Positioning System GPS and RTK VRS Type, Using The Internet as a Base, A Network Of Multiple Stations

Gabriel BĂDESCU, Ovidiu ŞTEFAN, Rodica BĂDESCU, Mircea ORTELECAN and Samuel Ioel VEREŞ, România

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SUMMARY

Multiple reference station networks using GNSS navigation have been established for high precision applications in many countries around the world and in Romania. Nevertheless, real-time application is still a task which is difficult to put into practice. The concept of virtual reference station (VRS) is an efficient means of transmitting corrections to network users for a RTK positioning. Nowadays, the challenge regarding VRS with RTK positioning resides in communication technologies with wireless adaptation feeder for real-time corrections. Using GPRS technology, a system based on VRS Internet RTK with GPRS positioning infrastructure was developed and tested. This paper talks about the VRS data transmission mechanism, and offers an overall image over VRS with generated RTK positioning data. The results of the tests are presented in order to be able to evaluate the performance of the above mentioned system. The results show that based on VRS Internet and RTK positioning, one can achieve a little over 2-3 centimeters accuracy in horizontal position.

Precision when it comes to height is found in the interval 2-5 centimeters, depending on the precision of the quasi-geoid, for transformation in the national altitude system (normal altitude system Black Sea 1975).

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1. INTRODUCTION

GPS Real Time Kinematics (RTK) positioning becomes ever more important for many GPS precision applications – high-precision photogrammetry, topography, constructions, agriculture, and precision, like: the Geographical Information System (GIS).

Basically, a mobile receiver needs a field reference station at approximately 8-12 km, in order to insure the centimeter precision level. Recently, more networks which use the reference stations have been installed in many countries around the world and they surpass the limits of the standard RTK systems.

Over the years, different approaches have been tested in order to take advantage of the existing multitude of reference stations, mentioning here the doctorate thesis entitled “Some contributions regarding the use of GPS technology in cadastre surveys” – Gabriel Bădescu-2005. A great part of the research involved the spatial modeling of distance errors – base station receiver (errors mainly regarding the ionosphere and, on the side, of the troposphere). Nevertheless, the research was made on a distribution of these corrections for the potential GPS users located inside and around the GPS RTK positioning system and must be appropriately handled before the effective construction of the multiple reference station network and application (Fotopoulos et al, 2001).

Recently, using the VRS (Virtual Reference Station) as a concept was suggested by many research groups as a more reliable approach for transmitting and correcting inside the information network for the RTK network users (see Wanninger, 1997; Vollath et al,. 2000;). This approach does not require a reference station from a physical point of view.

On the other hand, it allows the user to have access to data coming from a non-existing reference station, but virtual in any location in the permanent station network’s cover area. Among other facilities, the VRS approach is more flexible in what concerns allowing the users to use their current receivers and software without involving any special software in order to simultaneously administrate the corrections in a series of reference stations(G.R. Hu et al, 2002). With regards to the Virtual Reference Stations (VRS), the users in the reference station network can operate constantly at great distances, while precision only slightly changes (a couple of centimeters). However, there must be a communication connection for transmitting reliable VRS data from a control centre to a receiver which is being used as a mobile receiver (rover) by the user.

There are more ways to transfer GPS data for RTK positioning.
For certain wireless transmission services there are frequency and power restrictions, which regulate the use of such data transmission devices. GSM is a widely available public service and can be used as a distribution channel for VRS data (Vollath et al, 2000.). Using GSM as a communication link is, unfortunately, relatively expensive, because GSM data transmission services are very expensive and the cover areas differ from one GSM carrier to another (G.R. Hu et al, 2002).

From an operational point of view, cost is a very important aspect especially in the context we are in, meaning a crisis, especially in Romania. This cost can be reduced by using the GPRS technique (General Packet Radio Service).

Each wireless communication module has pro and against arguments related to it, but must, generally, support the VRS and RTK data transmission connection with small data latency, good performance in moving the mobile receivers, cheap user equipment and national service cover. The main objective of this paper is to demonstrate once more that the new method mentioned below based on Internet and GPRS positioning using RTK and VRS. The transmission of VRS data based on the Internet is a communication method which is being tested and discussed, regarding the results of the field tests made using the Romanian Positioning System, GNSS system named ROMPOS, in order to evaluate the performance of the suggested system.

2. GENERAL PRESENTATION OF THE VIRTUAL REFERENCE STATIONS (VRS) USED IN ROMÂNIA

This paper will present the VRS used in Romania and of the NTRIP utilitarian together with the Internet, when transmitting data.
In order to create data at a virtual reference station from the observations in the Real Reference Stations National Network, there are a number of processing steps which must be taken in order to reach the data. The first step is to solve the double-difference phase ambiguities between the network's stations.
One can observe that the double-difference phase ambiguities between the network's stations must be known, together with the precise coordinates for the reference stations.
The reference stations' coordinates can be provided by the Geodesy Department, through the National Geodesy Fund service, in the case of a permanent national and regional reference network for the National Network of Permanent Stations. Alternatively, these coordinates can be obtained through a static measurement on every station over long periods of time, using also the traditional long-area effect procedure for static positioning. However, even with a precision of the known coordinates, it is not easy to establish ambiguities between reference stations for the real-time network, because time is short and the stations are at approximately 60-70 km away from each other.
In order to support the RTK positioning method, the whole ambiguities of the double-differences between the reference stations of the network must be solved in real-time, because these ambiguities should be instantly recalculated in case the satellite constellation changes and new satellites appear, or the connection with the ones located in the receiving area is lost

or the delay is longer for the received data. At this point, an adjusted residual Kalman filter is suggested, to solve the double-difference phase ambiguities between the stations of the observed network, filter which has the ability to be used in real-time. This method, using the Kalman filter, is based on data which was received at previous dates and not only in current ones.

So as to help in solving the ambiguities in the network process, the error caused by orbits can be reduced or eliminated using type IGS orbits, ultra-fast predictable Orbit (IGU), instead of emissive orbits. Exact ephemeredes can be obtained from GPS International Service (IGS), ephemeredes centers, which include a day of predicted orbits.

After the double-difference ambiguities associated with reference stations have been established at their correct values, the terms for the so-called correction for atmospheric deviations regarding the troposphere and ionosphere and other errors can be generated as residual in the L1 and L2 phase measurements from satellite to satellite and from one date to another(G.R. Hu et al, 2002). The purpose of these corrections is to reduce the influence of spatially correlated errors. This means that, when the user applies corrections to the code and the phase observations, the influence in the atmospheric errors and other errors shall be reduced or eliminated. This leads to improving the positioning performance in the network in which it is calculated and the measurements are made. There are numerous methods to set corrections for the user paper mentioned above showed that performance, regardless of the method used, is the same.

In the following step, the VRS data for user receivers are generated because it is necessary. In order to generate VRS data if there were no reference station at the user's location, the approximate position of the user and the position of the user related to this VRS, in relation to the transport carrier and the pseudo-range observations at the master reference station must be geometrically moved and improved, by applying corrections to the network according to the approximate position of the user, namely the VRS position. The approximate position of the user can be obtained through absolute GPS positioning or positioning code.

The approximate position of the user can be obtained through absolute GPS positioning or by using the codes.

After this, the VRS data are generated as a RTCM or CMR format and are then transmitted to the users. In order to generate VRS data we need to fulfill three steps. The first step is to solve the double-difference ambiguities for phase measurements in real-time, between the stations in the network inside of which the work occurs. The second step is to generate correlations for a satellite used as a base satellite, date by date for the users of the network in which the measurements are made, according to the user's approximate position. The third step is to transform the VRS data into RTCM format or CMR messages, by applying correlations to the master reference station data and by then sending them to the location requested by the users as VRS data. VRS data are then transmitted to the user as unique RTK correlations of the reference station for the receiver. The receiver can then use these correlations as if there were a unique approach of the reference station for RTK.

3. THE VIRTUAL REFERENCE STATIONS (VRS) HAVE MORE WAYS OF TRANSMITTING THE DATA FOR A VERY ACCURATE POSITIONING.

An efficient communication connection is essential for Virtual Reference Station (VRS) and for RTK positioning, because the transfer in due time (real time) of the VRS data is necessary for such a system. The communication connection must insure reliability in transferring the data and should not cause any significant delay in the transmission time. It is expected that, also, the links are to be without restrictions, so as to cover a wide range of users. Up to now, there are a number of practical manners of distributing the VRS data to users in real time, like GSM and the Internet (Hada et al, 1999;. Vollath et al, 2000;. Liu şi Gao, 2001; Ko et al , 2001).

In the case of a developed mobile telephone network, the easiest transmission mechanism is GPS technology, because it holds the lowers risk of data loss. A mobile phone allows the bi-directional communication between a user and the data control center of the VRS, so, the user can transmit his approximate position to the control center.

Other advantages include the fact that there is no need to apply radio frequencies which are limited to the maximum power of 1 wat, and the low cost of installing this system. One of the disadvantages of GSM is the limited number of users at the same time dictated by the control center, because each GSM line can only support a single user, but there is some software which simulates more users (the Trimble Company). Another important disadvantage of GSM is its high price, because the user must be constantly logged while the RTK system with VRS is being used.

There is, also, the possibility to use the Internet as a data connection between the control center and the user. The Internet is the worldwide network system which is, and will become, the most important means of common communication, mostly viewed from the point of view of its fast data transmission rhythm, and the opening to an unlimited number of users. The Internet uses bi-directional communication and, because of this, the user can also send his approximate position and his requests to the control center, and then the control center can provide data to the Virtual Reference Station (VRS) for the request of each user according to his approximate position.

With the Internet's increased capacity and recent developments in communications technology, especially in what concerns GPRS technology, the Internet is a trustworthy choice for transmitting GPS data of the VRS type for RTK positioning, through a GPRS. Using the GPRS technology we can send and receive information directly from the Internet, the media for transferring the VRS data through the Internet being favorable, and much cheaper than the GSM telephone media. As a result, a GNSS system with Virtual Reference Stations (VRS) and Real Time Kinematic (RTK) through the Internet is being used in Romania and it is a NTRIP type (the system was developed by a specialized university in Germany). This system uses GPRS technology as a communication connection between the control center which is coordinated by the ANCPI and administrated by ROMPOS and the stations which are made use of by the users.

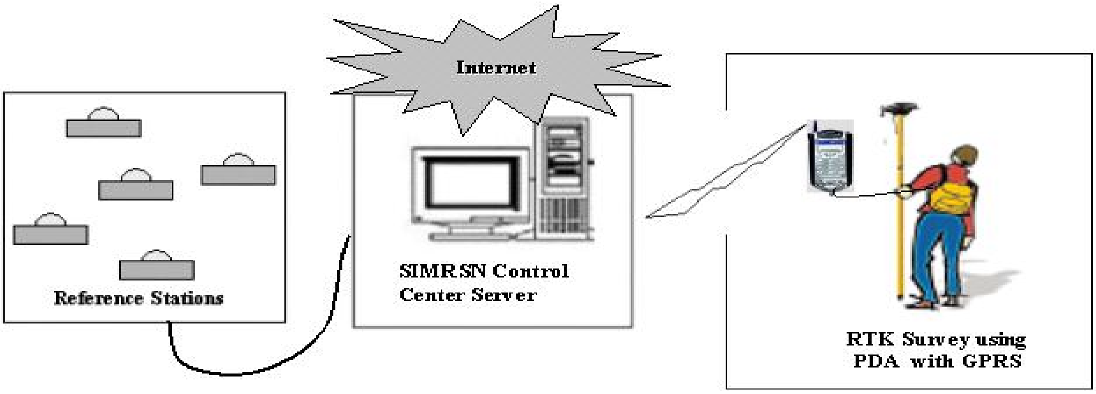

Fig.1. Setup of Internet-based VRS RTK positioning via GPRS (G.R. Hu et al, 2002).

Consequently, a GNSS system with Virtual Reference Stations (VRS) and Real Time Kinematic (RTK) through the Internet is being used in Romania and it is a NTRIP type (the system was developed by a specialized university in Germany). This system uses GPRS technology as a communication connection between the control center which is coordinated by the ANCPI and administrated by ROMPOS and the stations which are made use of by the users.

The observation files for each reference station are transmitted to a control center (ANCPI-ROMPOS), using the Internet. The user is equipped with a RTK receiver and a pocket PC with GPRS or a mobile phone, as shown in Illustration no. 1. This user uses the client software to connect to the control center server (ANCPI-ROMPOS) through GPRS Internet, and his approximate position is transmitted to the control center. The control center software (ANCPI-ROMPOS) automatically receives the user's approximate position and selects the closest reference station for the user as a master reference station (the permanent stations in the A class GNSS Network or the A class EUREF stations). The raw data from the reference station are then corrected as a geometrical position and improved by applying network corrections according to the user's approximate position. This is in a VRS data format, which is then transmitted as RTCM or CMR messages to the user's receiver through the GPRS Pocket PC serial port, at a rate of 9,600 bps or greater.

The receiver can then use these messages as is the case with the unique reference RTK stations.

Six testing points in the North and North-West part of Romania (Class A stations), with different distances from the master reference station have been used in order to test the new communication method, as shown in fig.2. Using the Internet and GPRS are of good omen and they bring a level of novelty and at the same time a saving in what concerns the price of data transmissions.

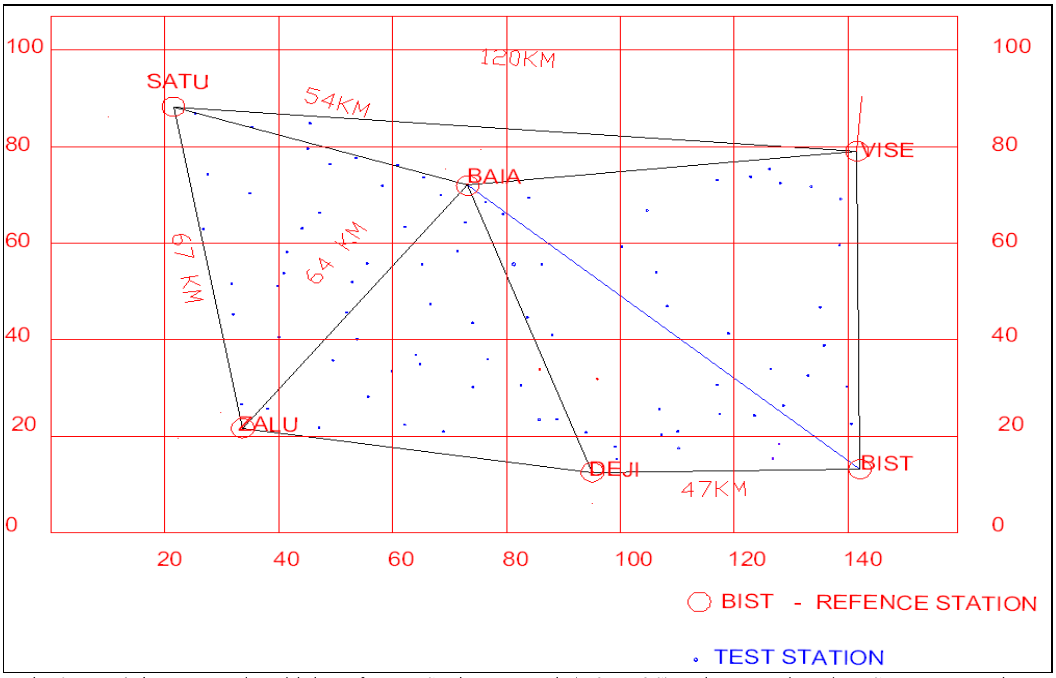

Fig. 2. România Integrated Multiple Reference Station Network (ROMPOS) and Internet-based VRS RTK test stations

The test site of the testing center identified as ŢAPU is considered to be the first example, 17,3 km away from the BAIA master reference station. A Leica 1200 with a dual receiver frequency was used together with a GX1230 antenna. This test was carried out in the time interval 10:23-15:45 UTC (12:23-17:45 local time), on July 25st 2010.
The real-time positions during the test have been continuously recorded in the receiver's memory. As a result, the real base position could be calculated before, if the connection to raw data is made.
The standard deviations (interior precision) of East path and North, and the height elements are 0.015m, 0.012m and 0.024m. As it was expected, the standard deviation in the horizontal position is a factor with 1,5-2 better than in height. The reason for the significant compensation in the height element is caused by the troposphere residual delay, which has a much greater effect than the horizontal coordinates.
One can observe that 99% horizontal (2D) position precision is smaller than 2 cm and 99% vertical position precision is smaller than 4 cm.
Besides precision, a crucial factor in using the operational usage of the RTK GPS is the speed with which it can initiate (e.g. to solve complete ambiguities). This is expressed as TTF (Time To Fix) or TTFA (Time To Fix Ambiguities) value (Edwards et al, 1999; Wübbena et al 2001). TTF of RTK refers to the observation moment which is required in order to solve complete ambiguities in real-time, after re-initiation.
Six seconds after each successful fix – or 2 minutes at the most, if the fix did not take place – the RTK receiver engine is totally reset. In consequence, a TTF analysis was possible. For the ŢAPU radio station, the time of the test series TTF for RTK vs. the number of satellites and a HDOP value.
The initiation time and the precision were analyzed on all testing stations which were used. In this section, the six trial stations were compared in order to evaluate performance based on

Internet VRS with RTK positioning in different locations in Romania, and the results are presented in Table no.1.

Test Station	Distance from Master Reference Station (km)	Standard Deviation (m)		
		Northing	Easting	Height
ŢAPU	17.3	0.015	0.012	0.024
SEINI	20.3	0.015	0.024	0.040
TURŢ	20.7	0.016	0.017	0.038
FELDRU	12.3	0.013	0.015	0.039
ODOREU	4.2	0.012	0.005	0.021
JIBOU	25.3	0.011	0.016	0.046

Initiation is much more difficult when there is a greater PDOP value and fewer satellites. The reason for greater dispersion at certain times is the weak satellite geometry, which leads to a higher PDOP value. It is responsible on many occasions, because ambiguities have to be set each time.

4. CONCLUSIONS AND SUGGESTIONS

The precise RTK positioning on longer distances requires a GNSS reference stations network, which presently has an average density of 60-70 km between them. In Romania, the Romanian Positioning System named ROMPOS has been used for almost 2 years. It is based on Internet with the use of VRS and RTK technology, GPRS positioning infrastructure and NTRIP which was developed and is used in Romania. The active operation of the multiple reference stations network in Romania and the various field tests in different locations in Romania confirmed the fact that horizontal precision is much better, roughly 2-3 cm, and the vertical one still depends on an exact determination of the quasi-geoid with 2-5 cm precision, which can occur with an initiation time of less than 1-2 minutes.
Based on the Internet, the system which uses VRS and RTK real-time positioning technology has a precision of centimeters and is used at the level of services in constructions, fast topography and GIS. With a better communication through the wireless technologies and RTK positioning using multiple VRS reference stations if used, we will be able to see it being used, very soon, in different domains across the world and especially in Romania.
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BIOGRAPHICAL NOTES

Lecturer.univ.dr.ing. Geodesy Gabriel BĂDESCU,
Birth date: March 27, 1973, Employment: The Northern University, Baia Mare, Teaching position: Lecturer, Undergraduate education: The Faculty of Geodesy, Bucharest, 1997, Scientific titles and activity: PHD Doctor of Engineering Sciences, with the major of Civil Engineering, in the area of expertise of Geodesy, Cartography, Fotogrammetry and Remote Sensing, Astronomy, GPS, GIS.
Professional activity: Geodesy engineer,

1997-1999, ISPE(RESEARCH AND DESIGN INSTITUTE OF ENERGY), Bucharest, Assistant, 1999-2005 TECHNICAL UNIVERSITY OF CIVIL ENGINEERING BUCHAREST, Senior lecturer, 2006-prezent, the teaching lines of Geodesy, Cartography, Fotogrammetry and Remote Sensing, Astronomy, GPS, geodetic network design and optimization , The Northern University, Baia Mare. Articles published abroad, in international field journals, in the books of some international scientific meetings; 170(60 ISI), Published Books, Manuals, Workbooks of problems and Tutorials: 10.

CONTACTS

PhD Lecturer.Gabriel N. BĂDESCU,
North University Baia Mare,
Department Geodesy of Mines
str.Victor Babes nr.62 A
430083 BAIA MARE, Maramures,
ROMANIA
Phone 0040262289226, Mobile 0040723899714 ; 0040749387147
Fax 0040262276153
Email gabrielbadescu@yahoo.com, gabrielbadescu3000@gmail.com
Web site: www.ubm.ro

CONTACTS

PhD. Associate Prof. Eng.Ovidiu Ştefan,
North University Baia Mare,
Department Geodesy of Mines
str.Victor Babes nr.62 A
430083 BAIA MARE, Maramures,
ROMANIA
Phone 0040262289226, Mobile 0040744630254
Fax 0040262276153
Email o.stefan@ymail.com,
Web site: www.ubm.ro

CONTACTS

Master.ing.Rodica BĂDESCU,
North University Baia Mare,
Department Geodesy of Mines
str.Victor Babes nr.62 A
430083 BAIA MARE, Maramures,
ROMANIA
Phone 0040262289226, Mobile : 0040741395916
Fax 0040262276153
Email badescu_rodica@yahoo.com
Web site: www.ubm.ro

CONTACTS

PhD University Professor Eng. ORTELECAN MIRCEA
ortelecanm@yahoo.fr

CONTACTS

PhD. Associate Prof. Eng. VERES IOEL SAMUEL
veresioel@yahoo.com