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**UPD67297SGE76398**

**Establishment of GNSS Geodetic Controls in University of Benin Using Cors\_GeoSystems.**

**A Final Thesis Presented to**   
**the Academic Department**

**of the School Science and Engineering**   
**in Partial Fulfillment of the Requirements**

**for the Degree of Doctor of Science**

**in Geomatics Engineering**

**ATLANTIC INTERNATIONAL UNIVERSITY**

**HONOLULU, HAWAI**

**SUMMER 2022**

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**1.0 Introduction**

The purpose of this Thesis is to establish Global Navigation Satellite Systems (GNSS) 1st order control in University of Benin with reference to the Continuous operating Reference Station (CORS) currently install in Benin city by the Author of the Thesis.

University of Benin founded 1972 without the Department of Geomatics not until 2014 when the department of Geomatics was created the Department of Civil Engineering. Since 1972 when the university was founded, there was not any form of Geodetic infrastructure until 2014 when the first sets of three (3) second order Geodetic control was established by the author of the thesis.

Since 2014, the author of this thesis has made personal effort to change the narratives by extending some second other controls for student training, erosion control and Gully monitoring and rehabilitations.

The recent installation of CORS Network in Benin City by the author of this Thesis is the drive to Establish 1st other Geodetic control in University of Benin where other controls in the future with be Referenced.

CORS Geosystem provide Global Navigation Satellite System (GNSS) data, supporting three-dimensional positioning, meteorology, space weather, and geophysical applications manufactured by TERSUS GNSS in China.

Surveyors, GIS users, engineers, scientists, and other people who collect GPS/GNSS data can use RINEX data, acquired at fiducial geodetic control stations, to improve the precision of their positions, and align their work within the Nigeria Geospatial Reference System. Tersus GNSS (David) is enhanced for post-processed coordinate accuracies can approach a few centimeters, both horizontally and vertically as well as equipped with the capacity of Real Time kinematic on detail, Control, and continuous modes.

The CORS network is a multi-purpose, multi-agency cooperative endeavor, combining the efforts of hundreds of government, academic, and private organizations. The stations are independently owned and operated. Each agency shares their GNSS/GPS carrier phase and code range measurements and station metadata with other users, which are analyzed and distributed free of charge.

2.0 **Description**

In 1994, Federal Radionavigation Plan, promulgated by the United States Government, states that the Standard Positioning Service component of the Global Positioning System (GPS) supports autonomous positioning accuracies of that is not adequate of Surveying and mapping purposes. For most GPS applications in surveying, mapping, and related disciplines, these accuracies are insufficient and need improvements. In order to improve positional accuracies to the level of a few meters or better, a relative positioning technique is usually employed. Relative GPS positioning involves the collection of observables by a GPS reference station whose position is known. These data are then combined with data collected by other receivers whose positions are to be determined. This process may be performed either in real-time (Continuous, controls) or in a Static or post-processed mode. If performed in real-time for navigation purposes, the technique is generally known as differential GPS. Differential GPS involves the generation and transmission to users of reference station correction data. The equipment and procedures utilized in a relative GPS positioning technique determine the level of accuracy that is attainable [1,2].

In addition to supplying GPS observational data needed for relative positioning, a reference station may also, depending on its configuration, contribute to a variety of efforts such as the generation of precise satellite ephemerides and clock correction data, crustal motion monitoring, and atmospheric and earth rotation studies [2]. While automated reference stations are referred to by a variety of names in the literature, such as base stations, active control stations, tracking stations, etc., the term continuously operating reference station (CORS), which has been adopted by the National Geodetic Survey, an office of the United States Department of Commerce's National Oceanic and Atmospheric Administration. The National Geodetic Survey is embarking on an ambitious CORS program in support of its fundamental mission of providing an accurate and consistent national coordinate system, known as the National Spatial Reference System [2].

In the last few years, CORS has been developed and adopted all over the world. In Nigeria, this technology is still new, and Engineers are still trying to understand the Technology. Although office of the Surveyor General of Federation has made some meaning efforts be establishing about 18 CORS across Nigeria. This number is grossly inadequate. CORS Geosystems was acquired and installed to serve as a permanent, reliable Geomatics infrastructure in the City of Benin which will further increase the numbers of CORS in Nigeria.

The intent of this Thesis is to densify 1st order controls in University of Benin for the purposes of research, Teaching and learning, control of erosion and gully, Mapping and developing, Facilities and as-built survey etc.

**2.1 Geodetic Network**

A geodetic network is a collection of triangles that have been precisely measured using terrestrial surveying techniques or satellite geodesy. This is done in "classical geodesy" (up to the 1960s) through triangulation, which is based on angles and some spare lengths; the accurate orientation to the geographic north is acquired using geodetic astronomy methods. Theodolites and tachometers are the most common instruments, which are now equipped with infrared distance measuring, data bases, communication systems, and, in certain cases, satellite links. When the prototype apparatus became compact enough to be utilized in the field, Electronic Distance Measurement (EDM) was introduced around 1960. EDM improved network accuracies to 1:1 million (I cm every 10 km; currently, at least 10 times better) while also lowering surveying costs. Around the same time, satellites were being used for geodetic purposes. Global networks were determined utilizing bright satellites like as Echo I, Echo II, and pages, which eventually offered support for the idea of plate tectonics **[32].**

Several hundred geodetic satellites are currently in orbit, in addition to a large number of remote sensing satellites and navigation systems such as GPS and GLONASS, which will be followed by the European Galileo satellites until 2013. While these advancements have made satellite-based geodetic network surveying more versatile and cost-effective, fixed-point networks are still required for administrative and legal purposes at the local and regional levels. Because geodynamics changes the position of all continents by 2 to 20cm every year, global geodetic networks cannot be defined as fixed. Modern worldwide networks such as ETRF and ITRF display not only the coordinates of their "fixed points," but also their annual velocities **[4]**

A geodetic control point is a survey point that has been monumented or otherwise designated for the purpose of providing geodetic reference for mapping and charting activities, as well as a range of engineering and scientific purposes. Geodetic controls are a set of coordinated horizontal or vertical position data that serve as a framework for referencing and adjusting other surveys. They serve as the foundation or starting point for all types of survey projects. They also show where data for land and geographic information systems can be found. The stability of the controls used, the tools and procedures used in completing the task, the mathematical models used for data manipulation, the reference surfaces, and the coordinate systems all contribute to the accuracy of survey work [7]**.**

**2.2 Geodetic Network Densification**

Up until recently, network densification was the only option to make the placements of measured points both technically and economically accessible to consumers. It's a requirement for putting together an integrated survey system **[6].** Various position information and point locations, monumentation, and spacing are among the requirements imposed on points of the integrated survey system by a diverse range of users. The strict accuracy criteria for 1:500 large scale mapping and relocation surveys in metropolitan areas are 5 cm and 1 centimeter (with 499m spacing or less), respectively, and the much lower 9.19m required for medium scale mapping at 1:50000 scale **[5].** These needs are met in multiple phases through network densification. The main issue is that the densification network can be defined incorrectly within the current network at each tier of the hierarchy. However, because there are numerous ways that lead to rigorous solutions, this study will look into the techniques as well as the rigor of the solution in terms of practicality and cost.

**2.3 Horizontal Control**

Horizontal control is given by two or more permanently or semi permanently monumented sites on the ground that are accurately set in horizontal position by distance and direction, or coordinates. Traditional ground surveying methods such as accurate traversing, triangulation, trilateration, and a combination of these basic procedures, as well as more recent technologies such as GPS, can be used to establish horizontal control. Azimuth, latitude, and longitude have also been determined using astronomical measurements. To densify the control in a given area, rigorous photogrammetric approaches were applied. Until recently, triangulation and trilateration were the most cost-effective methods for establishing fundamental control for large-scale mapping projects, such as those for regions and states. These methods have now been replaced by GPS, which has shown to be not only more accurate but also more efficient. Monuments whose placements have been established through higher-order control surveys and referenced in state plane coordinate systems are used to commence all types of surveys, although more are unfortunately required in most areas.

**2.4 Vertical Control**

Benchmarks in or near the track to be surveyed give vertical control, which serves as the foundation for accurately depicting terrain on topographic maps. Running lines of differential levels starting from and closing on set benchmarks are commonly used to establish vertical control. The elevations of project or temporary benchmarks are derived by including them as turning points in differential leveling lines in strategic areas, usually close and around the project area. With the rise in popularity of total stations, trigonometric leveling has become a viable option for establishing vertical control for mapping, particularly in difficult terrain. Vertical control can also be established via GNSS surveying; however, the ellipsoidal heights must first be translated to orthometric heights.

**2.5 Geodetic Networks in Nigeria**

* + 1. The Nigerian (Minna) Geodetic Network

First-order triangulation chains and traverse control networks cover Nigeria. These networks were created using the Nigerian geodetic datum, which was created using the astrogeodetic approach and has its genesis at station L40 (the northern terminal of the Minna base of the Nigerian Primary triangulation network). As a result, the datum is a local geodetic datum known as "Minna B" (the Minna datum used in the Republic of Cameroun is known as "Minna A"). The Clarke 1880 ellipsoid (Semi-major axis, a = 6378249.145m; Flattening, f = 1/293.465) is the basis for the Minna B datum. The L40 origin has the following adopted geodetic co-ordinates **[40]:**

Latitude φ = 09o 38′ 09″ N

Longitude λ = 06o 30′ 59″ E

Height H = 279.6m above the geoid. Details of the establishment of Nigerian Datum can be found in **[40]**

**2.5.2** Coordination of The Nigerian Primary Geodetic Network

**[12]** used GPS to observe some existing Nigerian Primary Triangulation stations, while re-establishing others. To give access to high accuracy GNSS control, the GNSS geodetic network, as well as its reference frame, must be refreshed on a regular basis. From October 2010 to April 2011, a GNSS campaign was conducted. To build the strengthening network, a total of 60 stations were observed for 48 hours. These stations were dispersed throughout the GNSS network in order to link the existing Nigerian Primary Triangulation Network to the Zero Order Geodetic Network (NIGNET), resulting in the formation of a new Nigerian Primary Geodetic Network (NPGN) based on the NGD2012 reference frame.

The NIGNET stations processing approach was used to process the observed data from the sixty (60) GNSS monuments. The network was strengthened through two rounds of network adjustment: the free network and the strongly constrained network. NIGNET stations were held stable during the restricted adjustment to adjust the observed baseline vectors in order to get the link station's coordinates to conform to NGD2012. The network's quality assessment demonstrates that variations of less than 10 mm are obtained. Due to poor data quality, only one station in the NPGN could be processed. The final extremely constrained adjustment used 11 NIGNET stations that were fixed with their respective standard deviations introduced from the prior adjustment (Fixed NIGNET stations). The GPS vectors were able to spin throughout the network as a result of this method.

The new NPGD has been successfully built, with its coordinates according to the ITRF2008 Epoch 00.0 with an accuracy of 1 to 10 mm and a connection to the Zero Order Geodetic Network.

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**Fig 2.0 NIGNET and Nigerian Primary Geodetic Network (GPS Monuments)**

Conclusion Derived from the Nigerian Primary Geodetic Network Coordination:

The African Reference Frame (AFREF) goal is realized in the Nigerian Geocentric Datum NGD2012. It served as the backbone for all surveying and mapping activities, with a precision of 10 mm stated in ITRF2008. The new NGD2012 will be maintained and administered by the Nigerian Permanent GNSS Network of Continuously Operating Reference Stations (CORS), which together form the Zero Order Geodetic Network, ensuring that the nation always has a high-accuracy, homogeneous, and up-to-date datum. The NGD2012 will, without a doubt, provide an internationally compatible system for all spatial data. As a result, the application of satellite positioning, particularly GNSS, in the country will profit more. The challenge for the OSGoF is to adapt strategies and structure so that it is ideally positioned to continue to serve the requirements of the country, especially now that the country is experiencing rapid development and the government is encouraging the growth of the spatial information business In this new millennium, with an ever-increasing demand for geodetic goods, it is envisaged that OSGoF will continue to create and implement its modernization programs by adopting more creative surveying and mapping methodologies. Without a doubt, OSGoF will be able to realize its mission and objectives in accordance with the Federal Government Transformation strategy as a result of this endeavor.

* + 1. GNSS Networks in Nigeria

Many geodetic controls are currently being established throughout Nigeria using observations provided with GPS navigation satellites. The Federal Government of Nigeria established eleven (11) Continuously Operating Reference Stations (CORS) in strategic locations across the country in the recent past (2009-2010) to capture and stream data to the Office of the Surveyor-General of the Federation (OSGoF) Coordinating Centre in Abuja on a continuous basis (the Federal Capital territory). However, many oil companies operating in Nigeria's Niger Delta region had already set up numerous GPS control networks to help them with their oil drilling operations. All of these GPS measurements are reduced and calculated using the World Geodetic System of 1984 (WGS84 - datum), which employs a geocentric ellipsoid with the following dimensions: 1/298.257223563 a = 6378137.0 m f = 1/298.257223563

The coordinates derived from GPS can be expressed in Cartesian (X, Y, Z), geodetic (latitude, longitude, and ellipsoidal height), or Universal Transverse Mercator (UTM) planes.

**2.6 Global Navigation Satellite System (GNSS).**

The global navigation satellite system (GNSS) is a space-based radio positioning system that includes one or more satellite constellations, augmented as needed to support the intended operation, and provides three-dimensional position, velocity, and time information to suitably equipped users anywhere on or near the earth's surface 24 hours a day, seven days a week.

GNSS is a generic phrase that refers to a number of existing and future satellite constellations, as well as accompanying infrastructure systems, that are used to determine location across the globe. They are coordinated with data communications methods such as radio or the internet, playing a vital role in the operation of powerful, integrated information management and control systems with a diverse range of applications affecting many parts of the national and regional economies, the core element of GNSS are;

* Global positioning system (GPS).
* Global orbiting navigation satellite system (GLONASS).
* Galileo.
* Beidou/ COMPASS.

The Global Navigation Satellite System (GNSS) is a relatively new critical instrument that has transformed nearly all applications that require extremely precise positioning, navigation, and timing in the frequency domain. As a result of this advancement, high-accuracy stations have been installed all over the world. Positioning with GNSS can now be performed by either point positioning or differential (relative) [2].

Positioning. One GNSS receiver is used in GNSS point positioning, whereas two (or more) GNSS receivers are used to track the same satellites simultaneously in differential positioning **[19].** To drastically reduce common station errors, most GNSS users who demand higher precision now operate differently with regard to a known reference [16]**.** The prevalence of errors decreases as the distance between a roaming receiver and its reference rises, thus using range corrections from a single reference station may not produce optimal results for point placement **[6].** One of the most widely used technologies is global navigation satellite systems (GNSS). Satellite navigation applications are included in billions of smartphones and other devices. GNSS has been ingrained in our daily lives, assisting us in a variety of domains such as transportation, precision machine control, and surveying. The global installed base of GNSS devices in operation is expected to reach about 6.5 billion by 2020. **(Carlo des Dorides).**

GNSS has made precise navigation accessible to the general public. They analyse signals provided from satellites in known orbits to generate an estimate of position, velocity, and time. The GNSS, or global positioning system, is the single most essential and widely used tool in modern navigation (GPS). Many users prefer it to other navigation and timing systems because of its accuracy, worldwide availability, and low cost.

**2.7 GNSS components**

The Global Navigation Satellite System (GNSS) is made up of three key satellite technologies: GPS, Glonass, and Galileo. Each one is made up of three sections: a space segment, a control segment, and a user segment. In the three satellite technologies that make up the GNSS, these parts are essentially identical. As of today, the GPS technology is the entire satellite technology, and most of the present global applications are related to the GPS technology. After the functioning of Galileo and the reconstruction of GLONASS in the coming years, the GNSS technology will become clearer.

**2.7.1** Space segment.

The space segment is made up of 24 satellites that operate in six orbital planes that are 60 degrees apart around the equator. As backups, four other satellites are kept in reserve. The orbital planes are inclined at 55 degrees to the equator. The satellites orbit the Earth in near-circular orbits with a mean altitude of 20,200 km and a 12 sidereal hour orbital period. 1 Individual **satellite** can be identified by their Pseudo Random Noise (PRN) number (explained below), but they can also be identified by their satellite vehicle number (SVN) or orbital position.

**2.7.2** Control segment.

The control segment is made up of monitoring stations that keep an eye on the signals and track the satellites' movements over time. The first GPS monitoring stations will be located in Colorado Springs, as well as on the **Hawaiian Islands** of Ascension, Diego Garcia, and Kwajalein. The tracking data is sent to the Consolidated Space Operations Centre (CSOC) at Schriever Air Force Base in Colorado Springs, where it is routed to the master control station. This information is used by the master control station to create precise near-future predictions of satellite orbits and clock correction parameters. This data is uploaded to satellites, which then send it as part of their broadcast message for receivers to utilize in predicting satellite positions and clock biases (systematic errors).

**2.7.3** User segment**.**

In GPS, the user segment is divided into two groups of receivers, each of which has access to one of the system's two services. The Standard Position Service (SPS) and the Precise Positioning Service (PPS) are the two services (PPS). The SPS is available for free on the L1 broadcast frequency and, more recently, the L2. The PPS is broadcast on both the L1 and L2 frequencies, and it can only be received by receivers who have valid cryptographic keys, which are almost exclusively reserved for DoD usage.

Diagram

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Figure 2. 1 GPS segments

**2.8 Principle of Operation of GNSS**

Each satellite transmits two signals, each of which consists of carrier waves that undergo phase shifts in a predetermined sequence at highly specific rates and durations. A receiver creates a replica of the phase-change pattern and transfers it back and forth in time to correlate it with the signals it receives. If the signal it's trying to correlate with is received, the received and internally created patterns will eventually match. After that, the correlator circuit will produce a huge output. This pattern match, along with the related correlator output, constitutes satellite lock-on, and provides a pattern generator in the receiver that is precisely in phase with the received signal. Knowing how much this generator was displaced in time allows the receiver to determine when the signal arrived in relation to its own internal clock. If the receiver could figure out how its clock was changed in relation to genuine GPS time, it could figure out how long it took the satellite signal to reach it. The distance between the satellite and the receiver is calculated by multiplying the time by the speed of light [2]. Additional data is added to the signal in addition to delivering a distinct phase-change pattern that is unique to each satellite. The Navigation Message is made up of this information. It contains the current time to the closest second, as well as the data required to calculate the satellite's location at the time of transmission. The receiver can use this information to set its clock to the correct second and calculate the satellite's current position. It can now tell how far away it is from the satellite and where it is. The receiver now knows it is somewhere on the surface of a sphere centered on that satellite, with a radius equal to the distance from the satellite, according to simple geometry. Let's have a look at the process from beginning to end. Several satellites transmit their patterns, each one unique, which are received by a receiver's antenna. The relative distance between the receiver and the satellite providing the pattern determines when each pattern arrives. The receiver looks for specific satellites by generating and altering a pattern for each possible broadcasting satellite. Once a match is detected, the receiver may calculate the distance between each satellite, known as pseudo range. If the receiver's clock is perfectly synced with GPS time, it can quickly calculate its position using basic mathematics. Regrettably, the receiver's clock is rarely set precisely to GPS time. As a result, the pseudo range includes not only the time it took for the signal to reach the receiver, but also an amount that indicates the difference between the receiver clock and the GPS time. This is known as clock offset, and it represents a fourth unknown (in addition to the x, y, and z positions of the receiver). Because the receiver clock could be ahead of or behind GPS time, the clock offset could be positive or negative. The pseudo range is measured in time units. We can translate the signal to a distance by multiplying it by the speed of light because we know it traveled to the receiver at that pace. Similarly, clock offset is expressed in time units and can be expressed in a variety of ways. Because the receiver measures all pseudo ranges with the same clock, this distance or time inaccuracy is common to all of them. When a receiver acquires a satellite, it keeps an eye on the satellite's navigation message. The current GPS time, stated in seconds, is part of the data in the navigation message. The number of seconds since midnight on January 5 and 6, 1980 is the GPS time. As a result, the receiver can set its own time indicator to the exact second (the receiver computes fractions of a second later). The ephemeris, a series of numbers that jointly represent the satellite's orbit in space and where it is in that orbit at any given time, is another part of the navigation message. The ephemeris and the current time are used by the receiver to calculate the exact location of the satellite in orbit. The result is a set of x, y, and z coordinates indicating the location of the satellite at the time the signal was sent. These numbers indicate the satellite's position in relation to a coordinate system established by the World Geodetic System in 1984 (referred to as WGS84).

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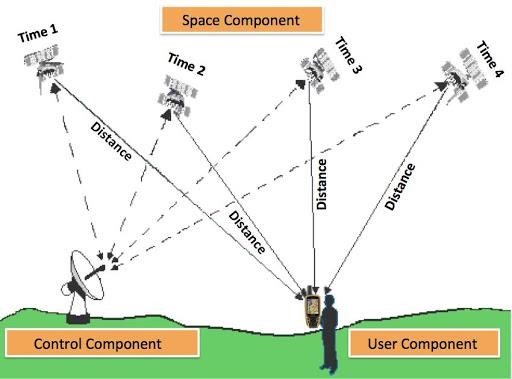


Figure 2. 2 Component of GNSS

* 1. **GNSS Positioning Modes**

**2.9.1** Static positioning.

Static GPS surveying is a technique for relative location that relies on carrier-phase readings **[27].** It uses two (or more) stationary sensors to track the same satellites at the same time (see Figure2.5). A base receiver is placed above a point with precisely defined coordinates, such as a survey monument (sometimes referred to as the known point). The remote receiver, on the other hand, is placed over a point whose coordinates are being sought (sometimes referred to as the unknown point). A minimum of four common satellites must be visible at both the base and remote sites for the base receiver to support any number of remote receivers.

In theory, this approach works by taking simultaneous measurements at both the base and remote receivers for a set amount of time, which are then processed to reveal the unknown point's coordinates. The duration of the observation, or occupation, varies between 20 minutes and several hours, depending on the distance between the base and the remote receivers (i.e., the baseline length), the number of visible satellites, and the satellite geometry. The measurements are usually taken at a recording interval of 15 or 20 seconds, or one sample measurement every 15 or 20 seconds. After completing the field measurements, the collected data is downloaded from the receivers into the PC for processing. Different processing options may be selected depending on the user requirements, the baseline length, and other factors.

Radar chart

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Figure 2. 3 Static observation setup

**2.9.2** GNSS Real Time Kinematics (RTK)

Real-time kinematics refers to a DGNSS process where carrier-phase corrections are sent in real-time from a reference receiver at a known location to one or more remote This is the most productive of the survey methods but is also the least accurate.

A carrier phase is RTK surveying. Based relative positioning approach that, like the preceding methods, uses two (or more) receivers to track the same satellites at the same time (Figure 2.6). When the survey involves a large number of unknown points in close proximity (i.e., within around 10.15 km) of a known location, the unknown points' coordinates are required in real time, and the line of sight, or propagation path, is reasonably unobstructed, this method is appropriate **[28].** Many people favor this method because of its ease of use and ability to determine coordinates in real time. The base receiver is coupled to a radio transmitter and remains stationary over the known spot in this method. The rover receiver is usually linked to a radio receiver and carried in a backpack. A data rate as high as 1 Hz (one sample per second) is required, similar to the traditional kinematic GPS approach. Through the communication (radio) link, the base receiver measurements and coordinates are sent to the rover receiver **[28].** To acquire the rover coordinates, the built-in software in a rover receiver collects and processes the GPS data collected at both the base and rover receivers. The initial ambiguity parameters are established nearly instantly using an ambiguity resolution technique called on-the-fly (OTF), which will be detailed in the next chapter. The receiver (or its handheld computer controller) will display the rover coordinates in the field once the ambiguity settings have been fixed to integer values. That is, there is no need for postprocessing. Positioning precision is estimated to be on the range of 2 to 5 cm (rms). This can be enhanced by hovering over the spot for a short length of time. However, the positioning accuracy of the RTK approach is slightly worse than that of the classic kinematic GPS method under the same conditions. This is due to the fact that in the processing, the time tags (or time stamps) of the traditional kinematic data from both the base and the rover coincide exactly. However, using RTK, the data from the base receiver reaches the rover after a delay (or latency). The base data is formatted, packetized, transmitted, and decoded, resulting in data delay **[28].** The base data must be extrapolated to match the time tag of the rover data, which reduces location accuracy.

In big construction projects, kinematic surveys have been used to successfully position sounding vessels during hydrographic surveys and aerial cameras during photogrammetric surveys, as well as in machine control to guide earthwork activities. Non-surveying uses, such as high-precision agriculture, can also benefit from it.

Diagram, engineering drawing

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Figure 2. 4 Real Time kinematics setup

**2.10** GNSS Application in Geodetic Control Project

GNSS is revolutionizing geodesy and all surveying applications. Surveyors and researchers are currently using GNSS techniques to increase their efficiency, productivity, and accuracy. GNSS, on the other hand, can be used for cadastral surveying, airborne photogrammetry, dynamic positioning, hydrographic survey, road and rail survey, and navigation, among other things. GNSS is used to create a homogeneous and precise geodetic control network that serves as the foundation for subordinate surveys and various types of projects, as well as to create a cadastral or topographical map for specific purposes, in large-scale applications such as cadastral mapping or engineering surveying. Establishing a secondary control project using traditional survey methods or a modern methodology (GNSS) necessitates the development of guidelines and specifications for the start and completion of a new project.

**2.11** PSEUDORANGE OBSERVATION EQUATIONS

Navigation and positioning is the art of determining position, speed and orientation of an object. The GPS programme was born in 1972 out of the quest for the US Navy and Air force to develop all weather Global Radio Navigation System. The GPS was designed to be a passive survivable continuous system which will provide any suitably equipped user with three-dimensional position (x, y, z) velocity and precise time information [4].

The principle involves measurement of distance or range to at least three Satellites whose X, Y and Z positions are known, in order to define the user’s Xp, Yp and Zp position. In its simplest form, the satellite transmits a signal on which the time of its departure (tD ) from the satellite is modulated. The receiver in turn notes the time of arrival (tA) of this time mark. Then the time which it took the signal to go from satellite to receiver is given as [1]:

(tA – tD ) = ∆t (called the delay time).

The measured range R is obtained from

R1 = (tA – tD) C = ∆t C (1)

where c = the velocity of light.

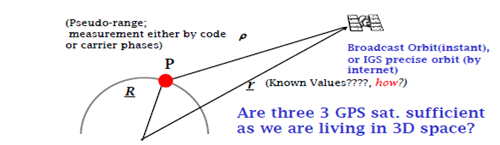


Figure 2.5: Pseudo – Range measurement

By setting the clock time T equal to the true receive time t plus a clock bias τ, model observation can be developed for both the receiver and satellite clocks as presented in equation 2 below [2]:

 (2)

The Receivers record data which are regular are usually set at intervals say, every 1, 2, 5, 10, 30 seconds, as defined by the receiver user and a function of the task at hand. Receiver clock time T, readings are used to say exactly when the measurement was made [2]. Therefore, the value of T at a measurement epoch is known exactly and is written to the data file along with the observation, the unknown parameter is the true time of measurement. Therefore, the actual observation to satellites can be written thus [2]:

 (3)

By substituting equating (2) into (3), we have

 (4)

By re - arranging, yields

 (5)

Where, T is time when the transmitted signal was received at Receiver ground station, TS is the satellite transmitted time, ρ is the range, C is the speed of light is given as 299792458m/s

The Pseudorange from Satellite to Receiver is thus given as:

 (6)

The Navigation message allows us to compute the satellite position (xS , y S , z S ) and the satellite clock bias τ*S* . The 4 unknowns are the receiver position (x, y, z) and the receiver clock bias τ [2].

It is important to determine the satellite position at transmission time, t S. This is because the satellite range can change as much as 60 meters within 0.07 seconds from the time the signal was transmitted, to the time the signal was received. Starting with the receive time, t, the transmit time can be computed by an iterative algorithm known as “the light time equation,” which can be written as follows [2]:

 (7)

The satellite position (and hence the range ρ**S** (t, t*S* ) is calculated at each step using the Keplerian-type elements from the Navigation Message. The algorithm is discontinued when there is convergent. Although more rapidly converging methods have been implemented, the above method is probably the easiest to understand [2].

From equation (6) we can write a system of simplified observation equations from 4 satellites in view of the receiver. Using the above notation, we can write the pseudoranges equations for 4 satellite as [2]:

 (8)

Where Xn, Yn, Zn = the coordinates of satellites 1, 2, 3 and 4 (n = 1 to 4)

Xp, Yp, Zp = the coordinates required for point ρ

**2.12** Phase differencing modes

There are three types of phase differencing modes in GNSS observation, these are the single, double and triple differencing modes.

**2.13** Single difference mode**.**

In this method, two receivers ground stations setup at different stations are simultaneously acquiring data from one single satellite in the orbit. It involves subtracting two simultaneous observations made to a single satellites from two points. This difference eliminates the satellite clock bias and much of the ionospheric refraction from the solution [15].

Diagram

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Figure 2.6: Single Differencing mode

The mathematical representation of single differencing mode are presented thus:

 (9)

The difference in these two equations that eliminate satellite clock bias error yield

 (10)

Where, 







2.14 Double differencing mode

The double-difference mode is executed between a pair of receivers and pair of satellites as shown in figure (3). It involves taking the difference of two single differences obtained from two satellites j and k. The procedure eliminates the receiver clock bias as follows [15]:

 (11)



Figure 2.7: The double-difference technique.

Taking the differences between the two equations in (11) the receiver clock errors,

and are eliminated thus;

**

Using the short hand notation as in the single-difference

(12)



The result of this mode is the omission of the receiver clock offsets. The double-difference model for long baselines when there is a significant difference in the atmospheric effect between the two baselines ends can be expressed [8]:

(13)



2.15 Triple differencing mode

This involves taking the difference between two double differencing obtained from two different epochs of time. This method eliminates integer ambiguity in equation (13), while leaving the differences in the phase shift observation and ranges of geometry. Two double differences equations are given by [15]:

 (14)

Diagram

Description automatically generated

Figure 2.8: The Triple-difference technique.

The difference of equations (14) yields the triple differencing mode in which integer ambiguities has been eliminated.

 (15)

 (16)

2.16 Linearised Model

For completeness, we summaries the linearisation procedure and the development of the least squares method specifically for the GPS point positioning problem. First, we assume we can write the actual observation to be the sum of a modelled observation, plus an error term [2]:

 (17)

The provisional parameter values is given as (x0, y0, z0, τ0), using Taylor’s theorem the computed model can be expanded thus by ignore second and higher order terms [2].

 (18)

The residual observation is the difference between the actual observation and the computed using the provisional parameter values i.e. [2]

 (19)

The matrix form is given as:

 (19)

The above equation is for one satellite, for n satellite, we can develop similar equation which is often written as:

Eight (8) new Geodetic control points will be established in University of Benin for the purpose of this Thesis using CORS Geosystems as reference control point. A total of eight (8) GNSS receivers will be deploy. Least Squares solution equation model for the parametric method (Observation equation Least Squares will be used for data processing.

The Least square is given as:

 (20)

 (21)

The Least square solution of the unknown parameters is given as:

 (22)



 (23)

 (24)

The estimated variance factor is:



(25)

The estimated variance covariance matrix of parameters is:

 (26)

 (27)

Where N is the solution of normal Equation

Finally, the variance covariance matrix of the adjusted observations can be computed as:

 (28)

**Null and alternative hypothesis test:** The null hypothesis (Ho) states that a population parameter (such as the mean, the standard deviation, and so on) is equal to a hypothesized value. The alternative hypothesis (HA) states that a population parameter is smaller, greater, or different from the hypothesized value in the null hypothesis.

**3.0 GENERAL INFORMATION**

**3.10 Guidelines for conducting GNSS project**

The directions and recommendations in this study are solely applicable to secondary controls. A rigorous survey-planning step is required to complete these surveys in the most efficient and cost-effective manner possible, as well as to ensure that the required accuracy criteria are met. One of the most significant components of GNSS surveying is project planning, since thorough preparation increases the likelihood of the survey obtaining the target accuracy in a fair amount of time and at a low cost. Before commencing the planning of a GNSS survey for large-scale applications, the following preliminary questions must be established first:

* Install Tersus David product of CORS
* Observer and determine the absolute position of the Antenna using existing 1st order control in Benin city.
* Verify the positional accuracy of the CORS
* Establish new points within University of Benin.
* Determine standard deviation using Least squares techniques
* Use various mathematical models as much as possible
* Software like Trimble Business center, Hi – Target Geomatics office etc.

In the second step of GNSS planning survey for large-scale applications, surveyor try to answer the following questions:

* Which satellites must be observed?
* During how much time and at what moment of the day must be observed?
* Which observations modes must be applied for the network conception?
* Which precautions must be taken during the GNSS mission?
* And how to assure the existing network connection by GNSS?

Before answering the previous questions, it will be necessary to do various phases of preparations, which require the execution of the following tasks:

1. Calibration and system tests
2. Reconnaissance and definition of the project.
3. Demarcation of points
4. Field operations and GNSS observations
5. All GNSS processing and analysis (planimetric, levelling, adjustment and adequate method of transformation)
6. Final report (GNSS and transformed coordinates, stations descriptions of all new GNSS points, and historic of GNSS project).

**3.11 Reconnaissance Guidelines**

The goal of the reconnaissance is to determine the project region's maximal capabilities in order to develop a more cost-effective and homogeneous network concept. This condition is satisfied if the number of points and needed observations are kept to a bare minimum to meet control network design constraints (number of connections, redundancy, geometry, etc.). The quality of GNSS surveys as well as the time it takes to create a GNSS control network would be affected by this economic concept. Field reconnaissance must always be preceded by work on a map that outlines the shape and description of the eventual control network. The project will only be successful if the papers used are recent and precise; nevertheless, if their contribution to the GNSS project is more extensive, ancient documents with varied scales may be employed. While conducting early reconnaissance, keep the following things in mind and incorporate them in the project description: Walking time, GNSS receiver disassembly and setup time, road travel time between all sites, the best possible routing, and the required vehicle Record the azimuth and vertical angle of any site obstacles, and make sure that all stations have a clear view of the horizon from 15 degrees upwards, with satellites below 10 degrees not visible.

**3.12 Field Operations Guidelines**

The field manipulation of a GNSS receiver is relatively straightforward. It is essential to organize the amount of observation sessions for each day in order to ensure a high rate of success and advancement for the GNSS project. The receivers' organization for each observation day, on the other hand, is critical to the survey's success. The following requirements must be considered:

i. Point demarcation must be well defined, appropriate, secure, and stable.

ii. To be surveyed are both old and new points.

iii. The availability of estimated coordinates of sites to introduce into the receiver in the field.

iv. The survey propagation approach should be utilized (a logistical problem). Prudent survey practice, requiring redundancy and check measurements to be incorporated into the network design.

v. The antenna height must be double-checked (at the beginning and at the end of observation session).

vi. Confirm that all sites are collecting enough common data at the same time.

vii. Check data quality to ensure that appropriate results are produced.

viii. If the station has not acquired enough data, it may be required to reoccupy it.

ix. To eliminate potential antenna phase offsets, all antennas should be aligned to true north for high accuracy surveys.

x. For each session, field observation recording sheets should be completed. These sheets must include the type of receiver, serial number, and software used for reductions.

xi. Taking meteorological measurements readings is not required. However, it is advised that aberrant meteorological circumstances be noted on field sheets in general.

**3.13 GNSS Observations Guidelines**

There are four survey techniques that may be suitable for use for any particular application. They are the Static, rapid static, stop and go kinematic and continuous kinematic survey techniques. Surveyors must decide which technique is most suitable the specific application. In most cases, a combination between these techniques is desirable. For example, static survey procedures may be used to connect the survey to control points. Kinematic techniques can then be used in the local survey region and a total station used to complete the obstruction portions of the survey.

**3.14 GNSS Processing Guidelines**

If more than two receivers are deployed to performing a GNSS project for large scale application, there are two main methods of processing to use:

1. Baseline processing where the data from a single pair of receivers is processed independently of other such pairs. The result is a single baseline between the points.
2. Multi-station processing where the complete data set from all receivers is processed together in a simultaneous adjustment of all the data. The result is a set of coordinates or baselines together with full covariance information between points.

**3.15 Computations/Adjustments**

Most observations should be pre-processed, preferably in the field, to ensure that they meet the required accuracies. Any systemic mistakes, such as meteorological adjustments should also be rectified.

Finally, Least Squares techniques should be used to adjust the network, not only to identify point coordinates but also to perform a statistical analysis of the results.

**3.16 GNSS Network Schemes**

A GNSS survey network architecture is similar to traditional triangulation or traversing in terms of planning. The sort of survey design used is determined on the GNSS technique used and the user's requirements. To expand project control over a larger area, a GNSS network is built. The network design specifies the stations that will be occupied (both new and existing) as well as the exact baselines that will be monitored. The GNSS observation sequence with a particular number of GNSS receivers is also included in the network design. Furthermore, the network design should be geometrically sound, with weak geometrically weak triangles avoided if at all possible.

**3.17 GNSS Equipment and Systems Tests**

Validation of receiver hardware, field operations, and processing may necessitate a system test. The test will consist of measuring a small test network with geodetic control points spaced to reflect the project's size (minimum 4 points polygon). This will be used to evaluate the performance of a multi-receiver system that is used simultaneously. Another test is the measurement of a zero baseline. A zero-baseline test is carried out to ensure that a pair of GNSS receivers, associated antennas and cabling, and data software are all operational. The test is carried out by connecting two GNSS receivers to a single antenna using an antenna splitter suitable with the receiver and antenna brands (as recommended by GNSS manufacturer). This straightforward test can be used to evaluate the precision of both the receiver and the data processing software.

**3.18 MONUMENTATION**

All control stations pegged out as control points were beaconed in accordance with survey specifications before the actual observations were carried out. A frame work of wood with the dimension of 40cm x 40cm x 150cm was prepared for the purpose of casting each of the Beacons. The Frame work was positioned in the dugout points for each of the beacons with the frame work extending 40cm above the ground level and reinforced by galvanized iron pipe at the center and with an iron rod sunk at the center to define the point. The beacons were then cast with gravel, sand and cement concrete mixed in the proportion of four parts of sand and gravel to one part of cement i.e. ratio of four to one. The beacons were buried 110cm beneath the earth and 40cm projecting above ground level as shown below and the identification numbers then engraved on the beacons.

Figure 3.2 below shows a diagram of a typical first – order control monument.

1

c

10

m

40

cm

40

cm

40

cm

0 1

Nail

Reinforced

Galvanized Iron

GROUND LEVEL

RAPH

GNSS

Fig. 3.1: A typical Second Order Control Beacon

**3.19 NUMBERING OF PILLARS**

The beacons were numbered serially according to the pillar prefixes and numbers that had been issued by Prof Raph Ehigiator. The numbers given started from RAPH 04 – GNSS.





****

Fig. 3.2: Control Beacons and Data Acquisition

**4.0 CURRENT INFORMATION**

**4.10 Earth’s surface**

The topographical surface on which surveying observations are carried out for the purposes of obtaining coordinates of terrain points as well as the geometry between such points made and points are placed is referred to as the Earth's physical surface. The physical surface, however, cannot be characterized mathematically because to its irregular lumpy surface and general shape, and so location cannot be simply computed on its surface where the earth surface is not the ideal reference surface. As a result, while the Earth may be believed to be flat in limited surveys and plane trigonometry used to determine position, this assumption would not hold true in geodetic surveys covering a greater area.

**4.12 The geoid**

The geoid is an equipotential gravitational surface that is perpendicular to gravity in all directions. It's also known as the equipotential surface beneath the continents, which corresponds to the undisturbed mean sea level (MSL). The geoid has an uneven shape as a result of fluctuations in the Earth's mass distribution and rotation. The geoidal surface is the closest approximation of the Earth's surface, even smoother than the physical surface, but it still has numerous minor flaws that make it inappropriate for planimetric and topographic position mathematical placement. These anomalies are caused by mass abnormalities all around the planet.

**4.13 The Ellipsoid**

The ellipsoidal surface, which includes the sphere, biaxial ellipsoid, and triaxial ellipsoid, is by far the most mathematically acceptable geodetic reference surface. A mathematical surface created by rotating an ellipse around the Earth's polar axis is known as an ellipsoid. The closest mathematically definable form to the Earth's figure is an ellipsoid of rotation. The earth is represented as a squashed sphere, sometimes termed a spheroid or oblate spheroid, by an ellipse rotated about its minor axis, with the ellipse specified by its semi-major axis a and the flattening f. Although the ellipsoid is only a shape and not a physical reality, it does represent a smooth surface for which methods to determine ellipsoidal distance, azimuth, and other parameters can be established. Due to the variable shape of the geoid, it is not possible to have a single global ellipsoid of reference which is a good fit to the geoid for use by all countries. The best fitting global geocentric ellipsoid is the Geodetic Reference System 1980 (GRS80), which has the following dimensions:

semi-major axis 6 378 137.0 m

semi-minor axis 6 356 752.314 m

the difference being approximately21km.

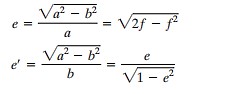
The dimensions of the ellipse are selected to give a good fit of the ellipsoid to the geoid over a large area and are based upon surveys made in the area.

A two-dimensional view, which illustrates conceptually the geoid and ellipsoid, is shown in Figure 2.15. As illustrated, the geoid contains non-uniform undulations (which are exaggerated in the figure for clarity) and is therefore not readily defined mathematically. Ellipsoids, which approximate the geoid and can be defined mathematically, are therefore used to compute positions of widely spaced points that are located through control surveys. The *Clarke Ellipsoid of 1866* approximates the geoid in North America very well and from 1879 until the 1980s it was the ellipsoid used in NAD 27 as a reference surface for specifying geodetic positions of points in the United States, Canada, and Mexico. Currently, the *Geodetic Reference System of 1980* (GRS80) and *World Geodetic System of 1984* (WGS84) ellipsoids are commonly used in the United States because they provide a good worldwide fit to the geoid. This is important because of the global surveying capabilities of GNSS. Sizes and shapes of ellipsoids can be defined by two parameters. Table 19.1 lists the parameters for the three ellipsoids noted above. For the Clarke 1866 ellipsoid, the defining parameters were the semi axes *a* and *b.* For GRS80 and WGS84, the defining parameters are the semimajor axis *a* and flattening *f.* The relationship between these three parameters is

Shape

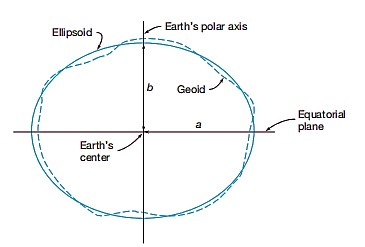
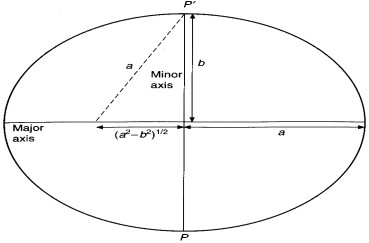
Description automatically generated with medium confidence (29)

Other quantities commonly used in ellipsoidal computations are the *first eccentricity*, *e*, and the second eccentricity, of the ellipse, where



(30a)

(30b)



a = One-half of the major axis = semi-major axis

b = One-half of the minor axis = semi-minor axis

PP2= Axis of revolution of the Earth's ellipsoid

Figure 4.1: Elements of an ellipse

**4.14 The ellipsoid and Cartesian coordinate system**

To fully describe positions in relation to the earth, the geodetic coordinate system and Cartesian coordinate system are employed. The geodetic coordinate system comprises a right –handed orthogonal three-dimensional coordinates made up of geodetic latitude (ϕ), geodetic longitude (λ) and ellipsoidal height (h). They refer to the surface of specific ellipsoid of revolution about its minor axis. The Cartesian coordinate system is the three-dimensional orthogonal axes in the X, Y, and Z directions. Thus, a corresponding triplet of Cartesian coordinates refers to these axes. The X-axis is directed towards the intersection of the Greenwich meridian and equatorial plane. The Z-axis is aligned towards the North Pole of the earth’s rotation. The Y-axis is orthogonal to X and Z axes and completes the right–handed coordinate system.

Diagram

Description automatically generated

Figure 4.2: Ellipsoidal Coordinate Systems

**4.15 Datum transformation**

In Nigeria, locations are calculated using both a geographic and a rectangular coordinate system. With respect to the ellipsoid employed for geodetic computation in Nigeria, Clarke 1880, the rectangular coordinates of points are computed in either the Nigerian (Modified) Transverse Mercator (NTM), Universal Traverse Mercator (UTM), or both. Each grid system has its unique set of characteristics. These attributes are used to calculate position.

The Nigeria Minna datum, according to **[40]**, is a geodetic datum suited for onshore and offshore application in Nigeria. The Clarke 1880 (RGS) ellipsoid (Semi main axis, a = 6378249.145m; Flattening, f = 1/293.465) and the Greenwich prime meridian are used in the Minna datum. The fundamental point is Minna base station L40, which serves as the datum origin. Longitude: 6°30'58.76"E, latitude: 9°38'08.87"N (of Greenwich). It is a topographic mapping geodetic datum. Information from NIMA was used to define it. The orthometric height, H, of station L40 was given as 281.13 meters **(Uzodinma and colleagues, 2013).** The processing of DGPS observations on the Minna datum involves the following:

1. Conversion of geodetic coordinates (latitude ∳, longitude λ, and ellipsoidal height *h*,) on the WGS84 datum/ellipsoid to (latitude ∳, longitude λ, and ellipsoidal height *h*,) on Nigeria Minna datum.
2. Conversion of geodetic coordinates (latitude ∳, longitude λ, and ellipsoidal height *h*,) on the Minna datum/ellipsoid to Cartesian rectangular coordinates on the local datum, Minna datum.
3. Conversion of the geodetic coordinates (∳, λ, *h*) to plane rectangular systems, Nigeria Traverse Mercator (NTM) and Universal Traverse Mercator (UTM) coordinates.

**4.16 Conversion from Geodetic Coordinates to Cartesian Rectangular Coordinates**

According to **Janssen, V. (2009):** on the ellipsoid, positions are either expressed in Cartesian coordinates (*X*, *Y*, *Z*) or in curvilinear coordinates (∳, λ, *h*), i.e. geodetic latitude, longitude and ellipsoidal height (see Figure 1).

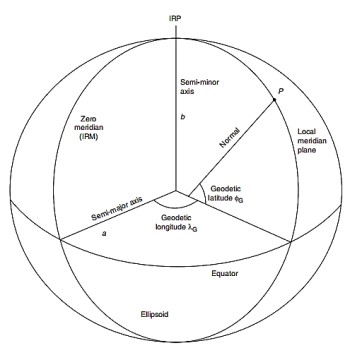
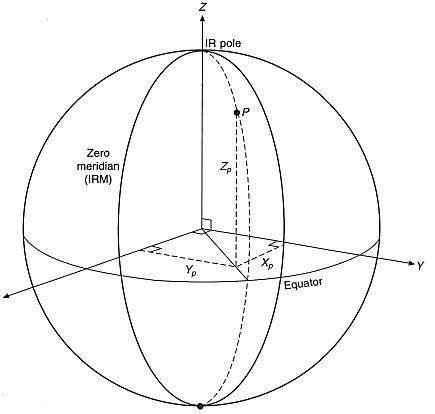
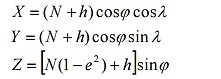


Figure 4.3: Geocentric Cartesian coordinates Source: Janssen, V. (2009)

In a geocentric, rectangular Cartesian coordinate system, the *Z*-axis coincides with the mean position of the earth’s rotation axis. The *X*-axis passes through the intersection of the Greenwich meridian and the equator, and the *Y*-axis completes a right-handed coordinate system by passing through the intersection of the 90°E meridian and the equator.

Regarding curvilinear coordinates, geodetic latitude is defined as the angle in the meridian plane between the equatorial plane and the ellipsoid normal through a point P. Geodetic longitude is measured in the equatorial plane as the angle between the Greenwich meridian (*X*-axis) and the meridian through a point P, while the ellipsoidal height is measured from the ellipsoid surface along the ellipsoid normal. A single ground point can have different geodetic coordinates depending on which ellipsoid the coordinate system refers to Geodetic coordinates can be converted to rectangular Cartesian coordinates.

(31)



Where, (∳, λ, *h*) are respectively the geodetic latitude, geodetic longitude and ellipsoidal height while X, Y, Z are the Cartesian coordinates to be estimated. *h* is ellipsoidal height (orthometric height, H + geoidal height, N). *N* in equation (1) is the radius of curvature in the prime vertical given by Ono, M. N. (2009) as:



(32)

Where, *a* is the semi-major axis while *f* is flattening given as



(33)

b = semi-minor axis

The conversion of the geodetic coordinates on the global ellipsoid to Cartesian positions still on the global datum is necessary to enable the transformation of the coordinates to positions on a local datum/ellipsoid using the seven datum transformation parameters.

The constants a and f are the dimensional parameters of either the regional or geocentric ellipsoids. In local ellipsoids, the parameter h is not known but if Geoid-ellipsoid separation is known along with orthometric height (H), then we can use the relationship between orthometric and geoidal height to find h, as given by **(Heiskanen et al 1967).**

*h* =*H +N* (34)

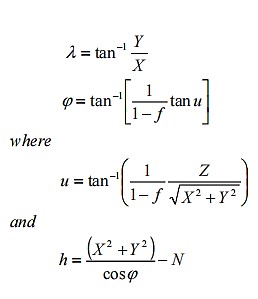
where

H - orthometric height

N - Geoid- ellipsoid separation (no confusion with prime vertical radius of curvature N)

h- ellipsoidal height

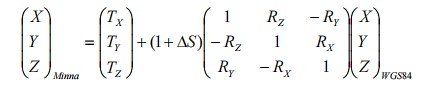
Conversely, Cartesian coordinates can be converted to geodetic coordinates, which may involve iterative procedure to realize latitude (∳). Thus from (4), (5) and (6) we have a close solution by Featherstone and Reit in the year 1998 as:



(35)

**4.17 Transformation between WGS84 and Minna Datums**

The processing of the DGPS observations which are always acquired on the WGS84 ellipsoid to obtain positions on the Minna datum/Clarke1880 ellipsoid requires datum transformation. This is because GNSS uses the WGS84 ellipsoid while the end datum is a local one with different ellipsoid which best fit the region of application, for instance, Minna datum. The accurate transformation of positions on the WGS84 ellipsoid to Minna Datum, Clarke 1880 ellipsoid requires the application of the seven datum transformation parameters. The application of the seven datum transformation parameters, requires their combination with the Cartesian coordinates, X, Y and Z. These parameters consist of an origin shift in three dimension, (T*x* T*y* T*z*), a rotation about each coordinate axis (R*x* R*y* R*z*) and a change in scale (S). The model (Bursa-Wolf model) required for the transformation of positions from WGS84 ellipsoid to Minna datum is given as (Featherstone et al 1999)



(36)

The new set of transformation parameters that enables positions determined in Nigeria using

DGPS receivers to be transformed between the WGS84 and Minna Datums are given by the

Office of the Surveyor-General of the Federation, OSGOF, [13] and [14] as: Transformation

Parameters from WGS 84 to Minna Datum

Tx= 93.809786m ± 0.375857310m

Ty = 89.748672m ± 0.375857310m

Tz = -118.83766m ± 0.375857310m

Rx = 0.000010827829 ± 0.0000010311322

Ry = 0.0000018504213 ± 0.0000015709539

Rz=0.0000021194542±0.000001300597 S = 0.99999393 ± 0.0000010048219

Transformation Parameters from Minna Datum to WGS 84

Tx= -93.809786m ± 0.375857310m

Ty = -89.748672m ± 0.375857310m

Tz=118.83766m ± 0.375857310m

Rx = -0.000010827829 ± 0.0000010311322

Ry = -0.0000018504213 ± 0.0000015709539

Rz=-0.0000021194542 ± 0.0000013005997

S= 1.0000061 ± 0.0000010048219

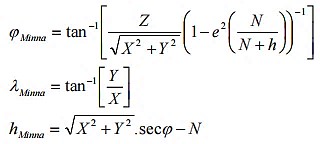
Having applied the transformation parameters given above, the Cartesian coordinates (X-Y-Z) are now on the Minna datum.

**4.18 Conversion of the Cartesian Rectangular Coordinates on the Local Datum to**

**Geodetic Coordinates (**∳, λ, *h***) on the Local Datum/Ellipsoid**

Having obtained the Cartesian coordinates on the Minna datum, they still need to be converted to curvilinear/geodetic positions on the Minna datum before they can be converted to plane rectangular coordinates such as NTM and UTM coordinates. The equations required to convert the local datum Cartesian coordinates to curvilinear coordinates are given as Janssen, V. (2009):

(37)

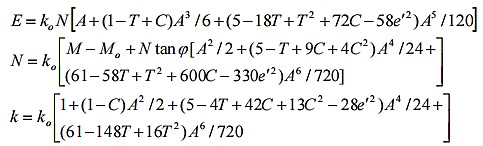


Where, *e’*= eccentricity squared = 2 *f – f 2*

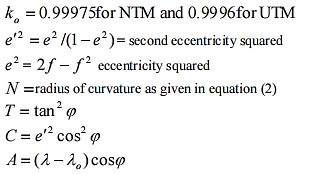
*N* = radius of curvature as given in equation (7).

**4.19 Conversion of the Geodetic Coordinates (**∳, λ, *h***) to Plane Rectangular Systems, Nigeria Traverse Mercator (NTM) and Universal Traverse Mercator (UTM) Coordinates**

To obtain the positions of points in local plane rectangular systems, the local ellipsoid curvilinear coordinates have to be converted to either NTM or UTM. The models and procedure for conversion of the local ellipsoid geodetic coordinates to either of the two local planes rectangular (NTM or UTM) coordinates are the same. The difference in the two plane systems is in the properties to be used in the conversion. Thus, the origin, and scale factor. To convert the geographic coordinates (latitude and longitude) on the local ellipsoid to either NTM or UTM northing and easting, equations (8) to given by are used**. Idowu, (2012); Manchuk, J. G. (2009)**.



Where



(7)

(

(38)

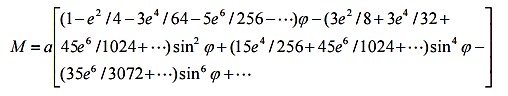
*N =* Northing opoint. *E =* Easting of point.

∳ = latitude of point

λ=longitude of point

λ*o* =longitude of point of center meridian of belt or zone

(39)



*M* = Distance on the meridian from parallel of false origin (4oN for NTM and 0o for UTM) to the parallel, of point.

∳= Latitude of the point.

Mois computed using Equation (39) which is the latitude crossing the central meridian at the origin of the (*E*, *N*) coordinates **[40**].

Equations (4) to (21) are used to develop programs which the transformation/conversion (GNSS) post processing software normally apply during computation / Conversion or post processing of static DGPS observations.

**4.20 Properties/Characteristics of Nigeria (Modified) Transverse Mercator Projection (NTM)**

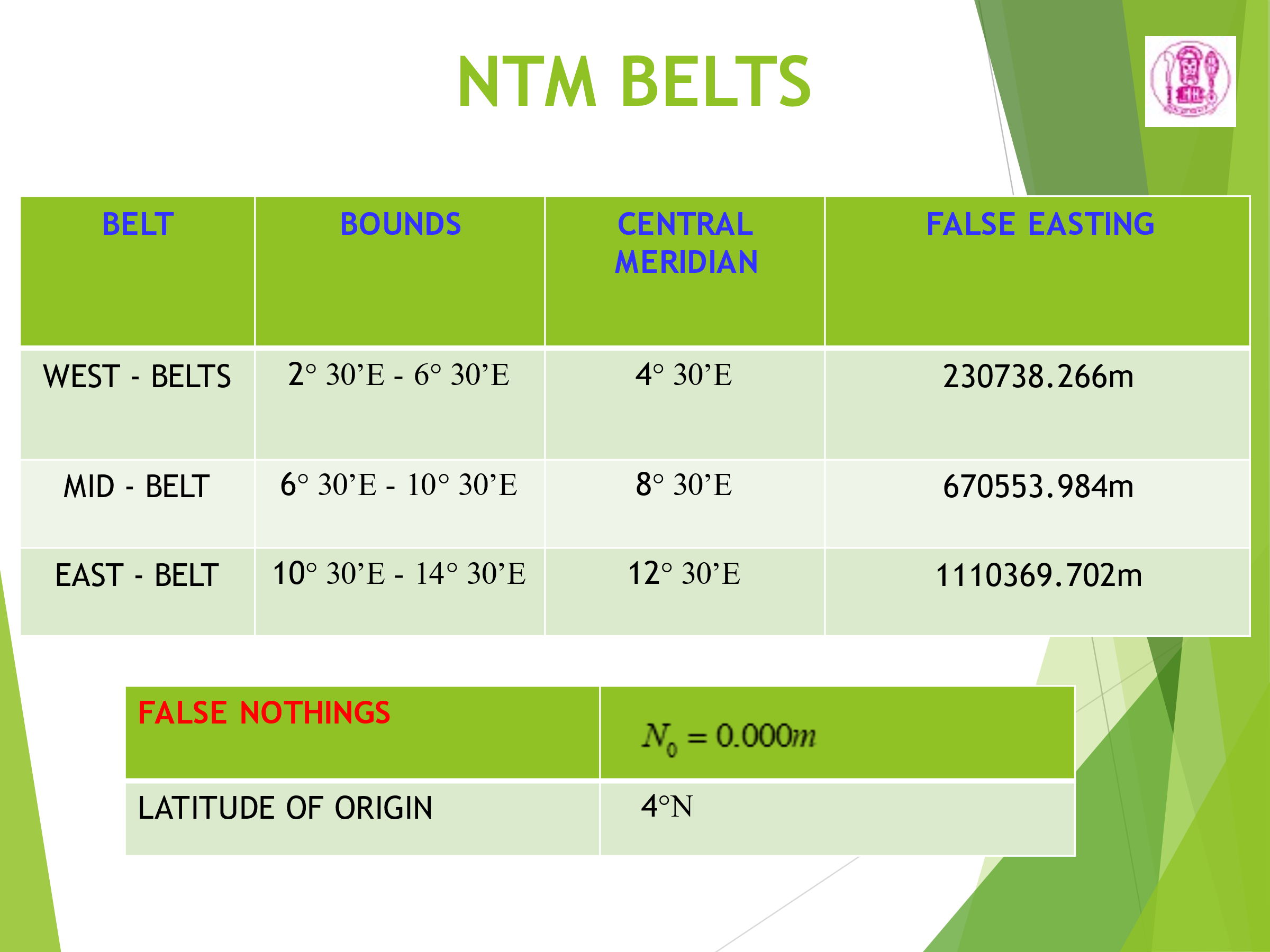
The NTM is a Nigerian-adapted variant of the TM. The changes account for the country's vast size, which spans around l00 (i.e. 4°N - 14°N) latitude and 12° (i.e. 2° 30° - 14° 30°E) longitude. The 3-belt system is the most common name for it.

In 2013, **Uzodinma, Oguntuase, Alohan, and Dimgba** identified the following properties of the Nigeria (modified) Transverse Mercator Projection (NTM):

1. NTM is a conformal projection
2. The country is divided into 3 belts each 4o wide (Figure 18).
3. The 3 belts are bounded in the north by the 14oN parallel and in the south by 4oN

Hence the false origin of northing is at latitude 4o N and False Northing, No = 0.000m (see Table 4.4 and Figure 4.5).

**Table1: NTM Grid Parameters**



Diagram

Description automatically generated

Source: Uzodinma, V. N., et al. (2013):*Practical GNSS Surveying*. Professor’s Press Ltd, Enugu.

Figure 4.4: Nigerian Transverse Mercator Belts

1. The scale factor at each central meridian is 0.99975.
2. A rectangular metric grid is superimposed on the three belts such that they intersect along the 9°N parallel.

**4.21 Properties/Characteristics of Universal Traverse Mercator (UTM) as Applied in Nigeria**

The properties/characteristics of the UTM as applied in Nigeria as follow:

1. Nigeria is covered by zones 31, 32 and 33 of the UTM.
2. Each zone has its own independent coordinate system with X-axis 500,000.0m west of the central meridian and Y-axis lying along the equator. The UTM grid parameters are shown in table below

**Table 2: UTM Grid Parameters**



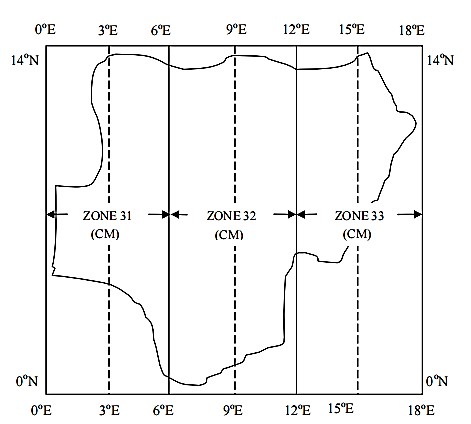


Figure 4.5 UTM Zones in Nigeria

1. UTM in Nigeria is computed on the Clarke 1880 reference ellipsoid.

In the UTM, the maximum angular distance of a point in a belt, from the central meridian of the belt is 3º. Thus, each belt is 6o wide. Its application is limited to between latitudes 84oN and 80o S. The properties/parameters of each of the plane rectangular systems, NTM and UTM are applied during DGPS observations post processing. The parameters to be applied in each plane rectangular system depend on either the belt or the zone in **which the observations were carried out.**

**4.22 ERROR IN GNSS OBSERVATIONS.**

**4.22.1 Ionospheric Delay.**

The sun's ultraviolet and x-ray rays interact with the gas molecules in the atmosphere, resulting in a huge amount of free negative charged electrons. This is referred to as gas ionization, and the region of the atmosphere where gas ionization occurs is referred to as the ionosphere (Hofmann et al 1997). The ionosphere ranges in altitude from roughly 50 km to about 1000 km. Because the electron density inside the ionosphere is not constant and varies with altitude, the ionosphere is split into subregions based on electron density. The troposphere is the electrically neutral atmospheric region that extends up to 50 km from the earth's surface, and its refractive index (n) is a function of frequency (and thus the ionosphere has the property of "dispersion") and the density of free electrons, and can be expressed as a first-order approximation. For radio frequencies below 15 GHz, the troposphere is a non-dispersive medium.

**4.22.2 Tropospheric Delay.**

The GNSS carrier and codes are the same. The tropospheric delay, unlike the ionospheric delay, cannot be eliminated by merging GNSS waves L1&L2. This is due to the fact that the tropospheric delay is frequency agnostic. Pressure, Temperature, Humidity, and Tropospheric Delay are all factors that influence Tropospheric Delay. The tropospheric delay is minimized at the user's zenith and maximized at the horizon on the signal path through the troposphere. At zenith, the tropospheric delay produces values of around 2.30 m, 9.30 m for a 150° elevation angle, and 20-28 m for a 50° elevation angle **[26].** Tropospheric delay is determined by the satellite elevation angle and the receiver's height. However, defining it in terms of the refractive index, integrated along the signal ray path, is a reasonable place to start.

**4.22.3 GNSS Orbital Biases.**

As the velocity of the GNSS satellites is perturbed by gravitational and non-gravitational forces, the satellites' coordinates in regard to the WGS84 reference system must be continually calculated through the analysis of tracking data **[8].** The difference between a satellite's true position and velocity and its known value is known as the satellite Ephemeris bias. This disparity can be parameterized in a variety of ways, but the three orbit components: along track, cross track, and radial are the most common. When it comes to GNSS satellites, the along track component has the most error.

**4.22.4 Selective availability.**

The civilian C/A code receivers used in GPS were originally planned to be less precise than military P-code receivers for real-time autonomous locating and navigation. Surprisingly, the accuracy acquired from both receivers was nearly identical. The US Department of Defense (DoD) deployed selective availability (SA) on Block II GPS satellites to prevent illegal users from obtaining precise real-time autonomous location. On March 25, 1990, SA became operational (Hoffmann). Two types of mistakes are introduced by SA (Georgiadou 1990). The first, known as delta error, is caused by dithering the satellite clock and is experienced by all users across the world. The second, referred to as epsilon error, is a slowly fluctuating orbital error. At the 95 percent likelihood level, nominal horizontal and vertical errors can be up to 100m and 156m, respectively, with SA turned on.

**4.22.5 Multipath error.**

For both carrier-phase and pseudo range measurements, multipath is a significant cause of inaccuracy. When the GNSS signal arrives at the receiver antenna through multiple pathways, multipath error occurs **[15].** The direct line of sight signal and reflected signals from objects surrounding the receiving antenna are examples of these routes (Figure 2.21). By interfering with reflected signals at the GPS antenna, multipath distorts the original signal. Both carrier-phase and pseudo range measurements are affected, although the pseudo range measurements have a much greater influence. The carrier-phase multipath can be as large as a quarter of a cycle in size (about 4.8 cm for the L1 carrier phase). For C/A-code measurements, the pseudo range multipath can theoretically reach many tens of meters. However, with to recent developments in receiver technology, actual pseudo range multipath is now much decreased. The Strobe correlator (Ashtech, Inc.) and the MEDLL are two examples of similar technology (NovAtel, Inc.). Even in a highly reflecting environment, the pseudo range multipath error can be minimized to a few meters with these multipath mitigation approaches **[15].** Diagram

Description automatically generated

Figure 4.6 Multipath error

**4.22.6 Receiver measurement noise**

The receiver measurement noise is caused by the receiver's electronic constraints. A decent GNSS system should have a low degree of noise. When a GNSS receiver is turned on, it usually does a self-test. However, for high-cost precise GNSS systems, the user's evaluation of the system may be necessary. For analyzing a GPS receiver (system), two tests can be used: zero baseline and short baseline tests. The receiver performance is assessed using a zero-baseline test. One antenna/preamplifier is used in the test, followed by a signal splitter that feeds two or more GNSS receivers. This test can detect a variety of receiver issues such as inter channel biases and cycle slippage. The baseline solution should be 0 because just one antenna is employed. In other words, the receiver noise is blamed for any nonzero number. The zero-baseline test is important for determining receiver performance, but it does not reveal anything about antenna/preamplifier noise. The contribution of receiver measurement noise to range error will be highly dependent on the GNSS receiver's quality.

**4.3 Results of Observations**

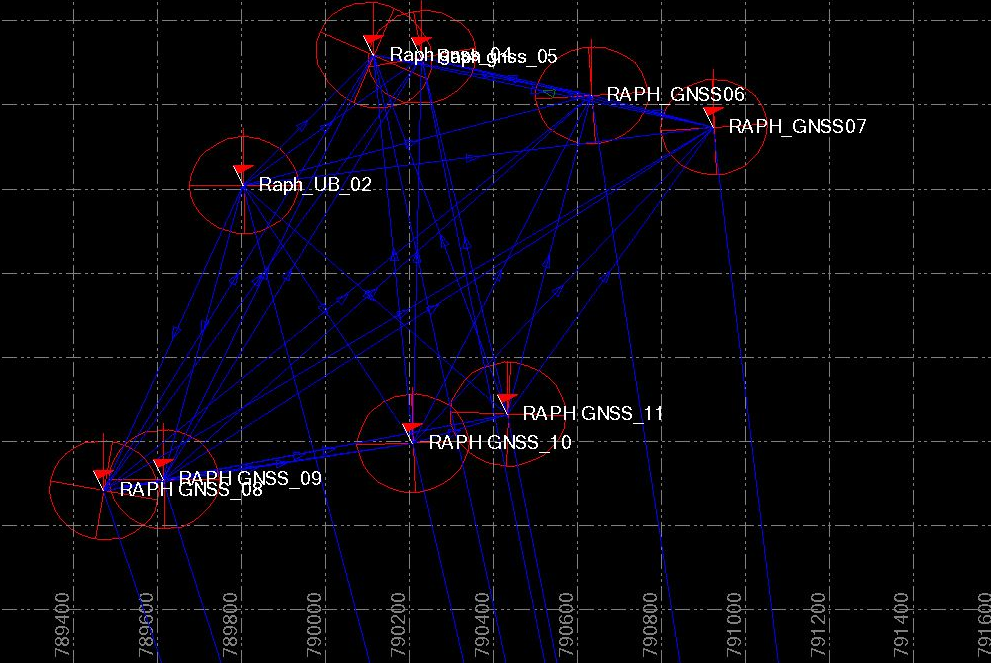
Data acquired was processed using Trimble Business center. The results are presented below:

Figure 4.7:Network of observation

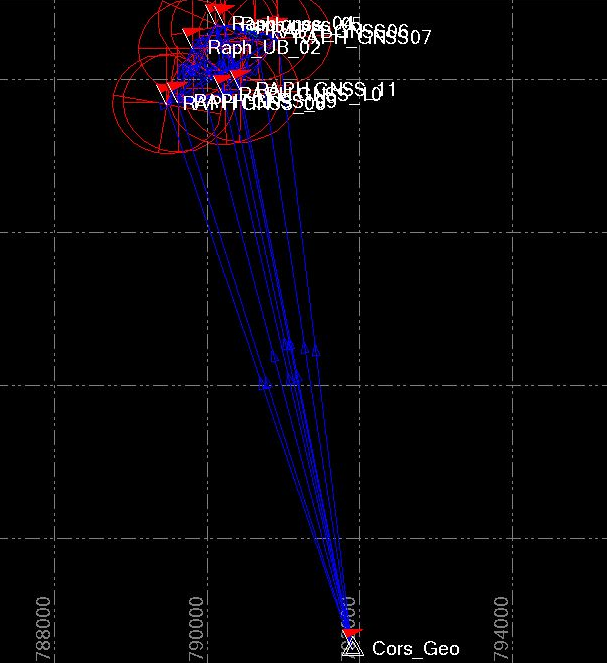


Figure 4.8: Cors\_Geosystems and Network of observation

**Table 4.6: Results of Processed Data using Trimble Business center**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  | | --- | --- | --- | | |  | | --- | | **Project File Data** | | | | Name: | C:\Users\Dell\Users Dell\Desktop\RINEX PROF RAPH\_ DATA\DS\_REPORT. | | Size: | 143 KB | | Modified: | 2/17/2022 4:26:41 PM (UTC:1) | | Time zone: | W. Central Africa Standard Time | | Reference number: |  | | Description: |  | | Comment 1: |  | | Comment 2: |  | | Comment 3: |  | | |  |  |  | | --- | --- | --- | | |  | | --- | | **Coordinate System** | | | |  | | | Name: | World wide/UTM | | Datum: | WGS 1984 | | Zone: | 31 North | | Geoid: | EGM08-25 | | Vertical datum: |  | | Calibrated site: |  | |

**Network Adjustment Report**

**Table 4.6.1: Adjustment Settings**

|  |
| --- |
| **Set-Up Errors** |
| **GNSS** |
| **Error in Height of Antenna:** | 0.000 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 |

**Table 4.6.2: Adjustment Statistics**

|  |  |
| --- | --- |
| **Number of Iterations for Successful Adjustment:** | 2 |
| **Network Reference Factor:** | 1.00 |
| **Chi Square Test (95%):** | Passed |
| **Precision Confidence Level:** | 95% |
| **Degrees of Freedom:** | 120 |

|  |  |
| --- | --- |
| **Post Processed Vector Statistics** | |
| **Reference Factor:** | 1.00 |
| **Redundancy Number:** | 120.00 |
| **A Priori Scalar:** | 1.19 |

**Table 4.6.3: Control Point Constraints**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Point ID** | **Type** | **East σ (Meter)** | **North σ (Meter)** | **Height σ (Meter)** | **Elevation σ (Meter)** |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223)Systems | Global | Fixed | Fixed | Fixed |  |
| Fixed =  0.000001(Meter) | | | | | |

**Table 4.6.4: Adjusted Grid Coordinates**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Point ID** | **Easting (Meter)** | **Easting Error (Meter)** | **Northing (Meter)** | **Northing Error (Meter)** | **Elevation (Meter)** | **Elevation Error (Meter)** | **Constraint** |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223)Systems | 791979.716 | 0 | 700426.07 | 0 | 108.163 | 0 | LLh |
| [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | 790196.019 | 0.002 | 708605.325 | 0.002 | 114.733 | 0.010 |  |
| [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | 790309.969 | 0.002 | 708599.165 | 0.001 | 112.99 | 0.009 |  |
| [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | 789552.402 | 0.002 | 707567.514 | 0.002 | 124.409 | 0.011 |  |
| [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | 789693.985 | 0.002 | 707593.159 | 0.002 | 122.84 | 0.010 |  |
| [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | 790289.661 | 0.002 | 707681.041 | 0.002 | 114.5 | 0.009 |  |
| [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | 790514.686 | 0.002 | 707749.147 | 0.002 | 111.709 | 0.010 |  |
| [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | 790714.857 | 0.002 | 708509.201 | 0.002 | 110.82 | 0.010 |  |
| [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | 791005.079 | 0.002 | 708433.175 | 0.001 | 110.654 | 0.009 |  |
| [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | 789884.712 | 0.002 | 708294.453 | 0.001 | 121.023 | 0.009 |  |

**Table 4.6.5: WGS84 Adjusted Geodetic Coordinates**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Point ID** | **Latitude** | **Longitude** | **Height (Meter)** | **Height Error (Meter)** | **Constraint** |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223)Systems | N6°19'51.73746" | E5°38'17.82973" | 109.626 | 0 | LLh |
| [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | N6°24'18.11798" | E5°37'21.18151" | 116.282 | 0.010 |  |
| [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | N6°24'17.89867" | E5°37'24.88613" | 114.538 | 0.009 |  |
| [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | N6°23'44.46252" | E5°37'00.07956" | 125.958 | 0.011 |  |
| [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | N6°23'45.27337" | E5°37'04.68800" | 124.387 | 0.010 |  |
| [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | N6°23'48.03372" | E5°37'24.07348" | 116.041 | 0.009 |  |
| [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | N6°23'50.21204" | E5°37'31.40243" | 113.248 | 0.010 |  |
| [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | N6°24'14.90471" | E5°37'38.03802" | 112.362 | 0.010 |  |
| [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | N6°24'12.38321" | E5°37'47.46329" | 112.192 | 0.009 |  |
| [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | N6°24'08.05630" | E5°37'11.00637" | 122.573 | 0.009 |  |

**Table 4.6.6: Adjusted ECEF Coordinates**

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Point ID** | **X (Meter)** | **X Error (Meter)** | **Y (Meter)** | **Y Error (Meter)** | **Z (Meter)** | **Z Error (Meter)** | **3D Error (Meter)** | **Constraint** |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223)Systems | 6308934.864 | 0 | 622853.021 | 0 | 698666.792 | 0 | 0 | LLh |
| [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | 6308209.016 | 0.010 | 621032.047 | 0.002 | 706800.095 | 0.002 | 0.010 |  |
| [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | 6308196.884 | 0.009 | 621145.250 | 0.002 | 706793.205 | 0.002 | 0.010 |  |
| [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | 6308396.785 | 0.010 | 620398.903 | 0.002 | 705773.739 | 0.002 | 0.011 |  |
| [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | 6308378.608 | 0.010 | 620539.423 | 0.002 | 705798.318 | 0.002 | 0.010 |  |
| [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | 6308302.604 | 0.009 | 621130.565 | 0.002 | 705881.657 | 0.002 | 0.010 |  |
| [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | 6308270.348 | 0.010 | 621353.707 | 0.002 | 705947.846 | 0.002 | 0.010 |  |
| [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | 6308165.324 | 0.009 | 621548.266 | 0.002 | 706701.564 | 0.002 | 0.010 |  |
| [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | 6308145.345 | 0.009 | 621837.348 | 0.002 | 706624.569 | 0.002 | 0.010 |  |
| [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | 6308280.174 | 0.009 | 620724.847 | 0.002 | 706493.635 | 0.002 | 0.010 |  |

**Table 4.6.7: Error Ellipse Components**

|  |  |  |  |
| --- | --- | --- | --- |
| **Point ID** | **Semi-major axis (Meter)** | **Semi-minor axis (Meter)** | **Azimuth** |
| [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | 0.002 | 0.002 | 114° |
| [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | 0.002 | 0.002 | 80° |
| [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | 0.002 | 0.002 | 100° |
| [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | 0.002 | 0.002 | 89° |
| [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | 0.002 | 0.002 | 88° |
| [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | 0.002 | 0.002 | 93° |
| [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | 0.002 | 0.002 | 86° |
| [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | 0.002 | 0.002 | 86° |
| [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | 0.002 | 0.002 | 89° |

**Table 4.6.8: Adjusted GNSS Observations**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Observation ID** |  | **Observation** | **A-posteriori Error** | **Residual** | **Standardized Residual** |
| [RAPH GNSS\_09 --> Raph gnss\_05 (PV18)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1787) | **Az.** | 31°46'15" | 0.270 sec | 0.067 sec | 0.377 |
|  | **ΔHt.** | -9.849 m | 0.006 m | -0.046 m | -4.352 |
|  | **Ellip Dist.** | 1178.856 m | 0.002 m | -0.002 m | -1.571 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| [Raph\_UB\_02 --> Raph gnss\_05 (PV3)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1751) | **Az.** | 54°40'08" | 0.529 sec | -0.236 sec | -0.585 |
|  | **ΔHt.** | -8.035 m | 0.004 m | 0.009 m | 3.347 |
|  | **Ellip Dist.** | 522.822 m | 0.001 m | 0.000 m | 0.168 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| [Cors\_Geo --> Raph gnss\_05 (PV2)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1719) | **Az.** | 348°44'45" | 0.040 sec | 0.034 sec | 0.776 |
|  | **ΔHt.** | 4.912 m | 0.009 m | -0.028 m | -2.410 |
|  | **Ellip Dist.** | 8336.499 m | 0.001 m | -0.005 m | -3.282 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| [Cors\_Geo --> RAPH GNSS\_10 (PV9)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1707) | **Az.** | 347°10'44" | 0.047 sec | -0.020 sec | -0.546 |
|  | **ΔHt.** | 6.415 m | 0.009 m | 0.033 m | 3.042 |
|  | **Ellip Dist.** | 7444.385 m | 0.002 m | 0.002 m | 1.490 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| [Cors\_Geo --> RAPH GNSS\_11 (PV27)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1709) | **Az.** | 348°58'45" | 0.053 sec | 0.058 sec | 1.355 |
|  | **ΔHt.** | 3.622 m | 0.010 m | 0.016 m | 1.218 |
|  | **Ellip Dist.** | 7463.330 m | 0.002 m | 0.004 m | 2.694 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| [RAPH GNSS\_08 --> Raph gnss\_05 (PV12)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1771) | **Az.** | 36°34'56" | 0.266 sec | 0.168 sec | 0.772 |
|  | **ΔHt.** | -11.419 m | 0.007 m | -0.034 m | -2.683 |
|  | **Ellip Dist.** | 1279.107 m | 0.002 m | 0.001 m | 0.879 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| [Cors\_Geo --> RAPH\_GNSS06 (PV81)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1717) | **Az.** | 351°23'55" | 0.044 sec | -0.113 sec | -2.619 |
|  | **ΔHt.** | 2.736 m | 0.010 m | 0.002 m | 0.145 |
|  | **Ellip Dist.** | 8176.172 m | 0.002 m | -0.002 m | -1.382 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| [Raph\_UB\_02 --> RAPH GNSS\_10 (PV6)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1737) | **Az.** | 146°51'38" | 0.467 sec | -0.057 sec | -0.131 |
|  | **ΔHt.** | -6.532 m | 0.005 m | -0.007 m | -1.969 |
|  | **Ellip Dist.** | 734.551 m | 0.002 m | -0.001 m | -0.399 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| [Raph\_UB\_02 --> RAPH GNSS\_08 (PV11)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1733) | **Az.** | 204°51'31" | 0.475 sec | -0.027 sec | -0.030 |
|  | **ΔHt.** | 3.384 m | 0.007 m | -0.014 m | -1.855 |
|  | **Ellip Dist.** | 798.782 m | 0.002 m | 0.001 m | 0.435 |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
|  |  |  |  |  |  |
| [RAPH GNSS\_09 --> RAPH\_GNSS06 (PV75)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1785) | **Az.** | 48°23'22" | 0.259 sec | 0.174 sec | 0.585 |
|  | **ΔHt.** | -12.025 m | 0.007 m | -0.031 m | -1.717 |
|  | **Ellip Dist.** | 1370.728 m | 0.002 m | 0.000 m | -0.013 |
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| [Cors\_Geo --> Raph\_UB\_02 (PV5)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1701) | **Az.** | 345°22'58" | 0.041 sec | -0.009 sec | -0.203 |
|  | **ΔHt.** | 12.947 m | 0.009 m | -0.019 m | -1.607 |
|  | **Ellip Dist.** | 8137.237 m | 0.001 m | 0.002 m | 1.543 |
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| [RAPH GNSS\_10 --> Raph gnss\_05 (PV7)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1803) | **Az.** | 1°33'33" | 0.372 sec | -0.516 sec | -1.535 |
|  | **ΔHt.** | -1.503 m | 0.005 m | -0.001 m | -0.173 |
|  | **Ellip Dist.** | 917.759 m | 0.001 m | 0.001 m | 0.571 |
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| [RAPH GNSS\_08 --> RAPH GNSS\_11 (PV22)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1759) | **Az.** | 79°36'08" | 0.401 sec | 0.570 sec | 1.472 |
|  | **ΔHt.** | -12.709 m | 0.008 m | 0.012 m | 0.776 |
|  | **Ellip Dist.** | 978.648 m | 0.002 m | -0.001 m | -0.754 |
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| [RAPH GNSS\_09 --> Raph gnss\_04 (PV19)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1773) | **Az.** | 26°40'22" | 0.388 sec | 0.671 sec | 1.059 |
|  | **ΔHt.** | -8.105 m | 0.007 m | 0.011 m | 1.453 |
|  | **Ellip Dist.** | 1129.108 m | 0.002 m | -0.001 m | -0.218 |
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| [Raph\_UB\_02 --> RAPH GNSS\_09 (PV17)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1735) | **Az.** | 195°30'22" | 0.509 sec | -0.588 sec | -0.708 |
|  | **ΔHt.** | 1.814 m | 0.006 m | -0.009 m | -1.349 |
|  | **Ellip Dist.** | 726.302 m | 0.002 m | 0.001 m | 0.353 |
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| [RAPH GNSS\_09 --> RAPH\_GNSS07 (PV42)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1781) | **Az.** | 57°38'38" | 0.207 sec | 0.090 sec | 0.439 |
|  | **ΔHt.** | -12.195 m | 0.006 m | -0.019 m | -1.331 |
|  | **Ellip Dist.** | 1556.109 m | 0.002 m | 0.001 m | 0.334 |
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| [Raph\_UB\_02 --> RAPH\_GNSS07 (PV45)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1743) | **Az.** | 83°14'00" | 0.234 sec | -0.194 sec | -1.298 |
|  | **ΔHt.** | -10.381 m | 0.005 m | 0.004 m | 0.488 |
|  | **Ellip Dist.** | 1128.196 m | 0.001 m | 0.000 m | 0.009 |
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| [RAPH\_GNSS07 --> RAPH\_GNSS06 (PV73)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1819) | **Az.** | 284°58'20" | 0.997 sec | 0.492 sec | 0.562 |
|  | **ΔHt.** | 0.170 m | 0.005 m | -0.004 m | -1.259 |
|  | **Ellip Dist.** | 299.821 m | 0.002 m | -0.001 m | -0.757 |
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| [RAPH GNSS\_08 --> RAPH\_GNSS07 (PV37)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1765) | **Az.** | 59°30'01" | 0.202 sec | 2.390 sec | 1.054 |
|  | **ΔHt.** | -13.765 m | 0.007 m | 0.068 m | 1.241 |
|  | **Ellip Dist.** | 1689.960 m | 0.002 m | 0.005 m | 0.279 |
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| [RAPH\_GNSS06 --> Raph gnss\_04 (PV80)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1823) | **Az.** | 280°47'20" | 0.703 sec | -0.421 sec | -0.512 |
|  | **ΔHt.** | 3.920 m | 0.006 m | -0.006 m | -1.178 |
|  | **Ellip Dist.** | 527.327 m | 0.002 m | -0.002 m | -0.689 |
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| [Cors\_Geo --> RAPH\_GNSS07 (PV48)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1713) | **Az.** | 353°21'08" | 0.040 sec | 0.010 sec | 0.261 |
|  | **ΔHt.** | 2.566 m | 0.009 m | -0.010 m | -0.892 |
|  | **Ellip Dist.** | 8060.947 m | 0.001 m | -0.002 m | -1.169 |
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| [Raph\_UB\_02 --> Raph gnss\_04 (PV4)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1731) | **Az.** | 45°19'55" | 0.875 sec | -0.250 sec | -0.369 |
|  | **ΔHt.** | -6.291 m | 0.005 m | -0.003 m | -1.135 |
|  | **Ellip Dist.** | 439.665 m | 0.002 m | -0.001 m | -0.412 |
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| [Raph gnss\_04 --> RAPH\_GNSS07 (PV40)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1725) | **Az.** | 102°18'16" | 0.421 sec | 1.656 sec | 1.115 |
|  | **ΔHt.** | -4.090 m | 0.006 m | -0.005 m | -0.245 |
|  | **Ellip Dist.** | 826.639 m | 0.002 m | -0.004 m | -0.548 |
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| [RAPH GNSS\_08 --> Raph gnss\_04 (PV13)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1753) | **Az.** | 32°05'50" | 0.353 sec | -0.362 sec | -1.086 |
|  | **ΔHt.** | -9.675 m | 0.007 m | -0.005 m | -0.341 |
|  | **Ellip Dist.** | 1220.404 m | 0.002 m | 0.000 m | -0.053 |
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| [RAPH GNSS\_09 --> RAPH GNSS\_11 (PV21)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1777) | **Az.** | 79°31'47" | 0.468 sec | 0.661 sec | 1.035 |
|  | **ΔHt.** | -11.139 m | 0.007 m | 0.005 m | 0.815 |
|  | **Ellip Dist.** | 834.858 m | 0.002 m | 0.001 m | 0.249 |
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| [RAPH\_GNSS07 --> Raph gnss\_05 (PV46)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1821) | **Az.** | 283°43'25" | 0.369 sec | 0.106 sec | 0.393 |
|  | **ΔHt.** | 2.346 m | 0.004 m | 0.002 m | 0.982 |
|  | **Ellip Dist.** | 714.193 m | 0.001 m | 0.000 m | 0.287 |
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| [RAPH GNSS\_10 --> RAPH GNSS\_11 (PV23)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1791) | **Az.** | 73°27'10" | 1.592 sec | 0.617 sec | 0.414 |
|  | **ΔHt.** | -2.793 m | 0.006 m | -0.004 m | -0.970 |
|  | **Ellip Dist.** | 234.955 m | 0.002 m | 0.000 m | -0.019 |
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| [Raph gnss\_04 --> RAPH\_GNSS07 (PV47)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1723) | **Az.** | 102°18'16" | 0.421 sec | -0.192 sec | -0.391 |
|  | **ΔHt.** | -4.090 m | 0.006 m | -0.004 m | -0.885 |
|  | **Ellip Dist.** | 826.639 m | 0.002 m | -0.001 m | -0.588 |
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| [Raph\_UB\_02 --> RAPH\_GNSS06 (PV78)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1749) | **Az.** | 75°47'17" | 0.357 sec | -0.110 sec | -0.298 |
|  | **ΔHt.** | -10.211 m | 0.005 m | 0.004 m | 0.884 |
|  | **Ellip Dist.** | 856.920 m | 0.002 m | 0.001 m | 0.285 |
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| [RAPH GNSS\_10 --> Raph gnss\_04 (PV8)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1789) | **Az.** | 354°30'25" | 0.449 sec | 0.082 sec | 0.131 |
|  | **ΔHt.** | 0.241 m | 0.006 m | 0.005 m | 0.854 |
|  | **Ellip Dist.** | 928.419 m | 0.002 m | 0.000 m | -0.030 |
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| [RAPH GNSS\_10 --> RAPH\_GNSS07 (PV44)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1795) | **Az.** | 43°51'32" | 0.314 sec | -0.057 sec | -0.148 |
|  | **ΔHt.** | -3.849 m | 0.005 m | 0.004 m | 0.782 |
|  | **Ellip Dist.** | 1037.371 m | 0.002 m | 0.002 m | 0.821 |
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| [RAPH GNSS\_08 --> RAPH GNSS\_10 (PV10)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1757) | **Az.** | 81°32'14" | 0.476 sec | 0.116 sec | 0.195 |
|  | **ΔHt.** | -9.917 m | 0.007 m | 0.004 m | 0.802 |
|  | **Ellip Dist.** | 745.470 m | 0.002 m | 0.000 m | -0.002 |
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| [RAPH GNSS\_08 --> RAPH\_GNSS06 (PV76)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1769) | **Az.** | 51°16'51" | 0.247 sec | 0.072 sec | 0.248 |
|  | **ΔHt.** | -13.595 m | 0.007 m | -0.013 m | -0.744 |
|  | **Ellip Dist.** | 1495.059 m | 0.002 m | 0.001 m | 0.674 |
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| [Cors\_Geo --> RAPH GNSS\_08 (PV14)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1703) | **Az.** | 341°31'11" | 0.049 sec | 0.039 sec | 0.674 |
|  | **ΔHt.** | 16.332 m | 0.011 m | 0.009 m | 0.574 |
|  | **Ellip Dist.** | 7537.808 m | 0.002 m | 0.000 m | -0.079 |
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| [Raph\_UB\_02 --> RAPH GNSS\_11 (PV24)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1739) | **Az.** | 131°10'16" | 0.462 sec | 0.078 sec | 0.140 |
|  | **ΔHt.** | -9.325 m | 0.006 m | -0.004 m | -0.640 |
|  | **Ellip Dist.** | 832.667 m | 0.002 m | 0.000 m | -0.039 |
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| [RAPH GNSS\_09 --> RAPH GNSS\_10 (PV16)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1775) | **Az.** | 81°53'56" | 0.559 sec | 0.223 sec | 0.414 |
|  | **ΔHt.** | -8.346 m | 0.006 m | 0.002 m | 0.635 |
|  | **Ellip Dist.** | 601.737 m | 0.002 m | 0.000 m | 0.271 |
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| [Raph\_UB\_02 --> RAPH\_GNSS07 (PV39)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1745) | **Az.** | 83°14'00" | 0.234 sec | -0.924 sec | -0.515 |
|  | **ΔHt.** | -10.381 m | 0.005 m | 0.014 m | 0.449 |
|  | **Ellip Dist.** | 1128.196 m | 0.001 m | -0.007 m | -0.634 |
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| [RAPH GNSS\_10 --> RAPH\_GNSS06 (PV77)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1801) | **Az.** | 27°28'09" | 0.399 sec | 0.348 sec | 0.608 |
|  | **ΔHt.** | -3.678 m | 0.005 m | 0.003 m | 0.486 |
|  | **Ellip Dist.** | 930.336 m | 0.002 m | 0.001 m | 0.229 |
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| [RAPH GNSS\_11 --> Raph gnss\_05 (PV25)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1815) | **Az.** | 346°45'04" | 0.459 sec | 0.004 sec | 0.008 |
|  | **ΔHt.** | 1.290 m | 0.006 m | -0.003 m | -0.574 |
|  | **Ellip Dist.** | 873.759 m | 0.002 m | 0.000 m | -0.212 |
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| [RAPH GNSS\_08 --> RAPH\_GNSS07 (PV43)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1763) | **Az.** | 59°30'01" | 0.202 sec | 0.069 sec | 0.309 |
|  | **ΔHt.** | -13.765 m | 0.007 m | -0.008 m | -0.537 |
|  | **Ellip Dist.** | 1689.960 m | 0.002 m | 0.000 m | 0.273 |
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| [Cors\_Geo --> RAPH GNSS\_09 (PV20)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1705) | **Az.** | 342°36'13" | 0.049 sec | 0.016 sec | 0.262 |
|  | **ΔHt.** | 14.761 m | 0.010 m | 0.002 m | 0.090 |
|  | **Ellip Dist.** | 7517.880 m | 0.002 m | -0.001 m | -0.510 |
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| [RAPH GNSS\_08 --> RAPH GNSS\_09 (PV15)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1755) | **Az.** | 80°01'29" | 2.504 sec | 1.344 sec | 0.487 |
|  | **ΔHt.** | -1.570 m | 0.007 m | -0.001 m | -0.291 |
|  | **Ellip Dist.** | 143.795 m | 0.002 m | 0.000 m | 0.027 |
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| [RAPH GNSS\_11 --> RAPH\_GNSS07 (PV35)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1811) | **Az.** | 35°55'47" | 0.464 sec | 1.867 sec | 0.347 |
|  | **ΔHt.** | -1.056 m | 0.006 m | 0.029 m | 0.480 |
|  | **Ellip Dist.** | 841.109 m | 0.002 m | 0.003 m | 0.165 |
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| [RAPH GNSS\_11 --> Raph gnss\_04 (PV26)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1805) | **Az.** | 339°52'38" | 0.492 sec | 0.357 sec | 0.436 |
|  | **ΔHt.** | 3.034 m | 0.006 m | 0.002 m | 0.208 |
|  | **Ellip Dist.** | 912.971 m | 0.002 m | 0.001 m | 0.242 |
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| [Cors\_Geo --> Raph gnss\_04 (PV1)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1699) | **Az.** | 347°59'24" | 0.046 sec | -0.016 sec | -0.417 |
|  | **ΔHt.** | 6.656 m | 0.010 m | 0.001 m | 0.057 |
|  | **Ellip Dist.** | 8366.055 m | 0.002 m | 0.001 m | 0.412 |
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| [RAPH\_GNSS06 --> Raph gnss\_05 (PV79)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1825) | **Az.** | 282°49'12" | 0.687 sec | -0.194 sec | -0.416 |
|  | **ΔHt.** | 2.176 m | 0.005 m | 0.000 m | -0.106 |
|  | **Ellip Dist.** | 414.495 m | 0.002 m | 0.000 m | 0.306 |
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| [RAPH GNSS\_10 --> RAPH\_GNSS07 (PV38)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1797) | **Az.** | 43°51'32" | 0.314 sec | -0.505 sec | -0.207 |
|  | **ΔHt.** | -3.849 m | 0.005 m | 0.013 m | 0.375 |
|  | **Ellip Dist.** | 1037.371 m | 0.002 m | 0.003 m | 0.249 |
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| [RAPH GNSS\_11 --> RAPH\_GNSS07 (PV41)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1809) | **Az.** | 35°55'47" | 0.464 sec | 0.161 sec | 0.243 |
|  | **ΔHt.** | -1.056 m | 0.006 m | 0.000 m | -0.007 |
|  | **Ellip Dist.** | 841.109 m | 0.002 m | 0.001 m | 0.257 |
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| [RAPH GNSS\_11 --> RAPH\_GNSS06 (PV74)](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1813) | **Az.** | 15°02'49" | 0.550 sec | 0.165 sec | 0.185 |
|  | **ΔHt.** | -0.886 m | 0.006 m | -0.001 m | -0.063 |
|  | **Ellip Dist.** | 785.463 m | 0.002 m | 0.001 m | 0.253 |

**Table 4.6.9: Covariance Terms**

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| --- | --- | --- | --- | --- | --- | --- |
| **From Point** | **To Point** |  | **Components** | **A-posteriori Error** | **Horiz. Precision (Ratio)** | **3D Precision (Ratio)** |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223) | [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | **Az.** | 347°59'24" | 0.046 sec | 1 : 4,712,663 | 1 : 4,715,307 |
|  |  | **ΔHt.** | 6.656 m | 0.010 m |  |  |
|  |  | **ΔElev.** | 6.234 m | 0.010 m |  |  |
|  |  | **Ellip Dist.** | 8366.055 m | 0.002 m |  |  |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223) | [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | **Az.** | 348°44'45" | 0.040 sec | 1 : 6,038,657 | 1 : 6,035,931 |
|  |  | **ΔHt.** | 4.912 m | 0.009 m |  |  |
|  |  | **ΔElev.** | 4.492 m | 0.009 m |  |  |
|  |  | **Ellip Dist.** | 8336.499 m | 0.001 m |  |  |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223) | [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | **Az.** | 341°31'11" | 0.049 sec | 1 : 4,432,022 | 1 : 4,432,363 |
|  |  | **ΔHt.** | 16.332 m | 0.011 m |  |  |
|  |  | **ΔElev.** | 15.959 m | 0.011 m |  |  |
|  |  | **Ellip Dist.** | 7537.808 m | 0.002 m |  |  |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223) | [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | **Az.** | 342°36'13" | 0.049 sec | 1 : 4,599,213 | 1 : 4,597,370 |
|  |  | **ΔHt.** | 14.761 m | 0.010 m |  |  |
|  |  | **ΔElev.** | 14.388 m | 0.010 m |  |  |
|  |  | **Ellip Dist.** | 7517.880 m | 0.002 m |  |  |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223) | [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | **Az.** | 347°10'44" | 0.047 sec | 1 : 4,923,023 | 1 : 4,922,175 |
|  |  | **ΔHt.** | 6.415 m | 0.009 m |  |  |
|  |  | **ΔElev.** | 6.042 m | 0.009 m |  |  |
|  |  | **Ellip Dist.** | 7444.385 m | 0.002 m |  |  |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223) | [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | **Az.** | 348°58'45" | 0.053 sec | 1 : 4,255,886 | 1 : 4,256,390 |
|  |  | **ΔHt.** | 3.622 m | 0.010 m |  |  |
|  |  | **ΔElev.** | 3.247 m | 0.010 m |  |  |
|  |  | **Ellip Dist.** | 7463.330 m | 0.002 m |  |  |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223) | [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | **Az.** | 351°23'55" | 0.044 sec | 1 : 5,378,060 | 1 : 5,377,724 |
|  |  | **ΔHt.** | 2.736 m | 0.010 m |  |  |
|  |  | **ΔElev.** | 2.323 m | 0.010 m |  |  |
|  |  | **Ellip Dist.** | 8176.172 m | 0.002 m |  |  |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223) | [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | **Az.** | 353°21'08" | 0.040 sec | 1 : 5,715,755 | 1 : 5,715,000 |
|  |  | **ΔHt.** | 2.566 m | 0.009 m |  |  |
|  |  | **ΔElev.** | 2.158 m | 0.009 m |  |  |
|  |  | **Ellip Dist.** | 8060.947 m | 0.001 m |  |  |
| [Cors\_Geo](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1223) | [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | **Az.** | 345°22'58" | 0.041 sec | 1 : 5,582,937 | 1 : 5,580,134 |
|  |  | **ΔHt.** | 12.947 m | 0.009 m |  |  |
|  |  | **ΔElev.** | 12.539 m | 0.009 m |  |  |
|  |  | **Ellip Dist.** | 8137.237 m | 0.001 m |  |  |
| [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | **Az.** | 212°05'52" | 0.353 sec | 1 : 669,540 | 1 : 669,709 |
|  |  | **ΔHt.** | 9.675 m | 0.007 m |  |  |
|  |  | **ΔElev.** | 9.725 m | 0.007 m |  |  |
|  |  | **Ellip Dist.** | 1220.404 m | 0.002 m |  |  |
| [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | **Az.** | 206°40'24" | 0.388 sec | 1 : 597,942 | 1 : 597,871 |
|  |  | **ΔHt.** | 8.105 m | 0.007 m |  |  |
|  |  | **ΔElev.** | 8.154 m | 0.007 m |  |  |
|  |  | **Ellip Dist.** | 1129.108 m | 0.002 m |  |  |
| [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | **Az.** | 174°30'25" | 0.448 sec | 1 : 494,334 | 1 : 494,615 |
|  |  | **ΔHt.** | -0.241 m | 0.006 m |  |  |
|  |  | **ΔElev.** | -0.193 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 928.419 m | 0.002 m |  |  |
| [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | **Az.** | 159°52'37" | 0.491 sec | 1 : 424,078 | 1 : 424,573 |
|  |  | **ΔHt.** | -3.034 m | 0.006 m |  |  |
|  |  | **ΔElev.** | -2.988 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 912.971 m | 0.002 m |  |  |
| [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | **Az.** | 100°47'18" | 0.706 sec | 1 : 258,297 | 1 : 258,649 |
|  |  | **ΔHt.** | -3.920 m | 0.006 m |  |  |
|  |  | **ΔElev.** | -3.911 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 527.327 m | 0.002 m |  |  |
| [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | **Az.** | 102°18'16" | 0.423 sec | 1 : 435,856 | 1 : 43,6171 |
|  |  | **ΔHt.** | -4.090 m | 0.006 m |  |  |
|  |  | **ΔElev.** | -4.076 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 826.639 m | 0.002 m |  |  |
| [Raph gnss\_04](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1308) | [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | **Az.** | 225°19'56" | 0.876 sec | 1 : 259,186 | 1 : 259,519 |
|  |  | **ΔHt.** | 6.291 m | 0.005 m |  |  |
|  |  | **ΔElev.** | 6.305 m | 0.005 m |  |  |
|  |  | **Ellip Dist.** | 439.665 m | 0.002 m |  |  |
| [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | **Az.** | 216°34'58" | 0.267 sec | 1 : 785,863 | 1 : 787,256 |
|  |  | **ΔHt.** | 11.419 m | 0.007 m |  |  |
|  |  | **ΔElev.** | 11.468 m | 0.007 m |  |  |
|  |  | **Ellip Dist.** | 1279.107 m | 0.002 m |  |  |
| [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | **Az.** | 211°46'17" | 0.270 sec | 1 : 761,264 | 1 : 762,503 |
|  |  | **ΔHt.** | 9.849 m | 0.006 m |  |  |
|  |  | **ΔElev.** | 9.897 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 1178.856 m | 0.002 m |  |  |
| [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | **Az.** | 181°33'33" | 0.371 sec | 1 : 640,682 | 1 : 640,783 |
|  |  | **ΔHt.** | 1.503 m | 0.005 m |  |  |
|  |  | **ΔElev.** | 1.550 m | 0.005 m |  |  |
|  |  | **Ellip Dist.** | 917.759 m | 0.001 m |  |  |
| [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | **Az.** | 166°45'04" | 0.459 sec | 1 : 510,600 | 1 : 510,550 |
|  |  | **ΔHt.** | -1.290 m | 0.006 m |  |  |
|  |  | **ΔElev.** | -1.245 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 873.759 m | 0.002 m |  |  |
| [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | **Az.** | 102°49'11" | 0.689 sec | 1 : 258,355 | 1 : 258,615 |
|  |  | **ΔHt.** | -2.176 m | 0.005 m |  |  |
|  |  | **ΔElev.** | -2.169 m | 0.005 m |  |  |
|  |  | **Ellip Dist.** | 414.495 m | 0.002 m |  |  |
| [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | **Az.** | 103°43'22" | 0.370 sec | 1 : 499,637 | 1 : 499,719 |
|  |  | **ΔHt.** | -2.346 m | 0.004 m |  |  |
|  |  | **ΔElev.** | -2.333 m | 0.004 m |  |  |
|  |  | **Ellip Dist.** | 714.193 m | 0.001 m |  |  |
| [Raph gnss\_05](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1313) | [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | **Az.** | 234°40'09" | 0.531 sec | 1 : 349,735 | 1 : 350,513 |
|  |  | **ΔHt.** | 8.035 m | 0.004 m |  |  |
|  |  | **ΔElev.** | 8.048 m | 0.004 m |  |  |
|  |  | **Ellip Dist.** | 522.822 m | 0.001 m |  |  |
| [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | **Az.** | 80°01'29" | 2.516 sec | 1 : 75,462 | 1 : 75,640 |
|  |  | **ΔHt.** | -1.570 m | 0.007 m |  |  |
|  |  | **ΔElev.** | -1.571 m | 0.007 m |  |  |
|  |  | **Ellip Dist.** | 143.795 m | 0.002 m |  |  |
| [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | **Az.** | 79°36'08" | 0.403 sec | 1 : 476664 | 1 : 477,065 |
|  |  | **ΔHt.** | -12.709 m | 0.008 m |  |  |
|  |  | **ΔElev.** | -12.712 m | 0.008 m |  |  |
|  |  | **Ellip Dist.** | 978.648 m | 0.002 m |  |  |
| [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | **Az.** | 51°16'51" | 0.248 sec | 1 : 818,572 | 1 : 819,772 |
|  |  | **ΔHt.** | -13.595 m | 0.007 m |  |  |
|  |  | **ΔElev.** | -13.636 m | 0.007 m |  |  |
|  |  | **Ellip Dist.** | 1495.059 m | 0.002 m |  |  |
| [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | **Az.** | 59°30'01" | 0.203 sec | 1 : 991,882 | 1 : 992,740 |
|  |  | **ΔHt.** | -13.765 m | 0.007 m |  |  |
|  |  | **ΔElev.** | -13.801 m | 0.007 m |  |  |
|  |  | **Ellip Dist.** | 1689.960 m | 0.002 m |  |  |
| [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | **Az.** | 79°31'47" | 0.471 sec | 1 : 398,416 | 1 : 398,428 |
|  |  | **ΔHt.** | -11.139 m | 0.007 m |  |  |
|  |  | **ΔElev.** | -11.142 m | 0.007 m |  |  |
|  |  | **Ellip Dist.** | 834.858 m | 0.002 m |  |  |
| [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | **Az.** | 48°23'22" | 0.260 sec | 1 : 764,027 | 1 : 764,724 |
|  |  | **ΔHt.** | -12.025 m | 0.007 m |  |  |
|  |  | **ΔElev.** | -12.065 m | 0.007 m |  |  |
|  |  | **Ellip Dist.** | 1370.728 m | 0.002 m |  |  |
| [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | **Az.** | 57°38'38" | 0.208 sec | 1 : 932,373 | 1 : 932,471 |
|  |  | **ΔHt.** | -12.195 m | 0.006 m |  |  |
|  |  | **ΔElev.** | -12.230 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 1556.109 m | 0.002 m |  |  |
| [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | **Az.** | 261°32'17" | 0.479 sec | 1 : 394,049 | 1 : 394,980 |
|  |  | **ΔHt.** | 9.917 m | 0.007 m |  |  |
|  |  | **ΔElev.** | 9.917 m | 0.007 m |  |  |
|  |  | **Ellip Dist.** | 745.470 m | 0.002 m |  |  |
| [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | **Az.** | 261°53'58" | 0.562 sec | 1 : 327,575 | 1 : 327,889 |
|  |  | **ΔHt.** | 8.346 m | 0.006 m |  |  |
|  |  | **ΔElev.** | 8.347 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 601.737 m | 0.002 m |  |  |
| [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | **Az.** | 73°27'10" | 1.600 sec | 1 : 118,265 | 1 : 118,209 |
|  |  | **ΔHt.** | -2.793 m | 0.006 m |  |  |
|  |  | **ΔElev.** | -2.795 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 234.955 m | 0.002 m |  |  |
| [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | **Az.** | 27°28'09" | 0.400 sec | 1 : 548,192 | 1 : 548,285 |
|  |  | **ΔHt.** | -3.678 m | 0.005 m |  |  |
|  |  | **ΔElev.** | -3.719 m | 0.005 m |  |  |
|  |  | **Ellip Dist.** | 930.336 m | 0.002 m |  |  |
| [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | **Az.** | 43°51'32" | 0.315 sec | 1 : 643,693 | 1 : 643,552 |
|  |  | **ΔHt.** | -3.849 m | 0.005 m |  |  |
|  |  | **ΔElev.** | -3.883 m | 0.005 m |  |  |
|  |  | **Ellip Dist.** | 1037.371 m | 0.002 m |  |  |
| [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | **Az.** | 15°02'49" | 0.549 sec | 1 : 418,075 | 1 : 417,964 |
|  |  | **ΔHt.** | -0.886 m | 0.006 m |  |  |
|  |  | **ΔElev.** | -0.924 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 785.463 m | 0.002 m |  |  |
| [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | **Az.** | 35°55'47" | 0.464 sec | 1 : 459,109 | 1 : 458,889 |
|  |  | **ΔHt.** | -1.056 m | 0.006 m |  |  |
|  |  | **ΔElev.** | -1.089 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 841.109 m | 0.002 m |  |  |
| [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | **Az.** | 284°58'20" | 1.001 sec | 1 : 183,011 | 1 : 183,098 |
|  |  | **ΔHt.** | 0.170 m | 0.005 m |  |  |
|  |  | **ΔElev.** | 0.165 m | 0.005 m |  |  |
|  |  | **Ellip Dist.** | 299.821 m | 0.002 m |  |  |
| [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | [RAPH GNSS\_08](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1398) | **Az.** | 204°51'31" | 0.474 sec | 1 : 475,924 | 1 : 475,975 |
|  |  | **ΔHt.** | 3.384 m | 0.007 m |  |  |
|  |  | **ΔElev.** | 3.420 m | 0.007 m |  |  |
|  |  | **Ellip Dist.** | 798.782 m | 0.002 m |  |  |
| [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | [RAPH GNSS\_09](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1411) | **Az.** | 195°30'22" | 0.508 sec | 1 : 446,997 | 1 : 446,941 |
|  |  | **ΔHt.** | 1.814 m | 0.006 m |  |  |
|  |  | **ΔElev.** | 1.849 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 726.302 m | 0.002 m |  |  |
| [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | [RAPH GNSS\_10](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1387) | **Az.** | 146°51'38" | 0.466 sec | 1 : 470,065 | 1 : 469,994 |
|  |  | **ΔHt.** | -6.532 m | 0.005 m |  |  |
|  |  | **ΔElev.** | -6.498 m | 0.005 m |  |  |
|  |  | **Ellip Dist.** | 734.551 m | 0.002 m |  |  |
| [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | [RAPH GNSS\_11](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1426) | **Az.** | 131°10'16" | 0.462 sec | 1 : 436,695 | 1 : 436,895 |
|  |  | **ΔHt.** | -9.325 m | 0.006 m |  |  |
|  |  | **ΔElev.** | -9.293 m | 0.006 m |  |  |
|  |  | **Ellip Dist.** | 832.667 m | 0.002 m |  |  |
| [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | [RAPH\_GNSS06](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1671) | **Az.** | 75°47'17" | 0.359 sec | 1 : 495,895 | 1 : 496,720 |
|  |  | **ΔHt.** | -10.211 m | 0.005 m |  |  |
|  |  | **ΔElev.** | -10.217 m | 0.005 m |  |  |
|  |  | **Ellip Dist.** | 856.920 m | 0.002 m |  |  |
| [Raph\_UB\_02](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1318) | [RAPH\_GNSS07](http://localhost:59529?Project=11b5f730-8705-4d48-9fe8-10b747b0f768&SerialNumber=1521) | **Az.** | 83°14'00" | 0.236 sec | 1 : 771,628 | 1 : 771,725 |
|  |  | **ΔHt.** | -10.381 m | 0.005 m |  |  |
|  |  | **ΔElev.** | -10.381 m | 0.005 m |  |  |
|  |  | **Ellip Dist.** | 1128.196 m | 0.001 m |  |  |

|  |  |  |
| --- | --- | --- |
| Date: 2/17/2022 4:31:06 PM | Project: C:\Users\Dell\Users Dell\Desktop\RINEX PROF RAPH: DATA\DS\_REPORT. | Trimble Business Center |

**5.0 DISCUSSIONS**

The setout go for this Thesis is to establish first order Geodetic control in University of Benin, benin City Nigeria using Cors\_GeoSystems as reference point. The following recommendations can therefore be made:

**5.1 RECOMMENDATIONS**

* For precise GNSS observation, it is important to know the type of GNSS receivers required. In this case dual frequency receivers are to be deploy.
* The mathematical model, functional and Stochastic to be used in processing of data should be adequate.
* Estimation and model validation results are based on this model.
* The measured data should be examined on systematic effects, not captured by the functional model.
* It is recommended that receiver be calibrated on a known baseline.
* To attain the type of accuracy obtained in this research work, stations should be selected clear of obstruction that may create errors due to multipath.
* It’s recommended that researchers, Engineers, Students, etc should make use of the control for her various needs
  1. **CONTRIBUTION TO KNOWLEDGE**

1. Application of Cors\_GeoSystems is a pioneering work in establishment of Controls points in Edos State.
2. This is a novel research area in that it is still evolving and developing globally. In Nigeria, not much has been contributed to the Application of CORS GNSS in Control establishment.
3. The study revealed that in areas with favourable satellite constellation and appropriate reduction or elimination of multipath and other noise like errors, static Differential GNSS techniques with a combination of code and carrier phase measurement gives a better result.
4. sequence can uncover previously unseen issues in an otherwise established problem.
5. **CONCLUSION**

This study has evaluated the positional accuracy and standard for GNSS first and second order geodetic

coordinates as specified by Federal Republic of Nigeria. The following conclusions can be made

conclusions can be drawn:

The accuracy standard for 1st order control is 1:100,000. The obtained standard is a lot more

better giving an indication that the GNSS equipment deploy for this study has high accuracy

standard. Results as presented in table 4.6.9. and table 4.6.7 for error ellipse.

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