

MULTIPATH EFFECT ANALYSIS ON SELECTED POINTS IN CONTROL NETWORK “WIÓRY”

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ABSTRACT

Geodetic networks are a basic constructions periodically measured on engineering constructions. They usually joint two objects: control objects and reference objects. Physical points and geodetic observations realize it. Moreover, the reference points and control points have to be checked for their stability and measuring technique (visibility between reference and control points for terrestrial observations, multipath effect for satellite observations). Multipath effect analysis on selected points in control network "Wióry" is presented in the paper.

1. INTRODUCTION

Terrestrial measurement techniques require optical visibility between the measurement points of the control network. Furthermore, in monitoring engineering facilities it is required that the reference points or benchmarks be founded beyond the area of influence of the monitored object. Moreover, reference points must be monitored in terms of their stability, which means that mutual visibility among the reference points is also indicated. In the case of optical measurements, atmospheric conditions are also of significance. Fog, rain or low temperatures can greatly impede or actually make impossible the conducting of measurements. Fluctuations in the states of the atmosphere influence the quality of optical observations and it is not always possible to take their effect into account in the form of appropriate adjustments. In the case of periodic measurement, when measurements taken in successive observation epochs are conducted subject to various weather conditions, their impact is systematic in character and can be erroneously interpreted as the movement of the point.

GPS satellite measurements introduce new properties into the monitoring of objects. The most important of these include:

1. The potential for continuous surveillance of the locations of the control network points in real-time or quasi-real-time in three dimensions (3D) with a sub-centimeter accuracy;
2. The possibility of synchronous surveillance of the examined object and of the reference object;
3. Significant freedom in stabilizing network points, limited only by the visibility of the satellite system (exposed horizon). The absence of the “vision” requirement among network points allows for stabilization of reference points beyond the zone of object influence at locations that are not subject to local surface movements (e.g. bedrock). Moreover, the reference points are “tied” by observations, which significantly facilitates analysis of their stability;
4. Ease of remote-control operation of the satellite receivers by way of radio or the Internet from any location;
5. Satellite measurements may be conducted regardless of atmospheric conditions and time of day. This opens up possibilities for continuous surveillance of the state of the object, which in many cases significantly improves the safety of exploitation.

2. OVERALL PRINCIPLES FOR SATELLITE MONITORING SYSTEMS

Numerous threats whose source may be environmental (floods, hurricanes, etc.) as well as manmade (e.g. mining) are the reason why engineering facilities (bridges, buildings, dams) are being fitted with satellite movement monitoring systems with increasing frequency. The structure of such a system should primarily take into account the possibility of procuring information about the state of the object in real-time.

Moreover:

Measurements should take place automatically and simultaneously on the examined object and on the reference object;

The system should have an open architecture allowing the supplementing of geometrical data with other data (terrestrial measurements);

- It should facilitate the archiving of observations;
- It should make possible the exchange of data with various geodesic movement analysis systems;
- It should provide the potential for registering parameters that allow the elimination of various systematic influences (e.g. registration of atmospheric conditions);
- It should have the possibility of transferring information to crisis management centers by electronic means;
- It should provide visualization of the geometric state of the object.

Such tools in conjunction with information from other sensors (i.e. inclinometers) may serve as parts of facility alarm systems.

However, the basic condition for the proper operation of monitoring systems is the guaranteeing of appropriate accuracy of the determined parameters.

In the case of satellite systems it is necessary to take into account external factors interfering with measurements such as the influence of the ionosphere and troposphere, and primarily the impact of secondary wave interference effects.

Satellite measurements of movements in monitoring systems are most often based on a kinematic solution. As is known, such a solution makes possible the determination of point coordinates for each measurement epoch. An unquestioned advantage of this algorithm is the possibility of receiving solutions (coordinates) at the moment of measurement (GPS-RTK). The downside is difficulty in estimating and eliminating systematic influences encumbering satellite measurements. In the case of relatively short vectors it may be stated that the dominant source of error in determined coordinates is the multipath effect. Obviously, this effect is caused by the reflection of waves from terrestrial obstructions (buildings) as well as terrain surfaces surrounding the GPS antenna. As a result of such reflections caused by differences in path length, the phase of the signal reaching the antenna is changed. The consequence of this change is the strengthening or weakening of the resultant signal amplitude. Both observations of the carrier wave phase and pseudo-range observations are obviously also encumbered by the impact of secondary wave interference. To a major extent, the size of this effect is dependent on the height of the satellite above the horizon as well as the characteristics of the GPS antenna (AXELRAD 1994, GÓRAL I SZEWCZYK, 2004).

Discovery of the multipath effect in GPS signal observations may take place using several methods. Analysis of the registered signal to noise ratio (SNR) parameter or satellite configurations that recur in a sidereal day cycle allow the identification of reflected signals in the registered observations (PARKINSON, 1996).

However, the elimination of the multipath influence from kinematic observations in real-time is troublesome. The impact of this effect may be minimized through an appropriate selection of measurement points as well as by using Choke Ring type antenna. Measurement experiments conducted on the Wióry dam demonstrate that in the case of precise movement measurement of engineering facilities observations using antennae safeguarded against the influence of the multipath effect are indicated.

3. MEASUREMENT EXPERIMENTS

Over the course of two-day observations of the Wióry dam, during the first day selected points were measured using geodetic antenna and receiver manufactured by Trimble (Microcentered L1/L2 antenna and Trimble 4700 receiver), while during the second day of measurements Leica 1200 receiver and Chock Ring antenna were used. Figure 3a, 3b, 4a, 4b presents specifications of the SNR parameter registered by both sets at point 101 (Satellite No. 13).

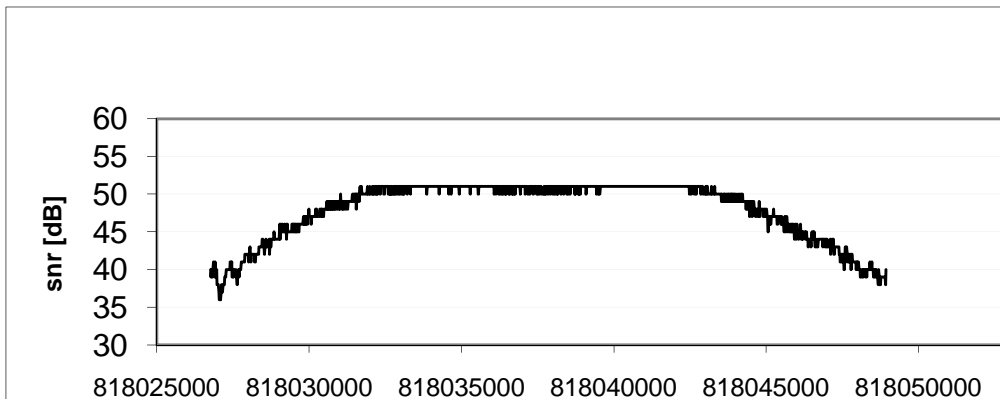


Fig. 3a. SNR L1 - Leica 1200, Choke Ring

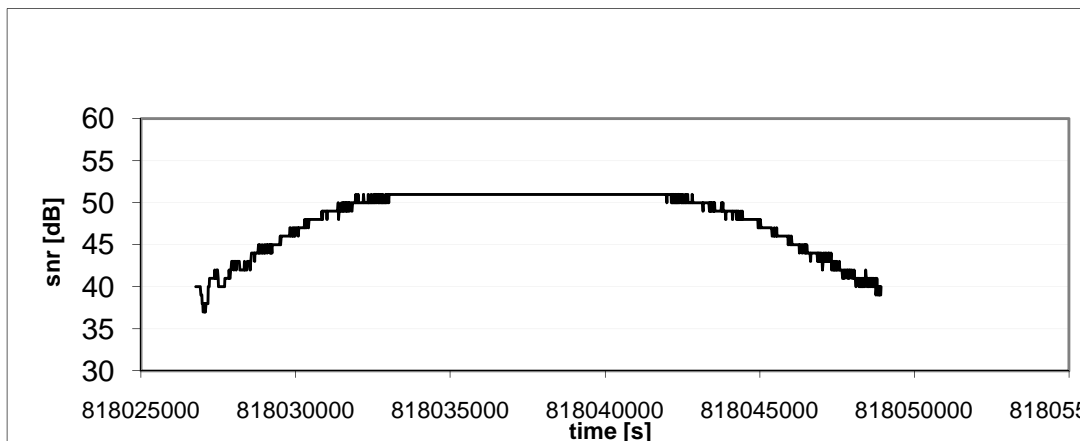


Fig. 3b. SNR L2 - Leica 1200, Choke Ring

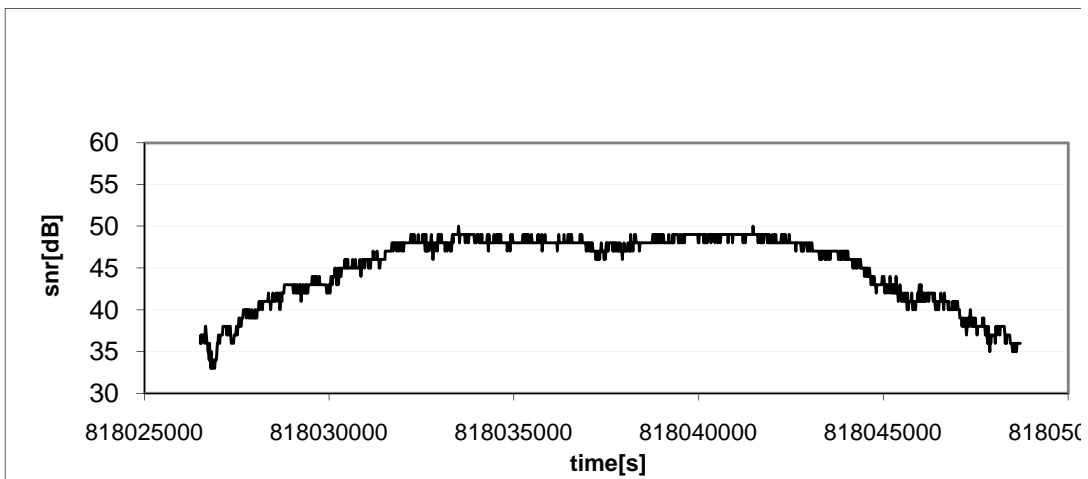


Fig. 4a. SNR L1 - Trimble 4700, MicroCentered

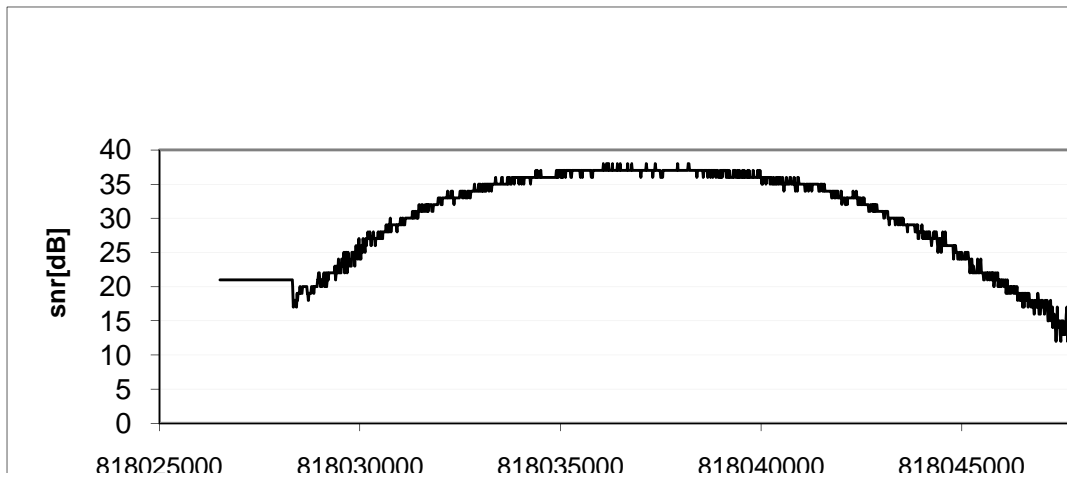


Fig. 4b. SNR L2 - Trimble 4700, MicroCentered

Worth noting is the fact that the average SNR value for the Trimble set amounted to 41.5 dB, while that for the Leica set was 43.5 dB. An even clearer difference in quality of received signal favoring the Leica 1200 set occurs for the L2 frequencies—the Trimble set returns an average SNR value of 22.5 dB while the Leica 1200 set gives 44 dB. A further analysis for the occurrence of the multipath effect was conducted on the basis of use of code and phase observations for the L1 and L2 frequencies. Using universally known formulas:

$$Mp_1 = p_1 - \frac{9592}{2392} \phi_1 + \frac{7200}{2392} \phi_2 + C_1$$

$$Mp_2 = p_2 - \frac{11858}{2392} \phi_1 + \frac{9529}{2392} \phi_2 + C_2$$

The error level caused by secondary wave interference on code observations was specified.

Figure 1a, 1b, 2a, 2b presents Mp1 and Mp2 parameters as determined for Satellite No. 13. In analyzing the received result it is possible to conclude that there is a significant improvement in the quality of observations (a decreased secondary wave interference effect) for the Leica 1200 and Choke Ring type antenna set as compared with the Trimble set (the 4700 receiver and MicroCentered antenna with screen).

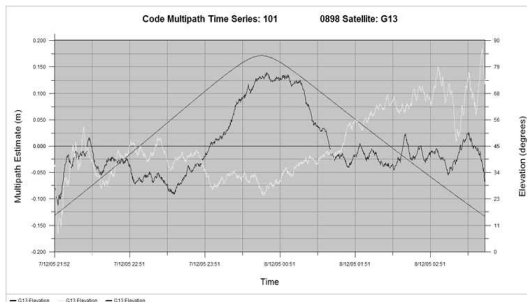


Fig. 1a. Mp1, Mp2 - Leica 1200, Choke Ring

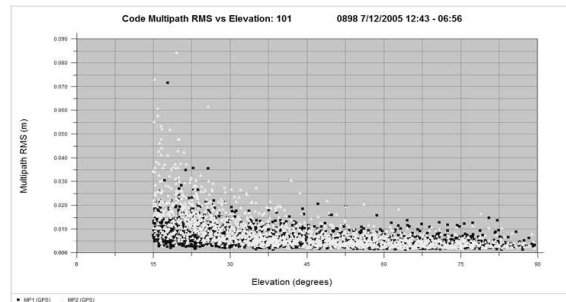


Fig. 1b. Multipath RMS - Leica 1200, Choke Ring

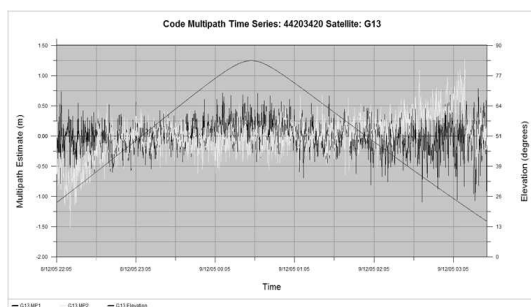


Fig. 2a. Mp1, Mp2 - Trimble 4700, Microcentered

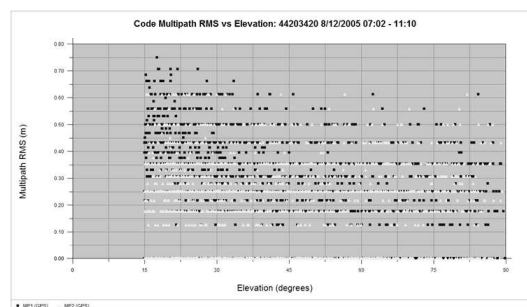


Fig. 2b. Multipath RMS - Trimble 4700, Microcentered

4. SUMMARY

The submitted paper presents a quality assessment of satellite observations conducted on selected points of the Wióry control network. The use of combinations of satellite code and phase observations for identifying the secondary wave interference effect demonstrated a significant decrease (threefold) in the influence of this effect on observations made using the Leica 1200 and Choke Ring type antenna set. Also worth noting is the difference in number of measured SNR parameters (for Satellite No. 13) for both measurement sets. The presented analysis shows that uniform equipment should be used during measurements. If not, the multipath effect will not be differentiated, even under similar observation conditions.

REFERENCES

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