GSA/JRC ECALL CONFORMANCE TESTING CAMPAIGN

ECALL DEVICES ASSESSMENT REPORT

European
Global Navigation
Satellite Systems
Agency

GALILEO EGNOS
NAVIGATION SOLUTIONS
POWERED BY EUROPE

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JOINT RESEARCH CENTRE

TABLE OF CONTENTS

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Acknowledgement

The European GNSS Agency (GSA) and the Joint Research Centre (JRC) wish to thank Receivers manufacturers for their valuable inputs and support to the eCall testing campaign and the preparation of this report.

INTRODUCTION

In connection with the Commission Delegated Regulation 2017/79 [RD1] which entered into force on 31 March 2018, the European GNSS Agency (GSA) launched a testing campaign, inviting all eCall device manufacturers to join and provide samples to be assessed with respect to their GNSS capability. GSA received a large number of positive expressions of interest from the main manufacturers of eCall On-Board Units located in Europe, USA, and Asia. Several eCall GNSS evaluation kits were delivered to the EU Global Navigation Satellite System (GNSS) testing facilities of the European Commission Joint Research Centre (JRC), in its Ispra (Italy) site, where the campaign has been carried out.

In support of this activity, JRC has set up a GNSS laboratory test bed for the eCall testing, including a suite of test scenarios to evaluate the performance of the eCall Devices Under Test (DUT). The detailed specification of the suite of test scenarios is provided in the eCALL Implementation Guidelines Report [RD2]. These scenarios, designed ad hoc to assess the DUTs compatibility with the European Geostationary Navigation Overlay System (EGNOS) and the Galileo Global Satellite Navigation Systems, as specified in Annex VI of the eCALL Commission Delegated Regulation [RD1], were used to test every DUT and later on complete an overall assessment of the compliance of all the DUTs.

In this context, GSA‘s role was that of launching, coordinating and following up closely the testing campaign. More precisely, GSA has taken care of the promotion of the testing opportunity among the manufacturers, interfacing with the manufacturers during the course of the campaign, the follow up of the signatures of the Non-Disclosure Agreements (NDA) to ensure trust and confidentiality, and finally, review and dissemination of the results through individual detailed test report delivered to each manufacturer.

This campaign started in March 2017 and was concluded in September 2018, spanning more than 18 months. Over this period the JRC team, in close contact with the GSA, has completed the following tasks:

- Definition and implementation of the test scenarios, according to Annex VI of [RD1], and a suite of scripts to automate the tests and the parsing of the logfiles to be able to assess the level of conformance of the DUTs;
- Execution of the tests on each device under test (DUT);
- Test results analysis;
- Evaluation of a number of close to market eCall test solutions to facilitate vendors' development, ensuring consistency with [RD1] and share lessons learnt;
- Preparation of implementation guidelines document [RD2];
- Interactions with eCall manufacturers and test/simulator solutions' vendors (i.e. progress teleconferences, presentation of the intermediate results, recommendations for improvements, etc.);
- Follow up of the various progress meetings and laboratory visits agreed with manufacturers;
- Generation of individual test reports for both DUT manufacturers and test/simulator solutions, detailing the observed results and providing recommendations in view of compliance with the Annex VI of [RD1];
- Aggregation of the results and generation of the present report.

Two types of reports were generated:

- An individual test report for each DUT which includes the full-set of detailed results for the specific unit. Such test reports were provided separately to each manufacturer and are covered by NDA.
- The present overall eCall OBUs assessment report, which describes the whole test campaign and details the main and noticeable results obtained during the batch of tests conducted on 15 DUTs made available from the manufacturers. Both aggregate and individual results are provided in this report. Given the sensitive nature of these results, they are presented without disclosing the identity of the device manufacturers.

In terms of overall test objectives, the performance of the receivers was thoroughly assessed with respect to a number of key performance indicators (KPIs):

- the actual usage of the SBAS corrections,
- the positioning accuracy under static, dynamic and dynamic with shadow areas conditions,
- the Cold Start Time-To-First-Fix (CSTTFF) at two different signal power levels (−130 dBm and −140 dBm respectively),
- the re-acquisition time of tracking signals after block out of 60 seconds, and
- the receiver sensitivity in cold start mode, tracking mode and re-acquisition scenario.

Among the test procedures to be assessed, due to the intrinsic very low power level of the satellite signals, the most critical KPI was the sensitivity test. In fact, with some of the DUTs, a careful calibration of the test set-up by measuring any insertion losses between the GNSS simulator and the RF input port of the eCall module has been required.

The analysis of the results reported hereafter has been derived from the typical observables exposed by the DUTs: horizontal positioning accuracy, Time-To-First-Fix (TTFF), re-acquisition time, number of GPS/Galileo satellites tracked and used, and percentage of time where a combined navigation solution is reached using GPS and Galileo satellites at the same time.

The present report has been structured to first present (Section II) an overall assessment of the results, with the statistics of the key performance parameters defined in the test scenarios.

Section III is devoted to the individual assessment of the devices in all the test scenarios considered. An extensive summary of the results obtained with each individual DUT according to each requirement of the regulation (Pt 2.2.1 to Pt 2.2.7 of the regulation) is given. In particular, the analysis of the results is intended to highlight the differences between the individual devices with focus on the contribution given by the use of Galileo satellites and EGNOS corrections. The section ends showing the overall performance of the DUTs for some specific performance metrics such as the percentage of time with a combined solution GPS plus Galileo. A synthesis of the CSTTFF and of the horizontal positioning accuracy is presented giving an overview for the full set of scenarios.

Some concluding remarks are provided in the final section together with a set of recommendations and lessons learnt from the eCall testing campaign.

II. OVERALL ASSESSMENT RESULTS

This section investigates and provides an overall assessment of the tested DUTs compliance with the technical requirements specified in Section 1 of Annex VI of the eCall Regulation [RD1].
The detailed results corresponding to each requirement are provided in Section III

II.1 Integration of SBAS corrections

The usage of SBAS corrections has been analysed through the NMEA logs, checking that the field #6 in the GGA messages was properly set to 2.
Among the full set of receivers tested, 73% (11 out of 15 DUTS) were found to be compliant. Regarding the remaining 27% of the units that did not pass the test:

1. For a 20% of the units (5 DUTs), it was concluded that SBAS corrections were not used because of the high latitude of the geographical location used for the tests. As mentioned in the guidelines [RD2], it is important to make sure that the units activate the corrections in the region where the test scenario is located, and this can be at a land point between 80 deg South and 80 deg North.
2. The remaining unit was found to have the use of SBAS disabled, simply due to a misconfiguration of the device.
   In conclusion, over the full batch of receivers tested **27% (4 out of 15 DUTs) of the receivers were found to be not compliant with the requirement 2.2.1 NMEA-0183 messages output test.**

In Figure 1 on the right side, some statistics including the minimum, maximum and average values are represented based exclusively on the 73% of the DUTs that passed the SBAS correction tracking test.

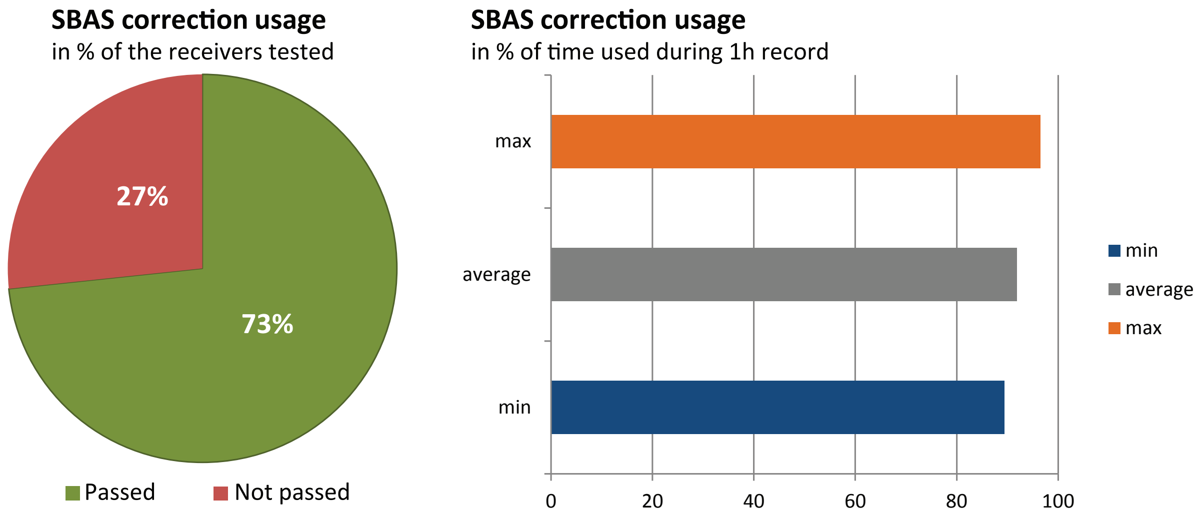


Figure 1: Percentage of receivers that passed and did not pass the test assessing the SBAS correction usage (left side). Among the receivers that passed the test the availability of SBAS corrections is given in percentage of the time acquired during the first hour of test.

II.2 Position accuracy and availability performance requirement

The tests have been performed using the three following conditions: static mode, dynamic mode and dynamic mode under urban canyons and intermittent reception of the navigation signals according to the test procedures mentioned in the regulation [RD1] under Sect 2.2.2; 2.2.3 and 2.2.4. For simplicity the latest condition will be referred as "*dynamic shadow*".

/ Assessment of positioning accuracy in autonomous static mode

All DUTs presented an overall horizontal positioning error below the requirement limit of 15 meters for the static case (Figure 2).

From the comparison between GPS+GAL+SBAS and GPS+SBAS with the Galileo only configurations, **it can be noted that the Galileo only has a better horizontal accuracy with respect to the other two configurations (Figure 2).** Specifically, the maximum horizontal error goes from 4.42 meters to 3.80 meters, the standard deviation is reduced of 0.07 meter, finally the mean horizontal error decreases of 3 centimetres. Although, the difference is very small the results were not foreseen. Currently, it is not possible to identify the cause of these results because the navigation algorithms are proprietary. Without access to the navigation algorithm implemented in the DUTs two aspects were identified as possible causes of such unforeseen results. The first one is relative to the different weighting of Galileo and GPS measurements in the combined navigation solution; if an improper weight is assigned to the measurements it could cause a degradation of the navigation solution. The optimization of the weights could enhance the multi-constellation navigation solution.

Another fundamental aspect is the intersystem bias between GPS and Galileo, i.e. GPS to Galileo Time Offset (GGTO). When GPS and Galileo measurements are used together the offset between the different time scales has to be taken into account. The common approach is the inclusion of an additional unknown in the navigation solution; the unknown allows the direct estimation of the offset due to the difference between the time scale including also the delay introduced by the receiver, like group delay differences or delays generated during the baseband or Digital Signal Processing, which cannot be directly recovered using the broadcast GGTO parameters. This effect is present only in the case of the multi-constellation solution; it is not evident in the case of Galileo only because the GGTO is absorbed in the receiver clock bias. A possible solution to limit the local delay introduced by the receiver could be a pre-calibration of the receiver considering the different processing chains of the GPS and Galileo signals.

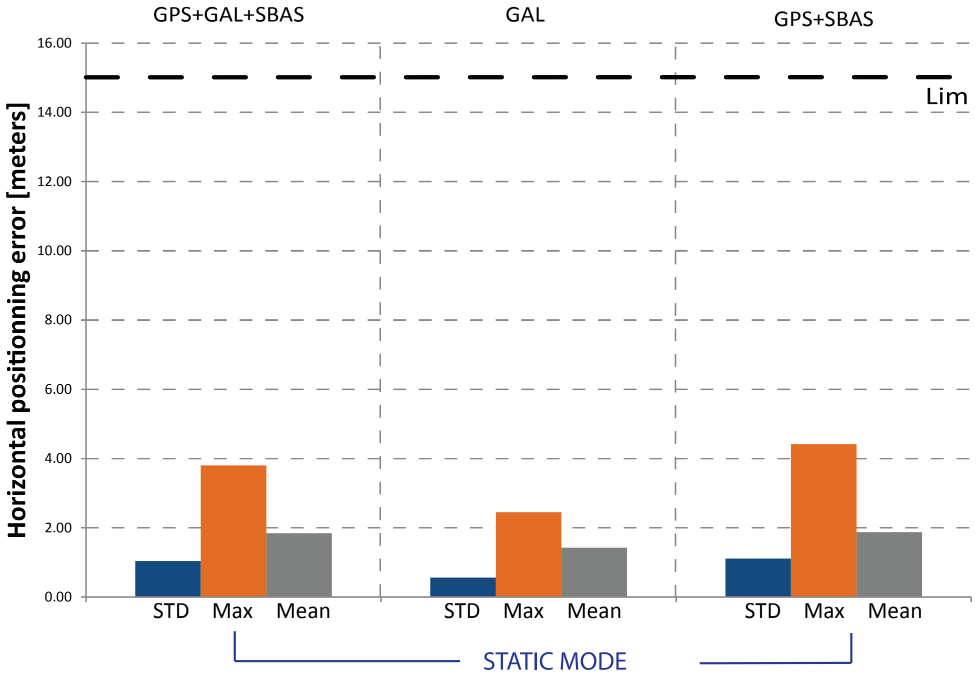


Figure 2: Horizontal positioning accuracy for all DUTs tested in static mode for the different configuration: GPS+GAL+SBAS; GAL only and GPS+SBAS, showing the average, standard deviation and maximum values, along with the limit set in the regulation.

/ Assessment of positioning accuracy in dynamic mode

As for the static case, **all DUTs present a horizontal positioning accuracy that is well below the limit of 15 m set in the regulation for the dynamic case** (left graph of Figure 3). For the dynamic shadow case, **the average value of the horizontal positioning error was 8 meters, which is well below the 40 meters fixed in the regulation for the dynamic shadow case** (right graph in Figure 3).

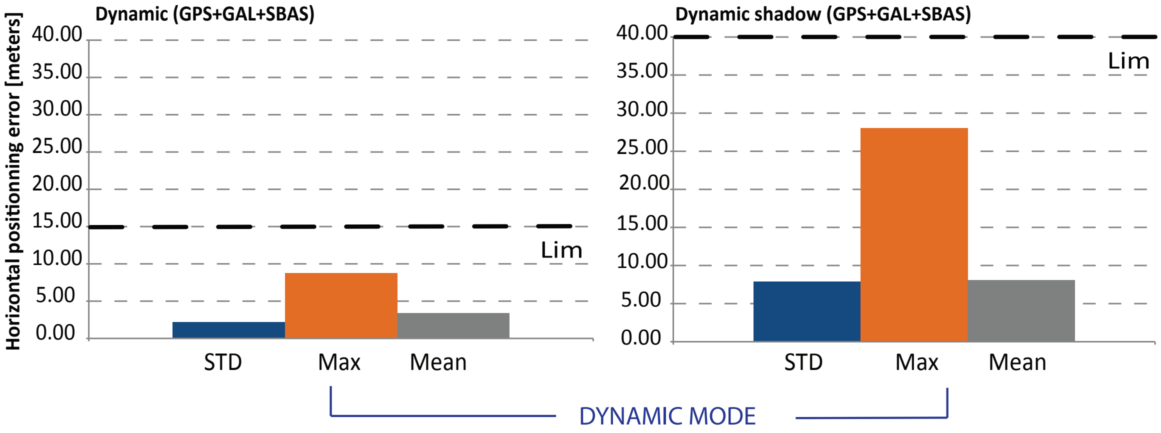


Figure 3: Horizontal positioning accuracy for all DUTs tested in dynamic and dynamic shadow mode for the combined configuration GPS+GAL+SBAS. The limit fixed in the regulation and the mean value computed for both modes are also indicated.

In section III, results are analysed in details. Some additional metrics such as the CSTTFF needed to reach such positioning accuracy are also presented.

II.3 Cold Start Time To First Fix (CSTTFF)

The statistics of the TTFF have been computed on at least 10 measurements at the signals power levels of −130 dBm and −140 dBm, respectively. Figure 4 reports the CSTTFF values for each DUT and the average value related to the scenario tracking both GPS and Galileo having at least 6 Galileo and 6 GPS satellites for the 15 receivers.

In average the CSTTFF obtained for the full set of receivers is below the limits of 60 seconds, at the signal power lever of minus 130 dBm, and 300 seconds at minus 140 dBm.

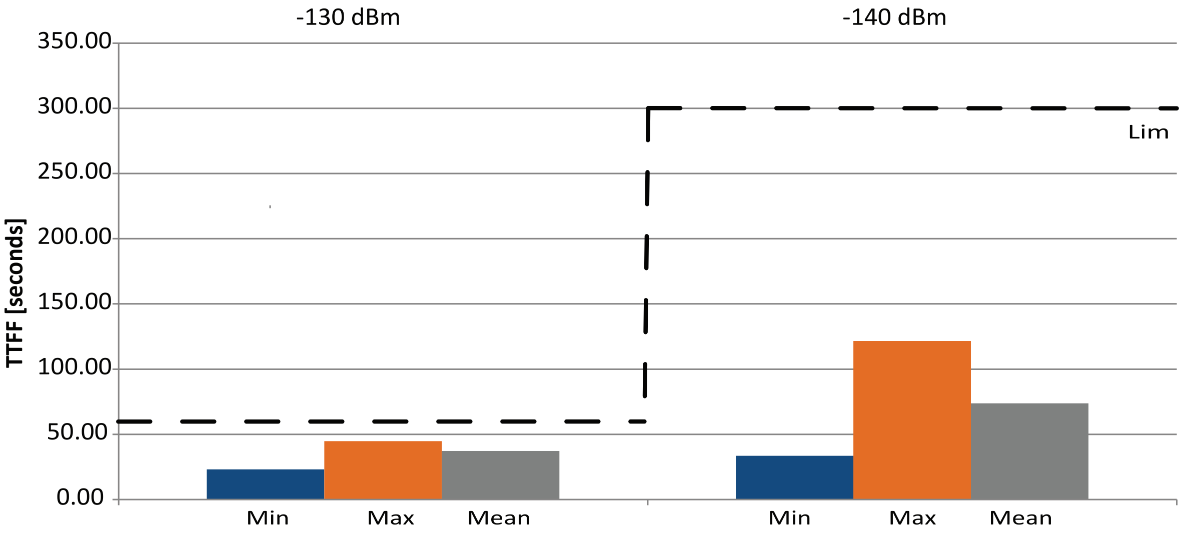


Figure 4: The average, minimum and maximum TTFF values in seconds for the overall 15 receivers are shown at the two signal power level of −130dBm and −140 dBm.

II.4 Re-acquisition time of tracking signals after block out of 60 seconds

The re-acquisition time is checked after a GNSS signal block out of 60 seconds. All 15 devices performed very well with an average re-acquisition time of less than 1.7 s, which is well below the requirement of 20 seconds. As summarized in Figure 5 the results show a high degree of similarity across all DUTs tested.

The re-acquisition times are all of same order of magnitude for all the units, and its average is well below the 20 seconds specified in the requirement.

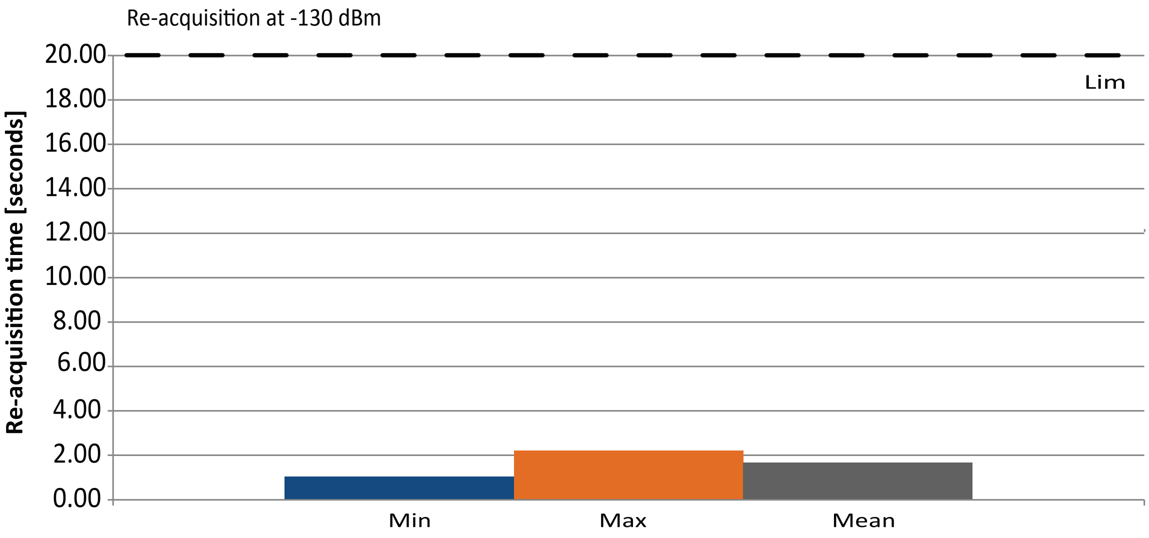


Figure 5: Re-acquisition time needed for every 15 receivers at −130 dBm. Minimum, maximum and average values computed with the 15 DUTs are presented.

II.5 Receiver sensitivity in cold start mode, tracking mode and re-acquisition scenarios

In the complete suite of test scenarios, the sensitivity test was certainly one of the most demanding test cases for the eCall units. The majority of them successfully passed this sensitivity test, and some of them demonstrated a proper use of Galileo signals in the positioning solution.

The results are presented as a function of the different signal power levels that need to be checked according to the regulation going from a first step equals to −144 dBm followed by a reduction of signal power level down to −155dBm. After checking that the position is re-acquired in no more than 60 seconds the signal power is then increased up to −150 dBm.

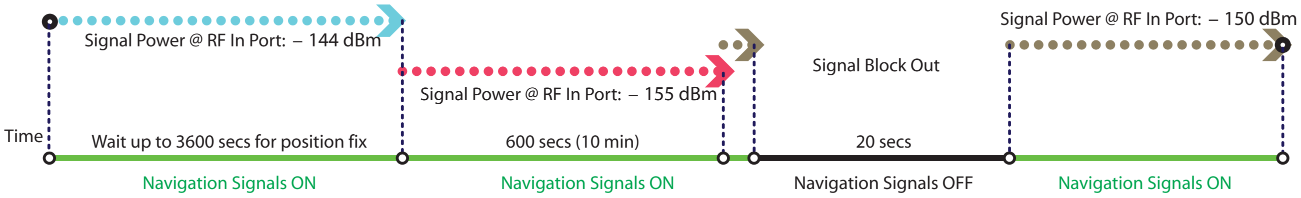


Figure 6: Timeline representing the sequence of different power levels to be used in the scenario taken from [RD2].

Firstly, the sensitivity acquisition is checked at −144 dBm verifying the CSTTFF (Figure 7). **The average of the CSTTFF of all devices was much below the limit of 3600 seconds fixed in the regulation.**

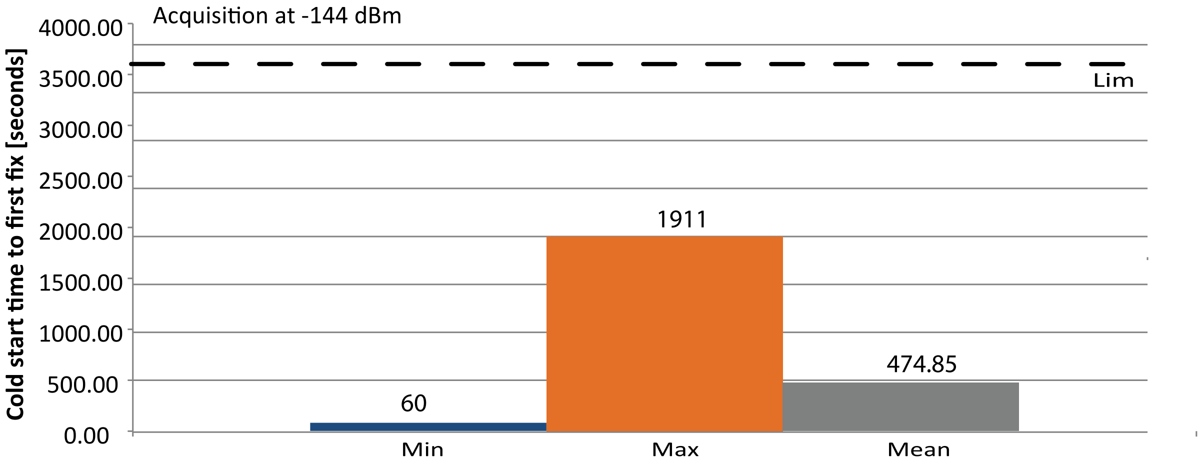


Figure 7: Minimum, maximum and average CSTTFF is computed for the 15 receivers during the acquisition at −144 dBm. The limit is also indicated by the break line.

Secondly, the **continuous fix availability is checked at −155 dBm**, for 87% of the receivers the navigation solution is maintained during at least 600 seconds Figure 8.

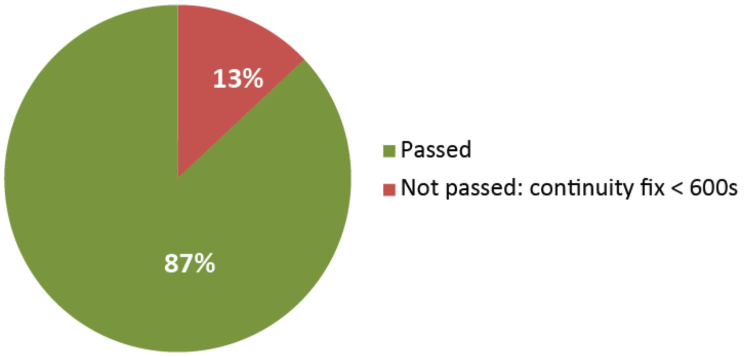


Figure 8: Percentage of the 15 DUTs in maintaining a fix for at least 600 seconds at signal power level of −155 dBm.

Finally, **the re-acquisition of GNSS signals and the calculation of the navigation solution are checked at −150 dBm. The re-acquisition time needed at -150 dBm** is 7.57 seconds in average. All DUTs had a re-acquisition time below the time of 60 seconds set in the regulation.

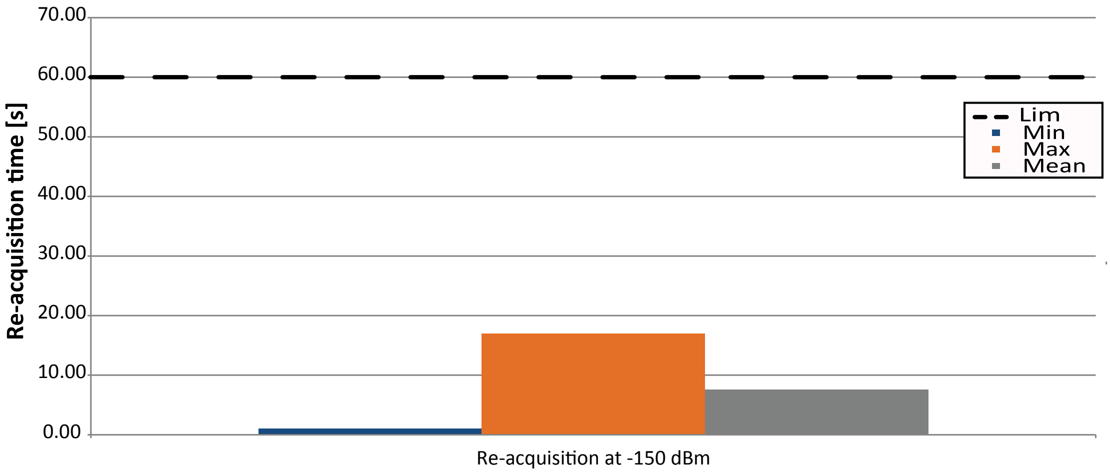


Figure 9: Re-acquisition time needed at signal power level of −150 dBm. Minimum, maximum and average values are depicted for the 15 DUTs.

Some units required a careful signal power calibration of the setup to be able to re-acquire successfully the position fix at −150 dBm within the time limit set.

	Min [sec]	Max [sec]	Average [sec]
Sensitivity TTFF (acquisition at −144 dBm)	60	1911	474.85
Sensitivity re-acquisition time (−150 dBm)	1	17	7.57

Table 1: Statistics computed for the sensitivity test scenario to evaluate the TTFF with acquisition at −144 dBm and the re-acquisition time needed at −150 dBm.

II.6 Number of GPS/Galileo satellites tracked and used in PVT

Two parameters are used to assess the performance of the DUTs: the first parameter is the percentage of satellite tracked, computed as the ratio between the number of tracked satellites, of a specific constellation, and the total number of visible satellites of the same constellation; the second metric adopted is the percentage of satellites used in the navigation solution, computed as the ratio between the number of satellites used in the navigation solution and the total number of visible satellites. Both parameters are computed separately for GPS and Galileo.

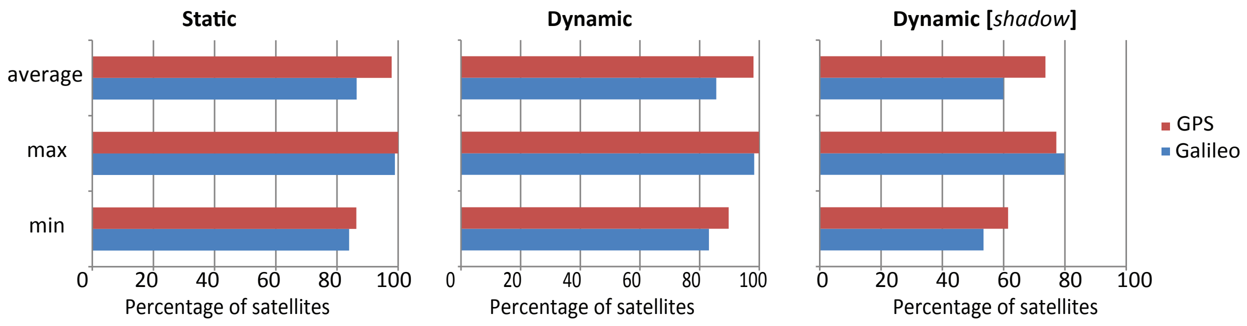
/ Static and dynamic cases

On average, more than 86% of the GALILEO and GPS satellites in view were tracked during the static scenario (Figure 10). Regarding the dynamic case, it must be noted that, three units were misconfigured and did not log GAGSV messages. As a result, the average of the tracking success rate for GALILEO is slightly below the average of the use success rate, which is clearly incongruent (i.e., use in PVT success rates have to be always below tracking success rates). The percentage of GPS and Galileo satellites used during the dynamic case is on average 93% and 87%, respectively.

As expected, the percentage of satellites tracked is slightly reduced in the dynamic shadow case compared to the dynamic case, with successful tracking ratios of 74% for the GPS satellites, and 60% for the Galileo satellites.

Analysing the usage of GPS and Galileo satellites (Figure 10, bottom) it appears that, on average, GPS satellites are used in the PVT slightly more frequently than the Galileo satellites. More precisely, on average, almost 86% of the Galileo satellites are used in the static scenario, compared to nearly 95% for GPS satellites. The usage is similar for the dynamic case and during the dynamic shadow case the percentage of satellites used decreased to 65% and 67% for Galileo and GPS respectively.

Percentage of *Tracked* satellites



Percentage of satellites *used in PVT*

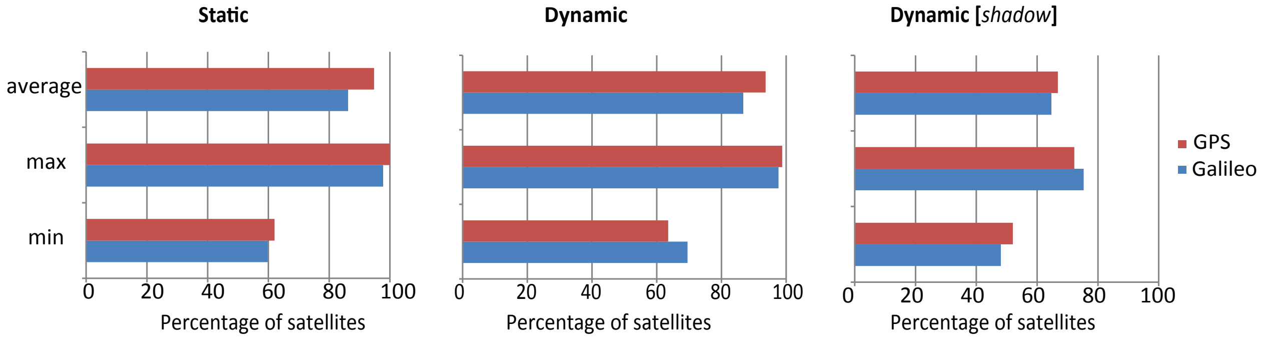


Figure 10: Percentage of GPS satellites and Galileo satellites that are tracked and used in PVT during the different test cases from left to right: static, dynamic and dynamic shadow cases. Average, maximum and minimum values computed among the 15 DUTs are represented for all cases.

/ Sensitivity test

The tests were performed using two different signal power levels (-144 dBm and -155 dBm), the two tests were carried out consecutively.

From the results of the two tests, it can be noted that on average more than 17% of the Galileo satellites in view were tracked when the signal power level was at -144 dBm; this value reached 27% when the signal power level was at -155 dBm. The increased percentage of satellites tracked at -155 dBm can be due to the longer time available. The percentage of GPS satellites tracked is 97% and 92% at -144 dBm and -155 dBm, respectively.

The average percentage of satellites used during the test at -144 dBm is 88% and 13% for GPS and Galileo respectively. When the signal power level was set to -155 dBm, for GPS the percentage of satellites used in the PVT reduced to 74%; while for Galileo it was increased to 15%.

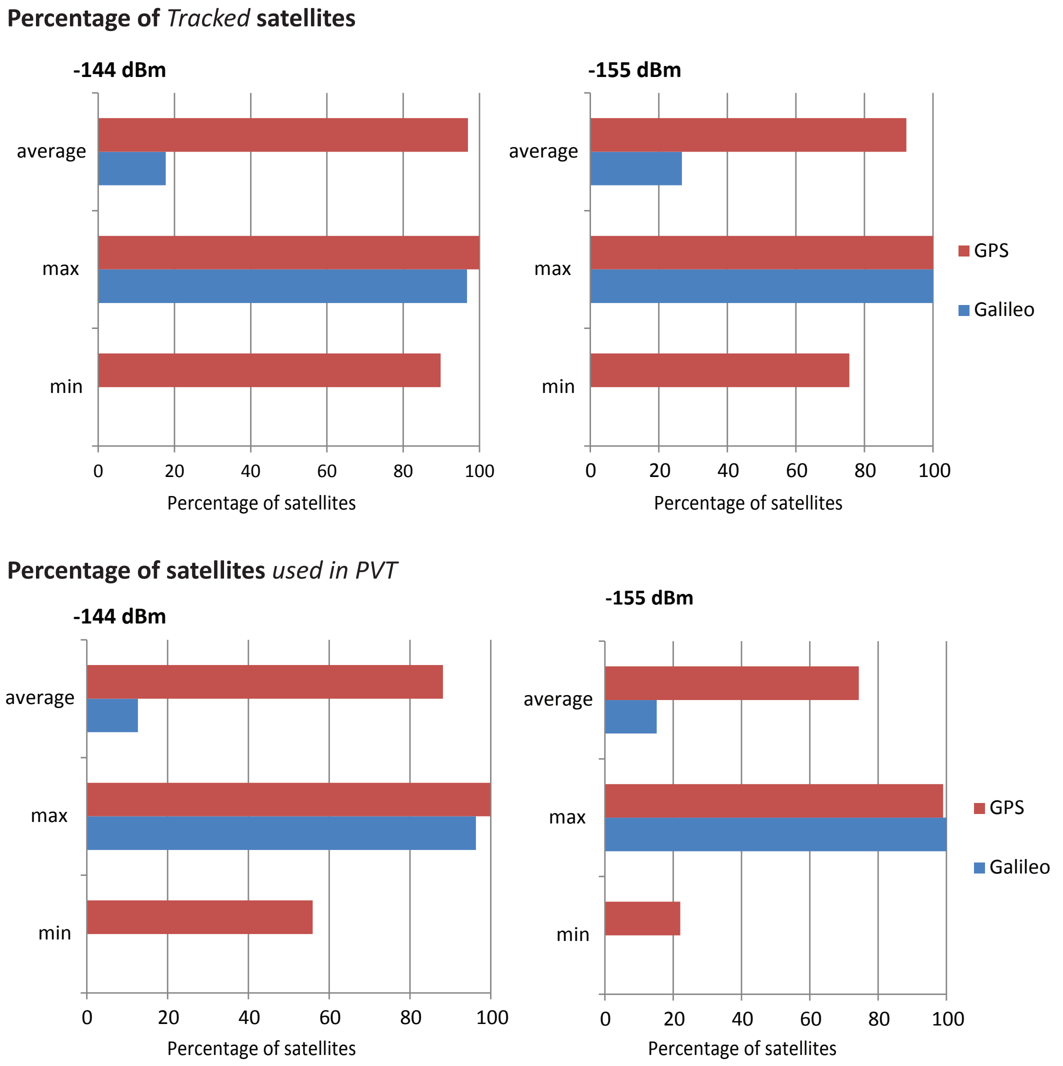


Figure 11: Percentage of GPS and Galileo satellites tracked and used in PVT during the different test cases from left to right: sensitivity test with a signal power of -144 dBm and at -155 dBm respectively. Average, maximum and minimum values computed among the 15 DUTs are represented for all cases.

II.7 Type of solution obtained for the static and dynamic cases

For the different test cases assessed (i.e. static and dynamic cases), the availability of a combined navigation solution with GPS plus GALILEO has been analyzed. Figure 12 represents the percentage of time where a combined (i.e., GPS+Galileo+SBAS) or a single-constellation (i.e., GPS or GALILEO) fix are reached in the static and two dynamic scenarios. On average, the navigation solution using a combined solution is reached 98% of the time for both the static and dynamic scenarios, and 96% of the time during the dynamic shadow scenario. The percentage of time with a navigation solution using only Galileo is marginal and is below 1% in all the three scenarios.

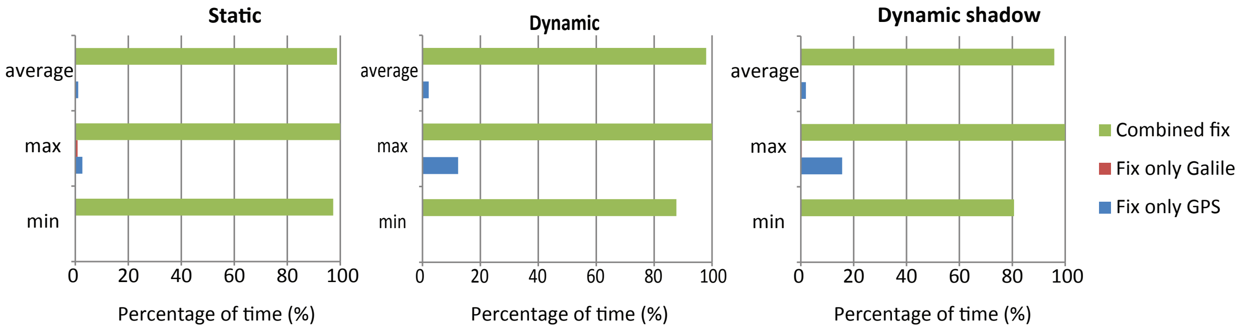


Figure 12: Type of navigation solution (i.e. combined fix or fix using only GPS or Galileo) achieved for the static and dynamic cases. Minimum, maximum and average computed among the 15 DUTs are represented as a function of time.

III.INDIVIDUAL ASSESSMENT RESULTS

The following sections present the results obtained for the 15 Devices Under Test (DUTs), following the structure of Annex VI of the regulation. The main goal is to discuss and highlight the most relevant outcomes of the eCall testing campaign. Comments on the results are provided with respect to every single requirement set in the legislation. Some specific comments are also provided to emphasize some relevant characteristics of individual (but anonymized) DUTs.

The detailed results section is organised following the points that needed to be checked in accordance with the regulation..

[Pt_2.2.1_Anx_VI] NMEA-0183 messages output test

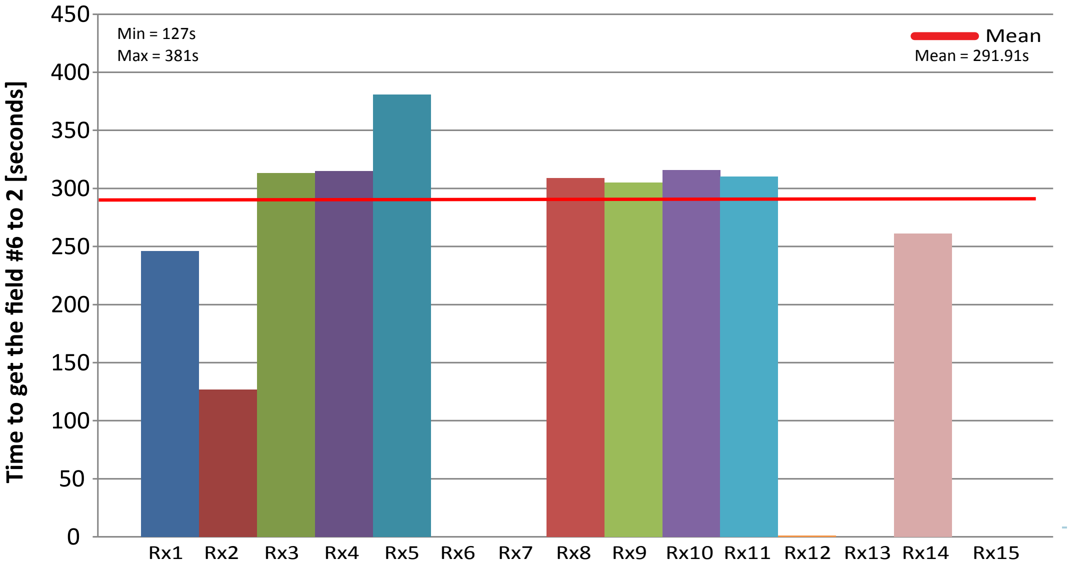
The goal of this test is to verify that the eCall DUT interface is compliant with the requirements set. For this purpose, the following actions have been carried out.

- Check that the NMEA talk IDs RMC, GGA, VTG, GSA and GSV are present and are formatted in accordance with the standard NMEA-0183, as specified in [RD4] and [RD5], with both GPS and Galileo satellites present.
- Parse the GGA messages and check if the field number 6 is set to 2. This flag represents the actual usage of SBAS corrections.

Among the 15 receivers tested, 73% (11 out of 15) were compliant using SBAS corrections, while 27% of the DUTs (4 out of 15) were not able to use the SBAS corrections. Among the four DUTs not able to use the SBAS corrections, one had a misconfiguration, SBAS corrections were disabled; whereas the other three devices did not use the SBAS corrections probably because of the high latitude of the location of the tests.

The performance of the DUTs was also assessed in terms of time required to use the SBAS corrections. This parameter was evaluated measuring the time interval between the star of the test and the first epoch where field number 6 was set to 2. The values of the parameter for the full set of receivers are shown in Figure 13. From the analysis, it emerged that in the considered scenario a minimum of some 2 minutes is required for using the SBAS corrections and that the average time is almost 5 minutes.

Figure 13: Time required for the use of SBAS corrections.



[Pt_2.2.2_Anx_VI] Assessment of positioning accuracy in autonomous static mode

The goal of this test case is to assess the positioning performance of the DUT in static mode and under open sky conditions. The test has been carried out by implementing the following constellation scenarios as specified in Section 2.2.2 of Annex VI [RD1].

- Combined constellation with GPS, Galileo and SBAS
- Single constellation with Galileo
- Single constellation with GPS/SBAS

On the suite of scenarios implemented at the JRC, the above three scenarios have been executed sequentially with no loss of continuity, with each scenario lasting one hour. The main parameters characterizing this test, specified in Section 2.2.2. of Annex VI [RD1], are summarized in Table 2. Specifically, the simulations have been carried out so to have a PDOP per constellation between 2 and 2.5, with signal strengths of −135.0 and −138.5 dBm, respectively, set on the Galileo and GPS satellites.

Parameters	Value
PDOP	2 ≤ PDOP ≤ 2.5
Galileo Signal Strength	−135.0 dBm
GPS Signal Strength	−138.5 dBm

Table 2: Main characteristics of the static scenario

/ CSTTFF

The CSTTFF has been computed for the 15 receivers for the static case. The time taken is on average 69 seconds. The CSTTFF in this static case spans from 34 seconds to a maximum of 193 seconds. The variability in the CSTTFF is represented in Figure 14.

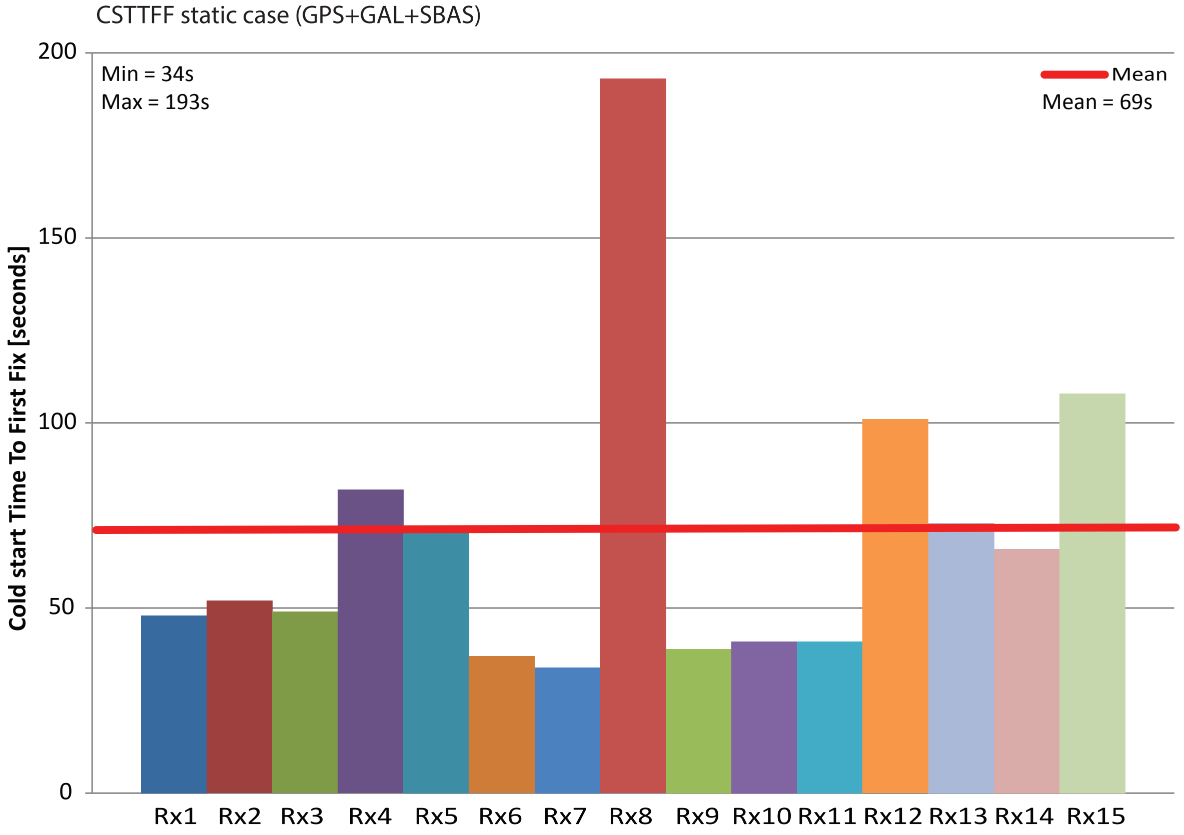


Figure 14: CSTTFF for the overall 15 receivers in the static scenario

For the sake of completeness, an additional test using the previous scenario but switching off all GPS and SBAS signals, such that the **CSTTFF using only GALILEO satellites** can be assessed and compared with that observed for GPS has been run. The measured CSTTFF are depicted in Figure 15. It can be seen that, in a Galileo only scenario, the CSTTFF varies significantly across all the devices, between 59 s to 2400 s. Further, one of the receivers did not reach a fix in this scenario. An 80% of the units showed a CSTTFF below 500 seconds in this Galileo only scenario.

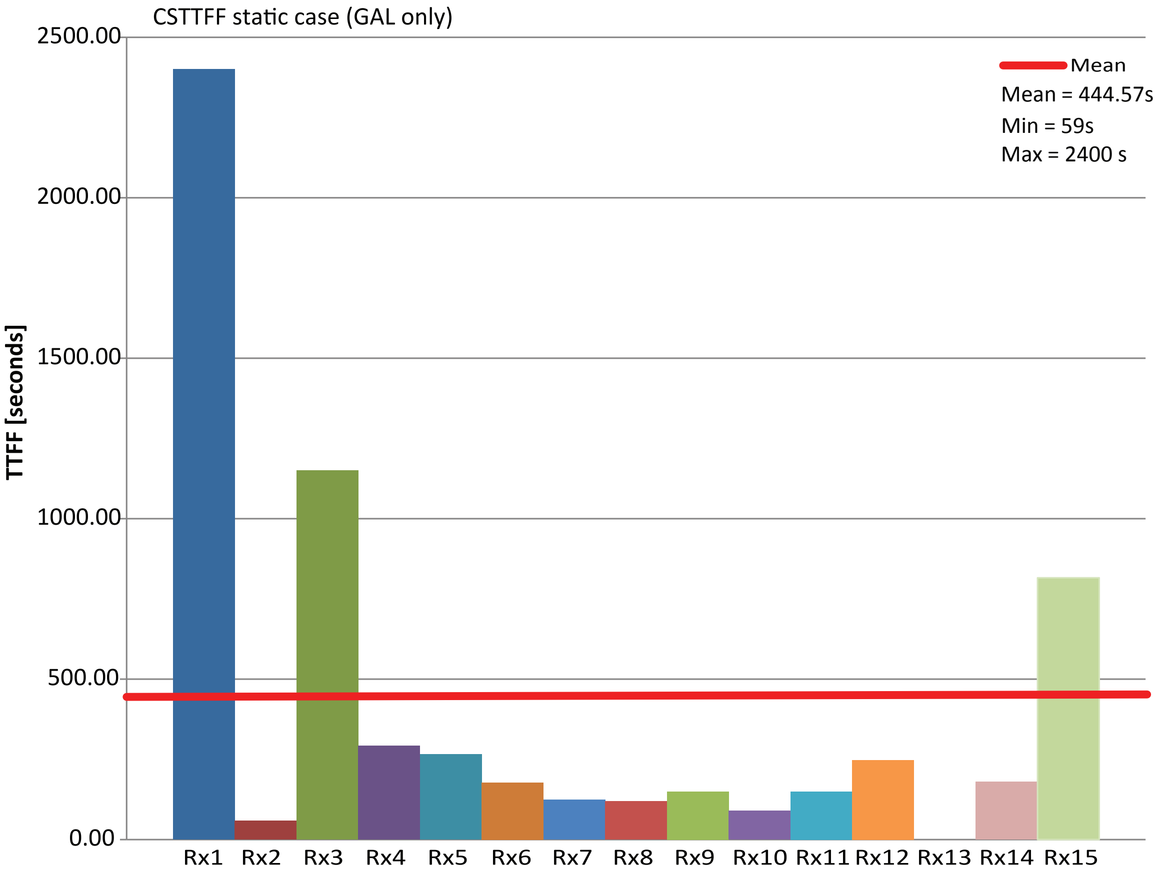


Figure 15: CSTTFF for the overall 15 receivers in the static scenario for the Galileo only scenario.

The results of this scenario underline the need to optimize further the acquisition of the Galileo signals right after a cold start.

/ Horizontal positioning accuracy

The horizontal positioning accuracy has been computed for the different constellation configurations GPS+GAL+SBAS, GAL only and GPS+SBAS in static mode and is depicted in Figure 16. The average trend is represented in red for the different configuration reaching respectively: 1.91m; 1.43 m and 1.93 meters. For all the receivers, the horizontal accuracy is well below the 15 meters limit fixed by the regulation for each configuration.

The accuracies reached during the combined GPS+GAL+SBAS scenario show a high variance, with a minimum of 0.8 m and a maximum of 3.8 m.

In the Galileo only scenario, results are more uniform and surprisingly better than in the previous case, with a minimum of 0.39 m and a maximum of 2.45 m. In the GPS+SBAS scenario, the observed horizontal position errors show the largest variance, with values ranging from 0.67 m to 4.42 m.

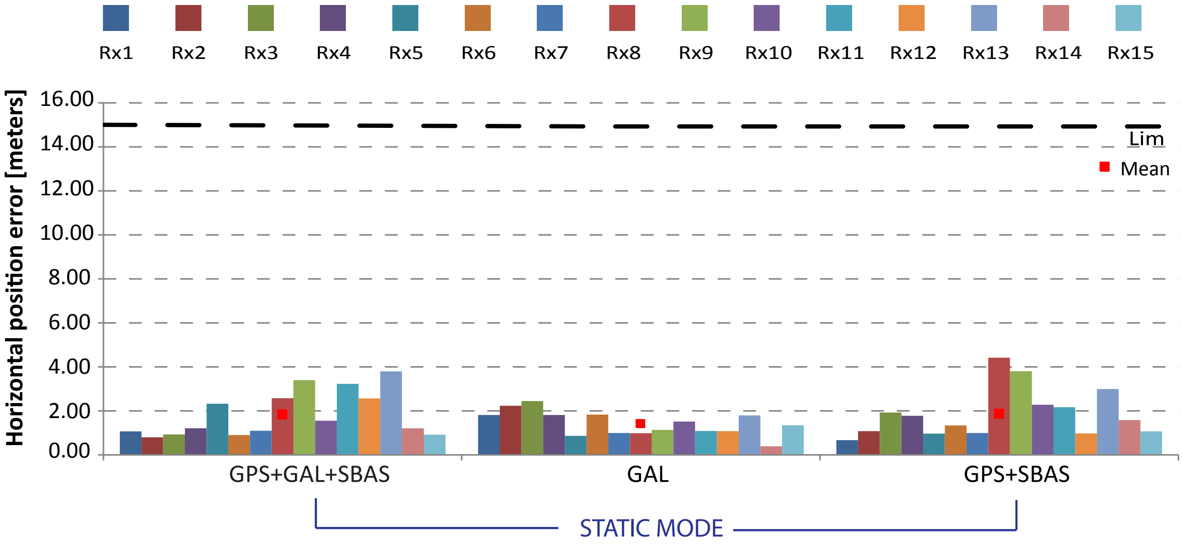


Figure 16: Horizontal positioning accuracy in autonomous static mode for the 15 receivers. The limit of the regulation is illustrated with the black dashed line.

/ Statistical analysis of horizontal positioning error distribution

The performance of the DUTs in the horizontal domain is evaluated using the average and maximum cumulative distribution functions (CDFs) across all the devices tested. The average and maximum of the CDF are shown in Figure 17. These parameters have been computed for the various configurations: GPS+GAL+SBAS blue line, GAL only red lines and GPS+SBAS yellow line.

It is interesting to see that, unexpectedly, the Galileo only scenario shows the lowest horizontal positioning error (1.6m) with a 95% confidence level interval, compared with the GPS+SBAS and the GPS+SBAS+GAL configurations, both reaching an error of more than four meters. Although, this behavior is present in the average CDF it has been observed just in a subset of all the units tested.

Once again the combined configuration (GPS+SBAS+GAL) produced an error of 2.5 m which is 36% greater than the error obtained for the Galileo only scenario.

In conclusion the average horizontal positioning error with a 95% confidence level spans from 1.6 m (Galileo only case) to 2.5 m (GPS+SBAS+GAL case). As mentioned in the section on the overall assessment results, the possible explanations for the unexpected smaller horizontal position error in the Galileo only scenario in comparison to that of the combined constellations could be twofold. The first one may be a different weighting of Galileo and GPS measurements in the combined navigation solution. The optimization of the weights could enhance the multi-constellation navigation solution. The second one may be linked to the GPS to Galileo intersystem bias, i.e. the GPS to Galileo Time Offset (GGTO). When GPS and Galileo measurements are used together the offset between the different time scales has to be taken into to limit the local delay introduced by the receiver.

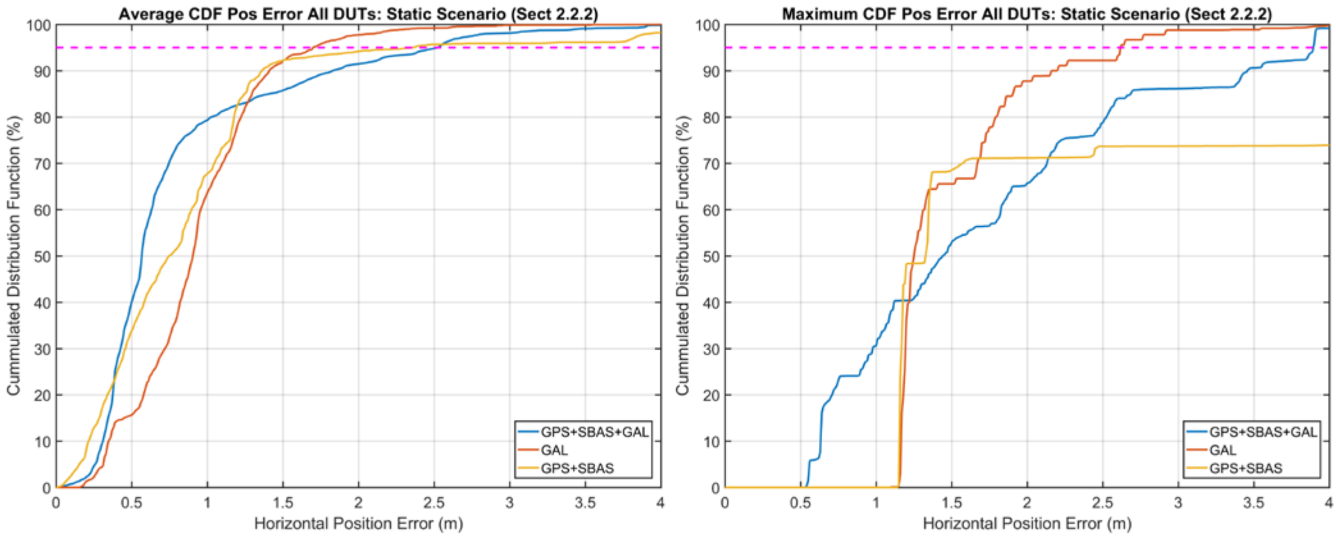


Figure 17: Maximum and average Cumulative Distribution Function (CDF) of positioning errors from all the DUTs during the static tests considering GPS+GAL+SBAS, GAL only and the GPS+SBAS configurations.

/ Percentage of satellites tracked and used

In this section, results relative to the percentage of satellite tracked and the percentage of satellites used in the navigation solution considering Galileo and GPS are presented. With respect to the section II.6 the results are broken down by receivers. The results discussed are obtained from the static scenario with GPS+GAL+SBAS satellites in view.

Due to a misconfiguration for this particular test, one unit did not record the GAGSV messages in the logs.

Figure 18 shows the satellite tracking/usage percentage for GPS and Galileo constellations. In the left side the values relative to GPS are reported while in the right side of the graph, the results relative to Galileo are shown. In this case, the values are computed using the epochs after the epoch of the first position fix.

From the left part of Figure 18, it can be noted that more than 90% of the devices (14 out of 15) tracked and used at least 80% of the GPS satellites simulated. Only 15% of the receivers have a usage rate for Galileo satellites below 80%.

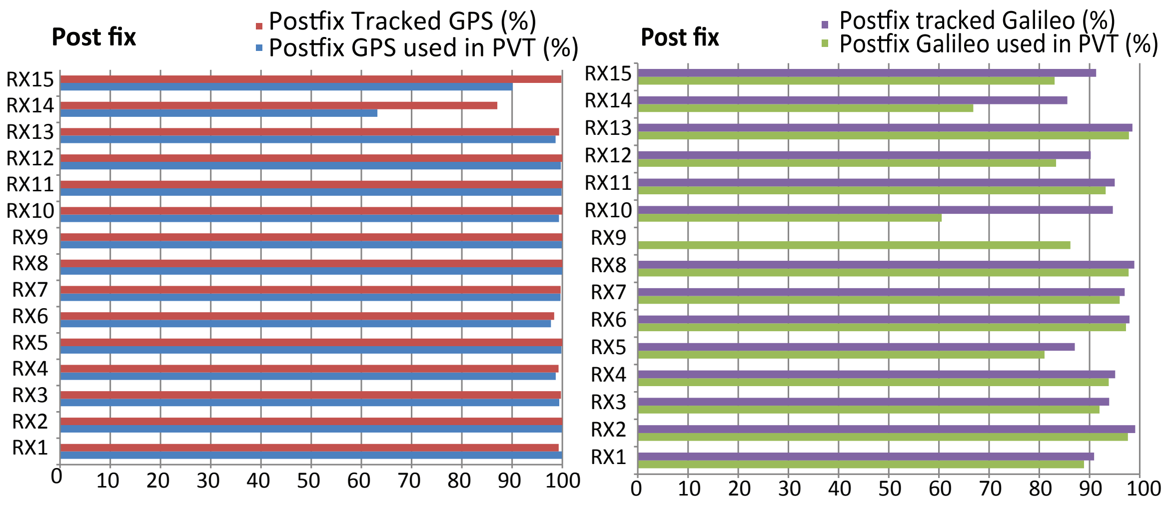


Figure 18: Percentages of satellite tracking/usage, considering only epochs after the first valid position fix. GPS is considered in the left side while Galileo on the right side. The results are obtained in the static scenario with the two constellations in view.

An additional static test exclusively with Galileo satellites was performed. The percentages of the satellites tracked and used considering epochs after the first position fix are given in Figure 19. In this scenario, the percentages are slightly higher than in the case of GPS and GALILEO multi-constellation. More specifically, all the DUTs were able to use about an 80% of the Galileo satellites in view.

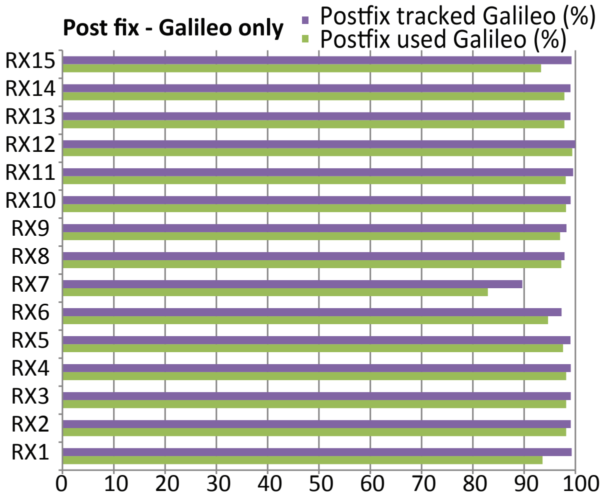


Figure 19: Percentages of satellite tracking/usage, considering epochs after the first valid position fix, considering Galileo only. The test was performed in the static conditions.

[Pt_2.2.3_Anx_VI] Assessment of positioning accuracy in dynamic mode

The purpose of this test case is to assess the performance of the DUT while following a pre-defined trajectory in open sky conditions. In this test, a unique scenario lasting 60 minutes, including Galileo, GPS and SBAS, is analysed.

The reference trajectory is simulated following the specifications given in Section 2.2.3 of Annex VI [RD1] and summarized in Table 3. An example of trajectory fulfilling the above specifications is shown in Figure 20. The trajectory includes two turns along the oval path whose specifications can be found in [RD1].

The characteristics of the trajectory have been fully explained and detailed in [RD2] and are summarized in Table 4. The specifications of the length, velocity, acceleration, and travel time of each section of this trajectory are reminded.

Simulated parameter	Value
Model of movement:	**Manoeuvring movement**
- maximum speed, km/h - turning radius, meters - turning acceleration along a circular trajectory of radius 500 m (m/s^2) - PDOP value	140 500 0.2 2 ≤ PDOP ≤ 2.5
GPS Signal Strength	
- Galileo - GPS	−135.0 dBm −138.5 dBm

Table 3: Main characteristics of the dynamic scenario

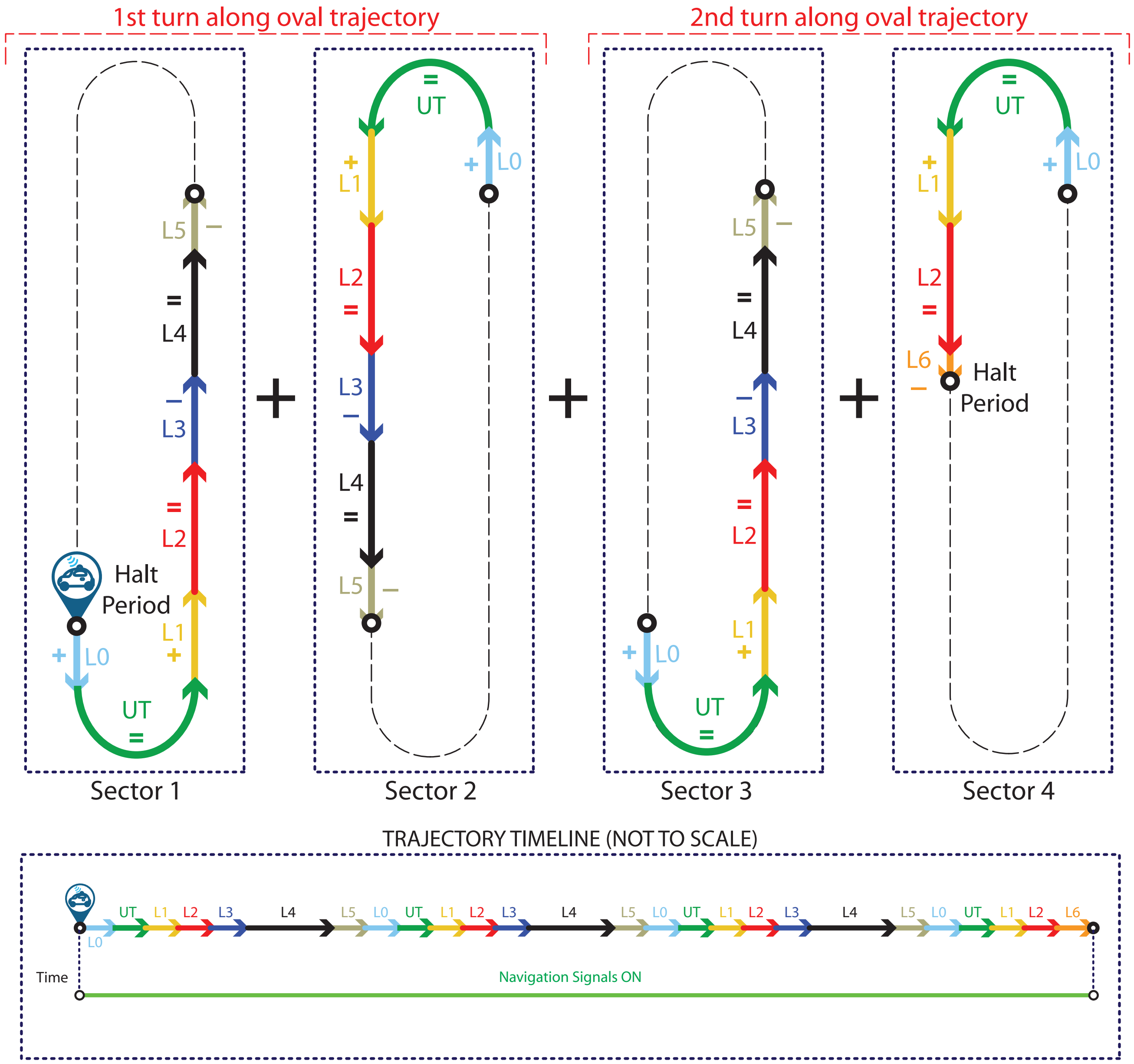


Figure 20: Sketch of a reference trajectory fulfilling the specifications of Section 2.2.3 in Annex VI (extracted from [RD2]).

	Trajectory Section	Length (m)	Speed (km/h)	Acceleration (m/s^2)		Travel Time (s)	
				Linear	Radial		
	Halt Period	0	0	0	0	320	
Sector 1	L0	174	Increase	+0.29	0	34.70	
	UT	1570.8	36	0	0.2	157.08	
	L1	750	Increase	+0.94	0	30.68	
	L2	1350	140	0	0	34.71	
	L3	750	Decrease	-0.74	0	25.47	
	L4	12000	72	0	0	600	
	L5	174	Decrease	-1.15	0	17.35	300 seconds
Sector 2	L0	174	Increase	+0.29	0	34.70	
	UT	1570.8	36	0	0.2	157.08	
	L1	750	Increase	+0.94	0	30.68	
	L2	1350	140	0	0	34.71	
	L3	750	Decrease	-0.74	0	25.47	
	L4	12000	72	0	0	600	
	L5	174	Decrease	-1.15	0	17.35	300 seconds
Sector 3	L0	174	Increase	+0.29	0	34.70	
	UT	1570.8	36	0	0.2	157.08	
	L1	750	Increase	+0.94	0	30.68	
	L2	1350	140	0	0	34.71	
	L3	750	Decrease	-0.74	0	25.47	
	L4	12000	72	0	0	600	
	L5	174	Decrease	-1.15	0	17.35	
Sector 4	L0	174	Increase	+0.29	0	34.70	
	UT	1570.8	36	0	0.2	157.08	
	L1	750	Increase	+0.94	0	30.68	
	L2	1350	140	0	0	34.71	
	L6	38.0	Decrease	-19.90 [2G]	0	1.95	
	Halt Period	0	0	0	0	320	
	Total	53665.2				3600	

Table 4: Length, velocity, acceleration and travel times of a dynamic trajectory in open sky meeting the requirements set in Annex VI. Note: red numbers are required to be compliant with the main parameters specified in Table 3 of Annex VI [1], whereas numbers in blue are required for compliance with the additional parameters for satellite visibility specified in Table 4 of Annex VI [1].

/ CSTTFF

The CSTTFF has been computed and shows large discrepancies among the 15 units (Figure 21). It can be noted that the variation of the CSTTFF in the dynamic scenario is noticeably larger than that of the static scenario. Two units showed a CSTTFF almost two times the average. This however did not have any measurable impact on the observed overall horizontal positioning error.

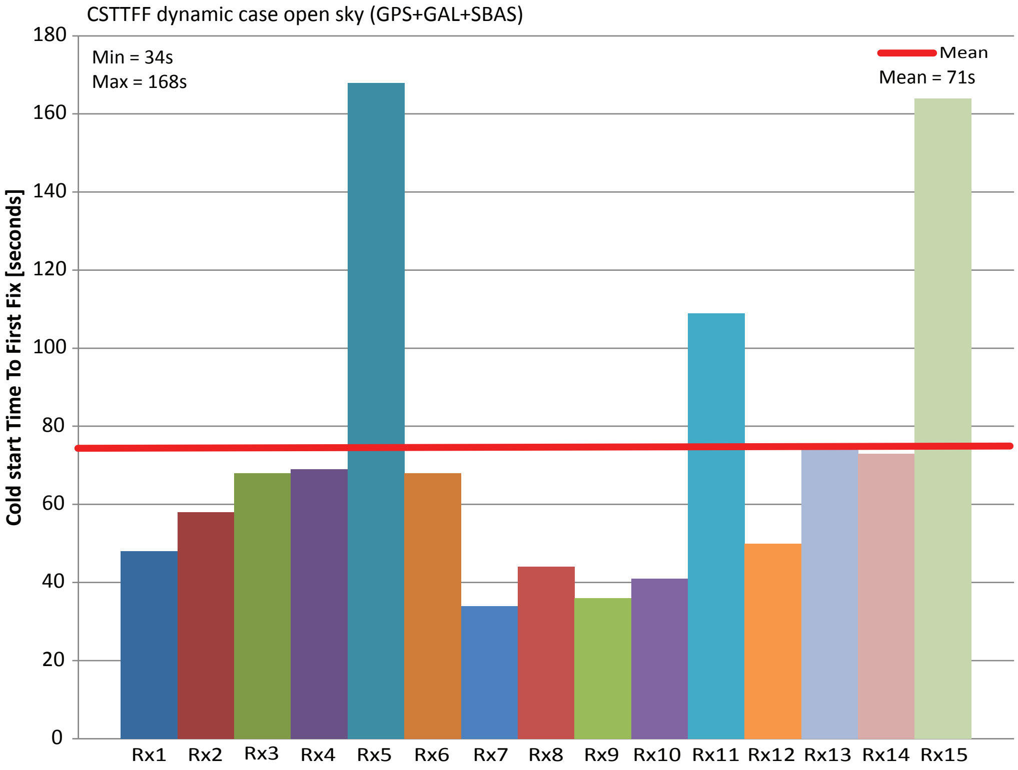


Figure 21: CSTTFF for the 15 receivers in the dynamic scenario for the combined solution.

/ Horizontal positioning accuracy

The horizontal positioning accuracy values for the dynamic case are summarized in Figure 22. It can be seen that the average horizontal positioning error for the 15 units is 3.36 m. Three units show a positioning error higher than the average; specifically, one of them exceeds the average by a factor of three. In any case, both the average and the individual positioning errors are below the limit of 15 m specified in the regulation.

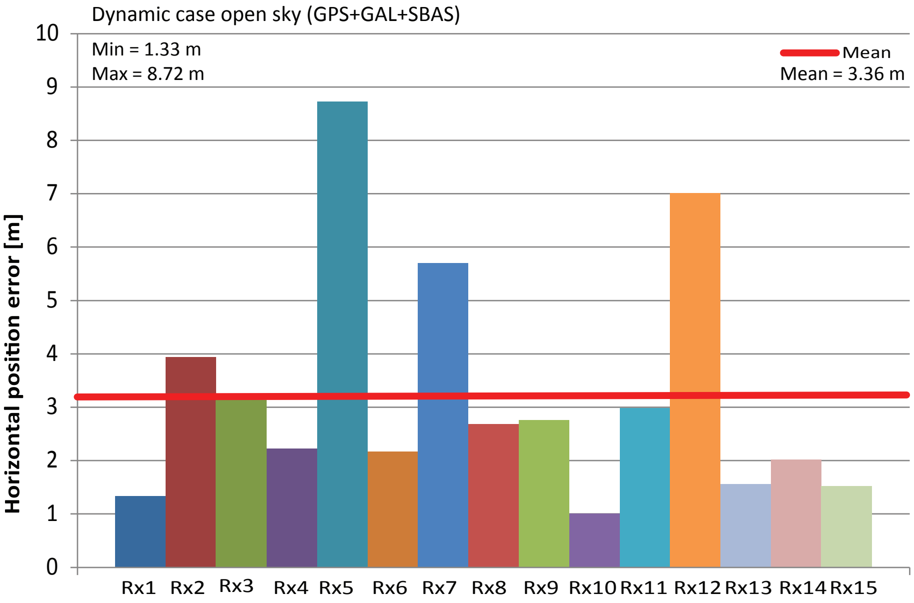


Figure 22: Horizontal positioning error values of the 15 units observed in the dynamic scenario. The average value is highlighted in red.

/ Statistical analysis of horizontal positioning error distribution

The CDF of the horizontal positioning errors has been computed for all the units in the dynamic scenario in open sky conditions (according to the requirements of Section 2.2.3 of [RD1]). The average CDF, maximum CDF and the error bound of 15 m for a confidence level of 95% are shown in Figure 23. From these results, it can be concluded that **the overall horizontal position error with a 95% confidence level is about 3 m which is well below the error bound limit of 15 m fixed in the regulation** (magenta dashed line).

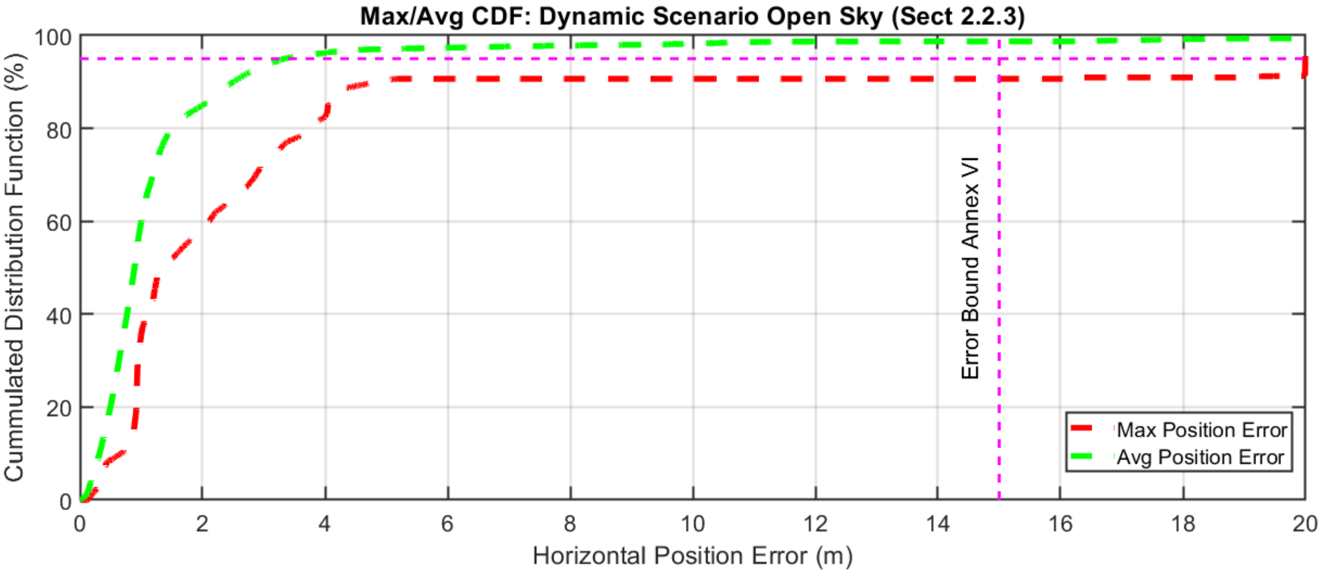


Figure 23: Maximum and average CDF of the horizontal position error during the dynamic scenario in open sky conditions.

/ Percentages of satellites tracked and used in the PVT

The percentage of satellites tracked and used after the first valid fix is shown in Figure 24. On the left side the values relative to GPS are reported while on the right side the values relative to Galileo are plotted. For the specific test, one receiver did not have GAGSV messages recorded; this was due to a misconfiguration of the device.

During the dynamic test, all DUTs tracked more than 90% of the visible GPS satellites, while only 12 receivers used more than 90% of the GPS satellites. For Galileo, 8 out 14 receivers tracked more than 90% of the visible satellites; a similar situation emerges considering the used satellites, also in this case 8 DUTs used more than 90% of the visible satellites, 4 devices used between 80% and 90% of the visible satellites and only three less than 80%.

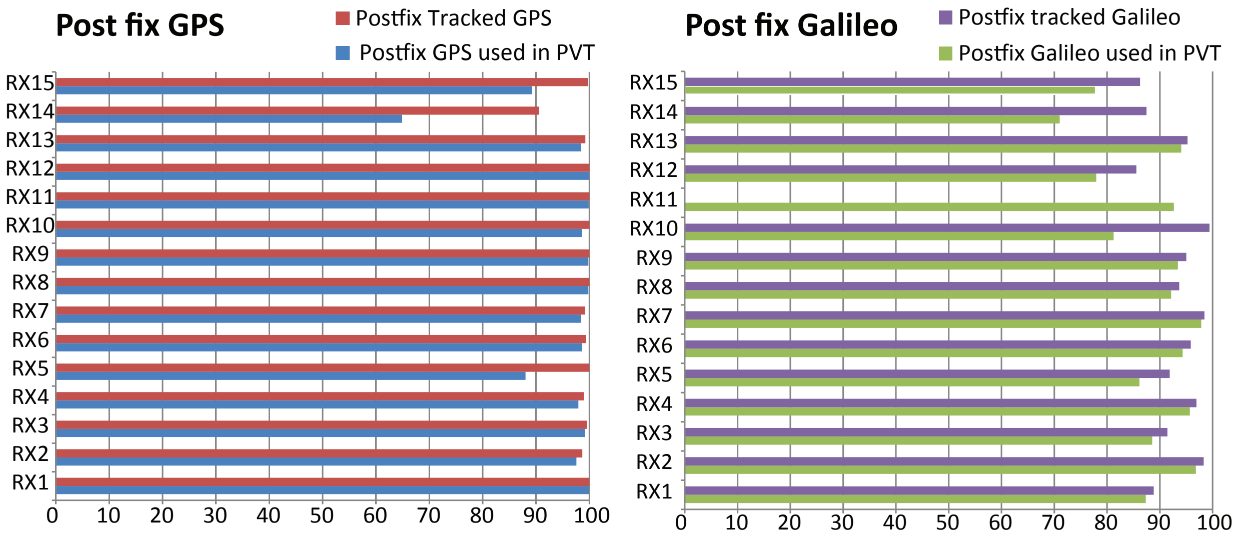


Figure 24: Repartition of the tracked and used GPS and Galileo satellites after the solution has been reached during the dynamic scenario.

In order to evaluate the exploitation of Galileo measurements together with GPS observables, the navigation solution is broken down considering the different types of solutions: GPS only, Galileo only, and combined. The results are shown in Figure 25. From the results, it emerges that 6 DUTs provided a combined navigation solution for the whole test; 8 devices provided a combined navigation solution for some 95% of the test duration. During the specific test, no receivers provided a navigation solution using only Galileo satellites.

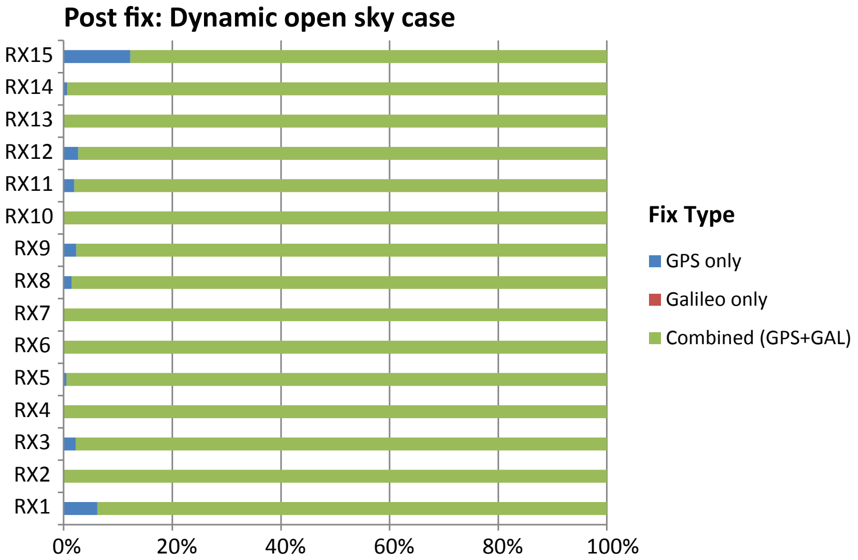


Figure 25: Percentage of time where the navigation solution was achieved using only GPS (blue), Galileo only (red) and a combined fix using GPS and Galileo (green) for the dynamic open sky case.

[Pt_2.2.4_Anx_VI] Movement in shadow areas, areas of intermittent reception of navigation signals and urban canyons

The objective of this test is to assess the performance of the DUT moving along the same path of the test described in [Pt_2.2.3_Anx_VI] but in an urban canyon characterised by shadow areas and intermittent signal reception.

As specified in Section 2.2.4 of [RD1] the trajectory must include sections lasting 600 seconds where all signals are completely blocked, so to simulate the presence of tunnels, alternated to sections lasting 300 seconds characterized by a reduced sky visibility conditions. The main characteristics of the simulated scenario are summarized in Table 5 while the sketch of a sample trajectory fulfilling the above specifics is illustrated in Figure 26.

Simulated parameter	Value
Model of movement	Manoeuvring movement
- speed, km/h - turning radius, meters - turning acceleration, metres/ second2	140 500 0.2
PDOP value	3.5 ≤ PDOP ≤ 4
Signal strength: - GNSS Galileo - GNSS GPS	 −135.0 dBm −138.5 dBm
Signal availability: - signal visibility intervals, seconds - signal absence intervals, seconds	 300 600

Table 5: Main characteristics of the dynamic scenario with intermittent signal

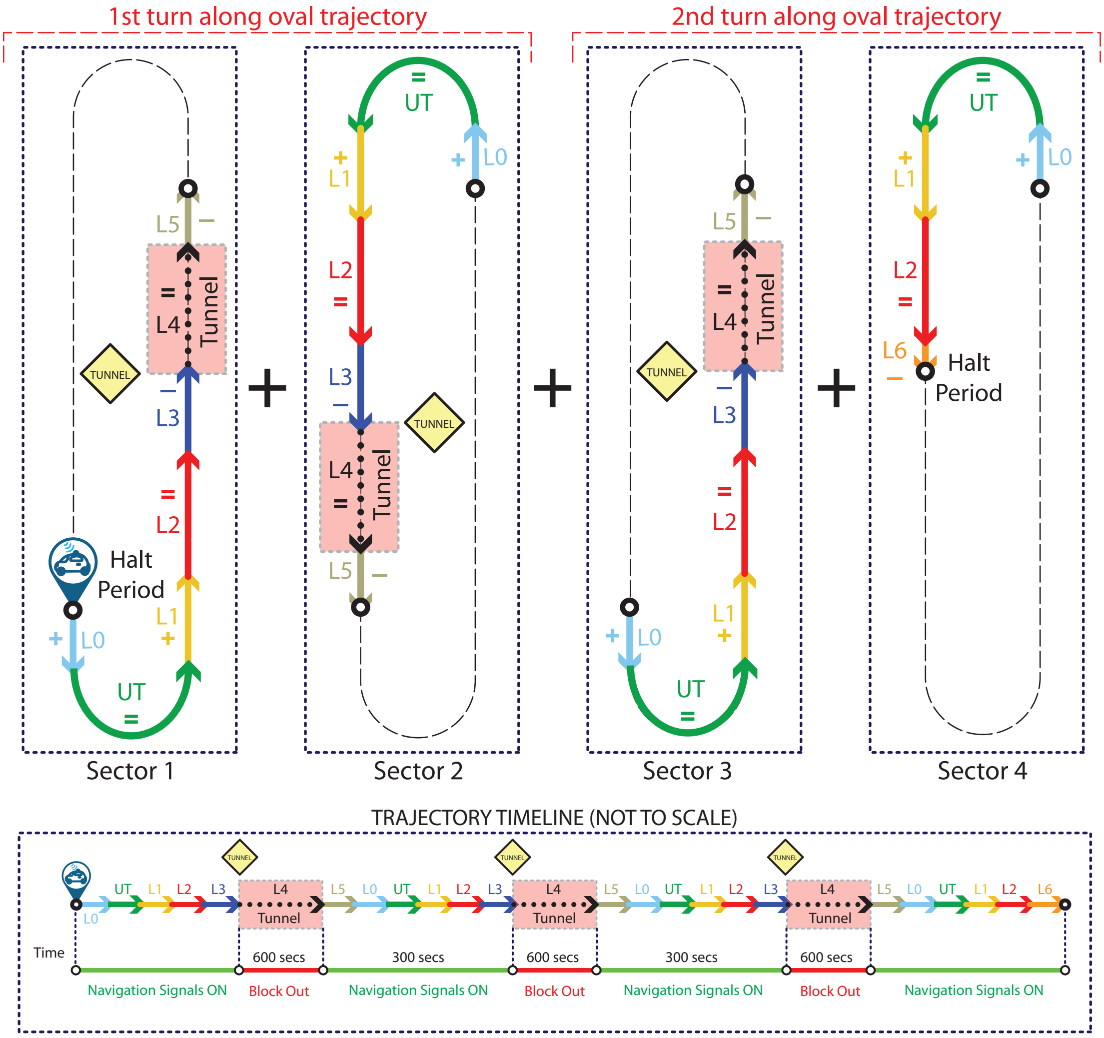


Figure 26: Sketch of a reference trajectory fulfilling the specifics of Section 2.2.3 in Annex VI (extracted from [RD2]).

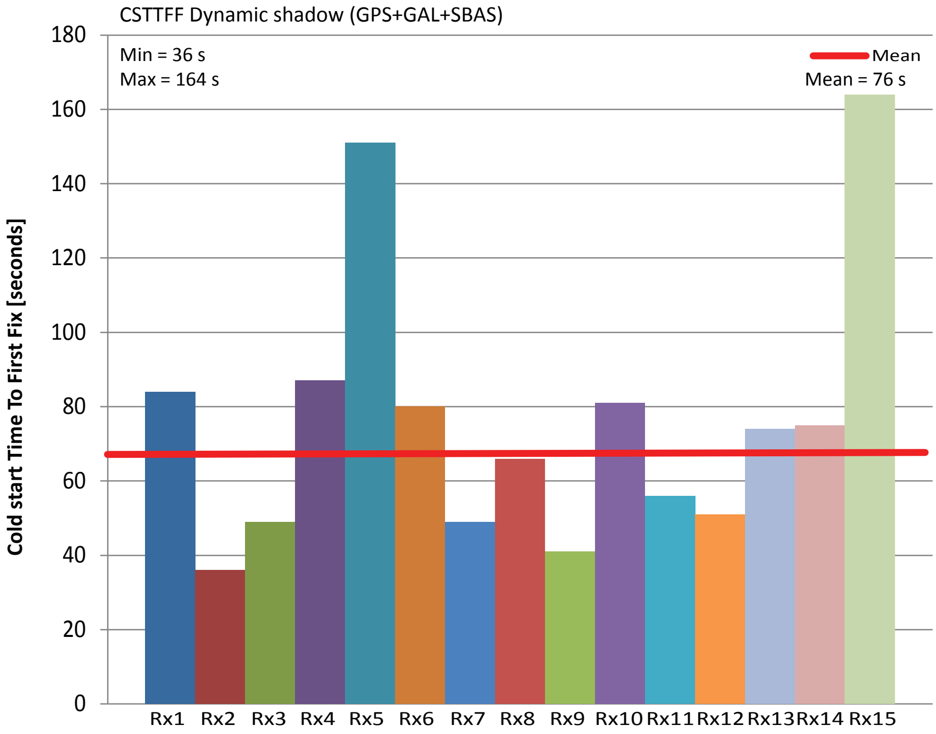


Figure 27: CSTTFF for the 15 receivers in the dynamic shadow scenario. The average value is highlighted in red.

Horizontal positioning accuracy for the dynamic shadow mode is represented in Figure 28 for the whole set of receivers. The average value among the 15 receivers is 8.08 m, a large difference can be noted among the receivers, and the minimum value is 1.04 m whereas the maximum value is 28.04m. For 8 receivers the values are below 5 meters, two receivers have accuracy between five and ten meters; finally five devices have values higher than 10 meters.

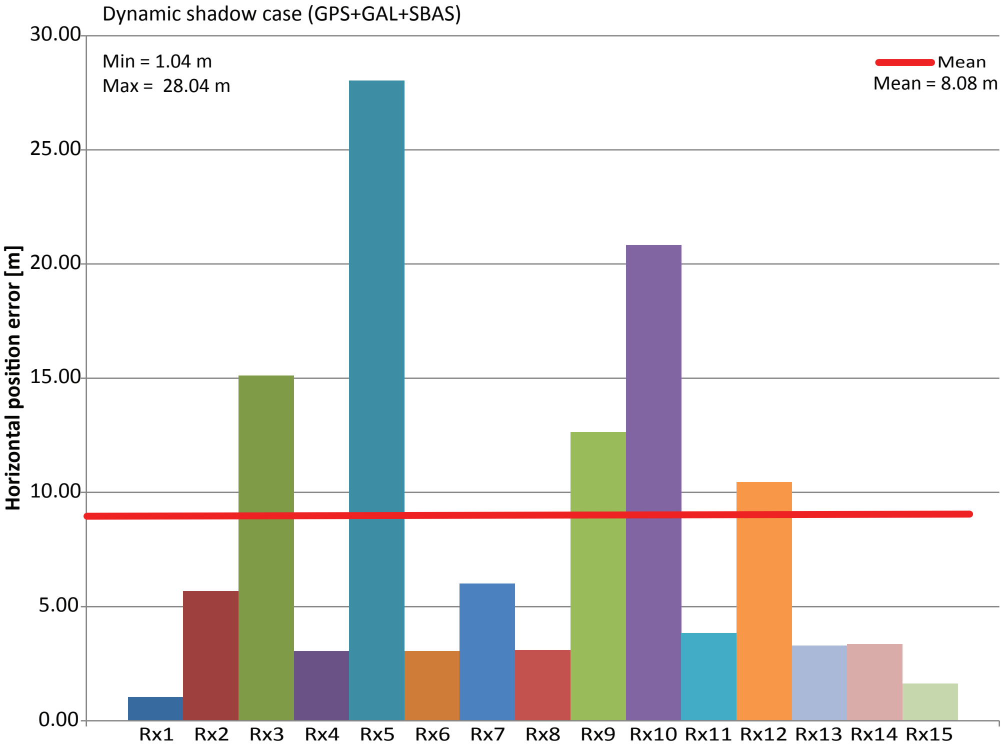


Figure 28: Horizontal positioning accuracy values among the 15 receivers for the dynamic shadow case. The average value is highlighted in red is of 8.08 meters.

/ Statistical analysi tribution

The CDF of the horizontal positioning errors is computed for every receiver for the dynamic scenario under urban canyon conditions (according to the requirements of Section 2.2.4 of [RD1]). Then the maximum and average CDF is computed and plotted in Figure 29; in order to assess the performance with respect to the limit reported in the regulation, the error bound of 40 m [RD1] is added in Figure 29.

From the CDF representation of the errors, it is well highlighted that in average the position error is about 10 m with a 95% confidence level which is well below the requirements of 40 meters.

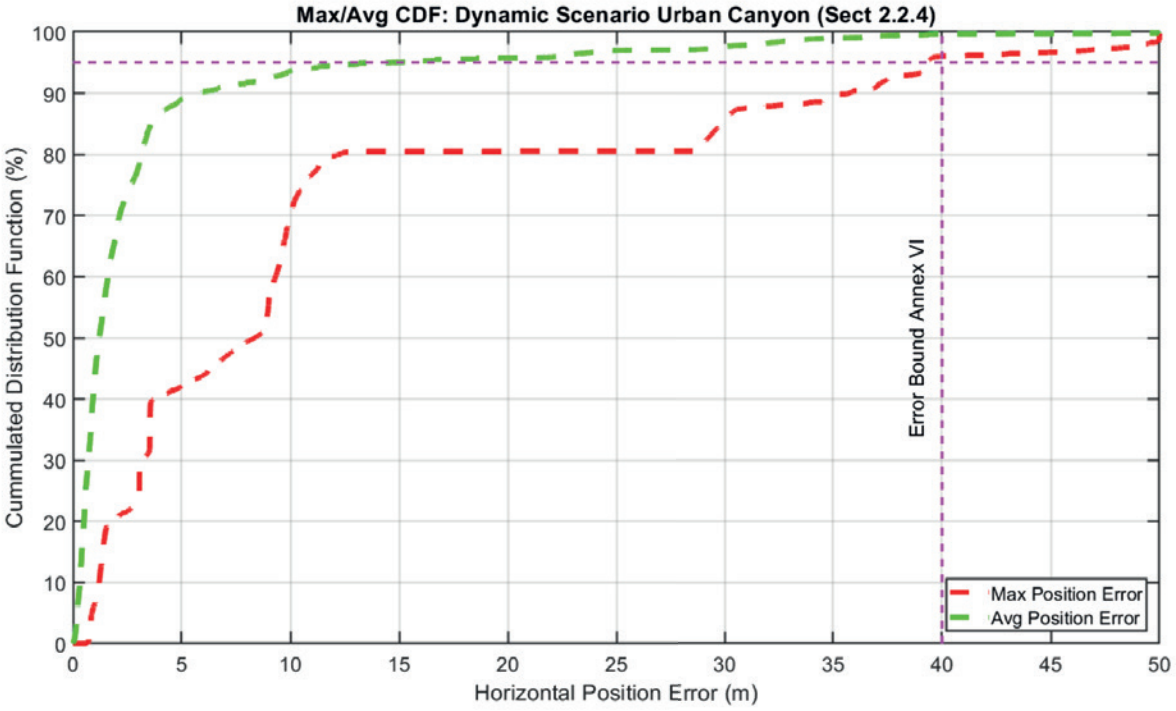


Figure 29: Maximum and average CDF of the horizontal position error during the dynamic shadow case.

/ Percentages of satellites tracked and used in the PVT

The percentage of GPS and Galileo satellites tracked and used considering only epochs after the first valid position fix are depicted in Figure 30. On the left side GPS is considered, while on the right side Galileo is plotted. Due to a configuration limitation, two receivers did not have GAGSV messages recorded; hence it was not possible to compute the percentage of tracked Galileo satellites. Therefore, only 13 receivers have the violet bar for tracked Galileo satellites in Figure 30 (right side).

During the dynamic scenario under urban conditions, **6 receivers (some 47%, the percentage is computed excluding the DUTs that do not provided the GAGSV message) tracked more than 70% of the visible Galileo satellites.** Considering GPS, only one receiver tracked less than 70% of the visible GPS satellites. From the analysis of the used satellites, it can be noted that the differences between GPS and Galileo are reduced. In both cases (GPS and Galileo) 13 DUTs out of 15 were using more than 60% of the visible satellites. In conclusion, the usage of GPS and Galileo is similar for the full set of receivers.
For the previous dynamic test performed under open sky conditions the percentage of the satellites tracked and used where in average 10% of the time greater for the GPS satellites compared with Galileo satellites.

From the comparison of the two scenarios, it can be emphasized that the percentage of Galileo satellites used in the PVT solution is reduced only by a 15% passing from open sky to shadowed scenario, while for GPS such reduction is in the order of 25%. This fact confirms the higher robustness of Galileo measurements in signal degraded scenarios. Moreover, the comparison between the tests allows to highlight the Galileo added value in urban navigation, a higher number of available satellites allows the DUT to properly exclude measurements which may be affected by multipath or other errors.

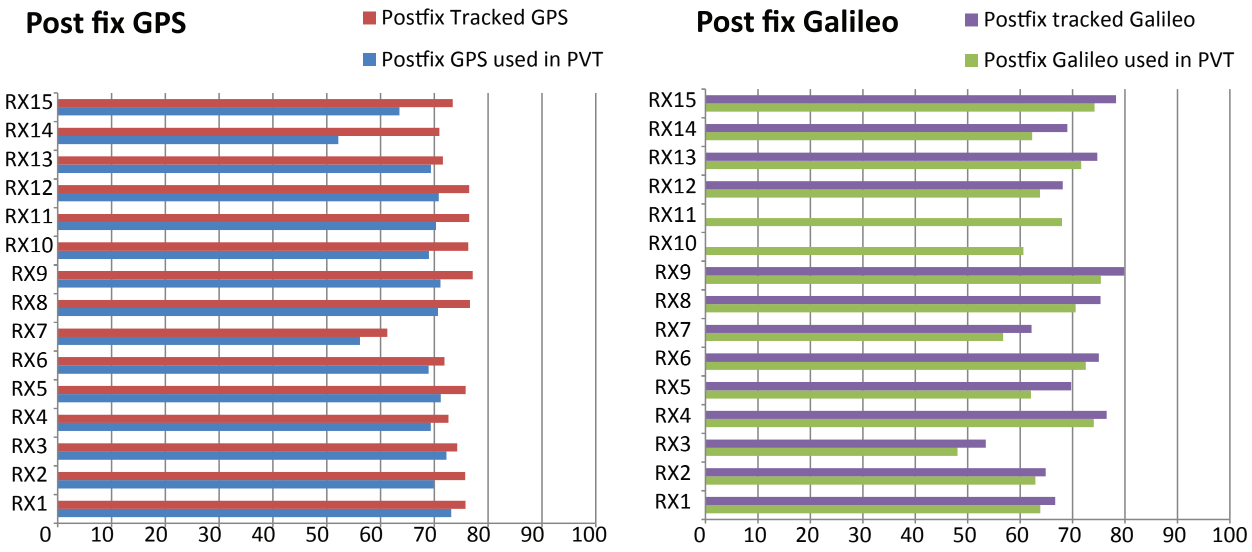


Figure 30: Percentage of tracked and used GPS satellites (left) and Galileo satellites (right) after the navigation solution has been reached during the dynamic shadow case.

The percentage of the type of solution provided by the DUT is shown in Figure 31. To compute the metrics only the epoch after the first valid fix were considered, only two DUTs provided a navigation solution using only Galileo satellites for few minutes during the test. 14 devices provided a combined solution for more than 90% of the time; only one DUT provided a single constellation solution for more than 15% of the test length.

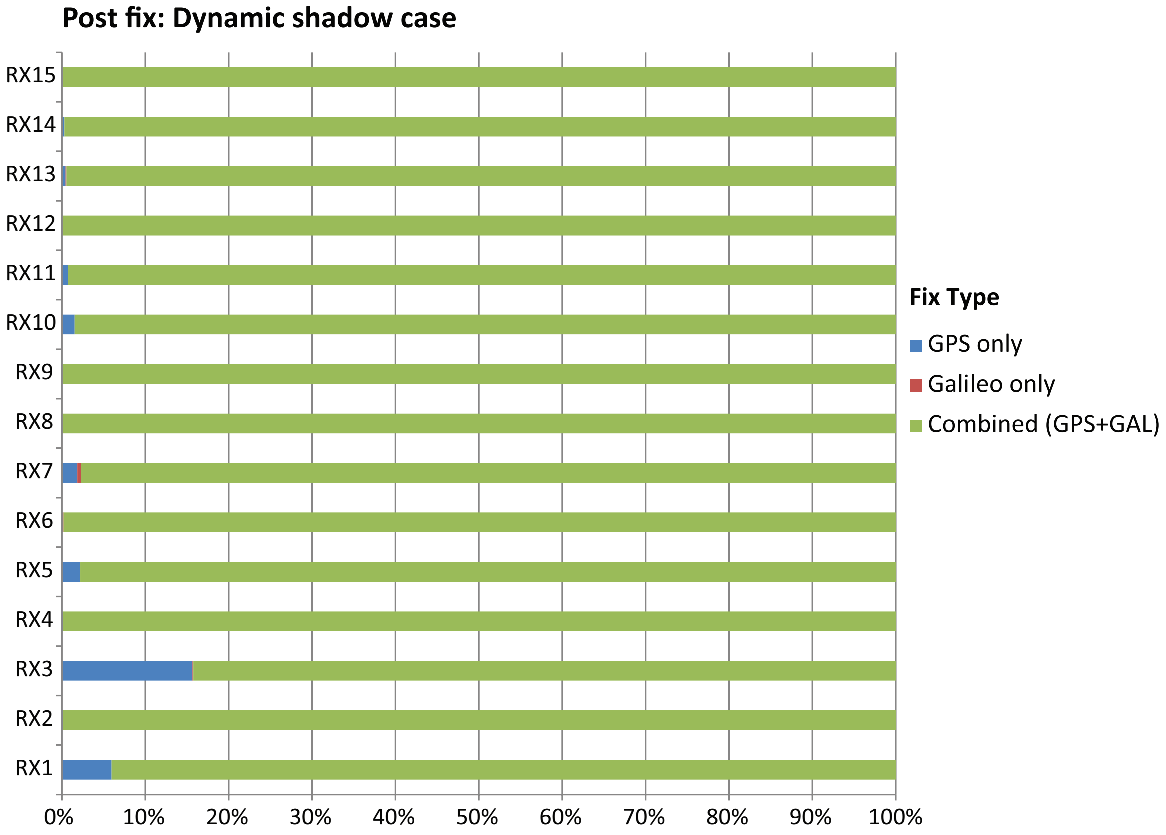


Figure 31: Percentage of time where the navigation solution was achieved using only GPS (blue), Galileo (red) and a combined fix using GPS and Galileo (green) for the dynamic shadow case.

[Pt_2.2.5_Anx_VI] CSTTFF

The goal of this test case is to assess CSTTFF performance of the DUT. The test is carried out by implementing two scenarios, one with power levels of −130 dBm and the other with power levels of −140 dBm. These powers are set for all GPS, GALILEO and SBAS satellites in view. As specified in the following, the pass/fail criteria on the average CSTTFF are different depending on the signal power level used.

The average TTFF at −130 dBm must be below 60 seconds. At signal level down to −140 dBm the average TTFF values must not exceed 300 seconds. For both cases, results have been computed using at least ten samples. The results are shown respectively in Figure 32 and Figure 33. Fifteen percent of the receivers could not provide TTFF measurements due to technical issue preventing the correct estimation of the TTFF.

The comparison among the 15 receivers shows similar TTFF values at signal power level of −130 dBm. The average TTFF value is 37.27 s with a minimum of 23.05 s and a maximum value of 44.79 s.

TTFF values observed at signal power level of −140 dBm are significantly more heterogeneous ranging from 33.45 s to 121.58 s. However even if signal power sensitivity is non negligible on the consequent TTFF computation, in average the TTFF value for the full set of analysed receivers is 4 times less than the threshold of 300 s set in the regulation.

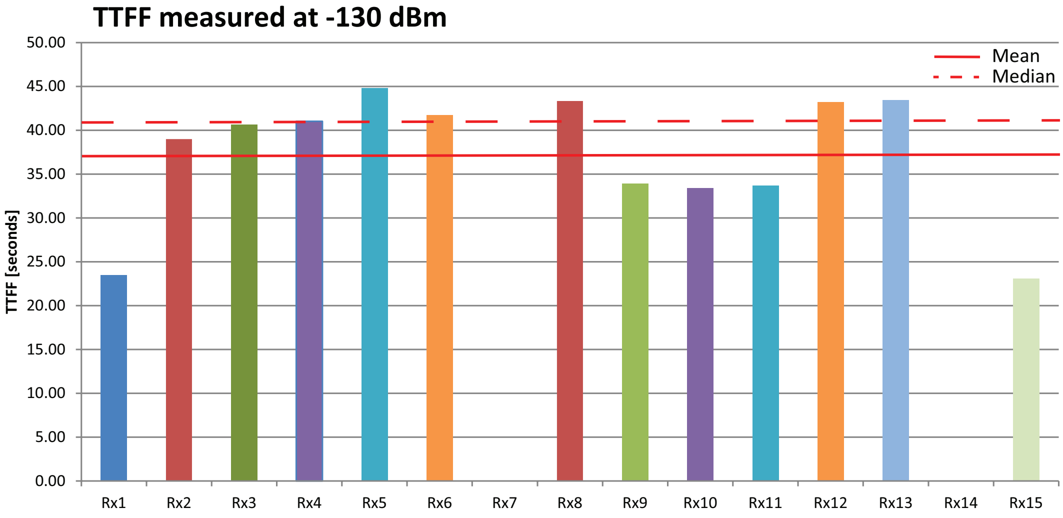


Figure 32: TTFF in seconds for the overall 15 receivers at signal power level of −130dBm. The average and the median values are depicted.

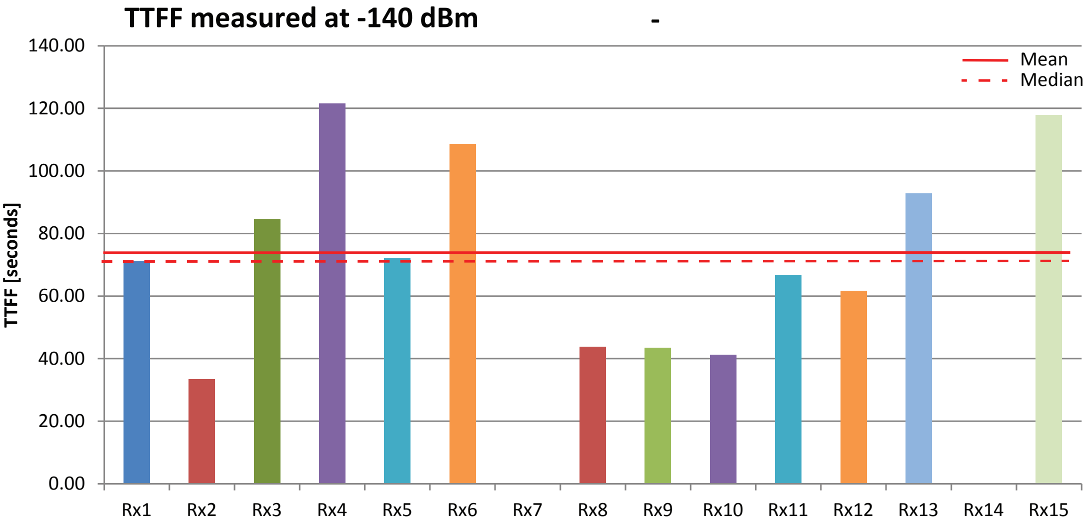


Figure 33: TTFF in seconds for the overall 15 receivers at signal power level of −140 dBm. The average and the median values are depicted.

TTFF has been computed at the two different signal power levels of −130dBm and −140 dBm. The percentage of time where a fix is reached is analyzed showing the configuration used: combined solution or fix obtained only with Galileo or GPS. The repartition of the configuration used to achieve the TTFF is shown in Figure 34. There is no fixes obtained only with Galileo at both signal power levels.

There is a clear difference in the way the solution is achieved. Indeed at −130 dBm, 66% of the receivers used a combined solution at least 20% of the time and nearly 60% of the receivers used a combined solution most of the time.

Looking to the other test conducted at −140 dBm (Figure 34), more than 90% of the receivers got a fix only using GPS. Only one receiver reached the solution in combined mode during 90% of the time.

At −130 dBm, TTFF is mainly achieved using a combined solution whereas at −140 dBm, the solution is achieved most of the time using only GPS. **This underlines the fact that all DUTs needed a long latency in acquiring Galileo satellites preventing them from being used in the solution. These histograms are very illustrative of the lack of sensitivity that is present at −140 dBm for the majority of the receivers.**

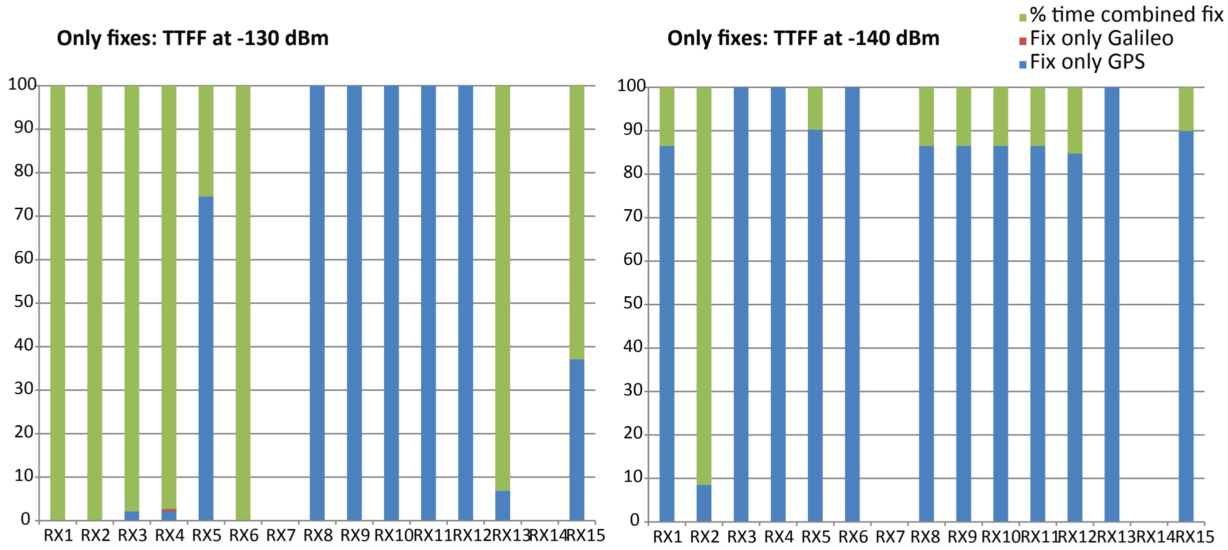


Figure 34: Percentage of time where the TTFF is reached with a combined solution (GPS+Galileo), with only Galileo or with only GPS satellites. The repartition is shown for the TTFF measured at −130 dBm (left side) and at −140 dBm (right side).

[Pt_2.2.6_Anx_VI] Test of re-acquisition time of tracking signals after block out of 60 seconds

The purpose of this test is to assess the time required by the DUT to provide a solution after being disconnected from any satellite for 60 seconds.

The scenario includes a sequence of at least 10 intervals of signal block out intervals lasting 60 seconds, and the average of the associated re-acquisition time must be below 20 seconds. This test scenario is carried out at the signal power level of -130 dBm, for all satellites in view. All the requirements are detailed in the regulation (see [RD1]).

As presented for the other requirements, the CSTTFF has also been computed for the different receivers and the values are depicted in Figure 35. The CSTTFFs recorded are more homogenous and faster than for the static case since the signals were set to a stronger signal power (−130 dBm instead of −138.5dBm). In average the CSTTFF are 40% reduced than the one observed in the nominal conditions set in the static case.

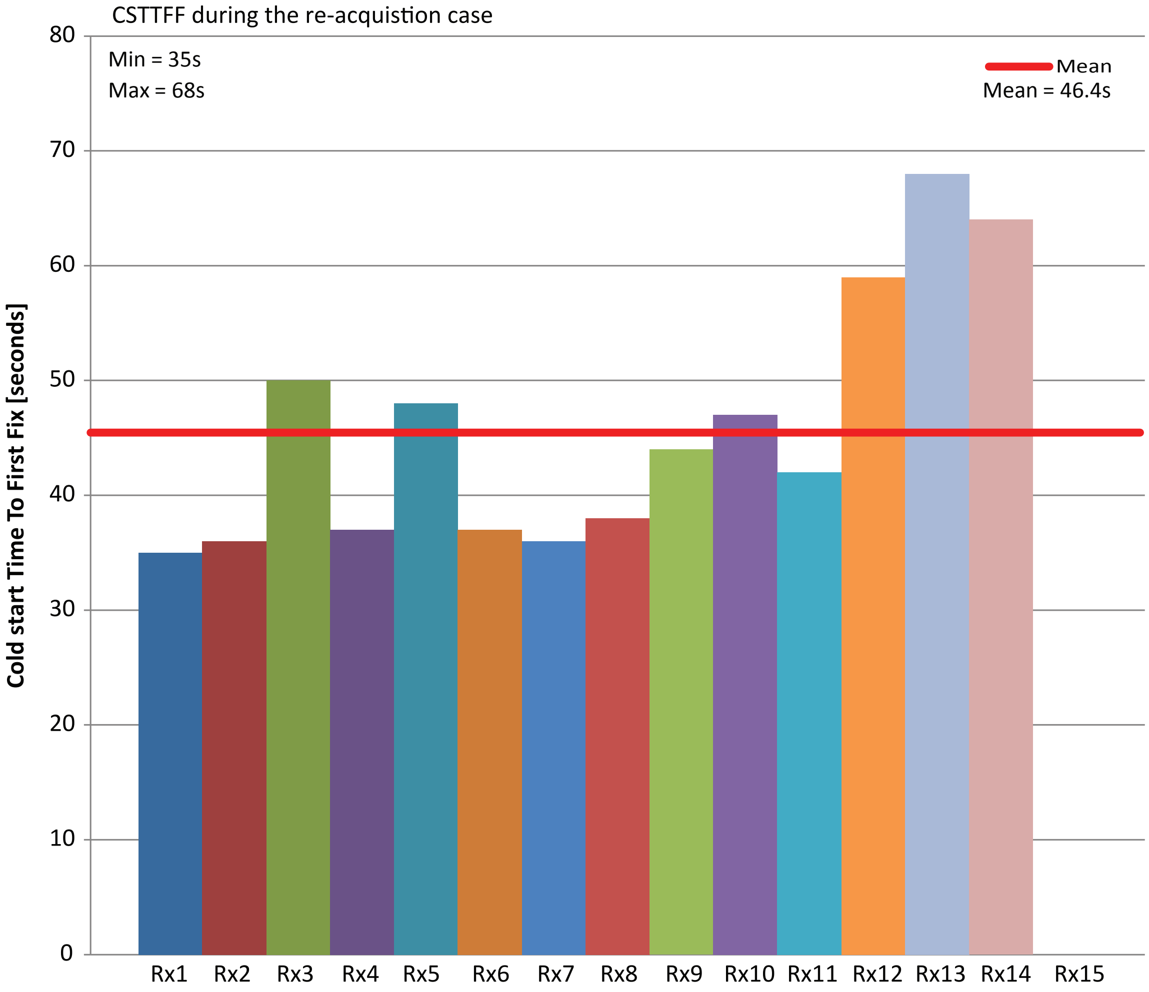


Figure 35: CSTTFF in seconds for the overall 15 receivers during the re-acquisition scenario.

In average the re-acquisition time needed with the signal power set to −130 dBm is 1.68 s for the whole set of receivers which is well below the limit imposed by the requirements (Figure 36). This test did not present any particular difficulty for the receivers. The full set of receivers tested shows a re-acquisition time of the same order.

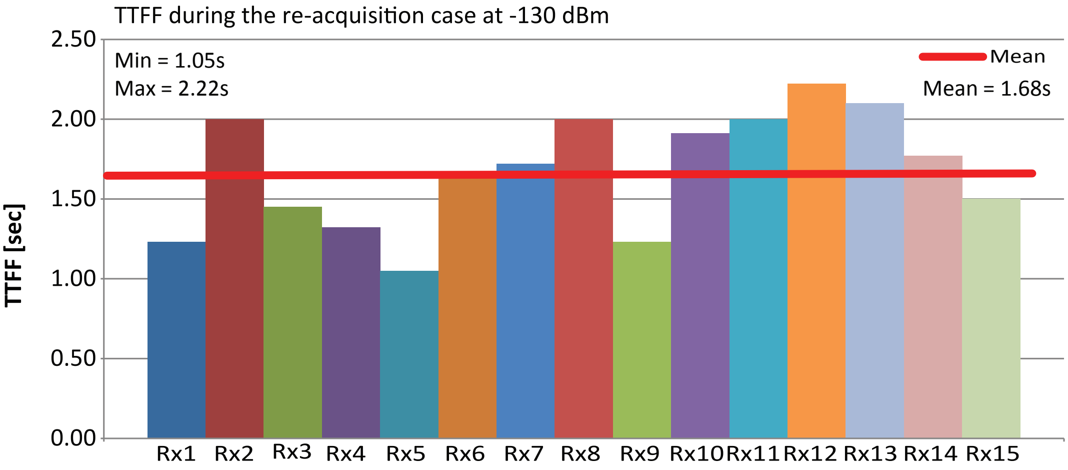


Figure 36: Re-acquisition time need for every 15 receivers at −130 dBm. Minimum, maximum and average values are also indicated.

The percentage of tracked and used satellites for GPS and Galileo is shown in Figure 37. From the figure, it can be noted that the percentage of the used Galileo satellites is slightly reduced in comparison with the GPS used for 5 DUTs. In these cases the difference between the percentage of Galileo and GPS used satellites is more than 10%, in the remaining cases only a small difference can be noted. For the tracked satellites the difference is even less evident, in only two devices a difference of more than 10% can be noted.

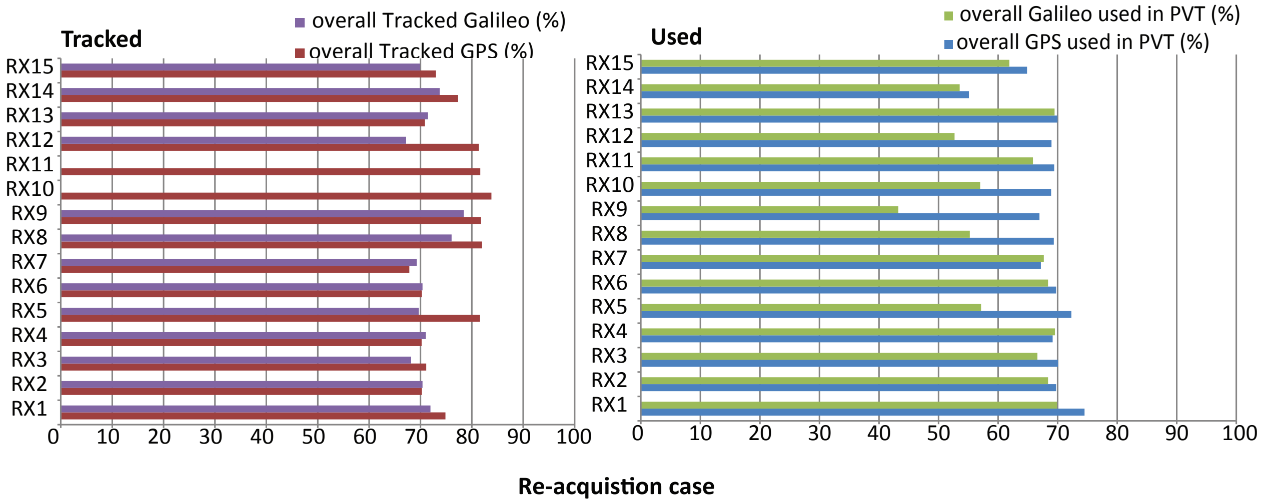


Figure 37: Bar plots of the tracked and used satellites after the navigation solution is achieved in the re-acquisition scenario. Percentage of tracked GPS and Galileo satellites are shown on the left side, percentage used GPS and Galileo satellites

[Pt_2.2.7_Anx_VI] Test of GNSS receiver sensitivity in cold start mode, tracking mode, and re-acquisition scenario

This test has the purpose to assess the DUT's sensitivity when fed with very low signal power levels.
For this purpose, the power levels of all signals is first set to −144dBm for 1 hour and then further decreased down to −155 dBm for 10 minutes. Then the signal is increased up to −150 dBm and a few seconds after a 20 second signal outage is introduced. The signal level is kept at −150 dBm until the end of the scenario. In Figure 38 the above sequence is illustrated specifying the temporal duration of each power interval.

In order to pass the test, the DUT has to meet the following [RD1]

- Provide a valid position solution when the signal power level is equal to −144dBm. The solutions should be provided within 3600 seconds after a cold start event.
- Maintain a valid position solution for at least 600 seconds after reducing the signal power level down to −155 dBm
- Re-acquire the position in no more than 60 seconds, when the signal power level is first increased up to −150 dBm and after that a 20 seconds navigation signal outage is introduced.

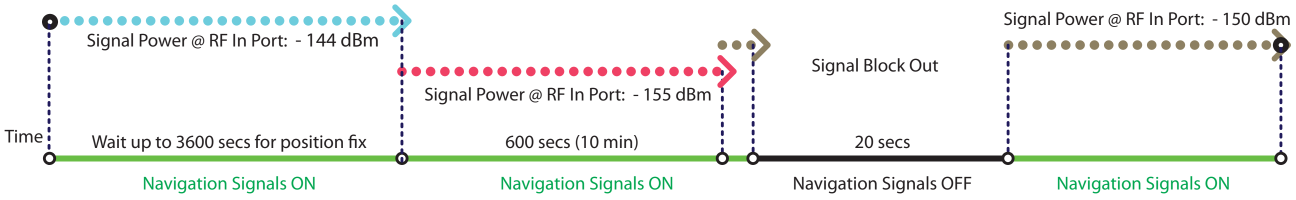


Figure 38: Timeline representing the sequence of different power levels to be used in the scenario taken from [RD2].

As a summary, some statistics have been computed using all devices to report on the sensitivity receiver evaluation in Figure 39. In the results presented below only the modules that were able to get a continuous fix at −155 dBm were included to compute the statistics.

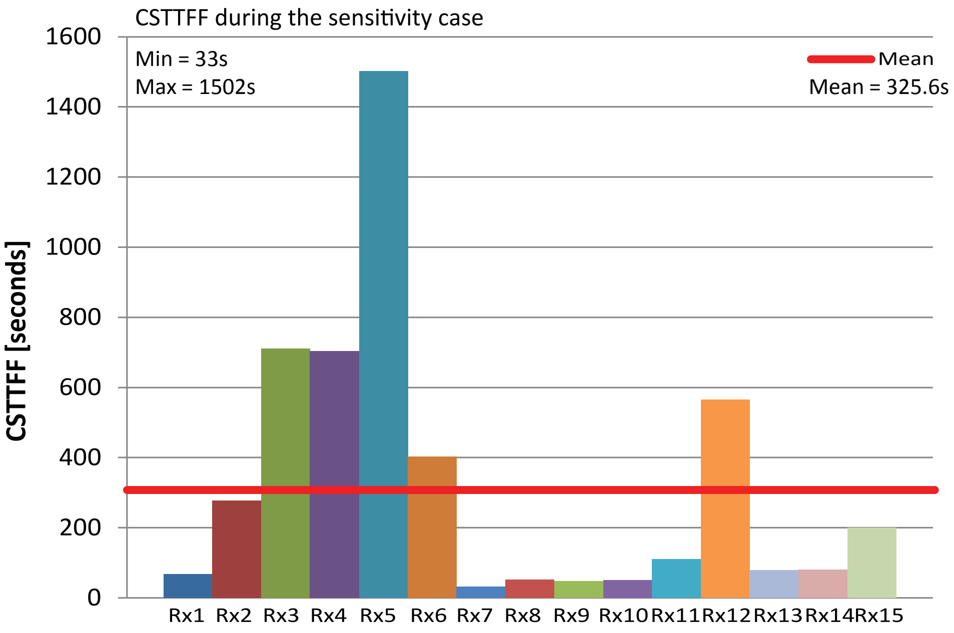


Figure 39: CSTTFF for the 15 receivers for the sensitivity scenario. The average value is highlighted in red.

The amount of satellites tracked and used has been computed using the NMEA GPGSV and GAGSV messages. The ratio of tracked and used satellites is then computed over the total number of simulated satellites. The ratio is given in percentage for the different requirements (2.2.2 to 2.2.7). The amount of satellites tracked and used is computed for each different signal power level at −144 dBm and at −155 dBm respectively (Figure 40).

At -144 dBm, 46% (7 over 15) of the DUTs tracked Galileo satellites and 33% (5 over 15) of the DUTs used them. When decreasing the signal power level to -155 dBm, only 40% (6 over 15) of the DUTs tracked Galileo but one of the devices was not able to use Galileo satellites in the navigation solution. The sensitivity test highlighted the difficulty existing to track and use Galileo satellites in comparison with the GPS satellites.

At -144 dBm, in average 97% of the available GPS satellites were tracked and 88% were used. Looking to the tracking of Galileo satellites only 18% were tracked in average and 13% were used. When decreasing the signal power level to -155 dBm, 92% of the GPS satellites are tracked in average and 74% are used. The latency in tracking the Galileo satellites allowed tracking more satellites at -155 dBm that at -144 dBm with an average of 26% of the Galileo satellites available also the percentage of Galileo satellites in the navigation solution is increased passing from 13% to 15%.

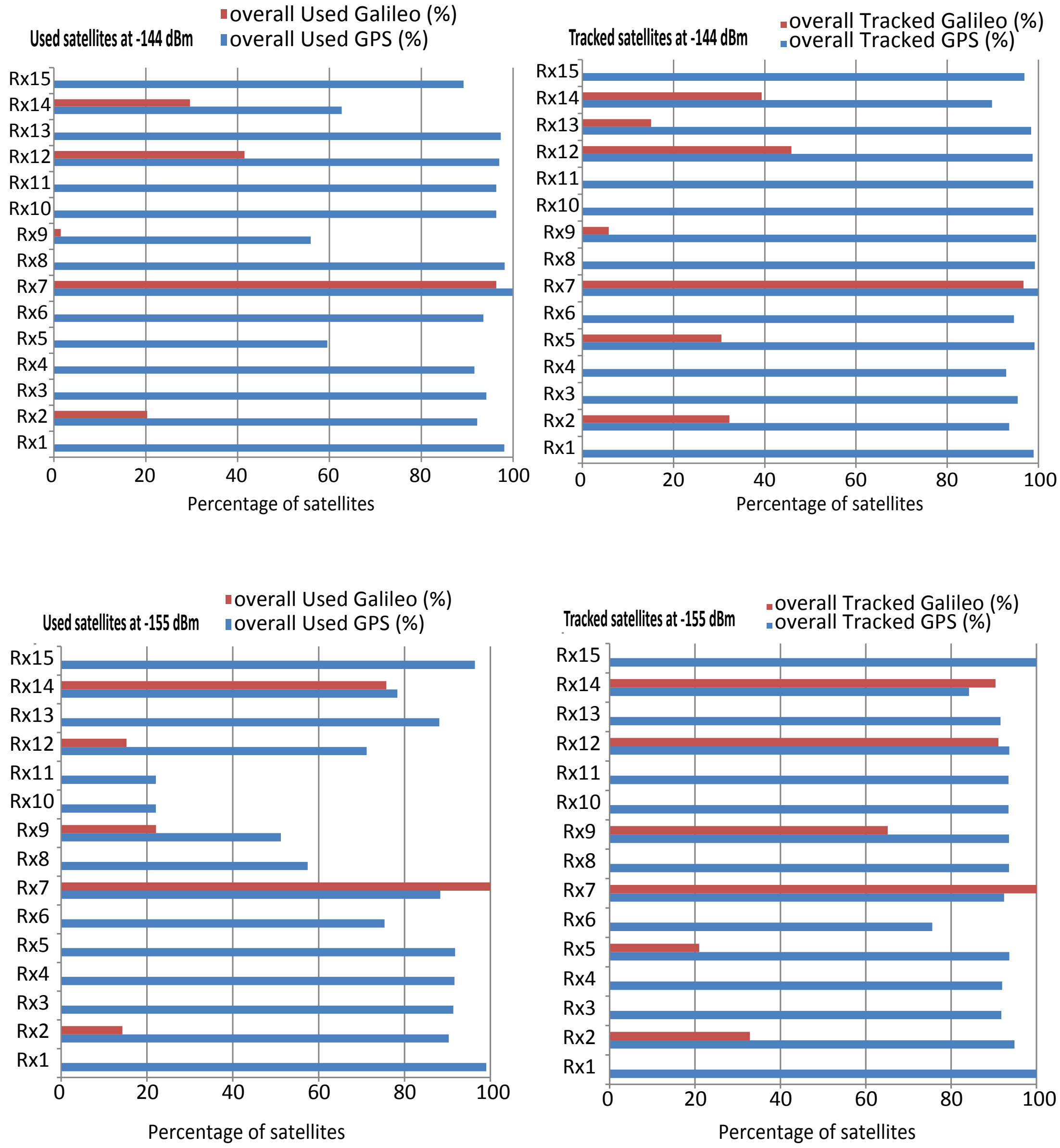


Figure 40: Overall used and tracked GPS and Galileo satellites monitored at the different signal power levels tested during the sensitivity test at −144 dBm and at −155 dBm.

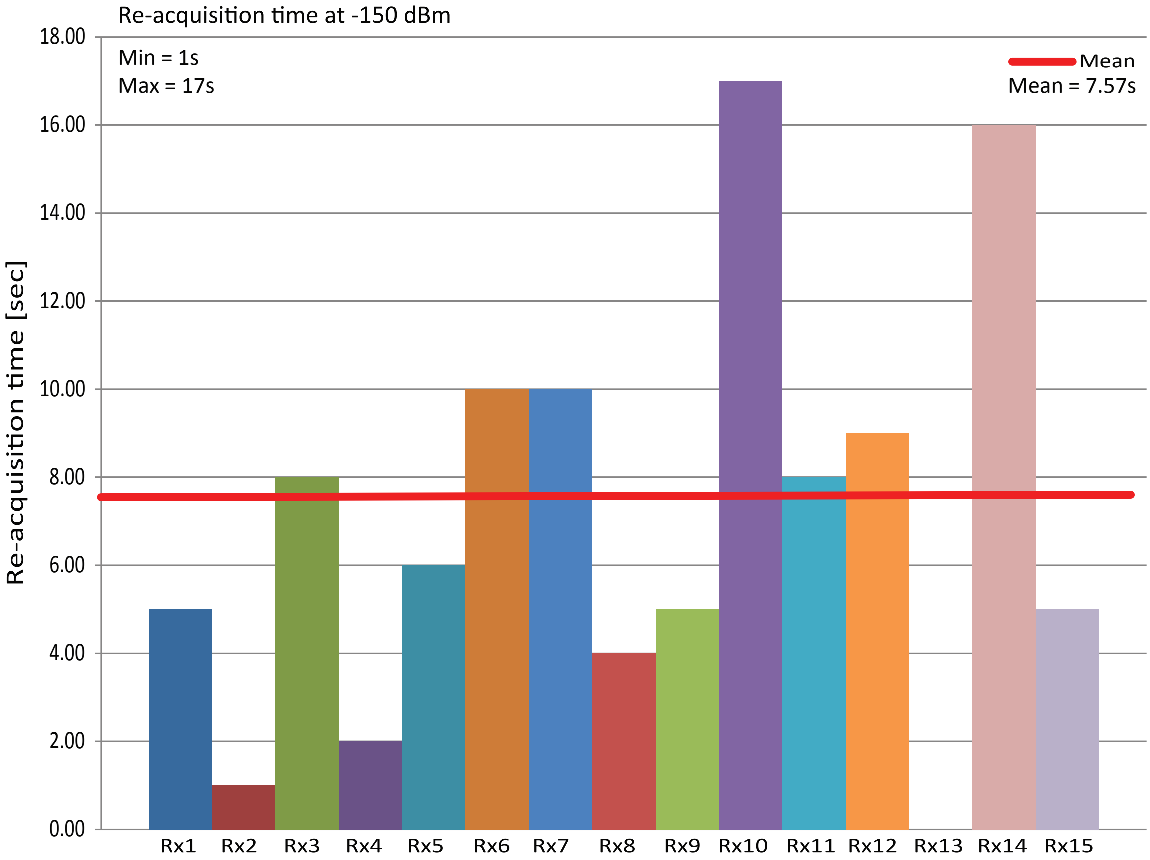


Figure 41: Re-acquisition time in seconds needed at −150 dBm for the 15 DUTs.

It clearly appears that the GPS satellites that were used at −144 dBm decreased by about 30% at −155 dBm. The re-acquistion time needed at −150 dBm was found well below the limit fix in the regulation of 60 seconds.

The re-acquisition at −150 dBm, was also found to be challenging for most of the receivers. Indeed, if almost 95% of the receivers were able to track GPS satellites and more than 60% were able to use them during at least 60% of the time the situation is drastically different for the tracking and usage of the Galileo satellites. **The need of improving the sensitivity in tracking and using the Galileo satellites is highlighted.** Only 20% of the receivers were able to track and use Galileo satellites. Less than 10% of the receivers used Galileo satellites during more than 60% of the time at −150 dBm.

IV. SYNTHESIS

In this section, a selection of the test results comparing the full set of devices is made. More precisely, the overall performance indicators with the percentage of time with a combined solution, the CSTTFF and the horizontal positioning errors are given.

/ Time availability of a combined solution in the static, dynamic and dynamic shadow scenarios

The percentage of time a combined solution is present during the first hour for the static, dynamic, and dynamic shadow scenarios has been analysed for each DUT in Figure 42. For the static case, all DUTs use a combined solution more than 90% of the time. The percentage of time a combined solution is used decreases slightly for the dynamic scenario. One DUT shows combined solution availability below 90%. Finally, 20% of the DUTs (3 over 15) give a combined solution during less than 90% of the time in dynamic shadow scenario.

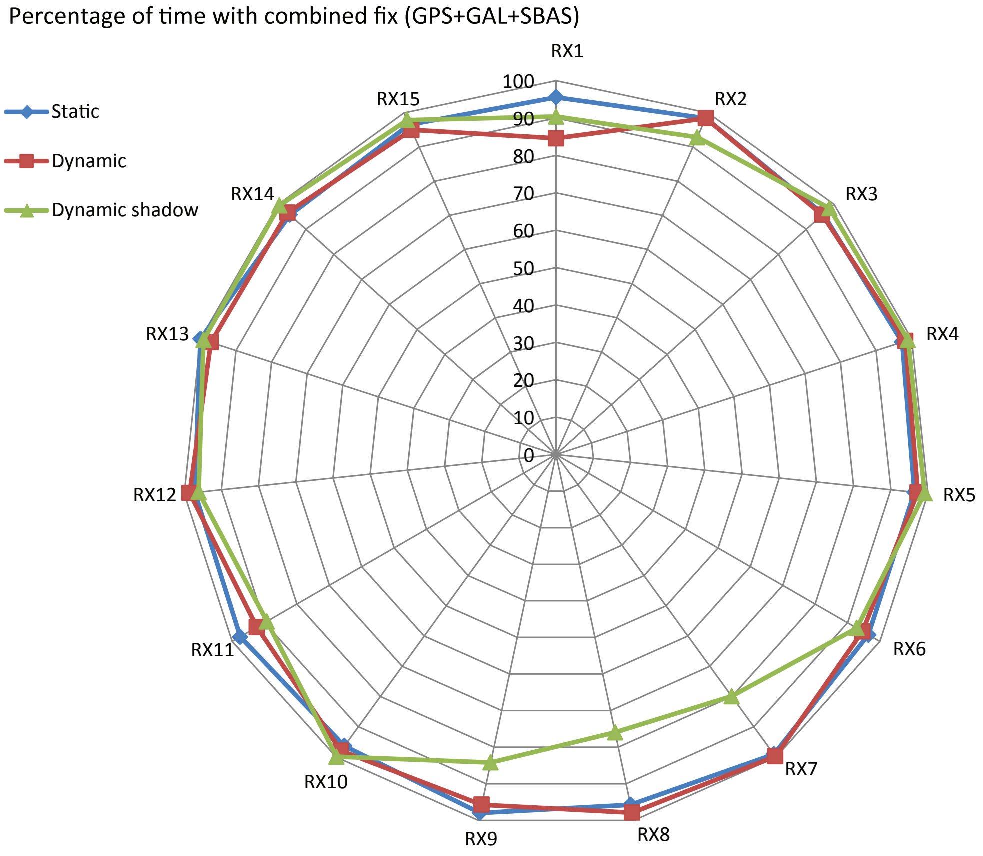


Figure 42: Multi-constellation solution availability for the static, dynamic and dynamic shadow scenarios, for the 15 units tested.

/ Cold start TTFF times in the static, dynamic, dynamic shadow, re-acquisition, and sensitivity scenarios

As a summary, all CSTTFF times observed in the static, dynamic, dynamic shadow, re-acquisition, and sensitivity scenarios are summarized in Figure 43.

It can be seen that, as expected, the scenario showing the longest cold start CSTTFF times is that assessing the sensitivity. In this test, a substantial disparity among the units is observed. However about 70% of the receivers reached a fix solution in less than 10 minutes at signal power level −144 dBm.

Results reported for the sensitivity scenario are those obtained after an accurate calibration of the test set-up, accounting for the power loss in the RF cables between the RFCS and the DUT. Such a calibration improved the performance of some of the units. The manufacturers of these units were informed about the need to have a calibrated test set-up.

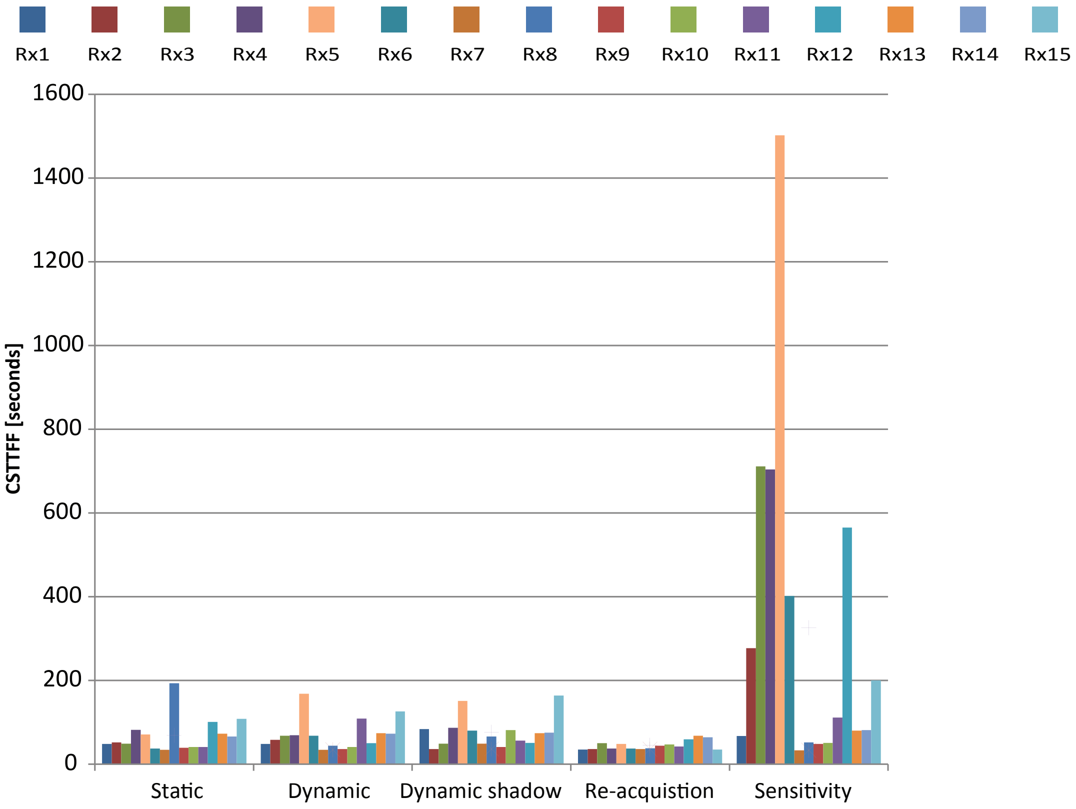


Figure 43: Cold start CSTTFF times observed in the static, dynamic, dynamic shadow, re-acquisition and sensitivity scenarios.

Case	Average CSTTFF [seconds] among the 15 DUTs
Static	69
Dynamic	71
Dynamic shadow	76
Re-acquisition	45
Sensitivity	326

Table 6: Average CSTTFF in seconds computed for the 15 DUTs for the different cases.

/ Overall horizontal positioning error in the static, dynamic and dynamic shadow scenarios

The overall horizontal positioning errors in the static, dynamic and dynamic shadow scenarios observed with all the units tested are shown in Figure 44.

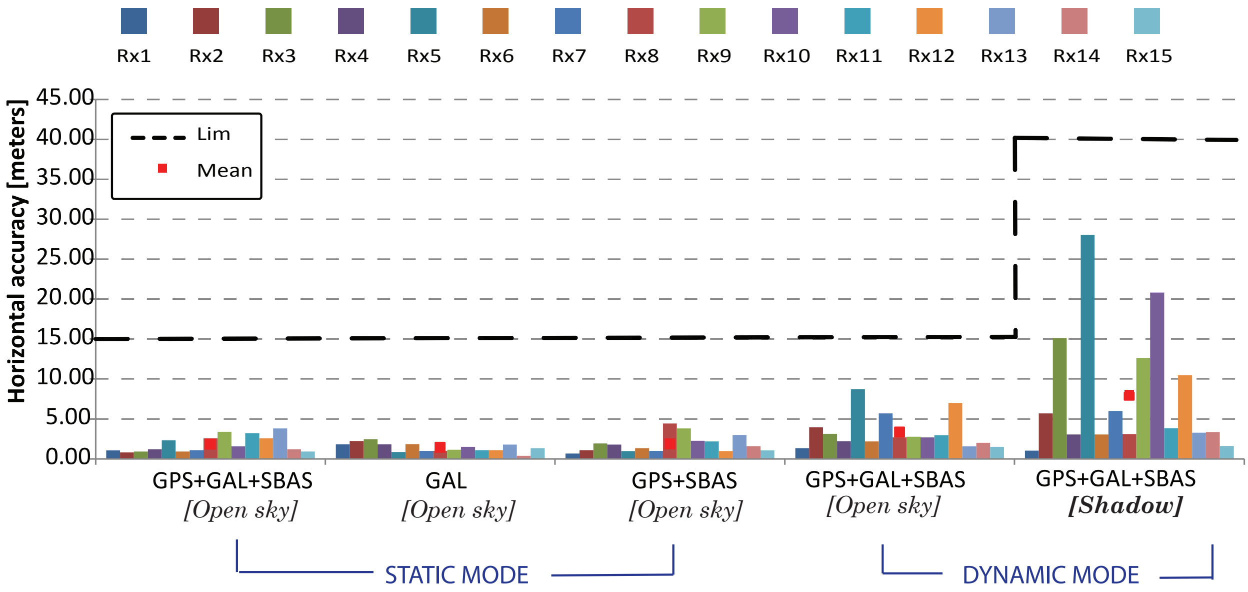


Figure 45: Overall horizontal positioning errors in the static, dynamic and dynamic shadow scenarios observed with all the units tested. The black dashed line indicates the limits set in the Regulation. The red square marker shows the average value.

The different values of horizontal positioning accuracy for the static and dynamic scenarios are summarised in Table 7.

Test Scenario	GNSS signals in view	Min	Max	Average horizontal error at 95% probability [m]	Threshold limit [m]
Static	GPS+GAL+SBAS	0.8	3.78	1.73	15
	GAL only	0.39	2.45	1.47	15
	GPS+SBAS	0.74	4.42	1.84	15
Dynamic	GPS+GAL+SBAS	1.33	8.72	2.95	15
Dynamic shadow	GPS+GAL+SBAS	1.04	27.99	6.68	40

Table 7: Average Horizontal position error at 95% confidence level computed for the 15 units.

V. SUMMARY OF THE MAIN LESSONS LEARNT

One of the objectives of the test campaign on the eCall devices was that of gathering a set of lessons that would help conduct a future batch of tests more efficiently.

During the execution of the tests on the 15 units made available, the following issues were identified and, in some cases, mitigation actions suggested:

1. Testbed set-up and scenario definition

/ Low Noise Amplifier (LNA) inclusion

The LNA may or may not be included, it is up to the eCall manufacturer to decide what is the configuration to be tested (and therefore type approved), depending on the actual commercial configuration of the eCall OBU.

/ Satellites geometry limitations

The relative geometry of the GNSS satellites with respect to the user location is very important to perform most of the tests, and it is constrained in terms of PDOP. The PDOP can be calculated as the one observed simulating a single GNSS constellation, which is either the GPS or Galileo constellation, separately. Both GPS PDOP and Galileo PDOP have to respect the limits set in the regulation individually, while the SBAS satellites are assumed to be used exclusively as a communication channel to receive the corrections (i.e. they are not used for ranging) and therefore are not accounted for in the estimation of the PDOP.

/ Galileo signal configuration

Each test procedure is characterised in terms of signal power level for each satellite. Regarding the configuration of the signal power level of the Galileo E1 OS signals, the power level values specified in Annex VI [1] needs to be set to each of the two components (GAL 1B – data channel and GAL 1C – pilot channel), separately. This point is particularly relevant in the test scenario where the sensitivity of the eCall DUT is assessed.

2. DUT minimum configuration requirements

/ NMEA standardized output

The eCall DUT has to output the data logs in accordance with the NMEA Standard 0183, the message rate should be at least 1 Hz during the entire duration of the test scenario.

/ SBAS corrections activated

A very small number of the devices were not configured such that the integration of the SBAS correction was made smoothly a few minutes after the start of the scenario. It is thus suggested that a verification of the correct SBAS configuration at the manufacturer’s premises is made in advance before shipping the units.

/ Baud rate setting

Some DUT were using a high baud rate which can cause some compatibility problems with commercial eCall testing platforms. It is recommended therefore to configure the units such that can be interfaced with a data rate not exceeding 115 200 baud per second.

Some cases where a device was not logging the NMEA messages continuously without any loss of data were observed. It is thus suggested that the interfacing and continuous logging of the data from the device can be made before at the manufacturer’s premises.

/ PRN ID standard allocation

The set of NMEA Talk IDs used by the various units tests showed some differences and that required the development of several ad-hoc NMEA parsing scripts. It is recommended that the manufacturer provides a detailed specification of the set of NMEA Talk IDs used in advance.

3. Convergence time to re-acquire a valid position solution

/ Dynamic scenario

On several occasions it has been noted that the 2D deceleration event present in the scenario had an evident impact on the overall horizontal position errors. An optimization of the position engine giving a faster convergence of the position solution after a sudden deceleration event was recommended to some of the manufacturers.

/ Dynamic shadow scenario

It has been observed that some units could improve their performance in terms of re-acquisition time under low visibility conditions when moving over a dynamic trajectory.

4. Sensitivity threshold of the DUT

As mentioned in the implementation guidelines [RD2], an accurate calibration of the eCall test bed has been observed to be a requirement when testing some of the units. When this was the case, manufacturers were informed about the need to enhance the sensitivity of the device to meet the requirements with a sufficient degree of repeatability.

/ SBAS sensitivity tracking

Some devices showed a limited sensitivity tracking the SBAS signals. An accurate calibration of the setup in this scenario needed in order to be able to integrate the SBAS corrections successfully. In these cases, manufacturers were informed about the need to raise the sensitivity threshold to track the SBAS signals.

5. Cold start TTFF

/ Galileo only scenario

Particularly in the static and dynamic scenarios, the need to adjust the GNSS processing engine in the devices to get a faster acquisition and integration of the Galileo signals was identified and communicated to some of the manufacturers. This was identified as a limitation towards a solid adoption of Galileo in the units.

VI. CONCLUSIONS

An extensive testing campaign was launched by the GSA in 2017. After a first phase to carry out preparatory activities (first trials, scenarios definitions and set-up preparation) the first tests were then run from June 2017 to September 2018 on a total of fifteen (15) eCall close to market units. The testing campaign was successfully carried out by a team at the JRC, in Ispra (Italy) coordinated by the GSA Market Development team. A detailed assessment of the various eCall modules against the requirements of the EGNOS/GALILEO eCall conformance testing (Annex VI) in the EU commission delegated regulation 2017/79 was completed.

Four main categories of test scenarios, ranging from horizontal positioning accuracy assessment under various conditions (static, dynamic and dynamic shadow), CSTTFF at various signal power levels, re-acquisition and sensitivity test scenarios were studied with scrutiny. A very large series of controlled measurements in the GNSS laboratory were analysed during this campaign.

The most demanding test was the sensitivity one for which different set-ups were tested to account for every single source of power loss that could interfere with the simulated signal power level. In order to ensure the proper calibration of the set up the tests were used with and without adding an external LNA to the setup.

The overall volume of collected and analysed raw measurements is estimated to about 5 GB, including all the observables generated by the seven scenarios.

Therefore, the recording, processing and analysis performed to provide a test report to every manufacturer, together with the overall assessment performance report of the eCall testing campaign was a demanding task requiring a substantial amount of time to be completed.

A comparative analysis of the performance of the DUTs was made using a selection of metrics including the horizontal positioning accuracy, the percentage of time with a combined solution, the proportion of satellites tracked and used, the CSTTFF estimated for all the scenarios tested.

In order to enable a quick comparison of the eCall DUTs performance, a heatmap has been produced. The KPI corresponding to each requirement of the regulation are summarised with the corresponding value needed to comply with the requirement in Table 8.

Annex VI test procedure number	Annex VI test procedure Name	Defined KPI
[Pt_2.2.1_Anx_VI]	NMEA-0183 messages output test	Field #6 in GGA messages sets to 2
[Pt_2.2.2_Anx_VI]	Assessment of positioning accuracy in autonomous static mode	Mean horizontal positioning error below 15 m with a confidence level of 95%
[Pt_2.2.3_Anx_VI]	Assessment of positioning accuracy in autonomous dynamic mode	Mean horizontal positioning error below 15 m with a confidence level of 95%
[Pt_2.2.4_Anx_VI]	Movement in shadow areas, areas of intermittent reception of navigation signals and urban canyons	Mean horizontal positioning error below 40 m with a confidence level of 95%
[Pt_2.2.5_Anx_VI]	Time to first fix test	TTFF below 60 seconds at -130 dBm TTFF below 300 seconds at -140 dBm
[Pt_2.2.6_Anx_VI]	Test of re-acquisition time of tracking signals after block out of 60 seconds	Re-acquisition time below 20 seconds
[Pt_2.2.7_Anx_VI]	Test of GNSS receiver sensitivity in cold start mode, tracking mode, and re-acquisition scenario.	CSTTFF below 3600 seconds at -144 dBm Navigation solution available at least 600 seconds at -155 dBm Re-acquisition time at -150 dBm below 60 seconds

Table 8 Summary of the KPIs and the corresponding requirements of the regulation.

With respect to Figure 46, the colour code is defined as follows:

- given the observed performance of the full set of DUTs, dark green represent the best KPI value(s) and light green indicates the worst KPI value(s), that are still within the threshold sets in [RD1].
- Red indicates test failure, i.e. KPI exceeded the [RD1]
- The cell is left blank, when no data were available

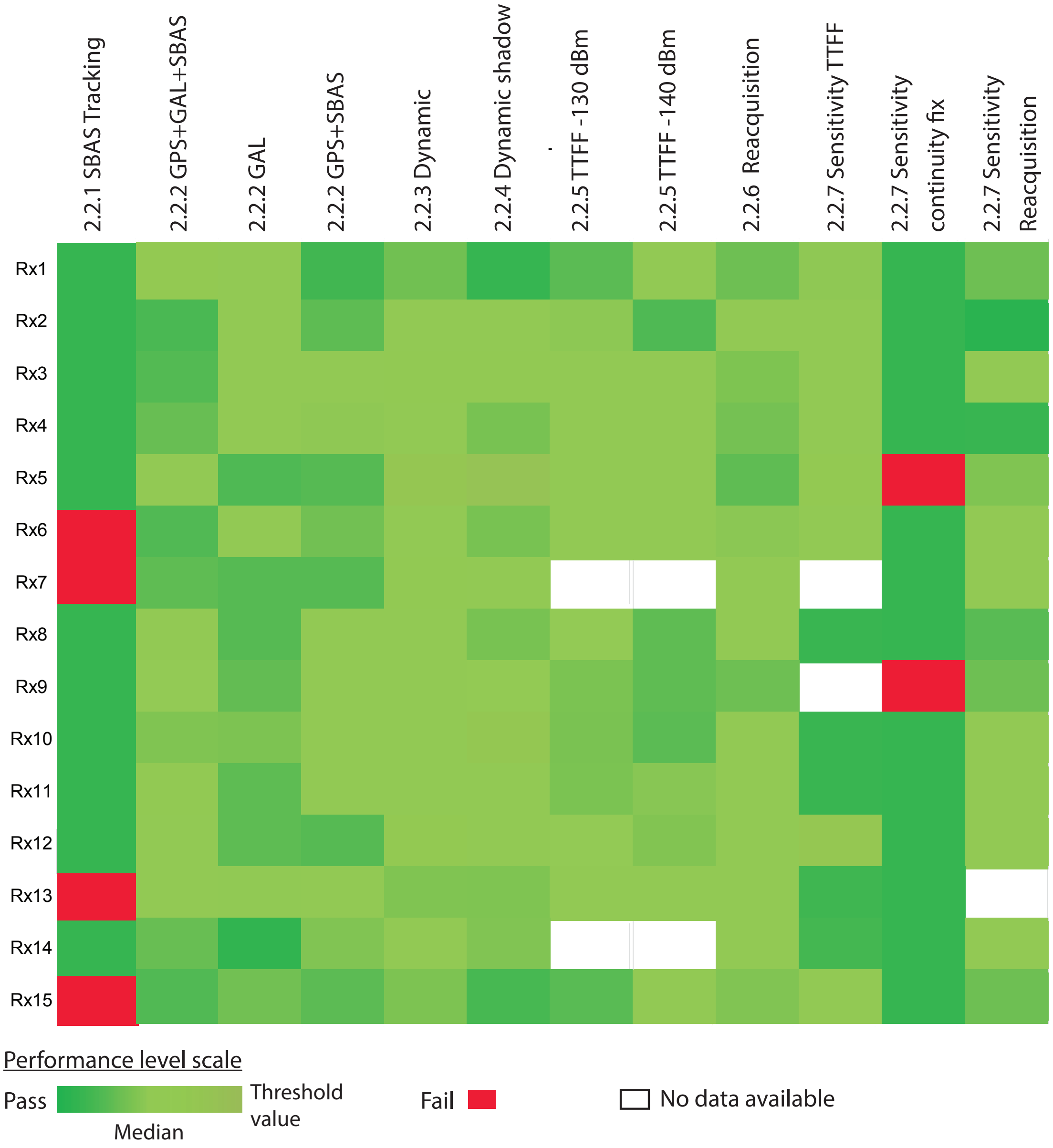


Figure 46: Heatmap of eCall requirements performance for all the 15 DUTs. Performance level is expressed following the colour bar from green to dark green. For the SBAS corrections tracking only fail (red color) or pass (green color) criteria are used. White cells are used when no data are available.

This map highlights that all DUTs performed very well against most of the requirements except for the SBAS correction tracking and the continuity fix at -155 dBm in the sensitivity scenario.

However, there is definitely a margin for improvement in terms of a more optimal use of Galileo at very low signal power level even if that did not affect the overall positive result thanks to the multi-constellation solution.

Overall, it has been concluded that:

- **The DUTs reached an overall good maturity of the implementation, in terms of Galileo and EGNOS adoption.**
- **Galileo signals and services demonstrated to provide a substantial contribution to ensure the type-approval of the eCall solutions in the interest of EU citizens and in particular providing quality positioning information to enable a safer emergency service in European roads. As an example, it is clearly visible in terms of positioning accuracy (Galileo only horizontal accuracy is better than GPS+SBAS horizontal accuracy, when in static conditions).**
- **The capability to acquire and track Galileo signals could in some circumstances be optimized especially when it comes to the sensitivity scenarios.**

For this particular test, even if the test is passed by all the receivers, almost half of them were not able to track Galileo satellites at such low power levels (e.g. −144 dBm down to −155 dBm and back to −150 dBm). In order to improve the sensitivity in acquiring signals from Galileo satellites the standard set-up was also tested using an additional LNA. For 40% of the receivers, the addition of an LNA was needed to be compliant with the sensitivity test requirement. Almost 30% of the DUTs were able to track Galileo signals with over half of them needing a long time to track Galileo satellites and then integrate those signals in the navigation solution.

First of its kind, this testing campaign allowed to strengthen mutual trust and cooperation with the On-Board unit manufacturers and the test/simulator solution vendors involved in the adoption of the EU commission delegated regulation 2017/79. The technical issues encountered during the preparation and execution of the tests were solved thanks to constructive and continuous discussion with the manufacturers.

The testing campaign opened a direct communication channel with the manufacturers, providing a deeper insight into their products maturity with respect to the EGNSS conformal tests. Thanks to the campaign, manufacturers received a thorough performance analysis, enabling them to early address a number of issues observed during the pre-test step at JRC premises before they moved to the official type-approval at the designated technical center.

In addition, in terms of number, type of DUTs tested and variety of scenarios simulated thanks to this campaign, it was possible to identify and early address key points regarding the state of the art adoption of the European GNSS.

VII. REFERENCES

[RD1] *Annex IV of Commission Delegated Regulation (EU) 2017/79*, 12 September 2016, establishing the technical requirements for compatibility of eCall in-vehicle systems with the positioning services provided by the Galileo and the EGNOS systems.

[RD2] JRC/GSA Implementation guidelines for On-Board Unit manufacturers, test solution vendors and technical centres, version 1.0 of December 2017, available on the GSA website.

[RD3] NMEA 0183 Version 4.1 Standard Specification, June 2012.

[RD4] NMEA 0183 Version 4.0 Standard Specification, November 2008.

How does EGNOS work?

EGNOS, the European Geostationary Navigation Overlay Service, uses geostationary satellites and a network of ground stations to increase the accuracy of existing satellite positioning signals while providing a crucial ‘integrity message’ that informs users in the event of signal problems.

The EGNOS reference stations pick up signals from GPS satellites, which are processed in Mission Control Centres (MCC). The accuracy of the original signals is determined and confounding factors are corrected.

This data is then incorporated into EGNOS signals and sent to its three geostationary satellites. The satellites relay these signals back to users on the ground, providing greater positioning accuracy than would be achieved through GPS alone.

Galileo Initial Services

With the declaration of Initial Services in December 2016, Galileo - the European Global Satellite Navigation System (GNSS) - has moved from testing to the provision of live services. Users around the world can now be guided using the positioning, navigation and timing information provided by Galileo’s global satellite constellation.

By working together with GPS, Galileo satellites provide better positioning and navigation for users, particularly in cities, where satellite signals can often be blocked by buildings. Plus, Galileo’s excellent timing accuracy helps make the synchronisation of banking and financial transactions and telecommunication and energy distribution networks more resilient, allowing them to operate more efficiently.

Galileo’s Search and Rescue service reduces the time it takes to detect emergency distress beacon signals from up to three hours to just ten minutes, potentially saving many more lives. The additional resiliency provided by Galileo is expected to help drive economic growth in Europe and beyond by enabling a range of new applications and services.

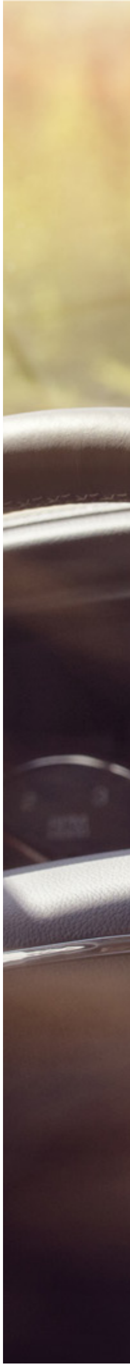
useGALILEO.eu

Mass-market devices containing a Galileo-enabled chipset, such as smartphones or vehicle navigation devices, can use Galileo signals for positioning, navigation and timing. The www.useGALILEO.eu tool helps you keep track of Galileo-enabled in-vehicle, portable, road tolling and fleet management systems, serving a variety of needs, as they become available.

GSA: linking space to user needs

The GSA is the European Union Agency in charge of managing operations and service provision of Galileo and EGNOS, ensuring that European citizens get the most out of Europe’s satellite navigation programmes in terms of innovation, competitiveness, economic growth, and benefit to users.

As Europe’s link between space technology and user needs, GSA keeps users at the centre of Galileo and EGNOS.



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