Division Duplex (FDD) (3GPP TS 25.171)".

History

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