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The Design and Use of Dual Modules System for Domestic Animals Monitoring (DMS)

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ABSTRACT

This article highlight the result of needs assessment studies that evaluates a sustainability based technological approach on combating the crises between cow herders and agricultural farmers, by the use of a monitoring system which involves dual modules technology. Dual modules implies a design that comprises of an off shelf GPS (global positioning system) and GSM (global system for mobile communication) receiver modules. The low cost GPS and GSM modules were chosen for this design due to the inbuilt integrated antenna found in the modules and the output GPS positional data with an enabled standard serial National Marine Electronics Association (NMEA) protocol as well as a standard AT command use in GSM technology. At any moment a quarry in form of a code (@C1) is texted to the SIM number embedded in the SIM card slot of the GSM module, a corresponding response indicating the exact location of the cow in longitude and latitude is transmitted via SMS to the owner's mobile phone number which was initially programmed (configured) into the microcontroller firmware. The GSM module provided with SIM card uses the same communication protocol and processes of a regular day to day mobile phone technology. The system is configured to be attached on the neck of the animal for easy monitoring and tracking as far as 200m from its exact position at any given time. The article revealed that major herders and farmers issues will be minimize once the movement of domestic animals are monitored to avoid the destruction of lives, farmland and properties. This research provide insight into major community concerns and the Nigerian nation at large.

Keywords: domestic animals, destruction of life, dual modules, exact position, wondering about

NOMENCLATURE

$C = \frac{\Delta P}{\Delta T}$	*velocity*	ADJ	Adjusted terminals
P	Change in distance	R_1	the resistor between OUT and ADJ terminal (ohms)
ΔT	Change in Time	R_2	the resistance between the ADJ terminal and ground (0V).
T^r	Receiver time	Vref	Reference voltage
T^s	Satelite time	X^s, Y^s, Z^s, and T^s.	the time sent
X, Y, Z	component of satellite position	L1 and L2	L- band frequency in HZ

INTRODUCTION

In Nigeria, individuals, communities and keepers of flocks have experience rustling. Clashes between farmers and herdsmen has been reported to have claimed so many lives, annihilate farm lands, crops,

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displacement and killing of thousands of farmers annually. However due to the vicious cycles of these clashes that have defy all government effort and military solutions. We felt the best method in which to address these issues is to introduce creative technological and scientific approach which bothered on information technology. Hence the introduction of dual modules technology with supported software to monitor the movement and locations of this animals.

The monitoring or tracking system developed uses dual modules (global positioning system (GPS) and global system for mobile (GSM)) technology to acquire information about the movement of the animals in its habitat. The information obtained will be used for both security and scientific purposes. The primary data needed is the movement and location of the animal at any point in time. To achieve this goal a GPS system was deployed since it was fashioned to provide global coverage and capability to serve high dynamical platform and was proved proficient as it satisfy the need of the United State governmental institutions and organizations many decades ago. Despite its military origin, GPS is used daily for a great variety of civil, scientific and technological applications which includes animal tracking, monitoring and positioning among others.

GPS is a global navigation satellite system (GNSS) use to detect the latitude and longitude of a particular position and also provides location and time information in all weather conditions anywhere on or near the earth. The satellites transmit radio signals, which are captured by a GPS receiver and used to calculate its geographical position. Its uses minimum of four satellites to compute its coordinates X, Y and Z which gives an edge over other pieces of technology for the same purpose. GSM as applied to this design is used for data transmission. The data from GPS (longitude and latitude) is transmitted to a configured mobile phone number through the GSM link.

RELATED WORKS

Noorossana et al made an illustration that is founded on quality improvement of designs. Real-time tracking and management of domestic animals has been a field of interest for many researchers. Over time, a good number of tracking systems had so far been developed with a wide range of tracking facilities by many researchers and a lot of research works are still ongoing. To achieve more results in this area depends on improving quality characteristics design of the tracking devices (Noorossana & Alemzad, 2003). Recently anti–theft modules like network tracking system and traditional electronics alarm were developed along with client identification to monitor real time performance (Nagaraja et al., 2009). In the power sector an improvement was notice on the introduction of automated fraud electrical signal monitoring and recording device (Faithpraise et al., 2018). An animal tracking system based on passive UHF, RFID technology was introduced which working prototype involved 6 built–in–lab (Catarinucci, 2010). Satellite (ARGOS) and wireless sensor networks introduced (Ahmed et al., 2010; Karlsson et al., 2010). Several studies that utilize GPS, GSM and sensors for animal identification include (Bagree, 2008; Clark et al., 2006; Kim et al., 2010; Yoo & Melde, 2011). Monitoring of animal behavior and environmental interaction by the use of wireless sensor networks, GPS collars and satellite remote sensing (Bishop–Hurley et al., 2009). Ahmed et al. (2010) further utilizes the widely accessible Google MAP API functionalities where location and sensor data are sent over GSM network. GPS, wireless communication and sensor networks applied to identify animals in digital zoo (Joshi, 2008; Rodgers et al., 1996). Radio transmitter and small and versatile transmitters which permit the tracking of insignificant objects (Mach, 1965; Weiss, 2012). Attendance of feedlot cattle with radio frequency technology (Gibb et al., 1998). Real time tracking system produced accurate localizations of the tracked vehicle with low cost (El-Medany et al., 2010). The designation of an automobile anti-theft system using GSM and GPS module with high speed vibration sensor (Li, 2012). The use of Map-merging in multi-robot simulteneous localization and mapping process to track robots and armed robbery and accident occurrences (Fleisher et al., 2012; Hadian Jazi et al., 2019). The use of GSM to convey text messages and SMS (Akpolat, 2003; Le-Bodic, 2005). SMS can convey up to 160 bytes of information received or sent from a mobile phone to another including subscriber identification module (Athavan, 2014; Mattson, 2001). The based station system further comprised of the base transceiver and controller responsible for connecting the main station to the network and assigned transmission and reception.

GSM technology is primary utilized in communication and is effective in achieving 2 to 5 meters of meridian error in room level tracking within a building and 70 to 200 meters of the same error outside (Athavan, 2014; Chen, 2005). Calculation of an intersection using standard trilateration techniques to determine the position of MS measurement (Le-Tien & Phung-The, 2010). Measures the tracking effect of GPS (Brida, 2014). Used algorithm of haverside formula to compute the nearest/distance between the source server

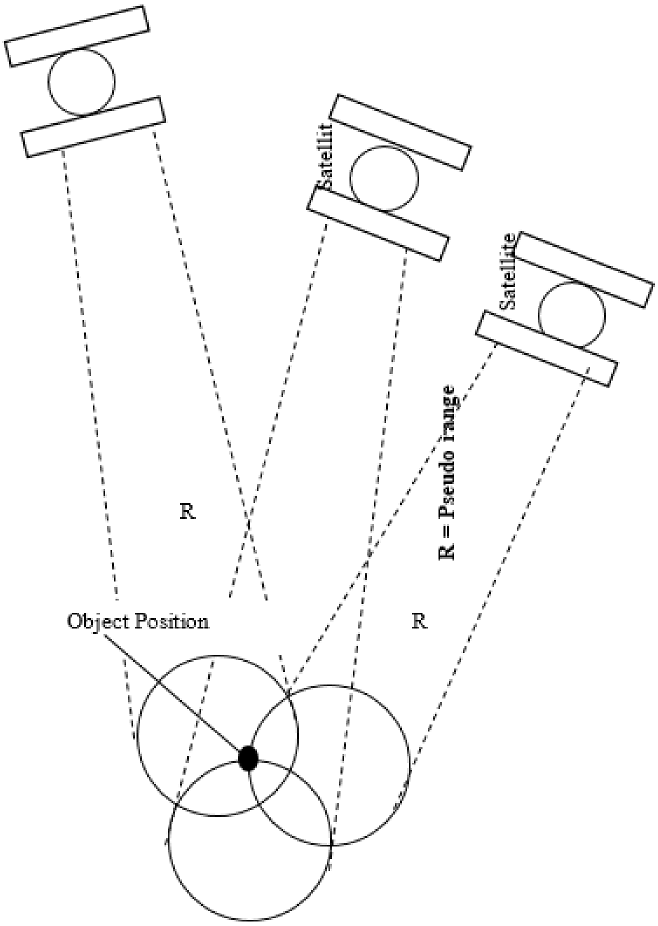

Figure 1. Concept of trilateration and triangulation

and the idle server to support cloud in more effective cost (Moen et al., 1996; Sinnott, 1984). Ahmed et al. (2010) however implemented vehicle tracking using the concept of trilateration and triangulation as shown in **Figure 1**.

The decision to attach a tracking device to an animal must be carefully done to limit the physiological nature of the animal to be tracked putting into consideration body weight guideline (Wilson & Mc-Mahon, 2006). Not overlooking signal strength as noise source/ obstacles also affects GPS signal strength (Effiong et al., 2019; Khalvati & Omidvar, 2019).

A significant difference was observed between the GPS signal strength with noise source/ obstacle (unstable GPS positioning) and GPS signal strength without noise source/ obstacle (stable GPS positioning) as shown in **Table 1**. Measurement of the respective distances and location of the handset through the process called trilateration (Drane & Rizos, 1998).

Table 1. GPS signal strength with/without noise source (obstacle)

Atomic clock (Cs,Rb) fundamental frequency	**10.23MHz**
L1 Carrier signal	154 x 10.23MHz
L1 Frequency	1575.42MHz
L1 Wavelength	19.0cm
L2 Carrier signal	120 x 10.23MHz
L2 Frequency	1227.60MHz
L2 Wavelength	24.4cm
P-code frequency (chipping rate)	10.23MHz (Mbps)
P-code wavelength	29.31m
P-code period	266 days,7day/ satellite
C/a-code frequency (chipping rate)	10.23MHz (Mbps)
C/a-code wavelength	293.1m
C/a-code period	1 millisecond
Data signal frequency	50bps
Data signal cycle length	30 second

Source: https://www.gpssignalstrength.com

Table 2. Structure of L1 Gps satellite signalsin bps

NO. OF SATELLITE	SIGNAL STRENGTH WITH NOISE SOURCE	SIGNAL STRENGTH WITHOUT NOISE SOURCE
1	40	55
2	35	48
3	38	56
4	34	54
5	30	55
6	20	38
7	45	79
8	38	58

MODEL DESCRIPTION

The device is made up of four subsystems (a microcontroller based, a GPS receiver unit, GSM module and power supply unit) integrated into a single whole as shown in **Figure 3**. The GPS receiver unit receives the location information from satellite upto 200m from the point of quary. The microcontroller processes this information and sends it to GSM module. The GSM module then transmit the location or positional information to the mobile phone number configured into the microcontroller.

GPS (Global Positioning System)

The GPS (Global Positioning System) uses GNSS (Global Navigation Satellite System) which is a network of about 24 satellites orbiting the earth at an altitude of 20,000km (Hoffman-Wellenhof et al., 2008). GPS signals starts in the satellite as a voltage which oscillates at the fundamental clock frequency of 10.23 MHz. The signal is then modulated using CDMA (code division multiple access) techniques by multiplying the fundamental frequency by the integers of 154 and 120 to create the L1 and L2 carrier signals.The signals are modulated using code division multiple access (CDMA) techniques. Thus, two carrier frequencies in the L-band are coherently derived from the fundamental 10.23MHz frequency generated by the on-board atomic oscillation; as outlined in **Table 2**.

L1: 154*10.23MHZ = 1575.42MHZ (=^= 19.0cm)

L2: 120*10.23MHZ = 1227.60MHZ (=^= 24.4cm)

CDMA techniques imply a set of pseudo-noise or code words. Each word is formed by a certain number of chips. These words serve the purposes of any spread spectrum technique; spread the signal along the frequency domain increasing its bandwidth, thus increasing resistance to natural interference and jamming, and to limit power flux density.

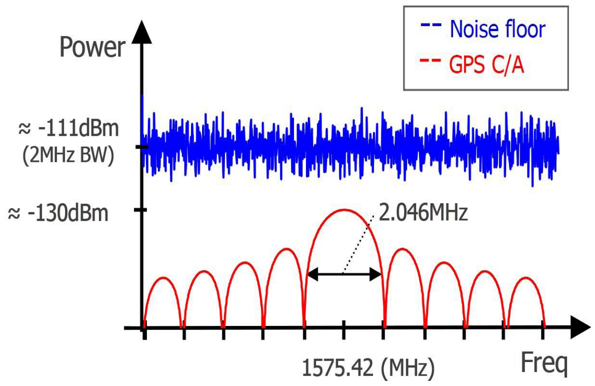

Figure 2. Signal over noise ratio spectra as seen from oscilloscope
Source: GPS Snapshot Technique (2011)

Computation of GPS Time and Position

At any time on the planet earth, at least three to four GPS satellites are always visible, such that each one transmits information about it position and the current time at regular intervals. These signals travelling at the speed of light are intercepted by the GPS receiver which calculate how far away each satellite is, based on how long it takes the messages to arrive through a process called trilateration or triangulation. Although it uses over-lapping spheres rather than circles. GPS positioning works on two basic mathematical concepts. The first is called trilateration as shown in **Figure 1**. This literally means positioning from three distances. The second concept is the relationship between distance travelled rate (speed) of travel and amount of time spent travelling, which is $Distance = Speed * Time$ The first concept, trilateration is the focus of this research. It centers around finding the object location on the planet. Hence trilateration method is used, by relating distance, speed and time. Where speed is how fast the radio signal travels, which is equal to the speed of light as 299,792,458 m/s.

Time is determined by how long it takes for a signal to travel from GPS satellite to GPS receiver on earth. With a known speed and time, we can solve for the distance between satellites and the receiver on earth. Once distances from three satellites are known, we can determined a three dimensional position on the earth's surface.

The receiver then synchronized its signal with the incoming satellite signals. Since the GPS signal was actually created in the satellite sometimes previously, the GPS receiver replica signal must be delayed in to match up the incoming signal with the replica signal. This time delay is actually what the receiver is fundamentally measuring. Clearly, this represents the time taken for the signal to pass from the satellite to the receiver. But it also includes any error in the satellite clock and any error in the receiver clock. The delay time is therefore related to the range of the satellite known as **pseudo- range**, as shown in **Figure 2**.

Therefore;

$$\Delta T = (T^r - T^s) \tag{1}$$

When a signal comes in from a satellite, the receiver computes the differences between satellite clock time and receiver clock time by auto correlation.

Where ΔT is time difference

The receiver uses messages received from satellites to determine the satellite position and time sent. The X, Y, Z component of satellite position and the time sent are designated as X^s, Y^s, Z^s, and T^s.

The distance can be calculated using the well-known formula to calculate the distance, which is velocity.

Assuming the message travel at the speed of light C, the distance travelled is

$$C = \frac{\Delta P}{\Delta T} \tag{2}$$

$$P = (T^r - T^s)C \tag{3}$$

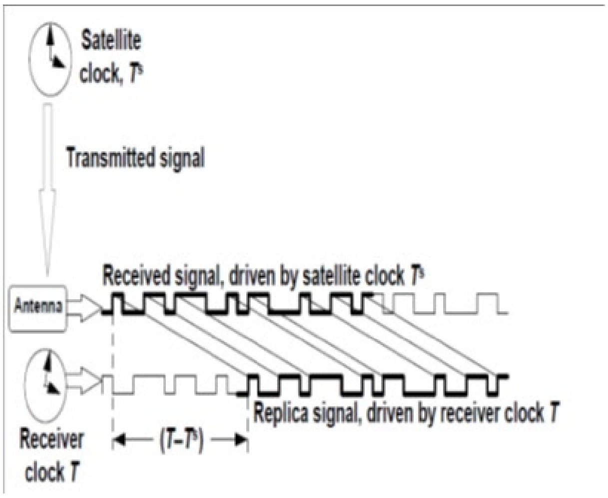

Figure 3. The relationship between GPS pseudo range, the satellite and receiver clocks
Source: Basics of the GPS technique (1997)

Where P (Pseudo range) is the range from receiver (at receive time) to the satellite (at transmition time). This model simplified by assuming the speed of light in the atmosphere to be C. This simplified model is useful to gain insight into the principles of GPS.

From Pythagoras theorem, we can write;

The navigation message allow us to compute the satellite position (X^s, Y^s, Z^s) and satellite clock bias T^s. Therefore the 4 unknown is the receiver position (X, Y, Z) and the receiver clock bias T^r (X, Y, Z, and T^r) . From the system of simplified observation equation from the satellite in view of the receiver.

Using (equation 4), the pseudo ranges to each satellite can be written as

$$P^s = \sqrt{(X^s - X)^2 + (Y^s - Y)^2 + (Z^s - Z)^2} \tag{4}$$

$$P^1 = \sqrt{[(X^{s_1} - X)^2 + (Y^{s_1} - Y)^2 + (Z^{s_1} - Z)^2]} + \Delta TC \tag{5}$$

$$P^2 = \sqrt{[(X^{s_2} - X)^2 + (Y^{s_2} - Y)^2 + (Z^{s_2} - Z)^2]} + \Delta TC \tag{6}$$

$$P^3 = \sqrt{[(X^{s_3} - X)^2 + (Y^{s_3} - Y)^2 + (Z^{s_3} - Z)^2]} + \Delta TC \tag{7}$$

$$P^4 = \sqrt{[(X^{s_4} - X)^2 + (Y^{s_4} - Y)^2 + (Z^{s_4} - Z)^2]} + \Delta TC \tag{8}$$

$$P^5 = \sqrt{[(X^{s_5} - X)^2 + (Y^{s_5} - Y)^2 + (Z^{s_5} - Z)^2]} + \Delta TC \tag{9}$$

Thus;

$$\Delta P = P_{observed} - P_{computed}$$

In matrix form

$$\Delta P = \frac{\partial p}{\partial x} \frac{\partial p}{\partial y} \frac{\partial p}{\partial z} \frac{\partial p}{\partial \Delta T} \begin{matrix} \Delta T \\ \Delta y \\ \Delta z \\ \Delta(\Delta T) \end{matrix}$$

Thus; for 3 satellites (P^1.....P^3) we have;

$$\begin{pmatrix} \Delta P^1 \\ \Delta P^2 \\ \Delta P^3 \end{pmatrix} \begin{matrix} \frac{\partial p_1}{\partial x} \frac{\partial p_1}{\partial y} \frac{\partial p_1}{\partial z} \frac{\partial p_1}{\partial \Delta T} \\ \frac{\partial p_2}{\partial x} \frac{\partial p_2}{\partial y} \frac{\partial p_2}{\partial z} \frac{\partial p_2}{\partial \Delta T} \\ \frac{\partial p_3}{\partial x} \frac{\partial p_3}{\partial y} \frac{\partial p_3}{\partial z} \frac{\partial p_3}{\partial \Delta T} \end{matrix} \begin{pmatrix} \Delta x \\ \Delta y \\ \Delta z \\ \Delta T \end{pmatrix}$$

METHODS/EXPERIMENTAL DESIGN

The model consists of the following subsystems;

- GPS receiver unit
- Microcontroller unit
- GSM module
- Power supply unit

The GPS receiver unit has an inbuilt antenna that received the signal from the satellite. The antenna detects the electromagnetic waves arriving from the satellites, converts the waves energy into an electric current, which amplifies the signal strength and hothouse the signals over to the receiver electronics.

The GPS signals on arrival at the antenna appears to be extremely weak, so that a spread spectrum technique is employed to transmits and detect the signal information. The advantage of the technique is that the signals are quite resistant against disturbances and can be detected within a noisy environment. It is through this process that small antenna can provide the necessary signal-to-noise ratio (SNR) for the GPS receiver.

A microcontroller is a small computer on a single integrated circuit with embedded design, interrupts and programs. When the system is on, the unit initialized the GPS receiver unit to acquire satellite almanac information with GGA (global geographical array), its then processes the information into NMEA (national marine electronics association) protocol. The SIM number of the user mobile phone was captured in the software program in order to receive the location value.

The NMEA protocol consists of set of messages. These messages are ASC11 (America Standard Code Information Interchange) character set in the form of ASC11 comma – delimited message strings. '$' sign is used at the starting of each message.

The NMEA standard explains how each message string is formed with a dollar sign ($) leading each new GPS message for example; $ GPGGA, 002153.000, 3342.6615N, 10751.3868W where $ GPGGA is the GGA (Global Geographic Array) protocol header, 00215.3000 is UTC time hh-mm-ss format.3342.6615 is the Latitude of GPS fixed data in ddmm.mmmm format, 10751.3868 is the Longitude of the GPS position fixed data in ddmm.mmmm format and 'N' stands for North and 'W' stands for west.

The locations (Latitude and Longitude) have the format of ddmm.mmmm that is degree minutes and decimal minutes. The microcontroller is serially connected to the GSM module with Myserial Lib software, to enhance serial data communication.

The GSM module is compatible with 850MHZ/900MHZ/1800MHZ/1900MHZ frequencies of cellular networks, which make it capable of working in any GSM network around the world. This GSM device consists of SIM (subscriber identification module) slot in which a SIM can be inserted which has a unique number, this unique number is used for contact. In this research, the device is used for transmitting and receiving data. The data from GPS is transmitted to a configured mobile number through the GSM module.

Power supply (Battery)

9 volts DC was used as a driving force to enable the operation of the device over a wide temperature range with a good energy density and a long shelf life.

Design Description

The complete circuitry of domestic animals monitoring system using dual modules is shown in **Figure 4.** It consists of an off the shelf GPS and GSM receiver modules, an ATmega328 AVR microcontroller. The ATmega328 microcontroller was chosen because of its performance – it has a 32-bit processor, the clock runs up to 40MHz and it has a large integrated Flash memory (128KB). But the best feature of this high performance chip is that, it is cheap and arrived in a standard 28-pin DIP package that can plug into an IC socket, and other active electronic components as shown in **Figure 4**. The different subsystems are integrated to make the hardware design. A 12 volts step- down transformer was incorporated to step- down the 220 volts AC to 9 volts. The 9 volts was rectified with a bridge rectifier which converts the AC to 9 volts ripple DC. A filtering capacitor of 2200μF was used to filter the ripple before connected to voltage regulator that regulated the voltage to 9 volts.

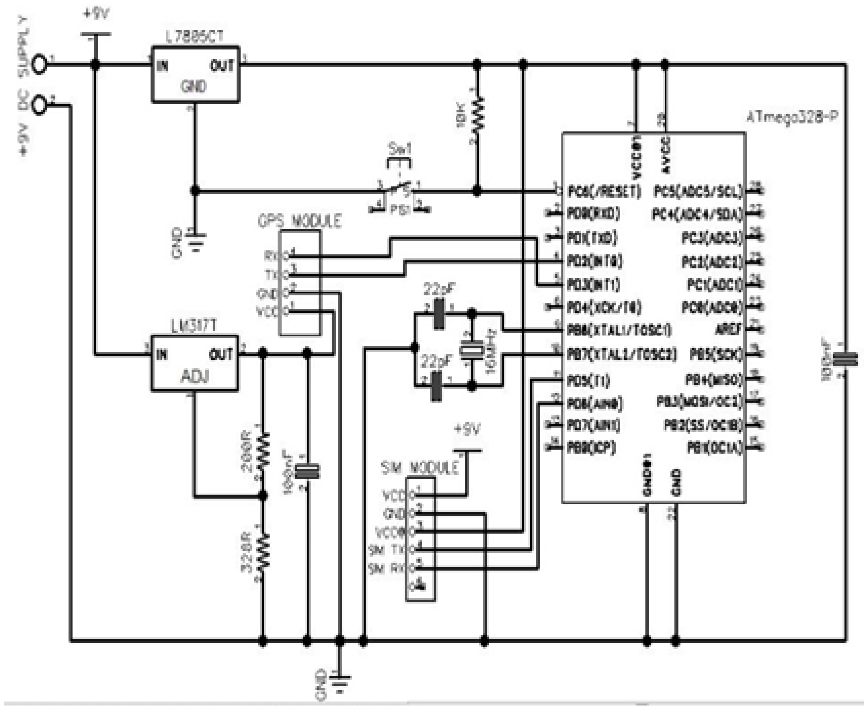

Figure 4. The domestic animal monitoring system

The power supply unit produces +9 volts and the earthen connected to the ground and Vcc (supply voltage) of the devices onboard. The microcontroller is the main control unit that controls the communications between other devices onboard.

The microcontroller accepts National Marine Electronic Association (NMEA) serial data stream and standard AT command from the GPS and GSM module, then processes this data to extract the needed and required information. From the information received, it works out the location of the animal and continuously updates the information before sending an SMS with the position and location of the animal. The microcontroller runs from its own internal clock oscillator which has its frequency set by a 16MHz crystal connected between pins 9 & 10. The two 22pF capacitors provide the correct loading for the crystal, to ensure reliable starting of the oscillator. Switch sw1 and the resistor connected to the reset line of the microcontroller provide a reset function to reset the system in the event of malfunction or software crash.

The NMEA, GPS serial data stream from the GPS receiver module arrives at pin 3 and 4 of the GPS module connector, while that of the GSM module arrives at pin 4 and 5. Because the signal has the same polarity as normal RS-232C data, the generated data are then fed into pin 4 and 5 (Port PD2/PD3), pin 11 and 12 (Port PD5/Port PD6) of the microcontroller for processing and extraction of the required data, as well as sending of an AT command by the GSM module. The circuit (**Figure 4**) and the accompanying program software was designed to allow it cope with both TTL and RS232 signals level with a data rate of 9600bps. Irrespective of whether the signal from the GPS and the GSM modules arrives using RS232 or TTL signal levels, the microcontroller expects the data to conform to NMEA protocol type 'RMC', and standard AT command which is the standard employed by the vast majority of GPS and GSM receivers.

Power for the tracking system is derived from DC supply voltage; a two fixed voltage is design into the system to protect the microcontroller, GPS and the GSM modules from spikes and excess supply voltage. Since The ATmega328 runs at 16 MHz, it allows it to have a supply voltage between 2.7 V and 5.5 V. The most common microcontroller runs at 5 V so the on-board fixed voltage regulator L7805, generates the required fixed +5V DC supply to the controller, GSM module and any other circuit components that requires 5V DC supply. The second Voltage Regulator type LM317 provide the needed 3.3V DC required by the GPS module. The output voltage level of this regulator is set by 200Ω and 328Ω resistors connected between the Output, Adjust and the Ground terminal of the regulator. Two 100nF capacitors in the DC rail provide filtering to ensure that the circuit is not affected by any unwanted voltage spike.

Figure 5. DAMS attached on the neck of a cow

Figure 6. GSM phone showing result in longitude and latitude

Voltage regulator is an LM317T 1.5A adjustable that provides a nominal reference voltage of 1.25V between its **OUT** and **ADJ** (adjust) terminals. The output voltage from the voltage regulator is set using equation 10:

$$V_{out} = V_{ref}\left(1 + \frac{R_2}{R_1}\right) \tag{10}$$

Dams System Development

The DAMS is attached to the neck of the animal (cow) as illustrated in **Figure 5**. The device is position so as to receive request location from the satellite in form of SMS and send forth the information in form of latitude and longitude to the user mobile phone. As illustrated in **Figures 6** through **7**.

When a quarry is sent (sending a code @C1) to the number at the GSM module, the system automatically transmit the reply to the configured mobile phone number indicating the position of the animal in terms of latitude and longitude.

The SMS sent would come through the GSM service provider and locate the wondering animal through the DAMS system via the embedded SIM card in the device. The GSM module will receive the SMS and send to the microcontroller. The microcontroller l receives this SMS, correlate the number and the command. If everything matches, it will then perform the request as required by the user, which is to send the location

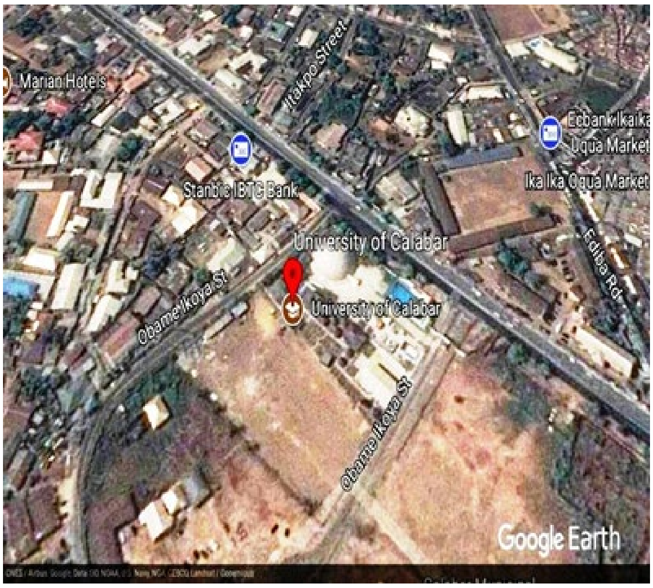

Figure 7. The exact location of the cow using Google earth

alert of the animal to the already registered number in the memory of the microcontroller. With the enabling web application (Google earth map) as illustrated in **Figure 7** the exact location can be identified on the map.

DISCUSSION OF RESULTS

The result of the output voltage was calculated using equation 10, where the voltage regulator provides a normal reference voltage of 1.25V between its OUT and ADJ terminal. The output voltage regulator was set by the value of R_1 and R_2 and the current set at 6.25mA. This is calculated by dividing the voltage between the OUT and ADJ terminal that is 1.25V by R_1. This current also flows through R_2. R_2 is set at 328Ω then voltage across this resistor will be 328*6.25mA which is 2.05Ω. This voltage was then added to the reference voltage (2.05V+1.25V) to derive the output voltage of 3.3V.

The Calculated GPS location was based on the system while actual GPS location was founded on the GPS location derived from google earth map by the use of the internet.

The system control was achieved using programs written in C programming language with Mikro C PRO Integrated Development Environment (IDE). Myserial Lib software and google earth map software. The source code was written with a view for future improvement, maintenance and expansion. The code was written in line with the three steps of microcontroller program development format (Compilation, Burning and Evaluation) before it was written to the microcontroller.

CONCLUSION

A successful domestic animal monitoring system via dual modules technology was successfully designed and developed as it was able to track the position and location of a particular animal (cow) at the University of Calabar farmland at a distance of >200m at a particular time. The results have proven to be sufficient in monitoring domestic animals (cow), so as to curtail the wondering and destruction of crops and farmland. This system will directly and indirectly help to prevent farmers / herders crises as the causative agent (Cow) is been monitored from future and unforeseen destruction. Compared to other tracking devices, the DAMS is proven to be economically cheap, affordable, easy to operate and user's friendly with considerable advantages over other tracking systems. This system will save animals from theft, communal clashes between communities and national embarrassment ensuing from herder /farmer clashes.

Recommendation

The system is recommend to be use in countries where there are no Ranching like Nigeria and other African countries where nomadic farming and cow rustling is common. It should also be used in countries where there is proper geographic information system (GIS) based mapping.

Further research should include Wi-Fi and cameras for real time animal feature identification.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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