RECURSIVE MULTIPATH EFFECT MITIGATION IN KINEMATIC SATELLITE OBSERVATIONS

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ABSTRACT

The satellite kinematic observations are currently used in many precise point positioning applications. Unfortunately the multipath is the limiting error source for high precision measurement. This is important problem in the real time GPS monitoring applications. The paper presents, recursive multipath effect mitigation in kinematic satellite observations, for one-day GPS observation series in geodetic control networks.

1. INTRODUCTION

The identification of the presence of multipath effects in observations may be done using several methods. It is a known fact that satellite configurations recur twice every twenty–four hour period. This property may be utilized to discover the multipath effect in the registered signal (Parkinson, 1996, Góral and Szewczyk, 2004). The frequency of this effect is proportional to the distance from reflective elements, as well as inversely proportional to the wavelength (of course, it is also a function of the height of the satellite above the horizon) (Leick, 1995). Another method used to identify this effect is analysis of the signal to noise ratio (SNR). The finding of the same periodic components in the SNR spectrum as well as in the spectrum of double difference residuals points to the presence of the multipath effect (AXELRAD, et al. 1994).. Methods of eliminating the multipath effect applying adaptive filters of finite impulse response have also made their appearance in literature. Such filters may be used to eliminate the multipath effect from pseudoranges as well as from phase measurements.

The elimination of the multipath effect in real–time or almost real–time is not easy, however. The influence of this effect may be minimized primarily through an appropriate selection of measurement points as well as through the use of Choke Ring type antennae(Seeber, 2000). Modern instruments also apply special multipath effect reduction algorithms.

2. THE CONCEPT MULTIPATH EFFECT MITIGATION FROM KINEMATIC OBSERVATIONS

Measurement experiments were planned and performed on a test station. Two methods of moving the antenna were planned: oscillation shifts in the 10 mm range (an amplitude of 5 mm) with a period of duration of sixty–six minutes and shifts in the 5 mm range (an amplitude of 2.5 mm) with a period of six hours (Szpunar, Walo 2007). The primary objective of the performed experiments was analysis of registered kinematic observations in terms of identifying shifts in the GPS antenna. In light of the small distance separating the mobile antenna from the base receiver, the basic undesirable influence to be limited was the effect of secondary wave interference. Due to the fact that real–time kinematic (RTK) observations were conducted (data on antenna positions were gathered in real–time), the reduction in the impact of the multipath effect should take place during measurement (also in real–time). On the basis of collected data, what was proposed is an iterative method of eliminating the multipath effect that may be applied for GPS–RTK observations.

The proposed method for eliminating the multipath effect is based on a spectral analysis of the registered signal (length of the measured vector). Such an analysis was conducted using the discrete Fourier transform (FFT algorithm).

Due to the fact that only low frequencies are of interest, the high ones were bypassed and the X–axis was described as the time scale. In line with expectations, it is clear that the largest amplitude of the signal is for the stria of a period closest to the model motion period. Bearing in mind that the discrete Fourier transform, being a correlation operation between the input series and individual harmonics, gives as its result an estimate of the frequency structure of input data, an amplitude of 1.4 mm for kinematic solutions and 1.9 mm for RTK solutions provides very good results (fig. 1 and fig. 2).

The structure of observation frequency is seen more clearly than in the previous case in analyzing the amplitude of GPS antenna motion in the 10 mm range. The highest striae correspond to motion in the 1.14 hour period and the 1.08 period, respectively, which corresponds to model antenna movement with an accuracy of several minutes. The motion amplitude is somewhat closer to the real one for kinematic solutions (3.9 mm) rather than for RTK observations (3.4 mm) (fig. 3 and fig. 4).

Antenna motion identified through the above procedure was subtracted from the registered observation in the subsequent part of the handling of the observation (signal). The resultant time series is mainly encumbered by secondary wave interference. A property (characteristic) of this disturbance—the repetition of this effect in each successive sidereal day—was used to identify the multipath effect.

The following graphs (Fig. 5) allow the observation of the specified effect identified by comparing vector determinants over two successive days.

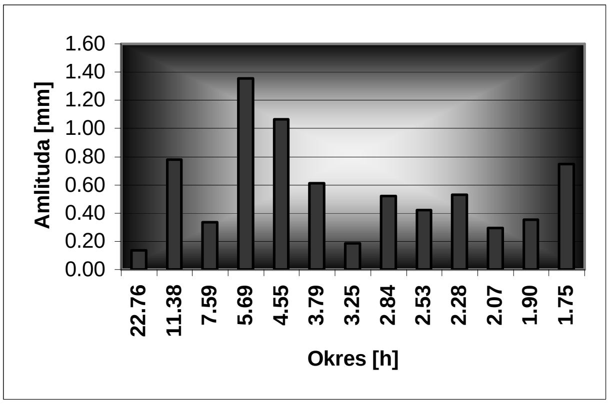

Fig. 1. Frequency structure for kinematic solution (5 mm)

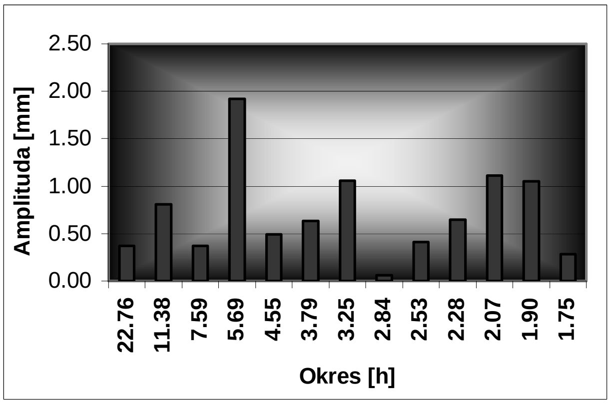

Fig. 2. Frequency structure for RTK solution (5 mm)

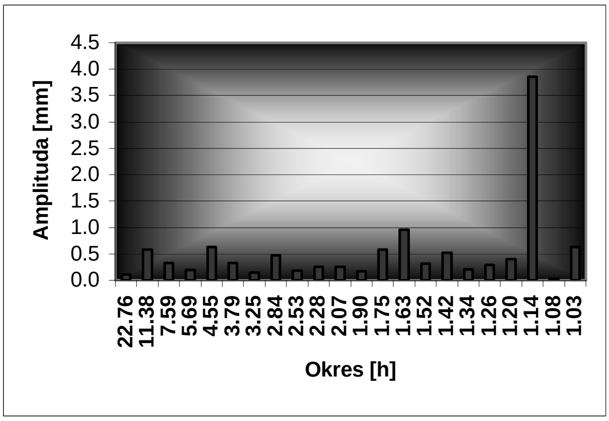

Fig. 3. Frequency structure for kinematic solution (10 mm)

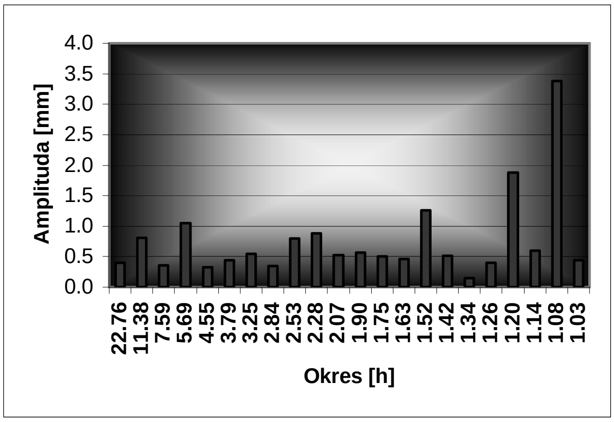

Fig. 4. Frequency structure for RTK solution (10 mm)

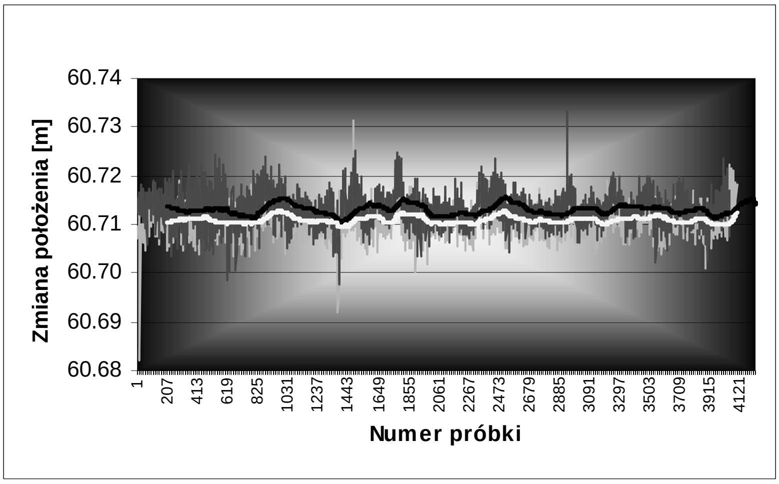

Fig. 5. Multipath effect in two successive days

The identified coefficient of correlation among the average motion values of a window length equal to 200 samples amounts to 0.9. Such a high correlation confirms the occurrence of the multipath effect in these observations. Varying the observations significantly reduces the multipath effect. The previously defined antenna motion model is reinstated in the successive step.

Unfortunately, this easy to use method has a significant fault involving the possibility of a change in the effect of the secondary interference waves resulting from a sudden change or a unique satellite configuration (this dictates the need for paying attention to satellite configuration, which means the number of satellites and the PDOP parameter). What should be done in such a case is the introduction of an adjustment into the multipath model using another method for identifying the effect or starting the identification from the beginning using the discussed method. At the same time, it should be remembered that the greater the accuracy in eliminating motion resulting from physical changes in the mutual positioning of points from each other, the better the interference effect can be seen. Thus, what can be proposed at this point is an iterative approach identifying and eliminating the "motion" of the points, identifying and eliminating the multipath effect, reinstating the "motion", and subsequently again determining the harmonic components present in the observed series.
Graphs 6 and 7 show the result of such an analysis. The amplitude caused by antenna shift decreased slightly (0.2 mm) (Figure No. 6), but the remaining strip also underwent shortening, where this is clearest in the case of the strip for the 1.63 hour period by 0.8 mm.

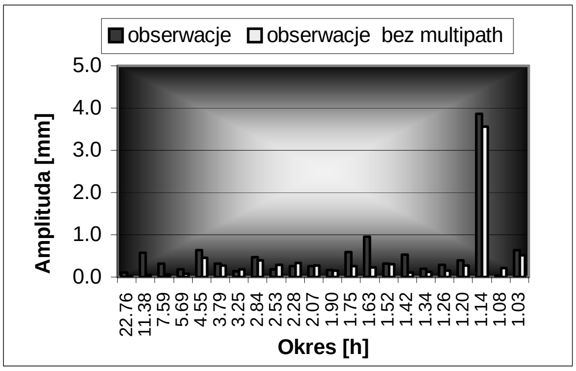

Fig. 6. Frequency without multipath effect (5 mm)

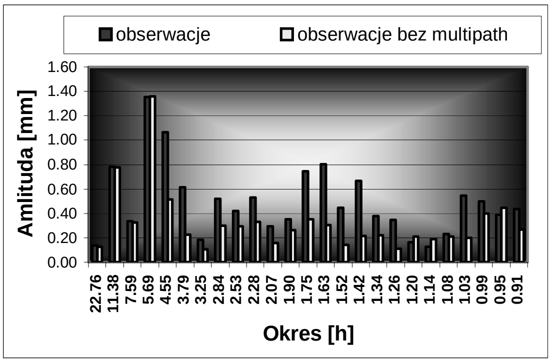

Fig. 7. Frequency without multipath effect (10 mm)

3. SUMMARY

The multipath effect significantly influences the accuracy of the determination of point locations. This is especially important in monitoring systems that often utilize kinematic technology (the software installed in the receiver usually does not eliminate this effect during the measurement).

Therefore, the method presented in this paper can find application in algorithms for handling the observations in monitoring systems (both in real–time and in post–processing). Use of the fast Fourier transform in the proposed method for reducing the multipath effect also makes possible the conducting of analysis serving the identification of object motion in an efficient way. Thus, the method may be useful in constructing models of the change in location of the measured points.

REFERENCES

1. **AXELRAD, P., C. COMP, P. MACDORAN (1994): Use of Signal to Noise Ratio for Multipath Error Correction in GPS Differential Phase Measurements: Metodology and Experimental Results, Proc. 7th International Technical Meeting of the Satellite Division of the Institute of Navigation Salt Lake City, Utah, 20-23 September, 655-666.**

2. **GÓRAL W., J. SZEWCZYK (2004): Zastosowanie technologii GPS w precyzyjnych pomiarach deformacji, Uczelniane Wydawnictwa Naukowo-Dydaktyczne AGH Kraków 2004.**

3. **LEICK, A. (1995) GPS Satelite Surveying, Second Edition, A Wiley-Interscience Publication 1995.**

4. **SEEBER, G(2000): Real-Time Satellite Positioning on the Centimeter Level in the 21st Century using Permanent Reference Stations; Paper at Nordic Summer School, Fevik, Norway.**

5. **SZPUNAR, R., J. WALO: Displacement monitoring of engineering objects using GPS-RTK technique. "EGU Symposium" REPORTS ON GEODESY No. 2 (83) Geodetic and Geodynamic Programmes of the CEI" Vienna, Austria 15-20 April 2007.**