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Joining to EUREF permanent network with Multi GNSS CORS stations in Montenegro

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Abstract

In this paper will be introduced the project MontePN, financed by the Ministry of Science of Montenegro, wherewith the integration of Montenegrin scientific institutions into World and European scientific and professional organizations, participation in European projects, adoption of standards and usage of innovative potentials are improving. The subject of the project relates to an establishment of the infrastructure of a permanent station network with the possibility of receiving signals from GPS, GLONASS, Galileo and BEIDOU systems. The existing permanent station network on the territory of Montenegro, which realizes the national reference system, does not participate in the European Permanent Network (EPN). The national reference system of Montenegro is implemented through the existing permanent stations network and is related to the ITRS. One of the goals of the MontePN project is the to constitute a new permanent station that will fulfill the conditions for the accession of the EPN in order to achieve the preconditions for adopting the new national reference system ETRS89 in the territory of Montenegro, which is a practice in all European countries. The paper will describe the conceptual solution related to the method of stabilization of the new reference geodetic points of the permanent GNSS antenna in accordance with the rules of density increasements of the EUREF network and the given guidelines for connecting the GNSS networks of permanent stations to the EPN.

Introduction

Terrestrial Reference System (TRS) is a spatial reference system, materialized by points on the surface of a solid Earth, which rotates with the Earth in its daily motion in the space. The physical realization of this system represents the Terrestrial Reference Framework (TRF) based on the measurement at points which lead to obtaining the estimated coordinates. The spatial position of these points is in direct correlation with the geodynamic effects and phenomena, which are succumbing to time variations. The International Terrestrial Reference System (ITRS) defines the regulations and procedures for creating reference frames suitable for observations on the Earth's surface. The ITRS system and its realization ITRF satisfy the following conditions:

- It is a geocentric system, with commencement at the center of the Earth's mass, including the oceans and the atmosphere;
- The Z axis is in situated the direction of the Conventional Terrestrial Pole;
- The X axis is located in the direction of the cross-section of the reference Greenwich Meridian and the plane of the conventional terrestrial equator;
- The Y axis makes the right-hand orientation system with axes X and Z.

Within the of Article 22 of the Law on State Surveying and Cadastre of the Republic of Montenegro, the spatial reference system is defined as a terrestrial three-dimensional coordinate system, which, by definition of the coordinate origin, orientation of the coordinate axes, the scale, the unit of length and time evolution, coincides with the ITRS (International Terrestical Reference System).

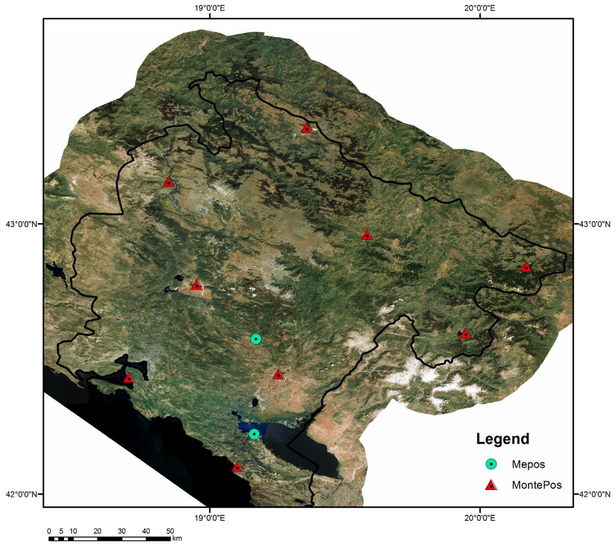

Figure 1. Disposition of existing networks of permanent stations on the territory of Montenegro

The national coordinate system of Montenegro is defined by the points of the network of permanent stations MontePos, which consists of nine continuously operating stations. MontePos is a part of the state infrastructure realized in 2005 by the Real estate administration as the patronizing institution for the area of geodesy in Montenegro. MontePos provides continuous real-time corrections as well as GNSS observations for positioning in subsequent processing. Post-processing data are compressed in Rinex format and placed on an internet site for user access. Network-RTK is a centimeter-accurate, phase-based, real-time positioning technology able to function at distances up to several tens of kilometers with equivalent performance as well as current RTK systems (*http://www.nekretnine.co.me*).

In late 2008, the Seismological Institute of Montenegro (today the Hydrometeorological and Seismological Service of Montenegro) started establishing the network of the geodynamic stations of Montenegro (Mepos). Two stations are operational, which include types of receivers Leica GPS GRX 1200 and antenna Leica AT504. Using the GNSS QC computer program, the quality of GPS data is checked, the performance of the receiver is tested, etc. The right side of the image below shows the graphical environment of the GNSS QC software. Data processing is performed using Bernese software. The purpose of the geodynamic network of Montenegro is a high precision observation in the spatial position changes of the stations in time, resulting from the kinematic characteristics of the segments of the Earth crust on which the stations are located, which can be directly correlated with the active local tectonic processes. Data from this network can also be used to study the regional geodynamic processes which condition the seismotectonic movements of regional scale.

The Seismology Sector in the continuous mode takes over the data of the national permanent network MontePos (http://www.seismo.co.me/GPS_mreza.htm). Receivers which refer to both networks have the capability to receive GPS and GLONASS satellites.

Project MontePN

The national reference system implemented through MontePOS is connected to ITRS. The European continental plate moves about 1cm per year compared to the ITRS. For this reason, the recommendation of the Commission for Reference Frames and subcommittees of EUREF is that in continental Europe the national reference systems bind to ETRS89 through the ETRF framework at a certain epoch.

By establishing a new permanent station through the MontePN project, which fulfills the requirement for access to the EPN, the preconditions for accepting the new national reference system in the ETRS89 coordinate system will be met, which is a practice in all European countries. The basic difference between the ETRS89 system and the ITRS is that this coordinate system is linked to the Euro-Asian plate with which it moves together. The annual shifts are considerably smaller as the moving of the whole plate is eliminated. By receiving signals from the Galileo navigation system, it would be possible to test the performance of a new system that brings certain novelty in comparison to other similar systems and an adequate transfer of knowledge to economic projects.

The aim of the MontePN project is to establish the infrastructure of a permanent station network with the possibility of receiving GPS, GLONASS, Galileo and Beidou signals. The infrastructure includes geodetic GNSS receivers and antennas that permanently monitor GNSS signals and are installed in stable geodetic markers, computer system for managing, receiving and transmitting data over the Internet, quality control and archiving. The location of the antenna should be chosen to ensure the stability of the reference geodetic point of the GNSS antenna, ie., to maintain a fixed position in three dimensions, and to minimize other surface effects that may degrade the accuracy of the measurement.

In accordance with the recommendations for an increase in density the EUREF network and given guidelines for linking GNSS permanent network stations to the EPN, the establishment of MontePN will be conducted in accordance with the tendency to access the EPN. After completing sufficient conditions for joining MontePN to the EPN, an official procedure for receiving and registering an operation center will be launched. During the project, after the commissioning of the system, the performance of the Galileo satellite system will be analyzed and the possibilities of application in government agencies, public companies and other economic sectors interested in precise positioning will be performed.

The key activities of the project are: establishment of the network of permanent stations of MontePN, joining the station to EPN, performance analysis and the possibility of using the Galileo system for the needs of commercial projects and government agencies.

Concept of realization

The primary goal of the EPN Densification Working Group is the realization of a continental scale European network of permanent stations, with highly precise determined long-term positions and velocities of the stations in a homogeneous reference system, with comparable data quality on the surface from Greenland to Crete.

Considering the fact that Montenegro does not participate with any station within the EPN network, in the initial phase it is planned to set up a new permanent station at the University of Donja Gorica in Podgorica, which has the capability to receive GPS, GLONASS, Galileo and Beidou signals.

Figure 2. Location of the permanent station GNSS antennas Monte PN (left) with locations of existing EPN stations (modified image from Google Earth)

The proposed solution in the form of equipment selection for the CORS system relates to the following:

- ❑ CORS station SinoGNSS M300 mini
- ❑ Choke ring antena SinoGNSS AT350
- ❑ GNSS rover SinoGNSS T300
- ❑ Data collector SinoGNSS R500
- ❑ Software for CORS Station BKG Standard Ntrip Caster
- ❑ Cloud server

Adjustable CORS station The M300 mini has the most modern GNSS module K708 and an external module for connecting through the computer network GL-AR-150, while BKG Standard NtripCaster is an open source software system. The antenna is mounted on a pillar with a plate for forced centering, at whose base is a cabinet for storing a CORS station with a 220 V supply and a network connection for the Internet near the pillar.

Signal Tracking	Performance	Positioning Specifications	Communications	Data Format & Other Performances
Number of channels: 496	Cold start: <50s; Warm start: <45s; Hot start: <15s	PP: 2.5mm+0.5ppm HZ 5mm+0.5ppm V	TNC connector for GNSS anntena	I/O: RTCM3x(with MSM messages);
GPS: L1 C/A, L1P, L2C, L2P, L5	RTK Initialization time: <10s	Long Obs Static: 3mm+0.1ppm HZ 3.5mm+0.4ppm V	2 DB9M serial connectors	Output: NMEA (20Hz), raw binary (100Hz); BINEX
BeiDou: B1, B2, B3	Signal reacquisition: <1.5s	SB RTK (<30km): 8mm+0.5ppm HZ 15mm+0.5ppm V	USB port	Aluminum alloy housing
GLONASS: L1 C/A, L1P, L2 C/A, L2P	Initialization reliability: >99.9%	E-RTK (<100km): 0.2m+1ppm H 0.4m+1ppm V	LAN Ethernet port, NTRIP v2 server	Designed to survive a 1m drop onto concrete
Galileo: E1, E5a, E5b	Velocity accuracy: 0.03m/s	DGPS: 0.4m 3D RMS	SIM card slot	Remote access and config. singSSHprotocol
SBAS: WAAS, EGNOS, MSAS, GAGAN	Acceleration: 4g; Overload: 15g	SBAS: 1m 3D RMS	2 PPS output	Ability to work using dynamic IP adress
	Time accuracy: 20ns	Standalone: 1.5m 3D RMS	Event Marker input	Ability to connect with meteo station

The characteristics of the selected GNSS antenna refer to the following:

- Axial Ratio:<3dB
- Azimuth Coverage:360°
- Noise Figure: <2
- Gain at Zenith:7dBi
- Phase Center Accuracy:1mm
- LNA Gain: 50dB±2dB
- Noise Figure:<2dB
- VSWR Output:<2
- Operation Voltage:3.3-12VDC
- Operation Current:<55mA
- Ripple:±2dB
- Group Delay:<5ns
- Connector:TNC F
- Weight:<7kg
- Operating Temp.:40°C to +85°C
- Storage Temp.:55°C to +85°C
- Humidity: 95% No-condensing

Figure 3. The building of the University of Donja Gorica in Podgorica as the location of the permanent station MontePN

In accordance with the recommendations on the establishment of permanent stations International GNSS Service, the location selection is in direct correlation with satellite visibility, stability, multiple reflection and interference, taking into account the fulfillment of the following conditions:

- absence of physical hindrance and obstacles in all directions with a vertical angle greater than 50;
- the minimum envisaged changes in the environs, in terms of existing or new facilities, plants, etc.;
- the stability of the substrate, ie the choice of a place that is not susceptible to movement due to subsidence and landslides, or vibrations due to intensive traffic;
- the absence of large reflecting natural or artificial objects in the immediate environment, such as metal and glass surfaces, wire fences, pools, lakes and still water;
- long-term location with minimal probability of relocation;
- the absence of strong radiation sources in the immediate environment, such as high-voltage lines, substations, radar stations or wireless communication devices.

The planned control center will have adequate hardware and access to the Internet with sufficient bandwidth. The computer server on which the corresponding permanent network management software is installed will have adequate protection against unauthorized access, guaranteed 24/7 power supply and Internet access.

The GNSS permanent station management software will perform the following tasks:

- full telemetric and direct control of permanent stations;
- download original GNSS data, their analysis, archiving and distribution;
- generate log files about all occurrences;
- distribution of RTK and DGPS network connections to ultimate users;
- administration of user accounts;
- estimation of dominant measurement errors;
- monitoring of stations and their stability;
- providing services in real time and for subsequent processing;
- the ability to check user access by an authorized person.

As an alternative to establishing a control center with high maintenance costs and network infrastructure, it is proposed to lease infrastructure with professional ISP providers. Cloud or dedicated servers ISP providers offer services that include:

- a hardware leasing;
- a redundant power supply system;
- Infrastructure with the cooling system and maintenance of humidity as well as fire protection system;
- functionality and guaranteed availability of 99.95%;
- guaranteed privacy of data and change of resources optionally;
- using a fixed public IP address and domain registration;
- connector up to 100Mbps port;
- using a guaranteed flow of Internet link;
- insight into the flow of realized Internet traffic through the web interface;
- quick intervention in case of hardware damage;
- Backup and technical support.

System administration will perform secure internet communication and remote access from any PC regardless of the operating system, using devices and tablets with Android operating system. This will enable efficient and flexible management of servers and software services, insight into status, quick interventions and the ability to provide 24/7 support. The control center will always be with the administrator, wherever it is, and the technical support of the ISP provider will provide all the prerequisites for the functioning of the server.

The specified station will be permanent and continuously operational, including compliance with all recommendations and procedures defined in the "Guidelines for EPN Stations & Operational Centers" and "Procedure for Becoming an EPN Station". An application procedure for obtaining a 4-character identification code and DOMES number request for the station is in the progress. Given that the national coordinate system in the territory of Montenegro does not apply to ETRS89, the coordinates of the XYZ station within the ETRS89 system will be determined in relation to other EPN stations in the environment. In the application process, the following data will be presented:

- the a priori station coordinates;
- the station location compared to other EPN stations;
- the receiver and antenna (+radome) type using standard IGS naming;
- the GNSS (GPS/GLONASS/Galileo) tracked by the receiver;
- the calibrations available for the antenna/radome pair (type mean calibration from the IGS or individual calibration by a recognized calibration agency, e.g. GEO++ or University of Bonn);
- the planned data flow (primary and secondary data centre) for hourly and daily uploads and broadcasters for real-time streams;
- the station installation date and availability of historical data.

Conclusion

Montenegro does not participate with any station within the EPN network, so this will significantly contribute to the realization of the international project EPN Densification. Products EPN Densification will be used in close cooperation with the EUREF Deformation Models working group to support ETRS89 not only in a stable part of Europe, but also across areas that are under constant tectonic influences, such as the Mediterranean region. The velocities of the stations which represent the products of this project will be useful for general and specific tectonic studies in order to understand the processes in regions susceptible to deformation. The current network of permanent stations on the territory of Montenegro is not included with any of its points into the Central European Geodynamic Reference Network (CEGRN) as opposed to the surrounding countries.

Accepting of the ETRS as an official system in Montenegro, according to the EUREF recommendations, requires the amendment of the Law on State Surveying and Cadastre and the implementation of the appropriate strategy for transition to a new framework. In addition, the MontePN project should become a scientific development base covering multidisciplinary areas of research (spatial planning, geodetic surveying, precise navigation, geodynamics and geo-hazard, precise agriculture, forestry, and many others).