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Study the Effect of High Voltage Power Lines on the Results of Differential Static-GPS Applications.

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STUDY THE EFFECT OF HIGH VOLTAGE POWER LINES ON THE RESULTS OF DIFFERENTIAL STATIC-GPS APPLICATIONS

دراسة تأثير خطوط الضغط العالي علي القياس باستخدام أنظمة الاقمار الصناعية بالطريقة التفاضلية

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ملخص البحث

.من أحدث المشاكل التي تواجه المساحين المستخدمين لنظام تحديد المواقع بالأقمار الصناعيه هو تأثير خطوط الضغط العالي التي تعلو للنقاط المساحية الارضية..في هذا البحث تم دراسة تأثير خطوط الضغط العالي علي القياس باستخدام أنظمة الاقمار الصناعية بالطريقة التفاضلية.كما تم اختيار شبكة ميزانية دقيقة وتم مقارنتها بمثيلتها التي تم تحديدها عن طريق أنظمة الاقمار الصناعية.كذلك تم اختيار نقاط هذه الشبكة بشكل مختلف بحيث تتباعد وتتقارب عن خطوط الضغط العالي في الاتجاهين الرأسي والافقي.في البحث تم استخلاص أن:

- كلما اقتربت النقاط من خطوط الضغط العالي كلما زادت الفروق(الخطأ) في مناسيب نقاط شبكة الميزانية الدقيقة عن أرصدة أنظمة الاقمار الصناعية حيث وصل الخطأ من ٤ سم الي ١٨ سم.لوصي انه في حالة التطبيق العملي يجب الابتعاد عن تأثير خطوط الضغط العالي وذلك بأختيار نقاط شبكات المثلثات أبعد ما يكون عن هذه الخطوط.

Abstract

Some surveyors claimed that problems were experienced when one collects GPS observations beneath high voltage power lines. They had reported quite large anomalies. Still others had reported no problems beneath high voltage power lines. The current papers study the effect of High Voltage Power Lines "HVPL" on Differential Static GPS observations and results. The research introduces the comparative study for the results of a GPS network. The cases of study are chosen to illustrate the effect of different types and location of high voltage tower lines.

Although the results of GPS network analysis have shown a very high accuracy away from tower lines, the worst case discrepancies in elevation ranged between 4 cm to 18 cm under or near tower lines, and small values discrepancies in east and north (2-8) mm in position of points.

Finally, available conclusions and recommendations are obtained.

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Introduction

Over the past few years, we have witnessed a dramatic increase in the use of the Global Positioning System (GPS) for many types of survey applications. Like most technologies, GPS surveying techniques are not infallible. A GPS receiver that fails to reliably resolve ambiguities can have serious legal and resource ramifications for the practicing surveyor. It is therefore important to understand those physical conditions likely the affect the ambiguity resolution process. Several such conditions have been identified in the past, for example, obstructions to the viewing window and multipath.

Identification and understanding of these factors is important since it highlights some of the limitations of the Differential Static System and how to overcome them. This research provides empirical results that indicate that less than 100% reliability is to be expected with On-The-Fly (OTF) ambiguity resolution in the Differential Static mode when operating beneath high voltage power lines.

BACKGROUND - ELECTROMAGNETIC RADIATION

The following information provides an overview on electromagnetic radiation. This has been included to aid understanding of test results and is not meant to be definitive. No background information is provided on multipath since it is assumed readers will have an understanding of this phenomenon. Electromagnetic radiation as it relates to electrical noise arises in two forms. One, *intrinsic noise*, is the result of the random movement of electrons within the circuit elements of the electrical device itself. The second form is *interference*, which occurs as a result of signals being emitted from other circuits or systems. This is known as interference. (Fish,1994.) This electrical noise corrupts the signal of interest and introduces an uncertainty into the information that it contains. It was expected that electromagnetic radiation emitted from the high voltage transmission lines would be the most likely cause of any inconsistency with RTK GPS. This interference could be arriving at the RTK GPS receiver through any element of the receiver acting as an antenna. (Manuel, unpub). The effects that the electrical noise has on the Differential Static System will be dependent on the circuitry used. This project did not investigate the electrical circuitry as a part of this testing, but only concentrated on collecting empirical data on what effect electromagnetic interference may have on initializations. The electrical noise could cause errors in either, or both, the measurement of the signal timing and the phase of the signal. If errors in the phase of the signal are present, this could result in incorrect rover positions being calculated by the Differential Static System. The electrical noise will manifest itself in the form of an electric field and a magnetic field around the high voltage wires.

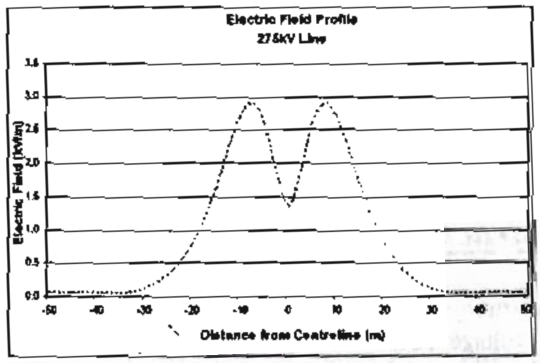


Figure 1 - Electrical Field under High Voltage Power Lines (Source: Pers. Comms. June 2001, Transmission Environment Branch, Power link Queensland)

Figure 1 displays the strength of the electrical field produced from a 250 kV transmission line in relation to a ground distance at right angles to the lines away from a point directly beneath the centre of the transmission lines. It indicates that at approximately 30 meters from the centre line most of the electrical field influences are minimal.

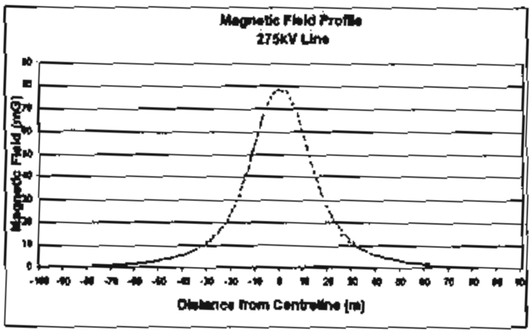


Figure 2 - Magnetic Field under High Voltage Power Lines (Source: Pers. Comms. June 2001, Transmission Environment Branch, Power link Queensland)

Figure two displays the strength of the magnetic field produced from a 250 kV transmission line in relation to a ground distance at right angles to the lines away from a point directly beneath the centre of the transmission lines. It indicates that at approximately 60 meters from the centre line most of the magnetic field influences are minimal.

Both graphs are based on nominal wire height with a minimum height above the ground of seven meters and maximum height of 18 meters (Power link Queensland).

Equipments

The following equipments were provided to achieve the specified task:

a. A minimal of four dual Geodetic GPS receivers of LEICA RTK-GPS SYSTEM1200 were used, which are capable of recording Pseudo-range and carrier phase measurements from at least 12-14 satellites simultaneously.

b. Processing capability for all receiver station to detect and correct cycle-slip for data verification.

c. A precise LEICA DNA03 digital Level with 0.3mm standard deviation per km doubles leveling.

Data Acquisition and Validation

Time-tagged pseudo-ranges and continuously integrated carrier wave beat phase differences shall be measured simultaneously at all receivers and shall be recorded at intervals not greater than 15 seconds.

Data shall be logged from all visible satellites above the 15 degree elevation cut off.

All control points (existing and new) used in the survey shall be independently occupied on two occasions during the course of the survey. In the event that a control point is occupied on two successive observation periods, the antenna shall be re-leveled and re-centered before the second observation occurs.

Based on the method of data acquisition (static), the observation period was of adequate duration such that sufficient phase data remains available in the final solution to satisfy the requirements of ambiguity fixing process.

SITE RECONNAISSANCE

An expedition was done to check the location of existing control points and PM's new control pts. The over all site plan is displayed in the following figure.

The Quality and the Consistency of the Main Control Points Elevation (fig. 3)

Transferring the "PWD" Vertical Geodetic Frame to Project Site

To transfer the vertical reference frame "PWD" to the site, precise leveling loops have been done by using LEICA DNA03, (fig.3) for its physical characteristics. The following table outlined the leveling loops and their results, shown in table 1.

(Table-1)

Leveling Loop		Level Of Ref. BM	Computed BM	Closing Error
From	To			
BM187 BM188	BM188 BM187	W351 / PPBM187=18.541	BM188=15.022	2mm
BM188 NGN95	NGN95 BM188	PPBM188=15.022	NGN-Level 17.269	4mm
NGN95 PM-08	PM-08 NGN95	NGN95 Level= 17.269	PM08-Level= 9.851	3mm
PM-08 PM-09 PM-10 PM-11 PM-12 PM-16 PM-12 PM-11 PM-10 PM-09	PM-09 PM-10 PM-11 PM-12 PM-16 PM-12 PM-11 PM-10 PM-09 PM-08	PM-08 Level= 9.851	PM-08=9.851 PM-09=6.803 PM-10=5.804 PM-11=6.044 PM-12=5.143 PM-16=4.200	4mm
PM-16 PM-17 W344 PM-18 PM-19 PM-21 PM-22 PM-15 PM-14 PM-13	PM-17 W344 PM-18 PM-19 PM-21 PM-22 PM-15 PM-14 PM-13 PM-16	PM-16 Level = 4.200	PM-17=5.841 W344=9.421 PM-18=3.754 PM-19=5.3[illegible]5 PM-21=3.732 PM-22=3.346 PM-15=3.8·5 PM-14=3.768 PM-13=4.137	4mm
PM-13 PM-23	PM-23 PM-13	PM-13 Level = 4.137	PM-23=3.521	1mm

The Effect of High Voltage Transmission Power Lines (HVTPL) on GPS signal

Initially, no previous study approved that the "HVTPL" have any effect on GPS observation. Dr. Abdullah S A Alsalman published an article in Survey Review Journal, Volume 36 No 282 October 2001, confirming that "there is no statistical evidence of any degradation of GPS positioning accuracy due to the high voltage electric power lines".

Theoretically, as it is known, the "HVTPL" generates an electro-magnetic field. This electromagnetic field created by the "HVTPL" interact with the gas molecules found in the space surrounding the power lines, which results in a large number of ions. This is called the gas ionization. GPS signals, like any electromagnetic signal propagating through an ionized medium are affected by the linear and non linear dispersion characteristics of this medium. For example, free electrons in the ionosphere influence the propagation of microwave signals (speed, direction) as they pass through the layer. The largest effect is on the speed of the signal and hence the ionosphere primarily affects the measured range.

Based upon the above results, it is essential to rely on the point W344 as the main reference point for the following processing; especially it is located in the site and still has good monumentation. In addition its location is relatively far "HVTPL". Also, its elevation, either resulted from Leveling Process or GPS analysis, is consistent. Additionally a categorization for the other PM's should be outlined. This categorization should be dependent on the environmental conditions that surround the point such as how far the "HVTPL" is from the point, how many "HVTPL" surrounding it, what is the height of the electric cables and How much the voltage that is transmitted through the "HVTPL".

Based upon the a forementioned factors the PM's have been classified to four ranks according to the "HVTPL" degree of effects. (Table-2)

(Table-2)

Pt. ID	The distance to Nearest Line, Direction	The distance to Nearest Line, Direction	The distance to Nearest Line, Direction	Line Power	The Height of the electric cable
PM-08	61 N	43 S		One Line	Near
PM-09	64 N	54 S		One Line	Near
PM-10	66 N	55 S		One Line	Near
PM-11	99 N	67 S		One Line	Near
PM-12	111 E	129 NE	127 NW	One Line	Near
PM-13	35 NE	55 SW		Multi	High
PM-14	29 NE	58 SW		Multi	High
PM-15	34 N, NE	56 S, SW		Multi	High
PM-16	69 S	42 W	213 NW	One Line	Near
PM-17	52 S			Two Lines	High
PM-18	400 E	561 S		Two Lines	High
PM-19	959 SW			One Line	High
PM-20	328 SW			One Line	High
PM-21	12 EN			One Line	High
PM-22	495 SW & S			Multi	High
PM-23	465 SW			Multi	High
W344	170 N	10 S		One Line	High

The table-3 demonstrated the PM's classification according to the "HVTPL" - Degree of Effect. Keep in mind that the current GPS processing is baseline dependent i.e. two points one is the base, the reference, and the other is the rover. So if the two baseline end points are classified in the same rank, a little bit deviation, especially in height will be occurred, otherwise if the two end points are lying in two different ranks, the effect will be varied according to how far the ranks of the two points.

(Table-3)

"HVTPL" - Degree of Effect	Stations	Comments
First	PM-19, PM-18, PM-20, PM-21 & W344	Less effect
Second	PM-22, PM-23	
Third	PM-13, PM-14 & PM-15	
Fourth	PM-08, PM-09, PM-11, PM-12 & PM-16	More effect

To prove the above correlation between the ranks of baseline two ends, three different baselines, (namely W344 to PM-21, W344 to PM-22 & W344 to PM-13) were processed epoch by epoch to give us indication of how the effect is appeared on the epoch-wise solution. The base (reference) point for the three baselines is W344 laid in the first rank and the other point of the first baseline is in the same rank of the base while the other two points of the two baselines are located in the second and third two ranks.

The figure-4 explains how size the correlation of the epoch-wise solution of each baseline. As it is shown in the figure the solution behavior of the two baselines W344 to PM-22 & W344 to PM-13 are strongly correlated, where the minimum & maximum values occurred in the same epoch while the baseline W344 to PM-21 is completely different, weak correlation.

The table-4 shows the resulted values of elevation computed by Leveling & GPS analysis.

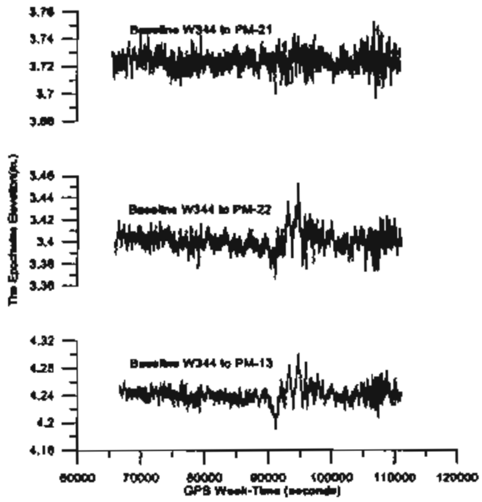
(Table-4)

Baseline		Elevation by GPS	Elevation by Leveling	Elevation Differences
W344	PM-21	3.724	3.732	0.008
W344	PM-22	3.401	3.346	-0.055
W344	PM-13	4.243	4.137	-0.106

As it is displayed in the table-4, the differences in height of the three baselines solutions is varied according to the different HVTPL conditions i.e. the rank of both the base & rover (the other end)

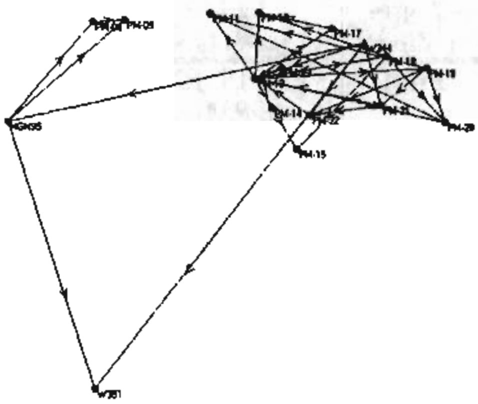
The Quality and the Consistency of the Primary Monument "PM's" Control Points

Transferring the U.T.M Geodetic Frame to Project Site three PM's were chosen, namely PM-13; PM-21 & PM-22 as preliminary references for the other PM's. Twelve hours GPS data observation Session have been done over all the three chosen PM's and W344. All points have been observed and processed from at least two different directions. The results give accuracy better than 1 mm. The three chosen PM's were considered as references for one hour observation session covering all the rest points. The results accuracy of all PM's points does not exceed.



The effect of "HVTPL" on GPS baseline solution (fig.4)

The network configuration (fig.5) is demonstrated in the following figure. Due to the W344 given by Kuwait Municipality is defined in UTM38 over WGS84, to exclude any anther affect, like Transformation Process, we utilize the same parameters to check the height values. The following Geodetic and Map projection have been utilized in the processing. The final results were obtained from applying minimal constrained adjustment for all processed baselines. (Table-6)



(Fig.5)

(Table-5)

[illegible]	Sol. Type	East	North	[illegible] Height	[illegible]	Height [illegible]
NGN95	Adjusted	234604.403	3180412.773	17.268	0.002	0.004
PM-08	Adjusted	236618.466	3182526.913	9.737	0.002	0.005
PM-09	Adjusted	237328.137	3182535.806	6.654	0.002	0.005
PM-11	Adjusted	239251.862	3182558.970	6.180	0.002	0.004
PM-12	Adjusted	240337.101	3182527.901	5.231	0.003	0.006
PM-13	Adjusted	240165.606	3181077.388	4.243	0.001	0.002
PM-14	Adjusted	240514.765	3180383.594	3.858	0.003	0.006
PM-15	Adjusted	240999.488	3179448.527	3.885	0.001	0.003
PM-17	Adjusted	241931.228	3182088.399	5.862	0.003	0.006
PM-18	Adjusted	243123.530	3181387.700	3.727	0.001	0.003
PM-19	Adjusted	243996.530	3181079.872	5.313	0.001	0.002
PM-20	Adjusted	244364.367	3179864.487	4.649	0.002	0.004
PM-21	Adjusted	242934.016	3180318.405	3.724	0.001	0.001
PM-22	Adjusted	241343.872	3180193.391	3.401	0.001	0.001
PM-23	Adjusted	240768.328	3181260.775	3.593	0.004	0.009
W344	Control	242647.410	3181718.556	9.421	0.000	0.000
W351	Adjusted	236240.532	3174391.672	18.463	0.001	0.003

THE HEIGHT SYSTEM VERIFICATION

The table-6 shows discrepancies between the processed values and the given values of the client ranged between 3mm at PM-18 and 17.8 cm at PM-12. Actually, the reason behind those differences is not clear because up till now we know nothing about the processing or the parameters that have been utilized by the client representative.

(Table-6)

Pt. Id	UTM38 based on W344 as defined by Kuwait Municipality in UTM38			Elevation computed By Level	Differences bet. Both Elevations (m.)
	East	North	Elevation. By GPS		
NGN95	527616.619	3178691.093	17.268	17.269	0.001
PM-08	529575.947	3180854.282	9.737	9.851	0.114
PM-09	530284.856	3180881.028	6.654	6.803	0.149
PM-11	532206.559	3180952.589	6.18	6.044	-0.136
PM-12	533291.779	3180948.855	5.231	5.143	-0.088
PM-13	533156.908	3179495.092	4.243	4.137	-0.106
PM-14	533523.263	3178810.59	3.858	3.768	-0.09
PM-15	534031.147	3177888.395	3.885	3.805	-0.08
PM-17	534895.806	3180549.791	5.862	5.841	-0.021
PM-18	536104.884	3179879.595	3.727	3.754	0.027
PM-19	536985.008	3179593.949	5.313	5٤5.3	2٣0.0
PM-21	535942.404	3178806.296	3.724	3.732	0.008
PM-22	534356.549	3178641.378	3.401	3.346	-0.055
PM-23	533754.575	3179693.508	3.593	3.521	-0.072
W351	529402.797	3172715.732	18.463	18.541	0.078

The ascending arrangement for the absolute values of the height differences is tabulated in the following table:

(Table- 7)

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
PM-21	3.724	3.732	0.008	0.008
PM-17	5.862	5.841	-0.021	0.021
PM-18	3.727	3.754	0.027	0.027
PM-19	5.313	5.345	0.032	0.032
PM-22	3.401	3.346	-0.055	0.055
PM-23	3.593	3.521	-0.072	0.072
W351	18.463	18.541	0.078	0.078
PM-15	3.885	3.805	-0.08	0.08
PM-12	5.231	5.143	-0.088	0.088
PM-14	3.858	3.768	-0.09	0.09
PM-13	4.243	4.137	-0.106	0.106
PM-08	9.737	9.851	0.114	0.114
PM-11	6.18	6.044	-0.136	0.136
PM-09	6.654	6.803	0.149	0.149

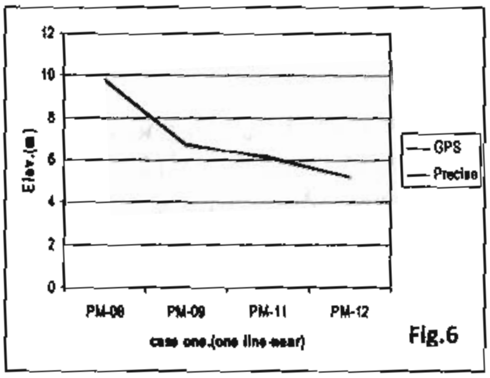


Fig.6

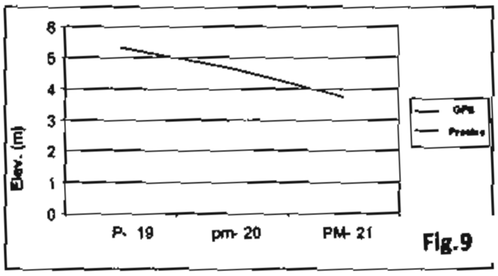


Fig.9

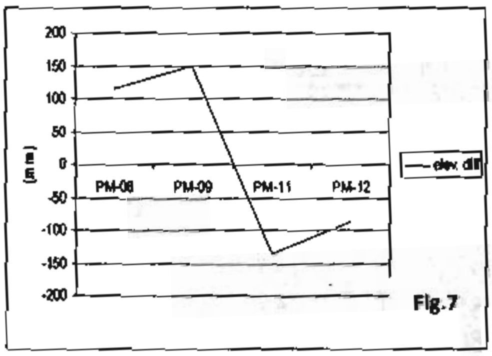


Fig.7

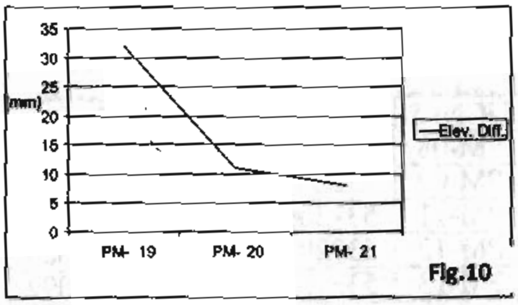


Fig.10

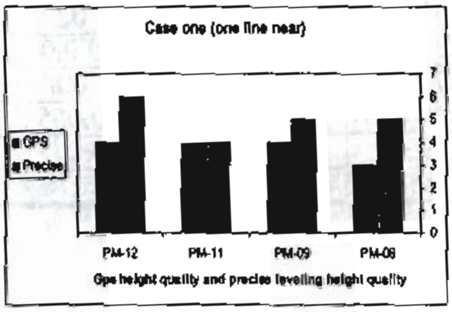


Fig.8

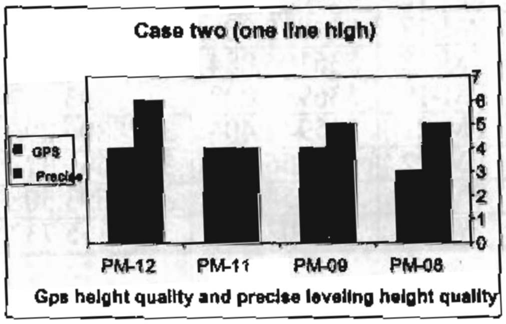


Fig.11

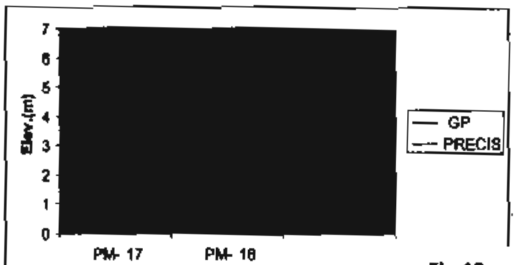


Fig.12

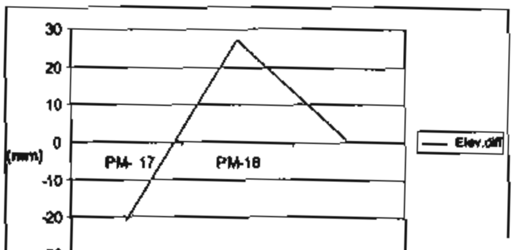


Fig.13

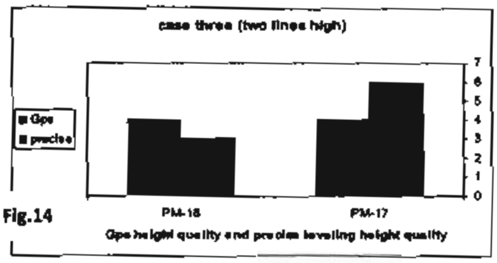


Fig.14

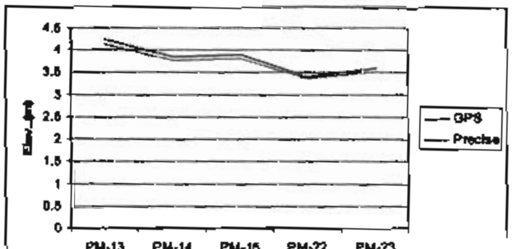


Fig.15

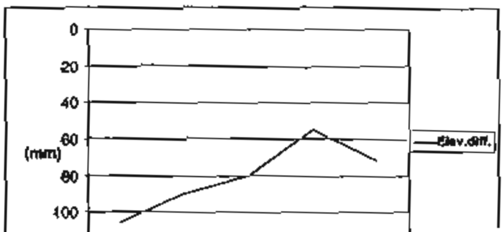


Fig.16

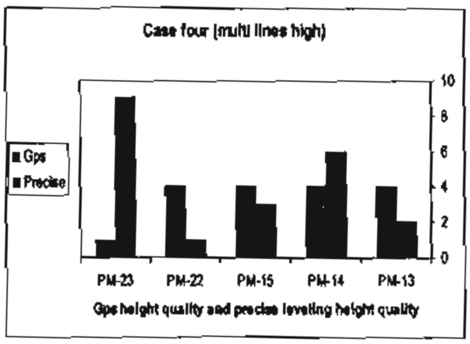


Fig.17

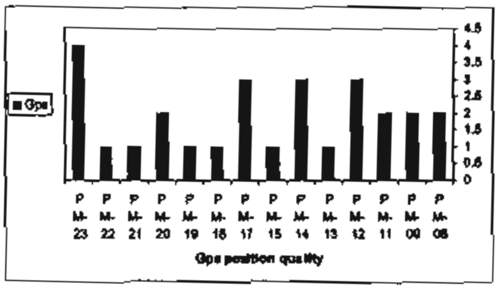


Fig.18

Conclusions

From the previous analysis and numerical results obtained the following conclusions can be summarized:

1- The first case (one power line and near) the effect of high voltage in power line has clear effect in our observations especially in height determination and the big differences between the elevations obtained by GPS and precise level. The height quality from GPS observations was more than that in the other cases.

2- The second case (one power line and high) in this case appeared that less effect of high voltage power lines on GPS observations, less differences levels between GPS results and precise leveling results, so the height quality obtained from GPS results was less than other cases.

3- The third case (two power lines and high) from analysis it is clear that the differences in level between GPS and precise leveling was more than case of two and less than case one. Maybe that happened due to increase power lines numbers.

4- The fourth case (multi power lines and high) the differences in level between GPS and precise leveling was more than case two and three and less than case one.

From the previous rates we deduce that the nearest to power lines is more affected than number of power lines, but we can not ignore the increasing of the number of power lines increase the effect in observations.

So, to reduce the effect of power lines we should make our observations faraway from the power lines. But what distance should we be away from there, from our search we found that the computations of safety distance from power lines is so difficult because there are many affecting variables such as :

a- The value of voltage.

b- Type of voltage AC or DC.

c- Tower configuration.

d- The distance between conductors.

e- The difference in power transportation from others counties (132,220,275,500, and so.)

But we can compute SNR (signals noise ratio)

$$\text{SNR} = \frac{Signals\ from\ sattelite}{Signals\ from\ noise} \leq 5$$

SNR is the ratio between master signals from satellite and the noise on the area coming from H.V. power lines and any electric line near from receiver. If the SNR is more than 5, that effect will be very small and we can neglect it. This SNR can be measured with special electronic instruments.

From researching in this points we found few tests have been done to investigate the effects of power lines on GPS signals reception. If we get away from power lines a distance from 90 m to 180 m we will avoid interference, but given that most of there lines are located on towers so that clearance may already be sufficient.

Recommendations

- The computation of safety distance is as difficult as shown in conclusions. We should change the position of receiver more times if we will take into account the signal noise ratio obtained from receiver or another instrument.
- Finally, we can't consider any observations under high voltage power lines.
- In the future we recommend designing a metal shell pointed above the receiver to transmit the noise around the receiver to the earth's surface.

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