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The effect of GPS[1] antenna's phase center offset and satellite DOP[2]'s on the exact positioning

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Abstract

In this study, the effect not being in the same orientation of the antennas error in a triangular network with approximate dimensions of 19,12 and15 meters has been tested. Satellite observations of the three sides traverse were tested in four consecutive days and every 6 hour. Four times of traverse have been done during 0,6,12 and 18 hours of day. In all observations on the first and second day, the antennas direction has been to the West, in the third day observations, the direction of antennas to the outside of each Baseline and on the fourth day observations, antenna direction has been located inside the Baseline. Thus, a total of 16 times of the traverse, has been carried at a rate of 1" in the metropolitan area with excellent viewing angles and free of annoying GPS signals. The observations of each Baseline have been lasted for twenty minutes. In all processing times of Baseline absolutely identical name satellites and completely identical time interval have been used. Finally, the effect of antennas direction in positioning as well as DOP satellite impact on different days and other possible errors on satellite traverse have been evaluated.

KeyWords: Antenna Phase Center, GPS, DOP, Baseline, Satellite travers.

1- Global Positioning System
2- Dilution of Precision

Introduction

One of the newest and best methods for determining the exact position of the points, is satellite positioning. GPS satellite positioning system is one of the ways of satellite positioning in which, the system itself, according to the type of signals used in satellite traverse as well as the type of receivers, can be divided in several ways. localization of error sources is unique to their own satellite just like every geometric-per-view that has its own absolute and relative error and its sources of errors. Some of these errors are systematic and some other enter randomly to the observations. It is possible to find the strategies used to reduce the effect of that error through identifying the origin and structure of each error in addition to using of mathematical relations. Travers conducted in this study has been done using satellite orbital data received from the satellite traverse message localization (using inaccurate information circuit) in a Post Processing way to form a closed loop method. In this research, using a pair set of dual frequency GPS receivers (L1, L2) Leica SR530 model and by using a pair Leica AT502 model antenna, positioning has been done to determine the exact position of the three fixed ground stations using static observations and triple differential (satellite-receiver-time).

Main sources of error in determining the satellite position in the study were divided into two categories

1- Evaluated and reduced errors in processing of software and practical solutions.
2- Reduced errors, due to positioning (Differential triple) and receiver.

The effect of satellite geometry on the accuracy of positioning error Dilution of Precision (DOP):

GPS satellites is approximately 20200 kilometers to its nadir point on the earth surface. The amount of time that lasts for a GPS satellite to orbit a full circle around the Earth is approximately 11:58 hours. In other words, the position of each satellite is changing moment by moment. As the result, these displacements make the spatial resection with different triangles in which differences in forms of resection can lead to error in positioning. Each of these spatial triangle which in shape are in four dimensions of X, Y, Z and time, earn their own points which are called DOP. DOP is a term used in satellite traverse and geometrics engineering to specify the additional multiplicative effect of traverse satellite geometry on positional measurement precision. Whatever The DOP is less, the value positioning will be more accurate. The effect of satellite geometry for each Baseline observations on the accuracy of positioning (DOP) at different times has been evaluated. The more the DOPs' results are close to 0, the more it is close to the optimum of DOPs and the fewer errors can be made ultimately. Usually, Observations with DOP higher than 5 or 6 are removed from the domain of the processor and ground operatio ns should be repeated.

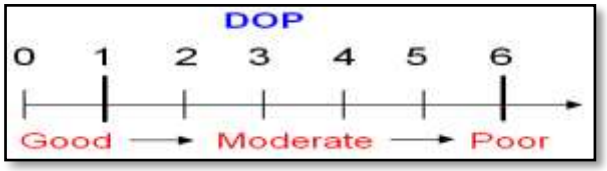


Figure (1) Interval & DOP'S Score

Satellite geometry is evaluated from several aspects:

PDOP: The satellite geometry score on the accuracy of positioning in three dimensions X, Y, Z.
HDOP: The satellite geometry score on the accuracy of Positioning, in two dimensions X, Y.
VDOP: The satellite geometry score on the accuracy of Positioning, in one-dimension Z.
TDOP: The satellite geometry score on the accuracy of Positioning, on dimension of time.
GDOP: The satellite geometry of final score on the Positioning accuracy (result of the previous four dimensions).

$$\sqrt{\sigma} \qquad (1)$$

Phase Center Offset Error (PCO):

The carrier received signals of the satellite, get away from center of antenna due to the nature of antenna's wavelength and (satellite's) Azimuth and Vertical Angle. So this error is called antenna phase center offset. Error antenna phase center for each carrier signal is divided in two parts including a height and horizontal part. Usually these shifts must be declared by the manufacturer to correct it. In the case of, Vertical Phase Center Offset (VPCO), it is more convenient because it changes is in one dimension (height) and these errors can be mostly eliminated by entering the VPCO parameter in information processing. If you are using two or more non-model antennas, enough attention should be paid in introducing separate parameters of the antenna. In shifting of the Horizontal Phase Center Offset (HEPCO), we are dealing with two dimensions of X, Y. Since, on one hand, at the time of the observations, the antennas can be in any direction and on the other hand, satellites are continually moving and as the result, the horizontal phase center error is variable, these make it more difficult. Practical solution to reduce the HEPCO error is making the used antenna aligned or orientation, in careful observations.

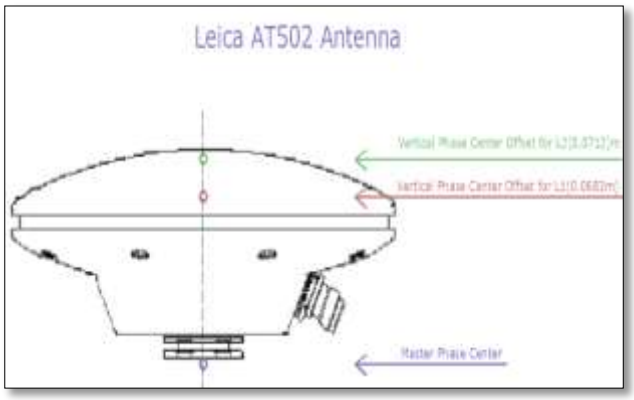


Figure (2) Leica AT502 Antennas Vertical Phase Center Offset

Error due to the lack of satellite numbers that by itself is rooted in the inappropriate Visibility:

The existence of a ground barrier between satellites and receivers lead to the disconnection, and resulting in a reduction in the number of satellites used in the positioning points. In this study for the integration of Visibility, observations of satellites that have participated fully in the desired time period used and the remaining half signals were eliminated. It has been attempted to a homogeneity be created in frame of the number of satellite of each Baseline through using the same number of satellites as well as a full signal.

Multipath error:

Ideally sent signals route is directly from the satellite to the receiver. If the land agent causes a deviation in the straight line, the error is called (multi-path) error. These factors include tall buildings, power lines, etc. In this research the following observations were made to further reduce this error:

Observations in a high place and above than any ground intruders.

Signal cut at an angle less than 15 degrees

Conduct observations in four times in four days

Undertake research in a rough area and with low reflection

Strong winds error influence on GPS signals:

According to forecasts by the Meteorological Department, the days were chosen in a manner that the least amount of wind has been existed in four days of the observations.

Antenna deployment error:

A special screw of GPS antenna that has been quite fixed, was used with an antenna height of zero to eliminate the antenna's error establishment. However, since in the observations, antenna should be placed in different

directions, sometimes antenna height were changed in the range of 0 to 2 mm and through using Collis tool these amount were measured and applied in processing.

Disconnect error or Cycle Slip with earthly and spatial origin:

The satellite momentary Disconnection with receiver that can have an earthy or spatial source is called phase jumps error. The spatial sources of phase mutation include the existence of an obstacle between the satellite and the receiver, software failure and GPS sudden acceleration. The spatial origin of the phase error can include the obstacle between the satellite and the receiver, satellite signal interference with other signals, ionosphere disorders and… Incomplete signals (signals that have been off two or more times) as Section 1-3 were excluded from the observation. It should be noted that in the 1-3 just once cut off signals that have been out of sight of receiver or they were not presented at the beginning of each Baseline, have been removed But in this part , signals that are interrupted and joined two or more times, were processed out of stock.

Reduced errors due to the Positioning method (Differential triple) and receiver:

This research method that uses L1 and L2 GPS carrier signales through static method, has reduced following errors spontaneously:

2-1 Satellite and receiver clock error
2-2 Orbiting satellites error
2-3 Atmospheric errors
2-4 Phase ambiguity error

Research Method:

This research method for determining the position is relative. Initial coordinates M1 station that obtained in the first travers as a FIXED point is intended for traverse in four days. The Place of the test is at latitude of the 34°21'50.4" North and 47°08'02.7" East located on an apartment high-rise in Kermanshah, (Figure 3) was higher than any magnetic field and Visibility was excellent.



Figure (3) location of Stations



Figure (4) Structure of Stations

Stations using steel screws for GPS antenna with Zero antenna height for perfectly vertical walls in the stable roof with an approximate distance of 15,19,12 meters have been placed. So enough efforts have been made to stablish these distances in the way that this triangle (trigonometric) has a relatively good geometric strength.

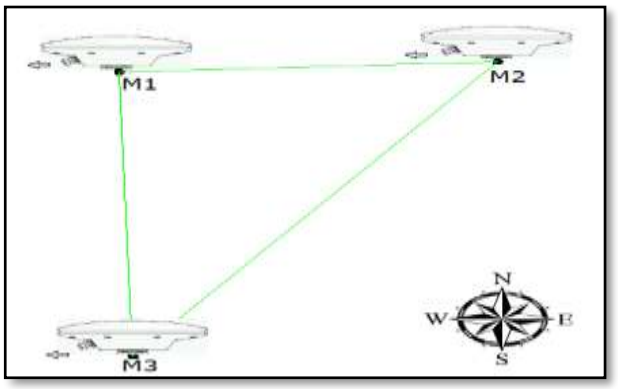


Figure (5) Antenna Orientation For The First day

GPS observations were done using L1 and L2 carrier waves and the observation rate of 1". observation period for each Baseline (M1-M2 and M2-M3 and M3-M1) was 20-minute and as a close traverse. In this study, two Leica AT502 antennas company has been used. the time of traverse has been in four days on early spring. It has been done four times per days round 0-6-12-18 hours and satellite travers has been done 16 times on the above-mentioned three stations totally. In all the traverses of the first and second day, antenna's direction in all observations was to one side (West) and placed in azimuth 270 degrees. (Figure 5). Detailed directions of antenna were marked before starting the Main traverse and by using the coordinates of a previous traverse (out of 16 main traverse of this research), Using a Total Station in the vicinity of stations. In the quadripartite traverse of the third day, antennas direction has been diverse and outward from each Baseline.

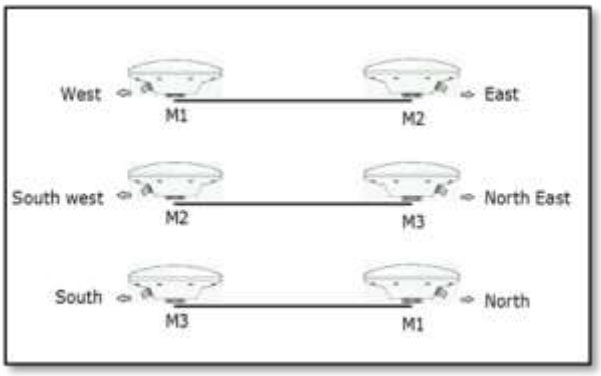


Figure (6) Directions Antennas On the Fourth day

The four-quarter traverses were conducted in the way that the antenna direction has been located on the inside of each Baseline.

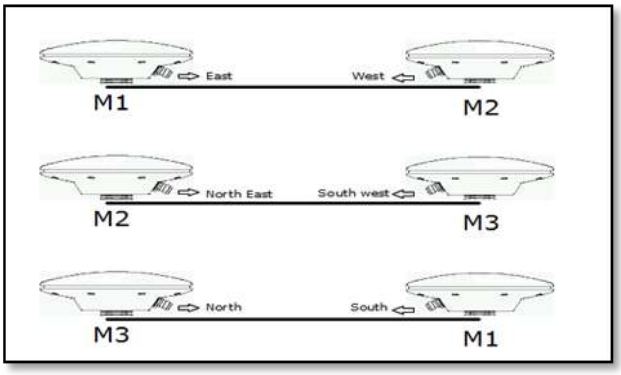


Figure (7) Directions Antennas On the Fourth day

to create the same conditions in the everyday traverse, every Baseline observation were performed in half-hour intervals and after the end of all the observation, a joint 20 minutes interval was selected from half-hour intervals. such Baseline observations start and end exactly in a definite time (Table 1). The satellite signals which have been disconnected (slip) during each Baseline observations or have not existed since the beginning of observations, have been removed. (Table- 2) Shows the numbers of used satellite in each Baseline. Thus, only the complete signal and common satellites is used in both receiver. Leica Geo Office Combine software has been used in this study.

Table 1-Static observation period every 24 hours

	M1-M2		M2-M3		M3-M1	
	Start	End	Start	End	Start	End
Traverses at 0	0:05:01	0:25:01	1:11:02	1:31:02	0:36:02	0:56:02
Traverses at 6	6:00:01	6:20:01	7:10:01	7:30:01	6:36:00	6:56:00
Traverses at 12	12:09:00	12:29:01	13:10:01	13.30:01	12:35:00	12:55:00
Traverses at 18	18:05:02	18:25:02	19:10:01	19:30:01	18:35:01	18:55:01

Table 2-Number of satellites used in any Baseline

	M1-M2	M2-M3	M3-M1
Traverses at 0	10 15 16 18 20 21 26 29	10 14 15 16 18 21 26 27 32	10 15 16 20 21 26 27 29
Traverses at 6	1 3 11 14 23 31 32	1 3 9 11 23 26 31	1 3 11 23 31
Traverses at 12	5 7 8 9 28 30	5 7 8 9 13 28 30	5 7 11 13 17 28 30
Traverses at 18	2 6 12 19 24 25	2 5 6 12 24 25 29	2 6 12 19 24 25

Tables 3 to 6 shows the mean of DOP's observation for Baseline M1-M2.

Table 3-The Average DOP'S of First Day Of M1-M2

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
First Day	0:00	2.95	2.5	1.1	2.2

6:00	3.15	2.75	1.65	2.15
12:00	3.25	2.75	1.3	2.45
18:00	4.3	3.55	1.7	3.05

Table 4-The Average DOP's of First Day Of M1-M2

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
Second Day	0:00	2.8	2.35	1.1	2.05
	6:00	3.05	2.65	1.55	2.15
	12:00	3.1	2.65	1.25	2.3
	18:00	4.4	3.6	1.7	3.2

Table 5-The Average DOP's of First Day Of M1-M2

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
Third Day	0:00	2.9	2.45	1.1	2.2
	6:00	4.05	3.4	1.6	2.95
	12:00	3.2	2.7	1.3	2.4
	18:00	4.55	3.7	1.75	3.3

Table 6-The Average DOP's of First Day Of M1-M2

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
Fourth Day	0:00	2.85	2.4	1.1	2.15
	6:00	2.85	2.55	1.55	2
	12:00	3.15	2.7	1.25	2.35
	18:00	4.65	3.8	1.75	3.3

Tables 7 to 10 shows the mean of DOP's observation for Baseline M2-M3.

Table 7-The Average DOP's of First Day Of M2-M3

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
First Day	0:00	2.35	2.05	1	1.75
	6:00	3.55	3.05	1.35	2.75
	12:00	3.1	2.7	1.3	2.35

	18:00	3.1	2.7	1.3	2.35

Table 8-The Average DOP's of First Day Of M2-M3

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
Second Day	0:00	2.2	1.95	1	1.7
	6:00	2.75	2.4	1.35	2
	12:00	3.3	2.8	1.35	2.5
	18:00	2.75	2.35	1.25	2

Table 9-The Average DOP's of First Day Of M2-M3

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
Third Day	0:00	2.3	2.05	1	1.75
	6:00	2.45	2.15	1.1	1.9
	12:00	3.2	2.75	1.35	2.45
	18:00	2.35	2.05	1.1	1.75

Table 10-The Average DOP's of First Day Of M2-M3

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
Fourth Day	0:00	2.3	2	1	1.7
	6:00	2.45	2.2	1.15	1.9
	12:00	3.25	2.8	1.35	2.45
	18:00	2.35	2.05	1.1	1.75

Tables 11 to 14 shows the mean of DOP's observation for Baseline M3-M1.

Table 11-The Average DOP's of First Day Of M3-M1

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
First Day	0:00	2.6	2.3	1	2.1
	6:00	5.4	4.45	1.65	4.15
	12:00	2.5	2.15	1.15	1.85
	18:00	4.05	3.35	1.65	2.9

Table 12-The Average DOP's of First Day Of M3-M1

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
Second Day	0:00	2.5	2.2	1.05	1.95
	6:00	5.35	4.45	1.65	4.1
	12:00	2.35	2.05	1.1	1.75
	18:00	3.85	3.2	1.6	2.8

Table 13-The Average DOP's of First Day Of M3-M1

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
Third Day	0:00	2.9	2.6	1.15	2.3
	6:00	5.3	4.4	1.65	4.05
	12:00	2.4	2.1	1.15	1.8
	18:00	3.7	3.05	1.6	2.6

Table 14-The Average DOP's of First Day Of M3-M1

Day	Time Traverse	ave GDOP	avePDOP	aveHDOP	aveVDOP
Fourth Day	0:00	2.5	2.2	1.05	1.95
	6:00	5.1	4.3	1.7	3.9
	12:00	2.4	2.1	1.1	1.75
	18:00	3.5	2.9	1.55	2.45

Chart (1) shows the coordinates of the M2 point in four days, along with the coordinates of the mean of observations of the first two days.

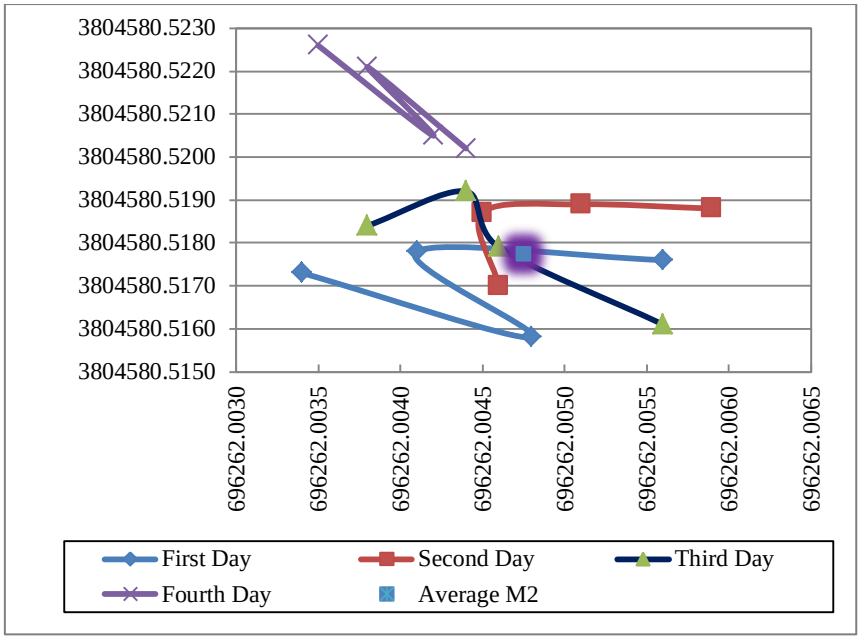


Chart (1) M2 plot Changes coordinates in four days

Chart (2) shows the coordinates of M3 in four days, along with the average of coordinates of the first two days of ervations.

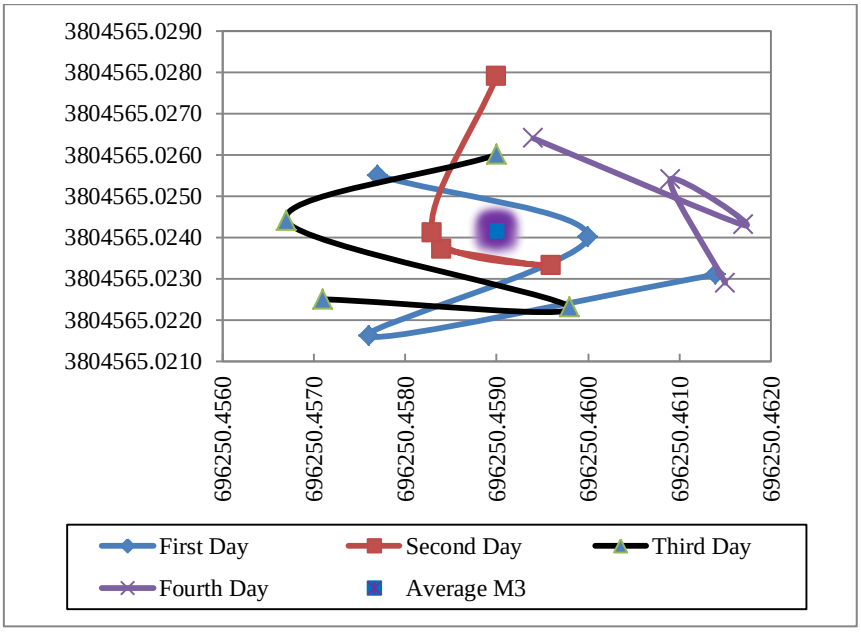


Chart (2) M3 plot Changes coordinates in four days

Table 15 shows M2 statistical data points obtained from octal observations of the two first day (antenna direction to the same side).

Table 15- M2 Descriptive statistics for the first two days

	N	Minimum	Maximum	Mean	Std. Deviation	Variance

East	8	696262.003400	696262.005900	696262.00475000	.000801784	.000001
North	8	3804580.515800	3804580.518900	3804580.51773750	.001063603	.000001
Z	8	1345.006100	1345.013500	1345.00902500	.002149917	.000005

Table 16 shows M3 statistical data points obtained from octal observations of the two first day(antenna direction to the same side).

Table 16- M3 Descriptive statistics for the first two days

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
East	8	696250.457600	696250.461400	696250.45900000	.001288410	0.000002
North	8	3804565.021600	3804565.027900	3804565.02415000	.001868537	0.000003
Z	8	1344.998400	1345.007600	1345.00251250	.003123843	0.000010

Table 17 shows M2 statistical data points obtained from observations of the second and third days.

Table 17- M2 Descriptive statistics for Third & Fourth Day

	Number of satellites	X	Deviation from the mean X	Y	Deviation from the mean Y	Z	Deviation from the mean Z	Average in a day X	Average in a day Y	Average in a day Z
Third DAY	8	696262.0038	0.0010	3804580.5184	0.0007	1345.0052	0.0038	696262.0046	3804580.5179	1345.0060
	7	696262.0044	0.0004	3804580.5192	0.0015	1345.0044	0.0046			
	6	696262.0046	0.0002	3804580.5179	0.0002	1345.0054	0.0036			
	6	696262.0056	0.0008	3804580.5161	0.0016	1345.0089	0.0001			
Fourth Day	8	696262.0044	0.0004	3804580.5202	0.0025	1345.0073	0.0017	696262.0040	3804580.5214	1345.0090
	7	696262.0038	0.0010	3804580.5221	0.0044	1345.0062	0.0028			
	6	696262.0042	0.0006	3804580.5205	0.0028	1345.0087	0.0003			
	6	696262.0035	0.0013	3804580.5226	0.0049	1345.0138	0.0048			

Table 18 shows the statistical data of M3 point obtained from observations of the second and third days.

Table 18- M2 Descriptive statistics for Third & Fourth Day

	Number of satellites	X	Deviation from the mean X	Y	Deviation from the mean Y	Z	Deviation from the mean Z	Average in a day X	Average in a day Y	Average in a day Z
u DA y	9	696250.456	0.0023	3804565.026	0.0018	1344.9999	0.0026	50.4 577	565. 0238	.998 7

		7		0						
	7	696250.4598	0.0008	3804565.0244	0.0002	1344.9972	0.0053			
	7	696250.4571	0.0019	3804565.0223	0.0019	1344.9985	0.0040			
	7	696250.4570	0.0020	3804565.0225	0.0017	1344.9991	0.0034			
Fourth Day	9	696250.4615	0.0025	3804565.0229	0.0013	1345.0010	0.0015	696250.4609	3804565.0248	1345.0024
	7	696250.4609	0.0019	3804565.0254	0.0012	1344.9992	0.0033			
	7	696250.4617	0.0027	3804565.0243	0.0001	1345.0050	0.0025			
	7	696250.4594	0.0004	3804565.0264	0.0022	1345.0043	0.0018			

Conclusions

1- In the first two days of observations that extracted coordinates has been considered as the basis for comparing other days' observations (in addition to practical and applied software correction, antennas direction has been to the same side) the average of vector length of three-dimensional error M2 and M3 points has been equaled to 2.5 and 3.8mm.

2- In the third day observations that the antennas direction is located on the outside of each Baseline, the average of vector length of three-dimensional error M2 and M3 points has been equaled to 3.0 and 4.4 mm, respectively.

3- In the fourth day observations that antennas direction has been located within each Baseline, the average of vector length of three-dimensional error M2 and M3 has been equaled to 4.5 and 3.2 mm, respectively.

4- The following Results can be concluded from1 to 3:

4-1 The impact of horizontal antenna direction AT502 Leica (Horizontal Phase Center Offset) is less than 2 mm.

2-4 According to the results, it appears that in typical mapping projects, which are done in small sites in which a high relative accuracy is not required, If the AT502 antenna is used, and antenna were not used in the same direction, it will not have an adverse impact on the project.

5- According to Table 2, the best time of observation in this study in terms of the number of full signal, is 0 hour and hours of 6 and 12 are also the worst of times.

6- According to the DOP tables, the best time for observation in the place of study is 0 hour and the worst time were paid to hours of 6 and 18.

7- It can be concluded from two cases above (case 5 and 6), that from a good satellite embellishment view and the number of full signal, the best time of observations in project location is 0 hour.

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