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Tractors and machinery for agriculture and forestry — Test procedures for positioning and guidance systems in agriculture —

Part 1: Dynamic testing of satellite-based positioning devices

Tracteurs et matériels agricoles et forestiers — Modes opératoires d'essai des systèmes de positionnement et de guidage utilisés en agriculture —

Partie 1: Essai dynamique des dispositifs de positionnement par satellite

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 12188-1 was prepared by Technical Committee ISO/TC 23, *Tractors and machinery for agriculture and forestry*, Subcommittee SC 19, *Agricultural electronics*.

ISO 12188 consists of the following parts, under the general title *Tractors and machinery for agriculture and forestry — Test procedures for positioning and guidance systems in agriculture*:

— *Part 1: Dynamic testing of satellite-based positioning devices*

The following parts are under preparation:

— *Part 2: Satellite-based auto-guidance systems tested during straight and level travel*

Introduction

Satellite positioning devices have become more common in agricultural applications. They are not only used as position sensors for georeferencing data or site-specific application tasks, but are also part of more complex navigation systems for agricultural machines.

In the early stages of development of this part of ISO 12188, the only existing standards for satellite-based, positioning-device performance specification focused on the static accuracy of the device. There was no existing standard that adequately specified methods for testing or reporting the accuracy of the receivers while they are in motion. This part of ISO 12188 is intended to fill this void by providing a framework for testing receivers that are subject to the type of motion typically experienced by receivers used in agricultural field operations. It provides an implementable methodology for conducting the tests while still providing a means to equitably compare the performance of different satellite-based positioning devices.

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Tractors and machinery for agriculture and forestry — Test procedures for positioning and guidance systems in agriculture —

Part 1: Dynamic testing of satellite-based positioning devices

1 Scope

This part of ISO 12188 provides a procedure for evaluating and reporting the accuracy of navigation data determined using positioning devices that are based on GPS, GLONASS, Galileo or similar global navigation satellite systems (GNSS). It focuses on the performance of the positioning devices while they are subject to motions typical of ground-based agricultural field operations and specifies common performance parameters that can be used to quantify and compare the dynamic performance of different positioning devices.

2 Terms and definitions

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

2.1 General terms related to positioning device testing

2.1.1
positioning device
PD
instrument that is capable of determining and reporting the position of its antenna centre point in geographic coordinates and in real time using satellite-based radio-navigation signals

2.1.2
navigation data record
NDR
report of geographic coordinates, elevation, course, travel velocity and other navigation-related parameters computed by a PD

2.1.3
travel course
TC
predefined route of travel during the test

2.1.4
reference navigation system
RNS
fixture or measurement device capable of either precisely controlling the path of the PD or recording the actual path that the PD traversed

2.1.5
geographic coordinates
geographic latitude, longitude and elevation with respect to an internationally defined geodetic coordinate system

2.1.6
travel speed
distance travelled in a unit of time

NOTE Travel speed is expressed in metres per second.

2.1.7
course over ground
horizontally projected direction of travel measured clockwise from true north, as defined by NMEA 0183

NOTE The projected direction of travel is expressed in degrees.

2.1.8
time
Universal Time Coordinated (UTC) with corresponding date, as defined by NMEA 0183

2.1.9
initialization time
time elapsed between the point in time when the positioning device is powered and the beginning of the first test run

2.2 Terms describing position accuracy and error measurements

2.2.1
off-track error
perpendicular deviation from the actual travel course

2.2.2
horizontal position error
horizontally projected deviation from absolute position

NOTE This measurement does not include positioning device latency.

2.2.3
vertical position error
vertically projected deviation from absolute position

2.2.4
latency
time between reception of satellite signals at the antenna and transmission of the first character or message of the NDR

2.2.5
absolute horizontal [vertical] positioning accuracy
extent to which an NDR conforms to RNS data

2.2.6
relative horizontal [vertical] positioning accuracy
extent to which an NDR conforms to other NDRs from the same PD at the same location at different times

2.2.7
short-term dynamic accuracy
short-term dynamic performance determined from off-track errors along straight segment passes occurring within a 15 min time frame

NOTE Short-term dynamic accuracy is similar to what is commonly called pass-to-pass accuracy.

2.2.8
long-term dynamic accuracy
dynamic performance determined from off-track errors along straight segment passes occurring within a time period of not less than 24 h

2.2.9
U-turn accuracy
dynamic performance determined from off-track errors occurring during traverse of a 180° turn

3 Requirements

3.1 General

The following applies for testing.

a) The travel course (TC) shall include at least two straight segments and a U-turn segment. The straight segments shall be at least 90 m long and shall be oriented between 35° and 55° from true north. The U-turn shall traverse 180° at a constant radius of turn between 5 m and 10 m and shall connect directly at either end to straight segments. The course shall have a change in elevation no greater than 1 m. There shall be no obstructions visible from any point on the test course, at an elevation of the PD antennae higher than 10° above a horizontal horizon, that interfere with or block satellite signals. There shall be no metallic or other surfaces within 50 m of the course that could cause multipath interference. Course location and geometry shall be documented with appropriate detail to allow exact replication.

b) Before the initialization time begins, all firmware and user-configurable settings on the PD shall be reset to default. Changes to user-configurable settings are permitted after this reset; they shall be made before the initialization period and shall not be altered throughout the entire test. All device settings shall be explicitly documented.

   NOTE User-configurable settings include, but are not limited to, firmware version, differential correction services and settings, mask angle, enabled filters, output data format, and other device-specific parameters.

c) NDRs shall be logged at the maximum rate facilitated by the PD and shall include at least the date, time, position, elevation, geoidal separation, speed, course over ground, number of satellites, correction status, and satellite constellation configuration. All receiver outputs shall be described and documented clearly. The PD output port and data communication protocol used shall also be documented clearly.

   NOTE The satellite constellation configuration can be quantified by the horizontal dilution of precision (HDOP).

d) The RNS shall have sufficient absolute position accuracy and data output rate to produce reference navigation data that are at least an order of magnitude (10 times) more accurate than the tested PD anywhere along the TC. Reference navigation data shall be synchronized with the PD output to ±1 m/s uncertainty. The specifications of the RNS shall be reported and any interpolation or other computational techniques used to calculate the actual TC shall be clearly documented. Reference measurement devices are not limited to satellite-based equipment.

e) When conducting tests on a non-fixed course, the test course shall be replicated during each pass by the carrying vehicle with a deviation of less than 1 m.

f) During all tests an independent tool shall be used to record actual (not predicted) satellite signal and constellation parameters such as satellite visibility, configuration and signal quality for the test location and time. In addition to graphs of critical parameters, the report shall include mean, minimum and maximum values for numerical parameters.

3.2 Horizontal positioning test

3.2.1 Initialization time

The initialization time for the PD shall be recommended by the PD manufacturer. The actual initialization time used during the test shall be reported to the nearest 5 min increment. The PD shall remain static during this initialization time.

3.2.2 Date and time recording

The date and time at the start and end of each test run shall be recorded.

3.2.3 Conduction of test runs

The test shall be conducted in 1 h time blocks called test runs. During each test run, the PD shall be traversed continually around the TC at a single speed and direction. Test runs shall be conducted at travel speeds of (0,1 ± 0,05) m/s, (2,5 ± 0,2) m/s and (5,0 ± 0,2) m/s. At the lowest travel speed, it is permissible to accelerate the receiver on turns between straight segments to ensure ample data collection on straight segments within the allotted time block. Each combination of speed and direction shall be tested four times, resulting in 24 total test runs. All test runs shall be completed within a 25 h time period (a few minutes are necessary between tests to adjust or maintain the test apparatus or carrier vehicle).

3.3 Dynamic signal reacquisition test

3.3.1 Purpose of dynamic signal reacquisition test

The purpose of the dynamic signal reacquisition test is to evaluate the PD's ability to reacquire signals and begin transmitting NDRs after a loss of signal. Since this loss of signal is more common in agriculture at the edge of fields, the test will be conducted on the U-turn segment of the TC.

3.3.2 Simulation of signal loss

When conducting the dynamic signal reacquisition test, a signal loss of the PD shall be simulated by either covering the receiver antenna with a metal housing to block satellite signals or using a switched attenuator of at least 60 dB inserted at a safe point in the feed line from the antenna to the receiver. During a test run, the receiver shall be continually traversed around the test course. Only one direction (clockwise) and one speed (1,0 m/s) shall be used. The signal outage shall occur during the entire 180° U-turn (typical headland situation). After a signal blockage, a subsequent blockage event shall be initiated at the next traverse through a U-turn segment after the PD has begun to transmit valid NDRs. A test run begins at the initiation of the first signal blockage event. Each test run shall last 1 h followed by a 3 h break. Three test runs shall be completed within a 13 h period.

4 Calculations and report

4.1 General

4.1.1 Test validity

In order for a test to be considered valid, the data set collected during the test shall be populated by at least 75 % of the total expected NDRs based on data sampling rate.

4.1.2 Use of NDRs

NDRs collected at speeds outside the tolerances specified in 3.2.3 shall not be used in subsequent analyses.

4.1.3 Reporting signed/unsigned error distributions

Each test report shall include observed distributions (in graphical and/or tabular form) of signed error estimates. A statistical analysis for the presence of bias may be conducted to determine the significance of direction that can be associated with a given error distribution. Unsigned error distributions shall be used to report the median, 95 % and maximum errors.

4.1.4 Additional elements in test reports

In addition to error summaries, each test report shall include the above-mentioned elements of test description, including

a) a detailed description or reference to the test facility and procedure,

b) a description of the PD (including the model and serial number) and settings used during the test,

c) the time (2.1.8) corresponding to the beginning and the end of each test run,

d) the satellite and differential correction system parameters,

e) the solar activity quantified by the average sunspot number, and

f) any observations with respect to other conditions of the test that could affect the results.

NOTE Examples of conditions that can affect results include weather observations, necessary interventions and equipment malfunctions.

4.1.5 Calculation of linear distances and errors

All linear distances and errors shall be calculated using the equations listed in Annex A to eliminate location biases that might be induced using other data projections. The test operator shall choose a consistent sign convention to differentiate between directions of the signed error estimates.

4.2 Positioning accuracies

4.2.1 Absolute dynamic accuracy

Absolute dynamic accuracy shall be represented by the mean plus the standard deviation of all signed horizontal position errors $\left(\bar{x} + S_x\right)$.

4.2.2 Relative dynamic accuracy

Relative dynamic accuracy shall be represented by the standard deviation of all signed horizontal position errors.

4.2.3 Absolute vertical position accuracy

Absolute vertical position accuracy shall be represented by the mean plus the standard deviation of all signed vertical position errors $\left(\bar{x} + S_x\right)$.

4.2.4 Relative vertical position accuracy

Relative vertical position accuracy shall be represented by the standard deviation of all signed along-track vertical position errors.

4.2.5 Short-term dynamic accuracy

Short-term dynamic accuracy shall be represented by the square root of two times the geometric mean of the standard deviations of the off-track errors of the identified data in each valid time window. Data from each test run shall be divided into four 15 min non-overlapping time windows. In each time window, all NDRs falling along the centremost 50 m portions of the straight segments of the TC shall be identified. If the number of these identified NDRs is at least 25 % of the total expected number of NDRs based on PD data output rate, and if there are at least four points occurring within 30 s of the beginning of the time window and four points occurring within 30 s of the end of the time window, then that time window is considered valid and shall be used for calculation of pass-to-pass error. A minimum of nine valid time windows for each combination of speed and direction shall be identified for a valid test.

4.2.6 Long-term cross-track accuracy

Long-term cross-track accuracy shall be represented by the square root of two times the mean plus the standard deviation of off-track errors of all NDRs that fall along the centremost 50 m portion of the straight segments [$\sqrt{2}\left(\bar{x}+S_x\right)$].

4.2.7 U-turn accuracy

U-turn accuracy shall be represented by the square root of two times the mean plus the standard deviation of all off-track errors that occur along the U-turn segment(s) and the first 20 m of the straight segment following the turn(s) [$\sqrt{2}\left(\bar{x}+S_x\right)$].

4.2.8 Absolute accuracy after signal loss

The time elapsed between the reintroduction of the satellite signals and the output of the first valid NDR shall be recorded. The mean plus the standard deviation of off-track errors shall be determined separately from all NDRs falling along five consecutive 10 m portions of the straight segment occurring immediately after transmission of the first valid NDR.

4.3 Course-over-ground accuracy

Course-over-ground accuracy shall be represented by the mean plus the standard deviation of course error of all valid NDRs $\left(\bar{x}+S_x\right)$. Course accuracy shall be reported separately for straight segments and curved segments.

4.4 Course latency

Course latency shall be represented by the mean latency of all valid NDRs occurring along the U-turn section for tests conducted at medium and high speeds. To calculate latency at each NDR, a virtual point is located along the actual TC in the opposite direction to the direction of travel where the course given by the NDR would be correct. The latency is measured as the time that would be required for the receiver to travel from that virtual point to the actual location of the NDR.

4.5 Speed accuracy

Speed accuracy shall be represented by the mean plus the standard deviation of speed errors of all valid NDRs $\left(\bar{x}+S_x\right)$. Speed accuracy shall be reported separately for straight segments and curved segments.

4.6 Latency

Latency shall be represented by the elapsed time between the reception of the corresponding signal [determined using a pulse per second (PPS) signal — an electrical signal that very precisely indicates the start of a second] and the first output of an NDR character.

Annex A
(normative)

Error and accuracy computation

The following relationships shall be used to project geographic coordinates from NDRs into a localized Cartesian coordinate system for error and accuracy computations:

$$F_{\text{lon}} = \frac{\pi}{180^\circ}\left(\frac{a^2}{\sqrt{a^2\cos^2\varphi + b^2\sin^2\varphi}} + h\right)\cos\varphi$$

$$F_{\text{lat}} = \frac{\pi}{180^\circ}\left(\frac{a^2 b^2}{\left(a^2\cos^2\varphi + b^2\sin^2\varphi\right)^{\frac{3}{2}}} + h\right)$$

where

F_{lat}, F_{lon} are location-specific conversion factors, in metres per degree, that can be used to convert the latitude and longitude components of an NDR into associated Cartesian coordinates in metres;

φ is the latitude location of the test site, in degrees, which value may be chosen by the tester, but which shall be located no more than 1 000 m from any point on the test course;

h is the average height of the test course above the ellipsoid;

a is the semi-major axis of the ellipsoid, in metres;

b is semi-minor axis of the ellipsoid, in metres.

Table 1 gives the values of a and b for the geographic datums that may be used during testing.

Table 1 — a and b values for geographic datums

Ellipsoid	Scope	a m	b m
IERS Conventions (2003)[a]	EU	6 378 137	6 356 751,858 0
GRS-80[b]	Galileo	6 378 137	6 356 752,314 1
WGS 84[c]	GPS	6 378 137	6 356 752,314 2
PZ-90.02[d]	GLONASS	6 378 136	6 356 751,361 8

[a] International Earth Rotation and Reference Systems Service (2003).

[b] Geodetic Reference System 1980.

[c] World Geodetic System (1984).

[d] Geodetic system used in GLONASS.

Bibliography

[1] NMEA 0183 Interface Standard[1)]

1) National Marine Electronics Association, Severna Park, MD, USA.

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