Construction of an Optimized Yagi Uda Antenna for Wildlife Applications

[1]Amos Ibrahim saleh, [2]Atijosan A, [3]Gajere E.N., [4]Rakiat H., [5]Alaga A. and [6]Isa Ibrahim,
[1,2,3,4,5,6]Cooperative Information Network, National Space Research and Development Agency, Mathematics Building, Obafemi Awolowo University, Ile- Ife, S/W Nigeria

Abstract: In this work, construction of a high performance 12-elements Yagi-Uda antenna designed using Bacterial Foraging Algorithm (BFA) was carried out. The constructed antenna is to be used at the receiver end of a wildlife radio tracking applications. Performance evaluation of the constructed BFA optimized Yagi-Uda antenna was carried out via simulations and field test in open (light vegetation) and thick vegetation areas using a signal test meter. The maximum and minimum value of directivity obtained via simulation was 13.5dBi and -34.9dBi respectively. From the field test in open areas (areas with low vegetation) it was found that inclusion of the antenna increases the signal strength by an average of 39.3%. In areas with thick vegetation, it was equally observed that inclusion of the antenna increases the signal by an average of 37%. The decreased in signal strength observed in areas with thick vegetation agrees with Tamir's model of signal propagation in thick vegetation or forest areas. From the results obtained, the constructed BFA optimized Yagi-Uda is found suitable for wild life tracking applications. From the result obtain, the constructed BFA optimized Yagi-Uda antenna was found to be effective for used in VHF radio tracking applications.

Keywords: *Construction, Antenna, Wildlife, Tracking, Applications.*

I. INTRODUCTION

A. Preamble

Tracking wildlife has an old history, in the pasts the process was simply carried out by following and observing the movement and habits of animal or by capturing an animal and putting a tag on it and hoping that at some time in the future the same animal would be captured. Today's technological advancement has brought significant change in this trend; wildlife can now be tracked and monitored using radio tracking techniques.

B. Radio Tracking Technology

Radio-tracking technology is the technique of obtaining useful information about an animal through the use of radio signals from or to a device carried by the animal. The process involves attaching a portable radio transmitter to the animal body which emits radio signal detectable by an antenna at the receiving end (Richards et al., 2003). The radio-tracking technique is so revolutionary (Mech et al., 2002) that there is no other wildlife research technique that comes close to approximating its many benefits. For example, before radio-tracking, the study of animal movements sorely relied on live-trapping and labelling animals hoping to recapture them somewhere else. A refinement was the use of visual markers such as color-coded collars that allowed observers to identify individuals from afar. The crudeness and biases inherent in this method are obvious (Diemer, 2003). There are three (3) major tracking techniques; Satellite tracking; Global Positioning Systems (GPS) tracking and Very High Frequency (VHF) radio tracking. Figure 1.1 shows the system architecture of a radio tracking system.

C. Satellite Tracking

This technique has been in used since the mid-1980s. Most current satellite telemetry uses the two polar-orbiting Argos satellites to receive ultra-high frequency signals from platform transmitter terminals (PTTs) (Mech, 2002). The Argos satellite system is operated under an agreement between the French Government (French Space Agency) and the United States (NOAA and NASA) fully for the collection and distribution of environmental and natural resource data (Freitas et al., 2008). Most (about 80 percent) of the transmitters are on drifting or moored buoys, fixed land locations, or on ships and they transmit meteorological and/or oceanographic data. With the miniaturization of PTTs in the mid-1990s, more PTTs are being attached to animals to track their movements (Fancy et al.,1988). An animal-borne PTT location is determined by calculations that rely on the Doppler Effect; that is, the perceived change in frequency that results from the movement of a transmitter and receiver. With satellite telemetry, the user can obtain locations of the animal borne PTT to within 100 meters (m) to 4 kilometers (km) radius (330 feet to 2.5 miles). Most readings obtained by the satellite are in the middle of this range. Obviously, any technology that has an error range that broad is best used only for far-ranging species (Costa et al., 2010).

D. Global Positioning Systems Tracking

GPS tracking telemetry usually involves attaching a GPS receiver (collar) to an animal to record (track) the animal's location over time. The GPS collar/receiver logs (stores) the location (and time) data on the device until it is retrieved either by: (a) recapturing the animal to extract GPS data stored on the collar, (b) remotely (i.e., wirelessly) downloading the GPS data stored on the collar to a separate, portable (usually handheld) receiver; or (c) remotely relaying the GPS data to the Argos Satellite system. Global Positioning System (GPS) tracking of animals is the cutting-edge development in wildlife telemetry. It uses a GPS receiver in an animal collar to calculate and record the animal's location, time, and date at programmed intervals, based on signals received from a special set of satellites. With GPS telemetry, a different set of satellites function as transmitters, while the animal's telemetry unit acts as a receiver. The signal information is used by the animal's telemetry unit to calculate its location based on current positions of satellites and the time taken for the signal sent from each satellite to reach the animal's receiving unit. These location data are then stored by the animal's unit for later unit retrieval or remote downloading. Figure 1.2 is a pictorial representation of a G.P.S satellite system (constellation).

1. GPS/Satellite telemetry

GPS/satellite telemetry is a combination of two separate technologies; GPS and satellite telemetry. In this case both the GPS receiver and satellite transmitter are in one device to collect data on animals within a limited range. An animal attached with GPS/satellite device stores its GPS location data (over time) on the device; this data is then transmitted every few days to the Argos satellite, where it been distributed worldwide (Figure 1.2). This technology allows a user to collect latest movement data of these animals with limited ranges and have this data transmitted to any location. Figure 1.3 is a pictorial representation of a G.P.S/Satellite telemetry process.

E. VHF Radio Tracking

This technique requires an operator or the tracker to receive the VHF transmitted signal from a VHF transmitter (usually in a collar form attached to the animal) via a hand-held /vehicle mounted antenna. The position of the transmitter is usually determined by acquiring the transmitted signal, from three (or more) different locations to triangulate the location of the device. The advantages of VHF tracking are relatively low cost, reasonable accuracy for most purposes, and long life. Although, it could be labor-intensive and can be weather-dependent, nevertheless, VHF radio-tracking is by far the most useful and versatile type of radio-tracking (Mohammed, 2014). Figure 1.4 is a pictorial representation of a V.H.F telemetry showing a directional hand-held antenna tracking system.

Figure 1.1 Radio Tracking System Architecture

Figure 1.2 GPS satellite system (from gps.gov)

Figure 1.3 GPS/satellite telemetry process (from Argos 2008:11)

Figure 1.4 VHF telemetry uses a directional, hand-held antenna to receive transmissions. (Photo by U.S. Fish & Wildlife Service)

F. Importance of a well Designed Antenna in wildlife tracking systems

A well designed antenna is a key component of wildlife radio tracking systems (Shrutika, 2016). Typically, Yagi-Uda antenna are widely used in wildlife VHF radio tracking applications due to their relatively high directivity, but are often plagued with poor performance because of poor design approach (Thakur et al., 2015). Poor performance of the antenna would invariable lead to poor performance of the radio tracking system. This could cause the loss of vital data essential for monitoring, tracking and locating different wildlife species (Andrew, 2016).

G. Statement of Research Problem

The design of Yagi-Uda antenna is a challenging task owing to the sensitivity of the antenna performance to the physical parameters used in its design. Finding the optimum parameters of the antenna using simple intuition, experience, or practical measurement is very difficult (Biswa et al., 2016). In order to get the best design within a minimal time there is the need for the use of an optimization technique.

Aim

Construction of an optimized Yagi-Uda antenna for wildlife tracking applications.

Objectives

1. Construct a Yagi-Uda antenna designed using Bacteria Foraging Algorithm (BFA) global optimization technique.
2. Evaluate the performance of the constructed antenna.

I. Project Scope

The scope of this work is limited to the construction of an optimized Yagi-Uda antenna for used at the receiver end of a wildlife tracking system.

II. LITERATURE REVIEW

A. Introduction

Wildlife monitoring is important for keeping track of animal habitat utilization, movement patterns, population demographics, poaching incidents and breakouts. Valuable information; gathered from wildlife monitoring has numerous applications (Andrew, 2016), for example, using radio tracking techniques, scientists can have insights into behavioral patterns of animals. In addition, information about their habitat, feeding, and mating patterns are greatly simplified (Pat Halpin, 2016).

B. Wildlife Tracking System

The general concept of wildlife tracking systems is the use of a portable transmitter attached to the animal body which emits electromagnetic signals detectable by an antenna at the receiver end (Durham, 2016). There are three major tracking techniques; V.H.F tracking, Satellite tracking and Global Positioning System tracking.

C. Yagi-Uda Antenna

An antenna is an electrical device that converts radio-frequency (RF) fields into an electrical power (alternating current (AC)) and vice-versa. The two basic types are: the receiving antenna and the transmitting antenna. The receiving antenna intercepts the RF energy and delivers AC to electronic equipment, and the transmitting antenna, which is fed with AC from electronic equipment and generates an RF field (Mingyao, 2016). An antenna forms the interface between free space radiation and the transmitter or receiver. The choice of an antenna normally depends on many factors such as gain, band-width, directivity, frequency, logistics, location method etc. A high gain directional antenna is required where signals need to travel long distance (Rao, 2013). Yagi-Uda antennas been highly directional are mostly used in animal tracking applications. They are multi-element array antennas available with two to more number of elements (Andersen, 2000) .Yagi-Uda antenna Operates in the HF to UHF bands, and are directional (because it radiates power in one direction).The antenna transmits and receives signal with less interference in a particular direction. This is made possible with the help of the three major elements; reflectors, driven element and directors. These elements are shown in Figure 2.1. The left-most element, called a reflector is typically slightly longer than resonant length and is. The next element is a dipole element with a feed line. The right-most elements are typically slightly less than resonant length and are called directors. This descriptive terminology originated in Yagi's paper and is still used today (Lohn et al.,2001). Spacing between elements is typically 0.2–0.3. In operation, radiation is largely to the right of the array, and the gain of the array increases with the number of directors that are used. This is in contrast to a single dipole element, having a gain of 2.2 dB. In operation, the Yagi–Uda antenna functions as an end-fire array, meaning that radiation is along the axis of the array in the direction of the director elements. The non-driven (reflector and director elements) are excited through mutual coupling between themselves and the fed dipole. The effectiveness of Yagi-Uda antenna in wildlife VHF radio tracking depends on the designed approach (Rahim et al., 2014).

D. Basic Description and Operation

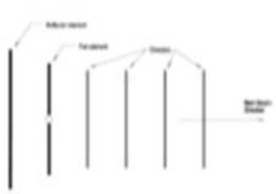


Figure 2.1 Geometry of the Yagi–Uda dipole array antenna

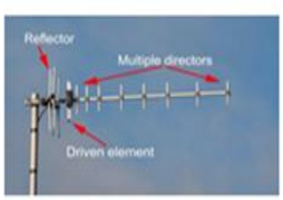


Figure 2.2 Yagi-Uda antenna

The parasitic elements of the Yagi-Uda antenna operate by re-radiating their signals in a slightly different phase to that of the driven element. In this way the signal is reinforced in some directions and cancelled out in others. (Alam,2014) As a result these additional elements are referred to as parasitic elements. In view of the fact that the power in these additional elements is not directly driven, the amplitude and phase of the induced current cannot be completely controlled. It is dependent upon their length and the spacing between them and the dipole or driven element. Figure 2.2 shows the pictorial representation of a mounted Yagi-Uda antenna showing the elements.

E. Design of Yagi- Uda Antennas

The design of a Yagi-Uda is a difficult task due to the sensitivity of thepattern to physical parameters (Rahim, 2014; Singh et al., 2012). The gain of a Yagi antenna is governed mainly by the number of elements in the particular radio frequency (RF) antenna. However the spacing between the elements also has an effect. A Yagi antenna develops an end fire radiation pattern and for best gains the reflector and driven elements are spaced 0.25 to 0.354 wavelengths, director-to-director spacing is 0.15 to 0.25 wavelengths apart. Reflector length is typically 0.5 wavelengths to 1.05 that of the driven element. The driven element is designed at resonance without the presence of parasitic elements. The directors are 10 to 20% shorter than driven elements at resonance (Zhang, 2004). As the overall performance of the RF antenna has so many inter-related variables, many early designs were not able to realize their full performance because finding the optimum parameters of the antenna using simple intuition, experience or practical measurements is very difficult (Biswa et al., 2016). To get the best design; improve the antenna gain and directivity within a minimal time, design optimization technique is always the key (Pawar et al, 2016).

F. Conventional Design of Yagi-Uda Antenna

The conventional yagi-uda antenna was invented in 1926 by ShintaroUda of Tohoku Imperial University, Japan along with his colleague HidetsuguYagi. These antennas are used in HF (3-30MHz), VHF (30-300MHz), and UHF (300-3000MHz) ranges. Mainly, yagi-uda antennas comprise of three different types of linear dipole elements as shown in figure 2.2. The elements are active element, reflectors and directors (Constantine et al., 2005). An active element is the one to which the source or excitation is applied. Generally, length of this element is slightly less than $\lambda/2$ i.e. ranges from 0.45λ to 0.49λ. Active element is also known as a feeder or a driven dipole. Length of reflector is 5% greater than the length of active element. Having a length greater than the active element causes good reflections to forward direction. Basically, more than one reflector can be used, but it does not add any advantage specifically. A reflector is located behind active element at a distance of 0.25λ. In the designs of yagi-uda antennas, directors play a key role in achieving better gain and directivity. Usually, their length is 5% smaller than the active element i.e. lies between 0.4λ to 0.45λ. Generally, gain is enhanced by adding number of directors as well as by optimizing the spacing between them. In the standard designs, spacing between the directors and the spacing between active elements, directors varies between 0.35λ to 0.4λ. Radius [a] of each element is 0.00425λ (Balanis et al., 2016).

There are no simple formulas for designing Yagi–Uda antennas due to the complex relationships between physical parameters such as element length, spacing, and diameter, and performance characteristics such as gain and input impedance. But by conventional method one can calculate the performance given a set of parameters and adjust them to obtain the gain. Since with an N element Yagi–Uda antenna, there are 2N − 1 parameters to adjust (the element lengths and relative spacings), this is not a straightforward method at all, the real antenna element lengths, relative spacing using conventional methods is only an approximation and not accurate. Antennas designed using these empirical approaches are based on trial and error, often starting with an existing design modified according to one's hunch. Conventional design is time consuming and not so effective (Kalro et al., 2000). Examples of conventionally designed Yagi-Uda antennas can be found in the works of (Hofmann et al.,2007, andKaneda et al., 2002).

G. Optimization Technique for Yagi-Uda Antenna

Optimization is the selection of a best element (with regard to some criterion) from some set of available alternatives. In the simplest case, an optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function. Use of optimization techniques in antenna design helps in tackling reception challenges by providing best values for antenna parameters, increased antenna performance and reduced cost of implementation (Biswal et al, 2016). The optimized antenna patterns show lower localization errors in the trajectory simulation. These results are key enablers for developing a low cost received signal strength based localization system. Optimization technique will enable the selection or computation of best values from the standard table of values. These will be used to achieve highly efficient Yagi-Uda antenna parameters.

1. Types of Optimization Techniques

To get the best design of an antenna within a minimal time, optimization technique is key (Biswa et al. 2016). Various types of optimization techniques such as; Gradient Descent Learning (GDL) (P. Baldi, 1995). Genetic Algorithm (GA), Ant Colony Optimization (ACO), Simulated Annealing Algorithm (SAA), Particle Swarm Optimization (PSO), Differential Evolution (DE), Cuckoo Search (CS) Bacteria Foraging Optimization (BFO), and many others have been used to optimize design parameters of antennas (Altshuler et al,1997; Mangaraj et al.,2013,Coleman et al.,2004; Lee,2005; Behera, 2013; Cheng et al.,2001).In comparison to the above listed techniques BFA has been found to be robust and efficient for optimization of multi objective, multi parameter antenna design problems (Biswa et al.,2016).

2. BFA Optimization of Yagi-Uda Antenna

Bacteria Foraging Algorithm (BFA) is a powerful optimization method that is framed by considering the elimination of creatures with poor food searching strategies. Though there are several optimization methods but BFA is regarded as a powerful algorithm to deal with global optimization problems (Tripathy et al.2007); due to its inbuilt superiority such as low convergence time, strength, and precision (Mangaraj et al., 2007). In dealing with antenna optimization problems using BFA, it is of utmost importance to formulate a fitness function which is basically multi parameter, multi objective, and nonlinear in nature. From a biological point of view, the term foraging is considered as an optimization technique with a thought that the work done by the bacterium in searching the amount of food per unit time should be as small as feasible. Thus, a fitness function would be there with some objectives as a measure of the work done by the bacterium in seeking the nutrient. The work done can also be interpreted as the cost observed by the bacterium during the process of searching for nutrients. Therefore, the primary objective of the BFA is to make the cost incurred to be as small as possible. The whole procedure in attaining the small cost considers four unique biological steps, that is, chemotaxis, swarming, reproduction, and elimination-dispersal (Alon et al., 1999). The movement features of bacterium in BFA, such as swimming, tumbling, and swarming are accountable for the change in design parameters of any antenna structure in order to make the fitness values of the fitness functions as small as possible and thus enabling the BFA optimized antenna to attain all the required performance parameters within a reasonable computational time.

III. METHODOLOGY

A. Brief Overview of the Method Used

The design of antenna array with desirable multiple performance parameters such as directivity, gain, (input impedance, beam width, and side-lobe level using any optimization algorithm is a highly challenging task (Altshuler et al., 1997). Bacteria Foraging Algorithm (BFA), as reported in (Biswa et al., 2016) was found to be, robust and efficient in comparison with other presently available algorithms for global optimization of multi-objective, multi-parameter antenna based design problems. In this work, the constructed antenna parameters were obtained using BFA optimization techniques as described by (Biswa et al.,2016).The optimized antenna was designed for wildlife tracking applications.

The fitness function FT used is as follows (Biswa et al., 2016).

$$\mathrm{FT}\ (x) = a|\mathrm{DR} - 20| + b|\mathrm{Re}\ (Z_{IN}) - 50| + c|\mathrm{Im}\ (Z_{IN})| + d|\mathrm{EHPBW} - 5| + e|\mathrm{HHPBW} - 5| + f|\mathrm{FTBR} - 40| + g|\mathrm{FSLL} - 40| \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

Where, DR,Z_{IN}, EHPBW HHPBW, FTBR and FSLL are the directivity, input impedance, E-Plane half power beam width, H-plane half-power beam width ,front to back ratio, front to maximum side lobe level respectively and the scalar constant values a, b, c, d, e, f, and g are 0.0294, 0.004167, 0.004167, 0.00152, 0.00152, 0.00128, and 0.00128. The scalar constant values are considered by taking into account highest weightage to directivity (DR) and other parameters are of equal importance. Table 3.1 shows the design parameters for a 12-element Yagi-Uda at 300MHz using conventional method (approach).While Table 3.2 is the design parameters for the Yagi-Uda at 300MHz with BFA optimization. These are the lengths and spacing of the respective elements used in the antenna construction. Performance evaluation of the BFA optimized Yagi-Uda antenna was found to exceeded that of conventional design approach.

B. Materials and Method

The method adopted by this work is summarized in the workflow diagram figure 3.0

WORKFLOW DIAGRAM

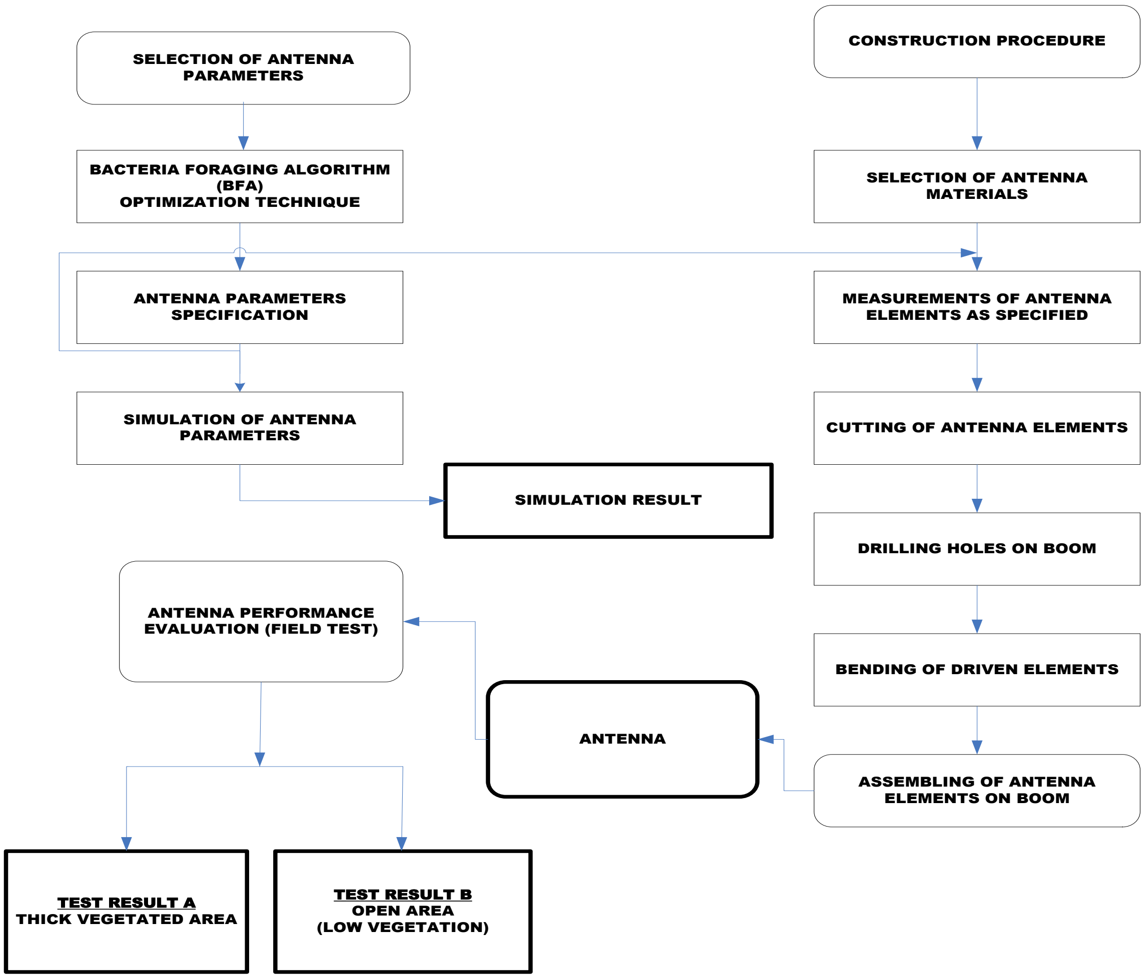


Figure 3.0: Work flow diagram

1. Materials used for Antenna Fabrication

The choice of materials used in this construction was based on National Bureau of Standards (NBS) and Institute of Electrical and Electronics Engineers (IEEE) standards.

The following materials were used:

i. Aluminum (2.6 square centimeters) tube of appreciable thickness was used for the boom because of its desirable property - light weight,
ii. 1cm diameter's copper round tube for the antenna elements-due its higher electrical conductivity, corrosion resistance, ease of soldering and availability.
iii. 75 ohms coaxial cable RG 6L
iv. Rubber caps for closing the ends of both boom and dipoles.

C. Machine/Tools Used for the Construction

The lists of tools and machine used for this construction work are; Safety glasses, Measuring tape, Straight Edge Ruler, Hacksaw, Tube cutting and bending set, Marking and punching tools, fliers, Soldering iron, and drilling machine. Figure 3.1 shows a cross section of some of the tools and machine used for the optimized Yagi-Uda antenna construction.

D. Construction Procedure

In the construction the following steps were taken:

i. Measurements of the optimized antenna elements and the boom.
ii. Cutting of the elements according to the optimized design specifications.
iii. Bending of the driven element
iv. Drilling of the respective elements holes on the boom as shown.
v. Assembling of the elements on the boom.

1. Measurement and Cutting of Antenna Elements

The 2.6 square centimeter aluminum boom was first measured and marked as specified by Table 3.2. The 1cm diameter copper pipe was cut according to directors, exciter and reflector length of the optimal design. Figure 3.2 shows the measurements and marking of the boom and the cutting of the respective elements as specified in Table3.2.

2. Folding Of Driven Element and Drilling of the Antenna Boom

The driven element, (a folded dipole) was fabricated by folding two lengths of the size of the driven element into two different arms (using spacing S= $\lambda/100$ between the arms) (Raju, 2004). And the aluminum boom which was initially marked according to the spacing was drilled on both sides to make 1cm diameter hole. The holes were drilled with precision to ensure tight fitting of the directors to the boom. This process is shown in Figure3.3.

3. Installation of the Antenna Elements

Finally, the elements were assembled and combined to form the antenna. Figure 3.4 is the pictorial representation of the installation of optimized Yagi-Uda antenna to the boom.

E. Performance Evaluation

RF transmitter module was used alongside the encoder (HT12E) to generate signals at the transmitter end as shown in Figure 3.5. This signal was tracked at different locations (open area (OA) and vegetation area (VA)) and distance by the constructed optimized Yagi-Uda antenna at the receiver end. Measurement of signal strength was carried out using a signal strength meter, the values obtained was recorded in percentages and these values were converted to decibels (dBm) using the conversion for Cisco at RSSI_max =100 (Table 3.3 shows the Cisco RSSI values at the left and the corresponding dBm values at the right. Table 3.4 is the data specification of the RF transmitter module used to transmit signal up to 100 meters. However, this distance also depends on the designed antenna, working environment and supply voltage which seriously have impact on the effective distance covered. When the voltage is higher, the range becomes greater. This device is good for short distance.

Table 3.1 Design parameters for the Yagi-Uda at 300MHz without BFA optimization (Biswa et al., 2016) 12-element Yagi-Uda (conventional)

Fixed design parameters: a =0.0032512λ, l/D = 100, f_0 = 300MHz

Number (n)	Length (ln) in m	Spacing dmn in m	SWG
1	0.510	_	10
2	0.490	0.250	10
3	0.450	0.300	10
4	0.445	0.300	10
5	0.440	0.300	10
6	0.435	0.300	10
7	0.430`	0.300	10
8	0.425	0.300	10
9	0.420	0.300	10
10	0.415	0.300	10
11	0.410	0.300	10
12	0.400	0.300	10

Table 3.2 Design parameters for the Yagi-Uda at 300MHz with BFA optimization (Biswa et al., 2016) 12-element Yagi-Uda (optimized)

Fixed design parameters: a=0.0032512λ, l/D = 100, f_0 = 300MHz Optimized design parameters

Number (n)	Length (ln) in m	Spacing dmn in m	SWG
1	0.492	_	10
2	0.487	0.226	10
3	0.441	0.228	10
4	0.422	0.206	10
5	0.428	0.226	10
6	0.426	0.448	10
7	0.424	0.396	10
8	0.422	0.372	10
9	0.424	0.452	10
10	0.416	0.434	10
11	0.420	0.446	10
12	0.428	0.326	10

Table 3.3 Cisco Practical Conversion from Percentage to dBm

RSSI=dBm	RSSI=dBm	RSSI=dBm
0 = -113	34 = -78	68 = -41
1 = -112	35 = -77	69 = -40
2 = -111	36 = -75	70 = -39
3 = -110	37 = -74	71 = -38
4 = -109	38 = -73	72 = -37
5 = -108	39 = -72	73 = -35
6 = -107	40 = -70	74 = -34
7 = -106	41 = -69	75 = -33
8 = -105	42 = -68	76 = -32
9 = -104	43 = -67	77 = -30
10 = -103	44 = -65	78 = -29
11 = -102	45 = -64	79 = -28
12 = -101	46 = -63	80 = -27
13 = -99	47 = -62	81 = -25
14 = -98	48 = -60	82 = -24
15 = -97	49 = -59	83 = -23
16 = -96	50 = -58	84 = -22
17 = -95	51 = -56	85 = -20
18 = -94	52 = -55	86 = -19
19 = -93	53 = -53	87 = -18
20 = -92	54 = -52	88 = -17
21 = -91	55 = -50	89 = -16
22 = -90	56 = -50	90 = -15
23 = -89	57 = -49	91 = -14
24 = -88	58 = -48	92 = -13
25 = -87	59 = -48	93 = -12
26 = -86	60 = -47	94 = -10
27 = -85	61 = -46	95 = -10
28 = -84	62 = -45	96 = -10
29 = -83	63 = -44	97 = -10
30 = -82	64 = -44	98 = -10
31 = -81	65 = -43	99 = -10
32 = -80	66 = -42	100 = -10
33 = -79	67 = -42	

Table 3.4: Specification of the RF Transmitter Module

S/N	Specification	RF-transmitter module
1	Operating voltage	3v-12v
2	Operating current Max	≤ 40mA (12V), Min ≤ 9mA (3V)
3	Oscillator SAW	(Surface Acoustic Wave) oscillator
4	Frequency	300MHz~433.92MHz
5	Frequency error	±150kHz(max)
6	Modulation	ASK/OOK
7	Transfer rate	≤ 10Kbps
8	Transmitting power	25mW (315MHz@12V)

IV. RESULTS AND DISCUSSION

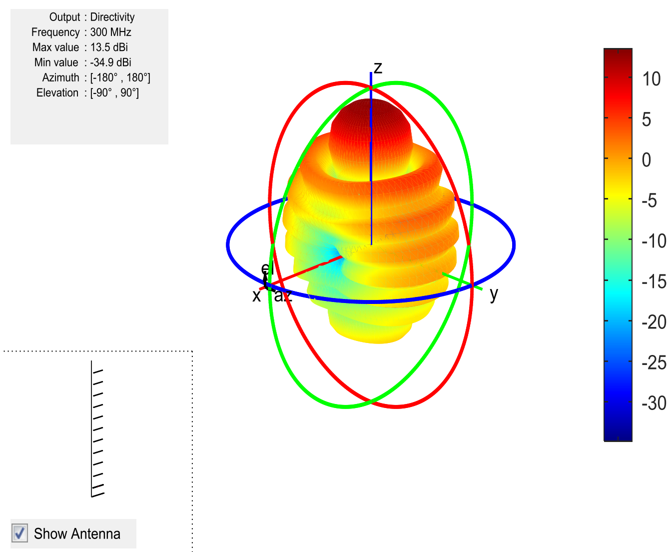
A. Constructed Optimized Yagi-Uda Antenna

The optimized Yagi-Uda antenna was constructed based on the design parameters. Figure 4.1 is a pictorial representation of the optimized 12-elements Yagi-Uda Antenna. The constructed antenna in operation function as an end fire array, i.e radiation is along the axis of the array in the direction of the ten (10) director elements. The director elements and the single reflector were excited through mutual coupling between themselves and the fed dipole (driven element). The main beam of the antenna array is in the direction of the director elements. Radiation was found to be predominantly along the director elements, the ten director elements used in this design led to increase in directivity of the array. Therefore, the constructed antenna was found to be very effective in wild life tracking applications. Performance evaluation was carried out via simulation of the antenna parameters and field test.

B. Simulation of the Antenna Parameters

Simulation was carried out using MATLAB 7.12.0635 (R2011) to assess the performance of the antenna in terms of maximum and minimum directivity. The result of the simulation performance (radiation pattern) of the constructed BFA optimized Yagi-Uda antenna (in terms of its directivity, front to back ratio and beam width) are shown in figures 4.2 and 4.3.Maximum value of directivity was 13.5dBi while the minimum value of directivity was -34.9dBi.From Figure 4.2 it can be observed that the maximum radiated power is along the Z-axis (required area).This shows that the antenna is highly directional. The side lobes and back-lobes were greatly reduced due to the optimization of the antenna parameters. These greatly reduced losses as incidence of unwanted radiations are greatly reduced. Also, from figure 4.3 the maximum radiation tends towards the Z-axis. The Beam width was obtained to be 33° (E plane) and 35° (H plane). This is a key factor in determining directivity because the narrower the beam width the higher the directivity. Also, the front to back ratio of the major lobe was found to be 22.29:1.This shows that the antenna as expected has high directivity. This result is good for VHF radio tracking applications, because directivity enables the antenna to focus or concentrates the transmission/ received power along a given direction.

Figure 4.1: The constructed optimized 12-elements Yagi-Uda antenna.



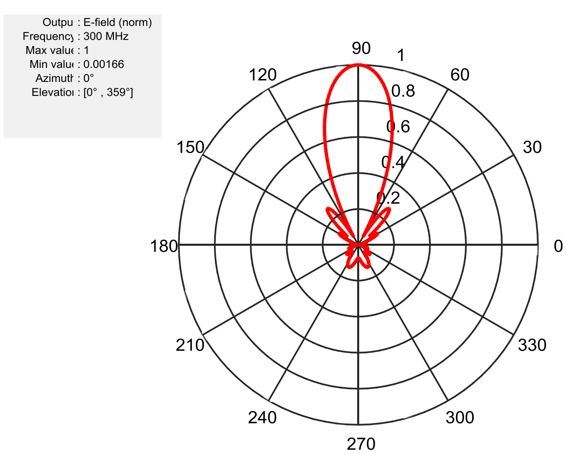


Figure 4.3.Plot of the normalized magnitude of the electric field in the E plane.

C. Field Test

The field test was carried in two different sites: open area (area with law vegetation) and thickly vegetated area (areas with high vegetation).

1. Signals Strength values at different ranges and locations.

The signal strength values of the received were measured at different location with and without the Yagi-Uda Antenna using a hand held signal strength meter and the values obtained are shown in Tables 4.1 (a & b), and 4.2 (a & b).

2. Open Area

Field test was carried out with a signal strength meter to measure the signal strength at intervals of 20, 40, 60, 80, and 100 meters and the values were recorded. Table 4.1(a) shows the values of signals measured at open area without the antenna. The signal was tracked up to 80 meters, no signal was observed at 100 meters. This was so because signal strength decreased with increased in distance covered, therefore, a well-designed antenna is required to enhance the signal strength for effective tracking in wild life radio applications.

Table 4.1(b) shows the values of signals measured at open area with the antenna. The maximum signal value recorded was 90% at 20 meters compared to 50.7% recorded at same distance without the antenna, a difference of about 39.3%. The signal strength was observedto extend up to 100 meters whereas without the antenna no signal was recorded at this range. This result shows the effectiveness of the constructed Yagi-Uda antenna for wild life tracking application. Figure 4.4a and Figure 4.4b shows the variations of signal strength with distance at open area with and without the antenna respectively. It can be clearly seen that the inclusion of the antenna greatly enhances the signal strength at the receiver.

3. Areas with Vegetation

In the same vein, Table 4.2a and Table 4.2b show the signal measurements at areas with thick vegetation. Without the antenna, the maximum value of signal strength was 25% at 20 meters, above 40 meters no signal was detected by the signal strength meter. With the antenna, the maximum signal strength was 62% at 20 meters, a difference of 37% compared to the one measured without the antenna. Signal strength was traceable up to 80 meters, and no signals at 100 meters.

Figure 4.5a and Figure 4.5b shows the variations of signal strength at areas with thick vegetation with and without the antenna respectively. The coverage when antenna was used was very appreciable. This result demonstrates the effectiveness of the constructed antenna in wild life radio tracking application.

Figure 4.6a and Figure 4.6b is the line graph representations of the signal strength variations at both open area and thickly vegetated areas with and without the antenna respectively. The signal coverage was observed to extend more when antenna was used. This result shows that the extension in signal coverage was as a result of the constructed BFA optimized Yagi- Uda antenna used.

Figure 4.7 shows the signal strength variation at both open and thickly vegetated areas without antenna. The maximum coverage was 50.7% in open and 25% at areas with vegetation. Similarly,

Figure 4.8 shows the signal strength variation at both locations with antenna. A maximum of 90% signal strength was recorded at an open area and 62% at areas with thick vegetation. This result compared to that in Figure 4.7 shows 39.3% increase in signal strength when antenna was used in open area and 37%

increase in signal strength when the antenna was used in areas with thick vegetation. The wider signal coverage was observed when the antenna was used than without the antenna.

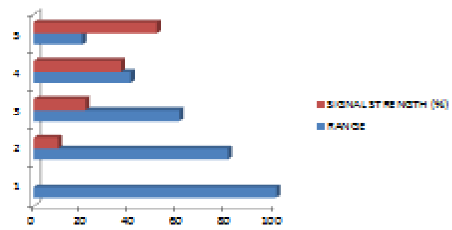
The maximum signal strength at both locations was recorded at 20 meters range. The plots of signal strength variation with distance between these locations show that signal strength decreased with increased in distance between the transmitter and the receiving antenna. The decreased in signal strength at areas with vegetation (VA), compared to that at open area (OA) agrees with Tamir's model of signal propagation in vegetation or forest areas. In general the result shows an increased in signal strength when the receiving antenna was used hence, proving the effectiveness of a well-designed antenna in VHF tracking application.

Table 4.1 (a) Signal strength values at open Area (OA) without antenna (WOA)

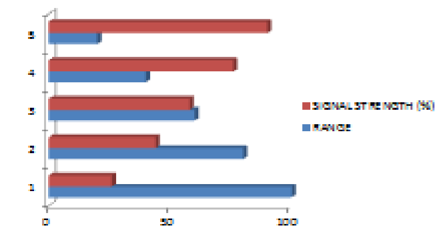
S/N	RANGE (m)	SIGNAL STRENGTH (%)	SIGNAL STRENGTH(dBm)
1	100	–	–
2	80	10	-103
3	60	21.3	-91
4	40	36	-75
5	20	50.7	-56

Table 4.1 (b) Signal strength values at open Area (OA) with antenna (WA)

S/N	RANGE (m)	SIGNAL STRENGTH (%)	SIGNAL STRENGTH(dBm)
1	100	26	-86
2	80	44	-65
3	60	58	-48
4	40	76	-32
5	20	90	-15



(a)



(b)

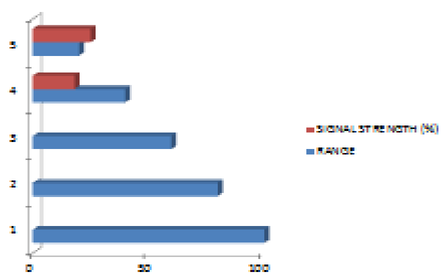
Figure 4.4 (a&b) Variation of signal strength with distance at both locations with and without antenna (WA)

Table 4.2 (a) Signal strength values at vegetation area (VA) without antenna (WOA)

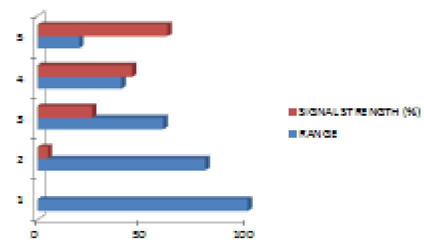
S/N	RANGE (m)	SIGNAL STRENGTH (%)	SIGNAL STRENGTH(dBm)
1	100	–	–
2	80	–	–
3	60	–	–
4	40	18	[illegible]
5	20	22	[illegible]

Table 4.2(b) Signal strength values at vegetation area (VA) with antenna (WA)

S/N	RANGE (m)	SIGNAL STRENGTH (%)	SIGNAL STRENGTH (dBm)
1	100	–	–
2	80	5	-108
3	60	26	-86
4	40	45	-64
5	20	62	-45



(a)



(b)

Figure 4.5 (a & b) Variation of signal strength with distance at areas with thick vegetation with and without antenna

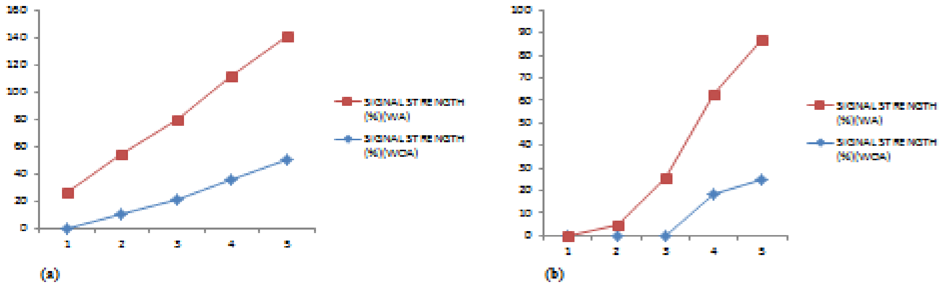


Figure 4.6 (a & b) signal strength variations at both open area and thickly vegetated areas with and without the antenna

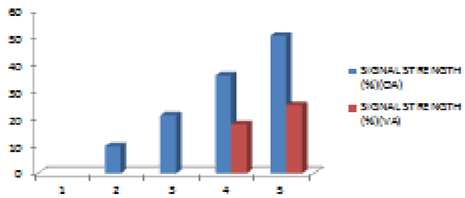
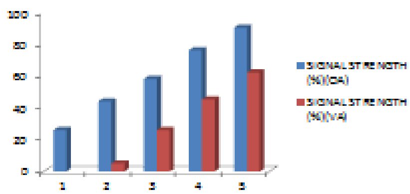


Figure 4.7 Signal Strength variations at both locations without antenna (WA)



Graph 4.8 Signal Strength variations at both locations with antenna (WA)

CONCLUSION

Fabrication of a BFA optimized 12-element Yagi-Uda antenna was successfully achieved in this work. Performance evaluation of the constructed BFA optimized Yagi-Uda antenna, and the simulation of the antenna parameters as well as field testing in open and thick vegetation areas were carried out. Results obtained shows that the maximum directivity of the antenna was 13.5dBi. From the field test in open area (areas with low vegetation) it was found that inclusion of the antenna increases the signal strength by an average of 39.3%. Also, in areas with thick vegetation area it was equally observed that inclusion of the antenna increases the signal by an average of 37%. From the result obtain, the constructed BFA optimized Yagi-Uda antenna was found to be effective for used in VHF radio tracking applications.

Recommendation

It is recommended that the constructed antenna should be utilized for wildlife radio tracking applications. Utilization of other optimization techniques in the design of Yagi-Udaantennas for wildlife tracking applications should also be considered in future research works.

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