THE USE OF RTCM 2.X DEKODER SOFTWARE FOR ANALYSES OF KODGIS AND NAWGIS SERVICES OF THE ASG-EUPOS SYSTEM

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A b s t r a c t

The paper presents preliminary results of KODGIS and NAWGIS analyses with the use of RTCM 2.x Dekoder software. The software was created in the Chair of Satellite Geodesy and Navigation in Olsztyn. It allows analyzing values of pseudo-range corrections (PRC) being transmitted in the RTCM format by the ASG-EUPOS system. The analyses of PRC values over time for each satellite can allow to research the accuracy of differential positioning in KODGIS and NAWGIS services with the use of different GNSS receivers. The paper presents initial tests of the RTCM 2.x Dekoder software as well as some general information on the RTCM structure.

WYKORZYSTANIE AUTORSKIEGO PROGRAMU RTCM 2.X DEKODER DO BADAŃ SERWISÓW KODGIS I NAWGIS SYSTEMU ASG-EUPOS

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A b s t r a k t

W pracy przedstawiono wstępne wyniki badań serwisów KODGIS i NAWGIS z wykorzystaniem autorskiego oprogramowania RTSM 2.x Dekoder. Program RTCM 2.x Dekoder opracowano w Katedrze Geodezji Satelitarnej i Nawigacji, UWM Olsztyn. Umożliwia on analizę wartości poprawek kodowych (PRC), transmitowanych w czasie rzeczywistym przez system ASG-EUPOS, w formacie RTCM. Analiza wartości przebiegu PRC dla poszczególnych satelitów umożliwia badanie wpływu dokładności wyznaczonych pozycji z wykorzystaniem różnych odbiorników GNSS oraz serwisów KODGIS i NAWGIS. W pracy przedstawiono wstępne testy wykorzystania programu RTCM 2.x Dekoder, jak również informacje dotyczące formatu RTCM.

Introduction

The data transmission protocols defines the terms of transmission of data from one place to another. The wrong choice of them can cause incorrect transmission or lack of it. The most of GNSS equipment producers develop their own data transmission protocols (usually in binary mode). Producers develop a couple of protocols for different hardware or applications. For instance, Trimle company;s hardware is based on RT17, TSIP, CMR/CMR+ or combination of them. Another producers also have their own protocols: Leica (LB2), Ashtech (MBEN/PBEN, DBEN), AOA (ConanBinary, TurboBinary), Javad (JPS), Topcon (TPS), u-blox (MBX) and JPL(SOC). The structure of most of this protocols is binary but some of them, for example MBEN/PBEN (Ashtech) or LB2 (Leica) are formatted in ASCII standard (YAN 2006).

NTRIP (*Network Transport of RTCM via Internet Protocol*) is the standard built on client-server model, which transmits GNSS data from reference station to receiver. It is based on HTTP (*Hypertext Transfer Protocol*) and uses TCP protocol to transmission, in spite of that its architecture was originally built on internet radio system Icecast (its works with the aid of a couple of data sources connected to single server, from which information are transmit to many users) (WEBER 2004). NTRIP is capable of transmission data stream, which contains body of RTCM messages and data of every type (MCKESSOCK 2007). The protocols version 1.0 was accepted and was published as the RTCM standard in 2004. Work on its modernization is continued, which effect is version 2.0 of the protocol (WEBER 2004).

The full NTRIP system consists of: NTRIP caster, NTRIP server and sources and clients of NTRIP. Figure 1 shows the scheme of NTRIP protocol (MCKESSOCK 2007).

The NTRIP sources generates streams of binary data and transmit it to a client. This sources can be based on every type data, but originally the DGNSS corrections was transmitted in RTCM format.

RTCM is the most popular standard that transmit corrections. The standard was developed by Radio Technical Commission For Marine Services. It is used in most of GNSS applications that work in real time (*http://www.rtcm.org* 10.01.2009). The program RTCM Dekoder, which can be used to analyze RTCM data, is based on the RTCM standard.

RTCM Standard

In 1983 the Radio Technical Commission for Maritime Services (RTCM) appointed the Special Committee 104 (SC-104), which established the
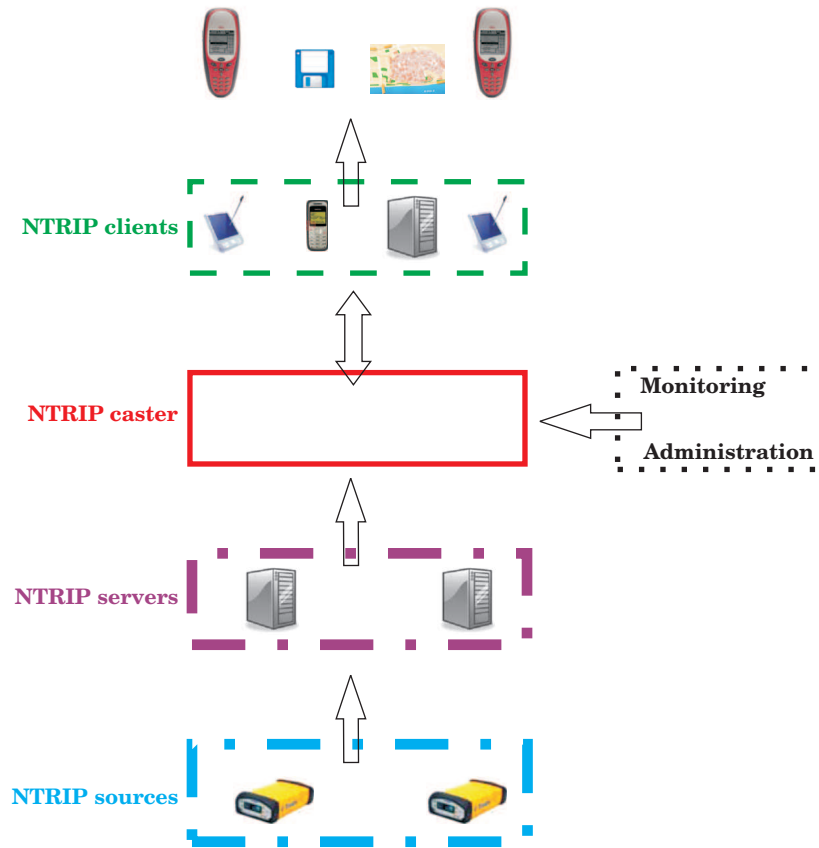
Fig. 1. The components of NTRIP protocol

Table 1

Development of RTCM

RTCM version	The year of application	Changes applied
RTCM 1.0	1985	Temporary recommendation for DGPS (PRC and RRC)
RTCM 2.0	1990	DGPS corrections and additional information Messages 1-17, 59
RTCM 2.1	1994	Extension for RTK Messages 18/19 and 20/21
RTCM 2.2	1998	Extension for DGLONASS Messages 31-37
RTCM 2.3	2001	Additional information for RTK Messages 23,24
RTCM 3.0	2004	New solution for RTK
RTCM 3.1	2008	Solution for transformation

Table 2

Types of RTCM messages

Number of message	Status	Message type	
1	specified	GPS differential corrections	
2	specified	GPS delta-differential corrections	
3	specified	Position of reference station	
4	proposed	Reference station datum	
5	specified	GPS constellation health	
6	specified	GPS null frame	
7	specified	DGPS radiobeacon almanac	
8	proposed	Pseudolite almanac	
9	specified	GPS partial correction set	
10	warranted	P-code differential corrections	
11	warranted	C/A-code L1, L2 delta corrections	
12	warranted	Pseudolite (pseudo-satellite) station parameters	
13	proposed	Ground transmitter parameters	
14	specified	GPS time of week	
15	specified	Ionospheric delay message	
16	specified	GPS special message	
17	proposed	GPS ephemerides	
18	specified	RTK uncorrected carrier phases	Messages 18-21 added in RTCM 2.1
19	specified	RTK uncorrected pseudoranges	
20	specified	RTK carrier phase corrections	
21	specified	RTK/high-accuracy pseudorange corrections	
22	proposed	Extended reference station parameters	
23	proposed	Type of antenna	Messages 23-24 added in RTCM 2.3
24	proposed	Reference station: (ARP - Antenna Reference Point)	
25-26	not defined		
27	proposed	Extended almanac of DGPS	
28-30	not defined		
31	proposed	GLONASS differential corrections	Messages 31-36 added in RTCM 2.3
32	proposed	Differential GLONASS reference station parameters	
33	proposed	GLONASS constellation health	
34	proposed	DGLONASS corrections	
35	proposed	GLONASS radiobeacon almanac	
36	proposed	GLONASS special message	
37	proposed	GNSS system time offset	
38-58	not defined		
59	specified	Proprietary message used in VRS 2.3 and FKP2.3	
60-63	reserved	Multipurpose usage	

structure and the format of transmitting the data within the DGPS system (SPECHT 2007). It established definitions of the elements and data units, the minimum time interval between transmissions, data segment size, their protocols and range. RTCM Standard is the most widely used model for the transmission differential GPS.

RTCM message consists of two main parts: a header and the rest remaining words of the message. The header consists of two words. The second part contains up to 31 words (usually it does not extend the length of 12 words) (WILLGALIS 2005). The scheme of the structure of RTCM message is presented in the Figure 2.

HEADER		THE REST OF WORDS			
WORD 1	WORD 2	WORD 3	WORD 4	...	WORD 33

Fig. 2. The structure of RTCM message

The header

The header is constructed by the two first words in each message. They are identical for every type of message. The main function of the header is to maintain the timing of receipt the corrections by means of a *modified counter* Z.

Fig. 3. The header of RTCM 2.x message

Message 1

The first message is the main type of a message. It concerns the measurements based on C/A code. It contains the corrections to pseudorange and the rate of their changes. There is an Issue of Data (IOD – the age of data) parameter connected with every correction. Mobile receiver uses the same parameters, which are used by the reference station. In this method the need to apply the same ionospheric and tropospheric model for the reference station and the mobile receiver is eliminated.

Table 3

The elements of RTCM 2.x message header

COLOUR	NAME	NUMBER OF BITS	MEANING
	PREAMBLE	8	Identical for all types of messages (01100110)
	IDENTIFIER OF NAVIGATION MESSAGE TYPES	6	Identifies the message type 0-63
	IDENTIFICATION NUMBER OF THE BASE STATION	10	Identification number of the DGPS base station; band 0-1023
	MODIFIED Z COUNTER	13	Represents reference time for differential data transmission
	NUMBER OF SEQUENCES	3	Number of sequences
	THE LENTH OF THE MESSAGE	5	The number of words in messages; 0-31
	STATE OF WORKING	3	State of reference station; 8 states: 0 = scale factor UDRE = 1 1 = scale factor UDRE = 0.75 2 = scale factor UDRE = 0.5 3 = scale factor UDRE = 0.3 4 = scale factor UDRE = 0.2 5 = scale factor UDRE = 0.1 6 = transmission is not monitoring 7 = incorrect working of reference station
	PARITY CONTROL	N*6	*N* – number of words in the message
	NONSIGNIFICAT BITS	N*10	*N* – number of words in the message

Fig. 4. Structure of RTCM 2.x. Messgage 1

Table 4

Content of 1 message

COLOUR	NAME	NUMBER OF BITS	MEANING		
	S	1	Scale factor – precision of measurement	Scale factor for PRC	Scale factor for RRC
			Value - 0 – for corrections of low precision pseudorange corrections	0.02 m	0.002 m/s
			Value - 1 – for corrections of higher precision pseudorange corrections	0.32 m	0.032 m/s
	UDRE	2	User Differential Range Error – estimated root-mean-square of pseudorange measurement; 4 states; $$UDRE = \sqrt{\delta_r^2 + \delta_g^2}$$ δ_r^2 – root-mean-square of base station pseudorange measurement δ_g^2 – root-mean-square of base station antenna position calculation $0 \Rightarrow UDRE \leq 1$ meter $1 \Rightarrow 1$ meter $< UDRE \leq 4$ meters $2 \Rightarrow 4$ meters $< UDRE \leq 8$ meters $3 \Rightarrow UDRE > 8$ meters		
	Id NUMBER OF SATELLITE	5	Number of satellite; 1-32 (Value 0 means satellite number 32)		
	PSEUDORANGE CORRECTION	16	Value of pseudorange (with „+" or „-"); when value 100 000 comes the satellite shouldn't be used; range +/- 655,34 m (for 0,02 m scale factor) or +/- 10485,44 m (for 0,32 m scale factor)		
	RANGE RATE CORRECTION	8	Value of range rate correction (with „+" or „-"); range +/- 0,254 m/s (for 0,002 m/s scale factor) or +/- 4,064 m/s (for 0,032 m/s scale factor)		
	AGE OF DATA	8	When reference station data are older than data that are used, then the data shouldn't be used		
	FILLING	8 x [Ns mod 3]	N_S – number of satellites		
	PARITY CONTROL	$N*6$	N – number of words in the message		
	NONSIGNIFICANT BITS	$N*10$	N – number of words in the message		

Message 2

The second message contains the delta differential corrections. It was mentioned in the first message that when the method, which involves sending the corrections to pseudorange, is used, the mobile receiver and the reference station must be based on the same IOD parameters. If the receiver does not decode new ephemerides of the satellites as soon as they are received, it means that the time data and ephemerides of satellites which are used, are older than the data used by the reference station. The delta differential corrections enable the pseudorange correction (PRC) and range-rate correction (RRC). There are PRC and RRC determined at the reference station on the basis of old and new IOD. That's why:

$$\text{DELTA PRC} = \text{PRC (OLD)} - \text{PRC (NEW)} \tag{1}$$

$$\text{DELTA RRC} = \text{RRC (OLD)} - \text{RRC (NEW)} \tag{2}$$

The second message is transmitted together with the first message. Finally, the pseudorange correction is calculated from the formula:

$$\text{PRC}(t) = \text{PRC}(N_{d1}) + \text{DELTA PRC } (S_{d2}) + \text{RRC } (N_{d1}) \cdot (t\text{-}t_1) + \\ + \text{DELTA RRC } (S_{d2}) \cdot (t\text{-}t_2) \tag{3}$$

S_{d2} – parameter regarding old data – RTCM message 2,
N_{d1} – parameter regarding old data – RTCM message 1,
t – time of PRC calculation,
t_1 – „*modified Z counter*" from message 1,
t_2 – „*modified Z counter*" from message 2 (SPECHT 2007).

Message 3

The third message contains the information about ECEF (Earth-Centred Earth-Fixed) geocentric coordinates of the antennas of the reference receiver of DGPS station. Coordinates are given in the system WGS-84 (BETKE 2001).

Message 9

There are two methods of formatting pseudorange corrections. The first one uses the first message, whereas the second one uses the ninth message. In contrast to the first message, which includes PRC and RRC for all the satellites
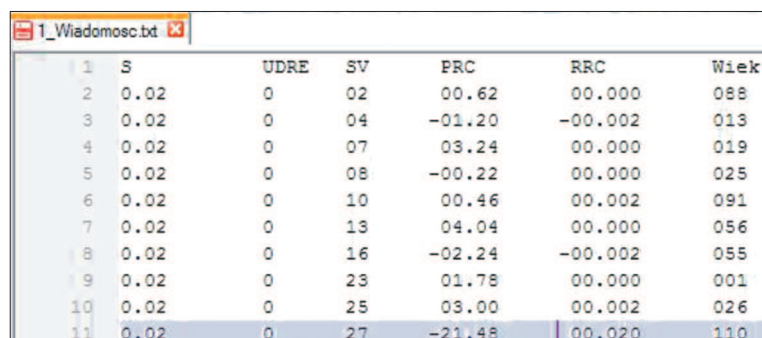
available for each reference station, the ninth message includes the corrections only to a few satellites (three satellites or one satellite). In the event of a damage to a single bit in the first message, the mobile receiver loses the corrections to all satellites. Compressing information for three each, results in decreasing the age of corrections. It also enables to use the remaining PRC corrections by the receiver (SPECHT 2007). The diagram of binary numeral system of the ninth message and the interpretation of its content are presented in the 4th illustration. The meaning and the range of data are identical as in the case of the first message (Tab. 5).

The RTCM 2.x Dekoder Program

To execute the program mentioned above, the Microsoft Visual Studio 2008 environment was used. Software source code was written in C#. It is an object-oriented language and it is based on the safe data types. The advantage of the selected language is the fact that there is no need to define the interface component by means of *Interface Definition Language* (IDL). There is also no point in creating the types of library to use them (WRIGHT 2002).

RTCM 2.x *Decoder* decodes and analyses initially the data included in the main messages RTCM 2.x. There are following basic tasks, which can be achieved by using the created application (RTCM 2.x *Decoder*):

– Decoding the RTCM data from a binary file (1st, 2nd, 3rd, 9th, 18th, 19th, 20th, 21th messages).

– Decoded data recording (in TXT format) divided by message types (e.g. '1_Message.txt' – 5th illustration).

– Visualization of the contents on the screen sent by the provider of message system,

	S	UDRE	SV	PRC	RRC	Wiek
1	S	UDRE	SV	PRC	RRC	Wiek
2	0.02	0	02	00.62	00.000	088
3	0.02	0	04	−01.20	−00.002	013
4	0.02	0	07	03.24	00.000	019
5	0.02	0	08	−00.22	00.000	025
6	0.02	0	10	00.46	00.002	091
7	0.02	0	13	04.04	00.000	056
8	0.02	0	16	−02.24	−00.002	055
9	0.02	0	23	01.78	00.000	001
10	0.02	0	25	03.00	00.002	026
11	0.02	0	27	−21.48	00.020	110

Fig. 5. The effect of decoding 1 message from file

1 Message

2 Message

3 Message

4 Message

Fig. 6. Examples of decoded in RTCM 2.x Dekoder messages

There are following additional functions of *RTCM 2.x*:
– Displaying the message types transmitted in ASG-EUPOS system,

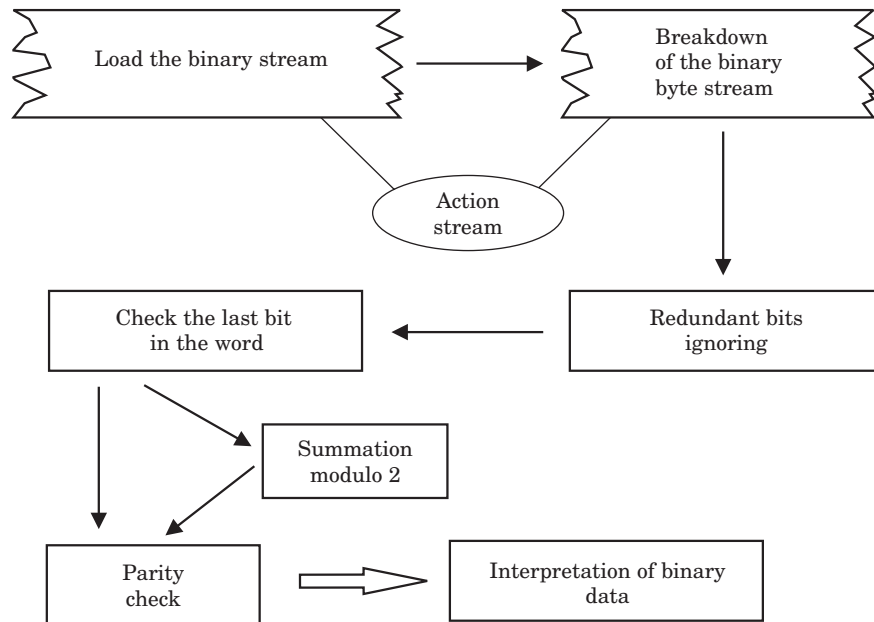Fig. 7. The KODGIS RTCM message types

Fig. 8. Decoding process

– Presentation in the charts the dependence between the change of the value of the correction to pseudorange and the time for particular satellites (zooming in and zooming out the displayed data in the chart, highlighting the value, the possibility to save the charts as: Jpeg, GIF, PNG, Emf, Tiff, Bmp, direct print).

– Comparison the values of corrections to pseudorange from 1st message (NAWGIS) and 9th message (KODGIS) in the chart for any satellites,

Optional addition to particular data, for each satellites, information from the header (ID of the station, a counter Z, the status of work of the station).

The process of decoding the binary stream transmitted in KODGIS and NAWGIS is presented in the 8th illustration.

The comparative analysis of KODGIS and NAWGIS services were performed in two stages:

1. General summary of the types of transmitted messages in services.

2. Comparison of the transmitted PRC corrections for the north part of Poland in the charts.

Message types KODGIS and NAWGIS

Service	Pseudorange corrections	Coordinates of base station	Text message	Private message	Additional information about reference station
KODGIS	2, 9	3	16	59	–
NAWGIS	1, 2	3	16	59	22, 23, 24

As a result of decoding RTCM messages, transmitted in NAWGIS PÓŁNOC and POŁUDNIE, the coordinates of referential station for the service were set. An example of comparison the PRC corrections for NAWGIS PÓŁNOC and POŁUDNIE are presented in the following illustration.
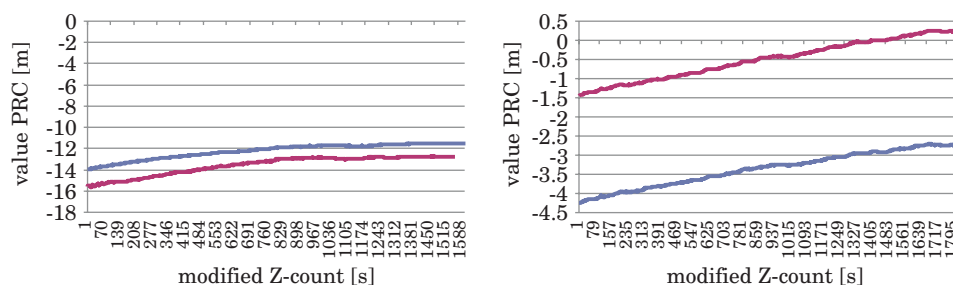
Fig. 9. Comparison of PRC values for NAWGIS PÓŁNOC (blue) and POŁUDNIE (red) for 9 and 11 satellites

The following illustrations present the summary of corrections for NAWGIS PÓŁNOC and KODGIS. The PRC values are generated by ASG-EUPOS system for Olsztyn. The chart of the corrections in RTCM Decoder 2.x transmitted in the services: KODGIS and NAWGIS PÓŁNOC.
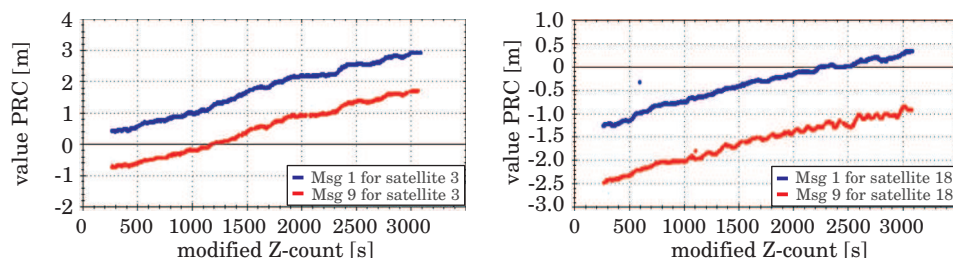
Fig. 10. PRC values for NAWGIS (blue) and KODGIS (red) for 3 and 18 satellites
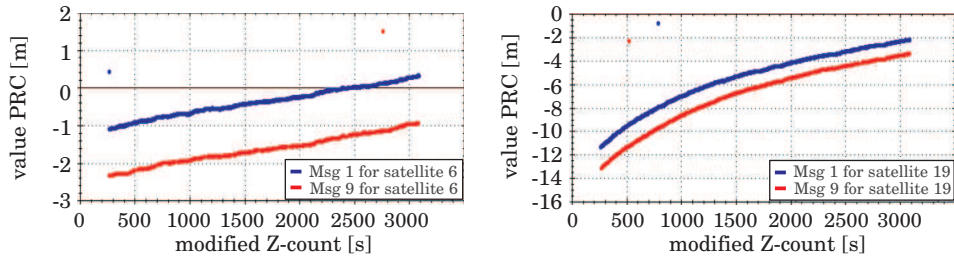
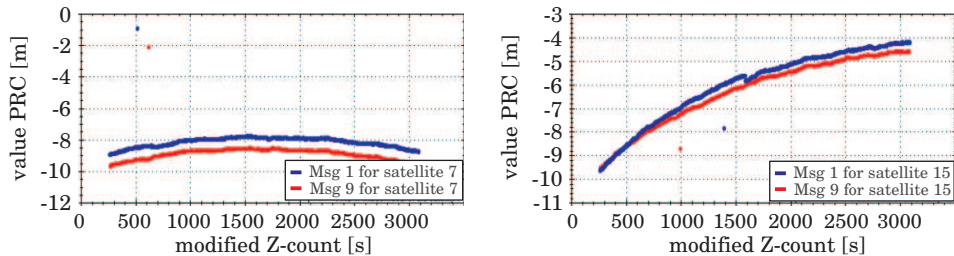Fig. 11. PRC values for NAWGIS (blue) and KODGIS (red) for 6 and 7 satellites

Fig. 12. PRC values for NAWGIS (blue) and KODGIS (red) for 15 and 19 satellites

Conclusion

The developed RTCM 2.x Decoder programme enables to visualize and to record the corrections to pseudorange with differential DGPS positioning. It is possible due to decoding the RTCM 2.x format. There are three main stages which can be distinguished during the process of decoding the data. The first of them is to load the binary stream and to omit the redundant bits. The second stage is to check the last bit in a byte and the parity checking. The last element of decoding the RTCM data is the interpretation of binary values. Using the programme enables to observe the changes of corrections to pseudorange. Differences in the pseudorange corrections, which are presented in the charts in this article, mean that in order to achieve for both DGPS services ASG-EUPOS accuracy, it is necessary to use GNSS receivers, which are respectively dedicated with DGPS ASG-EUPOS services. Differences in pseudorange corrections to NAWGIS PÓŁNOC and POŁUDNIE are between 2 and 4 meters during the test period. These values depend on the position of the particular satellite. The summary of NAWGIS PÓŁNOC and KODGIS values (for Olsztyn) presents also the differences in corrections to particular satellites. If

the types of the messages in KODGIS and NAWGIS are taken into account, it can be noticed that the differences in pseudorange corrections are one of the main reasons of achieving accuracy in tested services.

Translated by Autors

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