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The Benefit and Importance of Mobile Satellite Signal in Northern Nigeria: GPS Approach

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Abstract: Lack of equipment to study mobile satellites signal propagation in colleges and universities prone this research work. A Handheld GPS receiver used as a tool for training college students to learn mobile satellite signal propagation using Global Positioning System (GPS) approach. These refer to the experimental setup of the equipment that is the connection done between the GPS receiver with a computer. The satellite propagation data received from the GPS machine can be recorded continuously with an updates rate of 2 seconds. The experiment was carried out in an open space environment at predetermine locations using simple setup, where a cheap, readily and available portable GPS receiver were connected to the computer to acquire propagation data. The computer was equipped with a self-developed package graphical user interface (GUI) monitoring the propagation information from the GPS satellites and saving the data. The developed system can be set up anywhere at any location. The sate-up will serve as a database for satellites view and analysis of mobile satellite data orbiting the sky of Northern part of Nigeria. Cost effective referring to a low-cost and readily available GPS receiver that can be easily set-up as compared to equipment designed specifically for an experimental purpose that is normally very expensive.

Keywords: SNR, GPS receiver, PRN, Kano, L-Band satellite

1. Introduction

Mobile Satellites (MS) in communication system has become a vital part in human daily life as these can be seen from the number of antennas or parabolic dishes that are fixed in many homes for the television broadcast services. Besides, satellite also play an essential part such as navigation and position allocation, terrain observation, weather monitoring, deep-space exploration, remote sensing and others as stated in [1], [2].

Communication satellites function as a microwave repeater station for the exchanging of information between the users in different forms [3], [4]. However, Global Positioning System (GPS) is best known as a worldwide positioning system and the main purpose is to provide accurate positioning location at all points on the earth's surface at all times. It

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is intended mainly for military defense purposes, but the civilian community now constitutes the bulk of users. The GPS signals consist of carrier frequencies such as; L1:1575420KHz (0.19029m wavelength) C/A-Code (Code acquisition) and L2: 1227600MHz (0.24421m wavelength) which normally controlled by the Military users with basic signal of higher precision [5], Table 1 gives the summary of the frequency bands [6], [7]. L1 and L2 are particularly utilize by the GPS signal and L1 is access by the civilian. The remaining frequencies L3, L4 and L5 are completely used by the American military.

Table 1 - 1-band frequencies range units

Frequency Band	Centre Frequency(KHz)	Applications
L1	1575420	Transmit C/A code, military P-codes, NAV message & new L1C on future Block III satellite
L2	1227600	P-code, NAV message & new L2C code on the Block IIR-M and newer satellite.
L3	1381050	Used for the signal detection of nuclear detonations and other high-energy infrared event.
L4	13799130	Used for the study of the ionospheric correction
L5	1176450	Proposed for use as a civilian safety-of-life (SoL) signal.

Handheld receivers are used for positioning and geo-catching using DGPS-service or WASS/EGNOS signals. This position is realized using code pseudo-range [8], [9]. By using Garmin handheld receiver, the phase and code information may be transformed in real time on a computer and stored in text file. Some experiment works have been carried out in some developed countries such as Europe, North America, Japan and Australia [10], but little data represents the less developed countries such as Latin America, Africa and some part of Asia. Therefore, experiment works are needed in those less develop countries.

The satellite propagation parameters received from the GPS satellite are recorded. The signal statues command to view the satellites currently tracked by the receiver and the sentences allocated are saved in a .txt' file format in series of NMEA sentences. see example of GPGSV.

"$GPGSV,3,1,12,02,40,083,49,04,15,114,47,05,18,024,45,09,36,173,50*78
$GPGSV,3,2,12,12,22,205,47,15,64,355,50,18,09,282,37,26,07,219,42*7F
$GPGSV,3,3,12,27,44,157,50,29,42,307,50,30,15,236,42,34,00,000,00*74"

GP refers to the prefix for the GPS receiver. GSV refer to the satellite in view. '3' refers to the number of sentences for full data. '1' means the sentence 1 of 2. '12' refers to the number of satellites in view. '02' is the satellite PRN number. The number of '40' and '083' respectively represents both the satellite elevation and azimuth angles. '49' refers to the SNR and *78 is the checksum data and always begin with *. Since the sentence contained four satellites propagation data, thus, the numbers will be repeated continuously for the other satellite in view [8], [11].

This paper focuses on the utilization of GPS receiver and developed software program that can be used as training kits for the tertiary institutions and Universities. Also, the designed graphical user face will serve as database for satellite propagation data.

2. Methodology

The approach for this research was divided into; Low-cost data acquisition system development that served as tools for training and empirical data analysis for open space signal performance in Kano, Nigeria. The study work process was summarized in Fig. 1 where the system set-up for monitoring and recording the propagation data from GPS satellites is shown. The acquisition hardware system set-up was completed, and the system was compared with the previous hardware acquisitions using handheld GPS receiver conducted at Fukuoka Japan and Stuttgart Germany [4], [12], [13]. The identification of reasonable system components was done to match the required components for the data system acquisition. The experiment set-up has done through the connection between the GPS receiver to a computer. However, the design of data acquisition system that will store the satellite signal propagation sentences for open space environment. The data includes the predetermined site in Kano Nigeria. The data was used for the analysis purposes. The low-cost data acquisition system is formed with the GPS receiver connected to the computer and the propagation data will be recorded continuously. The data acquisition system is monitored using the graphical software. Submit your manuscript electronically for review.

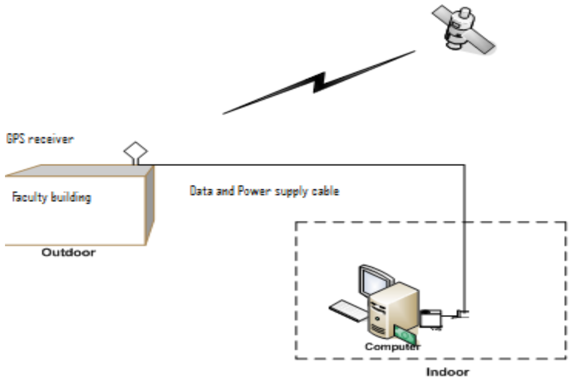

Fig. 1 - Sketch for the system setup

This research used direct current power supply that replaced the GPS receiver's batteries to ensure continuous operation of the receiver. The PC placed inside electronic workshop and was connected to the GPS receiver via CAT5 data cable.

CAT5 cables have an inherent different conductor that tends to degrade digital signals. The longer the length of cable, the greater the signal is degraded. Flat telephone type cable is not as good as CAT5, but better than twin-shielded audio cable. CAT5 cable has eight wires consisting of four twisted pairs. Only three wires will be used for the serial connection, one for transmits, second for receive and third is for ground. Another two wires have been used for the receiver DC supply. Fig. 2 shows cable four pairs. The cabling was connected in two ways; the first is the data communication cable between the GPS receiver and the computer system through serial connections. Then, it lay down from the rooftop to the communication laboratory. The second cabling will be that for the DC supply voltage to the receiver.

Fig. 2 - CAT5 cable four pairs

Fig. 3 demonstrated the block diagram of the AGUI that was designed and programmed, to works on all the types of Microsoft windows operating system. Hence, not as HT that is limited only to Windows 95/98/NT/ME/2000 and XP. The software developed using Visual Basic 2005 edition and it will be user friendly. This software will include the GPS satellite communication setting and environmental temperature monitoring part.

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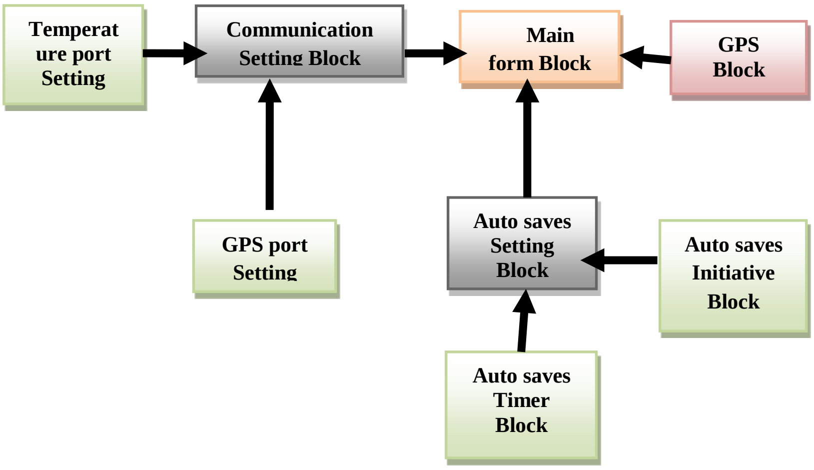

Fig. 3 - AGUI process flow chart

3. Results and Discussion

The finding of this research project comes with the analysis of the satellite SNR and the bar chart of all the PRNs machine that are visible in the sky of Kano.

Satellites time range for the data recorded between 17 to 18 May 2019 was chosen randomly, where all the visible satellite appearances were given in Table 2. Table 2 consists of four columns, where the first column has serial number, second column is the pseudorandom numbers for the visible satellites, and third column is the duration for each PRN. The fourth column contains the duration for the data measurement. PRN 2 has local time range of 23 hours 49 minutes 50 seconds to 10 hours 21 minutes 10 seconds. This means the satellite appeared for a period of 10 hours before it disappears.

Table 2 - Satellite appearance for all the visible Satellite 18th May 2019

No	PRN	Local time range	Duration
1	2	234950-102110	10Hrs 31min 20sec
2	3	14164-215944	7Hrs 42min 56sec
3	4	223352-083930	10Hrs 5min 38sec
4	5	012946-114552	10Hrs 16min 6sec
5	6	141656-211954	7Hrs 3min 0sec
6	7	194754-031218	7Hrs 24min 24sec
7	8	212116-061956	8Hrs 58min 50sec
8	9	024026-123414	9Hrs 53min 48sec
9	10	011424-08118	6Hrs 47min 27sec
10	11	174802-011422	7Hrs 26min 20sec
11	12	033840-141516	10Hrs 36min 36sec
12	13	183212-044254	10Hrs 10min 42sec
13	14	102442-191016	8Hrs 49min 4sec
14	15	044256-110944	6Hrs 26min 48sec
15	16	124128-223350	9Hrs 52min 20sec
16	17	205436-065954	10Hrs 5min 18sec
17	18	080120-160750	8Hrs 6min 30sec
18	19	160752-231450	7Hrs 6min 30sec
19	20	161156-023906	10Hrs 27min 10sec
20	21	083932-161154	7Hrs 32min 22sec
21	22	110946-174640	6Hrs 36min 52sec

22	23	17001-033720	10Hrs 37min 10sec
23	24	114554-194456	7Hrs 18min 26sec
24	26	051138-141610	9Hrs 4min 30sec
25	27	031336-120020	8Hrs 46min 42sec
26	28	220120-051136	7Hrs 10min 16sec
27	29	065956-164630	9Hrs 46min 34sec
28	30	061958-153236	9Hrs 12min 36sec
29	31	120022-205434	8Hrs 54min 12sec
30	32	153238-012746	9Hrs 55min 10sec

A bar chart was plotted in Fig. 4 for all the visible satellites appearance time. The tabulated results also show all the visible PRNs appeared more than five hours. This data can be used for analysis purposes since longer period of appearance will enable more data to be analyzed. From Table 2, PRN 3, 9, 12, 18, 29, 30 and 31 were selected for the empirical data analysis. The bar charts for PRNs 3, 9, 12, 18, 29, 30 and 31 was provided in Fig. 4.

There are 21 operational satellites with an additional 3 satellites as redundant backup. The satellites are positioned in six earth-centered orbital planes with each plane contains four satellites. The nominal orbital period of GPS satellite is 11 hours, 58 minutes, 4.1 seconds. This means that each GPS satellite orbits the earth twice each day. GPS satellites visibilities durations vary according to their position each respective orbit, so the visibility among the satellites will not be the same. Some satellites appear longer than others because of the architecture of GPS satellites constellation, where satellites orbits are in a separation of 60o with nominal inclination to the equatorial plane of 55^{o}.

However, earth is spherical in shape so satellite observations will not be the same at each location of the earth. This gave reasons why some GPS satellite appearance will be longer in some location of the earth, while others satellites will appear for short period. Among the advantage for a many PRNs to appear longer period is that many satellites can be observed, and this can have many data for experimental used from many satellites. Also, same satellite position can be studied, since after every 24 hours the satellite will return to its position with difference of 4 minutes from the actual position.

The reason for the bar chart is to select the PRNs that appear for more than 6 hours continuously. PRN 1, 4, 8 and 13 were not selected for propagation data analysis purpose because their appearance was less than 5 hours as indicated from the Bar chart of Fig. 4.

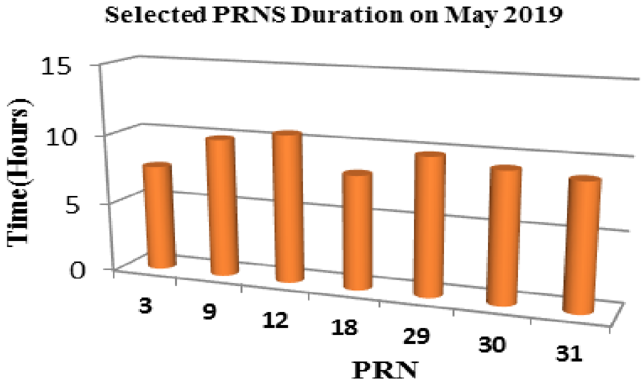

Fig. 4 - Bar chart of all the visible satellite on 18th May 2019

However, the analysis of the satellite SNR was carried out for the measured satellites of PRN 3, 4, 8 and 28. The comparison was made based on the measured range of the satellite. SNR for the signal arriving at elevation $\theta \geq 15^{o}$ should be ≥ 44 dBHz based on the study conducted in Japan [14], [15] If the SNR is less than 44 dBHz, then the received signal considered experiencing attenuation effect.

For the entire graph, the azimuth angle will be divided by a factor of 4 so that the axis of elevation and azimuth are well suited. Local Time (MTime) will be replaced by the numbering at x-axis to give a suitable range for the axis. The time axis is standardized to start at 0 s with the increment of every 2 s. This is to simplify the analysis process. The graph of 44dB Hz was plotted onto the other graphs for PRNs 4, 8 and 28 as a reference for the comparison of SNR from the other satellites (SNRref).

From Fig. 5 of PRN 3, the time axis starts at 0 s to 25000. This means that the data is collected for 6 hours 56 minutes 4 s. From 0 s to 24000 s, the SNR is above the reference 44 dBHz most of the time which is an indication of a good signal. Also serves as the references to other satellite signals collected in Kano. The signal come with a sequence of fluctuations due to the multipath effect as for open space, the signal will experience less than 5 dBHz drops from peak-to-peak as explained in [8]. From 24000 to 27000 s, the SNR starts to drop below 44 dBHz and dropped to 0 dBHz at 27000 s with the decrease in the elevation angle. This is due to the design of the receiver antenna as the gain is low at lower elevation angle [16]. For the purpose of analysis, only SNR of $\theta \geq 15^o$ will be considered because the signal drops significantly at lower θ angle due to the receiver antenna design [15]. The radiation pattern of the patch antenna used in this GPS receiver allows perfect signal reception from boresight with the response attenuated as elevation angle decrease. Satellite signals are received via the right-hand circularly polarized (RHCP) antenna [17]. Typical coverage is 160° with gain variations from about 2.5 dBHzic at zenith to near unity at an elevation angle of 15°. Below 15° of elevation, the gain is usually negative. The analysis of the selected PRNs shows the following Fig. 5, 6, 7 and 8 respectively.

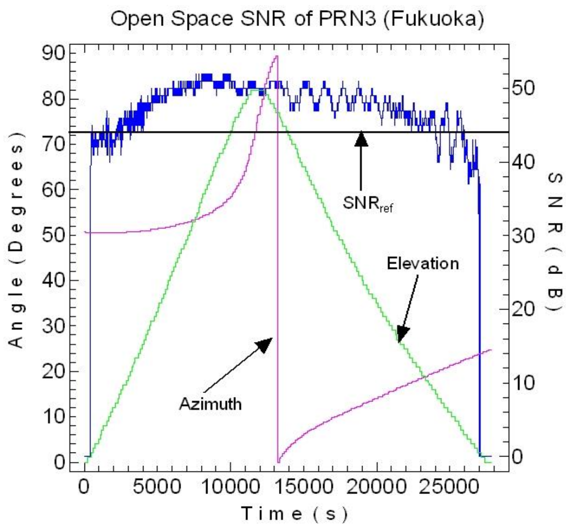

Fig. 5 - SNR of PRN 3

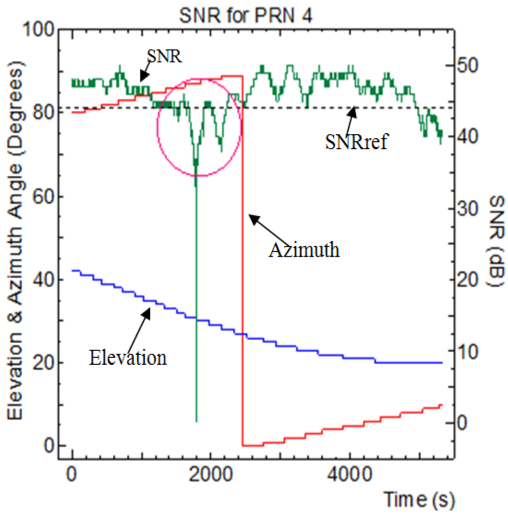

Fig. 6 - SNR for PRN 4

In Fig. 6, the NMEA data for SNR for PRN 4 is collected within roundly in 1 hour. The SNR is above the reference SNR, 44 dBHz most of the time. The fluctuation of the signal is due to the multipath effect encountered by the arriving signal in open space.

At 1800 s, the SNR dropped to 0 dBHz at elevation angle of 31° (as highlight in the red circle from the graph) due to the ionospheric effect. Also, in Fig. 7, the data is taken within 1 hour 40 minutes. The SNR is above the reference SNR, 44 dBHz from the elevation angle of 55° to 17° with azimuth angle from 55° to 40° showing some signal fluctuations. The signal fluctuations are caused by the multipath effect in open space. At 3650 s, the SNR dropped below to 0 dB Hz (highlight in circle) due to the ionospheric effect. At 4400 s the elevation angle starts to decrease from 15° to

9°, the SNR dropped to below 44 dB Hz and even dropped to 0 dB Hz at 5800 s (highlight in red circle). This is due to design of the receiver antenna as the gain is low at $\theta < 15°$. However, Fig. 8 shows the SNR for PRN 28 is at 0 dBHz at elevation angle of 7° and azimuth angle of 81° due to the design of the antenna. The SNR is then increased continuously from 100 s until 6000 s when the elevation angle increased. The SNR reached at 44 dBHz and above at 1500 s onwards with fluctuations. The fluctuations of the signal are due to the multipath effect encountered in open space. From 2300 s to 4600 s, the SNR is above 44 dBHz except for certain interval of time the signal dropped below 44 dBHz due to the ionospheric effect [7].

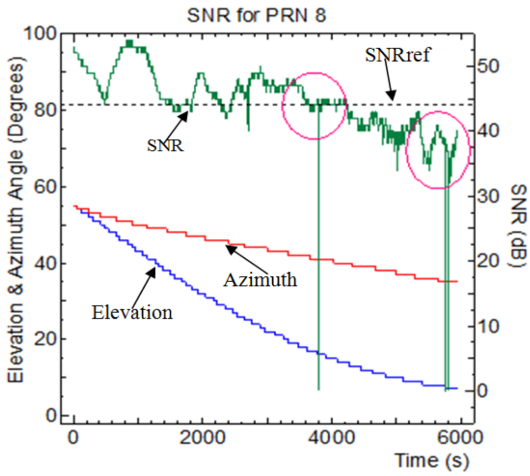

Fig. 7 - SNR for PRN 8

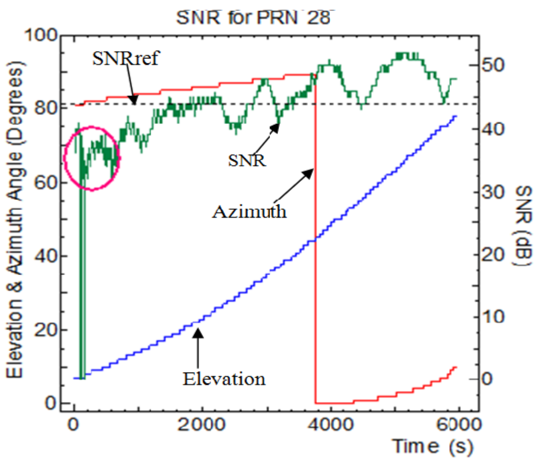

Fig. 8 - SNR for PRN 28

3.1 Cumulative Distribution Function (CDF) for the Selected PRNs

Without factors such as multipath or shadowing that could significantly affect the SNR, the CDFs of all the satellites should follow the similar fading characteristics. The Fig. 9 shows the CDFs of satellites that are visible in Kano for open space condition. Measurements have been carried out under similar set up and clear sky condition. Every satellite appeared and disappeared through the time of the day from the different elevation and direction (azimuth) and thus providing of measured data.

Fig. 9 also illustrates the CDF curves for all the visible satellites orbiting the sky of Kano. Almost all signals show a good agreement with each other indicates that the signal characteristic for open space measurement is similar and in the absent of significant fading effect. PRN 1, 2, 4, 5, 6, 8 to 32 at 10% probability, SNR difference of 3 - 8 dB HZ was obtained for Kano open space data. But SNR for PRN 4 was affected by fading as its CDF curve falls within – 30 dB HZ. Hence, all signals have shown similar result and no significant attenuation effect was present since all SNR value have always been within 5 dB range of fluctuation from peak to peak.

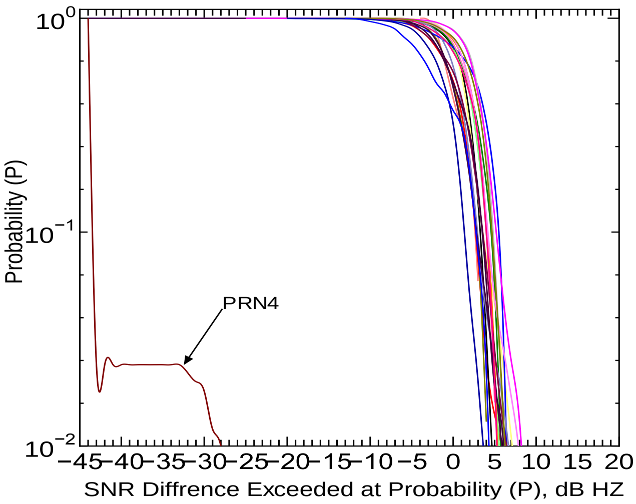

Fig. 9 - Show the CDF of the visible satellites in Kano

4. Conclusion

This study work has addressed one of the most essential requirements needed to learn the GSP satellite propagation sentences based on data acquisition system. The originality of these findings is the development of a new technology for GPS signal data mining using handheld receiver attached with built in antenna. The study also introduced the application of cumulative density function program for analyzing GPS signal parameters.

The developed system can be set up anywhere at any location. The sate-up will serve as a database for view and analysis of mobile satellite orbiting the sky of Northern part of Nigeria. The research contributes significantly by providing useful information to various stakeholders for efficient services to users towards mobile communication development in Kano, Nigeria and other less developed countries located in low latitude regions. It also contributes for encouraging more experimental works in less developed countries where propagation data for an open space environment can be used as a reference to determine the MS signal quality for the shadowing environment.

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