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Development of Microstrip Patch as HDTV Antenna for Terrestrial Indoor TV Reception

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Abstract: This paper presents design, construction and analysis 4 by 2 corporate fed circular patches as High Definition Television (HDTV) antenna configuration for Ultra High Frequency (UHF) indoor reception. The single element was designed based on transmission line method. The single element radiation pattern is omnidirectional with high beamwidth of about 6dB and low gain of about2dBi which are poor for UHF television reception. As a result, single element patch was optimized to achieve 8elements which was arranged in 4 by 2 corporate fed circular patches as HDTV antenna configuration. By calculation, the 4 by 2 corporate fed circular patches antenna produced directional radiation pattern of low beamwidth of about 3dB and high gain of about 9dBi. The antenna was then fabricated by depositing resin of relative permittivity of 4.5 and thickness of 0.2cm using wet etching technique on un-galvanized aluminium of radius 2cm. The antenna's gains in passive and active modes were measured by Gain – Comparison Technique (GCT) with the aid of GSP 810 Spectrum Analyzer. The results obtained show that the peak gain at various frequencies in passive and active modes were 9, 8.83, 9, 8.99, 8.97dBi, at 487.6, 497.9, 531.4, 549.7, 566.9MHz, and 9.62, 11.23, 9.20, 8.99,8.97,9.09dBi, at 480.3, 499.1, 531.6, 549.7, 566.9,588.6MHz respectively.

Keywords: High Definition Television, Indoor, UHF Antenna, High gain

I. INTRODUCTION

An antenna is a metallic conductor that is cut into size and shape which radiates and receives electromagnetic waves effectively. The major function of an antenna is to couple radio waves in free space to an electrical current used by a radio receiver or transmitter. In reception, the antenna intercepts some of the power of electromagnetic waves in order to produce a tiny voltage that the radio receiver can amplify. Antennas are of different types based on their frequency of operation, application and characteristics [1] – [5]. Examples of the convectional antennas that are employed for Very High Frequency (VHF) and Ultra High Frequency (UHF) Television (TV) reception are Yagi-Uda, Log Periodic, Folded Dipole and Helix.

High definition Television (HDTV) antennas are the antennas that are incorporated to HDTV through card slot port at indoor reception [6] – [8]. In recent years HDTV has been popular due to high pixel level of picture and ability to interface with various memory elements with an inbuilt slot card. The beginning of terrestrial digital TV broadcasting may considerably reduce the need for on-roof, outdoor, remote control, directional antennas and increase the use of indoor antennas. Also, for the storming tropical weather conditions that usually destroy antenna's mast, high gain indoor antenna will be the best option. Moreover, the conventional outdoor antenna are pure electric field antennas, and hence, their performance is significantly deteriorated in vicinity of conductive objects such as concrete walls [9], [10]. In addition, the convectional Terrestrial antennas for receiving TV signal are quite large in size such that they are not suitable for indoor applications. However, the small and omnidirectional monopole antennas which could have been preferable as indoor antennas also have low gain, and an attempt to increase the gain will make the antenna size large [6] – [11].

This paper therefore presents the characteristics of the 4 by 2 corporate fed circular patch antenna designed and constructed as HDTV antenna for indoor applications at frequency range of 470MHz to 900MHz.

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II. MATERIALS AND METHODS

A. Design of the Antenna

From the literature review, the effective radius of circular patch is found by [1], [5], [10], [11]:

$$r = \frac{F}{\{1 + \frac{2h}{\pi \varepsilon_r F}[\ln(\frac{\pi F}{2h}) + 1.7726]\}^{1/2}} \qquad (1)$$

$$Where,\ F = \frac{8.791X10^9}{f_r \sqrt{\varepsilon_r}}$$

$$r = 2cm$$

The radiated field of the E-plane and H-plane for a single element circular patch can be expressed by [6]:

$$E_\theta = E_\theta - jV_o \frac{ak_o e^{-jk_o r}}{2r} \cos\theta J_1(k_o a \sin\theta) \qquad (2)$$

$$H_\theta = -jV_o \frac{ak_0 e^{-jk_o r}}{2r} \cos\theta J_1(k_o a \sin^2\theta) \qquad (3)$$

Where V_o is the voltage across radiating slot of the patch, which is 0.03934.
k_o is the wave number given by:

$$k_0 = \frac{2\pi}{\lambda} \qquad (4)$$

To determine the gain of a circular patch antenna some parameters need to be determined from [2]:
Where D = Directivity, e_r = radiation efficiency and G = gain.

$$G = e_r D \qquad (5)$$

The directivity of the circular patch antenna is given by [5}

$$D = \frac{K\,r}{120Grad} \qquad (6)$$

Where, Grad = $\frac{K\,r}{480}$

$G_{rad} = 6.09 \times 10^{-1}$

Therefore, D = 1.16dB

$$e_r = \frac{R_r}{R_{in}} \qquad (7)$$

Where R_r= Radiation resistance and R_{in}= input resistance

$$R_{in} = 9.54\Omega \qquad R_r = 16.42\Omega \qquad e_r = 1.72 \qquad G = 2dB$$

The single element has gain of 2dB and is omnidirectiona with broad beamwidth as shown in the Figure 1. This gain is low to receive signal at UHF band. Then the array of the single patch is formed based on the equation [7]:

$$N = \frac{BW(desired)}{BW(\sin gle\ \ element)} \qquad (8)$$

To determine the bandwidth of a single circular patch element, it was discovered that the fractional bandwidth of the circular patch is inversely proportional to the total Quality factor Q_t [6]. The quality factor is a figure of merit which is

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a representative of three antenna losses. Typically radiation, conduction (ohmic) and dielectric, the summation of which gives the total quality factor Q_t, which is influenced by all these loses.

Qt=Q_{rad} -1 + Q_C-1 + Q_d-1, Q_c =h$\sqrt{\pi f \mu \sigma}$, Q_c = 3.16x10^{-3}, Q=$\frac{1}{\tan \delta}$

$$Q_{rad^{-1}} = 1.10395 \times 10^{-13}$$

$$Q_t = 3.16\,x\,10^{-3}$$

Single element bandwidth = 316.46

$$Desired \quad \text{bandwidth} = 1.2\left(\frac{\text{h}}{\tau}\right) \qquad (9)$$

Where, τ = Surface wave losses

$$\tau = 9\,x\,10^{-5}$$

Bandwidth = 2666.66

N = $\frac{2666.66}{316.46}$

N= 8 elements

Circular patches with 8elements are arranged in an array in which each row and column of array consisting of 4 by 2.

W = Width of the patch

W =1.5L, L=23cm

D = 5.06dB

$$D = 4\left(\frac{W}{\lambda_o}\right) \qquad (10)$$

$$G = e_r D$$

Therefore, G = 9.0dB

$$Af = A_0 \frac{Sin\left(N \sin \psi/2\right)}{NSin\left(\psi/2\right)} \qquad (11)$$

The array factor deduced is then multiplied with E-field and H-field in equation 3 and 4 to generate array radiation pattern as shown in the figure 2.

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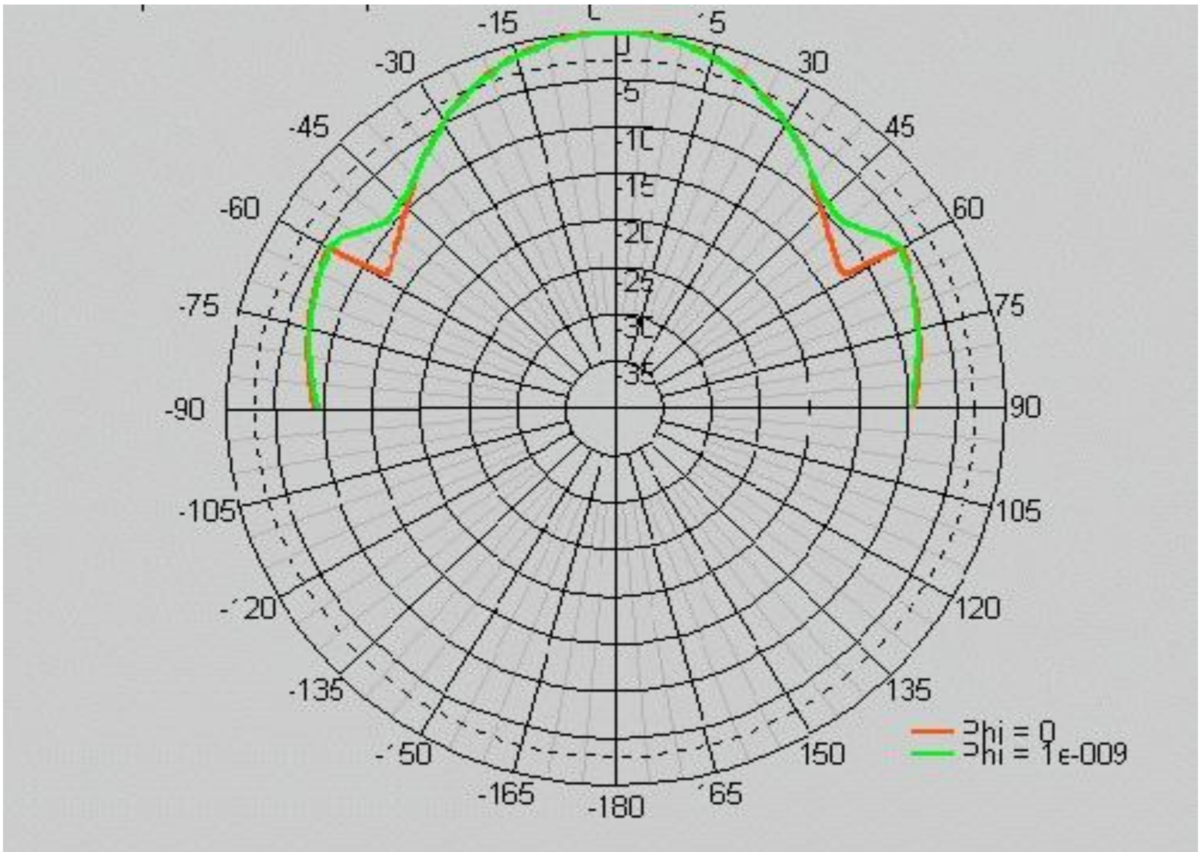

Fig. 1: showing the E and H radiation pattern of a single element microstrip patch.

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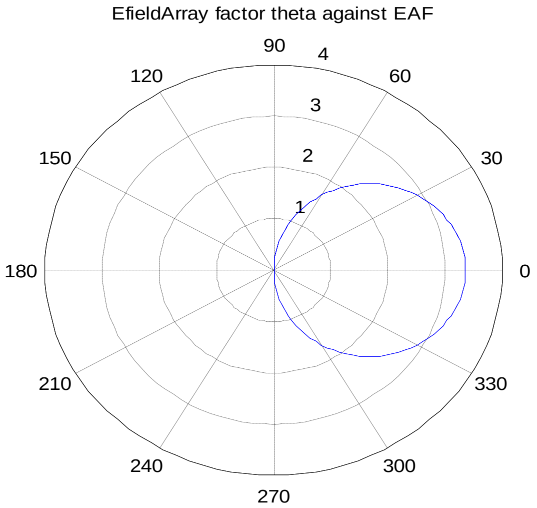

Fig. 2: showing the E-field and H-field of the 8elements array.

B. Construction and Experimental Measurement of the Antenna's Characteristics

The un-galvanized aluminium plate was cut into circular diameter of 4cm each using lathe machine. Then the edge of the circular patch was smoothened using a metal file. The thickness of the patch was measured using micrometer screw gauge 0.28mm. After this, 2grams of plaster of Paris (POP) was evenly mixed with resin(C19H29COOH) inside a glass slide using capillary rod for stirring.

Two drops of accelerator Stanum Chloride ($SnCl_2$) were added to the mixture followed by 2ml of catalyst. 50Ω coaxial cable was screwed with each of the patch for proper ohmic contact. The mixed chemical was then applied on the surface of each circular patch metal immediately using a tiny brush and was left for five minutes to dry. The etched patch was then arranged on a drilled wood using corporate fed method. The wood was drilled using hand drilling machine of one and half inches bits. Then circular patch was then fixed into each holes made with hand drilling machine on the wood. There after coaxial cable was then connected from one patch to another and then coupled together with couplers to form corporate feed arrangement which was later covered at the back with a fiber glass. The front view of the newly constructed antenna configuration is shown in the Figure 3, and the back view is shown in the Figure 4. After the construction, the new antenna was put on test in the passive mode which was later made active by inclusion of amplifier circuit to increase the power received level.

Experimental measurements were carried out indoor to measure the passive and active modes signal power received by the new antenna under test (*AUT*), a folded dipole array (Standard Century WA-10000TG) and existing linear dipole as standard antennas (*SA*) with the aid of GSP-810 spectrum analyzer. The gain, *G* of the new antenna was determined using Gain-Comparison technique (GCT) given by the formula [12]:

$$G_{AUT} = G_{SA} + 10\log_{10}\left(\frac{P_{R(AUT)}}{P_{R(SA)}}\right), \qquad \text{dB} \qquad (20)$$

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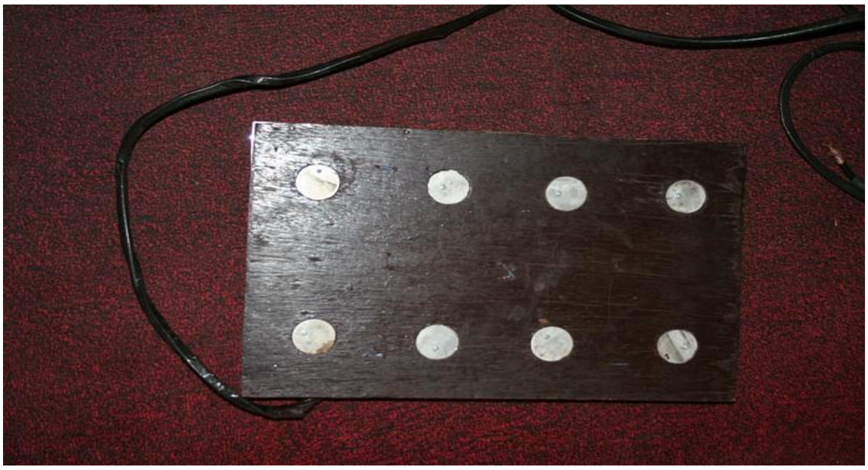

Fig.3: showing the front view of the active microstrip patch antenna

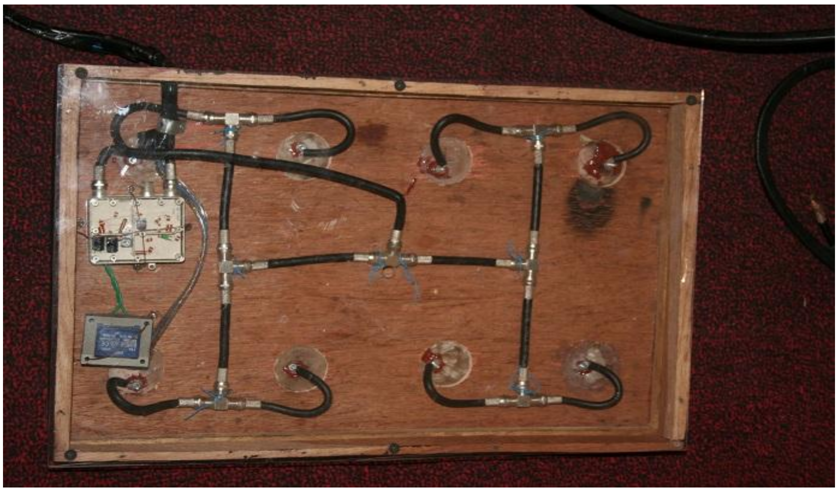

Fig. 4: Sowing the backview of active microstrip patch antenna

III. RESULTS AND DISCUSSION

High definition television (HDTV) antennas are the antennas that are incorporated to HDTV through card slot port at indoor reception. In recent years HDTV has been popular due to high pixel level of picture and ability to interface with various memory elements with an inbuilt slot card. The antenna was designed, constructed, and analysed for the frequency range of 470MHz to 900MHz. The single element designed was carried out using transmission line method to compute the various parameters. The simulation process was done using matlab 2009 version with single element radiation pattern demonstrated omnidirectional property with high beamwidth (~6dB) as shown in the Figure 1, and low gain of 2dBi.

All the properties exhibited by single element were not enough for ultra high frequency (UHF) Television reception. As a result, single element patch was optimized to achieve 8elements which was arranged in 4 by 2 corporate fed circular

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patch HDTV antenna configuration. Hence, from the computation, the new designed antenna produced directional radiation pattern of low beamwidth (~3dB) as shown in the Figure 2and high gain of ~9dBi. The antenna was fabricated by depositing resin of relative permittivity, $\varepsilon_r = 4.5$ and thickness of 0.2cm using wet etching technique on un-galvanized aluminium of radius 2cm.The new 4 by 2 corporate fed circular patch HDTV antenna configuration is shown in the figures 3 and 4.

Experimental measurement was carried out by Gain-Comparison technique (GCT) in passive and active modes to determine the new antenna gain. A standard folded dipole array (Century WA-10000TG) and existing linear dipole were employed as standard antennas. Figures 5 and 6 are the plots of the power received versus frequency under passive and active conditions by the new antenna under test (AUT), and existing standard antennas: folded dipole array and linear dipole for compare and performance evaluation. The results obtained show that the peak gain at various frequencies in passive and active modes were 9, 8.83, 9, 8.99, 8.97dBi, at 487.6, 497.9, 531.4, 549.7, 566.9MHz, and 9.62, 11.23, 9.20, 8.99,8.97,9.09dBi, at 480.3, 499.1, 531.6, 549.7, 566.9,588.6MHz respectively as shown in the Figure 7.

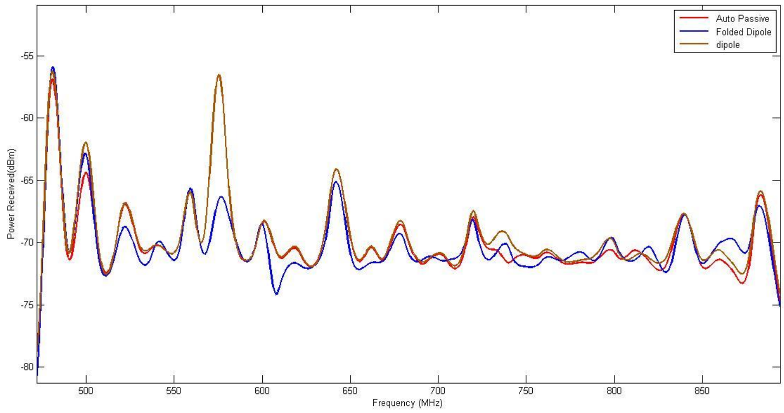

Fig. 5: Showing the graph of signal power received (in dBm) against the frequency (in MHz) by AUT(passive), linear dipole and folded dipole.

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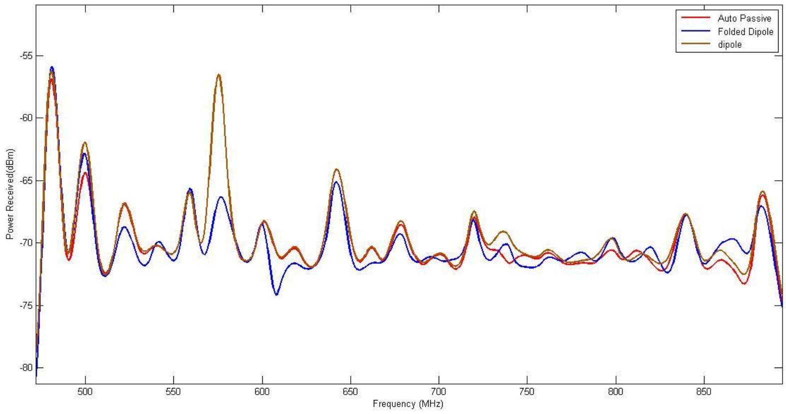

Fig. 6: Showing the graph of signal power received against the frequency by AUT (active) linear dipole and folded dipole.

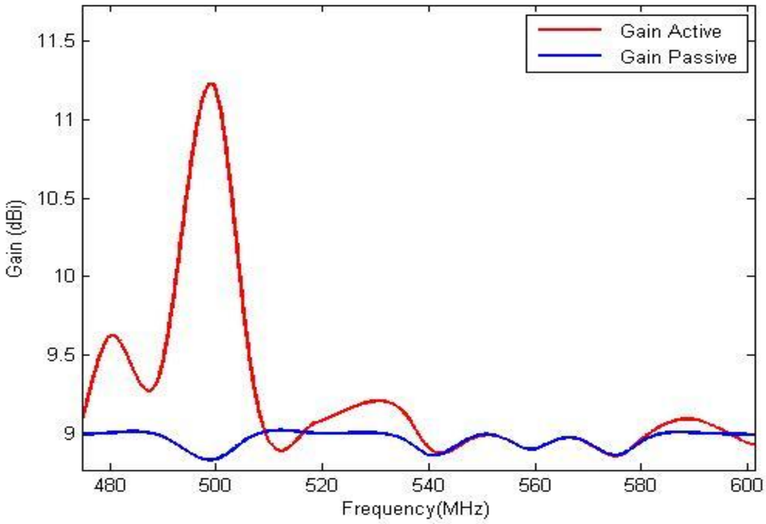

Fig. 7: Showing the graph of gain against frequency for AUT under active and passive modes.

IV. CONCLUSION

A new HDTV microstrip patch antenna has been presented. The antenna has been designed and constructed for terrestrial TV reception. The designed has been done using transmission line method, and matlab 2009 version for calculation. The new antenna has shown good performance in terms of gain and radiation pattern. There is good agreement between design caculation and experimental measurement results, providing validation of the design procedure. The antenna will be useful as HDTV indoor antenna.

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REFERENCES

[1] Milligan T. A., ''Modern Antenna Technology'', 2nd edition, John Willey & sons, New Jersey and Canada, 2005.
[2] Heng-Tung.H, James .C. R and San-wen. C., ''Novel planar Wideband omni-directional Quasi Log-periodic Antenna'', IEEE, 59:824-827, 2005.
[3] Jeng B.M Lee.C.M and Luo C.H ., "Multiple – ring monopole Antenna with sleeve – shaped ground for DVB – T Application'', Progress in Electromagnetic research.14:155-161, 2010.
[4] Karim M.N.A, Rahim M.K.A, Majid H.A, Ayop. O, Abu M. and Zubir F., ''Log periodic fractal Koch Antenna for UHF Band Applications'', Progress in Electromagnetic research.100:201-218, 2010.
[5] Kwaha B.J, Inyang O. N & Amalu.P., ''The circular microstrip patch antenna – Design and Implementation". International Journal of research and review of applied sciences, 8 171-187, 2011.
[6] Li.X and Liao.J., ''Eye-shaped segmented Reader Antenna for Near-field UHF RFID Applications'', Progress in Electromagnetic Research.114: 481-493, 2011.
[7] Anitha V. R and Narayana R. S., ''Design of an 8X1 square Microstrip patch Antenna Array'', International journal of Electronic Engineering research 1 (1): 71-77, 2009.
[8] Mohamed .S and Noha .H., ''A novel internal Dual-polarized EBG Antenna for indoor reception of UHF Terrestial Digital TV Broadcasting'', International journal of microwave science and technology 2012:1155-2012, 2012.
[9] Ollikainen.J and Vainikainen .P., ''Radiation and Bandwidth characteristics of two planar multistrip Antennas for mobile communication systems'', Vehicular Technology conference, Ottawa, Ontario, Canada, 2: 1186-1190, 1998.
[10] Sarabandi.k, Azadegan.R., ''Design of an efficient miniaturized UHF planar Antenna'', IEEE Transactions on Antenna and propagation, 51(6):43-54, 2003.
[11] Zhi N.C. and Michale Y.W.C., ''Broadband planar-Antennas Design and Applications. 1st edition, John Willey & sons chichester England, 2005.
[12] Alade .O.M., ''On the antenna formula'', International Journal of Applied Science and Technology, 3(1): 43 – 49, 2013.

BIOGRAPHY

Alade Olusope Michael was born in Nigeria, in 1970. He received the B.Sc, M.Sc degrees from University of Jos, Nigeria in 1994 and 1998 respectively. Also, he received the Ph.D from Ladoke Akintola University of Technology, Nigeria in 2005. His research interests include design, construction and analysis of electronic devices; and radio wave propagations. From 2010 to till date he is working as Associate Professor of Communication Physics.

Olabisi Olusegun was born in Nigeria, in 1974. He obtained his first degree in pure and applied physics (Electronics option) in 2002 from Ladoke Akintola University of technology, Ogbomoso, Nigeria. In 2008, he graduated with distinction in M.Tech degree in Electronics and communication physics from the same institution. He is currently pursuing his PhD in electronics and communication physics. He is a lecturer II in the department of science laboratory technology, in the same institution.