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ON THE USE OF PSEUDO-KINEMATIC GPS SATELLITE POSITIONING TECHNOLOGY IN SURVEYING RECLAIMED LANDS IN EGYPT

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Abstract

Planning, developing, and policy making of land reclamation require economical and accurate source of collecting spatial data to produce different types of maps. Advances in satellite positioning in the last years have focused attention on the use of the satellite-based GPS system for a wide range of applications. GPS techniques have been used world wide to acquire very precise positioning data in an economically suitable way. Of the various GPS observation methods, the pseudo-kinematic approach is considered to be more sensible in open areas. Due to specific characteristics of this GPS mode, it would be more productive and easy-to-use in surveying reclaimed lands. It is demonstrated that the precision of pseudo-kinematic GPS surveying could achieve the first order geodetic network specifications. An overview of the satellite-based GPS positioning is presented along with the advantages of the pseudo-kinematic GPS observation method. Based on results of surveying projects, it is proposed to use this advanced technology in mapping large areas of reclaimed lands in Egypt with high level of precision and with reduced costs.

1. Introduction

One of the most exciting aspects after any research and development stage is the actual implementation of the newly developed technology in novel ways where mankind can make potentially extensive use of it. It is a common belief world wide that the application of surveying with the satellite-based Global Positioning System (GPS) has reached this level. With the extensive use of GPS data all over the world, with Egypt being no exception, the increased productivity and superior precision that had not been economically available prior to GPS have been demonstrated. Increases in productivity of a factor of six over conventional terrestrial surveying techniques have been shown (Goad 1989).

The NAVSTAR (Navigation Satellite Time And Ranging) Global Positioning System (GPS) is a satellite-based positioning system currently under development by the U.S Department of Defense (DoD). In its final constellation (by the end 1993), the GPS may consist of 21 operational satellites plus 3 in-orbit spares. Once fully operational, GPS will provide 24-hour all-weather navigation and positioning capabilities any part of the world. There are more than six different observation techniques to collect and process GPS data (Kleusberg 1990). The classic GPS observation approach is the static mode in which more then one receiver are kept fixed over ground stations and record satellite signals for more then one hour of observations. of the different GPS observation techniques, the Pseudo-Kinematic (or semi-kinematic) mode is now within grasp. The idea is to have one GPS receiver moving from one station to another while another receiver is not moving and therefore providing a reference to location determination. Because of some observation difficulties (details in section 3), the pseudo-kinematic GPS surveying technique becomes more practical, easy-to-use, and economically suitable system in open areas. In agricultural and reclaimed lands, this mode of the GPS technology gains more popularity. Studies show that accuracy of 1 part per million (i-e., 1 mm error in a 1-Km distance length) could be achieved in a production environment (Remondi 1985).

This paper demonstrates the applications of the GPS surveying technology especially for the agricultural and reclamation community. The paper proposes the use of the pseudo-kinematic GPS technique in surveying the new reclaimed lands citing the advantages of this mode in gaining high precision positioning and mapping data in a matter of few hours rather than few weeks as in the traditional surveying techniques. An overview of the GPS system is provided in section two. Section three gives a simple idea about the technical problems in using the pseudo-kinematic approach in urban areas and why it would be more applicable in open lands. Results of previous studies are shown in section four with some numerical tables about the expected accuracies of the pseudo-kinematic GPS technique. Section five concludes the paper and provides some recommendations about the use of this satellite-based advanced technology in the agricultural and reclamation environment in Egypt.

2. Global Positioning System (GPS)

Since the early 1980s, many geodetic networks have been established using GPS measurements to provide baseline vector components at or better than 1 part per million (ppm) level of precision (Goad 1985, Remondi 1985). With this high precision, accurate maps could be produced and used in many development stages and policy making process. Each of the 21 GPS satellites continuously transmits at two frequencies: L1=1575.42 MHz; and L2=1227.060 MHz modulated with two types of code and with a navigation message. The L1 signal is modulated with a precise (P) code, and a Coarse Acquisition (C/A) code, which is known as the Standard Positioning Service (SPS); the L2 signal is modulated with only the P code, which is known as the Precise Positioning Services (PPS). The P code is 10 times more precise than the C/A code (Spilker 1978). For national security purposes, the U.S DoD may restrict access of the PPS only for military users. The 50 Hz navigation message contains, among other data, the broadcast satellites coordinates parameters so that the ground receivers consider the satellites as " fixed targets " in the sky. With this description in mind, the GPS can be thought of as a "space-triangulation " techniques which revolutionizes the surveying concepts. No visibility between ground stations is required, no atmospheric-dependant restrictions are included, and no personal interface is needed. Observing these advantages, the GPS has been used all over the world for a wide range of civil applications (Fig. 1).

Cadastral Surveying Geodetic Network identification High precision aircraft positioning Photogrammetry without ground control Monitoring deformation Hydrographic Surveys	World Wide GPS	Navigation on land Navigation on seas Navigation in rivers Resources management GIS/LIS Kinematic Surveys

Figure 1: Some Civil GPS Applications

There are two types of GPS observations: pseudo ranges and carrier phases. The pseudo range is a measure of the distance between the satellite and the receiver at the epochs of transmission and reception of the signals. In high-precision surveying the carrier phase observations are used. The phase observable is complicated and involves advanced techniques in electronics. However, we have to understand the basic concepts in using the phase mathematical model in order to infer the potential advantages of the pseudo-kinematic mode which will be presented in section 3. In a simplified expression (neglecting satellite clock errors, receiver clock errors, and tropospheric and ionospheric effects) the phase equation can be written as (Leick 1990):

$$\phi^p_k = \phi^p(t) - \phi_k(t) + N^p_k + \text{noise} \qquad (1)$$

where ϕ^p_k is the phase observables in units of cycles for satellite p and receiver k, $\phi^p(t)$ is the received phase of satellite p as measured at the receiver k, and $\phi_k(t)$ denotes the receiver oscillator phase. The constant term indicates N^p_k an integer ambiguity unknown parameter of the first epoch of measurements. The four unknowns in a typical GPS adjustment process are the three station coordinates (X, Y, and Z) and the receiver clock correction. Consequently, at least four GPS satellites must be tracked simultaneously. But, more than four satellites are desired to increase the redundancy and reliability of the estimation process.

3. Pseudo-Kinematic GPS Technique

The surveying techniques used to collect GPS observations can be divided, in general, into three categories: static; kinematic; and pseudo-kinematic (Dawod 1991). In this paper, the pseudo-kinematic mode is given more emphasis. Pseudo- (or Semi-) kinematic surveying is tracked back to the pioneering work of Remondi (1985 and 1988), where one receiver is kept fixed over a known station while another receiver moves to survey other stations for few minutes of observations at each site. The two main sources of troubles in GPS phase observations are the phase ambiguity and the cycle slip. The phase ambiguity unknowns (one per each satellite) are the constant term $N^p{}_k$ that appears in equation 1. Some mathematical procedures are used to estimate these unknowns, with the result that unambiguous rang measurements are processed in order to increase the precision of the station position determination (for more details, the interested reader can refer to, for example, Goad and Mueller 1988 and Schaffrin and Bock 1988). The second observation-dependant problem is the so-called "cycle-slip". In simple words this critical situation occurs when the satellite signals are blocked by some obstructions, for example trees or buildings, and when the receivers re-record the signals, the phase ambiguity takes on a new unknown value. Cycle slips can be considered as the main restriction for using pseudo-kinematic GPS technique in urban areas due to the huge number of expected obstructions.

With the current constellation of the GPS satellites, four satellites can be observed in Egypt for eighteen hours while a five-satellite window is available for about 5 hours each day (Fig. 2). Concerning the cycle slip restriction, it is clear that this is not a problem at all in open areas such as agricultural and newly-reclaimed lands. That is the main advantage of using the pseudo-kinematic approach in obtaining high-precision geodetic positioning information about large open areas. The output of GPS surveying could be:

Cartesian coordinates of ground marks (X, Y, and Z)
Geographic coordinates (latitude, longitude, and height)
which could be used to produce :
Topographic maps
Contour maps
Digital data bases
Base maps for a Land Information System (LIS)
Reference frame for a Geographic Information System (GIS)

Figure 2: Approximate GPS satellites Window in Egypt for January 1992

4. Results of Pseudo-Kinematic Surveys

The pseudo-kinematic GPS technique has been used in many production projects in the last few years. Because of the specific characteristics of this mode of satellite positioning, most of the surveys have been carried out in open areas with no obstructions. e.g. airports and dams. Many studies show that the precision of first order geodetic networks could be achieved, in lees time and reduced costs, with the pseudo- kinematic GPS technology.

Goad (1989) concludes that the results of a comparison between the static and pseudo-kinematic GPS approaches are better than 1 ppm over relatively short base lines. Table 1 shows that the largest difference in repeatability was 10 mm, with 5 mm or less being more typical.

Table 1: Comparison between static and pseudo-kinematic GPS surveys

Base Line	dx (m)	dy (m)	dz (m)	Distance (m)
A-B	355.079 355.074	126.428 126.426	-305.280 -305.286	485.037 485.037
B-C	365.674 365.684	56.560 56.562	-305.761 -305.754	479.986 479.982
C-D	458.894 458.884	70.984 70.979	-308.012 -308.015	600.026 600.020

Another study over relatively long base lines was reported by Minkel (1989). Table 2 summarizes the differences between the vector components as derived from pseudo-kinematic and static GPS solutions over long base lines along with their root mean square error (rms).

Table 2: Results of Long Base Lines pseudo-kinematic GPS survey: Component Differences in meters

Base line	Distance (Km)	DDX	DDY	DDZ	RMS
A-B	54.4	0.012	-0.027	0.029	0.041
A-C	46.8	0.016	-0.027	0.064	0.076

Both surveys' results have verified that the pseudo-kinematic could achieve centimeter level accuracy over traversing chains up to few tens of kilometers.

5. Conclusions

One of the main factor in the future of land reclamation and development is the accuracy and costs of providing maps and spatial information. Satellite-based GPS positioning technology has been used in Egypt for an extensive amount of surveying, mapping, and natural resources applications. The pseudo-kinematic GPS technique is an easy-to-use, automatic, time-saving, cost-reducing, and accurate surveying method. When fully operation, GPS will provide 24-hour, all-weather positioning technology that will be a very helpful tool in developed areas. The pseudo-kinematic mode of GPS surveying has been used to obtain high precision spatial information and accurate maps especially in open areas such as reclaimed lands. Within few hours of observation, geodetic positions in a large piece of land could be determined accurately and with a great deal of cost reduction than the traditional surveying methods. Having accurate and complete set of spatial data about the lands, the policy making and planning processes could be benefit a lot.

References

Dawod, G., 1991, Some considerations in the adjustment of GPS-derived base lines in the network mode, MSc Thesis, Geodetic Science and Surveying department, The Ohio State University, Columbus, Ohio, USA.

Goad, C., 1985, Precise relative positioning with the GPS, Proceedings of the First International Symposium on Precise Positioning with the Global Positioning System, Volume II, April 15-19, 1985, Rockville, Maryland, USA, pp.347-356.

Goad, C. Mueller, A., 1989, An automated procedure for generating an optimum set of independent double difference observables using Global Positioning System carrier phase measurements, Manuscripta Geodaetica, 13, pp. 365-369.

Goad, C., 1989, Kinematic survey of Clinton Lake dam, ASCE Journal of Surveying Engineering, 115, No. 1, pp.67-77.

Kleusberg, A., 1990, A review of kinematic and static surveying procedures, Proceedings of the Second International Symposium on Precise Positioning with

the Global Positioning System, September 3-7, 1990, Ottawa, Canada, pp. 1102-1113.
Leick, A., 1990, GPS satellite surveying, John Wiley & Sons, Inc., New York.
Minkel, D., 1989, Demonstration and discussion of the pseudo-kinematic method, Proceedings of the Fifth International Geodetic Symposium on Satellite Positioning, March 13-17, 1989, New Mexico, USA, pp. 577-588.
Remondi, B., 1985, Performing centimeter accuracy relative surveys in seconds with GPS carrier phase, Proceedings of the First International Symposium on Precise Positioning with the Global Positioning System, Volume II, April 15-19, 1985, Rockville, Maryland, USA, pp.789-797.
Remondi, B., 1988, Kinematic and pseudo-kinematic GPS, Paper presented at the ION GPS-88 in Colorado Springs, Colorado, USA.
Schaffrin, B., Bock, Y., 1988, A unified scheme for processing GPS dual-band phase observations, Bull. Geod., 62, pp. 142-160.
Spilker, J., 1978, GPS signal structure and performance characteristics, in GPS papers in navigation, reprinted by the U.S. Institute of Navigation, Volume I, 1980, pp.29-54.