UTILIZATION OF THE ASG–EUPOS SYSTEM NAWGEO SERVICE IN MONITORING DISPLACEMENT

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1. INTRODUCTION

Thanks to uniform coverage of the area of Poland by a network of GNSS reference stations, the ASG–EUPOS precision positioning satellite system has made possible the utilization of satellite technology for the highly–precise specification of position throughout the whole of the country. Moreover, by including the reference station network into the dual–function first order network, it has become possible to conduct spatial measurements applying a reference system that is consistent throughout the entire area of the country.

This paper presents an analysis of the possibility for utilizing network RTK adjustments made available in real time by the NAWGEO service for monitoring the displacement of points. The analysis was conducted in terms of frequency of movement of the examined point, the accuracy of the defining of the registered components of the point (in the N–S and E–W directions), and the reliability of motion identification of the monitored point as a function of point position measurement errors and the age of the RTK correction.

A leveling head equipped in a stepping motor, making possible the precision programming of motion frequency, amplitude, and direction (Figure No. 1), was used to estimate the monitoring accuracy of the displacement for motion modeling. Table No. 1 contains the motion model parameters that were used during the measurement experiments. The motion amplitude (1 cm) was selected so that the studied displacement values were on the level of the theoretical accuracy of point location determination as based on the NAWGEO service (the theoretical accuracy guaranteed by the service is ±0.03 m for the horizontal component). The Fast Fourier Transform (FFT) was used to analyze the frequency and amplitude of time series.

Fig. 1. Automatic motion system.

Table 1. Parameters of displacement model

Type of motion	harmonic
Amplitude	1 cm
Frequency	high (period: 16 sec)
	medium (period: 16.5 min)
	low (period: 70 min)
Motion azimuth	135°

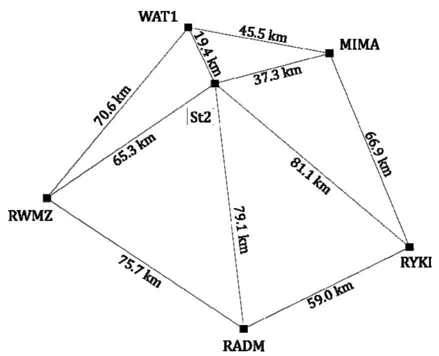

Fig. 2. Józefosław test field.

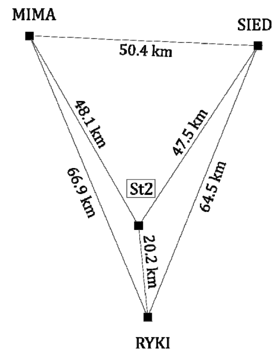

Fig. 3. Żelechów test field.

2. FIELD TESTS

Measurement experiments were conducted on two testing fields (Figures No. 2 and No. 3)—Józefosław and Żelechów. This is because the structure of the ASG–EUPOS network station on the day of the measurements (February 17, 2009) on the test field in Józefosław were not representative for the entire network (data from the JOZE and CBKA stations were not available). A Leica GX1230GG GPS receiver with a Leica AX1202CG antenna (10° mask angle) were used for the test. NMEA data were registered with a 1 second interval. The positions of the points were specified on the basis of the RTK MAC RTCM 3.1 adjustment received by way of the NTRIP protocol and GSM/GPRS packet transmission.

The first of the conducted measurement experiments (conducted at the Józefosław test field) was a measurement of the displacement of a point for which the motion model period amounted to 16 seconds at an amplitude of 1 cm and a measuring time of 34 minutes (2,048 determinations). Figure No. 4 presents the time series for the N–S (a) and E–W (b) motion components as well as the displacement of the point in the motion azimuth (c). Figure No. 4 (d) presents an enlarged fragment of the registered displacement. Analysis of the above graphs shows that although over a long time period the determined values are encumbered by errors (the long term trend was present over the entire time of measurement), the short–term cohesiveness of the data is large (clearly registered harmonic motion with an amplitude of 1 cm). It is possible to isolate two basic motion frequencies on the basis of the amplitude spectrum (Figure No. 5)—the S1 wave (a period of 34 minutes and an amplitude of 0.005 m) and S2 waves (a period of 16 seconds and an amplitude of 0.008 m). The modeled motion was unequivocally interpreted as the

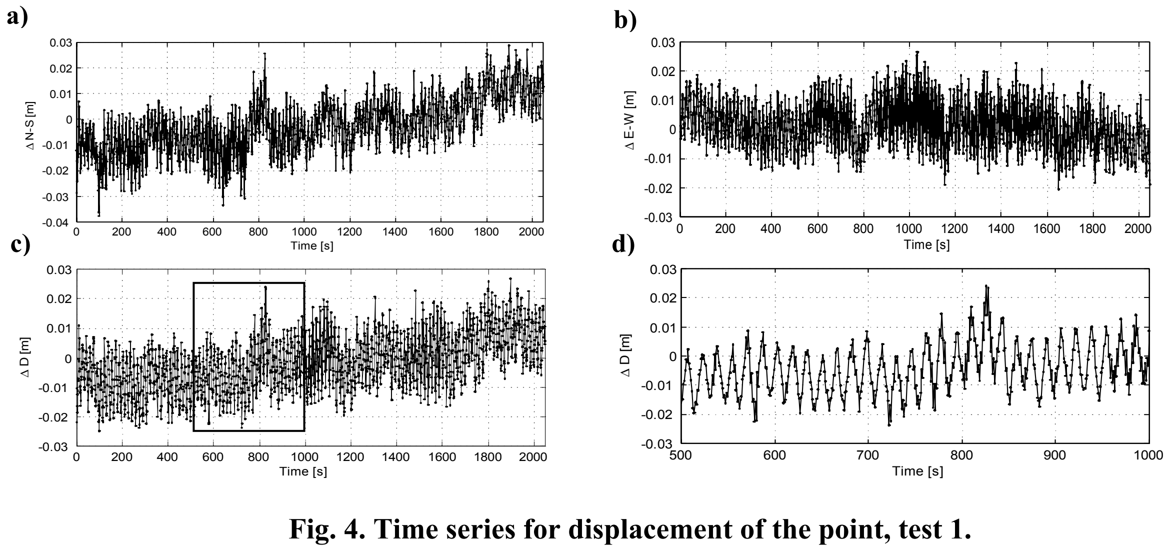

Fig. 4. Time series for displacement of the point, test 1.

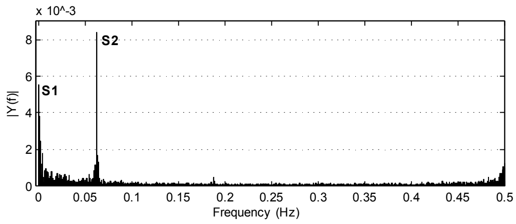

Fig. 5. Spectral analysis for displacement of the point in the motion azimuth, test 1.

S2 wave (the error in defining the amplitude amounts to 0.002 m). For its part, the S1 wave described the long–term coordinate trend that was present over the duration of the whole of the measurement.

A successive test measurement (the Żelechów test field) was conducted for point motion with a period of 16 minutes and 32 seconds and an amplitude of 1 cm. The duration of the measurement was 134 minutes (8,029 determinations). Figure No. 7 presents registered time series for the N–S and E–W components as well as for the displacement of the point in the motion azimuth. It is possible to define four main motion components on the basis of the spectral analysis (Figure No. 6): the S1 wave (a period of 136.5 minutes and an amplitude of 0.005 m), the S2 wave (a period of 45.5 minutes and an amplitude of 0.005 m), the S3 wave (a period of 27.3 minutes and an amplitude of 0.005 m), and the S4 wave (a period of 17.0 minutes and an amplitude of 0.006 m). Figure No. 8 presents the filtered point motion—waves S1 + S2 + S3 + S4. Spectral analysis does not make possible an unequivocal defining of point motion parameters (the motion model was defined as the S4 wave with a period error of 30 seconds and amplitude of 0.004 m). It was additionally discovered that the frequencies are linear combinations of the S4 (f S1 = 3 · f S2 = 5 · f S3 = 8 · f S4).

The reason behind the lack of unequivocal identification of point motion may be significant measurement errors in the determination of the component in the direction of the local meridian, which is also visible in the time series of the N–S component, where the harmonic motion is not visible (Figure No. 7). Spectral analysis conducted separately for

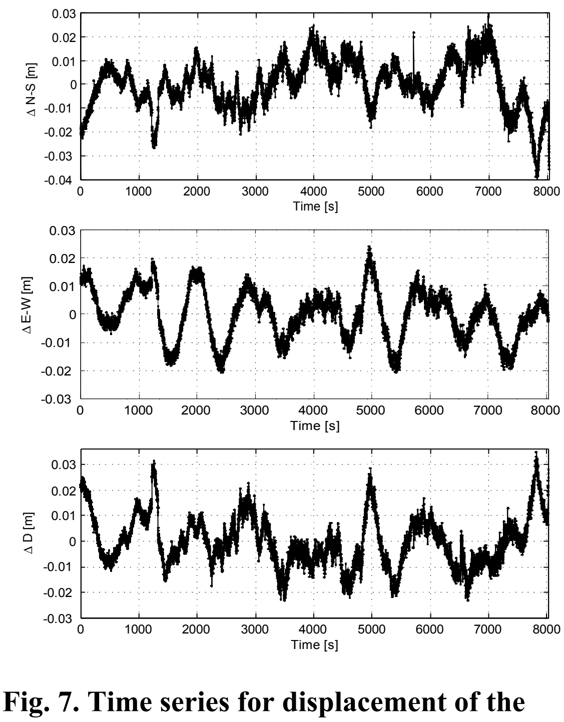

Fig. 7. Time series for displacement of the point, test 2.

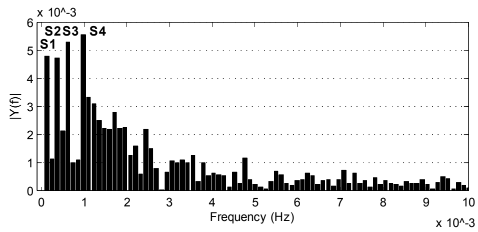

Fig 6. Spectral analysis , test 2

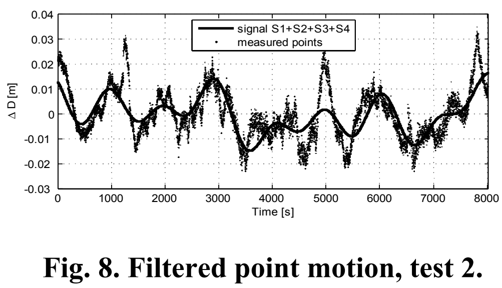

Fig. 8. Filtered point motion, test 2.

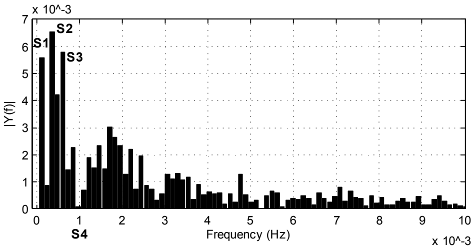

Fig. 9. Spectral analysis, N-S component.

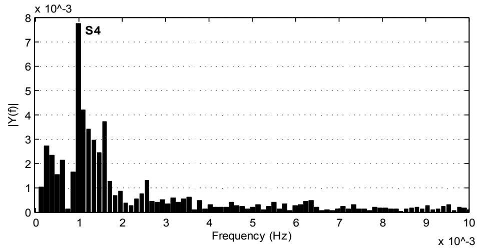

Fig. 10. Spectral analysis, E-W component.

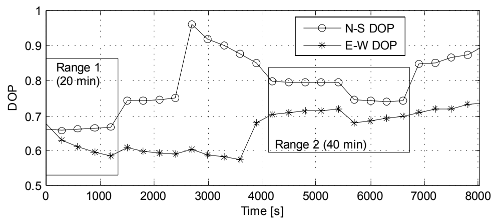

Fig. 11. Geometrical coefficients DOP.

Table 2. Determinations of S4 wave amplitude

Amplitude of S4 wave	Total	Interval 1	Interval 2
N-S	0.000 m	0.009 m	0.007 m
E-W	0.008 m	0.010 m	0.008 m
D	0.006 m	0.013 m	0.011 m

the N–S and E–W components (Figures No. 9 and No. 10) also confirm that in as much as the S4 wave, corresponding to the motion model (a period of 17.0 minutes and an amplitude of 0.008 m) was univocally defined in the direction of the first vertical, for the N–S component that wave is completely suppressed. The reason for such a disproportion in spectral analyses for the two directions is primarily the unfavourable geometry of the GNSS satellite measurement section for medium geographical latitudes (40°–60°). Figure No. 11 presents errors involving the geometry of the satellite constellation for the GPS system, which presents the N–S DOP and E–W DOP geometrical coefficients, respectively for components of the local meridian in the first vertical.

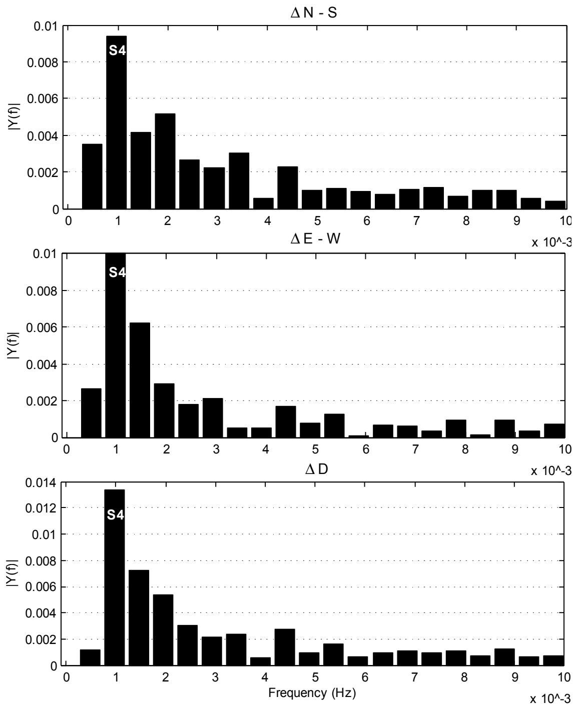

Fig. 12. Spectral analysis, interval 1.

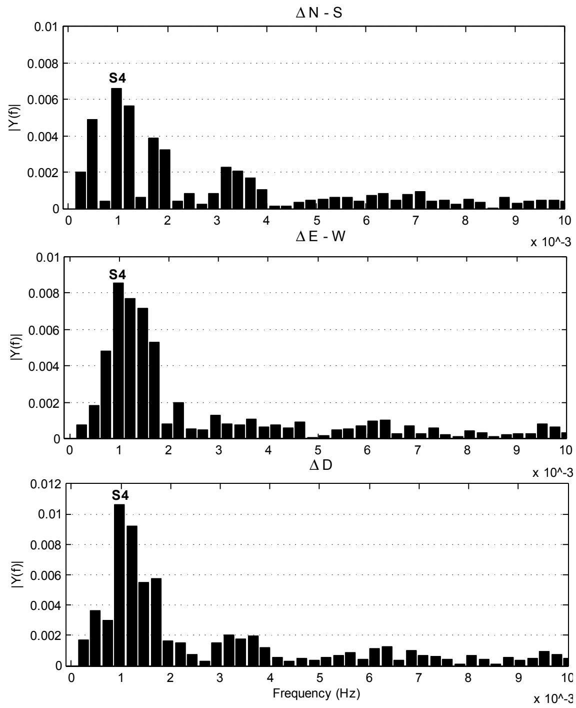

Fig. 13. Spectral analysis, interval 2.

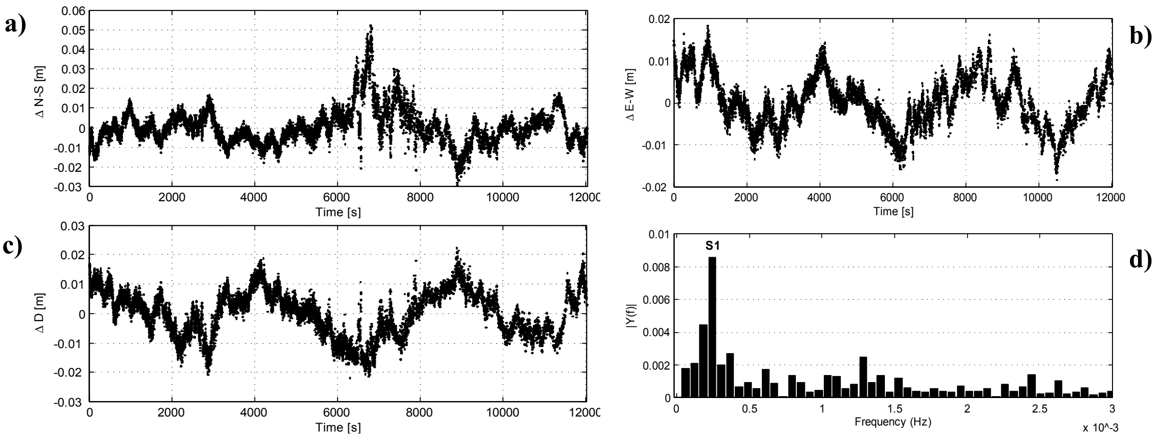

Fig. 14. Time series for displacement of the point (a,b,c) and spectral analysis (d), test 3.

In order to improve the certainty of determining the motion of the point on the basis of registered motion components, two time intervals were selected for analysis (interval 1 of a length of 20 minutes and interval 2 with a length of 40 minutes) for which the accuracy of determination of both components is on a similar level (see Figure No. 11). The spectral analysis for both intervals (Figures No. 12 and No. 13) for the N–S and E–W motion components as well as point motion in the azimuth demonstrated that for so selected intervals the motion model was precisely and unequivocally defined for each of the analyzed signals (see Table No. 2).
The last field test (Żelechów test field) was conducted for the motion model with a 69 minute 54 second period and an amplitude of 1 cm. The duration of the test amounted to 200 minutes (12,029 determinations). In analyzing the time series (Figure No. 14) for the motion components (a, b) as well as for the change in length at the motion azimuth (c), it should be stated that the short–term disruptions caused by measurement errors did not have a significant impact on the long–term motion of the point. The conducted spectral analysis for the point motion at the azimuth is defined by the basic S1 wave with a frequency of 68 minutes 18 seconds and an amplitude of 0.009 m (Figure No. 14d).

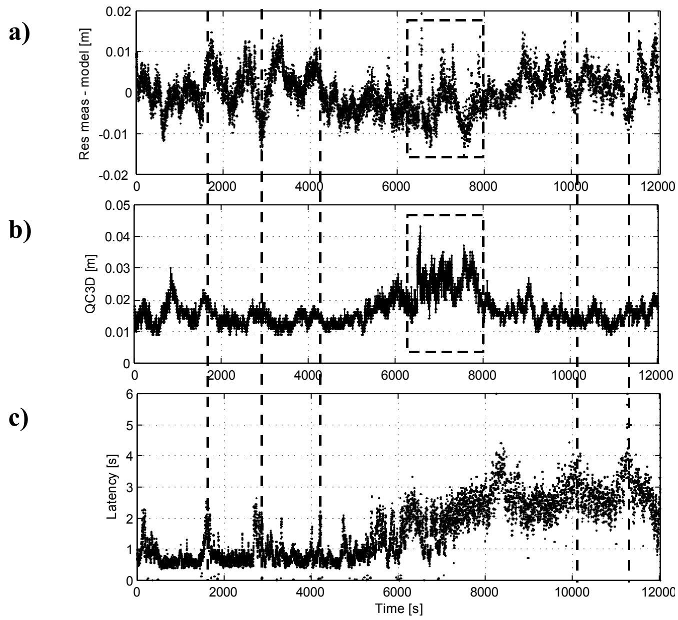

Fig. 15. Correlation between residual values (a), error in determining the position of the point (b) and the age of RTK corrections (c).

The graph (a) in Figure No. 15 presents the residual values for the registered point displacements in the motion azimuth following the subtraction of the S1 wave. In analyzing these values it is possible to notice periodic disturbances that may impede the interpretation of results. The remaining graphs in Figure No. 15 present the error in determining the position of the point (b) and the age of the RTK correction (c) as registered by the receiver. In analyzing the error change jumps determining the position of the point as well as the age of correction it is possible to notice a correlation between those values and the periodic disruptions for point displacement residuals (marked using a dotted line for individual changes and depicted as areas for the whole of the period where residual disruptions correlate with the jump in accuracy). Thus, such an analysis raises the reliability of determination of displacement identifying changes in coordinates that were caused by changes in the precision of determining the position of the point or changes in the age of correction.

3. CONCLUSIONS

The following conclusions may be drawn on the basis of the conducted field tests in monitoring the position of a point on the basis of Network RTK corrections as delivered by the NAWGEO service of the ASG–EUPOS network:

- Monitoring the positions of points on the basis of the NAWGEO service makes possible the identification of harmonic motion with an amplitude of 1 cm (the theoretical accuracy guaranteed by the NAWGEO service should not exceed ±0.03 m for the horizontal component).
- Determination of coordinates on the basis of network RTK technology is characterized by significant cohesion over the short time interval—harmonic motion with a period of 16 seconds was precisely identified.
- The N–S component of the point location is harder to determine than the E–W component. This is a result of the geometrical placement of the satellites (see the N–S DOP and E–W DOP coefficients), where in registering the components of point displacement, only those intervals should be taken into account for which the precision of the determination was on a similar level,
- Analysis of the age of the RTK correction as well as the accuracy of determination of position allow for the identification of time intervals for which determination of displacement should be treated with care.

REFERENCES

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