COMPARISON OF PSEUDOLITE OBSERVATION AND EDM SURVEY INFLUENCE ON GPS VECTOR ESTIMATION

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1. INTRODUCTION

In last few years GNSS positioning developed to the one of the most popular geodetic survey methods. Overlooking all of the benefits coming from GPS surveys, it is impossible to achieve required accuracy in not favorable environment. This is why it has to be augmented with additional techniques such as pseudolites (ground based GPS – like signal transmitters) or classic surveys. Basically survey from the pseudolite is an indirect measurement of distance. The same distance measured with EDM (Electronic Distance Meter) and processed along with GPS observations should successfully replace pseudolite data. In this paper authors show analysis of relevance of replacing pseudolite signal with EDM along with difficulties and benefits of such approach.

2. DIFFICULTIES WITH GPS SURVEYS AND ITS POSSIBLE SOLUTIONS

The benefits coming from GPS, such as fast and accurate survey, are well known. In the „open sky" environment GPS survey is self-sufficient and its accuracy is satisfying for most of geodetic surveys. The problem arise when the survey takes place in places with a lot of high obstacles (urban area, woods, open pit mines), where it is difficult to observe enough satellites (minimum 4) for positioning. Such a situation generates a data set with small number of observations with a lot of cycle slips. Using this kind of data gives poor accuracy or even makes solution impossible.

The solution lies in additional survey techniques used to augment GPS.

First method that can be used to augment GPS is use of pseudolites. Pseudolite is a generator and transmitter of GPS – like signal placed on the ground on the point with known coordinates.

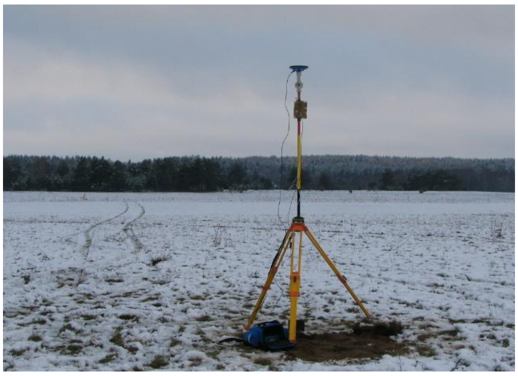

Fig. 1. Pseudolite during experiment.

Pseudolites works well when it comes to augment GPS surveys. It creates an additional observations that can be used in the vector processing.
Another possibility is so called „integrated survey" - integration of GPS and classical distance measurement.
There are two ways of attaching distances measured classically to GPS surveys. First one is widely used and relies on common adjustment of GPS vectors and classical observations. This kind of augmentation improves accuracy of network but does not allow to use GPS when there is less than 4 satellites visible.
The other way is to add measured distances to the GPS vector estimation process. This approach should successfully replace satellite or pseudolite signal.

3. THE EXPERIMENT

Experiment took place on the airfield in Gryźliny near Olsztyn. Test network consisted of two known reference points, nine unknown points and a pseudolite or EDM (Electronic Distance Meter) location.

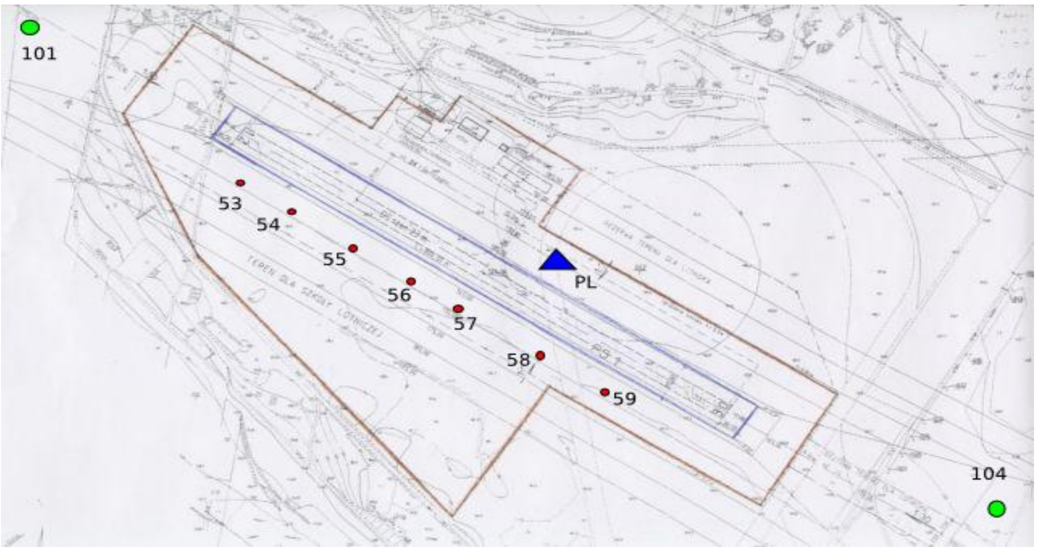

Fig. 2. Test area.

In Fig. (2) points 101 and 104 denote known reference points and PL stands for pseudolite location. Two Ashtech Z-xtreme receivers on points 101 and 104 as well as one additional over pseudolite antenna were used to obtain PL location. Since Ashtech receivers can not track pseudolite signal Novatel receiver were used on points 53 to 59. Additionally distances between pseudolite location and points 53-59 were measured using precise tachymeter Leica TC2002. The pseudolite antenna location was derived from three hour long observation session. The rest of measurement sessions took 45 minutes each.

4. ALGORITHM OF DATA PROCESSING

Linear model of double differenced observations was used to process measurement data.

$$\Phi_{AB}^{jk}(t) = \frac{1}{\Lambda}\rho_{AB}^{jk}(t) + N_{AB}^{jk}$$

Where term $\rho_{AB}^{jk}(t)$ **consists of four following elements:**

$$\rho_{AB}^{jk}(t) = \rho_B^k(t) - \rho_B^j(t) - \rho_A^k(t) - \rho_A^j(t)$$

For GPS measurements:

$$\rho_{k-s} = D_{k-s} + (\delta t^s - \delta t_k)c + \lambda N_{k-s} - \delta_{jon} + \delta_{trop} + \varepsilon$$

For pseudolite measurements:

$$\rho_{k-s} = D_{k-s} + (\delta t^s - \delta t_k)c + \lambda N_{k-s} + \delta_{trop} + \varepsilon$$

For classical distance measurements:

$$\rho_{k-s} = \lambda(D_{k-s} + k + \delta_{trop})$$

Where:

D – geometrical distance,

k – influence f earth curvature ($l^3/6R^2$),

δ_{trop} **– influence of tropospheric refraction (varies for satellites pseudolites and EDM),**

δ_{tjon} **– ionosphere refraction (only for GPS satellites),**

e – noise

Influence of tropospheric refraction on pseudolite and EDM measurements can be written as function of meteorological parameters:

$$N = 77.6\frac{P}{T} + 3.76 \cdot 10^5 \frac{e}{T^2}$$

$$gdzie:$$

$$e = RH \cdot \exp(-37.2465 + 0.2133 \cdot T - 2.569 \cdot e^{-4} \cdot T^2)$$

If the meteorological parameters are assumed to be the same for small measurement area, tropospheric refraction for single differenced observation can be written as:

$$\Delta\delta_{trop} = \left(77.6\frac{P}{T} + 3.73 \cdot 10^5 \frac{e}{T^2}\right) \cdot 10^6 \Delta\rho$$

where:

- **P** - **atmospherical pressure (1013 hPa),**
- **T** - **temperature in Kelvin (273.15 K),**
- **e** - **partial water vapour pressure,**
- $\Delta\rho$ - **difference in geometrical distances between two points and a pseudolite,**
- **RH** - **humidity (50%).**

The influence of tropospheric refraction during the measurement for single differenced observations was about 3 cm.

Fig. (3) presents scheme of differencing between two points (A, B), GPS satellite (sat) and a pseudolite or EDM (PL).

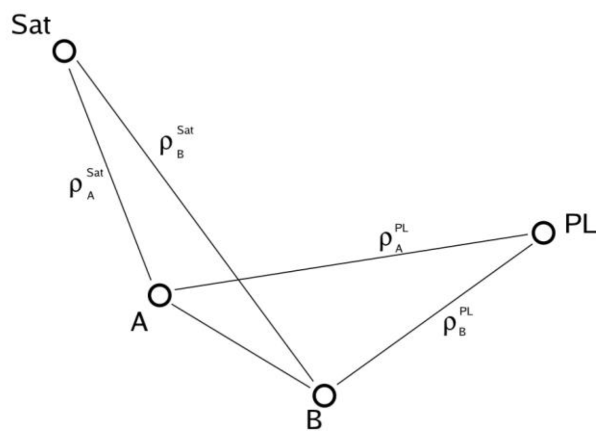

Fig. 3. Double differences forming scheme.

For the adjustment of GPS vector double differenced data algorithm was used after cycle slips detection and correction.

Authors own software was used for data processing. Software PLite was developed in C/C++ under Linux Fedora Core 6 with gcc 4.0.2 compiler and GPSTk library. Network adjustment was performed with SNAP (Survey Network Adjustment Program) from Land Information New Zealand.
Following steps were taken to compare results from GPS, GPS+PL and GPS+EDM measurements:

1. **Calculation of PL antenna coordinates.**

2. Calculation of coordinates of points 53-59 using Ashtech's GPPS software. These coordinates were used as „true coordinates" since all of the errors obtained from adjustment were less then 1 cm.
3. Simulation of difficult survey environment by setting elevation mask to 40 degrees. In such conditions it was impossible to solve vector 53-54 because of insufficient observations. Differences between „true coordinates" and calculated coordinates (from GPS only and GPPS) were about 40 cm horizontal and 30 cm vertical.
4. Calculations repeated with pseudolite.
5. Calculations repeated with EDM measurement instead of pseudolite. Calculations were made with modified PLite software. While forming single differences, every time the program found data from pseudolite (prn 12) it was replaced with distance measured with EDM.

Fig. (4) shows double differenced data from GPS+PL (red line) and GPS+EDM (green line) measurement. It can be seen that both lines are almost the same. The differences are shown on fig. (5).

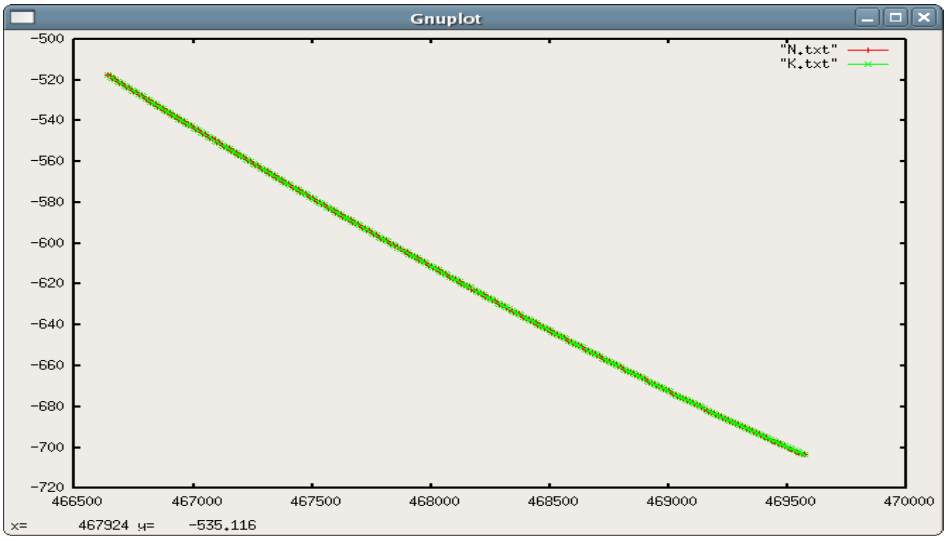

Fig. 4. Double differences from
GPS+PL(red) and GPS+EDM (green).

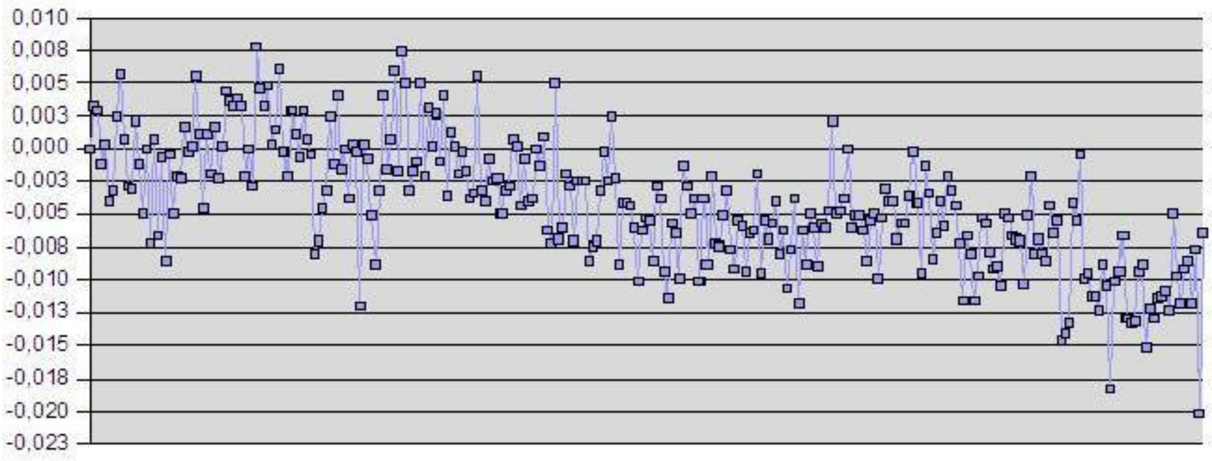

Fig. 5. Differences between double differences from GPS+PL and GPS+EDM in meters.

In every simulated survey condition, no matter how many satellites were visible in both cases vector coordinates are the same.
Fig (6) presents differences between B, L and H coordinates in meters from undisturbed GPS survey and GPS+PL, GPS+EDM in difficult survey environment.

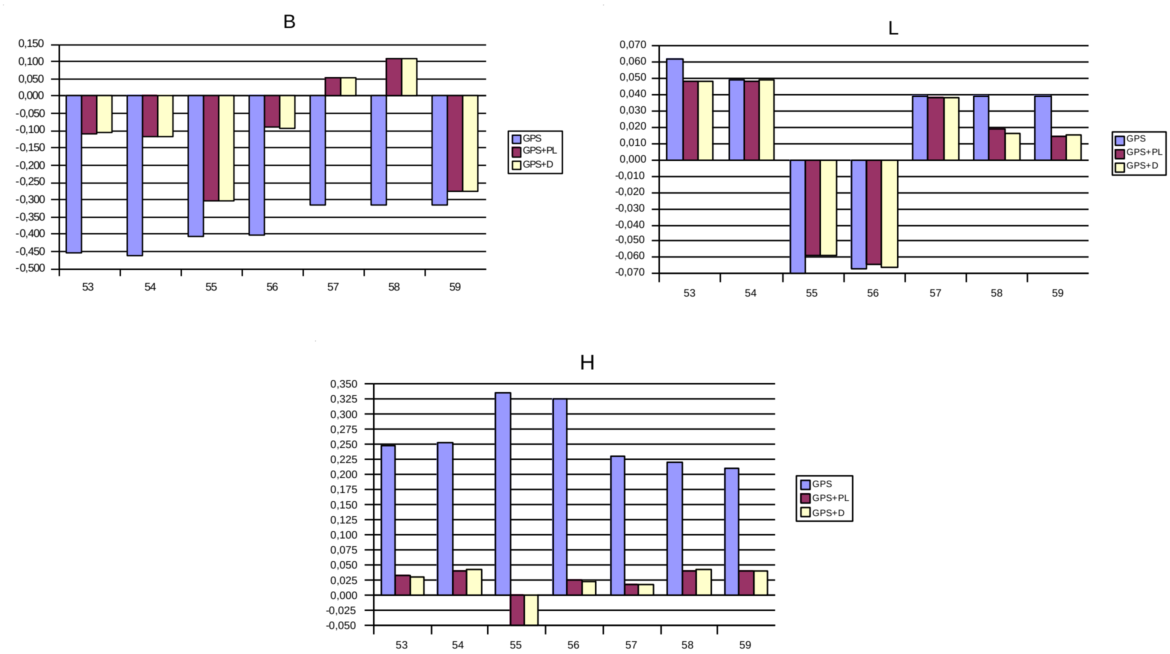

Fig. 6. Differences between B, L and H coordinates in meters.

5. CONCLUSIONS

EDM can successfully augment GPS surveys in difficult survey environment. It can work as well as pseudolite. Differences between PL and EDM in GPS vector determination are shown in Table 1.

Table 1.

PL	*EDM*
• multiple points at a time • allmost unlimited interval • can be used in kinematic surveys • need of simulationeus survey • high price limited usability	• one point at a time • interval limited by EDM • can be used only in static surveys • ability to survey in different time than GPS survey • cheap – use of standard surveyors equipment • high accuracy of distance measurement