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GB/T 47422-2026

Field calibration method for the absolute phase centre of BeiDou/global navigation satellite system (GNSS) geodetic antennas

北斗/全球卫星导航系统（GNSS）测量型天线绝对相位中心室外标定方法

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1.Scope This document describes the calibration principle for outdoor calibration of the absolute phase center of a BeiDou/Global Navigation Satellite System (GNSS) measurement antenna. Calibration system, calibration procedure, and calculation of calibration results. This document applies to the design, production, testing, use, acceptance, and maintenance of BeiDou/Global Navigation Satellite System (GNSS) survey antennas. Outdoor calibration of the absolute phase center of the antenna.

4.Abbreviations The following abbreviations apply to this document. BDS. BeiDou Navigation Satellite System Galileo. Galileo Navigation Satellite System GLONASS. Global Navigation Satellite System GNSS. Global Navigation Satellite System GPS. Global Positioning System

5 Calibration Principle

5.1 General Rules A high-precision industrial robotic arm is used to tilt and rotate the antenna under test, constructing multiple difference observations between epochs, and utilizing the differences between different attitudes Phase change calculations include antenna phase center offset and antenna phase center change. The calibration of the absolute phase center of the antenna should include the unification of spatiotemporal references, planning of robotic arm movements, calculation of the antenna phase center, and evaluation of results. The requirements for the antenna absolute phase center calibration parameters are shown in Table 1.

5.2 Unification of Spatiotemporal References A GNSS timing terminal is used to synchronize the computer recording the position and attitude information of the robotic arm, thus ensuring that the recorded position and attitude information of the robotic arm is synchronized. The time is consistent with the observation time of the GNSS receiver. The antenna phase center calibration process involves the GNSS coordinate system, the robotic arm body coordinate system, the robotic arm tool coordinate system, and the antenna coordinate system. The transformation relationship between the robot arm's body coordinate system and the robot arm's tool coordinate system is known and defined by the manufacturer. The antenna coordinate system takes the antenna reference point as the origin O and the antenna axis as the U-axis. Within the normal plane of the U-axis passing through the origin, the coordinates pointing towards the antenna are defined. The north direction or designated direction is represented by the N-axis, and the E-axis is determined by the left-hand rule. The left-handed coordinate system formed by the N, E, and U axes is shown in Figure

1.Antenna phase The position center is now expressed in the antenna coordinate system. The N-axis and U-axis of the antenna coordinate system are aligned with the X-axis and Z-axis of the robotic arm tool coordinate system. Antenna bottom mounting interface. The antenna reference point coincides with the origin of the robotic arm tool coordinate system, the N-axis direction coincides with the X-axis of the tool coordinate system, and the antenna geometric center U... The axis coincides with the Z-axis of the robotic arm tool coordinate system.

5.3 Robotic Arm Motion Planning The robotic arm rotates the antenna to be calibrated around the Z-axis and tilts it around the X-axis in the robotic arm tool coordinate system, and performs motion planning according to formula (3).

5.4 Antenna Phase Center Calculation According to formula (4), the original non-differential phase observations are as follows:

6 Calibration System

6.1 Calibration Site The outdoor calibration site and the robotic arm installation area should be flat and far away from areas prone to vibration, such as roads, and where there are no BeiDou/GNSS signals. The interference signal that is normally received is in an open, unobstructed area at an elevation angle of 5° or higher.

6.2 Climate and Environment Unless otherwise specified, all calibration work shall be carried out in an environment free from significant meteorological interference, with the specific indicators as follows:

a) Temperature. -10°C~40°C;

b) Relative humidity. <=80%;

c) Wind speed. Wind force level <= 3;

d) Precipitation. No rain or snow.

6.3 Calibration Equipment and Connections The main uses and requirements of the calibrated equipment are shown in Table

2.The equipment connection diagram is shown in Figure 2.

6.4 Equipment Conditions Before installing the antenna, the necessary equipment should be inspected to ensure that it is complete and in good condition. The satellite navigation system measurement receivers and other equipment used in the calibration should be verified or calibrated by a legally authorized metrology institution, and the institution should issue a certificate of verification. The calibration or standard certificate is valid.

6.5 Conditions of the device under test The antenna under test should be structurally intact, in good condition, with a smooth surface, and its label and serial number should be complete. The antenna should also have a north-pointing beacon. The antenna is functioning normally, and signal reception is continuous and good.

7 Calibration Procedure

7.1 Seven-parameter measurement The short baseline method was used to perform coordinate transformation and seven-parameter measurement.

a) Select two measurement antennas with known phase center correction models to form a short baseline (< 100m). One antenna is fixed at... The reference station has another receiver antenna mounted at the end of the robotic arm.

b) Adjust the robotic arm to move the antenna and observe GNSS values at multiple baselines (no less than 3 displacement points) at different time periods. Baseline calculation yields the GNSS coordinates of the robotic arm's end effector, which are then read by a computer for the corresponding time period. The coordinate values of the robotic arm body in the coordinate system.

c) Calculate the seven parameters for coordinate transformation between the antenna coordinate system and the GNSS coordinate system.

d) The seven parameters should be measured regularly, and should be remeasured when the robotic arm device changes.

7.2 Data Acquisition The robotic arm is tilted and rotated to collect GNSS observation data and position and attitude information of the robotic arm's end effector.

a) After confirming that the equipment is working properly and the antenna is installed, connect the receiver to the power supply and set the receiver's data receiving frequency band to the antenna phase center. Observations will begin after the operating frequency band is reached, with a data sampling rate of no less than

b) The antenna to be calibrated transmits the received GNSS signal via a feeder, sending one signal to the timing terminal to enable computer and robotic arm control. The local time of the controller is synchronized with the GNSS time, and another signal is sent to the GNSS receiver to store the GNSS observation data.

c) Driven by the robotic arm, the antenna to be calibrated begins observation from a 0° azimuth angle, first rotating around the Z-axis in 5° steps, stopping to observe at each step. The duration is 5s to 7s, and the rotation angle is denoted as alpha, which ranges from 0° to 360°.

d) Driven by the robotic arm, the antenna to be calibrated starts observation from 0° zenith distance, tilting around the X or Y axis in 5° steps, stopping at each step. The duration of residence is 5s to 7s, and the rotation angle is denoted as gamma, which ranges from 0° to 30°.

e) After completing one azimuth rotation observation according to step c), complete one step of zenith distance observation according to step d), and then mechanically... The position and orientation information of the arm's end effector are transmitted back to the computer in real time for recording and storage.

f) Continuous observation for 4-6 hours constitutes one observation period. At least three observation periods must be conducted, with a total observation period of no less than 24 hours, forming no less than three [unclear - possibly related to observation timelines]. GNSS observation data file, and position and attitude information files of the three robotic arm ends.

8.Calculation of calibration results The GNSS carrier ranging observations and the robotic arm attitude data are processed to obtain the absolute antenna phase center calibration results.

a) Decode the observation data from the GNSS receiver in accordance with GB/T 39399.