ISSN 2229-5518

Assessing Accuracies of Position Fix Using GNSS in Real Time Kinematic (RTK) From Base Station for Surveys in Abuja, Nigeria

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Abstract Controls are used by surveyors and Engineers to locate portions of land and position of a point by way of definition and location and for setting out of engineering structure. In most cases, these control points are established using conventional methods. But advancement in satellite technology has made Global Navigational Satellite System (GNSS) receivers to be used. This technology is everywhere in use now in Abuja – the Federal Capital Territory and many practitioners have started to abuse the access to this technology. Usually, GNSS in static mode is employed to establish control point. The Real Time Kinematic (RTK) mode is used for defining second or third positions of limited accuracies. Many data collectors use this mode to extend controls as far as 45km. In this study, CHC 91+ - GNSS receiver was used to verify selected control points at Herbert Macaulay Way, Abuja, Nigeria. Also, CHC 91+ DGNSS receiver was used for data acquisition in three different RTK mode and the results were compared with the original coordinates of these selected control points. The accuracy of each selected observed point was calculated and compared with the original coordinates. The results show that the longer the observation time of receiver on an observed point, the accuracies increase and actually better. On the contrary, the increase in distances of control points from the base station, the lowers the accuracies. So, the RTK mode should not be used for observation on very long distances from the base station.

Index Terms— Accuracy, Base station, Control Points, DGNSS, Observation time, RTK mode, Satellite Technology

1 Introduction

THe needs to connect survey and engineering work using control point as orientation is very important in surveying, Engineering works, and navigation. Many developed and established reference station such as WGS 84 and Minna datum, and Continuous Referencing System (CORS) station have been used to provide reference and orientation for the survey,of engineering work, and navigation. The principles and methods of using these reference stations must be clearly understood to have an accurate result.

Geodetic (GNSS) method of measuring points and tracking trajectory on, below and above the surface of the earth is an interesting and attractive technology in the field of geodesy. Several methods have been adopted in the past to carry out measurements and to represent the measured quantities in form of maps and chart [1]. Maps makers especially surveyors and geodesist are expert in making maps. They had adopted different methods in producing these maps.

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The method adopted depends on the accuracy required, timely execution, and cost implications of the project. Starting from the era of pacing, using compass and tape, EDM and theodolites, Total station and the new Global Navigational Satellites System (GNSS) method; the accuracy, timely execution and the cost implications of establishing positions has been improved over time as reported in several works of literature [2], [3], [4], [5], [6], [1], [8]. In large-scale mapping, the surveys need to be controlled and checked for scale and orientation [9], [10], [11]. This is done by carrying out observations at Laplace station.

The current study adopted DGNSS techniques to carry out geodetic measurements on control stations using Real Time Kinematics (RTK). This provided checks on the accuracy of the control and the precision of the GNSS receiver to develop measuring techniques. These techniques if appropriately adapted for measurement could be used for direct land parcel survey, engineering surveys, setting out and deformation monitoring. This has created more insight about GNSS application in large-scale mapping, deformation monitories, earth crust movement, and parcel survey to enhance and improve safety and revenue generation in Nigeria. The timely execution of position determination in x, y and z coordinate system using DGNSS receiver in RTK mode is the reason why some users of GNSS receiver use the DGNSS RTK method erroneously for position fix without a thorough investigation of the accuracy of the position fix. Because, all measurement contains error, and no matter how careful and meticulous a measurement is made, it can never be exact. The interest of a geodesist is to identify and eliminate error (mistakes, systematic) and use adjustment principle to minimize random errors that exist in the coordinates derived from measurement. These coordinates could be direct or indirect; this depends on user's requirements: distances, angles and directions, longitude and latitudes.

Since the position of the point can be determined by carrying out observations to celestial bodies as a reference point or target, geodesist began to investigate the error introduced to this measured quantities. These measured quantities are latitude and longitude to determine the position of a point on the surface of the earth.

In the past, surveyors observed either sun or the star each time he want to define a position. This necessitated the need to determine and establish control points, and these control points are evenly distributed across the world known as the geodetic datum. There is global and local geodetic datum, such as WGS84 and Mina datum. Because of the global and regional geodetic datum, there is the need to transform between global and regional geodetic datum [11], [12]. Measurements are made using this established datum as referenced origins for orientation. These measurements are subject to error due to many factors [1], [9].

The use of a statistical method of observation is required to carry out an error analysis of these measured quantities and necessary adjustment carried out on them to refine the measured points [11], [13]. The discovering of position determination, the method of measurement and adjustment of measured quantity at any instant of observation need to be sequentially follow, to define an accurate position. Therefore, Measurement needs to be referred to a known established datum any time you need to determine a position, [7], [10]. These primary control points are broken down to secondary and tertiary controls. The vertical component, which is the elevation above the mean sea level, was established using tide gauge through redundant observation at the mean sea level over a period of 19 years. This was also distributed through trigonometric and spirit leveling [8], [7].

All these factors need to be considered and necessary computations carried out on measured points to determine the accurate positions of points [7], [10], [9]. This study investigated the accuracy of using RTK mode in solving geodetic problems and to determine possible factors that could degrade the accuracy of carrying out observations using GNSS receiver in RTK mode.

2 Materials And Methods

2.1 Study Area

Abuja was carved out from Niger, Kaduna, and Plateau States in 1976 as the federal capital City of Nigeria. It is bounded by latitude 8^0 25'N to latitude 9^0 25' N and longitude 6^0 45'E to longitude 7^0 39'E. It has a boundary with Kogi State in the South, Nasarawa State in the East, and Niger state in the west and northern side. The major language spoken among the people are mainly Gbagyi, Nupe, Koro, Gwandara, and Gade. Its total area is about 724,473.9 hectares. The specific study area is Hebert Macaulay way, which is in the central business district of Abuja. It is located within the city center of Abuja (Fig. 1.0)

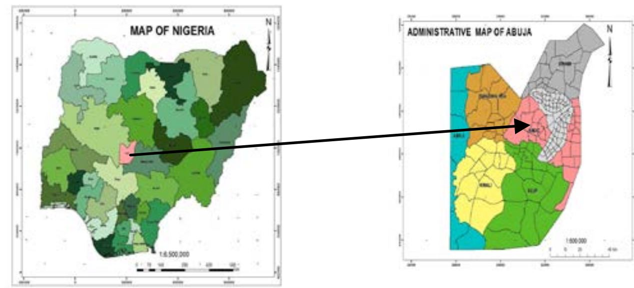

Fig.1.0. Map of the Study Area

2.2 Hardware and Software Requirement

CHC 91+ DGNSS receivers and accessories were used for data acquisition. HP laptop computer system was used for data processing. The software used for data processing is Microsoft Excel, 2007 for editing and data compilation.

2.3 Methods

CHC 91+ DGNSS receivers were used to carry out observations on selected control along Hebert Macaulay way Abuja. The coordinates of the selected control points were collected from the Department of Surveying and Mapping, Area 11, Abuja. The primary control points used for connecting the survey is FCT 9P and 12P located at Jahi and Mpape, Abuja.

The primary data are the coordinates computed as a result of observations carried out on the selected controls points, while the secondary data were the original coordinates of the selected controls. The coordinates of the selected controls are listed in Table 2.1.

Table 2.1 Coordinates of Selected Control for Comparison

Pillar Numbe	Easting (m)	Northing (m)	Heights(m)
FCT9P	1007612.091	329821.512	497.253
FCT17381T	1002374.301	331690.105	459.171
FCT17382T	1002091.057	332378.498	486.404
FCT17383T	1001974.108	332911.170	473.239
FCT17384T	1001333.441	333354.568	479.399
FCT17385T	1000534.096	333830.965	489.930
FCT17386T	1000268.944	333995.768	492.271

Table 2.1 the original coordinates of the selected control points that were used for the observation and investigation.

2.4 Data Acquisition

The Auto Base mode was used for the survey. The base receiver was set at old Police barracks in Wuse Zone 6, Abuja and calibration were carried out at control station FCT 9P and FCT 12P which served as a check station. The check station is necessary to verify the correctness of the calibration. The base receiver automatically determines its correct position immediately after calibration was carried out and the datum parameter replaced. The error difference from the differencing techniques is broadcasted and sent to the rover receiver through the radio signal fixed at the base station. An observation was carried out on selected controls in three modes of RTK namely: control survey, 180 seconds; Topo survey, 5 seconds and a rapid survey, 3 seconds. Observations were carried out on selected control points at different time intervals: 180 seconds, 5 seconds and 3 seconds.

2.5 Data Processing

The acquired data were copied and transferred to excel command delimited format using a USB cable to connect the communication links between the GNSS receiver's data collector and computer system. The copied data was compared with the original coordinates of the selected control points. The discrepancies between the original coordinates and the observed computed coordinates were compared and analyzed. The three modes of observations were compared with the original coordinates of the selected control at different observation modes. The coordinates of the observed selected control points are in Table 2.2.

Table 2.2 Coordinate of the Observed Selected Control points at Different Modes

Pillar Numbe	Obs Time (s)	Easting (m)	Northing (m	Heights (m)
FCT9P	180	1007612.299	329821.404	497.214
FCT17381T	180	1002374.307	331690.105	459.174
FCT17382T	180	1002091.065	332378.450	486.532
FCT17383T	180	1001974.126	332911.099	473.309
FCT17384T	180	1001333.502	333354.473	479.564
FCT17385T	180	1000534.190	333830.863	490.049
FCT17386T	180	1000268.944	333995.768	492.502
FCT17386T	5	1000268.944	333995.768	492.502
FCT17386T	3	1000268.944	333995.768	492.502
FCT17385T	5	1000534.190	333830.863	490.049
FCT17385T	3	1000534.190	333830.863	490.048
FCT17384T	5	1001333.502	333354.473	479.564
FCT17384T	3	1001333.502	333354.473	479.564
FCT17383T	5	1001974.126	332911.099	473.309
FCT17383T	3	1001974.126	332911.099	473.309
FCT17382T	5	1002091.065	332378.450	486.532
FCT17382T	3	1002091.065	332378.450	486.532
FCT17381T	5	1002374.307	331690.105	459.174
FCT17381T	3	1002374.307	331690.105	459.174

From table 2.2, the first stretch of observations was carried out on the selected control points starting from FCT 17381T to FCT17386T for 180 seconds each. The second observations stretches were carried out at a time interval of 5 seconds and 3 seconds, starting from FCT17386T to FCT17381T respectively. These observations at different modes and time duration were compared with the original coordinates of those points. The differences in nothings, easting and height coordinates were compared and the accuracy of each observed points calculated.

2.6 Data Comparison

The difference in northings, eastings, and heights of the measurement from the original coordinates at each control point were calculated at the various observation time generated from each selected control point. These differences are shown in Table 2.3:

Table 2.3 Difference in Northing, Easting, Height for the Selected control Points with Time Duration

Pillar Number	Obs Time (s)	Northing (m)	Easting (m)	Heights (m)
FCT17381T	180	0.006	0	0.003
FCT17382T	180	0.008	0.048	0.128
FCT17383T	180	0.018	0.071	0.07
FCT17384T	180	0.061	0.095	0.165
FCT17385T	180	0.094	0.102	0.119
FCT17386T	180	0.093	0.146	0.231
FCT17386T	5	0.081	0.153	0.243
FCT17386T	3	0.0081	0.153	0.247
FCT17385T	5	0.073	0.113	0.17
FCT17385T	3	0.054	0.108	0.155
FCT17384T	5	0.056	0.095	0.137
FCT17384T	3	0.053	0.099	0.121
FCT17383T	5	0.026	0.088	0.062
FCT17383T	3	0.058	0.091	0.065
FCT17382T	5	0.006	0.052	0.136
FCT17382T	3	0.007	0.042	0.143
FCT17381T	5	0.017	0.003	0.016
FCT17381T	3	0.012	0.003	0.018

In table 2.3 the error difference in northing, easting, and height varies significantly from control point FCT17381T to FCT17386T depending on the occupation time of the GNSS's receiver on the control points. The variation in the results is due to the control point distance from base receiver's station and the location of the control point on which observation was carried out and time duration of the observations.

2.7 Determination of Linear Accuracy

The linear accuracy for each control point was determined using Bowditch method as shown in equation (1). The results from the calculated accuracy provided a better explanation of the degree of the errors in the measured quantities for analyses and discussions.

Linear Accuracy: $$\frac{1/\sqrt{\Delta N^2 + \Delta E^2}}{\sum D} \qquad (1)$$

Where:
ΔN = Misclosure in Northing =0.006
ΔE = Misclosure in Easting = 0.000
ΣD = Total length or summation of all the distance = 1634.159

$$\frac{\left(\sqrt{0.006^2 + 0.000^2}\right)^{-1}}{1634.159}$$

Linear Accuracy = 1:272,359.833

The accuracy varies with the distance of the survey point to the base station. And it also depends on the occupation time of the receiver at the station. For one hundred and eighty seconds, the accuracies are 1:272000, 1:48000, 1:39000, 1:31000, 1:31000, and 1:26000 for distance of 1634.159, 2371.432, 2915.974, 3547.315, 4335.607, and 4614.690 respectively.
Similarly, for observation time of 5 seconds, the accuracy are: 1:132000, 1: 55000, 1:55000, 1:31000, 1:58000, 1:26000 for distance of 1634.159, 2371.432, 2915.974, 3547.315, 4335.607, 4614.690 respectively and 1:132000, 1:55000, 1:27000, 1:31000, 1:35000, and 1:30000 for distance of 1634.159, 2371.432, 2915.974, 3547.315, 4335.607, 4614.690 respectively for 3 seconds.

3 Results, Analysis, and Discussions

3.1 Results

The results of the study are coordinates (northings, eastings, and heights). And the accuracy of each control point which was determined using three different time durations of RTK observations

3.2 Analysis of Results

The Surveyor's council of Nigeria SURCON (2007) classifications, accuracy standards and specification for National Horizontal Control Accuracy Standard in Nigeria are categorized as follows: first order = 1:100,000. Second order = 1:50,000. Second order class 2 = 1: 30,000. Third order class 1 = 1: 10,000. Third order class 2 = 1: 5,000. The results from the calculations of linear accuracies show that the GNSS RTK mode could provide good measurement accuracies at first, second and third order, depending on the distances of survey points from the base station and time duration of the observations.

3.3 Discussions

The results generated from the calculated linear accuracies show that, for observations on control points using receiver occupation time of 180 seconds, the accuracy decreases with an increase in distance of the fixed point from the base station. Similarly, there is a decrease in the accuracies computed with an observation time of 5 seconds and 3 seconds when compared with results obtained using an observation time of 180 seconds. The results generated from the three modes show that, higher occupation time gives better accuracy than a short time of observations. The accuracy achieved from an observation time of 180 seconds is better than that of 5 seconds and 3 seconds.

Multipath is a factor that affects position fix using RTK mode. Control point FCT17384T and FCT1785T are seriously affected by multipath due to the electrical communication line and traffic light that are closer to the control point. However, at FCT17385T, the accuracy seems to be better with an observation time of 5 seconds and 3 seconds. From the results, it is clear that, quick observation time at multipath affected area seems to give a better result than when you spend a long time on the point. Also, the accuracy of determined point reduces with increase of distance of fix point to the based station.

These established control points could be used for controlling Engineering structures and monitoring the relative movement of structures. This is why control points should be verified from time to time to know if its position is in-situ. Mostly, the static method has been used to establish control points with higher observation time. The use of CORS station for reference during position fix is an advantage to strengthen the control positions especially in the rural area where there are none or sparse controls point.

4 Conclusion

The use of GNSS in RTK mode could provide a better accuracy if the observation time on a measured point is high. The results of this study have shown that longer observation times on a station provide better results than fewer observation times. Also, the accuracy of the observed point reduces with increase of fixpoint from the based station. Since position fix by RTK mode could go as far as 15km to 20km, care should be taken to investigate the accuracy of position fix using RTK mode as was verified in this study.

The results from the study could be used for the following areas of applications: Setting out of Engineering structure, Cadastral surveying, Deformation monitoring, Digital mapping, GIS surveys, Utility surveys, Topographic surveys, Minefield surveys, and Hydrographic survey.

4.1 Recommendations

Having investigated position fix using GNSS CHC 91+ receivers in RTK mode, it is recommended that the accuracies of position fix should be verified to know the type and standard of accuracy achieved in a particular measurement using RTK mode. Also, to have better results of the measured quantity, the base station should not be too far away from the site of the survey.

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