The impact of the antenna mounting on the phase centre variation

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Abstract

NETPOS is a RTK network for governmental authorities of the Netherlands. The reference stations are equipped with Topcon PG-A1 antennas on a steel pipe mast. The influence of the mast on antenna phase centre variation appeared to be almost a centimetre. This is called the near field effect. The impact on rover positioning can be more that three times as large, resulting in an impact of more than 3 cm on the measured height. Calibration of the antenna including (the upper part of) the mast can eliminate this effect. This might be relevant for all GNSS users with a permanent reference station.

1 Introduction

Kadaster is a self-administering state body of the Netherlands. Its responsibilities are: 1. the cadastre and public registers (real estate, ships and aircrafts), 2. projects for reallocation of land, 3. national topographic mapping, and 4. the national coordinate reference system. To be independent in efficient GNSS surveying, Kadaster has built a RTK network service. This service is named NETPOS (Netherlands Positioning Service). Kadaster and the Ministry of Transport, Public Works and Water Management use NETPOS.

NETPOS consists of 31 reference stations (figure 1). The reference stations are equipped with a Topcon Odyssey RS receiver and a Topcon PG-A1 antenna. We selected this receiver, among other reasons for the possibility to connect it directly to a communication network without a PC and for its ability to also receive GLONASS signals. Some of the reasons to select the PG-A1 antenna were the small size (14 cm) and light weight (0,5 kg). The GNSS data of the reference stations are send to the computing centre by mainly in-company networks. Geo++ software at the computing centre is processing the data and supplying surveyors with VRS or FKP corrections by GSM connection. The specified precision for NETPOS is 1 cm for the longitude and latitude and 3 cm for the ellipsoidal height.

2 Quality validation

To validate the geometric quality of NETPOS, test measurements were executed on 84 reference points of the base net. The base net is a network of over 400 passive reference points in the Netherlands. The coordinates of the base net are computed relative to AGRS.NL (Active GPS Reference System for the Netherlands) using the Bernese software. AGRS consists of five permanent GPS stations (mainly the Dutch EPN stations) with better monument stability than the NETPOS stations and choke ring antennas. This results in a precision of the base net better than 1 cm horizontally and 3 cm vertically. On each of the 84 base net points, a rover was positioned using NETPOS to perform 10 initialisations with 10 observations each. These observations were used to compute the precision (one sigma) of NETPOS relative to the mean value, which was found to be 6 mm for the longitude, 9 mm for the latitude, and 17 mm vertically. This is within the specified precision for NETPOS.

Figure 1. NETPOS reference stations and coverage (www.netpos.nl).

3 Problem: height offset

During the quality validation a problem appeared. Although the precision of the height was within the limits, it appeared to have a systematic offset of 31 mm. All measured height coordinates with NETPOS were too high! Many tests and checks followed. However, the coordinates of the reference stations, the antenna height and all other possible parameters that could cause an error in the height component were correct. Determining the height offset was difficult since the error was not completely constant and about the size of the standard deviation of the measurement noise. As we could not find the cause in the parameters we entered, we contacted the software provider Geo++. At Geo++ it was suggested that although the antenna was calibrated, the steel pipe mast for mounting the antenna (figure 2) could influence the phase centre variation. Geo++ offered to calibrate the antenna again, together with the mast.

Figure 2. A NETPOS antenna and mast.

4 Solution: Calibration with mount

Antenna calibration at Geo++ is done in absolute mode, using a robot that rotates and tilts the antenna in all directions. Fast, precisely known changes in the orientation of the antenna are essential for the separation of phase centre variations and multipath (Wübbena *et al.* 2000). For both GPS frequencies the absolute, three-dimensional mean position of the phase centre as well as the absolute, elevation and azimuth dependant phase centre variations are determined. The phase centre variation is modelled by a spherical harmonic expansion of degree 8 and order 5 (figure 3). The accuracy (repeatability) of the calibration is approximately 1 mm (Schmitz *et al.* 2004).

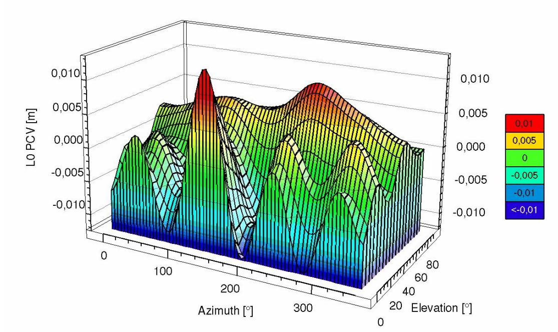

Figure 3. Modelled phase centre variation of the PG-A1 antenna including the upper part of the mast.

Calibrating the antenna together with the complete mast was not possible, as the weight of the steel pipe would be too much for the calibration robot. Because the nearest objects have the most impact on the antenna, just the upper and most important part of the mast was used for the recalibration. This included the 10 cm prism spacer, the central clamping screw with bearing target, and the round steel plates with adjustment screws to level the upper plate (figure 4).

The differences in the mean phase centre of the calibrations with and without the upper part of the mast were 3 mm for L1 and 9 mm for L2. The main affected component was the height. The variations around this mean phase centre depending on elevation and azimuth showed a maximum difference between the two calibrations of 3 mm for L1 and 8 mm for L2 (figure 5).

Such influence of the mounting and the direct environment of the antenna on the phase centre variations is called the near field effect. This effect is mainly caused by very long periodic multipath and electromagnetic interaction of the antenna and objects in the vicinity (Schmitz *et al.* 2004).

Figure 4. Calibration robot with NETPOS antenna and the upper part of the mast.

The use of the antenna calibration corrections that included the upper part of the mast eliminated the height offset of 31 mm in the positioning of the rover. This is remarkable, considering that the differences in the antenna calibrations are smaller than 1 cm for the mean phase centre and for the phase centre variations. Moreover, one generally expects that the error resulting from the near field effect on the mean phase centre should be cancelled out by the same error in the coordinate computation of the reference station.

A small near field effect can have an increased impact on the RTK positioning with a rover. According to Geo++ there are three reasons for this. Firstly, the different influence on the L1 and L2 frequencies results in an influence on the ionosphere free linear combination of a factor three larger than the effect on the phase centre itself. This effect is present. Therefore, the maximum difference for the two calibrations in the phase centre variations for the ionosphere free linear combination is 17 mm (figure 6). Secondly, the near field effect is amplified by any tropospheric modelling. Atmospheric effects and phase centre variations both affect the range in the direction of the satellite. Therefore, unmodelled phase centre variations cannot be separated from the tropospheric error component by the network software and will be interpreted as tropospheric effects. This effect, which mainly affects the height component, is present too. Thirdly, the satellite geometry can have an influence on the error due to unmodelled phase centre variations. This gives additional systematic and time dependant effects. These three components of the near field effect together explain the height error of 31 mm that disappeared by calibrating the antenna including the upper part of the antenna mast.

Probably, the influence of the antenna mounting on a choke ring antenna would have been less. Nevertheless, we were surprised by the influence the antenna mounting can have on the mean and variations of the phase centre and, more important, the subsequent larger impact on the measured heights with a rover.

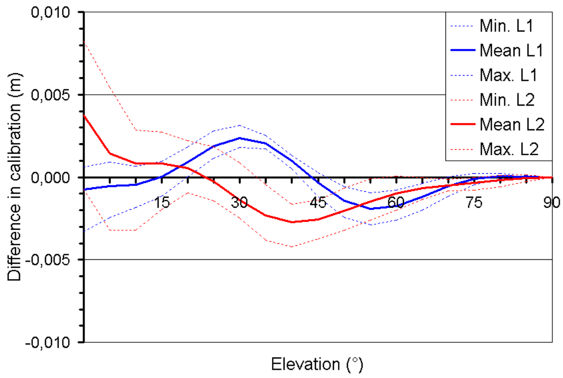

Figure 5. The difference between the two calibrations in the phase centre variation for the two GPS frequencies (L1 and L2).

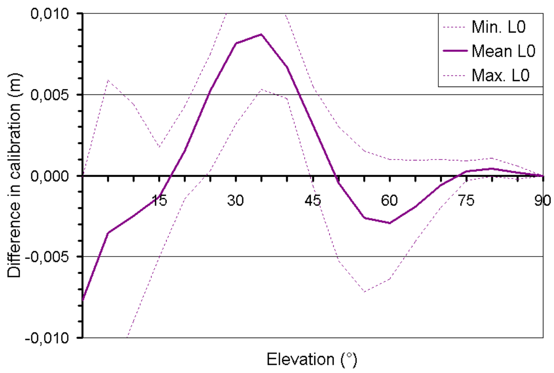

Figure 6. The difference between the two calibrations in the phase centre variation for the ionosphere free linear combination (L0).

5 Conclusions

The influence of the mounting mast on a non choke ring GNSS antenna phase centre can be almost a centimetre for the mean as well as for the elevation and azimuth dependant variation. This is called the near field effect.

The impact on rover positioning is not of the same size as the influence on the antenna phase centre. This can be more than three times as large, due to different influence on the phase centre variations for the L1 and the L2 frequency and additionally because not properly corrected phase centre variations disturb the tropospheric models. The resulting impact of the mounting mast can be more than 3 cm in the measured height with a rover.

Calibration of the antenna including (the upper part of) the mast can eliminate this effect.

The near field effect of the antenna mounting might be relevant for all GNSS users with a permanent reference station.

Kadaster decided that it will calibrate all its future antennas for permanent reference stations individually including the mounting.

References

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