High Performance Virtual GPS Permanent Stations

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Abstract: *Recent developments in differential GPS (DGPS) services have concentrated mainly on the reduction of the number of permanent reference stations required to cover a certain area and the extension of the possible ranges between reference and rover stations. Starting from networked DGPS stations where all stations are linked to a central control station for data correction and modeling, the most advanced technique nowadays is based on the virtual reference station (VRS) network concept. In this case, observation data for a non-existing "virtual" station are generated at the control center and transmitted to the rover. This leads to a significant improvement in positioning accuracy over longer distances compared to conventional DGPS networks.*

1. Introduction

High accuracy Real-Time Kinematic Positioning with GPS is one of today's most widely used surveying techniques. But, the effects of the ionosphere and troposphere, which create systematic errors in the raw data, restrict its use. In practice, these mean that the distance between a rover receiver and its reference station has to be quite short in order to work efficiently.

In the countries from Europe, the GPS reference station networks exist, and provide data to individual users. For RTK, due to the need for short distances between reference and rover, the networks need to be very dense. Although of sufficient density for good DGPS, some national networks are just not dense enough to provide complete coverage for RTK.

The use of a network of reference station allows modeling the systematic errors in the region and thus provides the possibility of an error reduction. This allows a user not only to increase the distance at which the rover receiver is located from the reference, it also increases the reliability of the system and reduces the RTK initialization time. The concept can be used not only to set-up new networks, but also to improve the performance of old, established networks.

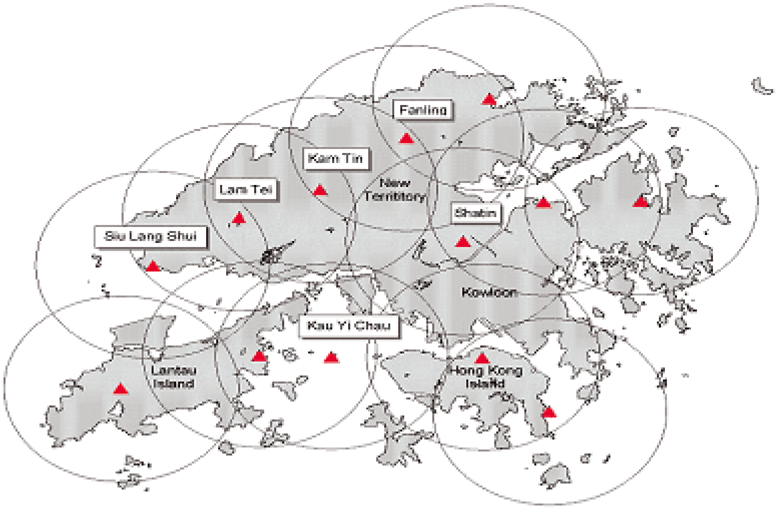

Fig.1 Virtual Reference Stations in Europe

Into the European context is required the adjustment of the Romanian strategy in the GNSS field according to the necessities and tendencies manifested in the technical and scientifically domain of the applications and positioning in real time.

2. The Reference stations in Romania

According to the development tendencies of the services at European and global level of the GPS technology, after 1990 appeared even in Romania the technology of global positioning (GNSS). At present, the most used GNSS system into our country is the NAVSTAR-GPS system.

For the long-term requirements of the Geodesy it was projected and accomplished, in our country, a National Network of Permanent GPS Stations (RN_SGP).

The main objectives aimed for the accomplishment of this network were:

- Realization of an active space-temporal reference system;
- Using the satellite observations for determining the position of the points from the National Geodesic Network;
- Using the satellite observations for determining the position of the points from other networks of planimetric and altimetric support;
- Using the satellite observations for determining the position of some points of interest in different fields: Topography, Cadastre, GIS, Cartography;
- Using the satellite observations in the scientifically research.

History of the realization of the RN-SGP from Romania had the following stages:

- **Stage 1 –** year 1999- realization of the first permanent GPS station, within the Faculty of Geodesy from Romania;
- **Stage 2 –** 2000-2003 – establishment of the RN-SGP as a "passive" network including a number of 5 stations installed at: Braila, Cluj, Sibiu, Suceava , Timisoara;
- **Stage 3 –** 2004-2005 – establishment of the Extended National Network of Permanent GPS stations as active network of gathering/transmission of the data and extension of that with other stations installed at: Craiova, Constanta, Deva, Baia Mare, Bacau, Sfantu Gheorghe, Cluj, Oradea;
- **Stage 4 –** 2005-2006 – Modernization and continuation of the RN-SGP extension through installation of 10 new permanent GPS;
- **Stage 5 –** 2006-2007 – Continuation of the RN-SGP extension through the installation of new permanent stations that will ensure a cover area of 70 km around of those on the whole territory of Romania;
- **Stage 6 –** 2007-2008 – Modernization and continuation of the RN-SGP extension, simultaneous with the preparation for the learning of the new technology provided, the European navigation system (Virtual Reference Station, GALILEO).

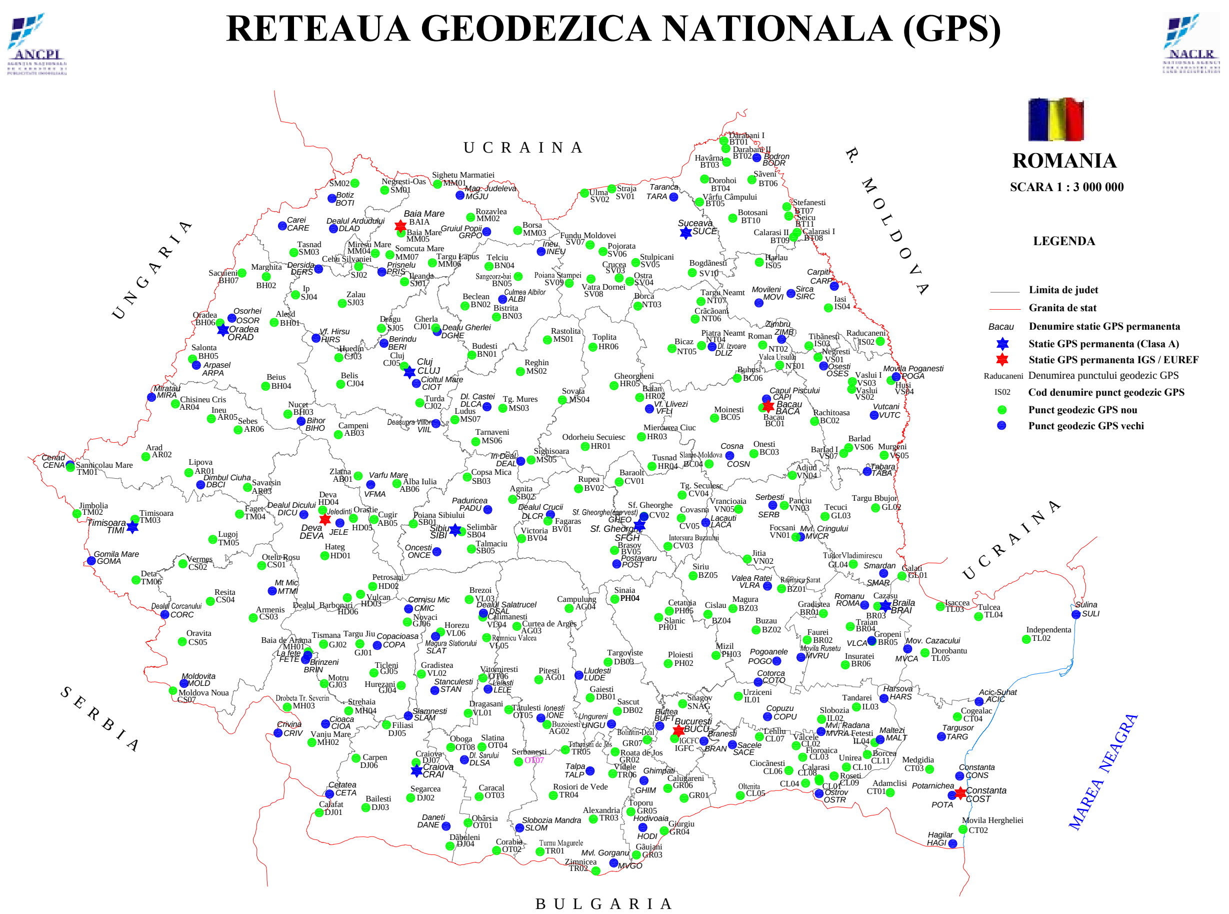

Fig.2 The National Network of Permanent GPS Stations in Romania

3. The Virtual Reference Station Concept

The Virtual Reference Station concept is based on having a network of GPS reference stations continuously connected via data links to a control center. A computer at the control center continuously gathers the information from all receivers, and creates a living database of Regional Area Corrections.

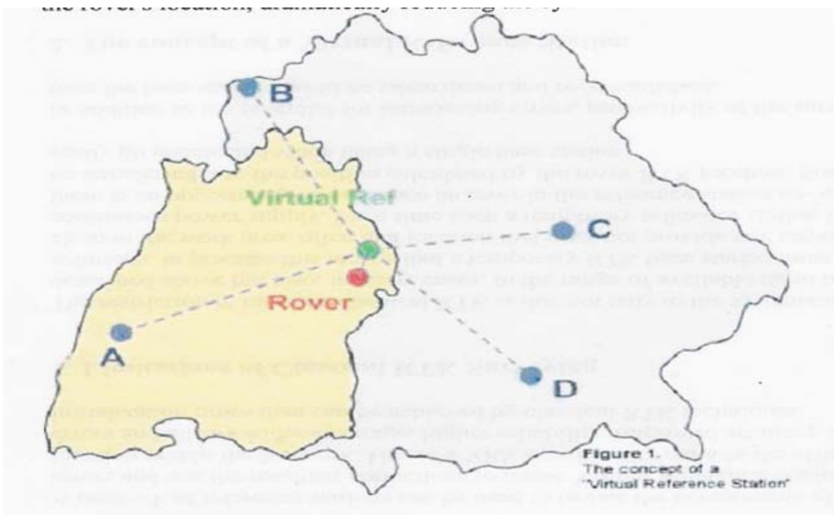

Fig..3 The concept of a Virtual Reference Station

These are used to create a Virtual Reference Station, situated only a few meters from where any rover is situated, together with the raw data, which would have come from it. The rover interprets and uses the data just as if it has come from real reference station. The resulting performance improvement of RTK is dramatic.

The implementation of the VRS idea into a functional system solution follows the following principles. First we need a number of reference stations, which are connected to the network server via some communication links.

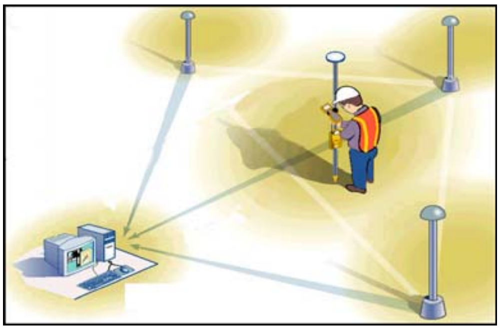

Fig. 4 Network Sketch

The GPS rover sends its approximate position to the control center that is running GPSNet. It does this by using a mobile phone data link, such as GSM, to send a standard NMEA position string called GGA. This format was chosen because it is available on most receivers.

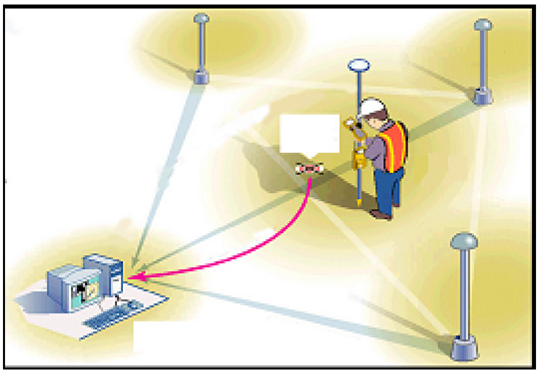

Fig. 5 Rover transmits NMEA message for VRS position to the network server

The control center will accept the position, and responds by sending RTCM correction data to the rover. As soon as it is received, the rover will compute a high quality DGPS solution, and update its position. The rover then sends its new position to the control center.

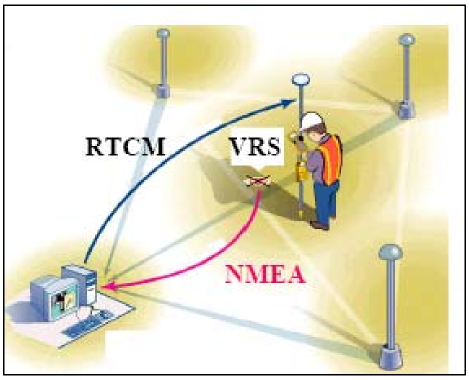

Fig. 6 Network server transmits RTCM correction stream for VRS position

The network server will now calculate new RTCM corrections so that they appear to be coming from a station right beside the rover. Transmission can be directly from the stations or via other suitable locations. Communication for transmission of RTK and DGPS data will usually be by radio, high-speed wireless (GSM, GPRS, etc.) or even by the Internet.

3.1. Setting up a reference station

There are significant advantages in setting up reference stations on buildings, as power and telephone connections are usually available and the equipment should be relatively safe.

Buildings are usually suitable for reference stations that form part of a geodetic control network, that support surveying and engineering applications, and that transmit RTK and DGPS data to RTK and GIS rover units.

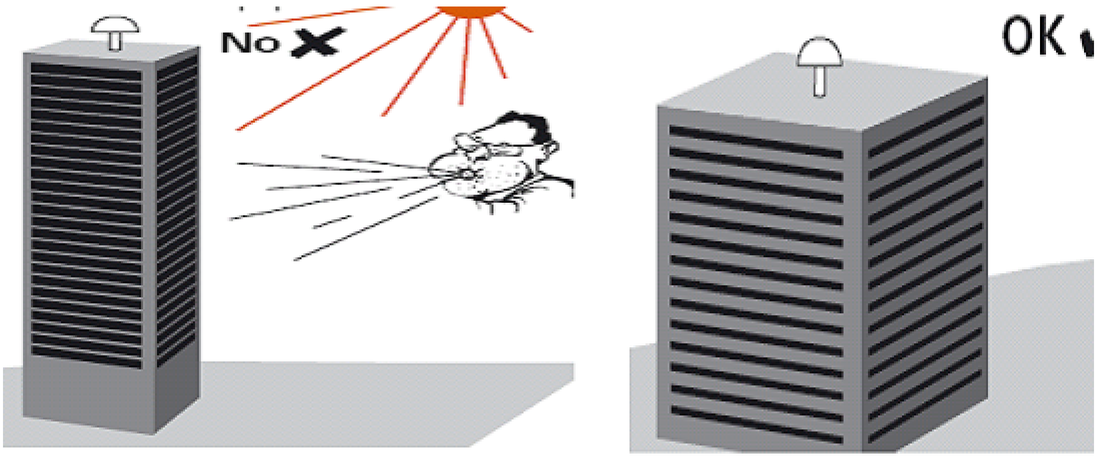

Fig. 7

Although it is usually advantageous to place the GPS antenna as high as possible, towers and thin, tall, skyscraper-type buildings are often not suitable as they may sway in strong winds. In hot climates, very tall structures may also deform slightly due to expansion caused by the sun. Flat-roofed buildings of medium height with a relatively large base will normally be very stable and suitable for reference stations.

3.2. Accuracy of reference stations

When receiving standard RTK data from a reference station, an RTK rover can usually operate successfully at ranges up to about 30km in reasonably favorable conditions. In some regions of the World, where conditions for RTK are often exceptionally good, ranges of about 40km or more may be achieved at times.

In developed areas with high populations, such as around metropolitan areas, most GPS survey work will be carried out with RTK. Thus the main requirement will be to provide complete RTK coverage.

Purely as an example, imagine that RTK/DGPS services have to be provided throughout an area of about 60km x 60km. A relatively simple solution would be to have 4 or 5 reference stations spaced about 30km apart. This would provide good RTK coverage throughout the area and the accuracy of RTK is normally quoted as about 10mm+1ppm root mean square.

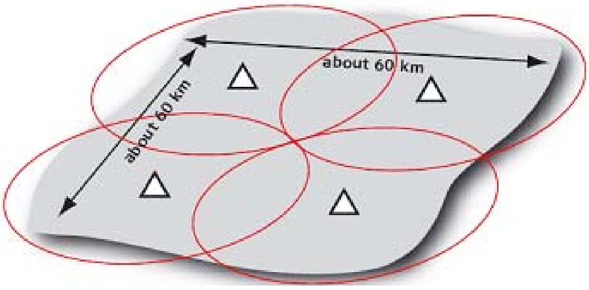

Fig. 8

Thus the positional accuracies that can be expected are approximately as follows:

- At 1km: 10mm + 1mm = 11 mm
- At 10km: 10mm + 10mm = 20mm
- At 30km: 10mm + 30mm = 40mm

For each location, the RTK software selects the nearest reference station, performs a geometric displacement to the location of the VRS, interpolates and applies corrections for ephemeris, troposphere and ionosphere, generates corrected RTCM messages and transmits them to the rover.

With these corrected RTCM messages it is possible to perform improved RTK positioning within the network. The expected Horizontal error is 1-3 cm using distances of approximately 50km between the reference stations.

3.3. Operating Virtual Reference Stations in Romania

The first Virtual Reference Stations installed in Romania are located:

- In Bucharest, on the top of the building of the company S.C. TopGeocart S.R.L;

Fig. 9 Reference Stations in Bucharest

The Permanent references Station GNSS, type Leica GRX1200 was installed in 2005, having the working range around 30-40 km and transmits RTK data through radio or GSM.

- In Timisoara, on the top of the building of the company S.C. Black Light S.R.L;

Fig. 10 Reference Stations in Timisoara

Is the same type as one from Bucharest and has the same parameters, being installed in 2006.

4. Conclusions

The use of a network of GPS Reference Stations to create VRS for RTK has the following advantages over classical, single station RTK positioning:

- Systematic errors are significantly reduced resulting in extended operating range with improved initialization and accuracy.
- Permanent (or semi-permanent) Reference Stations remove the problems associated with physical security, power supply, environmental conditions and communications.
- Productivity is increased through one-person surveying and no time is lost in setting up a Reference Station.
- Integrity of data is continuously monitored before it is sent to the user.
- Potential for gross errors is removed. The coordinate frame is established by the network of Reference Stations and network baselines are continuously checked for consistency

Appendix

RTCM – Radio Technical Comission for Maritime (services)
NMEA – National Marine Electronics Association
DGPS – Differential GPS
GNSS – Global Navigation Satellite System
GMS – Ground Monitoring Equipment

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