SLOVENSKI STANDARD
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Vesolje - Ugotavljanje položaja z uporabo sistema globalne satelitske navigacije (GNSS) pri inteligentnih transportnih sistemih (ITS) v cestnem prometu - Opredelitev terenskih preskusov za osnovno zmogljivost

Space - Use of GNSS-based positioning for road Intelligent Transport Systems (ITS) - Field tests definition for basic performance

Definition von Feldtests für Grundleistungen

Espace - Utilisation de la localisation basée sur les GNSS pour les systèmes de transport routiers intelligents - Définition des essais terrains pour les performances générales

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Definition von Feldtests für Grundleistungen

This Technical Report was approved by CEN on 23 February 2020. It has been drawn up by the Technical Committee CEN/CLC/JTC 5.

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European foreword

This document (CEN/TR 17465:2020) has been prepared by Technical Committee CEN/TC 5 “Space”, the secretariat of which is held by DIN.

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1 Scope

This document is the output of WP1.2 “Field test definition for basic performances” of the GP-START project.

The GP-START project aims to prepare the draft standards CEN/CENELEC/TC5 16803-2 and 16803-3 for the *Use of GNSS-based positioning for road Intelligent Transport Systems (ITS). Part 2: Assessment of basic performances of GNSS-based positioning terminals* is the specific target of this document.

This document constitutes the part of the Technical Report on *Metrics and Performance levels detailed definition and field test definition for basic performances* regarding the field tests definition.

The purpose of WP1.2 is to define the field tests to be performed in order to evaluate the performances of road applications’ GNSS-based positioning terminal (GBPT). To fully define the tests, this task addresses the test strategy, the facilities to be used, the test scenarios (e.g. environments and characteristics, which should allow the comparison of different tests), and the test procedures. The defined tests and process will be validated by performing various in-field tests. The defined tests focus essentially on accuracy, integrity and availability as required in the statement of work included in the invitation to tender.

This document will serve to:

- the consolidation of EN 16803-1: *Definitions and system engineering procedures for the establishment and assessment of performances*;
- the elaboration of EN 16803-2: *Assessment of basic performances of GNSS-based positioning terminals*;
- the elaboration of EN 16803-3: *Assessment of security performances of GNSS-based positioning terminals*.

The document is structured as follows:

- Clause 1 is the present Scope;
- Clause 5 defines and justifies the global strategy for testing;
- Clause 6 defines and justifies the retained operational scenario;
- Clause 7 defines the metrics and related tools;
- Clause 8 defines the required tests facilities;
- Clause 9 defines the tests procedures;
- Clause 10 defines the validation procedures;
- Clause 11 defines how to report the tests results.

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*

3 Terms and definitions

No terms and definitions are listed in this document.

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/

4 List of acronyms

- GNSS Global navigation satellite system
- GPS Global positioning system
- SBAS Satellite based augmentation system
- COTS Commercial on the shelves
- GBPT GNSS based positioning terminal
- OTS On the shelves
- ITS Intelligent transport systems
- ETSI European telecommunications standards institute
- A-GNSS Assisted GNSS
- FAR False alarm rate
- PFA Probability of false alarm
- PMD Probability of miss detection
- PPK Post processing kinematic
- AIA Accuracy, integrity, availability
- SW Software
- LoS Line of Sight

5 Definition of the general strategy: what kind of tests?

5.1 General

The technical solutions for ITS (road environment), focused in the targeted standard, are more and more complex.

One consequence is that their performances and behaviours will no more only depend on their design but also, and strongly, depend on a lot of external situations and parameters, uncontrolled by the stakeholders. Among those parameters, we can quote the dependencies on the status of international worldwide space systems (GNSS), on physical atmospheric conditions, and other environmental conditions in the proximity of the vehicle (traffic, tree foliage, buildings in vicinity 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 at a different date and hour (neither ergodic nor 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 homologation 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 (See ETSI TS 103 246-1, −2, −3, −4, −5). As a conclusion of its work, ETSI, selected a solution exclusively based on simulations (see Annex A).

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 representation of the reality.

New paradigms have to be seriously considered, and this Clause 5 aims to open solutions by analysing the best way to select and phase the tests to be performed in a standardized performance assessment.

5.2 GBPT characterization

5.2.1 An hybrid and heterogenic system

According to Figure 3 of (see EN 16803-1), Positioning-based road ITS system is the integration of the GBPT into the road ITS application. Moreover, GBPT is presented also as a complex assembly of sensors, with multiple interfaces with external systems.

The positioning level, focused in this part of document for the definition of tests, is still an assembly of more or less complex components where at least one (1) component is a GNSS sensor.

The generic architecture of a Road ITS system ((EN 16803-1), Figure 4) shows directly that the evaluation of the metrics related to the positioning (accuracy, integrity, availability) will be complex, since it:

- covers intermediate outputs (position, speed) of a global integrated system, likely not easy to capture in some future finally packaged and installed products: *specific prescriptions and communication protocols should be standardized*;

- *depends on worldwide and independently evolving infrastructures*, namely GNSS infrastructure and telecommunication networks, interacting each other's (Assisted, Differential GNSS) and with the system itself, and in particular influencing strongly its performances;

- covers *sensing of the external environment*[1] and consequently *depends on a huge number of external environmental conditions* (radio propagation for GNSS and telecommunications, light, fog and dust for cam and LIDAR, etc.);

- covers in the same time *sensing of the motion of the vehicle*[2] through odometers and inertial sensors and consequently depends on the vehicle and its driving as well as additional external environmental conditions (ex: meteorological, or road-holding for odometer).

In EN 16803-1:2016, Clause 8 presents a long (even if not exhaustive) list[3] of parameters which should impact the definition of the tests.

Synthesizing together, namely in an integrated lab test facility, the effects of worldwide radio infrastructures (as existing currently or evolving in the future), their local radio propagation in road environment, the motion sensing by inertial sensors, and others phenomena like climatic for odometer or imaging for computer vision is today unfeasible.

Today, the lab facilities for making tests in the environmental conditions interesting each sensor exist separately but are never integrated.

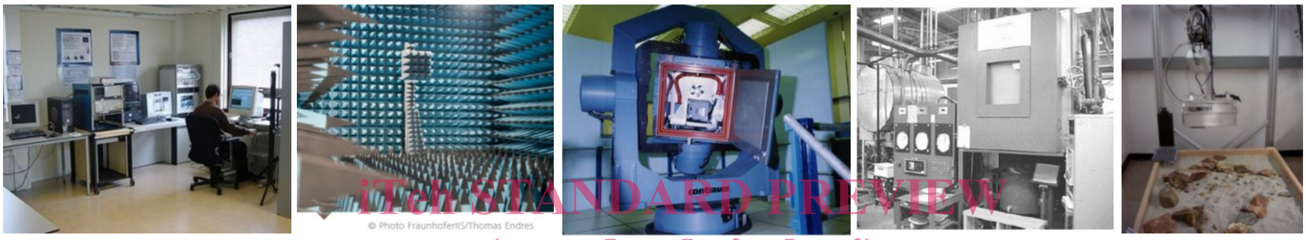

Figure 1 — Typical test bench in laboratories facilities

Left to right: GNSS signal generation (ESA radio navigation lab), radio oriented for radio navigation or telecommunications, motion oriented and climatic oriented for inertial sensors (AIAA 092407), computed vision oriented (JPL robotics facilities)

However, techniques like fusion of sensors and data (e.g. maps) appear more and more mandatory to leverage the potential of automotive applications and businesses, considering the weakness of the GNSS signals propagation environments.

5.2.2 Test combinatory explosion: an issue

It is the purpose of sensor fusion to make each sensor impacting (improving is expected) the performances of the hybridized solution. However, each sensor has two (2) types of errors:

- principles: imperfections of the used physic law modelling the real world (ex: the GNSS propagation is line of sight, except when refraction like in ionosphere or reflection like multipath are encountered, accelerometer measuring only the sum of motion acceleration and gravity, etc.);

- measures: imperfections in the design and manufacturing (ex: bias and scale factors in inertial sensors, thermal noise in electronic, etc.).

[1] Also called ‘exteroceptive’ sensors: GNSS sensors, cam, LIDAR measure physical phenomenon of their extern environment to deduce location data, to be compared to eyes, nose, (…) on the animals.

[2] Also called ‘proprioceptive’ sensors: inertial units, odometer measure physical parameter changes due to motion in order to deduce location data, to be compared to sensors belonging to muscles on the animals.

[3] In particular when the performances of other sensors than GNSS are considered – required for hybridized systems.

By capturing information from a lot of parameters of the external environment or from the motion, and because many physical principle errors of the measurements exist in the reality, the sensor fusion multiplies also the risks of performance degradations. A strict performance assessment should consequently measure the performances in any combination of favourable/unfavourable conditions for good measurements, sensor by sensor. For GBPT, these combinations are still to be combined to the multiplicity of the road usages, road environment varieties, and finally combined with the multiplicity of installation and set-up in the vehicles. There are then a so vast set of possible combinations that it becomes incredible to build reliably and exhaustively the list of the necessary test scenarios covering correctly the computation of performance metrics.

This combinatory explosion affects as much the lab tests in terms of facilities and scenario diversity, as the field tests or the simulation techniques, where, in addition, some of the physical effects are very complex to model representatively.

This implies that experimenting field tests (where the sensors capture during each test one true representation of the real life, namely one instance at a given instant and in a given location of all of the parameters which control the GBPT performances) provide a unique and not reproducible representation. This representation is thus unable to provide, on one test, whatever its length, a total characterization of the statistical properties (like expected in the metric definition).

In this sense, GMV experiment on Madrid (TR WP1/D1) illustrated that very well: 12 samples of a similar procedure (same location) have been run giving 12 separate cumulated distributive functions of the accuracy metric:

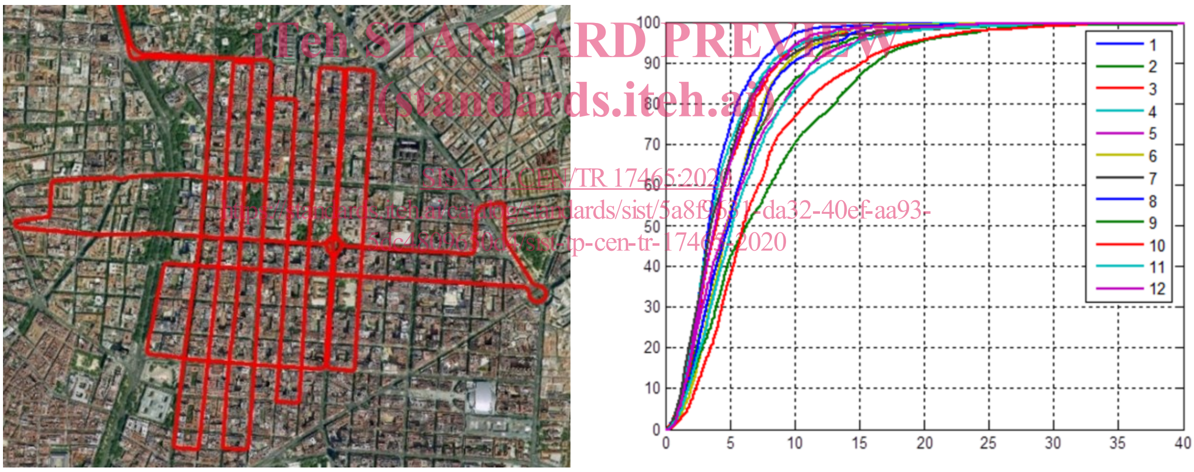

Figure 2 — Diversity of field tests results [TR WP1/D1]

This experiment shows that the metric itself, as assessed by field tests, becomes a random function, with a significant dispersion and that the field test proposition gives a non-ergodic random process, preventing to become the best solution for the selected metric assessment.

A more practical approach should then be agreed in the standard, preventing useless, unreasonable testing effort and costs.

The combinatory explosion finally prevents an exhaustive coverage by the metrics of all environmental situations impacting the performances.

5.2.3 Proposed approach

In EN 16803-1, the standardization working group has already and clearly separated the performance of the application in two (2) layers:

- the positioning level with the GBPT;

- the ITS application level.

The described previously problematic necessitates to propose an additional breakdown in several sub-problematics.

The proposed approach to deal with the GBPT (hybridized systems) performance assessment through testing is to impose a dichotomy between additive sensors (supplemental with respect to geolocation) and primary sensor (GNSS) and positioning solution, as identified on the Figure 3.

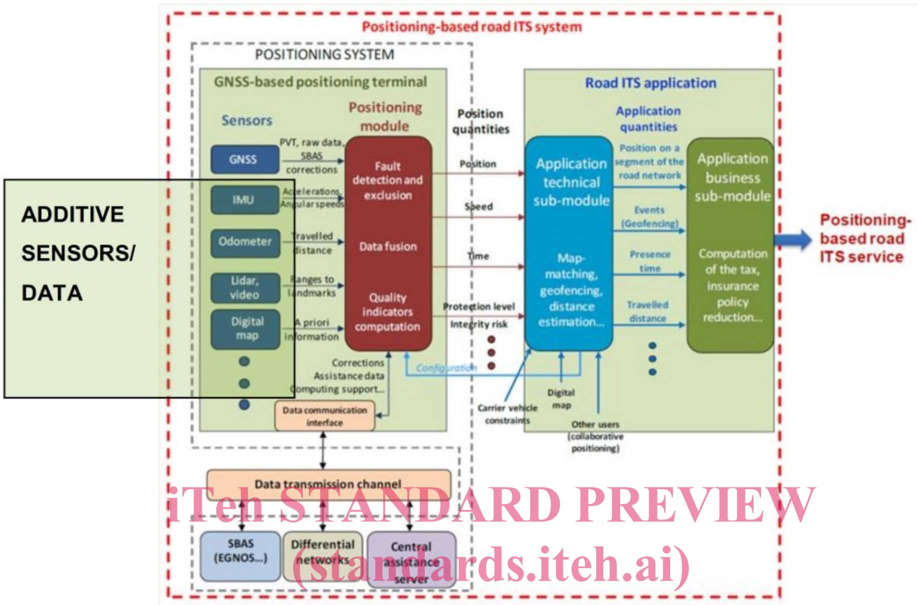

Figure 3 — Proposed approach for the testing requirements

It should thus be retained for the future ITS applications a gradual verification and homologation process.

This process could support three assessment levels:

- additive sensor level:
  - o separately, inertial sensors, odometer, vision sensors should be evaluated in terms of performance, with their own metrics (e.g. measurement errors on ranges to the landmarks for LIDAR, video, opening range[…], accelerometers biases, gyro drift, etc.);
  - o at their manufacturing level;
  - o covering, for example with lab tests, quasi exhaustively the specific environmental conditions, up to limits of functioning, which affects their performances (weather, road grip, vibrations in addition to motion, dust, etc.);
  - o leading to characterize separately the sensors with labels and classifications;
  - o leading to propose, for each sensor device an ‘equivalent reference additive sensor’ and/or a ‘additive sensor model’.
- GNSS based positioning level (optionally including fusion of sensors and data):

- for the test purpose, the *GBPT device under test shall be able to receive GNSS signals* (radiated or conducted according to the antenna integration level);
- for the test purpose, the GBPT device under test shall be able to receive 'reconstructed test stimuli' in place of each integrated additive sensors (necessitates standardized input/outputs protocols);
- the scenario list shall represent a selected set (not exhaustive) agreed typical but realistic combinations of operational situations as input/outputs of any sensors (including GNSS) so that the fusion of sensors could be tested in, without trying to reach an exhaustive set of situations.

- *application level*: PVT error models and sensitivity analysis as proposed in EN 16803-1.

In the above proposal, one should understand that:

- 'equivalent reference additive sensor' means a COTS sensor (among a list of homologated devices) of same nature (inertial, odometer, visual) and same class of performances giving similar availability behaviour and performances statistic behaviours, possibly used in GBPT field test for capturing data;

- 'sensor error model' means an open SW model dedicated to one sensor kind (inertial, odometer, etc.), whose inputs are physical parameters of the environment, like temperature, pressure, humidity […] which may be easily measured during a data collection (possibly acquired during the GBPT field tests) and sufficient to describe the performance behaviour and availability of the sensor;

- 'reconstructed test stimuli' are data aresued either from the 'equivalent reference additive sensor' capturing directly the environment during field tests, or from the 'additive sensor model' using inputs issued data acquired during field tests (temperature, pressure, humidity, etc.).

At positioning level, only an agreed selection of typical operative situations would have been performed in field tests (or recorded for 'Record and Replay' solutions), avoiding the combinatory explosion. That necessarily assumes that at lower level of manufacturing, sensors have typically be submitted to a quite exhaustive coverage of any environmental conditions, comprising the limits of the operating domain in order to get enough trust in a sensor model or in a reference sensor.

It is not in the scope of this document to go further in the definition of the process dedicated to the characterization of additive sensor level, for which the involvement of the own industry (inertial units, vision, wheel coding) is mandatory. *We only recommend opening a complementary process to standardize those issues, which are of utmost importance to address hybridized systems*.

We now assume in this document that the proposed approach might be retained, that 'equivalent reference additive sensors' are existing and known as well as 'additive sensor error models', and that the standardized interfaces with additive sensors for test purposes are also known.

5.3 Stakeholders and responsibilities

5.3.1 Industry value chain

The life cycles of the development, production, integration of the electronic devices are industrials features depending on the business models usually applied in the corresponding market.

To illustrate the GBPT for road ITS application, it is interesting to refer to the value chain elaborated by the GSA (GNSS market report for road applications). This value chain allows to identify the