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Accuracy Assessment of GNSS Positioning: Effect of Antenna Phase Center Variations

Reham Nagib[1], Ashraf EL-Kutb Mousa [2] and Gamal EL-Fiky[1]

Instroctor Professor Professor

(1) Construction Eng.& Utilities Department, Faculty of Engineering, Zagazig University, Egypt.
(2) National Research Institute of Astronomy and Geophysics, Helwan, Cairo, Egypt.

ملخص البحث

هدف هذا البحث هو التحقق من طرق تقليل ومعالجة الخطأ الناتج من تغير المركز الالكترونى لهوائى جهاز المستقبل بهدف زياده دقه النتائج المستخرجه من النظام العالمى للملاحه بالاقمار الصناعيه. وهناك بعض المستخدمين لنظام GNSS يقومون بتجاهل تأثير تغيرات المركز الالكترونى لهوائى جهاز المستقبل فى تحليل البيانات وهناك آخرون يأخذون تأثيره فى الاعتبار أو يقيمون بتقييمه. وفى هذه الدراسه نقوم بدراسه تأثير تغير المركز الالكترونى لهوائى جهاز المستقبل على كلا من خط أساس قصير (Short Baseline) وخط أساس طويل (Long Baseline). وبيانات خط الاساس القصير تم الحصول عليها بالرصد الحقلي علي نقاط تم تثبيتها علي أسطح مباني كلية الهندسة بجامعة الزقازيق في حين أن البيانات الخاصة بخط الاساس الطويل تم الحصول عليها من أرصاد 7 نقاط من الشبكة المصريه الخاصة بالمعهد القومى للبحوث الفلكيه والجيوفيزيقيه بحلوان.

وقد تم تحليل معالجة بيانات خط الأساس القصير ببرنامج شركة سوكيا والمسمي بـ Magnet tools (V.2.7.1). وأظهرت نتائج التحليل أن طريقه الحل باستخدم المركز الالكترونى لهوائى جهاز المستقبل تعطى نتائج أفضل من طريقه تجاهله. أما بيانات خط الأساس الطويل فإستخدمت للتحقق من ثلاث طرق لتقليل الخطأ الناتج من تغير المركز الالكترونى لهوائى جهاز المستقبل. وهذه الطرق هى (أخذ تأثير المركز الالكترونى لهوائى مستقبل في الإعتبار - تجاهله - حسابه). وبعد معالجه هذه البيانات من قبل برنامج Bernese (V.5) وأشارت النتائج إلى أن الحل بطريقتى استخدام وتجاهل المركز الالكترونى لهوائى جهاز المستقبل لهم قيم متشابهه تقريباً وأن طريقه حساب وتقييم المركز الالكترونى لهوائى جهاز المستقبل تعطى أفضل قيم مقارنه بالطريقتين الآخرتين.

Abstract

Global Navigation Satellite System (GNSS) is the only system today capable of calculating your exact position on the earth anywhere, any time and in any weather. However, there are many errors that affect GNSS accuracy. The antenna phase center variation is one of GNSS errors. Antenna phase center variations reduce accuracy of GNSS and accuracy of extracted data.The antenna phase center is the point where GNSS signal is received. It's not matching the geometrical (physical) center of the antenna. It depends on the azimuth, the elevation of the GNSS satellite and intensity of the observed signal.

In this research, various mitigation ways are investigated to treat the error of the antenna phase center variations to increase GNSS results accuracy. Some GNSS users ignore the effect of the antenna phase center variation (PCV) and others take the effect of the antenna phase center variation into account using calibration results or by estimating the antenna phase center.In this study, the effect of antenna phase center variations using short baseline and long baseline are tested. The short baseline is a field experiment while the long baseline data is from the Egyptian network (NRIAG).

The static field experiment has been performed at the roof of the faculty of engineering, Zagazig university, Egypt to evaluate the influence of using antenna phase center and ignoring it. These data have been analyzed by commercial Sokkia software magnet tools v.2.7.1. After analyzing these data and comparing between using the antenna phase center and ignoring it, the results indicate that the difference between the two methods in the range of 0.001 m for R.M.S. While the difference between them, for horizontal and upper loop closure errors is in the range of 0.0008 m and 0.0019 m, respectively. Significant variations are observed on the upper loop closure errors than horizontal loop closure errors due to antenna phase center variations. These results showed that using the antenna phase center give slightly better accuracy than ignoring it for short baseline.

Using the Egyptian network for long baseline gives the chance to check three mitigation methods. These are; using the IGS antenna phase center information, ignoring it and estimating it. After treating this data by Bernese software (v. 5), The calculated R.M.S for the three coordinates components (Easting , Northing and Height) is within limits 0.04 m, while loop closure errors within 0.01 m. The results showed that the two ways of solution (using the antenna phase center and ignoring it) almost similar in values (both are around 0.03 m), but the way of estimating it has given the best values compared to the other two ways. So, recommented to use this method in the GNSS data analysis.

Keywords: Phase Center Variation; GNSS Data Processing; Antenna Calibrations; Egypt.

1. Introduction

The GNSS receiver antenna is the connecting unit between the GNSS satellite and the GNSS receiver which transform the incoming signal from satellites into an electrical signal that can be treated by the receiver. The GNSS signal is received at a point called Antenna Phase Center (APC) but this point is not identical with the antenna physical center (e.g., Braun, 1993; Elósegui et al., 1995; Seeber et al., 1998). Therefore, it is necessary to calculate a mean position of the electric antenna phase center (MPC) for the offset calibration (Fig. 1). The point used by the receiver manufacturer to measure the vertical antenna height is called antenna phase reference point (ARP) (Rothacher et al., 1995; Rothacher, 2001; Zhu et al., 2003). These are produced from the junction of the symmetrical vertical axis of the antenna with the bottom of the antenna. Hence, the antenna phase center offset (PCO) is estimated as the difference between the ARP and the MPC (e.g. Dawidowicz, 2010; EL-Hattab, 2013).

Deviations that arise as a result of comparing the electricity of an individual measurement with the mean electrical antenna phase center are called the antenna phase center variations (PCV) (Fig.2).There are three offset components (east, north and up). Some researchers proved that the vertical offset is larger than the horizontal offset. The L1 and L2 the frequencies of GPS have different phase center (Fig. 3).

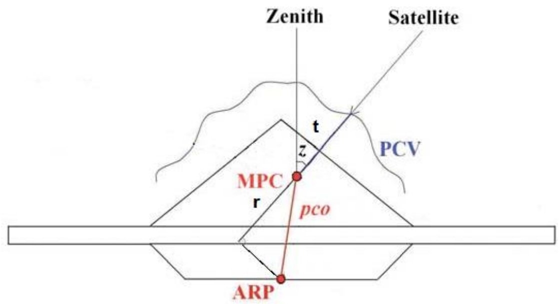

Fig. (1): Diagram of locations of the GNSS antenna phase center variations modified from Dawidowicz (2010).

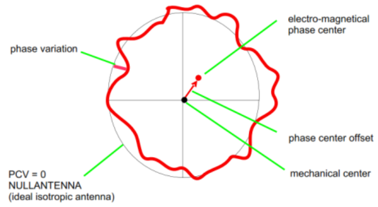

Fig. (2): Variations and offset of antenna phase center (PCV) modified from Schmitzey al, (2017).

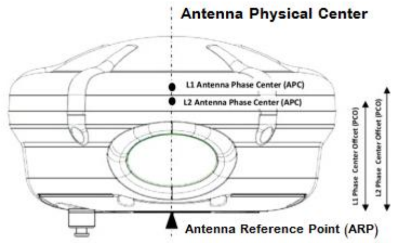

Fig. (3): Location of two phase center for L1, L2 frequencies modified from El-Hattab (2013).

Schmid and Rothacher (2003) used the GPS data to estimate PCV of GPS satellite antennas using two methods. First estimations have between the satellite of the same block and second estimations have two different satellite antenna for Block IIR and for Block II/IIA. They collected the data used for more than 100 IGS stations for the days (14 to 19 July) of the year 2002.

Dawidowicz. (2010) used data collected at four measurement points that obtained from Institute of Geodesy University of Warmia and Mazury in Olsztyn to estimate PCV corrections to phase and code in commercial software. The baseline length was limited (25-49) m. He treated this data using two types of commercial software (Ashtech Solutions and Topcon Tools). He used three types of antenna (ASH700228A, ASH700718A and AOAD/M_T).

Dawidowicz (2014) studied the influence of the different calibration models on the height differences in GPS/GLONASS observations processing. He used three types of calibration models (absolute, relative, absolute converted) for receiver antennas and two types of calibration models (absolute and standard) for satellite antennas. He used data collected at three points on one day 24 hour observation sessions (NOV 20) of the year 2012. He used two types of antenna (JAVAD RINGANT G3T and TPSHIPER_PLUS).

EL-Hattab. (2013) used data collected from static and kinematic field experiments to evaluate the effect of using the manufacturer’s recommended antenna phase offset. The baseline length was limited (27 m - 70 m). He treated this data using two types of commercial software (LGO and TBC) using the manufacturere’s recommended PCO and ignore the effect of PCV.His results showed that the height component of the PCO is larger than horizontal components. The height component and north component were about 8 and 4 cm in the maximum variations.His results showed that the mean phase center offsets and phase and amplitude patterns for L1, L2 express the GNSS antenna phase center were shifted.

It's well known that the PCO plus the azimuth and elevation dependent PCV are affecting the total antenna phase center correction for an individual phase measurement (Hofmann-Wellenhof, 2008). On the other hand, to determine the antenna phase center variation for GNSS receiver antennas there are three ways: (1) Relative field calibration: The antenna offsets and phase center variations are calculated with respect to a reference antenna (AOAD/M-T antenna), (2) Absolute field calibrations: The antenna phase center variations were obtained by using a high precision robot which tilts and rotates the antenna while the reference antenna remains fixed, (3) Anechoic chamber measurements: obtained by placing the robot which rotates and tilts in an anechoic chamber.

Some GNSS users ignore the effect of the antenna phase center variation (PCV) and others take the effect of the antenna phase center variation into account using calibration results or by estimating the antenna phase center. The aim target of this paper is concentrate efforts in how to treat the error of the antenna phase center variations to increase GNSS results accuracy. This will have the positive effects in the estimated positioning.

2. Data Collection

In the present study, two types of observations were used to estimate the influence of the antenna phase center offset and the antenna phase center variation on baseline solution. The first type is obtained from a field experiment to study the case of short baseline solution. The field experiment is performed in the faculty of engineering, Zagazig university, Egypt, by setting up the devices above four roofs of faculty buildings. The four buildings used are mechanics building, civil engineering building, the lab building of the material department, and building of the architecture engineering department.

The second type of collected observations is the data of seven stations subtracted from the Egyptian network (NRIAG, 2017). This data is used for long baseline solution. The data span about one year. The data is available in RINEX format as daily file.

2.1 Field Experiment

There are two experiments to study the short baseline. In the first experiment four GNSS antenna were used; two TRM53406 and two SOK GRX2. Thoses four devices were installed above the surface of the lab building of material department. The baseline between devices is within the limits (40 m ~ 73 m) (Fig. 4). The four points were observed four times with the interchange of the devices every time. Observation days are (April 13), (May 4) and (May 5) of the year 2016. This case is named as short-short baseline.

Fig. (4): Locations of the devices for first experiment.

In the second experiment, the same of devices were used, but the devices were distributed above the main four buildings of faculty of engineering building, Zagazig University, Egypt. Each device was placed on a building. The baselines in this case between devices are within the limits (117 m - 301 m). The four points were observed three times with interchange of the devices every time. Observations days are (July 26) and (Augest2) of the year 2016. This case is named here as long-short baseline.

Campaign observations were repeated three times for each case. The data length spanning over two hours. The sampling interval and the elevation were fixed at 5 Sec and 5 degrees, respectively throughout the survey. Table (1) shows the list of the system used for collection data for both experiments.

2.2. Data of the Egyptian Network:

Seven GNSS stations were subtracted from continues observations of the Egyptian network of the year 2014 (NRIAG, 2017) (Fig. 5). Seven GNSS antenna were used; Five TRM55971 and two TRM41249. The data used for this study are three days of each month of the seven stations in 2014. Table (2) shows data availability of the seven stations during the mentioned three days.

Table (1): System used to interchange between the devices to collecte GNSS data.

Points	**First experiment (Short-short baseline)**				**Second experiment (Long-short baseline)**		
	First time (13/4)	Second time (4/5)	Third time (5/5)	Fourth time (5/5)	First time (26/7)	Second time (26/7)	Third time (2/8)
1	Sokkia (S)	Sokkia (S)	Trimble (T)	Trimble (T)	Sokkia (S)	Sokkia (S)	Trimble (T)
2	Sokkia (S)	Trimble (T)	Trimble (T)	Sokkia (S)	Sokkia (S)	Trimble (T)	Trimble (T)
3	Trimble (T)	Sokkia (S)	Sokkia (S)	Trimble (T)	Trimble (T)	Sokkia (S)	Sokkia (S)
4	Trimble (T)	Trimble (T)	Sokkia (S)	Sokkia (S)	Trimble (T)	Trimble (T)	Sokkia (S)

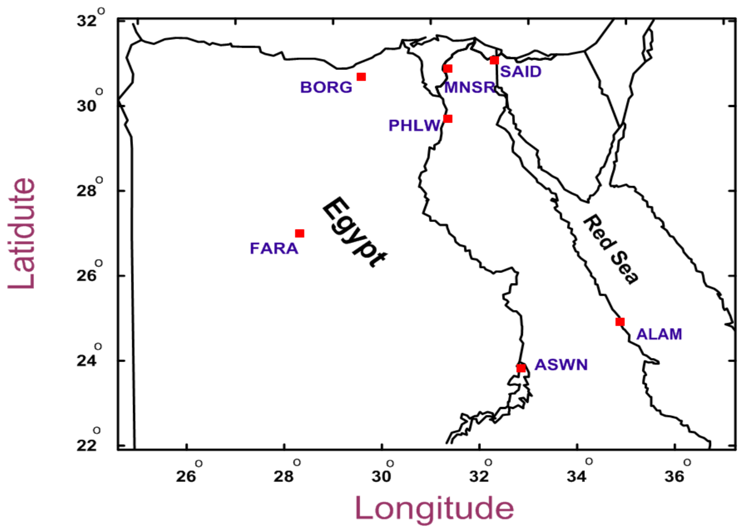

Fig. (5): Locations of the seven GNSS stations used in the present study.

3. Data Analysis

3.1 Field Experiment

The commercial Sokkia software magnet tools (v.2.7.1) is used to evaluate the influence of PCV in all cases of the field experiments. The analysis is performed in solution of the baseline using the antenna phase center and ignore the effect of it. There are two types of calibration in this software that are relative calibration and absolute calibration. In the present paper, absolute calibration is used. Parameters used in the software are WGS84 datum and the confidence level 95%. These parameters were kept fixed for data analysis in all cases. In the present paper, the effect of the antenna phase center in case of use it and the case of of ignoring it on the baseline are studied with different cut off angle. The cut off angles used are 5, 10, 15 and 20 degrees.

Table (2): Data availability of the seven stations during the selected three days. The numbers between brackets are the number of hours observed. Otherwise, it will be monitored as 24 hours. The stations that are not available are represented by the sign X.

MONTH	DAY	STATIONS						
JAN	28	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM(20)
	29	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	30	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
FEB	1	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	2	ASWN	BORG	MNSR	SAID	PHLW	FARA(17)	ALAM
	3	ASWN	BORG	MNSR	SAID	PHLW	FARA(19)	ALAM
MARCH	18	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	19	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	20	ASWN	BORG	MNSR	SAID(22)	PHLW	FARA	ALAM
APRIL	18	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	19	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	20	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
MAY	16	ASWN	BORG	MNSR(18)	SAID(18)	PHLW	FARA	ALAM(20)
	17	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	18	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
JUNE	19	ASWN	BORG	MNSR(6)	X	PHLW(10)	FARA	ALAM
	20	ASWN	BORG	X	SAID	PHLW	FARA	ALAM(1)
	22	ASWN	BORG	~~MNSR~~ (X)	SAID	PHLW	FARA	~~ALAM~~ (X)
JULY	3	ASWN	BORG	MNSR(16)	SAID	PHLW	FARA	ALAM
	5	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	6	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
AUG	25	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	26	ASWN	BORG	MNSR	SAID(20)	PHLW	FARA	ALAM(16)
	28	ASWN	BORG	MNSR(12)	SAID	PHLW	FARA	ALAM
SEP	20	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	21	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	22	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
OCT	18	ASWN	BORG	MNSR(18)	SAID	PHLW	FARA	ALAM
	19	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
	21	ASWN	BORG	MNSR	SAID	PHLW	FARA	ALAM
NOV	26	ASWN	BORG	MNSR(10)	SAID	PHLW	FARA(15)	ALAM
	27	ASWN	BORG	MNSR(18)	SAID	PHLW	FARA	ALAM
	28	ASWN	BORG	MNSR(12)	SAID	PHLW	FARA	ALAM
DEC	28	ASWN	BORG	MNSR(8)	~~SAID~~ (X)	PHLW	FARA	ALAM
	29	ASWN	BORG	MNSR(8)	~~SAID~~ (X)	PHLW	FARA	ALAM
	30	ASWN	BORG	MNSR(8)	SAID(20)	PHLW	FARA	ALAM

3.2 .The Egyptian Network

Bernese software (v.5) was used to analysis the network data (Dach, 2007). GPS and GLONASS signals were used in data analysis (Dach et al., 2007). The cut off angle 5 degrees and absolute calibration were applied. Data analysis were performed using some fixed parameters and models in all solutions. These parameters include absolute satellite information file (Satellite-I05), a satellite problem (Sat 2014.CRX), sub daily pole model IERS2000, nutation model coefficients (IAU2000) and phase center eccentricity files (Phase.COD-I05).

On the other hand, the double-differenced ionosphere was used to solve phase ambiguities. All baselines were processed separately and the ambiguities are resolved by using the quasi ionosphere free (QIF) technique (Dach, et al., 2007). Dry NIELL model was used for Zenithpath delay (ZPD). Wet NIELL model was used for mapping function. These files which used in processing were downloaded from [ftp://ftp.unibe.ch/aiub/ BSWUSER50_out_of_service]. Three types of solutions were applied: using the antenna phase center, ignoring the antenna phase center, and estimating the antenna phase center.

The following mathematical representation as formulated in Dach et al., (2007) is applied to correct the antenna phase center variation:

$$\Delta\varphi(\alpha,z) = \Delta\varphi'(\alpha,z) + \Delta r \cdot e \qquad (1)$$

Where

$\Delta\varphi(\alpha, z)$ is the total phase center correction in direction α,z.

α, z are are the azimuth and the zenith angle of the satellite line of sight.

Δr is the position of the mean antenna phase center offset with respect to the mechanically defined antenna reference point.

e is the unit vector in the direction from the receiver antenna to the satellite.

$\Delta\varphi'(\alpha,z)$ is the function modeling of the phase center variations. Two different model. Functions may be used in the Bernese GPS Software (Spherical harmonic function or Piece-wise linear function).

4. Results and Discussions

The paper investigates the influence of the antenna phase center, two cases from baseline (short baseline and long baseline) were studied. Section 4.1 discusses the influence of the antenna phase center about short baseline and section 4.2 discusses the influence of the antenna phase center about long baseline.

4.1. Short Baseline

The short baseline divided into two types (short-short baseline and long-short baseline). The network is analyzed using magnet field tools software. The results were in the form of the root mean squares(R.M.S) and loop closure errors under the effect of different cut off angles (5^o, 10^o, 15^o and 20^o) and distribution of the devices on the observation points. Here, R.M.S represent of antenna accuracy (precision), while loop closure errors represent of external accuracy (realability). Investigations are carried out using two strategies. The first time by using the antenna phase center and in the second time by ignoring the antenna phase center.

4.1.1 R.M.S of Antenna Accuracy

Figures 6, through 11 are examples from baselines to clarify the results in this research. The examples in figures 6, 7 and 8 show R.M.S for short-short baseline, while the figures 9, 10 and 11 show R.M.S for long-short baseline. These figures clarify the difference between two ways of solution. This difference was very small (almost identical) in all directions. A comparison between using the antenna phase center and ignoring it, is performed. The difference between the two methods is about 0.001 m for R.M.S for short baseline. In the short-short baseline, the antenna phase center has significant effect in R.M.S for mask angle less than 20 degrees, but in case of more than or equal 20 degrees there is no significant effect. For long-short baseline, due to change of environment about the antenna with increase of the length of the baseline, the antenna phase center is found to have a significant effect in R.M.S in case of mask angle less than or equal 5 degrees, but it has no significant effect for higher elevation angles. Therefore, using the antenna phase center given more accuracy than ignoring it in R.M.S for cut off angle 5 degrees.

**Short-Short Baseline

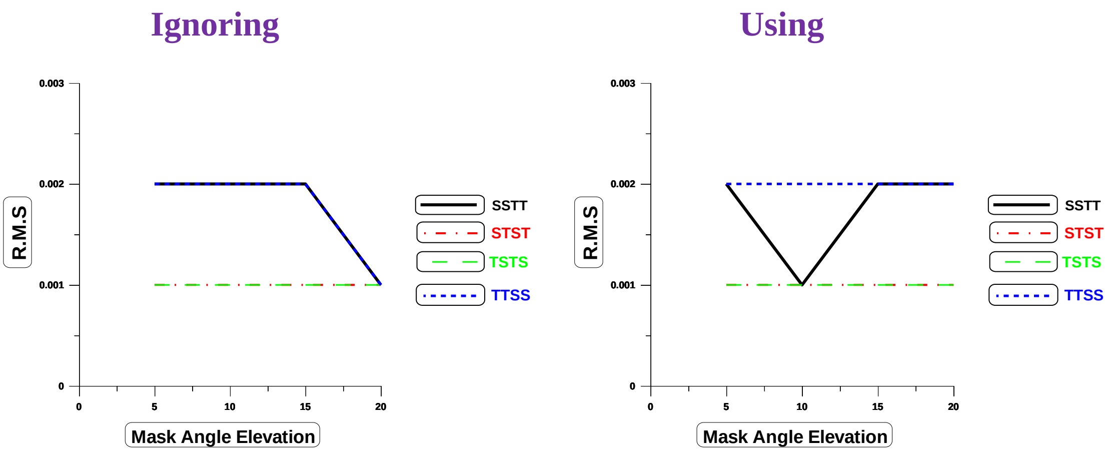

Fig. (6): Minimum length of the baseline (1-4) 40.38 m.

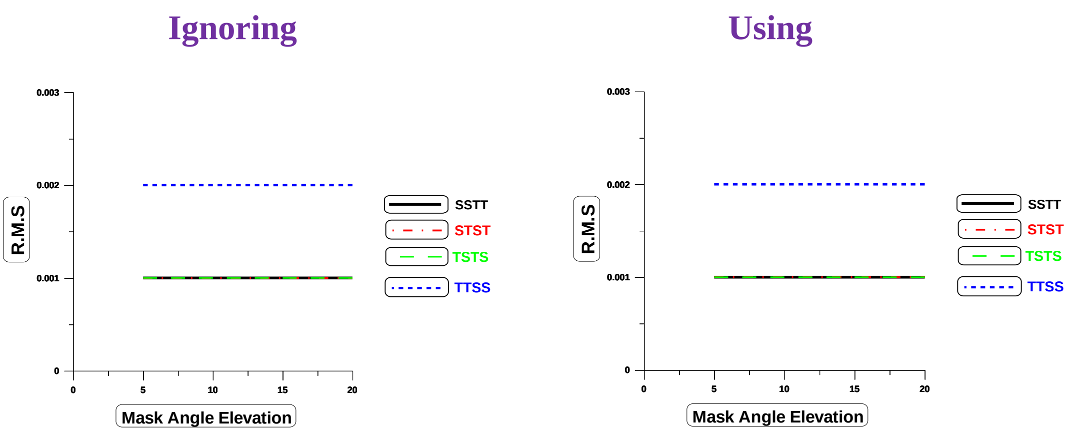

Fig. (7): Average length of the baseline (1-2) 52.35m.

Ignoring **Using**

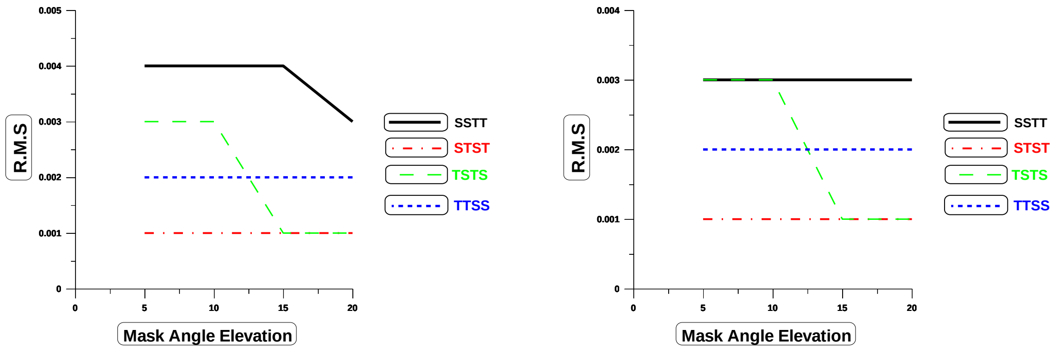

Fig. (8): Maximum length of the baseline (1-3) 72.25 m.

**Long-Short Baseline

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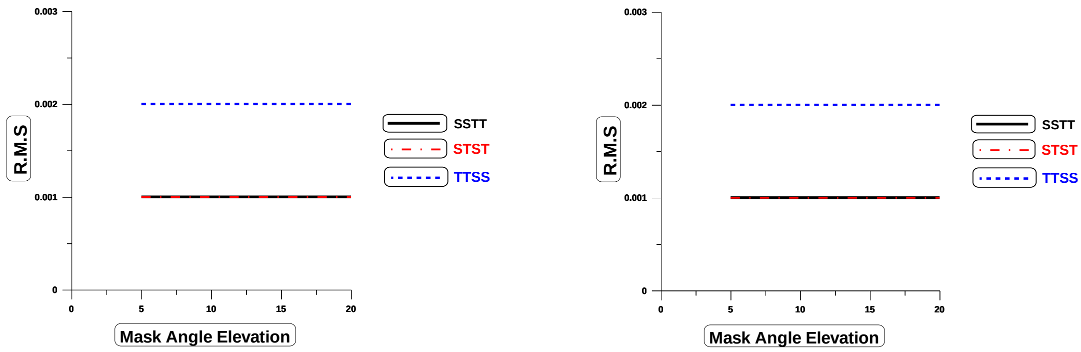

Fig. (9): Minimum length of the baseline (1-4) 117.5 m.

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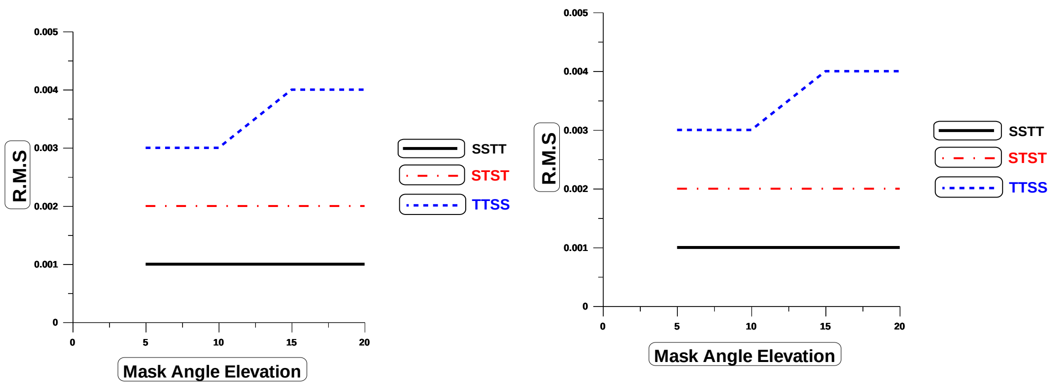

Fig. (10): Average length of the baseline (1-2) 256.6 m.

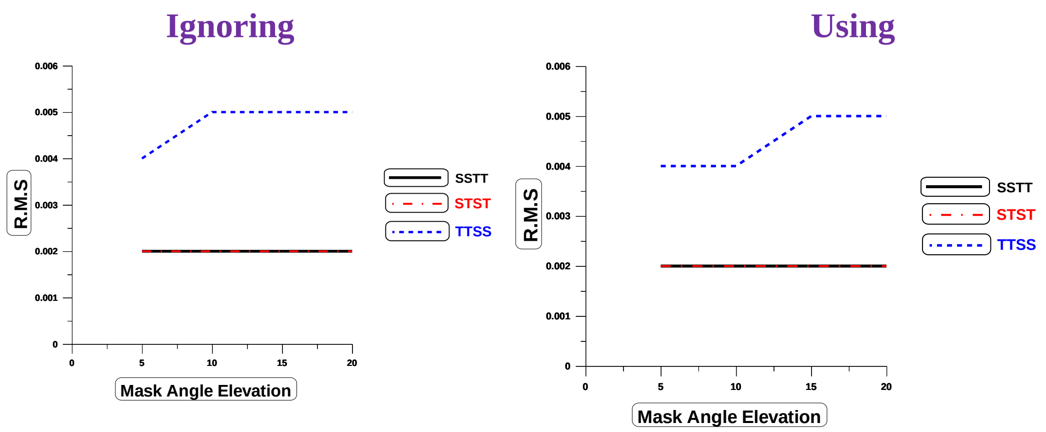

Fig. (11): Maximum length of the baseline (2-4) 301.5 m.

From the previous figures, it was found that diminishing the R.M.S with increasing of the mask angle about 10 degrees leads to increase of accuracy in case of short-short baseline, but in case of long-short baseline the R.M.S diminish with decreasing of the mask angle about 10 degrees leads to increase of accuracy.By the distribution of the devices on the points turns out that the situation STST has given the best accuracy in case of baseline less than 150 m, but in case of more than 150 m, the situation SSTT has given the best accuracy.

4.1.2 Loop Closure Errors

Figures (12~15) represent the difference in horizontal and upper loop closure errors in case of short-short baseline. Figures (16~19) show results for horizontal and upper loop closure errors. The difference between using the antenna phase center and ignoring it in horizontal loop closure errors range from 0.0001 to 0.0008 m, while they range from 0.0001 to 0.0019 m in upper loop closure errors. By comparing the difference between the two cases for long-short baseline, the difference in horizontal loop closure error is found to be in the range from 0.0001 to 0.0017 m and from 0.0001 to 0.0032 m in upper loop closure errors.

To represent these results for both two cases, two loops were chosen (minimum and maximum) from the lengths of the loop. These results indicates that the way of using the antenna phase center in solutions was the most accurate in state of mask angle less than or equal 15 degrees for case of short-short baseline, but it has no significant effect in case of mask angle 20 degrees. On the other hand, it was most accurate in state of mask angle less than or equal 20 degrees in case of long-short baseline. Also, it was noticed the situation SSTT has given the lowest difference of loop closure error between using antenna phase center and ignoring it in both two cases of short baselines. In conclusion, the antenna phase center influence on the horizontal and the upper loop closure errors, but its influence on the upper is more than the horizontal loop closure errors.

**Short-Short Baseline

Ignoring **Using**

Ignoring

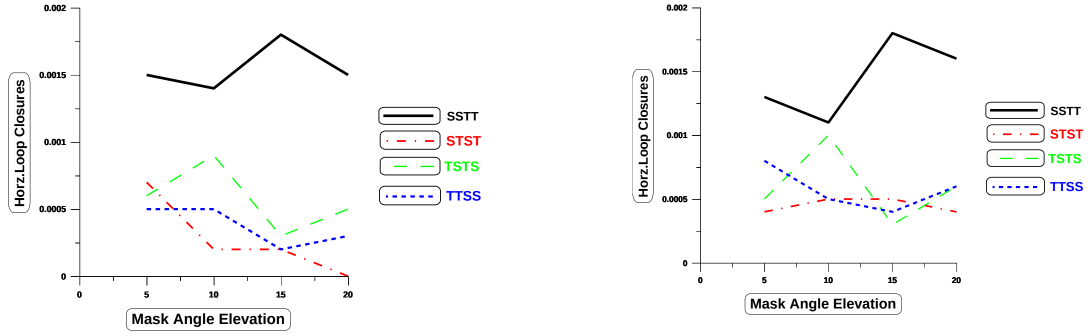

Fig. (12): Minimum length of loop for horizontal loop closure error.

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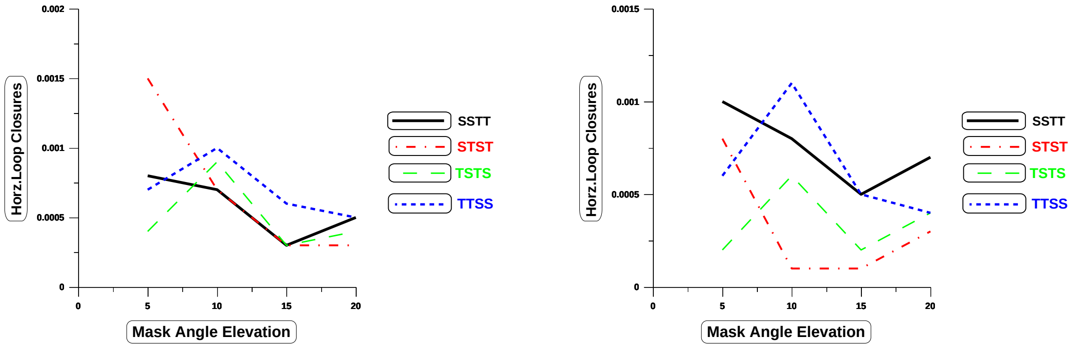

Fig. (13): Maximum length of loop for horizontal loop closure error.

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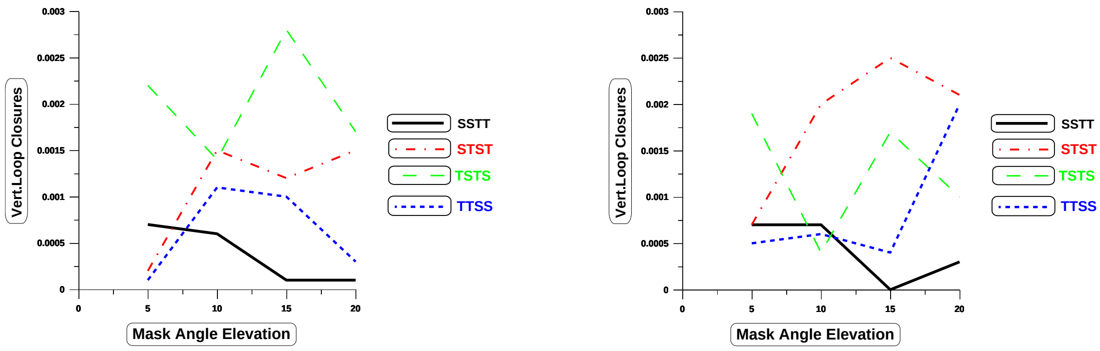

Fig. (14): Minimum length of loop for upper loop closure error.

Ignoring Using

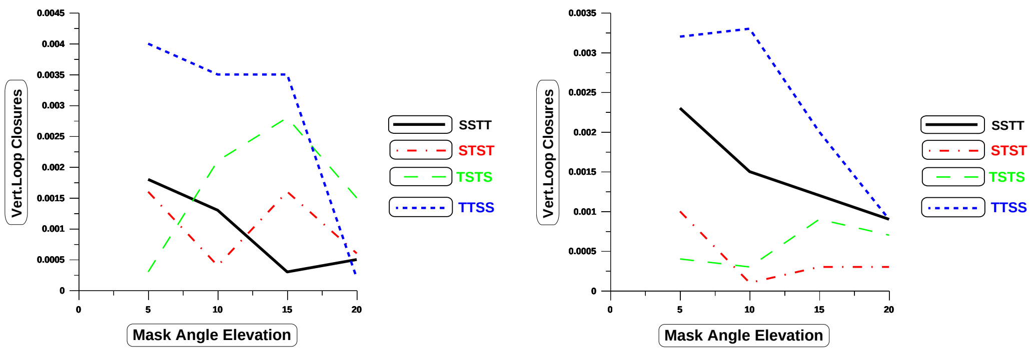

Fig. (15): Maximum length of loop for upper loop closure error.

** Long-Short Baseline

Ignoring Using

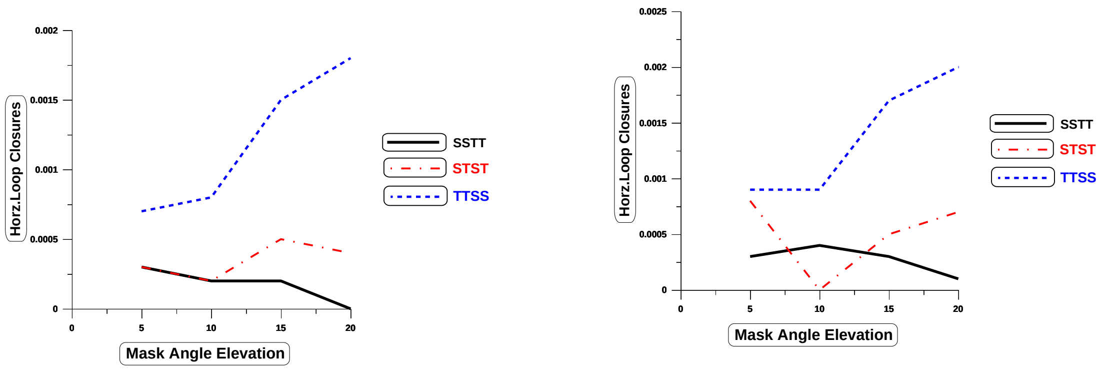

Fig. (16): Minimum length of loop for horizontal loop closure error.

Ignoring Using

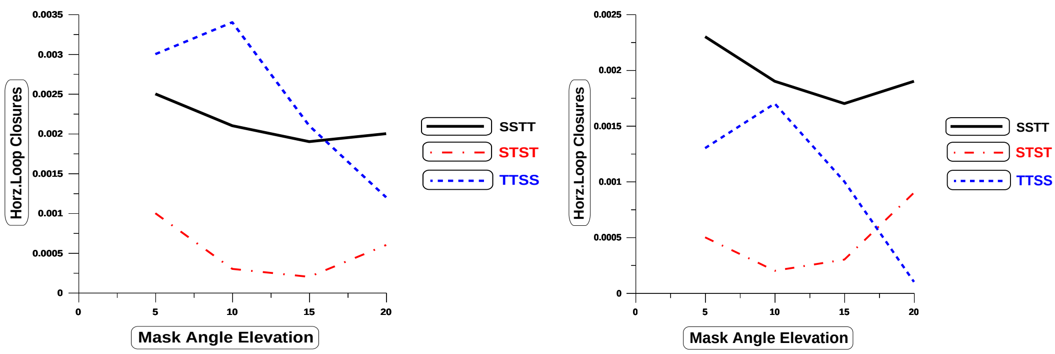

Fig. (17): Maximum length of loop for horizontal loop closure error.

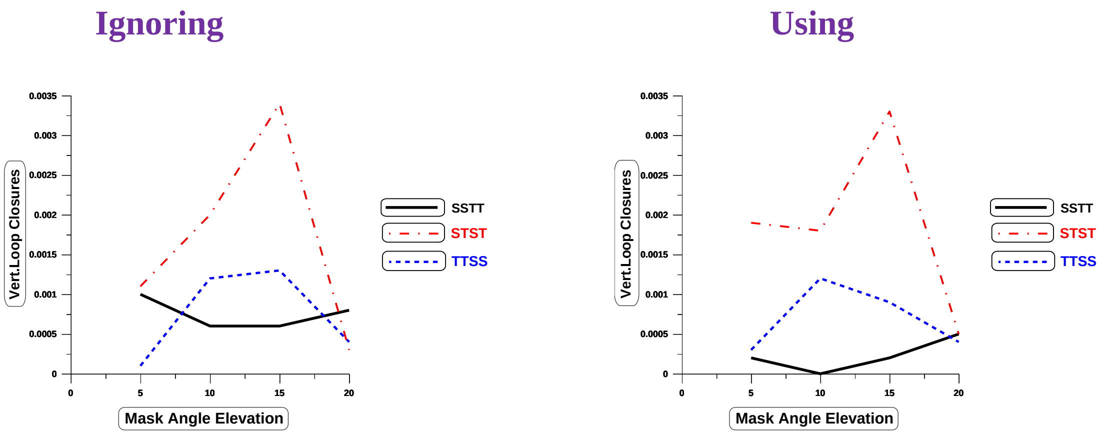

Fig. (18): Minimum length of loop for upper loop closure error.

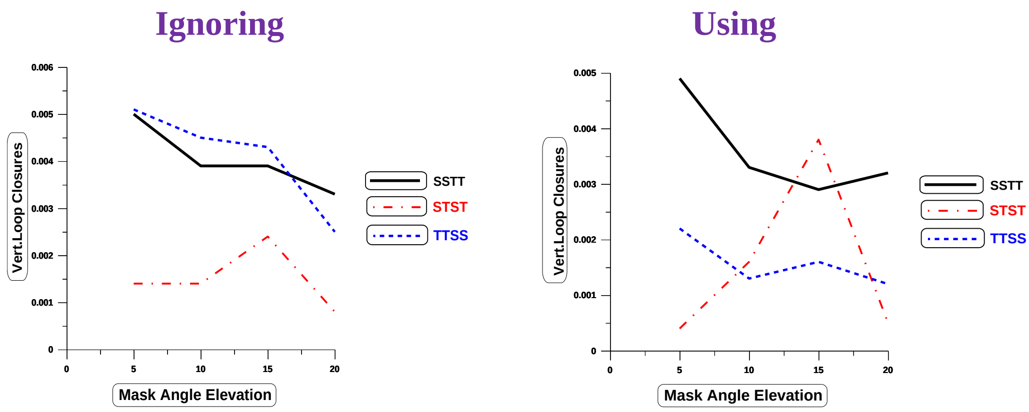

Fig. (19): Maximum length of loop for upper loop closure error.

4.2 Long Baseline

Bernese software (v.5) is used for data analysis for the present case. 36 days of GPS data of the year 2014 are used. A sample of days is presented here to clarify the influence of the PCV. The results were in the form of the root mean squares (R.M.S), change in coordinates of stations and loop closure errors under the effect of the three solutions. These are; using the antenna phase center, ignoring it and estimation of it. In addition, a comparison between the three obtained solutions is carried out to get the best solution.

The coordinates of the stations have been solved by applying PCV. The process is repeated two times to solve the coordinates by ignoring the PCV and estimating it. The difference between the three solutions, has been plotted and computed in Figs. (20~23). These figures show changing coordinates component due to antenna phase center (Ignoring, Using and Estimate).

From Figs (20~23), the two stations (FARA and PHLW) are likely to have a problem since they give the worst results. The change in coordinates components has reached more than 1.00 m.

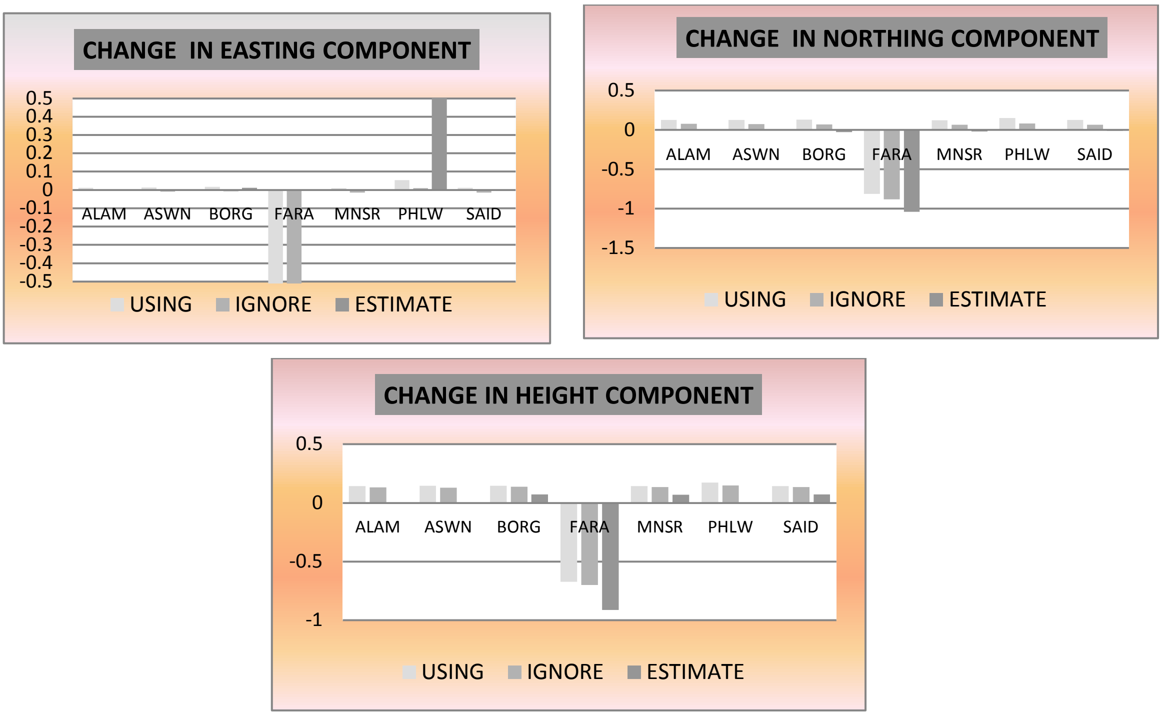

Fig. (20): Changing in the three coordinates components (Easting, Northing and height) for the day of Jan. 28.

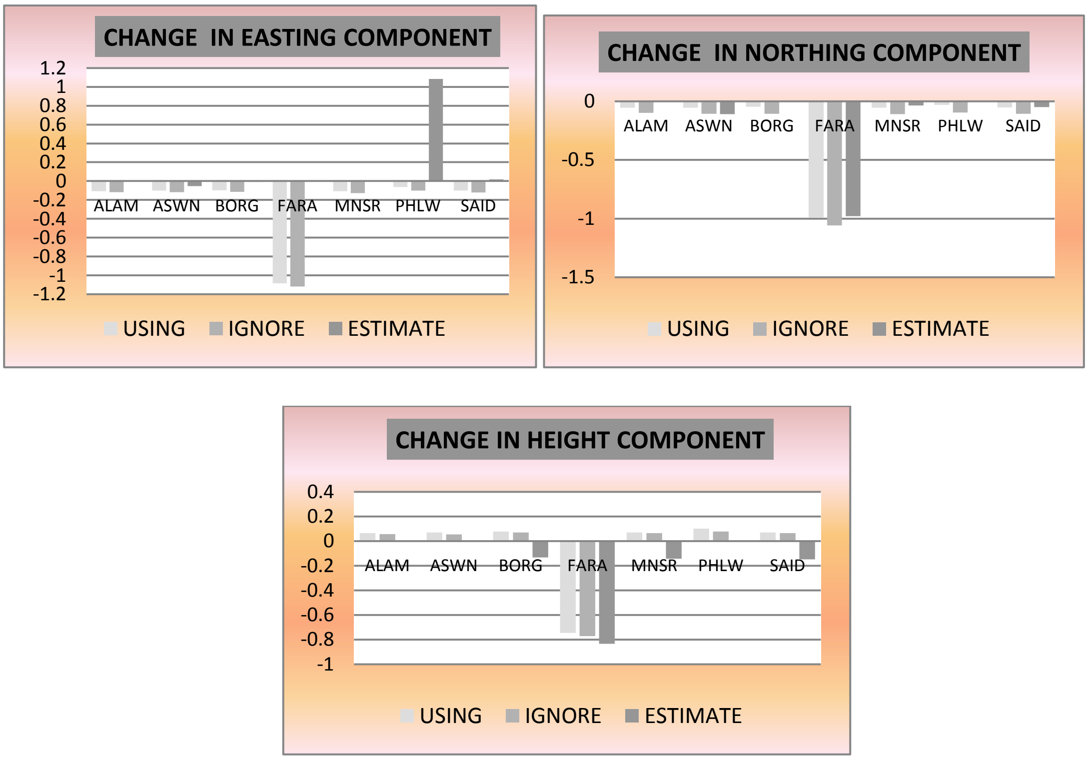

Fig. (21): The same like Fig. (20) but for the day of Apr. 18.

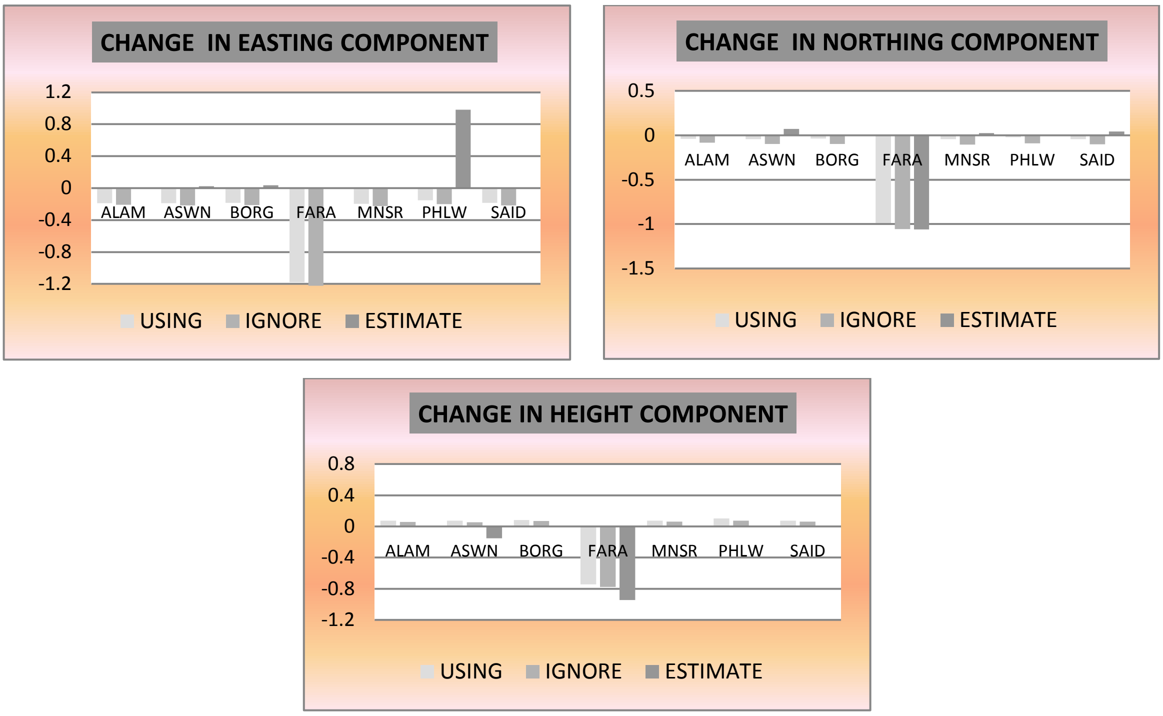

Fig. (22): The same like Fig. (20) but for the day of Aug. 25.

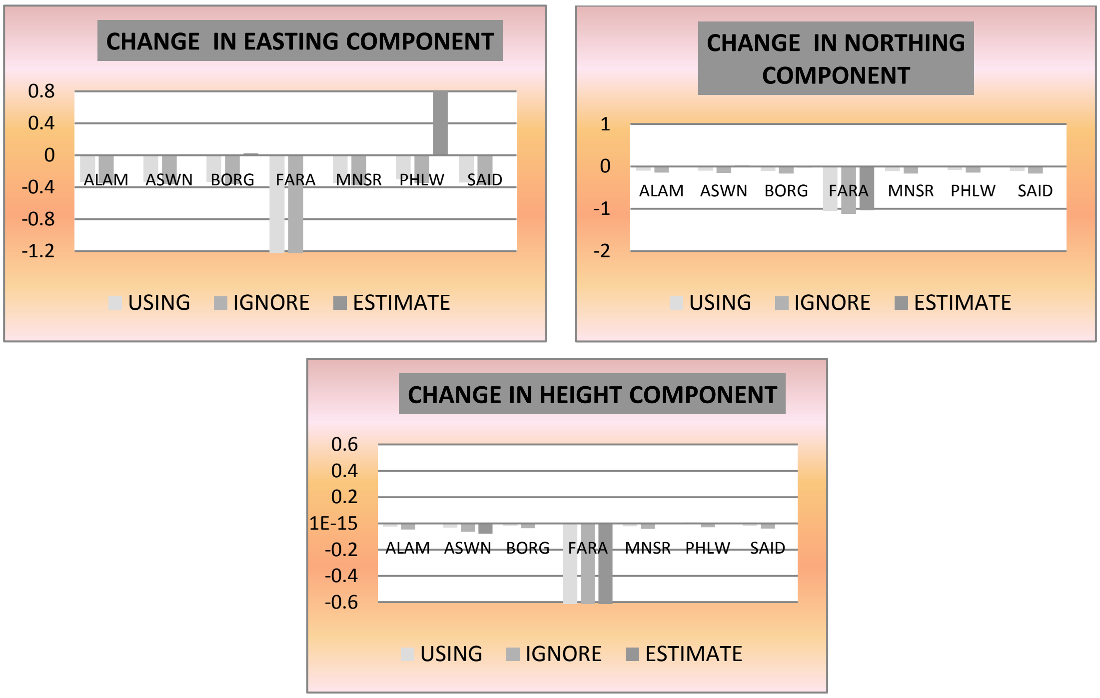

Fig. (23): The same like Fig. (20) but for the day of Dec. 30.

By comparing between the above three solutions, the result of method of using antenna phase center is almost similar to that of ignoring (both are around 0.35 m). The method of estimation of antenna phase center is found to be 0.15 m and approach to zero in some stations. So the way of estimation of the antenna phase center gives best results in all components (Easting, Northing and Height). Therefore, estimation of antenna phase center is more accurate than other two solutions. To further clarify these results, a sample of stations the change in coordinates components during one day of each month of the year 2014 (Figs. 24~26) are given here.

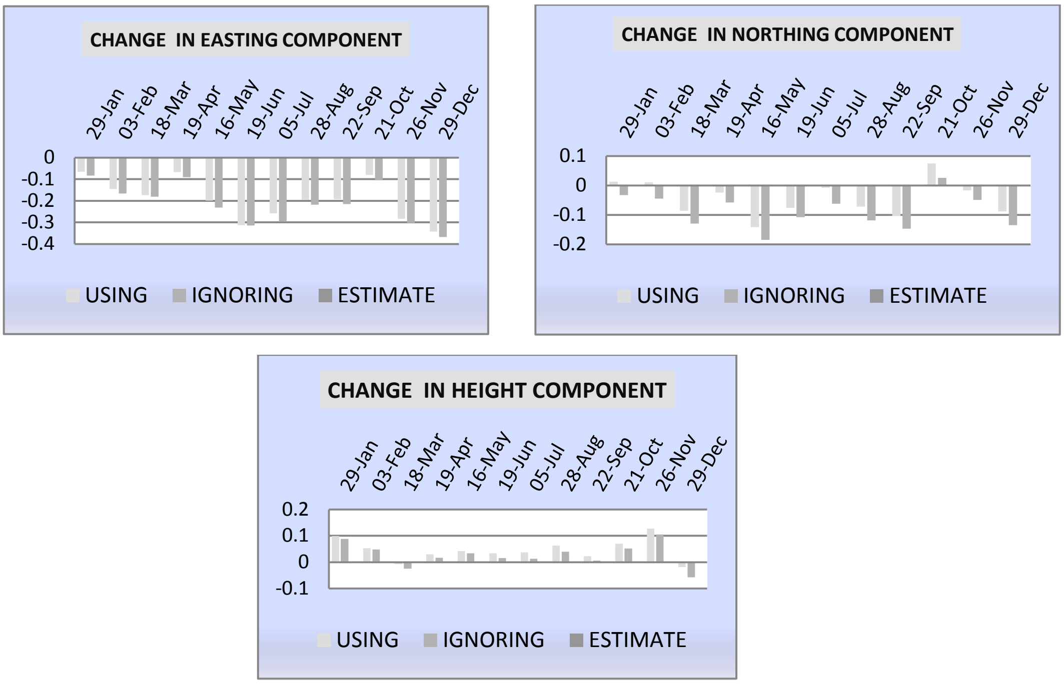

Fig. (24): Changing in the three coordinates components (Easting, Northing and Height) in one day of each month for station ALAM.

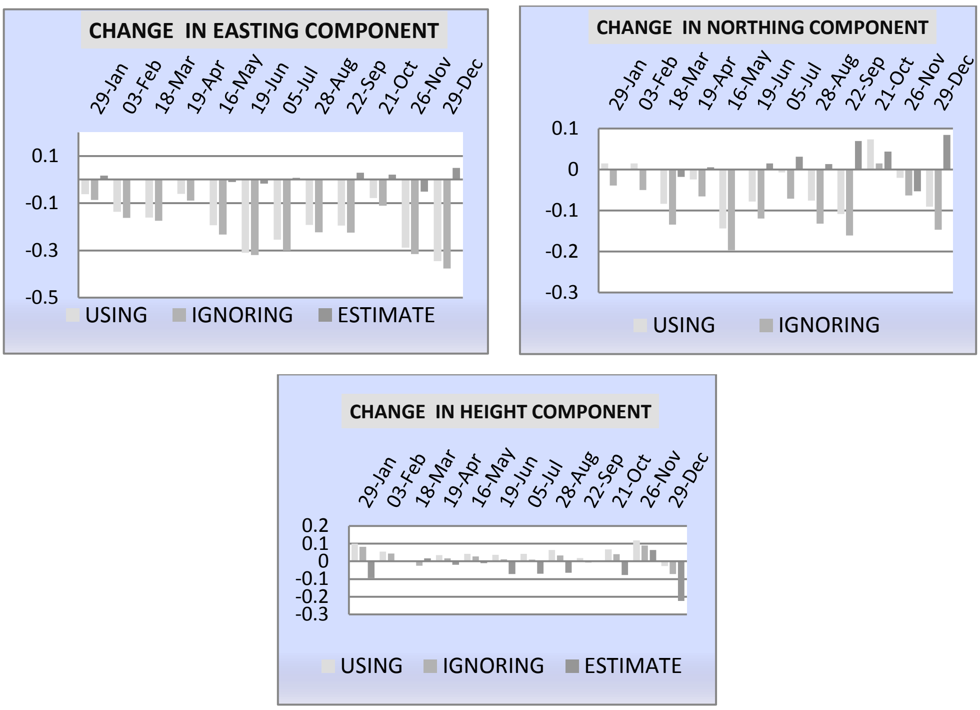

Fig. (25): Changing in the three coordinates components (Easting, Northing and Height) in one day of each month for station ASWN.

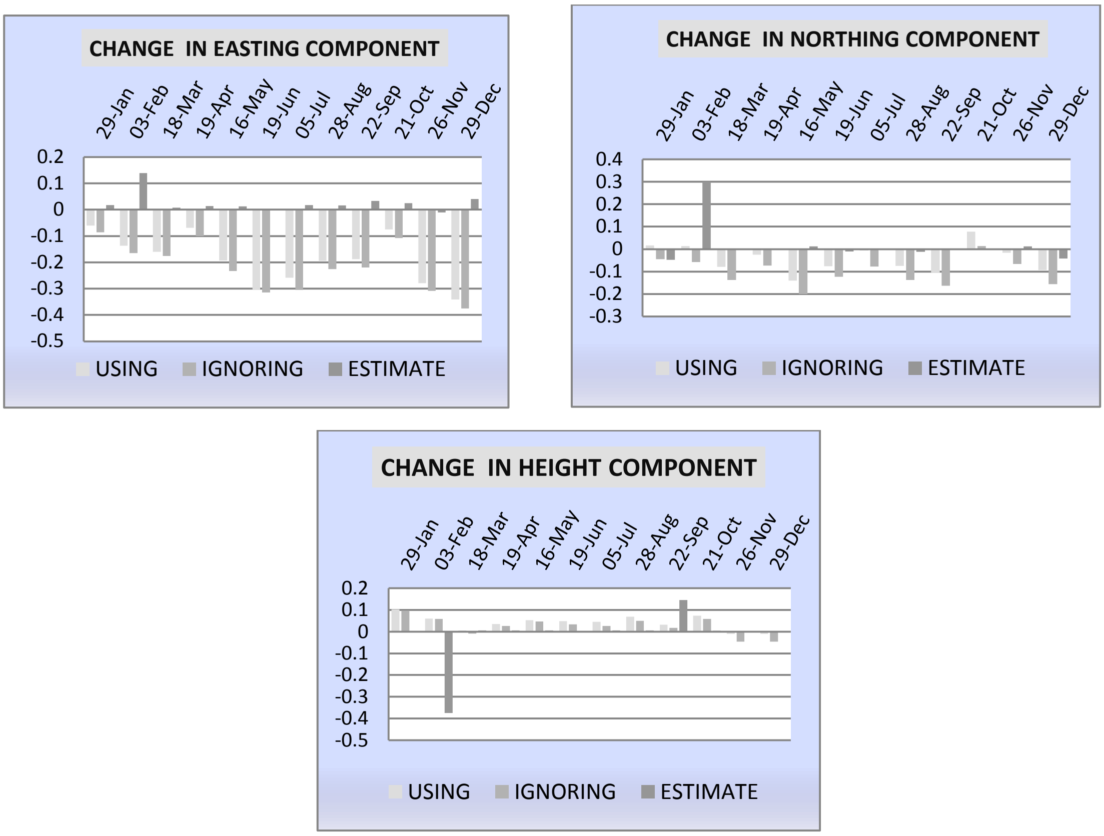

Fig. (26): Changing in the three coordinates components(Easting, Northing and Height) in one day of each month for station BORG.

The root mean square (R.M.S) is important to express accuracy of the solution of the above mentioned ways. To represent these results, a one day sample results are presented in Fig. (27). The obtained R.M.S is found to be within limits (0.01~ 0.04 m) for the three coordinates components (Easting, Northing and Height). The case of using antenna phase center is almost similar value to ignoring it (both are around 0.03 m). R. M. S. of the method of estimation of antenna phase center is about 0.02 m. Therefore, estimation of antenna phase center is more accurate than other solutions. It is noticed also that the height component has less variation than northing and easting components in terms of R.M.S.

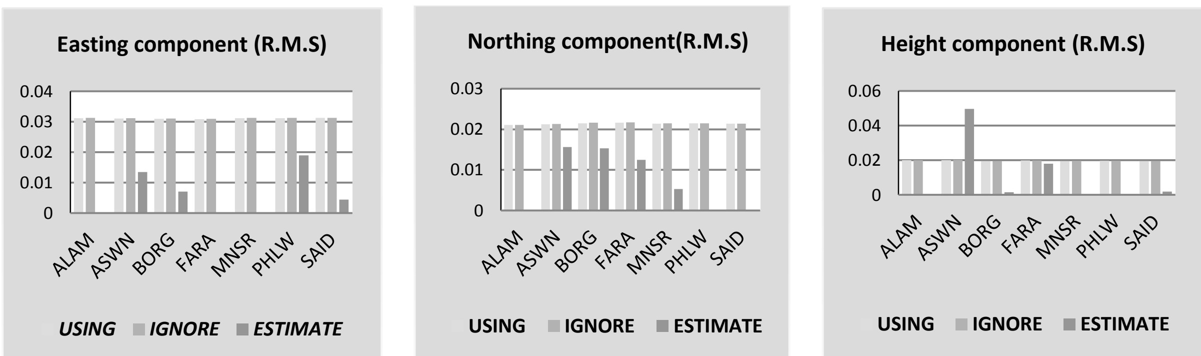

Fig. (27): R.M.S in Easting, Northing and Height components due to antenna phase center for day Dec 30.

Finally, four loops (SAID-MNSR-PHLW, MNSR-PHLW-BORG, ASWN-FARA-BORG and FARA-ALAM-ASWN) were analyzed. After solving these loops by applying the above mentioned three ways of solution, the loop closure is found to be within 0.01 m. On the other hand, to clarify the best results in solution, the results for each way is represented by a percentage the number times of the best solutions (solved four loops during day for 36 days). The results show that the way of using of PCV represents about 27.3% and ignoring of PCV about 24.3 while the way of estimation of PCV represent about 48.5%. Therefore, the way of estimation of PCV has given the best results compared to the other two ways of solution.To represent these results here, one loop was chosen (FARA-ALAM-ASWN). The results of this loop represented in Fig. (28) during one day for each month of days the previous mentioned.

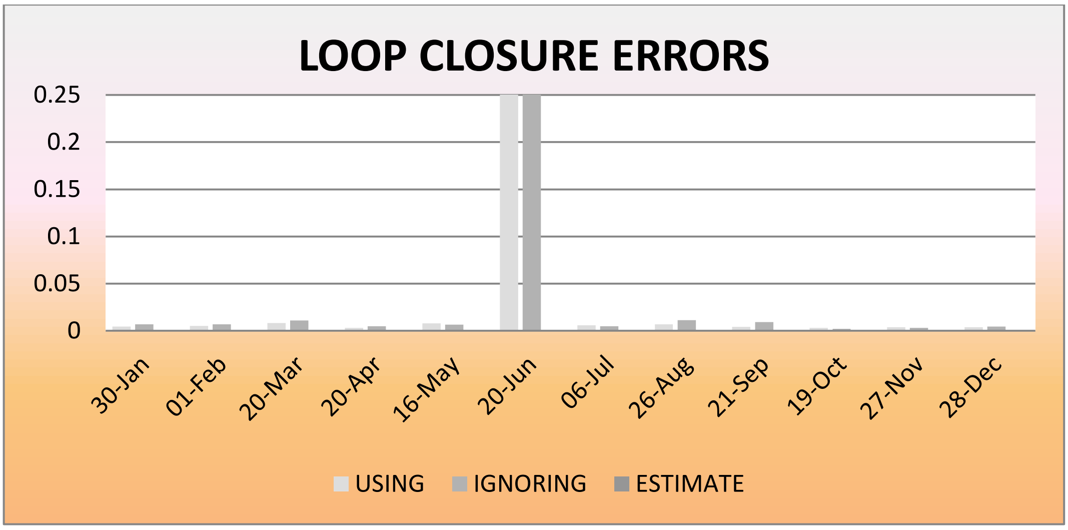

Fig. (28): Loop closure errors due to antenna phase center in one day of each month.

The previous figure and the above mentioned percentage indicates that the values of loop closure errors in both of using PCV and ignoring PCV are almost similar, while the results of estimation of PCV have almost zero values. So, It is preferably use the estimation of PCV way in the analysis of GNSS data. On the other side, the month of June gives the worst results, this might due to missed data as mentioned earlier in table (2).

5. Conclusions

This paper investigates the influence of the antenna phase center using two mitigation methods (using the antenna phase information and ignoring it) for short baseline and using three mitigation methods (using the antenna phase information, ignoring it, and estimating it) for long baseline. The effect of antenna phase center variations and its offset have been estimated using GNSS data from the Egyptian network (NRIAG) to study long baseline and some static field experiments to study short baseline. The data collected for short baseline have been analyzed by commercial SOKKIA software magnet tools V.2.7.1. The obtained results indicated that: (1) the difference between using the antenna phase center and ignoring it was very small in all directions, (2) at cut off angle 5^{o} method of using the antenna phase center gives a more accuracy than ignoring it, (3) changing the distribution of the devices on the data points effects on the obtained accuracy, (4) the antenna phase center influence both the horizontal and the upper loop closure errors, but its influence on the upper is more than the horizontal loop closure errors.

On the other hand, data collected for long baseline have been analyzed by using Bernese software (v. 5). The obtained results indicated that: (1) the method of estimation the antenna phase center has the best results in the three coordinate components (Easting, Northing and Height), (2) the values of loop closure errors in both of two ways (using of PCV and ignoring of PCV) are almost similar, while the way of estimation of PCV has almost zero closure error. Thus the method of estimation PCV is recommented for GNSS data analysis.

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