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# EFFECT OF RECORDING INTERVAL ON GPS ACCURACY

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## ABSTRACT

Static GPS survey technique is the most reliable applied technique for establishment of permanent reference stations and GPS network for various precise applications [1]. Differential GPS technique (DGPS) reduces most of the GPS observations errors. Moreover, numerous studies of the factors that affect GPS accuracy are accomplished by several researchers along the past years. In spite of that studies have been paid to overcome, or eliminate; to some extent; the effects of these errors, and although GPS has been studied extensively over the years, a study of the relation between the recording interval and GPS accuracy is missing. Surveyors have been dependent on the information from various sources (vendors of the GPS equipments, ambiguous guidelines by different companies and institutions, etc) as well as on their own experiences. The present work aims to study the effect of recording interval on GPS accuracy. At this study, the field experimental work has been carried out according to the static DGPS technique for a range of recording interval (1 through 60 seconds). This study has been performed within a short range of base line lengths (up to 20km [2,3 & 4]), and observation period of 40 minutes. The present work has been accomplished through five test groups taking the parameters (Base Line Length, Observing Time, PDOP and Number of Satellites in view of GPS receiver) into consideration. Accordingly, these tests are realized in form of the relation between the recording intervals and coordinates and point positional errors. The test results revealed that the GPS accuracy has an inverse positive relationship with the recording interval. The highest accuracy has been achieved at one second recording interval.

***Keywords*:** GPS accuracy, test Points, Base Line Length, Observing Time, PDOP, Number of satellites in view.

## 1 Introduction

Establishment of permanent GPS stations and GPS network observations as references for other surveying workings and applications must be of high accuracy [5, 6]. Attainable accuracy is not only a function of baseline length and observing time, it may also be influenced by sampling rate, satellite orbits, satellite geometry, atmosphere, carefulness of the observer, site-dependent effects like obstacles and multipath conditions, the equipments and post processing software [7]. Nevertheless exact information about

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accuracy, reliability and required observing times are missing. Surveyors were dependent on the information from various ambiguous sources (guidelines by GPS vendors, different institutions, etc) as well as on their own experiences. Even today surveying society may feel a lack of consistent and research-based knowledge of an optimum way of using GPS for practical surveying [7].

Following are some reviews of studies which are accomplished, as well as some recommendations and experts which are gained for reducing, eliminating GPS errors, or improving GPS accuracy in general manner. Additionally, some reviewed remarks through GPS workings referring to the effect of sampling (recording Interval) on GPS Observations are to be mentioned:

- PasiHäkli, HannuKoivula, and JyrkiPuupponen [7] handled in their research "Assessment of Practical 3-D Geodetic Accuracy for Static GPS Surveying" some reviews concerning with some factors that affect GPS accuracy as baseline length and observing time.
- In a case study on movements of female caribou (Rangifertarandusgranti) in the Forty mile Caribou, it has been noticed that as sample interval increased, estimates of movement rates decreased substantially. Also, it is estimated that hence, decreasing the sample interval to collect more locations per day will also decrease the maximum sample period [8].
- Among the attempts of increasing the GPS accuracy, "Warnant et-al" has developed a new method for detecting the smaller scale ionospheric irregularities by using GPS carrier phase measurements [9].
- To achieve acceptable accuracy of GPS observations, Surveyor General's Directions in form of "Standards and Practices for Control Surveys (SPI) are recommended by Intergovernmental Committee on Surveying and Mapping for using in field and processing GPS observations [10].
- Two applications which take advantage of the very high sampling rates of modern GPS receivers have been discussed. One is a "GPS seismometer", and the other a "GPS sea swell gauge" Even at the 30sec sampling rate GPS could detect slow/silent quakes or pre-seismic events [11].
- In an attempt for improving GPS accuracy through using multiple reference stations, the sampling interval used was 1 second [12].
- In a provided technical guidance on the use of GPS for monitoring structural deformations, it is advised to use 1 second data logging rate [13].
- It has been found that the accuracy percentage increase when using low sampling time interval and high number of sensor data points for both tracking and nontracking vehicles [14].
- To achieve more precise and reliable kinematic GPS positioning over distances up to, and even longer than, 75 km for the support of bathymetric surveys in real time (but not exclusively for bathymetric applications), the dual-frequency data were recorded at a one second sampling interval [15].
- In a study "Evaluation of Precise, Kinematic GPS Point Positioning, the resulting trajectories were used as the "truth" to which the post-processed point positioning solutions were compared. Both the fixed and the moving receivers were Ashtech Z-12s, collecting data at 1-second intervals [16].

- In a dissertation PHD, Thesis: “Algorithms and methods for robust geodetic kinematic positioning “, over short time intervals (a few seconds) the dynamics of errors (atmospheric, ephemeris, satellite clocks …) is smooth enough to allow acceptable interpolation values [17].
- In various RTK survey tests were executed at different distances from the permanent stations aiming at testing the substructure and the accuracy quality of the network. The campaign was scheduled in order to have the maximum GPS visibility. The recording interval for the kinematic chain was set equal to 2 sec [18].
- A contribution presents the results of an independent experimental verification of decimeter kinematic positioning accuracy with NASA’s Global DGPS system. This verification was carried out in the Netherlands, by means of both a static and a kinematic test. The standard deviations of individual real-time positions were about 10 cm for the horizontal components and about 20 cm for the vertical component. The latency of the global corrective information in the kinematic test was generally 7 to 8 seconds and more than 99% of the global corrections were available with the nominal 1-second interval [19].
- Selection of a sampling regime can have dramatic effects on the estimation of ecological parameters. Each component of a sample regime has a discernable effect [20].
- Several studies showed that the GPS sampling frequency does not need to be as high as possible. For accuracy, a sampling period of 1 second and a period of 30 seconds yielded the same results. Mostly these results were obtained by measuring in a 1 second interval and down sampling the data to an interval of 30 seconds. The measurements in this project were made with a period of 30 seconds [21].
- It has been concluded that recording intervals of 1-5 min provide reliable estimates of the times spent grazing, ruminating and resting. We also conclude that positioning of animals at 1 min intervals may provide estimates of walking distance with acceptable bias toward underestimation. These conclusions are strengthened by the relatively large variations in the behavior variables across animals and time (season and year) [22].

It can be said that the effect of sampling interval is not studied. The present work aims to study the effect of recording interval on GPS accuracy. It has been carried out taking the parameters (base line length, observing time, PDOP and number of satellites in view of the receiver) into consideration. Accordingly, the study has been accomplished through five test groups.

Field work and observations including the used equipment, experimental areas and points, downloading the field observations and its processing are illustrated in section (2).

Section (3) contains the operated computations and the results. Discussion of the results, conclusions and recommendations are recorded on section (4).

## 2 Field work and observations

### *2.1. Equipment*

The field equipment includes two GPS receivers (Z_Xtreme, Ashtech-Magellan, USA) of baseline accuracy ±(5mm + 1ppm) for horizontal and ±(10mm + 1ppm) for vertical through observing static technique. It includes, also, antennas, tools and devices such as tripods, tribrachs, cables, batteries and tapes, etc. Each receiver has 12 channels and full wavelength carried on L1 and L2.

### *2.2. Experimental areas and points*

For the static test field, permanent and semi-permanent sites were chosen. These sites lie among two Zones, the first zone is inside the campus of Assiut University and the second one runs along an area extending from Assiut University till New Assiut city. The test field consists of a permanent GPS station (fixed 1995 by the Egyptian Surveying Authority inside the campus of Assiut University), and a total of 12 semi permanent test points (selected and fixed by us) distributed along the two test zones. On Google earth, Figure (1) shows the site of the first zone including the permanent station "M" and the test points (M1, M2, M3, M5, M6, M7, M8 & M10). Figure (2) shows the second zone with the test points (MK1, MK6, MK9 & MK14). Table 1 contains reference station "M", test points as well as the baselines lengths (from M to each one of the field test points).

**Table 1.**
Position Specifications of the Reference Station and Field Test Points.

| **Reference Station** | **Zone** | **Field Point** | **Baseline Length [m]** | **Remarks** |
|---|---|---|---|---|
| M | First | M1 | 054 | $\Phi(M) = 27^\circ\ 11'\ 10.57796''N$<br>$\lambda(M) = 31^\circ\ 10'\ 13.83989''E$<br>h(M) = 78.175m<br>[Φ=Latitude, λ= Longitude]<br><br>E(M) = 631900.088m<br>N(M) = 498198.086m<br>h(M) = 078.175m<br>[E=Easting Coordinate<br>N=Northing Coordinate<br>h=height] |
| | | M2 | 121 | |
| | | M3 | 164 | |
| | | M5 | 191 | |
| | | M6 | 171 | |
| | | M7 | 216 | |
| | | M8 | 228 | |
| | | M10 | 57 | |
| | Second | MK1 | 1000 | |
| | | MK6 | 6000 | |
| | | MK9 | 9000 | |
| | | MK14 | 14000 | |

### *2.3. Field observations, downloading and data processing*

Study of the effect of recording interval on GPS accuracy has been accomplished under different parameters. The parameters, which are taken into consideration, are baseline length (BL), observing time (OT), position dilution of precision (PDOP) and number of satellites in view (NS) for GPS receiver. Therefore, field observations, its downloading as well as its specific processing have been performed to fulfill the requirements of this study.

#### *2.3.1. Field observations*

Differential Static GPS technique (DGPS) is the applied one for the present work with session time of ≅ 40 minutes, elevation mask of 12˚ [23], and input recording interval for field observations of one second.

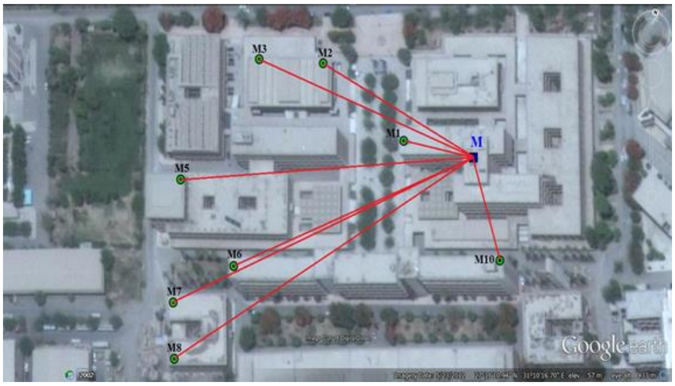



**Fig. 1.** Sites of the Base Station and Field Test Points of the First Zone.


**Fig. 2.** Sites of the Base Station and Field Test Points of the Second Zone.

The above mentioned test points (rovers) are occupied at different observing times among several days. It is to be referred that for all the observation sessions, one GPS receiver is set up at the reference station "M" and the second receiver (rover) is set up at each one of the test points. Occupied points, its baseline lengths as well as its observing times are included in table (2).

### *2.3.2. Downloading observation data and processing*

All field observations are downloaded into PC with help of the professional software "Ashtech Solution, Ashtech-Magillan, USA".

To satisfy the present study, the downloaded data are processed through specific manner as follows:

i. Corresponding to each observing time (OT) at each test point (BL) along the whole observation period, the downloaded data are processed; using Ashtech solution; in correspondence with each control interval to be studied (1, 2, 3, 4, 5, 10, 15,20, 25, 30, 35, 40, 45, 50, 55 & 60 seconds). This means that for a certain control interval, for example 1 second, the outcomes of processed downloaded observing data collected along 40 minutes are 40×60 = 2400 set of processed and adjusted values of (East and North coordinates together with its corresponding values of PDOP and NS). Also, for 2 seconds control interval, the processed and adjusted outcomes are 1200 similar sets.

ii. After, the above outcome coordinates from Ashtech Solution corresponding to a certain control interval are fed into Excel software for carrying out specific successive classification according to specific values for PDOP or/and NS to be selected for study. This phase of processing and classification is operated by own designed loops together with Excel functions.

iii. Results of classification processes performed at the preceding phase are studied through five groups. These groups of study are classified as follows:

1) First group through certain values for BL, OT, PDOP and NS with no varied parameter specifically.
2) Second group with varied values for (BL) and constant ones for (OT, PDOP & NS).
3) Third group through varied values for (OT) together with different BL and constant ones for (PDOP & NS).
4) Fourth group with varied values for (PDOP) together with (BL & OT) and constant NS.
5) Fifth group of varied values for NS together with different values for (BL, OT & PDOP).

Table (2) includes the study groups regulated according to the effect, to be investigated, of individual or collective variation of the considered parameters on the relationship between the recording interval and GPS accuracy.

**Table 2.**
Test groups of Observations in Accordance with varied Parameter / Parameters.

| Group | Test Point (Rover) | BL [m] | OT | PDOP | NS | Remarks |
|---|---|---|---|---|---|---|
| **First** | **M1** | 54 | 11.00 am | 1.4 | 8 | Reference Station (Base) = (M) |
| | **M10** | 57 | | | | |
| **Second** | **M5** | 191 | 11.00 am | 1.3 | 9 | |
| | **M7** | 216 | | | | |
| | **MK6** | 6000 | | | | |
| | **MK14** | 14000 | | | | |
| **Third** | **M8** | 228 | 01.00 pm | 1.3 | | |
| | **MK6** | 6000 | 11.00 am | | 9 | |
| | **MK9** | 9000 | 09.20 am | | | |
| **Fourth** | **M2** | 121 | 05.05 pm | 1.4 | | |
| | **M3** | 164 | 01.00 pm | 1.5 | 8 | |
| | **M6** | 171 | 01.35 pm | 1.8 | | |
| | **MK14** | 14000 | 11.45 am | 1.6 | | |
| **Fifth** | **M3** | 164 | 03.45 pm | 1.7 | 4 | |
| | **M6** | 171 | 01.35 pm | 1.8 | 5 | |
| | **M8** | 228 | 09.50 am | 2.2 | 6 | |
| | **MK1** | 1000 | 8.20 am | 1.3 | 8 | |
| | **MK6** | 6000 | 10.35 am | 1.1 | 9 | |
| | **MK14** | 14000 | 11.45 am | 1.6 | 7 | |

## 3. Computations and results

Investigating the effect of recording interval on GPS accuracy has been accomplished through computing the east and north coordinates and estimating the corresponding errors.

These errors are computed in form of the standard deviations (ME, MN and MP) of east, north coordinates as well as the point position respectively.

Estimating these errors is summarized as follows:

- East and north coordinates are computed through the final classified data through Excel software corresponding to each recording interval.
- These coordinates are treated mathematic-statistically for averaging and estimating the coordinates errors (standard deviation) using the equations below.

$$ME = \sqrt{\frac{\Sigma(E_i - E_m)^2}{n-1}} \quad , \quad MN = \sqrt{\frac{\Sigma(N_i - N_m)^2}{n-1}} \quad \text{and} \quad MP = \sqrt{(ME)^2 + (MN)^2}$$

Where: $E_i$ = the $i^{th}$ value for East coordinate.

$N_i$ = the $i^{th}$ value for North coordinate.

$E_m$ = average value of "n" values for east coordinates.

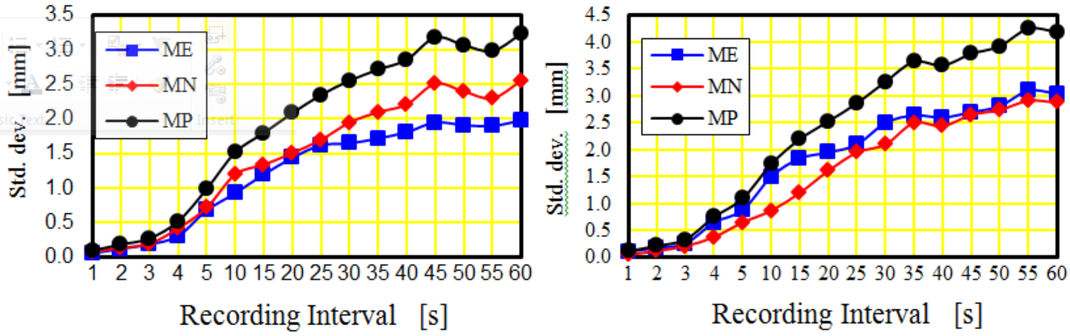
$N_m$ = average value of "n" values for north coordinates.

The whole results of the present study are included in tables (3 through 7) and represented in figures (3 through 7). It is tabulated and represented in the form of (the standard deviation of east, north and point positional errors) in correspondence to the (recording interval). These tables and figures are regulated in consistence of the parameter/ parameters taken into consideration with respect to its action on the relationship between the recording interval and GPS accuracy.

**Table 3.**
Coordinates and Point Positional Errors [mm] Corresponding to Recording Interval at Certain Values for (BL, OT, PDOP & NS).

| Recording Interval [s] | BL=54m | | | BL=57m | | | Remarks |
|---|---|---|---|---|---|---|---|
| | ME | MN | MP | ME | MN | MP | |
| **1.0** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | (BL = 54/57m, OT=11:00am, PDOP=1.4 & NS=8) |
| **2.0** | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.2 | |
| **3.0** | 0.2 | 0.2 | 0.3 | 0.3 | 0.2 | 0.3 | |
| **4.0** | 0.3 | 0.4 | 0.5 | 0.7 | 0.4 | 0.8 | |
| **5.0** | 0.7 | 0.7 | 1.0 | 0.9 | 0.7 | 1.1 | |
| **10.0** | 0.9 | 1.2 | 1.5 | 1.5 | 0.9 | 1.7 | |
| **15.0** | 1.2 | 1.3 | 1.8 | 1.8 | 1.2 | 2.2 | |
| **20.0** | 1.4 | 1.5 | 2.1 | 2.0 | 1.6 | 2.5 | |
| **25.0** | 1.6 | 1.7 | 2.4 | 2.1 | 2.0 | 2.9 | |
| **30.0** | 1.7 | 2.0 | 2.6 | 2.5 | 2.1 | 3.3 | |
| **35.0** | 1.7 | 2.1 | 2.7 | 2.6 | 2.5 | 3.6 | |
| **40.0** | 1.8 | 2.2 | 2.9 | 2.6 | 2.4 | 3.6 | |
| **45.0** | 2.0 | 2.5 | 3.2 | 2.7 | 2.7 | 3.8 | |
| **50.0** | 1.9 | 2.4 | 3.1 | 2.8 | 2.7 | 3.9 | |
| **55.0** | 1.9 | 2.3 | 3.0 | 3.1 | 2.9 | 4.3 | |
| **60.0** | 2.0 | 2.6 | 3.2 | 3.0 | 2.9 | 4.2 | |

BL = Base Line Length, s = Second.




**(a)** **(b)**

**Fig. 3.** Coordinates and Point Positional Errors According to Recording Interval at Certain values of (BL=54/57 m, OT=11:00am, PDOP=1.4 &NS=8).

**Table 4.**
Coordinates and Point Positional Errors [mm] vs. Recording Interval at Varied BL.

| **Recording. Interval [s]** | BL [m] | | | | | | | | | | | | **Remarks** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 191 | | | 216 | | | 6000 | | | 14000 | | | |
| | ME | MN | MP | ME | MN | MP | ME | MN | MP | ME | MN | MP | |
| **1.0** | 0.02 | 0.01 | 0.02 | 0.1 | 0.1 | 0.1 | 1.2 | 1.1 | 1.6 | 10.5 | 5.7 | 11.9 | (OT=11:00am, PDOP=1.3 & NS=9) |
| **2.0** | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 2.4 | 2.1 | 3.2 | 11.8 | 8.1 | 14.3 | |
| **3.0** | 0.1 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 | 2.8 | 2.5 | 3.8 | 12.5 | 10.2 | 16.1 | |
| **4.0** | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.2 | 3.1 | 2.9 | 4.2 | 13.7 | 11.5 | 17.8 | |
| **5.0** | 0.2 | 0.1 | 0.2 | 0.2 | 0.2 | 0.3 | 3.7 | 3.4 | 5.0 | 14.1 | 12.5 | 18.8 | |
| **10.0** | 0.3 | 0.2 | 0.4 | 0.3 | 0.3 | 0.4 | 4.6 | 4.4 | 6.4 | 15.3 | 13.7 | 20.5 | |
| **15.0** | 0.4 | 0.3 | 0.5 | 0.3 | 0.4 | 0.5 | 5.7 | 5.1 | 7.6 | 16.1 | 14.2 | 21.4 | |
| **20.0** | 0.5 | 0.4 | 0.6 | 0.4 | 0.5 | 0.6 | 6.9 | 5.8 | 9.0 | 16.8 | 15.1 | 22.5 | |
| **25.0** | 0.5 | 0.4 | 0.6 | 0.5 | 0.5 | 0.7 | 7.8 | 6.7 | 10.2 | 17.1 | 16.2 | 23.5 | |
| **30.0** | 0.5 | 0.5 | 0.7 | 0.6 | 0.5 | 0.8 | 8.9 | 7.4 | 11.5 | 16.5 | 15.8 | 22.8 | |
| **35.0** | 0.6 | 0.4 | 0.7 | 0.5 | 0.7 | 0.8 | 9.9 | 8.7 | 13.1 | 17.3 | 16.8 | 24.1 | |
| **40.0** | 0.7 | 0.6 | 0.9 | 0.6 | 0.7 | 1.0 | 9.8 | 8.4 | 12.9 | 17.2 | 16.7 | 24.0 | |
| **45.0** | 0.7 | 0.6 | 0.9 | 0.6 | 0.7 | 1.0 | 9.7 | 8.2 | 12.7 | 18.1 | 17.7 | 25.3 | |
| **50.0** | 0.8 | 0.7 | 1.0 | 0.6 | 0.8 | 1.0 | 10.1 | 9.1 | 13.5 | 20.1 | 18.8 | 27.5 | |
| **55.0** | 0.8 | 0.7 | 1.1 | 0.6 | 0.8 | 1.0 | 10.0 | 9.1 | 13.4 | 21.3 | 19.4 | 28.8 | |
| **60.0** | 0.9 | 0.7 | 1.2 | 0.8 | 0.9 | 1.2 | 10.4 | 9.3 | 13.9 | 22.0 | 20.4 | 30.0 | |

**Table 5.**
Coordinates and Point Positional Errors [mm] According to Recording Interval for Varied OT at Different Values of (BL).

| Recording. Interval [s] | OT=1:00pm (BL=228m) | | | OT=11:00am (BL=6000m) | | | OT=9:20am (BL=9000m) | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| | ME | MN | MP | ME | MN | MP | ME | MN | MP | |
| **1.0** | 0.0 | 0.1 | 0.1 | 1.2 | 1.1 | 1.6 | 2.5 | 1.8 | 3.1 | (PDOP=1.3 & NS=9) |
| **2.0** | 0.1 | 0.2 | 0.2 | 2.4 | 2.1 | 3.2 | 3.8 | 2.7 | 4.7 | |
| **3.0** | 0.1 | 0.2 | 0.3 | 2.8 | 2.5 | 3.8 | 4.7 | 3.8 | 6.0 | |
| **4.0** | 0.2 | 0.3 | 0.4 | 3.1 | 2.9 | 4.2 | 5.2 | 4.4 | 6.8 | |
| **5.0** | 0.3 | 0.5 | 0.6 | 3.7 | 3.4 | 5.0 | 6.2 | 5.4 | 8.2 | |
| **10.0** | 0.4 | 0.7 | 0.8 | 4.6 | 4.4 | 6.4 | 6.8 | 5.4 | 8.7 | |
| **15.0** | 0.6 | 0.8 | 1.0 | 5.7 | 5.1 | 7.6 | 7.5 | 6.8 | 10.1 | |
| **20.0** | 0.7 | 0.9 | 1.2 | 6.9 | 5.8 | 9.0 | 8.6 | 7.5 | 11.4 | |
| **25.0** | 0.9 | 1.2 | 1.5 | 7.8 | 6.7 | 10.3 | 9.3 | 8.2 | 12.4 | |
| **30.0** | 1.1 | 1.4 | 1.8 | 8.9 | 7.4 | 11.6 | 10.2 | 9.1 | 13.6 | |
| **35.0** | 1.0 | 1.6 | 1.9 | 9.9 | 8.7 | 13.2 | 11.5 | 10.5 | 15.5 | |
| **40.0** | 1.2 | 1.6 | 2.0 | 9.8 | 8.4 | 12.9 | 12.3 | 11.4 | 16.7 | |
| **45.0** | 1.1 | 1.5 | 1.8 | 9.7 | 8.2 | 12.7 | 13.1 | 11.6 | 17.5 | |
| **50.0** | 1.2 | 1.7 | 2.0 | 10.1 | 9.1 | 13.6 | 12.9 | 11.4 | 17.2 | |
| **55.0** | 1.1 | 1.6 | 2.0 | 10.0 | 9.1 | 13.5 | 13.2 | 11.9 | 17.7 | |
| **60.0** | 1.2 | 1.8 | 2.1 | 10.4 | 9.3 | 14.0 | 13.4 | 12.1 | 18.0 | |

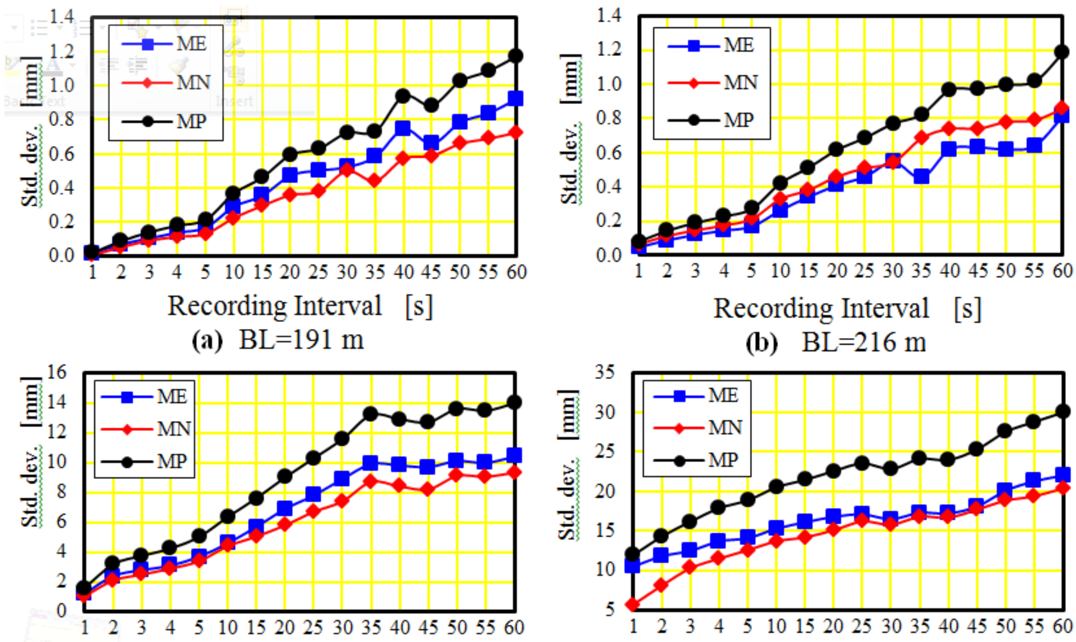



**Fig. 4.** Errors of GPS Observations versus Recording Interval for varied BL (OT=11 am, PDOP=1.3 & NS=9).

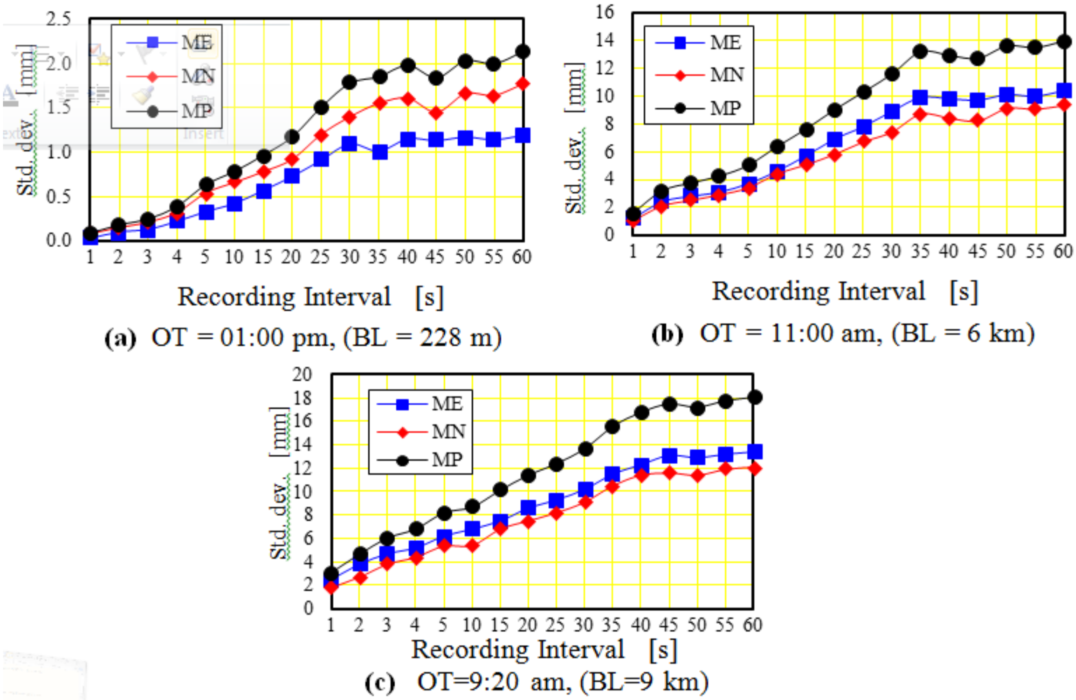



**Fig. 5.** Coordinates and Point Standard Deviations Corresponding to Recording Interval for Varied OT at Different BL (PDOP=1.3, NS=9).

**Table 6.**
Coordinates and Point Positional Errors [mm] Corresponding to Recording Interval for Varied PDOP at Different Values of (BL & OT).

| Recording Interval [s] | PDOP=1.4 (BL=121m, OT=5:05pm) | | | PDOP=1.5 (BL=164m, OT=1:00pm) | | | PDOP=1.8 (BL=171m, OT=1:35pm) | | | PDOP=1.6 (BL=14km, OT=11:45am) | | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **ME** | **MN** | **MP** | **ME** | **MN** | **MP** | **ME** | **MN** | **MP** | **ME** | **MN** | **MP** | |
| **1.0** | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | 0.3 | 0.5 | 0.6 | 0.8 | 11.5 | 7.5 | 13.7 | NS = 8 |
| **2.0** | 0.1 | 0.3 | 0.3 | 0.4 | 1.0 | 1.1 | 1.1 | 1.6 | 2.0 | 12.2 | 10.3 | 15.9 | |
| **3.0** | 0.2 | 0.4 | 0.4 | 0.6 | 1.7 | 1.8 | 1.6 | 2.5 | 3.0 | 13.8 | 11.4 | 17.9 | |
| **4.0** | 0.4 | 1.0 | 1.1 | 0.9 | 2.3 | 2.4 | 1.9 | 3.4 | 3.9 | 13.7 | 11.3 | 17.8 | |
| **5.0** | 0.6 | 1.4 | 1.5 | 0.8 | 2.7 | 2.8 | 2.6 | 3.8 | 4.6 | 15.2 | 13.2 | 20.1 | |
| **10.0** | 0.7 | 1.9 | 2.1 | 1.2 | 3.5 | 3.7 | 4.1 | 4.3 | 6.0 | 16.9 | 14.4 | 22.2 | |
| **15.0** | 1.0 | 2.4 | 2.6 | 1.4 | 3.7 | 4.0 | 4.4 | 4.8 | 6.5 | 17.7 | 15.8 | 23.7 | |
| **20.0** | 1.5 | 2.8 | 3.2 | 2.1 | 3.9 | 4.5 | 4.7 | 5.1 | 6.9 | 19.2 | 16.8 | 25.5 | |
| **25.0** | 1.7 | 3.0 | 3.4 | 2.1 | 3.8 | 4.3 | 4.8 | 5.4 | 7.2 | 20.8 | 17.1 | 26.9 | |
| **30.0** | 1.8 | 3.5 | 4.0 | 2.7 | 4.1 | 4.9 | 5.1 | 5.8 | 7.7 | 20.7 | 16.9 | 26.7 | |
| **35.0** | 2.1 | 4.2 | 4.7 | 3.1 | 4.7 | 5.6 | 5.5 | 5.9 | 8.1 | 20.9 | 17.9 | 27.5 | |
| **40.0** | 2.8 | 4.8 | 5.5 | 3.6 | 5.5 | 6.6 | 5.4 | 5.8 | 7.9 | 21.2 | 18.7 | 28.2 | |
| **45.0** | 2.9 | 5.1 | 5.9 | 3.4 | 5.4 | 6.4 | 5.4 | 5.7 | 7.8 | 21.5 | 18.9 | 28.6 | |
| **50.0** | 2.9 | 5.0 | 5.8 | 4.4 | 5.8 | 7.3 | 5.5 | 5.8 | 8.0 | 21.2 | 18.5 | 28.1 | |
| **55.0** | 3.4 | 5.4 | 6.4 | 4.9 | 6.2 | 7.9 | 5.5 | 6.1 | 8.2 | 22.0 | 19.1 | 29.1 | |
| **60.0** | 3.4 | 5.3 | 6.3 | 5.2 | 7.2 | 8.9 | 6.4 | 7.5 | 9.9 | 23.2 | 22.2 | 32.1 | |

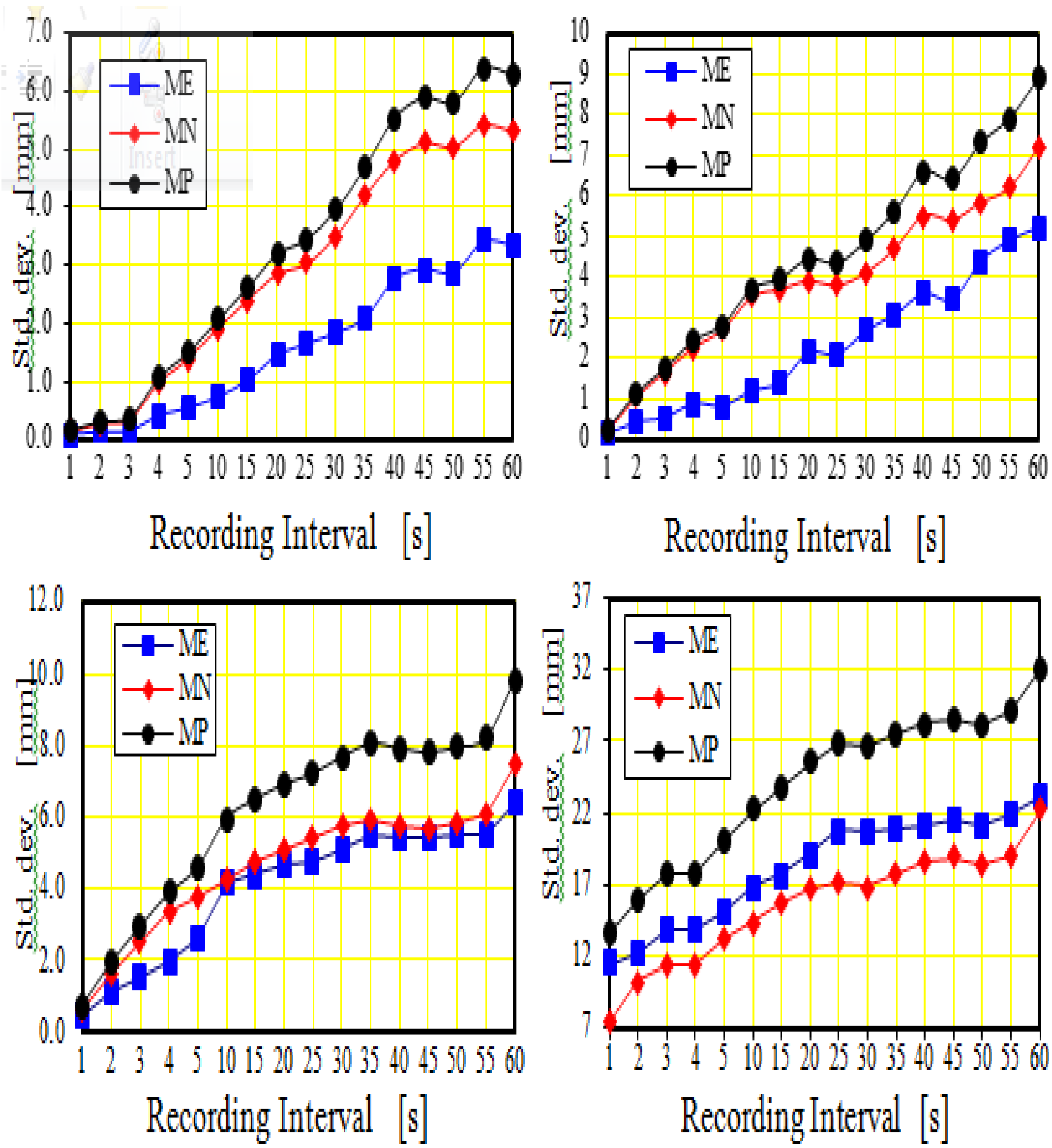



**Fig. 6.** Coordinates and Point Standard Deviations against Recording Interval at Varied PDOP and Different (BL &OT), (NS = 8).

**Table 7.**
Coordinates and Point Errors [mm] vs. Recording Interval for Varied NS at Different Values of (BL, OT & PDOP).

| **Recording Interval [s]** | **NS=4 (BL=164m OT=3:45pm PDOP=1.7)** | | | **NS=5 (BL=171m OT=1:35pm PDOP=1.8)** | | | **NS=6 (BL=228m OT=9:50am PDOP=2.2)** | | | **NS=8 (BL=1km OT=8:20am PDOP=1.3)** | | | **NS=9 (BL=6km OT=10:35am PDOP=1.1)** | | | **NS=7 (BL=14km OT=11:45am PDOP=1.6)** | | | **Remarks** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **ME** | **MN** | **MP** | **ME** | **MN** | **MP** | **ME** | **MN** | **MP** | **ME** | **MN** | **MP** | **ME** | **MN** | **MP** | **ME** | **MN** | **MP** | |
| **1.0** | 0.2 | 0.1 | 0.2 | 0.5 | 0.6 | 0.8 | 0.1 | 0.1 | 0.2 | 0.1 | 0.1 | 0.2 | 0.9 | 0.8 | 1.2 | 11.5 | 7.5 | 13.7 | **All parameters are varied.** |
| **2.0** | 0.3 | 0.3 | 0.5 | 1.1 | 1.6 | 2.0 | 0.4 | 0.3 | 0.4 | 0.1 | 0.2 | 0.3 | 1.8 | 1.4 | 2.3 | 12.2 | 10.3 | 15.9 | |
| **3.0** | 0.4 | 0.4 | 0.5 | 1.6 | 2.5 | 3.0 | 0.4 | 0.4 | 0.5 | 0.2 | 0.3 | 0.4 | 2.7 | 1.9 | 3.3 | 13.8 | 11.4 | 17.9 | |
| **4.0** | 1.0 | 0.9 | 1.3 | 1.9 | 3.4 | 3.9 | 0.9 | 0.6 | 1.1 | 0.6 | 0.8 | 1.0 | 3.2 | 2.5 | 4.1 | 13.7 | 11.3 | 17.8 | |
| **5.0** | 1.2 | 1.1 | 1.6 | 2.6 | 3.8 | 4.6 | 1.4 | 0.8 | 1.6 | 0.7 | 1.3 | 1.5 | 3.9 | 2.8 | 4.8 | 15.2 | 13.2 | 20.1 | |
| **10.0** | 1.9 | 1.8 | 2.6 | 4.1 | 4.3 | 6.0 | 2.1 | 1.2 | 2.4 | 0.9 | 1.8 | 2.0 | 4.8 | 3.9 | 6.2 | 16.9 | 14.4 | 22.2 | |
| **15.0** | 2.4 | 2.1 | 3.2 | 4.4 | 4.8 | 6.5 | 2.2 | 1.5 | 2.7 | 1.4 | 2.0 | 2.4 | 5.7 | 4.4 | 7.2 | 17.7 | 15.8 | 23.7 | |
| **20.0** | 2.8 | 2.5 | 3.8 | 4.7 | 5.1 | 6.9 | 2.4 | 2.2 | 3.3 | 1.6 | 2.6 | 3.1 | 6.8 | 5.1 | 8.5 | 19.2 | 16.8 | 25.5 | |
| **25.0** | 3.1 | 3.0 | 4.3 | 4.8 | 5.4 | 7.2 | 2.7 | 2.4 | 3.6 | 1.7 | 2.9 | 3.4 | 7.5 | 6.2 | 9.7 | 20.8 | 17.1 | 26.9 | |
| **30.0** | 3.5 | 3.2 | 4.8 | 5.1 | 5.8 | 7.7 | 3.0 | 2.8 | 4.1 | 2.0 | 3.3 | 3.8 | 7.4 | 6.1 | 9.6 | 20.7 | 16.9 | 26.7 | |
| **35.0** | 3.7 | 3.4 | 5.0 | 5.5 | 5.9 | 8.1 | 3.6 | 3.2 | 4.8 | 2.3 | 4.1 | 4.7 | 7.8 | 6.8 | 10.3 | 20.9 | 17.9 | 27.5 | |
| **40.0** | 4.1 | 3.9 | 5.7 | 5.4 | 5.8 | 7.9 | 4.2 | 3.7 | 5.6 | 2.5 | 4.3 | 5.0 | 8.1 | 7.2 | 10.8 | 21.2 | 18.7 | 28.2 | |
| **45.0** | 4.6 | 4.4 | 6.4 | 5.4 | 5.7 | 7.8 | 4.7 | 4.1 | 6.2 | 2.8 | 4.5 | 5.3 | 8.5 | 7.5 | 11.3 | 21.5 | 18.9 | 28.6 | |
| **50.0** | 5.2 | 5.0 | 7.2 | 5.5 | 5.8 | 8.0 | 4.6 | 4.0 | 6.1 | 3.1 | 4.9 | 5.8 | 8.7 | 7.7 | 11.6 | 21.2 | 18.5 | 28.1 | |
| **55.0** | 5.1 | 4.9 | 7.1 | 5.5 | 6.1 | 8.2 | 4.8 | 4.2 | 6.4 | 3.1 | 5.0 | 5.9 | 8.8 | 7.9 | 11.8 | 22.0 | 19.1 | 29.1 | |
| **60.0** | 5.3 | 5.1 | 7.4 | 6.4 | 7.5 | 9.9 | 5.0 | 4.2 | 6.5 | 3.4 | 5.2 | 6.2 | 8.2 | 7.5 | 11.1 | 23.2 | 22.2 | 32.1 | |

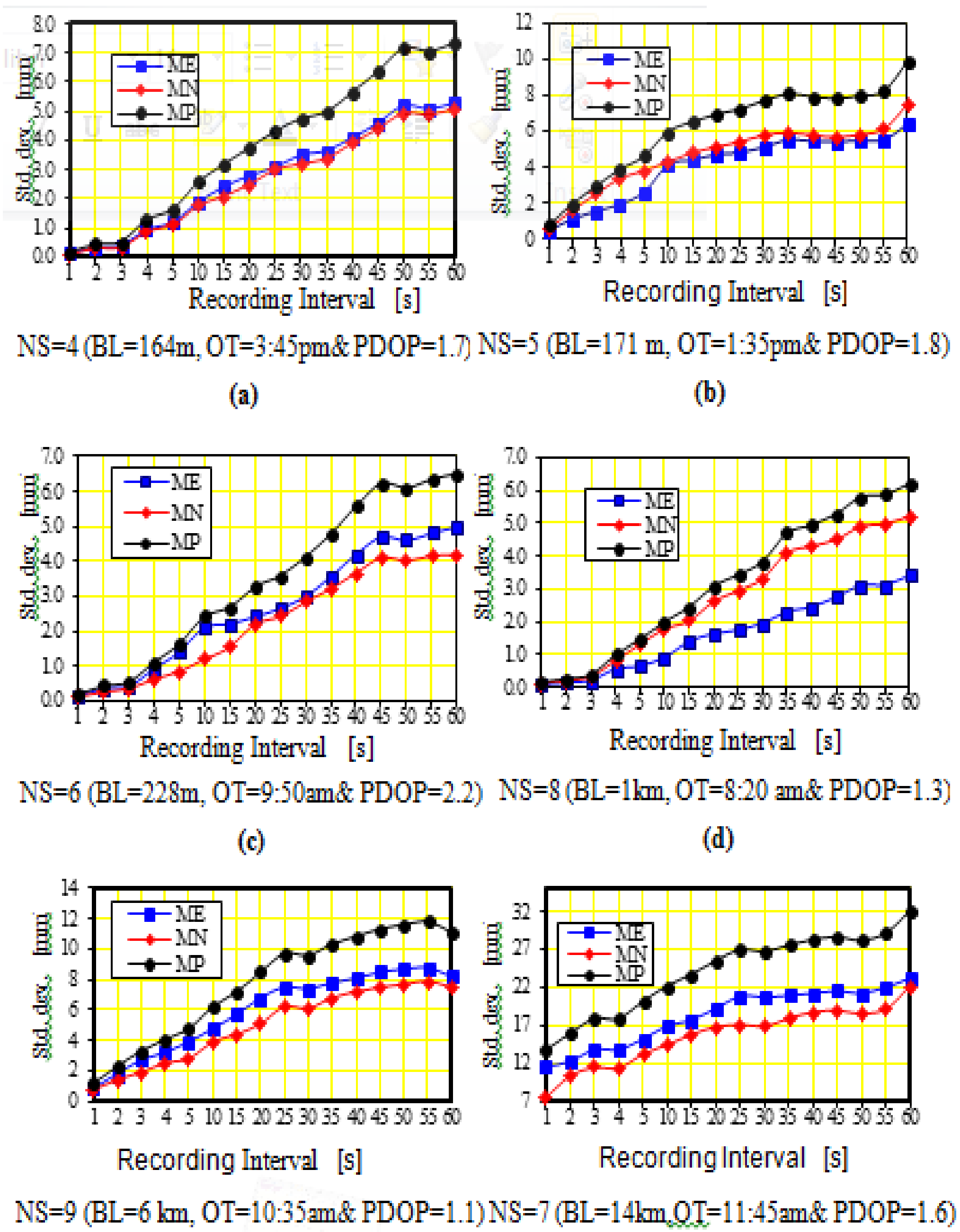



**Fig. 7.** Relation of Recording Interval into GPS observation Errors at Varied NS with Different Values of (BL, OT & PDOP).

## 4. Discussion, conclusions and recommendations

### *4.1. Discussion and conclusions*

With regard to tables (3 through 7) and figures (3 through 7), it can be seen that East, North and Point positional errors increase with increasing the recording interval. That is completely attainable for all the parameters taken into consideration within the present study. Therefore, it is generally concluded that GPS accuracy has inversely positive relationship with the recording interval.

The results in (table 3) and (figure 3.a & 3.b), which obtained from the first test group, reveal the same estimation described above. The slight differences between the errors values represented at figures 3.a and 3.b is originated to the small difference in base line lengths.

The results of the second experimental group which includes varied baseline lengths BL (table 4 and figure 4.a, b, c &d) illustrate the positive proportionality between the positions standard deviations and recording interval. Through comparison between the tabulated values and subfigures, it is noticed that the errors have an increasingly quantitative relationship with the base line length for the same recording interval. It may be concluded that the GPS accuracy is inversely proportional with the recording interval in spite of varied base line length.

The results included through table (5) and represented in figure (5) which correspond to the third test group indicate that the relationship between the recording interval and standard deviations according to varied observing time at different values of the baseline length is increasingly positive. The same conclusion as estimated from the preceding experimental groups is gained also through the results of the third group.

The results of fourth group (table 6 and figure 6) support the same conclusion as mentioned above in spite of varied PDOP at different values for baseline length (BL) and observing time (OT).

The same relation between the recording interval and coordinates and positional point errors is emphasized through the results of the fifth test group (table 7 and figure 7) which correspond to varied number of satellites in view for the receiver (NS) and different values of (BL, OT & PDOP).

<u>Through the above elementary discussion and estimations, it can be principally concluded that</u>:

- The parameters (Baseline Length, Observing Time, PDOP and Number of Satellites in view of GPS receiver) have no effect on the trend of the relation between the recording interval and GPS accuracy. Its effect, in individual or collective manner, can be investigated through a quantitative change for the accuracy only versus any individual recording interval value. Therefore, it is concluded strongly that the recording interval, which be input into the receivers at start of field observations, has a significant effect on GPS accuracy through inverse relationship.
- As shown among all tables (3 through 7) as well as through all figures (3 through 7), the minimum values of coordinates and point positional errors occur at one second recording interval. Then, the most important conclusion from the present

work is that the best GPS accuracy is gained through input value for the recording interval at one second.

### *4.2. Recommendations*

For purpose of gaining the optimum GPS accuracy, it is recommended that the effect of Base Line Length, Observing Time, PDOP and Number of Satellites in view of GPS receiver is to be individually studied in an independent manner.

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# تاثير الفترة البينية للتسجيل على دقة نظام التثبيت العالمى GPS

**الملخص العربى:**

الفترة البينية لتسجيل الأرصاد هى أحد المدخلات إلى مستقبلات نظام التثبيت العالمى GPS قبل الرصد مباشرة.

لقد لوحظ من خلال الأرصاد الحقلية على مدار السنوات الماضية اختلاف دقة نتائج الأرصاد باختلاف تلك الفترة.

يهدف هذا البحث إلى دراسة تأثير الفاصل الزمنى لتسجيل الأرصاد على دقة نظام التثبيت العالمى GPS.

تمت الدراسة بإجراء الأرصاد الحقلية والمعالجات التحليلية مكتبياً.

تمثل العمل الحقلى فى اختيار وتثبيت عدد 12 نقطة اختبار تقع فى منطقتى حرم جامعة أسيوط والمساحة الممتدة من مدينة أسيوط إلى مدينة أسيوط الجديدة. أجريت الأرصاد طبقاً لتقنية الرصد الثابت باتخاذ نقطة GPS معلومة تقع فى حرم الجامعة كمحطة مرجعية (Base) لنقط الإختبار (Rovers). أجريت الأرصاد باحتلال نقط الإختبار عدة مرات فى أوقات مختلفة فى العديد من الأيام.

وحيث أن تلك الدراسة تتمثل فى استنتاج العلاقة بين الفترة البينية للرصد (1، 2، 3، 4، 5، 10، 15، 20، 25، 30، 35، 40، 45، 50، 55، 60 ث) وأخطاء الأحداثيات والخطأ الموضعى لنقط الإختبار مع الأخذ فى الإعتبار العوامل (مسافة الرصد، وقت الرصد، جودة الموقع الهندسى للأقمار الصناعية وعدد الأقمار المرئية للمستقبل)، فقد تمت الأعمال المكتبية على النحو التالى:

- نقل الأرصاد إلى الحاسب ومعالجتها باستعمال البرنامج المساحى التخصصى Ashtech Solution.
- تقسيم و تصنيف تلك الأرصاد باستعمال البرنامج المذكور إلى جانب برنامج Excel طبقاً للعوامل المأخوذة فى الإعتبار إلى خمس مجموعات.
- إجراء الحسابات على كل مجموعة لاستنتاج قيم الأخطاء المذكورة عاليه المقابلة لكل فاصل زمنى، ثم جدولتها وتمثيلها.

أظهرت النتائج بصفة عامة أن الأخطاء تتناسب طردياً مع الفترة البينية لتسجيل الأرصاد وذلك سواءً فى كل حالات الدراسة للمجموعات الخمس المذكورة عاليه.

لقد وجد أن القيمة الفضلى لدقة أرصاد نظام التثبيت العالمى GPS تنتج عند الفاصل الزمنى لتسجيل الأرصاد ثانية واحدة (حيث أنها تعطى أقل قيم للأخطاء).