World Academics Journal of Engineering Sciences
Vol.9, Issue.2, pp.09-19, June (2022)

Research Paper

E-ISSN: 2348-635X

Design and Implementation of Antenna System for Live Video Streaming and News Gathering

Justin Akosuga Kpelai[1], **Celestine Mbakaan**[2*], **Seember Justin-Kpelai**[3]

[1]Department of Electrical/Electronic Engineering, Benue State Polytechnic, Ugbokolo
[2]Department of Science Laboratory Technology (Physics/Electronic section), Benue State Polytechnic, Ugbokolo.
[3]Department of Computer Science, Federal University Wukari

**Corresponding Author: celestinembakaan@gmail.com*

Available online at: www.isroset.org

Received: 23/Apr/2022, Accepted: 25/May/2022, Online: 30/Jun/2022

Abstract- This research aim to design a self-steering air to ground antenna- tracking system for live mobile video streaming and newsgathering. The design is such that it automatically track a signal transmitted constantly via a target through a source, such as a communication satellite or any transmitting device. The antenna was built by using a driven element, reflector and eleven directors. The antenna tracking system comprises of a unit composes of a microcontroller circuit board and pan-tilt mechanism. The tracking system also contain another unit, which is an array of three Yagi antennas each connected to a Wi-Fi adapter module. The tracking system adopts mechanical beam steering method and closed –loop antenna-tracking method for its operation. The antenna has a gain of 12.2 dB and beamwidth of 39.1°.The-tracking test validates that the designed antenna tracking system worked well. The Performance result at a speed of 0.9 m/s and 20 m distance between transmitter and receiver indicates that the tracking was more efficient with directional antenna compared with the omnidirectional antenna over the considered distance. Generally, the device proves to be very good enough for live mobile video streaming and newsgathering applications.

Keywords- Yagi antenna; live mobile video streaming; Newsgathering; Wireless transmission; Video delivery

I. INTRODUCTION

Today, Video delivery through wireless broadband networks is available in many forms and is anticipated to grow faster in the near future [1,2]. The demand for wireless infrastructure has tremendously increased in recent times triggering serious research efforts in the field [3]. To meet up with the demand requires checking the challenges of the existing system. The fundamental problem with the existing design in most systems is the range. If an omnidirectional transmitting antenna is used [4], the energy spreads into all directions resulting to high signal attenuation within a short range. The existing design of the tracking antenna has the tracking system mounted onto the remote station which takes the positional data of the unmanned aerial system and then measures the signal strength by applying the triangulation method the antenna tracks the unmanned aerial system [5,6]. This kind of system is not effective as tracking depends totally on the signal strength and if the aircraft is lost it is difficult to track it back. From the case above the unmanned aerial system radiates the signals in all directions using an omnidirectional antenna and the base station uses a tracking directional antenna. Thus, the signal strength would not be high since the sender is emitting data in all directions and even though the receiver is tracking the unmanned aerial system, the receiving signal strength is merely the same. In some existing models, even though the receiver is directional and the transmitter is omnidirectional the resultant signal strength is the same irrespective of the receiver direction, except distance. Therefore, the use of the tracking antenna at the receiver side is not efficient. In some models, the transmitter is continuously tracking the receiver and is directional; henceforth the signal strength will always be concentrated and strong irrespective of where the transmitter is located. The transmitter will constantly send signals towards the receiver. Therefore, the loss of signal strength is only due to distance, and as the beam is narrow the range is also very high [7,8].

In light of the investigation carried out on tracking antenna systems, most of the existing tracking systems are ground to air type, which is not effective as they have a directional antenna on the receiver side and an Omni-directional antenna on the transmitter side, and tracking is done based on signal strength. In addition, there is a very high signal-to-noise ratio and hence needs a high power and high gain antennas which makes the entire system costly and inefficient for small systems [9]. For a configuration where the sender has a tracking directional antenna and the receiver has an Omni directional antenna, the signal is sent to the sender directly with the least signal-to-noise ratio. This arrangement is more efficient and includes an on-board tracking system. The available commercial grounds to air tracking devices that are currently in the market are

RomTek Electronics, EZ tracker, and Orbit to the best of our knowledge.

Given these aforementioned issues, this research proposed an air to ground antenna-tracking system with a directional antenna (Yagi) mounted at the base station with a 2.4GHz video transmitter to continuously track a moving object at the remote station.

II. RELATED WORKS

Islam et al [10] emphasize on management of antenna systems and satellite tracking. The research work focused on solving antenna issues relating to location, direction, and size. The antenna management shows it has the capabilities to track communication satellites globally. Poochanya and Uthansakul [11] shows that the quality of signal and system performance based on Received signal strength indicator (RSSI) and other parameters at the receiving vehicle side is enhance by the application of both beam tracking mechanism for vehicle-to-vehicle (V2V) Dedicated Short Range Communication (DSRC) Technology and switched-beam antenna having optimum Half Power Beamwidth (HPBW). Miawarni et al [12] developed a tracking system for indoor TV antenna. The work reviewed that the process of decision making on the tracking antenna system in their design does not come from the results of electromagnetic analysis but rather resulted from Composite Video Baseband Signal (CVBS). The CVBS provides the reference information based on video clarity level conditions on TV screen. Nugroho and Dectaviansyah [13] developed antenna tracker, which can automatically track unmanned aerial vehicle (UAV). The RSSI was kept up with the use of high gain directional antenna with tracker as against its use without the tracker. Liu et al [14] carried out a study on artificial intelligence based mobile tracking. The study focused on ensuring that mobile stations and terminals have access to quality antenna signal without interference from other stations and terminals. Kelechi et al [6] extensively reviewed most of the modern UAV antenna tracking systems. Reddy et al [15] proves that the efficacy of integrated fuzzy logic PID controller on satellite antenna tracking system could be improved by the implementation of neural networks. Subba et el [16] designed a Yagi Turnstile array antenna and simulation was carried out to analyse the emitted radiation.

III. METHODOLOGY

A. Antenna Design

The antenna was built by using a driven element known as the dipole, a coupled reflector and eleven directors as shown in Figure 1 (a). The prototype of the antenna was designed with specifications shown in Table 1. The proposed antenna was made from a 6 mm multipurpose self-adhesive copper foil tape and foam board. The copper foil was first cut using scissors and trimmed down to the specific dimensions. The reflector, driven and director's elements were shaped from the copper foil and then placed on the mark foam board as shown in Figure 1(b).

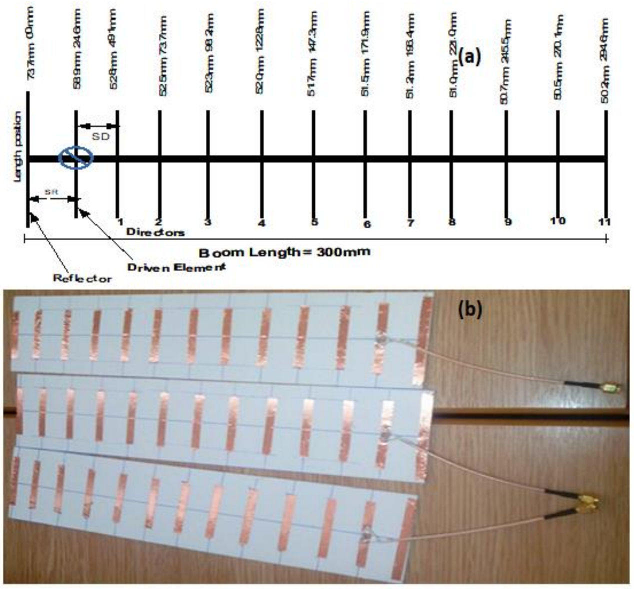


Figure 1(a). Proposed Yagi-Uda Antenna (b) A picture of the Yagi Antenna scale model

Table 1. Specifications of the Prototype Antenna

Frequency Range	2.4-2.5 GHz in S-band
Bandwidth	8.5%
Polarisation	Linear and Circular
Beam Steering: Elevation Azimuth	Mechanical 180^0 (Electrical) 360^0 (Mechanical)
Scan Angle	Elevation: 30^0 – 90^0 (by 10^0 step) Azimuth: 0^0 – 360^0 (by 10^0 step)
Configuration	13-Elements (Array of 3 Yagi Antennas)
Gain	12.2dBi (El = 45^0)
Beamwidth	39.1^0

B. Determination of Antenna System Design Parameters

The array antenna system will be using the beam steering method to track the signal sent by the moving object from the remote station. Before configuring the hardware of the system, the operating parameters need to be determined via some simulations or an online antenna calculator. The parameters that need to be determined are element spacing, scan angle, half-power beamwidth (HPBW), gain, number of elements, polarization, and ground plane size. Designing a system is deciding on what and how much to sacrifice, taking into account all aspects such as economic, material, and time constraints. The array antenna operates in the band from 2.4 to 2.5 GHz [17,18]. The lowest frequency, which is 2.4 GHz, was selected for the calculation of most parameters.

The design of a Yagi-Uda antenna is quite easy because they have been widely analyzed and experimentally tested. The procedure follows the outline below:

i. Check in the table of design parameters for Yagi-Uda antennas
ii. Build the Yagi (or model it numerically), and tweak it until the performance is acceptable.

Table 2 shows the parameters used for this design, computed using an Excel spreadsheet, and the element lengths with positions. The summary of the calculation of the parameters is as follows:

$$\lambda = \frac{c}{f} = \frac{(3*10^8)}{(2.44*10^9)} = 0.122764947 \approx 0.123m = 123mm.$$

L = DS (director spacing) = 0.2λ ≈24.6 mm
S = SD (driver to director) = 0.2λ ≈ 24.6 mm
S_1= SR (Reflector to driver) = 0.2λ ≈ 24.6 mm
R = Reflector length = 0.6λ ≈ 73.8mm
F = Driver length = 0.48λ ≈ 59.04 mm
The antenna length = 2.4λ ≈ 300 mm

Table 2: Main Parameters of the Proposed Yagi WiFi Antenna

Element	Length Ratio (m)	Length (mm)	Separation (mm)	Position (mm)
R (Reflector)		73.7	-	
F (Driven Element)	0.9950	58.9	24.6	24.6
1 (Director)	0.4300	52.8	24.6	49.1
2 (Director)	0.4279	52.5	24.6	73.7
3 (Director)	0.4257	52.3	24.6	98.2
4 (Director)	0.4236	52.0	24.6	122.8
5 (Director)	0.4215	51.7	24.6	147.3
6 (Director)	0.4194	51.5	24.6	171.9
7 (Director)	0.4173	51.2	24.6	196.4
8 (Director)	0.4152	51.0	24.6	221.0
9 (Director)	0.4131	50.7	24.6	245.5
10 (Director)	0.4110	50.5	24.6	270.1
11 (Director)	0.4090	50.2	24.6	294.6

For the connection, the coax cable was soldered directly to the dipole, connecting the ground to one dipole element and the center wire to the other as shown in Fig. 2.

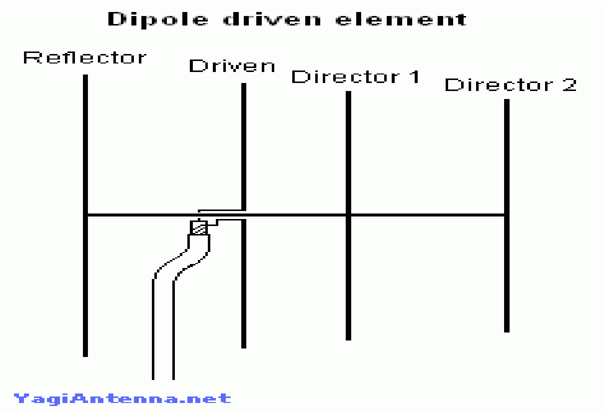


Fig. 2: Yagi antenna Connected as a Dipole

B. The Antenna Tracking System Design

The tracking system comprises of two main units: the first unit composes of a microcontroller circuit board and pan-tilt mechanism (Figure 3). The second unit is an array of three Yagi antennas each connected to a Wi-Fi adapter module as shown in Figure 3. The design is in such a way that the microcontroller is connected to the computer system's battery but when the computer is turned off the system will go to the power switch on/off. The microcontroller is connected to the computer serially since the microcontroller expects command from its serial port. The PC commands the microcontroller to read the motion information of an object placed at the remote station and made its decision on where to turn the servo motor. The second unit is the monitoring unit, which consists of a Wi-Fi adapter module and three Yagi antennas connected to a PC via USB port. It is important to know that the data, which is received from the motion of an object placed at the remote station, should be displayed on the screen of the PC. Table 3. displays the list and cost of materials used for the tracking antenna design.

Table 3: List of Materials used for the tracking Antenna Design

S/N	Make & Model	Type	Quantity	Unit Cost
1	ATmega328	Arduino Uno	1	£25
2	IEEE 802.11n	∑DiMAX	3	£75
3	6mm Self Adhesive Copper foil tape	Multipurpose	2	£3.70
4	USB HUB	Four ports	1	£1
5	3mm A4 Board	Foam Board	2	£4.86
6	15cm 6" cable connector	RP.SMA Male Jack	3	£7.07
7	MG995 Servo mount for Arduino	2 DOF Pan and Tilt	1	£14.25
	Total			**£130.88**

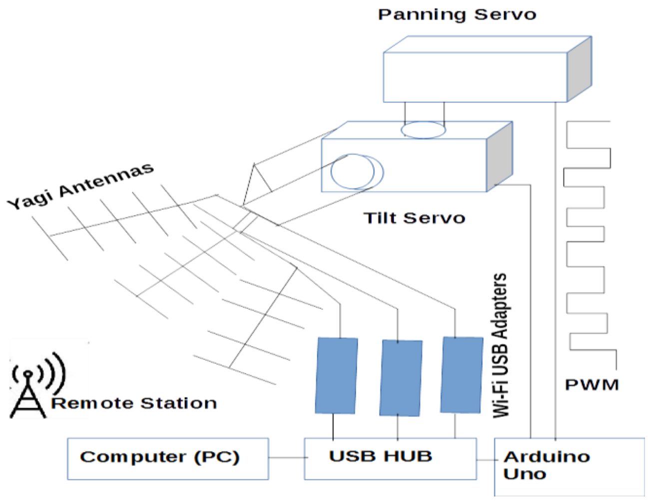


Figure 3. Architecture and modes of communication in the tracking antenna system

C Description of some Hardware Components

Pan and Tilt Mechanism

This is the main mechanism that holds the directional antennas and always points them towards the remote station. It contains two torque half-rotational servomotors, which are connected to the microcontroller. The pan mechanism has 360 degrees of freedom technically, but the motor allows only 180 degrees, the other half is achieved using the motor used for tilt. When the pan motor reaches 180 degrees and cannot go beyond the tilt motor applies a complement on its current angle such that it points in the reverse direction hence covering a 360 degrees pan. Figure 4 shows two half-rotational servomotors for which a pan of 360 degrees can be obtained. The servomotors are lighter and faster than stepper motors [5,19] and these servos require higher current.

Figure 4. Pan and tilt mechanism using servomotors [20]

Microcontroller ATmega 328 (Arduino Uno)

The microcontroller is the “brain” of the entire system that behave exactly as central processors [21] and provides the commands needed to control the pan and tilt mechanism responsible for the steering of the array of Yagi antennas. The use of a microcontroller was not either determined at the start of the research, but as the research progresses, there was the need for a microcontroller to be used. This appeared to be a quite big task, as there were many different manufacturers with many chips. There exist different kinds of microcontroller in the market [22], however, the microcontroller used is an ATmega328, which comes with a development/programming board named “Arduino” as shown in Figure 5. This microcontroller was chosen because of its low price, simple programming language, and ease of reprogramming. Table 4 shows the features of the microcontroller.

Figure 5. Arduino Uno microcontroller board [23]

Table 4. Features of microcontroller ATmega328

Characteristics	**Value**
Voltage	5V
Input voltage (recommended)	7-12V
Input voltage (limits)	6-20V
Digital I/O pins	14 (of which 6 provide PWM output)
Analog input pins	6
DC current per I/O pin	40mA
DC current for 3.3V pin	50mA
Flash Memory	32 KB (ATmega328) of which 0.5KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Source: [23]

Wireless High Gain USB Adapter ($\sum \boldsymbol{DiMAX}$)

This wireless adapter (Figure 6) conforms to IEEE 802.11g standards with a connection speed of up to 300 Mbps, connects the desktop computer to the wireless network easily. It can be connected to any public wireless hotspot for the internet to retrieve e-mail, surf the web sites or use instant messaging. The merit of using this adapter is it supports 64/128-bit WEP data encryption that protects the wireless network from eavesdropping. In addition, this adapter supports specific ways to improve the data transfer rate at a time; compress the data, and lessen the waiting time to send the next data to the Routers or APS [24]. This feature is referred to as Turbo Mode. Additional features of this adapter include the followings:

i. Works with both IEEE 802.11b and IEEE.11g products
ii. High-speed transfer data rate up to 300 Mbs
iii. High throughput supports multi-media data bandwidth requirement
iv. Supports 64/128-bit WEP, WPA (TKIP with IEEE 802.1x), and AES functions for a high level of security
v. Detachable antenna with long length cable provides convenience to locate the antenna
vi. Automatic fallback increases data security and reliability
vii. Supports 32-bit PCI interface

Figure 6. Wi-Fi Antenna Adaptor

D. Software Design and Implementation

The software was designed using Arduino Integrated Development Kid Environment, which allows writing, compiling, and uploading code to the board. The sketch or program is written in a C compiler or C programming language and IDE, which comes with the microcontroller itself [23]. The compiler is free to use but limits the memory usage to 2 Kb, still, it works fine because the written program in this application is relatively small. The entire system comprises hardware and software and the software major function is to read data sent from PC to an Arduino, compare these and set the pulse length of the

PWM so that the servomotor will steer the antenna towards the target. This process is known as 'serial communication', which means you can send one instruction at a time (Figure 7).

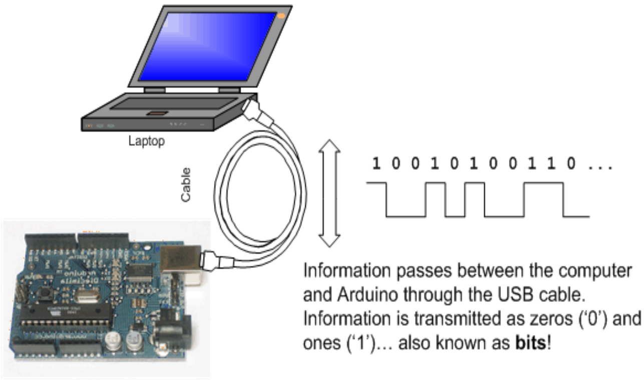


Figure 7. Illustration of serial communication

As can be seen in Figure 7, a serial connection can be activated between the Arduino board and the PC. On the Arduino, one can implement a sketch that will take care of "to listen" for any value (angle) sent from the PC. From the PC side, instead, one can activate a serial session in a Python shell (but it can be replaced by any program in Python) that will read the contents of the file (CSV or TXT) by sending appropriate signals via serial to the Arduino. A Researcher chose the servomotor as an actuator also because it can be connected directly to the Arduino without the use of appropriate control boards. Refer to Figure 8 for the process.

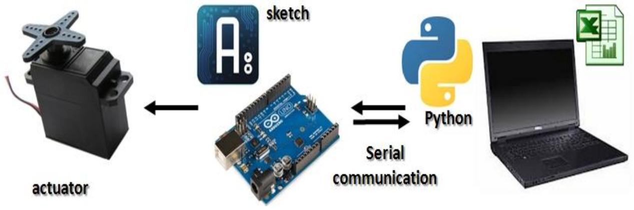


Figure 8. Illustration of how data is sent from PC to Arduino by serial communication

E. Antenna Tracking Algorithms

The basic tracking method used in this research is the so-called beam-lobing tracking [9,25,26,27]. The beam-lobing tracking operation begins when the antenna is commanded to make an initial turn in any direction, after which is acquired by comparing two received signal powers with two symmetrically-shaped antenna beams before the turn. If the signal strength of one were stronger than the other, the antenna would turn in the direction of a stronger signal. In another way, if the signal strength has decreased, the turn of the antenna is reversed. This is possible because it uses only the feedback information of the electric field intensity; it has the advantages of an economic hardware configuration and relatively simple control software.

In practice, the beam-lobing tracking operation should be performed uniformly toward the possible space where the target object may exist after adequately determining the order of the traversal and longitudinal turnings. Figure 9 presents a flowchart of the tracking algorithm.

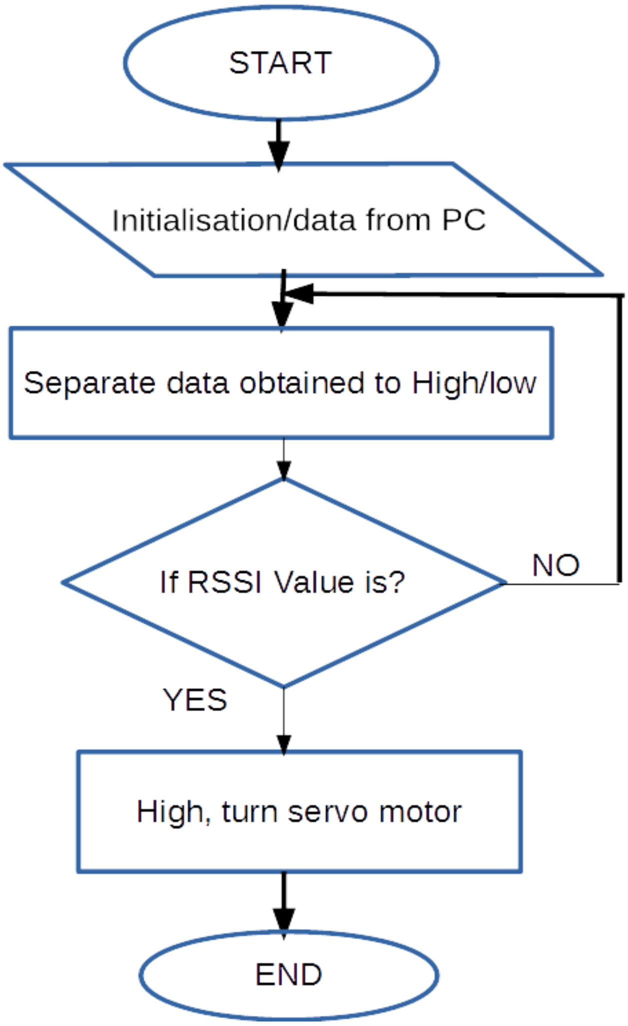


Figure 9. Tracking Algorithm Program Flow Chart

F. Functional and Performance Test Coverage Environment Description

The experiments were conducted in a free space parking area of about 100m × 60m at the University of Wolverhampton City Campus. This site is a large central atrium surrounded by office buildings for the accommodation of over 2000 employees. The location of the server is unknown to the Researchers until the designed antenna was tested, about 200 networks were discovered. One access point, which stuck out, was named **"HUGGNET".** The direction in which a Researcher discovered this access point was appropriate, and the corresponding signal strength was about 22 dB smaller than the signal strength of the strongest access points. This access point according to Google Earth is located at a distance from the University of Wolverhampton (MI 157) about a 1km airline. Figure 10 shows the map where measurement was taken.

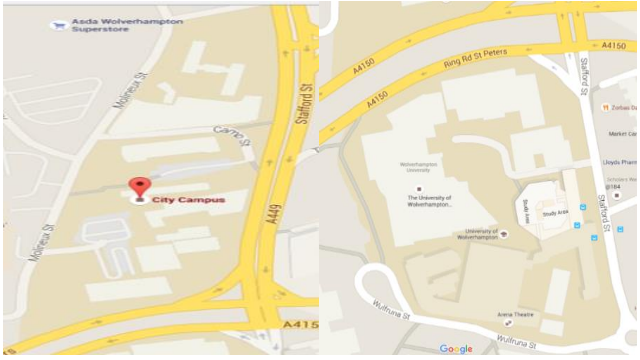


Figure 10. Map showing where measurement was taken

.

IV. RESULTS AND DISCUSSION

A. Discussion on Antenna Design Specifications/Considerations

From the antenna design, it was made from a 6 mm multipurpose self-adhesive copper foil tape and foam board. The design employed copper foil because of two reasons: eliminating electrical hum and noise, and replacement of tracks on electrical and printed circuit boards (can solder). The copper foil was first cut using scissors and trimmed down to the specific dimensions. The reflector, driven and director's elements were shaped from the copper foil and then placed on the mark foam board. The proposed Yagi antenna was built this way for two reasons: the copper foil and the foam board paper were cheap and easy to work with. The drawback of cutting out the Yagi antenna from copper foil was that the design became final upon cutting and no further adjustments were possible.

The proposed antenna comprises a dipole as a driven element, a parasitically coupled reflector, and eleven directors as shown in Figure 1 above. The reflector element is placed on the opposite side of the dipole. In comparison with the dipole, it has a lesser resonant frequency and longer length. The function of the reflector is to create a wave, which blocks the backward wave (radiations) from the dipole by destructive interference [28]. This leads to a radiation pattern with very low power transmitted in the reverse direction. For the driven element, it could be either a simple dipole or a folded dipole. For this research, a simple dipole is used, which is the medium by which the driven element is energized. It comprises two aligned conductors of length approximately $\frac{\lambda}{4}$ (i.e. a dipole). These two conductors were connected to the shield of the coax cable (copper) and the signal respectively as shown in Figure 2 above.

In order to realize good resonance, the length of the dipole element must be one-half of the wavelength. It is thus, determined by the frequency the antenna should work on. For this research, a frequency of $f = 2.44GHz$ is used which give rise to a wavelength of $\lambda = \frac{c}{f} = 122.7\ mm$. As a result, the length of the dipole element was computed to be 61.35 mm. In the experimentally found designs, this length is usually rather lower [25,29]. The reason is that matching was not done to ascertain the size of cable to be used, which is a very important point. A bad matching result gives rise to a high reflection coefficient and thus poor performance because a big fraction of the power is reflected into the WiFi, instead of being transmitted into the air. The directors are used to make the antenna directional. They are energized by the field of the driven element and create fields of their own, which are phase-shifted to the dipole. The phase shift is gotten by the element's length and position on the boom. The far-field of the antenna is a mirror of all elements' assistance. Looking in the direction of the boom, there is a constructive interference of the diverse fields, while in the direction perpendicular to the boom, the interference is destructive. This destructive interference is not ideal and there will always be some slight side lobes, but a good directionality is achieved.

The spacing of the director elements has great effects on the bandwidth of the antenna [30]. For equally spaced elements of the same length, the gain might improve, but only at a very small frequency band. Changing both, the lengths and the spacing makes the bandwidth bigger and the antenna more usable [31]. Good results are achieved by constantly increasing the spacing by a constant factor and reducing the lengths by another factor.

The common guidelines for describing the size and shape of a Yagi antenna include obtaining the reflector length, driver (feeder) length, director's lengths, and reflector to driver spacing, driver to first director spacing, and spacing between the directors [32–36]. The directional gain of a Yagi antenna is usually 7-9 dB per wavelength (λ) of overall antenna length [32]. The addition of more reflectors yields no small or any gain. However, the addition of directors improves considerably the general directive gain of the antenna. As a rule, the reflector length is a bit higher than λ/2, the driver and director lengths are a bit less than λ/2, director lengths are usually between 0.4-0.45λ [25,29]. The spacing between the reflector and the driver is about λ/4 while the spacing between directors can be between 0.2 to 0.4λ. Adequate care must be taken when the director spacing is greater than 0.3λ as the overall gain of the antenna would decrease by 5-7dB.

Yagi calculator was used to determine the gain of the antenna and the results shows a gain of 12.2 dB and a Beamwidth of 39.1^0. From the calculation, the wavelength is 0.123 m. One of the biggest concerns is the occurrence of grating lobes. Grating lobes that appear in the visible region might limit the performance of the antenna system. Grating lobes can be avoided if the element spacing satisfies $d < \frac{\lambda}{1+\sin\theta_{\max}}$, $\theta_{\max}$ stands for the maximum beam scan angle with regards to the axis of the array [37,38]. To determine the functionality of the built Yagi antenna, the SMA plug was connected to the wireless Hi-Gain USB adapter through the computer system and the antenna was able to detect the various networks found within the university of Wolverhampton city campus. Figure 11 shows the screenshot of available networks and APs.

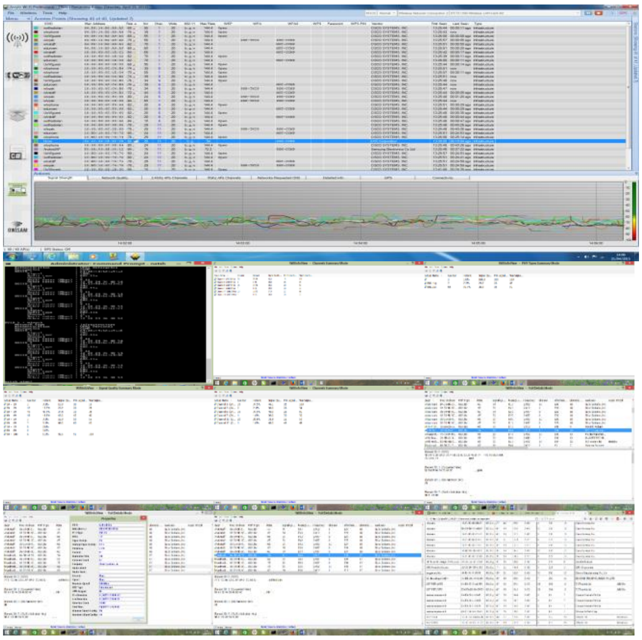


Figure 11. The screenshot of Acrylic Software showing various networks and Aps

B. Beam Steering and Tracking Methods

Because this research aimed to develop an antenna tracking system for live video streaming and newsgathering application, therefore it is required that the whole system including the antenna should be reduced and the beam switching should be fast. There are two kinds of beam steering methods to track the moving object at the remote station. The mechanical method that makes use of motors [39] and the electronic method which utilize phase shifters and a feeding circuit controller to electrically deflect the beam [40,41]. In the mechanical type making use of motors, the whole system is generally large, and fast tracking is difficult from the switching speed point of view. On the contrary, as for the electronic method, a miniaturization of the feeding control circuit can be considerably designed due to the small size of the electronic components and their technical advantages. The drawback of this type of antenna is the use of phase shifters for beamforming, which makes it quite expensive owing to its large quantity requirement. In addition, to avoid beam squinting, the phase shifter needs to be properly designed in which the beam direction may considerably differ at receive and transmit frequencies.

Because of the above reasons, this research used the mechanical steering method because of the cost implication and the required three directional Yagi antennas mounted on a pan-tilt servo device. Furthermore, the mechanically rotated tracking antenna system is proficient in being rotated 360^0 in azimuth and 180^0 in elevation to provide hemispherical coverage below and around the base station. In addition, a simple method for beam scanning by ON and OFF each feeding element of each antenna element is used in this research. By use of such a method, no stepper motors or phase shifters are required; hence, antenna system miniaturization, low cost, and high-speed tracking are possible to be implemented.

Two antenna-tracking methods namely closed-loop and opened-loop are usually used for mobile communications. In a closed-loop method, the antenna tracks an object from a remote station by receiving a signal from the object and the other is an open-loop tracking method, which uses output data from sensors. This method does not use signals from the base station antenna in the system, but it requires sensors to provide information on the mobile's position.

With the above consideration to develop a simple algorithm for automatic tracking and ease to implement into the system, the closed-loop method by using a beam-lobbing method, in which the object at the remote station direction is required by comparing two received signal powers with symmetrically-shaped antenna beams was adopted for use in this research. These closed-loop methods require line-of-sight between a moving object at the remote station and a base station to achieve a good tracking performance since these methods use base station signals. Apart from these reasons, the method have the following advantages:

i. Since an antenna's cost, size and shape are important key factors for practical mobile applications, a simple tracking method, such as the beam-lobbing method is a good candidate.
ii. Possible to apply for news gathering and reporting

C. Performance Analysis

To validate the tracking antenna system design for newsgathering and live video streaming, two kinds of performance tests have been done: (1) range/distance test (2) the tracking test. The first step taken before placing the antenna for measurements was to verify that the antenna could transmit and receive a signal.

Range/Distance Test

A field test to show how much improvement can be obtained in terms of range/distance with the proposed system was first carried out. During this test, an individual was manually controlled to move along a path with an almost constant speed of 0.9 m/s, as shown in Figure 13.

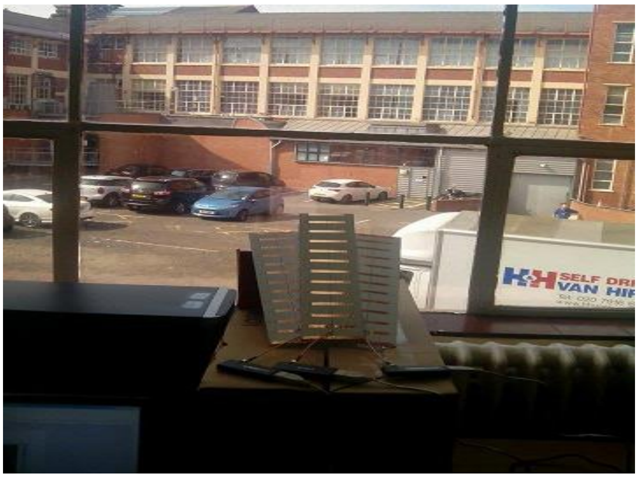


Figure 13. Experimental setup for Range/distance test at Wolverhampton City Campus car park

Figure 14 shows the results of averaged throughput with a standard deviation versus the distance that the person covered. Looking at the results, when the person was equipped with an omnidirectional antenna, the distance traveled could reach up to 15 m from the command center and throughput decreased steeply. On the other hand, when the person was equipped with a directional antenna, it reaches up to 20 m. The person could have moved much further distances, but due to the limited space of the environment, it was stopped at 20 m. From this test, it can be seen that the second antenna selection significantly outperformed the other antenna selection in both range/distance and throughput measurements. A window in a brick wall will lessen signal strength by 2dB and the brick wall by 3dB. However, the attenuation produced by windows did not prove to be substantial when testing the tracking antenna in operation during the experiment. The maximum range/distances were not affected by the opening or closing of windows and doors.

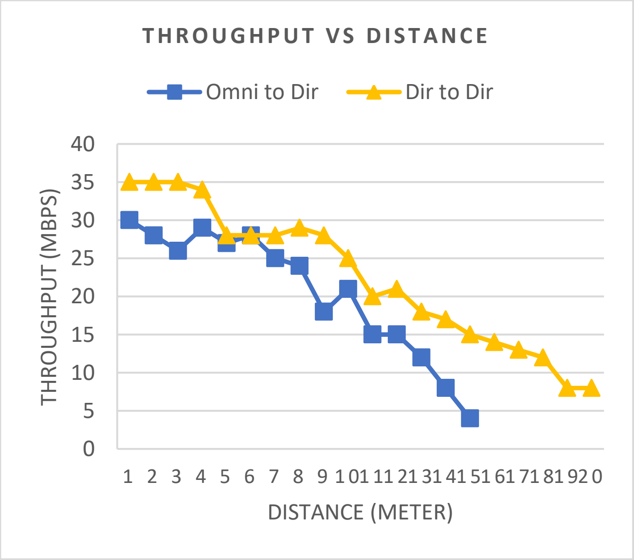
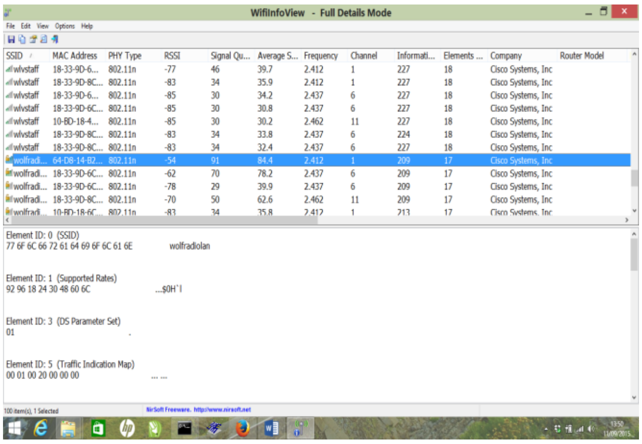


Figure 14. Throughput versus distance test-throughput was measured as the person move along a long path

Testing the Tracking Antenna

A prototype-tracking antenna has been used successfully to track a moving object under the range discussed previously. A dedicated software application called WifiInfoView, which does not require any installation process or additional DLL files, was used. To start using it, simply run the executable file-WifiInfoView.exe. It scans the wireless networks in your area and interface devices on the system and provides extensive information about them, such as Network name (SSID), MAC Address, PHY Type (802.11n), RSSI, Signal Quality, Frequency, Channel Number, Maximum Speed, Company Name, Router Model and Router Name. When you select a wireless network in the upper pane of this tool, the lower pane displays the Wi-Fi information elements received from this device, in hexadecimal format. WifiInfoView also has a summary mode, which displays a summary of all detected wireless networks, grouped by channel number, company that manufactured the router, PHY type, or the maximum speed. Figure 15 shows a screenshot of one of the networks selected during the test.



SSID	MAC Address	PHY Type	RSSI	Signal Qu...	Average S...	Frequency	Channel	Informati...	Elements ...	Company	Router Model
wlvstaff	18-33-9D-6...	802.11n	-77	46	39.7	2.412	1	227	18	Cisco Systems, Inc	
wlvstaff	18-33-9D-8C...	802.11n	-83	34	35.9	2.412	1	227	18	Cisco Systems, Inc	
wlvstaff	18-33-9D-6...	802.11n	-85	30	34.2	2.437	6	227	18	Cisco Systems, Inc	
wlvstaff	18-33-9D-6C...	802.11n	-85	30	30.8	2.437	6	227	18	Cisco Systems, Inc	
wlvstaff	10-BD-18-4...	802.11n	-85	30	30.2	2.462	11	227	18	Cisco Systems, Inc	
wlvstaff	18-33-9D-8C...	802.11n	-83	34	33.8	2.437	6	224	18	Cisco Systems, Inc	
wlvstaff	18-33-9D-8C...	802.11n	-83	34	32.4	2.437	6	227	18	Cisco Systems, Inc	
wolfradi...	64-D8-14-B2...	802.11n	-54	91	84.4	2.412	1	209	17	Cisco Systems, Inc	
wolfradi...	18-33-9D-6C...	802.11n	-62	70	78.2	2.437	6	209	17	Cisco Systems, Inc	
wolfradi...	18-33-9D-6C...	802.11n	-78	29	39.9	2.437	6	209	17	Cisco Systems, Inc	
wolfradi...	18-33-9D-8C...	802.11n	-70	50	62.6	2.462	11	209	17	Cisco Systems, Inc	
wolfradi...	10-BD-18-6C...	802.11n	-83	34	35.8	2.412	1	213	17	Cisco Systems, Inc	

```
Element ID: 0  (SSID)
77 6F 6C 66 72 61 64 69 6F 6C 61 6E          wolfradiolan


Element ID: 1  (Supported Rates)
92 96 18 24 30 48 60 6C                  ...$0H`l


Element ID: 3  (DS Parameter Set)
01                                       .


Element ID: 5  (Traffic Indication Map)
00 01 00 20 00 00 00                     ... ...
```

Figure 15. Screenshot showing the Wi-Fi information elements received from the device

Figure 16 demonstrates how the tracking test was carried out. To track the moving object, a simple 802.11n domestic access point (AP) connected to the prototype antenna was used. For this experiment, the AP was placed at the edge of open space and the maximum distance at which the target's signal could be recorded with a direct line of sight was 20 m with the windows closed. Scanning was initiated and the readings of the received signal strength (RSS) of the 802.11n signal from the three selected networks were taken at increasing distances. These readings were derived with the aid of a command Wi-Fi tool that is linked with the Arduino board to enable serial communication between the three PCs and the Arduino board. Table 5 below shows the readings for the RSSI and signal strength for the three antennas. A simple comparison helps to decide whether the antenna has to move left or right.

Figure 16. Experimental setup for the tracking system

Table 5: Results of three selected networks and signal quality via motion tracking

	Antenna 1		Antenna 2		Antenna 3	
Distance (m)	**RSSI (%)**	**Signal quality (dB)**	**RSSI (%)**	**Signal quality (dB)**	**RSSI (%)**	**Signal quality (dB)**
3	-60	76	-60	76	-70	50
6	-66	60	-68	55	-68	55
9	-62	70	-66	60	-74	39
12	-66	60	-58	81	-70	50
15	-56	86	-62	70	-66	60
18	-72	44	-54	91	-67	66

Looking at the results indicates that the pair of directional antennas were adjusted and aligned well while the object was moving. In other words, it validates that the designed antenna tracking system worked successfully. To support this argument, Figure 17 shows the results of the plot of signal quality versus distances for the three antennas.

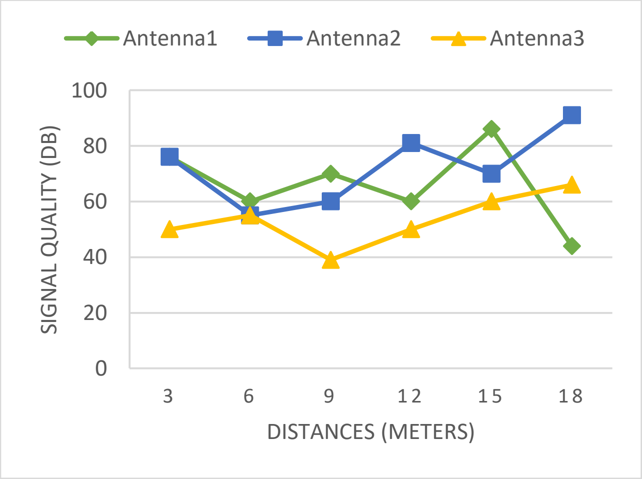


Figure 17. Plots of Signal quality vs distances of the three antennas

V. TRACKING PERFORMANCE AND COST FACTORS

The use of a manual beam switch was performed with the aid of a control program; three beams were separately generated in a certain azimuth direction as expected (see Figure 18a). Since the beam is possible to be switched at a minimum gain of 5.3 dB, the researcher decides to switch at azimuth angles of 57.9^0, $92.1^{0,}$ and 126.3^0 as shown in the diagram of Fig. 18b. With this development, the gain can be switched automatically at the aforementioned azimuth angles.

The performed RSSI scans at various distances and positions from the results obtained show that the tracking performance is higher due to low signal-to-noise ratio and receiving of higher signal strength.

Considering other available tracking system discussed earlier that uses the ground to air tracking, this particular mechanism of air-to-ground employed in this research is cheaper to implement and the average cost is one-tenth of the ground-to-air tracking antenna.

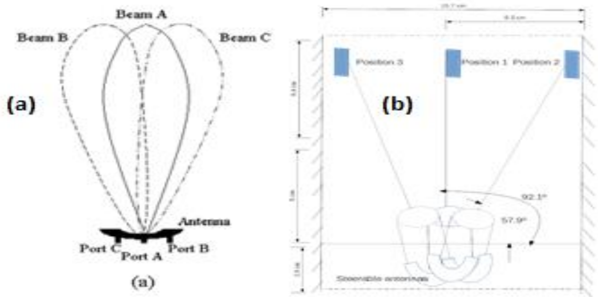


Fig.18: Illustrate experimental setup of the steerable antenna at various positions

VI. CONCLUSION AND FUTURE SCOPE

The research successfully design and implement an air to ground antenna-tracking system with a directional antenna (Yagi) mounted at the base station with a 2.4GHz video transmitter to continuously track a moving object at the remote station. The antenna was built by using a driven element, reflector and eleven directors. The antenna tracking system is made up of a unit of a microcontroller circuit board and pan-tilt mechanism. It also contain a unit of an array of three Yagi antenna connected to a Wi-Fi adapter module. The tracking system make use of mechanical beam steering method and closed –loop antenna-tracking method. The presence of various networks resulting from functionality test shows that the system functions proper. The performance test in terms of range/distance test shows the antenna covers longer distance with directional antenna but most effective over short-distance wireless communication. The tracking test validates that the designed antenna tracking system performs well. Much improvement is needed for longer-distance Newsgathering and live video streaming applications.

ACKNOWLEDGMENT

We thank Tertiary Education Trust fund, Abuja, Nigeria for the financial support. We also thank the University of Wolverhampton Particularly Professor Robert Newman & Dr. Chris Dennett for supervising the research.

REFERENCES

[1] M. Draxler, H. Karl, "Cross-Layer Scheduling for Multi-Quality Video Streaming in Cellular Wireless Networks," *In the proceedings of the 2013 IEEE International conference on Wireless Communications and Mobile Computing (IWCMC),* **Sardinia, Italy** pp.**1181–1186, 2013.**

[2] R. Immich, E. Cerqueira, M. Curado,"Towards the Enhancement of UAV Video Transmission with Motion Intensity Awareness," *In the proceedings of the 2014 IFIP Wireless Days (WD),* **Rio de Janeiro, Brazil,** pp. 1-7**, 2014.**

[3] D.B. da Costa, H.-C. Yang,"Grand Challenges in Wireless Communications, Front. Commun. Networks," *Frontiers in Communications and Networks,* Vol. **4**, pp. **1-5**, **2020.**

[4] C. Ziółkowski, J.M. Kelner, J. Krygier, A. Chandra, A. Prokeš, "Radio channel capacity with directivity control of antenna beams in multipath propagation environment," *Sensors*, Vol. **21**, Issue, **24**, pp. **8296**, **2021**.

[5] S.R. Ganti, Y. Kim," Design of Low-Cost On-Board Auto-tracking Antenna For Small UAS," *In the proceedings of the 2015 12th International Conference on Information Technology - New Generations (ITNG),* **Las Vegas, Nevada, USA,** pp. **273-279, 2015**.

[6] A.H. Kelechi, M.H. Alsharif, D.A. Oluwole, P. Achimugu, O. Ubadike, J. Nebhen, A. Aaron-Anthony, P. Uthansakul, "The recent advancement in unmanned aerial vehicle tracking antenna: A review, *Sensors*, Vol. **21**, Iss, **16**, pp. **5662, 2021.**

[7] T. Siegel, S.P. Chen, "Investigations of Free Space Optical Communications Under Real-World Atmospheric Conditions,"*Wireless Personal Communications,* Vol. **116**, Iss, **1**, pp. **475–490, 2021**.

[8] L. Shaohua, D. Cho, "Directional Antenna based Time Division Scheduling in Wireless Ad hoc Networks," *In the proceedings of the 2008 IEEE Military Communications Conference,* **San Diego, California, USA,** pp. **1-7, 2008**.

[9] M. Owen, T. Mclain, "Moving Ground Target Tracking in Urban Terrain Using Air / Ground Vehicles," *In the proceedings of 2010 IEEE International Workshop/Conference on Wireless Networking for Unmanned Aerial Vehicles,* **Miami, USA,** pp. **1816-1820, 2010.**

[10] M. Islam, A.S.M. Rashedul-Hug, R.B. Kashem, N.Hassan, M.R. Islam, K.M.A. Salam,"GPS Based Automatic Antenna Management System and Satellite Tracking," *Journal of Modern Science and Technology,* Vol.**5**, No. **1**, pp. **11-27, 2017**.

[11] S.Poochaya, P.Uthansakul," Beam Tracking in Switched -Beam Antenna System for V2V Communications," *International Journal of Antennas and Propagation,* Vol. **2016**, pp. **1-2, 2016.**

[12] H.Miawarni, M.Hidayat, S. Sumpeno, E. Setijadi," Tracking System for Indoor TV Antenna Based on CVBS Signal Processing," *Jurnal Elektonika dan Telekomunikasi (JET),*Vol. 17, No.**2**, pp.**48-55, 2017**.

[13] G. Nugroho, D. Dectaviansyah," Design, Manufacture, and Performance Analysisof an Automatic Antenna Tracker for an Unmanned Aerial Vehicle (UAV)," *Journal of Mechatronics, Electrical Power and Vehicular Technology,* Vol. **9**, pp. **32-40, 2018**.

[14] Q. Liu, J.Yang, C.Zhuang, A.Barnawi, B.A Alzahrani," Artificial Intelligence Based Mobile Tracking and Antenna Pointing in Satellite Network," *IEEE Access,* Vol. **7**, pp.**177497-177503, 2019.**

[15] R.O Reddy, S.Kautish, V.P. Reddy, N.S.Yadav, M.M. Alanazi, A.W. Mohamed," Effects of Integrated Fuzzy Logic PID Controller on Satellite Antenna Tracking System," *Computer Intelligence and Neuroscience,* Vol. **2022**, pp. **1-11, 2022**.

[16] B.Subba, S. Rai, T. Dhendup, J.Chimi, C. Dema, T.Tobgay," Radiation Analysis of satellite Tracking UHF/VHF Yagi Turnstile Array Antenna for APRS Digipeater Ground Station," *International Advanced Research Journal in Science, Engineering and Technology,* Vol. **9**, Iss, **3, 2022.**

[17] W.K. Toh, X. Qing, Z.N. Chen, "A planar dualband antenna array," *Transactions on Antennas and Propagation,* Vol. **59**, Issue. **3**, pp. **833-838**, **2011**.

[18] S.D. Assimonis, T. Samaras, V. Fusco, "Analysis of the microstrip-grid array antenna and proposal of a new high-gain, low complexity and planar long-range WiFi antenna," IET *Journals of Microwaves, Antennas Propagation,* Vol.**12**, Issue. **3**, pp.**332-338**, **2017**.

[19] M.R. Anjum, H. Tang, A.A. Syed, K. Sultan, M. Imran, "Design and analysis of the critical parameter of Yagi antenna for Ku band," *International Journal of Science,* Vol. **26**, Issue. **3**, pp. **1051-1055**, **2014**.

[20] C. -C. Lan, Y.-C. Lee, J.-F. Jiang, Y. –J. Chen, H. –Y. Wei, Z. Xvlqj, D.Q. Jhdu, R.U. Olqndjhv, "Design of a Compact Camera-Orienting Mechanism with Flexural Pan and Tilt Axes," *2011 IEEE/RSJ International Conference on Intelligent Robots and Systems,* San Francisco, CA, **USA**, pp.**1962-1967**, **2011**.

[21] S.Salim, L.Mudi,"Microcontroller Based Digital Clock Interfaced with Liquid Cystal,"*World Academics Journal of Engineering Sciences,* Vol. **7**, Issue, **3**, pp. **27-30, 2020.**

[22] M.M. Abdulwahab, A.A. Mohammed, A.H. Mohammed, M.M. Hamza," Design of Wireless Sensor System of Monitoring and Controlling Parking Cars,'' *World Academics Journal of Engineering Sciences,* Vol. **9**, Issue, **1**, pp. **18-22, 2022.**

[23] A.M. Elshafee, K.A. Hamed, "Design and Implementation of a WiFi Based Home Automation System," *Journal of World Academy of Science, Engineering and Technology,* Vol. **8**, Issue. **1**, pp. **2177-2183**, **2014**.

[24] D. Lymberopoulos, Q. Lindsey, A. Savvides, "An Empirical Characterization of Radio Signal Strength Variability in 3-D IEEE 802.15.4 Networks using Monopole Antennas," *in the Proceedings of European Workshop on Wireless Sensor Networks,* Zurich, **Switzerland**, pp. **326-341**, **2006**.

[25] H. Zhang, Y. Jiang, K. Sundaresan, S. Rangarajan, B. Zhao, "Wireless Multicast Scheduling with Switched Beamforming Antennas," *IEEE/ACM Transactions on Networking,* Vol.**20**, Issue.**5**, pp.**1595-1607**, **2012**.

[26] K. Gwosch, B. Hartmann, J. Jakubek, S. Pospisil, O. Jiikel, M. Martisikova, "3D Beam Monitoring for 12C Radiotherapy by Tracking of Secondary ions using the Timepix Detector," *2012 IEEE Nuclear Science Symposium and Medical Imaging Conference Record (NSS/MIC),* Anaheim, CA, **USA**, pp. **1291-1294**, **2012**.

[27] J.H. Kim, J. Choi, Y.S. Cho, "An Efficient Beam-tracking Techniques for mmWave Communication Systems," *2014 International Conference on Information and Communication Technology Convergence (ICTC),* Busan, **Korea (South),** pp.**845-846**, **2014**.

[28] S. Singh, E. Mittal, G. Sachdeva, "Multi-objective Gain-Impedance Optimization of Yagi-Uda Antenna using NSBBO and NSPSO," *International Journal of Computer Applications,* Vol.**56**, Issue.**15**, pp.**1-6**, **2012**.

[29] A. Bekasiewicz, S. Koziel, L. Leifsson, "Computationally Efficient Multi-Objective Optimization of and Experimental Validation of Yagi-Uda Antenna," *In the proceedings of the 2014 International Conference on Simulation and Modelling Methodologies, Technologies and Applications (SIMULTECH),* **Vienna**, **Austria,** pp.**798-805, 2014**.

[30] V.K. Kothapudi, K. Nalini, B.T.P. Madhav, B.V. Raj Gopala Rao, B.S.Kumar, K.V.H. Naga, "Design and Analysis of 3-Element Yagi-Uda Antenna for Wind Profiling Radar," *International Journal of Computer Science and Communication Networks,* Vol.**1**, Issue, **3**, pp. **242-246**, **2013**.

[31] R. Cicchetti, E. Miozzi, O. Testa, "Wideband and UWB antennas for wireless applications: A comprehensive review," *International Journal of Antennas and Propagation,* Vol. **2017**, Article ID, 2390808, **45**pp. , **2017**.

[32] M. Delgadillo, M. Panggabean, " EE 172 Extra Credit Project 2.4GHz Yagi-Uda Antenna," *San Jose State University Publication,* **California**, pp. 1-25, 2010.

[33] M.F. Adaramola, E.B. Balogun, “Analysis Techniques on Yagi-Uda Antenna Configured for Wireless Terrestrial Communication Applications,” *Journal of Information Engineering and Applications,* Vol. **6**, Issue. **4**, pp. **8-20**, 2016.

[34] B.I. Neelgar, G.S.N. Raju, “Impedance Characteristics of Yagi –Uda Antenna,” *International Journal of Electronics and Communication Engineering,* Vol. **4**, Issue. **1**, pp. **115-130**, **2011**.

[35] A. Agnihotri, A. Prabhu, D. Mishra, “Improvement in Radiation Pattern of Yagi-Uda Antenna,” *Research Inventy: International Journal of Engineering and Science,* Vol. **2**, Issue. **12**, pp. **26-35**, **2013**.

[36] M. Rakibul Islam, “Study and Implementation of Wideband Bow-Tie Antennas,” *Georgia Southern University,* **Georgia, USA**, pp. **1-74, 2017.**

[37] T. Torres, N. Anselmi, P. Nayeri, P. Rocca, R. Haupt, “Low discrepancy sparse phased array antennas,” *Sensors,* Vol. **21**, Issue. **23**, P. **7816**, **2021**.

[38] B.R.S. Reddy, D. Vakula, “Grating Lobe Suppression with Element Count Optimization in Planar Atenna Array,” *Journal of Electromagnetic Analysis and Applications,* Vol.**7**, Issue.**2**, pp. **31-40**, **2015**.

[39] H. Bayer, R. Stephan, M.A. Hein, “Land-Mobile Ka-Band Satcom Tracking Antenna Employing a Printed Circuit Board Based Multimode Monopulse Feed,” *2014 IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications (APWC),* Palm Beach, **Aruba**, pp.**296-299**, **2014**.

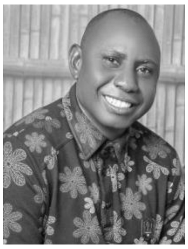
[40] H. Aliakbarian, E. Van Der Westhuizen, R. Wiid, “A digitally Beam-Steerable Antenna Array System for Positioning-Based Tracking Applications,” *In IEEE Antennas and Propagation Magazine,* Vol. **55**, Issue. **6**, pp. **35-49**, **2013**.

[41] A. V Räisänen, D. Chicherin, Z. Du, A. Generalov, A. Karttunen, “Antennas for electronic beam steering and focusing at milimeter wavelengths,” *2012 International Conference on Electromagnetics in Advanced Applications,* Cape Town, **South Africa**, pp.**1235-1237**, **2012**.

AUTHORS PROFILE

Kpelai Akosuga Justin, MNSE, NIEEE is a Ph.D. student and Lecturer I in the Department of Electrical and Electronics Engineering, Benue State Polytechnic Ugbokolo, Benue State, Nigeria with over twelve years (12) experience, outstanding communication, and analytical skills, lecture room management and presentation skills using both ICT platforms and interactive means.

He has several academic laurels in his portfolio among which are B.Eng (Electrical and Electronics Engineering) from the Federal University of Agriculture Makurdi, Benue State, Nigeria. In his passion for attaining higher academic attainments, he applied and got admission into the University of Wolverhampton, the United Kingdom in 2014 where he bagged an M.Sc Mobile and wireless System Engineering. With a burning zeal that continues to drive him higher, he enrolled for a Ph.D. in Electrical and Electronics Engineering at the University of Ilorin Kwara State, Nigeria in the area of Wireless Optical Communication system design for 5G mobile communication applications for Urban areas.



Dr. Celestine Teryange Mbakaan
Celestine Teryange Mbakaan received his B.Sc. degree in Physics from Benue State University Makurdi, Benue State, Nigeria. He got both M.Sc. and Ph.D. in Engineering Physics from Joseph Sarwuan Tarka University Markurdi in 2014 and 2019 respectively. He specialized in Nanophysics and Nanoengineering. He also has interest in Electronics and wireless communication systems. He has many publications in reputable journals across all the areas of research interest. He is a lecturer in the Department of Science Laboratory Technology, Benue State Polytechnic, Ugbokolo.

Seember Justin-Kpelai holds a BSc in Computer Science from the Benue State University, Makurdi in the year 2012. She proceeded for the compulsory one-year National Youth Service for the 2012/2013 service year and picked a lecturing job thereafter with the Federal University Wukari in Taraba State as a graduate assistant in 2013. She is currently on the verge of completing her MSc in Computer Science from the Joseph Saawuan Tarka University, Makurdi. Seember is a member of Nigeria Computer Society (NCS) and Nigeria Women in Information Technology (NIWIIT). She has an interest in Artificial Intelligence.