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Comparison between Differential GNSS Code and phase solution with

Wide Area Differential GPS (WADGPS) and omniSTAR Network.

F.Zarzoura[1,1], R. Ehigiator – Irughe[1*]

[1] Faculty of Engineering, Mansoura University, Egypt

[2] Siberian State Geodesy Academy, Department of Engineering Geodesy and GeoInformation Systems, Novosibirsk, Russia.

[1]fawzyhamed2011@yahoo.com, *raphehigiator@yahoo.com,

Abstract

Global Navigation satellite System (GNSS) has become an important tool in any endeavor where a quick measurement of geodetic position is required. GNSS observations contain both Systematic and Random errors. Differential GPS (DGPS) and Real Time Kinematic (RTK) are two different observation techniques that can be used to remove or reduce the errors effects arising in ordinary GNSS. This study has utilized procedure to compare DGPS with WADGPS and omniStar network accuracy.

Key words: GNSS, Code and Phase solution, WADGPS and omniSTAR.

1.0 Introduction

Real time GPS applications are commonly based on the code (range) measurements. These measurements are affected by many biases, which cause the derived three-dimensional coordinates to be deviated, significantly, from the true positions [1]. One of the approaches that can be used to eliminate these GPS range errors is the Wide Area Differential GPS (WADGPS) and omniSTAR.

This study is concentrated on the evaluation of Wide Area Differential GPS (WADGPS) technique with the dual frequency DGPS technique. It is also oriented to study the performance of WADGPS in the determination of 2-D coordinates. To achieve the stated objectives of this research, the required field tests are divided into two categories [1]:

a) The first approach concentrated on the assessment of Static DGPS technique where a field test was carried out, the results obtained from the processed dual frequency data were compared and analyzed in CODE and PHASE solutions of short surveyed distances of 10km.
b) The second category of field tests is to process and evaluate the results (coordinates) obtained, using WADGPS technique using Omni STAR network.

1.2 Test Field Procedure:

A dual frequency GPS receiver of LEICA RTKGPS 1200 system, was setup at the reference point (NGN95), which serve as the control station (master) throughout the research. The receiver at the master station was on static mode and at observation rate of (5) seconds. The rover receiver of the same LEICA type was setup at point number (PM-08) that is about 3 km from the reference receiver with the same parameters as the master receiver as presented in figure (1) below. All other stations were similarly occupied as presented in figure (1) and table (1) below.

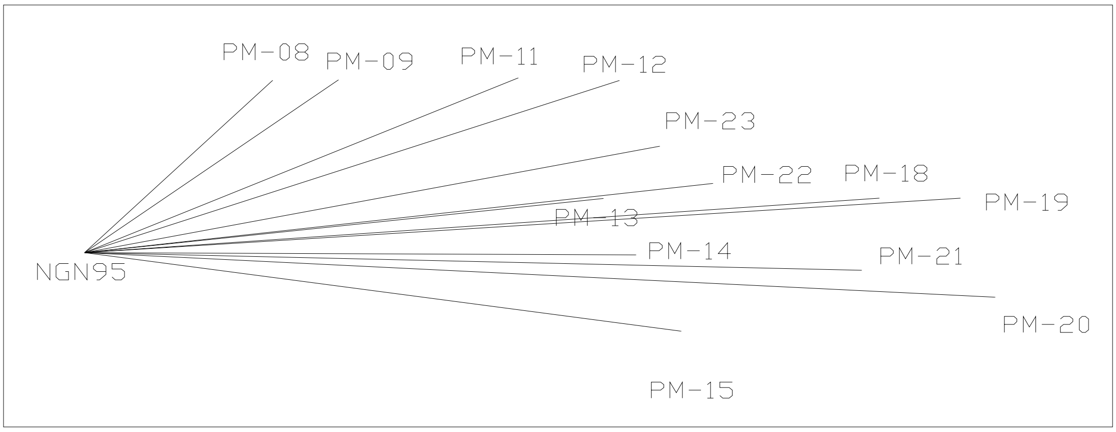


Figure 1: GPS observation

Table 1: schematic diagram of distance relationship.

NGN95	PM-08	PM-09	PM-11	PM-12	PM-13	PM-14	PM-15
Dis.,(m)	2920	3453	5119	6110	5601	5910	6467
NGN95	PM-17	PM-18	PM-19	PM-20	PM-21	PM-22	PM-23
Dis.,(m)	7516	8575	9416	9775	8330	6743	6222

In addition, the other essential observation operating parameters are the same for both reference and rover receivers, which are: the Health/L2 mode is selected as Auto, the minimum elevation angle (mask angle) is (10) degrees, the data rate (5) seconds, initialization period is (10) minutes and the minimum number of (4) satellites.

1.3 GPS Observation Equations

Two different models for the GPS observations can be applied: one model for the code measurements and the other model for phase measurements. The code observation is the difference between the transmission time of the signal from the satellite and the arrival time of that signal at the receiver multiplied by the speed of light [2]. The time difference is determined by comparing the replicated code with the received one. The time difference is the time shift essential to align these two codes. The code observation represents the geometric distance between the GPS satellite and the receiver plus the bias caused by the satellite and the receiver clock offsets. Moreover, the atmospheric bias and the noise influence the code observations [3].

The basic observation equation related to the code measurement of a receiver (a) to a satellite (j) can be written as [4].

$$R_a^j(t) = \rho_a^j(t) + C\,\delta^j(t) - C\,\delta_a(t) + \Delta_a^j Ion(t) + \Delta_a^j Trop(t) + \zeta \qquad (1\text{-}1)$$

Where:

$R_a^j(t)$	The biased code geometric range
$\rho_a^j(t)$	The space distance between the satellite and receiver
C	Speed of light.
$\delta^j(t)$	The bias of the satellite clock .

$\delta_a(t)$	The bias of the receiver clock
$\Delta_a^j Ion(t)$	The ionosphere delay in m.
$\Delta_a^j Trop(t)$	The tropospheric delay in m.
ζ	The observation noise

The phase measurement is the difference between the generated carrier phase signal in the receiver and the received signal from the satellite. The phase measurement is in range units when it is multiplied by the signal wavelength. It represents the same range and biases as the code observation, and additionally the range related to the unknown integer ambiguities. The observation equation for the phase measurement can be written as the follows [4]:

$$\varphi_a^j(t) = \frac{1}{\lambda}\rho_a^j(t) + N_a^j + f\,\delta^j(t) - f\,\delta_a(t) - \frac{1}{\lambda}\Delta_a^j Ion(t) + \frac{1}{\lambda}\Delta_a^j Trop(t) + \varepsilon \qquad (1\text{-}2)$$

Where:

$\varphi_a^j(t)$	The phase difference between the received code and the replica generated phase in receiver
N_a^j	The unknown integer ambiguity.
λ	The wavelength of the carrier wave.
f	The signal frequency.
ε	The phase observation noise.

1.4 Double-difference mode

The double-difference mode is executed between a pair of receivers and pair of satellites as shown in figure (2). Denoting the stations by a (a), (b) and the satellites involved by (j), (k). Two single-differences according to equation (1-3) can be applied [4]:

$$\left.\begin{aligned}\phi_{a,b}^{j}(t) &= \frac{1}{\lambda}\rho_{a,b}^{j}(t) + N_{a,b}^{j} - f^{j}\delta_b(t)\\ \phi_{a,b}^{k}(t) &= \frac{1}{\lambda}\rho_{a,b}^{k}(t) + N_{a,b}^{k} - f^{k}\delta_b(t)\end{aligned}\right\}. \qquad (1\text{-}3)$$

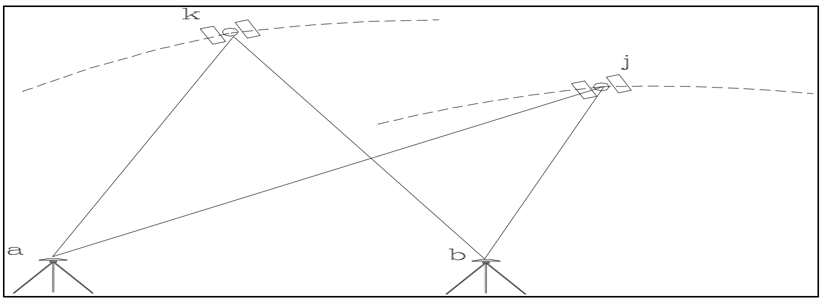


Figure 2: The double-difference technique.

These single-differences are subtracted to get the double - difference model as:

$$\phi^{j}_{a,b}(t)-\phi^{k}_{a,b}(t)=\frac{1}{\lambda}\left[\rho^{j}_{a,b}(t)-\rho^{k}_{a,b}(t)\right]+\left[N^{j}_{a,b}-N^{k}_{a,b}\right] \quad (1\text{-}4)$$

Using the short hand notation as in the single-difference

$$\phi^{j,k}_{a,b}(t)=\frac{1}{\lambda}\rho^{j,k}_{a,b}(t)+N^{j,k}_{a,b} \quad (1\text{-}5)$$

The result of this mode is the omission of the receiver clock offsets. The double-difference model for long baselines when there is a significant difference in the atmospheric effect between the two baselines ends can be expressed [2]:

$$\phi^{j,k}_{a,b}(t)=\frac{1}{\lambda}\rho^{j,k}_{a,b}(t)+N^{j,k}_{a,b}-\frac{1}{\lambda}\Delta^{j,k}_{a,b}Ion(t)+\frac{1}{\lambda}\Delta^{j,k}_{a,b}Trop(t) \quad (1\text{-}6)$$

1.5 Network Double-difference Error Observable

Assuming that a network of *n* GPS reference stations is available, the network single observable vector *(ℓ)* is defined as follows:

$$\ell_n=\left[\overline{\phi}^{\,l}_{l},\cdots,\overline{\phi}^{\,n_{sv}}_{l},\cdots,\overline{\phi}^{\,l}_{n_{rx}},\cdots,\overline{\phi}^{\,n_{sv}}_{n_{rx}}\right]^T \quad (1\text{-}7)$$

Where $\overline{\phi}^{n_{sv}}_{n_{rx}}$ is the phase measurement minus true - range observable from receiver *rx* to satellite *sv* in single form. The geometric ranges are calculated using precise coordinates of the reference stations. n_{rx} is the number of reference stations, and n_{sv} is the number of satellites observed at each station. The network double -difference observable vector is [2]:

$$\nabla\Delta l_n=\left[\nabla\Delta\overline{\phi}^{\,l2}_{l2},\cdots,\nabla\Delta\overline{\phi}^{\,\ln_{sv}}_{l2},\nabla\Delta\overline{\phi}^{\,l2}_{l3},\cdots,\nabla\Delta\overline{\phi}^{\,\ln_{sv}}_{l3},\cdots,\nabla\Delta\overline{\phi}^{\,l2}_{\ln_{rx}},\cdots,\nabla\Delta\overline{\phi}^{\,\ln_{sv}}_{\ln_{rx}}\right]^T \quad (1\text{-}8)$$

Where: $\nabla\Delta\overline{\phi}^{xy}_{ab}$ is the double - difference measurement minus true - range observable between receivers *a, b* and satellites *x, y*. mathematically, a double -difference matrix *B* can be used to relate the network single observables and the network double - difference observables such that:

$$\nabla\Delta l_n=B_n l_n \quad (1\text{-}9)$$

$$B_n=\frac{\partial\nabla\Delta l_n}{\partial l_n} \quad (1\text{-}10)$$

The dimension of the double - difference matrix is (d_m *x m*), where d_m is the number of network double - difference observables and m is the number of network single observations [2]. For example, consider an example of 2 receivers *a, b* where each receiver tracks 3 satellites *1, 2, 3*.

The network single observable vector is: $\left[l^1_a,l^2_a,l^3_a,l^1_b,l^2_b,l^3_b\right]$

Choosing satellite *1* to be the base satellite, the double - difference vector, is given as:

$$\left[\nabla\Delta l_{ab}^{12}, \nabla\Delta l_{ab}^{13}\right] = \left[(l_a^1 - l_b^1) - (l_a^2 - l_b^2), (l_a^1 - l_b^1) - (l_a^3 - l_b^3)\right] \qquad (1\text{-}11)$$

Performing the partial derivative as shown in equation (1-12),

matrix B is: $B_n = \begin{bmatrix} 1 & -1 & 0 & -1 & 1 & 0 \\ 1 & 0 & -1 & -1 & 0 & 1 \end{bmatrix}$

If the double - difference ambiguities of network baselines are correctly resolved, the network double - difference error vector is:

$$\nabla\Delta\delta l_n = \nabla\Delta l_n - \lambda\nabla\Delta N_n = \nabla\Delta d_c\phi(p, p_0) + \nabla\Delta\delta_u\phi \qquad (1\text{-}12)$$

Where: $\nabla\Delta d_c\phi(p, p_0)$ is the network double - difference spatially correlated errors and $\nabla\Delta\delta_u\phi$ represents the network double - difference uncorrelated errors. A Kalman filter is used to estimate the float ambiguities using L1 observations, L2 observations and stochastic modeling of the ionospheric error. The ratio test is used to validate the fixed ambiguities. The network double - difference errors are also called the estimated network double - difference corrections. These will be used as input measurements for the linear minimum error variance estimator.

2.0 The theory of WAAS

WAAS consists of approximately 25 ground reference stations positioned across the United States that monitor GPS satellite data. Two master stations, located on either coast, collect data from the reference stations and create a GPS correction message. This correction accounts for GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere. The corrected differential message is then broadcast through one of two geostationary satellites, or satellites with a fixed position over the equator. The information is compatible with the basic GPS signal structure, which means any WAAS-enabled GPS receiver can read the signal. The WAAS message is broadcast on the same frequency as the GPS signal [5].

WAAS provides extended coverage both inland and offshore compared to the land-based DGPS (differential GPS) system. Another benefit of WAAS is that it does not require additional receiving equipment while DGPS does [5]. WAAS testing in September 2002 confirmed accuracy performance of 1 - 2 meters horizontal and 2 - 3 meters vertical throughout the majority of the continental U.S. and portions of Alaska [6].

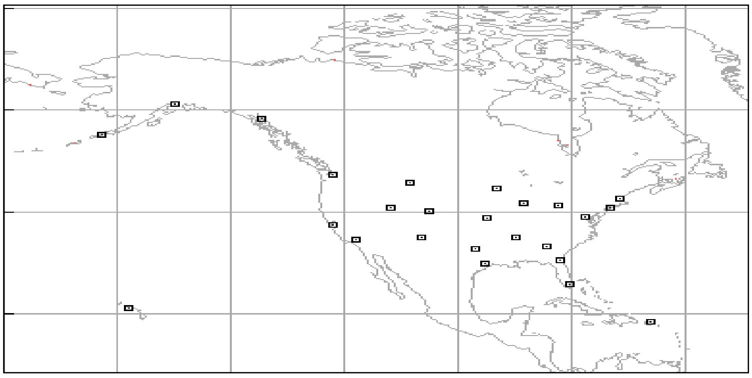


Figure 3: WAAS Coverage

2.1 The Theory of OmniSTAR

The OmniSTAR Network consists of ten permanent base stations in the Continental U.S., plus one in Mexico. These eleven stations track all GPS Satellites above 5 degrees elevation and compute corrections every 600 milliseconds. The corrections are in the form of an industry standard message format. The corrections are sent to the OmniSTAR Network Control Center (NCC) in Houston via wire networks. At the NCC these messages are checked, compressed, and formed into packets for transmission up to the OmniSTAR satellite transponder. This occurs approximately every few seconds. A packet will contain the latest corrections from each of the North American base stations [6].

Fortunately, this requirement of giving the user's OmniSTAR an approximate location is easily solved. OmniSTAR is normally purchased as an integrated GPS/DGPS System, and the problem is taken care of automatically by using the position of the GPS receiver as an approximation. The output of that least-squares solution is a synthesized Correction Message that is optimized for the user's location. This technique of optimizing the corrections for each user's location is called the "Virtual Base Station Solution". It is the technique that enables the OmniSTAR user to operate independently and consistently over the entire coverage area without regard to where he is in relation to the base stations. As far as we have determined, users are obtaining the predicted accuracy over very large coverage areas [6].

Accuracy can only be predicted in statistical terms. In general, the accuracy depends on the quality of the GPS receiver used with OmniSTAR; that is, a "Recreational" class GPS will give poorer results than a "commercial quality" receiver. In this case, poorer means larger semi-random errors relative to the true position [7]. While one may occasionally experience a small error with this type of receiver. The better "Commercial" GPS receivers can achieve horizontal errors of less than a half-meter 67 to 73% of the time, less than a meter 95 to 97% of the time and less than 1.5 meters 99% of the time. Vertical error will be 2 to 2.5 times greater than the horizontal error.

2.2 Data Processing:

After collecting the field data, using dual frequency DGPS receivers, as mentioned above, both L1 data and L2 data becomes available. Consequently, to satisfy the objective of this research, the collected data was processed using LGO software. The run is performed using CODE and PHASE solution approach. In the same vain, OmniSTAR Network was also processed.

3.0 Results and analysis.

The main objective of this research is to investigate the practical significance differences, in the final resulted coordinates of surveyed points, between WADGPS, Omni STAR network, and dual frequency DGPS.

Evaluation of WADGPS, Omni STAR Network, results by Dual Frequency DGPS CODE AND PHASE results is presented as follows:

Table (2) outline the Omni STAR coordinates versus the LGO Code Phase solution.

The coordinates discrepancies (ΔE_3, ΔN_3), and the positional discrepancies (ΔP_3), are evaluated in the following manner:

$$\Delta E_3 = E_{\text{code and phase}} - E_{\text{WADGPS, Omni STAR}}$$

$$\Delta N_3 = N_{\text{code and phase}} - N_{\text{WADGPS, Omni STAR}}$$

$$\Delta P_3 = \sqrt{\Delta E_3^{\,2} + \Delta N_3^{\,2}}$$

From Table (2), it the determination of discrepancies, for the all thirteen points under consideration. In addition, figure (2) also displays the variations of coordinates discrepancies, (ΔE3, ΔN3, ΔP3), as computed at each point, and defined by the point ID.

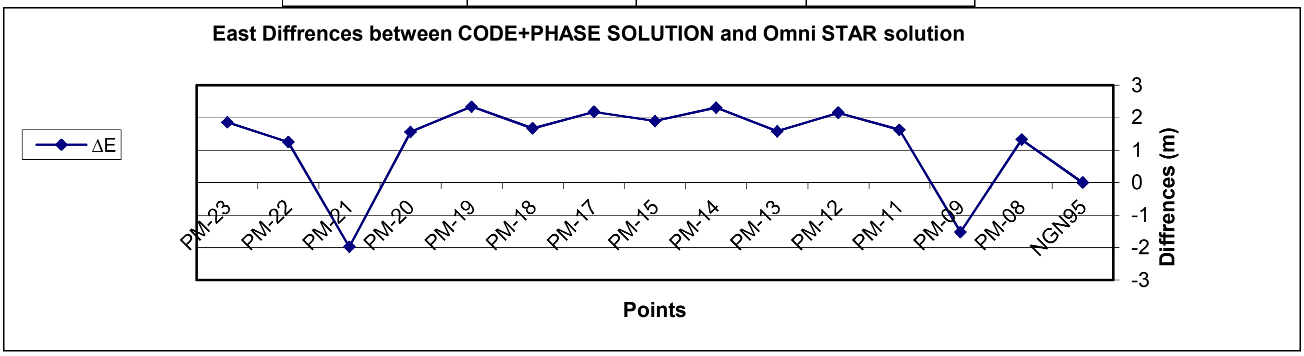
From table (3) and figure (4) one can see that all resulted discrepancies are fluctuating round the zero value, in both positive and negative directions, with some values showing relatively large discrepancies.

Table (2): LGO CODE AND PHASE solution, and Omni STAR results

Pt. Id	(code +phase) solution		(Omni STAR) solution	
	East	North	East	North
PM-08	236618.466	3182526.913	236619.791	3182528.368
PM-09	237328.137	3182535.806	237326.614	3182537.273
PM-11	239251.862	3182558.970	239253.492	3182560.49
PM-12	240337.101	3182527.901	240339.251	3182530.111
PM-13	240165.606	3181077.388	240167.186	3181079.028
PM-14	240514.765	3180383.594	240517.075	3180385.934
PM-15	240999.488	3179448.527	241001.385	3179450.481
PM-17	241931.228	3182088.399	241933.408	3182085.649
PM-18	243123.530	3181387.700	243125.2	3181385.83
PM-19	243996.530	3181079.872	243998.87	3181077.062
PM-20	244364.367	3179864.487	244365.927	3179865.947
PM-21	242934.016	3180318.405	242932.036	3180320.375
PM-22	241343.872	3180193.391	241345.122	3180194.961

Table (3): Discrepancies between CODE AND PHASE and Omni STAR solutions

Pt. Id	ΔE(m)	ΔN (m)	ΔP(M)
PM-08	1.325	1.455	1.968
PM-09	-1.523	1.467	2.114
PM-11	1.63	1.52	2.229
PM-12	2.15	2.21	3.083
PM-13	1.58	1.64	2.277
PM-14	2.31	2.34	3.288
PM-15	1.897	1.954	2.723
PM-17	2.18	-2.75	3.509
PM-18	1.67	-1.87	2.507
PM-19	2.34	-2.81	3.657
PM-20	1.56	1.46	2.137
PM-21	-1.98	1.97	2.793
PM-22	1.25	1.57	2.006



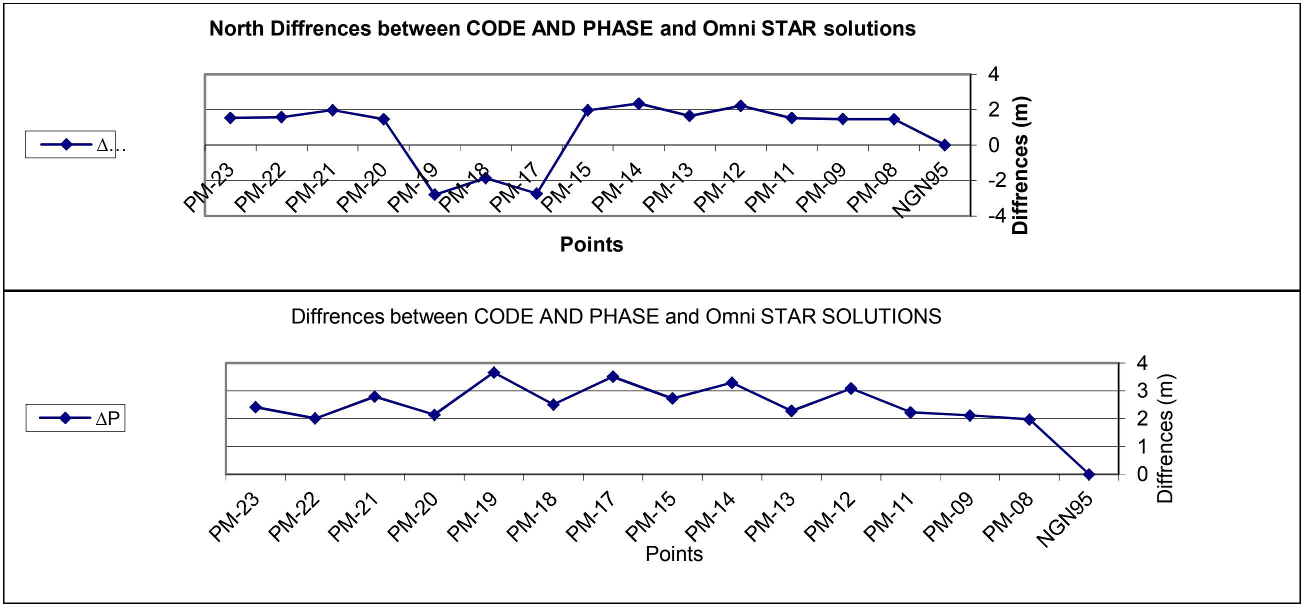


Figure (4) Variations between CODE AND PHASE and Omni STAR solutions

In order to visualize the range of discrepancies variations, the corresponding statistical parameters (Maximum, Minimum, Mean, and standard deviation for single determination) are computed for the 2-D coordinates discrepancies, (ΔE3, ΔN3, ΔP3), and summarized in table (4).

From table (4), for instance, as an example, the positional discrepancies, (ΔP3), are varying between zero, 3.657, with mean value of 2.621, and STDV of 0.567for single determination. Similar statements can be stated for the other evaluated discrepancies, (ΔE3), and (ΔN3).

Table (4.6): standard deviation

	ΔE(m)	ΔN(m)	ΔP(m)
STDV.	1.341	1.829	0.567
Max.	2.34	2.34	3.657
Min.	-1.98	-2.81	0

REFERENCES

1. F. Zarzoura (2008) Accuracy study of wide area GPS networks MSc thesis department of public work Mansoura University Egypt.
2. Elghazoly.A , (2005) "Accuracy Aspects of Static GPS With Special Regard to Internet- Aided Techniques "Faculty of engineering ,Alexandria. Egypt.
3. Enge, P.K., and Van Dierendonck, A.J.,(1995) "Wide Area Augmentation System, in Global Positioning System": Theory and Applications, Vol. II, ed. B.W.
4. Hofmann-Wellenhof, B., Lichtenegger, H. & Collins, J., 2001 GPS: Theory & Practice. Springer-Verlag, Vienna New York, 5th ed.
5. http://www.environmental.studies.de/precision_farming/EGNOS-WAAS
6. http://www.omnistar.com/faq.html.
7. Liao.X, (2000) "Carrier Phase Based Ionosphere Recovery Over A Regional Area GPS Network", Department of Geomatics Engineering, The University of Calgary, Canada.