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PREPARATIONS FOR THE INTRODUCTION OF FOREIGN PERMANENT STATIONS INTO SK*POS*

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Abstract

Compliance with the *EUPOS* document Guidelines For Cross-Border Data Exchange represents the basis for the possibility of foreign permanent station introduction into *EUPOS* member countries national positioning services. Moreover, computation of coordinates of those stations homogenous with a national solution, as well as the monitoring of quality of their connections to service centre software is also very essential before their introduction. As an important item can be considered also GPS/GLONASS capability of selected close border stations especially in dual system positioning services because they can reduce this dual system capability in affected areas. The present paper deals with experience of preparing the introduction of foreign permanent stations into Slovakian Positioning Service (SK*POS)*, considering the above-mentioned remarks. The conclusion is that suitably selected foreign permanent stations can improve the quality of DGNSS and Network RTK measurements in border regions.

Introduction

Nowadays many countries, which use Global Navigation Satellite Systems (GNSS) for positioning and navigation purposes, prefer network Real-Time Kinematic (RTK) concepts despite conventional single station RTK. One of the main reasons of this transfer is that network RTK enables us to perform better modelling or rather better elimination of distance dependent systematic errors caused especially by troposphere or ionosphere (Janssen, 2009). From the same source we know that maximal distance from the base station to a rover is, if conventional single station RTK is used and reliable results are expected, only 10-20km. After its exceeding, the accuracy of the results falls off. Advantage of the network RTK is the achievement of the same quality of the results throughout the whole area where the permanent stations are systematically distributed. Optimal and recommended distance between neighbouring permanent stations, according to *EUPOS* standards (EUPOS, 2006), vary between 50-70km and depends on topography and networking software performance. But modelling of systematic errors is correct only inside the area of permanent stations (errors are interpolated). Outside the area, the method for the error source modelling is changed from interpolation to extrapolation (statistically lesser accuracy method) and due to the fact that external geometrical information is missing lower quality of results is expected and descends to the quality of single station RTK method.
If we take into account that it is usually impossible to distribute permanent stations of one country to geometrically sufficient constellation fulfilling the above mentioned condition of interpolation, especially despite of the shape of the country or possibility/impossibility to establish stations everywhere (nature obstruction, sea boundary, power supply needs etc.), it is essential to cooperate with neighbouring countries and involve their border permanent stations into national solution to assure and guarantee the same quality for RTK measurements around the whole territory.

Recent situation in Slovakia

Slovakian Positioning Service (SK*POS*), as an integral part of *EUPOS*, recently consists of 26 GNSS permanent stations equally distributed around the whole country. Despite the homogenous distribution of the stations, their constellation does not ensure the full inclusion of the whole country to one zone, where only the interpolation method for modelling of systematic errors is used. There are also few regions where extrapolation has to be used (see red colour areas on fig.1). Those regions are situated in border areas and bring worsened conditions for SK*POS* users (rem. the results quality still lets on required centimetre accuracy). For research of RTK measurements condition and quality degradation in those areas, an experiment with continual RTK measurements on GKU1 marker was performed.

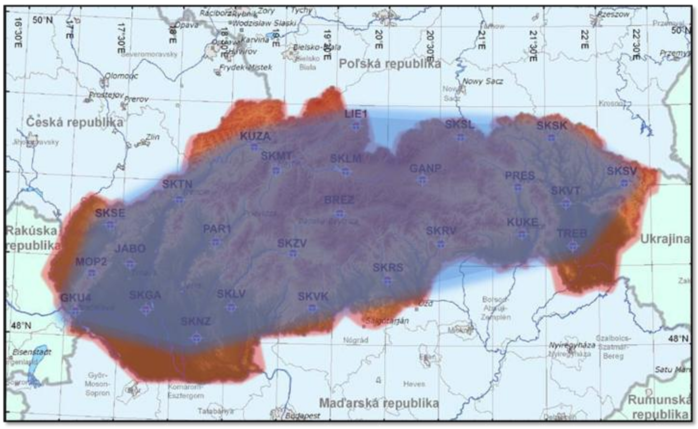

Fig.1 Regions of Slovakia where interpolation (blue area) or extrapolation (red area) is used for systematic error source modelling (status October 2011).

Experiment with continual RTK measurements on GKU1 marker

Original aim of the experiment was not the confirmation of RTK measurements quality degradation in border regions but the monitoring of performance of long (taking several days) continual RTK measurements. For the experiment a GKU1 marker was selected, which is situated on the roof of the Geodetic and Cartographic Institute (GKU) close to the SK*POS* reference station GKU4 (around 20 meters). The Marker GKU1 was for the experiment equipped with a standard rover receiver with an integrated antenna. From the philosophy of interpolation/extrapolation systematic error source modelling point of view this was the situation when the correct interpolation method was used (see fig. 2a where GKU1 marker is inside network of permanent stations). During the few days of continual RTK measurements there occurred one moment, when in the GKU4 reference station was an unplanned outage, so for a few hours the GKU1 marker became a station which was outside the correct interpolation territory (see fig. 2b).

a.) b.)

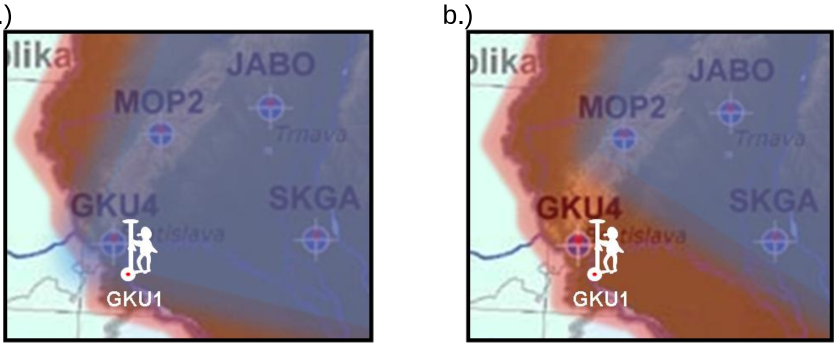

Fig.2 Situations when GKU1 marker is inside (left) or outside (right) of the SK*POS* network area.

When we had depicted the results of this continual RTK measurement on the GKU1 marker separately for horizontal and vertical position into graphs, we recognized that several values were unexpectedly systematically shifts. So we had decided to use different colours for visualisation of RTK measurements when GKU4 reference station was included (blue dots on fig. 3) and was not included (red dots on fig. 3) into the inside part of SK*POS* network. The resulting graphs confirmed our expectation. The horizontal as well as vertical quality of resulting coordinates for the moments when on GKU4 station had been an outage was evidently worse, but not very dramatically only in centimetres (see fig. 3).
Results from the presented experiment fully confirm the fact that not involving the border permanent stations from neighbouring countries may decrease the quality of RTK measurements in areas outside the national network towards the country borders. Quality is falling off with enlarging the distance from the network border and affects RTK measurement also by longer initialisation.

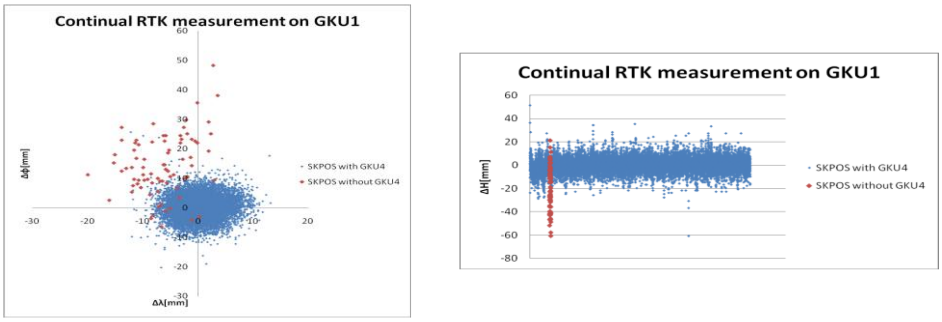

Fig.3 Results from continual RTK measurement on GKU1 marker.

Preparations for the introduction of a foreign permanent station into SK*POS*

Since SK*POS* as one of *EUPOS* member countries has an enormous interest to comply with all *EUPOS* standards and documents, where in one point it is stated that *EUPOS* member country services are designed so, that homogenous DGNSS and network RTK positioning can be guaranteed throughout the whole EUPOS coverage area (EUPOS, 2006), it was decided few years ago to start preparations of foreign permanent station introduction into national SK*POS* solution.

Preparation works were divided into three phases:

1. Bilateral negotiations with each border country about cooperation in the field of GNSS border permanent station data exchange,
2. Introduction of foreign permanent stations into SK*POS* solution for test purposes,
3. Testing and monitoring of the SK*POS* solution with integrated foreign permanent stations.

Bilateral negotiations with border countries

The first step towards starting the border permanent stations data exchange was signature of bilateral agreements which confirms their legal usage. By signing the agreement both sides accept that they will cooperate with each other and both sides will share selected border permanent stations data in a defined format (usually RTCM, and RINEX) and other related information of importance. In that way bilateral contracts with all of Slovakian border countries were signed during 2007 - 2010 . Totally 20 foreign permanent stations can enter into SK*POS* right now. There are 7 stations from Hungarian GNSSNet.hu, 2 stations from Austrian APOS, 2 stations from Ukrainian ZAKPOS, 4 stations from Czech CZEPOS and 5 stations from Polish ASG-EUPOS. Their distribution is shown on fig.4. From the picture is also evident how can foreign stations help to incorporate whole regions of Slovakia into homogenous solution for network RTK usage, despite the recent situation depicted on fig.1.

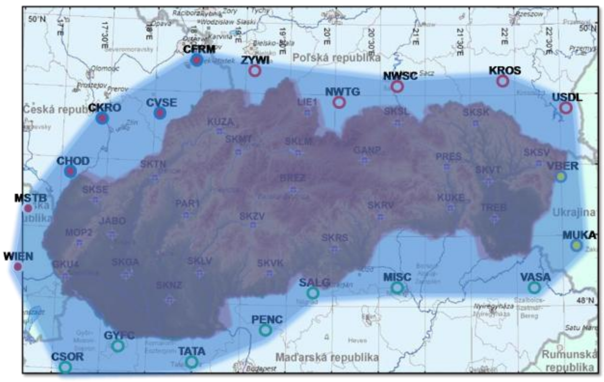

Fig.4 Distribution of foreign permanent stations with potential for incorporation into SK*POS* solution

Introduction of foreign permanent stations into SK*POS* solution for test purposes

For correct foreign border permanent station introduction into national solution it is important to know all relevant information about stations which are usually available in station site log files. Site logs

consist of all useful information like antenna and receiver type, antenna height, ARP etc. and also contain full history of its changes. Our advantage as a *EUPOS* member state is, that we could use that information from *EUPOS* Station Database (ESDB, 2011). For non *EUPOS* countries classic email exchange communication was used. It is also very important to get and use antenna PCV values from individual calibration if this exists and to keep all the information up to date.
Another very important issue is computation of coordinates for all foreign permanent stations homogenous with the national reference frame. At first we thought that it will be sufficient just to adapt the coordinates sent from neighbouring service centres, but later (after some comparison of ours own computed coordinates of foreign stations with the sent ones was performed) we have decided to use coordinates for all stations only from our own solution. We recognized that all border countries, despite the fact they all are using ETRS89 coordinate system, use its different reference frame or epoch and this caused differences on cm level.
For our own coordinate determination the scientific Bernese software (Dach et al., 2007) is used, in which all stations (SK*POS*, EPN, foreign etc. see fig. 5) are computed together. Strategy of computation can be found e.g. in (Droščák a Ferianc, 2010). Coordinates from our own solution is from time to time compared with neighbouring services results to ensure that there are no gross errors. For future *EUPOS* Combination Center (ECC) project (Kenyeres et al., 2011) can serve as a very good tool for this kind of comparison.

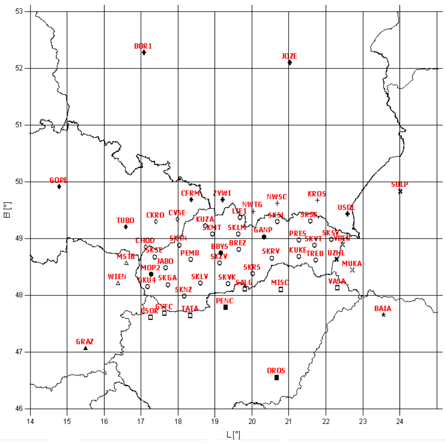

Fig.5 Network of permanent stations entered to GKU solution.

For foreign station connection test purposes a new server, which is totally identical with the original control software, was established. Foreign stations data flows connection to that test server was performed for all countries according to *EUPOS* guidelines (EUPOS, 2006).

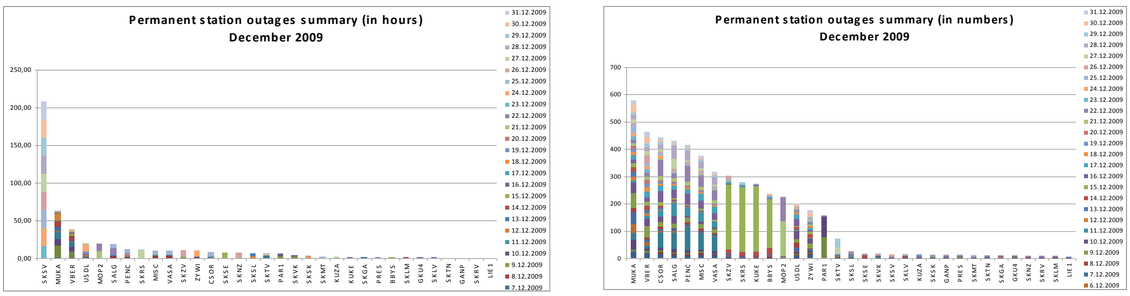

Fig.6 Example of the statistics results from the foreign permanent station outages monitoring.

Testing and monitoring of the SK*POS* solution with integrated foreign permanent stations

Testing and monitoring of the solution with integrated foreign permanent stations was divided into three parts:

1. Monitoring of the foreign stations performance (monitoring of delays, stations outages),
2. Monitoring of the behaviour of foreign permanent station coordinates,
3. Monitoring of the real performance in terrain.

Two kinds of statistics for monitoring of foreign permanent stations outages were performed. One was summary for the number of stations outages per time interval (e.g. day, month, year) and the second one for the time (hours) summary of foreign station outages per the same time interval. Examples of those statistics are visible on fig.6. On the level of service control software also incoming data delays from all stations were routinely monitored (see fig.8). A totally different example of permanent stations coordinates monitoring (time series analysis) achieved from precise coordinates processing is visualised on fig.7. Detailed information about the strategy used in this permanent station stability monitoring can be found in (Droščák, 2010).

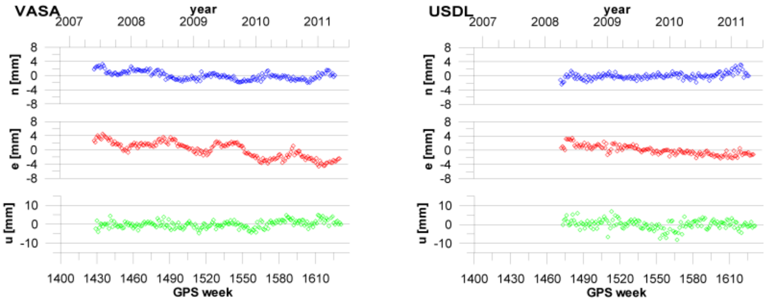

Fig.7 Example of the results from the permanent station coordinates monitoring.

All kinds of monitoring were performed due to the importance of full knowledge about quality and reliability of all integrated stations not only from our own stations. This information will help us to do right decisions in questions focused on station adding or excluding. For future this monitoring could be partly replaced with the activities from ECC project described in (Kenyeres et al., 2011) as well.

Experience of monitoring

We have performed neighbouring stations monitoring for more than three years and during that period we have gained a lot of useful experience. The first is that in spite of our big effort for its elimination, all from the incoming foreign permanent stations data have bigger delays than SK*POS* stations have (see example of a screenshot on fig.8). Those delays are caused by different kinds of communication links used for data flow. Usually only ordinary communication channels are used despite of private links used by SK*POS* stations. In future this problem can be solved by the improving the existing communication links or by establishing private channels which could join neighbouring network services.

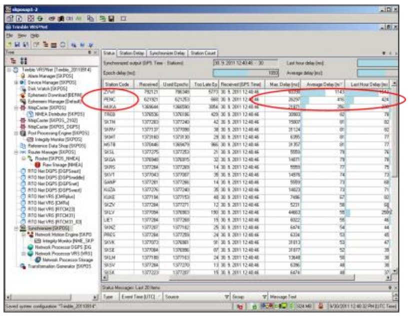

Fig.8 Bigger foreign permanent stations incoming data delays monitored by service control software.

The next experience presents a problem with the loss of GLONASS satellites for users observing near GPS-only reference stations in spite of the GPS+GLONASS capability of the service. We recognised this problem for the first time in the year 2007 when GPS-only station BBYS was being integrated into SK*POS*. At that time, for all users equipped with dual system receivers, which performed measurement close to the BBYS station, it was made impossible to use GLONASS satellites for network RTK processing. We checked this problem by generating of some VRS stations within close vicinity of BBYS and the results confirmed the existence of the problem. To avoid this undesired effect it was decided to exclude GPS-only station BBYS from SK*POS*. Considering that experience, we have tried to depict influence of this effect for all foreign border stations on the territory of the Slovak Republic (see fig.9 left image).

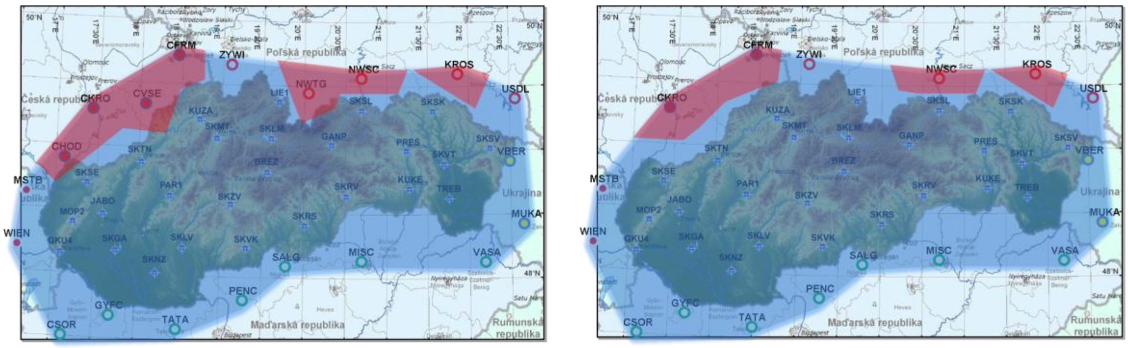

Fig.9 Situation before (left) and after (right) the selection of foreign stations if full GNSS capacity for whole country territory was considered.

Because we would not like to lose the GLONASS satellites anywhere, we have tried to find such kind of solution which will enable us to profit from foreign station extension on one side and to fulfil GNSS capability for the whole of Slovakia on the other side. The result is depicted on fig.9 (right image). Two GPS-only stations (CHOD, CVSE) from CZEPOS and one GPS-only station (NWTG) from ASG-EUPOS were excluded when full GNSS capacity for whole country territory was considered.

Conclusion

From presented information it is clear that is important to integrate to the national solution also border stations from neighbouring countries. On the other side it is also clear what everything is important to have on mind before its integration e.g. wise site selection because of full GNSS capacity exploitation or importance of knowledge about station coordinates behaviour. This is why GKU decided to integrate to his official SK*POS* solution for first four foreign stations within the end of the year 2011.

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