Possibility of precise positioning and precise inshore navigation using RTK and Internet

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ABSTRACT: The practical need for GNSS positioning in real time led to the development of a medium for data transmission. DGPS correction data can be transmitted over an area of several hundred square kilometers using longwave radio frequencies. The RTK technique needs greater radio line throughput capacity as well as shorter distances between ground based reference stations. The RTK data from the reference stations can be transmitted through the DARC system by local stations using UHF channels, but the local stations in Poland are not interested in the propagation of RTCM data. The authors present test results of RTK and DGPS measurements using data transmission by Internet and mobile phones. The rover user is equipped with a GPRS (General Packet Radio System) modem in a GSM phone, which is connected to a laptop computer or receiver controller with special RTCM Client software that receives the RTCM data stream from the server via the TCP/IP protocol and transmits it via the serial port to the rover GPS receiver. The new Polish EUPOS–ASGPL active control network allows the use of the RTK technique with a practical range of ten nautical mile in Poland's inshore area.

1 INTRODUCTION

Performed experiments involving the providing of access to satellite data through the Internet and GSM fully confirmed the effectiveness and capacity of the utilized media as specified. Attempts at applying the Internet and GSM were undertaken in parallel at several research centers throughout Europe. This concept garnered the interest of the IAG/EUREF sub–commission and a resolution was passed at the Ponta Delgada conference in June of 2002 to create the infrastructure for a pilot project. Due to the standardization of data transmission protocols as well as GPS data formats, this was an important step. The standards were approved in both Europe and the United States, which makes possible the utilization of information derived from many reference stations using a single equipment and software set.

An accuracy in terms of centimeters in determining position in real time creates new possibilities for such tasks as the maneuvering efforts of watercrafts as well as the parameterization of the maneuvering properties of watercrafts, the specifying of navigation marker positions, and precision navigation in the inshore zone. Unfortunately, GSM operators lack information regarding the actual range of their cellular networks in the Baltic area. Nevertheless, it may be assumed that important navigation regions such as port approaches are within telephony range. The same question regarding Polish territorial waters and the Polish economic zone are more difficult to answer.

2 THE EUREF–IP NTRIP STANDARD

The approved data transmission standards have been named "Networked Transport of RTCM via Internet Protocol" (Ntrip). Ntrip is a general protocol that is based on the Hypertext Transport Protocol (HTTP), version 1.1. It was designed to propagate differential corrections in the RTCM–104 and RAW formats. Ntrip makes possible connection with desktop, laptop, and personal digital assistants (PDA) as well as certain new field receivers. Ntrip is fully adapted for wireless access to the Internet using GSM networks (GPRS, EDGE, and UMTS) because it uses the TCP/IP protocol. The structure performing data transmission tasks has been subdivided into several elements for safety as well as organizational reasons. In addition to the a receiver generating the data stream in RTCM format and sending those data to the RS port, the reference station is equipped in a data server whose task is to acquire information at the RS port and transfer that information to the TCP/IP port addressed to the broadcaster. The newest GPS transmitters have a built–in network card, which makes possible direct forwarding of data to the Internet. The task of the broadcaster is to amass data from many reference stations and make them available to users. The introduction of a broadcaster is not vital, except for the convenience of users, who can select from among many reference stations under a single IP address as well as guaranteeing greater safety of the local reference station network. The last element of the tele–information structure is the NtripClient software, which allows users to conveniently connect with the broadcaster and download data.

Thanks to NtripCaster it is possible to transmit the following data streams:

- Data in RTCM format for DGPS and RTK,
- Data in RTCA format for EGNOS,
- RAW observational data as well as in RINEX format,
- Correction in the VRS system,
- Precise orbit parameters in SP3 format.

Currently, data from all of the stations collaborating within the framework of the EUREF–IP project are sent to the broadcaster located at the GPS/GLONASS Data Center (BKG) in Frankfurt a/Main. That is also the location of the most important information relating to the current state and functioning of the project. The list of Polish reference stations may be found below.

Fig. 1. Field set for RTK and DGPS measurements

Real–Time GNSS Data Streams from EUREF–IP Ntrip Broadcaster at "www.euref-ip.net:2101"

	Network	Country	Mountpoint	Identifier	System	Carrier	Lat	Lon	Solution	Charge	Generator	Format	Format–Details
16	EUREF	POL	JOZ20	Jozefoslaw	GPS+GLO	L1&L2	52.02	21.03	Single Base	A	Ashtech Z18	RTCM 2.3	1,3,18,19,22,31
18	EUREF	POL	KRAW0	Krakow	GPS	L1&L2	50.01	19.92	Single Base	A	Ashtech UZ12	RTCM 2.2	1,3,16,18,19,22
28	EUREF	POL	WROC0	Wroclaw	GPS	L1&L2	51.11	17.06	Single Base	A	Ashtech Z18	RTCM 2.2	3,9,18,19
136	Test	POL	BOGI0	Borowa G.	GPS/GLO	L1&L2	52.48	21.04	Single Base	A	JPS Eurocard	RTCM 2.1	3,18,19,22
137	Misc	POL	JOZ30	Jozefoslaw	GPS	L1&L2	52.02	21.03	Single Base	A	Trimble Cors	RTCM 2.2	1,3,16,18,19,22

3 FIELD STATION EQUIPMENT

The experimental work involved the use of various sets of equipment. Trimble 4700 and 5700 as well as Javad Legacy receivers made available by the Institute of Geodesy and Cartography were used in the measurement experiments linked with RTK techniques. On the other hand, experiments relating to DGPS measurements used a Garmin 12 XL receiver. The receiver sets were equipped in several alternative sets of devices facilitating the registration of data as well as communications with the data broadcaster. The Trimble TSC1 field receivers used did not have a built–in GSM modem nor any possibility of adding in–house applications. In their case it was necessary to use a notebook computer, and a PocketPC at this time. The use of a PocketPC equipped in a GSM modem eliminates earlier inconvenience as well as the need to have a cellular phone set with a GPRS modem. The above described inconveniences have been eliminated in new field receivers such as the Trimble ACU and TSC2. TSC1 receivers and Siemens ME45 and Sony Ericsson T68i cellular phones were available during the conducting of field tests. It has now become possible to use a PocketPC Fujitsu Siemens Loos 720 computer with a GPRS Pretec modem. The configurations of available equipment sets are presented in Figure 1.

4 USER SOFTWARE

Free user software is available in the following versions:

- Windows Client GNSS Internet Radio, Version 1.4.3
- Linux Client Perl NtripClient Program for Linux, Version 0.5
- Windows CE Client GNSS Internet Radio, Version 1.4.7 WinCE, PocketPC 2002/3,
- Palm OS Demo NtripClient Program, Version 1.2.1 © by Guenther Thalmann.

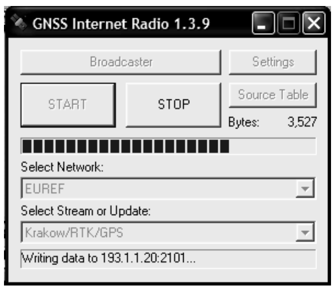

Fig. 2. The Windows and Windows CE version of NtripClient

4.1 *The Józefosław Astrogeodetic Observatory Data Access System*

A correction transmission system in the RTCM–104 format has been developed by the Institute in collaboration with the ARMIKRO company. The system consists of server and DCTSRV broadcasting software receiving corrections from the GPS receiver and forwarding them to the Internet as well as DCTGUI client software receiving corrections from the Internet. A diagram depicting the operation of the system is presented in Figure 3. The programs use their own transmission protocol and can work with any TCP port. The DCTGUI program for receiving corrections was written in the FreeBSD operating system environment using free Open Source tools so as to make possible its use under the control of the Windows system as well. DCTSERV software may work under the control of FreeBSD, OpenBSD, and Linux operating systems. It collaborates with the Apache www server providing access to an administration panel facilitating supervision over operation and configuration using the SSL.

Fig. 3. Diagram depicting system operations

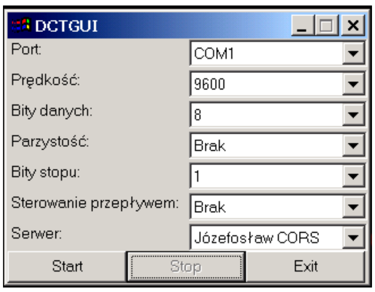

Fig. 4. DCTGUI program user's menu

5 INTERNET AND GSM NETWORK CORRECTION ACCESS SYSTEM TESTS

A parameter of significance to the user is the delay of the correction packet. In analyzing the time of passage of the packets between the reference station, broadcaster, and user it is necessary to isolate the part of the delay in the Internet and the part caused by GPRS transmission. It turns out that regardless of paths taken by the packets in the Internet, delays are not large and amount to approximately 100 ms, where the percentage of data loss does not exceed 1%. The major portion of the delay is caused by transmission in the GSM network; it amounts to approximately 700 ms, where the quantity of lost packets amounts to approximately 6%. Average total time for the acquisition of packets in the EUREF–IP amounts to 805 ms with data loss at a level of 7%. The results of tests of data packet delays conducted using one–day samples are presented in Figure 5.

Data packet acquisition time was investigated in the Institute of Geodesy and Geodetic Astronomy system — i.e. between the DCTSERW server operating in Józefosław and the rover user using a GPRS connection in the GSM network. For the most part, results received do not diverge significantly from those presented above, because the average packet acquisition time amounts to 686 ms for the entire day–long experiment, with a loss of 5% of packets. Also tested was the age of RTK corrections as received by the GPS receiver from the EUREF–IP system. It is to this end that the specified positions were registered using RTK mode on a computer. The age of the corrections as received by the receiver are presented in Figure 6. It was confirmed that the average age of the RTK correction amounts to 1.5 s, and that 99% of the results are in the 1.0–2.0 s range. The age of the received corrections is sufficient to measurements because it is less than the 4 s (the border value).

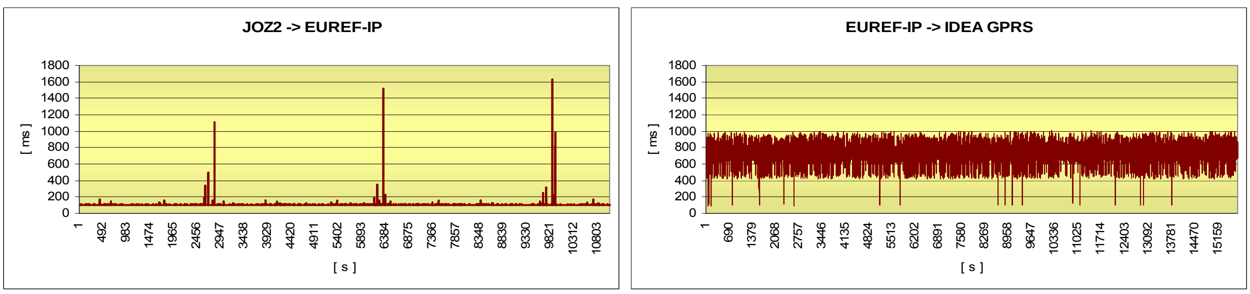

Fig. 5. Packet acquisition time from Józefosław to the EUREF–IP broadcaster as well as from the broadcaster to the user

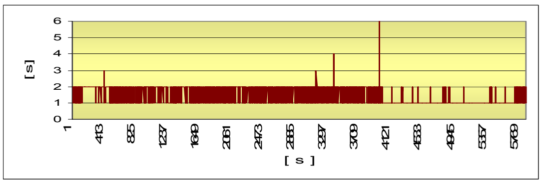

Fig. 6. Correction age

In order to examine the availability and repeatability of RTK measurements using the data transmission system, the RTK position was registered with a frequency of 1 Hz over three days. Figure 7 presents breaks in reception of corrections as well as their duration.

Breaks in reception of corrections for the duration of the test were very short, with a maximum of 6.0 s, where the average duration amounted to 4.1 s. The reason for the occurrence of breaks was the load on the Internet. Average correction availability was defined at a level of 99.85%. Figure 8 presents differences between registered position in RTK mode and known coordinates.

Position availability in the RTK–Fixed mode for the duration of the three–day experiment amounted to 99.42% on average.

6 TEST TRAVERSE MEASUREMENTS

A test traverse consisting of points set up from 5 km to 35 km at mutual distances of 5 km was built in order to study the accuracy of RTK measurements as a function of the distance to the reference station. Careful measurements were conducted using static techniques at the test point as was a series of RTK measurements encompassing the registration of 200 positions at each point. Differences received in the RTK and static modes did not exceed 1 cm at distances of 5, 10, and 15 km from the reference station. Figure 9 presents the differences for a distance of 35 km.

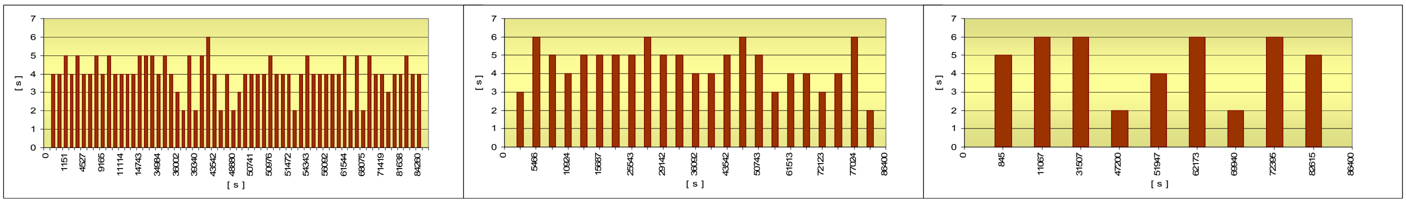

Fig. 7. Breaks in reception of corrections over successive days

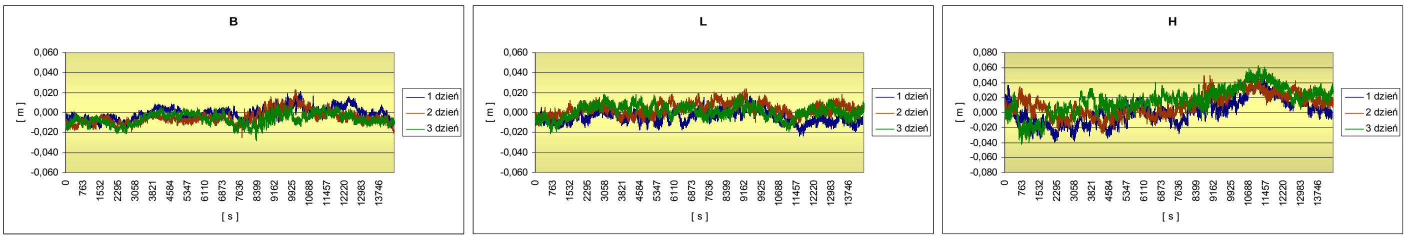

Fig. 8. Changes in coordinates

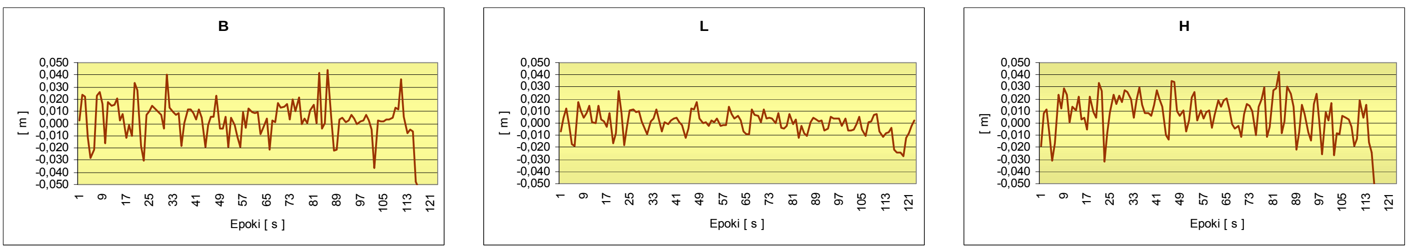

Fig. 9. Differences in coordinates for Point No. 1 at a distance of 35 km

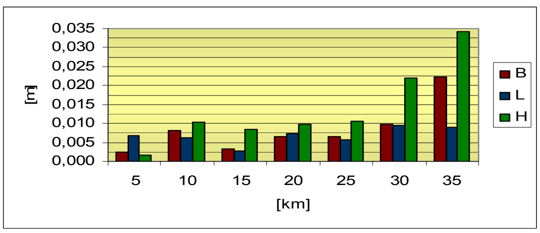

Fig. 10. Standard deviation from the RTK measurements at the test traverse points

Analysis of results as received demonstrates that measurements using the RTK technique utilizing the Internet and GPRS for the transmission of corrections provide a highly accurate solution at distances of up to 30 km from the reference station. Receiver initialization time grows longer at distances in excess of 30 km.

7 SUMMARY

We have confirmed, on the basis of experimental measurements aimed at examining the usefulness and effectiveness of the application of the Internet and GSM in DGPS and RTK measurements, that the presented solutions form an effective medium for the transmission of corrections in the RTCM formats. It may be predicted that transmission using the RTCM v. 3.0 format, will be equally effective.

The proposed tele–transmission solutions do not require investment in special infrastructure, they have a very large range, and they demonstrate no significant dependence on obstruction in the field and electromagnetic interference. The proposed solution only necessitates the startup of the data server program at the reference stations. On the user's side, in work in the field, what is required is connection to the Internet, which can be achieved through an inexpensive GPRS connection in the GSM networks. What is needed for currently used receivers is an additional module for the reception of corrections that can be implemented through the use of personal computers of the PDA type or GSM telephones servicing the JAVA or SYMBIAN languages. The newest GPS and GPS/GLONASS receivers are equipped in software facilitating direct reception of corrections through the Internet and the GSM network.

After conducting the experiments, it was confirmed that delays in transmission through the Internet and GPRS are insignificant and do not have an impact on the effectiveness of the applied technology. After conducting the measurements on the test base it was confirmed that the effective range of RTK measurements using the Internet and GSM telephony amounts to approximately mainly 30 km from the reference station and is determined by limitations in RTK techniques. Together with an increase in distance from the reference station, initialization time of he measurement grows in length and amounts to two minutes at a distance of 5 km, increasing to 10 minutes at distances of over 30 km. Measurement using RTK techniques is an effective technology providing results of significant accuracy that can be applied in most high–precision surveying and navigation.

The experience gained thanks to the series of measurement experiments demonstrates that measurements using the RTK technique with the greatest of precision should be conducted twice at the same point with different satellite configurations in order to eliminate errors that may occur.

The availability of RTK and DGPS measurements utilizing corrections in the RTCM format transmitted through the Internet and GPRS amounts to over 99%. Breaks in reception of corrections are very short and have a duration of not more than 4 seconds.

The proposed solution may find broad application in the transmission of corrections generated by the reference stations of the fixed network. It is also possible to transmit other data in real time, including orbit parameters, coefficients of the current models of the ionosphere and troposphere, observation data in the receiver's format (RAW), and others.

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