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PERFORMANCE OF GNSS FOR SIMULTANEOUS STATIC AND RTK ON TOPOGRAPHIC SURVEYS IN REMOTE AREAS

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BSc Geomatics

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PERFORMANCE OF GNSS FOR SIMULTANEOUS STATIC AND RTK ON TOPOGRAPHIC SURVEYS IN REMOTE AREAS

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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 of dissertation titled **"Performance of GNSS for Simultaneous Static and RTK on Topographic Surveys in Remote Areas"** in partial fulfilment of the requirements for University Examination.

……………………………...

Dr. ELIFURAHA SARIA

(Supervisor)

Date: ……………………….

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I, Nyumba Baraka O declare that this dissertation is my own original work and that to the best of my knowledge, it has not been presented to any other University for similar or any other degree award except where due to acknowledgements have been made in the text.

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DEDICATION

I Dedicate this work to my mother Esther Ibrahim Mkaugala, for everything she has been to me, I am able to do what I do today because of her. Also my father Mr. Said Mkinga for the wisdom and teachings he has been giving me through different course of this life, my little sisters Leila, Haika and Suzana, my brothers Juma and Ramadhan, my uncle and aunt Mr. and Mrs. Wema may GOD bless them abundantly.

ABSTRACT

In Geomatics particularly in detail survey, it is usually a norm to establish, observe, process and adjust the perquisite survey control before collecting the details. Establishing the control will require extending them from existing one what are always every far, during observation, and later post processing and adjustment to get the final coordinate to start the work. This procedure is costly and time consuming because may require a surveyor go to site several times for both controls as well as detail surveying. Although this traditional way has been seeming challenging, costly and time consuming, Surveyors are still using it and there is no effort to rectify and reduce time on these two surveying operations. This research aims to investigate the possibilities of minimizing the need for extensive control extension and reduces costs associated with additional field time

This research examined the performance and accuracy of conducting simultaneous Control extension and at the same time conducting detail survey. This study assessed the precision by comparing the coordinate from two methods. The normal method of control extension, adjustment and later conduct detail survey to the method of simultaneous conducting the operation using GNSS techniques in Static for control extension and Real Time Kinematics and Detail Surveying

The maximum horizontal accuracy was found to be 7cm for horizontal accuracy and 8cmfor vertical positional accuracy. The method being able to achieve centimeter accuracy, can be used for cadastral surveys, detail surveys for land use planning as well as engineering surveys according to the requirements of the client.

Key words: Real Time Kinematics, Detail Surveying, control extension

TABLE OF CONTENTS

LIST OF FIGURE

LIST OF TABLES

ACRONYMS

ARU	Ardhi University
WGS84	World Geodetic System of 1984
SSR	Simultaneous Static and RTK
GNSS	Global Navigation Satellite System
ITRF	International Terrestrial Reference Frame
GPS	Global Positioning System
TBC	Trimble Business Centre
RINEX	Receiver Independent Exchange
DGPS	Differential GPS

CHAPTER ONE

INTRODUCTION

This chapter introduces the topic of performance of GNSS for simultaneous static and RTK on topographic surveys in remote areas. The problem statement identified the need to conduct the simultaneous static and RTK techniques. Also the limitations, significance and beneficiaries of this research are discussed in this chapter.

1.1 Background

In the field of Geomatics, specifically in detail surveying, it is a custom to establish and adjust survey control points prior to conducting detailed survey. This process involves extending control points from existing ones, which are often located far apart. It requires on-site observations, followed by post-processing and adjustment to obtain the final coordinates needed to commence the survey. Unfortunately, this procedure is both expensive and time-consuming, often necessitating multiple visits to the site for control point establishment and detailed surveying. Despite its challenges and associated costs, surveyors continue to employ this traditional approach without actively seeking solutions to reduce the time required for these two surveying operations.

This study examines the performance and accuracy of doing simultaneous Control extension and at the same time conducting detail survey. This study assesses the positional accuracy of a point by conventional method to that of simultaneous control extension and surveying of the features. By comparing the coordinate from two methods, if there is no significant difference between them, then the method can be termed reliable for detail surveys in remote areas.

GPS can be used to position static objects or moving objects. Although the observations (ranges) are the same, the fact that the antenna is either stationary or moving introduces significant differences. If the antenna is stationary, we can observe many repeated ranges to each of several satellites. This gives us redundant observations, overdetermined solutions (e.g., least squares), and consequently a higher accuracy of the determined position, this is referred to as Static technique (Wells et al, 1987).

RTK positioning, on the other hand, uses real-time corrections from a reference station to provide centimeter-level accuracy in real-time, RTK mode is fast and quite productive method for geodetic determinations (Minchev, M. et al, 2005).

The Static Mode requires a lot of time for gathering of raw data, adjusting them and process to get the required high accuracy coordinates. Also RTK mode requires an accurate reference station to perform observations in real time with high accuracy (Kostov, 2011).

The use of simultaneous static and RTK techniques has been proposed as a way to combine the benefits of both methods. By using both techniques, the receiver can benefit from the increased accuracy of RTK while reducing the time it takes to achieve a stable solution, which is typically several minutes for static positioning.

1.1.1 Previous Researches

In 2011, Gintcho Petkov KOSTOV conducted research on "Using of both fast Static and RTK Modes for GNSS Determinations to Obtain Required High Accuracy and Productivity, according to the Current Possibilities of the IT". From the research it was concluded that, this combination could be very useful if the geodetic activities are performed for instance in regions, where the network is demolished, has insufficient quality, usage of other survey method is inappropriate, etc. This fits most of the criteria for conducting detailed survey on remote areas due to the challenge of having high accuracy reference points on those areas.

Despite the potential benefits of simultaneous static and RTK techniques, there is very limited research on the use of these techniques in topographic surveying in remote areas. This research proposal aims to fill this gap in the literature by evaluating the performance of simultaneous static and RTK techniques for GNSS in topographic surveying in remote areas and identifying any challenges or limitations that need to be addressed.

1.1.2 The current research

This research will include the simultaneous control extension at the same time as detail survey, with one receiver placed at a known control conducting static observations, another receiver placed at unknown control operating as static receiver as well as arbitrary reference station for detail surveying and also a rover which will be for taking real time coordinates of the selected points .the static data will later be processed and the coordinates will be used for transformation of the detail survey points which were tied to an arbitrary reference station.

1.2 Problem statement

It is indeed crucial to consider both required accuracy and productivity when planning and conducting topographic surveys using GNSS (Global Navigation Satellite Systems). The accuracy of the survey is influenced by factors such as the quality of the reference station used and the survey technique employed (e.g., static, RTK). On the other hand, productivity is influenced by factors like time, operational costs, and the quality of the survey output.

In the case of the TAREF11 geodetic network, where the reference points are situated far apart from each other, performing a detailed survey in the area would often require significant control extension. This means that additional surveying needs to be conducted to connect the reference points to the specific work area. Consequently, this results in increased costs and time requirements, ultimately affecting productivity.

To address these challenges, the simultaneous use of static and RTK techniques can be employed. This approach aims to reduce costs and minimize the additional field time required. By leveraging the advantages of each technique, surveyors can achieve the desired output quality more efficiently.

The static technique involves occupying GNSS receivers at fixed positions for an extended period to collect precise observations. This method is typically used to establish accurate reference points and control measurements. On the other hand, the RTK (Real-Time Kinematic) technique enables real-time positioning using a base station and a rover receiver. RTK provides quicker results by utilizing corrections from the base station to enhance the rover's accuracy.

By combining both static and RTK techniques, surveyors can optimize their workflow. They can use static measurements to establish accurate reference points, including those from the TAREF11 geodetic network, while employing RTK for the detail survey in the work area. This approach minimizes the need for extensive control extension and reduces costs associated with additional field time. It also ensures the desired output quality is achieved, striking a balance between accuracy and productivity in the topographic survey. As result in this research am going to investigating the performance of GNSS for simultaneous static and RTK on topographic surveys in remote areas

1.3 Research objectives

1.3.1 Main objective

Examining the performance and accuracy of doing simultaneous Control extension and at the same time conducting detail survey. This study assessed the accuracies of position solutions by comparing the coordinate from two methods. The static method for control establishment as well as RTK solutions was used to check how Simultaneous static and RTK solutions perform.

1.3.2 Specific objectives

i. To identify the limitations and challenges of implementing simultaneous static and RTK techniques for GNSS in topographic surveying in remote areas, and to propose strategies for addressing these challenges.

ii. To evaluate the effectiveness of GNSS simultaneous Static and RTK methods in Topographic surveys in terms of time and cost savings.

1.4 Scope and limitations

The research focused on analyzing the accuracy, efficiency and precision of GNSS simultaneous Static and RTK method as compared to the common used method of control extension. The research focused on performance of GNSS simultaneous Static and RTK method for topographic survey in remote areas, using LEICA GS15 receiver and processed by using Leica Infinity software conducted around Ardhi University.

1.5 Significance of the research

This research will benefit surveyors to reduce the burden of time of work by reducing the time to visit and revisit the site area into only one site visit, also this means a less cost will be implied on the performance of the job. This will also help to reduce the need for strong antenna for long baseline. This research will also benefit professional such as Construction engineers as well as Land use planners as this can help to work on more than one site simultaneously regardless of the distance between them.

1.6 Dissertation outline

This dissertation consists of five chapters;

Chapter 1; introduces the topic of performance of GNSS for simultaneous Static and RTK on topographic survey in remote areas. It highlights the need as to why we should employ this method, limitations significance as well as beneficiaries of this research. This also gives the general outline of the dissertation

Chapter 2; briefly describe the reviews and ideas of GNSS positioning techniques, explain the sources of errors as well as the coordinates transformation process

Chapter 3: explains the method and procedures that were undertaken in order to achieve the objectives of the research

Chapter 4; presents the obtained results and discusses them in a significant manner

Chapter 5; provides the conclusion and recommendation

CHAPTER TWO

LITERATURE REVIEW

2.1 GNSS Positioning System;

Global Navigation Satellite System (GNSS) refers to a global, satellite-based, all-weather, 24-hour operational radio-navigation and time transfer system which is designed to provide positioning, timing and navigation (PNT) services primarily for military as well as civilian applications. GNSS is the collective name for the US Navigation Satellite System with Timing and Ranging (NAVSTAR), Global Positioning System (GPS), the Russian Global Navigation Satellite System (GLONASS), European Galileo, Chinese BeiDou and the Japan Quasi-Zenith (QZSS). The use of GNSS has made the extra-terrestrial survey easier and will give better precision. GNSS can not only be used world-wide, all weather and all times but also can be used to determine position to all manner of user especially for surveying and geodetic applications.

2.2 GNSS Point Positioning;

By positioning we understand the determination of positions of stationary or moving objects (Vanic'ek, P. et al, 1986). These positions can be determined: (1) With respect to a well-defined coordinate system usually by three coordinate values. (Here we assume that the 'well-defined coordinate system is itself positioned and oriented with respect to the earth.) (2) With respect to another point, taking one point as the origin of a local coordinate system. The modes are known as Absolute and Relative Positioning respectively.

2.3 Absolute Positioning;

Absolute positioning involves determining the receiver position directly in relation to GNSS satellites. The measurement is done with only one receiver, which is the standard method for measurements with simpler GNSS receivers and in car navigation systems. The measurement uncertainty in absolute positioning can be relatively large, as it normally doesn’t include any method to reduce the effect of the sources of errors that affect the GNSS signals. Absolute positioning is therefore rarely used in geodetic measurements with GNSS. However, in order to reduce the effect of sources of errors in absolute positioning, external information about these can be added when measuring with Precise Point Positioning (PPP) (Wells et al,1987).

2.4 Relative positioning;

In relative positioning, the position of the receiver is determined relative to the one or more points with known positions. This requires more than one receiver that simultaneously measure against the same GNSS satellite. By forming differences between the mutual observations, one can reduce several sources of errors. A rule of thumb is that this works better the closer the receivers are to each other, as the GNSS signals that reach the respective receivers are affected in a similar way (Eunice Menezes de Souza et al, 2009). Figure 2.1 illustrates Relative GNSS positioning

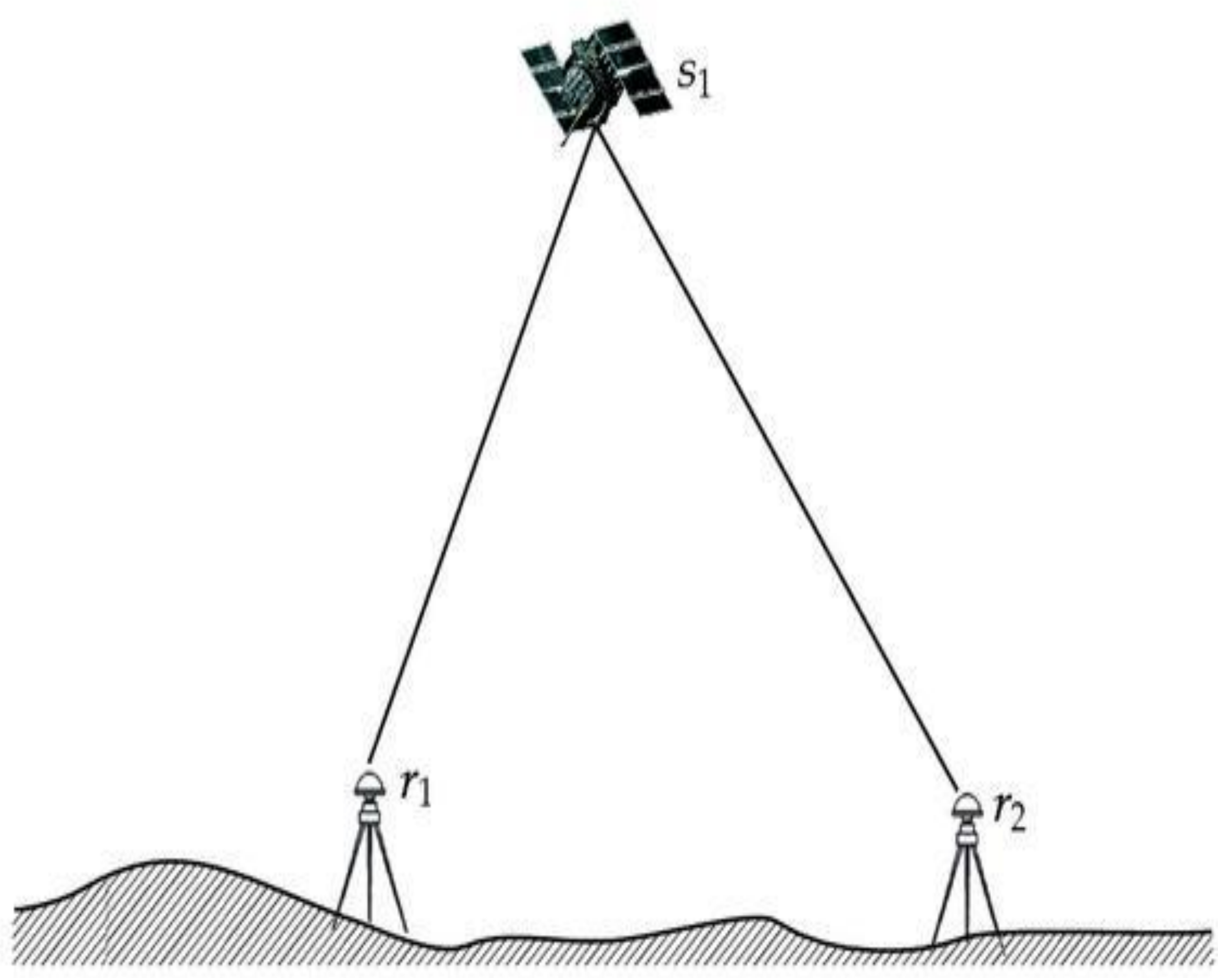

Figure 2. 1 Relative GNSS positioning (Eunice Menezes de Souza et al, 2009).

2.5 Static and Kinematic Positioning

GPS can be used to position static objects or moving objects. If the object to be positioned is stationary, we speak of static positioning. When the object is moving, we speak of kinematic positioning. Both positioning modes can be and are being used for either kind of positioning. Both modes and both kinds are dealt with in this guide. We note that static positioning is used in surveying; kinematic in navigation (Wells et al,1987).

2.5.1 Static positioning;

Static measurement means that you set up the GNSS receiver over the point you want to determine the position. Then it can store measurements over a long period of time - ideally for several hours. The set-up can often be done very accurately with the help of a tripod and optical plummet, so-called forced centering. The static measurements are then combined with simultaneously performed measurements at one or more reference stations with a known position. Static measurement with post-processing is mainly used when establishing or supplementing geodetic control networks. Post-processing of static GNSS measurements with long observation times are often the most accurate way to determine the position, as this gives you the opportunity to use better orbits and make better estimates of other sources of error (for example ionosphere models). Post-processing of static measurements can be done with special software, or by sending the stored GNSS observations in so-called RINEX (Receiver Independent Exchange format) format which is a receiver-independent transmission format that works as a standard for raw data, i.e. code and carrier observations from the GNSS receiver (Wells et al,1987).

2.5.2 Kinematic positioning;

In kinematic positioning, the real-time solution is normally sought. This solution consists of one position (fix) at a time. The resulting string of fixes can be also post processed using one of a number of existing smoothing operations. The kinematic positioning can be either Real Time kinematics (RTK) or Post Processing Kinematics (PPK) whereas PPK requires some post processing while RTK gives the real time position with up to centimeter level accuracy.

2.6 Common errors in GNSS observations;

2.6.1 Ionospheric delay

The ionosphere is the layer of the atmosphere at a height of 50 km to 1000 km above the earth. It contains free electrons due to the sun's radiation, the solar activity and geomagnetic disturbances. In normal atmospheric conditions, its delay is about 1-3 m at night and about 5-15 m in the mid afternoon at mid-latitudes. Furthermore, its magnitude increases at the equator (Misra et al, 2006). The ionosphere advances the carrier- phase measurements and delays the pseudo-range measurements as they travel through the ionosphere. Therefore, the carrier-phase measurements are measured longer and the pseudo-range measurements are measured shorter. The ionospheric delays for the pseudo-range and carrier-phase measurements depend of the total electron content (TEC) along the propagation path of a signal and the frequencies of the measurements due to the dispersive medium property of the ionosphere. TEC depends on the geographic location of the receiver (well behaved in the mid-latitude), time (active at noon and quiet at night) and the solar activities. In DGPS, for the short baselines, the ionospheric error is mitigated by differencing techniques due to fact that the reference and the rover stations are most likely affected by the same magnitude ionospheric delay. For the long baselines, the ionospheric error can be mitigated through a linear combination of the L1 and L2 frequencies, known as an ionosphere-free linear combination.

2.6.2 Tropospheric delay

The troposphere is the layer of the atmosphere from the surface of the earth up to 40 km (Hoffmann-Wellenhof et al., 2001). It can be separated into dry (0-40 km) and wet (0-11km) components. The dry component consists of dry gas molecules and represents about 90% of the total tropospheric error while the wet component consists of the water molecules and represents about 10% of the total tropospheric error. The troposphere is a non-dispersive medium for the frequencies below 15 GHZ and delays both code and carrier-phase measurements. Therefore, it cannot be eliminated by using dual-frequency measurements. The dry tropospheric error can be modelled successfully at zenith direction, but the wet tropospheric error cannot be modelled easily due to the irregular variation of the water molecules over time. Once they are computed at zenith direction, they should be projected to the receiver-satellite direction.

2.6.3 Multipath and Noise

Multipath describes the observable event in which signals from the GNSS satellites travels 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 (Hofmann-Wellenhof, 2008). Since the indirect path are longer than the direct path, multipath arrivals are delayed compared to the direct one. Multipath reflection from nearby objects can arrive at short delays after the arrival of direct path which introduces errors in pseudo range and carrier phase measurements (Miller & Spanis, 2015). Therefore, the multipath errors are dependent on the surrounding environment at large extent, the satellite signals are being reflected by taller obstructions close to the receiver such as buildings, towers, trees and other factors that contribute to multipath effect. This may result to incorrect calculation of the signal propagation time for each satellite to arrive to the receiver as may result to positioning errors.

2.6.4 Receiver clock error

The receivers are generally equipped with the inexpensive crystal clocks which are not set exactly to GNSS reference time and also, they can drift easily over time (Hofmann- Wellenhof et al., 2001). This offset between the GNSS reference time and the receiver time is called the receiver clock error. In PPP, it can be mitigated by estimating as an unknown parameter, while in DGPS, it can be eliminated by the between satellite differences techniques without depending on the separation between the reference and rover stations.

2.6.5 Satellite Orbit and Clock error

These satellite orbits can be obtained from the broadcast orbits or the precise orbits (Hofmann-Wellenhof et al., 2001). The broadcast orbits can be computed in a system-related Earth-Centered, Earth- Fixed (ECEF) coordinate system using the orbital parameters transmitted by the satellites in real-time as a part of their navigation messages in the accuracy range of about 1-6 meters while the precise orbits can be obtained in International Terrestrial Reference Frame (ITRF) coordinate system from International GNSS Service (IGS) via Internet free of charge in different latencies and accuracies, but generally in the range of about 5 centimeters. The satellite orbit error is the difference between its actual and predicted orbits. In DGPS, the satellite orbit errors are significantly mitigated by differencing techniques. However, the mitigation success depends on the separation between the reference and rover stations. Note that the precise orbits can also be used for DGPS to increase the positioning accuracy. The satellite clock error refers to the offset between GNSS reference time and satellite clock time due to a lack of synchronization of the satellite clock with respect to GNSS reference time. The satellite clock error can be mitigated using the broadcast clock corrections in the navigation messages with the precision of 7 nanoseconds, or precise clock corrections with precision of about 0.1 nanoseconds depending on the latency from IGS. Note that 1 nanosecond clock error causes to a range error of about 30 cm. In DGPS, these satellite clock errors are eliminated completely by differencing techniques without depending on the separation between the reference and rover stations (Parkinson et al., 1996; Sanz Subirana et al., 2013).

CHAPTER THREE

METHODOLOGY

This chapter presents the methods and procedures applied in this study. It is a breakdown of every process that was involved in obtaining the required results for our research. This include the data collection methods, conditions that were put into considerations and the like. This process was accomplished in the following order; Data search and reconnaissance, Network design, Monumentation and Data collection, Quality check and Data processing

3.1 Data search and reconnaissance

This process involved physical survey and gathering of initial information of the area to be researched. During reconnaissance various resources to be used are likely to be analyzed. Including data search to identify the presence and existence of coordinates for control points to be used, understanding the nature of environment, to identify if they met the requirements. In this study the reconnaissance is divided into two parts namely office and field reconnaissance. In office reconnaissance involved searching necessary information and data availability including acquired coordinates of existing control points from the survey office at Ardhi University. In field reconnaissance, it involves familiarization with the projected area, nature of the terrain and identify boundaries. Where by all the control stations were found on the stable ground. The control point used was MKG 09 at Ardhi University whose coordinates are shown in table 3.1 below.

Table 3. 1; Coordinates of control point MKG 09 in UTM (WGS 84)

S/No	Point ID	Easting(m)	Northings(m)	Elevation(m)
1	MKG 09	523946.770	9252343.692	39.403

3.2 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 network.

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 area, 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.

There are two methods of establishment of control point, which are a) Conventional surveying consisting of Triangulation, Trilateration, Traverse, Resection. Conventional surveying performed using traditional precise surveying techniques and instruments, it needs intervisibility between adjacent stations. b) Space technique which consist of Static and rapid static for HZ and VT (GNSS surveying) in GNSS surveying relative technique mostly preferred and it needs visibility to sky.

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 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 involves 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 mostly preferred and it needs visibility to sky.

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 GPS (Global Positioning System).

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. The network design in this research followed the above mentioned criteria and is as shown in figure below

Figure 3. 1; GNSS observation network

3.3 Monumentation

This process involves placing of permanent markers on survey area for the purpose of identifying position on the ground and specified during the completion of a professionally conducted survey. A hole of about 50 cm deep and 20cm wide was dug, then prepared a concrete of sand, cement and fine gravels, Iron pin at center of the hole. Then fed with concrete in the hole and maintained that the pin was almost at the center of the hole. The whole process is as shown in Figure 3.2

Figure 3. 2; Monumentation process for control points SSR 01 and SSR 02

3.4 Instrumentation

Selection of instrument used during data acquisition was based on GNSS receiver that is capable of performing Static observations and RTK at the same time which was LEICA GS15 receivers. Other instruments used during data collection were tripod stand, tribrach, receiver pole, GPS tape measure.

3.5 Data acquisition and GNSS survey

The data acquisition stage was completed under three important phases;

The first phase involved the static observation of the control points in which MKG 09 was set as known point and the two new points SSR01 and SSR 02 were established. The observation time was about 2 hours for this phase

Second phase involved the RTK observation of some selected points that were named from SSR to SSR7. A normal detail survey was used to obtain the 3D coordinates of these points and they were marked by using pegs.

The final phase involved the performance of simultaneous Static and RTK in which all the points were observed together at the same time. The RINEX files were obtained were obtained for both static and simultaneous static and RTK observations which were used for post processing. Figure 3.3 illustrates the observation process.

Figure 3. 3; GNSS data acquisition process

3.7 Data Quality check

The quality of RINEX files were checked using Effix Geomatics Office (Eoffice) software. Eoffice is a software provided by China. The data quality check is important as it compares the actual observed data versus standard for observed data. The data were collected at open sky and minimum sky obstruction which indicates the quality for data processing. The data quality was assessed in percentage where by the percentage below 60% indicated poor observation, between 60% and 80% indicated good observation and above 80% indicated excellent observation. The obtained data quality is as shown in the Figure 3.4

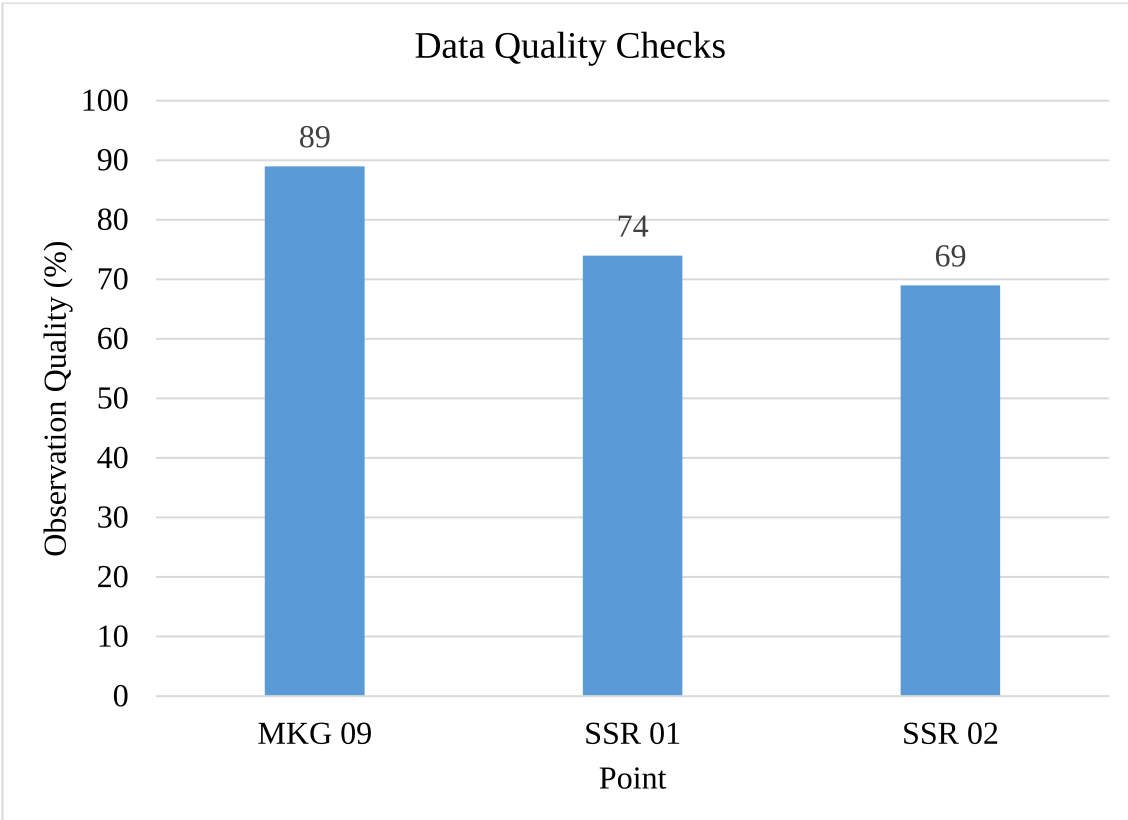

Figure 3. 4; Data quality checks by Eoffice software

3.8 Data processing

Data processing was done using two different software, Trimble Business Centre (TBC) and LEICA infinity software. TBC software was used to process baselines and perform the adjustment for coordinates of static observations for points MKG 09, SSR 01 and SSR 02. These coordinates were later used for transformation of the obtained SSR coordinates from arbitrary reference station to their corresponding coordinates on the ground.

3.8.1 Baseline processing

The baselines were processed so as to assess the accuracy of the observations as well as the fixed control in the observation network. The files used for baseline processing were RINEX observational and navigational files and the frequencies were L1 and L2. Figure3.5 Shows processed baselines using TBC

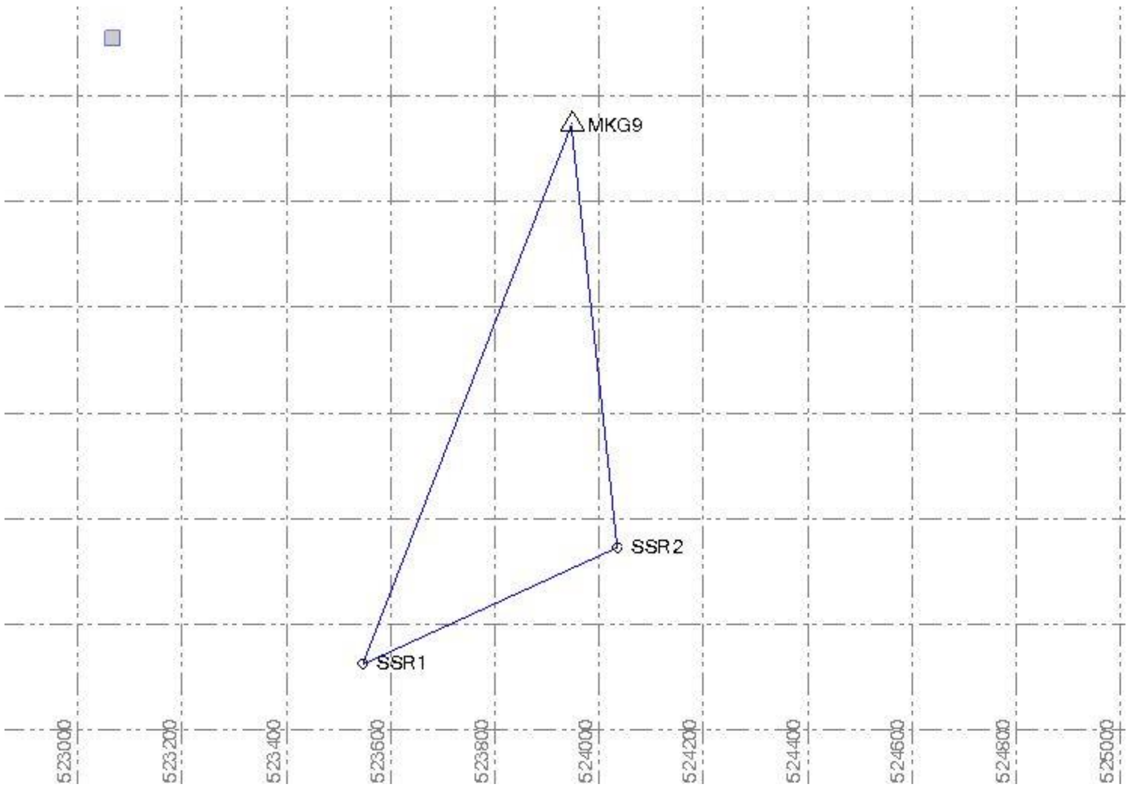

Figure 3. 5; Processed baselines using TBC

3.8.2 Network adjustment

The aim of network adjustment is to fix the coordinates in accordance to the control point used and reduce some errors found during baseline processing. The type of adjustment used was constrained adjustment and the fixed point was MKG 09 which is considered errorless during network adjustment. The following figure shows the adjusted network

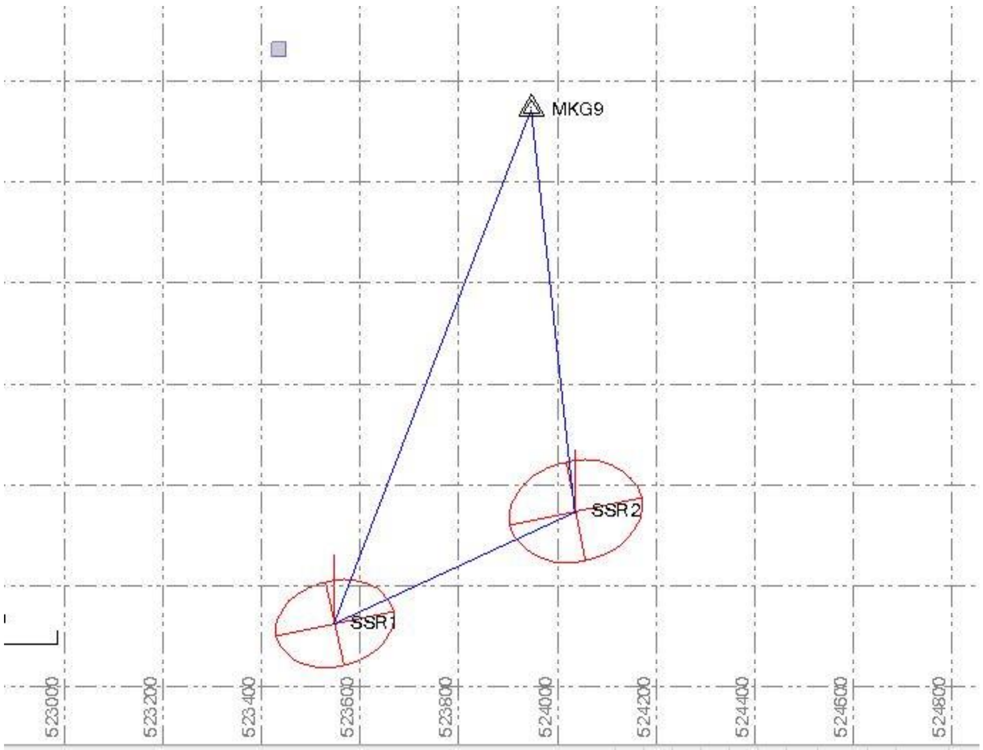

Figure 3. 6; Adjusted network using TBC

3.8.3 Coordinates transformation

For coordinates transformation LEICA infinity software was used in which three points were used to shift, rotate and scale the points for them to be transformed to new coordinates. The points used were SSR 01, SSR02 and MKG09 and the transformation method used was by using common points. MKG09 was used for height transformation only whilst SSR 01and SSR 02 were used for both positions and height transformation. Figure 3.7 shows the transformation process by LEICA infinity software

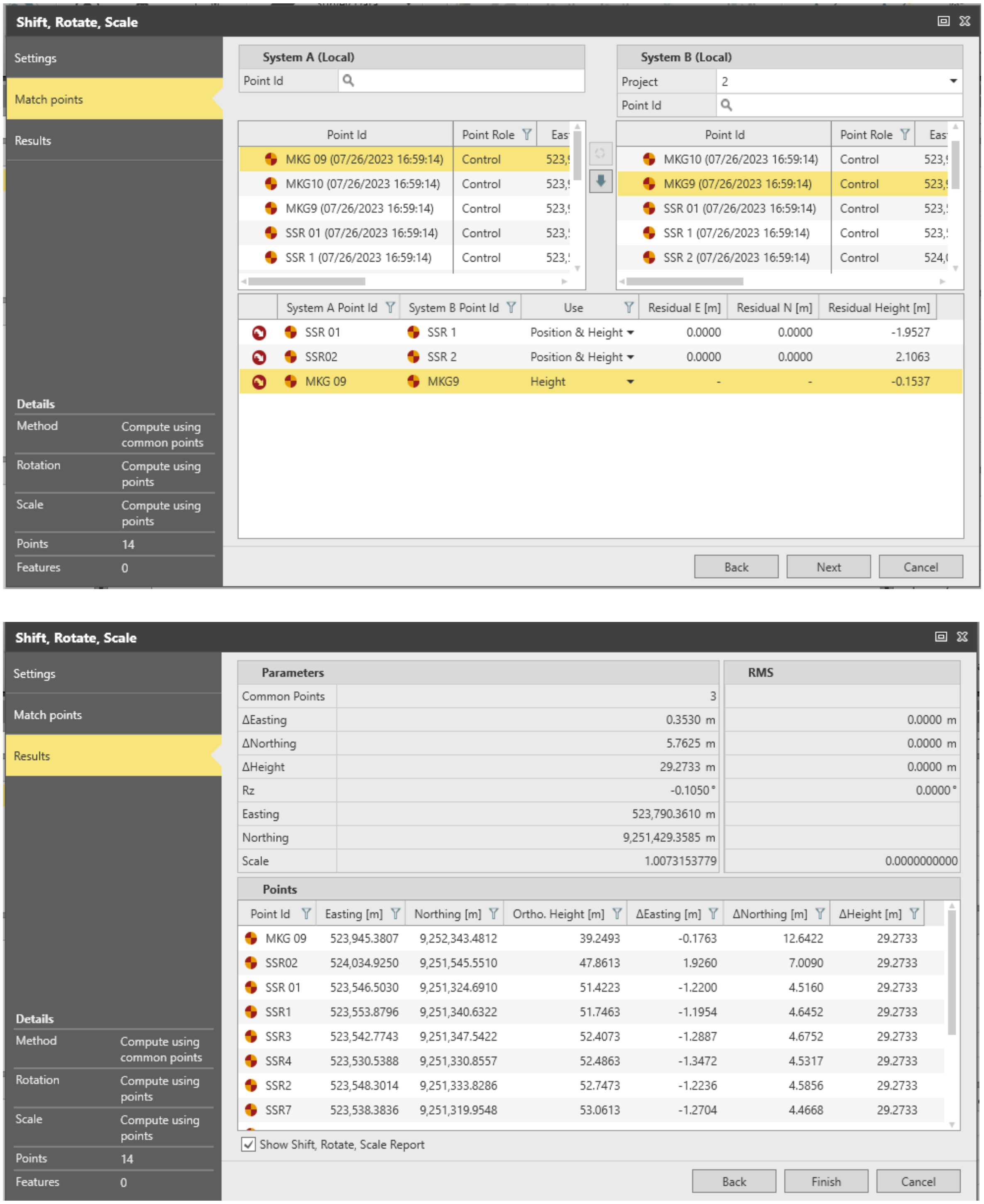

Figure 3. 7; Coordinates transformation by LEICA infinity software

CHAPTER FOUR

RESULTS AND ANALYSIS

This chapter presents the final results obtained after processing GNSS data using Trimble Business Center (TBC) as well as LEICA infinity software and analysis of the results will be thoroughly discussed, and statistically displaying the final results.

4.1 Baseline Processing Results

4.1.1 Static observations results

Using the TBC software, baseline processing was done for the static observation raw data, then the adjustment was done using constrained adjustment method and coordinates were obtained in the UTM (WGS84) format. Table 4.1 shows an extract from the report that includes adjusted coordinates of the points MKG 09, SSR1 and SSR

Table 4. 1;Adjusted Grid coordinates for static observation in UTM (WGS84)

Point ID	**Easting (m)**	**Easting Error (m)**	**Northing (m)**	**Northing Error (m)**	**Elevation (m)**	**Elevation Error (m)**	**Constraint**
MKG9	523946.770	0.00	9252343.692	0.00	39.403	0.00	ENe
SSR1	523546.503	0.003	9251324.691	0.002	53.375	0.011	
SSR2	524034.925	0.003	9251545.551	0.003	45.755	0.010	

4.1.2 RTK observations

The RTK coordinates were obtained in which the points were referenced from known control SSR 01 and tabulated as in table below

Table 4. 2; RTK Coordinates in UTM (WGS 84)

RTK COORDINATES			
STATION	EASTINGS (m)	NORTHINGS(m)	ELEVATION(m)
SSR1	523553.838	9251340.596	51.685
SSR2	523548.291	9251333.771	52.705
SSR3	523542.828	9251347.511	52.361
SSR4	523530.544	9251330.817	52.451
SSR5	523513.693	9251299.59	53.966
SSR6	523527.032	9251313.379	53.618
SSR7	523538.428	9251320.002	53.033

4.1.3 Simultaneous Static and RTK observations

Simultaneous Static and RTK coordinates were taken in which they were referenced from an arbitrary control placed at SSR 01 and tabulated as in table below

Table 4. 3; Simultaneous Static and RTK Coordinates in UTM (WGS84)

SSR COORDINATES			
STATION	EASTINGS(m)	NORTHINGS(m)	ELEVATION(m)
SSR1	523553.880	9251340.622	51.706
SSR2	523548.301	9251333.829	52.747
SSR3	523542.774	9251347.542	52.407
SSR4	523530.538	9251330.857	52.486
SSR5	523513.653	9251299.566	54.006
SSR6	523527.000	9251313.354	53.645
SSR7	523538.378	9251319.955	53.063

4.2 Analysis of the results;

In order to evaluate the accuracy of the coordinates from different strategies, the Grid coordinates for the seven stations have been computed from LEICA infinity software. The RTK only solution coordinates were taken as the true coordinates and used as the reference coordinates. The coordinate differences and positional accuracy between base coordinate and other position solution were taken into consideration.

4.2.1 Analysis of the coordinate difference, horizontal and positional accuracy for all the position solution

The coordinate difference is obtained from the difference between the RTK solution and other solution.

Position difference (Δ) =RTK solution – other solution

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

Position accuracy = $\sqrt{\Delta N^2 + \Delta E^2 + \Delta h^2}$ (Ashour, 2021)

The maximum difference in coordinates for horizontal coordinates was found to be less than 6cm for East, 6cm Northings. And 5cm in vertical direction. Maximum horizontal accuracy was found to be 7cm for horizontal accuracy and 8cmfor vertical positional accuracy

The following table shows the coordinate difference, positional and horizontal accuracies for the simultaneous Static and RTK observations

Table 4. 4; the coordinate difference, horizontal and positional accuracies in UTM (WGS 84)

COORDNATE DIFFERENCE				HORIZONTAL ACCURACY(m)	POSITIONAL ACCURACY(m)
STATION	ΔE(m)	ΔN(m)	ΔH(m)		
SSR1	-0.042	-0.026	-0.021	0.0494	0.05367
SSR2	-0.01	-0.058	-0.042	0.05886	0.0723
SSR3	0.054	-0.031	-0.046	0.06227	0.07741
SSR4	0.006	-0.04	-0.035	0.04045	0.05349
SSR5	0.04	0.024	-0.04	0.04665	0.06145
SSR6	0.032	0.025	-0.027	0.04061	0.04876
SSR7	0.05	0.047	-0.03	0.06862	0.07489

4.2.3 Graphical analysis of horizontal accuracy of a point

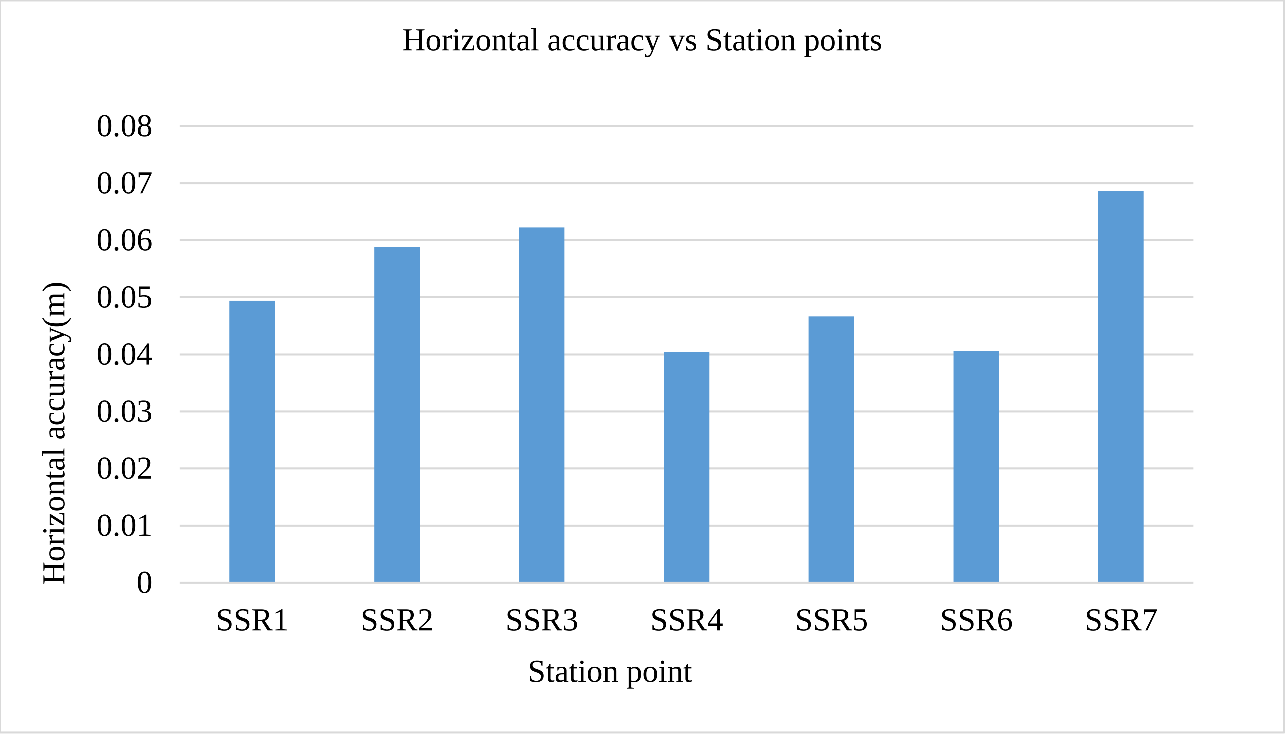

Figure 4. 1; Horizontal accuracy for the points

4.2.4 Graphical analysis of positional accuracy for Simultaneous Static and RTK

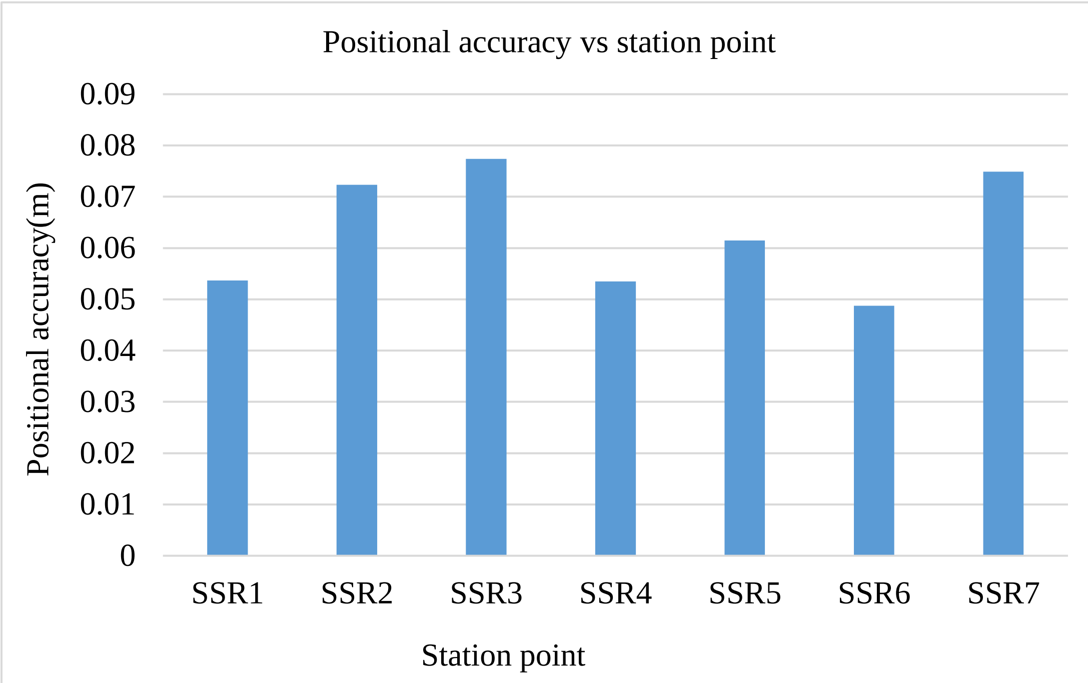

Figure 4. 2; A graph of positional accuracy for points

4.3 Discussion of the results

The main objective of this research was to assess the accuracies of position solutions by comparing the coordinate from two methods, Simultaneous Static solutions and RTK and normal RTK solutions. By evaluation of positional differences and respective accuracy it was found that

i. The horizontal accuracy for the observation of simultaneous Static and RTK had a maximum value of 7cm
ii. The positional accuracy was found to have a maximum accuracy of 8cm.

The coordinates obtained by Simultaneous static and RTK solution can be used for positioning works such as Cadastral surveys and even topographic surveys and Fast Static Surveys for Control extension.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The performance of Simultaneous Static and RTK has been assessed and it has shown to be able to achieve centimeter accuracy for both horizontal and 3 dimensional positioning. This shows that the method can effectively be used as a substitute for the traditional method that involves conducting control extension and detail survey separately. Application of this method will help to the cost and time for conducting detail survey in remote areas also the surveyors will not have to worry much about the distance between base and receiver or the use of strong antenna to make the radio signal strong.

The method being able to achieve centimeter accuracy can be used for cadastral surveys, detail surveys for land use planning as well as engineering surveys according to the requirements of the client.

5.2 Recommendations

From the results obtained, the following are the recommendations;

i. The coordinates obtained by Simultaneous static and RTK solution can be used for horizontal positioning works such as Cadastral surveys and even topographic surveys and Fast Static Surveys for Control extension.

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APPENDIX

Project File Data	Coordinate System	
Name:	Name:	World wide/UTM
Size:	Datum:	WGS 1984
Modified:	Zone:	37 South
Time zone:	Geoid:	EGM96 (Global)
Reference number:	Vertical datum:	
Description:	Calibrated site:	
Comment 1:		
Comment 2:		
Comment 3:		

Network Adjustment Report

Adjustment Settings

Set-Up Errors

GNSS

Error in Height of Antenna:	0.003 m
Centering Error:	0.000 m

Covariance Display

Horizontal:	
Propagated Linear Error [E]:	U.S.
Constant Term [C]:	0.000 m
Scale on Linear Error [S]:	1.960
Three-Dimensional	
Propagated Linear Error [E]:	U.S.
Constant Term [C]:	0.000 m
Scale on Linear Error [S]:	1.960

Adjustment Statistics

Number of Iterations for Successful Adjustment:	2
Network Reference Factor:	0.72
Chi Square Test (95%):	Passed
Precision Confidence Level:	95%
Degrees of Freedom:	3

Post Processed Vector Statistics

Reference Factor:	0.72
Redundancy Number:	3.00
A Priori Scalar:	1.00

Control Point Constraints

Point ID	Type	East σ (Meter)	North σ (Meter)	Height σ (Meter)	Elevation σ (Meter)
MKG9	Grid	Fixed	Fixed		Fixed
Fixed = 0.000001(Meter)					

Adjusted Grid Coordinates

Point ID	Easting (Meter)	Easting Error (Meter)	Northing (Meter)	Northing Error (Meter)	Elevation (Meter)	Elevation Error (Meter)	Constraint
MKG9	523946.770	?	9252343.692	?	39.403	?	ENe
SSR1	523546.503	0.003	9251324.691	0.002	53.375	0.011	
SSR2	524034.925	0.003	9251545.551	0.003	45.755	0.010	

Adjusted Geodetic Coordinates

Point ID	Latitude	Longitude	Height (Meter)	Height Error (Meter)	Constraint
MKG9	S6°45'50.10564"	E39°13'00.12486"	11.511	?	ENe

SSR1	S6°46'23.29573"	E39°12'47.09980"	25.510	0.011	
SSR2	S6°46'16.09625"	E39°13'03.00834"	17.872	0.010	

Adjusted ECEF Coordinates

Point ID	X (Meter)	X Error (Meter)	Y (Meter)	Y Error (Meter)	Z (Meter)	Z Error (Meter)	3D Error (Meter)	Constraint
MKG9	4907369.923	?	4004735.784	?	-746215.364	?	?	ENe
SSR1	4907540.467	0.009	4004358.708	0.007	-747229.489	0.003	0.012	
SSR2	4907245.938	0.008	4004748.893	0.006	-747008.967	0.003	0.011	

Error Ellipse Components

Point ID	Semi-major axis (Meter)	Semi-minor axis (Meter)	Azimuth
SSR1	0.004	0.003	78°
SSR2	0.004	0.003	78°

Adjusted GNSS Observations

Observation ID		Observation	A-posteriori Error	Residual	Standardized Residual
MKG9 --> SSR1 (PV4)	Az.	201°25'10"	0.519 sec	-0.142 sec	-0.807
	ΔHt.	13.999 m	0.011 m	0.016 m	1.645
	Ellip Dist.	1095.225 m	0.002 m	0.000 m	-0.315

SSR2 --> SSR1 (PV5)	**Az.**	245°38'32"	0.791 sec	-0.059 sec	-0.286
	ΔHt.	7.639 m	0.008 m	-0.002 m	-1.580
	Ellip Dist.	536.247 m	0.002 m	0.000 m	0.404
MKG9 --> SSR2 (PV6)	**Az.**	173°40'18"	0.858 sec	0.077 sec	0.152
	ΔHt.	6.361 m	0.010 m	-0.003 m	-1.222
	Ellip Dist.	803.310 m	0.002 m	0.001 m	0.412

Covariance Terms

From Point	To Point		Components	A-posteriori Error	Horiz. Precision (Ratio)	3D Precision (Ratio)
MKG9	SSR1	**Az.**	201°25'10"	0.519 sec	1 : 452275	1 : 447279
		ΔHt.	13.999 m	0.011 m		
		ΔElev.	13.972 m	0.011 m		
		Ellip Dist.	1095.225 m	0.002 m		
MKG9	SSR2	**Az.**	173°40'18"	0.857 sec	1 : 323173	1 : 321650
		ΔHt.	6.361 m	0.010 m		
		ΔElev.	6.352 m	0.010 m		
		Ellip Dist.	803.310 m	0.002 m		
SSR1	SSR2	**Az.**	65°38'34"	0.794 sec	1 : 216012	1 : 214851
		ΔHt.	-7.639 m	0.008 m		
		ΔElev.	-7.620 m	0.008 m		
		Ellip Dist.	536.247 m	0.002 m		