APARATURA
BADAWCZA I DYDAKTYCZNA

Estimation differential code biases (DCB) P1-C1 using GLONASS data in flight experiment on the Dęblin aerodrome (01.06.2010)

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Keywords: GLONASS, DCB, CODE, least square estimation

ABSTRACT:

The studies results of instrumental biases DCB (Differential Code Biases) P1-C1 and their accuracy are presented in this paper. The research test was realized using GLONASS kinematic data (e.g. code observations P1 and C1) from dual-frequency Topcon Hiper Pro receiver. The Topcon Hiper Pro receiver was installed in Cessna 172 plane during flight experiment on the Dęblin military aerodrome on 1st June 2010. The instrumental biases DCB P1-C1 were estimated in SciTEC Toolbox software package in post-processing mode. The instrumental biases DCB P1-C1 are applied for correction the values of receiver and satellite clock bias in adjustment processing of GLONASS observations. In this article, the instrumental biases DCB P1-C1 for satellites are also compared with CODE products. The mean difference of DCB P1-C1 bias for satellites between SciTEC and CODE solution amounts to 0.136 ns, whereas the RMS bias equals to 3.783 ns.

Wyznaczenie opóźnień sprzętowych DCB P1-C1 z użyciem obserwacji GLONASS w eksperymencie lotniczym na lotnisku w Dęblinie (01.06.2010)

Słowa kluczowe: GLONASS, DCB, CODE, metoda najmniejszych kwadratów

STRESZCZENIE:

W artykule zaprezentowano rezultaty badań dotyczące wyznaczenia opóźnień sprzętowych DCB P1-C1 oraz ich dokładności. Test badawczy został zrealizowany z użyciem obserwacji kinematycznych GLONASS (P1 i C1) z dwuczęstotliwościowego odbiornika Topcon Hiper Pro. Odbiornik Topcon Hiper Pro został zainstalowany w samolocie Cessna 172 podczas eksperymentu lotniczego na lotnisku w Dęblinie w dniu 01.06.2010. Opóźnienia sprzętowe DCB P1-C1 zostały wyznaczone w programie SciTEC Toolbox w trybie post-processingu. Opóźnienia sprzętowe DCB P1-C1 są stosowane w opracowaniu obserwacji GLONASS do korekcji wartości poprawki chodu zegara odbiornika i satelity. W artykule dokonano również porównania opóźnień sprzętowych dla satelitów DCB P1-C1 z produktami CODE. Średnia różnica wartości opóźnień sprzętowych dla satelitów DCB P1-C1 pomiędzy rozwiązaniem SciTEC i CODE wynosi 0,136 ns, a błąd RMS jest równy 3,783 ns.

1. INTRODUCTION

The implementation of GNSS satellite technique in the air transport is focused on three basic components, e.g. ABAS, SBAS and GBAS augmentation systems [4]. The major rules of ABAS system are based on:
- determination of aircraft position using onboard GNSS receiver,
- the accuracy assessment of the aircraft's coordinates,
- the blunder errors detection in GNSS observations,
- implementation of the RAIM module for onboard FMS system,
- the Kalman filter application for mathematical solution of aircraft's position,
- estimation of the atmosphere delay (e.g. ionosphere and troposphere delay) from GNSS observations,
- estimation of multipath effect and measurement noise for GNSS observations,
- estimation of the satellite coordinates of GNSS system,
- designation the clock corrections for GNSS satellite technique (e.g. receiver and satellite clock biases, relativistic effects, instrumental biases for satellites and receiver).

The instrumental biases DCB in GLONASS[1] system are divided into three major types:
- DCB P1-C1 (this type of DCB parameter is utilized for correction the receiver and satellite clock bias in precise positioning in GLONASS system) [2],
- DCB P1-P2 (this type of DCB parameter is called as an Inter-Frequency Code Biases and it is applied in Geometry-Free linear combination) [1, 6, 12-14],
- DCB P2-C2 (this type of DCB term is estimated as a difference between P2 and C2 observations codes in GLONASS system) [11].

In this paper, the instrumental biases DCB P1-C1 are estimated using GLONASS data from onboard Topcon Hiper Pro receiver. The Topcon Hiper Pro receiver was mounted in pilot's cabin in Cessna 172 plane during flight experiment on the Dęblin aerodrome. The instrumental biases DCB P1-C1 were determinated for all visible satellites and receiver. The instrumental biases DCB P1-C1 are designated using mathematical solution of least square estimation in this paper. The article was divided into 5 sections: introduction, mathematical model for designation the instrumental biases DCB P1-C1, research experiment, results and discussion, conclusions.

[1] GLONASS, in English: GLONASS Navigation Satellite System, in Russian: Global'naya Navigatsionnaya Sputnikovaya Sistema

2. METHODOLOGY OF RESEARCH

The mathematical model for designation the Differential Code Biases (DCB) P1-C1 is described, as below [9]:

$$DCB_{P1-C1} = P1 - C1 \tag{1}$$

where:
$P1$ – P code at 1st frequency in GLONASS system,
$C1$ – C code at 1st frequency in GLONASS system.
The DCB_{P1-C1} term is divided into Satellites DCB_{P1-C1} and also Receiver DCB_{P1-C1} parameters:

$$DCB_{P1-C1} = SDCB_{P1-C1} + RDCB_{P1-C1} \tag{2}$$

where:
$SDCB_{P1-C1}$ – Satellites DCB_{P1-C1},
$RDCB_{P1-C1}$ – Receiver DCB_{P1-C1}.
The mathematical model of equations (1) and (2) is solved using least square estimation as follows [7]:

$$\begin{cases} \mathbf{A} \cdot \boldsymbol{\delta}\mathbf{x} - \mathbf{dl} = \mathbf{V} \\ \boldsymbol{\delta}\mathbf{x} = \left(\mathbf{A}^{\mathbf{T}} \cdot \mathbf{P} \cdot \mathbf{A}\right)^{\mathbf{-1}} \cdot \mathbf{A}^{\mathbf{T}} \cdot \mathbf{P} \cdot \mathbf{dl} \\ \mathbf{Qx} = m0 \cdot \left(\mathbf{A}^{\mathbf{T}} \cdot \mathbf{P} \cdot \mathbf{A}\right)^{-1} \\ \mathbf{m}_{\boldsymbol{\delta}\mathbf{x}} = \sqrt{\mathbf{Qx}} \end{cases} \tag{3}$$

where:
$\mathbf{A}$ – matrix of scheme,
$\boldsymbol{\delta}\mathbf{x}$ – vector with unknown parameters,

$$\boldsymbol{\delta}\mathbf{x} = \left[SDCB^{s1}_{P1-C1}, SDCB^{s2}_{P1-C1}, ..., RDCB_{P1-C1}\right]^T,$$

$\mathbf{dl}$ – misclosure vector,
$\mathbf{V}$ – vector of residuals,
$\mathbf{P}$ – matrix of weights,
$\mathbf{Qx}$ – covariance matrix,
$m0$ – standard error of unit weight,
$\mathbf{m}_{\boldsymbol{\delta}\mathbf{x}}$ – standard deviations of unknown parameters.
The matrix of scheme $\mathbf{A}$ has a rank deficient, usually equals 1. In connection with it, the additional constraint must be attached to matrix $\mathbf{A}$. The typical constraint includes relation that reference sum of $SDCB_{P1-C1}$ instrumental biases equals 0, as follows [8]:

$$\sum_{1}^{ns} SDCB_{P1-C1} = 0 \tag{4}$$

where:
ns – number of visible satellites of GLONASS system.
After this mathematical operation from equation (4), the matrix $\mathbf{A}$ is now full rank matrix. In addition, the mathematical model of least square estimation can be applied to determinate the instrumental biases DCB_{P1-C1} for all GLONASS satellites and receiver. The values of $SDCB_{P1-C1}$ and $RDCB_{P1-C1}$ parameters are estimated based on GLONASS code observations from all measurements epochs. The accuracy of $SDCB_{P1-C1}$ and $RDCB_{P1-C1}$ parameters are also designated using mathematical solution in equation (3).

3. THE RESEARCH EXPERIMENT. RESULTS AND DISCUSSION

In research experiment, the DCB_{P1-C1} parameters are estimated using GLONASS kinematic data. The raw GLONASS observations (e.g. code P1 and C1) were taken from dual-frequency Topcon Hiper Pro receiver. The Topcon Hiper Pro receiver was utilized in flight test on the Dęblin military aerodrome on 1st June 2010. Topcon Hiper Pro receiver was installed in pilot's cabin in Cessna 172 plane during the test. The Topcon Hiper Pro receiver collected and registered GNSS observations (e.g. code, phase and Doppler) during flight experiment. The GNSS observations from Topcon Hiper Pro receiver were applied for designation the precise coordinates of the aircraft [3].
The instrumental biases DCB_{P1-C1} were calculated in SciTEC Toolbox 1.0.0 software under Windows system [5]. The algorithm of determination the DCB_{P1-C1} parameters in SciTEC software is presented in section 2 of article. The configuration of initial parameters in SciTEC software were set, as below:
- GNSS system: GLONASS,
- Type of RINEX file: 2.11,
- Type of observations: kinematic pseudorange data (code P1 and C1),
- Mode of computations: post-processing,
- Interval of computations: 5 s,
- Cutoff elevation: > 0^0,
- Adjustment processing: applied,
- Constraint for $SDCB_{P1-C1}$: see equation (4),
- Method of solution DCB_{P1-C1}: least square estimation,
- $SDCB_{P1-C1}$ parameters: estimated for all visible GLONASS satellites,
- $RDCB_{P1-C1}$ parameter: estimated for Topcon Hiper Pro receiver,
- Basic unit of DCB_{P1-C1} parameters: 1 ns,
- Accuracy of DCB_{P1-C1} parameters: estimated.

4. THE RESULTS AND DISCUSSION

In this section, the results of DCB_{P1-C1} parameters from SciTEC Toolbox 1.0.0 software are presented and analyzed. The Figure 1 presents values of $SDCB_{P1-C1}$ terms in nanosecond unit for all visible GLONASS satellite. The six results of $SDCB_{P1-C1}$ terms have a negative value, e.g. R01, R02, R03, R11, R19 and R20. The three results of $SDCB_{P1-C1}$ terms have a positive value, e.g. R10, R13 and R18. The reference sum of all $SDCB_{P1-C1}$ parameters equals 0, according to equation (4) in section 2. The minimum value of $SDCB_{P1-C1}$ is around -4.373 ns for R11 satellite, whereas the maximum value is around 6.956 ns for R10 satellite. The difference between minimum and maximum value of $SDCB_{P1-C1}$ equals to 11.329 ns.

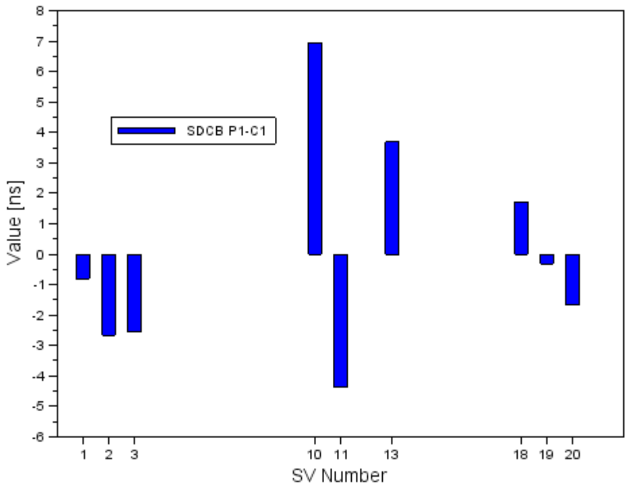

Figure 1 The values of $SDCB_{P1-C1}$ from SciTEC software

Rysunek 1 Wartości parametrów $SDCB_{P1-C1}$ z programu SciTEC

All results of instrumental biases $SDCB_{P1-C1}$ for GLONASS satellites are presented in Table 1. The accuracy term of $SDCB_{P1-C1}$ parameters are also showed in Table 1. The accuracy of seven instrumental biases $SDCB_{P1-C1}$ (e. g. R01, R02, R03, R11, R13, R19 and R20) is higher than 0.25 ns. The standard deviation of $SDCB_{P1-C1}$ parameter for R10 satellite is close to 0.28 ns and reliable for R18 is around 0.32 ns, respectively. The value and accuracy of $RDCB_{P1-C1}$ is also presented in Table 1. The mean value of $RDCB_{P1-C1}$ equals -0.525 ns, with standard deviation 0.231 ns.

Table 1 The statistical values of DCB_{P1-C1} parameters

Tabela 1 Wartości statystyczne parametrów DCB_{P1-C1}

SV Number / Receiver	Mean value [ns]	Standard deviation [ns]
R01	-0.808	0.241
R02	-2.662	0.241
R03	-2.551	0.241
R10	6.956	0.279
R11	-4.373	0.241
R13	3.699	0.242
R18	1.718	0.318
R19	-0.314	0.243
R20	-1.666	0.249
Topcon Hiper Pro	-0.525	0.231

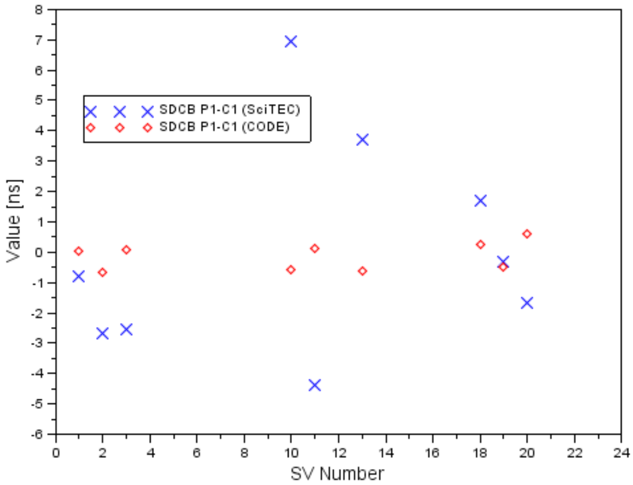

Figure 2 The comparison of $SDCB_{P1-C1}$ values based on SciTEC solution and CODE product

Rysunek 2 Porównanie wartości $SDCB_{P1-C1}$ na podstawie rozwiązania SciTEC oraz CODE

The Figure 2 presents the comparison of $SDCB_{P1-C1}$ values based on SciTEC solution and CODE (Center for Orbit Determination in Europe) product. The CODE estimates the instrumental biases DCB_{P1-C1} using GLONASS daily observations from all receivers within IGS service. The CODE Analysis Center distributed the values of instrumental biases $SDCB_{P1-C1}$ and $RDCB_{P1-C1}$ as a daily and also monthly product [10]. The values of instrumental biases $SDCB_{P1-C1}$ in CODE solution are designated using constraint from equation (4). In presented paper, the range of $SDCB_{P1-C1}$ parameters from CODE solution are less than ±1 ns. The five instrumental biases $SDCB_{P1-C1}$ have a positive value, e.g. R01, R03, R11, R18 and R20. The four instrumental biases $SDCB_{P1-C1}$ have a negative value, e.g. R02, R10, R13 and R19.

Table 2 The difference of $SDCB_{P1-C1}$ parameters based on SciTEC and CODE solution

Tabela 2 Różnica wartości parametrów $SDCB_{P1-C1}$ na podstawie rozwiązania SciTEC oraz CODE

SV Number	Difference [ns]	RMS bias [ns]
R01	-0.868	3.783
R02	-1.994	
R03	-2.646	
R10	7.517	
R11	-4.509	
R13	4.332	
R18	1.483	
R19	0.158	
R20	-2.252	
Mean difference	0.136	

The Table 2 presents results of difference for $SDCB_{P1-C1}$ parameters based on SciTEC and CODE solutions. The difference of $SDCB_{P1-C1}$ parameters is determined as offset between SciTEC and CODE solutions. The range of difference for $SDCB_{P1-C1}$ terms is between -4.509 ns and 7.517 ns, respectively. The value of mean difference for $SDCB_{P1-C1}$ terms is around 0.136 ns, whereas the RMS bias equals 3.783 ns.

5. CONCLUSIONS

In this paper the results of instrumental biases $SDCB_{P1-C1}$ and $RDCB_{P1-C1}$ are presented and analyzed. The instrumental biases DCB_{P1-C1} are designated using GLONASS kinematic observations from dual-frequency Topcon Hiper Pro receiver. The Topcon Hiper Pro receiver was installed in Cessna 172 plane during flight experiment on the Dęblin military aerodrome on 1st June 2010. The instrumental biases DCB_{P1-C1} are estimated within the ABAS augmentation system in air transport. The DCB_{P1-C1} parameters are calculated using least square estimation in SciTEC Toolbox 1.0.0 software in post-processing mode. In addition, the values of $SDCB_{P1-C1}$ parameters are compared with CODE monthly product. The value of mean difference of $SDCB_{P1-C1}$ terms based on SciTEC and CODE solutions equals 0.136 ns, with RMS bias around 3.783 ns.

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