BS EN 16803-2:2020



BSI Standards Publication

Space — Use of GNSS-based positioning for road Intelligent Transport Systems (ITS)

Part 2: Assessment of basic performances of GNSS-based positioning terminals

bsi.

Documents
Document Sharing Hub

Full document details: BS EN 16803-2:2020

National foreword

This British Standard is the UK implementation of EN 16803-2:2020.

The UK participation in its preparation was entrusted to Technical Committee ACE/68, Space systems and operations.

A list of organizations represented on this committee can be obtained on request to its committee manager.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2020
Published by BSI Standards Limited 2020

ISBN 978 0 539 01835 6

ICS 33.060.30; 03.220.20; 35.240.60

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 September 2020.

Amendments/corrigenda issued since publication

Date	Text affected

Documents
Document Sharing Hub

Full document details: BS EN 16803-2:2020

EUROPEAN STANDARD **EN 16803-2**

NORME EUROPÉENNE

EUROPÄISCHE NORM September 2020

ICS 03.220.20; 33.060.30; 35.240.60

English version

Space - Use of GNSS-based positioning for road Intelligent Transport Systems (ITS) - Part 2: Assessment of basic performances of GNSS-based positioning terminals

Espace - Utilisation du positionnement GNSS pour les systèmes de transport routier intelligents (ITS) - Partie 2 : Évaluation des performances de base des terminaux de positionnement GNSS

Raumfahrt - Anwendung von GNSS-basierter Ortung für Intelligente Transportsysteme (ITS) im Straßenverkehr - Teil 2: Bestimmung der grundlegenden Leistungen von GNSS-basierten Ortungsendgeräten

This European Standard was approved by CEN on 15 June 2020.

CEN and CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CEN and CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN and CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CEN and CENELEC members are the national standards bodies and national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and United Kingdom.





CEN-CENELEC Management Centre:
Rue de la Science 23, B-1040 Brussels

© 2020 CEN/CENELEC All rights of exploitation in any form and by any means reserved worldwide for CEN national Members and for CENELEC Members.

Ref. No. EN 16803-2:2020 E

AVA Documents Document Sharing Hub

Full document details: BS EN 16803-2:2020

Contents

Page

European foreword 5
Introduction 6
1 Scope 8
2 Normative references 8
3 Terms and definitions 9
3.1 Definitions 9
3.2 Acronyms 10
4 Overview of the whole assessment process 11
4.1 Definition of the general strategy: what kind of tests 11
4.1.1 Rationale 11
4.1.2 Record and Replay choice 12
4.2 Construction of the operational scenarios: how to configure the tests 13
4.2.1 General 13
4.2.2 Basic principles 13
4.2.3 Definition of the operational scenarios 15
4.3 Definition of the test facilities: which equipment to use 20
4.3.1 For the record phase 20
4.3.2 For the replay phase 21
4.4 Description of the record phase: how to elaborate the data sets of the test scenarios 21
4.4.1 General 21
4.4.2 Test plan 21
4.4.3 Test bench preparation and good functioning verification 22
4.4.4 Field test execution 22
4.4.5 Data control and archiving 22
4.5 Replay phase: assessing he DUT performances 24
5 Definition of the metrics 24
5.1 General considerations 24
5.2 Basic notation 25
5.3 Time interpolation procedure 25
5.4 Accuracy metrics 26
5.5 Availability and Continuity metrics 27
5.6 Integrity metrics 32
5.6.1 Definition of the Protection Level performance metrics 32
5.6.2 Definition of the Misleading Information Rate metrics 33
5.7 Timing metrics 34
5.7.1 Timestamp resolution 34
5.7.2 Nominal output latency 34
5.7.3 Nominal output rate 34
5.7.4 Output latency stability 34
5.7.5 Output rate stability 35
5.7.6 Time to first fix 36

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

6 Description of the replay phase: how to assess the DUT performances 37
6.1 General 37
6.2 Checking of the content of the test scenario 37
6.3 Setting-up of the replay test-bench 38
6.4 Validation of the data processing HW and SW by the RF test laboratory 39
6.5 Replaying of the data 39
6.6 Computation of the ACAI performances 42
6.7 Computation of the TTFF performances 42
6.8 Establishment of the final test report 47
7 Definition of the validation procedures: how to be sure of the results (checks) 47
7.1 Definition of the validation 47
7.2 Pass/Fail criteria for the verification of the test procedures 49
8 Definition of the synthesis report: how to report the results of the tests 50
Annex A (informative) Homologation framework 58
A.1 The road value chain 58
A.2 Roles of the different stakeholders 59
A.3 Responsibilities of the different stakeholders 60
Annex B (informative) Detailed criteria for the testing strategy (trade-off) 62
B.1 Main criteria for testing strategy 62
B.2 Metrological quality 62
B.2.1 Reproductibility 62
B.2.2 Representativeness 63
B.2.3 Reliability 63
B.3 Cost efficiency 63
B.3.1 Cost of test benches 63
B.3.2 Cost of the test operations 64
B.4 Clarity in the sharing of responsibilities 64
B.5 Scenario-management authority 64
Annex C (informative) Record and replay testing considerations 66
C.1 General 66
C.2 Experimentation considerations 66
C.3 Equipment justification 68
C.3.1 Equipment for in-field data collection 68
C.3.2 Record and Replay Solutions 71
C.3.3 Recommended equipment 73
C.4 Presentation of a scenario: rush time in Toulouse 74
C.5 Quality of the reference trajectory 76
C.6 Availability, regularity of the DUT's outputs for the metrics computations 77
Annex D (informative) Perspectives on record and replay of hybridized GBPT 79

AVA Documents
Document Sharing Hub

Full document details: BS EN 16803-2:2020

Annex E (informative) Considerations on coordinate systems, reference frames and projections.....84

Bibliography.....87

Documents
Document Sharing Hub

Full document details: BS EN 16803-2:2020

European foreword

This document (EN 16803-2:2020) has been prepared by Technical Committee CEN-CENELEC/TC 5 “Space”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 2021, and conflicting national standards shall be withdrawn at the latest by March 2021.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document has been prepared under a mandate given to CEN and CENELEC by the European Commission and the European Free Trade Association.

According to the CEN-CENELEC Internal Regulations, the national standards organisations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

AVA Documents
Document Sharing Hub

Full document details: BS EN 16803-2:2020

Introduction

The EN 16803 series of CEN-CENELEC standards deals with the use of GNSS technology in the intelligent transport domain and address more particularly the issue of performance assessment.

As recalled in the generic functional architecture of a road ITS based on GNSS, two main sub-systems can be considered: the positioning system (GNSS-based positioning terminal (GBPT) + external sources of data) and the road ITS application processing the position quantities output by the terminal to deliver the final service to the user.

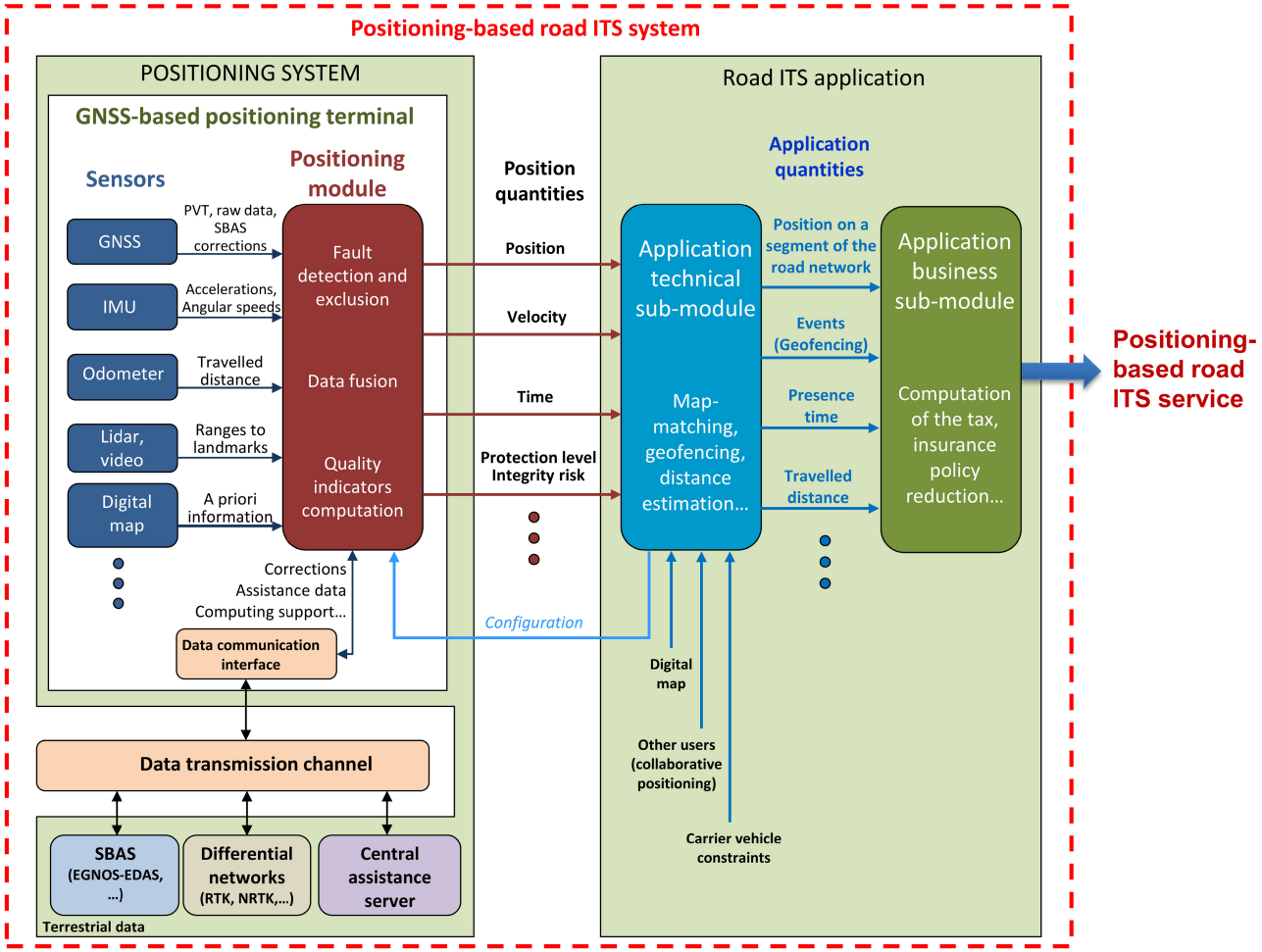


Figure 1 — Generic functional architecture of a Positioning-based road ITS system

This document is the second one of the EN 16803 series.

The performance assessment issue can also be considered at these two levels.

According to Figure 3 in the Introduction of EN 16803-1, the performances of the application cannot be assessed independently from the GBPT and the adequacy of the GBPT's performances to the end-to-end performance of the system cannot be assessed independently from the application. For these two kinds of assessment, the EN 16803-1 standard proposed a method called "Sensitivity analysis". In addition, this first document defined the generic architecture, the generic terms and the basic performance metrics for the Positioning quantities.

EN 16803-1 can be of interest for many different stakeholders but is targeting mainly the ITS application developers.

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

EN 16803-2, EN 16803-3 and EN 16803-4 address specifically the performances of the GBPT itself, as they can be measured by the metrics defined in EN 16803-1:

— EN 16803-2 proposes a test methodology based on the replay in the lab of real data sets recorded during field tests, assuming no security attack during the test.

— EN 16803-3 proposes a complement to this test methodology to assess the performance degradation when the GNSS signal-in-space (SIS) is affected by intentional radio-frequency (RF) perturbations such as jamming, spoofing or meaconing, also applicable to unintentional RF perturbations.

These 2 (two) ENs are targeting mainly the generalist RF test laboratory that will be in charge of assessing the performances of GBPTs for different applications.

EN 16803-4 (in preparation) will propose the methodology for the recording of the real data sets and is targeting mainly the GNSS-specialized test laboratories that will be in charge of elaborating the test scenarios that will be replayed by the previous category of test laboratories.

AVA Documents
Document Sharing Hub

Full document details: BS EN 16803-2:2020

1 Scope

Like the other documents of the whole series, this document deals with the use of GNSS-based positioning terminals (GBPT) in road Intelligent Transport Systems (ITS). GNSS-based positioning means that the system providing position data, more precisely Position, Velocity and Time (PVT) data, comprises at least a GNSS receiver and, potentially, for performance improvement, other additional sensor data or sources of information that can be hybridized with GNSS data.

This new document proposes testing procedures, based on the replay of data recorded during field tests, to assess the basic performances of any GBPT for a given use case described by an operational scenario. These tests address the basic performance features **Availability**, **Continuity**, **Accuracy** and **Integrity** of the PVT information, but also the **Time-To-First-Fix** (TTFF) performance feature, as they are described in EN 16803-1, considering that there is no particular security attack affecting the SIS during the operation. This document does not cover the assessment tests of the timing performances other than TTFF, which do not need field data and can preferably be executed in the lab with current instruments.

"Record and Replay" (R&R) tests consist in replaying in a laboratory environment GNSS SIS data, and potentially additional sensor data, recorded in specific operational conditions thanks to a specific test vehicle. The data set comprising GNSS SIS data and potential sensor data resulting from these field tests, together with the corresponding metadata description file, is called a "**test scenario**". A data set is composed of several data files.

This EN 16803-2 addresses the "**Replay**" part of the test scenario data set. It does not address the "Record" part, although it describes as informative information the whole R&R process. This "Record" part will be covered by EN 16803-4 under preparation.

Although the EN 16803 series concerns the GNSS-based positioning terminals and not only the GNSS receivers, the present release of this document addresses only the replay process of **GNSS only terminals**. The reason is that the process of replaying in the lab additional sensor data, especially when these sensors are capturing the vehicle's motion, is generally very complex and not mature enough to be standardized today. It would need open standardized interfaces in the GBPT as well as standardized sensor error models and is not ready to be standardized. But, the procedure described in the present EN has been designed to be extended to GBPT hybridizing GNSS and vehicle sensors in the future.

This EN 16803-2 does not address R&R tests when specific radio frequency signals simulating security attacks are added to the SIS. This case is specifically the topic of EN 16803-3.

Once standardized assessment tests procedures have been established, it is possible to set minimum performance requirements for various intelligent transport applications but it makes sense to separate the assessment tests issue from minimum performance requirements, because the same test procedure may be applicable to many applications, but the minimum performance requirements typically vary from one application to another. **So, this document does not set minimum performance requirements for any application**.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 16803-1:2016, *Space - Use of GNSS-based positioning for road Intelligent Transport Systems (ITS) - Part 1: Definitions and system engineering procedures for the establishment and assessment of performances*

EN 16803-3, *Space — Use of GNSS-based positioning for road Intelligent Transport Systems (ITS) — Part 3: Assessment field tests for security performances of GNSS-based positioning terminals*

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

3 Terms and definitions

For the purposes of this document, the following terms and definitions.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at http://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

3.1 Definitions

3.1.1
GBPT
GNSS-Based Positioning Terminal
term used to define the component that basically outputs PVT

3.1.2
DUT
Device under Test
term used to define a device that is assessed

Note 1 to entry: In the context of EN 16803-2, DUT refers to GPBT.

3.1.3
test scenario
composed of GNSS SIS data and potential sensor data resulting from field tests, complemented by a metadata description file; a test scenario is a non-empty combination of UTS that allows to assess a GBPT in the desired environments

Note 1 to entry: Data inside a Test Scenario are raw data, either RF signals from GNSS satellites, or raw data from other embedded sensors.

Note 2 to entry: A Test Scenario is the whole package that a GNSS-specialized test laboratory delivers to a Generalist RF test laboratory in charge of performance assessment tests according to the EN 16803 series.

Note 3 to entry: Considering the 6 (six) different environments as defined in EN 16803-1, there's a combination of 2^6 - 1 = 63 possible test scenarios; from let's say "Rural only" test scenario up to "All environment" test scenario that covers the 6 different environments. See 4.2.2 for more details.

3.1.4
Unitary Test Scenario (UTS)
elementary brick of a Test Scenario, resulting from a specific field test; in other words, a Test Scenario is composed of a concatenation of several Unitary Test Scenarios

Note 1 to entry: See 4.2.2 for more details.

AVA Documents
Document Sharing Hub

Full document details: BS EN 16803-2:2020

3.1.5
Uniform Environment Data Set (UEDS)
output of the DUT collected after a replay in laboratory sorted by environment; it is a concatenation of the output of the DUT for all UTS restricted to a unique environment

Note 1 to entry: See 6.4 for more details.

Note 2 to entry: Considering the 6 (six) different environments as defined in EN 16803-1, there is the same number of UEDS; i.e. 6.

Note 3 to entry: Data composing a Uniform Environment Data Set are PVT data, as they are output by a GBPT.

Note 4 to entry: Uniform Environment Data Sets are the data sets to which the metrics shall be applied to assess the performances of the device under test.

3.1.6
GNSS-specialized test laboratory
laboratory in charge of producing Test Scenarios for generalist RF test laboratories

3.1.7
Generalist RF test laboratory
laboratory in charge of assessing the performances of GBPTs thanks to Test Scenario

3.1.8
Benchmark Unitary Test Scenario (B-UTS)
dedicated UTS used specifically for the validation procedure as defined in Clause 7

3.1.9
Benchmark Uniform Environment Data Set (B-UEDS)
each of the UEDS obtained with the benchmark receiver at the GNSS specialised lab (used by the generalist lab to validate their test platform and procedures)

3.2 Acronyms

Acronym	Description
ACAI	Availability, Continuity, Accuracy, Integrity
BPM	Benchmark Performance Metrics
B-UEDS	Benchmark Uniform Environment Data Set
B-UTS	Benchmark Unitary Test Scenario
CDF	Cumulative Distribution Function
DUT	Device Under Test
GBPT	GNSS Based Positioning Terminal
GNSS	Global Navigation Satellite Systems
I/Q	In-phase and Quadrature – I/Q format is an efficient way to store RF signals so that it is possible to reproduce RF signals in laboratory after modulation. I/Q format is the format used to store GNSS signals in UTS
ITS	Intelligent Transport Systems
KML	Keyhole Markup Language

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

Lab-A	GNSS-specialized test laboratory
Lab-B	Generalist RF test laboratory
PVT	Position Velocity and Time
RAMS	Reliability, Availability, Maintainability, and Safety
RF	Radio frequency
R&R	Record and Replay
SIS	Signal In Space: RF signals coming from the GNSS satellites
UTS	Unitary Test Scenario
UEDS	Uniform Environment Data Set
TTFF	Time To First Fix

4 Overview of the whole assessment process

4.1 Definition of the general strategy: what kind of tests

4.1.1 Rationale

Performances and behaviours of GNSS-based positioning terminals not only depend on their design but also, and strongly, on a lot of external situations and parameters, uncontrolled by the stakeholders. Among those parameters, we can quote the status of international worldwide space systems (GNSS), the physical atmospheric conditions, and other environmental conditions in the proximity of the vehicle (buildings in vicinity, traffic, tree foliage, etc.).

As an example, this situation implies that any realization of one field test procedure of a given product at a given date and hour, will give a different result than the same test procedure of the same product in the same location, but at a different date and hour (not stationary stochastic process).

The obvious consequence is that, if a pure field test strategy is targeted as a preferred solution for the performance assessment aiming certification of devices, the analysis of the tests results would require specialists, and may frequently result in intangible and unreliable interpretations, the opposite of metrology.

A solution to avoid this issue is to have a total trust in simulations where all the tests conditions are controlled, and which could be perfectly repeatable. ETSI addressed a similar issue during its standardization process targeting the GNSS based Location Based Services. As a conclusion of its work, ETSI, selected a solution exclusively based on simulations (see [1]).

Considering that the real-life environment remains complex to be simulated, the pure simulation technique will lead to scenarios with a very great number of parameters to be set-up, inducing risk of human manipulation errors, and anyway a remaining lack of true representation of the reality.

A standardized performance assessment process, designed for certification, needs to be unquestionable (undisputable?), repeatable, realistic with respect to the real conditions the GBPT will operate in and cost-effective. Since the reality of all the physical phenomena impacting the behaviour of GNSS receivers is quite impossible to be simulated with mathematical models, but still has a significant impact, the principle of field tests is preferred in this standard to the principle of simulating the GNSS SIS with constellation simulators.

But, in pure field tests where the device under test (DUT) is on-board the test vehicle, this latter is stimulated with various environmental features that remain unpredictable and uncontrolled, rarely reproducible from one run to another and leading to large difficulties to interpret the results.

AVA Documents
Document Sharing Hub

Full document details: BS EN 16803-2:2020

Consequently, the present EN made the choice of "**Record and Replay**" (R&R) technique that combines realism, repeatability and cost effectiveness. R&R technique covers all constellation and all frequencies by allowing recording lower L-Bands and upper L-Bands of GNSS SIS.

4.1.2 Record and Replay choice

The "**Record and Replay**" technique **starts on the field, by recording** of the test data collection according to an agreed scenario. This step shall guarantee a **high-fidelity digitalization of numerous parameters, in particular the capture of radio signals** issued from the worldwide infrastructure (GNSS) in a realistic local environment of propagation. It **ends in the lab to replay as many times as required the same scenario**, using exactly the same radio signal inputs and thus the same environmental conditions of reception.

With respect to pure simulation, the R&R technique offers a better representation of reality since it comes from real situations, but less flexibility of tested situations (rare events are unlikely). The chance to integrate a satellite failure in one recorded test scenario is near to zero. However, as with simulations, a lot of devices can be tested in exactly the same conditions.

With respect to field tests, the R&R technique offers better metrological features since the repeatability can be reached.

It also saves money, since the setup of the test bench for recording is similar to one field test, but the setup of the test bench for replaying is largely less expensive and enables to test a multitude of receivers with less additional cost.

Finally, a very interesting feature of the R&R approach, is that **the interface between the record phase and the replay phase is a repository of files**, offering capabilities like copies and licensing, cut and paste (in smaller files if a customization by application would become necessary as an example…), browse, etc. Today, the amount of data are important for storage techniques (2TB/min of recording) but remains feasible for some hours of recording. It is expected that in few years, improved solution could be available (currently no data compression is used).

Since the record phase needs recognized skills and experience in GNSS metrology, this work shall be performed by **GNSS-specialized laboratories**, ISO/IEC 17025 homologated, and accredited for that job by a certification authority. They shall follow standardized procedures for recording the data sets that shall become themselves **standardized scenarios** that can be replayed by a larger panel of homologated, but not GNSS-specialized, radio frequency (RF) test laboratories.

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

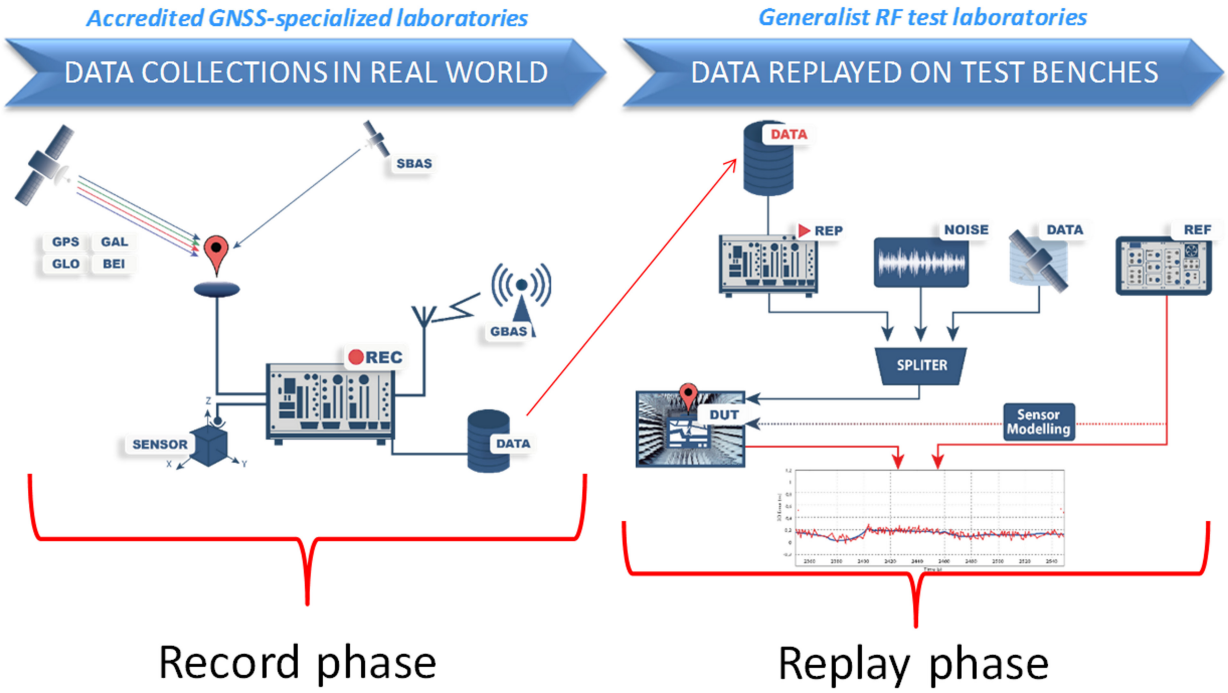


Figure 2 — The "Record and Replay" principle

This feature has a true interest in the worldwide economy. First it enables to make in Tokyo a field test recorded in Paris, or inversely to replay anywhere in Europe and with few expenses a record performed in Shanghai. Moreover, it is interesting, as an additive business model for GNSS, offering a European capability to export standardized data sets towards other regional economies, enabling worldwide competitors to accept and apply the European standards, and even promoting the European methodologies to be extended to world.

4.2 Construction of the operational scenarios: how to configure the tests

4.2.1 General

Foreword: most of this section is informative in the sense that in provides informative material on how to proceed to record a scenario that is compatible with the quality required for high-level standards. This information is necessary to understand the complete R&R process, but this is not the aim of this EN to standardize the record procedure. The record procedure and its quality framework will be totally and precisely described in EN 16803-4 (under preparation).

4.2.2 Basic principles

4.2.2.1 Unique data collection for all the metrics

Availability, continuity, accuracy and integrity shall be evaluated from a Uniform Environment Data Set (UEDS).

The metrics for measuring the GBPT performances with respect to these different performance features are introduced in EN 16803-1 and precisely described in the present document In Clause 5.

These performances are totally linked in the applicative needs, since a position or velocity output can make sense for any application only if it is simultaneously available (declared as valid), accurate (at a certain level), and that we can have trust on it (at a certain level of risk). Therefore, the metrics of the 4 (four) types (except the integrity risk, see 4.2.2.2 below) shall be established on the same data collection campaign.

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

4.2.2.2 Particular case of the integrity risk

The integrity functionality is particularly worthy in safety critical or liability critical operations. Its main interest relies on the ability of detection and of exclusion of positioning process faulty behaviours, caused by unexpected situations (feared events) susceptible to lead with the highest probability (with regard to normal operations) towards an accident (safety) or disputable operations like undue payment (liability).

The purpose is to avoid the propagation in the positioning errors of potential rare events (from sensors, from GNSS particular inputs). The proper behaviour for an integrity-compliant GBPT is to avoid outputting a declared valid position while a positioning error is greater than the protection level and especially greater than the acceptable alarm limit for the critical operation. This proper behaviour, preventing from hazardous misleading information, while unexpected situations are present upstream the process, avoids the propagation of the effects of rare feared events related to the positioning level in further computations.

In this standard, only **nominal** test scenarios are considered, meaning that the test cases are representative of normal conditions, and, for most of them, do not contain (per definition) rare feared events that could lead to very hazardous situations for the application.

If the GBPT provides a protection level (PL), supposed to bound the error on the protected component (e.g. the horizontal position) with a specified target integrity risk (TIR), there will be no problem in measuring the availability and the performance of this PL, e.g. its size, by the corresponding metrics of EN 16803-1.

But concerning the integrity risk (IR), the problematic is quite different since it refers to the behaviour of the GBPT in specific risky operation; So, the other integrity metric concerning the verification of the integrity risk itself (supposed to be lower than the TIR, which is itself very small, of the order of 10^{-4}, 10^{-5} or 10^{-6}), will not be correctly estimated with the replay of the test scenarios for 2 (two) reasons:

1) The feared events have not necessarily been recorded in the scenarios.

2) The number of samples is not high enough for estimating the IR with a good level of confidence.

What will be possible to measure, additionally to the PL size, will be the **misleading information rate (MIR)**, i.e. the ratio of epochs, over the total number of epochs, showing an error greater than the PL. This MI rate can converge toward the IR when the number of samples is high enough, e.g. several days of test, which is not economically acceptable.

Consequently, the test procedures that are described in the EN 16803 series are designed to measure the protection level performance in terms of size, but not the integrity risk. Only the MI rate over the test period, that is not the IR, can be measured, as an indicator of the reliability of the PL.

Other kinds of tests, involving a large number of simulations including some specific feared events, have to be designed for assessing the IR.

4.2.2.3 Same data collection for a flexible list of road applications

This EN standard has been setup to deal with a long list of ITS applications without distinctions. However, the applications can cover local/global areas, slow/high speeds, etc.

While the global set of ITS applications may cover any type of road trips into any type of environment (and even parking), one selected application could require only some specific conditions, like for instance low speed near parking locations, or typical places of virtual gantry, etc.

To cover representatively any road applications, the data set collection shall cover a maximum of different types of road trips, with their typical road environment and motion dynamics:

— long range road transport (transnational deliveries, individual/collective European tourism…);

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

— very short range deliveries (frequent stops);

— quotidian worker journey with typical traffic jam (urban, rural…);

— etc.

More refined descriptions are given in 4.2.3.

4.2.3 Definition of the operational scenarios

4.2.3.1 General

This section recalls the current definition of an operational scenario issued from EN 16803-1, and then makes a proposal for defining the operational scenario to be used for recording the operational data to be replayed for the metrics assessment. This section is just informative and not included in the normative part of this document. The precise definition of the scenarios will constitute the topic of EN 16803-4.

4.2.3.2 Standardized definition of an operational scenario

4.2.3.2.1 General

The definition of the **operational scenario** (cf EN 16803-1:2016, 5.1) is recalled here: *"description of the conditions in which the GNSS-based road ITS system is operating and particularly affecting the GBPT"*.

The operational environment is also important to define the test conditions in which the system's performances and metrics shall be assessed.

As highlighted in the standard EN 16803-1, three sets of parameters would have to be defined in order to accurately describe an operational scenario and subsequent test cases, since they would likely impact the assessed performance metrics:

— the **set-up conditions** of the terminal and of all its sensorial organs (GNSS antenna, inertial measurement unit, odometers, cameras…) conditioning the sensing properties;

— the **trajectory** of the vehicle: its location in the world, and its cinematic impacting the capability to correct or filter any sensor's defaults;

— the **environmental conditions** impacting the sensing measurements.

This general definition applies for any kind of tests.

EN 16803-1:2016, 5.2.1 affirms furthermore that the GNSS reference environments shall be used to interpret test results and to compare results of tests [1)] which are similar but executed at different places. This is the reason why the presentation of the tests results should refer to the high-level categories of GNSS reference environments, as defined in EN 16803-1:2016, 5.2.2. Construction of the test scenarios

The goal of the standard is to characterize the exclusive part of errors imputable to the terminal's processing, when it is operating on the road.

This terminal, when it is in operation or during field tests operates in some environmental conditions, that it undergoes, as well as the systematic errors due to the GNSS infrastructure or due to the atmosphere that are not imputable to it. These environmental conditions are, along the road operations, sometimes favourable and sometimes unfavourable to the GNSS SIS properties, alternatively. Not only those environmental conditions, individually taken, will influence the capability of the GBPT to provide all its potential in terms of AIA performances, but also their changing rates.

1) Not to obtain the data set collection, but to compute the metrics.

AVA Documents Document Sharing Hub

Full document details: BS EN 16803-2:2020

This EN series relies on a pragmatic manner to get a sufficient combinatory of the test conditions, without customization to one or *another final application, by crossing different roads and different kinds of trip*:

— the road selection imposes the GNSS geometry and the propagation channel: it is not possible in field test to change the topology of a road or of its neighbours, so it is important to integrate in the selection of roads a variety of landscapes, and landscape changes impacting visibility and reflection/diffraction effects in the same manner than typical use cases;

— the kinds of trips can impact the kinematic, in particular the proportion and amplitude between low and high speeds, and this factor, mixed with the GNSS environments, will involve alternative best uses between inertial or local vision sensors and GNSS sensors, and consequently stimulating the hybridization systems, and various errors correlation times in the same manner than typical use cases;

— a cross between road selection and nature of trip for the car will naturally cover the range of the positioning errors (up to 95 %) by covering the major part of environmental conditions with effects both on DOPS and on ranging measurements errors;

— no extreme limits of environmental parameters will be looked for, but a preference for worst cases regarding some usual parameters: thus most of the test records shall be done at the end of spring and in the afternoon so that no advantageous effects of foliage and ionospheric delays could be found.

Figure 3 illustrates the philosophy of the test scenarios definition proposed in the EN 16803 series.

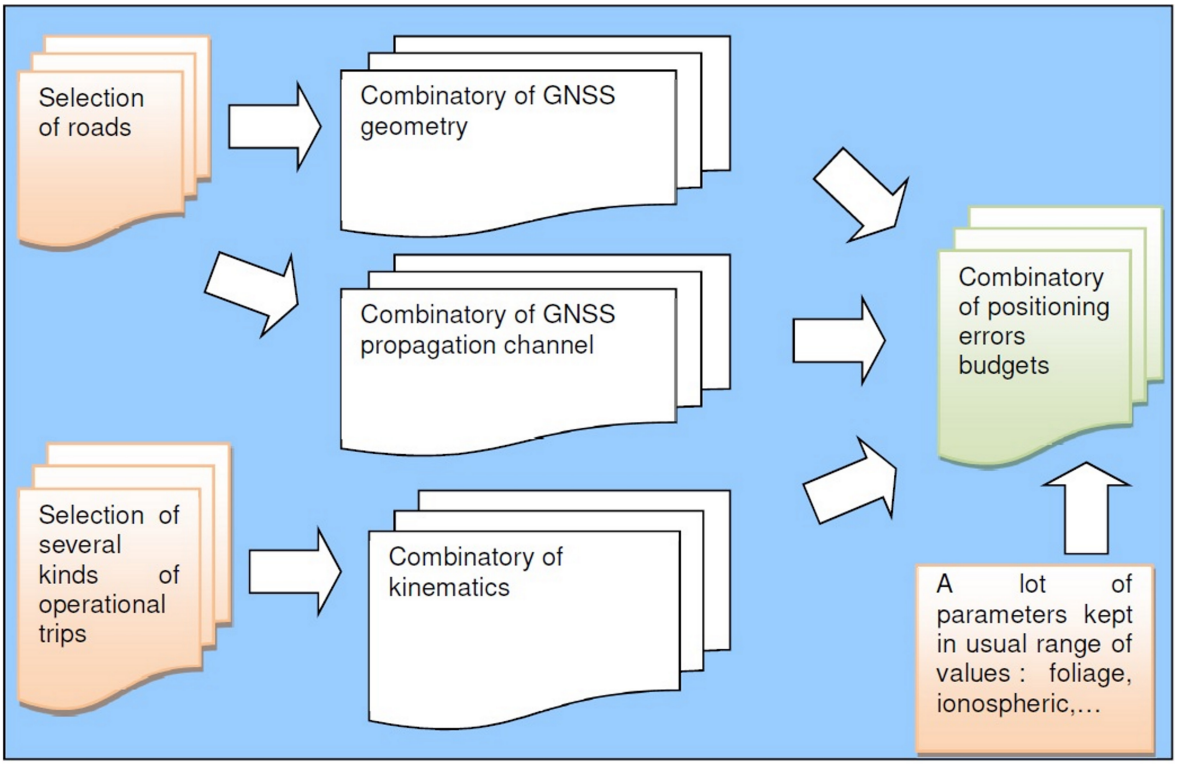


Figure 3 — Methodology to build the combinatory of operational scenarios

4.2.3.2.2 Set-up conditions

The data recording is performed once on each operational scenario, and the recording has to be homologated for being replayed for any other devices. The GNSS antenna (bandwidth, omnidirectional beam, ground plane, noise figure, stability of phase centre…) is not necessarily the GBPT's antenna. In

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

contrary, the GNSS antenna characteristics and the antenna installation shall be carefully selected so that they will not disturb the quality of the broadcast GNSS signal beyond the propagation up to the installation point of the antenna: hemispheric beam, no supplemental masking, no supplemental multipath, no supplemental attenuation… Furthermore, the selected GNSS antenna should preferably be the common source for the reference receiver to validate the R&R data and the Reference trajectory Measurement System (RTMeS).

4.2.3.2.3 Selection of roads

Concerning the trajectories to be used to cover the operational scenarios that may be typically encountered by car's applications, it could be important, to include in the operational scenario a diversity of trajectory situations regarding a number of parameters:

— **Directivity** of roads, linearity/curvatures: several test cases should be differentiated covering as well long regular heading-fixed road and frequent heading changing roads, both for rural environment and in urban environments. Indeed, the variation of the masking of the satellites by the buildings along the street border can be slow for linear streets while it can be quite fast for roads with frequent changes of heading, accentuating the effect of satellite signal reacquisition time in the second case;

— **Declivity** of roads flat/medium slope/long slope/ambiguous altitude: as well for vertical performances, it is important too to get a various topology between flat and mountainous.

Variety exists in the trajectory paths by crossing the two features: directivity and declivity.

4.2.3.2.4 Selection of kinds of trips

Variety exists also in the motion dynamic characteristics. We will consider in this document five typical situations which well identify typical dynamic situations:

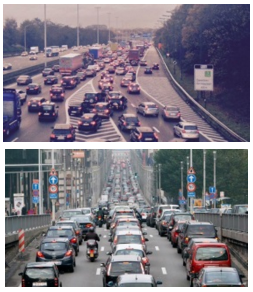
Regular long range	Professional frequent stops	Rush time	Sunday in the city	Sunday in the countryside
				

Figure 4 — Segmentation of trips

— **"Regular long range"**: tourism or international transport on highway from one city to another city. This typical road journey should define a velocity profile with no stop, regular long acceleration from 0 to 100 km/h for start, regular velocity to 100 km/h during a long period (no acceleration except just few velocity changes of short amplitude and duration for traffic adaptation or passing vehicles), regular long deceleration for stop.

— **"Professional frequent stops"**: door to door delivery, urban collective transport. This typical road journey which can apply both in urban or rural (flat or mountainous) will comprise frequent acceleration and deceleration (one each 3 (three) minutes for example) from a medium speed to a stop and inversely. Stops can be present in any GNSS environment, even under a bridge.

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

— **"Rush time and irregular due to traffic"**: suburban to urban parking at rush time. This typical road journey is characterized by an irregular velocity, portions with a mean speed of 35 km/h, with optional stops for traffic lights as an example, and portions with stop/start for few meters and maximum speed at 15 km/h, sometimes high acceleration/decelerations and finally stop in an urban parking near high buildings. Stop for few hours then start again for the return journey, same rush time. it seems important, in particular for specific applications related to safety, to test the performances of the system with speed irregularities: sudden brakes for avoiding a collision, or to respect traffic bulks.

— **"Sunday in the city"**: suburban to urban underground parking. This typical road journey should define a suburban to urban journey, low traffic but stops due to traffic lights.

— **"Sunday in the countryside"**: small roads, regular velocity on small legs, speeds changing due to curvatures or due to urbanization. This typical journey should alternate small roads and medium traffic road in rural or mountainous environment. Minimal mean speed at 25 km/h and maximal mean speed at 75 km/h. normal traffic.

4.2.3.2.5 Crossing selected roads and trips: proposed list of unitary test scenarios

Table 1 — Proposal for a list of unitary test scenarios

UTS ID	Typical trip	Typical duration	List of GNSS reference environments typically encountered along the trip	Typical road topology
A	Regular long range	60 min	Flat Rural Tree Lined Rural Mountainous European Peri-urban	Large highway or national road with long straight lines between large curves, relatively frequent bridges over the road, light long slopes.
B	Professional frequent stops	15 min	Flat Rural Tree Lined Rural	Typically, a scholar bus in the countryside: frequent change of directions, both due to curves and to navigation, essentially in flat area or with slight slopes.
C	Professional frequent stops	15 min	Tree Lined Rural Mountainous	Narrow roads with sharp slopes, and high masks. Typically, a scholar bus in mountainous areas: starts in a mountain pass, with isolated houses, ends in the valley.
D	Professional frequent stops	15 min	European Peri-urban European Urban	Typically, an urban bus line.

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

UTS ID	Typical trip	Typical duration	List of GNSS reference environments typically encountered along the trip	Typical road topology
E	Rush time	15 min	European Peri-urban European Urban	Highway, urban ring road with large curves, frequent bridges over the road, or short tunnels. High traffic jam.
F	Rush time	15 min	Modern Urban Canyon European Urban	Narrow streets in urban canyon and larger streets with high glass buildings. High traffic jam.
G	Sunday in the city	15 min	European Peri-urban European Urban	Typically, the same path than E but when low traffic density is observed as generally on Sunday.
H	Sunday in the city	15 min	Modern Urban Canyon European Urban	Typically, the same path than F but when low traffic density is observed as generally on Sunday.
I	Sunday in the countryside	20 min	Flat Rural Tree Lined Rural	Typically, the same path than B, but longer and without stops.

This table can also be represented with the following figure:

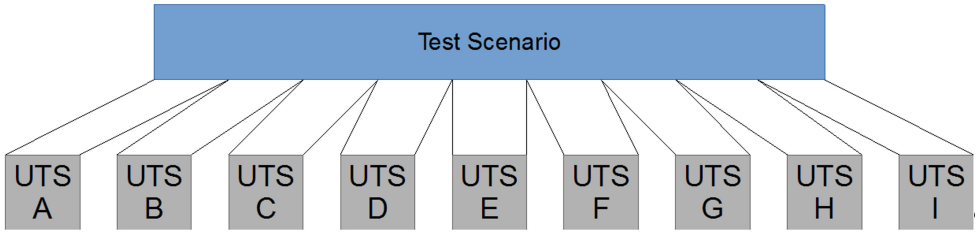


Figure 5 — Composition of test scenarios with UTS

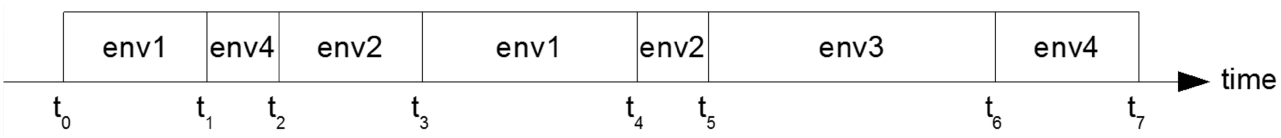


Figure 6 — Example of UTS-A composition

This example of UTS-A contains the 4 (four) "high-level categories of GNSS reference environments" (from env1 to env4 as defined in Table 1 and Table 2). Separation times (ti) between each environment shall be provided by the Lab-A.

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

Table 2 — Environment coverage according to UTS

Environments	UTS A	UTS B	UTS C	UTS D	UTS E	UTS F	UTS G	UTS H	UTS I	UTS Concatenation
env1 Flat Rural	yes	yes							yes	A-B-I
env2 Tree Lined Rural	yes	yes	yes						yes	A-B-C-I
env3 Mountainous	yes		yes							A-C
env4 European Peri-urban	yes			yes	yes		yes			A-D-E-G
env5 European Urban				yes	yes	yes	yes	yes		D-E-F-G-H
env6 Modern Urban Canyon						yes		yes		F-H

4.3 Definition of the test facilities: which equipment to use

4.3.1 For the record phase

The data sets of the scenarios shall be recorded on-board of a dedicated test vehicle. This test vehicle shall offer specific features that will be described in detail EN 16803-4. The most important ones are listed below:

— The capability to embed a GNSS SIS recording device, also called “Bit grabber”.

— The capability to embed a reference GNSS antenna mounted on the roof of the vehicle in an optimal set-up (no masking, no multipath).

— The capability to embed an RTMeS, which shall provide a better accuracy/availability than the DUT, of at least one order of magnitude.

— The capability to embed a Benchmark test receiver, as defined in EN 16803-1:2016, 5.2.3.2, necessary to measure the Fine environment characterization metric, as defined in EN 16803-1:2016, 5.2.3.3, and to apply the validation procedure, described later in this document in Clause 7. This benchmark receiver shall be able to output PVT data and raw measurements (at least pseudo-ranges). [2)]

— The capability to embed a video system using a frontal camera, to record images of the environment.

2) Comparison between recorded PVT and PVT obtained by replaying the SIS data into the benchmark receiver can be used by the GNSS-specialized laboratory to validate its own replay procedure.

AVA Documents Document Sharing Hub

Full document details: BS EN 16803-2:2020

— The possibility to access to internal data of the vehicle (e.g. CAN bus) and/or to install additional sensors (e.g. wheel odometer) for the measurement of the travelled distance.

4.3.2 For the replay phase

This part will be described with more details in Clause 6. This phase shall be realized by a generalist RF test laboratory. This laboratory shall provide the following features:

— The capability to re-build SIS from I/Q database logged with the GNSS SIS recording device mentioned in the previous paragraph and provided by the accredited GNSS-specialized laboratory.

— The capability to apply these re-built SIS to a DUT whatever the GNSS interface of the DUT. If the DUT has an external GNSS antenna connector, it shall be preferred a conducted way to replay SIS. If the DUT has no external connector (i.e. internal antenna), an anechoic chamber shall be used to radio-broadcast the SIS.

— The capability to log and analyse the PVT output from the DUT by following this current standard and by using the ground truth trajectory provided by the accredited GNSS-specialized laboratory.

— The capability to set the device in such a mode that TTFF test can be performed.

4.4 Description of the record phase: how to elaborate the data sets of the test scenarios

4.4.1 General

The record phase aims at recording the data sets that will constitute, together with the meta-data describing the test, the standardized test scenario. It shall be followed once, unless some problem necessitates repeating it. It is briefly described in this EN for information but will be more precisely defined in EN 16803-4 under preparation.

The laboratory applying this procedure shall be a high skilled team in GNSS possessing an agreement granted by the convenient national/European road authorities, recognizing both the GNSS competency and the lab's quality assurance management (type ISO/IEC 17025). In addition, a regular inspection of data aresued by the lab for this stage shall be done by the authorities before enabling the transmission of the data sets to generic laboratories or manufacturers in charge of the performance assessments of commercial devices.

Once actors are authorized to proceed, the field tests campaign for recording the data (GNSS SIS + additional sensors + RTMeS + benchmark receiver) in the retained operational scenario can be broken down into 4 (four) successive steps:

1) test plan establishment;

2) test bench preparation and good functioning verification;

3) field test execution;

4) data control and archiving.

4.4.2 Test plan

This first step integrates four activities:

— campaign plan elaboration and documentation;

— key personal allocation;

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

— test bench inventory;

— test sheets preparation.

4.4.3 Test bench preparation and good functioning verification

Before starting the test campaign, the laboratory in charge of the test shall perform a “dry run” in order to:

— control all testing procedures, going from setups to results and including data analysis,

— check before any operation all piece of the instruments having a significant effect on the accuracy or integrity of measurements.

4.4.4 Field test execution

The execution of the data campaign shall be performed in a very methodological way.

A “Vehicle Safety Checklist” and a “Driver Safety Declaration” shall be filled in by the driver.

A “Mission report” shall be filled in at the end of every journey mentioning all the relevant information affecting the route (e.g. traffic jams, car stalling, route variations due to traffic diversions, etc.).

4.4.5 Data control and archiving

4.4.5.1 General

This last step integrates four activities:

— field test data archiving;

— reference trajectory elaboration;

— segmentation of the data with respect to the environment;

— validation of data by replay on the Benchmark receiver.

4.4.5.2 Field test data archiving

Specific procedures, approved with the quality manager, have to be applied to protect the collected data. These procedures take into account the integrity of the data collected, their storage, their transfer and treatments.

4.4.5.3 Reference trajectory elaboration

The data recorded from the RTMeS shall be processed in order to elaborate the reference trajectory that will be used to compute the errors experienced by the DUT and the metrics.

Documented verification procedures shall be applied and reported to assess the quality of the reference trajectory and to check that it is compatible with the expected accuracy of the DUT.

4.4.5.4 Segmentation of the data with respect to the environment

The in-file data have been recorded along field test performed on a selection of roads. Selecting these roads, a mix between different GNSS reference environments has been coarsely selected.

Most of the time, the performance assessment of GBPT in the context of road transport has to take into account the environment in which the GBPT will operate (cf. 4.2.2.1). Consequently, the time periods of the recorded data files corresponding to such and such environment shall be provided together with the data, in order that the generalist RF laboratory that carries out the Replay phase is able to separate the

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

PVT data output by the DUT according to this time periods and compute the metrics respectively to the different environments.

To do so, the GNSS-specialized laboratory producing the scenarios shall:

— apply to the collected data of each scenario a standardized segmentation procedure (that will be included in EN 16803-4 under preparation). This segmentation procedure can be based upon several complementary signal, processing methods (Fine environment characterization metric as per EN 16803-1:2016, 5.2.3.4, characteristics of the recorded signal to noise density (C/N0) from the GNSS receiver of the RTMeS, analyses of the recorded videos, etc.);

— deduce from this procedure location and/or time filters enabling to differentiate the different high-level categories of environments, for each scenario:

— *{[Tbegin11..Tend11], {[Tbegin12..Tend12],...., {[Tbegin1n1..Tend1n1] defines the time filter to be applied to the DUT positioning outputs in order to compute the metrics and defines the DUT class for the "**Flat rural**" environment*

— *{[Tbegin21..Tend21], {[Tbegin22..Tend22],...., {[Tbegin2n2..Tend2n2] defines the time filter to be applied to the DUT positioning outputs in order to compute the metrics and defines the DUT class for the "**Tree-lined Rural**" environment*

— *{[Tbegin31..Tend31], {[Tbegin32..Tend32],...., {[Tbegin3n3..Tend3n3] defines the time filter to be applied to the DUT positioning outputs in order to compute the metrics and defines the DUT class for the "**Mountainous**" environment*

— *{[Tbegin41..Tend41], {[Tbegin42..Tend42],...., {[Tbegin4n4..Tend4n4] defines the time filter to be applied to the DUT positioning outputs in order to compute the metrics and defines the DUT class for the "**European peri urban**" environment*

— *{[Tbegin51..Tend51], {[Tbegin52..Tend52],...., {[Tbegin5n5..Tend5n5] defines the time filter to be applied to the DUT positioning outputs in order to compute the metrics and defines the DUT class for the "**European urban**" environment*

— *{[Tbegin61..Tend61], {[Tbegin62..Tend62],...., {[Tbegin6n6..Tend6n6] defines the time filter to be applied to the DUT positioning outputs in order to compute the metrics and defines the DUT class for the "**Modern Urban canyon**" environment*

— Computes the total time duration of each filters and verify its compliance with the general requirement declined in the present document - 4.2.2.2.4.

4.4.5.5 Validation of data by replay on the Benchmark receiver

The objective of this procedure is to validate the correct functioning and the consistency of all the R&R process by comparing the PVT data output in real time by the Benchmark receiver to the PVT data output by the same Benchmark receiver when the recorded data files are replayed and injected into it in the lab.

This comparison shall be done at the position or velocity signal level, but also at the metrics level. That is to say that some specific metrics (i.e. horizontal position accuracy, speed accuracy, to be defined in EN 16803-4 under preparation) shall be applied to both PVT data and standardized distances between both results shall be applied to check that the deviations between them do not exceed a given threshold.

These results will be included inside the test scenario and shall be used by the generalist RF laboratory for applying its own validation procedure, detailed in Clause 7 of this document.

Documents
Document Sharing Hub

Full document details: BS EN 16803-2:2020

4.5 Replay phase: assessing he DUT performances

This subclause is closing the overview of the whole assessment process. The final step is to test the GPBT or the DUT thanks to all the previous elements. This replay phase could be broken down into the following steps that will be detailed in Clause 6:

— checking of the content of the test scenario: step needed to verify that data can be used by RF test laboratory;

— setting-up of the replay test-bench: step needed to prepare the test-bench accordingly to the GPBT to assess;

— validation of the data processing HW and SW by the RF test laboratory: step needed to verify that test-bench (hardware and software) are fully operational;

— replaying of the data: step during which the GPBT is computing its outputs;

— computation of the ACAI performances: offline step during which ACAI metrics of the GBPT are computed;

— computation of the TTFF performances: offline step during which timing metric of the GBPT are computed;

— establishment of the final test report: final step of the assessment procedure.

5 Definition of the metrics

5.1 General considerations

In what follows, the mathematical definitions of the metrics used to evaluate the GBPT performance are presented. The aforesaid performance metrics are the ones established in EN 16803-1.

The definitions given in EN 16803-1 are of a statistical nature in most cases (e.g. making use of concepts such as statistical distributions and their percentiles). As such, they refer to random variables (e.g. horizontal position error may be considered as a random variable whose statistical distribution is the object under analysis). The goal of the metrics and the test procedures is to characterize these random variables from a statistical point of view for a given GBPT and a variety of scenarios. However, the true statistics of these random variables can never be known exactly, but only estimated by means of statistical sampling. Each time a test is carried out, a statistical sample is obtained which provides an estimate of the true statistical parameters of the random variable at hand. If the test is properly conducted and the amount of gathered data are large enough, then the estimated statistics will be rather close to the real ones.

The mathematical procedures described hereafter provide estimates of statistical parameters based on data gathered through testing, and hence differ from the theoretical definitions given in EN 16803-1 in that they refer to (finite) samples of random variables and not to the (true) random variables themselves. An example of this nuance is the difference between the mean of a random variable (or a population) and the sample mean: the latter is an estimate of the former, used for practical purposes when the former cannot be known. The same applies to other statistical parameters such as the variance, the higher order moments or the percentiles of a random variable's distribution.

The presented procedures and formulas also address practical aspects such as the fact that the reference data (i.e. the data provided by the reference trajectory measurement equipment (RTMeS), which is assumed to measure the true trajectory of the test vehicle) and the GBPT data are not necessarily synchronised (i.e. reference data may refer to different time instants from those to which GBPT output

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020

refers), hence requiring interpolation of one of the 2 (two) data sets to the time instants which the other one refers to.

As far as possible, metrics and their computation procedures will be described in terms of generic output parameters. For instance, accuracy metrics may refer to a variety of different output parameters (such as heading, cross track position or horizontal speed, to mention just a few), all of which would be computed following identical processes and using identical formulas, and hence can be treated at once with a single formulation that makes use of a generic variable which may be considered to represent any of them.

5.2 Basic notation

Unless otherwise specified, the following notation will be used: let *X* be a parameter of interest with regard to the computation of the metrics. Note that *X* can be a raw output of the GBPT, such as the horizontal protection level, or can be the result of applying some transformation to an output of the GBPT (or of the RTMeS), such as expressing the GBPT position output in the local horizontal reference frame of the reference position, and then, perhaps, taking the norm of its horizontal component. *X* (*t*) shall denote the value that the parameter *X* takes at a specific time instant *t*. Subscripts *G* and *R* shall be added to refer to the parameter at hand as provided by the GBPT and by the reference (ground truth) equipment respectively, so, for instance, X_G shall denote the output parameter *X* as provided by the GBPT and $X_R(t)$ shall denote the value of *X* provided by the RTMeS at time *t*. When a parameter's value is obtained by interpolation (e.g. because no data exists at the time instant of interest for that particular parameter), then an upper horizontal bar shall be added, as in $\overline{X}_R(t)$, which denotes the value obtained by interpolating at *t* the time series X_R (that is, the time series of *X* as provided by the RTMeS).

It is noted that reference data, in order to be used as the truth, shall be much more accurate than GBPT output data. Accuracy figures at least one order of magnitude better (i.e. error figures at least 10 times smaller) that those expected from the GBPT shall be targeted for the RTMeS.

Whenever interpolation is required in order to bring GBPT and reference data to a common time basis, the reference RTMeS data shall be interpolated to the time of the GBPT data rather than the converse. Interpolation shall never be applied to GBPT output data as that would distort the information about its instantaneous error.

Throughout the forthcoming sections, X_G shall refer to the sample of the output parameter *X* as provided by the GBPT, obtained by running one of the Uniform Environment Data Set (UEDS) identified in EN 16803-2. Likewise, X_R shall refer to the sample of *X* as provided by the RTMeS during the same test case run. Hence, all metrics' computation procedures described hereafter are to be applied to individual test cases (e.g. one value of accuracy at 95 % is to be obtained for each test case, rather than a global value that considers the data gathered through all test cases). Some procedures (e.g. those associated to time-to-first-fix determination) may not be applicable to all test cases, but only to a subset of test cases specifically designed for the purpose.

5.3 Time interpolation procedure

Let $\tau_G = \{t_1, t_2, \ldots, t_n\}$ (with $t_i < t_j$ for each $i < j$) be the collection of time instants for which the time series X_G is defined. Likewise, let $\tau_R = \{S_1, S_2, \ldots, S_m\}$ (with $s_i < s_j$ for each $i < j$) be the collection of time instants for which the time series X_R exists.

Documents
Document Sharing Hub
Full document details: BS EN 16803-2:2020