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# Technology of Reliable Static GNSS Surveying in Urban Areas

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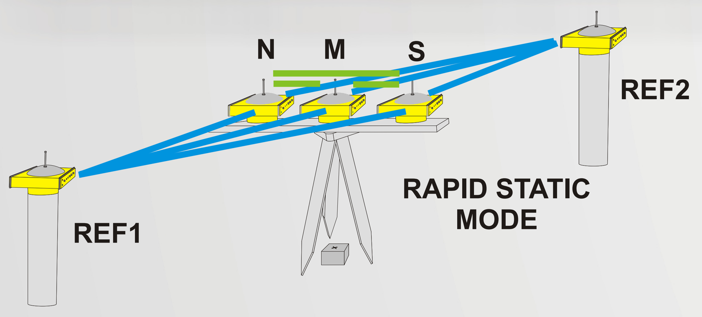
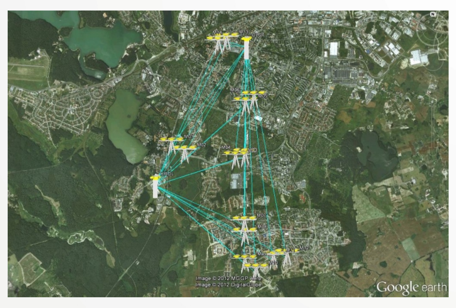
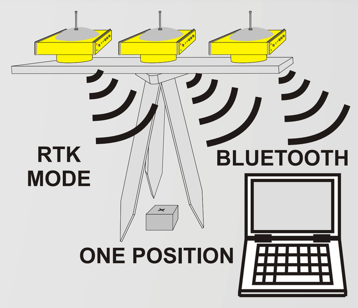
## Abstract

**The research presents a methodology of reliable rapid static GNSS surveying for applications in urban areas where availability to satellites is limited. The technology is based on the use of three GNSS receivers positioned simultaneously in line on a special base at a distance of 0.5 m from one another. Given the possible gross errors of the determined baseline coordinates, the simultaneous application of three GPS/GLONASS receivers for a single point allows reliable determination of coordinates even in locations with severe obstructions. Presented technology can also be used for reliable RTK positioning, however post-processing procedures of rapid static can give much more accurate results. Based on presented practical results of survey and data processing methodology, reliable coordinates with accuracies expressed in sub centimeters during rapid static survey sessions can be obtained in the urban areas where obstructions caused by trees, buildings, power lines etc. limit satellite availability.**




## Introduction

Permanent GNSS reference stations commonly used currently improved the efficiency of GNSS surveys. In Poland, start-up of the permanent reference stations network (the so-called ASG-EUPOS system) for the entire country took place in mid-2008. Establishment of the ASG-EUPOS system, and the RTK services in particular, caused immense interest in satellite technologies among land surveyors.A serious limitation to the satellite methods comes from the need to perform the survey in the open terrain without any obstructions along the satellite-receiver line. In case of terrain obstructions presence the survey is more difficult and frequently even impossible, particularly for RTK surveys. The coordinates of points determined in that case not once contain gross errors in case of both static surveys (Bakuła, 2012) and real time RTK surveys (Bakuła et. al. 2009). Sometimes it is found out that despite redundant observations and appropriate survey network adjustment the coordinates of points situated around various terrain obstructions such as a building, power transmission line or at the edge of the forest, etc., contain errors expressed even in decimeters.

## Baselines layout in rapid static surveying

Generally, in case of rapid static survey at least two reference stations are used. In case of using three GNSS receivers, two of them would have to be positioned on points with known coordinates while the third one moved across the terrain and collected satellite observations on points the coordinates of which would require determination. Application of three receivers only, however, resulted in too small a number of redundant observations. As a consequence survey was conducted using a larger number of receivers, e.g. three reference stations.The current development in GNSS receivers design, their compactness, provide the natural opportunity for a change in the current procedures of survey with entirely new ones that are faster and more reliable. As a consequence, the synchronic sessions can be converted to radial sessions where the surveys are conducted by three GNSS receivers positioned in every survey point.

Although the virtual reference stations (VRS) may also be the reference stations, in case of ultra-rapid static surveys where the session length is just a few minutes the use of a local reference station is recommended because, as known, the accuracy of the coordinates for the point being determined depends on the accuracy of the reference station (BASE or VRS). Usually, the local reference station (BASE) gathers observations for a relatively long time (e.g. 1-2 h), which additionally allows accurate determination of its coordinates on the base of a permanent reference stations at the distance of some tens of kilometers. The rover positioning accuracy depends on the quality of the atmospheric corrections.

Fig. 1. GPS/GLONASS survey unit for ultra-rapid static survey.

The accuracy in determination of the atmosphere errors and their appropriate consideration in the VRS observations determine as a consequence the accuracy of relative positioning. However, when we are interested in sub-centimeter accuracy, the survey using rapid or ultra-rapid static survey techniques would be much more reliable when conducted in relation to the local reference station (BASE). As in GNSS relative positioning the determined coordinates accuracy depends on the reference observation quality, the authors recommend use of own local reference stations for determination of survey networks coordinates by rapid and ultra-rapid survey techniques while the virtual station should be treated as the control station or the station connecting the local reference stations.

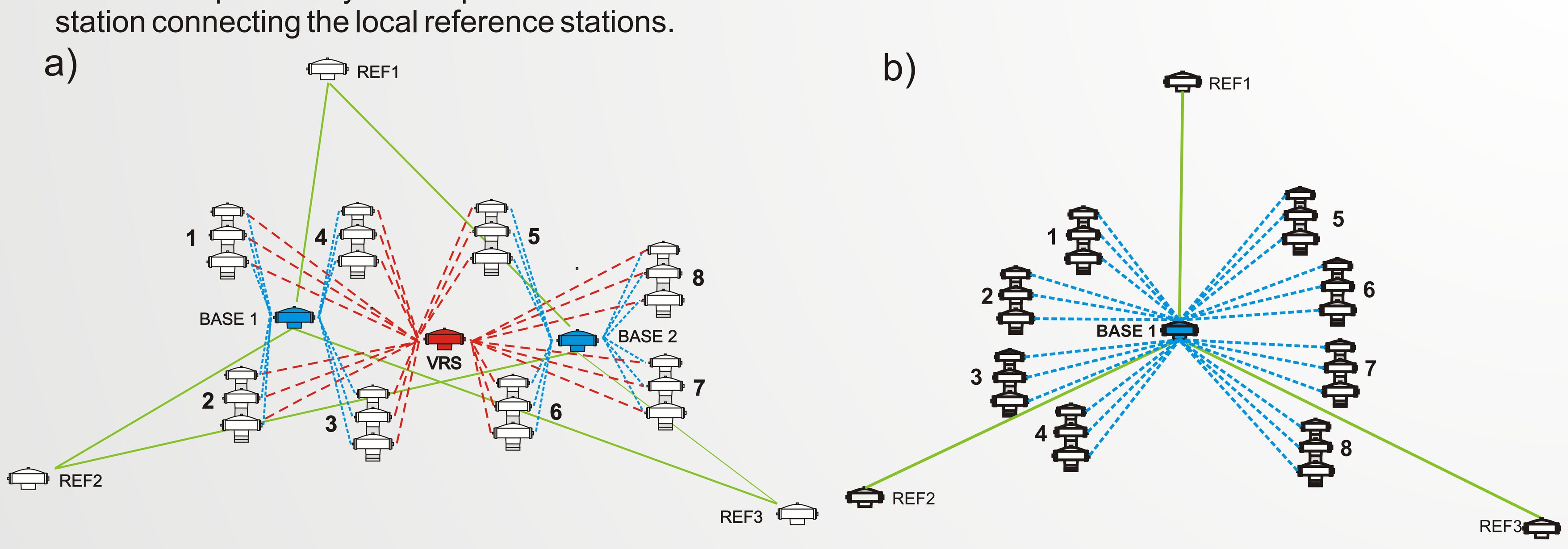



*Fig.2. Redundant and reliable GNSS Network in ultra-rapid static survey with the use of additional VRS station (a) and without use of additional reference station (b).*

Appropriate network design (e.g. Fig. 2) allows full reduction of ionosphere and troposphere errors' reduction in the observations of the second differences because at both the local reference station and the points several hundred meters of a few kilometers away from one another almost identical observation conditions are encountered.

## Description of field survey

The measurements were performed on 14 points located in Olsztyn, with various conditions for the satellites observations. Three Trimble SPS 882 receivers (installed on spetial base) were used for data recording. Each of the receiver recorded positions in RTK mode and raw data with interval of one second. Positions were determined using the KROL station (GPS/GLONASS), which is a part of the ASG-EUPOS system. Recorded 10-minute static sessions were divided into: two sessions of five minutes, four 2.5-minute sessions and ten sessions of 1 minute. In RTK measurement mode there were used appropriately averaged results for 600 epochs and twice for 300 epochs.

After conducting the adjustment process for many small sub-networks we additionally verify the height, length and orientation consistency conditions for all the three baselines in the given sub-network. That stage can be achieved by computing the differences of coordinates (dN, dE, dh) between the outside receivers and the central receiver.

$$dN=(x_{North} + x_{South})/2 - x_{Middle}$$
$$dE=(y_{North} + y_{South})/2 - y_{Middle}$$
$$dH=(h_{North} + h_{South})/2 - h_{middle}$$

where x, y represent horizontal coordinates in the north and east direction but *h* is vertical value.

If the horizontal values are lower than assumed, then the final coordinates are computed as the arithmetic averages, for nothing (N), easting (E) and height (H):

$$N=(x_{North} + x_{South} + x_{Middle})/3$$
$$E=(y_{North} + y_{South} + y_{Middle})/3$$
$$H=(h_{North} + h_{South} + h_{Middle})/3$$

After satisfying the sub-network consistency conditions, we can add computed baselines to the local reference stations ( permanent reference stations or virtual reference stations).

The left side of Figure 3 shows differences in determined coordinates for the receivers NORTH, SOUTH and the MIDDLE for the horizontal coordinates (dN, dE) and the vertical coordinate (dH). The right side of Figure 3 presents differences of coordinates obtained from processing 10-minute sessions and shorter sessions.

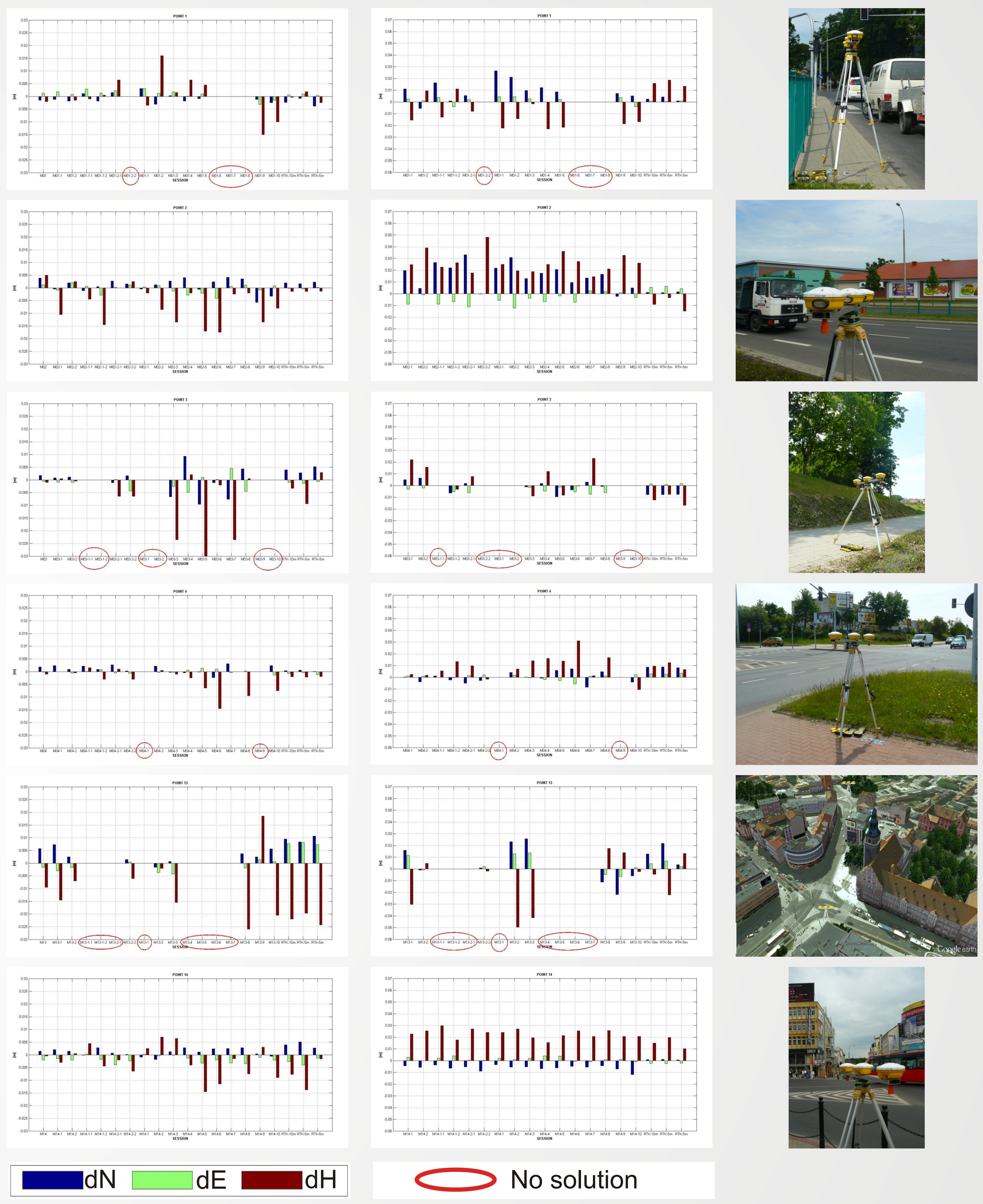



Fig. 3. Results of analysis for static and RTK measurements.

## Summary and conclusions

Establishment of permanent reference stations resulted in the natural change of survey and GNSS observations processing methodology in rapid static survey. According to the methodology proposed, conducting observations during rapid static survey (with sessions of a few minutes) the field survey is conducted by one survey team that collects observations from consecutive points using at the same time three GNSS receivers that assure the appropriate number of redundant observations. Additionally, the GNSS receivers positioned on the linear base at predetermined distances and along the north-south axis provide the additional control. The presented technique allows obtaining better accuracies from rapid static surveys than in case of applying the traditional survey methodologies (Bakuła at. all, 2012). Reliable coordinates can be obtained from sessions lasting for a few minutes. Thanks to those conditions the presented methodology of survey and GNSS observations processing offers reliable and accurate determination of control networks' coordinates, even in case of highly extensive terrain obstructions.

### References

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