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Section: Technologies of Geodesy and Cadastre

Analysis of the code and carrier phase measurements performed with LEA-6T GPS receiver

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Abstract

LEA-6T GPS receiver is an integrated navigational GPS module created by uBlox. Unlike most receivers of this type, not only does it send a position but also transmits raw observation data (carrier phase, pseudorange and Doppler). The main purpose of this study is to examine the usefulness of these findings for precise positioning, which would allow to use the test receiver in satellite geodesy. The evaluation platform made at the Institute of Geodesy served as a tool which enabled to record and store data sent from LEA-6T receiver. The recorded data were converted into a universal format for the raw observation data (RINEX 2.11). Then, the positioning quality and signal tests were investigated through a thorough analysis of the recorded data with the help of a surveying and navigation antenna. The test results are shown in the following study.

Keywords: Low – cost receiver; LEA-6T; GPS observation.

1. Introduction

Due to the development and miniaturization of electronic devices it is possible to create very small and efficient GPS receivers. Devices of this types are commonly known as MEMS (Micro Electro-Mechanical Systems). Because of their size (eg. 17.0×22.4×2.4 mm for LEA-6T) they are commonly installed into cell phones, tablets and other mobile devices. Most of low-cost micro GPS receivers does not allow for access and collect observables (pseudorange, carrier phase ect.), but provide the user only with the calculated position. The LEA-6T receiver uses ublox communication protocol which allows to record all raw data that are stored during measurement. The following paper presents the quality tests performed on data stored by the LEA GPS receiver.

2. Performance of observation

This section of paper is devoted to description of tests conducted on observational data recorded from LEA-6T receiver. The first study focused on determining the quality of satellite tracking by comparing the values C/N_0 ratio recorded by LEA-6T and *SNR* obtained from geodetic class receiver. Second study concerned the determination of the quality of pseudorange measurements by examining the observed range deviation. Third research involved calculation of double-difference for the carrier phase measurements on zero-baseline. At the end of this section the results of LEA-6T satellite positioning conducted for navigation and geodetic application are shown.

2.1. Signal to noise

There are two parameters commonly used to describe the strength of signal observed by the GPS receiver: signal to noise ratio (*SNR*) and carrier to noise density C/N_0. This two values are often used interchangeably, however there is a fundamental difference between them.

The *SNR* refers to the ratio of the signal and noise power at given bandwidth. The value of this parameter will depend on receivers front-end, acquisition and tracking parameters. It will be different on every stage of signal processing within the GPS receiver. Due to that fact, it can be assumed that the *SNR* is the C/N_0 value that was transformed during the navigation process.

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$$SN = SNR = S - N \quad (1)$$

where:

S – the signal power,

N [db] – is the noise power in a given bandwidth.

The value of C/N_0 allows to specify the signal power of the tracked satellite and the density of the noise observed by the receiver front-end. It refers to the ratio of the carrier power and the noise power per unit bandwidth. If one uses two GPS receivers with one antenna, registered values of the C/N_0 may differ. It is due to the difference in the construction of receivers front-end. The information contained within the value of C/N_0 are used to check the signal quality that is independent of the front-end bandwidth, acquisition and tracking algorithms implemented within the receiver. The value of C/N_0 may also be affected by the set up of the installation used during observation [3].

The LEA 6T receiver allows to measure the C/N_0 value.

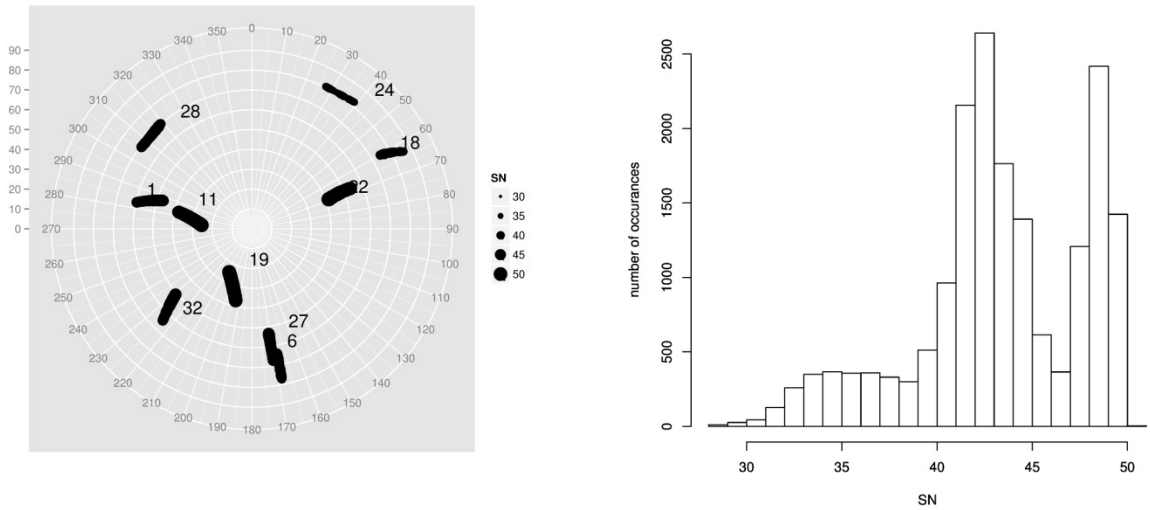
$$SN = C / N_0 = C - N_0 \left[\{dB\} - \{Hz\} \right] \quad (2)$$

where:

C – carrier power

N_0 – the noise power density.

The typical values of C/N_0 varies from 37 to 45 [3]. In the case of test measurement with LEA 6T C/N_0 value varies from 28 to 51 with a mean of 43.79. In Figure 1(a) SN value is depicted with the width of a line. It shows the dependency between elevation angle, azimuth and SN. Figure 1(b) depicts the histogram of SN for all satellites during measurement. This shows that most observations are within the typical range.



(a) Skyplot of signal to noise

(b) Histogram of signal to noise

Fig. 1. Performance of signal to noise

Equation (3) shows the dependency between the values of this two parameters.

$$C - N_0 = SNR - BW \quad (3)$$

where BW – the noise of receivers bandwidth.

The value of BW is constant for a period of performed observations. Takeing the above equation into consideration, it can be noticed that the difference between the C/N_0 and SNR will be constant not only for observations preformed with one receiver but also for observations performed with two receivers connected to one GPS antenna. Figure 2 depicts the values of SNR for Trimble 4000 geodetic GPS (red line) and values of C/N_0 for LEA 6T GPS (black line) observed while the receivers where connected to the same antenna. The blue line depicts the value of difference between the parameters. In case of these measurements the mean difference is 32.47 dB with standard deviation 0.50 dB. The results on performed tests allow to assume that the quality of LEA-s C/N_0 measurements is close to the one achieved in geodetic GPS receivers. The correlation between these two parameters is 0.97 which proves similar performance of both frontends.

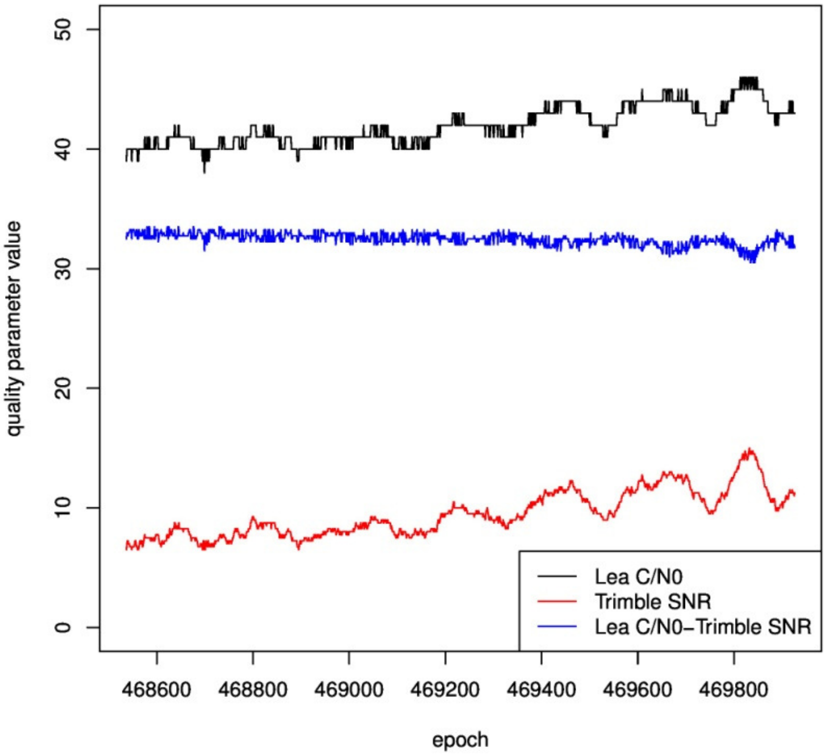


Fig. 2. Difference in C/N0 and SNR value

2.2. Observed range deviation

ORD (Observed Range Deviation) is a difference between an observed pseudorange and its predicted value [1]. The computation of this value requires a various algorithms. Calculated clock offsets are depicted in Figure 3 while ORDs are depicted in Figure 4. From these figures it is clear that the performance of receivers clock is typical for a navigation class receiver. Due to its large drift the clock rests every half an hour.

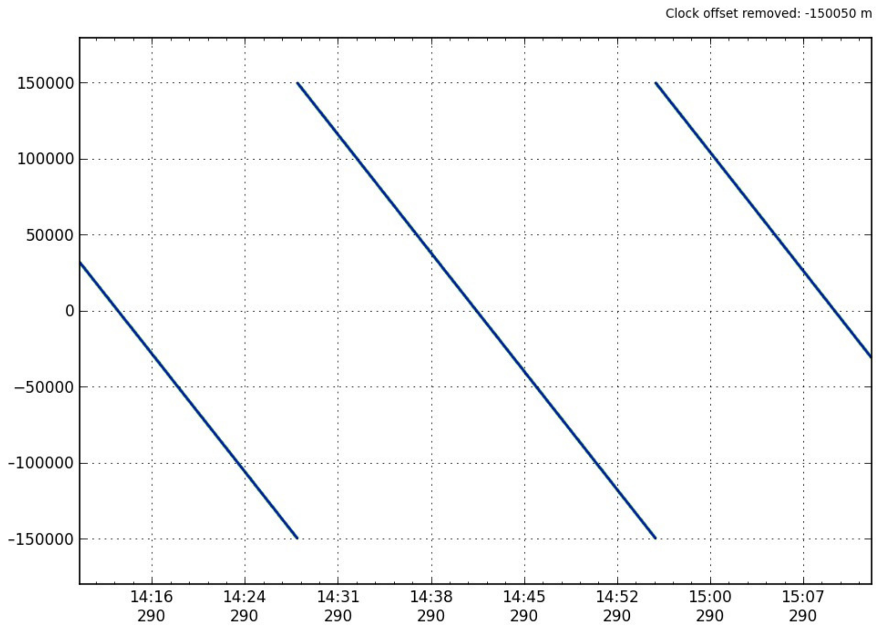


Fig. 3. Clock offsets

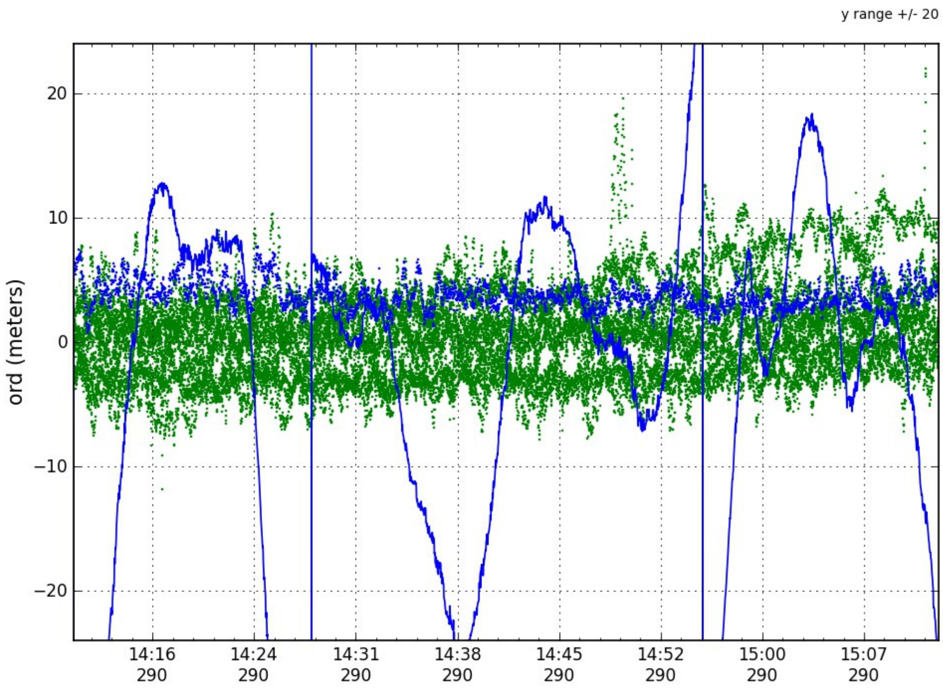


Fig. 4. Observed range deviation

Figure 4 shows that there is a lot of noise in pseudoranges. To check whether it is an underlying systematic effect or receivers noise, autocorrelation of ORDs for different lags were calculated. The plot of autocorrelations is depicted in Figure 5.

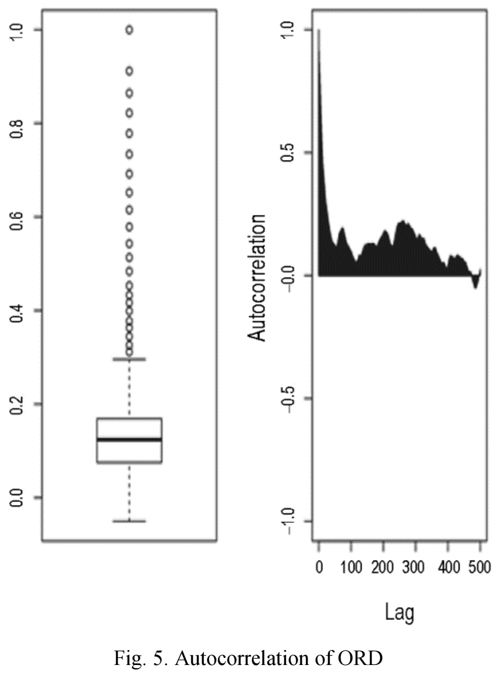


Fig. 5. Autocorrelation of ORD

On the left side of Figure 5 there is a boxplot which depicts that the value of autocorrelation median is less then 0.2. The right side of this Figure presents the values of autocorrelation calculated for 500 neighboring points. It can be observed that the autocorrelation is more the 0.5 only for 10 points. Analyzing Figure 5 I can be concluded that the ORD's does not show any autocorrelation. Therefore it can be stated that the noise in pseudorange observations is mostly random.

In [2] the standard deviation for the GPS C/A code can be calculated with the use of the following equation:

$$\sigma_{\tau ML} = \frac{3.4444 \times 10^{-4}}{(C / N_0)WT} \tag{3}$$

where:

C / N_0 – carrier to noise value,

W – bandwidth,

T – observation time.

This values of L1 C/A pseudorange ORD's and elevation angles are plotted in Figure 6. It shows that for the reasonable elevation angle $\sigma_{\tau ML}$ is close to the ORD's mean value.

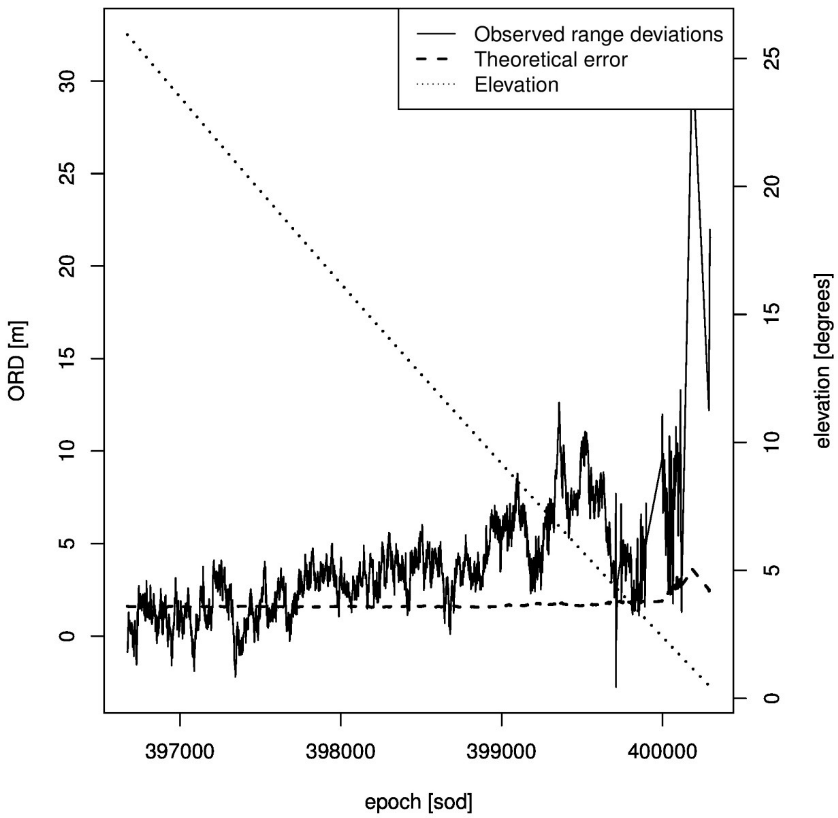


Fig. 6. ORD's vs. elevation and $\sigma_{\tau ML}$ measured

2.3. *Double differenced observations*

In order to evaluate receivers performance a zero-baseline double differenced observations were created. Receivers used for zero-baseline were LEA 6T and Ashtech zXtreme. The measurement was performed in the open area with low possibility of multipath error. Data were collected during one hour static session. The summary of created double differences quality is comprised in Table 1.

Table 1. Summary of double differences

Type of observations	Elevation	noise(mad)	median	# DDE	# SVE	kurt	jumps
C1	10–20	0.7641	4.970e–01			2.84	0
L1	10–20	0.0017	–2.713e–04	6156	6156	4.67	2
D1	10–20	0.1984	4.483e–01			2.15	0
C1	20–60	0.7469	5.027e–01			3.17	0
L1	20–60	0.0018	6.106e–05	19059	22735	4.97	3
D1	20–60	0.2049	3.290e–01			2.14	0
C1	60–90	0.4865	–3.692e–02			3.19	0
L1	60–90	0.0007	1.595e–05	3378	3378	4.89	0
D1	60–90	0.0775	1.737e–01			3.23	0
C1	10–90	0.7159	4.115e–01			3.21	0
L1	10–90	0.0015	–1.345e–05	28593	32269	6.08	5
D1	10–90	0.1874	3.224e–01			2.31	0

The value on median for double–differenced L1 carrier observations is very low and accounts to only 0.000013 m as can be seen in Table 1. The mean value of noise (calculated as an median absolute variation) for carrier observation is 0.0015 m which indicates the high quality of these measurements. As it can be predicted the lowest noise in preudorange, carrier phase and doppler measurement can be observed in satellites at high elevation.

2.4. Quality of estimated position

After a series of previously presented calculations, the tests of positioning quality were made. The first survey was carried out to check the accuracy of autonomous positioning calculated from measurements made by LEA-6T receiver. Figure 7 depicts the result of 25 minute measurement performed on a point with known coordinates. The position of the LEA-6T receiver was calculated on every epoch of the observations. Black points are measured points, red point is a true antenna position and dashed line is a reference 1x1m square. Geodetic grade Ashtech antenna was used for this measurement. Gathered data was converted to rinex 2.10 observation file. The position in single measurement epoch was determined by use of *PRSolve* program from the gpstk library.

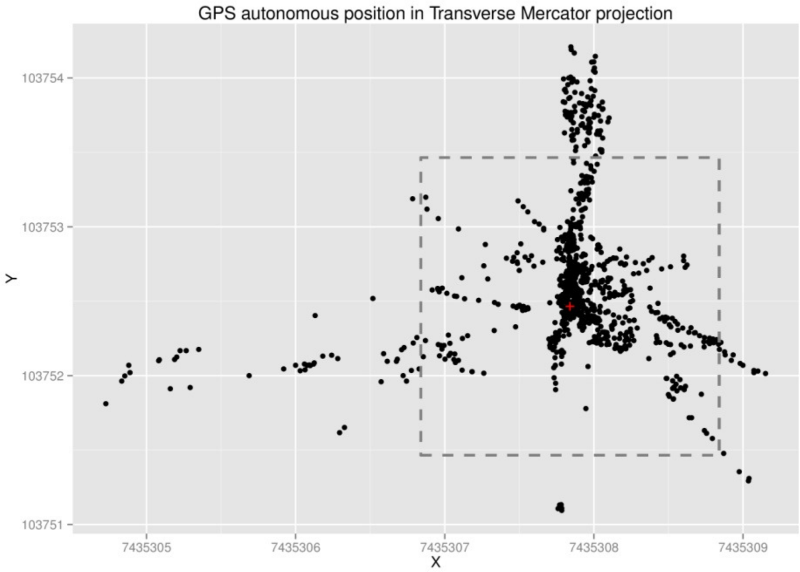


Fig. 7. Autonomic position of calculated during 25 min session

The second test was performed to check the possibility of using LEA-6T receiver for static survey. To carry out that task the 60 minutes static session was performed out on the point with known coordinates, which were previously measured with high class geodetic receiver. After measurement the adjusted position was calculated with a use of observations downloaded from two neighbouring ASG-EUPOS stations (LAMA,KROL). Draft of adjusted network is presented in Figure 8.

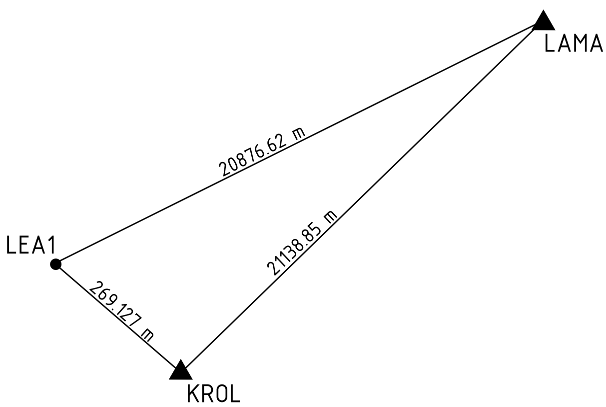


Fig. 8. Draft of adjusted vectors

As a result of performed calculations the adjusted vectors were obtained. The accuracy of these vector is shown in Table 2. Obtained coordinates were transformed to 2000 coordinate system (Polish national coordinate system, generated with a use of Gauss-Krüger projection on GRS 80 ellipsoid) and compared with previous measurements. Differences of obtained values were respectively Δx = 0:043m, Δy = 0:023m, Δh = 0:091m. Obtained results indicate high quality of measurements performed with LEA-6T receiver.

Table 2. Accuracy of adjusted vectors

Vector	mLat.(m)	mLon.(m)	mVert.(m)
LAMA – LEA1	0.024	0.039	0.039
KORL – LAMA	0.000	0.000	0.000
KROL – LEA1	0.024	0.039	0.039

3. Summary

Based on the carried out tests it can be stated that the quality of observations performed with LEA-6T receiver is on satisfactory level. The calculated carrier to noise ratio values indicate that LEA's tracking quality is as good as in geodetic receivers. Computed values of ORD's indicate that measured pseudoranges have accuracy corresponding to other navigational class receivers. The performance of carrier phase measurement determined by calculating the double – differences on zero-baseline shows that the observations done with the tested receiver are comparable with observations made with high class geodetic receivers. The positioning quality test, made at the end of this paper, confirms the possibility of using LEA-6T receiver for geodetic applications.

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