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POSITIONAL PRECISION ASSESSMENT OF DIFFERENT GNSS RECEIVERS IN SURVEY STATIC MODE UNDER MULTIPATH EFFECT

MAKARABO, SAMMY A

BSc (Geomatics) Dissertation

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POSITIONAL PRECISION ASSESSMENT OF DIFFERENT GNSS RECEIVERS IN SURVEY STATIC MODE UNDER MULTIPATH EFFECTS

MAKARABO, SAMMY A

A Dissertation Submitted to the Department of Geospatial Sciences and Technology in Partially Fulfilment of the Requirements for the Award of Science in Geomatics (BSc. GM) of Ardhi University

CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the Ardhi University dissertation titled **"Positional Precision Assessment of Different GNSS Receivers in Survey Static Mode Under Multipath Effects"** in partial fulfillment of the requirements for the award of degree of Bachelor of Science in Geomatics at Ardhi University.

……………………………….	**………..**
Dr. Elifuraha Saria	**Ms. Valerie Ayubu**
(Main Supervisor)	(Second Supervisor)
Date: ……………………….	**Date: ……………………….......**

DECLARATION AND COPYRIGHT

I, MAKARABO SAMMY A hereby declare that, the contents of this dissertation are the results of my own findings through my study and investigation, and to the best of my knowledge they have not been presented anywhere else as a dissertation for diploma, degree or any similar academic award in any institution of higher learning.

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MAKARABO SAMMY A

22823/T.2019

Date……………………………

DEDICATION

I dedicate this dissertation work to my beloved Parents; Mr and Mrs Ahmed Makarabo for their outstanding support throughout my studies. This work is also highly dedicated to my uncle Mr Sammy Mbegalo. Last but not least, I would like to thank my brothers and sister, for their courage and support. I sincerely appreciate and I'm indebted for their love, concern, comfort, encouragement and support they have provided to me.

May almighty GOD bless them all forever.

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Any errors that might appear in this report are my sole responsibility and should not be associated with any of the individuals referred above. No words can express my gratitude and my appreciation, but all I can say is, GOD blesses you all.

ABSTRACT

The rapid advancement of Global Navigation Satellite System (GNSS) technology has led to an increased reliance on GNSS receivers for precise surveying applications. However, the presence of multipath effects, caused by signal reflections, can significantly impact the positional accuracy of GNSS receivers. This study aims to assess the positional precision of various GNSS receivers in survey static mode under the influence of multipath effects.

To achieve this objective, a field experiment was conducted in a diverse range of environments, including points located under trees, buildings and open space. Leica GS15 and CHCNAV i50 GNSS receivers from different manufacturers were deployed, and their performances were evaluated by comparing their positional data with ground truth coordinates obtained through traditional surveying methods. The assessment of positional precision under multipath effects involved a rigorous analysis of the GNSS receivers' data, considering factors such as satellite visibility and satellite constellation geometry. The impact of multipath on positional accuracy was quantified, and the receivers' performance was ranked based on their ability to mitigate multipath-induced errors.

The results of the study provide valuable insights into the strengths and limitations of the above mentioned GNSS receivers in surveying static mode on their performance under challenging environments. The study found that Leica GS15 for the horizontal position accuracy of points located under tall buildings was the best compared to the CHCNAV i50 and for the points located under trees, CHCNAV i50 provided the best horizontal positional accuracy. Also, for the points located on a good horizon both of the receivers performed well in providing horizontal position accuracy. This finding contributes in improving the understanding of GNSS receiver behavior under multipath conditions and can aid surveyors, engineers, and researchers in making informed decisions regarding receiver selection and data processing techniques to enhance positional accuracy in diverse surveying applications. Moreover, this research serves as a crucial step towards optimizing GNSS surveying methodologies in complex environments, ultimately supporting the development of more accurate and reliable positioning solutions.

Keywords: Global Navigation Satellite System (GNSS), Multipath effect.

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LIST OF ABBREVIATIONS

ARU	Ardhi University
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GAMIT	General Aviation Multi-Engine Instrument Trainer
TBC	Trimble Business Center
TEQC	Translating Editing and Quality Check (TEQC)
UTM	Universal transverse Mercator
WGS84	World Geodetic System of 1984
DOP	Dilution of Precision
QC	Quality Check
RINEX	Receiver Independent Exchange Format
MP	Multipath
CP	Control point
TP	Tree point
GS	Good sky
BP	Building point

CHAPTER ONE

INTRODUCTION

This chapter describes the topic of positional precision assessment of different GNSS receivers in static survey mode under multipath effect. It provides background information on GNSS technology and challenges of GNSS positioning including multipath effect. The problem statement identified the need to evaluate the positional precision of different GNSS receivers under multipath effect in static mode.

1.1 Background

Positional accuracy refers to ability of obtaining precise Geodetic position of a point. This is contributed by method of data collection and data processing strategies. Precise position of a point can be determined using terrestrial method e.g., Total station / Theodolite or Space method using GNSS or other methods. This study investigates Positional accuracy of points using different GNSS receivers under different Sky view condition. The reason for different sky view condition is to study multipath effect on positioning.

The position accuracy of GNSS receivers depends on various factors such as; The Geometry of satellite relate to the receiver can affect the accuracy of the positioning information, Environmental conditions e.g., weather can also affect the accuracy of positioning information example heavy rain or fog can reduce signal quality or the nature of Environment (clear sky view versus canopy areas), the algorithms and Software used to process the positioning information affects the accuracy. The use of advanced algorithms such as Kalman filters help to improve the accuracy of the positioning information and lastly is Receiver design and technology, the technology used in a receiver such as the antenna and processing power also affects the accuracy of the positioning information since more advanced receivers with better antennas and processing power provides greater accuracy (Andrew *et al*., 2007).

Due to Environmental factors the position accuracy is likely to be affected by the presence of multipath errors. Multipath errors occur when GNSS signals are reflected off by buildings, trees or other obstacles before reaching the GNSS receiver, causing the receiver to calculate an incorrect position (Wellenhof, 2008). The degree to which the multipath effect influences position accuracy depends on the specific GNSS receiver being used and the conditions under which the measurement is taken (either open sky view or under canopy areas).

Different studies have shown that GNSS receivers can perform differently in areas affected by the multipath effect, hence in positioning these GNSS receivers have some differences.

Different GPS receivers may have different sensitivity to multipath, depending on factors such as their antenna design and receiver technology. For example, some GPS uses specialized antennas to mitigate the effect of multipath and achieve greater accuracy. Other receivers use advanced algorithms to filter out the multipath signals and improve accuracy. Multipath occurs when GPS signals are reflected off to the buildings, trees or other objects before reaching the receiver, causing the receiver to receive multiple copies of the same signals with different phase shifts, these results in positioning errors and decreases accuracy.

1.1.1 Development of satellite technology and their errors

Today's application of global positioning systems (GPS) as a means of fast, efficient and relatively inexpensive data collection is increasing and has been used for many different purposes compared to the conventional methods which proved to be weak comparing to satellite positional techniques. The use of conventional methods such as triangulation, trilateration and traversing require the line of sight during measurements/observations which has the effects in some areas with number of obstructions. Satellite technology has improved the weakness of conventional methods by means of providing accurate positions in real time quickly and inexpensively all around the world (Pirti, 2008). The Global positioning system (GPS) is one of the systems which is most important tools for data collection in natural resources, environment and urban forest management.

The urban forest may be defined as the assemblage of woody and other vegetation that lies within an urban area, or that forest structure which is regularly subjected to influences of an urban nature. Management of urban forests where conditions change rapidly can be challenging and requires the availability of current and comprehensive information. Geospatial tools such as GPS works extremely well for gathering information. These provide extensive, timely and low-cost spatial data. Since the satellite technology uses the satellite found in space for providing the position to the receiver by means of satellite signals transmission from the space to the receiver through its path, electromagnetic waves can be affected by several sources of error during their transmission.

Source of errors which affect satellite technology include;

i. antenna height measurements and satellite geometry
ii. satellite and receiver clock biases
iii. ionospheric and tropospheric refraction
iv. satellite ephemeris errors
v. multipath
vi. instrument mis centering

All of these errors contribute to the total error of satellite-derived coordinates in the ground stations (Mwaisenye, 2021).

1.1.2 Review of previous work

Previous research e.g., Ijaware & Nnamani (2020), Investigated the performance three different GPS receivers in environment with obstructions. The receivers used in the research were SouthH66/H88, Sokkia radian IS and ProMark3. The results from study found that the comparison of the average horizontal misclosure between the receivers show that south was the best since it had lower value of 0.1337m followed by Promark with 0.1625m and Sokkia had 0.2425m, hence South was the best in obtaining geographical information in horizontal position. While in average vertical misclosure showed that Sokkia had the lowest value of 0.0902m followed by Promark with 0.2336m and lastly was South with 0.2771m, hence Sokkia was the best in obtaining geographical information in vertical positioning. Therefore, this study evaluated the accuracy of coordinates of selected points obtained from three GPS receivers using appropriate statistics (Ijaware & Nnamani, 2020).

Previous research e.g., Mauro & Valbuena (2010), Investigated the performance of four different GPS receivers under forest canopies in mountainous environment and the receivers used in the research were Leica GS50, SR530, Topcon HiperPro and GMS2. The GNSS observations for 16plot-landmark situated under canopy were acquired in 2007 with Leica GS30 and SR30 at 1s logging rate. In 2008 observations were repeated by setting up a HiperPro and a GMS2 receivers at each plot-landmark, observations were obtained with all receives at the same time by shifting them from one plot-landmark to the next so that it can be assumed no differences in their recording conditions and these observations were taken with all receivers and antenna height ranged from 1.01m to 1.86m. The accuracy of each measurement was evaluated by means of the horizontal and vertical positional absolute errors, therefore the study provided different results from different receivers at different intervals of time observation (Mauro & Valbuena, 2010)

A most recent study e.g., Jain & Schon (2021), Investigated the performance evaluation of GNSS receiver clock modeling in urban navigation using geodetic and high sensitivity receivers. The receivers used in the study were JAVAD 0082 and HS u-blox 1771. The results show that urban positioning with HS u-blox 1771 and JAVAD 0082 receivers integrated with external clock (e.i RCM applied) surpasses the results with RCM, with RCM there is a significant improvement in precision of height component and vertical velocity, vertical component of both the JAVAD 0082 and HS u-blox 1771 receivers are largely reduced when RCM is applied. The standard deviation along the horizontal component with RCM for the complete experiment duration was about 1.5m for JAVAD 0082 and 2.5m for u-blox 1771 respectively. Without RCM, there is no significant difference in precision of horizontal components. In terms of availability the HS u-blox 1771 receiver performs slightly better than JAVAD 0082 (Jain & Schon, 2021).

The final study investigated GPS signal multipath error mitigation technique (Bidikar, *et al*, 2020). The study developed an algorithm to mitigate multipath error on the pseudorange measured from L1 carrier frequency. The algorithm proposed aimed at avoiding the complex calculations parameters such as reflection coefficient of the nearby reflectors when removing multipath errors. The GPS positioning was calculated considering pseudorange correction for all visible satellites during observations. The results obtained after using the proposed algorithm shown maximum multipath error reduction of 30m in receiver position estimates Since the algorithm proposed avoids the complex sensitive parameters, it is then useful for observations obtained from the sites where reflection coefficients are difficult to be measured.

In contrast to the current research, the receivers used are Leica GS15 and CHCNAV i50 in which static method was employed on areas with different sky view condition e.g., areas located close to tall buildings, trees and good horizon. By observing the diverse locations of the established control points at Ardhi University helped to reach research's objectives and the software used to process GPS data was Trimble Business Center. The study aimed to assess the GNSS receiver that perform the best among the two GNSS receivers tested in the research, the study compared the repeatability of position measurements taken in conditions where multipath errors are present and the results obtained from the study provides insight to which GNSS receiver gives a reasonable accuracy in area affected by multipath.

1.2 Statement of problem

In recent years GNSS receivers have become widely used to improve efficiency and accuracy since it provides a position within a few centimeters-level of accuracy, centimeter positioning requires accurate measurements that means position or a point should be free from obstructions, therefore due to multipath effect which are influenced by increase/rapid population growth some of areas of survey are be affected, many of GNSS receivers that are used in surveying fields are highly affected by multipath effect this is because many of GNSS receivers found in our survey field are those affordable GNSS receivers that are highly affected compared to the costly advanced GNSS receivers produced by Leica and Trimble company. Since different GNSS receivers are used there is a lack of understanding on how different GNSS receiver designs and configurations affect their performance under multipath effect. Therefore, it is necessary to assess the performance of different GNSS receivers in static survey mode under multipath effect. The GNSS receivers which used in this study are Leica GS15 and CHCNAV i50 to come up with a receiver that provides a reasonable accuracy in areas affected by multipath.

1.3 Objectives of the study

1.3.1 Main objective

The main objective of this research is to assess the positional precision of different GNSS receivers in static survey mode under the effect of multipath. The study aims to compare the performance of different GNSS receivers, specifically the precision and accuracy of their calculated positions in an urban environment where multipath errors are prevalent.

1.3.2 Specific objectives

i. To compare the performance of different GNSS receivers in terms of the precision and accuracy of their calculated positions under multipath effect
ii. To determine the impact of multipath errors on the performance of GNSS receivers in an urban environment (area surrounded by multipath).
iii. To provide a better understanding of the impact of multipath errors on GNSS receiver performance and help to identify methods for mitigating these errors.

1.4 Significance of the research

This research provides knowledge on understanding of GNSS receivers performance. The study provides valuable insight into the performance of different GNSS receivers under multipath effect in different Sky view condition. Through this research it will help in making selection of GNSS receivers which is more favorable to perform under canopy areas and bring a reasonably accurate data works in terms of horizontal (X, Y) and vertical (Z) positions.

1.5 Beneficiaries of the research

Expected users of this research includes:

i. The professionals (Land surveyors).

The level of accuracy required from different survey applications like cadastral survey, topographic survey, engineering survey and others varies greatly. Therefore, selecting a GPS receiver with acceptable accuracy and a reasonable price is important for the surveyors.

ii. Societies.

For the work which is done by the surveyor which gives us accurate measurements/results by providing true positioning then it benefits the society example in cadastral survey, recovery of lost boundary marks (beacons) and conflicts is reduced between neighbors in boundary sub-divisions.

1.6 Scope of the research

This research focuses on assessing the positional precision of different GNSS receivers in static survey mode under multipath effect, the study conducted at Ardhi University in which two GNSS receivers was used in static observations, Observation was carried out in different Sky view condition (multipath versus clear sky view). After observation done the data collected was processed by Trimble software.

1.7 Dissertation outline

The dissertation report consists of five chapters, arranged by following all the procedures to accomplish the preparation and presentation of the study; Positional precision assessment of different GNSS receivers in static survey mode under multipath effect.

Chapter one, it introduces the background information on GNSS technology and challenges of GNSS positioning including multipath effect. The problem statement identified the need to evaluate the positional precision of different GNSS receivers under multipath effect in static mode. Chapter two, it briefly describes the reviews and theories on GNSS, explains the current research, and the sources of error in GPS observation. Also, it explained about Multipath effect with impact and contribution to multipath as well as the method and techniques for mitigating multipath effect. Chapter three, it briefly provides an explanation of the steps/procedures taken to achieve the research's objective. Chapter four, it explains the obtained results and discussion. Chapter five, it provides the conclusion obtained from the results and discussion of the finding and recommendations for the further studies.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter consists of Reviews and Theories on GNSS and its relationship to source of error in GPS observation. Also, it describes about Multipath effect with impact and contribution to multipath as well as the method and techniques for mitigating multipath effect.

2.2 Global Navigation Satellite System (GNSS)

The term GNSS is used to refer to all the satellite-based navigation systems, which includes all satellite radio-navigation systems that are accessible globally and provide signals for navigation, positioning, surveillance and timing information for ground, marine, aviation and space application (Wellenhof, 2008). Global Navigation Satellite Systems (GNSS) have become an essential tool for a wide range of applications, such as surveying, navigation, and precision positioning.

GNSS provides autonomous geo-spatial positioning with global coverage, the GNSS allows small electronic receivers to determine their location (latitude, longitude, altitude) to within a few meters using time signals transmitted along a line of sight by radio from satellites. Receivers on the ground with fixed position can also be used to calculate the precise time as a reference for scientific experiments.

Receivers that use GPS satellites and another system such as the Global Navigation Satellite System which is operated by the Russians military (GLONASS), Galileo is the satellite navigation system developed by Europeans, Indian Regional Navigation Satellite System (IRNSS) and Beidou which is a Chinese system. These systems provide precise timing and positioning information anywhere on the Earth with high reliability and low cost. These systems can be operated day or night, rain or shine, and do not require cleared lines of sight between survey stations (Wellenhof, 2008).

2.2.1 GNSS Positioning.

Global Navigation Satellite System Is a timing system whereby all satellites know their exact positions and all satellite clocks have been synchronized. The satellites broadcast coded signals at exact times and the users receive these coded messages and can estimate time taken by each satellite signals to travel from the GNSS satellite antenna to the receiver's antenna. Once the time of flight is estimated, the distance can be approximated by multiplying the time of flight by the speed of light, arriving at a distance in meters for each satellite.

The GNSS also broadcasts messages that enable the user's receiver to determine the satellite antenna position at the time the signal was received. To estimate the ground antenna position the receiver must measure the time delay from at least four numbers of satellites, for unknown has to be estimated (X, Y, Z and T) (Schofield & Breach, 2007). In Figure 2.1 shows the intersection of the four measured ranges.

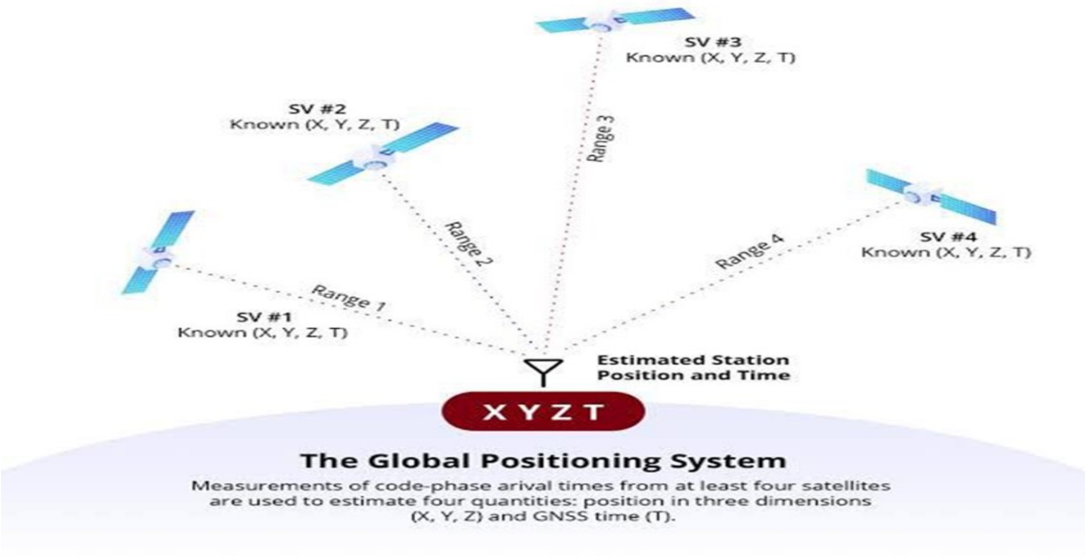

Figure 2. 1 GNSS Trilateration, code Positioning (Tallysman, 2019)

2.2.2 Static positioning

This method is used to give high precision over long baselines such as are used in geodetic control surveys. One receiver is set up over a station of known X, Y, Z coordinates, preferably in the WGS 84 reference system, whilst a second receiver occupies the station whose coordinates are required. Observation times may vary from 30 min to several hours. This long observational time is necessary to allow a change in the relative receiver/satellite geometry in order to calculate the initial integer ambiguity terms. Accuracies in the order of 5 mm ± 1 ppm of the baseline are achievable as the majority of errors in GPS such as clock, orbital and atmospheric error are eliminated or substantially reduced by the differential process. The use of permanent active GPS networks established by a government agency or private company could result in a further increase in accuracy for static positioning.

Apart from establishing high precision control networks, it is used in control densification using a leap-frog technique; measuring plate movement in crustal dynamics and oil rig monitoring (Schofield & Breach, 2007).

2.2.3 Source of Errors in GPS Observations

GPS pseudo range and carrier phase measurements are both affected by several types of errors and biases (systematic errors). These errors may be classified as

i. those originating at the satellites,
ii. those originating at the receiver and
iii. those originating due to signal propagation (atmospheric refraction).

Most high-performance receivers generate range and phase measurements. The range measurement from a receiver is referred to as the pseudorange. As it denotes the receiver antenna to satellite antenna distance plus the clock bias. The range measurement from a receiver also contains various other small error components and is given by (Wells & Beck, 1987).

$$P = p+dp + c(dt-dT) + dion + dtrop + dhw +Ep + Emp \text{ (Pseudorange)} \quad [2.1]$$

where

P is the measured code range

p is the geometric range between the satellite and receiver antennas

dp is the orbital error

c is the velocity of light

dt is the satellite clock error with respect to GPS time

dT is the receiver clock error with respect to GPS time

dion is the ionospheric delay error

dtrop is the tropospheric delay error

dhw is the hardware delay in the satellite and in the receiver

Emp is the code range multipath error and

Ep is the receiver code noise

Similar to the code measurement. The carrier phase measurement from a receiver contains many error components and is given by (Wells & Beck, 1987).

Φ = p+dp + c (dt-dT) + λN-dion + dtrop +dhw +Eq +Emq (Carrier phase) ⌊2.2⌋

where

Φ is the measured carrier phase (rn)

λ is the carrier wavelength (m)

N is the integer cycle ambiguity (cycles)

Emq is the carrier phase multipath error (m). And

Eq is the receiver carrier noise (m).

By comparing these Equations, it can be seen that the code range and carrier phase measurements differ in the following ways:

a) Phase measurement contains one additional term corresponding to the integer cycle ambiguity

b) The ionospheric delay error has an opposite sign in the two expressions

c) The code multipath error in Equation 1 is replaced by carrier multipath error in Equation 2

d) The code noise in Equation 1 is replaced by carrier noise in Equation 2

(a) Satellite clock error

Excessive temperature variations in space may result in the variation of the satellite clock from GPS time. GPS position calculations depend on measuring signal transmission time from satellite to receiver, this (Gottapu & Kumar, 2014)depends on knowing the time when the signal left the satellite and reached to the receiver. NAVSTAR satellites use atomic clocks which are more accurate but they can drift up to a millisecond which is enough to make an accuracy difference. Careful monitoring allows the amount of drift to be assessed and included in the broadcast message and therefore eliminated if the user is using the same data.

The satellite clock error is the difference between the true GPS time and the time maintained by a satellite. Though the satellite contains highly stable atomic clocks. They drift with time. This drift is closely monitored by the monitor stations. The master control station estimates the drift and transmits clock correction parameters to the satellite for rebroadcast in the navigation message which is used to correct the time and measurements in a receiver (Van Dierendonck, 1980).

(b) Receiver clock error

This error is a result of the receiver clock not being compatible and in the same time system as the satellite clock. Range measurement is thus contaminated (pseudo-range). As the speed of light is approximately 300 000 km s–1, then an error of 0.01 s results in a range error of about 3000km, this error can be obtained using four satellites or canceled using differencing software.

The receiver noise in the code measurement is due to high frequency thermal noise jitter and the effect of dynamic stress on the code tracking loop (Leva, 1996). Other sources of receiver error include hardware and software resolution and oscillator stability. The C/A code receiver noise is generally one order of magnitude higher compared to that of P code because the chip width of C/A code is ten times that of P code. It is in the order of a few decimeters in most modem receivers. The receiver noise in the phase measurement is mainly due to thermal noise. Dynamic stress and the oscillator phase noise. When a frequency lock loop is used for carrier tracking instead of a Phase lock loop (PLL). the phase noise is an order of magnitude higher. The signal to noise ratio (SNR) of the carrier directly affects the phase measurement accuracy. The phase noise is in the order of a few millimeters in most modem receivers (Leva, 1996).

(c) Ionospheric delay errors

The ionospheric delay is the error in range and range rate due to the propagation of the GPS signal through the ionospheric medium. located 50-1000 km above the earth's surface. The lower 100 km of the ionosphere has negligible effect on the GPS signal. It is the upper part of the ionosphere that has the highest variability causing potential problems to the GPS receiving systems (Klobuchar & Goodman, 1996). The major effects of the ionosphere on GPS are group delay or pseudorange error, phase advance or carrier phase error, doppler shift, faraday rotation of linearly polarized signal, refraction of the radio wave, distortion of the pulse waveform, signal amplitude fading or scintillation and signal phase scintillations. The magnitude of ionospheric error is a function of the sunspot number. time of day. receiver location and satellite elevation angle.

The ionosphere is a dispersive medium which enables dual frequency (L1-L2) receivers to take advantage of it and estimate the first order ionospheric delay error directly. However, slow varying multipath errors corrupt the L1 and L2 measurements and are hindrances to accurate estimation of ionospheric errors.

The equation below shows ionospheric range delay error at LI and L2 is

$$d_{ion} = \frac{f_2^2}{f_1^2 - f_2^2}(P_1 - P_2) \qquad [2.3]$$

Where,

f_1, f_2 are the GPS L1, L2 frequencies (Hz). and

P_1, P_2 are the GPS range measurements at L1 and L2 frequencies.

For single frequency users the ionospheric delay error can be partially corrected up to50% on an average by utilizing the satellite broadcast ionospheric delay coefficients in the half-cosine ionospheric delay model (Klobuchar *et al*., 1987).

Taking advantage of the ionosphere's dispersive nature, the ionospheric delay can be determined with a high degree of accuracy by combining the P-code pseudo range measurements on both L1 and L2. Unfortunately, however, the P-code is accessible by authorized users only. With the addition of a second C/A-code on L2 as part of the modernization program, this limitation will be removed. The L1 and L2 carrier-phase measurements may be combined in a similar fashion to determine the variation in the ionospheric delay, not the absolute value. Users with dual- frequency receivers can combine the L1 and L2 carrier phase measurements to generate the ionosphere-free linear combination to remove the ionospheric delay. The disadvantages of the ionosphere-free linear combination, however, are:

i. it has a relatively higher observation noise, and
ii. it does not preserve the integer nature of the ambiguity parameters.

As such, the ionosphere-free linear combination is not recommended for short baselines. Single-frequency users cannot take advantage of the dispersive nature of the ionosphere. They can, however, use one of the empirical ionospheric models to correct up to 60% of the delay.

(d) Tropospheric delay error

The troposphere affects the GPS L-band signal in terms of signal attenuation. Scintillation and delay. The delay error is caused by wet (up to about 11km) and dry (up to about 40 km) components of the atmosphere. and is a function of the satellite elevation and atmospheric conditions such as temperature pressure and relative humidity.

The dry component of the tropospheric error constitutes around 80% of the total error. and can be modeled within 2-5%. The wet component of the error is due to water vapour in the atmosphere and is more difficult to model. There are several models that estimate the tropospheric error. (Black & Eisner, 1984) proposed a constant lapse rate model for troposphere that estimates delay as a function of elevation. (Hopfield, 1963) developed separate zenith models for the dry and wet components of the troposphere. That is further extended by (Black & Eisner, 1984) to include elevation angle mapping function.

(e) Human error (Slant Height Measurement)

In satellite surveying, pseudoranges are observed to the receiver antenna's phase center. For precise work, the antennas are generally mounted on fixed height tripods, set up and carefully centered over a survey station, and leveled. Miscentering of the antenna over the point is another potential source of error. Setup and centering over a station should be done carefully; any error in miscentering of the antenna over a point will translate directly into an equal-sized error in the computed position of that point. Observing the height of the antenna above the occupied point is another source of error in satellite surveys (wellenhof, 2008). The ellipsoid height determined from satellite observations is determined at the phase center of the antenna. Therefore, to get the ellipsoid height of the survey station, it is necessary to measure carefully, and record the height of the antenna above the occupied point.

(f) Multipath error

Multipath describes the observable event in which signals from the GNSS satellites travel over multiple paths before they arrive at the receiver, the satellite signals arrive at the receiver on two kinds of different paths, direct one and indirect ones. Since the indirect path is longer than the direct path, multipath arrivals are delayed compared to the direct one (Wellenhof, 2008). These multiple paths are due to the fact that the signal gets reflected back to the antenna off surrounding objects, including the earth's surface. The GPS receiver tracks both the direct and reflected signal components. The radio wave transmitted from a satellite radiates in all directions, these radio waves including reflected waves that are reflected off due to various obstacles, diffracted waves, scattering waves, and the direct wave from the satellite to GPS receiver. In this case, since the path lengths of the direct, reflected, diffracted, and scattering waves are different, the time each takes to reach the GPS receiver will be different. In addition, the phase of the incoming wave varies because of reflections. As a result, the receiver receives a superposition consisting of several waves having different phase and times of arrival. The generic name of a radio wave in which the time of arrival is retarded in comparison with this direct wave is called a delayed wave. Then, the reception environment characterized by a superposition of delayed waves is called a multipath propagation environment. In a multipath propagation environment, the received signal is sometimes intensified. This phenomenon is called multipath fading and the signal level of the received wave changes from moment to moment.

Multipath is a major error source for both the carrier-phase and pseudo range measurements. It occurs when the GPS signal arrives at the receiver antenna through different paths. These paths can be the direct line of sight signal and reflected signals from objects surrounding the receiver antenna. Multipath distorts the original signal through interference with the reflected signals at the GPS antenna. It affects both the carrier-phase and pseudo range measurements. In figure 2.3 shows how the radio wave transmitted from the satellite radiates in all directions, these radio waves including reflected waves that are reflected off due to various obstacles, diffracted waves, scattering waves, and the direct wave from the satellite to GPS receiver.

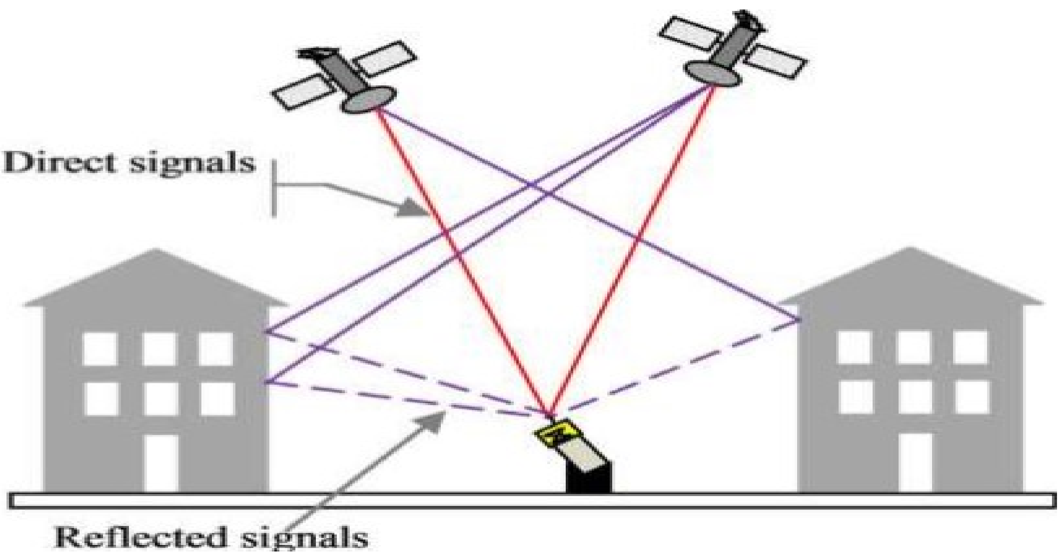

Figure 2. 2: Principle of multipath. Un-reflected signals (red) and reflected signals (purple) (Gottapu & Kumar, 2014)

2.3 Impact of Multipath effect

The impact of multipath error on pseudo range measurement is much larger than that on the carrier phase. The inaccuracy in pseudorange directly affects the receiver position estimation, causing error directly to the required position. For carrier phase measurement the multipath effect will lead to a wide ambiguity search space and hence takes a longer time to resolve the ambiguity.

This results in incorrect determination of the initial ambiguity which further leads to positioning errors. The signal delay due to multipath is very sensitive to the reflection coefficients of the nearby reflectors. These parameters limit the efficiency of the multipath modeling techniques. Multipath error differs depending on the reflecting surfaces, the range and phase multipath errors can reach as much as 5cm and 15m respectively using state-of-the-art receivers (Bidikar, *et al*., 2020). The following are the method and technique for mitigating multipath effect on GPS observation.

2.3.1 Multipath Estimation Technique

The multipath and geometric parameters may be estimated using different estimation techniques. Such as a Least Squares Estimator, a modified Wave Estimator or an Extended Kalman Filter. Multiple antennas are placed close together on a horizontal plane to ensure strongly related multipath signals. Generally, at least six antennas are to be used (Ray *et al*., 1999).

One of the antennas in the antenna assembly is defined as the reference antenna. All the parameters of the reflected signal and the placement of other antennas are defined with respect to the reference antenna.

a) Multipath Mitigation using Simulations

The multipath mitigation algorithm was first tested on simulated code, carrier and SNR data. Different multipath mitigation models were used to mitigate the simulated multipath errors in the code and carrier and their performances were evaluated in the simulated multipath environment. Later the simulated measurements were replaced by the actual measurements from the field data. The core mitigation algorithms however remained the same (Kumar, 2009).

b) Code Multipath Mitigation using Code Measurements

In this simulation six antennas are used in a closely-spaced cluster at approximately 5-10 cm from each other (center to center). A reflector which has a reflection coefficient of 0.3 is placed at a distance of 6 meters from the antenna cluster and is assumed to be the only reflector in the environment. The multipath phase is computed from the path delay alone (Shen & Xu, 2020).

c) Carrier Phase Multipath Mitigation Using Carrier Phase Measurements

In this simulation a reflector with a reflection coefficient of 0.6 is placed at a distance of 9 meters from the antenna cluster. The location of the reflector is different when compared to the location in code multipath mitigation simulation. That was done to check whether the mitigation technique works for different multipath scenarios. The multipath phase is computed from the differential path delay only (Leva, 1996).

d) Code and Carrier Phase Multipath Mitigation using SNR Measurements

As the multipath parameters are common for code carrier and SNR measurements in a receiver. It is in principle. Possible to estimate the code and the carrier multipath errors from SNR measurements. Only multipath errors due to a close-by reflector are considered for this simulation. In the simulation a reflector with a reflection coefficient of 0.8 is placed at a distance of 7 meters from the antenna cluster. The location of the reflector is different when compared to the locations used for code and carrier multipath mitigation simulations to evaluate the effectiveness of this technique at different multipath scenarios. The multipath phase is computed directly from the differential path delay (Ray *et al.*, 1999).

e) Code and Carrier Multipath Mitigation using Code, Carrier and SNR measurements

In this simulation a reflector with a reflection coefficient of 0.5 is placed at a distance of 6meters from the cluster. The antenna gain pattern is assumed to be uniform in all directions and the multipath phase is computed from the differential path delay only (Kumar, 2009).

2.4 Review of previous work

Previous research e.g., Ijaware & Nnamani (2020), Investigated the performance three different GPS receivers in environment with obstructions. The receivers used in the research were SouthH66/H88, Sokkia radian IS and ProMark3. The results from study found that the comparison of the average horizontal misclosure between the receivers show that south was the best since it had lower value of 0.1337m followed by Promark with 0.1625m and Sokkia had 0.2425m, hence South was the best in obtaining geographical information in horizontal position. While in average vertical misclosure showed that Sokkia had the lowest value of 0.0902m followed by Promark with 0.2336m and lastly was South with 0.2771m, hence Sokkia was the best in obtaining geographical information in vertical positioning. Therefore, this study evaluated the accuracy of coordinates of selected points obtained from three GPS receivers using appropriate statistics (Ijaware & Nnamani, 2020).

Previous research e.g., Mauro & Valbuena (2010), Investigated the performance of four different GPS receivers under forest canopies in mountainous environment and the receiver used in the research were Leica GS50, SR530, Topcon HiperPro and GMS2. The GNSS observations for 16plot-landmark situated under canopy were acquired in 2007 with Leica GS30 and SR30 at 1s logging rate. In 2008 observations were repeated by setting up a HiperPro and a GMS2 receivers at each plot-landmark, observations were obtained with all receives at the same time by shifting them from one plot-landmark to the next so that it can be assumed no differences in their recording conditions and these observations were taken with all receivers and antenna height ranged from

1.01m to 1.86m. The accuracy of each measurement was evaluated by means of the horizontal and vertical positional absolute errors; therefore the study provided different results from different receivers at different intervals of time observation (Mauro & Valbuena, 2010)

A most recent study e.g., Jain & Schon (2021), Investigated the performance evaluation of GNSS receiver clock modeling in urban navigation using geodetic and high sensitivity receivers. The receivers used in the study were JAVAD 0082 and HS u-blox 1771. The results show that urban positioning with HS u-blox 1771 and JAVAD 0082 receivers integrated with external clock (e.i RCM applied) surpasses the results with RCM, with RCM there is a significant improvement in precision of height component and vertical velocity, vertical component of both the JAVAD 0082 and HS u-blox 1771 receivers are largely reduced when RCM is applied. The standard deviation along the horizontal component with RCM for the complete experiment duration was about 1.5m for JAVAD 0082 and 2.5m for u-blox 1771 respectively. Without RCM, there is no significant difference in precision of horizontal components. In terms of availability the HS u-blox 1771 receiver performs slightly better than JAVAD 0082 (Jain & Schon, 2021).

The final study investigated on GPS signal multipath error mitigation technique (Bidikar *et al*, 2020). The study developed an algorithm to mitigate multipath error on the pseudorange measured from L1 carrier frequency. The algorithm proposed aimed at avoiding the complex calculations parameters such as reflection coefficient of the nearby reflectors when removing multipath errors. The GPS positioning was calculated considering pseudorange correction for all visible satellites during observations. The results obtained after using the proposed algorithm showed maximum multipath error reduction of 30m in receiver position estimates. Since the algorithm proposed avoids the complex sensitive parameters, it is then useful for observations obtained from the sites where reflection coefficients are difficult to be measured.

In contrast to the current research, the receivers used are Leica GS15 and CHCNAV i50 in which static method was employed on areas with different sky view condition e.g., areas located close to tall buildings, trees and good horizon. By observing the diverse locations of the established control points at Ardhi University helped to reach research's objectives and the software used to process GPS data was Trimble Business Center. The study aimed to assess the GNSS receiver that perform the best among the two GNSS receivers tested in the research, the study compared the repeatability of position measurements taken in conditions where multipath errors are present and the results obtained from the study provides insight to which GNSS receiver gives a reasonable accuracy in area affected by multipath.

CHAPTER THREE

METHODOLOGY

This chapter provides an explanation of the steps/procedures taken to achieve the research's objective. This chapter consists of reconnaissance, which includes office reconnaissance and field reconnaissance, data collection, data quality check and data processing.

3.1 Reconnaissance

This refers to the initial survey that was conducted so as to gather the information and data which are meaningfully for the study/research. The information and data were gathered in both the field and the office. In office reconnaissance involved data searching in which MKG8, MKG9, MKG10 and MKG11 monuments at Ardhi University were discovered as existing control points were found on stable ground. In field reconnaissance, it involves familiarization with the area of interest, -and identify boundaries. Table 3.1 shows the list of the coordinates of control points in WGS 84 visited during field reconnaissance.

Table 3. 1: List of the coordinates of control points in UTM (WGS 84).

S/NO	Point ID	Easting(m)	Northing(m)
1	MKG8	523978.034	9252212.145
2	MKG9	523946.770	9252343.692
3	MKG10	523901.492	9252067.634
4	MKG11	523881.731	9251926.603

3.2 Study area

Prior to setting up survey control stations or points, Geomaticians or surveyors take into account the guidelines that must be followed, such as the need for the control point to be situated in a location free from nearby vegetation, buildings, electrical poles, and telephone poles that could cause damage. But due to development caused by population increase some of control points are highly affected by multipath due to these factors. Therefore, positioning precision assessment was carried out in static survey mode employing two different GNSS receivers on those locations contributing to multipath effect versus to the installation on the good horizon. The study was conducted at Ardhi University in which the static observations were carried out by using two different GNSS receivers which are Leica GS15 and CHCNAV i50.

3.3 Network Design

Control Network is a network, often of triangles which are measured exactly by techniques of terrestrial surveying or by space techniques (i.e GNSS, VLBI, SLR and LLR). Control networks provide a reference framework of points for Topographical mapping, Deformation surveys for all manner of structures, Construction works, the extension and densification of existing control networks. There are two different methods used in control established which are conventional surveying and GNSS surveying.

Conventional surveying refers to the use of traditional surveying methods that involve physical measurements using specialized instruments and tools such as theodolites, total stations, and levels to measure angles, distances, and elevations. The following are the methods used in conventional surveying which are; Triangulation: is a surveying technique that involves measuring the angles and distances between three or more points on the ground to determine the location of an unknown point. Trilateration: is a surveying technique that involves determining the position of an unknown point by measuring its distance from three or more known reference points. Traverse: is a surveying technique used to measure the location and elevation of points along a straight line or a series of connected straight lines. It involves measuring the angles and distances between points in a sequence, starting from a known point and proceeding to an unknown point, and then back to the starting point or a known point. Resection: is a surveying technique that involves determining the location of an unknown point by measuring angles and distances from two or more known points. It is also known as intersection. Spirit leveling: is a surveying technique used to measure the elevation of points on the Earth's surface relative to a reference level. Thus, conventional surveying is performed using traditional precise surveying techniques and instruments and it needs intervisibility between adjacent stations (Barry, 2002).

Global Navigation Satellite System (GNSS) surveying is a type of surveying that uses satellite signals to determine the precise location and elevation of points on the Earth's surface. This method relies on a network of satellites in orbit around the Earth, which transmit signals that can be received by GNSS receivers on the ground. The following are the methods used in GNSS surveying which are;

Static: is the method that involves placing GNSS receivers at stationary locations for an extended period of time (typically several hours) to allow the receivers to collect data continuously. Rapid-static: is the method is similar to static GNSS surveying, but involves shorter observation periods (typically a few minutes) at each location. Real-time kinematic (RTK): is the method involving using a fixed base station and a roving receiver to collect data simultaneously in real-time. Stop-and-go: is the method involves moving a GNSS receiver along a survey route, but stopping at predefined locations to collect data for a few minutes before moving on to the next location. Kinematic: is the method involves moving a GNSS receiver along a survey route while collecting data continuously. In GNSS surveying relative technique is mostly preferred and it needs visibility to the sky (Barry, 2002).

Classification of control networks are of three groups which are; a) primary or First order control network which is used to establish geodetic points, Determine the size, shape, and movement of earth. b) Secondary or Second order control network which is used for network densification in urban areas, Precise engineering projects. c) Tertiary or third order control network which is used for surveying and mapping projects, for network densification in non-urban areas (Anderson *et al*., 2000).

Criteria for network design are as follows; Network density: The network should be designed with a sufficient number of control points to ensure that the required accuracy is achieved. The number and distribution of control points should be based on the size and complexity of the survey area, Control point selection: The control points should be selected carefully, taking into consideration the location, accessibility, and stability of the ground. The points should be located on stable terrain and away from any areas that may be subject to significant movement or deformation, Observation methods: The observation methods used for establishing the control points should be appropriate for the level of accuracy required. Third-order control networks typically require high-precision geodetic surveying techniques, such as Global Positioning System (Saleh, 2003).

Some criteria for design triangles on a geodetic control network include the following; Minimum Included Angle: The minimum included angle of a triangle should be greater than 30 degrees to ensure good geometric configuration and minimize the effects of observational errors, Aspect Ratio: The aspect ratio of a triangle, defined as the ratio of the longest side to the shortest side, should be less than 5 to ensure that the network is well-conditioned and the accuracy of the results is maintained, Redundancy: The network should have sufficient redundancy to detect and correct errors. This can be achieved by including additional triangles that overlap with existing triangles, Baseline length: The length of the baselines within the triangle should be carefully chosen to balance accuracy and cost. Longer baselines can provide higher accuracy, but they may also increase the risk of atmospheric disturbances and other error sources, Triangle geometry: The geometry of the triangle should be designed to minimize the dilution of precision (DOP) values. A low DOP value means that the positions obtained from the triangle is more accurate (Saleh, 2003).

Some of the ill conditions that can affect the design of a geodetic control network include; Non-uniform distribution of control points: If the control points are not evenly distributed throughout the area of interest, the resulting mapping and surveying may be inaccurate. Therefore, it is important to carefully plan the location and spacing of control points to ensure proper coverage, poor quality of control point coordinates: The accuracy of a geodetic control network depends on the quality of the coordinates of the control points. Errors in the measurement or calculation of control point coordinates can lead to inaccurate mapping and surveying. Thus, it is important to use high-quality surveying equipment and techniques to ensure accurate measurements, insufficient redundancy: Redundancy refers to the number of control points used to determine the position of a point on the Earth's surface. Insufficient redundancy can lead to inaccuracies in the geodetic control network. Therefore, it is important to have enough control points to provide a high level of redundancy, Changes in the Earth's surface: The Earth's surface is constantly changing due to natural and human activities. These changes can affect the accuracy and reliability of a geodetic control network. Therefore, it is important to periodically update and adjust the network to account for these changes (Kobryn, 2020).

In this research, a short baseline was proposed to be used because of the area coverage to be small around ARU and the controls available near the site area contributed to the decision made of selecting a short baseline (controls are not exceeding 1 km).

In terms of clear sky view selection, in this research the location of places where the control points are going to be established are in multipath/canopies area due to the requirement of the research.

In this research the network in Figure 3.1 was designed due to the criteria mentioned above.

Figure 3. 1: GPS designed network (Red lines and white lines represent major and minor networks respectively).

3.4 Monumentation

This involves placing of permanent markers on ground for the purpose of identifying position on the ground, it involves placing iron pins filled with concrete. During monumentation selection of the area of interest includes the following factors such as stable ground, security, intervisibility to sky, intervisibility between points and accessibility.

The points which are monumented were as follows; CP01, CP02, BP01, BP02, TP01, TP02, GS01 and GS02. In Figure 3.2 shows monumentation procedures in which control points were monumented by iron pin concrete method, it involves placing iron pins filled with concrete on a stable ground.

Figure 3. 2: Monumentation Process

3.5 Mission planning.

Mission planning is the method used by surveyors to determine the number of satellites and their arrangement within a certain time, which is required for conducting a survey within a specified time. For a surveyor to get a better accuracy it is important to know the availability of satellites and time which gives a good observation. Good satellite geometry also plays a great role in GPS observation, it’s expressed as the dilution of precision (DOP). The mission planning was carried out by using online software known as Trimble GNSS planning online. In a Figure 3.3 and 3.4 shows the number of satellite active with respect to their arrangement within a period of time and dilution of precision in observation.

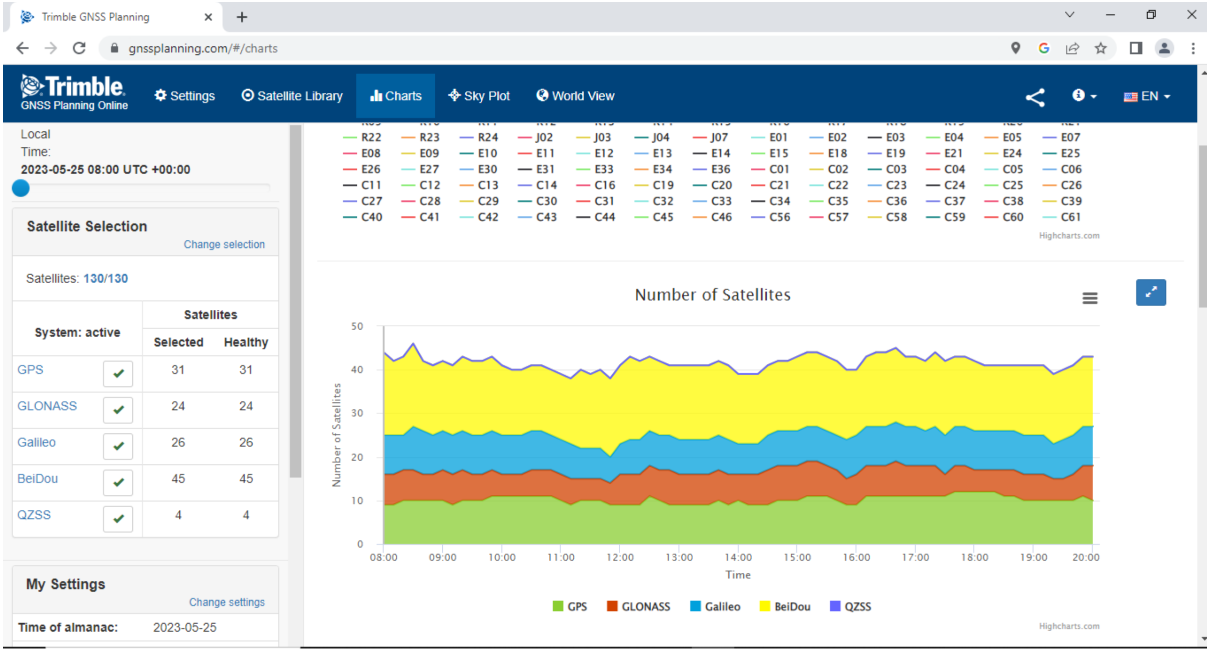

Figure 3. 3: A mission planning file with number of satellite visible during observation

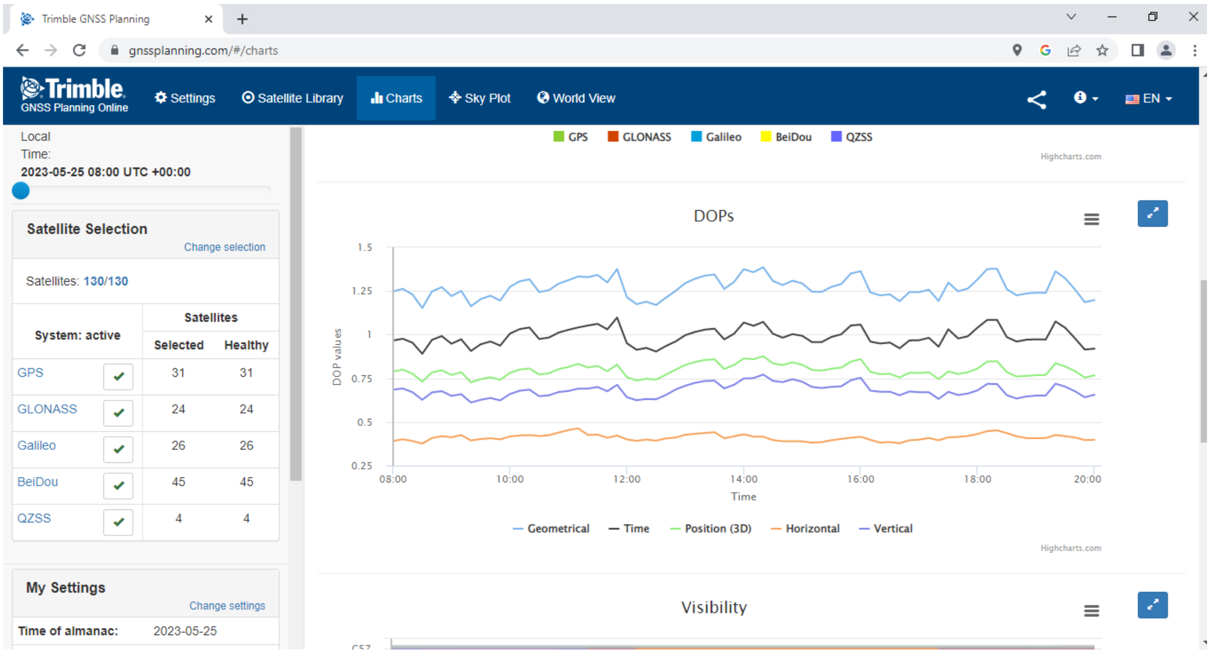

Figure 3. 4: A mission planning file with Dilution of Precision during observation

3.6 GPS observation

Following network design and mission planning, static mode observation was used to carry out GPS observation. In this scenario, two control locations were employed as the base station, additional controls served as places of interest and observation were made over time so as to obtain coordinates of points by using different GNSS receivers. In Figure 3.5 shows static observation conducted around Ardhi university areas in different sky view condition, in which total observation time was 2 hours by using Leica GS15 and CHCNAV i50 receivers.

Figure 3. 5: Static Observation Conducted at Ardhi University

3.7 Quality check

The data were downloaded from the GPS receiver and the quality checks were done using software called Eofice. In Figure 3.6 shows the quality check results which is assessed in percentage where by below 60% indicates poor observation, between 60% and 80% indicates good observation and above 80% indicates excellent observation.

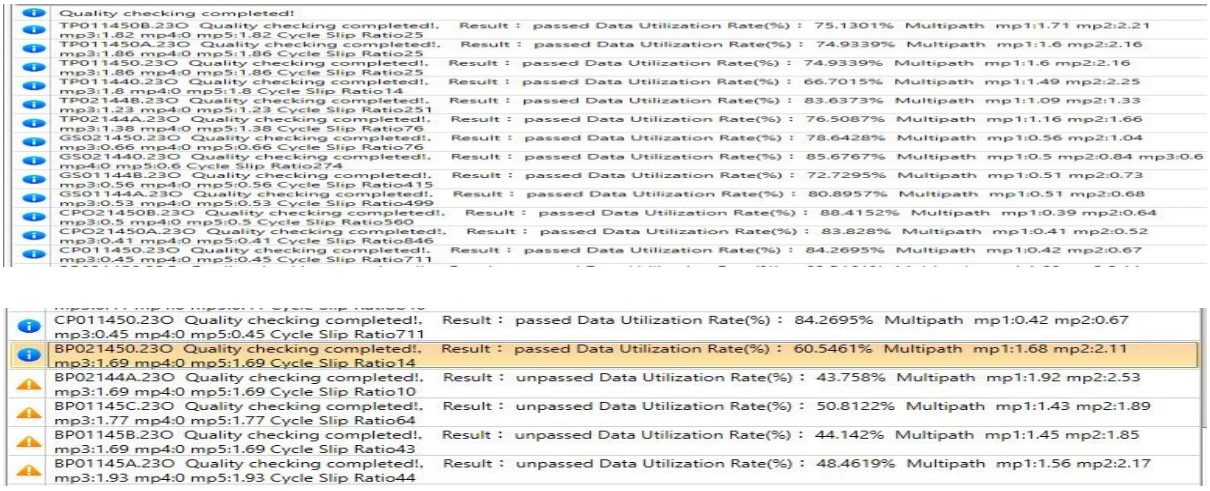

Figure 3. 6: Quality Check Results

3.8 Data processing

The GPS data processing and network adjustment were done using Trimble Business Center (TBC) software. TBC software is a desktop application for processing and managing optical, GNSS and image surveying data. Before the data processing the GPS, files were obtained from each station, the RINEX data were processed in each station. The reason for having various observation files is to check how these observed coordinates vary from assumed original coordinates which were obtained by conventional method through traversing.

3.8.1 Baseline processing

The baselines were processed by using TBC software. GPS observations require the baseline to be taken between fixed control stations (CP01 & CP02). The reason is to assess the accuracy of both the GNSS observational system and control being held fixed. The files used in baseline processing were observation and navigation files. The frequency used was L1 and L2 as observed and recorded from Rinex files and all baselines were processed and joined. In Figure 3.7 shows the baseline processing for network in which the points found on multipath have red flags and yellow flags which indicates the points exceed the computation settings for survey tolerances due to multipath factors.

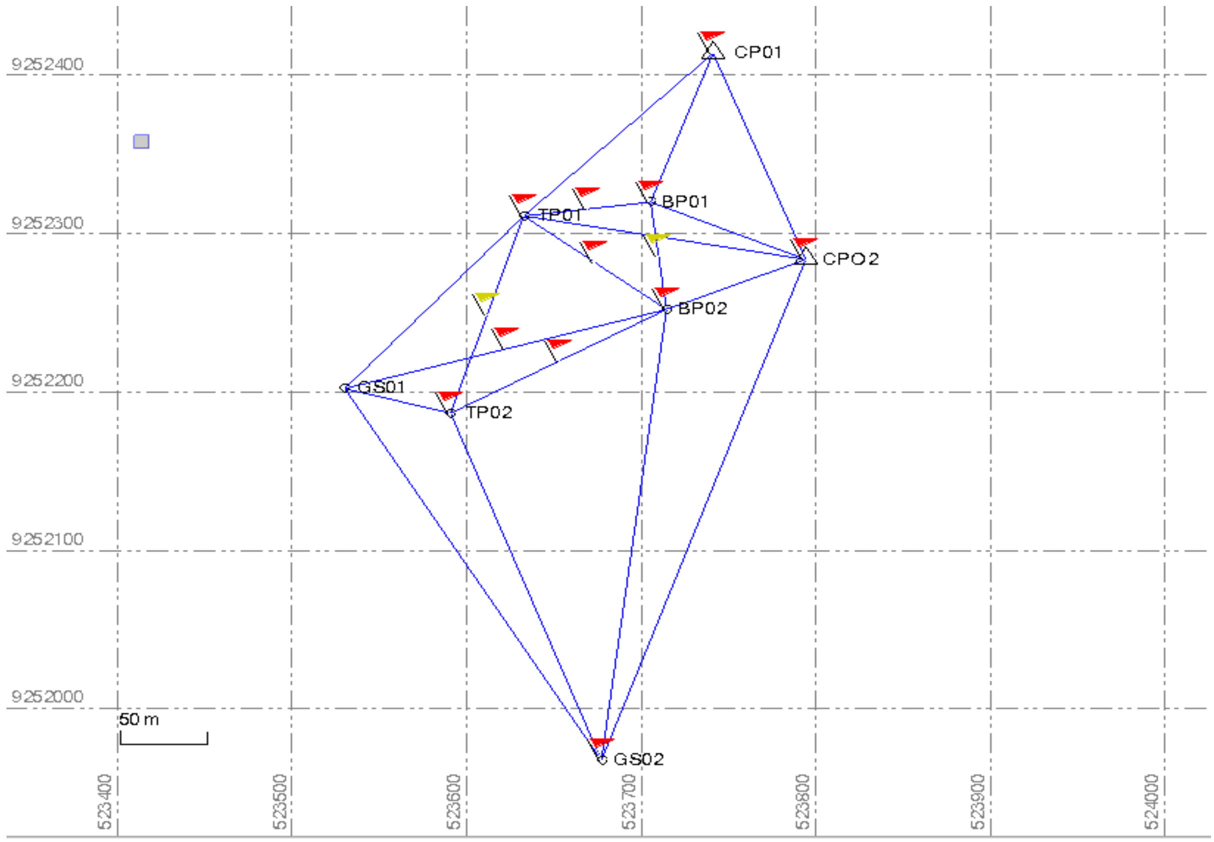

Figure 3. 7: Processed baselines using TBC

3.8.2 Network adjustment

During network adjustment, it was vital to fix an observation to a specific value. This is called constrained adjustment, whereby all observations are forced to fit the control coordinates. The control station fixed was regarded as errorless and its error was distributed among the observations. Two control points which are CP01 &CP02 were used as fixed stations to adjust the network. In Figure 3. 8 and 3. 9 shows the adjusted network for both CHC i50 and Leica GS15 receiver, in which the points found on multipath have red flags and yellow flags which indicates the points exceed the computation settings for survey tolerances due to multipath factors.

For CHCNAV Receiver

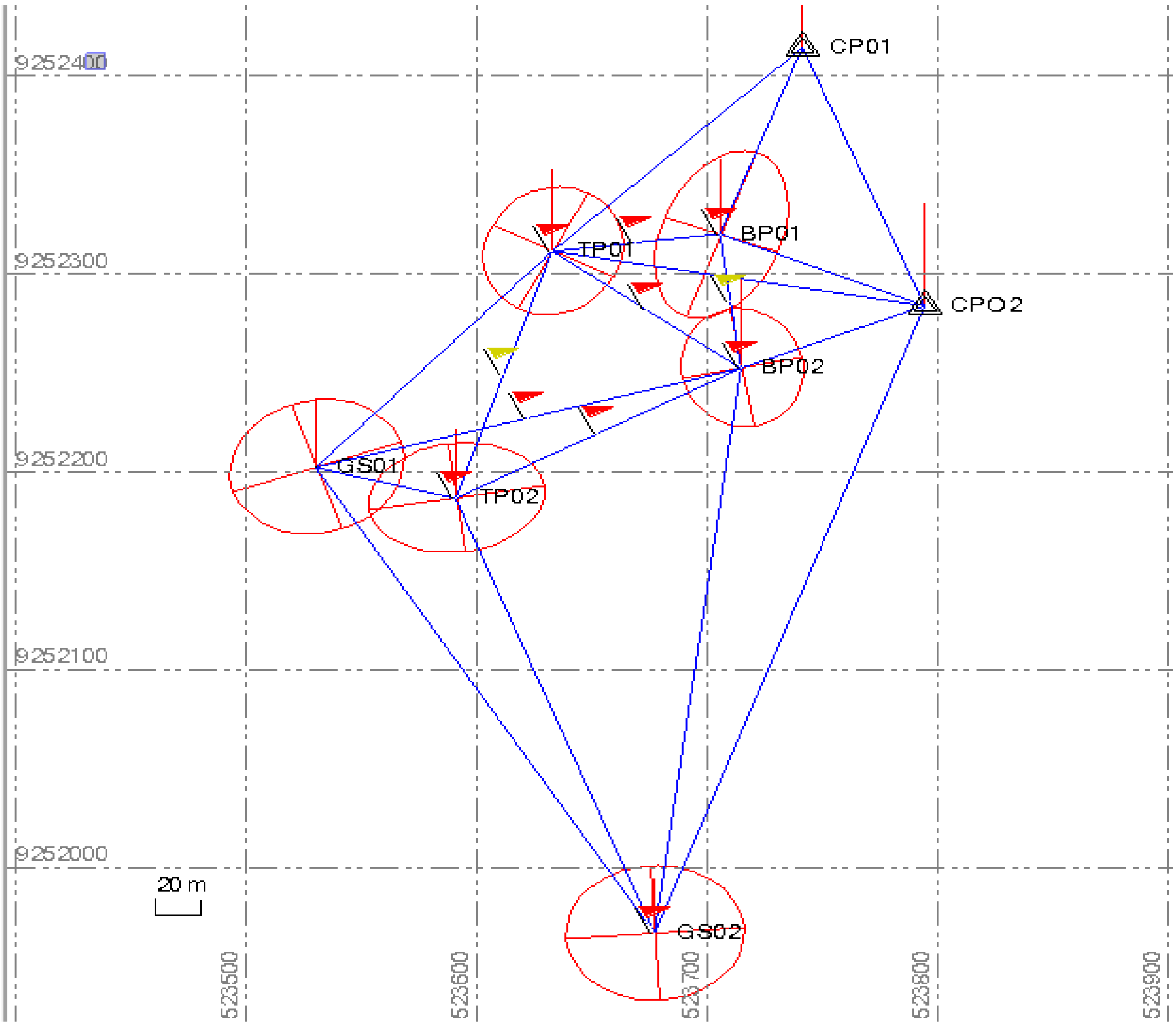

Figure 3. 8: Network Adjustment using TBC

For LEICA Receiver

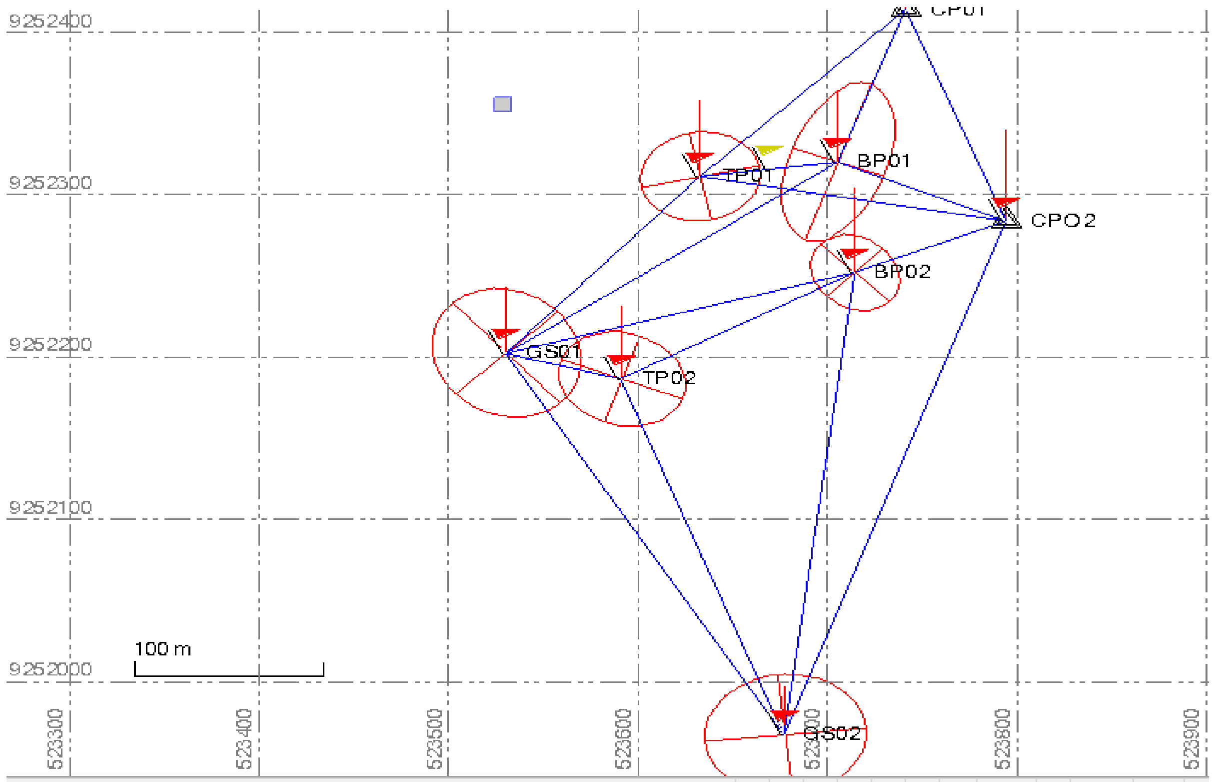

Figure 3. 9: Network adjustment using TBC

3.8.3 List of control points coordinates for main and minor network in WGS 84.

Table 3. 2: Point list of CHC receiver in UTM (WGS84)

Point ID	Easting (meter)	Northing (meter)	Elevation (meter)	Remark
BP01	523705.345	9252319.944	2.963	Building point
BP02	523714.447	9252252.128	0.625	Building point
CP01	523741.138	9252413.946	1.632	Control point
CP02	523794.180	9252283.740	-0.263	Control point
GS01	523531.918	9252199.857	20.702	Good sky
GS02	523677.148	9251967.343	8.473	Good sky
TP01	523632.747	9252311.147	7.142	Tree point
TP02	523590.930	9252186.147	10.921	Tree point

Table 3.3: Point list of Leica receiver in UTM (WGS84)

Point ID	Easting (meter)	Northing (meter)	Elevation (meter)	Remark
BP01	523705.331	9252319.994	2.924	Building point
BP02	523714.410	9252252.151	0.868	Building point
CP01	523741.138	9252413.946	1.596	Control point
CP02	523794.180	9252283.740	-0.234	Control point
GS01	523530.115	9252202.186	20.737	Good sky
GS02	523677.033	9251967.292	8.521	Good sky
TP01	523632.709	9252311.213	7.166	Tree point
TP02	523590.693	9252186.612	10.931	Tree point

3.9 Traversing

The traverse was executed using Leica Total Station with its components. Angles were recorded in the angle sheets and also the distances were recorded in the measurement sheets. In Figure 3.10 shows designed traverse route in which at first the instrument was set at MKG09 with orientation at MKG08 as an opening datum, passing through the points of interest which were CP01, CP02, BP01, TP01, BP02, TR01, TP02, GS01, TR02, TR03, TR04, GS02 and finally the instrument was set at MKG11 with orientation at MKG10 as a closing datum. Traverse computations were done by CadPro software.

Figure 3. 10: Shows traverse route

3.9.1 Data processing

CadPro software was used in the processing of all computations of coordinates of traverse points from angles and distances obtained during traversing. Whereby the final reports from data processing were the coordinates of traverse points. Also shows the accuracies of the data observed including relative linear accuracy and angular misclosure.

Datum check was done in Table 3.3 as shown:

Table 3. 3: Join computations (and check distances)

Station	**X(meter)**	**Y(meter)**		**o**	**'**	**"**	
MKG08	9252212.145	523978.034	Brg	166	37	51	
MKG09	9252343.692	523946.770	S(c)	135.211		MS	
DX, DY	-131.547	31.264	S(m)	135.266		Diff	0.045
MKG10	9252067.634	523901.492	Brg	352	1	26	
MKG11	9251926.603	523881.731	S(c)	142.409		MS	
DX, DY	141.031	19.761	S(m)	142.441		Diff	0.032

CHAPTER FOUR

RESULTS AND ANALYSIS

This chapter generally presents the results obtained from the processed data of different GNSS receivers and computations of traverse. This includes the coordinate list of each station and traverse computations made from data obtained on methodology.

4.1 Results

4.1.1 Computations for traverse

After the acquisition of data from the field, traverse routes for control point densification were processed using CadPro software. In Figure 4.1 shows traverse computation results obtained from cadpro software.

TRAVERSE COMPUTATIONS. cadPro - 5/22/2023 [Eval.Ver]

STATION	ANGLE	cor	BEARING	DISTANCE	DX	corr	DY	corr	NORTHINGS	EASTINGS	STATION	A/Ms
MKG8									9252212.145	523978.034	MKG8	
			166:37:51									
MKG9	081:55:05	4							9252343.692	523946.770	MKG9	
			248:33:01	163.945	-59.952	-.015	-152.590	.006				
CP01	269:17:01	4							9252283.740	523794.180	CP01	
			337:50:07	140.595	130.205	-.013	-53.042	.005				
CP02	043:01:15	4							9252413.946	523741.138	CP02	
			200:51:27	100.577	-93.986	-.009	-35.810	.004				
BP01	242:17:19	4							9252320.041	523705.431	BP01	
			263:08:51	73.110	-8.723	-.007	-72.588	.003				
TP01	042:42:07	4							9252311.275	523632.781	TP01	
			125:51:03	100.821	-59.049	-.009	81.720	.004				
BP02	278:02:53	4							9252252.262	523714.573	BP02	
			223:54:01	79.920	-57.586	-.007	-55.417	.003				
TR01	219:26:02	4							9252194.540	523659.044	TR01	
			263:20:08	68.693	-7.972	-.006	-68.229	.003				
TP02	201:05:14	4							9252186.677	523590.854	TP02	
			284:25:27	62.629	15.601	-.006	-60.655	.002				
GS01	047:19:56	4							9252202.239	523530.160	GS01	
			151:45:28	81.018	-71.373	-.008	38.338	.003				
TR02	225:50:04	4							9252130.776	523568.498	TR02	
			197:35:37	110.024	-104.878	-.010	-33.256	.004				
TR03	072:59:46	4							9252025.888	523535.242	TR03	
			090:35:28	113.350	-1.169	-.011	113.344	.004				
TR04	243:02:06	4							9252024.708	523648.587	TR04	
			153:37:39	64.038	-57.373	-.006	28.446	.002				
GS02	127:37:07	4							9251967.353	523677.066	GS02	
			101:14:51	208.706	-40.707	-.019	204.698	.008				
MKG11	086:43:39	4							9251926.603	523881.731	MKG11	
		m	007:57:25	1367.426	-416.962		-65.041		-417.089	-65.039		
MKG10		c	007:58:34		-417.089		-65.039		9252067.634	523901.492	MKG10	

Stns: 14 Ang.Corr:4s Misc:56s Dist: 1367.426 X.Miscl: -.127 Y.Miscl: .002 Accuracy 1 : 10,766

Figure 4. 1: Established control point coordinates by traverse Method

(i) Relative linear accuracy

Relative accuracy = $(\sqrt{(\Delta x^2 + \Delta y^2)})/L$ [4.1]

Where:

Δx = linear misclosure in Northing

Δy = linear misclosure in Easting

L = Total distance of the traverse route

From the traverse computation

Δx = -0.127 m,

Δy = 0.002 m and

L = 1367.426m

Hence the Relative linear accuracy is 1:10,766

The computation sheets for the traverse are shown above.

(ii) Angular Misclosure

Angular misclosure should not exceed the allowable misclosure which is normally obtained from the equation given by;

Allowable Misclosure $= \pm 15''\sqrt{n}$ [4.2]

Where "n" stands for number of stations in the traverse route

For our traverse n were 14

$= \pm 15''\sqrt{n}$

$= \pm 15''\sqrt{14}$

$= \pm 56''$

Allowable Misclosure = $\pm 56''$

Angular misclosure obtained from the Traverse Computation was 4" and hence ranges within the allowable misclosure.

4.1.2 Static method

Major and minor network were processed by using TBC software in which the coordinate list of eight stations were by CP01 and CP02 are the stations located in good horizon and used as reference stations, BP01 and BP02 are the stations located in sites near by tall buildings (Multipath factor), TP01 and TP02 are the stations located in sites near by Trees (Multipath factor), GS01 and GS02 are the stations located in good horizon (Multipath free). The obtained coordinate list from different GNSS receivers (Leica GS15 and CHC i50) in specified time led to come up with baseline processing report and network adjustment report.

Table 4. 1: Coordinate list for Leica GS15 Receiver in UTM (WGS84)

Point ID	Easting (Meter)	Northing (Meter)	Remark
BP01	523705.331	9252319.994	Building point
BP02	523714.410	9252252.151	Building point
CP01	523741.138	9252413.946	Control
CP02	523794.180	9252283.740	control
GS01	523530.115	9252202.186	Good horizon
GS02	523677.033	9251967.292	Good horizon
TP01	523632.709	9252311.213	Tree point
TP02	523590.693	9252186.612	Tree point

Table 4. 2: Coordinate list for CHCNAV i50 Receiver in UTM (WGS84)

Point ID	Easting (Meter)	Northing (Meter)	Remark
BP01	523705.087	9252320.018	Building point
BP02	523714.741	9252252.055	Building point
CP01	523741.138	9252413.946	Control
CP02	523794.180	9252283.740	control
GS01	523530.131	9252202.202	Good horizon
GS02	523677.025	9251967.299	Good horizon
TP01	523632.728	9252311.218	Tree point
TP02	523590.733	9252186.616	Tree point

4.2 Analysis of the result

Grid coordinates from eight stations done by static observation technique were derived using trimble business center software in order to assess the positional accuracy of coordinates from various strategies. The conventional method (total station) coordinates were used as the reference / base and the measured/observed coordinates obtained by GNSS method (static) were used in assessments. The differences in coordinates between the base coordinates from the total station and other coordinates from GNSS method and their positional accuracy were taken into consideration.

4.2.1 Analysis of the coordinate difference for all the position solution

The coordinate difference and positional accuracy are obtained from the difference between the conventional solution (Total station) and GNSS solution (GPS receiver). Position difference **(Δ)** = conventional solution – GPS solution

Horizontal position accuracy $=\sqrt{\Delta E^2 + \Delta N^2}$ [4.3]

The following are the tables showing the coordinate differences between conventional solution in Easting and Northing (E, N), and GPS solution in Easting and Northing (E1, N1) together with horizontal position accuracy of each control station. The following are the tables showing the analysis of the results from two GNSS receivers which are Leica GS15 and CHCNAV i50.

Table 4. 3: showing difference in coordinates with Horizontal position accuracy of Leica GS15 in UTM (WGS84).

Point ID	E(m)	N(m)	E1(m)	N1(m)	ΔE(m)	ΔN(m)	Horizontal Position accuracy(m)
BP01	523705.441	9252320.041	523705.331	9252319.994	0.11	0.047	0.120
BP02	523714.473	9252252.262	523714.41	9252252.151	0.063	0.111	0.128
CP01	523794.18	9252283.74	523794.18	9252283.74	0	0	0.000
CP02	523741.138	9252413.946	523741.138	9252413.946	0	0	0.000
GS01	523530.139	9252202.214	523530.115	9252202.186	0.024	0.028	0.037
GS02	523677.056	9251967.323	523677.033	9251967.292	0.023	0.031	0.039
TP01	523632.751	9252311.275	523632.709	9252311.213	0.042	0.062	0.075
TP02	523590.784	9252186.657	523590.693	9252186.612	0.091	0.045	0.102

Table 4. 4: showing difference in coordinates with Horizontal position accuracy of CHCNAV i50 in UTM (WGS84).

Point ID	E(m)	N(m)	E1(m)	N1(m)	ΔE(m)	ΔN(m)	Horizontal Position accuracy(m)
BP01	523705.441	9252320.041	523705.087	9252320.018	0.354	0.023	0.355
BP02	523714.473	9252252.262	523714.741	9252252.055	-0.268	0.207	0.339
CP01	523794.18	9252283.74	523794.18	9252283.74	0	0	0.000
CP02	523741.138	9252413.946	523741.138	9252413.946	0	0	0.000
GS01	523530.139	9252202.214	523530.131	9252202.202	0.008	0.012	0.014
GS02	523677.056	9251967.323	523677.025	9251967.299	0.031	0.024	0.039
TP01	523632.751	9252311.275	523632.728	9252311.218	0.023	0.057	0.061
TP02	523590.784	9252186.657	523590.733	9252186.616	0.051	0.041	0.065

4.2.2 Statistics summary of coordinate difference for all the position solution

The table 4.5 shows the standard deviation of coordinate's difference in easting, northing and Horizontal position accuracy for Leica GS15 receiver and CHCNAV i50 receiver.

Table 4. 5: Statistics summary of coordinate difference and Horizontal position accuracy

Receiver type	ΔE(m)	ΔN(m)	Horizontal Position accuracy(m)
LEICA GS15	0.034	0.036	0.039
CHCNAV i50	0.167	0.068	0.157

4.2.2.1 Analysis of Horizontal position accuracy for Leica GS15 receiver

For station BP01 and BP02 which are located in areas nearby tall buildings, the graph in Figure 4.2 shows that the value of horizontal position accuracy was higher by 0.12m in BP01 and 0.128m in BP02, while in station TP01 and TP02 which are located in areas nearby trees show that the value of horizontal position accuracy of 0.075m in TP01 and 0.102m in TP02, And for station GS01 and GS02 which are located in good sky view, the graph shows the value of horizontal position accuracy was lower by 0.037m in GS01 and 0.039 in GS02. From these results the study shows that in areas located/found nearby tall buildings are more affected multipath effect hence lowers the performance of positioning than those which are found in trees.

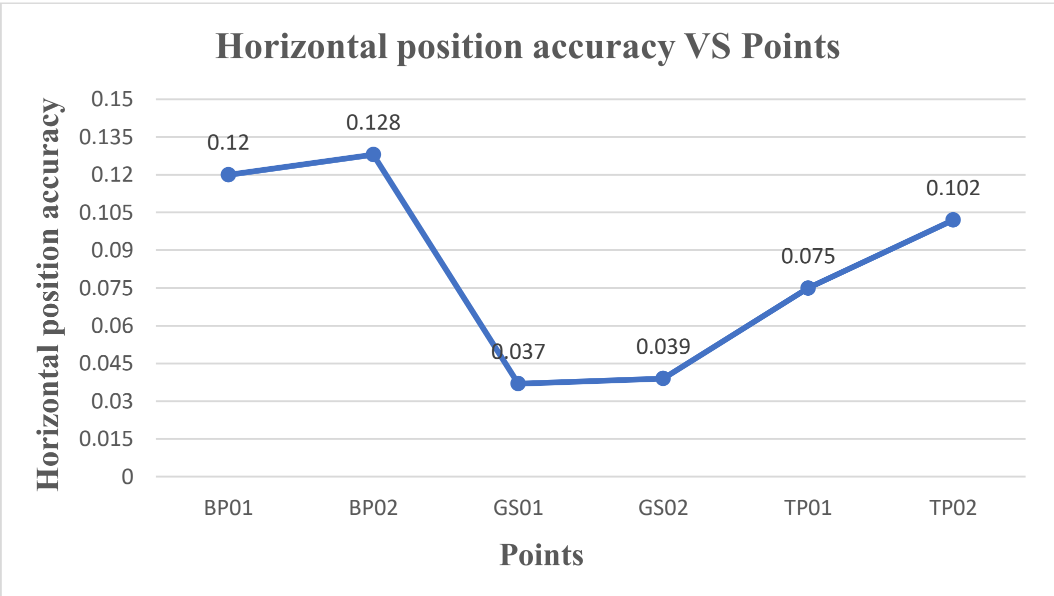

Figure 4. 2: Horizontal position accuracy for the points

4.2.2.2 Analysis of Horizontal position accuracy for CHCNAV i50 receiver

For station BP01 and BP02 which are located in areas nearby tall buildings, the graph in Figure 4.3 shows that the value of horizontal position accuracy was higher by 0.355m in BP01 and 0.339m in BP02, while in station TP01 and TP02 which are located in areas nearby trees show that the value of horizontal position accuracy of 0.061m in TP01 and 0.065m in TP02, And for station GS01 and GS02 which are located in good sky view, the graph shows the value of horizontal position accuracy was lower by 0.014m in GS01 and 0.039 in GS02. From these results the study shows that in areas located/found nearby tall buildings are more affected multipath effect than those in trees hence it lowers the performance of positioning.

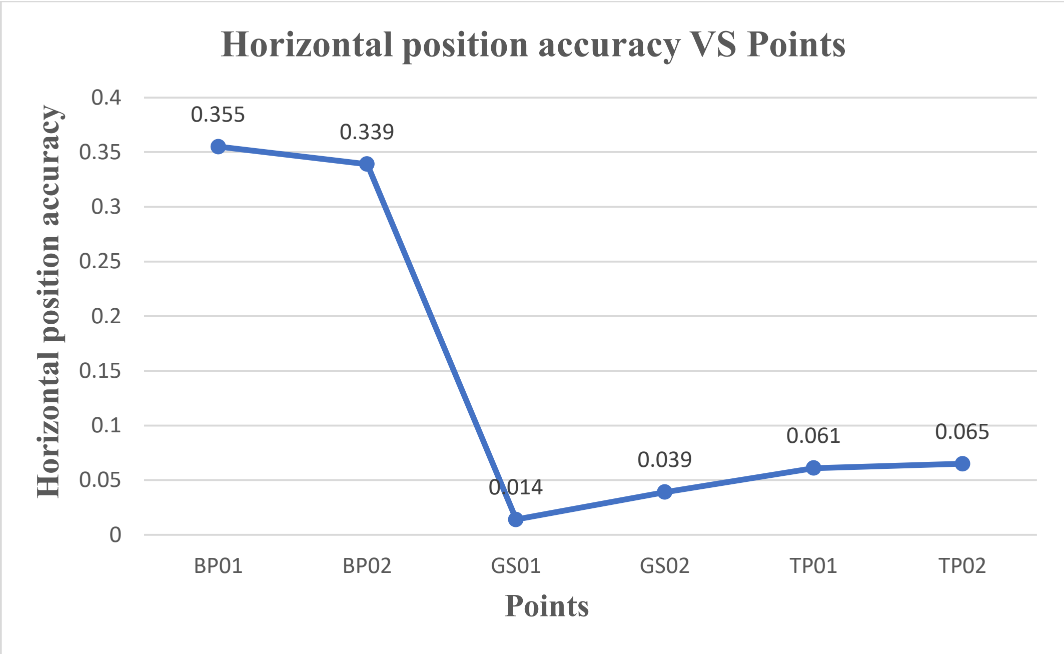

Figure 4. 3: Horizontal position accuracy for the points

4.3 Discussion of the results

The aim of the study is to assess the position precision of different GNSS receivers in static survey mode under the influence of multipath effects. The study contains the coordinate list of each station obtained by GNSS method together with coordinate list obtained by conventional method (traverse) which used as reference on the study. The difference in easting and northing of these coordinates made up a way to assess how GNSS receiver had performed compared to conventional method (traverse) under the influence of multipath factor and to the sites located in good sky. The result from study found that the comparison of the average horizontal position accuracy shown that Leica GS15 was the best since it had lower value of 0.120m in BP01 and 0.128m in BP02 to the points located nearby tall buildings compared to the CHCNAV i50 which had higher value 0f

0.355m in BP01 and 0.339m in BP02 to the points located nearby tall buildings. Also, For the points found under the trees CHCNAV i50 was the best in providing horizontal position accuracy since it had lower value of 0.061m in TP01 and 0.065m in TP02 compared to the receiver Leica GS15 which had higher value of 0.075m in TP01 and 0.102m in TP02 and lastly for the points which are found on good horizon (GS01 and GS02) in GS01 a CHCNAV i50 receiver perform better than Leica GS15 but in point GS02 all both performed better in providing horizontal position accuracy.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The study provides valuable insights into the performance of LEICA GS15 and CHCNAV i50 GNSS receivers when operating in challenging environments affected by multipath interference. The research aimed to assess the positional precision of these receivers, crucial for accurate surveying and geospatial applications through experimentation and data analysis, it was observed that Leica GS15 for the horizontal position accuracy of points located under tall buildings was the best compared to the CHCNAV i50 and for the points located under trees, CHCNAV i50 provided the best horizontal positional accuracy. Also, for the points located on a good horizon both of the receivers performed well in providing horizontal position accuracy.

In conclusion, this study contributes valuable information to the surveying and geospatial community, aiding professionals and researchers in making informed decisions when selecting GNSS receivers for static surveying applications. It is evident that accurate positioning in challenging conditions requires careful consideration of receiver characteristics and proper mitigation techniques.

5.2 Recommendation

The following are recommendations and potential features research on the reliability and availability of position solutions using GNSS. Based on the results analysis of this study, The study recommend further research:

i. To increase the time for observation under multipath to get high accuracy positioning.
ii. To use different types of the receivers that might result to high accuracy in different sky view condition apart from Leica GS15 and CHCNAV i50 receivers.

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