PALESTINE POLYTECHNIC UNIVERSITY

COLLEGE OF ENGINEERING & TECHNOLOGY

CIVIL ENGINEERING DEPARTMENT

SURVEYING ENGINEERING AND GEOMATICS

GRADUATION PROJECT

EVALUATION OF REAL TIME KINEMATIC METHOD IN GPS

PROJECT TEAM

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PROJECT SUPERVISOR

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HEBRON-PALESTINE

JUNE -2009

CERTIFICATION

PALESTINE POLYTECHNIC UNIVERSITY

HEBRON-PALESTINE

EVALUATION OF REAL TIME KINEMATIC METHOD IN GPS

AHMAD BHAIS MOAD TALAHMEH

By the guidance of our supervisor, and the approval of member of the testing Committee, this project is delivered to the Department of Civil and Architectural Engineering, in the College of Engineering and Technology to be as partial fulfillment of the requirements of the department for the degree of B.Sc in Surveying and Geomatics Engineering

Supervisor signature: Head of Dep. Signature:

Name:………….……… Name:………………….

Committee member's signature:

Name:………….……… Name:…………..…..… Name:…..…..………

HEBRON-PALESTINE

JUNE -2009

DEDICATION

الإهـــــــــــداء

إلى أرواح الشهداء الأطهار ......

إلى أسرانا وجرحانا البواسل ......

إلى والدتي ......

إلى والدي ......

إلى كل من امن بفكرته وسعى لأجلها بكل جهد وفكر.

إلى أحبائنا الذين تتوق أنفسهم للتفوق والنجاح

إلى كل من تعاون معنا وسهل لنا طريق النجاح والتفوق

اهدي هذا الجهد المتواضع راجين المولى عز وجل أن ينال الرضا.

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نتقدم بالشكر والتقدير تعالى دائما الذي وفقنا لهذا العمل.

كما نتقدم بأرفع وأسمى آيات الشكر والامتنان والتقدير إلى كل من

جامعة بوليتكنك فلسطين

دائرة الهندسة المدنية والمعمارية

نهر العطاء الدائم م. فيضي شبانه

الذي قدم لنا العون والمشورة في كل صغيره و كبيرة

وكذلك نشكر م. معتز قفيشة على جهده وتعاونه معنا

وإلى جميع أعضاء الهيئة التدريسية في الجامعة

ABSTRACT

EVALUATION OF (RTK) METHOD IN GPS

PROJECT TEAM

AHMAD BHAIS MOAD TALAHMEH

PROJECT SUPERVISOR

ENG. FAYDI SHABANEH

Despite the vast researches in Palestine on the positioning systems, little is known about the global positioning system (GPS), the real time kinematic (RTK) method is one of the fastest method used in GPS and if we use it on ideal conditions, we will avoid 75% of wasting time on other GPS techniques. Accordingly, there is a need for evaluate and test the used method. The immediate objective of this research project is to know the circumstances surrounding the errors that appear in the (RTK), so that an advanced evaluation will be developed. In this study we measured random points by the fast static technique, and then we measured the same points with the (RTK) technique at different times. After measuring points and calculating errors, Results show that positioning accuracy on the cm-level can be routinely achieved by the (RTK).

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ABBREVIATIONS

DGPS	Differential Global Positioning System
DOD	Department Of Defense
DOP	Dilution Of Precision
RMS	Root Mean Square (error)
FOC	Full Operational Capability
GPS	Global Positioning System
GSM	Global system for mobile communications
HDOP	Horizontal Dilution of Precision
MCS	Master Control Station
OTF	On-the-Fly
PDOP	Position Dilution of Precision
PPS	Precise Positioning Service
RTK	Real Time Kinematics
SA	Selective Availability
SPS	Standard Positioning Service
UTC	Universal Time Coordinated
UTM	Universal Transverse Mercator
VDOP	Vertical Dilution of Precision
WGS	World Geodetic System

CHAPTER

1

INTRODUCTION

INTRODUCTION

1.1 BACKGROUND

1.2 OVERVIEW OF GPS

1.3 PROJECT IMPORTANCE

1.4 PROBLEM DEFINITION

1.5 OBJECTIVES

1.6 STUDY AREA

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1.9 STRUCTURE OF THE REPORT

1.1 Background

Graduation project is one of the requirements of the Bachelor of Surveying and Geometrics engineering in the university.

This project will study and evaluate the RTK in the GPS, as it became one of the most popular GPS methods, to get high speed and accuracy.

This project will calculate the percentage of errors and determine the ideal conditions to use the RTK method in our study area, and by this way can improve the conditions to reduce these errors to obtain the required accuracy.

1.2 Overview Of GPS

The Global Positioning System is a satellite-based navigation system that was developed by the United States Department of Defense in the early l970s. Initially, GPS was developed as a military system to fulfill U.S. military needs.

GPS provides continuous positioning and timing information, any where in the world under any weather conditions. It serves an unlimited number of users as well as being used for security reasons. GPS is a one-way-ranging (passive) system. That is, users can only receive the satellite signals.

1.3 Project Importance

The space-based GPS technique is radically different from conventional earth-based surveying technology. It requires rethinking traditional methodologies and techniques for survey planning, optimum design, accuracy estimation and data processing, the RTK take its importance from the importance of the GPS, how we can make this method more effective is very important to achieve higher speed and accuracy, which is required in most of the positioning projects.

1.4 Problem Definition

The research problem may be summarized in the following questions: what is the field accuracy of the RTK surveying? Can we develop this method to get few errors? Certainly, this method is not the best one; but how can we depends on it in the deferent fields surveying, when we use the RTK method to get the best accuracy?

1.5 Objectives

- Using the GPS techniques to take different measurements to some old grid points and unknown points in different times.
- Calculating errors then connect these errors with the reasons.
- Evaluate the RTK method by knowing reasons of errors and standard deviation's.
- Reducing or avoid the circumstances leading to these errors. And will be recommending the use of the RTK method in the regular meteorological and geodetic accuracy achieved by this method.

1.6 Study Area

The study was in Hebron city; in two places, the first place is trig points around Al-Ahli hospital, the second place is in wadi-alhariya around the Palestine Polytechnic University. The following figure shows the trig points position that using in base lines.

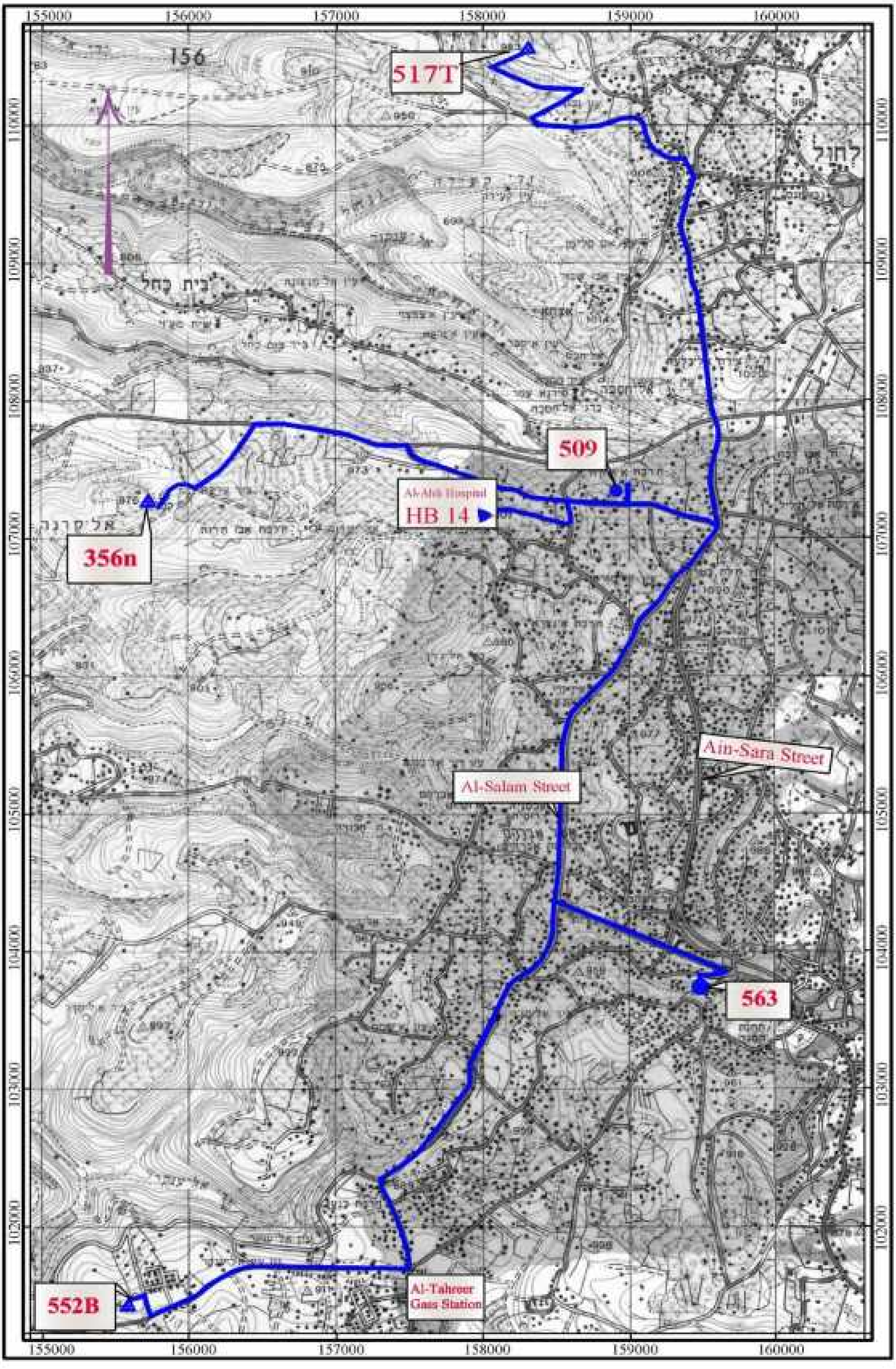

Figure (1.1): The trig point's position in the Hebron city

1.7 Previous Studies

We can't say that there aren't pre-studies about the evaluation of RTK in GPS, because there is some related studies talk about it, led to:

1. Comparison between surveying techniques static and real time kinematic using GPS/PPU/Graduation Project/2004.

Conclusions of this study:

- Static better than RTK in accuracy.
- The accuracy didn't notably improve when measuring with long time by RTK.
- The accuracy in static notably improves when measuring with long time.
- The accuracy in RTK changes at any time (increasing or decreasing).

2. Performance Analysis of the RTK Technique in an Urban Environment/ UAE University/June.2000

Conclusions of this study:

- For the short distances, differences between the RTK system and the precise traditional surveying were about 2 cm for the horizontal Plane coordinates, and less than 3 cm along the height.
- The RTK was also capable, at all times, of achieving cm level accuracy throughout the changing geometry of satellites.

1.8 Methodology

The approach taken in reaching the objectives was as follows:

- The Trimble Planning software was used before heading out to the field.
- The measurements for the coordinates were taken by static and RTK.
- The calculations of errors were calculated.
- Various affection on the RTK were used for analysis the errors.
- Drawings and tables were done by Excel.
- Information gathered was then normalized, analyzed and summarized.
- Comments or recommendations based on the field work were included.

1.9 Structure Of The Report

This report included six chapters as follows:

Chapter I: contains a general definition about the project, the problem definition, the desired objectives and results of the project, beside it contains the work methodology.

Chapter II: contains a summary of the GPS system, contents and details of the system and errors occur when using this system.

Chapter III: contains a detailed explanation of the main methods and techniques used in the process of monitoring the use of GPS.

Chapter IV: contains the readings and measurements on the field and that have been taken to evaluate the RTK technique in the project.

Chapter V: contains calculation of errors, standard deviation's charts, and evaluation of the RTK technique.

Chapter VI: contains the final conclusion and recommendations.

CHAPTER

2

GLOBAL POSITIONING SYSTEM

GLOBAL POSITIONING SYSTEM

2.1 Introduction

GPS consists, nominally, of a constellation of 24 operational satellites. To ensure continuous worldwide coverage, GPS satellites are arranged so that four satellites are placed in each of six orbital planes see Fig (2.1). With this constellation geometry, four to ten GPS satellites will be visible anywhere in the world, if an elevation angle of 10º is considered.

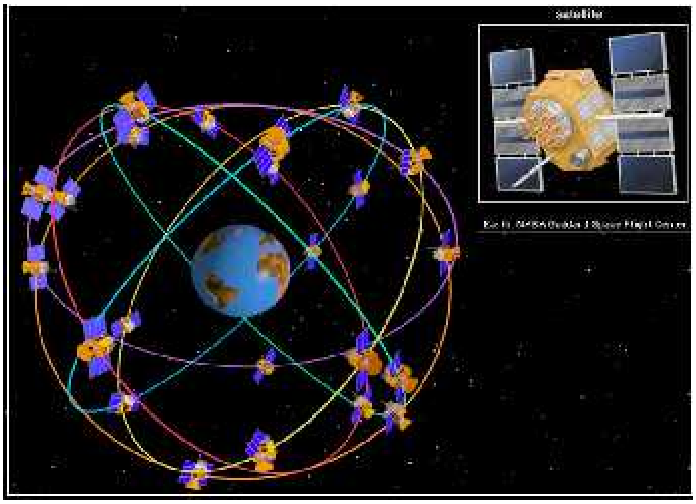

Figure (2.1): Twenty Four GPS satellites in six orbits [6]

GPS satellite orbits are nearly circular (an elliptical shape), with an inclination of about 55° to the equator. The semi major axis of a GPS orbit is about 26,560 km and the satellite altitude of about 20,200 km above the Earth’s surface.

2.2 Elements Of GPS Surveying

Before talking about GPS segment, the breakdown of the GPS system has to be said and to understand the basic elements of the system, which is significant primarily for his work, these systems are:

- **Coordinate system:**

  GPS techniques require precisely defined coordinate systems, there are satellites and earth's coordinate systems, GPS system based on WGS-1984 Ellipsoid and universal transverse Mercator projection for reference coordinate system, so that if we don't use WGS84 in our place we should convert our data from WGS84 to the ellipsoid we used.

- **Time system:**

  The time in GPS is very important to calculate the distance between the satellite and the receiver position. GPS use some atomic clocks and other kinds which must be related with scales to check the errors. A number of time systems are used world wide for various purposes. Of these, the Coordinated Universal Time and the GPS Time are the most important to GPS users.

- **Satellite orbital motion:**

  The orbital motion of satellites is a result of the earth's gravitational attraction and a number of other forces acting on the satellite, mathematically; the equations of motions for satellites are differential equations that are solved by numerical integration over time, so it should be noted that any thing will affect our system.

2.3 GPS Segments

The usage of GPS system consists of three segments: The satellite space segment, the ground control segment, and the user segment as shown below in Fig (2.2).

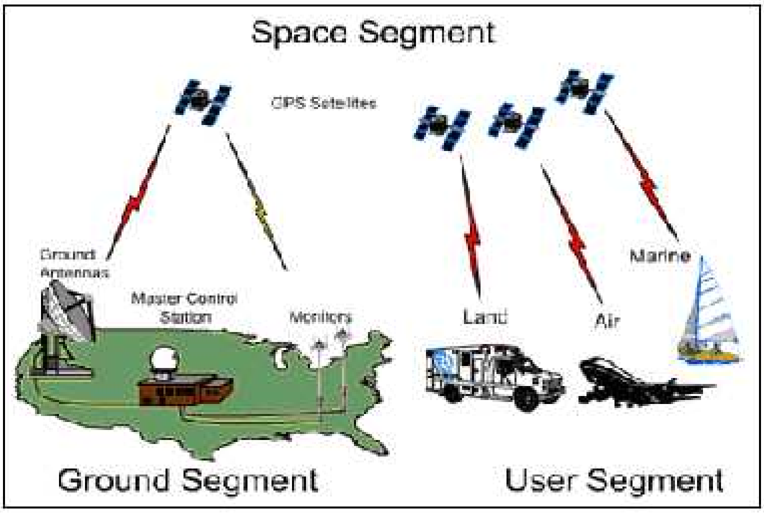

Figure (2.2): The GPS segments [11]

2.3.1 Space Segment

27 Earth-orbiting satellites (24 in operation and three extras in case one fails), each GPS satellite transmits a signal, which has a number of components: two sine waves (carriers), two digital codes, and a navigation message.
The carriers and the codes are used mainly to determine the distance from the user's receiver to the GPS satellites. The navigation message contains, along with other information, the difference between GPS and UTC time scale and the location of the satellites as a function of time.

2.3.2 Ground Control Segment

The ground segment consists of a world wide network of tracking stations, with a master control station located in the United States at Colorado.
The primary task of the operational control segment is tracking the GPS satellite in order to determine and predict satellite locations, system integrity, and behavior of the satellite atomic clocks, atmospheric data, the satellite almanac, and other considerations. This information is then packed and uploaded into the GPS satellites.

2.3.3 User Segment (Receiver)

The user segment includes all military and civilian users. With a GPS receiver connected to a GPS antenna, a user can receive the GPS signals, which can be used to determine his or her position anywhere in the world.

2.4 How dose GPS work?

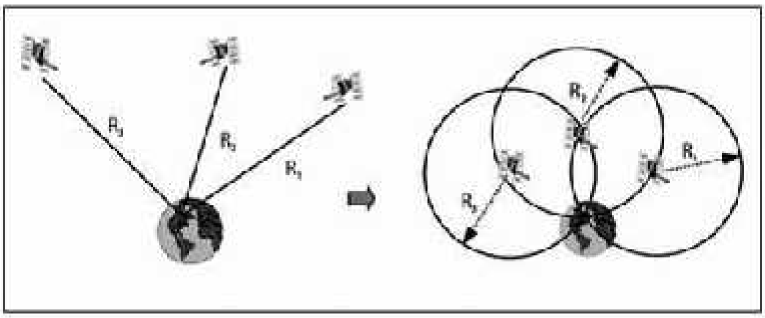

Figure (2.3): The idea of GPS positioning [4]

The idea behind GPS is simple. If the distances from a point on the earth to three GPS satellites are known R1,R2,R3 as in Fig (2.3) above, then the location of the point can be determined by simply applying the well-known concept of resection, the resection is led to three known points and one point is unknown coordinates.
But how dose GPS calculate the distance?

2.4.1 Calculating The Distance To The Satellite

One of Newton's laws of motion is used:

Distance = Velocity x Time

The Velocity is the velocity of the radio signal, (the speed of light, 290,000 km/s). And the time is the time taken for the radio signal to travel from the satellite to the GPS receiver.

Theoretically, only three distances are needed. In this case, the receiver would be located at the intersection of three spheres; however, fourth satellite is needed to account for the receiver clock offset.

2.4.2 Calculating The Position On The Earth

A GPS receiver determines its position by using the following four equations:

$$R_1^2 = (X-x_1)^2+(Y-y_1)^2+(Z-z_1)^2+v^2$$
$$R_2^2 = (X-x_2)^2+(Y-y_2)^2+(Z-z_2)^2+v^2$$
$$R_3^2 = (X-x_3)^2+(Y-y_3)^2+(Z-z_3)^2+v^2$$
$$R_4^2 = (X-x_4)^2+(Y-y_4)^2+(Z-z_4)^2+v^2$$

where (x_1,y_1) (x_2,y_2) (x_3,y_3) and (x_4, y_4) stand for the location of satellites respectively, R1, R2, R3, R4 are the distances of satellites from the receiver position Fig (2.4), and v is the clock error computed as distance.

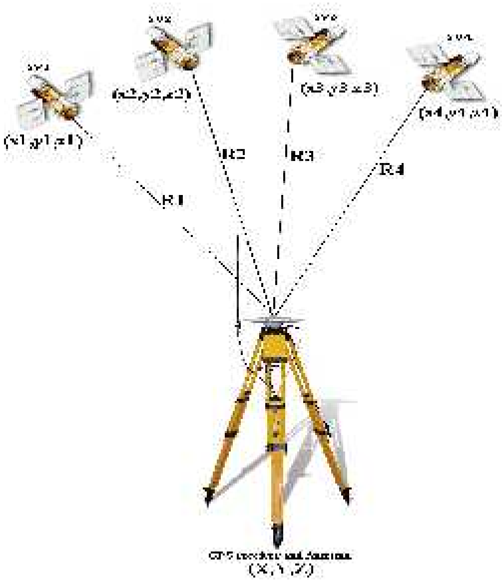

Figure (2.4): User's position on the earth [8]

2.5 GPS Positioning Service

As stated earlier, GPS was originally developed as a military system, but was later made available to civilians as well. However, to keep the military advantage, the U.S. DoD provides two levels of GPS positioning and timing services:

- **Precise Positioning Service (PPS):**

PPS is the most precise autonomous poisoning and timing service. It uses one of the transmitted GPS codes, known as P(Y)-code, which is accessible by authorized users include U.S. military force.

- **Standard Positioning Service (SPS):**

SPS, less precise than PPS. It uses the second transmitted GPS code, known as the C/A-code, which is available free of charge to all users worldwide.

2.6 GPS Errors Budget

GPS random errors and biases (systematic errors), can be classified as:

- The errors originating at the satellites include: Ephemeris or orbital errors, Satellite clock errors, and the effect of selective availability.

- The errors originating at the receiver include: The receiver clock errors, multipath error, receiver noise, and antenna phase center variations.

- The signal propagation errors include: The delays of the GPS signal as it passes through the Ionospheric and Tropospheric layers of the atmosphere.

- In addition to the effect of these errors, the accuracy of the computed GPS position is also affected by the geometric locations of the GPS satellites as seen by the receiver. The more spread out the satellites are in the sky, the better the obtained accuracy. The satellite geometry effect can be measured by a single dimensionless number called the dilution of precision (DOP) . The lower the value of the DOP number, the better the geometric strength.

2.7 Why use GPS?

GPS has revolutionized the surveying and navigation fields since its early stages of development, its civil applications have grown much faster.

On the surveying side, GPS has replaced the conventional methods in many applications. GPS positioning has been found to be a cost-effective process, in which at least 50% cost reduction can be obtained whenever it is possible to use the so-called real-time kinematics (RTK) GPS, as compared with conventional techniques. In terms of productivity and time saving, GPS could provide more than 75% timesaving whenever it is possible to use the RTK GPS method.

GPS has numerous applications in land, marine, and air navigation. Vehicle tracking and navigation are rapidly growing applications. It is expected that the majority of GPS users will be in vehicle navigation, future uses of GPS will include automatic machine guidance and control

CHAPTER

3

GPS SURVEYING TECHNIQUES

GPS SURVEYING TECHNIQUES

3.1 Introduction

The selection of the observation techniques in a GPS surveying depends upon the Particular requirements of the project; the desired accuracy especially plays a dominant role. The GPS surveying techniques are divided into two parts: GPS point positioning, and GPS Relative positioning (Differential).

3.2 GPS Point Positioning

GPS point positioning, also known as standalone or autonomous positioning, involves only one GPS receiver. That is, one GPS receiver simultaneously tracks four or more GPS satellites to determine its own coordinates with respect to the center of the Earth Almost all of the GPS receivers currently available on the market are capable of displaying their point positioning coordinates. See Fig (3.1).

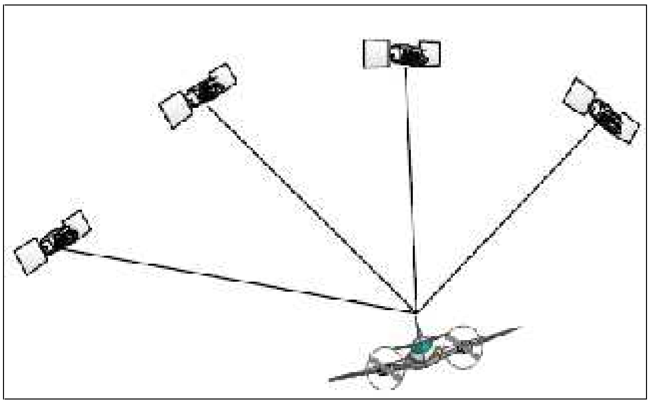

Figure (3.1): GPS Point Positioning At One Receiver [11]

To determine the receivers point position at any time, the satellite coordinates as well as a minimum of four ranges to four satellites are required. The receiver gets the satellite coordinates through the navigation message, while the ranges are obtained from either the C/A-code or the P(Y)-code, depending on the receiver type (civilian or military).

It should be pointed out that if more than four satellites are tracked, the so-called least-squares estimation or Kalman filtering technique is applied. As the satellite coordinates are given in the WGS84 system, the obtained receiver coordinates will be in the WGS84 system as well.

3.3 GPS Relative Positioning

GPS relative positioning, also called differential positioning, This technique is based on the use of two (or more) receivers simultaneously tracking the same satellites to determine their relative coordinates Fig (3.2), where one stationary reference or base receiver is located at a known point, and the position of the rover receiver has unknown coordinates. The rover receiver may or may not be stationary, depending on the type of the GPS operation.

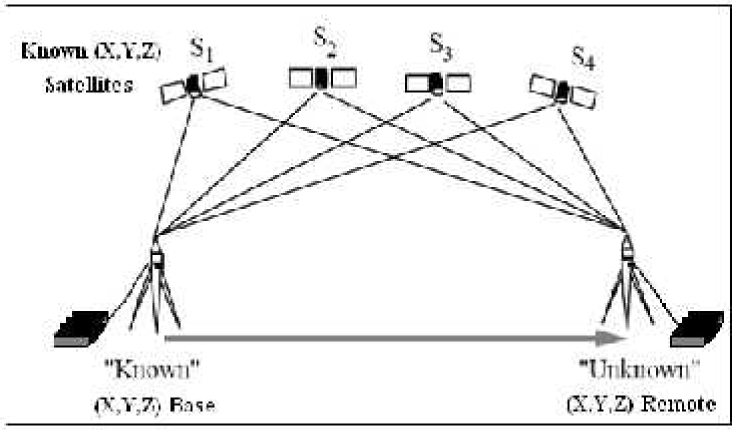

Figure (3.2): Concept of GPS Relative Positioning [11]

The known position of the reference receiver is used to calculate corrections to the GPS derived position or to the observed pseudoranges. These corrections are used by the roving receiver to allow the computation of the rover position with far more accuracy (depend on the baseline length) than for the single-point positioning mode.

3.3.1 Static GPS Surveying

This was the first method to be developed for GPS surveying. It can be used for measuring long baselines.

One receiver is placed on a point whose coordinates are known accurately. This is known as the Reference Receiver. The other receiver is placed on the other end of the baseline and is known as the Rover. Data is then recorded at both stations simultaneously. It is important that data is being recorded at the same rate at each station. The receivers have to collect data for a certain length of time. This time is influenced by the length of the line, the number of satellites observed, and the satellite geometry too.

The fast static GPS surveys are similar to static GPS surveys, but with shorter observation periods (approximately 5 to 10 minutes), Used to densify existing networks, establishing control …etc. When starting work in an area where no GPS surveying has previously taken place, the first task is to observe a number of points, whose coordinates are accurately known in the local system. If no known point is available, it can be set up anywhere within the network. The data is recorded and post-processed back at the office. The accuracy depends on the baseline length and the type of receiver.

3.3.2 Kinematics GPS Surveying

The Kinematics technique is typically used for detail surveying (great number of points), The technique involves a moving Rover whose position can be calculated relative to the Reference. The Rover has to perform what is known as an initialization.

The reference base and rover are switched on and remain absolutely stationary for (5-20) Seconds collecting data. A major point to watch during kinematic surveys is to avoid moving too close to objects that could block the satellite signal from the Rover receiver. If at any time, less than four satellites are tracked by the Rover receiver Kinematics on the Fly, you must stop, move into a position where four or more satellites are tracked and perform an initialization again before continuing. If they walk under a tree and lose the satellites, upon emerging back into satellite coverage, the system will automatically reinitialize.

3.3.3 Real Time Kinematics Surveying (RTK)

What is the RTK?

The Real Time Kinematic is a differential positioning technique that uses known coordinates of a reference station occupied by one receiver to determine coordinates of unknown points visited by a rover receiver.

The technique employs phase measurements, and processing in real time, giving computed coordinates at the cm level of the visited point while still occupying it for a few seconds, In other words, what the surveyor sees is what he gets.

Data link in RTK:

To process the data in real time, the reference station coordinates and measurements are transmitted to the rover via data links.

Most RTK GPS systems make use of small Ultra High (UHF) Frequency radio modems (used to transmit data for distances less than 15 km). Radio communication is the part of the RTK system that most people experience difficulty with. It is worth considering the following influencing factors when trying to optimize radio performance. The radio signals are horizontally coverage, when communication is cutting; use repeater to increase the radio coverage.

How dose it work?

The Reference Station has a radio link attached and rebroadcasts the data it receives from the satellites, the Rover also has a radio link and receives, the signal broadcast from the Reference. The Rover also receives satellite data directly from the satellites via its own GPS Antenna. These two sets of data can be processed together at the Rover to resolve the ambiguity and therefore obtain a very accurate position relative to the Reference receiver, Fig (3.3).

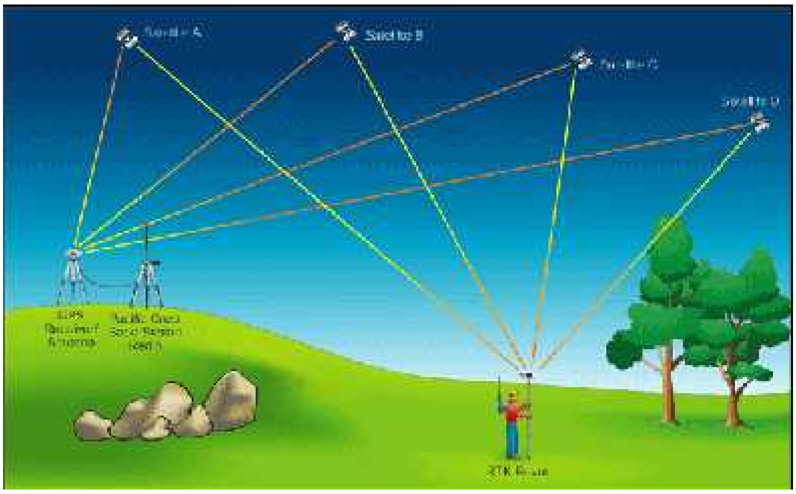

Figure (3.3): Concept of RTK Relative Positioning [2]

The RTK is quickly becoming the most common method of carrying out high precision, high accuracy GPS surveys in small areas and can be used for similar applications as a conventional total station, additionally using RTK to check points in some orders of geodetic networks.

Advantage and disadvantages:

The advantage of RTK method is in saving money; no cost for post-processing, and saving time; the RTK is fast and accurate. Problems may be encountered when surveying close to obstructions such as tall buildings, trees…etc. as the satellite signal may be blocked, and the radio signals are non coverage.

Applications:

In general, the RTK technique is contains many applications, such as: Monitoring points and the borders of the territories, the distribution of points in support of the users of the station overall, contribute to the search for points of triangles removed or lost, construction, and topography.

CHAPTER

4 FIELD MEASUREMENTS

FIELD MEASUREMENTS

4.1 INTRODUCTION

4.2 GPS SURVEY EQUIPMENTS

4.3 GPS FIELD PROCEDURES

4.4 GPS SPECIFICATIONS

4.5 USING THE PLANNING SOFTWARE

4.6 STATIC GPS OBSERVATIONS

4.7 RTK GPS OBSERVATIONS

4.8 USING THE TRIMBLE GEOMATICS OFFICE SOFTWARE

4.1 Introduction

This sections the outlines measurements of the project. The outgoing task for this work part is to check the position of the points measured by the static method. These points are used then to compare with RTK method; the RTK points are placed near the PPU University, to have a good connection between the rover and the base.

The GPS receiver (Trimble 5700) used to take field measurements for two groups of points; the first group is consisting of thirteen points around the PPU, The second is six points around Al-Ahli hospital.

4.2 GPS Survey Equipments

Before heading out into the field, the surveyor needs to prepare for the survey. Items that must be considered are:

- Receiver Units
- Auxiliary devices (i.e. metrological sensors, tribrachs, tripods, bipods)
- Radio Licenses
- Power - charged batteries
- Spare cables
- Communication between survey parties
- Coordinates of Reference Station
- Memory cards - have enough spare memory
- Observation schedule.

4.3 GPS Field Procedures

The following are some general GPS field survey procedures that should be performed at each station, observation, and/or session on a GPS survey.

- Devices used and the installation of the system depends on whether the principle of Differential GPS or Point positioning GPS, and here the work is Differential GPS, which means that there are two receivers, one fixed and the other movable.

- In the case of GPS static Technique, which does not need to radio, setup the base receiver with antenna at known coordinates point, measure the antenna height, connecting with data collector.

- On data collector making a new job, enter the coordinates of the reference point and the antenna height, defining the base line at two base receivers if we need that.
- Setup the rover receiver, connecting it with data collector and starting point observing.

- In the case of GPS RTK technique, connecting the base receiver with external pottery, as well as radio (Data links), and wireless connects to rover receiver to transform the corrections.

- These readings are taken directly in the field, stored in the Data collector and downloading to a special program (Trimble Geomatics Office) to deal with them.

4.4 GPS Specifications

While using the GPS techniques, there is some specifications you should take in mind. Table (4.1) shows the general, field, and office specifications for the fast static And RTK to get the best accuracy.

Table (4.1): GPS Surveying Specifications [5]

Specifications **General**	**Fast-Static (First Order)**	**Fast-Static (Second Order)**	**Fast-Static (Third Order)**	**RTK (Third Order)**
Minimum number of reference stations to control the project	3 first-order (horz.) or better	3 second-order (horz.) or better	3 third-order (horz.) or better	3 third-order (horz.) or better
Maximum distance between the survey project boundary and network control stations	30 miles	30 miles	30 miles	30 miles
Location of reference network control (relative to center of project); minimum number of "quadrants," not less than	3	3	2	2
Minimum percentage of all baselines contained in a loop	100%	100%	50%	50%
Minimum percentage of repeat independent baselines	5% of total	5% of total	5%	5%
Percent of stations occupied 2 or more times	100% (2 times) 10% (3 or more times)	75%	75%	100%
Direct connection between inter visible azimuth pairs	Yes	Yes	NO	NO
Field				
Maximum PDOP during station occupation	5	5	5	5
Minimum observation time on station	15 minutes	10 minutes	5 minutes	5 Epochs
Minimum number of satellites observed simultaneously at all stations	5	5	5	5 (100% of time)
Maximum epoch interval for data sampling	10 seconds	10 seconds	10 seconds	1 - 15 seconds
Minimum time between repeat station observations	60 minutes	45 minutes	20 minutes	20 minutes
Antenna height measurements in feet and meters at beginning and end of each	Yes	Yes	Yes	Yes

session				
Minimum satellite mask angle above the horizon	10 degrees	10 degrees	10 degrees	10 degrees
Office				
Fixed integer solution required for all baselines	Yes	Yes	No	No
Ephemeris	Precise	Broadcast	Broadcast	Broadcast
Initial position: max. 3-d position error for the initial station in any baseline solution	33 feet	66 feet	330 feet	330 feet
Loop closure analyses, maximum number of baselines per loop	6	8	12	12
Maximum loop length	60 miles	45 miles	30 miles	30 miles
Maximum misclosure per loop, in terms of loop length	10 ppm	50 ppm	100 ppm	100 ppm
Maximum misclosure per loop in any one component (x, y, z) not to exceed	0.15 feet	0.26 feet	0.03 feet	0.03 feet
Repeat baseline length not to exceed	30 miles	30 miles	6 miles	6 miles
Repeat baseline difference in any one component (x, y, z) not to exceed	10 ppm	50 ppm	100 ppm	100 ppm
Accuracy	Sub-centimeter level	Sub-centimeter level	centimeter level	Sub-decimeter level

The following table shows the GPS Range measurement accuracies for the absolute and differential positioning, so it may help while surveyor looking for reasons for the errors accrued.

Table (4.2): GPS Range Measurement Accuracy [10]

GPS Range Measurement Accuracy

Segment Source	Error Source	Absolute Positioning: C/A code Pseudo-range, m	Absolute Positioning: P code Pseudo-range, m	Differential Positioning, m (P-code)
Space	Clock stability	3.0	3.0	Negligible
	Orbit perturbations	1.0	1.0	Negligible
	Other	0.5	0.5	Negligible
Control	Ephemeris predictions	4.2	4.2	Negligible
	Other	0.9	0.9	Negligible
User	Ionosphere	3.5	2.3	Negligible
	Troposphere	2.0	2.0	Negligible
	Receiver noise	1.5	1.5	1.5
	Multipath	1.2	1.2	1.2
	Other	0.5	0.5	0.5
1-σ UERE		±12.1	±6.5	±2.0

* Without S/A.

The following table shows the GPS specifications for the order of accuracy.

Table (4.3): Specifications for GPS Surveys (Order of accuracy) [10]

Order	Allowable error Ratio	Parts-Per-Million(PPM)
AA	1:100,000,000	0,01
A	1:10,000,000	0,1
B	1:1,000,000	1,0
C-1	1:100,000	10
C-2-I	1:50,000	20
C-2-II	1:20,000	50
C-3	1:10,000	100

4.5 Using The Planning software

The Trimble planning Limited Software is used before heading out into the field, the surveyor needs to prepare for the survey, which appears drawings for numbers of Dilution of precision with time, satellite visible, and satellites numbers. The Planning software needs to be a set of inputs in addition to time to give the correct values and graphics, so we shall determine our position table (4.4), and the time table (4.5) for field observation. Our position and time were:

Table (4.4): Input data for the Trimble planning limited software

Station name	**Hebron-WadiAlhariya Bulling A**
Latitude	31° 30' 29.45"
Longitude	35° 06' 30.03"
Height	915.376 m
Time zone	(GMT+03:00)
Offset UTC	+ 3.0 h
Elevation cutoff	10°
GPS Satellites	2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32

Table (4.5): Times for the field RTK Observation

Day	Measuring Date	Duration
1st	27/11/2008	11:00:00-02:00:00
2nd	31/03/2009	08:00:00-11:00:00
3rd	02/04/2009	08:30:00-11:30:00
4th	05/04/2009	11:00:00-02:00:00

The following are the values of DOP numbers after using program, and drawings with the observed time:

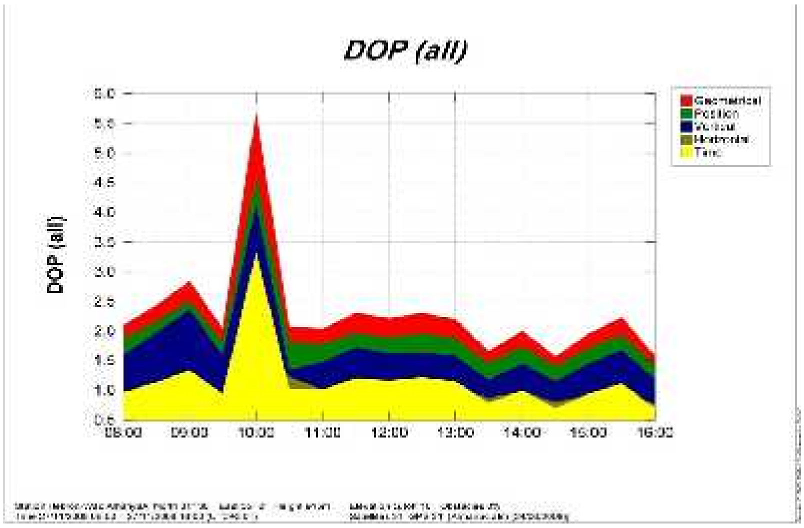

Figure (4.1): The DOP Values for the time duration at the first day

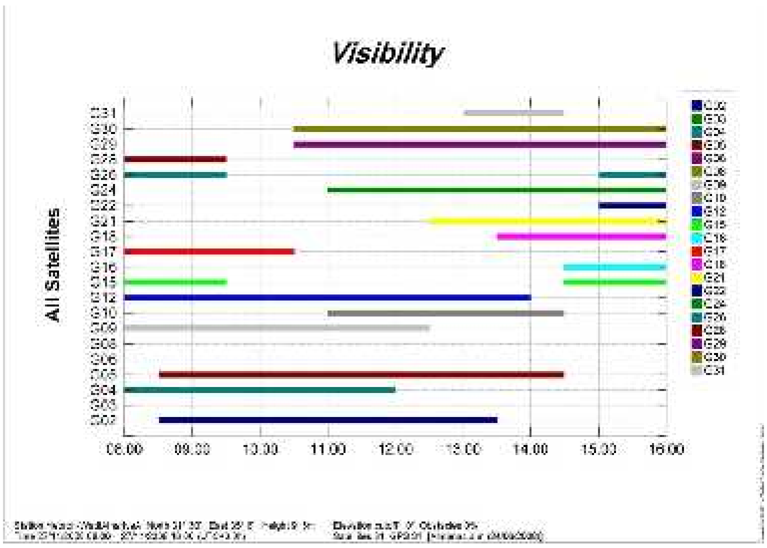

Figure (4.2): The Satellite visibility for the time duration at the first day

Table (4.6): DOP Values for the time duration at the first day

Time	GDOP	TDOP	PDOP	HDOP	VDOP	GPS
08:00	2.09	0.96	1.85	0.96	1.59	8
08:30	2.43	1.12	2.15	0.88	1.96	9
09:00	2.83	1.33	2.50	0.86	2.35	9
09:30	2.02	0.93	1.80	0.86	1.58	9
10:00	5.65	3.31	4.58	2.06	4.10	6
10:30	2.07	1.01	1.80	1.22	1.33	8
11:00	2.03	1.00	1.77	0.99	1.46	9
11:30	2.30	1.19	1.96	0.96	1.71	9
12:00	2.21	1.15	1.88	0.97	1.61	9
12:30	2.29	1.21	1.95	1.08	1.62	9
13:00	2.20	1.14	1.88	1.03	1.57	9
13:30	1.65	0.78	1.45	0.86	1.17	10
14:00	1.99	0.99	1.73	0.97	1.44	9
14:30	1.56	0.69	1.39	0.80	1.14	10
15:00	1.94	0.93	1.70	0.91	1.44	9
15:30	2.22	1.10	1.93	0.98	1.66	9
16:00	1.57	0.69	1.40	0.76	1.18	11

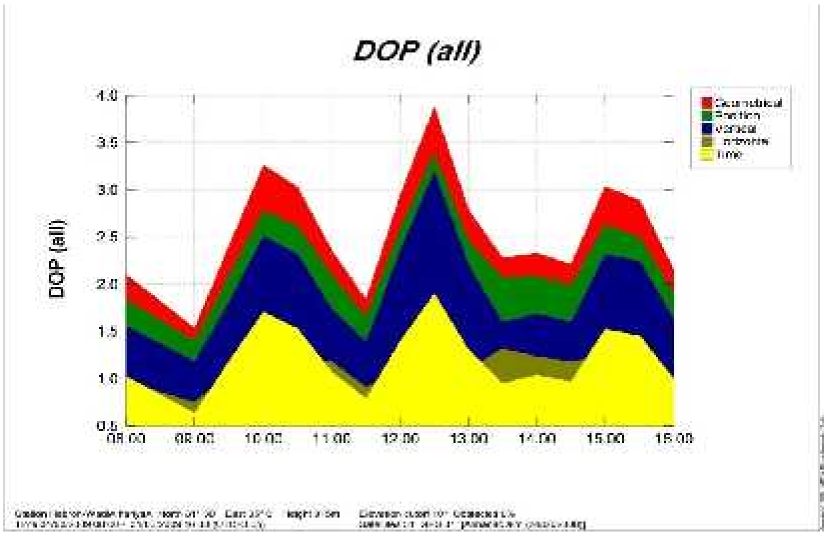

Figure (4.3): The DOP Values for the time duration at the second day

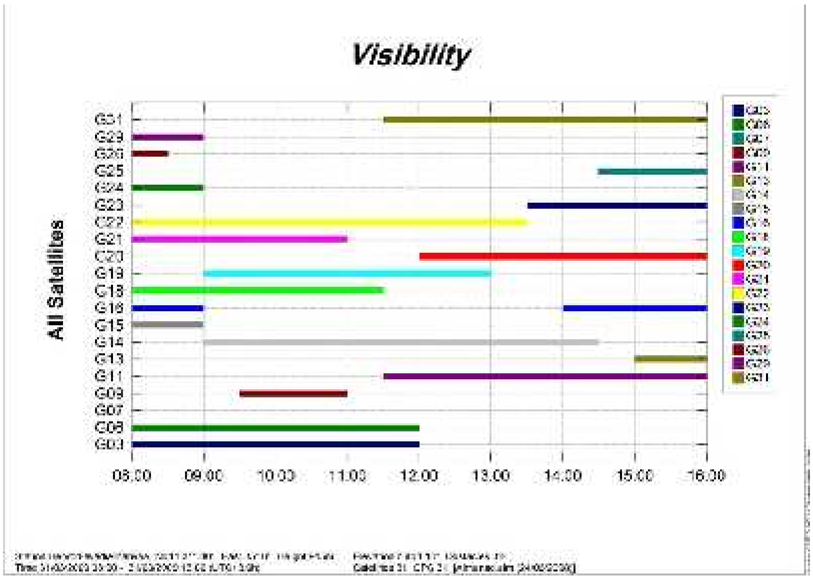

Figure (4.4): The Satellite visibility for the time duration at the second day

Table (4.7): DOP Values for the time duration at the second day

Time	GDOP	TDOP	PDOP	HDOP	VDOP	GPS
08:00	2.10	1.02	1.84	0.97	1.56	10
08:30	1.81	0.83	1.61	0.86	1.37	10
09:00	1.53	0.63	1.40	0.75	1.18	11
09:30	2.42	1.19	2.10	1.06	1.82	8
10:00	3.26	1.70	2.78	1.19	2.51	8
10:30	3.03	1.52	2.61	1.22	2.31	8
11:00	2.35	1.07	2.09	1.18	1.73	8
11:30	1.83	0.79	1.66	0.90	1.39	8
12:00	2.94	1.39	2.59	1.07	2.36	8
12:30	3.87	1.89	3.38	1.12	3.19	6
13:00	2.78	1.31	2.46	1.09	2.20	6
13:30	2.28	0.95	2.07	1.32	1.60	6
14:00	2.33	1.04	2.09	1.23	1.69	6
14:30	2.21	0.96	1.99	1.18	1.60	7
15:00	3.03	1.52	2.62	1.24	2.31	7
15:30	2.89	1.45	2.49	1.09	2.24	7
16:00	2.14	0.99	1.90	0.98	1.62	8

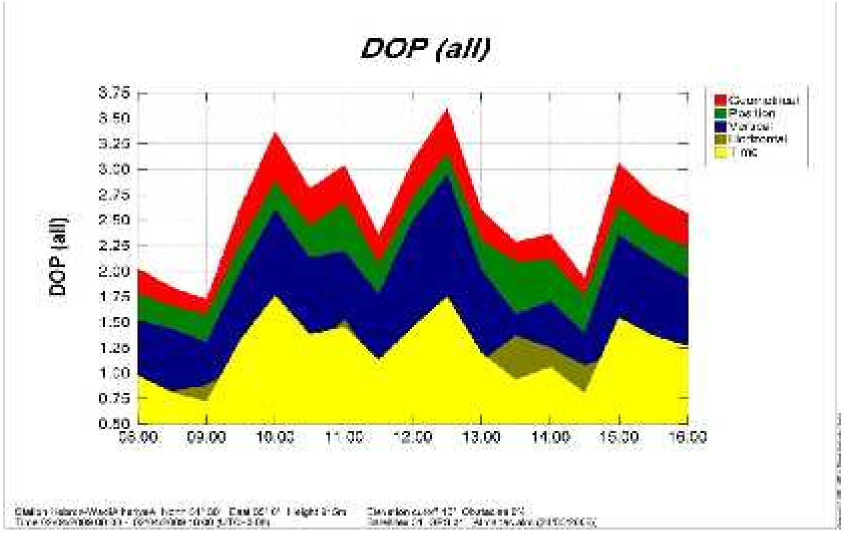

Figure (4.5): The DOP Values for the time duration at the Third day

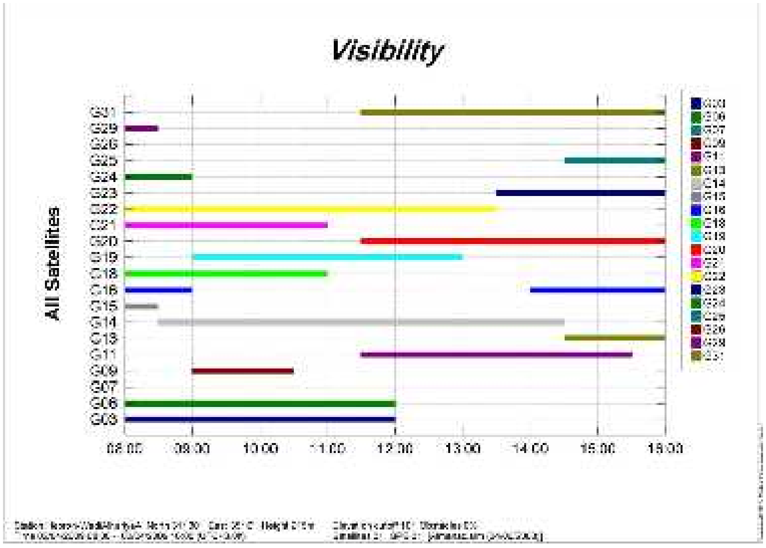

Figure (4.6): The Satellite visibility for the time duration at the Third day

Table (4.8): DOP Values for the time duration at the Third day

Time	GDOP	TDOP	PDOP	HDOP	VDOP	GPS
08:00	2.02	0.97	1.78	0.93	1.51	10
08:30	1.84	0.80	1.65	0.82	1.43	10
09:00	1.72	0.72	1.57	0.88	1.30	10
09:30	2.64	1.33	2.28	1.08	2.00	8
10:00	3.37	1.76	2.87	1.22	2.60	8
10:30	2.81	1.38	2.44	1.20	2.13	8
11:00	3.04	1.45	2.67	1.52	2.19	7
11:30	2.35	1.13	2.06	1.05	1.77	8

12:00	3.08	1.45	2.72	1.08	2.50	8
12:30	3.60	1.75	3.14	1.10	2.95	6
13:00	2.59	1.20	2.30	1.11	2.01	6
13:30	2.28	0.93	2.08	1.36	1.57	6
14:00	2.36	1.06	2.11	1.24	1.70	6
14:30	1.92	0.80	1.75	1.07	1.39	8
15:00	3.05	1.54	2.64	1.19	2.35	7
15:30	2.74	1.37	2.37	1.06	2.12	7
16:00	2.56	1.26	2.23	1.11	1.93	7

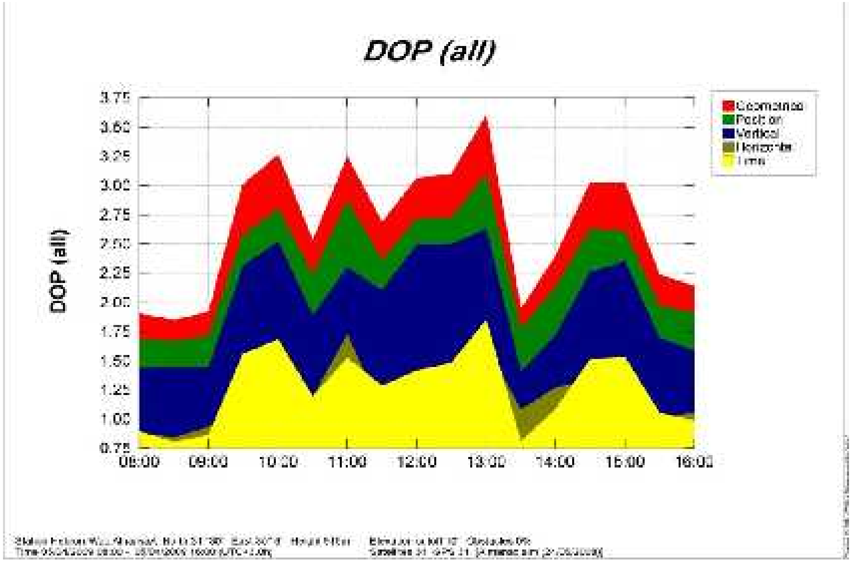

Figure (4.7): The DOP Values for the time duration at the Fourth day

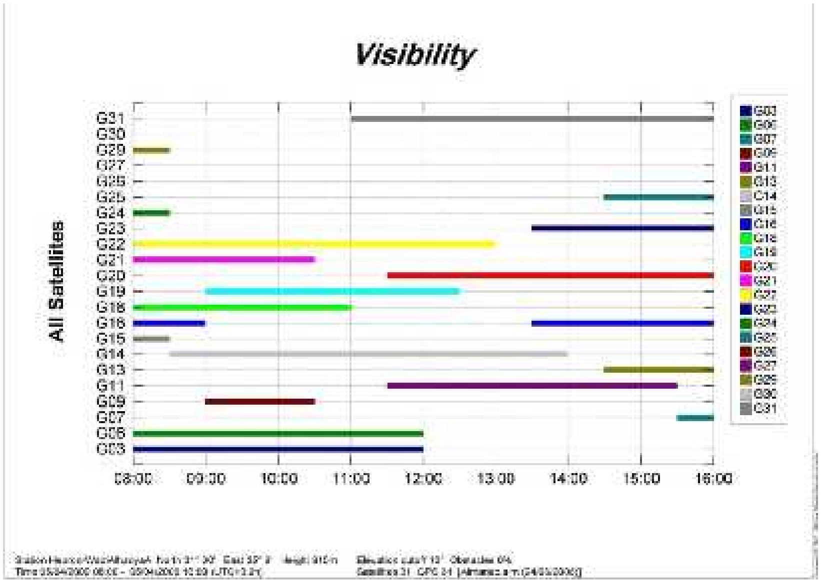

Figure (4.8): The Satellite visibility for the time duration at the Fourth day

Table (4.9): DOP Values for the time duration at the Fourth day

Time	GDOP	TDOP	PDOP	HDOP	VDOP	GPS
08:00	1.90	0.89	1.68	0.88	1.43	10
08:30	1.85	0.80	1.67	0.83	1.44	10
09:00	1.92	0.86	1.71	0.93	1.44	9
09:30	3.01	1.56	2.57	1.14	2.31	8
10:00	3.26	1.68	2.80	1.22	2.52	8
10:30	2.52	1.19	2.23	1.18	1.89	8
11:00	3.25	1.52	2.87	1.72	2.29	7
11:30	2.68	1.28	2.36	1.06	2.10	8
12:00	3.06	1.41	2.72	1.08	2.49	8
12:30	3.10	1.48	2.72	1.09	2.50	6
13:00	3.60	1.85	3.09	1.63	2.63	5
13:30	1.94	0.80	1.77	1.07	1.40	7
14:00	2.39	1.08	2.13	1.26	1.71	6
14:30	3.02	1.51	2.62	1.33	2.26	7
15:00	3.02	1.53	2.61	1.14	2.35	7
15:30	2.23	1.05	1.97	1.00	1.69	8
16:00	2.14	0.99	1.90	1.05	1.59	8

4.6 Static GPS Observations

We use the fast static technique for two times; first to check the trig points, the second as a reference for testing the RTK points. Every Fast Static point was taken in 5 minutes time epoch, and then taken available from the Trimble Geomatics office. The fast static Readings are listed in the tables below:

Table (4.10): The Trig points

Point No.	Easting (m)	Northing (m)	Height (m)	Description
517T	158318.86	110556.15	982.67	خلف منتزه حلحول
563	159541.73	103774.6	910.68	مكتب غالب زاهدة
509	159595.18	107257.13	1017.55	عمارة النورس دائرة السير
HB14	157933.1	107161.35	1020.04	المستشفى الأهلي
552B	155582.17	101424.37	913.81	سنجر
356n	155722.87	107271.25	875.47	المحزم

Table (4.11): Five Minutes Fast Static GPS for the Trig Points

Point No.	Easting (m)	Northing (m)	Height (m)	Description
517T	158318.86	110556.150	982.67	خلف منتزه حلحول
563	159541.426	103774.533	911.018	مكتب غالب زاهدة
509	159595.107	107256.778	1017.773	عمارة النورس دائرة السير
HB14	157933.291	107161.139	1019.905	المستشفى الأهلي
552B	155582.50	101424.370	913.810	سنجر
356n	155723.341	107271.120	875.461	المحزم

Table (4.12): Five Minutes Fast Static GPS points for Test Points

Point No.	Easting (m)	Northing (m)	Height (m)	Description
ST.1	158769.893	101830.693	899.270	بجانب مكتبة التصوير
ST.3	158740.591	101809.509	895.050	بداية الطريق الجانبي
ST.4	158836.20	101811.393	897.951	أمام كافيتيريا كناري
ST.5	158727.520	101853.571	897.751	أمام مسجد مبنى A
ST.6	158664.900	101788.412	891.332	بداية سور أمام مبنى C
ST.7	158643.110	101739.460	888.996	نهاية سور أمام مبنى C
ST.8	158668.855	101715.341	889.894	بداية ساحة مبنى C
ST.9	158680.315	101707.221	890.255	بداية ساحة مبنى C
ST.10	158692.534	101700.924	890.006	بداية ساحة مبنى C
ST.a	158785.810	101805.066	898.168	أمام بوابة مبنى A
ST.c	158632.445	101697.228	888.391	الطريق جنب مبنى C
C1	158655.310	101709.213	902.008	سطح مبنى C
C2	158643.543	101681.892	901.983	سطح مبنى C

4.7 RTK GPS Observations

The points were observed with 10 seconds time interval. These measurements were done in relation to the base station. All the time intervals were observed separately, with no correlation to each other. During the observations, the times for all events were noted. This way the decision of when we will read can accrue using planning software.

We used two base stations; station one located on point HB14, station two on control point A (Building A at PPU), figures (4.9), (4.10) show that.

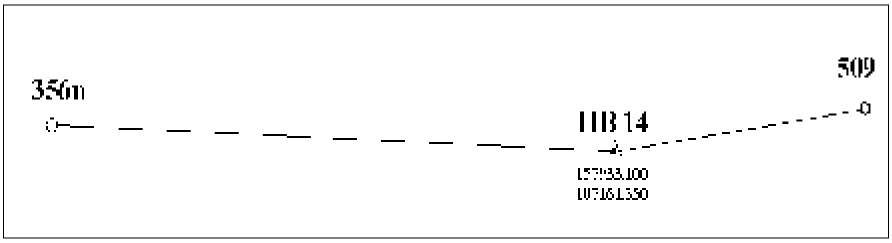

Figure (4.9): The position of The Base at (HB14) Trig point

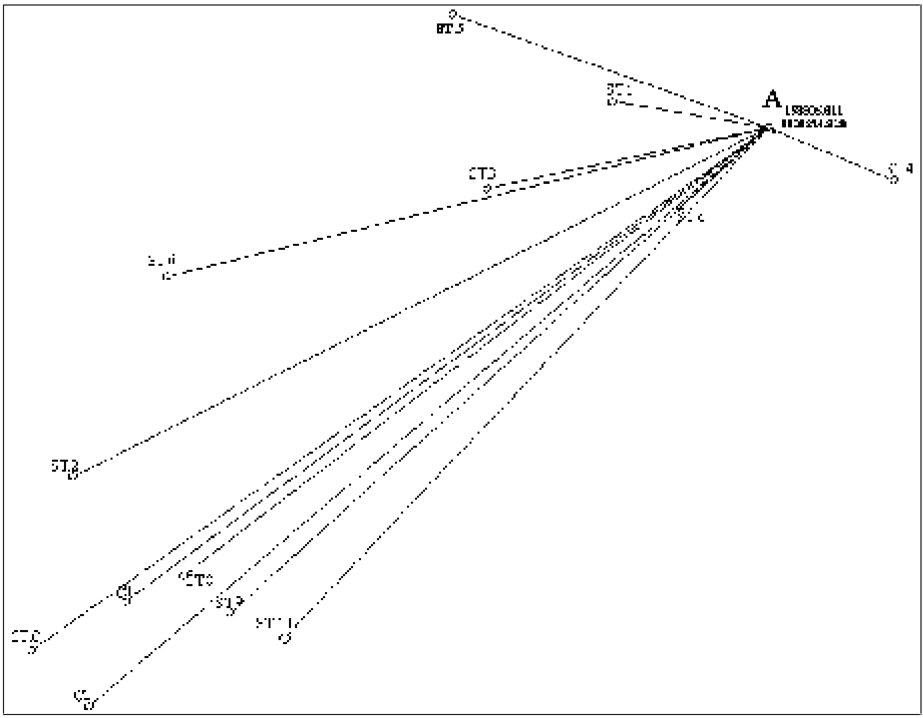

Figure (4.10): The position of The Base at (A) control point

The tables bellow shows the RTK readings for the two groups of points.

Table (4.13): Ten Seconds RTK GPS Trig Points

Point No.	Easting (m)	Northing (m)	Height (m)	Description
HB14	157933.100	107161.350	1020.040	المستشفى الأهلي
509	B1=159094.919 B2=159094.921	B1=107256.976 B2=107256.980	B1=1017.903 B2=1017.900	عمارة النورس دائرة السير

356n	B=155723.166 N=155723.174	B=107271.319 N=107271.313	B=875.599 N=875.600	المحزم

Table (4.14): Ten Seconds RTK GPS Readings for Point (ST.1)

Point No.	Easting (m)	Northing (m)	Height (m)
ST.1	158769.921	101830.696	899.272
ST.1a	158769.943	101830.685	899.216
ST.1b	158769.938	101830.691	899.254
ST.1c	158769.918	101830.686	899.270
ST.1d	158769.922	101830.690	899.222

Table (4.15): Ten Seconds RTK GPS Readings for Point (ST.3)

Point No.	Easting (m)	Northing (m)	Height (m)
ST.3	158740.553	101809.569	895.024
ST.3a	158740.545	101809.584	895.012
ST.3b	158740.552	101809.544	894.952
ST.3c	158740.555	101809.551	894.987
ST.3d	158740.541	101809.576	895.003

Table (4.16): Ten Seconds RTK GPS Readings for Point (ST.4)

Point No.	Easting (m)	Northing (m)	Height (m)
ST.4	158836.225	101811.358	897.945
ST.4a	158836.240	101811.388	897.975
ST.4b	158836.230	101811.366	897.949
ST.4c	158836.229	101811.387	897.973
ST.4d	158836.236	101811.374	897.969

Table (4.17): Ten Seconds RTK GPS Readings for Point (ST.5)

Point No.	Easting (m)	Northing (m)	Height (m)
ST.5	158727.675	101853.525	897.794
ST.5a	158727.691	101853.526	897.794
ST.5b	158727.690	101853.525	897.793
ST.5c	158727.688	101853.528	897.794
ST.5d	158727.679	101853.525	897.793

Table (4.18): Ten Seconds RTK GPS Readings for Point (ST.6)

Point No.	Easting (m)	Northing (m)	Height (m)
ST.6	158664.975	101788.398	891.294
ST.6a	158664.981	101788.378	891.268
ST.6b	158664.977	101788.395	891.292
ST.6c	158664.976	101788.394	891.277
ST.6d	158664.975	101788.401	891.292

Table (4.19): Ten Seconds RTK GPS Readings for Point (ST.7)

Point No.	Easting (m)	Northing (m)	Height (m)
ST.7	158643.069	101739.646	889.246
ST.7a	158643.097	101739.613	889.255
ST.7b	158643.101	101739.633	889.251
ST.7c	158643.084	101739.620	889.255
ST.7d	158643.072	101739.645	889.254

Table (4.20): Ten Seconds RTK GPS Readings for Point (ST.8)

Point No.	Easting (m)	Northing (m)	Height (m)
ST.8	158669.017	101715.401	890.185
ST.8a	158669.025	101715.391	890.200
ST.8b	158669.024	101715.399	890.191
ST.8c	158669.022	101715.397	890.186
ST.8d	158669.015	101715.394	890.198

Table (4.21): Ten Seconds RTK GPS Readings for Point (ST.9)

Point No.	Easting (m)	Northing (m)	Height (m)
ST.9	158680.171	101706.983	890.315
ST.9a	158680.177	101706.978	890.333
ST.9b	158680.175	101706.981	890.329
ST.9c	158680.176	101706.980	890.317
ST.9d	158680.173	101706.977	890.335

Table (4.22): Ten Seconds RTK GPS Readings for Point (ST.10)

Point No.	Easting (m)	Northing (m)	Height (m)
ST.10	158692.646	101700.805	890.322
ST.10a	158692.635	101700.800	890.330
ST.10b	158692.636	101700.800	890.325
ST.10c	158692.644	101700.806	890.322
ST.10d	158692.646	101700.801	890.327

Table (4.23): Ten Seconds RTK GPS Readings for Point (ST.a)

Point No.	Easting (m)	Northing (m)	Height (m)
ST.a	158785.837	101805.112	898.161
ST.aa	158785.807	101805.110	898.161
ST.ab	158785.856	101805.107	898.100
ST.ac	158785.815	101805.109	898.160
ST.ad	158785.855	101805.115	898.154

Table (4.24): Ten Seconds RTK GPS Readings for Point (ST.c)

Point No.	Easting (m)	Northing (m)	Height (m)
ST.C	158632.420	101697.240	888.389
ST.Ca	158632.411	101697.246	888.400
ST.Cb	158632.449	101697.249	888.345
ST.Cc	158632.419	101697.245	888.390
ST.Cd	158632.42	101697.246	888.385

Table (4.25): Ten Seconds RTK GPS Readings for Point (C1)

Point No.	Easting (m)	Northing (m)	Height (m)
C1	158655.363	101709.299	902.063
C1a	158655.365	101709.313	901.974
C1b	158655.365	101709.310	901.993
C1c	158655.366	101709.309	902.005
C1d	158655.365	101709.313	901.975

Table (4.26): Ten Seconds RTK GPS Readings for Point (C2)

Point No.	Easting (m)	Northing (m)	Height (m)
C2	158643.693	101681.760	902.046
C2a	158643.693	101681.748	902.115
C2b	158643.692	101681.752	902.110
C2c	158643.693	101681.759	902.075

C2d	158643.693	101681.759	902.111

4.8 Using The Trimble Geomatics Office Software

This program is used to download the readings of the inclusive data for the calculation of the points coordinates are correct, which was meant to monitor, and The values of the DOP numbers and number of satellites that were taken from the planning software, used to compare with the same values, which are taken from the Trimble Geomatics office for the same day as follows:

Table (4.27): PDOP Values by Trimble Geomatics Office at the first day

Time	PDOP	GPS
12:03:30	1.27	9
12:13:25	1.61	7
12:17: 13	2.097	7
12:25:34	2.134	8
12:30:20	1.946	7

Table (4.28): PDOP Values by Trimble Geomatics Office at the second day

Time	PDOP	GPS
09:40:04	2.352	7
09:43:19	2.401	6
10:43:26	2.359	9
10:45:21	2.331	9

Table (4.29): PDOP Values by Trimble Geomatics Office at the Third day

Time	PDOP	GPS
10:11:37	3.199	6
10:17:37	2.963	8
10:22:52	2.809	7
11:02:31	2.609	9
11:03:14	2.931	9

Table (4.30): PDOP Values by Trimble Geomatics Office at the Fourth day

Time	PDOP	GPS
12:47:28	3.076	6
12:52:20	2.785	7
13:00:49	3.531	7
13:15:48	2.1	8
13:22:12	3.029	5

CHAPTER

5

CALCULATIONS

CALCULATIONS

5.1 COMPARISON THE PDOP NUMBERS WITH THE OBSERVING TIME

5.2 MEAN VALUE FOR RTK COORDINATES

5.3 MEAN STANDARD DEVIATION FOR RTK COORDINATES

5.4 COMPARISON BETWEEN THE STATIC AND RTK MEASUREMENTS

5.5 EVALUATING THE RTK TECHNIQUE

5.6 ACCURACY IN RTK

5.1 Comparison the PDOP Numbers with the observing time

The values of PDOP and satellites numbers from the Trimble planning software are different about the same values from the Trimble Geomatics office, so we can draw the relation between them to show the difference as follow:

Figure (5.1): Comparison the PDOP numbers at the first day

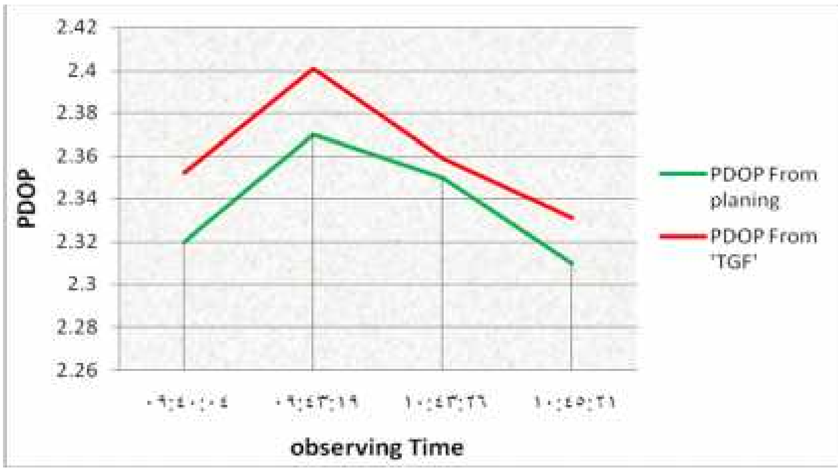

Figure (5.2): Comparison the PDOP numbers at the Second day

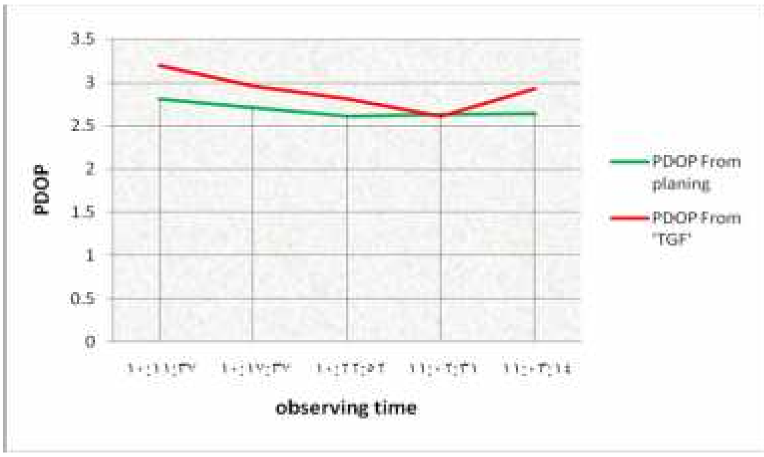

Figure (5.3): Comparison the PDOP numbers at the Third day

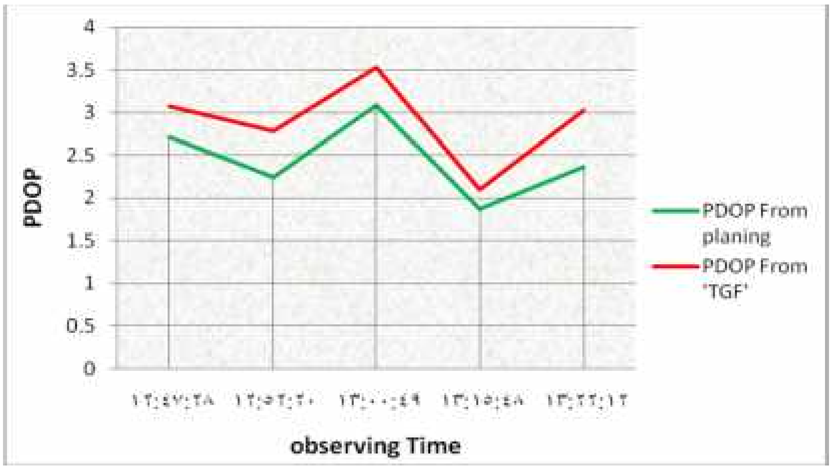

Figure (5.4): Comparison the PDOP numbers at the Forth day

The readings from the TGF is the correct values reflect the geometry of satellites at the moment of reading, we note that there is little difference between the values of PDOP, but follow the same path at the same moment in both ways.

5.2 Mean value for RTK coordinates

Mean= $\bar{x} = \frac{\sum_1^n x}{n}$, where x= reading, n= number of readings.

Mean value for the trig points:

From The Table (4.13):

$\bar{x}_{\text{Easting 509}}$ = (159094.921+159094.919)/2 = 159094.920 m

$\bar{x}_{\text{Northing 509}}$ = (107256.976+107256.980)/2 = 107256.978 m

$\bar{x}_{\text{Elevation509}}$ = (1017.904+1017.900)/2 = 1017.902 m

$\bar{x}_{\text{Easting 356n}}$ = (155723.166 +155723.174)/2 = 155723.170 m

$\bar{x}_{\text{Northing 356n}}$ = (107271.319 +107271.313) /2 = 107271.316 m

$\bar{x}_{\text{Elevation356n}}$ = (875.599 +875.600)/2 = 875.600 m

Table (5.1): Mean value for the RTK Trig points

Point No.	Easting (m)	Northing (m)	Height (m)
509	159594.920	107256.978	1017.902
356n	155723.170	107271.316	875.600

Mean value for the RTK test points:

From The Table (4.14):

$\bar{x}_{\text{Easting ST.1}}$ = (158769.921+158769.943+158769.938+158769.918+158769.922)/5 = 158769.928 m

$\bar{x}_{\text{Northing ST.1}}$ = (101830.696+101830.685+101830.691+101830.686+101830.690)/5 = 101830.689 m

$\bar{x}^{\text{Elevation ST.1}}$ = (899.272+899.216+899.254+899.270+899.222)/5 = 899.247 m

From The Table (4.15):

$\bar{x}$ Easting ST.3 = (158740.553+158740.545+158740.552+158740.555+158740.541)/5
= 158740.549 m

$\bar{x}$ Northing ST.3 = (101809.569+101809.584+101809.544+101809.551+101809.576) /5
= 101809.565 m

$\bar{x}$ Elevation ST.3 = (895.024+895.012+894.952+894.987+895.003)/5 = 894.996 m

From The Table (4.16):

$\bar{x}$ Easting ST.4 = (158836.225+158836.24+158836.23+158836.229+158836.236) / 5
= 158836.232 m

$\bar{x}$ Northing ST.4 = (101811.358+101811.388+101811.366+101811.387+101811.374)/5
= 101811.375 m

$\bar{x}$ Elevation ST.4 = (897.945+897.975+897.949+897.973+897.969)/5 = 897.962 m

From The Table (4.17):

$\bar{x}$ Easting ST.5 = (158727.675+158727.691+158727.69+158727.688+158727.679)/5
= 158727.685 m

$\bar{x}$ NorthingST.5= (101853.525+101853.526+101853.525+101853.528+101853.525)/ 5
= 101853.526 m

$\bar{x}$ Elevation ST.5 = (897.794+897.794+897.793+897.794+897.793)/5 = 897.794 m

From The Table (4.18):

$\bar{x}$ Easting ST.6 = (158664.975+158664.981+158664.977+158664.976+158664.975)/5
= 158664.977 m

$\bar{x}$ Northing ST.6 = (101788.398+101788.378+101788.395+101788.394+101788.401)/5
= 101788.393 m

$\bar{x}$ Elevation ST.6 = (891.294+891.268+891.292+891.277+891.292)/5 = 891.285 m

From The Table (4.19):

$\bar{x}_{\text{Easting ST.7}}$ = (158643.069+158643.097+158643.101+158643.084+158643.072)/5

= 158643.085 m

$\bar{x}_{\text{Northing ST.7}}$ = (101739.646+101739.613+101739.633+101739.62+101739.645) /5

= 101739.631 m

$\bar{x}_{\text{Elevation ST.7}}$ = (889.246+889.255+889.251+889.255+889.254)/5 = 889.252 m

From The Table (4.20):

$\bar{x}_{\text{Easting ST.8}}$ = (158669.017+158669.025+158669.024+158669.022+158669.015)/5

= 158669.021 m

$\bar{x}_{\text{Northing ST.8}}$ = (101715.401+101715.391+101715.399+101715.397+101715.394)/5

= 101715.396 m

$\bar{x}_{\text{Elevation ST.8}}$ = (890.185+890.2+890.191+890.186+890.198)/5 = 890.192 m

From The Table (4.21):

$\bar{x}_{\text{Easting ST.9}}$ = (158680.171+158680.177+158680.175+158680.176+158680.173)/5

= 158680.174 m

$\bar{x}_{\text{Northing ST.9}}$ = (101706.983+101706.978+101706.981+101706.98+101706.977) /5

= 101706.979 m

$\bar{x}_{\text{Elevation ST.9}}$ = (890.315+890.333+890.329+890.317+890.335)/5 = 890.326 m

From The Table (4.22):

$\bar{x}_{\text{Easting ST.10}}$ = (158692.646+158692.635+158692.636+158692.644+158692.646)/5

= 158692.641 m

$\bar{x}_{\text{Northing ST.10}}$ = (101700.805+101700.8+101700.8 + 101700.806+101700.801) /5

= 101700.802 m

$\bar{x}_{\text{Elevation ST.10}}$ = (890.322+890.33+890.325+890.322+890.327)/5 =890.325 m

From The Table (4.23):

$\bar{x}_{\text{Easting ST.a}}$ = (158785.837+158785.807+158785.856+158785.815+158785.855)/5

= 158785.834 m

$\bar{x}_{\text{Northing ST.a}}$ = (101805.112+101805.11+101805.107+101805.109+101805.115) /5

= 101805.111 m

$\bar{x}_{\text{Elevation ST.a}}$ = (898.161+898.161+898.1+898.16+898.154)/5 = 898.147 m

From The Table (4.24):

$\bar{x}_{\text{Easting ST.c}}$ = (158632.42+158632.411+158632.449+158632.419+158632.42) / 5

= 158632.424 m

$\bar{x}_{\text{Northing ST.c}}$ = (101697.24+101697.246+101697.249+101697.245+101697.246) /5

= 101697.245 m

$\bar{x}_{\text{Elevation ST.c}}$ = (888.389+888.4+888.345+888.39+888.385)/5 = 888.382 m

From The Table (4.25):

$\bar{x}_{\text{Easting C1}}$ = (158655.363+158655.365+158655.365+158655.366+158655.365)/5

= 158655.265 m

$\bar{x}_{\text{Northing C1}}$ = (101709.299+101709.313+101709.310+101709.309+101709.313) /5

= 101709.309 m

$\bar{x}_{\text{Elevation C1}}$ = (902.063+901.974+901.993+902.005+901.975)/5 = 902.002 m

From The Table (4.26):

$\bar{x}_{\text{Easting C2}}$ = (158643.693+158643.693+158643.692+158643.693+158643.693)/5

= 158643.693 m

$\bar{x}_{\text{Northing C2}}$ = (101681.76+101681.748+101681.752+101681.759+101681.759) /5

= 101681.755 m

$\bar{x}_{\text{Elevation C2}}$ = (902.046+902.115+902.11+902.075+902.111)/5 = 902.091 m

Table (5.2): Mean Value for the RTK Test points

Point No.	Easting (m)	Northing (m)	Height (m)
ST.1	158769.928	101830.689	899.247
ST.3	158740.549	101809.565	894.996
ST.4	158836.232	101811.375	897.962
ST.5	158727.685	101853.526	897.794
ST.6	158664.977	101788.393	891.285
ST.7	158643.085	101739.631	889.252
ST.8	158669.021	101715.396	890.192
ST.9	158680.174	101706.979	890.326
ST.10	158692.641	101700.802	890.325
ST.a	158785.834	101805.111	898.147
ST.c	158632.424	101697.245	888.382
C1	158655.265	101709.309	902.002
C2	158643.693	101681.755	902.091

5.3 Mean standard deviation for RTK coordinates

We use The Excel Program to calculate the Standard Deviation:

Standard Deviation = ±S = $\sqrt{\frac{\sum_{1}^{n}(x-\bar{x})^2}{n-1}}$, x= reading, $\bar{x}$ = Mean value, n= number of readings.

Standard Deviation for Mean = ±S$_m$ = $\frac{\pm S}{\sqrt{n}}$

We Have Five Readings for each point ➔ (±S$_m$ = $\frac{\pm S}{\sqrt{5}}$)

Horizontal Error = $\sqrt{(S_{mE})^2 + (S_{mN})^2}$

Vertical Error = $\sqrt{(S_{mElevation})^2}$

Position Error or (RMS) = $\sqrt{\Delta_{Easting}{}^2 + \Delta_{Northing}{}^2 + \Delta_{Elevation}{}^2}$

From The Table (4.13):

$\pm S_{Easting\ 509}$ = 0.00141421

$\pm S_{Northing\ 509}$= 0.00282843

$\pm S_{Elevation\ 509}$=0.00212132

$\pm S_{m\ Easting\ 509}$= 0.00141421/√2 = 0.001

$\pm S_{m\ Northing\ 509}$=0.00282843/√2 =0.002

$\pm S_{m\ Elevation\ 509}$=0.00212132/√2 =0.0015

Horizontal Error =$\sqrt{((0.001)^2 + (0.002)^2)}$ = 0.00224

Vertical Error =$\sqrt{(0.0015)^2}$ =0.0015

$\pm S_{Easting\ 356n}$ = 0.005657

$\pm S_{Northing\ 356n}$ = 0.00424264

$\pm S_{Elevation\ 356n}$ =0.000707

$\pm S_{m\ Easting\ 356n}$ =0.005657 /√2 =0.004

$\pm S_{m\ Northing\ 356n}$ =0.00424264/√2 =0.003

$\pm S_{m\ Elevation\ 356n}$ =0.000707/√2 =0.0005

Horizontal Error =$\sqrt{((0.004)^2 + (0.003)^2)}$ = 0.005

Vertical Error =$\sqrt{(0.0005)^2}$ =0.0005

Table (5.3): Mean Standard Errors in the RTK Trig coordinates

Point No.	Easting (m)	Northing (m)	Height (m)	Horizontal Error (m)	Vertical Error (m)
509	159594.920	107256.978	1017.902	0.002	0.002
356n	155723.170	107271.316	875.600	0.005	0.001

From The Table (4.14):

$\pm S_{Easting\ ST.1}$ = 0.01128273

$\pm S_{Northing\ ST.1}$= 0.004393177

$\pm S_{Elevation\ ST.1}$ =0.026404545

$\pm S_{m\ Easting\ ST.1}$ = 0.01128273/√5 = 0.00504579

$\pm S_{m\ Northing\ ST.1}$ =0.004393177 /√5 =0.001964688

$\pm S_{m\ Elevation\ ST.1}$ =0.026404545/√5 =0.011808472

Horizontal Error =$\sqrt{((0.00504579)^2 + (0.001964688)^2)}$ = 0.005414795

Vertical Error =$\sqrt{(0.011808472)^2}$ =0.011808472

From The Table (4.15):

$\pm S_{\text{Easting ST.3}}$ =0.005932959

$\pm S_{\text{Northing ST.3}}$=0.016843396

$\pm S_{\text{Elevation ST.3}}$ =0.027862161

$\pm S_{\text{m Easting ST.3}}$ =0.005932959/√5 =0.0026533

$\pm S_{\text{m Northing ST.3}}$=0.016843396/√5 =0.007532596

$\pm S_{\text{m Elevation ST.3}}$ =0.027862161/√5 =0.012460337

Horizontal Error =$\sqrt{((0.0026533)^2 + (0.007532596)^2)}$ = 0.007986238

Vertical Error = $\sqrt{(0.012460337)^2}$= 0.012460337

From The Table (4.16):

$\pm S_{\text{Easting ST.4}}$ =0.005958188

$\pm S_{\text{Northing ST.4}}$ =0.013069047

$\pm S_{\text{Elevation ST.4}}$ =0.014113823

$\pm S_{\text{m Easting ST.4}}$ =0.005958188/√5 =0.002664583

$\pm S_{\text{m Northing ST.4}}$ =0.013069047/√5 =0.005844656

$\pm S_{\text{m Elevation ST.4}}$ =0.014113823/√5 =0.006311894

Horizontal Error =$\sqrt{((0.002664583)^2 + (0.005844656)^2)}$= 0.006423395

Vertical Error =$\sqrt{(0.006311894)^2}$= 0.006311894

From The Table (4.17):

$\pm S_{\text{Easting ST.5}}$ =0.007162402

$\pm S_{\text{NorthingST.5}}$=0.00130384

$\pm S_{\text{Elevation ST.5}}$ =0.000547723

$\pm S_{\text{m Easting ST.5}}$ =0.007162402/√5 =0.003203123

$\pm S_{\text{m NorthingST.5}}$=0.00130384/√5 =0.000583095

$\pm S_{\text{m Elevation ST.5}}$ =0.000547723/√5 =0.000244949

Horizontal Error =$\sqrt{((0.003203123)^2 + (0.000583095)^2)}$ = 0.003255764

Vertical Error =$\sqrt{(0.000244949)^2}$= 0.000244949

From The Table (4.18):

$\pm S_{Easting\ ST.6}$ =0.00248998

$\pm S_{Northing\ ST.6}$ =0.008927486

$\pm S_{Elevation\ ST.6}$ =0.011523888

$\pm S_{m\ Easting\ ST.6}$ =0.00248998/√5 =0.001113553

$\pm S_{m\ Northing\ ST.6}$ =0.008927486/√5 =0.003992493

$\pm S_{m\ Elevation\ ST.6}$ =0.011523888/√5 =0.005153639

Horizontal Error = $\sqrt{((0.001113553)^2 + (0.003992493)^2)}$ = 0.004144876

Vertical Error = $\sqrt{(0.005153639)^2}$ = 0.005153639

From The Table (4.19):

$\pm S_{Easting\ ST.7}$ =0.014363147

$\pm S_{Northing\ ST.7}$ =0.014741099

$\pm S_{Elevation\ ST.7}$ =0.003834058

$\pm S_{m\ Easting\ ST.7}$ =0.014363147/√5 =0.006423395

$\pm S_{m\ Northing\ ST.7}$ =0.014741099/√5 =0.00659242

$\pm S_{m\ Elevation\ ST.7}$ =0.003834058/√5 =0.001714643

Horizontal Error = $\sqrt{((0.006423395)^2 + (0.00659242)^2)}$ = 0.009204347

Vertical Error = $\sqrt{(0.001714643)^2}$ = 0.001714643

From The Table (4.20):

$\pm S_{Easting\ ST.8}$ =0.004393177

$\pm S_{Northing\ ST.8}$ =0.003974921

$\pm S_{Elevation\ ST.8}$ =0.006819091

$\pm S_{m\ Easting\ ST.8}$ =0.004393177/√5 =0.001964688

$\pm S_{m\ Northing\ ST.8}$ =0.003974921/√5 =0.001777639

$\pm S_{m\ Elevation\ ST.8}$ =0.006819091/√5 =0.00304959

Horizontal Error = $\sqrt{((0.001964688)^2 + (0.001777639)^2)}$ = 0.002649528

Vertical Error = $\sqrt{(0.00304959)^2}$ = 0.00304959

From The Table (4.21):

$\pm S_{Easting\ ST.9}$ =0.002408319

$\pm S_{Northing\ ST.9}$ =0.002387467

$\pm S_{Elevation\ ST.9}$ =0.009230385

$\pm S_{m\ Easting\ ST.9}$ =0.002408319/√5 =0.001077033

$\pm S_{m\ Northing\ ST.9}$ =0.002387467/√5 =0.001067708

$\pm S_{m\ Elevation\ ST.9}$ =0.009230385/√5 =0.004127953

Horizontal Error = $\sqrt{((0.001077033)^2 + (0.001067708)^2)}$ = 0.001516575

Vertical Error = $\sqrt{(0.004127953)^2}$ = 0.004127953

From The Table (4.22):

$\pm S_{Easting\ ST.10}$ =0.005458938

$\pm S_{Northing\ ST.10}$ =0.002880972

$\pm S_{Elevation\ ST.10}$ =0.003420526

$\pm S_{m\ Easting\ ST.10}$ =0.005458938/√5 =0.002441311

$\pm S_{m\ Northing\ ST.10}$ =0.002880972/√5 =0.00128841

$\pm S_{mElevation\ ST.10}$ =0.003420526/√5 =0.001529706

Horizontal Error = $\sqrt{((0.002441311)^2 + (0.00128841)^2)}$ = 0.002760435

Vertical Error = $\sqrt{(0.001529706)^2}$ = 0.00152970

From The Table (4.23):

$\pm S_{Easting\ ST.a}$ =0.022494444

$\pm S_{Northing\ ST.a}$ =0.00304959

$\pm S_{Elevation\ ST.a}$ =0.026546186

$\pm S_{m\ Easting\ ST.a}$ =0.022494444/√5 =0.010059821

$\pm S_{m\ Northing\ ST.a}$ =0.00304959/√5 =0.001363818

$\pm S_{m\ Elevation\ ST.a}$ =0.026546186/√5 =0.011871815

Horizontal Error = $\sqrt{((0.010059821)^2 + (0.001363818)^2)}$ = 0.010151847

Vertical Error = $\sqrt{(0.011871815)^2}$ = 0.011871815

From The Table (4.24):

$\pm S_{Easting\ ST.c}$ =0.014584238

$\pm S_{Northing\ ST.c}$ =0.003271085

$\pm S_{Elevation\ ST.c}$ =0.021300235

$\pm S_{m\ Easting\ ST.c}$ =0.014584238/√5 =0.00652227

$\pm S_{m\ Northing\ ST.c}$ =0.003271085/√5 =0.001462874

$\pm S_{m\ Elevation\ ST.c}$ =0.021300235/√5 =0.009525755

Horizontal Error = $\sqrt{((0.00652227)^2 + (0.001462874)^2)}$ = 0.00668431

Vertical Error = √ $(0.009525755)^2$= 0.009525755

From The Table (4.25):

±$S_{Easting\ C1}$ =0.001095445

±$S_{Northing\ C1}$ =0.005761944

±$S_{Elevation\ C1}$ =0.036482873

±$S_{m\ Easting\ C1}$ =0.001095445/√5 =0.000489898

±$S_{m\ Northing\ C1}$ =0.005761944/√5 =0.00257682

±$S_{m\ Elevation\ C1}$ =0.036482873/√5 =0.016315637

Horizontal Error = √ (($0.000489898)^2$+ $(0.00257682)^2$) = 0.002622975

Vertical Error =√ $(0.016315637)^2$= 0.016315637

From The Table (4.26):

±$S_{Easting\ C2}$ =0.000447214

±$S_{Northing\ C2}$ =0.005319774

±$S_{Elevation\ C2}$ =0.030071581

±$S_{m\ Easting\ C2}$ =0.000447214/√5 =0.0002

±$S_{m\ Northing\ C2}$ =0.005319774/√5 =0.002379075

±$S_{m\ Elevation\ C2}$ =0.030071581/√5 =0.01344842

Horizontal Error = √ (($0.0002)^2$+ $(0.002379075)^2$) = 0.002387467

Vertical Error =√ $(0.01344842)^2$= 0.01344842

Table (5.4): Mean Standard Error for the RTK Test points

Point No.	±$S_{m\ Easting}$ (m)	±$S_{m\ Northing}$ (m)	±$S_{m\ Height}$ (m)	Horizontal Error (m)	Vertical Error (m
ST.1	0.00504579	0.001964688	0.011808472	0.005414795	0.011808472
ST.3	0.0026533	0.007532596	0.012460337	0.007986238	0.012460337
ST.4	0.002664583	0.005844656	0.006311894	0.006423395	0.006311894
ST.5	0.003203123	0.000583095	0.000244949	0.003255764	0.000244949
ST.6	0.001113553	0.003992493	0.005153639	0.004144876	0.005153639
ST.7	0.006423395	0.00659242	0.001714643	0.009204347	0.001714643
ST.8	0.001964688	0.001777639	0.00304959	0.002649528	0.00304959
ST.9	0.001077033	0.001067708	0.004127953	0.001516575	0.004127953
ST.10	0.002441311	0.00128841	0.001529706	0.002760435	0.00152970
ST.a	0.010059821	0.001363818	0.011871815	0.010151847	0.011871815

ST.c	0.00652227	0.001462874	0.009525755	0.00668431	0.009525755
C1	0.000489898	0.00257682	0.016315637	0.002622975	0.016315637
C2	0.0002	0.002379075	0.01344842	0.002387467	0.01344842

Table (5.5): Mean Standard Errors in the RTK coordinates

Point No.	Easting (m)	Northing (m)	Height (m)	Horizontal Error (m)	Vertical Error (m)	Position Error (m)
ST.1	158769.928	101830.689	899.247	0.005	0.011	0.012
ST.3	158740.549	101809.565	894.996	0.008	0.012	0.014
ST.4	158836.232	101811.375	897.962	0.006	0.006	0.008
ST.5	158727.685	101853.526	897.794	0.003	0.001	0.003
ST.6	158664.977	101788.393	891.285	0.004	0.005	0.006
ST.7	158643.085	101739.631	889.252	0.009	0.002	0.009
ST.8	158669.021	101715.396	890.192	0.003	0.003	0.004
ST.9	158680.174	101706.979	890.326	0.002	0.004	0.005
ST.10	158692.641	101700.802	890.325	0.004	0.002	0.005
ST.a	158785.834	101805.111	898.147	0.011	0.012	0.017
ST.c	158632.424	101697.245	888.382	0.007	0.009	0.012
C1	158655.265	101709.309	902.002	0.003	0.016	0.016
C2	158643.693	101681.755	902.091	0.002	0.013	0.014

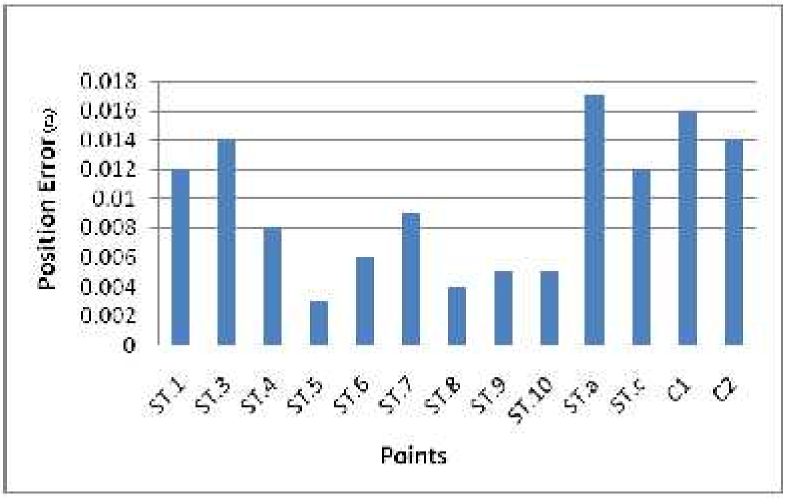

Figure (5.5): Comparison between the RTK points and position error

The figure above shows the magnitude of error in RTK at the short base line length, this error varies from reading to another; the maximum error is 0,017m between the RTK readings with different observation days. The figure used to find the RTK accuracy.

5.4 Comparison between the static and RTK measurements

$\Delta_{\text{Easting}} = (\text{Easting}_{\text{GPS point}} - \text{Easting}_{\text{Trig point}})$

$\Delta_{\text{Northing}} = (\text{Northing}_{\text{GPS point}} - \text{Northing}_{\text{Trig point}})$

$\Delta_{\text{Elevation}} = (\text{Elevation}_{\text{GPS point}} - \text{Elevation}_{\text{Trig point}})$

a) Comparison between static and Trig points:
From The Table (4.10) and the Table (4.11):

Table (5.6): Comparison between static and Trig points

Point NO.	Δ Easting (m)	Δ Northing (m)	Δ Height (m)	Horizontal Error (m)	Vertical Error (m)
563	-0.304	-0.067	0.338	0.311	0.338
509	-0.073	-0.352	0.223	0.359	0.223
HB14	0.191	-0.211	-0.135	0.285	0.135
552B	0.33	0	0	0.330	0
356n	0.471	-0.13	-0.009	0.489	0.009
Maximum Error				**0.489**	**0.338**

b) Comparison between Static and RTK for the trig points:
From The Table (4.11) and the Table (5.1):

Table (5.7): Comparison between Static and RTK trig points

Point NO.	Δ Easting (m)	Δ Northing (m)	Δ Height (m)	Horizontal Error (m)	Vertical Error (m)	Position Error (m)
509	0.187	-0.2	-0.129	0.274	0.129	0.303
356n	0.171	-0.196	-0.139	0.260	0.139	0.295
Error Average				**0.267**	**0.134**	**0.299**

c) Comparison between Static and RTK test points:

From The Table (4.12) and the Table (5.2):

Table (5.8): Comparison between Static and RTK Test points

Point NO.	Δ Easting (m)	Δ Northing (m)	Δ Height (m)	Horizontal Error (m)	Vertical Error (m)	Position Error (m)
ST.1	-0.035	0.004	0.023	0.035	0.023	0.042
ST.3	0.042	-0.056	0.054	0.070	0.054	0.088
ST.4	-0.032	0.018	-0.011	0.037	0.011	0.039
ST.5	-0.165	0.045	-0.043	0.172	0.043	0.177
ST.6	-0.077	0.019	0.047	0.080	0.047	0.093
ST.7	0.025	-0.171	-0.256	0.173	0.256	0.308
ST.8	-0.166	-0.055	-0.298	0.175	0.298	0.345
ST.9	0.141	0.242	-0.071	0.280	0.071	0.288
ST.10	-0.107	0.122	-0.319	0.162	0.319	0.357
ST.a	-0.024	-0.045	0.021	0.051	0.021	0.055
ST.c	0.021	-0.017	0.009	0.027	0.009	0.028
C1	0.045	-0.096	0.006	0.106	0.006	0.106
C2	-0.15	0.137	-0.108	0.203	0.108	0.229
Average Error				**0.121**	**0.097**	**0.166**

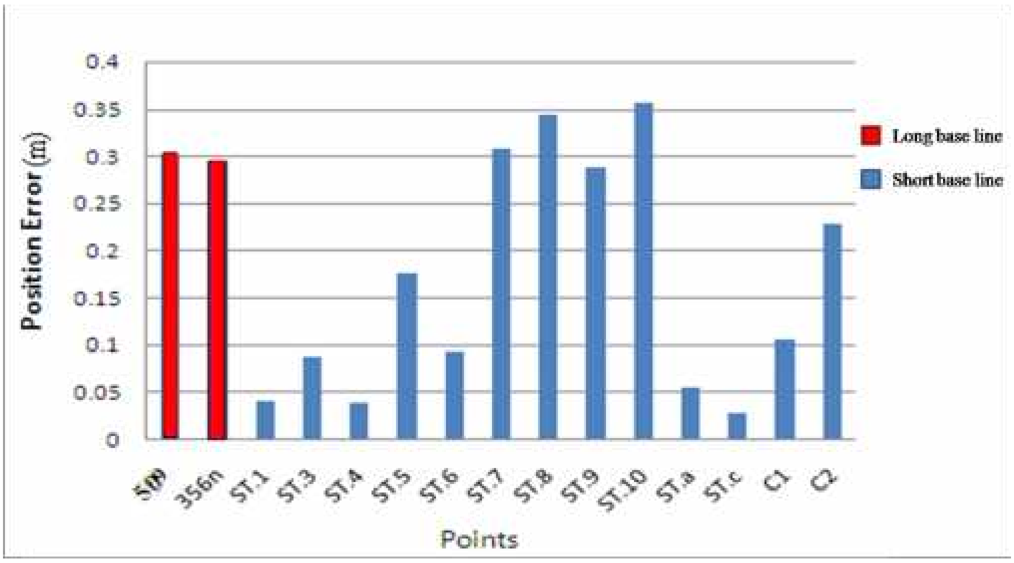

Figure (5.6): Comparison between static and RTK position error

The Figure above shows the error in the difference between Static and RTK in locations, the red columns for 2.5 Km base line, the blue for 220 m maximum base line. We note that no difference between the long base line position error and the short base line, so here; the distance error doesn’t effect.

5.5 Accuracy in RTK

The field accuracy for the RTK coordinates depends on the static measurements, from the table (5.8), RTK accuracy achieved to 2.7 cm in horizontal, and 0.6 cm in vertical.

But for the point around Al-Ahli hospital we calculate the repeated baseline difference, and then we specify the point order. Figure (5.9) shows below the computed PPM values.

Figure (5.9): The repeated baseline difference

Point No.	Max. Difference (m)	Baseline length (m)	PPM
509	0.004	1664.392	2.4
356n	0.008	2217.566	3.6

Depending on the table above ،these points can be classified using the PPM for order accuracy from the table (4.3), (1 < 3.6 < 10) PPM that means these points are classified as 4th order. And depending on the table (4.1), (3.6 < 100) PPM, so it's from 3rd order.

5.6 The Evaluation

The main task for this part is to evaluate the RTK technique regarding accuracy. Only human support was used so a big part of the error is related to the centering of the antenna over the point and measured antenna height.

To evaluate performance of the RTK method, test was carried out to assess the RTK achievable accuracy, and check the repeatability of the results; the test included a group of 15 points, marked on the ground. Two of them were taken approximately on Al-Ahli base station, and 13 were taken around the PPU University.

The static measurements are taken as reference to test the RTK points. The RTK and static field measurements were taken by Trimble 5700 receiver; the Field specifications are proportional to the standard specifications of the work as in the table (4.1).

Totally the position standard error of the RTK readings was sub-millimeter. The accuracy in vertical, horizontal and total (position) is different. The difference in RTK accuracy refer to change reading day to day, waiting for satellites and not having connection with at least five satellites, the receiver could not determine phase ambiguities and that are needed for the initialization.

While us observing measurements in the field we faced so many obstacles that make the readings impossible or hard to observe, such as radio link, and trig points are not seen form the base station and haven't known accuracies.

Improvements could be added to the conditions of reading through the use of planning software to choose the best time of monitoring and avoiding high DOP values, as well as the need to obtain a license for operating high powered radio links can represent a limitation in some countries. To achieve the best results, the antenna of the reference station should be placed in locations free from multipath and mounted as high as possible to maximize range coverage. And the possibility of using modern technology such as GSM.

CHAPTER

6 CONCLUSION AND RECOMMENDATIONS

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

6.2 RECOMMENDATIONS

This chapter outlines a summary of the main conclusions made in this project. A more detailed discussion could be read in chapter five.

This project is to evaluate the performance of RTK GPS observation technique regarding accuracy. The result of this study brought out many important conclusions. The main conclusions and recommendations drawn from the present study are summarized below.

6.1 Conclusion

1) For the short distances (less than 5km), differences between the RTK system and the fast static were about 2.7 cm for the horizontal Plane coordinates, and less than 1 cm along the height.
2) The RTK GPS does denote to have the capability of static GPS technique in positioning.
3) The Trimble planning software is useful for predicting the reading condition.
4) The RTK is more suitable and effective in open areas.
5) Using the specifications of the RTK GPS, yield to 3^{rd} order point position for the trig points and 4^{th} order for the RTK test points.

6.2 Recommendations

1) Building a geodetic network in Hebron.
2) Establish reference stations all over Palestine, which transmit there data, and so anyone in the area can receive these corrections and radically improve the accuracy of their GPS measurements.
3) Using the planning software for all GPS projects.
4) Using RTK with GSM communication instead of radio link.
5) Reference station should be placed in locations free from multipath and mounted as high as possible.

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APPENDIX A

TRIMBLE 5700 GPS RECEIVER

The Trimble 5700 GPS system is a versatile Trimble GPS receiver that is ideal for control, measurement, design, stakeout, or as-built survey work. It enables you to conduct real-time differential GIS grade surveys and navigation. The Trimble 5700 series offers fast and efficient data storage and communications. The Trimble 5700 can be set up on a pole or tripod, on a vehicle or in a backpack.

Application of the Trimble system include: bank top surveys, at point measurements and bathymetry (in channel surveying). The applications of all these can be extended to the creation of Digital Elevation Models (DEMs)/TINS/Meshes and application to the modeling of the environment including relative flow conditions.

Performance specifications:

Measurements

- Trimble R-Track technology
- Advanced Trimble Maxwell TM Custom Survey GNSS Chip
- High precision multiple correlator for GNSS pseudorange measurements
- Unfiltered, unsmoothed pseudorange measurements data for low noise, low multipath error, low time domain correlation and high dynamic response
- Very low noise GNSS carrier phase measurements with <1 mm precision in a 1 Hz bandwidth
- Signal-to-Noise ratios reported in dB-Hz
- Proven Trimble low elevation tracking technology
- 24 Channels L1 C/A Code, L1/L2 Full Cycle Carrier
- 2 additional channels for SBAS WAAS/EGNOS support

Code differential GPS positioning

Horizontal . . . . ±0.25 m + 1 ppm RMS

Vertical. . . . . ±0.50 m + 1 ppm RMS

WAAS differential positioning accuracy. . . . . . Typically <5 m 3DRMS

Static and Fast Static GPS surveying

Horizontal. . . . . ±5 mm + 0.5 ppm RMS

Vertical . . . . ±5 mm + 1 ppm RMS

Kinematic surveying

Horizontal . . . . ±10 mm + 1 ppm RMS

Vertical . . . . ±20 mm + 1 ppm RMS

Initialization time. . . . . Typically <10 seconds

Initialization reliability . . . . typically >99.9%

APPENDIX B

LEAST SQUARE ADJUSTMENT OF GPS

GPS network contain redundant measurements, they must be adjusted to make all coordinate difference consistent. In applying least squares to the problem of Adjustment baselines (Base To Rover) in GPS networks, observation equations are written that relate station coordinates to observed coordinate differences and their residual errors, an observation equation can be written for each measured baseline component as:

$X_R = X_B + \Delta X_{BR} + V_{X\,BR}$

$Y_R = Y_B + \Delta Y_{BR} + V_{Y\,BR}$

$Z_R = Z_B + \Delta Z_{BR} + V_{Z\,BR}$

If the observation equation for adjusting the network are written in the same order that the measurement are listed in chapter four in tables, the A, X, L ,V ,and W matrices would be. The system of observation equation is solved by least squares using equation:

$AX = L + V$

$X = N^{-1} (A^T W L).$

$N = (A^T WA).$

A= Jacobian matrix, L= known's matrix, V= residual matrix, X= unknown's matrix, N= normal matrix.

Calculate the reference standard deviation for the adjustment using the matrix expression of Equation $S_0 = \sqrt{\frac{V^T WV}{r}}$.

r = m-n, m is the number of observation and n is the number of unknown.

The estimated standard deviation S_i, for any unknown parameter, having been computed from a system of observation equations, is expressed as:

$S_i = S_0 \sqrt{Q_{Xi\,Xi}}$, where $Q_{xi\,xi}$ is the diagonal element (from the i^{th} row and i^{th} column) of The Q_{xx} matrix, $Q_{xx} = (A^T WA)^{-1}$.

APPENDIX C

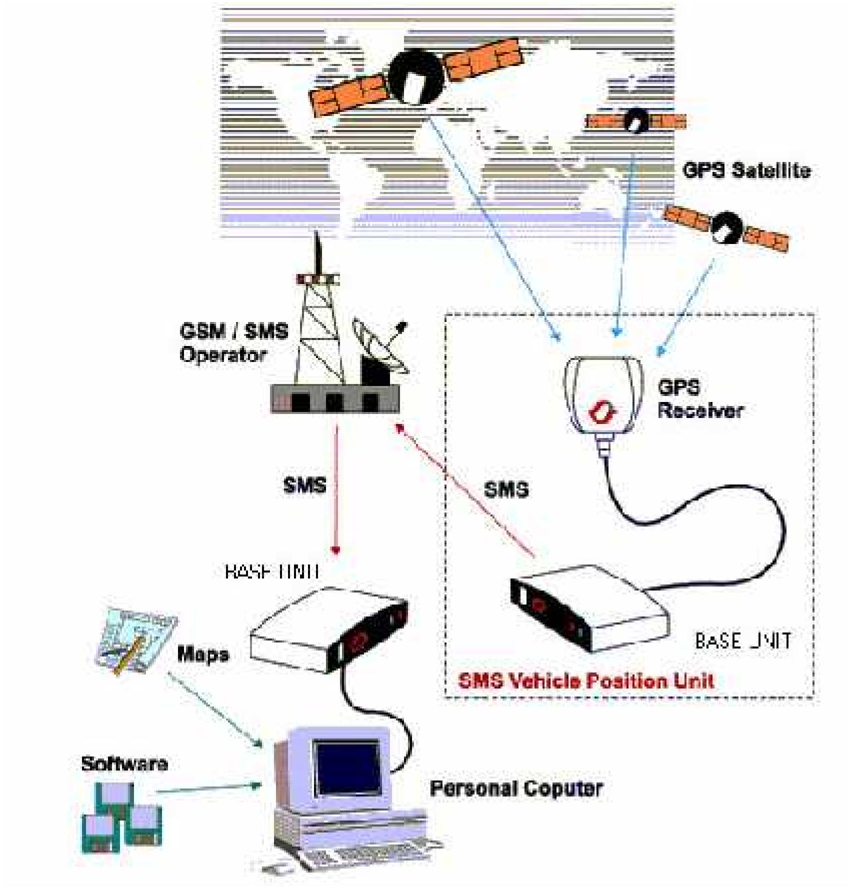
GENERAL PACKET RADIO SERVICE (GPRS)

GPRS is a packet oriented mobile data service available to users of the 2G cellular communication systems global system for mobile communications (GSM), as well as in the 3G systems. In the 2G systems, GPRS provides data rates of 56-114 Kbit/s.

GPRS data transfer is typically charged per megabyte of traffic transferred, while data communication via traditional circuit switching is billed per minute of connection time, independent of whether the user actually is using the capacity or is in an idle state. GPRS is a best-effort packet switched service, as opposed to circuit switching, where a certain quality of service (QOS) is guaranteed during the connection for non-mobile users.

2G cellular systems combined with GPRS are often described as 2.5G, that is, a technology between the second (2G) and third (3G) generations of mobile telephony. It provides moderate speed data transfer, by using unused time division multiple access (TDMA) channels in, for example, the GSM system. Originally there was some thought to extend GPRS to cover other standards, but instead those networks are being converted to use the GSM standard, so that GSM is the only kind of network where GPRS is in use. GPRS is integrated into GSM Release 97 and newer releases. It was originally standardized by European Telecommunications Standards Institute (ETSI), but now by the 3rd Generation Partnership Project (3GPP).

GPRS was developed as a GSM response to the earlier CDPD and I-mode packet switched cellular technologies.



GPRS upgrades GSM data services providing:

- Multimedia messaging service (MMS)
- Short message service (SMS)
- Push to talk over cellular (POC/PTT)
- Instant messaging and presence-wireless village
- Internet applications for smart devices through wireless application protocol (WAP)
- Point-to-point (P2P) service: inter-networking with the Internet (IP)
- Future enhancements: flexibility to add new functions, such as more capacity, more users, new accesses, new protocols, new radio networks.