The accuracy of geodetic GNSS antennas

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SUMMARY

The GNSS technology has rapidly grown in the last ten years and the achieved accuracy is getting higher and higher. However, while most people just focus on the parameters of the GNSS receivers, the accuracy of the antennas themselves has a big impact on the overall accuracy of the measurement as well. What are the usual faults of a GNSS antenna? What has to be considered regarding the place of the GNSS antenna? And what about the calibration of the antenna? The present paper gives answers to these questions. The ANTEX data files of different GNSS antennas are analyzed and the antenna patterns are discussed.

RESUMEN

La tecnología GNSS ha crecido inmensamente en los últimos diez años y la precisión alcanzada aumenta continuamente. Sin embargo, mientras la mayoría de la gente sólo presta su atención a los parámetros de los GNSS receivers, la precisión de las antenas GNSS también tiene un gran impacto sobre la exactitud de la medición. ¿Cuáles son los defectos usuales de las antenas GNSS? ¿Qué hay que considerar en cuanto a su posición? ¿Y qué hay de la calibración? El presente trabajo da respuestas a estas preguntas. En él, analizamos los “ANTEX data files” de diferentes antenas y discutimos las respectivas características.

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1. PRELIMINARY

The GNSS technology has grown up rapidly in the last ten years. The firmware of the receivers promises more accuracy, faster fixing and more features. Also developer of GNSS software bond higher accuracy. In long term observations we measured the continental drift with an accuracy of one mm and monitoring embankment dams, landslides, volcanos, bridges and buildings with the same accuracy. The manufactures of machine control and precise farming systems get more exactness in the solutions. The better receiver hardware and software is one part. Another part is the quality and accuracy of the GNSS antenna. In this paper I write about fault effects of GNSS antennas and how to compare antennas. Unusually you will find the specifications of GNSS antennas in a brochure.

2. THE FAULT EFFECTS OF GNSS ANTENNAS

2.1 The diffraction of the GNSS signal

Diffraction of GNSS signal negotiates always when a Satellite comes above an obstruction like a building or a tree. Also when the direct way of the GNSS signal is barred it is possible to receive the signal with a good signal to noise ratio (S/N) and the receiver measures a longer distance. This fault can have a dimension of a few centimeters and in an extreme case of a few decimeter (Wanninger L. Frevert V. Wildt S. 2000).

2.2 Near field effects of the GNSS antenna

How the word explains is the near-field effect to be impact from objects in immediate adjacency of the antenna. Every antenna reacts in a different way. In calibration experiments was determined that the near-field effect can make differences of the phase center in the height of centimeters (Zeimetz P. 2010).

2.3 The Multipath scattering

The multipath scattering is not a direct antenna fault. The signals reflect from buildings, masts, bridges etc. If the reflect is one times the polarization change and a good GNSS antenna abort these signals. You can check it if you compare the antenna pattern. If the reflection is two times and the signal lost low S/N ratio you measure a longer distance to the satellite. A GNSS antenna is not able to filter these signals. Only the GNSS receiver firmware can solve it. According to the rawness of the reflecting surface and the angle of dip the influences are different (Eisfeller B. 1997).

2.4 The phase center variation

The phase center of a GNSS antenna is in an ideal case stabile, punctual and constant. It is not possible to build an antenna in such a precision. At every antenna the phase center is flitting according to the azimuth and elevation angle of the satellites. GNSS antennas with azimuth dependence are very bad antennas.

3. THE CORRECTION OF THE FAULTS

3.1 The diffraction

The correction of the diffraction is very difficult. There is no chance for the GNSS antenna to do it. A good code of practice is to work with an longer observation period. In case of real-time application you need very good software. One approach is the loading of the undifferentiated phase observation as a function of the satellite elevation with the anticipate S/N ratio (Wanninger L. Frevert V. Wildt S. 2000).

3.2 Near-field effects

It is not so easy to eliminate the near-field effects. The best way is a long distance (min. 20 cm) between the ground and the antenna. But every antenna is different. The best way to find it out is to ask the manufacture about the near-field effects of his antenna.

3.3 Multipath scattering

The multipath scattering is a dangerous fault during the GNSS measurement. The best way to reduce the left hand signals is to work with an antenna with good multipath reduction. For the right hand multipath signals with high S/N ratio you need a good firmware on the receiver side. Also a large distance from the ground is positive for the multipath reduction.

3.4 Calibration

To calibrate an antenna you need a fixed point wherefrom you affix the correction. This point is the Antenna Reference Point (ARP). From ARP we have the localization to the geodetic coordinate system and to the correction from the ANTEX Data File (Rothacher M. Schmid R. 2006). In the following chapter I describe three different ways to calibrate GNSS antennas.

4. THE CALIBRATION PROCEDURE

4.1 Relative calibration

The relative calibration is the easiest method and for everybody operable. You need a place with a perfect view to the sky (360° azimuth with 0° max. 5° elevation) and a short baseline

(3 to 10 m). After 24 hours you have to turn the antenna around 180° and measure again for 24 hours again. At observation in two positions you have the horizontal components absolute intended, but the vertical components only relative. To calibrate a GNSS antenna in this way needs a lot of time and if you need high accuracy the expense is very high. But it is a good method to check the horizontal phase center offset. A practical method is to turn the antenna every 4 hours around 90° at four times and if you cannot see any different in the baseline you can be sure to work with a good antenna.

4.2 Calibration hall

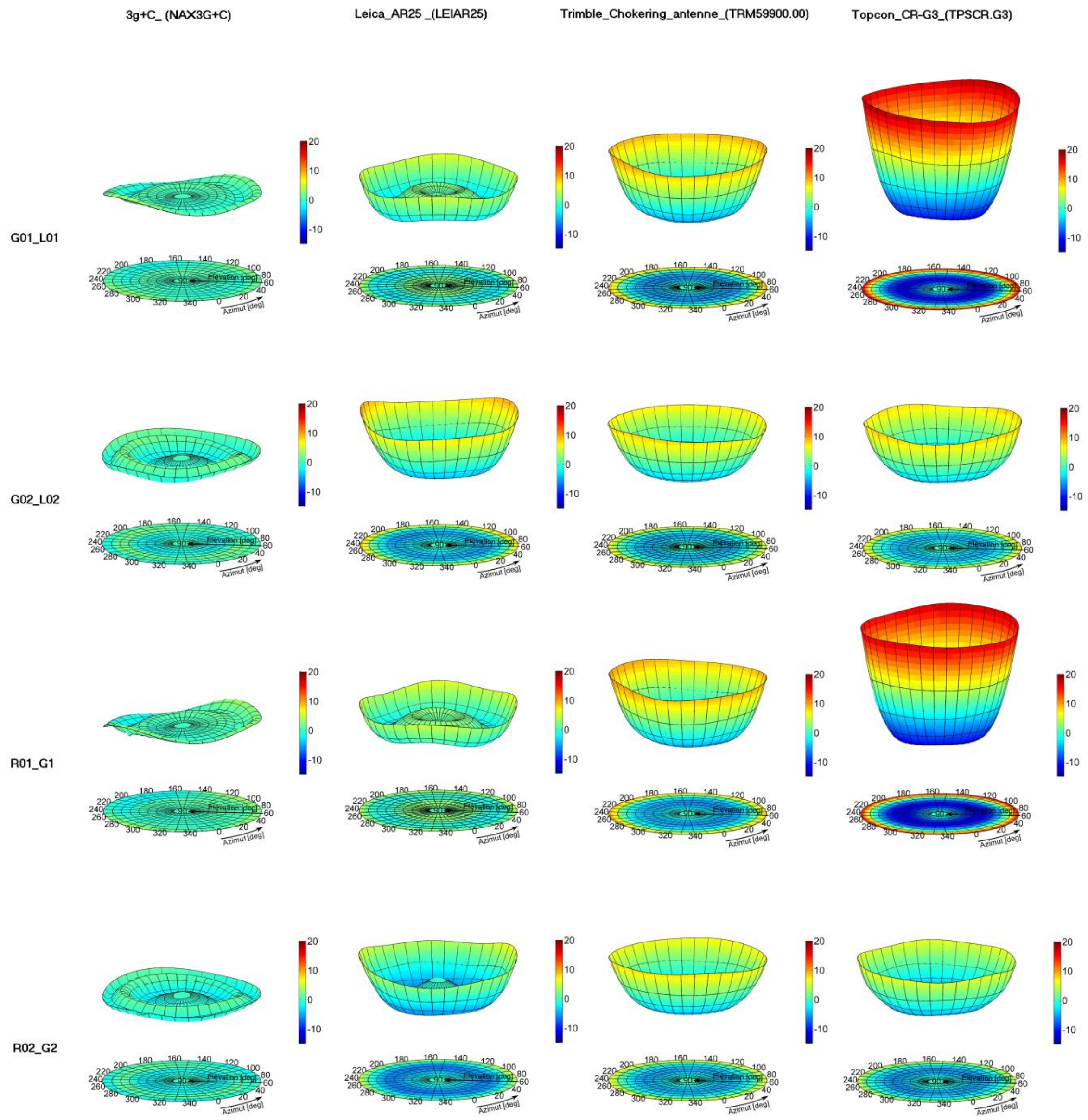
In a calibration chamber a simulated signal with a small-angle radiation lobe will be generated and send to the GNSS antenna. The biggest problem is to absorb the signals which not directly impact on the antenna. These signals must absolutely have no reflection. To achieve this you need pyramidal absorber of synthetic resin with carbonate impregnated. In the absorber the signal must be transmitted from electric magnetic energy to thermal energy. For a transmitting antenna a broadband antenna for the GNSS signals is needed. The advantage is that you don't have to change the transmitting antenna. The big goal of a chamber is that you can calibrate the antenna also with Galileo and Compass signals. The measurements in a good calibration hall provide nearly the same results in one to two hours as the field calibration with a robot.

4.3 Robot calibration

The absolute field calibration with a robot is a certain method. Within 5 to 7 hours you have a complete calibration. Redundant dimensioning allowed an accuracy of 0.1 mm and no manipulation of near-field effects and multipath can be insulated. Positioning the antenna better than 0.1° satellite using with high elevation only is possible for better signal quality. The calibration results will be calculated by a special post-processing method (Wübbena G. 1996).

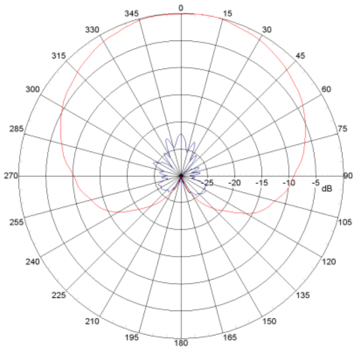
5. COMPARE THE CALIBRATION RESULTS OF PRECISE GNSS ANTENNAS

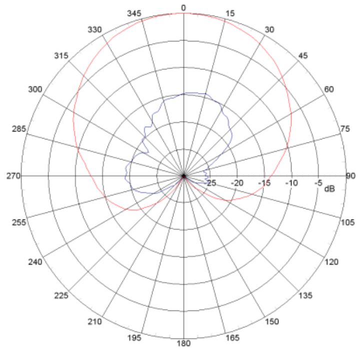
In this chapter I compare the antenna calibration results of four good GNSS antennas. I downloaded the ANTEX data files from the IGS websites. These files are typical calibration files - for those you have to calibrate minimum 6 antennas and the outcome is the ANTEX data file. The candidates are the high-end antennas for reference stations from Topcon, Trimble, Leica (Novatel) and navXperience. All of these antennas allowed to build up an IGS reference station. I original downloaded the ANTEX files from the IGS website and calculate it with MATLAB. The results are in the same scale for GPS L1 and L2 and also for GLONASS L1 and L2.


3g+C_ (NAX3G+C)
Leica_AR25 _(LEIAR25)
Trimble_Chokering_antenne_(TRM59900.00)
Topcon_CR-G3_(TPSCR.G3)
G01_L01
G02_L02
R01_G1
R02_G2
20
10
0
-10
Elevation [deg]
Azimut [deg]
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
90

6. OTHER ANTENNA PARAMETERS

6.1 Antenna Pattern





The GNSS Satellites send right hand circular pattern. That means: It is a polarized signal which plane rotates right handed. If this signal is reflected its plane rotates left handed. The antennas try to use the right handed rotating signals and avoid the left handed rotating signals. The pattern displays the amount of the receiving signals. On the left side you see an antenna which shows a bit better results than the antenna on the right side. The values of the good (red one) signals are a little bit greater as on the left side, whereas the values of the bad one are greater than the other on the right side.

6.2 The antenna gain

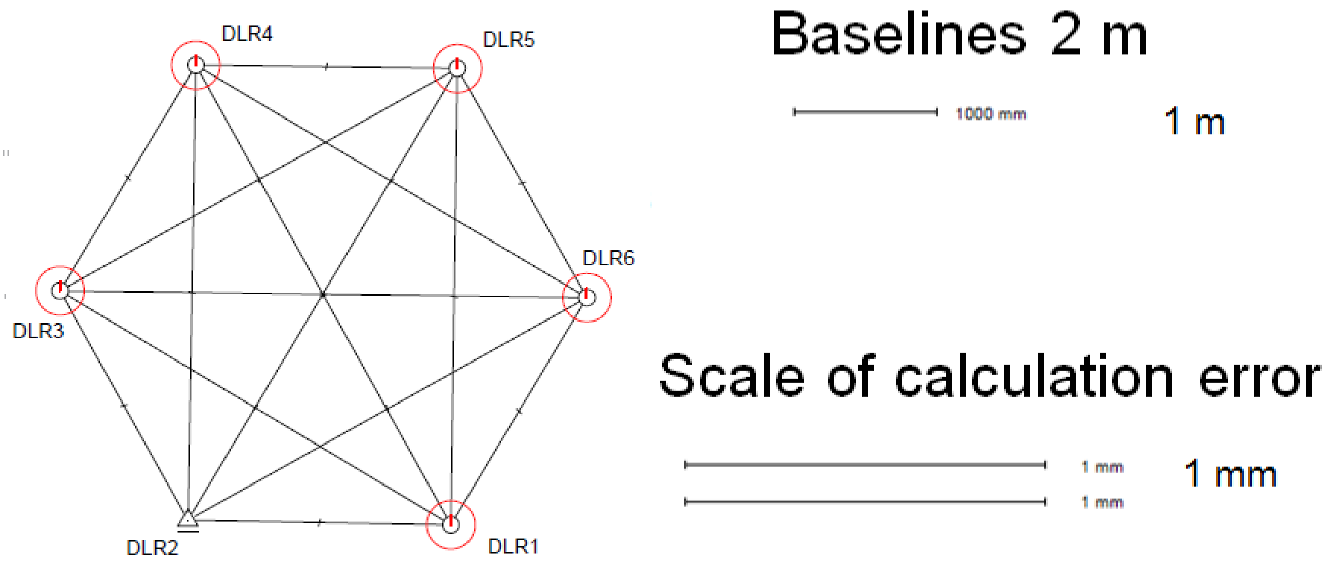
The gain of an antenna must be min. 20 db. Most of the geodetic GNSS antennas have a gain from 25 to 30 db. For the most solutions this result is good enough. If you must use longer cables (more than 50 m) you should use an antenna with a gain from 40 to 50 db. Also important is to use a good cable. The losses of a bad cable cannot be compensating from the receiver or the antenna. Attention: An antenna with high gain is also stepping up the bad signals (multipath, near-field effects). The consequence is that an antenna with high gain is not suitable for the most applications. For any observations you have to check what kind of antenna is appropriate!

6.3 The passive gain

The value of the passive gain is in dbic. For simplifying you can determine: If the value is higher the antenna is able to hear better the signals from the satellites. Normally the receiver hears nothing under a value of 2 dbic. At the most antennas the value of dbic grows up from 0° to 90° elevation. Read the technical data sheet exactly, a value of min. 5 dbic at 90° elevation means lower passive gain at 50° or 20° elevation. It is very important to know the passive gain up to 0°. The passive gain is a really important parameter to qualification a good GNSS antenna.

7. EXAMPLE FOR AN APPLICATION

This is a new GNSS antenna hexagon from the DLR in Oberpfaffenhofen. The baselines between the antennas are 2 m ± 1 mm. The metal construction is good for a lot of multipath and near-field effects. But they attend a lot of important things. The distance of the pole is 0.5 m and the cable is close to the pole. Good to eliminate near-field effects. The company ppm GmbH from Penzberg used this system for an observation of 24 hours. The antennas come from navXperience (3G+C) and they used Ashtech Receivers. They made the baseline processing with Waypoint software from Novatel and the made net adjustment with Cremer Software. Here are the results of the internal accuracy:



They fixed the Point DLR2 and made a free adjustment to all other points. The maximum deviation in the horizontal is 0.2 mm (red circle) and in the height is 0.1 mm (red line). I never saw a GNSS measurement with results like this before. The main reason seems to be the absolute high accuracy GNSS antenna with good multipath reduction and no near-field effects.

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BIOGRAPHICAL NOTES

1987 – 1991 Technische Fachhochschule Berlin Dipl.-Ing. Geodesy
From 2001 Founder and director of the Geo.IT Systeme GmbH
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2009 – 2012 Research projects: MoDeSh with GL and HSVA: Motion and Deformation of Ships

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