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GNSS Antenna Calibration Activities in Turkey

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***Abstract*—Coordinates can be calculated using satellites such as GPS, GLONASS and Galileo with known orbits. All of these systems including Compass are called GNSS. To increase the accuracy of point coordinates, the error sources of GNSS are being researched for a long time. One of these errors is the antenna phase center unknown. Due to the fact that the antenna phase center is a dynamic point, it cause an error and this error consists of antenna phase center offset and antenna phase center variations that have to be known.**

In this study, types of antenna calibration, specifications of an antenna calibration area and national studies on this subject are explained. Also, a study on antenna calibration network which established at Istanbul Technical University is mentioned.

***Keywords*—Antenna Calibration, Antenna Phase Center, Antenna Calibration in Turkey**

I. Introduction

Coordinates of a station that are evaluated from GNSS measurements are calculated according to a GNSS antenna point that satellite signals reach. This point is called as Antenna Phase Center – APC. Unlike desired, APC is not a fixed point. It is changing by antenna type, antenna radome, frequency of the incoming signal, satellite elevation and azimuth. Even in the same antenna type with increasing base lenght the place of APC is changing, because of different direction and path of incoming satellite signal. Ignoring the change of this point leads to incorrect calculation of the coordinates. If receiver antenna phase center correction is not taken into account, it can cause up to 10 cm vertical error [1].

Antenna average phase center is a theorotical point which is the mean of all accessed observations. The difference between APC and this point is defined as electrical antenna phase center offset (PCO). There is a deviation between a single electrical antenna phase center and average electrical antenna phase center. These deviations are called receiver antenna phase center variations (PCV). Antenna phase center calibration consists of PCO and PCV [2].

II. Antenna Calibration Methods

There are three basic ways to determine PCO and PCV:

- Anechoic chamber measurements
- Relative field calibration
- Absolute robotic field calibration [3].

A laboratory calibration (anechoic chamber calibration) has to be done beside relative and absolute antenna field calibrations to prevent multipath effects that the environment of the calibration area will cause [4]. The main idea of the calibration process in the laboratory is measurements with simulated GNSS signals [5].

Relative antenna calibration is made according to a reference antenna. Both antennas are set up to a base thats coordinates are precisely known and GNSS measurements are used to determine the phase center of the test antenna [3]. Actual GNNS measurements are realized on field.

Absolute field calibration is done with the help of a fixed reference antenna and a second test antenna on a robot that returns and tilts the test antenna with high accuracy [6]. This calibration method is more effective than relative calibration because of satellite coverage [7].

III. Environmental Specifications

For relative field calibrations some precautions should be taken.

- The area must be private and sheltered from the outside, entrances and exits must be kept under control.
- It is vital to search the soil structure, how temperature changes affect the soil, because any change at the ground such as soil expansion and contraction, soil consolidation or slope instability, affect the station coordinates or stability.
- The effects of the environment on the measurements should be considered. The test area should be away from multipath effects. Also, it should have a clear horizon and vegetation should be controlled along the horizon not just for now, but for the future. Calibration area should be away from radio frequency emitting devices [8].

IV. Calibration Bases

A base on ground or building roofs.

A. *Ground Base*

A ground base should have high stability (its coordinates must remain the same) and should not cause multipath or any effect changes the incoming signals.

- Increasing depth of a station below the ground, improves its stability. Consequently, the foundation of

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the monument should be deep. A ratio of 2:1 of the depth-to-hight means fine stability. This will also cause to keep center of the mass of the monument under the ground [9].

- The monument hight should be appoximately 1,5 meters. However, if there are obstacles, higher monuments could be preferred, because there should be no obstructions 10 degrees above the horizon from the antenna and between 0 – 10 degrees obstructions should be minimized. In this way, antenna could be protected from multipath effects.
- The upper part of the monument should be narrower than the lower part. So, reflected signals from the upper part of the monument will be minimized.
- Reinforcement material should be used to ensure the stability of the monument, but traditional rebar should be avoided, because it can affect the incoming signals [8].
- The base should be appoximately 5 meters, therefore the way that the signal travels will be approximately the same for both antennas and athmospheric effects could be easily removed [7].

B. *Roof Base*

The building that the station will be constructed, is vital for the stability of the station and environmental effects.

- To complete the settlement of the building foundation, it is important to be sure that structure which the station will be established, was built at least 5 years ago.
- It should be maximum a two-storey building for the stability of the station.
- The roof should be made of material that will not create multipath effect.
- Stainless steel should be preferred [8].

V. Antenna Calibration Studies in Turkey

In Turkey, a few studies has been done about antenna calibration. One of these was carried out in Karadeniz Technical University (KTU). In this study, GPS receiver antenna phase center error was examined. For this purpose, measurements were made on the base between two monuments in the seaside of KTU. By comparing base lenghts which were obtained from GPS measurements, the effects of antenna phase center parameters to the baseline solutions were investigated [10]. Another study in Turkey is in Yıldız Technical University (YTU), Davutpasa Campus. An antenna calibration test area was build on the roof of Civil Engineering Faculty. A research team has performed a study to determine antenna phase center and its variations [11]. In Fig. 1 calibration stations in YTU can be seen.

Figure 1. YTU antenna calibration test area [12].

A. *ITU Campus Antenna Calibration Network*

The ground calibration network at Istanbul Technical University, consists of 5 truncated pyramid shaped monuments. An area in the campus having the basic conditions and facilities were established as the calibration area. Fig. 2 shows the network in ITU [12].

B. *The Properties of The Antenna Calibration Network*

- In ITU Ayazaga Campus, huge temperature changes or frosts are rare.
- There is no inclination in the field.
- There are bedrocks under the ground.
- For electrical field copper pipes have been established into the area.
- Internet connection has been established.
- Illumination has been set up.
- Water has been brought to the area.

Figure 2. ITU Ayazaga Campus Antenna Calibration Network.

As seen in Fig. 2;

- the area lies high and the horizon is clear. However, the western part of the calibration area is wooded and for working in the evening electricity poles are provided to the area,
- campus entrances and exits are controlled by campus guards, still to protect against potential damage,
- the calibration area is fenced, electricity has been provided to the area [12].

In Fig. 3 a monument in the network can be seen. 5 monuments of the network are designed based on following principles;

- in order to minimize multipath, caused by surrounding obstacles, each monument has been built with about 2 meters height,
- for the foundation of monuments, holes for about one meter below the surface were dug and concrete poured,
- for the stability of the monument, in the concrete there is a steel reinforcement from under the ground to top of the monument has been equipped,
- as seen in Fig. 3 the upper part of the monument is narrower than the bottom part, because of avoiding multipath from the top of the monument and the reason for larger bottom part is stability,
- antenna mount was made of chrome steel.

After the monuments were built, the required measurements for antenna calibration were made. During this study, the relative positions of the monuments were determined with total station and the difference between pillars were determined with precise leveling. To determine absolute positions of the monuments, static GPS measurements were done connecting to IGS point ISTA with a reference frame ITRF2008. Furthermore, polar coordinates of the obstacles which are around the network area were measured [12].

At first distances between monuments were measured (Fig. 4). Then, total station was set up on the monument number 2 and oriented to the monument number one, azimuth and elevation angles of the obstacles such as trees and electricity poles were measured according to this point. In Fig. 5 obstacles around the antenna calibration area in ITU Ayazaga Campus was illustrated.

Figure 3. A monument from calibration network in ITU Ayazaga Campus.

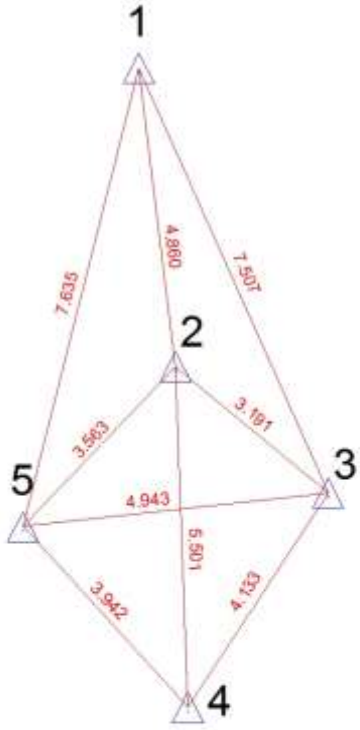

Figure 4. Distances between monuments.

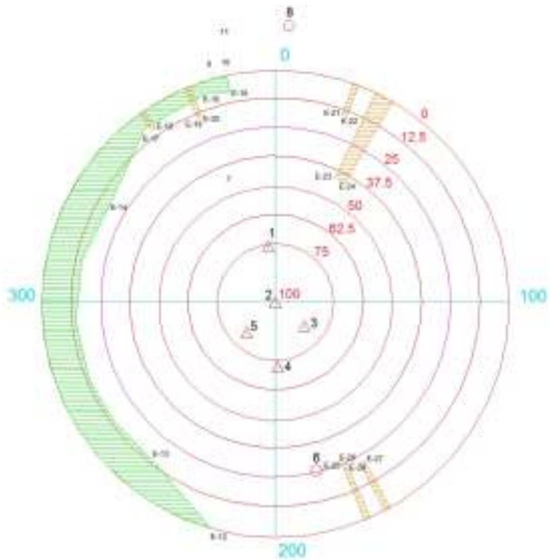

Figure 5. Obstacles around antenna calibration area.

In Fig. 5 obstacles around the calibration area are shown according to their elevation and azimuth angles. Striped green colour shows trees and brown shows electricity poles [12].

VI. Conclusion and Recommendations

Antenna phase center is a changing point that cause an error in point coordinates. To fix that error antenna calibration should be done, especially for high accuracy geodetic applications. A calibration area is required to make antenna calibration and spesifications of that area and the stations are vital.

By selecting the calibration area, not only the present state but also the future of the region should be considered. Besides, factors that could affect the measurements such as geological structure, tectonic movements, vegetation, infrastructure, slope, horizon, construction, weather conditions, surrounding radio stations should be considered.

The establishment of monuments is another issue. The center of mass of the monument should be under the surface. Therefore, the dimentions and the shape of the monument should be designed well. Concrete and reinforcing materials of the monument are necessary for stability of the monument but they should not influence the incoming signals. Antenna mount and the upper part of the monument should be designed as that they will not cause any multipath effect.

Safety of the monument is extremely important. Monument should not be built on an area that an outsider could come and harm the station, so safety precautions should be taken.

In Turkey, an anechoic chamber for antenna calibration has not been established yet. Some relative antenna calibration studies have been made. In KTU, an existing base was used and in YTU, antenna calibration has been made with roof stations. For the first time, in Istanbul Technical University, a ground network has been established for this purpose and environmental conditions were investigated.

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