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GPS Satellite Surveying in Developing Countries – A Review

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Abstract. The use of the GPS system for survey and geodesy is a technological breakthrough that will revolutionize the standards, accuracy, speed and practice of every day surveying. In particular this new satellite technology holds enormous potential for developing countries which lack both human and financial resources.

The aim of this paper is to introduce the GPS system and discuss its application to geodesy and mapping purposes. The paper will discuss some issues pertaining to the adaptation of GPS technology to the needs, capabilities and resources of developing countries. Special attention will be given to the choice of proper GPS receivers and available alternatives for obtaining satellite ephemerides.

1. Introduction

Most developing countries suffer from inadequate land information systems, geodetic control networks, topographical data bases (or maps), cadastral information, and other data related to land resources assessment and utilization [1]. The lack of land related information is only one of many obstacles to productivity and economic development. This chronic weakness is caused by many factors such as low levels of both financial and skilled human resources, the long time and extensive planning needed to collect, organize, store and disseminate this information; and the underestimation of the importance and complexities of such tasks.

Technological breakthroughs offer some hope in reducing the cost, human resources, and time needed to improve land information systems. These technologies include mini and micro-computers, remote sensing satellites, and satellite surveying using the Global Positioning System (GPS).

The GPS is a continuous, world-wide, all weather, satellite-based radio navigation system being developed by the United States Department of Defense (USDoD) [2-10]. The system will provide, to all users with proper receivers, the capability to obtain navigation and geodetic positions in three dimensions, velocity and time. Although GPS was orginally designed as a navigation aid (dynamic positioning), it is also well suited for static positioning (*i.e.*, surveying) on the ground surface. In fact, using GPS for static positioning is more straightforward and requires fewer satellite signals since there is no need for neither velocity nor time (if receivers are already synchronized with some time reference). On the other hand, the higher accuracy required in surveying applications (especially in geodesy) necessitates the use of more accurate, and hence more complex, receivers. GPS promises a revolution in surveying. It will reduce the cost, time, human resources and errors in establishing accurate geodetic control networks, cadastral references and topographical information. The conventional tasks and practice of today's survey profession are likely to change considerably. GPS holds a great potential for developing countries who are greatly constrained by acute shortage of surveying skills and finances, and also by difficult terrain access. Developing countries should fully recognize this potential and make plans to utilize this new "nearly-free" technological service.

This paper will introduce the GPS system and discuss its potential for geodetic and surveying applications with emphasis on the proper selection of GPS receivers suitable for use by developing countries. Two important issues related to the proper choice of a receiver are the coding of the satellite signals and the satellite orbital positions (ephemeris). Both issues, which are interdependent, are vital to developing countries' independence from relying on foreign support while using the GPS system.

Section 2 gives an overview of the GPS system. Next, signal structure and detection techniques are discussed. The fourth section reviews GPS satellite survey and geodetic receivers are examined in Section 5. Section 6 discusses satellite orbit determination (ephemeris).

2. GPS System Description

The GPS system consists of three main segments: space segment, control segment and user segment. When the GPS is fully operational in the early 1990s, the space segment will consist of a constellation of 18 satellites in six orbits plus three strategically located active spares. The six orbital planes are inclined by 55° to the equatorial plane and are separated by 60° in longitude with each plane containing three satellites spaced 120° apart. Satellites in each plane lead (are north of) the corresponding satellites in the adjacent plane to its west by 40°. The satellites will orbit around the earth in nearly circular paths at an altitude of 21,183 km and with a period of 12 sidereal hour (11hr: 58min solar time). With this constellation, at least four satellites will be simultaneously visible with a minimum of a 5° elevation angle at almost any time and any place worldwide.

At present (1988) there are seven working development and test (Block I) satellites out of 10 prototype satellites that have been successfully launched between 1978 and 1985. The seven prototype vehicles (NAVSTARS 3,4,6,8,9,10 and 11) are in two planes separated in longitude by 120° and inclined by 63° to the equatorial plane [2]. Figure 1 shows a polar plot of elevation and azmuth for Block I satellite coverage

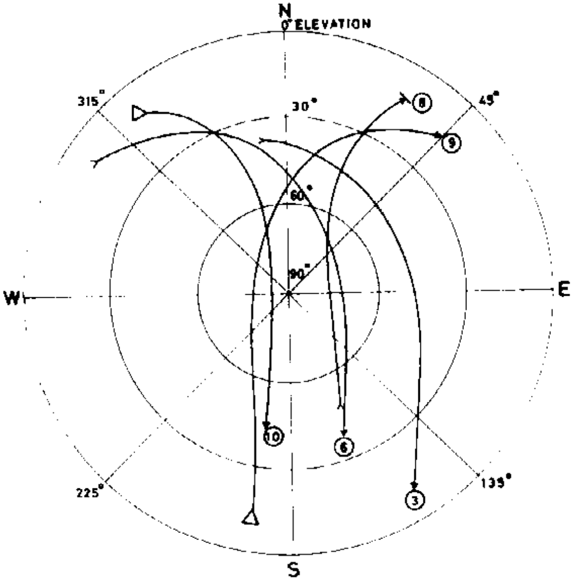

Fig. 1. GPS visibility plot over Riyadh (25°N, 46°E) on 1 August 1988

over Riyadh, Saudi Arabia (26N, 47E) projected between 6:15 AM and 12:12 PM on Aug. 1, 1988. As can be seen from the Figure, the coverage is quite good (with at least 4 satellites visible for more than 4 hours).

The GPS control segment is responsible for tracking and monitoring the orbiting GPS satellites, processing collected data, updating and uploading the navigation message for each satellite, and all other control functions. The control system which became operational in Sept. 1985, consists of a Master Control Station, five monitor stations and three ground antennas for message uploading.

The user equipment consists of an antenna, receiver electronics, a data processor, a control display unit and software. The receiver measures the psuedo-range and/or the carrier phase and computes a 3-coordinate geocentric position in the World Geodetic System reference frame (WGS-72 or the new WGS-84 [2]). Navigation receivers can also compute velocity and time. A minimum of three different satellites are needed to compute position and a fourth to determine time. The accuracy improves with increasing number of satellites and with satellite geometry [7, 11].

3. GPS Signal Structure and Receiving Techniques

Every satellite continuously transmits two downlink signals in the upper UHF band. The two microwave carrier frequencies are L1 at 1575.42 MHz ($\lambda \simeq 19$ cm) and L2 at 1227.6 MHz (24 cm). The L-band was chosen as a compromise between the smaller bandwidth and large ionospheric delay of the lower UHF (*e.g.* 400 MHz) and the greater space losses of the SHF band [11]. In addition, the frequency separation of 347.82 MHz (28.3% of L2 frequency) permits measurement of the ionospheric group delay error by dual frequency receivers.

The actual signal modulated on the carriers consists of a short pseudo-random noise (PRN) code known as the course/aquisition (or C/A) code, a long PRN code (precision or P-code) and the 50 bit per second (bps) navigation message data [7,11-13]. The navigation message contains, among other information, predicted satellite orbit parameters (broadcast ephemerides). For each satellite, the C/A code is unique 1023 chip Gold code with a repetition period of 1 ms and a clock rate of 1023000 chips per second* (cps). The P-code has a clock rate of 10.23 Mcps and repeats itself after 267 days. The code is divided into 38 seven-day segments, with each satellite assigned one unique segment. Both codes and the 50 bps data are bipolar (±1) digital signals.

The two codes are used to modulate the navigation data on the carriers using a direct sequence spread spectrum technique [12]. The reasons for using spread spectrum on the GPS signals include combating jamming and interference, high accuracy range measurements, and selective access capability (only users with either code can access the navigation message; in addition, the restricted P-code allows higher dynamic positioning).

There are three different detection techniques: correlation receiver, squaring receiver and code phase receiver. The correlation receiver requires the C/A and/or P-code and is the only type that can decode the navigation message. A receiver-generated code is delayed in time until maximum correlation is obtained with the incoming satellite code. The correlation receiver can output the pseudo-range, navigation message, carrier beat phase and satellite time.

The squaring receiver is a codeless receiver in which the received signal is simply squared. The output is a pure sinusoidal wave whose phase is directly related to the phase of the incoming signal. As a result of the squaring process, the PRN codes and the 50 bps data are lost, hence neither the pseudo-range nor satellite navigation message is available.

The code phase receiver (CPR) was developed in the early 1980s by Peter MacDoran at the Jet Propulsion Laboratory. The CPR which provides a measurement of the ambiguous phase of either the P or C/A code does not require explicit knowledge of either codes.

Only correlation receivers can access the navigation message. Codeless receivers (squaring or CPR) need an external almanac to operate and external orbit parameters to compute the required coordinates, which makes accurate real time positioning difficult. In addition, codeless receivers require time synchronization with each other and with the GPS or UTC time before a measurement session, while correlation receivers can synchronize themselves with GPS time after receiving signals from at least four satellites. Moreover, correlation receivers have higher signal-to-noise (SNR) and interference ratios because of the process gain resulting from the despreading of the satellite signal.

The main problem with correlation receivers is the requirement of knowing the codes (C/A and/or P-code). This is a matter of vital importance to developing countries planning to make use of the GPS. The P-code is a restricted military code; the C/A code is currently available but is less accurate. Its accuracy would be degraded even more (by the USDoD) with the operational Block II satellites. The declared policy is that it will remain available in the future (but not guaranteed). In addition, the C/A code is available on the L-1 frequency only, and thus, the C/A code correlation receivers are inherently single frequency receivers and cannot correct for ionospheric delay. On the other hand, the codeless receivers do not require either code and can, thus, be designed to receive both L1 and L2 (dual frequency) enabling them to correct for ionospheric delay.

4. GPS Surveying and Measurements

By the late 1970's, the conventional terrestrial surveying equipment like Theodolite and Electronic Distance Measuring (EDM) have approached their best possible capabilities in terms of accuracy, speed and efficiency. They still, however, have their inherent limitations such as intervisibility and clear weather. It takes a lot of time and effort to establish accurate control points using conventional instruments, which are also skilled-labor intensive. Developing countries have a chronic shortage of skilled professionals.

A great leap in geodesy and large scale surveying occurred when the TRANSIT Navy Navigation Satellite System (NNSS) [2,14,15], was made available to civilian use in 1967. The gradual change of everyday survey practice and standards, started by the use of TRANSIT, is expected to continue with a much faster pace with its successor, the GPS system, which has a higher accuracy with lower cost and shorter time. The advantages of satellite positioning (GPS in particular) over classical terrestrial survey include worldwide continuous weather-independent operation, no need for intervisibility between measurement points permiting longer baseline measurements, network-independent station selection, easier operation with less manpower and shorter observation time, 3-coordinate positioning, and finally higher accuracy.

In order to discuss the use of GPS for surveying applications, it would be helpful to adopt a classification for different surveying categories. Rizos *et al.* [16] presented a convenient classification based on typical ranges and accuracy requirements. This is shown in Table 1. The GPS broadcast ephemeris permits position determination accuracy to less than 10^{-5} (categories 1 and 2 in Table 1). Access to the broadcast ephemeris, however, requires knowledge of either the C/A or P codes. In addition, higher accuracy (the real advantage of GPS) requires access to precise ephemerides as baseline measurement errors are directly proportional to the satellite orbit error:

$$\text{GPS survey error (ppm)} \geqslant \frac{\text{orbit error (m)}}{\text{nominal satellite altitude } (= 20000 \times 1000)} \times 10^6$$

$$= \frac{\text{orbit error (m)}}{20} \qquad (1)$$

Table 1. Classification of survey services that can use GPS [16]

Category	Average accuracy requirement	Extent of survey (Km)	Relative positioning accuracy (m)
1: Exploratory/Geophysical	$1{:}10^4$	10-500	1-50
2: Large Scale Engineering Projects and Mapping	$1{:}10^5$	50-500	0.5-5
3: Geodsy	$1{:}10^6$	> 100	> 0.1
4: Geodynamics (Crustal Movement)	$1{:}10^7$	< 300	< 0.03

The precise ephemeris necessary for categories 3 and 4 of Table 1 must be obtained by other means independent of the observation session (see Section 6). With regard to the required accuracies shown in Table 1, developing countries can initially set less stringent requirements compatible with available financial and human resources, and adopt a multi-stage plan to improve the accuracy in the future to reach the required level.

4.1. Survey and Measurement Techniques

This paper is concerned with static positioning rather than kinematic positioning. Static positioning can be absolute (point positioning) or relative. Relative positioning using satellites depends on receiving signals at two (or more) locations to determine baseline(s) on the ground. Knowing one point's coordinates and the baseline vector(s), the coordinates of the other point (or points) can be easily found. This is called the differential method and is similar to Very Long Baseline Interferometry (VLBI) used in radio astronomy [2,17-20]. GPS relative positioning is much more accurate than point positioning and is the preferred method in geodesy and high accuracy surveying.

There are basically two kinds of measurements (observables) from the GPS signal:

First: the psuedo-range which requires knowledge of C/A and/or P codes. The pseudo-range is obtained by multiplying the speed of light by the time delay required for maximum correlation between the received satellite code and a receiver-generated replica of the code. The word "psuedo" is used because the receiver time frame is usually different from satellite time (clock bias). Only correlation receivers utilize this mode of measurement.

Second: The beat phase mode which can, in turn, be subdivided into code phase and carrier phase [21] modes. The code phase or integrated Doppler count measures the change in psuedorange over a given period [16]. In the carrier beat phase mode, the observable is the signal resulting from mixing the received Doppler-shifted satellite carrier with a receiver-generated reference carrier (of the same nominal frequency). The carrier phase is measured using either the code-free squaring receiver or as a by product of the correlation receiver.

For the same observation time, carrier phase results are much more accurate than either code phase or psuedo-range. This is because the frequency of either carriers (L1 or L2) is much higher, and hence its wavelength is much shorter, than either code. The frequencies of the L1 carrier, L2 carrier, P code and C/A code are 1575.42, 1227.6, 10.23 and 1.023 MHz; their periods are 0.635, 0.815, 97.75 and 977.52 nanosec; and their wavelengths are 0.19, 0.244, 29.326 and 293.256 meter respectively. Assuming that the ultimate measurement resolution is about 1% of the wavelength, the inherent accuracies will be limited to around 0.2, 0.25, 29 and 293 cm for L1, L2, P and C/A code respectively, ignoring other sources of errors (*e.g.* ionospheric and tropospheric delays, clock bias, etc.).

5. GPS Receivers

There are currently a number of GPS receivers intended for surveying and geodesy [2,7,10,16,22-36]. The aim of this section is to discuss the key selection criteria for a receiver to be used for geodetic and other survey applications in developing countries. Following is a brief description of the major factors to be taken into consideration:

5.1. Application Requirements

which include static or dynamic positioning, relative or point positioing, real-time or post-observation processing, and accuracy requirements. For surveying applications and specially for categories 3 and 4 indentified in Table 1, the proper choice would be for static positioning in the differential (baseline) mode. Real-time positioning is not usually required in geoditic positioning especially since post-processing generally yields better results.

5.2. Receiver type

which pertains to the following issues:

a) ***Single or dual frequency:*** Dual frequency receivers, which permit ionospheric delay correction, are preferred but not essential. As of early 1987 only two receivers can operate on two frequencies: TI4100 [2,29,34,35], Macrometer-II [2].

b) ***Continuous, switching or hybrid receivers:*** A continuous receiver has a number of hardware channels, each channel dedicated to receive signals from one satellite. Multichannel receivers are more reliable and enjoy a better SNR, but they may experience interchannel interference, and require more hardware. Switching receivers have one or two hardware channels that are shared (switched) among different satellites [7]. Although free from interchannel bias, they suffer from phase tracking difficulties and require more complex software. The choice between continuous or switching receivers is not critical for developing countries' needs.

c) ***Code dependent (C/A or P) or codeless receivers:*** This is by far the most critical issue for a receiver's selection. The C/A code is currently being made available to the public by the USDoD. It is officially called the Standard Positioning Service (SPS). According to the USDoD the SPS will continue to be available in the future but no gurantees are given. In addition, C/A psuedo-ranging has reduced accuracy. Moreover its accuracy will be further degraded (dithered) [intentionally by the USDoD] when Block-II satellites become operational in the early 1990's. A user-fee policy for the SPS service may also be adopted by the US Congress [2]. The P-code, which is officially called the Precision Positioning Service (PPS), will be available only to the US Military and its allies. Its access will be controlled by the use of classified crypto-graphic devices. It is, therefore, clear that a critical criterion in a GPS receiver is that it be code-independent. Nevertheless, in the meantime, C/A receivers can be used to simplify tracking and operation of codeless receivers or to obtain initial approximate coordinates.

d) ***Kind of observable:*** As explained in the previous section, carrier phase measurements inherently yield the most accurate results if used in the differential positioning mode. Most accurate GPS geodetic receivers are used with this method.

5.3. Receiver Features

This includes a number of practical characteristics of receivers that might influence the final decision. A partial list of these features includes:

- *temperature range.*
- *antenna type and mount.*

- *receiver size and weight.*
- *ruggedness and portability.*
- *electric power requirements.*
- *clock type and synchronization.*
- *software algorithms and utilities.*
- *ease of operation and user friendliness.*

5.4. Procurement Issues

which include matters that are most often overlooked by engineers and survey experts, but turn out to be very critical in the actual practice, especially in developing countries. Procurement issues include:

- *hardware cost which comprises the total cost of receivers* (number of units x unit price), *other hardware* (*e.g.* cables, computers, modems, etc.) *and other costs* (overhead, delivery, customs, tax and so on). Budgetary limitations can be the determining factor in selecting one receiver type over another.

- *Software and training* (brainware) *costs.*

- *warranties and user support services offered by the selling company or agent.*

- *availability and delivery time.*

- *compatibility with other receivers or software available to the buying party.*

The proper choice among the many available GPS receivers depends on a balanced consideration of the different factors given above, depending on each country's needs, environment and available resources. Reference [7] summarizes the characteristics of about 25 different GPS receivers which constitute nearly all the commercially available receivers at the end of 1986. Eleven of those 25 receivers can be used for static positioning, but only two of them are codeless receivers: MACROMETER-II and ISTAC-2002; a third codeless receiver, MACROMETER V-1000, has been discontinued.

To summarize, the essential features of GPS receivers to be considered by developing countries are accurate carrier phase relative positioning, reliability, ease of operation and maintenance, low cost and desirably code independence. Before concluding, two final points regarding GPS receivers need to be emphasized:

First: while correction receivers have access to broadcast ephemeris in the satellite navigation message and hence can give real time approximate positions, codeless receivers cannot access the broadcast ephemeris and hence require an externally supplied approximate ephemeris, before observation for real time initial results, or after observation for approximate positions. However, both kinds of receivers need external post-mission precise ephemeris for the most accurate results in such applications as monitoring crustal movements. This subject is discussed further in the next section.

Second: as with many high-technology products (*e.g.* computers), GPS receivers are rapidly evolving towards smaller, cheaper, more capable, more reliable and easier-to-operate receivers. When GPS enters the operational stage and with the increased use of GPS surveying, better and less expensive receivers may appear on the market. Waiting for this to happen is not necessarily the best decision as time has its own cost too. The need for timely application of this technology must be weighted against this factor.

6. Satellite Orbital Positions

All GPS positioning techniques require knowledge of satellite positions at the instant of received signal emission from the satellite. Ephemeris can be defined as the coordinates of the satellite orbital position at various time instants (*i.e.* trajectory). Two kinds of GPS ephemerides are considered here:

Predicted ephemerides: are extrapolated estimates of future satellite positions computed by knowing the satellite coordinates at some earlier time instant (epoch) and using the satellite orbital dynamic model. As the initial position is error prone and the orbital equations are not exact, predicted ephemeris cannot be very accurate, with prediction errors increasing with the difference between the initial epoch and the future epoch. The GPS broadcast ephemerides contained in the navigation message (Section III) are predicted ephemerides. They are, however, relatively more accurate because they are obtained through an elaborate extrapolation of actual ephemerides collected over a few days span of time by a sophisticated tracking network of monitoring stations (see Section II).

Post-processed ephemerides: are accurate estimates of the satellite positions in the past. They are much more accurate than predicted ephemeris because they are derived from elaborate processing of tracking data collected by highly accurate receivers (monitoring stations) located at precisely surveyed points. An ephemeris facility for generating post-processed precise ephemerides consists of the following components (1) a tracking network of at least 3 or 4 tracking stations, (2) a central computer to process the tracking data and compute the required ephemerides, and (3) reliable communication links between the tracking stations and the computer center.

Although not a real necessity, predicted ephemeris are important in GPS surveying for at least two reasons:

1. Access to broadcast ephemeris by code-dependent receivers permits fast (real time) approximate positioning. That is why navigation receivers, which must give instant fix, cannot be codeless.

2. Broadcast ephemerides simplify signal acquisition and tracking. Even a codeless receiver, such as MACROMETER-II, which cannot access the satellite navigation message, requires an almanac file containing predicted Doppler frequencies for the satellites to be observed within a given period of time. This

file must be prepared and loaded into the receiver before the measurement session.

Broadcast ephemerides will not satisfy the needs of all GPS users. For the accuracy levels of geodesy applications (Table 1), the availability of precise post-processed ephemerides is usually a must, as the minimum achievable baseline accuracy is directly proportional to orbital error [see equation (1)]. An orbital error of 20 meters (in a position 20,000 km above earth) could cause a baseline error of 1 ppm.

Precise orbit determination methodology is currently a topical research subject and there are world wide activities in this field [2]. Rizos *et al.* [37] discussed a number of GPS ephemeris facility schemes for Australia. Following is a brief summary of some options available to developing countries regarding precise orbit determination.

6.1. First Option: Externally Acquired Ephemeris

There are a number of presently available or planned sources for precise ephemeris [7,37] which include some U.S. Government agencies such as the Naval Surface Weapons Center (NSWC), National Geodetic Survey (NGS), Geological Survey (USGS) in cooperation with the University of Texas at Austin, Defense Mapping Agency (DMA), and NASA. Some receiver manufacturers also offer a post-processed ephemeris service either through mail or dial up telephone modems. Other countries such as Canada and Australia may also offer such services in the future. Cost of such services may be in the form of subscription fees, a contract or as per-unit price. Advantages of this option include:

1. Usually high accuracy of ephemeris due to typical wide separation of monitoring stations, sensitive receivers and sophisticated software employed especially if the service is offered by a government agency.
2. No need to build and operate expensive ephemeris facility. This is important for developing countries with their limited financial and skilled manpower resources.
3. Availablility of an integrated range of services from approximate ephemeris for observation scheduling or almanac file preparation to precise ephemeris for accurate position determination.

On the other hand, this option has a number of drawbacks:

a) Developing countries will not have much influence over such services with regard to accuracy level and independent validation, service procedures and fees, computation algorithms, data format or reference coordinate system.

b) There is no guarantee of continuing service availability in the future. This is a matter of critical importance for developing countries.

6.2. Second Option: Establishing an International Ephemeris Facility

By establishing a global or regional inter-governmental agency for GPS tracking and orbit determination, developing countries can avoid some drawbacks of the first option. This option is very attractive due to the following reasons:

1. It allows resource sharing (cost, knowledge, expertise, manpower and geographic spread).
2. It gives a guaranteed source of ephemeris without compromising the security, independence or national interests of participating countries.
3. It offers a channel for technology transfer and international cooperation.

In spite of its attractive advantage, the establishment of such an agency is very unlikely. It is a remote possibility even in the future due to a variety of political, administrative, technical and financial barriers. Even if such an international facility were to materialize, the influence and degree of utilization of such a facility by a developing country would depend on its effective participation, both in terms of cost, manpower and management.

6.3. Third Option: National Ephemeris Facility

A national tracking network and orbit determination facility is the optimum choice for guaranteeing a reliable source of GPS ephemerides. Such a facility can act as a national support center for all satellite surveying activities. It will consist of the following parts:

a) Three to four geographically spread tracking stations. The locations must be surveyed to the highest precision possible and be equipped with sensitive receivers having highly stable atomic clocks.

b) A computer center for processing tracking data coming from the tracking stations and generating precise post-processed ephemerides in addition to predicting future ephemerides. The center must be linked to the tracking stations by reliable communication channels. It can, in fact, be co-located with one tracking station and it can be used as the reference point in baseline differential positioning.

This option will solve most problems associated with orbit determination and will enable the country to make full utilization of the GPS system. However, this option is the most expensive. Its development to an operational system takes long years and requires many highly trained professionals in geodetic science, astronomy, computer science and engineering, telecommunications, and management and planning. If the country is geographically small, monitoring stations cannot be widely separated and orbits obtained may not be very accurate. Despite these problems, the national ephemeris facility is the only feasible solution that insures the independence of the country, security and continuity of the service.

Comparing the advantages and drawbacks of the three options, we reach the conclusion that a developing country can start by using the ephemeris services from external sources, temporarily, until more experience and knowledge is gained in the utilization of GPS capabilities. In the meantime, it should actively seek other alternatives and adopt a multi-stage plan to develop a national tracking network facility.

7. Conclusions

GPS is a new global, all-weather satellite-based radionavigation system that is well suited for survey and geodetic applications. It offers new important solutions to developing countries suffering from a chronic weakness in their land information systems. This paper was an attempt to present a general review of the different issues relating to GPS technology and its applicability to developing countries.

A summary of the GPS description and signal structure was given. Its application in surveying and geodesy was discussed together with measurement procedures and receiving techniques. A primary concern of the paper was the technical choices and decisions involved in developing countries' utilization of the GPS technology. Two important issues, in this regard, were discussed: proper choice of GPS receivers and available options for accurate GPS satellite orbit determination. It is recommended that codeless carrier-phase GPS receivers be used. Cost, reliability, ease of use and maintenance, and post-sale services are also important considerations. Developing countries may obtain precise ephemerides from different foreign sources, but must adopt long-term plans to establish national ephemeris facilities in the future.

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استخدام نظام تحديد المواقع العالمي بالتوابع في أغراض المساحة في الدول النامية ـ دراسة استعراضية

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ملخص البحث: يعتبر استخدام نظام تحديد المواقع العالمي عن طريق التوابع لأغراض المساحة والجيوديسيا قفزة تقنية ستؤدي إلى ثورة حقيقية في مقاييس الدقة والسرعة، وطريقة أداء الأعمال المساحية. وعلى وجه الخصوص فإن تقنية التوابع الجديدة ستفتح آفاقًا جديدة للدول النامية التي تعاني من نقص حاد في الموارد البشرية والمالية.

ويهدف هذا البحث إلى التعريف بنظام تحديد المواقع العالمي ومناقشة تطبيقاته في الجيوديسيا والمساحة. كما ستناقش هذه الورقة القضايا المتعلقة بتسخير هذه التقنية لحاجات الدول النامية وإمكاناتها ومواردها. وسيتم التركيز بصفة خاصة على قضيتين مهمتين بالنسبة للدول النامية وهما الاختيار الأمثل لجهاز الاستقبال، وتحديد مواقع التوابع في مداراتها.