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Potential of Static, Kinematic, and RTK in Open Sky Using GPS Only and GPS + Glonass Signals

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***Abstract*-It is now simple to use Global Navigation Satellite System (GNSS) anyplace due to the rapid developments and variety of GNSS satellite techniques. Several satellite systems, including GPS, GLONASS, BIUDO, and GALILEO, are widely available and used. The Differential Global Navigation Satellite System (DGNSS) is being utilized for many different applications, particularly those involving surveying and mapping. For establishing control points (Cps) in the open sky with moderate accuracy, it may be helpful to compare the usage of post-processing methods including static and kinematic also real-time kinematic (RTK) for position accuracy to differentiate their accuracies. The comparison depends on using the constellation of GPS only and GPS + GLONASS. For this purpose, fieldwork employing the three approaches with the two constellations (GPS and GLONASS) was done on five test points. The selected points were in the open sky, and the raw data was collected on tripods in the three methods. Leica 8.4 Geo Office software was used for the raw data processing after the five Cps were observed using a Leica Viva GS15 dual frequency receiver which supports GPS and GLONASS signals. The 3D position accuracy of the Cps was obtained by the three approaches using signals from GPS + GLONASS and GPS only. The advantages and disadvantages of using each approach were discussed.**

***Keywords*- GPS, GNSS, STATIC, KINEMATIC, RTK.**

I. INTRODUCTION

A satellite system that offers independent spatial location and global coverage is known as a "GNSS" (Global Navigation Satellite System). Currently, two well-integrated GNSS that 7are ready for use in many places are GPS and GLONASS. The United States of America developed GPS (USA) for military use. The system was initially launched on February 22, 1978. GLONASS is a Russian navigation system. Several users can now access and use GLONASS, it was Launched in 2010 and equipped with a full orbital constellation of 24 satellites. It is crucial to combine numerous GNSS signals in a way that maintains improved availability and position performance, especially when DGNSS is used. The quality of the position data gathered using GNSS receivers is useful for many applications, such as construction, and study of tectonic and earthquake activities. All these applications will be significantly improved by the collection and analysis of several GNSS signals [1], [2].

Although differential correction can be applied during data processing in the office or in real-time on-site. Despite the fact that both approaches are founded on the same ideas, the latter is more beneficial. Combining GPS and GLONASS data allows for greater data collection flexibility and increases data integrity [3]. Together, GPS and GLONASS satellites should provide two key benefits. First, more satellites are available at any given moment, improving satellite geometry and giving redundant data that enables users to calculate exact positions, especially for establishing control points. Second, GLONASS data might be utilized to conduct an independent evaluation of the GPS solution, which would enhance quality control. Moreover, the presence of the satellites from the GPS and GLONASS combination will prevent signal loss [4], [5], [6], and [7].

The advantages of combining GPS + GLONASS in terms of precise point positioning technology (PPP), RTK technique, navigation, etc. have been investigated and proven by numerous researchers [8]. For many non-construction projects, fast real-time control point installation is required, and they are used immediately in the project stage of implementation. Such projects could have a moderate Cps accuracy and it might be helpful to set control points quickly rather than taking more time while the post process in the office is done. The primary goal of this study is to demonstrate the variations in 3D position quality for control point determination utilizing the three observational techniques in the open sky under different conditions of the observations and the selected GNSS constellation.

A. Getting position using RTK mode by GPS only and with GPS + GLONASS combination.

Worldwide DGNSS tracking is extensive. RTK is a stop-and-go approach in which the coordinates of the points are provided in real-time. RTK and static methods are used on a daily basis in fieldwork. RTK uses a radio communication link to transmit carrier pseudo-range and phase measurements from the base receiver to the rover's receivers, which the rover then uses to determine its position and display the coordinates (Fig. 1). As long as the satellite lock is kept, the rover keeps updating its coordinates [9]. For RTK surveys, dual frequency LI and L2 GNSS receivers are necessary except for a receiver placed at a specific position.

GNSS receivers can move freely from one location to another. Real-time monitoring necessitates the use of a processor or data collector and a radio link. The radio link carries the raw data from the reference station to the rover. The achievable accuracy in RTK is often 10 mm or more. While installing control points, the recommended distance between the reference receiver and the rover is less than one kilometer. If you only use GPS satellites instead of GPS and GLONASS satellites for RTK, you will have fewer satellite availabilities, a lower accuracy in centimeters, a lower quality of position, and signal loss is common in blocked

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areas. This is true if baselines within 500 m to a maximum of 1 km are needed for observation.

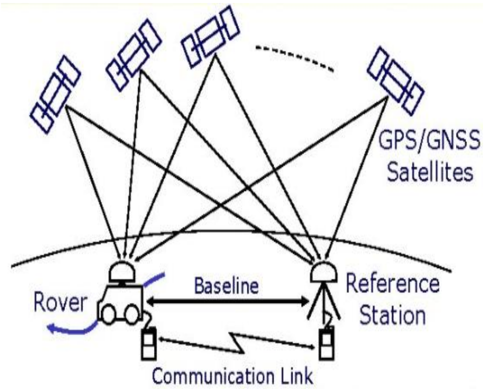

Figure 1. RTK communication.

However, running the RTK method with GPS and GLONASS provides better quality, accuracy, higher satellite availability, reliability, improved code measurements, reduced code noise, and models. Improved expansion of the ionosphere and troposphere, especially. The most obvious benefit of a combined system is the availability of twice as many satellites out of a total of 50 satellites. At least 12 satellites are visible anywhere, anytime.

B. *Getting position using post-processing kinematic mode by GPS only and with a GPS + GLONASS combination.*

The term "kinematic" refers to the continuous determination of a trajectory; consequently, when it is applied to GPS surveying, it would refer to the epoch-by-epoch solution to a baseline vector. The actual process that is being described here is referred to as "stop-and-go" or "semi-kinematic" GPS surveying.

Although baseline vectors at any epoch can be solved, the time frame in which a survey mark is occupied is what is most important. A mobile rover that takes initial positions and a base station that allows the rover to change positions make up the kinematic system. The rover is carried to each measurement location and stabilized for a limited period of time, typically between 5 and 30 seconds, in order to establish a starting position. The position of the rover is compared to that of the static base station to eliminate integer ambiguity and atmospheric delays. As a result, the rover's position can be pinpointed to within a few centimeters. If the rover receives correction information via radio or cellular connection, this correction may be applied in real-time or during post-processing [10].

C. *Getting position using Static mode by GPS only and with GPS + GLONASS combination.*

Static GPS surveying techniques eliminate several systematic inaccuracies when high-precision positioning is required. Static techniques are used to create baselines between stationary GPS devices by gathering data over an extended period to accommodate changes in the satellite's geometry. Each receiver in this system constantly records data at each location for a predetermined amount of time. Quick static GPS surveys are comparable to static GPS surveys, except they last for only 15 to 30 minutes [11]. Using the static technique, the GNSS receiver pairs are installed on stations with known and unknown positions. Most of the time, one of the GNSS receivers is located at a known place (they have moved forward like a traverse). The second receiver can also be set up in an arbitrary place with arbitrary coordinates. The coordinates of the second receiver are required for this technique.

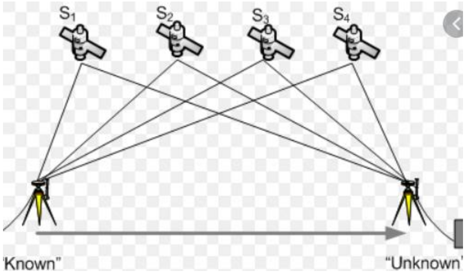

Figure 2. Static techniques.

Short baselines (for example, 500 m) measured from numerous temporary references are more advantageous than lengthy baselines (for example, 5 km) measured from a single central point in terms of accuracy and productivity. Standard Lengths Time and observation depend on the number of satellites being tracked, the ionosphere, the baseline length, and the satellite geometry. About the length of the baseline and the occupation time. Table 1 depicts the relationship between baseline lengths and observation times.

Table 1. Observation times and baseline lengths relation [12].

Baseline Length	observation times
1 km	10 min
2 km	15 min
3 km	15 min
4 km	20 min
5 km	20 min
6 km	25 min
7 km	30 min
8 km	30 min
9 km	35 min
10 km	45 min

II. RESEARCH SIGNIFICANCE

The study's importance lies in its ability to distinguish between 3D position accuracy from GPS+GLONASS and GPS-only constellations in open sky regions dependent on various observation techniques and ephemeris. Static, post-processing kinematic, and RTK approaches were used. The advantages and disadvantages of each approach are discussed. Results from each method were compared.

III. STUDY AREA

Fieldwork was performed in a location of 29°58'26"N, 30°54'3"E, on 6 October city, which lies northwest of Egypt. The area is in the open sky surrounded by low-high buildings. Four control points (CPs) were distributed inside the whole area. The base station whose coordinates are

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known is located over a building outside the project area. Distances between the selected location of the control points and the base station are nearly 350 to 600 meters. No obstacles were found in the selected area and the terrain was mostly flat. Study area extensions with the selected tested points are given below, Fig.3.

Figure 3. Satellite Images of the open sky studying area (October City, Egypt).

IV. METHODOLOGY

In this experiment, 4 control points were measured with GS15 GNSS Leica receivers in the static, kinematic, and RTK modes referenced to the base station (S1). S1 has 3D coordinates based on the ETM-red belt coordinates system. Each Cps was measured in static mode for a 30-minutes duration time. Even though all Cps have short baselines not greater than 600 m from the base station, an additional 30 minutes is enough time for each point. The same four control points (cp) were observed in kinematic mode by putting one GPS receiver over the known location (S1) and then observing the other four points on a tripod rather than a stick for two seconds following the stop-and-go technique. When the Cps were observed on tripods and the duration was 2 seconds, the RTK mode was like the kinematic mode. Also, to prevent any mistakes in the calculated coordinates caused by stick movement, the observation was done on tripods. Data processing for the acquired raw data over the control points was done using Leica Geo Office 8.4 software and DBX was the original raw data format as the LGO output. While using RTK, the coordinates of the test points were measured using a GPS signal one time and using the signals from GPS+GLONASS a second time and then recorded directly without processing needs. Position accuracy generally improves with (1) more available satellites, (2) better satellite geometry from the two systems, and (3) fewer multipath error channels. Utilizing GNSS (GPS and GLONASS), one may receive GPS L1, L2, L5, and GLONASS L1, L2 signals simultaneously. Moreover, because the project area is in the open sky, the potential for multipath may not arise. The geometry of the satellites will change as the number of satellites increases, as we obtained data from two constellations, the number of satellites will undoubtedly increase. These circumstances will affect all three employing modes.

Based on broadcast ephemeris and precise ephemerides, raw data acquired on the observation of control points via static and kinematic modes were processed. This may be useful for evaluation position accuracy depending on precise and broadcast ephemeris. Ephemeris and space vehicle clock corrections that are precise to less than a submeter are routinely computed by the International GPS Service for Geodynamics (IGS), a department of the International Association of Geodesy (IAG). Since the precise orbit/clock is free from selective availability (SA) flaws, accurate point placement and orbit determination may be achieved using high-quality pseudo-range data in a post-mission mode. The accuracy of the control points will thus be evaluated in relation to the two types of ephemeris, broadcast and precise. The obtained coordinates from the static and kinematic (precise and broadcast ephemeris), and RTK were compared, and the deviations in 3D coordinates are computed. The baseline is small; thus, measurements will be made under the same ionospheric conditions. The data was collected based on the WGS84 coordinates system and then projected to ETM in the red belt zone using the datum EGYPT 1907 Datum. The selected mask angle was 15°. As the relative accuracy of test points' 3D positions is examined, the used transformation parameters between the local and the global datum will have no significant effect. During the data post-process, some parameters are needed. The chosen post-processing parameters are displayed in Table 2. DBX raw data was collected over the selected test points and then processed in the office using Leica geo-office software LGO. Test points coordinates are obtained related to the base point, S1. The other test points are solved based on the base point by three methods, static, kinematic, and RTK. E, N, and elevations (of the tested points were obtained. Differences in E, N, and H coordinates between the test points obtained from the used methods were calculated. 3D Coordinates from the static method mode using signals from GPS+GLONASS and with the aid of the precise ephemeris are used as a reference case for coordinates comparison. The evaluation of the position accuracy is done by calculating the difference, and the standard deviation.

Table 2. Selected processing parameters for post-processing.

condition	Value
Solution type:	Automatic
GNSS type:	GPS + GLONASS
Frequency:	L1 + L2
Fix ambiguities up to:	80 km
Min. duration for float solution (static):	5' 00"
Sampling rate:	Use all
Tropospheric model:	Hopfield
Mask angle	15°

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V. RESULTS

During the coordinate calculations process, the position characteristics are calculated from the variance's fundamental matrix. The covariance matrix of each point's 3D coordinates was used to compute the 3D positional accuracy. For calculating position quality, the following equations were applied: 1, 2, 3, 4,5 and 6. [13].

$$C = \begin{pmatrix} Q11 & Q12 & Q13 \\ Q21 & Q22 & Q23 \\ Q31 & Q32 & Q33 \end{pmatrix} \quad (1)$$

$$\sigma E = S0\sqrt{Q11} \quad (2)$$

$$\sigma N = S0\sqrt{Q22} \quad (3)$$

$$\sigma H = S0\sqrt{Q33} \quad (4)$$

$$\sigma P = \sqrt{\sigma^2 E + \sigma^2 N + \sigma^2 H} \quad (5)$$

$$S0 = \sqrt{\sum_{k=0}^{n} \frac{v2}{n-1}} \quad (6)$$

Where,

C is the Variance-covariance matrix

Q11, Q22 and Q33 are the diagonal elements of the Variance-covariance matrix.

σ E, **σ** N, **σ** H are the standard deviation for E, N, and H coordinates.

σ P is the standard deviation (position quality) of coordinates components E, N, and H.

Coordinates from GPS + GLONASS with static mode using precise ephemeris were selected to be the reference in which all other coordinates obtained from the other methods will be compared. The coordinate differences, maximum, minimum, mean, and standard deviations of the test points using the three approaches are shown in Table 3 to Table 8. Figures 4 to 9 show the 3D quality charts for each method, again, getting coordinates from GPS+GLONASS using precise ephemeris are used as reference cases for the comparison. Figures 10 to 15 show the 3D differences between the coordinates resulting from the reference case and from the other approaches for the tested points. Tables are included the differences, (DE, DN, and DH), the maximum, the minimum, the mean, and the standard deviation for the differences in coordinates between the coordinates obtained from the reference case and the coordinates of the test points for each applied method. Table 9 shows the standard deviation (**σ**P) for DE, DN, and DH as a component for each method using GPS only and GPS+GLONASS.

Table 3. GPS+GLONASS Static-broadcast ephemeris

Items	DE(m)	DN(m)	DH(m)
P1	0.0110	0.0050	-0.0230
P2	-0.0140	0.0120	-0.0150
P3	-0.0310	0.0150	-0.0200
P4	0.0210	-0.0150	0.0250
max	0.0210	0.0150	0.0250
min	-0.0310	-0.0150	-0.0230
mean	-0.0033	0.0043	-0.0083
St.dv	0.0205	0.0118	0.0198

Table 4. GPS- only Static- broadcast ephemeris

Items	DE(m)	DN(m)	DH(m)
P1	0.0120	-0.0010	-0.0230
P2	-0.0140	0.0150	-0.0150
P3	-0.0420	0.0090	-0.0200
P4	0.0200	-0.0320	0.0360
max	0.0200	0.0150	0.0360
min	-0.0420	-0.0320	-0.0230
mean	-0.0060	-0.0023	-0.0055
St.dv	0.0244	0.0181	0.0243

Table 5. GPS+GLONASS Kinematic- broadcast ephemeris

Items	DE(m)	DN(m)	DH(m)
P1	0.0102	0.0081	-0.0226
P2	-0.0112	0.0102	-0.0016
P3	-0.0399	0.0169	-0.0090
P4	0.0209	-0.0166	0.0328
max	0.0209	0.0169	0.0328
min	-0.0399	-0.0166	-0.0226
mean	-0.0050	0.0047	-0.0001
St.dv	0.0233	0.0129	0.0204

Table 6 GPS Kinematic- broadcast ephemeris

Items	DE	DN	DH
P1	0.0100	0.0110	-0.0217
P2	-0.0050	0.0160	-0.0009
P3	-0.0300	0.0210	-0.0084
P4	0.0260	-0.0110	0.0355
max	0.0260	0.0210	0.0355
min	-0.0300	-0.0110	-0.0217
mean	0.0003	0.0093	0.0011
St.dv	0.0206	0.0129	0.0212

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Table 7. GPS+GLONASS RTK- broadcast ephemeris

Items	DE(m)	DN(m)	DH(m)
P1	0.0100	0.0040	-0.0250
P2	-0.0050	0.0150	0.0002
P3	-0.0410	0.0160	-0.0091
P4	0.0240	-0.0140	0.0381
max	0.0240	0.0160	0.0381
min	-0.0410	-0.0140	-0.0250
mean	-0.0030	0.0053	0.0011
St.dv	0.0243	0.0123	0.0232

Table 8. GPS RTK- broadcast ephemeris

Items	DE(m)	DN(m)	DH(m)
P1	0.0150	0.0020	-0.0270
P2	-0.0040	0.0160	0.0002
P3	-0.0320	0.0150	-0.0101
P4	0.0250	-0.0150	0.0371
max	0.0250	0.0160	0.0371
min	-0.0320	-0.0150	-0.0270
mean	0.0010	0.0045	0.0000
St.dv	0.0217	0.0127	0.0235

Table 9. Standard deviation (σP) for all methods

method	σP
GPS+GLONASS, Static	0.0308
GPS Static	0.0389
GPS+GLONASS - Kinematic	0.0335
GPS- Kinematic	0.0322
GPS+GLONASS - RTK	0.0357
GPS - RTK	0.0344

The standard deviation shown in Tables 3 to 8 is calculated for the difference between the coordinates of the tested points in the three dimensions, E, N, and elevations, H. results are computed related to the reference case, GPS+GLONASS using precise ephemeris in static mode.

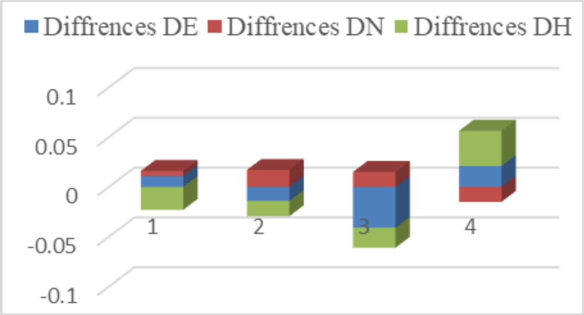

Figure 4. GPS+GLONASS Static-broadcast ephemeris.

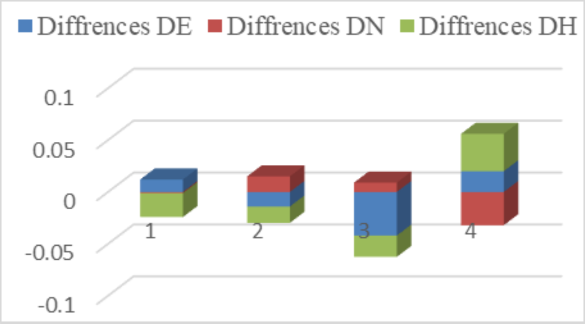

Figure 5. GPS Static- broadcast ephemeris.

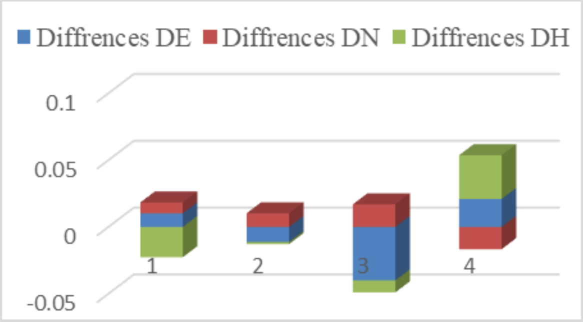

Figure 6. GPS+GLONASS Kinematic - broadcast ephemeris.

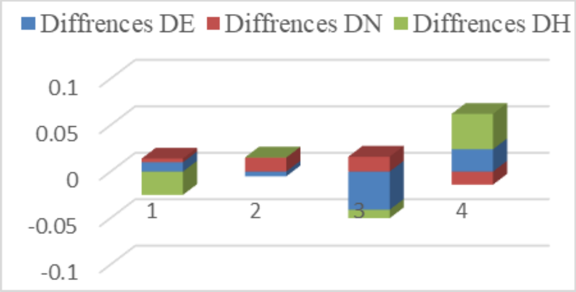

Figure 7. GPS- Kinematic- broadcast ephemeris.

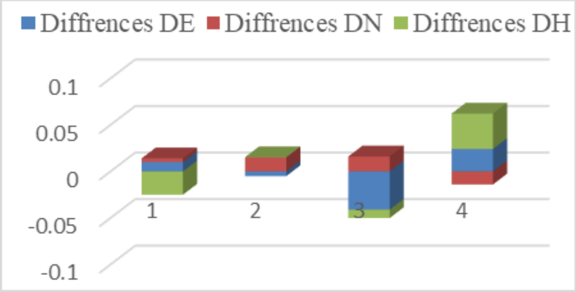

Figure 8. GPS+GLONASS - RTK - broadcast ephemeris.

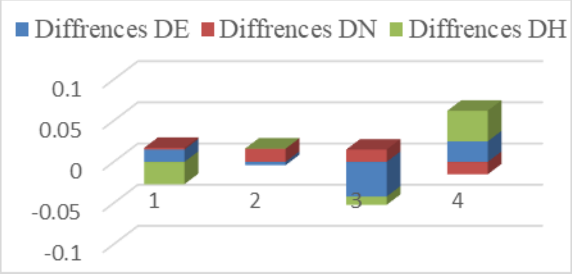

Figure 9. GPS - RTK - broadcast ephemeris.

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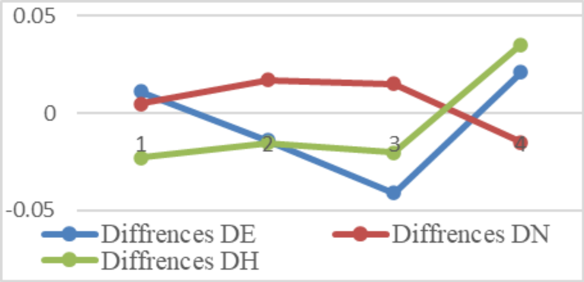

Figure 10. GPS+GLONASS Static- broadcast ephemeris.

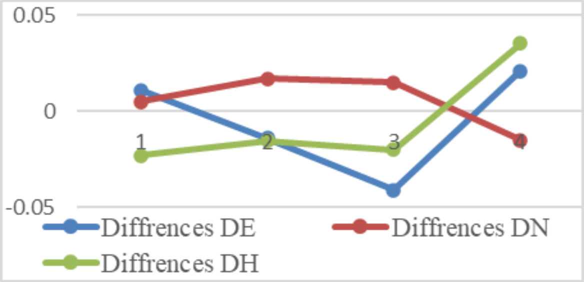

Figure 11. GPS Static- broadcast ephemeris.

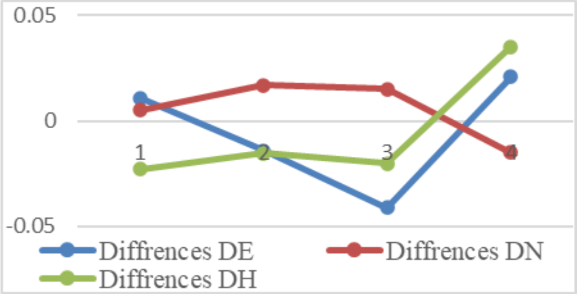

Figure 12. GPS+GLONASS Kinematic- broadcast ephemeris.

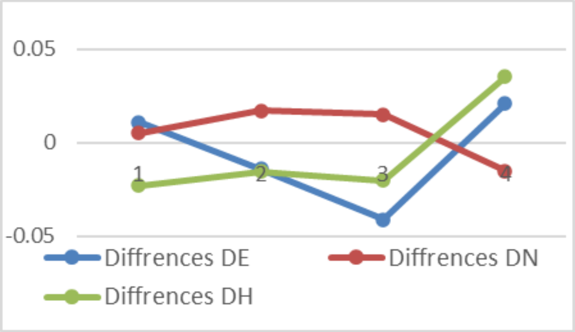

Figure 13. GPS Kinematic- broadcast ephemeris.

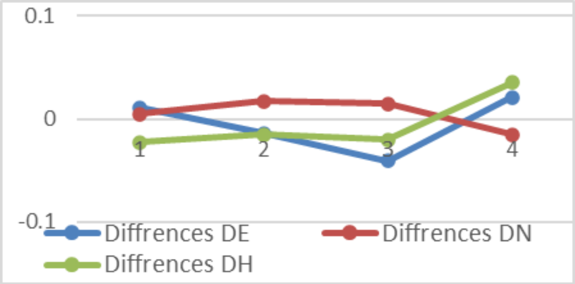

Figure 14. GPS+GLONASS RTK- broadcast ephemeris.

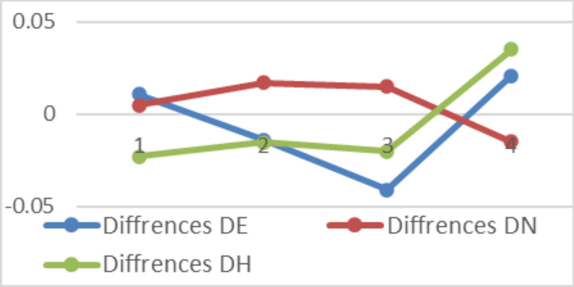

Figure 15. GPS RTK- broadcast ephemeris.

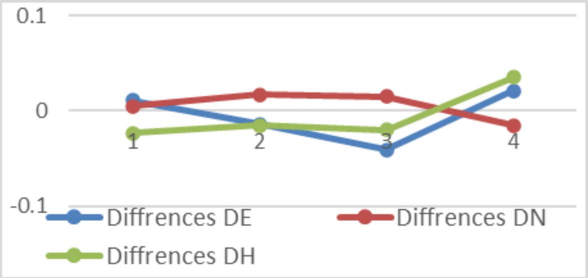

Figure 16.

VI. ANALYSIS AND DISCUSSION

Results from tables 3 to 8 for static, kinematic, and RTK showed that: In static mode, the mean error in the coordinates of the tested points are (0.003,0.0043,0.0083) m for GPS+GLONASS and (0.006,0.0023,0.0056) m for GPS-only, while the standard deviation for E, N, and H for GPS+GLONASS was (0.020,0.018, and 0.019) m and for GPS-only it was (0.024,0.018, and 0.0243) m. For E, N, and H, the accuracy of position between GPS-only and GPS+GLONASS in static mode is 2 to 4 mm. When GPS only was not used for static mode and GPS+GLONASS was used instead, the improvement was close to 47%. The standard deviation for E, N, and H for GPS+GLONASS were (0.020,0.018, and 0.019) m whereas it was (0.024,0.018, and 0.0243) m for GPS-only. For kinematics, the mean error of the measured positions is (0.003,0.0043,0.0083) m for GPS+GLONASS and (0.006,0.0023,0.0056) m for GPS-only. For E, N, and H, the position difference between GPS-only and GPS+GLONASS in kinematic mode was 1 to 3 mm. When GPS+GLONASS was used instead of only GPS, the improvement was close to 95%. For E, N, and H, the Position quality difference between GPS and GPS+GLONASS in RTK mode ranged from 1 to 3 mm. When GPS+GLONASS was used instead of only GPS, the improvement was close to 40%.

Based on the previous results, it is interesting that even discrepancies between GPS-only and GPS+GLONASS in static mode are significant. This results in a few millimeters differences in position accuracy when using GPS-only and GPS+GLONASS in three ways. In all cases, GPS+GLONASS performed better than GPS-only in terms of position accuracy. However, in terms of position accuracy, using the three methods—static, kinematic, and RTK—produced rather comparable results. Compared to the other two modes, the static mode was more efficient. The findings

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for the three modalities' position accuracy varied marginally, with position accuracy of only a few millimeters. The GPS+GLONASS combining system used by the RTK approach often showed better accuracy, position quality, and satellite availability.

The highest number of satellites that could be accessed using GPS alone in the selected open sky region with a 15° cut was 8, however utilizing GPS and GPS+GLONASS together made more than 14 satellites available. Due to the availability of additional satellites and the decreased likelihood of signal loss and multipath, better satellite geometry was delivered with less observation time when GPS-only and GPS+GLONASS were combined. As discussed, the results demonstrate that when utilizing GPS+GLONASS, the position quality or accuracy for the RTK method was close to 40% better than GPS alone. Following data analysis, the kinematic approach's findings show that, for cps installation, GPS + GLONASS produced good improvement in position quality, which is typically 1 to 2 mm better than using GPS alone. Combining GPS with GLONASS improves location quality by around 47% when utilizing a static approach in the open sky, which is at least 1 to 2 mm better than when using GPS alone. The inclusion of GPS+ GLONASS greatly improves availability and accuracy, according to field testing of all techniques.

Combining systems may lower the likelihood of signal loss and multipath issues. GPS+ GLONASS takes a more proactive approach to addressing error issues and identifying solutions. It is generally preferable to stay away from closed areas when using DGPS or in applications that require high precision accuracy because they interfere with the receiving of signals and decrease the availability of satellites. The open sky is always the best for any observation with a single GPS+ GLONASS, multiple GPS+ GLONASS, single frequency, or multiple frequencies. The real-time kinematic approach produced, to a certain degree, satisfactory results, as indicated in the preceding tables. In many survey applications, such as dividing agricultural lands, grading in highway projects, and even some infrastructure works for construction projects, this accuracy may be sufficient. The control points' positions' accuracy may be within the range of 5 mm to 8 mm and with little difference compared with the two other methods. It may be concluded that using this strategy in wide spaces devoid of obstructions may be a feasible way to construct quick control points accurately enough to provide a real-time and quick solution for the data. As a result, this quick approach may be used to determine the coordinates of the control points quickly and accurately to some extent. The instantaneous availability of the control point coordinates might help to solve a lot of issues and quicken the project implementation process. Waiting for the data to be processed at the office and getting the coordinates of the control points may have considerable advantages when using such a method.

Also, certain engineering projects would require speed and instant collection of coordinates of the ground control points so they can utilize them for observation or even for setting out different project components. For this kind of project, position accuracy may normally range between 5 mm and 1 cm, but not more. Therefore, it can be argued that real-time solutions may address many issues relating to the completion and cutting down on time for such projects, given that they are frequently placed under the open sky.

VII. CONCLUSION

As opposed to using a single GNSS system, combining systems from many GPS+ GLONASS has become a regular practice to provide increased availability, performance, dependability, and accuracy. In this study, testing for static, kinematic, and RTK approaches employing a multi-constellation of the locations was done for the placement of control points to illustrate the benefits of combined GPS + GLONASS in engineering projects during data collection. The test site had an open sky above. According to the findings, utilizing GPS+ GLONASS signals instead of only GPS signals increases position accuracy for static, kinematic, and RTK systems in the open sky by 47%, 95%, and 40%, respectively. A quick way to deploy control points with medium accuracy may be to integrate GPS with other GNSS in the RTK approach for Open Sky and in non-construction projects with limited baselines length for networks.

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