International Journal of Scientific & Engineering Research, Volume 5, Issue 2, February-2014 1011
ISSN 2229-5518

Global Positioning System Network Reference Control Optimization Using Dilution of Precision Variances in Gidan Kwano Area, Minna, Nigeria

Lazarus M. Ojigi, Etim E. Eyo, and Temel Bayrak

Abstract: *The precision of Global Positioning System (GPS) observables depends on the satellite geometry, represented by the Dilution of Precision (DOP) values, and range of errors caused by signal strength, ionospheric delay, tropospheric delay, and satellite clock offset from GPS time, multipath effects, receiver antenna phase shift, etc. One of the ways of assessing the integrity of satellite availability, positional and navigational accuracy of GPS observation is the use of dilution of precision (DOP) during field observations. This study therefore attempts to optimize GPS Network Reference Control in Gidan Kwano area of Minna, Nigeria, using pre-observation planning and post-observation DOP variances, for selecting the optimum reference point within an established survey network, for future observations and control extension in the study area. Twenty-five (25) GPS stations were observed in rapid-static mode with Leica SR20 DGPS Receivers. The estimates of the DOPs (GDOP, PDOP, HDOP, VDOP and TDOP) showed that, post-observation DOPs have mean values of 2.0, 1.8, 1.6, 0.9, and 0.9 for GDOP, PDOP, HDOP, VDOP and TDOP, respectively, which agree with the post-observation DOPs within about 80-90%. This implies that, the PDOP developed in the pre-observation planning is valid for rapid-static or kinematic surveys in the study area but less valid for a long-duration (30-minutes and above) static survey in the study area. Based on the DOPs variance analysis for each observed network point, control point GPS14 with PDOP and GDOP of 1.4 and 1.5, respectively was adjudged the optimum point as Reference for survey network observations and extension in the study area.*

Keywords: **GPS Network Reference, Optimization, Dilution of Precision, Variance Matrices**

1. INTRODUCTION

GPS satellite signals (see Figure 1), like any other navigation signals, are subject to some form of interference or signal propagation errors due to several factors, such as ionospheric delay, tropospheric delay, and satellite clock offset from GPS time, multipath effects, receiver antenna phase shift, etc. These bias factors unfortunately further jeopardize the integrity, availability and accuracy of the navigational and positional reliability of the GPS. The integrity is the dependability of the system to deliver reliable signal for positional and navigational signal, and to also alert users when GPS should not be used for navigation due to degraded signals. Availability assures users that the basic GPS civil service is accessible nearly 100% of the time, while Accuracy deals with the agreement of the measured values with regards to the expected vectors or geo-positional values and specifications, which is usually initiated from the estimation of precision of measurements in single or multiple epochs.

One of the ways of assessing the integrity, satellite availability, and positional and navigational accuracy is the use of dilution of precision during field observations. The final positional accuracy of a point determined by using absolute GPS solution techniques is directly related to the geometric strength of the configuration of satellites observed during the survey session.

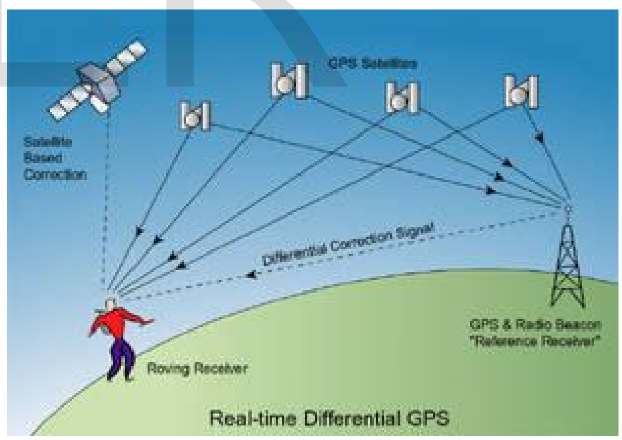

Fig. 1: GPS Signal Propagation between Satellite and User Segments [3]

1.1 GPS Observation Models

The basic observation model for Global Positioning System, for defining the observed pseudorange of the transmitted and the received radio signal is a function of the true, but unknown range from the receiver's position to the satellite, the velocity of light, the receiver and satellite clock errors (biases) and the problematic propagation delays caused by the atmospheric media through which the GPS signal travels.

GPS receiver computes its three-dimensional coordinates and its clock offset from four or more simultaneous biased ranged (pseu-

ISSN 2229-5518

dorange) measurements between the receiver's antenna and those of the satellites (Langley, 1999). The accuracy of the measured pseudoranges and the fidelity of the model used to process the measurement determine, in part, the overall accuracy of the receiver-derived coordinates. The basic pseudorange model is given by Langley (1999) as:

$$R = \rho + c(dT - dt) + d_{ion} + d_{trop} + e \qquad (1)$$

where R denotes the observed pseudorange; ρ is the geometric range between receiver's antenna at signal reception time and the satellite's antenna at signal transmission time; dt and dT represents receiver and satellite clock offsets from GPS time respectively; d_{ion} and d_{trop} are the ionospheric and tropospheric propagation delays; e accounts for measurement noise as well as effects which cannot be easily modeled, such as multipath; and c stands for vacuum speed of light (velocity of propagation). Assuming the receiver accounts for the satellite clock offset and atmospheric delays, we can simplify equation (1) into a generalized model expressed as follows

$$R = p^t + c(\Delta t) + d \qquad (2)$$

Where p^t = true range between the receiver and satellite (unknown), Δt = clock biases (receiver and satellite), d = propagation delays due to atmospheric conditions, and other variables are as defined earlier. The true range p^t *is* equal to the 3-D coordinate difference between the satellite and user, and it is expressed as follows.

$$p^t = [(X^S - X^U)^2 + (Y^S - Y^U)^2 + (Z^S - Z^U)^2] \qquad (3)$$

Where, X^S, Y^S, Z^S = known satellite coordinates from ephemeris data, and X^U, Y^U, Z^U = unknown coordinates of user which are to be determined.

When four Pseudo-ranges are observed, four equations from (2) and (3) are formed as in equations (4), (5), (6), and (7).

$$(R_1 - c\Delta t - d_1)^2 = (X_1^S - X_1^U)^2 + (Y_1^S - Y_1^U)^2 + (Z_1^S - Z_1^U)^2 \qquad (4)$$

$$(R_2 - c\Delta t - d_2)^2 = (X_2^S - X_2^U)^2 + (Y_2^S - Y_2^U)^2 + (Z_2^S - Z_2^U)^2 \qquad (5)$$

$$(R_3 - c\Delta t - d_3)^2 = (X_3^S - X_3^U)^2 + (Y_3^S - Y_3^U)^2 + (Z_3^S - Z_3^U)^2 \qquad (6)$$

$$(R_4 - c\Delta t - d_4)^2 = (X_4^S - X_4^U)^2 + (Y_4^S - Y_4^U)^2 + (Z_4^S - Z_4^U)^2 \qquad (7)$$

In these equations, the only unknowns are X^u, Y^u, Z^u, and Δt. The solution of these equations at each GPS update yields the user's 3-D position coordinates. Adding more pseudo-range observations provides redundancy to the solution. For instance, if seven satellites are simultaneously observed, seven equations are derived, and still only four unknowns result. Equations (4) to (7) are resolved in the form of (8), (9), (10) and (11), modified after [1].

$$R_1 = \sqrt{(X_1^S - X_1^U)^2 + (Y_1^S - Y_1^U)^2 + (Z_1^S - Z_1^U)^2} + c\Delta t + d_1 \qquad (8)$$

$$R_2 = \sqrt{(X_2^S - X_2^U)^2 + (Y_2^S - Y_2^U)^2 + (Z_2^S - Z_2^U)^2} + c\Delta t + d_2 \qquad (9)$$

$$R_3 = \sqrt{(X_3^S - X_3^U)^2 + (Y_3^S - Y_3^U)^2 + (Z_3^S - Z_3^U)^2} + c\Delta t + d_3 \qquad (10)$$

$$R_4 = \sqrt{(X_4^S - X_4^U)^2 + (Y_4^S - Y_4^U)^2 + (Z_4^S - Z_4^U)^2} + c\Delta t + d_4 \qquad (11)$$

Where R_1, R_2, R_3 and R_4 = noiseless Pseudorange, $[X_i\ Y_i\ Zi]^T$ = Cartesian position coordinates of satellite *i* $[x', y', z']^T$, = Cartesian position coordinates of observer, Δt = *receiver offset from the satellite system time and* c = *speed of light.* The WGS-84 geocentric Cartesian coordinate reference frame (X, Y, Z) used by GPS and local level coordinate reference frame (x′, y′, z′), is given in Fig. 2.

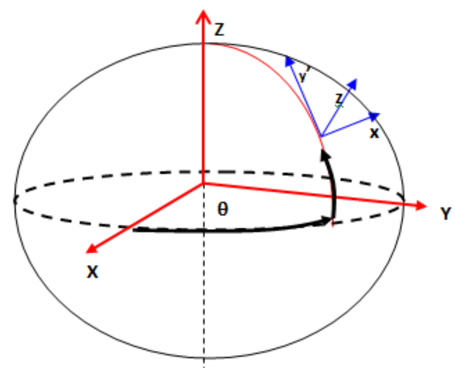

Fig. 2: The WGS-84 Geocentric Cartesian Coordinate Reference Frame (X, Y, Z) used by GPS and Local Level Coordinate Reference Frame (x′, y′, z′).

This solution is highly dependent on the accuracy of the known coordinates of each satellite (i.e., X^s, Y^s and Z^s), the accuracy with which the atmospheric delays d can be estimated through modeling, and the accuracy of the resolution of the actual time measurement process performed in a GPS receiver (clock synchronization, signal processing, signal noise, etc.). As with any measurement process, repeated and long-term observations from a single point will enhance the overall positional reliability. The observation equations of the code and carrier phase measurements on the Li frequencies (i = 1, 2) were expressed by [6], [11] and [10] in Equations (12) and (13), respectively, as:

$$P(Li) = \rho + c(dt - dT) + d_{orb} + d_{trop} + d_{ion/Li} + d_{mult/(Li)} + \varepsilon(P(Li)), \qquad (12)$$

Equation-12 is a modified or extended version of equation-2.

$$\Phi(Li) = \rho + c(dt - dT) + d_{orb} + d_{trop} - d_{ion/Li} + \lambda_i N_i + \lambda_i(\phi_r(t_0, Li) - \phi_s(t_0, Li)) + d_{mult/\Phi(Li)} + \varepsilon(\Phi(Li)) \qquad (13)$$

where *P(Li)* is the measured pseudorange on *Li* (m); *Φ(Li)* is the measured carrier phase on *Li* (m); ρ is the true geometric range (m); c is the speed of light (m/s); dt is the satellite clock error (s); dT is the receiver clock error (s); d_{orb} is the satellite orbit error (m); d_{trop} is the tropospheric delay (m); $d_{ion/Li}$ is the ionospheric delay on Li(m); λ_i is the wavelength on Li(m); N_i is the integer phase ambiguity on Li (cycle); ϕ_r (t_0, Li) is the initial phase of the receiver oscillator; $\phi_s(t_0, Li)$ is the initial phase of the satellite oscillator; $d_{mult/P(Li)}$ is the multipath effect in the measured pseudorange on Li(m); $d_{mult/\Phi(Li)}$ is the multipath effect in the measured carrier phase on Li (m) and ε is the measurement noise (m).

If the initial phase and the integer phase components are grouped to a single term as most literatures have done, equation-13 can be re-written as [6].

ISSN 2229-5518

$$(Li) = \rho + c(dt - dT) + d_{orb} + d_{trop} - d_{ion/Li} + \lambda_i N_i + d_{mult/\Phi(Li)} + \varepsilon(\Phi(Li)), \quad (14)$$

Where N_i is no longer an integer term.

1.2 Dilution of Precision (DOP)

The Dilution of Precision (DOP) is a measure of the geometrical strength of the observations model. DOP can also be a measure of the strength of the satellite-constellation geometry. The more satellites that can be observed and used in the final solution, the better the solution. In mathematical terms, DOP is a scalar quantity used in an expression of a ratio of the positioning accuracy. It is the ratio of the standard deviation of one coordinate to the measurement accuracy. Therefore, since DOP can be used as a measure of geometrical strength, it can also be used to selectively choose four satellites in a particular constellation that will provide the best solution [9], [8], [4].

The DOP values depend on the cofactor matrix $Q = \left(A^T A\right)^{-1}$ or covariance matrix.

$$Q_{xx} = \left(A^T A\right)^{-1} \sigma^2 = D\sigma^2 \quad (15)$$

This means, DOP values are a function of the diagonal elements of the covariance matrices of the adjusted parameters for the observed GPS signal.

1.2.1 Geometric DOP (GDOP)

The main form of DOP used in absolute GPS positioning is the geometric DOP (GDOP). GDOP is a measure of accuracy in a 3-D position and time. The final positional accuracy equals the actual range error multiplied by the GDOP. The GDOP is estimated using equation-16 [5], [6].

$$\left.\begin{aligned} GDOP &= \sqrt{trace(Q)} \\ GDOP &= \sqrt{Q_{11} + Q_{22} + Q_{33} + Q_{44}\sigma} \end{aligned}\right\} \quad (16)$$

According to Wu et al [10], the accuracy of a system can be generally decomposed into two components: User Equivalent Range Error (UERE) and GDOP. UERE is obtained by mapping all of the system and user errors into a single error in the user measured range, while GDOP is the satellite geometry dependent quantity that maps the UERE (an error in observation space) into the user accuracy (in position space). Therefore, the estimate of the root mean square value of the three position errors and the clock error, rms (x, b) may thus be expressed as:

$$\text{rms}(x, b) = \sigma_{UERE}.GDOP \quad (17)$$

The DOP factors used in GPS Positioning are derived from the diagonal elements of the inverse of the normal matrix of the observation. The normal matrix is computed as part of standard GPS Navigation solutions during the post processing of observed data. The navigation solution is based on the measured C/A-Code Pseudo ranges and solves for the 3-D receiver coordinates (X, Y, Z) and the receivers clock offset (dT) using the least squares algorithm. In the least squares solutions, the inverse of the normal matrix is, of course, the variance matrix of the estimated parameters and therefore takes the form of equation-18 [5], [6].

$$Q_{xx} = \begin{bmatrix} \sigma_X^2 & \sigma_{YX} & \sigma_{ZX} & \sigma_{TX} \\ \sigma_{XY} & \sigma_Y^2 & \sigma_{ZY} & \sigma_{TY} \\ \sigma_{XZ} & \sigma_{YZ} & \sigma_Z^2 & \sigma_{TZ} \\ \sigma_{XT} & \sigma_{YT} & \sigma_{ZT} & \sigma_T^2 \end{bmatrix} = \begin{bmatrix} \sigma_E^2 & \sigma_{EN} & \sigma_{Eh} & \sigma_{EdT} \\ \sigma_{EN} & \sigma_N^2 & \sigma_{Nh} & \sigma_{NdT} \\ \sigma_{Eh} & \sigma_{Nh} & \sigma_h^2 & \sigma_{hdT} \\ \sigma_{EdT} & \sigma_{NdT} & \sigma_{hdT} & \sigma_{dT}^2 \end{bmatrix} \quad (18)$$

where,

$$TDOP = \sigma_{dT} \quad (19)$$

$$VDOP = \sigma_h \quad (20)$$

$$HDOP = \left(\sigma_E^2 + \sigma_N^2\right)^{1/2} \quad (21)$$

$$PDOP = \left(\sigma_E^2 + \sigma_N^2 + \sigma_h^2\right)^{1/2} = \left(\sigma_X^2 + \sigma_Y^2 + \sigma_Z^2\right)^{1/2} \quad (22)$$

$$GDOP = \left(\sigma_E^2 + \sigma_N^2 + \sigma_h^2 + c\sigma_{dT}^2\right)^{1/2} = \left(\sigma_X^2 + \sigma_Y^2 + \sigma_Z^2 + c\sigma_{dT}^2\right)^{1/2} \quad (23)$$

c = velocity of light (≈ $3.0*10^8$m/s^{-2})

GDOP can also be decomposed into four parts, namely 3-D position, horizontal position, vertical position, and time: values are good measures of system availability as they represent the geometric strength of the solution. DOP values can also be used to represent system accuracy when it is assumed that all range measurements have the same UERE [12]. The precision of a position measurement output depends upon both the measurement geometry, as represented by the DOP values, and range errors caused by signal strength, ionospheric effects, and multipath errors [7], [2].

The Positional DOP (PDOP) is a measure of the accuracy in 3-D position, while the Horizontal DOP (HDOP) is a measurement of the accuracy in a 2-D horizontal position, and it roughly indicates the effects of satellite-range geometry on a resultant position. Vertical DOP (VDOP) is a measurement of the accuracy in the standard deviation of a vertical height, TDOP is the measurement of the accuracy in the standard deviation of time within which the signals were transmitted from the GPS and received by the observer's receiver. Table1 contains the rating of DOP values.

Table1: Jon's Interpretation of Dilution of Precision Values [13]

DOP Value	Rating
1	Ideal
2-3	Excellent
4-6	Good
7-8	Moderate
9-20	Fair
21-50	Poor

The final positional accuracy of a point *determined by using absolute GPS solution techniques* is directly related to the geometric strength of the configuration of satellites observed during the survey session. Therefore, this study attempts to optimize GPS network reference control in Gidan Kwano area of Minna, Nigeria using dilution of precision (DOP) matrices, with the goal of selecting the suitable reference control within the network.

1.3 Objectives of Study

The objectives of this study are to:

ISSN 2229-5518

i. Carry out GPS pre-observation and post-observation DOPs (GDOP, PDOP, HDOP, VDOP and TDOP) computation and analyses over Gidan Kwano area of Minna and 25 ground control network respectively for a 12-hour rapid-static survey campaign on the 9th of November, 2010;

ii. Compare the pre-observation planning with post-observation DOPs and satellite visibility;

iii. Select the optimum control point in the observed network as a reference for future network observations and extension in the area using the DOP variance analysis.

1.4 Study Test Site

Gidan Kwano, the main campus site of Federal University of Technology (FUT), Minna, Niger State, Nigeria, is located approximately on latitude 9.45⁰ N to 9.6⁰N and longitude 6.33⁰E and 6.35⁰E. The Gidan Kwano campus of the university covers a land mass area of about 10,650ha, located along Minna-Kateregi-Bida Road (see Figure 3). The network of 25 control stations and GPS14 selected as reference control for Gidan Kwano, Minna is given in Fig. 4.

Fig. 3: Part of FUT Main Campus, Gidan Kwano, Minna, Nigeria [14]

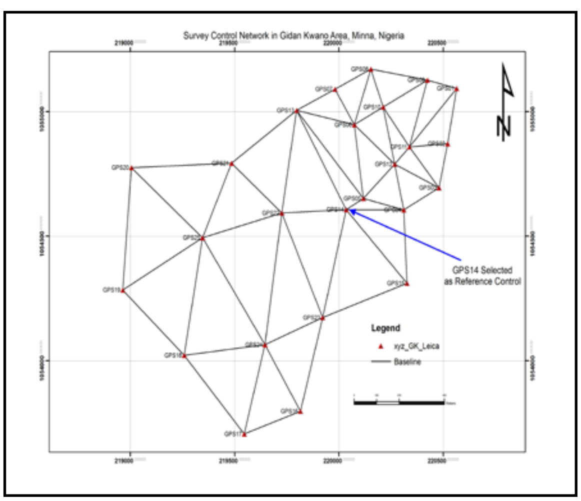

Fig. 4: The Network of 25 Control Stations and GPS14 selected as Reference Control for Gidan Kwano Area, Minna.

2.0 MATERIALS AND METHODS

2.1 Equipment and Materials Used

Leica SR20 Single Frequency Differential GPS with its receiver's components and accessories were used. The accessories include: 1 Nos. Tripod stand, 2 Nos. Antennas, 1 Tripod pole, 2 Nos. of Radio receiver, Connection cables, 1 No. 2m tape, 2 Nos. Bracket, Pentium-M HP Laptop (500GBHDD/4GB RAM), Leica GeoOffice (LGO) 5.0 and Trimble Total Control (TTC) Software. The GPS ground control reference network optimization and selection algorithm for the study area is given in Fig. 5.

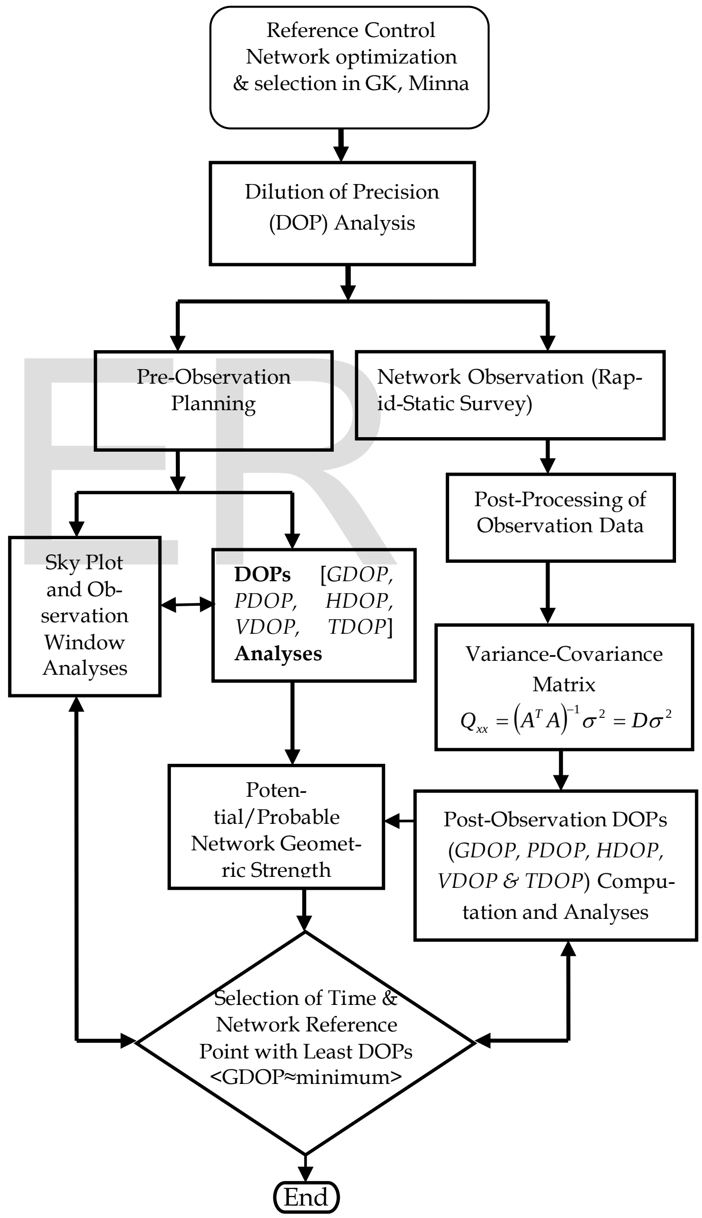

Fig. 5: GPS Ground Control Reference Network Optimization and Selection Algorithm for Gidan Kwano Area of Minna, Nigeria

2.2 GPS Observation Planning

ISSN 2229-5518

Project planning is a critical component of achieving successful and accurate GPS Surveys. Part of the planning is the use of the GNSS Software to visualise and analyse the satellite visibility, observation windows with DOP, and satellite cut-off elevation angles on the day of observation. The plans conducted for 9th November 2010 include sky visibility and observation windows for the study area.

2.2.1 Sky Visibility

As a minimum, it is recommended that visibility be clear in all directions from an altitude or cut-off angle of 15^0 from the horizon. The latitude, longitude and average ground elevation of the site were used as inputs for sky visibility planning**.** The *sky plot* and the satellite *visibility plot* over Minna, for the day of observation, are given in Figures 6 and 7, respectively. The satellite visibility plan was prepared using inputs such as latitude (9° 36'N), longitude (6° 33'E), mean elevation of 386m above mean sea level and satellite elevation cut-off angle of 15°.

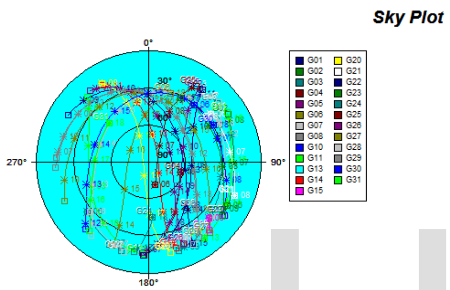

Fig.6: Sky Plot of the Visible Satellites

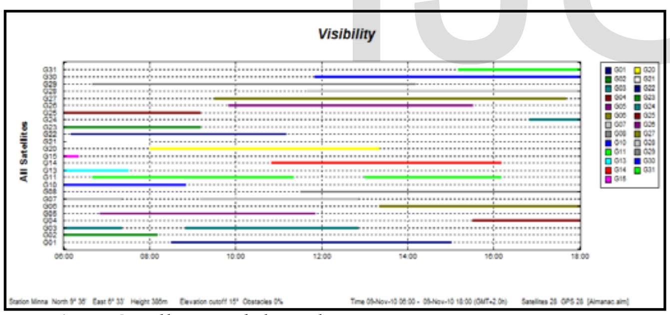

Fig. 7: Satellite Visibility Plot

2.2.2 Observation Windows

This consists of determining which satellites will be visible over Minna during a proposed observation period of 6:00hrs and 18:00hrs on the 9th November 2010. The required inputs for the observation windows were the station's latitude and longitude (*lat. 09° 36'N, long 06° 33'E*), date and time for the observation. In addition, a relatively current satellite almanac was used to generate this *multi-station analysis.* A multi-station analysis is carried out as the first step to determine the availability of the GPS satellites during observation sessions. This allows for checking simultaneous observation of the *same satellite, the satellite elevation and the Dilution of Precision (DOP). Low Geometry Dilution of Precision (GDOP) indicates strong satellite geometry with a higher possibility of accuracy.* The satellite elevation plot is given in Fig. 8.

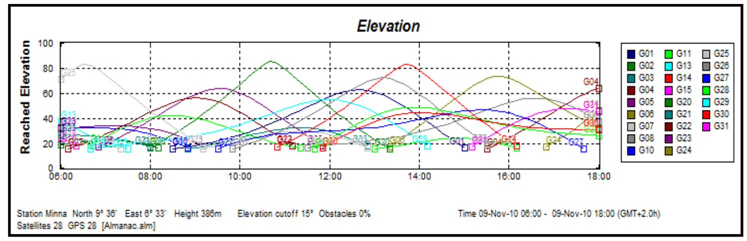

Fig. 8: Satellite Elevation Plot

2.3 Field Data Collection

The Reference receiver was set up on L40; the rover was moved to network area in Gidan Kwano, Minna where the observation was made in rapid-static mode. The observation was carried out in a minimum interval of 15 minutes per station for a total of twenty-five (25) stations. However, about 5-7 minutes were spent in taking the roving antenna between two stations and mounting it up on pre-leveled tripod. Aside this, in Leica SR20 the baseline length to which the observation is to be covered was set by the observer, (i.e 0-5km, 5-15km or above 15km as available in the instrument). The minimum number of satellite required for a two dimensional position to be defined was also set by the observer, and mask angle. The observation spanned between 8:00hrs and 17:00hrs on the 9th November 2010. The number of satellites tracked at control stations during the observation campaign is given in Fig. 9.

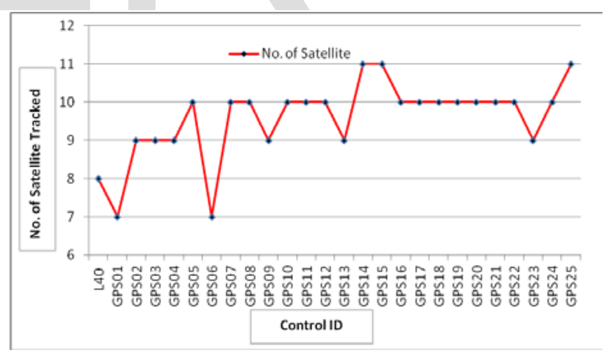

Fig. 9: Number of satellites tracked at control stations during Observations

2.4 Data Processing

The Leica Geo Office 5.0 was launched; a new project was created, using Data Exchange Manager from tools menu and a setting of selecting instrument brand (GPS 500 which has the same default setting with SR20) and the communication port. The raw data was then downloaded into a folder in the Computer. The raw data was then imported for processing, where the base station coordinates was corrected with the original values and selected as reference and others as rovers. The data was processed and the results were copied to the spreadsheet. The spread sheet data was then imported as batch in Franson Coordinate Transformation software where the data was converted to UTM Minna coordinate system.

3.0 RESULTS AND DISCUSSION

3.1 Results

The DOP factors in GPS positioning solution are derived from the diagonal elements of the inverse of the normal matrix of the observation (the trace of covariance matrix). Therefore, the estimate of the square root of the trace of the covariance matrix is equal to the pseudorange measurement and modeling error standard deviation (σ) multiplied by a scaling factor equal to the root of the trace of matrix Q (from equations 16, 18, 24 and appendix I). Equation-24 shows two covariance matrices for GPS01 and GPS02, while Appendix-I contain the tabulated covariance matrix elements of the remaining 23 observed controls in the study area.

$$Q_{XGPS01} = \begin{bmatrix} 1.44E-06 & -9.2E-07 & -4.9E-07 \\ & 4.53E-06 & -2.3E-06 \\ & & 9.87E-06 \end{bmatrix}; Q_{XGPS02} = \begin{bmatrix} 0.004202 & 0.004086 & 0.004119 \\ & 0.034344 & 0.010233 \\ & & 0.019811 \end{bmatrix} \quad (24)$$

The pre-observation DOPs values (and the available satellites) of the study area during the observation window are given in Figures 10 and 11.

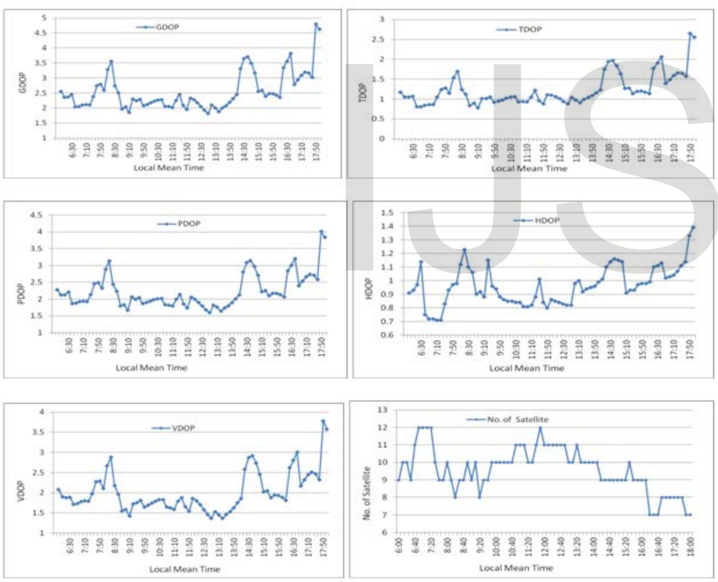

Fig. 10: Pre-observation DOPs [GDOP, PDOP, HDOP, VDOP and TDOP] values and available satellites

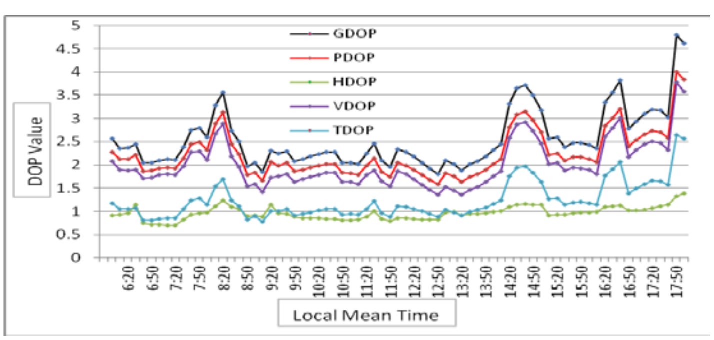

Fig 11: Combined Pre-observation DOPs values

The post-observation DOPs values (and the available satellites) of the study area during the observation window are given in Figures 12 and 13.

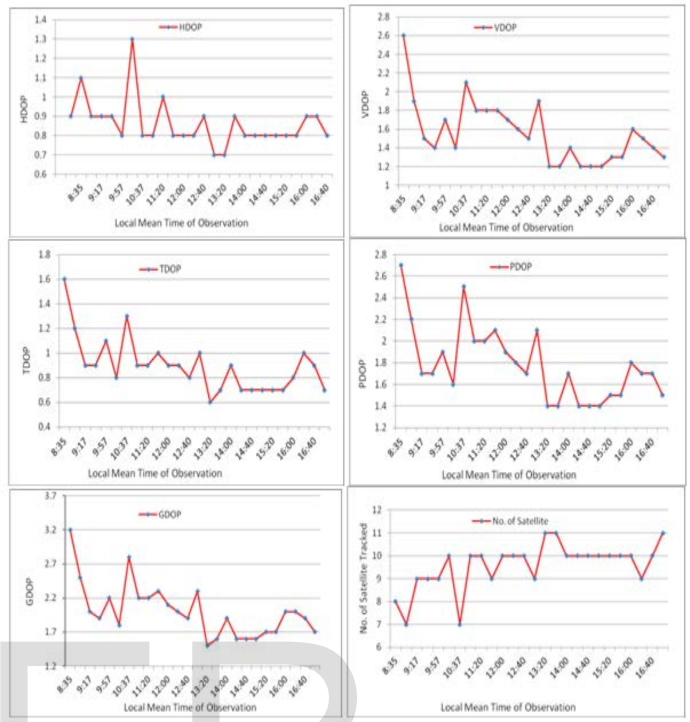

Fig. 12: Post-observation DOPs [GDOP, PDOP, HDOP, VDOP and TDOP] values and available satellites

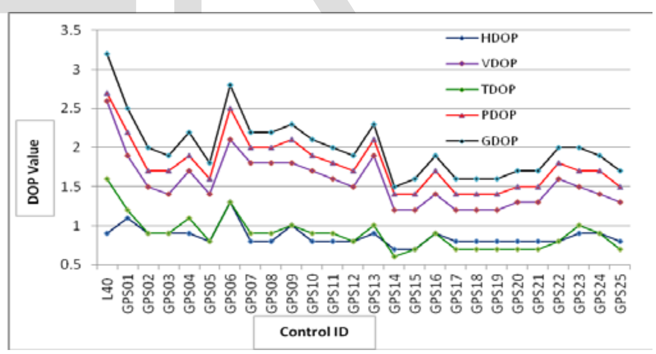

Fig. 13: Combined Post-Observation DOPs values

The mean values of the DOPs from pre-observation planning and post-observation computations are shown in Table 2 and Fig. 14.

Table 2: Mean Values of the DOPs from Pre and Post-observations

DOPs	Pre-Observation (Mean Value)	Post-Observation (Mean Value)	% of Agreement
GDOP	2.5	2.0	80
PDOP	2.2	1.8	82
HDOP	1.0	0.9	90
VDOP	2.0	1.6	80
TDOP	1.2	0.9	75

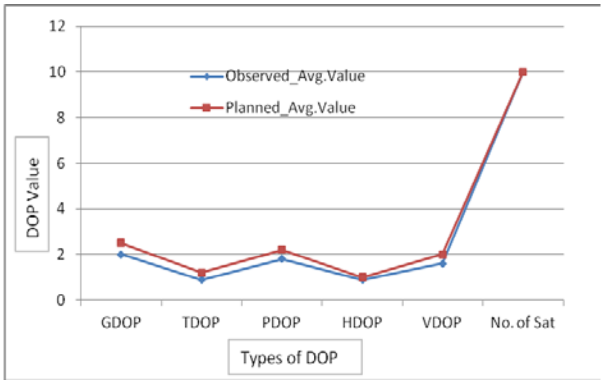

Fig 14: Comparison of the Mean DOPs from Pre- and Post Observations

3.2 Discussion

Figures 10 – 13 show the DOP values computed for the sky view GPS constellation viewed from Minna (*latitude 9° 36'N, longitude 6° 33', mean elevation of 386m above mean sea level, satellite elevation cut-off angle of 15°*). The time span was 6:00hrs to 18:00hrs of 9th November 2010. The HDOP values are less than those of VDOP, which is evidence that the horizontal position errors are less than the vertical errors.

The mean visible satellite from the sky plot shows an average of ten (10) GPS satellites at all times within the span of 6:00hrs to 18:00hrs of 9th November 2010.

From Table 2, the estimates of the DOPs from post-observation DOPs agree with the post-observation DOPs within an average of about 81%. This implies that, the PDOP developed in the pre-observation planning is valid for rapid-static or kinematic surveys in the study area but less valid for a long-duration (30-minutes and above) static survey in the study area. Based on the DOPs variance analysis for each observed network point, control point GPS14 (*x=220034.560m, y=1054606.580, h =236.178m, UTM Zone 32*) with PDOP and GDOP of **1.4** and **1.5**, respectively was adjudged the optimum point as *reference* for survey network observations and extension in the study area. A total of eleven (11) satellites were tracked by the antenna at control point GPS14, which was the second highest elevated point after GPS12 in the network.

The elements of matrix Q are a function of the receiver-satellite geometry only, but the scaling factor is typically non-unity; which by implication swells the pseudorange error and dilutes the precision of the position determination. This scaling factor is the GDOP. However, because specific components such as position (3-D), horizontal coordinate (2-D), vertical coordinate (1-D) and time (1-D) are involved, their respective dilution of precisions were computed and represented by Figures 12. A careful examination of the values of GDOP, PDOP and HDOP as shown in Figures 10 and 12 show that, high values can be associated with satellites in a constellation of poor geometry. The higher the PDOP/GDOP values, the poorer the solution for that instant in time, and this is critical in determining the acceptability of real-time positioning and navigation solutions.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The final positional accuracy of a point *determined by using absolute GPS solution techniques* is directly related to the geometric strength of the configuration of satellites observed during the survey session. This study has shown that DOPs computed from pre-observation planning and post-GPS observations are valid alternatives for rapid-static or kinematic observation procedures. Consequently, the DOP analysis for each stations occupied in a control network can be used for optimizing and selecting GPS Reference Network Control in Gidan Kwano area of Minna. The GDOP/PDOP developed in the pre-observation planning is valid for rapid-static or kinematic surveys in the study area but is less valid for a long-duration static survey.

It is recommended that for every reasonable GPS Survey Campaigns, a relatively current satellite almanac should be used to generate the *Multi-station Analysis*, as the first step to determine the availability of the GPS satellites during observation sessions. This allows for checking simultaneous observation of the *same satellite, the satellite elevation* and the *Dilution of Precision (DOP).*

It should be noted that, low Geometry Dilution of Precision (GDOP) indicates strong satellite geometry with a higher possibility of accuracy, therefore, effort should be made to use appropriate satellite elevation cut-off angle (e.g. 15°) and ensure adequate time in station occupation during the rapid-static or long static field procedures in order for higher numbers of satellites to be tracked by the receivers.

References

[1] Brown, R. G and Hwang, P.Y.C. (1992). Introduction to Random signals and Applied Kalman Filtering, NY, pp. 211-473.

[2] Dimc, F., Music, B., and Radko Osredkar, R (n.d). *Attaining Required Positioning Accuracy in Archeo-geophysical Surveying by GPS eologija.ff.uni-lj.si/music/Attaining_accuracy.pdf. 4pp.*

[3] Gakstatter, E. (2011). To Post-Process or Not to Post-Process, that is the Question. January 5,http://www.gpsworld.com/survey/to-post-process-or-not-post-process-question-10886)

[4] Gladstone, P. (2006). NAVSTAR GPS: Overview of GPS and Absolute Positioning. Chapter 8.

[5] Langley, B. R., (1999). Dilution of Precision. GPS World, May 1999. www.gpsworld.com Pp. 52-59

[6] Misra, P., and Enge, P. (2001). Global Positioning System, Signals, Measurements, and Performance.

[7] Odijk, D. (2002). Fast precise GPS positioning in the presence of ionospheric delays, PhD thesis, Delft University.

[8] Strang, G and Borre, K., (1997). *Linear Algebra, Geodesy, and GPS*, Wellesley-Cambridge Press, 1997.

[9] U.S. Army Corps of Engineers (1996). NAVSTAR Global Positioning System Surveying, Department of the Army, Engineer Manual EM 1110-1-1003, Washington, DC 20314-

1000
[10] Wu, F., Zhang, K., Yasuda, A., and Liu, G-J. (n.d). Performance Analysis of Hybrid Modernized GPS and Galileo System. Department of Geospatial Science, RMIT University, Melbourne, Australia and Laboratory of Communication Engineering, Tokyo University of Marine Science and Technology, Japan.
[11] Wu, F., Zhang, K., and Liu, G. J. (2006). A Study of GPS/Galileo Performance in Urban Environment Using a Simulation Tool. Proceedings of the 14th International Conference on Geoinformatics, Wuhan, China.
[12] Wu, F., Kubo, N., and Yasuda, A. (2004). Performance Evaluation of GPS Augmentation Using Quasi-Zenith Satellite System. IEEE Transactions on Aerospace and Electronic Systems, 40(4), 1249-1261.
[13] www.developerfusion.com
[14] www.googleearth.com

APPENDIX 1: Variance Matrix of the 25 GPS Stations in Gidan Kwano Area of Minna, Nigeria

Control	Q11	Q12	Q13	Q22	Q23	Q33
GPS01	1.44E-06	-9.2E-07	-4.9E-07	4.53E-06	-2.3E-06	9.87E-06
GPS02	0.004202	0.004086	0.004119	0.034344	0.010233	0.019811
GPS03	0.004292	0.003381	0.004354	0.033056	0.008483	0.021808
GPS15	0.003681	2.89E-05	0.002441	0.031604	-0.00034	0.021663
GPS14	0.00249	-0.00094	0.000497	0.025458	-0.00637	0.01464
GPS05	0.00377	-0.0014	0.000146	0.036834	-0.00656	0.023254
GPS12	0.003968	-0.00135	-0.00089	0.034446	-0.01109	0.019724
GPS11	0.004069	-0.00092	-0.00152	0.034309	-0.0118	0.018548
GPS10	0.004595	4.98E-05	-0.00244	0.029549	-0.00831	0.01497
GPS09	0.004735	0.001405	0.005943	0.009603	0.000474	0.040173
GPS08	0.004404	0.001083	0.006846	0.007157	0.002208	0.052231
GPS07	0.005591	0.003554	-0.00307	0.025701	-0.00604	0.011052
GPS06	0.008337	0.010047	-0.00333	0.050702	-0.0063	0.010659
GPS13	0.004136	-0.00166	-0.00423	0.009465	0.003823	0.073483
GPS22	0.004753	0.003788	0.000119	0.02524	-0.00126	0.012831
GPS25	0.00534	-0.00193	0.001488	0.010795	-0.00117	0.062483
GPS21	0.00512	0.002933	-0.00018	0.025956	-0.00107	0.021387
GPS20	0.004553	0.002071	0.000145	0.022519	-0.00026	0.024018
GPS19	0.004367	0.000692	0.000799	0.020816	-0.00047	0.032813
GPS18	0.004247	-0.00025	0.000664	0.022229	-0.0009	0.050989
GPS17	0.008545	-0.00183	0.003083	0.012765	-0.01134	0.043394
GPS16	0.014053	-0.00438	0.013159	0.012893	-0.01713	0.065895
GPS24	0.016599	-0.00659	0.025517	0.01414	-0.02291	0.101131
GPS23	0.006342	-0.00015	0.00128	0.007275	-0.00634	0.041218
GPS04	0.005338	-6.5E-05	0.000383	0.0069	-0.00683	0.047855

ABOUT THE AUTHORS:

(1) Dr. Lazarus Mustapha OJIGI

Lazarus Mustapha Ojigi is an Associate Professor of Surveying and Geoinformatics, and currently the **Acting Director** of Mission Planning, Information Technology and Data Management Department, National Space Research and Development Agency (NASRDA), Abuja Nigeria. He was born in Imane, Nigeria, and holds B.Sc. M.Tech and PhD degrees in Surveying and Applied Remote Sensing respectively from Ahmadu Bello University, Zaria and Federal University of Technology, Minna, Nigeria. He was the Head of department of Surveying and Geoinformatics and Deputy-Dean, School of Environmental Technology, Minna in 2006-2008 and 2008-2010 respectively. He is a registered Surveyor with the Surveyors Council of Nigeria (SURCON) and his areas of expertise include Space Geodesy, Engineering Surveying and Computing, Satellite Remote Sensing, and Geospatial Modeling. *His current research efforts are on 'Global Navigation Satellite System (GNSS), Earth Observation Satellites (EOS), and microwave data integration for mapping, geospatial modeling, and geodynamic studies in Nigeria.* He has attended several Local and International Conferences and Workshops with Geomatics related contents, and has several refereed scientific publications to his credit.

Address:
Mission Planning, Information Technology & Data Management Dept.,
National Space Research & Development Agency (NASRDA),
Umaru Musa Yar'Adua Way,
P. M. B. 437, Garki, Abuja, Nigeria
E-mail: drlazmojigi@gmail.com
Phone: +234-8166930684

ISSN 2229-5518

(2) Mr. Etim E. EYO

Etim Eyo is an academic staff in the Department of Surveying and Geoinformatics at Federal University of Technology, Minna, Nigeria. He holds a B.Sc. (Land Surveying) and M.Sc. (Surveying and Geoinformatics) degrees from Ahmadu Bello University, Zaria, Nigeria and University of Lagos, Nigeria, respectively. His PhD research is on *GPS Seismometer for Earthquake Early Warning Applications*, with focus on the integration of real-time GPS and seismic data.

Address:
Etim Eyo (or E. E. Eyo),
GNSS and Geodynamics Research Group,
Department of Geomatic Engineering,
Faculty of Geoinformation & Real Estate,
Universiti Teknologi Malaysia, Malaysia
E-mail: etim_eyo@yahoo.com
Tel.: +60 14958 7011

(3) Dr. Temel BAYRAK

Temel Bayrak is an Associate Professor of Geomatics Engineering, and currently the Director of Science and Technology Institute, Gümüşhane University, Turkey. He was born in Trabzon and holds a PhD in Geodesy and Photogrammetry Engineering from Karadeniz Technical University, Trabzon, Turkey. Dr. Bayrak's areas of expertise include: geodesy, satellite positioning and navigation, engineering surveying, adjustment computation, and computer programming. He has published and refereed in many national and international journals, and he is a member of various national and international scientific organisations.

Address:
Assoc. Prof. Dr. Temel Bayrak,
Faculty of Engineering,
Department of Geomatics Engineering,
Gümüşhane University, Turkey
E-mail: tbayrak@gumushane.edu.tr
Tel.: +90 456 2337425/6/1230