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GNSS Location System Performance Requirements

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Foreword

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

# Scope

The present document addresses integrated location systems that combine Global Navigation Satellite System (GNSS), with other navigation technologies in order to deliver location-based services to users.

The requirements herein are intended to address the growing use of complex location systems needed for the expansion of location-based applications in the mass-market.

The Location System architecture is defined in [7]

This Technical Specification defines the performance requirements applicable to these systems.

# 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.

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

## Normative references

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

1. Galileo OS Signal in Space ICD (OS SIS ICD), Draft 0, Galileo Joint Undertaking, May 23rd, 2006.
2. IS-GPS-200, Revision D, Navstar GPS Space Segment/Navigation User Interfaces, March 7th, 2006.
3. IS-GPS-705, Navstar GPS Space Segment/User Segment L5 Interfaces, September 22, 2005.
4. IS-GPS-800, Navstar GPS Space Segment/User Segment L1C Interfaces, September 4, 2008.
5. IS-QZSS, Quasi Zenith Satellite System Navigation Service Interface Specifications for QZSS, Ver.1.1, July 31, 2009.
6. Global Navigation Satellite System GLONASS Interface Control Document, Version 5.1, 2008.
7. ETSI TS 103 247 "Satellite Earth Stations and Systems (SES); Global Navigation Satellite System (GNSS) based location systems; Reference Architecture”

## Informative references

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.

1. ETSI TR 103 183 (V1.1.1): "Satellite Earth Stations and Systems (SES); Global Navigation Satellite Systems (GNSS) based applications and standardisation needs".
2. RTCA DO-229D (2006-12): "Minimum Operational Performance Standards for Global Positioning System/Wide Area Augmentation System Airborne Equipment".
3. OMA-TS-ULP-V2-0-20100816-C (2010-08): "User Plane Location Protocol".
4. ETSI TS 122 071 (V9.0.0): "Digital cellular telecommunications system (Phase 2+); Universal Mobile Telecommunications System (UMTS); LTE; Location Services (LCS); Service description; Stage 1 (3GPP TS 22.071 version 9.0.0 Release 9)".
5. ETSI TR 101 593 (V1.1.1): "Satellite Earth Stations and Systems (SES); Global Navigation Satellite Systems (GNSS) based location systems; Minimum performance and features ".

# Definitions, symbols and abbreviations

## Definitions

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

**Accuracy**: The term *accuracy* relates to the *location-related information* reported by the *location system*, i.e. the *mobile target* position, velocity, acceleration and GNSS system time estimate. The *accuracy* is thus characterized by the difference between the quantity estimated by the *location system*, and its actual value. It is expressed in m (position), m.s-1 (speed), m.s-2 (acceleration) or seconds (time), and usually characterized through statistical values (mean, standard deviation, root mean square, percentile, etc.). When not further specified in the present technical context, the term *accuracy* usually refers to the position accuracy. By extenstion, accuracy is one of the key performance features which can be required from a location system.

**Application module:** entity in charge of retrieving from a *Location system* the *Location-related information* associated to one or more *mobile targets*, and processing it in order to deliver to the application user(s) the *location based service* it has been designed for.

NOTE: The application module can be collocated with the *positioning module* inside a terminal*.*

**Authentication**: *Authentication* is the provision of assurance that the location-related information associated to a mobile target is trustworthy. By extenstion, authentication is one of the key performance features which can be required to a location system

**Availability**: *Availability* measures percentage of time when a *location system* is able to provide the required *location-related information*. Note that the required *location-related information* might vary from one *location based application* to the other: it can not only contain a required type of information (position, speed, …), but also a required *quality of service* (accuracy, protection level, authentication, etc. ).

**Coverage**: The *coverage* of the *location system* is the surface area or space volume in which the signals are adequate to determine the *mobile targets* *location-related information* to a specified level of accuracy. Coverage is influenced by receiver sensitivity and environmental conditions affecting the signal availability.

**Electromagnetic Interference**: Any source of RF transmission that is within the frequency band used by a communication link, which degrades the performance of this link. *Jamming* is a particular case of electromagnetic interference, where interfering radio signal is deliberately broadcast to disrupt the communication.

**Horizontal plane**: plane locally defined for the mobile target, orthogonal to the zenith/nadir axis.

**Integrity**: *Integrity* is an optional function of a *location system* that aims at measuring the trust that can be placed in the accuracy of the *location-related information* provided by the *location system*. In the present technical context, it is expressed through a pair *protection level* / *integrity risk*. By extenstion, integrity is one of the key performance features which can be required from a location system

**Integrity** **risk**: The *integrity risk* is the probability that the *actual error* of the *location-related information* is larger than the *protection level*. The *integrity risk* is, with the p*rotection level*, one of the 2 sub-features of *integrity* feature.

**Jamming**: Deliberate transmission of radio signals in order to disrupt communications by decreasing the signal to noise ratio. In the present technical context, targeted communication signals are GNSS or telecommunication signals.

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

**Location**: a place where something is or could be located. In the present technical context, the place where the mobile target is.

NOTE: the term *position* can have several meaning. In the present technical context, the only relevant meaning is considered to be equivalent to *location* (and therefore excludes interpretation such as “body posture”, “state of mind or principle”, “job or activity”). The term *location* will arbitrarily be preferred, except when referring to the action of “determining a location”, for which the term *positioning* will be used.

**Location based application:** application which 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 information* associated to one or several *mobile targets*

**Location-related information:** set of data associated to a given *mobile target*, containing one or several of the following information, all time-tagged: mobile target position, mobile target motion indicators (linear or angular speed and acceleration), and Quality of service indicators (estimates of the position accuracy, reliability or authenticity indicators).

NOTE: It is the main output of a *Location system*.

**Location system:** system in charge of providing to a *location based application* the *Location-related information* of one or several mobile targets.

**Location system central facility:** centralized logical entity, inside a *Location system*, that manages the provision of the *location-related information* to the *application module*, which is the location system external client.

**Mobile target:** physical entity whose position the *location system* builds the *location-related information* on, and with which the *positioning terminal* is attached

**Positioning terminal:** logical entity, inside a *Location system*, in charge of providing the relevant measurements to the *location system central facility* (enabling it to determine the *mobile target location-related information*) or directly providing the *mobile target location-related information* to the *“Application module”*. It is composed of a GNSS receiver and possibly additional sensors.

NOTE: It executes the measurements needed to determine its position, and implements part of the location determination functions. It embeds the group of sensors needed to execute these tasks. This group can include navigation sensors (GNSS, Inertial, Odometers, etc.), wireless network modems (terrestrial or satellite). It might be collocated with the *mobile target* or not.

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

**Protection** **level** : The *protection level* PL is an estimated error value which comply with the following condition: *P(*> PL*)* < Irisk , where Irisk is the *Integrity risk* and  the *actual error*. The *protection level* is provided by the location system, and is, with the integrity risk, one of the 2 sub-features of *integrity* feature. The protection level can be measured by a statistical metric similar the the one used for the size of the error (Accuracy).

**Quality of service**: the *quality of service* associated to a location based service is a set of indicators which can accompany the *mobile target*(s) position/motion information and is intended to reflect the quality of the information provided by the *location system*. QoS indicators can be *accuracy* estimate, *protection level* statistics / *integrity risk*, authentication flag, etc.

**Security**: *security* is a function of a *location system* that aims at ensuring that the *location-related information* is safeguarded against unapproved disclosure or usage inside or outsite the *location system*, and that it is alsoprovided in a secure and reliable manner that ensures it is neither lost nor corrupted.

**Time to First Fix** : The Time To First Fix (TTFF) is a measure of performance of a GNSS receiver that accounts for the time elapsed from the GNSS receiver switch-on until the output of a navigation solution within a certain performance.

**Vertical axis**: axis locally defined for the mobile target, collinear to the zenith/nadir axis.

## Symbols

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

ϕ Carrier phase

εAccel Error on sensor acceleration (from INS)

εAtt Error on sensor attitude (from INS)

εGyro Error on sensor gyroscopes (from INS)

εPos Error on sensor position (from INS)

εPos3D Uncertainty on sensor position (from GNSS)

εV Error on sensor attitude (from INS)

εV3D Uncertainty on sensor speed (from GNSS)

d Carrier Doppler

PGNSS Position estimate coming from GNSS sensor

PINS Position estimate coming from the INS

VGNSS Speed estimate coming from GNSS sensor

VINS Speed estimate coming from the INS

## Abbreviations

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

*All below to be reviewed*

3GPP 3rd Generation Partnership Project

ADAS Advanced Driver Assistance Systems

AL Alarm Limit

BTS Base station Transceiver System

DOA Direction Of Arrival

ECEF Earth Centred Earth Fixed

EDGE Enhanced Data for GSM Evolution

EGNOS European Geostationary Navigation Overlay System

EMI Electro-Magnetic Interference

FDAF Frequency Domain Adaptive Filtering

GCF Global Certification Forum

GEO Geostationary Earth Orbit

GIVE Grid Ionospheric Vertical Error

GLONASS Global Navigation Satellite System (Russian based system)

GNSS Global Navigation Satellite System

GPRS General Packet Radio Service

GPS Global Positioning System

GSM Global System for Mobile communications

HPE Horizontal Positioning Error

HPL Horizontal Protection Level

IMU Inertial Measurement Unit

INS Inertial Navigation Sensor

IRS Inertial Reference System

ITS Intelligent Transport Systems

LCS LoCation Services

LEO Low Earth Orbit

LOS Line Of Sight

LTE Long Term Evolution

MEMS Micro Electro-Mechanical Systems

MEXSAT Mexican Satellite System

MI Mis-Integrity

MMI Man-Machine Interface

MOPS Minimum Operational Performance Specification

MP Multipath

MPS Minimum Performance Standard

MS Mobile Station

NCO Numerically Controlled Oscillator

NMR Network Measurement Results

ODTS Orbit Determination and Time Synchronisation

OMA Open Mobile Alliance

OTDOA Observed Time Difference Of Arrival

PAYD Pay As You Drive

PE Positioning Error

PL Protection Level

PRS Public Regulated Services

PVT Position, Velocity and Time

QoS Quality of Service

QZSS Quasi-Zenith Satellite System

RAIM Receiver Autonomous Integrity Monitoring

RF Radio Frequency

RMS Root Mean Square

RTCA Radio Technical Commission for Aeronautics

RTK Real Time Kinematic

SBAS Satellite Based Augmentation System

SCN Satellite Communications and Navigation (Working Group of TC-SES)

SMLC Serving Mobile Location Center

SUPL Secure User Plane for Location

SV Satellite Vehicle

TBC To Be Confirmed

TBD To Be Defined

TC-SES Technical Committee Satellite Earth Stations and Systems

TTA Time To Alarm

TTFF Time To First Fix

UDRE User Differential Range Error

UERE User Equivalent Range Error

UHF Ultra-High Frequency

UMTS Universal Mobile Telecommunications System

VPL Vertical Protection Level

WAAS Wide Area Augmentation System

WI-FI Wireless Fidelity

# Location System Performance Features

Based on the Location System Architecture defined in [7], the associated location system performance requirements specified in clause 5 are:

1. **horizontal position accuracy**: The relevant parameter to be monitored is the horizontal position. This measurement parameter is contained in the xxx IE, which is included in the yyy IE provided in the LPPe message of type zzz.
2. **vertical position accuracy** --> parameter is vertical position (is it accurate ?)
3. **Availability of required accuracy** --> horizontal (vertical) position (is it accurate when available ?)
4. **Precise GNSS time restitution**
5. **Time to first fix** --> parameter is horizontal position (when is it available ?)
6. **Position Authentication** --> authentication flag
7. **Interference Localisation** --> interference position: [azimuth, elevation] or [latitude, longitude, altitude] + uncertainty
8. **Robustness to Interference** --> horizontal position (is it accurate ? it is available ?)
9. **GNSS denied survival** --> horizontal position (it is available ?)
10. **GNSS Sensitivity** --> horizontal position (it is available ?)
11. **Position Integrity Protection Level** --> protection level
12. **Position Integrity Alarm Limit and TTA** --> protection level

# Performance Requirements

This clause defines the minimum performance requirements for each of the performance features defined in clause 4. The definitions of performance metrics for these features are given in Annex A.

The Applicable Conditions for these features are given in Annex B.

*Other references to Annexes*

## Horizontal Position Accuracy

Location systems implementing performance feature “horizontal position accuracy” shall comply with the minimum performance requirements described in clauses 5.1.2 and 5.1.3 below.

### Operational conditions

Table 5‑1 below provides the operational conditions used to define the minimum required performance for feature “Horizontal Position Accuracy”, and the masking parameters tuning applicable for each of them.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Environment type | Applicability | Masking parameters | | |
| x1 | x2 | x3 |
| Open area | Yes | See table B.x6 | |  |
| Rural area | Yes | See table B.x6 | | |
| Suburban | Yes | See table B.x6 | | |
| Urban | Yes | See table B.x6 | |  |
| Assymetric area | Yes | See table B.x6 | | |
| Industrial area | Yes | See table B.x6 | | |

Table ‑: Environment applicability for “horizontal position accuracy”

### Use case: Moving Location Target

#### Target movement

The location target follows the trajectory described in clause B.3. The reference point {0;0;0} has coordinates expressed in [WGS84] system: longitude = [tbd], latitude = [tbd].

The trajectory parameters are provided in Table 5‑2 below.

|  |  |
| --- | --- |
| Trajectory parameter | Value |
| v1 | 25 km/h |
| v2 | 100 km/h |
| v3 | 100 km/h |
| d1 | 250 m |
| D2 | 250 m |

Table ‑: Mobile target movement parameters

#### Performance requirement

The location target position estimated by the location system shall meet the accuracy specified in Table 5‑3 to Table 5‑8 below, depending on:

* the grade of the location system
* the operational environment considered, as defined in clause B.2.3.

This performance level shall be met when the trajectory is travelled in both directions.

|  |  |  |  |
| --- | --- | --- | --- |
| Metric  (as per clause 4.2) | Performance requirement – Open Area | | |
| Low grade | Medium grade | High grade |
| Mean value | 8,4 | 0,5 | 0,2 |
| Standard deviation | Tbd | Tbd | Tbd |
| 67th percentile | 8,8 | 0,4 | 0,3 |
| 95th percentile | 22,1 | 0,8 | 0,4 |
| 99th percentile | 23,8 | 1,4 | 0,5 |
| Cross track error - Mean value | 4,8 | 0,2 | 0,1 |
| Cross track error - 67th percentile | 5,8 | 0,3 | 0,1 |
| Cross track error - 95th percentile | 16,5 | 0,7 | 0,2 |
| Cross track error - 99th percentile | 20 | 1,2 | 0,3 |
| Along track error - Mean value | 5,4 | 0,3 | 0,2 |
| Along track error - 67th percentile | 6,4 | 0,3 | 0,3 |
| Along track error - 95th percentile | 21,9 | 0,5 | 0,4 |
| Along track error - 99th percentile | 22,4 | 1 | 0,5 |

Table ‑: performance requirement for Horizontal position, Open Area, Moving target

| Metric  (as per clause 4.2) | Performance requirement – Rural Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | 9,6 | 1 | 0,4 |
| Standard deviation | Tbd | Tbd | Tbd |
| 67th percentile | 12,2 | 1,1 | 0,5 |
| 95th percentile | 19 | 2,1 | 0,9 |
| 99th percentile | 22,7 | 2,8 | 1,1 |
| Cross track error - Mean value | 5,3 | 0,6 | 0,3 |
| Cross track error - 67th percentile | 6,5 | 0,8 | 0,3 |
| Cross track error - 95th percentile | 13,7 | 1,8 | 0,8 |
| Cross track error - 99th percentile | 16,7 | 2,4 | 1,1 |
| Along track error - Mean value | 6,6 | 0,4 | 0,2 |
| Along track error - 67th percentile | 10,1 | 0,5 | 0,3 |
| Along track error - 95th percentile | 18,1 | 1 | 0,6 |
| Along track error - 99th percentile | 18,7 | 1,5 | 0,8 |

Table ‑: performance requirement for Horizontal position, Rural Area, Moving target

| Metric  (as per clause 4.2) | Performance requirement – Suburban Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | 9,3 | 1,5 | 0,4 |
| Standard deviation | Tbd | Tbd | Tbd |
| 67th percentile | 10,4 | 1,5 | 0,4 |
| 95th percentile | 15,1 | 5 | 0,7 |
| 99th percentile | 21,5 | 8,1 | 0,9 |
| Cross track error - Mean value | 5,1 | 1,1 | 0,2 |
| Cross track error - 67th percentile | 6,6 | 1 | 0,2 |
| Cross track error - 95th percentile | 12,4 | 4,3 | 0,5 |
| Cross track error - 99th percentile | 19,2 | 7,4 | 0,8 |
| Along track error - Mean value | 6,5 | 0,7 | 0,3 |
| Along track error - 67th percentile | 8,4 | 0,6 | 0,3 |
| Along track error - 95th percentile | 14,6 | 2,5 | 0,6 |
| Along track error - 99th percentile | 15,1 | 4,8 | 0,7 |

Table ‑: performance requirement for Horizontal position, Suburban Area, Moving target

| Metric  (as per clause 4.2) | Performance requirement – Urban Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | 40,8 | 24,2 | 1,6 |
| Standard deviation |  |  |  |
| 67th percentile | 52,5 | 29,2 | 0,8 |
| 95th percentile | 75,3 | 49,9 | 9,3 |
| 99th percentile | 98,7 | 62,9 | 19 |
| Cross track error - Mean value | 26,9 | 15,2 | 1 |
| Cross track error - 67th percentile | 37,9 | 18,8 | 0,6 |
| Cross track error - 95th percentile | 59 | 42,6 | 3,7 |
| Cross track error - 99th percentile | 66,9 | 51,4 | 13,8 |
| Along track error - Mean value | 21,9 | 15,4 | 1,1 |
| Along track error - 67th percentile | 25,6 | 19,2 | 0,5 |
| Along track error - 95th percentile | 68,3 | 44,3 | 6,2 |
| Along track error - 99th percentile | 90,4 | 56,3 | 14,6 |

Table ‑: performance requirement for Horizontal position, Urban Area, Moving target

| Metric  (as per clause 4.2) | Performance requirement – Assymetric Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | 31,7 | 12,1 | 0,5 |
| Standard deviation |  |  |  |
| 67th percentile | 45,4 | 13,6 | 0,5 |
| 95th percentile | 79 | 38 | 1 |
| 99th percentile | 99,5 | 54,9 | 1,2 |
| Cross track error - Mean value | 15,3 | 10,2 | 0,3 |
| Cross track error - 67th percentile | 19,3 | 11,4 | 0,4 |
| Cross track error - 95th percentile | 59 | 32,4 | 0,8 |
| Cross track error - 99th percentile | 77,3 | 50,4 | 1,1 |
| Along track error - Mean value | 21,4 | 5,1 | 0,3 |
| Along track error - 67th percentile | 33,6 | 5,6 | 0,3 |
| Along track error - 95th percentile | 68,1 | 18,3 | 0,6 |
| Along track error - 99th percentile | 92 | 28,3 | 0,9 |

Table ‑: performance requirement for Horizontal position, Assymetric Area, Moving target

| Metric  (as per clause 4.2) | Performance requirement – Industrial Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | 57,6 | 6,5 | 0,7 |
| Standard deviation | Tbd | Tbd | Tbd |
| 67th percentile | 75,2 | 5 | 0,8 |
| 95th percentile | 96,7 | 23,2 | 1,7 |
| 99th percentile | 100,2 | 44,1 | 2,4 |
| Cross track error - Mean value | 33,6 | 5,1 | 0,5 |
| Cross track error - 67th percentile | 46,5 | 3,7 | 0,6 |
| Cross track error - 95th percentile | 77 | 19,2 | 1,6 |
| Cross track error - 99th percentile | 81,8 | 40,9 | 2,2 |
| Along track error - Mean value | 38,3 | 2,7 | 0,4 |
| Along track error - 67th percentile | 62 | 2,1 | 0,5 |
| Along track error - 95th percentile | 84,6 | 10,9 | 1 |
| Along track error - 99th percentile | 88,5 | 22,1 | 1,4 |

Table ‑: performance requirement for Horizontal position, Industrial Area, Moving target

### Use case: Static Location Target

#### Target position

The location target is located in coordinates expressed in WGS84 [tbc] system: longitude = [tbd], latitude = [tbd].

#### Performance requirement

The location target position estimated by the location system shall meet the accuracy specified in Table 5‑9 to Table 5‑14 below, depending on:

* the grade of the location system.
* the operational environment considered, as defined in clause B.2.3.

| Metric  (as per clause 4.2) | Performance requirement | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | [tbd] | [tbd] | [tbd] |
| Standard deviation | [tbd] | [tbd] | [tbd] |
| 67th percentile | [tbd] | [tbd] | [tbd] |
| 95th percentile | [tbd] | [tbd] | [tbd] |
| 99th percentile | [tbd] | [tbd] | [tbd] |
|  |  |  |  |
|  |  |  |  |

Table ‑: performance requirement for Horizontal position, Open area, Static target

| Metric  (as per clause 4.2) | Performance requirement – Rural Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | [tbd] | [tbd] | [tbd] |
| Standard deviation | [tbd] | [tbd] | [tbd] |
| 67th percentile | [tbd] | [tbd] | [tbd] |
| 95th percentile | [tbd] | [tbd] | [tbd] |
| 99th percentile | [tbd] | [tbd] | [tbd] |

Table ‑: performance requirement for Horizontal position, Rural Area, Static target

| Metric  (as per clause 4.2) | Performance requirement – Suburban Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | [tbd] | [tbd] | [tbd] |
| Standard deviation | [tbd] | [tbd] | [tbd] |
| 67th percentile | [tbd] | [tbd] | [tbd] |
| 95th percentile | [tbd] | [tbd] | [tbd] |
| 99th percentile | [tbd] | [tbd] | [tbd] |

Table ‑: performance requirement for Horizontal position, Suburban Area, Static target

| Metric  (as per clause 4.2) | Performance requirement – Urban Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | [tbd] | [tbd] | [tbd] |
| Standard deviation | [tbd] | [tbd] | [tbd] |
| 67th percentile | [tbd] | [tbd] | [tbd] |
| 95th percentile | [tbd] | [tbd] | [tbd] |
| 99th percentile | [tbd] | [tbd] | [tbd] |

Table ‑: performance requirement for Horizontal position, Urban Area, Static target

| Metric  (as per clause 4.2) | Performance requirement – Assymetric Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | [tbd] | [tbd] | [tbd] |
| Standard deviation | [tbd] | [tbd] | [tbd] |
| 67th percentile | [tbd] | [tbd] | [tbd] |
| 95th percentile | [tbd] | [tbd] | [tbd] |
| 99th percentile | [tbd] | [tbd] | [tbd] |

Table ‑: performance requirement for Horizontal position, Assymetric Area, Static target

| Metric  (as per clause 4.2) | Performance requirement – Industrial Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | [tbd] | [tbd] | [tbd] |
| Standard deviation | [tbd] | [tbd] | [tbd] |
| 67th percentile | [tbd] | [tbd] | [tbd] |
| 95th percentile | [tbd] | [tbd] | [tbd] |
| 99th percentile | [tbd] | [tbd] | [tbd] |

Table ‑: performance requirement for Horizontal position, Industrial Area, Static target

## Vertical Position Accuracy

### Operational conditions

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Environment type | Applicability | Masking parameters  to be used | | |
| x1 | x2 | x3 |
| Open area | Yes | See table B.x6 | |  |
| Rural area | Yes | See table B.x6 | | |
| Suburban | Yes | See table B.x6 | | |
| Urban | Yes | See table B.x6 | |  |
| Assymetric area | Yes | See table B.x6 | | |
| Industrial area | Yes | See table B.x6 | | |

### Use case: Moving Location Target

#### Performance requirement

| Metric  (as per clause 4.2) | Performance requirement – Open Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | tbd | tbd | tbd |
| Standard deviation | tbd | tbd | tbd |
| 67th percentile | tbd | tbd | tbd |
| 95th percentile | tbd | tbd | tbd |
| 99th percentile | tbd | tbd | tbd |

Table ‑ Performance requirement for Vertical position, Open Area, Moving location target

### Use case: Static Location Target

#### Performance requirement

| Metric  (as per clause 4.2) | Performance requirement – Open Area | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value | tbd | tbd | tbd |
| Standard deviation | tbd | tbd | tbd |
| 67th percentile | tbd | tbd | tbd |
| 95th percentile | tbd | tbd | tbd |
| 99th percentile | tbd | tbd | tbd |

Table ‑ Performance requirement for Vertical position accuracy, Open Area, Static location target

## Availability of required accuracy

<Text>

## Precise GNSS time restitution

### Operational conditions

GNSS signals defined as per clause B.1.2.

The operational environment, applicable for the location system performance requirements in fault-free conditions are defined in Table 5‑17 below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Environment type | Applicability | Masking parameters  to be used | | |
| x1 | x2 | x3 |
| Open area | Yes | See table B.x6 | |  |
| Rural area | Yes | See table B.x6 | | |
| Suburban | Yes | See table B.x6 | | |
| Urban | Yes | See table B.x6 | |  |
| Assymetric area | Yes | See table B.x6 | | |
| Industrial area | Yes | See table B.x6 | | |

Table ‑ Environment applicability for feature “precise GNSS time restitution”

### Use case: Moving Target

#### Target movement

The location target follows the trajectory described in clause B.3. The reference point {0;0;0} has coordinates expressed in [WGS84] system: longitude = [tbd], latitude = [tbd].

The trajectory parameters are provided in Table 5‑18 below.

|  |  |
| --- | --- |
| Trajectory parameter | Value |
| v1 | 25 km/h |
| v2 | 100 km/h |
| v3 | 100 km/h |
| d1 | 250 m |
| D2 | 250 m |

Table ‑: Mobile target movement parameter

#### Performance requirement

The location target position estimated by the location system shall meet the accuracy specified in Table 5‑19 to […] below, depending on:

* the grade of the location system
* the operational environment considered, as defined in clause B.2.3.

This performance level shall be met when the trajectory is travelled both ways.

| Metric  (as per clause 4.2) | Performance requirement | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value |  |  |  |
| 95th percentile |  |  |  |

Table ‑ Performance requirement for Precise GNSS time restitution  
Open Area, Moving Location target

### Use case: Static Target

#### Target position

The location target is located in coordinates expressed in WGS84 [tbc] system: longitude = [tbd], latitude = [tbd].

#### Performance requirement

The location target position estimated by the location system shall meet the accuracy specified in Table 5‑20 to […] below, depending on

* the grade of the location system.
* the operational environment considered, as defined in clause B.2.3.

| Metric  (as per clause 4.2) | Performance requirement | | |
| --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Mean value |  |  |  |
| 95th percentile |  |  |  |

Table ‑ Performance requirement for Precise GNSS time restitution  
Open Area, Static Location target

## Time to First Fix

<Text>

## Position Authentication

Location systems implementing performance feature “Position authentication” shall comply with the performance requirements described in clauses and below.

The performance specification is organized as follows:

* Two main use cases are considered: static location target, and moving location target
* For each of these use cases, the requirements cover:
  + Fault-free scenario. In this scenario, no authentication threat is considered. Location system performance is measured as a probability of false alarm
  + Faulty scenarios. In these scenarios, elementary threats are considered. Location system performance is measured as the ability of the system to detect these threats.

### Operational conditions

GNSS signals defined as per clause B.1.2.

The operational environment, applicable for the location system performance requirements in fault-free conditions are defined in Table 5‑21 below.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Environment type | Applicability | Masking parameters  to be used | | |
| x1 | x2 | x3 |
| Open area | Yes | See table B.x6 | |  |
| Rural area | Yes | See table B.x6 | | |
| Suburban | Yes | See table B.x6 | | |
| Urban | Yes | See table B.x6 | |  |
| Assymetric area | Yes | See table B.x6 | | |
| Industrial area | Yes | See table B.x6 | | |

Table ‑ Environment applicability for feature “position authentication”

### Use case: Moving location Target fault free scenario

#### Target movement

The location target follows the trajectory described in clause B.3. The reference point {0;0;0} has coordinates expressed in [WGS84] system: longitude = [tbd], latitude = [tbd].

The trajectory parameters are provided in Table 5‑22 below.

|  |  |
| --- | --- |
| Trajectory parameter | Value |
| v1 | 25 km/h |
| v2 | 100 km/h |
| v3 | 100 km/h |
| d1 | 250 m |
| D2 | 250 m |

Table ‑: Mobile target movement parameter

#### Performance requirement

The false alarm probability achieved by the location system “position authentication” function shall meet the level specified in Table 5‑23 below, depending on:

* the grade of the location system
* the operational environment considered, as defined in clause B.2.3.

This performance level shall be met when the trajectory is travelled both ways.

|  |  |  |  |
| --- | --- | --- | --- |
| Environment type | Maximum False Alarm probability | | |
| Low grade | Medium grade | High grade |
| Open area | 0 [tbc] | 0 [tbc] | 0 [tbc] |
| Rural area | 0 [tbc] | 0 [tbc] | 0 [tbc] |
| Suburban | 0 [tbc] | 0 [tbc] | 0 [tbc] |
| Urban | 0 [tbc] | 0 [tbc] | 0 [tbc] |
| Assymetric area | 0 [tbc] | 0 [tbc] | 0 [tbc] |
| Industrial area | 0 [tbc] | 0 [tbc] | 0 [tbc] |

Table ‑: Authentication False Alarm performance

In addition to the requirements above, the latency to provide authenticity shall not exceed 6 [tbc] seconds.

### Use case: Moving location Target faulty scenarios

#### Target movement

The location target follows the trajectory described in clause B.3. The reference point {0;0;0} has coordinates expressed in [WGS84] system: longitude = [tbd], latitude = [tbd].

The trajectory parameters are provided in Table 5‑22 below.

|  |  |
| --- | --- |
| Trajectory parameter | Value |
| v1 | 25 km/h |
| v2 | 100 km/h |
| v3 | 100 km/h |
| d1 | 250 m |
| D2 | 250 m |

Table ‑: Mobile target movement parameter

#### Performance requirement

The location system shall meet the following performance requirements in terms of spoofing attempt detection performance.

For a given spoofing scenario, the indicated TSP and error values are the TSP and error (jump or drift depending of the applicable model in the scenario) values that the location system shall be able to detect. This required ability is given as a function of:

* the grade of the location system
* the operational environment considered, as defined in clause B.2.3.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Spoofing scenario | Probability of detection | Low grade | | Medium grade | | High grade | |
| TSP (dBW) | Error (m) | TSP (dBW) | Error (m) | TSP (dBW) | Error (m) |
| M-1 | 90% |  |  |  |  |  |  |
| 99% |  |  |  |  |  |  |
| 100% |  |  |  |  |  |  |
| M-2 | 90% |  |  |  |  |  |  |
| 99% |  |  |  |  |  |  |
| 100% |  |  |  |  |  |  |
| M-3 | 90% |  |  |  |  |  |  |
| 99% |  |  |  |  |  |  |
| 100% |  |  |  |  |  |  |
| M-4 | 90% |  |  |  |  |  |  |
| 99% |  |  |  |  |  |  |
| 100% |  |  |  |  |  |  |
| M-5 | 90% |  |  |  |  |  |  |
| 99% |  |  |  |  |  |  |
| 100% |  |  |  |  |  |  |
| M-6 | 90% |  |  |  |  |  |  |
| 99% |  |  |  |  |  |  |
| 100% |  |  |  |  |  |  |

Table ‑: Detection performance, Open Area, Static location target

[…]

Table ‑: Detection performance, Rural Area, Static location target

[…]

Table ‑: Detection performance, Suburban Area, Static location target

[…]

Table ‑: Detection performance, Urban Area, Static location target

[…]

Table ‑: Detection performance, Assymetric Area, Static location target

[…]

Table ‑: Detection performance, Industrial Area, Static location target

In addition to the requirements above, the latency to provide authenticity shall not exceed 6 [tbc] seconds.

### Use case: Static Location Target Fault-free scenario

#### Performance requirement

### Use case: Static Location Target Faulty scenarios

#### Performance requirement

### Use case: Threat scenario #1



#### Performance requirement

|  |  |
| --- | --- |
| Authentication | Requirements |
| Position, Velocity and Time | Y/Y/Y |
| Period | Once in <1 minute |
| Latency (Time To Authenticate) | Not to exceed 6 seconds |
| Availability | 99% |
| Error rate | <1% |

**Spoofing threat**(s) to be defined as part of this clause.

## Interference Localisation

<Text>

**Specific Interference conditions** to be specified: interference localisation to be specified.

## Robustness to Interference

<Text>

**Specific Interference conditions** to be specified: interference characteristics to be specified: received power, frequency, spectral shape (tbc), temporal shape (tbc). In this case, this definition supersedes the one provided as part of the typical environments.

## GNSS denied survival

### Operational conditions

Table 5‑31 below provides the operational conditions used to define the required performance for feature “Horizontal Position Accuracy”, and the masking parameters tuning applicable for each of them.

|  |  |  |
| --- | --- | --- |
| Environment type | Applicability | Masking parameters |
| Open area | Yes | Special |
| Rural area | Yes | Special |
| Suburban | Yes | Special |
| Urban | Yes | Special |
| Assymetric area | Yes | Special |
| Industrial area | Yes | Special |

Table ‑: Environment applicability for feature “horizontal position accuracy”

The specific masking conditions to be used are defined in clause below.

#### Special masking conditions

In order to measure the ability of a location system to maintain the mobile target position determination within GNSS denied environments, it proposed to use the operational environments defined in X.X, the trajectory defined in X.X but to remove all GNSS and telecommunications-derived (TELCO) signals over a portion of the trajectory, as described in the graph below.

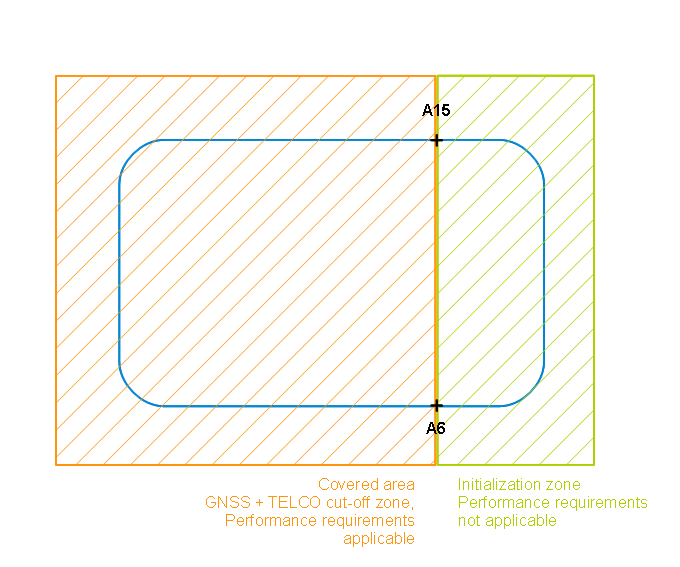


Figure B-1. Sky conditions definition method.

### Use case: Moving Target

#### Target movement

The location target follows the trajectory described in clause B.3. The reference point {0;0;0} has coordinates expressed in [WGS84] system: longitude = [tbd], latitude = [tbd].

The trajectory parameters are provided in Table 5‑2 below.

|  |  |
| --- | --- |
| Trajectory parameter | Value |
| v1 | 25 km/h |
| v2 | 100 km/h |
| v3 | 100 km/h |
| d1 | 250 m |
| D2 | 250 m |

Table ‑: Mobile target movement parameter

#### Performance requirement

The location target position estimated by the location system after crossing the covered area (i.e. in point A6 or A15 according to the way the trajectory is travelled) shall meet the accuracy specified in Table 5‑33 to Table 5‑38 below, depending on:

* the grade of the location system
* the operational environment considered, as defined in clause B.2.3.

This performance level shall be met when the trajectory is travelled in reverse directions.

| Metric  (as per clause 4.2) | | Requirements for position error after covered area crossing – Open Area | | |
| --- | --- | --- | --- | --- |
| Low grade | Medium grade | High grade |
| Horizontal Position error | Mean value |  |  |  |
| Std value |  |  |  |
| Max value |  |  |  |
| Cross track error | Mean value |  |  |  |
| Std value |  |  |  |
| Max value |  |  |  |
| Along track error | Mean value |  |  |  |
| Std value |  |  |  |
| Max value |  |  |  |
| Vertical Position error | Mean value |  |  |  |
| Std value |  |  |  |
| Max value |  |  |  |

Table ‑: performance requirement for GNSS denied survival, Open Area

Table ‑: performance requirement for GNSS denied survival, Rural Area

Table ‑: performance requirement for GNSS denied survival, Suburban Area

Table ‑: performance requirement for GNSS denied survival, Urban Area

Table ‑: performance requirement for GNSS denied survival, Asymmetric Area

Table ‑: performance requirement for GNSS denied survival, Industrial Area

## GNSS Sensitivity

<Text>

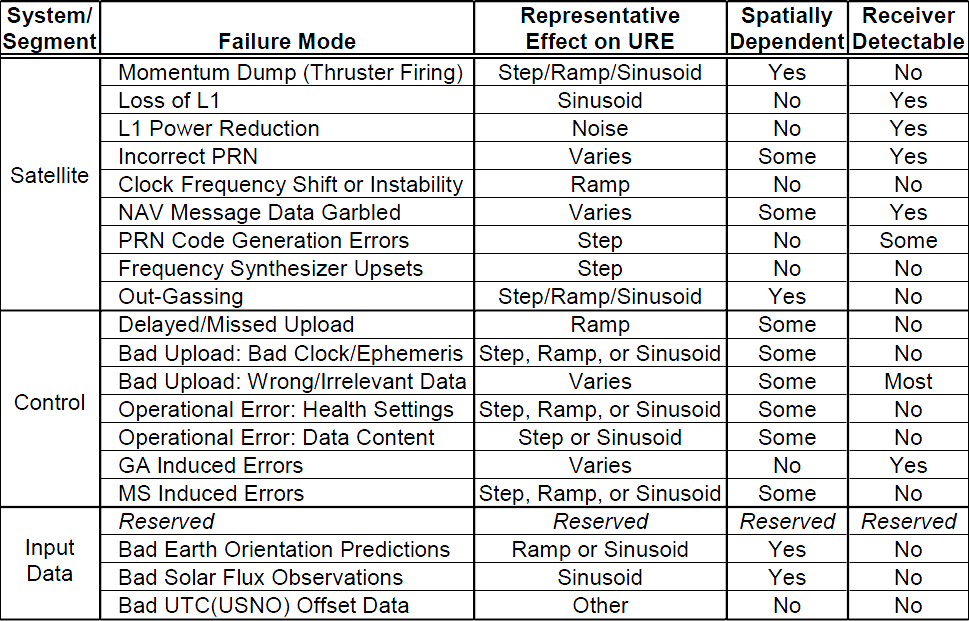
<Text>

## Position Integrity Protection Level

<Text>

**Threat scenarios** to be defined as part of this clause.

The following define the perimeter of the failing modes of GNSS systems:



|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Predicted MI Failure Type** | **Block I, II, IIA Predicted MI Probability** | **Assigned Test Range** | **Assigned MI Failure**  **Probability** |
| 1 | Ramp 0.01 m/s | 2×10-7/hour/SV | Ramp 0.01-0.05 m/s | 1×10-6/hour/SV |
| 2 | Ramp 0.1 m/s | 1×10-7/hour/SV | Ramp 0.05-0.25 m/s | 1×10-6/hour/SV |
| 3 | Ramp 0.5 m/s | 3×10-7/hour/SV | Ramp 0.25-0.75 m/s | 1×10-6/hour/SV |
| 4 | Ramp 1 m/s | 10×10-7/hour/SV | Ramp 0.75-2.5 m/s | 3.5×10-6/hour/SV |
| 5 | Ramp 5 m/s | 12×10-7/hour/SV | Ramp 2.5-5.0 m/s | 4.1×10-6/hour/SV |
| 6 | Step 300 m | 1×10-7/hour/SV | Step 300-700 m | 1×10-6/hour/SV |
| 7 | Step 3000 m | 34×10-7/hour/SV | Step 700-3000 m | N/A |

## Position Integrity Alarm Limit and TTA

<Text>

# 

# Annex A (Normative): Definition of performance metrics

This section defines how performance shall be determined for each parameter.

## Horizontal position accuracy

The horizontal position accuracy is the projection of the position accuracy on the horizontal plane containing the mobile target true position (i.e. 2-dimensional projection).

The metrics used in order to statistically characterize this accuracy is composed of the following quantities:

* + **Mean value** of the horizontal position error computed over a specified time interval.
  + **Standard deviation** of the horizontal position error computed over a specified time interval.
  + **67th, 95th and 99th percentiles** of the horizontal position error distribution computed over a specified time interval.

These metrics are defined as follows.

* + Let p be the true position of the mobile target
  + Let be the position estimates collected over a specified time interval (N samples), projected on the local horizontal plane containing the mobile target true position



* + i is the positioning error vector, defined as i = p - {p\*}i . Note that this vector is contained in the local horizontal plane.
  + The mean value is defined as:



* + The standard deviation is defined as:



* + The percentiles, noted σx (i.e. respectively σ67σ95 σ99 ) is defined as the smallest error verifying:



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

* + Along-track error
  + Across-track error

[definition with diagram to be added]

## Vertical position accuracy

The vertical position accuracy is the projection of the position accuracy on the vertical axis containing the mobile target true position.

The metrics used in order to statistically characterize this accuracy is composed of the following quantities:

* + **Mean value** of the vertical position error computed over a specified time interval.
  + **Standard deviation** of the vertical position error computed over a specified time interval.
  + **67th, 95th and 99th percentiles** of the vertical position error distribution computed over a specified time interval.

These metrics are defined as follows.

* + Let p be the true position of the mobile target
  + Let be the position estimates collected over a specified time interval (N samples), projected on the local vertical axis containing the mobile target true position



* + i is the positioning error vector, defined as i = p - {p\*}i . Note that this vector is contained in the local vertical axis.
  + The mean value is defined as:



* + The standard deviation is defined as:



* + The percentiles, noted σx (i.e. respectively σ67σ95 σ99 ) is defined as the smallest error verifying:



## Availability of required accuracy

The availability is expressed as the percentage of time the required location-related information is available, over a predefined time windows (e.g.: 1 hour). Consequently, in order to be properly characterized, the following information shall be provided:

* + The **availability rate**, expressed in percent.
  + A description of the required location-related information, including **required quality of service**.

The required quality of service can a maximum required accuracy, an integer position, an authenticated position, etc.

## Position Integrity performance

The integrity performance is characterized by a pair *protection level* / *integrity risk*.

As far as position integrity is concerned, the metrics to be used are therefore:

* + The **position protection level** (PPL) expressed in meters
  + The **integrity risk**, expressed as the probability that the actual position accuracy exceeds the position protection level under fault-free and faulty modes.

## Restituted GNSS time accuracy

The restituted GNSS time accuracy is the difference, measured in seconds, between the true GNSS time (as implemented in the GNSS system timing facility) and the GNSS time restituted by the GNSS sensor based on the PVT solution.

The metrics used in order to statistically characterize this accuracy is composed of the following quantities:

* + **Mean value** of the restituted GNSS time error computed over a specified time interval.
  + **Standard deviation** of the restituted GNSS time error computed over a specified time interval.
  + **67th, 95th and 99th percentiles** of the restituted GNSS time error computed over a specified time interval.

## Time to first fix (TTFF)

The time to first fix is the time elapsed between the time the location request is triggered by the location system (i.e. either from external immediate request, or following a location report trigger), and the time the position answer is delivered to the location system external interface.

The metrics used in order to statistically characterize this quantity is composed of the following quantities:

* + and **maximum values** of the TTFF computed over a specified number of trials.
  + **Mean value** of the TTFF computed over a specified number of trials.
  + **Standard deviation** of the TTFF computed over a specified number of trials.
  + **67th, 95th and 99th percentiles** of the TTFF computed over a specified number of trials.

## Position authentication

The authenticity performance is characterised by the ability of the system to identify accurately spoofing attempts cases.

For position authenticity, the metrics to be used are therefore:

* + **Probability of missed-detection** in case of spoofing attempt (threat scenario)
  + **Probability of false alarm** in case of no spoofing is attempted (fault free scenario)
  + **Mean time to provide position authenticity (latency)**

## Direction of arrival accuracy

The direction of arrival accuracy is the error between the actual direction of arrival of a signal coming from a given interference source, and the DoA of this same signal estimated by the location system.

The metrics used in order to statistically characterize this quantity is composed of the following quantities:

* + **Mean value** of the DoA error computed over a specified time interval.
  + **Standard deviation** of the DoA error computed over a specified time interval.
  + **67th, 95th and 99th percentiles** of the DoA error computed over a specified time interval.

## PVT degradation under interference sources

PVT degration is measured as increase of the position, speed and time estimation error caused by interference sources.

## Recovery time of normal performance after termination of pulse interference

# Annex B (normative): Applicable conditions

*RJM: needs an explanation of the purpose of this and a reference to the Annex introduced in the main body above.*

## B.1 General

### B.1.1 Parameter values

[This section provides the values to be used for testing for the parameters contained in the appropriate request addressed to the location system.]

### B.1.2 GNSS systems parameters

#### B.1.2.1 Systems constellation geometry and signal parameters

Table B.x5 below provides the reference documents applicable in the frame of the present performance specification. They provide for each system:

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

|  |  |  |  |
| --- | --- | --- | --- |
| GNSS system | System/User interface description | Number of visible satellites | HDOP range |
| GPS L1C/A | [2] | Variable | 1.6 to 2.5 [tbc] |
| GALILEO OS | [1] | Variable | 1.6 to 2.5 [tbc] |
| GLONASS | [6] | Variable | 1.6 to 2.5 [tbc] |
| GPS L5 | [3] | Variable | 1.6 to 2.5 [tbc] |
| GPS L1C | [4] | Variable | 1.6 to 2.5 [tbc] |
| Beidou | [x] | Variable | 1.6 to 2.5 [tbc] |

Table B.x5: Trajectory Parameters

#### B.1.2.1 GNSS System Time Offsets

If more than one GNSS is used in a test, the accuracy of the GNSS-GNSS Time Offsets used at the system simulator shall be better than 3 ns.

### B.1.2 SBAS systems parameters

### B.1.3 Cellular systems parameters

[tbd]

[rationale: list in the paragraph all relevant references towards standards for GSM, UMTS, LTE, WiFi, Bluetooth, DVB, allowing to properly define the applicable

## B.2 Operational environments

Operational environments applicable to the performance specification given in clause 5 are defined in sub clause B.2.3 of the present annex.

These environments are defined by a list of characteristics:

- characteristics related to the GNSS sensor performance, which are preliminarily described in sub clause B.2.1.

- characteristics related to the other sensors performance, which are preliminarily described in sub clause B.2.2.

### B.2.1 GNSS-related environment characteristics

The following characteristics are related to the reception conditions of the GNSS signals.

These reception conditions concerns:

GNSS signals masking or attenuation from a terminal perspective, due to obstacles (buildings, walls, trees, windows, vehicles, etc) located on the signal propagation path. This is referred to as “**sky conditions**” in the rest of the document

Existence of undesired GNSS signals echoes at terminal antenna input, caused by specular or diffuse reflections, and affecting the performance of the navigation solution. This is referred to as “**multipath**” in the rest of the document.

Presence of electro-magnetic interference sources in the terminal vicinity, causing an observable increase of noise in the terminal RF chain processing. This is referred to as “**interference**” in the rest of the document.

NOTE: the above phenomena are considered local contributors to GNSS signals quality. GNSS signal characteristics prior to being affected by these conditions (i.e. ignoring contribution of terminal vicinity, such as direction of arrival (and hence HDOP), received signal power) are assumed to be in line with Interface Control Documents of each of the considered GNSSs (see [1], [2], [3], [4], [5], and [6])

#### B.2.1.1 Sky conditions

Sky conditions are proposed to be defined as follows.

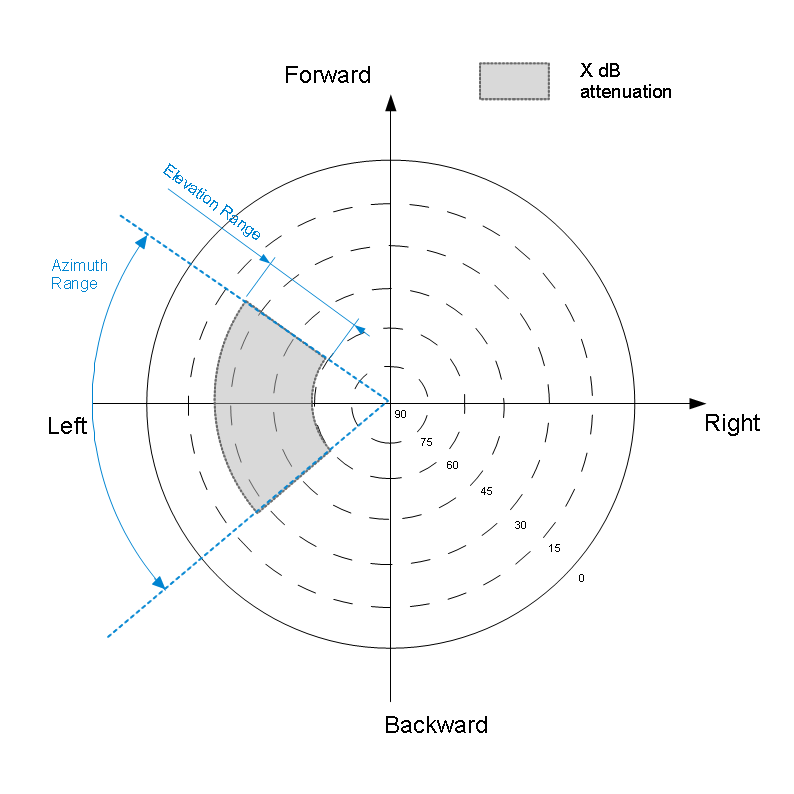


Figure B-1. Sky conditions definition method.

A sky plot provides:

* the area of the sky above the receiver being affected by total signal masking. When Satellite azimuth and elevation coordinates (from terminal point of view) falls into these area, GNSS signal is considered blocked.
* the area of the sky above the receiver being affected by partial signal masking. When Satellite azimuth and elevation coordinates (from terminal point of view) falls into these area, GNSS signal is considered attenuated. The amount of this attenuation is defined for each operational environment.

Note: several distinct areas can be defined for a single operational environment.

Typical sky conditions are defined in clause B.2.3.

#### B.2.1.2 Multipath

The multipath model applicable to the performance specification is described below.

Doppler frequency difference between direct and reflected signal paths is applied to the carrier and code frequencies. The Carrier and Code Doppler frequencies of LOS and multi-path for GNSS signal are defined in table B.x1

|  |  |  |  |
| --- | --- | --- | --- |
| 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: Discrete Doppler frequency is used for each tap. | | | |

Table B.x1: Trajectory Parameters

X, Y and N depend on the GNSS signal type. In addition, Y depends on the intensity of multipath 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 B.x below provides the parameters values of 3 levels of multipath intensity, from low to high. k in Table B.x3 is the GLONASS frequency channel number.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Multipath level | | | Low | Med | High |
| System | Signals | X [m] | Y [dB] | Y [dB] | Y [dB] |
| Galileo | E1 | 125 | [tbd] | -4.5 | [tbd] |
| E5a | 15 | [tbd] | -6 | [tbd] |
| E5b | 15 | [tbd] | -6 | [tbd] |
| GPS/Modernized GPS | L1 C/A | 150 | [tbd] | -6 | [tbd] |
| L1C | 125 | [tbd] | -4.5 | [tbd] |
| L2C | 150 | [tbd] | -6 | [tbd] |
| L5 | 15 | [tbd] | -6 | [tbd] |
| GLONASS | G1 | 275 | [tbd] | -12.5 | [tbd] |
| G2 | 275 | [tbd] | -12.5 | [tbd] |

Table B. x2: Parameter values

|  |  |  |
| --- | --- | --- |
| System | Signals | N |
| Galileo | E1 | 1540 |
| E5a | 115 |
| E5b | 118 |
| GPS/Modernized GPS | L1 C/A | 1540 |
| L1C | 1540 |
| L2C | 1200 |
| L5 | 115 |
| GLONASS | G1 | 3135.03 + k ⋅ 1.10 |
| G2 | 2438.36 + k ⋅ 0.86 |

Table B.x3 Ratio between Carrier Frequency and Chip Rate

#### B.2.1.3 Electro-magnetic Interference

The EMI model applicable to the performance specification is described below.

Interference conditions are modelled by the total noise power density after correlation , . It is derived from the interference source spectral characteristics according to the following formula:



where

- stands for considered GNSS signal (e.g. Galileo E5a, GPS L1C …)

- is the carrier frequency of the considered GNSS signal X

- is the GNSS sensor filtering bandwidth of the considered GNSS signal X

- is the external noise power density at the antenna level,

- is the spreading gain enabled by the receiver correlator while processing signal X

In the frame of this technical specification, three levels of impact of the interference environments are considered, from low to high.

|  |  |
| --- | --- |
| EMI level | NI |
| Low | -200 dBW/Hz |
| Medium | -195 dBW/Hz |
| High | -185 dBW/Hz |

Table B.x4 Interference levels

### B.2.2 Additional environment characteristics

Further to the above environment characteristics, addition characteristics are defined. They are relevant to the specification of performance for system embedding technical enablers other than GNSS sensor.

#### B.2.2.1 Telecommunication beacons deployment

According to [7], location systems might embed telecommunication sensors which enable the provision of measurements participating to the navigation solution. This sub clause defines additional environment characteristics relevant to these type of sensors.

Depending on the claimed compatibility of the location system under test, the beacon deployment(s) applicable to the present performance specification shall be as follows (one or several clauses applicable).

Quid of masking conditions to be applied to the base stations signals ?

##### B.2.2.1.1 Cellular telecommunications base stations caracteristics and deployment

Relevant standard reference, providing the Base Station (BS) signal specification (transmitter power, …) , is provided in clause B.1.3.

###### B.2.2.1.1.1 Base stations deployment height

###### B.2.2.1.1.1 Base stations deployment density

##### B.2.2.1.1 Wi-Fi access points characteristics and deployment

Relevant standard reference, providing the Base Station (BS) signal specification (transmitter power, …) , is provided in clause B.1.3.

###### B.2.2.1.1.1 Access points deployment height

[random from – to -]

###### B.2.2.1.1.1 Access points deployment density

##### B.2.2.1.1 Blue-tooth transmitters caracteristics and deployment

Relevant standard reference, providing the Base Station (BS) signal specification (transmitter power, …) , is provided in clause B.1.3.

##### B.2.2.1.1 DVB transmitters caracteristics and deployment

Relevant standard reference, providing the Base Station (BS) signal specification (transmitter power, …) , is provided in clause B.1.3.

###### B.2.2.1.1.1 Transmitters deployment height

###### B.2.2.1.1.1 Transmitters deployment density

#### B.2.2.2 Interference source definition

<Text>

Definition of the interference model chosen in the operational environment.

NB: user dynamics will be specified in each individual test scenarios (per key features, in section 5)

#### B.2.2.2 Magnetic conditions

### B.2.3 Operational environments definition

Typical environments. Each environments foresees a given set of values for each characteristics listed above.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Operational environment type | Masking conditions | | | Multipath Level | Interference level | Magnetic conditions | Telco beacons distribution |
| Polar plot | Zone | Atten |
| Open Area | Open sky | x1 | 0 dB | Null | Null | Nominal | Rural distribution |
| x2 | [tbd] (total) |
| Rural Area | Light masking | x1 | 0 dB | Low | Low | Nominal | Rural distribution |
| x2 | Total |
| x3 | 10 dB |
| Suburban Area | Dense masking | x1 | 0 dB | Medium | Low | Nominal | Suburban distribution |
| x2 | Total |
| x3 | Total |
| Urban Area | Urban Canyon | x1 | 0 dB | High | Medium | Degraded | Urban distribution |
| x2 | Total |
| Assymetric Area | Assymetric visibility | x1 | 15 dB | High | Medium | Degraded | Urban distribution |
| x2 | Total |
| x3 | Total |
| Industrial Area | Dense masking | x1 | 0 dB | High | High | Degraded | Suburban distribution |
| x2 | Total |
| x3 | Total |

Table B.x6 Operational environments definition

#### B.2.3.1 Open area

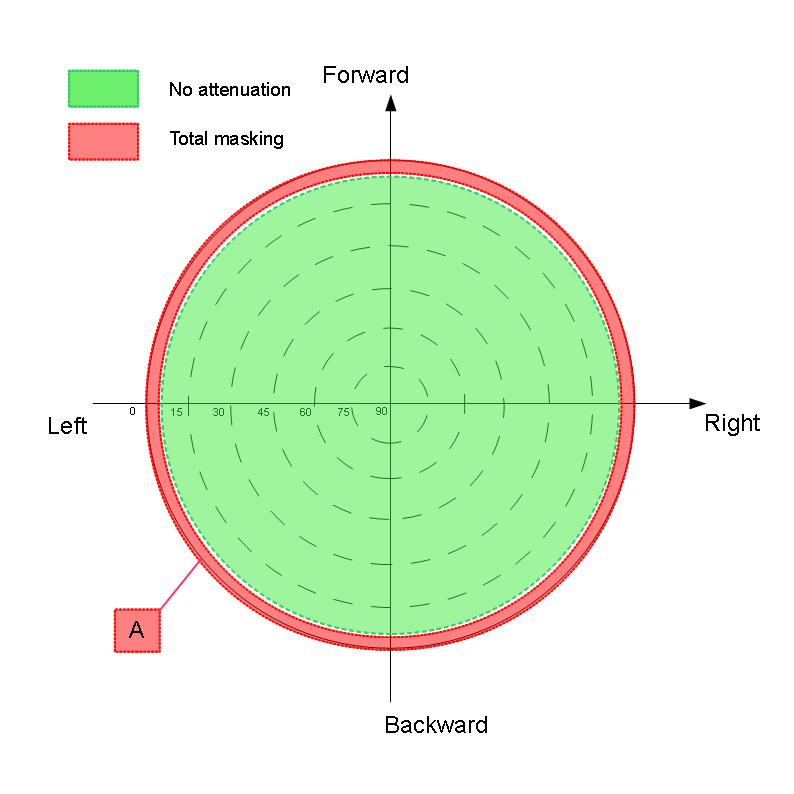


Figure B-2. Open area sky conditions

The following default parameters are defined:

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Zone | Elevation range | | Azimuth range | | Signal Attenuation | |
| A | 0 - 5 | degrees | 0 - 360 | degrees | Masked | dB |
| Background | Area out of Zone A | | | | 0 | dB |

Table B. x2: Open area default parameters

#### B.2.3.2 Rural area

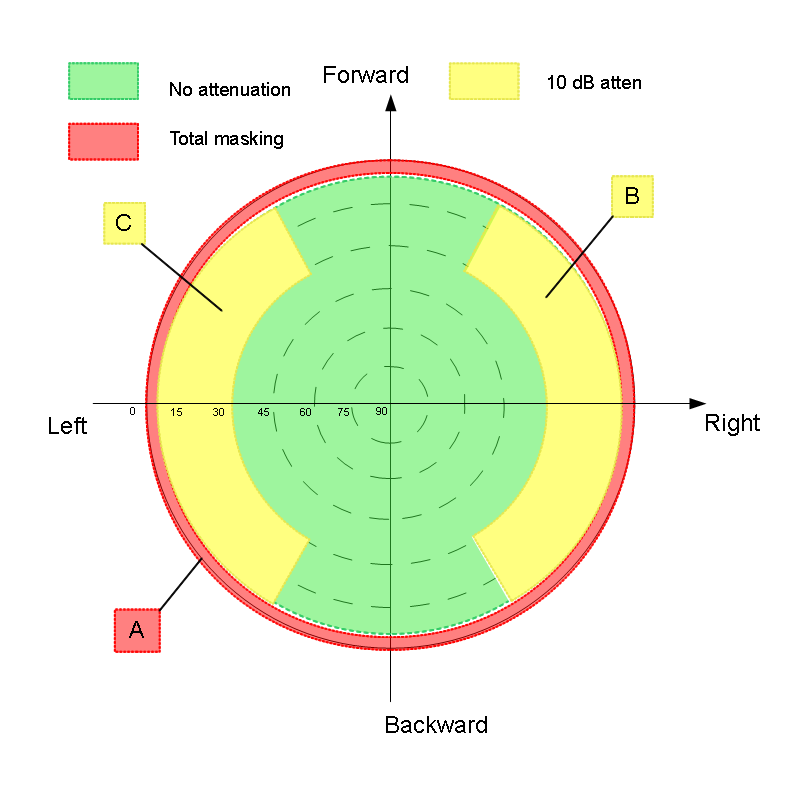


Figure B-3. Rural area sky conditions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Zone | Elevation range | | Azimuth range | | Signal Attenuation | |
| A | 0 - 5 | degrees | 0 - 360 | degrees | Masked | dB |
| B | 5 - 30 | degrees | 210 – 330 | degrees | 10 | dB |
| C | 5 - 30 | degrees | 30 - 150 | degrees | 10 | dB |
| Background | Area out of Zones A, B, C | | | | 0 | dB |

Table B. x2: Open area default parameters

#### B.2.3.3 Suburban area



Figure B-4. Suburban area sky conditions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| * Zone | * Elevation range | | * Azimuth range | | * Signal Attenuation | |
| * A | * 0 – 5 | * degrees | * 0 – 360 | * degrees | * Masked | * dB |
| * B | * 5 – 20 | * degrees | * 210 – 330 | * degrees | * Masked | * dB |
| * C | * 5 – 20 | * degrees | * 30 - 150 | * degrees | * Masked | * dB |
| * D | * 20 – 40 | * degrees | * 30 - 150 | * degrees | * 10 | * dB |
| * E | * 20 – 40 | * degrees | * 210 – 330 | * degrees | * 10 | * dB |
| * Background | * Area out of Zones A, B, C, D, E | | | | * 0 | * dB |

Table B. x2: Open area default parameters

#### B.2.3.4 Urban area



Figure B-5. Urban area sky conditions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Zone | Elevation range | | Azimuth range | | Signal Attenuation | |
| A | 0 - 5 | degrees | 0 - 360 | degrees | Masked | dB |
| B | 5 – 60 | degrees | 210 - 330 | degrees | Masked | dB |
| C | 5 – 60 | degrees | 30 - 150 | degrees | Masked | dB |
| Background | Area out of Zones A, B, C | | | | 0 | dB |

Table B. x2: Open area default parameters

#### B.2.3.6 Asymmetric area

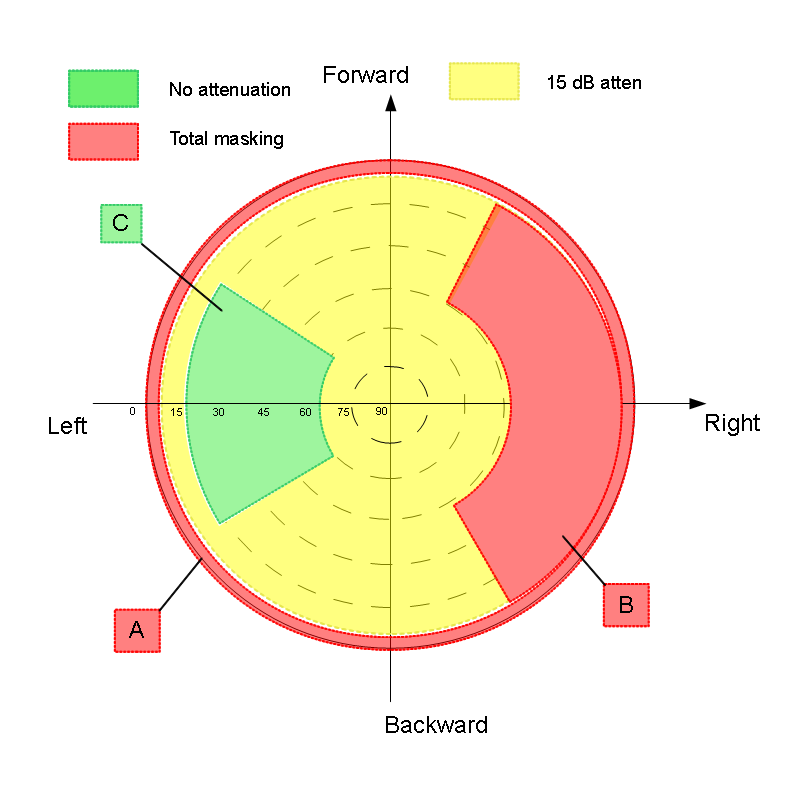


Figure B-6. Assymetric area sky conditions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| * Zone | * Elevation range | | * Azimuth range | | * Signal Attenuation | |
| * A | * 0 - 5 | * degrees | * 0 - 360 | * degrees | * Masked | * dB |
| * B | * 5 - 60 | * degrees | * 30 - 150 | * degrees | * Masked | * dB |
| * C | * 10 - 60 | * degrees | * 230 - 310 | * degrees | * 0 | * dB |
| * Background | * Area out of Zones A, B, C | | | | * 15 | * dB |

Table B. x2: Open area default parameters

#### B.2.3.7 Industrial area



Figure B-6. Industrial area sky conditions

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| * Zone | * Elevation range | | * Azimuth range | | * Signal Attenuation | |
| * A | * 0 – 5 | * degrees | * 0 – 360 | * degrees | * Masked | * dB |
| * B | * 5 – 20 | * degrees | * 210 – 330 | * degrees | * Masked | * dB |
| * C | * 5 – 20 | * degrees | * 30 - 150 | * degrees | * Masked | * dB |
| * D | * 20 – 40 | * degrees | * 30 - 150 | * degrees | * 10 | * dB |
| * E | * 20 – 40 | * degrees | * 210 – 330 | * degrees | * 10 | * dB |
| * Background | * Area out of Zones A, B, C, D, E | | | | * 0 | * dB |

Table B. x2: Open area default parameters

## B.3 Moving scenario description

The diagram below describes a reference trajectory used in clause 5.

Point {0;0;0} is used as reference of the local coordinate system (X,Y), defining an horizontal plane.

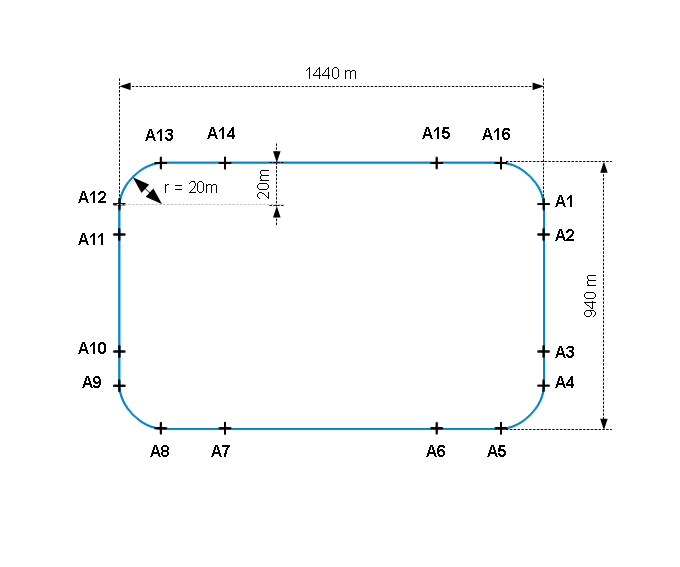


Figure B-7. Mobile target trajectory

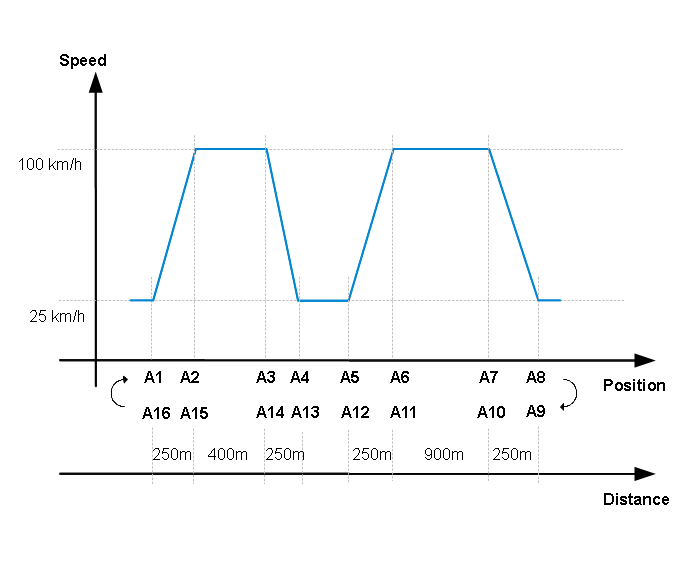


Figure B-7. Mobile target speed profile

# Annex C (normative): Threat scenario for Integrity and Authentication features

## Authentication threat scenarios

This clause described the threat scenario used as reference scenarios for the definition of the minimu performance requirements related to authentication key feature.

### Threat scenarios description

The threat scenarios all consider spoofing attempts on the mobile target GNSS sensor. Such spoofing is executed by the broadcast of an intentional RF signal whose characteristics make it processable by the GNSS sensor, and pushing towards it misleading information.

The misleading information considered concern the pseudo-range domain or the time and position domain.

#### Scenarios pre-conditions

The following pre-conditions apply to the location system:

- location-related information of the mobile target are available

- all tracked GNSS signals are authentic

#### Scenarios chronology

The considered scenarios all follow the chronology depicted in figure D-f1.:

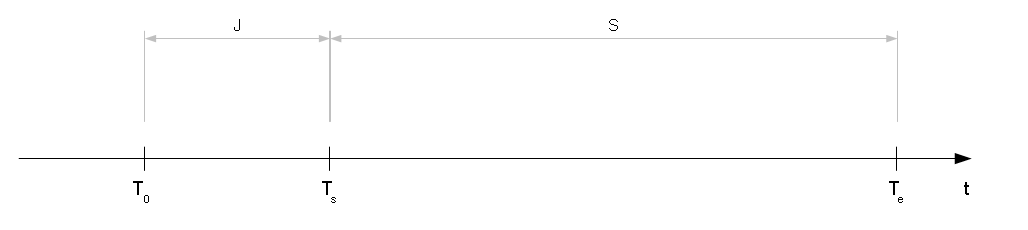


Figure D-f1. Threat scenario chronology

T0 is the start of the scenario

Ts is the time of occurrence of the threat. Duration J is the time elapsed between the scenario start and the occurrence of the threat.

Te is the end of the scenario. Duration S is the time elapsed between the occurrence of the threat and the scenario end.

#### Scenarios parameters

The scenarios are defined by the following list of parameters

- attack classification: it defines classes of spoofing attempts, based on the method used to have the GNSS sensor track the spoofed GNSS signals

- misleading information category: it determines categories of misleading information based on the impact of the spoofing attack on the GNSS sensor output.

- total spoofing power (TSP): it is the sum of signal powers for different spoofing GNSS signals.

, where is the power of the ith spoofed signal at the output of the GNSS sensor antenna.



- target movement: in case the target is moving, it provides the its trajectory and dynamics

The following sub-clause define each of these parameters.

##### Attack classification

Two main classes of attacks are identified based on the method used to have the GNSS sensor track the spoofed GNSS signals. Several spoofed PRNs can be generated. For both classes it is considered that the spoofed GNSS signal(s) is (are) radiated from a single antenna.

- *Direct* spoofed GNSS signal introduction

In this method, the spoofed GNSS signal is generated and radiated towards the GNSS sensor without consideration of the overall context (i.e. sensor position, authentic PRN visibility).

In order to enable the tracking of spoofed PRNs by the GNSS sensor, in case of *direct* signal introduction, an outage of authentic GNSS signals is applied between T0 and Ts.At Ts, the spoofed GNSS signals are radiated towards the GNSS sensor, and the power received by the GNSS sensor is in line with the TSP specified.

- *Shadowed* spoofed GNSS signal introduction

In this method, the spoofed GNSS signal is generated and radiated towards the GNSS sensor so that the correlation peak computed by the GNSS sensor using the spoofed PRN rises in the shadow of the correlation peak computed by the GNSS sensor using the same authentic PRN.

The figure D-f2 illustrates this concept.

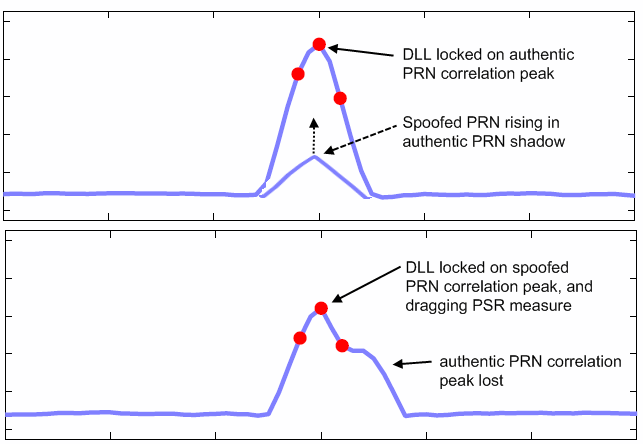


Figure D-f2. Spoofed PRN shadowed introduction

NOTE: It therefore means that GNSS constellation geometry, current GNSS time, and GNSS sensor position are known from the spoofing source in order to estimate the authentic PRN code delay, and that the spoofed PRN correspond to an actually visible authentic PRN.

##### Total spoofing power

The total spoofing power (TSP) is the sum of signal powers for different spoofing GNSS signals.

It is defined as:

[dBW]



where is the power of the ith spoofed signal at the output of the GNSS sensor antenna.



The TSP is variable for each scenario, and used as a metric to measure the location system authentication performance.

##### Misleading information category

The spoofing attacks can cause three types of misleading information at GNSS sensor level:

- erroneous PSR measurement

- erroneous GNSS resolved time

- erroneous GNSS sensor estimated position (for both static of moving scenario).

The following error models are used for each of the above misleading information.

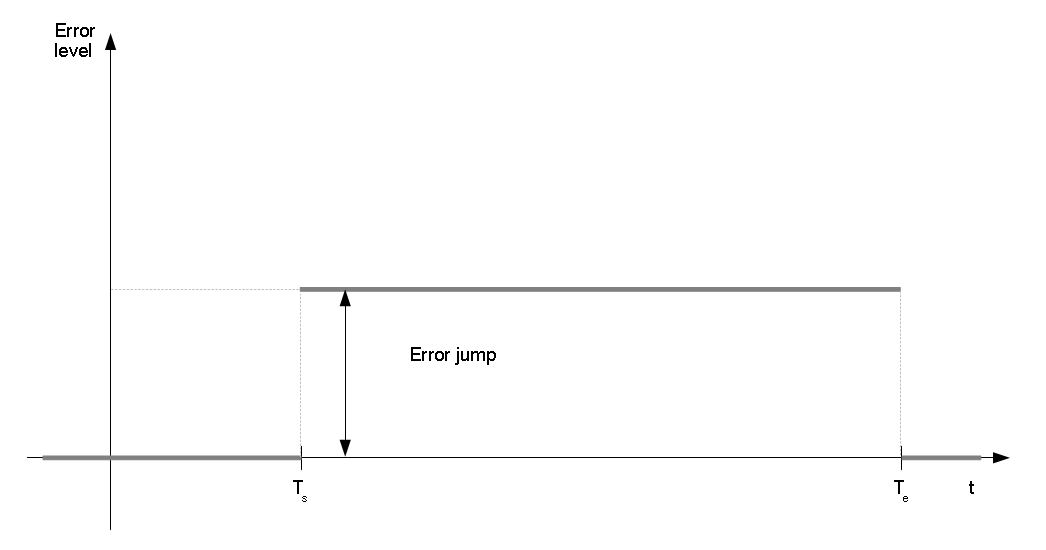
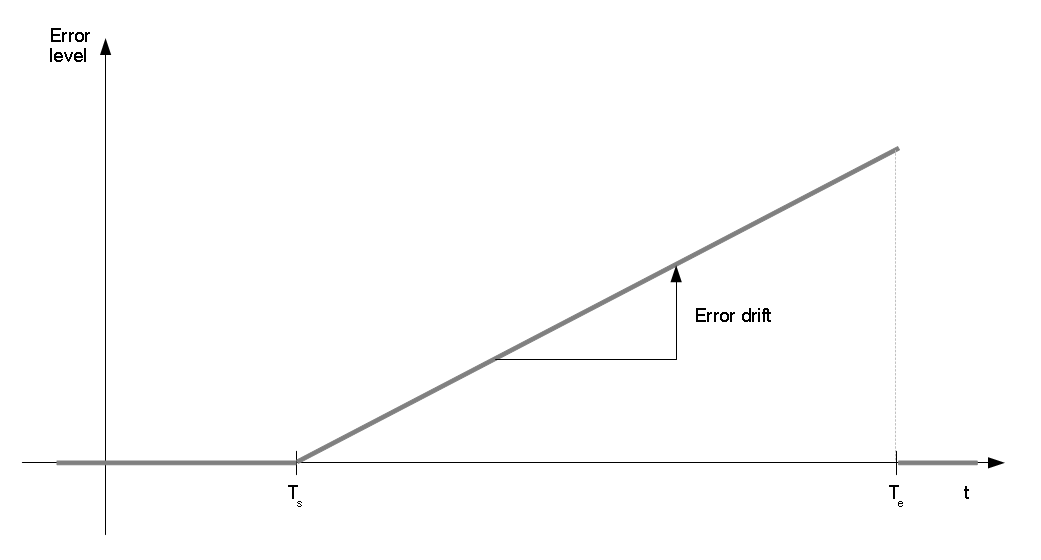


Figure D-f3. Threat scenario error models

These models are applied for each type of misleading information according to table D-t1 below:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Misleading information | Error | Error unit | Jump unit | Drift unit |
| PSR measurement | Pseudorange error | Meters | m | m/s |
| GNSS resolved time | Time delay | Seconds | s | s/s |
| Estimated position | Position error (1) | Meters | m | m/s |

Table D-t1: Misleading information model parameters

NOTE (1): The position error is measured on the across track axis.

The models parameters (jump and drift) are variable for each scenario, and used as a metric to measure the location system authentication performance.

##### Target movement

For use cases where target is moving the following trajectory shall be used.

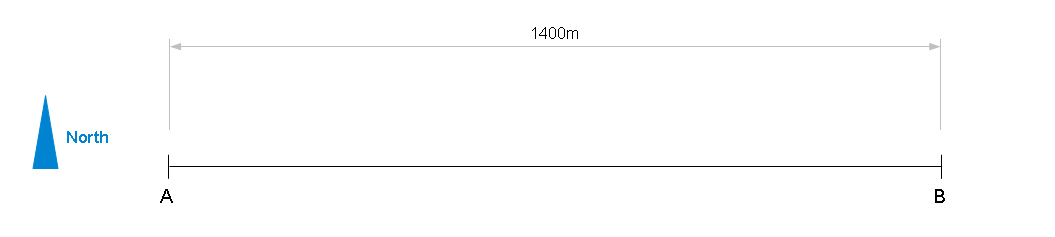


Figure D-f4. Threat scenario trajectory

Point A is crossed at T0, point B is crossed at Te.

The mobile target speed shall be 50 km/h on the entire trajectory.

### Threat scenarios for moving target

The threat scenarios listed in table D-t2 are defined for moving targets.

Pre-conditions defined in clause D.1.1.1 apply.

Trajectory defined in clause D.1.1.3.4 applies

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Scenario identifier | Attack class | Number of spoofed PRNs | TSP range  (dBW) | Misleading information category | Error model | Error value range |
| M-1 | Shadow | P | [tbd | GNSS resolved time | Drift | [tbd-tbd] s/s |
| M-2 | Shadow | 1 | [tbd | Pseudorange measurement | Drift | [tbd-tbd] m/s |
| M-3 | Shadow | P | [tbd | Esimated Position | Drift | [tbd-tbd] m/s |
| M-4 | Direct | P | [tbd | Esimated Position | Jump | [tbd-tbd] m |
| M-5 | Direct | P | [tbd | Esimated Position | Drift | [tbd-tbd] m/s |
| M-6 | Direct | P | [tbd | GNSS resolved time | Drift | [tbd-tbd] s/s |

Table D-t2: Threat scenario for moving target

Number of the spoofed PRNs P is [tbd].

### Threat scenarios for static targets

The threat scenarios listed in table D-t3 are defined for static targets.

Pre-conditions defined in clause D.1.1.1 apply.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Scenario identifier | Attack class | Number of spoofed PRNs | TSP range  (dBW) | Misleading information category | Error model | Error value range |
| S-1 | Direct | P | [tbd-tbd] | GNSS resolved time | Jump | [tbd-tbd] s |
| S-2 | Direct | P | [tbd | Esimated Position | Jump | [tbd-tbd] m |
| S-3 | Direct | P | [tbd | GNSS resolved time | Drift | [tbd-tbd] s/s |
| S-4 | Direct | P | [tbd | Esimated Position | Drift | [tbd-tbd] m/s |
| S-5 | Shadow | P | [tbd | GNSS resolved time | Drift | [tbd-tbd] s/s |
| S-6 | Shadow | 1 | [tbd | Pseudorange measurement | Drift | [tbd-tbd] m/s |
| S-4 | Shadow | P | [tbd | Esimated Position | Drift | [tbd-tbd] m/s |

Table D-t3: Threat scenario for static target

## Integrity threat scenarios

# Annex <X> (informative): Bibliography

The annex entitled "Bibliography" is optional.

It shall contain a list of standards, books, articles, or other sources on a particular subject which are not mentioned in the document itself *(see clause 12.2 of the EDRs* [*http://portal.etsi.org/edithelp/Files/other/EDRs\_navigator.chm*](http://portal.etsi.org/edithelp/Files/other/EDRs_navigator.chm)*)*.

It shall not include references mentioned in the document.

# History

|  |  |  |
| --- | --- | --- |
| **Document history** | | |
| V0.0.1 |  |  |
| V0.0.2 |  |  |
| V0.0.3 |  |  |
| V0.0.4 |  |  |
| V0.0.5 | April 2014 | Modified and commented by STF 474 |
| V0.0.6 | May 2014 | Inputs from TAS etc. |
| V0.0.7 | May 2014 | Previous Annex 5 reinstated and renamed, and further corrections |