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Optics and optical instruments — Field procedures for testing geodetic and surveying instruments —

Part 8:
GNSS field measurement systems in real-time kinematic (RTK)

Optique et instruments d'optique — Méthodes d'essai sur site des instruments géodésiques et d'observation —

Partie 8: Systèmes de mesure GNSS sur site en temps réel cinématique

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

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

ISO 17123-8 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 6, *Geodetic and surveying instruments*.

ISO 17123 consists of the following parts, under the general title *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments*:

— *Part 1: Theory*

— *Part 2: Levels*

— *Part 3: Theodolites*

— *Part 4: Electro-optical distance meters (EDM instruments)*

— *Part 5: Electronic tacheometers*

— *Part 6: Rotating lasers*

— *Part 7: Optical plumbing instruments*

— *Part 8: GNSS field measurement systems in real-time kinematic (RTK)*

Introduction

This part of ISO 17123 can be thought of as one of the first steps in the process of evaluating the uncertainty of measurements (more specifically of measurands). The uncertainty of a result of a measurement is dependent on a number of factors. These include among others: repeatability, reproducibility (between day repeatability) and a thorough assessment of all possible error sources, as prescribed by the ISO Guide to the expression of uncertainty in measurement (GUM).

These field procedures have been developed specifically for *in situ* applications without the need for special ancillary equipment and are purposely designed to minimize atmospheric influences.

Optics and optical instruments — Field procedures for testing geodetic and surveying instruments —

Part 8:
GNSS field measurement systems in real-time kinematic (RTK)

1 Scope

This part of ISO 17123 specifies field procedures to be adopted when determining and evaluating the precision (repeatability) of Global Navigation Satellite System (GNSS) field measurement systems (this includes GPS, GLONASS as well as the future systems like GALILEO) in real-time kinematic (GNSS RTK) and their ancillary equipment when used in building, surveying and industrial measurements. Primarily, these tests are intended to be field verifications of the suitability of a particular instrument for the required application at hand, and to satisfy the requirements of other standards. They are not proposed as tests for acceptance or performance evaluations that are more comprehensive in nature.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 3534-1, *Statistics — Vocabulary and symbols — Part 1: General statistical terms and terms used in probability*

ISO 9849, *Optics and optical instruments — Geodetic and surveying instruments — Vocabulary*

ISO 17123-1, *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments — Part 1: Theory*

ISO 17123-2, *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments — Part 2: Levels*

ISO 17123-5, *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments — Part 5: Electronic tacheometers*

GUM, *Guide to the expression of uncertainty in measurement, BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML*, 1993, corrected and reprinted in 1995

VIM, *International vocabulary of basic and general terms in metrology, BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML*, 1993

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3534-1, ISO 9849, ISO 17123-1, ISO 17123-2, ISO 17123-5, GUM and VIM apply.

4 General

4.1 Preamble

The real-time kinematic positioning method is a relative measuring procedure using reference (base) and moving (rover) receivers. For utilization of network RTK applications, a separate reference receiver is not required. Both receivers perform the observations simultaneously and merge their results by wireless transmission. Thus, the rover can display the instantaneous coordinates of the antenna in any appropriate datum e.g. ITRF (International Terrestrial Reference Frame). For practical use they are transformed to horizontal coordinates and ellipsoidal heights. Subsequently, only these types of coordinate are treated as original observables.

4.2 Requirements

Before commencing surveying, it is important for the operator to ensure that the equipment, the GNSS receiver and antenna, has sufficient precision for the task required.

The test should apply typically to a set of GNSS receivers and antennae listed in the manufacturer's reference manual. In case of using network RTK, consistency of antenna models (eg. antenna correction parameters) shall be ensured.

The receiver, antenna and their ancillary equipment for rovers points shall be checked to be in acceptable condition according to the methods specified in the reference manual.

The operator shall follow the guidelines in the manufacturer's reference manual for positioning requirements such as the minimum number of satellites, maximum PDOP (Position Dilution Of Precision) value, minimum observation time and possibly other required pre-conditions.

The operator shall initialize the receiver by resetting its power prior to every measurement and collect the data after the integer ambiguity fixing has been completed.

The following is the guideline for achievable centring precision expressed in standard deviation:

— centering: 1 mm;

— measuring the antenna height: 1 mm.

The results of the test are influenced by several factors, such as satellite configuration visible at the points, ionospheric and tropospheric conditions, multipath environment around the points, precision of the equipment, quality of the software running in the rover equipment or in the system generating the data transmitted from the base point.

This part of ISO 17123 describes two different field procedures, namely the simplified test procedure and the full test procedure, as given in Clauses 5 and 6 respectively. Therefore, the observation time of test procedure shall be so arranged to cover such variations.

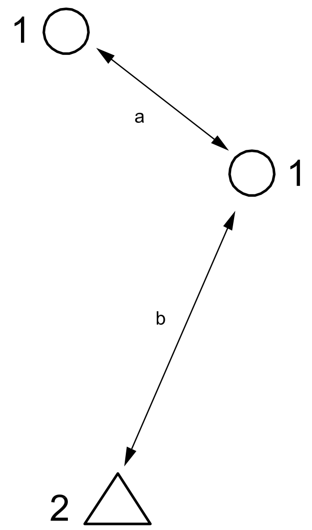
The operator shall choose the procedure that is most appropriate to the requirements of the project.

4.3 The concept of the test procedures

The test field consists of a base point and two rover points. The location of the rover points shall be close to the area of the task concerned. The separation of two rover points shall be a minimum of 2 m and shall not exceed 20 m. The positions of two rover points may be selected at convenience in the field (see Figure 1).

The horizontal distance and height difference between two rover points shall be determined by methods with precision better than 3 mm other than RTK. These values are considered as nominal values and are used in the first step of both test procedures. The horizontal distances and height differences calculated from the measured coordinates in each set of measurements shall be compared with these values in order to ensure that the measurements are free from any outlier. However, the nominal values are not used in the statistical tests.

A series of measurements consists of five sets. Each set of measurements consists of successive measurements at rover point 1 and 2.



Key

1 rover point

2 base point

[a] Minimum 2 m; shall not exceed 20 m.

[b] Corresponding distance according to the task concerned.

Figure 1 — Configuration of the field test network

The time lag between successive sets shall be approximately 5 min. This requirement makes the span of a series of measurements to be about 25 min and five sets of measurements at both rover points shall be uniformly distributed in this span. Due to the fact that the variation cycle of a typical multipath influence is about 20 min, the measuring procedure will mostly cover the period of this influence factor.

The start time for each successive series shall be separated by at least 90 min. Thus, multiple series of measurements tend to reflect influences such as changes in satellite configuration and variations in the ionospheric and tropospheric conditions.

The standard deviations calculated over all measurements will therefore represent a quantitative measure of precision in use including most of the typical influences in satellite positioning.

The simplified test procedure contains only one series of measurements and therefore only deals with the outlier detection and with no statistical evaluation. Conversely, the full test procedure consists of three series and additionally enables the estimation of standard deviations and statistical tests.

4.4 Procedure 1: Simplified test procedure

The simplified test procedure consists of a single series of measurements and provides an estimate as to whether the precision of the equipment in use is within a specified allowable deviation.

The simplified test procedure is based on a limited number of measurements. Therefore, a significant standard deviation cannot be obtained and the statistical tests are not applied. If a more precise assessment of the equipment is required, it is recommended to adopt the more rigorous full test procedure as given in 4.5.

4.5 Procedure 2: Full test procedure

The full test procedure shall be adopted to determine the best achievable measure of precision of the equipment in use.

The full test procedure consists of three series of measurements.

The full test procedure is intended for determining the experimental standard deviation for a single position and height measurement.

Further, this procedure may be used to determine:

- the measure of the precision of equipment under given conditions (including typical short and long term influences);
- the measure of the precision of equipment used in different periods of time or under different conditions (multiple samples);
- the measure of the capability of comparison between different precision of equipment achievable under similar conditions.

Statistical tests shall be applied to determine whether the sample from the experiment belongs to the same population as the one giving the theoretical standard deviation and to determine whether two samples from different experiments belong to the same population.

5 Simplified test procedure

5.1 Measurements

For the simple test procedure, one series of measurements shall be taken, in which the observer shall obtain five sets of measurements at two rover points. The sequence of the measurements is shown in Table 1 in which the column labelled “Seq. No.” explicitly indicates the sequence of the measurement.

Table 1 — Sequence of the measurements for one series

Seq. No.	Series i	Set j	Rover point k	Measurement x	y	h
1	1	1	1	$x_{1,1,1}$	$y_{1,1,1}$	$h_{1,1,1}$
2	1	1	2	$x_{1,1,2}$	$y_{1,1,2}$	$h_{1,1,2}$
3	1	2	1	$x_{1,2,1}$	$y_{1,2,1}$	$h_{1,2,1}$
4	1	2	2	$x_{1,2,2}$	$y_{1,2,2}$	$h_{1,2,2}$
5	1	3	1	$x_{1,3,1}$	$y_{1,3,1}$	$h_{1,3,1}$
6	1	3	2	$x_{1,3,2}$	$y_{1,3,2}$	$h_{1,3,2}$
7	1	4	1	$x_{1,4,1}$	$y_{1,4,1}$	$h_{1,4,1}$
8	1	4	2	$x_{1,4,2}$	$y_{1,4,2}$	$h_{1,4,2}$
9	1	5	1	$x_{1,5,1}$	$y_{1,5,1}$	$h_{1,5,1}$
10	1	5	2	$x_{1,5,2}$	$y_{1,5,2}$	$h_{1,5,2}$

A specific set of measurements is expressed as $x_{i,j,k}$, $y_{i,j,k}$ and $h_{i,j,k}$ where x, y and h are coordinates of a local coordinate system. The index i stands for the series number, the index j for the set number and the index k for the rover point number. For example $x_{1,3,2}$ is the x component of the third set of measurement at rover point 2 in the first series.

The sequence of measurements should follow Table 1 in the full test procedure (see 6.1).

5.2 Calculation

The individual measurements are compared directly with the nominal values available so as to detect any measurement with gross error.

For each set j (= 1,…,5) in the series i (= 1), calculate the horizontal distance and height difference between two rover points. Subsequently, calculate their deviations from the nominal values.

$$\begin{aligned} D_{i,j} &= \sqrt{(x_{i,j,2} - x_{i,j,1})^2 + (y_{i,j,2} - y_{i,j,1})^2} \\ \Delta h_{i,j} &= h_{i,j,2} - h_{i,j,1} \\ \varepsilon_{D\ i,j} &= D_{i,j} - D^* \qquad\qquad i = 1,\ \ j = 1,\dots,5 \\ \varepsilon_{h\ i,j} &= h_{i,j} - h^* \end{aligned} \tag{1}$$

where

$x_{i,j,k}$, $y_{i,j,k}$, $h_{i,j,k}$	are x, y, and h measurements respectively in the set j at rover point k in series i;
$D_{i,j}$, $\Delta h_{i,j}$	are the calculated horizontal distance and height difference respectively in the set j in series i;
D^*, Δh^*	are nominal values of the horizontal distance and height difference respectively;
$\varepsilon_{D\ i,j}$, $\varepsilon_{h\ i,j}$	are deviations of the horizontal distance and height difference respectively.

If any deviation fails to satisfy either of the two conditions in Equation (2) the inclusion of an outlier (or outliers) in the corresponding measurements is suspected, repeat the test procedure.

$$\begin{aligned} \left|\varepsilon_{D\ i,j}\right| &\leqslant 2{,}5 \times \sqrt{2} \times s_{xy} \\ \left|\varepsilon_{h\ i,j}\right| &\leqslant 2{,}5 \times \sqrt{2} \times s_h \end{aligned} \tag{2}$$

Where s_{xy} and s_h are either the pre-determined standard deviation according to the full test procedure or the values specified by the manufacturer.

6 Full test procedure

6.1 Measurements

For the full test procedure, three series of measurements shall be taken. The sequence of the measurements in each series is identical to the case of the simplified test. The start times of consecutive series shall be separated by at least 90 min.

