PRELIMINARY TEST OF GPS+PL POSITIONING ALGORITHM FOR ENGEENERING GEODESY.

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Abstract: The following paper presents preliminary solution algorithm of GPS + pseudolite positioning. Position was obtained from double differenced single frequency phase data. Ambiguity resolution was based on GPS satellite positions and coordinates of the receiver computed from GPS only solution.

1. Introduction

In the last few years the Global Positioning System (GPS) has become very popular in geodetic surveys. The system gained recognition because it enables faster and cheaper surveys with satisfactory accuracy for any purposes.

Despite many benefits of the GPS system, it has certain limitations in engineering geodesy. While horizontal accuracy is sufficient, vertical accuracy is often too weak. Another major disadvantage of GPS surveys is the fact that any obstructions, like buildings or trees, affect accuracy of surveying. Therefore, there is the need to find an a enhancing method for GPS positioning that would provide accurate results without the need to make additional surveys.

GPS positioning system augmented with pseudolite may offer solution to the above-mentioned problems. It can eliminate difficulties regarding poor satellite visibility and the need of making additional surveys by means of traditional methods.

2. Pseudolite

Pseudolite (from “pseudo-satellite”) is a GPS-like signal generator and transmitter placed on the ground location with known coordinates. The PL signal is transmited on GPS L1 frequency (1575.42 Mhz). IntegriNautics IN200D pseudolite with two NovAtell receivers were used in this experiment.

Each GPS satellite broadcasts its L1 signal with approximately +40 dBm of power. After traveling 20 000 km the signal is much weaker; about -130 dBm. Maximum pseudolite output power is approximately 0 dBm. Since the receivers are designed to track weak GPS satellite signal, much stronger pseudolite signal can jam it. To prevent jamming it is important that proper attenuation be provided between transmitter and receiver. It can be done by lowering output power of the pseudolite or by pulsing of the signal [1].

In IN200D pulsing signal was used with RTCM (variable) pulse delay. Both receivers were successfully tracking GPS signal as well as PL signal during whole experiment.

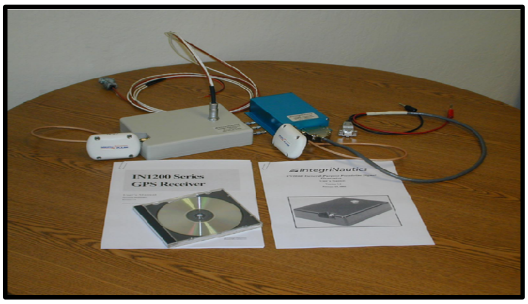

Figure 1: IntefgriNautics IN200D Pseudolite

To obtain the pseudolite position, a GPS antenna with Ashtech ZXtreme was placed on the holder above the PL antenna.

3. The experiment

The experiment was performed on the airfield in Gryzliny near Olsztyn, Poland. The test network consisted of two known reference points, two unknown points and the pseudolite location.

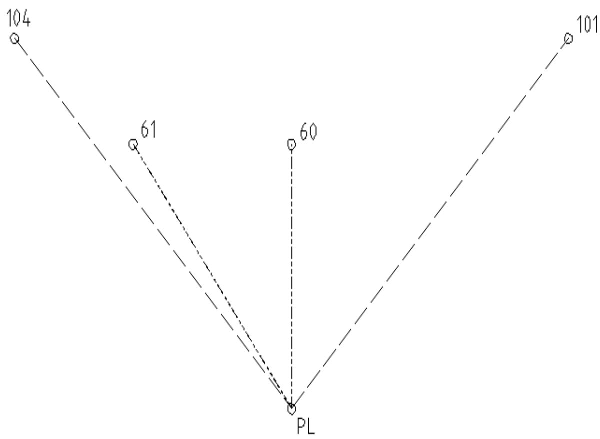

Figure 2: Test Network

Points 101 and 104 were known stations used to obtain pseudolite position. Ashtech Zxtreme receivers were used on these points and over pseudolite antenna. Points 60 and 61 were unknown points with NovAtell (marked with red circle in **Figure 3**.) receivers tracking GPS and PL signal. PL in **Figure 2**. denotes pseudolite location.

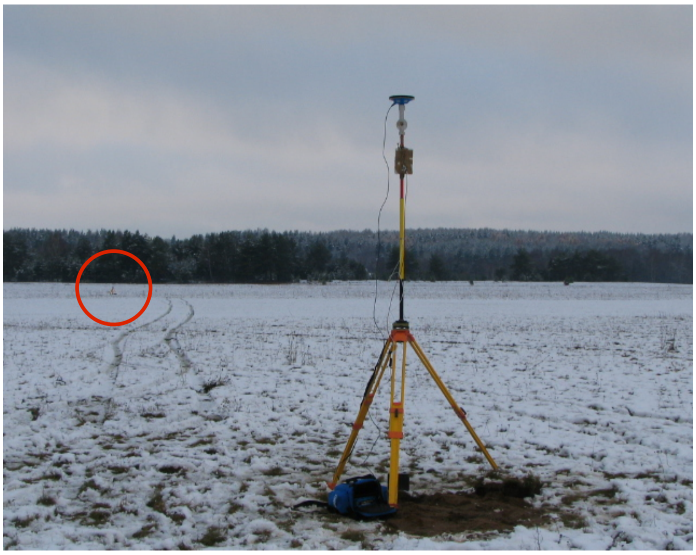

Figure 3: Psuedolite During Experiment

Pseudolite position measurement was made in a single three-hour session. Other receivers were tracking PL signal in a single 45-minute session.

4. Algorithm

For the purpose of the experiment, a simplified approach to ambiguity and cycle slips resolution was used. Good visibility of horizon allowed calculating the receiver position with 1~2 cm accuracy. Ambiguity was resolved using the GPS satellites positions and known station's coordinates. Subsequently, obstructions were added to simulate difficult survey environment.

Since PL signal is traveling different way through troposphere then GPS satellite signal, different then standard tropospheric correction must be calculated.

The refractivity for pseudolite signal can be described as function of meteorlogical parameters[2]:

$$N = 77.6\frac{P}{T} + 3.73 \cdot 10^5 \frac{e}{T^2}$$

$$with:$$

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

Because of the short baseline, we can assume that atmospheric parameters are the same, the tropospheric delay for single-differenced between receivers observable can be represented as:

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

where:

P - air pressure in hectopascals (1013 hPa)
T - temperature in degrees Kelvin (273.15 K)
e - partial pressure of water vapor

$\Delta\rho$ - difference in geometric ranges between pseudolite transmitter and two receivers
RH - relative humidity (50%)
The environment tropospheric correction for single-differences was about 27 mm.

After adding tropospheric correction to between receivers single-differences double-differences were formed.

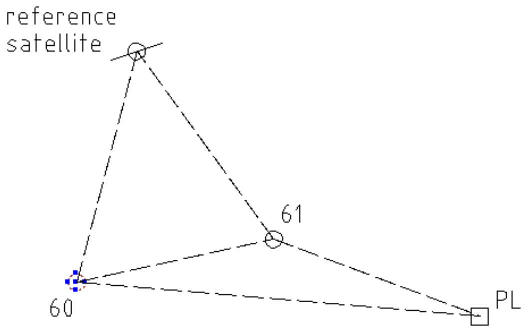

Figure 4: Double Differences Forming Scheme

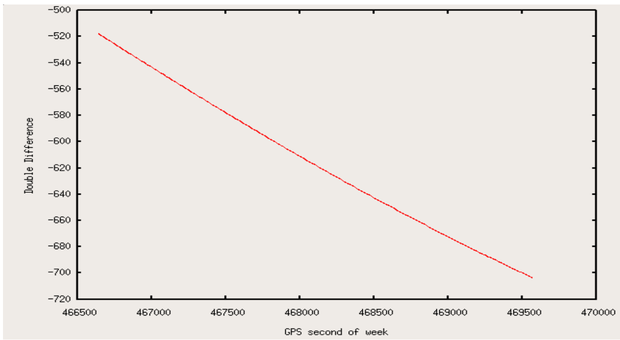

Figure 5: Double Differences Between PL and Reference Satellite

All of the calculations were made using software written by the authors of this paper in C++ programming language under Linux Fedora Core 4, and with use of open source library Gpstk.

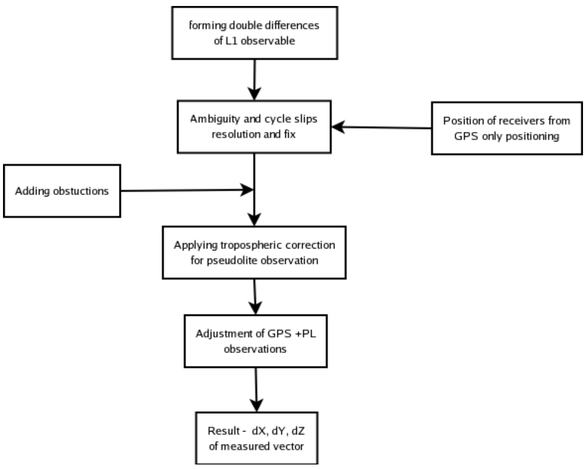

Figure 6: Calculation Agorithm

5. Experiment results

GPS only with “open” sky solution gave following vector coordinates:

ΔX = - 6,3720 m with sigma x = 0,0026 m
ΔY = - 95,5293 m with sigma y = 0,0019 m
ΔZ = 28,7543 m with sigma z = 0,0047 m
and 99,9663m length of vector.

Coordinates from these solution were used to determine the ambiguity and cycle slips.

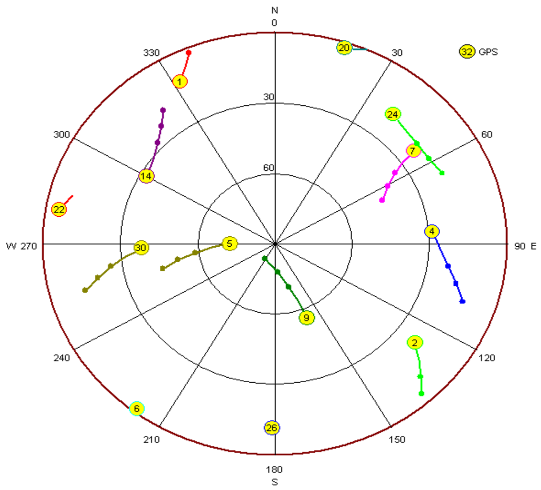

Figure 7: "Open" Sky View

Additional signal from pseudolite has changed vector coordinates less then 1 mm.

After adding obstructions wich resulted in removing satellites 4, 5, 7, 20, 24 and 26 from the view, vector coordinates changed as follows:

ΔX = - 6,3751 m with sigma x = 0,0031 m
ΔY = - 95,5440 m with sigma y = 0,0015 m
ΔZ = 28,7717 m with sigma z = 0,0030 m
and 99,9893 m length of vector.

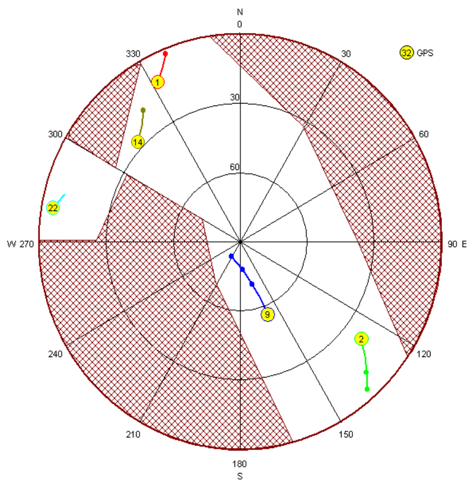

Figure 8: Obstructed Sky View

Additional observations from pseudolite gave:

ΔX = - 6.3620 m with sigma x = 0,0021 m
ΔY = - 95,5379 m with sigma y = 0,0012 m
ΔZ = 28,7491 m with sigma z = 0,0014 m
and 99,9805 m length of vector.

Differences between GPS only solution and GPS+PL solution with "open" sky and with obstructed horizont are presented on Figure 9.

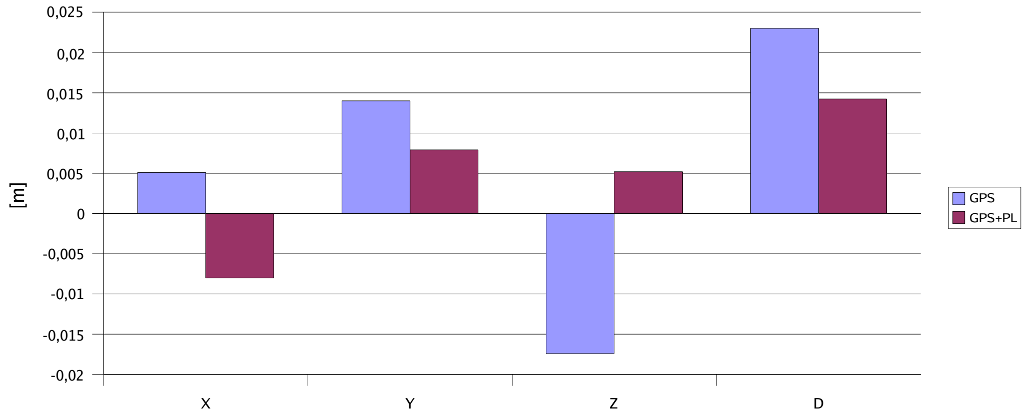

Figure 9: Differences between vector length from GPS and GPS+PL

6. Conclusions

Since GPS positioning in favorable survey environment (no obstructions, many high elevation satellites visible) results in a sufficient number of smooth observations, additional pseudolite does not affect the result significantly. It is worth noting, however, that adding the PL signal when only few satellites are visible can enhance the solution.

7. References

[1] Cobb S., 1997. GPS pseudolites: theory, design and applications. A disseration submitted to the departament of aeronautics and astronautics and the committee on graduate studies of Stanford University in partial fullfillment of the requirements for the degree of doctor of philosophy, SUDAAR 707.

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[4] Rzepecka Z., Wasilewski A., Cellmer S., 2005, Integration of GPS and Pseudolites – Studies of Effect on Vector Determination, Reports on Geodesy, No 3(74), Warszsawa.