1. MOTIVATION

For optimal estimation of the unknown parameters in the positioning model both functional and stochastic models need to be carefully defined. Whilst the GNSS functional model was the subject of detailed research conducted over the past twenty years and it is well documented for different types of positioning applications, the issue of proper definition of stochastic model has been undertaken in recent few years and is still an open research problem. It is a common approach to assume a constant accuracy of GNSS measurements and neglecting cross and time correlation between them. This is reflected in the design of variance-covariance matrix which is usually diagonal matrix with a priori defined entries. Especially with respect to instantaneous applications which are characterized by weakening model strength, unrealistic or simplified definition of stochastic properties of observations causes that the performance of ambiguity resolution as well as the positioning accuracy shows that the utilizing the individual empirical stochastic model of observations increase the imprecision of instantaneous performance.

2. EXPERIMENT DESIGN

Stochastic properties of observations were determined for GPS receiver Leica GX1200G (S. No. 466950) based on: GPS Signal generator observations: Spirent GNSS Generator Zero-baseline observations: WUT1 stations located on the roof of Warsaw University of Technology Main Building; reference receiver - Leica GX1200G (S. No. 466950)

The data used:
Observations: GPS - L1 / L2 / C1 / F2

Compare models: #1 Standard model: \( \alpha \) = 0.038 m, \( \sigma_n = 0.70 \) m, \( \sigma_x = 0 \)
#2 Standard evaluation model: \( \alpha \) = 0.035 m, \( \sigma_n = 0.035 \) m, \( \sigma_x = 0 \)
#3 Combined elevation model: \( \alpha \) = 0.2 m, \( \sigma_n = 0 \)
#4 Combined elevation + cross-correlation model: \( \alpha \) = 0.2 m, \( \sigma_n = 0 \), \( \sigma_x = 0 \)

Positioning model:
Observations: zero-baseline
Functional model: Geometry-Based Double-Differenced
Stochastic model: Ionosphere-Fixed Troposphere Fixed
Ambiguity resolution: one-epoch resolution
Stochastic model: Ionosphere-Fixed Troposphere Fixed

3. METHODOLOGY

GPS receiver testing procedure consists of two tests:
1. Signal generator test: the same 24-hours observations were generated two times; based on that double-differenced code and carrier-phase residuals for zero-baseline were calculated; the residuals were used to determine constant part of measurement noise and cross-correlations of GPS-observations;
2. Zero-baseline test: the same type of GPS receivers were connected to the one antenna; based on that the 24-hours of double-differenced code and carrier-phase residuals for zero-baseline were calculated; the residuals were used to determine elevation-dependent part of measurement noise

\[ P = (F + \delta F) \cdot \delta \cdot + (F - \delta F) \cdot \delta x \]
\[ L = (E + \delta E) \cdot \delta \cdot + (E - \delta E) \cdot \delta x \]

Double-differenced code and carrier-phase observation residuals for a zero-baseline:

\[ \text{Var}(L^2) = \text{Var}(P^2) = 2 \cdot \text{Var}(L \cdot P) \]

4. TEST RESULTS

Signal generator test:
Zero-baseline test:

5. STOCHASTIC PROPERTIES

Stochastic model:
Individual combined model = elevation dependency + constant part

6. STOCHASTIC MODEL & POSITIONING PERFORMANCE

Positioning performance:

7. CONCLUSIONS

- The stochastic modelling of individual components of the variance-covariance matrix of observation noise allows for increased reliability of solution in both the ambiguity resolution and solution accuracy aspects;
- The use of individual determined models of observations noise and cross-correlation is especially important for kinematic application based on a single observational epoch where instantaneous stochastic properties of observations could be significantly differ from parameters of standard stochastic model;
- The individual combined model (elevation dependency + constant part) based on noise test: signal generator test and zero-baseline test shows good capability to model the variance as well as the cross-correlation;
- Presented approach of stochastic modelling of GNSS observations can be important part in a comprehensive calibration procedure of GNSS equipment.

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