CadastralUltra: A Purpose-Built Low Cost GPS System for Cadastral Surveying in Nigeria

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Key words: CadastralUltra, Cadastral Surveying, Purpose-Built, Low Cost, GPS System, Professionalism

SUMMARY

The cost of modern survey-grade electronic and satellite technologies required for proper and professional cadastral surveying is on the high side for the average practitioners in Nigeria.

The practitioners have therefore resorted to the use of approximate devices based on such technologies such as consumer-grade handheld GPS devices which are ordinarily meant for outdoor activities as hiking, biking, backpacking, mountaineering, boating etc.

The use of such handheld GPS devices do result into the production of unfit-for- purpose data and also, the professionalism of the practitioners is been gradually eroded.

To stem this unhealthy trend, a purpose-built, easy to use, low cost GPS system for cadastral survey was conceptualized and built through a partnership between Darelash and Unistrong.

This paper presents the making, functionalities and performance of the low cost GPS system that is able to compare in accuracy of obtained coordinates with known survey grade GPS systems at a price that is less than that of the survey grade by a factor of 10.

Suggestions for improving current cadastral survey practice in Nigeria are put forward.

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1. INTRODUCTION

Cadastral surveying also variously known as Property Survey, Boundary Survey, Demarcation Survey and in Nigerian local parlance "Four Corner Job", constitute about 70% of discrete survey activities in Nigeria. It is the only aspect of survey profession that has legal status as the practice is regulated by the laws of the country.

Cadastral surveying as it is today started with the British colonialists in the mid 1800 albeit some forms of land parcel boundary demarcations have been in the traditional practices of the various tribes constituting Nigeria today.

The methods of carrying out the cadastral surveying have evolved with time and technological advancements; from simple compass and chain through optical theodolite and tape to electronic and satellite instrumentations and methodologies.

While the cadastral surveyors of the immediate time past can easily afford the technology of the day, such as the iconic Wild T2 optical theodolite and even Electronic Distance Meter (EDM), to carry out their practice professionally, the same cannot be said of the present day practitioners. The least Total Station costs about US$5000 and the least survey grade Global Navigation Satellite System (GNSS) device costs about US$9000.

To remain in practice and embracing the modern technology, present day cadastral survey practitioners have resorted to the use of consumer/recreational grade Global Positioning System (GPS) devices which are meant for such outdoor activities as; hiking, biking, mountaineering, backpacking, etc. This grade of GPS positioning devices cannot log satellite positioning data for post processing which could have improve the accuracies of coordinates obtained through them or to do this, require further specialized hardwares, softwares and knowledge.

Since handheld GPS devices cannot resolve coordinates better than two metres (2m), they are therefore not suitable for cadastral survey of land parcels of 15m X 30m which is what the practitioners do most of the time. Apart from not meeting the required accuracy, the use of these handheld receivers is gradually eroding professionalism from cadastral survey practice which is the jewel in the crown of survey practice in Nigeria. Most of the time, the coordinates obtained do not "jive" and the practitioners have to make such coordinates to "cooperate". This practice will lead to problems in future when such "forced coordinates" will be used to re-establish lost property beacons.

In view of this, Darelash Ltd – a technological solutions provider in Geomatics and Location

Information Services in partnership with Unistrong – a reputable GPS equipment manufacturer, conceptualized and produced a purpose-built low cost GPS system called "CadastralUltra".

2. CADASTRAL SURVEYING

Cadastral surveying is that branch of surveying which is concerned with the survey and demarcation of land for the purpose of defining the dimensions, location and orientation of land parcels in some coordinates system. While cadastre of a country is its register of titles, cadastral plan as obtained from cadastral survey is the foundation block of the cadastre.

Man probably started boundary demarcations, by using natural features such as; permanently flowing streams, hedges, stone walls, certain plant species, etc, when he advanced from a nomadic to a more settled existence.

The practice of cadastral surveying using man made features for boundary demarcations has been recorded in Babylonia over 3500 years ago as names of surveyors have been found inscribed on boundary stones. For over 1000 years, ancient Rome used surveyors to locate boundaries.

The Roman Groma (surveyor's cross) and Dioptra of Heron's era were surveying instruments which were probably used more for boundary demarcations than for construction purposes. The Roman cadastral surveyors were given distinctive title as AGRIMENSORES to differentiate them from other surveyors such as building and road surveyors who were called GROMATICI.

Evidence abound that cadastral surveying was carried out in ancient Egypt to set out the boundaries of individual plots of arable land along the Nile River. Even more importantly, cadastral surveying would have been carried out to recover the beacons and boundaries of these individual plots after they might have been destroyed by the annual flooding by Nile. The corner beacons of the might have been set out or recovered by measuring from permanent markers that were located at areas that were above the flooding line.

The practice of cadastral surveying has evolved over time and varies from country to country since the practice is regulated by the laws of each country which differ from country to country. The level of technological advancement of a country also determines the standard, methodology and procedure of cadastral surveying practice in such country.

The importance of cadastral survey hence cadastre in modern times cannot be overemphasized, Ojogi (2011) stated that a good cadastral layout is considered as part of the basic infrastructures in much the same as roads, electricity, pipe borne water, etc, in fact it is an essential element that expedites virtually all forms of national developments.

Fourie and Nino-Fluck (1999) acknowledged the fact that the Land Information Management System (LIS) of a nation should conventionally be subordinate to the characteristics of the cadastre system of such nation. They also acknowledged the fact that because, less than one percent of sub-Saharan Africa is presently covered by cadastral records and 90 percent of land parcels are undocumented in developing countries, decision makers are unable to obtain sufficient information to make informed decision.

3. DISCOVERY OF ARTIFICIAL SATELLITE AS A SURVEY TOOL

From the earliest times, people have been using heavenly bodies such as sun, moon and stars to; locate places, navigate from one place to the other and to determine time. This practice has continued into modern times.

The first realization of the possibility of using a satellite "artificial star" for navigation and hence surveying came from the launching of SPUTNIK 1 on the 4th of October, 1957 by the then USSR. This realization came about when researchers, at John Hopkins University's Applied Physics Laboratory, who were listening to the signals from SPUTNIK 1 noticed a large Doppler shift on the signals. The researchers were able to subsequently use this Doppler shift in the SPUTNIK 1 transmitted signals to precisely determine the orbit of the satellite. This led the researchers to the idea that; if the unknown position of the satellite can be determined from a known ground position then an unknown ground position can be determined from a known orbital position of a satellite.

This concept led to the development of TRANSIT Satellite System as the first Global Navigation Satellite System (GNSS) by the US Department of Defence. The TRANSIT satellites were used, inter alia, for surveying and positioning from July 1967 to 31st December 1996, (Bonnor, 2012).

3.1 Global Navigation Satellite System (GNSS)

The umbrella name for all the world satellite systems for navigation and timing is Global Navigation Satellite System (GNSS) and the well known US Global Positioning System (GPS) is a member of this family. However, some of these satellite systems have only regional coverage rather than global coverage and are thus appropriately called Regional Navigation System (RNSS) and a typical example of this is the Japanese Quasi-Zenith Satellite System (QZSS). Also, some of these satellite systems do not provide direct navigation and positioning services but rather act in support of the navigation systems, they are aptly called; Satellite-Based Augmentation Systems (SBAS) to differentiate them from the ground based systems called Ground Based Augmentation System (GBAS).

In this paper only GPS is of interest, Bonnor (2012) and United Nations (2012) contain details of all these satellite systems.

4. GLOBAL POSITIONING SYSTEM (GPS)

4.1 The System Description

Navigation Satellite Timing And Range Global Positioning System (NAVSTAR GPS) is a space-based radio-positioning and time transfer, all weather, 24-hour global navigation satellite system operated and maintained by the United States Department of Defense (DoD).

GPS as utilized for positioning is a three-dimensional (3-D) measurement system based on the observations of radio signals of the NAVSTAR GPS. The GPS observations are processed to determine station positions in Earth-Centered Earth-Fixed (ECEF) Cartesian Coordinates (X, Y, Z), which are centered on the World Geodetic System 1984 (WGS-84) reference ellipsoid (the best mean fit to the Earth). In turn, the (X, Y, Z) can be converted to geodetic coordinates (latitude, longitude, and height-above-reference ellipsoid).

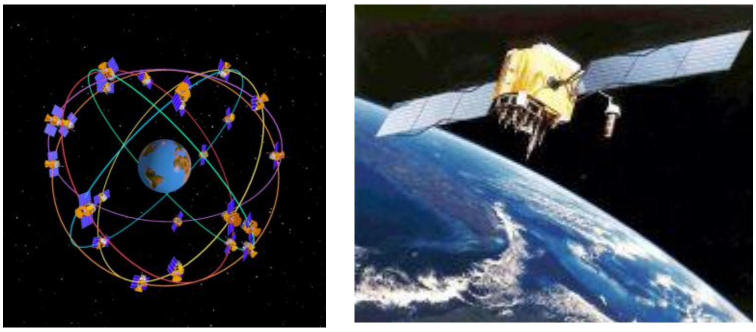


Figure 1: GPS Satellite

GPS is a current state-of-the-art surveying technology with its prominence in present and future surveys. GPS has several major advantages such as both day and night operation, intervisibility between stations is not required, mostly weather independent, geodetic accuracy, and is very productive with a possibilty of one man operation. GPS is becoming the first choice surveying technique for all types of surveys. GPS is the "tool of choice" for surveyors, except in those circumstances where it cannot be utilized due to obstructions or other restricting factors.

GPS surveying is an evolving technology. As GPS hardware and processing software are improved, and state-of-the-art new techniques are developed, new guidelines and specifications will be considered.

The system was initially designed as a military system, it became freely available for international civil use with certain restrictions to civilians for positioning.

GPS has three basic segments: Space, Control, and User as shown in Figure 2, Standards & Data Coordination Work Group (2007).

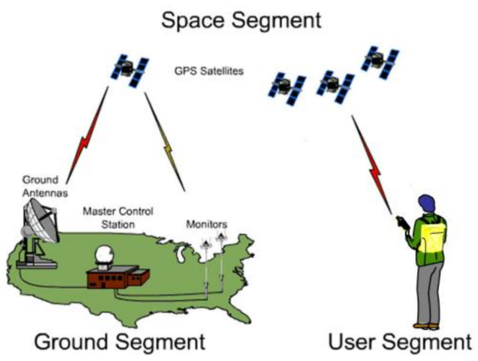


Figure 2: Illustration of the Three GPS System Segments

The Space Segment consists of 24 orbiting satellites making up the constellation with a minimum of 21 operating 98% of the time. The satellites orbit at an altitude of approximately 20,200 km above the earth, in one of six orbital planes. Each satellite broadcasts a unique "bar code", known as Pseudo Random Noise (PRN) code, which enables GPS receivers to identify the satellites from where the signals came, and makes positioning possible. Each satellite has about 11 hours 58 minute orbital period and is visible for approximately 5 hours above the horizon.

The Control Segment, under DoD's direction, oversees the building, launching, orbital positioning, monitoring, and providing GPS positioning services. A master control station updates the information (message) component of the GPS signal with satellite ephemeris data and other announcements to the users. This information is then decoded by the receiver and used in the positioning process.

The User Segment comprised of all users making observations with GPS receivers. Some applications of GPS are:

- Location - determining a basic position
- Navigation - getting from one location to another
- Tracking - monitoring the movement of people and things.
- Mapping - creating maps of the world
- Timing - bringing precise timing to the world

There are two classes of GPS service; the Precise Positioning Service (PPS) which is available only to users authorized by the military, and the Standard Positioning Service (SPS), which is available for civilian use. The SPS has been described as; a positioning and timing service provided by way of ranging signals broadcast at the GPS L1 frequency. The L1 frequency, transmitted by all satellites, contains a coarse/acquisition (C/A) code ranging signal, with a navigation data message, that is available for peaceful civil, commercial, and scientific use, USDoD(2008).

4.2 GPS Receivers

GPS receivers are the electronic devices with which users can make measurements from the signal broadcast from the orbiting GPS satellites. A typical receiver is essentially an electronic circuitry with a GPS chip, it comes with an internal/or external antenna.

4.2.1 Classification of GPS Receivers

GPS receivers are generally classified based on; method by which the receiver make distance measurements to the satellite and positional accuracy obtainable from the receiver. GPS receivers are also classified into two based on carrier wave frequency that they can access as single frequency (L1) and dual frequency (L1 and L2).

There are two classes based on range measurement methods namely; carrier phase based and code based, USDA FS and USDI BLM (2001).

4.2.2 Carrier Phase Based Receivers

Carrier phase receivers, mainly used in surveying, are capable of centimeter (cm) accuracy or better. These receivers measure distances to visible satellites by determining the number (N) of whole wavelengths (λ) and measuring the partial phase (Φ) signal wavelength between the satellites and the receiver's antenna. Once the number (N) of wavelengths is known, a pseudo range may be calculated by multiplying 'N' by the wavelength of the carrier signal (L1 and/or L2, 19cm and 24.4cm respectively) plus the partial wavelength. Figure 3 illustrates this ranging method.

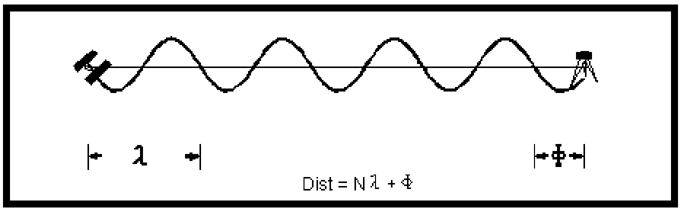


Figure 3: Carrier Phase Based Ranging

4.2.3 Code Based Receivers

Code based receivers use the speed of light and the time interval that it takes for the signal to travel from the satellite to the receiver to compute the distance to the satellites (Figure 4). The time interval (Δt) is determined by comparing the time in which a specific part of the "bar code" left the satellite with the time it arrived at the antenna. The pseudo range is computed by multiplying the time interval by the speed of light constant (c=299,792 Km/second).

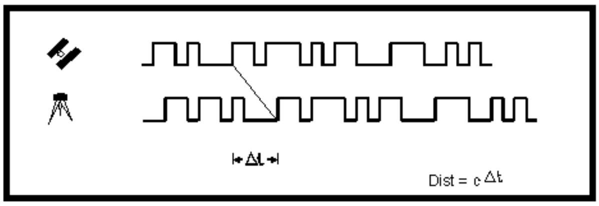


Figure 4: Code Based Pseudo Ranging

When the receivers are classified based on obtainable positional accuracy, there are four classes, Standards & Data Coordination Work Group (2007) adapted;

4.2.4 Recreational/Consumer Grade

Accuracy is from two to five meters. They are usually used to navigate from point to point.

4.2.5 Mapping/GIS Grade

Accuracy is from sub-meter to two meters. These GPS receivers have the ability to log raw GPS data, enabling these GPS-collected data to be post-processed.

4.2.6 Survey Grade

These include instruments with associated software that can achieve sub-meter to centimeter relative accuracy. These are used by land surveyors primarily for boundary and topographic surveys. This category of GPS receiver also has the ability to communicate with a base station, store attributes of features, use a data dictionary and upload data from the GPS device to a PC. Specialized training is needed to use this equipment.

4.2.7 Geodetic Grade

These include instruments with associated software that can achieve centimeter to millimeter relative accuracy. These are used by land surveyors primarily for geodetic surveys and other activities requiring high accuracy. Specialized training is needed to use this equipment.

4.3 GPS Measurements and Positioning

GPS measurements are simply distances from the satellites in view to the receiver antenna. The position of the receiver antenna is obtained by classical range-range resection technique using the obtained distances and the known positions of the satellites that were tracked in an epoch as shown by Figure 5 below. The receiver gets the position of the satellites from the broadcast ephemeris that is downloaded when the GPS receiver is turned on.

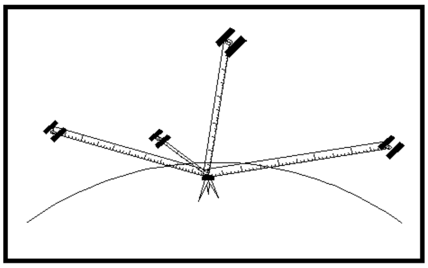


Figure 5: Position Determination by Measuring Distances to Satellites

4.3.1 GPS Positioning Modes

There are many names given to the various GPS positioning modes/techniques but generally these modes/techniques can be divided into two classes namely; 1) absolute also known as; stand alone, autonomous, or point positioning and 2) relative or differential. These two classes are further classified into two sub classes depending on whether the antenna is static or in motion (dynamic).These sub classes are further divided into two as post processed or real time depending on whether the coordinates are obtained realtime or after post processing. Table 1 below is the summary of the various GPS positioning modes and associated methods:

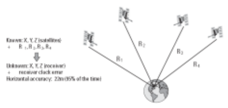
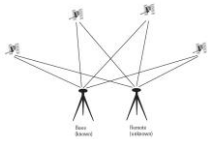
Main Class	Sub Class	Mode Decription	METHODS
Absolute 	Static	Post Processing	Precise Point Positioning (PPP)
		Real Time	Classical GPS Positioning
	Dynamic	Post Processing	
		Real Time	Navigation and tracking
Relative 	Static	Post Processing	Classical Static, Fast (Rapid) Static, Stop and Go
		Real Time	
	Dynamic	Post Processing	RTK, DGPS
		Real Time	RTK, DGPS

Table 1: GPS Positioning modes and Associated Methods

4.3.2 GPS Positioning Error Sources

GPS positioning is affected by a number of error some of which are inherent in the technology while others the well known traditional errors common to all survey tools. Figure 6 depicts some of these error sources.

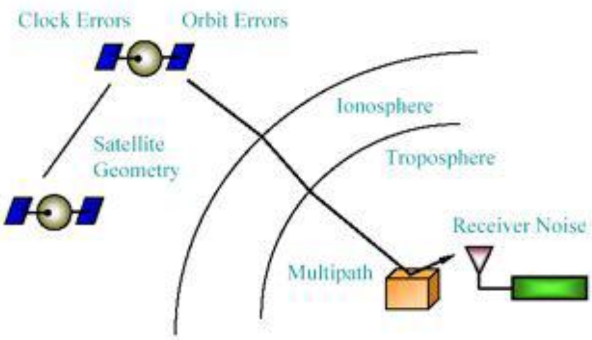


Figure 6: GPS Positioning Error Sources

These errors are mainly classified into two; 1) System Errors and 2) Operational Errors. These main classes are further classified as tabulated below in Table 2 as adapted from Standards & Data Coordination Work Group (2007).

Main Class	Sub Class	Error Description	Error Budget	Mitigation
System Errors	From Satellite	Ephemerides Error Errors in predicted positions of satellite.	Broadcast 5m Precise = 0.05m	Relative mode.
		Satellite Clock Error due to satellite clock drift	1.5m	Differencing observations from one satellite between two receivers. Receiver and satellite clock offsets as an unknown to be solved in parameter estimation.
		Tropospheric Delay Transmitted signal from satellites are refracted at lower part of atmosphere hence travel time is increased	0.5m	More accurate models for index of refraction. Higher elevation mask angle.
		Ionospheric Delay Dispersal of GPS signal leading to change in speed at upper atmosphere	5m	Dual frequency receiver and longer observation session for single frequency.
	From Receiver	Receiver Clock Error due to receiver clock drift.		Differencing observations between satellites can eliminate the receiver dock error. Receiver and satellite clock offsets as an unknown to be solved in parameter estimation.
		Receiver Noise Noise from receiver contaminates signal from satellite.	C/A-code = 3m P-code = 30cm Carrier Phase = 2mm	Relative mode
		Antenna Phase Center Difference in GPS antenna physical (optical) and phase (electronic) center.		Relative mode using same antenna model.
		Bull-Eye Level Bubble Collimation Error Verticallity bubble of the antenna pole	Several centimeters	Check, at least, before and after project.
		Tribrach Misalignment Cause offset in surveyed point and actual intended point..	centimeters	Check the optical plummet of tribrach before and after project.
	From Selected point	Multipath Reflected satellite signal getting to the antenna.	0.6	Avoid points near objects/structures with large reflective surfaces. Longer observation session to use changes in satellite geometry.
		Obstructions Complete obstruction of satellite thus reducing number of satellite in view. Partial obstruction that weaken satellite signal eg tree canopy.		Avoid points near objects /structures. Longer observation session to use changes in satellite geometr.y
		Interference Interference of satellite signal by radiation from wireless communication or high voltage power lines.		Avoid points in such area. Longer observation session to use changes in satellite geometry.

Main Class	Sub Class	Error Description	Error Budget	Mitigation
Operational Errors		Satellite Geometry Ideal satellite geometry for best position fix is a pyramid, significant departure from pyramid will give very poor position fix.		Set GDOP to less than 4.
		Length of Session Length of data collection determines the quality of obtained position fix.		For single frequency receiver: Baseline observation time = 10 minutes + 1 minute/km. For dual frequency receiver: Baseline observation time = 5 minutes + 0.5 minute/km.
		Instrument Setup Setup error translates directly into position error.		Proper attention to antenna instrument setup.
		Antenna Height Error in recorded antenna affects all three position parameters (X, Y, Z), but more critical for elevation survey.		Define the antenna reference point before project and measured antenna height twice before and after session.
	From Data Processing	Loop Closures Determine quality of measurements and depend on type of survey, similar to loop closure in conventional leveling or traversing.		Each loop shall contain baselines from at least two independent sessions.
		Ambiguity Resolution Error Error in the determination of the number of full carrier wave cycles between receiver and satellite.		Longer session and low GDOP.
		Cycle Slip Discontinuity in carrier phase observations due to signal loss and can lead to integer ambiguity.		Software will repair if slip is short otherwise discard if observation slip is long.
		Station Coordinates and Transformation Errors Errors in coordinates of known control points used as base stations in relative positioning and datum transformation parameters.		Tie survey to more than two control points.

Table 2: GPS Positioning Error Sources and Mitigation.

5. CADASTRAL SURVEYING IN NIGERIA

5.1 Nigeria Land Mass

Nigeria as a parcel of land, Figure 7, has been conservatively and liberally estimated to have an area of 92,376,800ha and 94,185,000ha respectively thus giving the most probable value of 93,280,900ha. 19,952,600ha or 21% is covered by various water bodies and floodplains thus leaving 73,328,300ha for a population of about 140million.

With the threat of desert encroachment from the north and Atlantic Ocean surge from the south coupled severe floodings experienced here and there within, the available usable land will continue to decrease thus putting more pressure on land.

Figure 7: Map of Nigeria

5.2 Cadastral Survey Practice in Nigeria

Cadastral surveys in Nigeria are carried out by; “government surveyors” i.e. persons employed by government in its service as surveyors or persons registered by Surveyor Council of Nigeria (SURCON).

Survey and mapping are on the concurrent legislative list of the Nigerian constitution (Njepuome, 2011), this means that the three tiers of government have responsibilities for survey and mapping. While the federal and states (36 of them) have well established departments for survey, the same cannot be said of the local governments (774 of them).

5.2.1 Types of Cadastral Surveys

The following forms of cadastral surveys can be identified in Nigeria:

Boundary Survey – this could be fresh boundary demarcation or re-establishment of previously surveyed boundary beacons.

Sub-division Survey – in this case, a large parcel of land, previously surveyed or not, is divided into two or more smaller parcels.

Layout Survey - this is essentially a setting out survey in which a town planning design/layout plan is transferred to the ground. The town planning design is usually based on a perimeter survey plan of the area as made by the surveyor previously.

Claims (compensation) Survey – this is a survey carried out for the purpose of claims or compensation when there is an infringement such as; acquisition, oil spillage, encroachment, etc.

Boundary Dispute Survey - this is survey carried out when there is dispute between adjacent land owners regarding their boundary line. This survey is usually carried out by the order of a court of law during litigation.

Minesfield Survey – many types of surveys with some variations are collectively put under this form and are detailed in Dashe, 1987. Essentially they are surveys carried out to demarcate an area of land where mineral extraction will be carried out, also the survey plan will form part of the mining license application documents.

5.2.2 Cadastral Survey Methodologies and Instrumentations

The laws of Nigeria that define cadastral survey specifications very well conform with the methodologies, instrumentations and formats that were available at the time the laws were written. These laws were not reviewed in recent times to accommodate new developments.

The law stipulates that property beacon be placed at every corner (point of boundary change in direction) of the land parcel or at interval not more than 400m if the distance between two consecutive corners is more than 400m. The horizontal coordinates of the beacons are also to be obtained at third order survey specifications in which the maximum linear misclosure is 1/3000.

A good number of these surveys are carried out using modern methodologies and instrumentations that yield accuracies that far exceed the stipulated accuracy despite the cost, however majority of the surveys are carried out with recreational grade GPS devices that yield accuracies that cannot be verified. Numerous test carried out on such devices have reported that they cannot achieve the required accuracy.

6. CADASTRALULTRA

CadastralUltra is a GPS positioning system that is based on Static-Relative-Post Processing method which is the most accurate of all available methods. As a system, it is a hybrid of hardware, software, method and procedure.

The system package consists of two handheld receivers running GPS carrier phase data acquisition software, two external GPS antennae with cable, a GPS data post processing software capable of network adjustment, an antenna pole fitted with Bull-Eye bubble and receiver clamp, Figure 8.

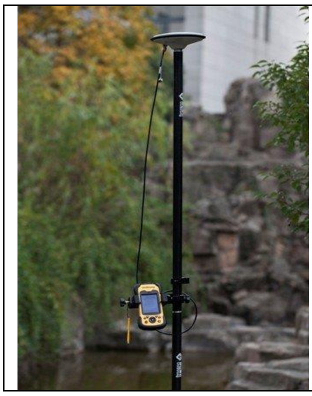
	**Specification** **System** • Microsoft Windows Mobile 6.5 • CPU: 600MHz **GPS** • Channel: 14, L1 C/A code • Hot-start: 1s • Cold-start: 29s • Real-time: < 3.5 m (CEP, -130 dBm) **Screen** • Screen: 3.5' QVGA TFT, sunlight - readable color touch screen • Keyboard: night visible	**Data Communication** • Storage: 128MB SDRAM£¬256M NAND flash • SD slot: Micro SD 32G • Port: Mini USB2.0 • Bluetooth: Bluetooth V2.0,EDR **Power** • Battery: 2800mAh Li-ion battery • Working time: 10h(typical) • External power: 3.3V~5V • Power consumption: 0.5W	**Environment** • Working temperature: -10`C -- +60`C • Storage temperature: -30`C -- +70`C • Shock: 1.5m drops to concrete • Waterproof/dustproof: IEC 529-IP66 **Extension** • Camera: 5 megapixel • Gravity sensor • Cellular modem **Physical** • Dimension: 179.5mm*91.2mm*31.5mm • Weight: 250g(Without battery)

Figure 8: CadastralUltra with Unistrong ODIN+ Specifications

6.1 Conceptualizing CadastralUltra

CadastralUltra was borne out of the results of a consumer grade GPS device survey as shown by Figure 9 and Table 3 below:

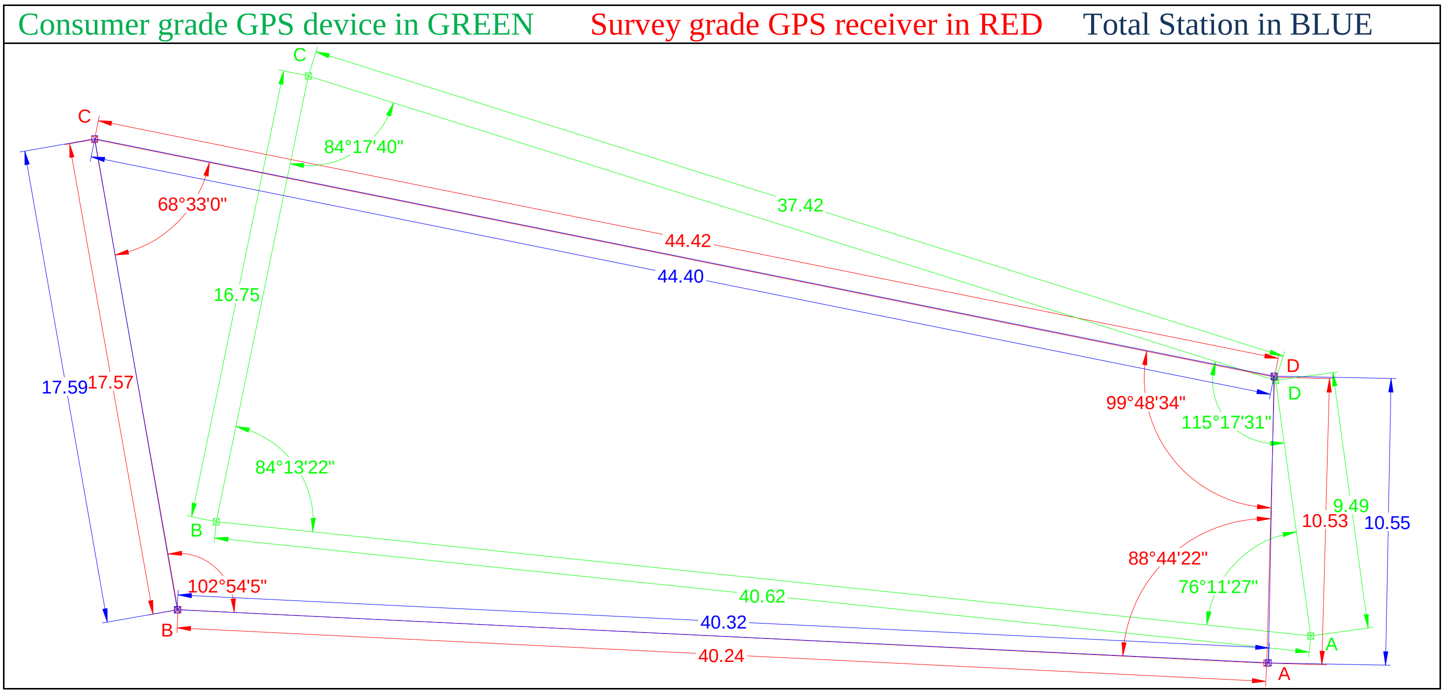


Figure 9: Plots of Survey Methods Results

SURVEY METHOD	DIMENSIONS OF THE LAND PARCEL(m)				PERIMETER (m)	AREA (m²)	Diff(m)	% Diff	Diff(m²)	% Diff
	AB	BC	CD	DA			PERIMETER (TAPE FIXED)		AREA (TOTAL STATION FIXED)	
Survey Grade GPS	40.24	17.57	44.42	10.53	112.76	574.991	-0.15	0.13	1.441	0.25

Consumer Grade GPS	40.62	16.75	37.42	9.49	104.28	498.930	8.33	7.40	77.502	13.45
Total Station	40.37	17.62	44.46	10.56	112.86	576.432	-0.25	0.22	0.000	0.00
Measuring Tape	40.22	17.56	44.30	10.53	112.61	NA	0.00	0.00	NA	NA

Table 3: Survey Methods Results Comparison

The usual practice is to use measuring tape to obtain the dimensions of the land parcel while the consumer grade GPS device is used to obtained the coordinates of the property beacons which are “adjusted” to conform to the dimensions as obtained with the measuring tape. During this particular survey, the issue of actual shape, location and orientation of the land parcel came up and it was decided to check these results by a survey grade GPS receiver and Total Station measurements.

Apart from the results, the usual survey procedure adopted in using this grade of GPS device has some inherent problems. For a proper understanding of these problems, it necessary to know the Nigerian survey parameter vis-a-vis GPS parameters applicable to Nigeria as tabulated below:

PARAMETER	**NIGERIA**			**GPS**		
Ellipsoid	Modified Clarke 1880 *Regional and not earth centerd*			WGS84 *Global and earth centered*		
Semi-major axis (a)	6378249.145			6378137.000		
Inverse of flattening (1/f)	293.465			298.257223563		
Projection	Modified National Transverse Mercator (NTM)			Universal Transverse Mercator (UTM)		
Zones	3 Belts			3 Zones		
	West	Mid	East	31N	32N	33N
Central Meridian(CM) Longitude of Origin	4^o 30’E	8^o 30’E	12^o 30’E	3^oE	9^oE	15^oE
Latitude of Origin	0^oN	0^oN	0^oN	0^oN	0^oN	0^oN
False Easting (FE)(m)	230738.266	670553.984	1110369.708	500000.000	500000.000	500000.000
False Northing (FN)(m)	0.000	0.000	0.000	0.000	0.000	0.000
Scale Factor (SF) at CM	0.99975	0.99975	0.99975	0.9996	0.9996	0.9996

Table 4 : Nigeria and GPS Survey Parameters

The procedure involves a pre survey "calibration" starting with inputting Δa, Δ1/f, CM, latitude of origin, FE, FN and SF into the GPS device firmware. The device is then used to obtain the coordinates of a point with known NTM coordinates. The means of 10 obtained coordinates are compared with the known coordinates and differences computed as ΔE and ΔN which are respectively used to adjust previously inputted FE and FN. The device is again checked on the known point and if the fix obtained is within 5m of the known, the device is deemed "calibrated" otherwise the FE and FN are "adjusted" until this is achieved. The device may be taken to another known point for "verification" and if obtained coordinates here are greater than 5m, the FE and FN are again "adjusted" to achieve this.

The problem with this "calibration" is that it is only valid for the moment of the calibration and may not be applicable the next moment also, the transformation from the GPS coordinates system to Nigeria system is partly ellipsoid and partly projection.

On this premise, CadastralUltra was conceptualized to fulfill four conditions namely; Price, Accuracy, Easy-of-use and Durability. It is also to improve the professional outlook of the cadastral surveyor by enabling the surveyor to use some of the advanced knowledge of mathematics that was part of the surveyor's training.

Standard survey grade GPS Systems are still expensive as they come with many capabilities and functionalities which a user may not require but have to pay for. For instance all such systems come with handheld controllers that are themselves GPS receivers of mapping/GIS grade. CadastralUltra consists of such controller, Unistrong ODIN+ which was modified to use external GPS antenna and to log carrier phase GPS L1data using Unistrong's Uni-POS and Mobile GIS field software. Unistrong also upgraded their GIS Office software to enable post processing of the GPS data logged by ODIN+. By these modifications and upgrading, a GPS positioning system was made that is both better than consumer grade GPS device to a surveyor both in terms of accuracy and professional outlook.

6.2 Application of CadastralUltra

CadastralUltra application involves using two GPS receivers to simultaneously track the same satellites to determine their relative coordinates.

One of the receivers is set on a point with precisely known coordinates in WGS84, this receiver remains stationary and continuously log GPS data throughout the duration of the survey. The other receiver, also known as the rover or remote receiver, is set on the property beacons in turn and GPS data is logged at each occupation for a period of time that depends on the factors listed in Table 2 above.

The logged data is downloaded into a PC running Unistrong GIS Office software post processing software back in the office. The software will carry out the baseline processing and adjust the network. Output will be the UTM coordinates of the beacon positions together with some statistical information regarding quality of the survey.

The transformation of the obtained UTM coordinates to Nigerian coordinates system is carried out by applying previously determined best fitting 2D conformal transformation parameters of; translations (t_E and t_N), rotation (θ) and scale (s), for the area of survey.

CadastralUltra receiver is fitted with a 5MP camera that enables pictures of the land parcel environment to be taken.

7. SUGGESIONS FOR IMPROVEMENTS IN CADASTRAL SURVEY PRACTICE

In support of proper land use planning and management, surveyors should only carry out survey of land parcels that are part of approved layout plans. In this case, all approved layout plans should be made accessible in digital format to the surveyors.

Since the world is in the Information Age now, the mandatory information and minimum size stipulated by law for the cadastral survey plan are no longer adequate as such the size of the plans should be increased to a minimum of 30cm X 45cm and information such as the approved layout plan should be inserted as key plan with the surveyed land parcel shown. Also, in support of land use monitoring, pictures of the four sides and center of the parcel at the time of survey should be included together with those of the beacons as shown by Figure 10 below:

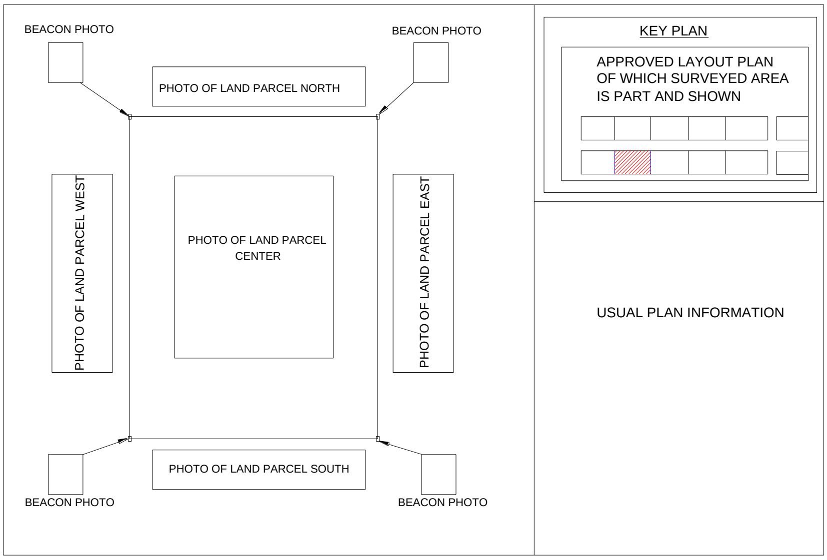


Figure 10: Proposed Survey Plan Format

The Nigerian GNSS Reference Network (NIGNET) can be augmented by having each state Surveyor General Office set up a GNSS Continuous Operating Reference Stations (CORS) and this can be extended to the Local Government Headquarters. Jatau et al (2010) stated that the NIGNET will be able to support RTK positioning in the future as the present phase cannot, but before this giant leap let us take a small step by making available GNSS data from the present network in RINEX format at a dedicated website to support simple static relative positioning GPS systems like CadastralUltra, this can be done at this phase and it does not cost a fortune.

Full-fledged survey departments, manned by qualified surveyors and survey technicians at the Local Governments of the federation, are long overdue. This is apparent from the fact that when the late President Musa Yar-adua initiated the recent land reform, it was found that there was dearth of surveyors and survey technicians hence the training of about 5000 para-survey personnel was proposed.

GPS positioning techniques are been used in cadastral surveying in Nigeria but there are no stipulated standards, hence it is hereby suggested that Nigerian Institution of Surveyors (NIS) together with the "Nigerian Surveyor Generals Forum" setup a committee that will define the standards for the use of such techniques since cadastral surveys in any country has legal connotation.

Since the world is becoming more and more digital and internet entrenched, cadastral surveys in Nigeria should follow suit, especially in the area of survey plans lodgement. Surveyors should be able to send their plans via internet and once such plans are received, acknowledgement of receipt can be done via SMS. eLODGEMENT should be implemented, it does not cost a fortune.

7.1 Future Improvements in CadastralUltra

The ultimate aim is to make CadastralUltra a standalone cadastral system from field data acquisition to final plan drawing.

The CadatralUltra software will have a module that enables the best 2D transformation parameters from WGS-84 UTM to Nigeria local grid system to be computed.

The CadastralUltra software will have a CAD module that will enable cadastral plans to be prepared by simply editing built-in templates.

The receiver been able to load layout plans in raster or CAD format and been able to navigate to the screen touched property beacon rather than the present mode of selecting from a list.

8. CONCLUSIONS

Cadastral survey is the commonest survey practice in Nigeria and it has direct link to poverty eradication process.

High cost of survey grade GPS positioning systems is responsible for the use of consumer grade version. CadatralUltra as a purpose-built GPS positioning system for cadastral surveys in Nigeria has been presented and it cost just 25% of the least alternative.

The continual use of the consumer grade GPS devices for cadastral surveys in Nigeria will lead to problems in future when obliterated property beacons have to be re-established.

Consumer grade GPS devices do not give correct dimensions, areas, shape and orientations of the surveyed land parcels. The percentage error in area can be up to ±13% of the most probable value, this margin of error cannot be sustained when land invariably becomes premium in Nigeria when land will be valued based on per meter square (m^2).

The use of CadtralUltra will enable cadastral surveyors in Nigeria to apply some of the high level knowledge of satellite geodesy and mathematics that were part of their training, also the professional outlook will be greatly improved.

The adoption of CadastralUltra will create employment opportunities for young graduate surveyors who are not yet registered but are computer savvies.

Nigerian Institution of Surveyors (NIS) together with the “Nigerian Surveyor Generals Forum” should act to modernize and improve cadastral survey practice in Nigeria as to create employment opportunities for the young surveyors.

Cadastral survey practice in Nigeria can be made to be professionally, intellectually and financially rewarding as any other aspect of the profession and in general any other profession.

REFERENCES

Bonnor, N. (2012) : "A Brief History of Global Navigation Satellite Systems.", THE JOURNAL OF NAVIGATION, The Royal Institute of Navigation, VOL. 65, NO. 1.

Dashe, J.D.J., (1987) : “Cadastral Surveying Practice (in Nigeria).” Kaduna Polytechnic, Kaduna,

Fourie, C. and O. Nino-Fluck (1999): "Cadastre and Land Information Systems for Decision-Makers in the Developing World.", Paper presented at the UN-FIG Conference on Land Tenure and Cadastral Infrastructures for Sustainable Development, Melbourne, Australia.

JATAU, B., FERNANDES, R., ADEBOMEHIN, A. and GONÇALVES, N.(2010) : "NIGNET – The new permanent GNSS network of Nigeria", FIG Congress 2010, Facing the Challenges – Building the Capacity, Sydney, Australia.

Njepuome, A.P.C. (2011) : "Cadastral Survey and Land Administration in Nigeria.", Workshop on New Developments in Cadastres, Nairobi, Kenya.

Ojigi, M. L. (2011): "Cadastral Layout Review and Re-Design of Jikpan Area of Minna Using High Resolution Imagery and Land Information System.", Journal of Environmental Management and Safety, Vol. 2, No. 1.

Standards & Data Coordination Work Group (2007) : "GPS Data Collection Guidelines", NYS GIS Coordination Program.

UNITED NATIONS, (2010) : "Current and Planned Global and Regional Navigation Satellite Systems and Satellite-based Augmentations Systems.", International Committee on Global Navigation Satellite Systems Provider's Forum, OFFICE FOR OUTER SPACE AFFAIRS, New York.

US DoD GPS Executive Committee (2008): "GLOBAL POSITIONING SYSTEM STANDARD POSITIONING SERVICE PERFORMANCE STANDARD." 4th Edition, 6000 Defense Pentagon, Washington, DC 2030-6000

USDA FS and USDI BLM (2001) : "Standards and Guidelines for Cadastral Surveys Using Global Positioning Methods.", Washington Office, Washington, D.C.

BIOGRAPHICAL NOTES

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