THE ACCURACY OF GEODETIC MEASUREMENTS USING VIRTUAL REFERENCE 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 modelling, 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.*
Today, with the widespread acceptance of high-precision GPS measurement techniques, virtual GPS reference stations are being established all over the world in ever increasing numbers. They are used to monitor Earth's crust, to provide geodetic control, to support surveying, engineering, GIS data collection, machine control and precise positioning, as well as to monitor natural and man-made structures. GPS reference stations provide the control needed for a wide variety of applications.

Keywords: *GPS, virtual reference station, RTK*

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 (mobile) receiver and its reference station has to be quite short in order to work efficiently.
In some countries GPS reference station networks exist, and provide data to individual user. 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 stations instead of a single reference station allows to model 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. The network error correction terms can be transmitted to the rover in two principle modes:

- A Virtual Reference Station mode as described below. This mode requires bi-directional communication. The basic advantage of this mode is that it makes use of existing RTCM and CMR standards implemented in all major geodetic rover receivers and thus is compatible with existing hardware;
- A broadcast mode, in which the error corrections due to atmospheric and orbit effects are transmitted in a special format, which requires changes of rover receiver hardware or additional hardware to convert the non-standard format to a standard RTCM data stream before used by the rover.

2. Aims and background

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.

These are used to create a Virtual Reference Station (VRS), 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 implementation of the VRS idea into a functional system solution follows the following principles. First we need a number of reference station (at least three), which are connected to the network server via some communication links.

Fig.1.The network of Virtual Reference Station

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. 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.

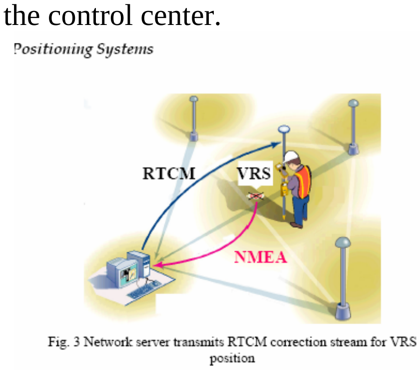

Fig.2.Rover transmits NMEA message for VRS position to the network server

The network server will now calculate new RTCM corrections so that they appear to be coming from a station right beside the rover. It sends them back out on the mobile phone data link. The DGPS solution is accurate to +/-1meter, which is good enough to ensure that the atmospheric and ephemeris distortions, modelled for the entire reference station network, are applied correctly.

3. Results and discussions

A network of continuously operating GPS reference stations is more efficient than a traditional triangulation and traverse network. The stations can be set up at convenient locations in areas where they are needed. Network geometry is not as critical as with traditional networks, and the accuracy is higher and more consistent. Users set up their field receivers in the areas in with they are working, download reference station data via the Internet, and compute their positions. The stations can also transmit RTK and DGPS data for direct use by RTK and GIS field rover equipment. Such a network can be of almost any size. Whilst one or two stand-alone reference stations may be all that is required for a local area, town, opencast mine or engineering site, a multi-station network will usually be needed to provide full GPS service coverage for a large county, region or entire country.

GPS reference stations and networks can be used in many ways for many applications. Stations and networks can be set up and configured for just one particular application and one user group. Or they can be designed to be multifunctional to support a wide range of applications and a multitude of users.

A single reference station may be perfectly sufficient for a small locality. A multi-station, multi-purpose network will often be preferred for an entire region. The permutations are endless.

One or more permanent reference stations will be needed whenever GPS surveying or monitoring has to be carried out repeatedly over the same area for a long period of time.

The GPS receivers at reference stations run continuously. The raw code and phase measurement data are usually logged internally in files of specified length. Depending on the application, the file length can be set to any required value from a few minutes to several hours or even to a full day. Reference station software running on a computer controls the receivers and downloads the data files at regular intervals. If required, the raw data can also be streamed continuously, second by second, from the receivers to the server. The reference station software running on the server converts the data to RINEX and produces compressed RINEX files. The RINEX files are pushed to an FTP server for easy WEB access by the GPS user community and are also archived for safekeeping.

A server running reference station software can control a single receiver at a stand-alone reference station or an entire network comprised of many receivers. In case of a single stand-alone station, the computer will often be connected directly to the receiver. In case of a multi-station network, the server will usually be at a control center and connected to the receivers by telephone, LAN, WAN or Internet. Once set up configured, the stations and network will run fully automatically.

A main requirement today is to provide the data needed by real-time survey and GIS rover equipment. The receivers at the reference stations can output data in standard RTCM formats and in other proprietary formats (CMR, CMR+, etc.) for transmission to and use by RTK and GIS field rover receivers. Transmission can be directly from the stations or via other suitable locations. Communications for transmission of RTK and DGPS data will usually be by radio, high-speed wireless (GSM, GPRS, CDMA etc.) or even by the Internet.

In GPS/GLONASS reference station networks the distances between adjacent reference stations often exceed 50 kilometres. The resulting baseline length between a rover station and the closest reference station is too long for cm-level positioning within short observation periods.

Shorter baselines can be created by installing a temporary reference station in the area to be surveyed. Such temporary reference stations can be substituted by virtual reference stations computed from the observations of the surrounding real reference stations. The position of the virtual reference station can be selected freely. Its distance to the rover stations should not exceed a few kilometres. Usually one virtual reference station is computed per local area and working day. The rover stations coordinates will then refer to the geodetic datum (e.g. WGS 84 or ETRS 89) which had been used before in positioning the real reference stations.

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

5. References

1. *Grecea C., Bălă A. – High Performance Virtual Permanente Stations, Journal of Geodesy and Cadastre, RevCAD nr., Alba Iulia, 2007;*
2. *Euler H J, Seeger S, Zelzer O, Takac F, Zebhauser B E - Improvement of Positioning Performance Using Standardized Network RTK Messages, ION GPS San Diego USA, 2004;*
3. *Herbet Landau, Ulrich Vollath, Xiaoming Chen – Virtual Reference Station Systems, Journal of Global Positioning Systems, 2002;*
4. *Euler H J, Keenan C R, Zebhauser B E, Wubbena G - Study of a Simplified Approach in*
5. *Utilizing Information from Permanent Reference Station Array, ION GPS Salt Lake City*
6. *USA, 2001;*
7. ** * * www.leica.com*