APPLICATION OF FULL ROVING GPS OBSERVATION STRATEGY FOR MONITORING LOCAL MOVEMENTS

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Abstract: The full roving GPS observation strategy - which was developed for the investigation of antenna mean phase centre offsets using the observations of micro scale networks (1-10 m) - was generalized for the deformation investigation of local scale networks (1-2 km). Because this method estimates the mean antenna offsets referring to the mean elevation angel of the actual observations, it can be used to cancel the phase biases of the individual antennas. It proved to be an optimal strategy for those campaign receivers which are not used continuously. The changes of the antenna characteristics can be recognized and cancelled during the deformation measurements. The method was successfully applied in the horizontal monitoring of the high loess wall on river banks.

1. Introduction

It is well known that the quality of the observations and the performance of the GPS receivers, which are permanently used in different networks have been controlled continuously. The high precision of the permanent networks is provided by the scientific data reduction softwares (e.g. Gipsy, Bernese, GAMIT), where the ionospheric and atmospheric effects and the antenna mean phase centre offsets and variations are modelled properly. The proper knowledge of the antenna characteristics is very important because usually different types of receivers and antennas are used in the networks.

The change of the data processing strategy, the change of the antenna characteristics and the ageing of the receiver or the use of new antennas can be recognised very easily on the time series of the permanent stations, if these effects became significant. One of the crucial points is the antenna phase centre offset and variation model. At the moment usually type specific relative models are used. However, in the future the absolute and individual antenna models will be preferred in the permanent networks. At the moment the anechoic chamber and the outdoor absolute calibration methods are not widely available and may be very expensive [1].

Based on the relatively simple method [2] a generalized full roving observation strategy was introduced and tested for the investigation of antenna mean phase centre offsets [3]. Because this method properly estimates the actual offsets, even without any main phase offset models, it was proposed as an observation strategy for a high precision campaign networks as well.

In this paper the method will be shortly introduced and the application for calibration and horizontal monitoring purposes will be presented. The investigations were carried out during the international OASYS project [4].

2. Full roving observation strategy

The method is introduced and tested very thoroughly for calibration purposes in [3]. Here only the basic idea and the main characteristics will be recalled. Imagine that the receivers occupy a small local network, where the antennas are very carefully mounted and oriented to the magnetic north. Next day the measurement will be repeated in the same duration of time but 4 minutes delayed providing the same satellite configuration. Next day the receivers occupy different places. If we connect the different places with the imaginary continues closed line, than the receivers have to rove clockwise or counter clockwise to the neighbouring points.

Adjusting the derived GPS baselines components of the two sessions (or the derived station coordinates) the unbiased station coordinates and the three components of the mean phase centre offset can be determined. The observation equations of the baseline components split up into two complementary parts including three coordinate and three phase offset defects respectively. The defects can be handled as a free network, or one of the stations coordinates and one of the antennas offset can be fixed as known parameters. In the first case the relative, at the second case an absolute mean phase offsets can be estimated. The GPS-NET baseline adjustment program was modified to perform these investigations.

The test measurements [3] showed that this concept remove the main phase biases in spite of the fact that the antenna heights were measured only to the ARP points and no antenna offset and variation model were used. Of course the lack of the variation model causes a larger noise level. Applying the adopted type specific antenna models this concept can be used to estimate only residual phase offsets. It can be used to investigate the individual antennas and the whole data processing strategy. Repeating the investigations we can control the performance of the campaign receivers, which are not used in permanent networks.

This method theoretically does not require the precise relative knowledge of the calibration network; however it can be used to estimate the accuracy of the method. It was demonstrated that the horizontal component can be determine by 0.6 mm and the vertical components by 1.5-2 mm accuracy respectively. In this investigation the GPS baselines were derived by Bernese software using precise ephemeris.

The real mean phase centre offsets can be determined only in anechoic chamber where the full elevation and azimuth regime can be controlled. In the outdoor tests the satellite scenario does not cover the whole sky, therefore the mean values refer only to the actual observation sessions and the used elevation mask.

3. Calibration network in the GGRI

Based on the results of the feasibility measurement at the FOMI Satellite Geodetic Observatory, Penc, Hungary, a local calibration network was built at the roof of the GGRI (Figure 1.) Because the method is basically a geometric approach six benchmarks ware placed around a central one in the nodes of a hexagonal shape, which allows a simultaneous investigation of seven receivers. The size of the triangles is approximately 1.80 m. The benchmarks are oriented according to the magnetic north. It is reflected in their name (Figure 2.). We plan to install a permanent station in the central benchmark. In that case only six receivers may be investigated.

During the international OASYS project the receivers were calibrated in 2004 and 2005. The serial numbers of the used Trimble 4000SST receivers and antennas are given in Table 1.

Similarly to the field circumstances the GPSurvey software and broadcast ephemeris were used. This software allows the application of additional phase offsets and variation models, too. The estimated residual phase offsets of the L1 carrier can be found in Tables 2 and 3. Because of local network the atmospherics effects were significantly reduced by double differencing and the inner precision of differential offsets (σ) is overestimated.

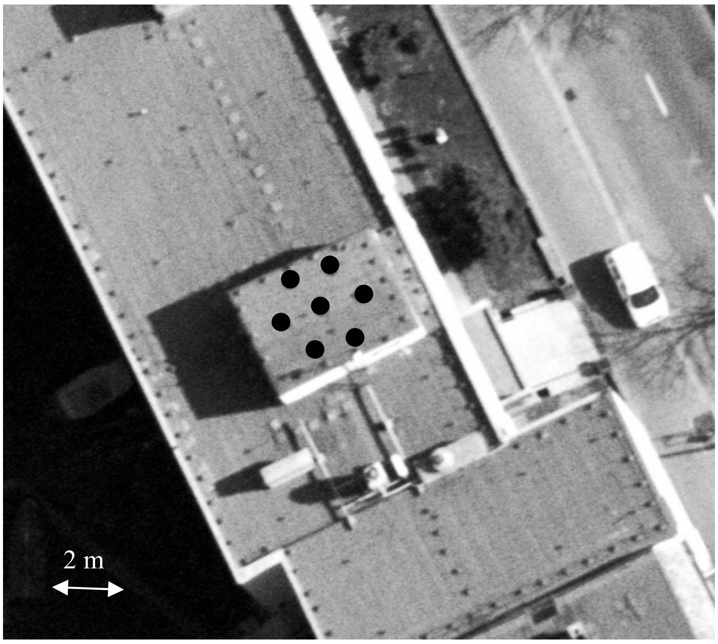

Figure 1: Calibration micro network in the GGRI

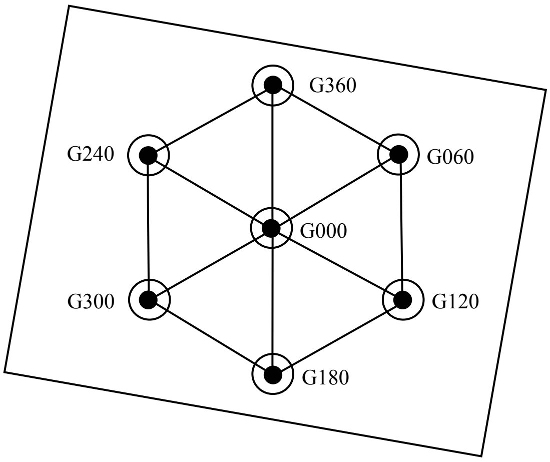

Figure 2: The triangles and the orientation of the network

	2004		2005	
no.	Rec.	Antenna	Rec.	Antenna
1	2818	2877	2818	2877
2	2812	3086	2812	3086
3	2821	3087	2821	3087
4	2814	3088	2814	3079
5	1740	6986	1740	6986
6	1055	6979	1055	6979

Table 1: Serial numbers of the used devices

no.	Phase centre offsets [mm]					
	North	σ	East	σ	Up	σ
1	0.4	0.0	-0.2	0.0	-0.1	0.1
2	0.2		0.2		-0.2	
3	-0.3		0.0		0.6	
4	-1.5		-0.2		0.4	
5	0.5		-0.2		-0.7	
6	0.8		0.4		0.1	

Table 2: Estimated residual offsets in 2004 (calibration network)

no.	Phase centre offsets [mm]					
	North	σ	East	σ	Up	σ
1	0.2	0.0	0.3	0.0	-0.3	0.1
2	0.3		-0.6		-1.0	
3	0.2		0.5		0.4	
4	0.0		0.5		0.7	
5	-0.9		-0.9		-0.1	
6	0.1		0.2		0.3	

Table 3: Estimated residual offsets in 2005 (calibration network)

Except one antenna (no.4, in 2004) the residual offsets are below 1 mm. This was the only antenna, which went wrong later, and has to be replaced by another one in 2005. Because not the same devices were calibrated the offsets given cannot be compared directly, however it can be concluded that the antennas are practically the same.

4. Application in deformation network

The transportation and the installation of the receivers between the micro calibration network in Sopron and the local deformation network in Dunafoldvar caused one day gap in the observation schedule. However the main drawback was the luck of precise centring and the height measurements of the antennas in the field.

The benchmarks were designed for levelling, gravimetry and horizontal investigations. Because the movement of a high bank of the river Danube was investigated, instead of heavy measuring pillars, 4-6 m deep boreholes were filled with reinforced concrete. Special metal half balls with central circles were cemented at their top. The problem was reduced by brand new hardwood heavy-duty telescopic tripods together with professional tribrachs and prism carrier supplied with antenna adapter. The centring was carried out with adjusted optical plumb lines and tube libels (Figure 3). The tripods were fixed to the ground by additional iron spikes screwed to the foot of the tripods (Figure 4). It is supposed that the receivers are centred and the antenna height is determined below 1 mm level.

The configuration of the local deformation network together with the direction of the full roving schema is given in Figure 5. The estimated residual phase offsets are given in Table 4 and 5. Comparing the results of the calibration and the field measurements the higher inner noise level of the field measurements can be recognised easily, especially in 2004. In spite of the centring problems the residual phase offsets were below 2 mm in 2004. In two cases the offsets were larger than 2 mm but less than 3 mm in 2005. The residual offsets show random behaviour, but the introduction of the phase offsets significantly reduced the discrepancies between the baselines components measured at two consecutive days. However the estimated offsets prove that the antenna characteristics are below 2 mm level.

Figure 3: Prism and antenna adapter
with optical plumb line

Figure 4: Iron spike for tripod fixing

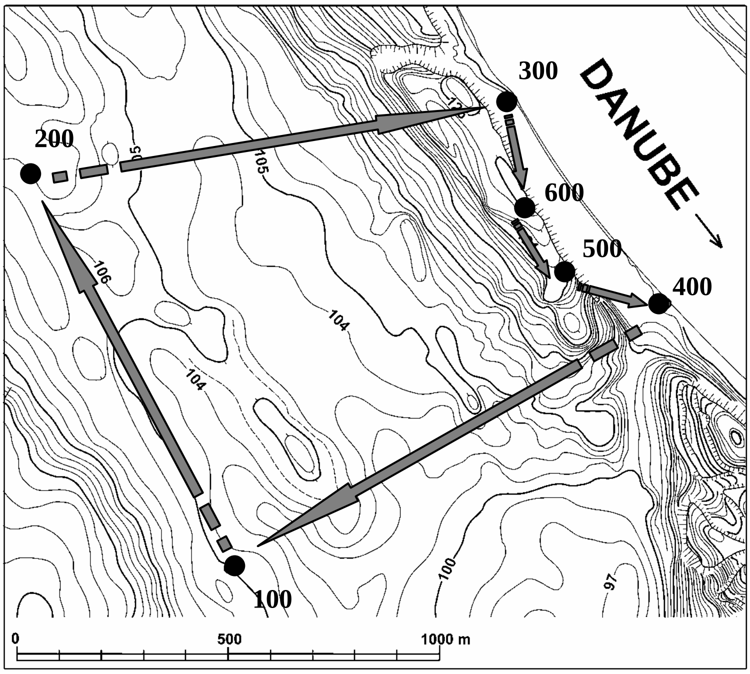

Figure 5: Local deformation network and the full roving schema

	Phase centre offsets [mm]					
no.	North	σ	East	σ	Up	σ
1	0.9	0.1	0.5	0.1	-0.9	0.7
2	1.0		0.1		-1.1	
3	0.2		-0.8		0.7	
4	-1.1		0.9		0.3	
5	-1.7		0.0		-0.4	
6	0.8		-0.6		1.3	

Table 3: Estimated residual offsets in 2004 (deformation network)

	Phase centre offsets [mm]					
no.	North	σ	East	σ	Up	σ
1	-0.2	0.0	-0.2	0.0	0.3	0.2
2	-0.8		0.1		-1.7	
3	-1.0		0.6		-1.2	
4	-0.4		0.2		2.9	
5	0.1		-0.3		-0.7	
6	2.4		-0.4		0.3	

Table 4: Estimated residual offsets in 2005 (Deformation network)

5. Conclusions

The relatively simple full roving observation strategy and micro calibration networks can be used regularly for the investigations of those GPS campaign receivers which are not used permanently. The change of the antenna characteristic and the usefulness of the nominal phase offset and variation models can be controlled.

This method estimates the actual main phase offsets or their residuals with respect to the nominal values therefore it can be used as an observation strategy. Because these values refer to the actual satellite scenario and elevation mask it may be advantageous in the case of local high precision deformation or engineering network as well.

The two consecutive days of observations significantly improve the redundancy. The comparison of two independent solutions can be used to qualify the results. The change of the mean phase centre offsets can be not only recognised, but removed from the solution as systematic bias.

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