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Investigating Precision of Network Based RTK Techniques: Baseline Length Is Concerned

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Abstract— **This paper investigates the precision of commonly used Network Based Real Time Kinematic (NRTK) techniques namely, VRS, FKP, MAC. Surveys were conducted within the Turkish Tusaga-Aktif CORS network. Two CORS stations were chosen whose interstation distance is approximately 100km. Within this baseline, eight test points were chosen to create the incremental baseline length as follows, 5, 20, 40, 50km between the CORS stations and the rover. Special apparatus was improvised to collect the NRTK data simultaneously for each technique from three high-grade GNSS receivers. Approximately 3000 epoch with two second interval was obtained for each test point and NRTK technique. Results show that horizontal and vertical precision depends on the baseline length between the rover and the CORS station which broadcasting the network correction for the rover.**

Index Terms—**FKP, MAC, VRS**

I. INTRODUCTION

Conventional Real-Time Kinematic (RTK) GNSS positioning technique has been widely used to obtain cm-level positioning accuracy in real-time. This system is based on the principle which at least one of the receivers serves as a base station with accurately known coordinates and the other receivers serve as rover station in which the coordinates are determined relative to the base station. It is generally accepted that baseline between rover and base station should not exceed 15km due to the tropospheric and ionospheric decorrelation [1]. This baseline limitation of conventional RTK is the main motivation behind using Continuously Operating Reference Stations (CORS) to model the distance-dependent errors more accurately and reliably for long baselines (several tens of kilometers) between the rover and the base stations.

The reference stations continuously stream raw GNSS observation data to the central server which operates the network. Network software at the central server calculates dispersive and non-dispersive errors at each reference station and interpolates these corrections w.r.t. the position of the rover. Then rover receives the interpolated corrections via the different communication means (radio, mobile phone or internet) between the rover and the central server. These three stages are the main infrastructure of NRTK. Closest CORS station to the rover within the network automatically chosen by the software on the server. This closest CORS station broadcasts the network correction for the rover. Within the Tusaga-Aktif CORS network, baseline length between the closest CORS station and the rover is generally within the range of 50km.

There are several NRTK correction techniques available. Virtual Reference Station (VRS) [2,3], Flat Plane Correction Parameter (FKP, German Flächen- Korrektur-Parameter) [4,5] and Master Auxiliary Concept (MAC) [6] are the most common ones which nearly all available GNSS receiver can obtain corrections from them.

Turkish Tusaga-Aktif CORS network consists of 145 active stations (Figure 1). Mean interstation distance between CORS stations within TUSAGA-AKTIF CORS network is approximately 80km.

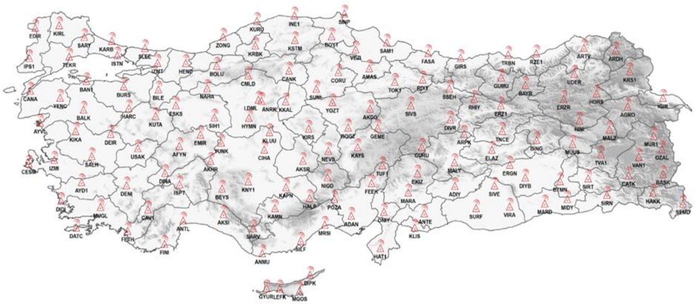

Figure 1: Locations of Tusaga-Aktif CORS stations

In the beginning of 2016, Tusaga-Aktif CORS network has undergone changes for hardware and software. GLONASS correction message types were defined for FKP and MAC. Servers updated to 64bit and Trimble Pivot Platform software were installed. Thanks to this update, initialization time and precision were improved comparing with the old system.

Several studies were conducted to evaluate accuracy and precision of NRTK techniques within TUSAGA-AKTIF CORS network. The authors conducted the evaluation test of NRTK techniques in 2016 and found that cm level of accuracy and mm level of precision (1 sigma) for horizontal and vertical component can be obtained for each NRTK technique [7]. Gumus and et al conducted similar evaluation but using the Directorate of Istanbul Water and Sewage Network for FKP and VRS and found the cm and dm accuracy can be obtained for horizontal and vertical component respectively [8].

In this study, precision of commonly used VRS, FKP and MAC NRTK techniques are investigated while taking into consideration of baseline distance between the closest CORS station and the rover. Figure 2 shows the two survey routes of 5-20-40-50km baseline lengths between the closest CORS station and the rover. Due to the lack of internet connection, data could not be collected on ciha-aksr 40km test point for

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each technique.

Figure. 2: Survey routes between CIHA and AKSR CORS station

II. Case Study

To maintain the same survey conditions (multipath, ionospheric and tropospheric effect, satellite geometry etc.), special apparatus was improvised to mount three GNSS receivers (Fig 3). Epoch50 high–grade GNSS receivers and Nomad data collectors were used at each test point for the NRTK measurement. Each receiver was set to different techniques, VRS, FKP and MAC by the data collector. Approximately 3000 epoch with two second interval were obtained for each technique and test point. Surveys were obtained consecutive days in April 2017. Each survey time interval is approximately 7:30am to 10:30am for each test points. We made sure that there is no object around the test points cause multipath effect. 15 degrees of elevation mask angle was applied for each test point. GPS and GLONASS satellites were used for each NRTK technique during the survey. Table 1 shows the mean satellite visibility number of NRTK techniques for each test point.

Table 1: Mean satellite visibility number of NRTK techniques for each test point

1			**2**			**3**		
FKP	**MAC**	**VRS**	**FKP**	**MAC**	**VRS**	**FKP**	**MAC**	**VRS**
14	14	14	14	14	13.5	16	14	15
4			**5**			**6**		
FKP	**MAC**	**VRS**	**FKP**	**MAC**	**VRS**	**FKP**	**MAC**	**VRS**
15	14.5	14.5	14	14	14	14.5	14.5	14.5
7								
FKP	**MAC**	**VRS**						
14	13	14						

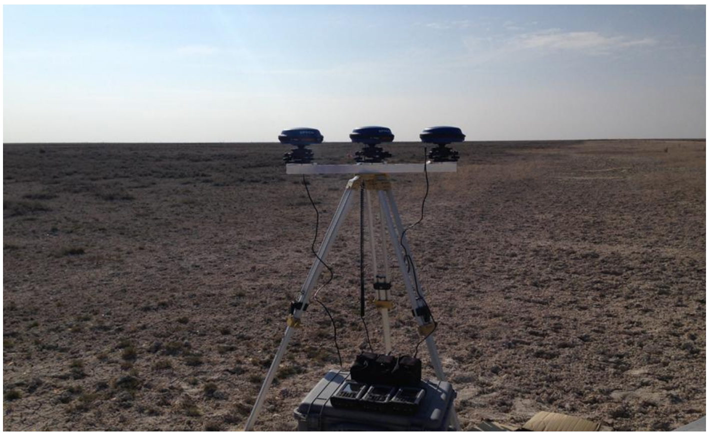

Figure 3: Apparatus for collecting GNSS data simultaneously for each NRTK technique

For each technique and test point, precision of population for horizontal and vertical components were calculated as follows;

$$\sigma_{northing} = \sqrt{\frac{\sum_{i=1}^{40}(x_{northing(i)} - \hat{x}_{northing})^2}{n}} \quad (1)$$

$$\sigma_{easting} = \sqrt{\frac{\sum_{i=1}^{40}(y_{easting(i)} - \hat{y}_{easting})^2}{n}} \quad (2)$$

$$\sigma_{h} = \sqrt{\frac{\sum_{i=1}^{40}(h_i - \hat{h})^2}{n}} \quad (3)$$

$$\sigma_{p\_2d} = \sqrt{\frac{\sum_{i=1}^{40}((x_{northing(i)} - \hat{x}_{northing}) + (y_{easting(i)} - \hat{y}_{easting}))^2}{n}} \quad (4)$$

Here, $\hat{x}_{northing}$, $\hat{y}_{easting}$ and $\hat{h}$ represent the mean value of projections coordinates and ellipsoidal height obtained after the NRTK measurements. $x_{northing(i)}$, $y_{easting(i)}$ and h_i represent the projections coordinates and ellipsoidal height for each epoch. $\sigma_{northing}, \sigma_{easting}, \sigma_h$ and σ_{p_2d} represent the standard deviation of northing, easting, ellipsoidal height and horizontal components. n is the epoch number. 3 sigma outlier detection was applied to remove outlier for each component [9].

III. Results

Residuals from the mean value of each component were combined for each 5-20-40-50km baseline length. Except 40km, there are approximately 6000 epoch residuals were created for each 5-20-50km baseline length. For 40km baseline length, only one measurement was performed (aksr_ciha_40km) and approximately 3000 epoch residuals were computed. Precision values of each component were given in Table 2.

Table 2. Standard deviation of NRTK techniques w.r.t. baseline length (mm)

Horizontal_std_dev (95%)				Vertical_std_dev (95%)		
	FKP	**VRS**	**MAC**	**FKP**	**VRS**	**MAC**
5km	11.5	10	9.1	16.5	14.9	15.1
20km	16.9	12.4	12.3	21.1	21.2	20.3
40km	18.6	20.5	16.5	26.4	31.7	31.0
50km	19.7	19	23.9	30.9	35.2	31.3

As it is seen from Table 1, precision is highly depends on the baseline length between the rover and the closest CORS station for both component. It is also observed that there is no significant difference between the NRTK techniques in terms of horizontal and vertical precision.

IV. CONSCLUSIONS

In this study, precision analysis of commonly used NRTK techniques in terms of baseline length between the rover and the closest CORS station were conducted. The results show that baseline length between the rover and the closest CORS station affects the horizontal and vertical precision. As rover move away from the closest CORS station, precision decreases for horizontal and vertical components.

Precision criteria of NRTK is significantly important for some kind of applications such as, structural deformation monitoring, measurement of bridge dynamic responses, landslide monitoring, etc. Therefore users need to be aware the obtainable precision of each component for specific applications. For close baseline, a few cm precision can be obtained for each component (95% probability). The results also show that any of three NRTK techniques can be safely chosen since there is no significant difference among the NRTK techniques in terms of precision.

The authors recommend that surveyors of Tusaga-Aktif CORS network need to take the baseline length into consideration for specific application which requires high precision.

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