Test methods for the navigation module

1. Definitions

For the purposes of this Annex:

1.1 *"Global Navigation Satellite System" (GNSS)* is a satellite system that is used to pinpoint the location, speed and time of a user's receiver in any point of the Earth surface, water area of the World Ocean, air space, and in the near-Earth space environment.

1.2 *"Global Navigation Satellite System receiver" ("GNSS receiver")* - a component of an AECD designed to determine time, the position and direction of the vehicle using signals from global navigation satellite systems.

1.3 *"Satellite-Based Augmentation System" (SBAS)* is a system ensuring the correction of local errors of GNSS systems due to interferences via a network of ground-based stations. (ex: EGNOS, WAAS, SDCM, QZSS)

1.4 *"Cold" start mode* – the condition of navigation module when position, velocity, time, almanac and euhemerizes data is not stored in the receiver, the navigation solution is to be calculated by means of a full sky search;

1.5 *"Test mode"* – the function mode of the AECD meant for the check of functions and parameters of the AECD during system operation in the vehicle and also during the AECD tests.

2. Test conditions

2.1 The test object is the AECD, which includes navigation receiver and global navigation satellite system antenna, specifying navigation characteristics and features of the tested system.

2.1.1   The number of the AECD test samples shall be at least 3 pcs.

2.1.2   The AECD is provided for the test with the installed SIM-card, operation manual and the software (provided on electronic media).

2.1.3   The attached documents shall contain the following data:

- device serial number;

- hardware version;

- software version;

- device provider identification number ;

- unique device identifier, assigned by the system operator in case of the first activation of the device.

N o t e: For carrying out tests the originals of the operation manual containing specified convergence shall be provided.

2.1.4 The navigation receiver shall be able to output the navigation solution in a NMEA-0183 protocol format (RMC, GGA, VTG, GSA and GSV message) [5]. The AECD setup for NMEA-0183 messages output to external devices shall be described in the operation manual

2.2 The purpose of the tests is to verify the compliance of navigation characteristics of the AECD calculated by its navigation module, to the following requirements:

2.2.1 The navigation receiver being a part of the AECD shall be capable of receiving and processing individual GNSS signals of standard accuracy in L1/E1 band from at least three global navigation satellite systems, including GLONASS, GALILEO and GPS.

2.2.2 The navigation receiver being a part of the AECD shall be capable of receiving and processing combined GNSS signals of standard accuracy in L1/E1 band from at least three global navigation satellite systems, including GLONASS, GALILEO, GPS and SBAS.

2.2.3 The navigation receiver being a part of the AECD shall be able to provide positioning information in WGS-84, PZ-90 and GTRF coordinate systems.

2.2.4   According to 2.2.2, horizontal position error shall not exceed:

- under open sky conditions: 15 m at confidence level 0.95 with Position Dilution of Precision (PDOP) not more than 2.5

- in urban canyon conditions: 40 m at confidence level 0.95 with Position Dilution of Precision (PDOP) not more than 4The specified requirements for accuracy shall be provided:

- at speed range from 0 to [140] km/h;

- linear acceleration range from 0 to [2] G;

2.2.5 GNSS signal re-acquisition time after block out of 60 sec and signal level down to minus 130 dBm shall not exceed 20 sec after recovery of the navigation satellite visibility.

2.2.6 Time to first fix shall not exceed:

- 60 sec for signal level down to minus 130 dBm

-300 sec for signal level down to minus 140 dBm.

2.2.7 The navigation receiver being a part of the AECD shall provide:

- GNSS signals search (detection) at the level of valid signal at the antenna input (antenna amplifier input) of minus144 dBm;

- GNSS signals tracking and navigation solution calculation at the level of valid signal at the antenna input (antenna amplifier input) of minus 155 dBm

- Re-acquisition of GNSS signals and calculation of the navigation solution at the level of valid signal at the antenna input (antenna amplifier input) of minus150 dBm.

2.3 Test conditions

2.3.1 Tests are carried out in normal climatic conditions in accordance with standard ISO 16750-1:2006:

- air temperature (23 ± 5) °C and

- relative air humidity of 25 % to 75 %.

2.3.3 Technical service of tested samples during tests is not conducted.

2.3.4 Tests of the AECD in respect of its navigation receiver shall be performed with test and auxiliary equipment specified in Table 4.

T a b l e 4 – Recommended list of measurement instruments, test and auxiliary equipment

Equipment name	Required technical characteristics of test equipment	
	Scale range	Scale accuracy

Equipment name	Required technical characteristics of test equipment	
	Scale range	Scale accuracy
Global navigation satellite system simulator of GLONASS, Galileo and GPS signals	Number of simulated signals – at least 18	Mean square deviation of random accuracy component of pseudo-range to GLONASS / Galileo / GPS satellites not more: *- stadiometric code phase – 0,1 m;* *- communication carrier phase – 0,001 m;* *- pseudovelocity– 0,005 m/sec.*
Digital stopwatch	Maximum count volume – 9h 59 min 59,99sec	Daily variation at (25+5)°C not more + 1,0sec. Time discreteness- 0,01sec.
Vector network analyzer	Frequency range 300 kHz .. 4000 kHz Dynamic range (minus 85 .. 40) dB	Acc_F $1 \cdot 10^{-6}$ Acc_A (0,1 .. 0,5) dB
Low-noise amplifier	Frequency range 1200.. 1700 MHz Noise coefficient not more 2,0 dB Amplifier gain coefficient 24 dB	
Attenuator	Dynamic range (0 .. 11) dB	Acc ± 0,5 dB
Attenuator	Dynamic range (0 .. 110) dB	Acc ± 0,5 dB
Power source	Range of direct current voltage setting from 0,1 to 30 V Current intensity of output voltage at least 3A	Acc_0 ± 3% Acc_1 ± 1%
N o t e – it is allowed to apply other similar types of equipment providing determination of characteristics with required accuracy.		

2.3.5 Unless otherwise specified, GNSS signal simulation shall follow "Open sky" pattern as shown in Figure 1.

Figure 1: Open sky definition

Zone	Elevation range (deg)	Azimuth range (deg)
A	0 – 5	0 – 360
Background	Area out of Zone A	
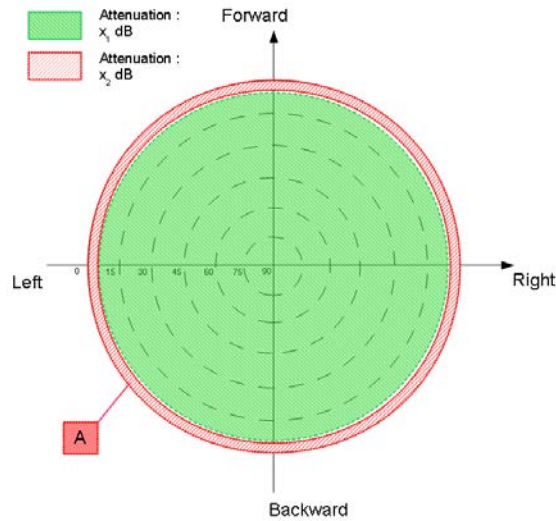
Open Sky plot.

Attenuation:

	0 dB
A	-100 dB

3. Test procedures

3.1 NMEA-0183 messages output test.

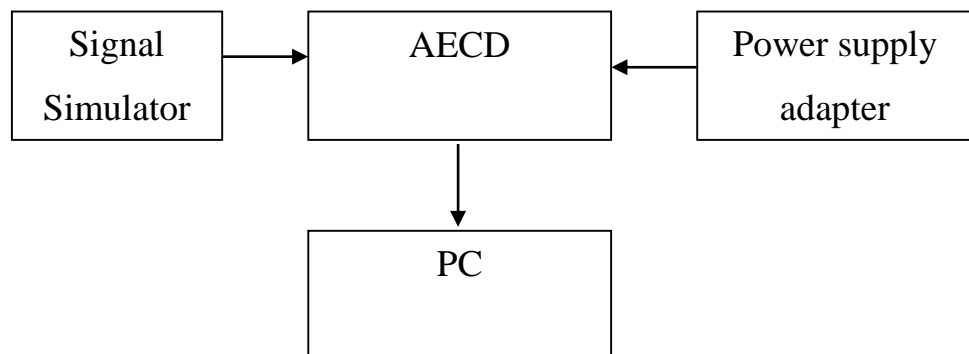3.1.1 Make connections according to Figure 2.

Figure 2 – Diagram of test stand

3.1.2 Prepare and turn on the AECD. By means of operation manual and developer software set up the navigation module for receiving signals from GLONASS, Galileo, GPS GNSS and SBAS . Set up the navigation module to output NMEA-0183 messages (messages RMC, GGA, VTG, GSA and GSV).

3.1.3 Set up the simulator according to the simulator user guide. Initialize simulator script with the parameters, given in Table 5 for GLONASS, Galileo, GPS GNSS and SBAS signals.

T a b l e 5 – Main parameters of simulation script for static scenario

Simulated parameter	Value
Test duration, hh:mm:ss	01:00:00
Output frequency	1 Hz
AECD location: - CS WGS-84;	Any specified land point between latitude range 80°N and 80°S
Troposphere: Ionosphere:	Standard predefined model by the GNSS simulator Standard predefined model by the GNSS simulator
PDOP value	≤ 2.5 in the test time interval
Simulated signals	- GNSS GLONASS (L1 frequency band CT code); - GNSS Galileo (E1 frequency band OS); - GNSS GPS (L1 frequency band C/A code); - GNSS GLONASS/Galileo/GPS/SBAS.
Signal strength: - GNSS GLONASS; - GNSS Galileo; - GNSS GPS	minus 141 dBm; minus 135 dBm; minus 138,5 dBm.
Number of simulated satellites	- at least 6 GLONASS satellites; - at least 6 Galileo satellites; - at least 6 GPS satellites; - at least 2 SBAS satellites

3.1.4 By means of corresponding serial interface set the connection between the AECD and PC. Control the possibility of receiving navigation information via NMEA-0183 protocol.

3.1.5 Test results are considered successful if navigation information via NMEA-0183 protocol is received.

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3.2 The assessment of positioning accuracy in autonomous static mode.

3.2.1 Make connections according to Figure 2.

3.2.2 Prepare and turn on the AECD. By means of developer software make sure that navigation module is set up for receiving global navigation satellite systems GLONASS, Galileo, GPS and SBAS combined signals. Set up navigation module to output messages according to the NMEA-0183 protocol (GGA, RMC, VTG, GSA and GSV messages)

3.2.3 Set up the simulator in accordance with its operational manual. Start simulation of for combined GNSS GLONASS, Galileo, GPS and SBAS signals script with set parameters, given in Table 5.

3.2.4 Upon receiving the navigation solution set up recording of NMEA-0183 messages output by navigation module to a file, up to the moment the simulation script is complete.

3.2.5 Extract coordinates: latitude (B) and longitude (L) contained in GGA (RMC) messages.

3.2.6 Calculate the systematic inaccuracy of coordinate's determination on stationary intervals according to formulas (1), (2), for example for latitude coordinate (B):

$$\text{(1)} \quad \Delta B(j) = B(j) - B_{truej},$$

$$\text{(2)} \quad dB = \frac{1}{N} \cdot \sum_{j=1}^{N} \Delta B(j),$$

Where Btruej – actual value of B coordinate in j–ed time moment, angle sec.;

B(j) – determined by the navigation module value of B coordinate in j time moment, angle sec;

N – amount of GGA (RMC) messages, received during the test of navigation module.

Similarly calculate the systematic inaccuracy of L (longitude) coordinate.

3.2.7 Calculate standard deviation (SD) value according to formula (3) for B coordinate:

$$\text{(3)} \quad \sigma_B = \sqrt{\frac{\sum_{j=1}^{N} (B(j) - dB)^2}{N - 1}},$$

Similarly calculate the (SD) value for L (longitude) coordinate.

3.2.8 Convert calculated SD values of latitude and longitude determination from angle seconds to meters according to formulas (4) – (5):

- for latitude:

$$\text{(4)} \quad dB(\textit{м}) = 2 \cdot \frac{a(1 - e^2)}{(1 - e^2 \sin^2\varphi)^{3/2}} \cdot \frac{0{,}5'' \cdot \pi}{180 \cdot 3600''} \cdot dB,$$

- for longitude:

$$\text{(5)} \quad dL(\textit{м}) = 2 \cdot \frac{a \cdot \cos\varphi}{\sqrt{1 - e^2 \sin^2\varphi}} \cdot \frac{0{,}5'' \cdot \pi}{180 \cdot 3600''} \cdot dL,$$

Where a – major semiaxis of ellipsoid, m

e – first eccentricity

φ – current latitude, rad.

3.2.9 Calculate horizontal coordinates error (at confidence level 0.95) according to formula (6):

$$(6) \quad \Pi = \sqrt{dB^2(m) + dL^2(m)} + 2 \cdot \sqrt{\sigma_B^2(m) + \sigma_L^2(m)},$$

3.2.10 Repeat test procedures according to 3.2.3 – 3.2.9 only for GLONASS GNSS signals with simulation parameters, given in Table 5.

3.2.11 Repeat test procedures according to 3.2.3 – 3.2.9 only for GPS GNSS signals with simulation parameters, given in Table 5.

3.2.12 Repeat test procedures according to 3.2.3 – 3.2.9 for GNSS Galileo signals with simulation parameters, given in Table 5.

3.2.13 Repeat test procedures according to 3.2.3 – 3.2.12 with other AECD samples, provided for the test.

3.2.14 Determine average values according to (6) obtained for all tested AECD samples.

3.2.15 Tests results are considered satisfactory if horizontal coordinates errors as defined by formula (6) obtained with all AECD samples do not exceed 15 m under open sky conditions at confidence level 0.95 for all simulation scripts.

3.3 The assessment of positioning accuracy in autonomous dynamic mode.

3.3.1 Repeat test procedures described in section 3.2, except 3.2.10 - 3.2.12 with simulation script for maneuvering movement (Table 6).

T a b l e 6 – Main parameters of simulation script for maneuvering movement

Simulated parameter	Value
Test duration, hh:mm:ss	01:00:00
Output frequency	1 Hz
AECD location: - CS WGS-84;	Any specified land point between latitude range 80°N and 80°S
Model of movement: - speed, km/h; turn radius, m; - turn acceleration, m/sec^2	Maneuvering movement 140 500 0,2
Troposphere: Ionosphere:	Standard predefined model by the GNSS simulator Standard predefined model by the GNSS simulator
PDOP value	≤ 2.5 in the test time interval

Simulated signals	- combined GLONASS / Galileo / GPS / SBAS.
Signal strength: - GNSS GLONASS; - GNSS Galileo; - GNSS GPS	minus 141 dBm; minus 135 dBm; minus 138,5 dBm.
Number of simulated satellites	- at least 6 GLONASS satellites; - at least 6 Galileo satellites; - at least 6 GPS satellites; - at least 2 SBAS satellites

3.3.2 Determine average values according to (6) obtained for all tested AECD samples.

3.3.3 Tests results are considered satisfactory if horizontal coordinates errors obtained with all AECD samples do not exceed 15 m under open sky conditions at confidence level 0.95.

3.4. Test of movement in shadow areas, areas of intermittent reception of navigation signals and urban canyons.

3.4.1 Repeat test procedures described in section 3.3 for simulation script for movement in shadow areas and areas of intermittent reception of navigation signals (Table 7) with an urban canyon signal pattern described in Fig.3.

T a b l e 7 – Main parameters of movement in shadow areas and areas of intermittent reception of navigation signals

Simulated parameter	Value
Test duration, hh:mm:ss	01:00:00
Output frequency	1 Hz
Motion start point: - CS WGS-84;	Any specified land point between latitude range 80°N and 80°S
Model of movement: - speed, km/h; turn radius, m; - turn acceleration, m/sec^2	Maneuvering movement 140 500 0,2

Simulated parameter	Value
Satellite visibility: - signal visibility intervals, sec; - signal absence intervals, sec.	 300 600
Troposphere: Ionosphere:	Standard predefined model by the GNSS simulator Standard predefined model by the GNSS simulator
Geometric factor PDOP	≤ 4 in the test time interval
Simulated signals	- combined GLONASS / Galileo / GPS / SBAS.
Signal strength: - GNSS GLONASS; - GNSS Galileo; - GNSS GPS	 minus 141 dBm; minus 135 dBm; minus 138,5 dBm.
Number of simulated satellites	- at least 6 GLONASS satellites; - at least 6 Galileo satellites; - at least 6 GPS satellites; - at least 2 SBAS satellites

Figure 3: Urban canyon definition

Zone	Elevation range (deg)	Azimuth range (deg)
A	0 – 5	0 – 360
B	5 - 30	210 – 330
C	5 - 30	30 - 150
Background	Area out of Zones A, B, C	
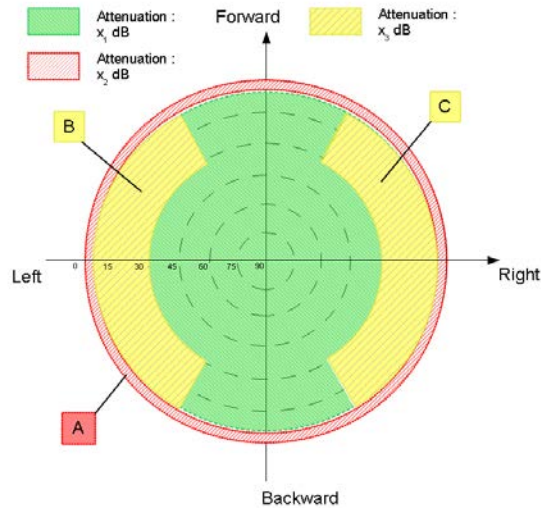
Urban canyon plot.

Attenuation:

	0 dB
B	-40 dB
C	-40 dB
A	-100dB

3.4.2 Tests results are considered satisfactory if horizontal coordinates errors obtained with all AECD samples do not exceed 40 m in urban canyon conditions at confidence level 0.95.

3.5 Cold start time to first fix test.

3.5.1 Prepare and turn on the AECD. By means of developer software make sure that GNSS module is set to receive GNSS GLONASS, Galileo and GPS signals.

3.5.2 Delete all position, velocity, time, almanac and euhemerizes data from the navigation receiver.

3.5.3 Set up the simulator according to the simulator user guide. Initialize simulator script with the parameters, given in Table 5 for GNSS GLONASS, Galileo and GPS signals.

3.5.4 By means of a stop watch measure time interval between signal simulation start and the first navigation solution result.

3.5.5 Conduct test procedures according to 3.5.2 – 3.5.4 at least 10 times.

3.5.6 Calculate average time to first fix in cold start mode based on measurements for all AECD samples, provided for the test.

3.5.7 The test result is considered to be positive, if average values of time to first fix, calculated as described in 3.5.6 do not exceed 60 sec.

3.6 Test of re-acquisition time of tracking signals after block out of 60 sec.

3.6.1 Prepare and turn on the AECD according to operational manual. By means of developer software make sure that navigation module is set up to receive GNSS GLONASS, Galileo and GPS signals.

3.6.2 Set up the simulator according to the simulator user guide. Initialize simulator script with the parameters, given in Table 5 for GNSS GLONASS, Galileo and GPS signals.

3.6.3 Wait for 15 minutes and make sure navigation module has calculated AECD position.

3.6.4 Disconnect the GNSS antenna cable from the AECD and connect it again after time interval of 60 sec.

By means of stopwatch determine time interval between cable connection moment and restoration of satellites tracking and calculation of the navigation solution.

3.6.5 Repeat test procedure according to 3.6.4 at least 10 times.

3.6.6 Calculate average value of re-acquisition time of satellite tracking signals by the AECD for all performed measurements and all AECD samples provided for the test.

3.6.7 The test result is considered to be positive, if average values of re-acquisition time after block out of 60 sec measured as described in 3.6.6 do not exceed 20 seconds.

3.7 Test of navigation receiver sensitivity in cold start mode, tracking mode, and re-acquisition scenario.

3.7.1 Turn on the vector network analyser. Calibrate the network vector analyser according to its operational manual.

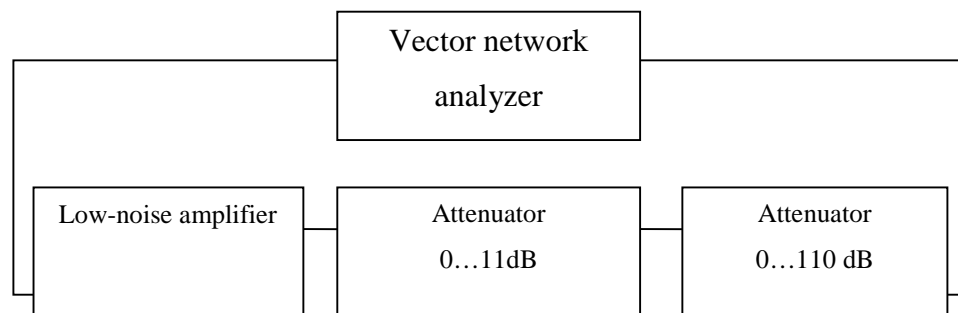3.7.2 Set up the diagram according to Figure 4.

Figure 4 – Diagram of path calibration

3.7.3 Set zero signal path attenuation on attenuators. Measure the frequency response for a given signal path in the L1/E1 band of GNSS GLONASS/Galileo/GPS. Record the average path transmission factor in [dB] in this frequency band.

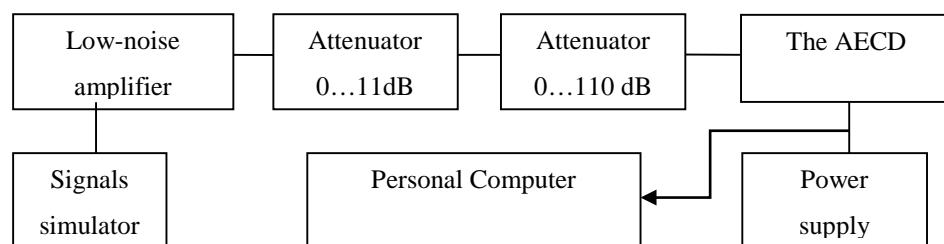3.7.4 Assemble the circuit shown in Figure 5.

Figure 5 – Arrangement for evaluation of GNSS module sensitivity

3.7.5 Prepare and turn on AECD according to operational manual. By means of developer software make sure that GNSS module is set to receive GNSS GLONASS, Galileo and GPS

signals. Clear the navigation module RAM such that the "cold" start mode of the navigation module of the AECD is achieved.

3.7.6 Set signal path attenuation value equal to 110 dB. Prepare GNSS signals simulator according to its operation manual. Start GNSS GLONASS/Galileo/GPS signals simulation script, with parameters given in Table 5. Set output power level of the simulator to minus 130 dBm.

3.7.7 Check that the position, velocity and time information is reset.

3.7.8 Decrease path attenuation using attenuators in 1 dB steps (increase the navigation signal power on the navigation module input) until the AECD acquires navigation fix. Record the signal level on the AECD GNSS module input.

N o t e – Time interval between path attenuation changes shall not be less than 120 s.

3.7.9 Set the signal path attenuation on attenuators such that the signal on AECD antenna input is equal to minus140 dBm. Wait for 15 min to allow the navigation module to collect the ephemerides and the GNSS almanac.

3.7.10 Increase the signal path attenuation setting on attenuators in 1 dB steps (decrease the navigation signal power) until the navigation fix is reset. Taking into account the initial transmission factor of the signal path, record such GNSS signal level on an input of the AECD GNSS module antenna that resulted in the last navigation fix of the GNSS module in tracking mode.

3.7.11 Decrease path attenuation using attenuators in 1 dB steps (increase the navigation signal power on the navigation module input) until the AECD acquires navigation fix. Record the signal level on the AECD GNSS module input.

3.7.12 The test results shall be considered positive if the GNSS signal level on the antenna input of the AECD does not exceed minus 144 dBm in cold start mode as recorded in 3.7.8, minus 155 dBm in tracking mode as recorded in 3.7.10, and minus 150 dBm in reacquisition mode as recorded in 3.7.11 for each AECD submitted to tests.