



A Comparative Study of the Effect of Variation of Resonant Frequency and Substrate Height on the Performance of a Designed Circular Microstrip Patch Antenna

B. J. Kwaha, [†]A. M. Batu

Department of Physics, University of Jos, Nigeria.

[†]Department of Science and Technology, Kaduna Polytechnic, Nigeria

ABSTRACT

This research compares the effects, on performance, of changing resonant frequency and height of substrates in the design and implementation of a circular microstrip patch antennas adaptable to microwave frequencies. Computations and simulations using a program developed in FORTRAN were done based on the cavity model. Alongside these, other parameters viz actual and effective patch radii, conductance, directivity, input resistance and quality factor, which dictate the ultimate performance of the antenna were also determined. It was observed that patch radius decreases as the required resonant frequency increases (0.2374cm at 10.0GHz and 0.05079 cm at 45.0GHz for GaAs). Directivity was seen to increase with resonant frequency, but at the expense of increase in conduction and dielectric losses. Radiation losses were observed to have reduced with increase in resonant frequency, which translates to the slight increase in the radiation conductance. Also, as the substrate height increases, the physical patch radius decreased, but the effective radius increases. This increase in effective radius implies that there is an increased fringing (radiation). It was also deduced that directivity increases with increase in substrate height, but at the expense of loading effect. A lower radiation conductance loss was observed at higher substrate height, but at the expense of increasing losses due to surface wave. The results obtained in this design compare favorably with results obtained from manual computation of the same parameters and these agree with other designs such as the rectangular patch.

Keywords: *Effect of Resonant Frequency, Height on Microstrip Patch Antenna*

1. INTRODUCTION

Microstrip antennas basically consist of a radiating patch on one side of a dielectric substrate, which has a ground plane on the other side. The patch is generally made of conducting material such as copper and gold [6]. The patch is very thin ($t \ll \lambda_0$ where λ_0 is free space wavelength) and is placed a small fraction of a wavelength ($h \ll \lambda_0$ usually $0.003 \lambda_0 \leq h \leq 0.05 \lambda_0$) above the ground plane. The microstrip patch is designed so its radiation pattern (maximum) is normal to the patch (broadside radiator). This is accomplished by properly choosing the mode (field configuration) of excitation beneath the patch. There are numerous substrates that can be used for the design of microstrip patch antennas and their dielectric constants are usually in the range of $2.2 \leq \epsilon_r \leq 12$. Those desirable for antenna performance are thick substrates whose dielectric constant are in the lower end of the range due to better efficiency, larger bandwidth, and loosely bound fields for radiation into space but at the expense of larger element size. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. The radiation increases with frequency, thicker substrates, lower permittivity, and originates mostly at discontinuities (Lewin, 1960)

Since microstrip antennas are often integrated with other microwave circuitry, a compromise has to be reached between good antenna performance and circuit design. The radiating element and the feed lines are usually photo etched on the dielectric substrate. The radiating patch may be square, rectangle, thin strip (dipole), circular, elliptical, triangle or any other configuration. A microstrip antenna is very versatile and made for a wide range of resonant frequencies, polarization

patterns and impedances. Due to its operational features viz low efficiency, low power, high quality factor, poor polarization purity, poor scan performance and very narrow frequency bandwidth, it is suitable for mobile and government security systems where narrow bandwidth are priority. They are also used on laptops, microcomputers, mobile phones etc [6].

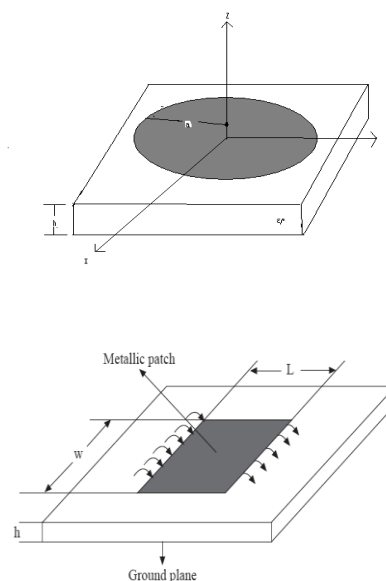


Fig 1: Circular and Rectangular Patches of Microstrip Antennas



2. METHODS OF ANALYSIS

[5] and [4] presented three main models for the analysis of microstrip antennas - viz transmission line model, cavity model, and full wave model. The transmission line model is the simplest. It gives a good physical insight but is less accurate. The cavity model, which is used in this work, is quite complex but gives good physical insight and is more accurate. The full wave model is the most complex. It is very accurate in the design of finite and infinite arrays or stacked structures.

The quantity associated with radiated EM wave is the Poynting vector given as[2]:

$$S = E \times H \tag{1}$$

where S is instantaneous Poynting vector, E is instantaneous electric field intensity and H is instantaneous magnetic field intensity. The complex fields E and H are related to their instantaneous counterparts by [5], [4]:

$$\left. \begin{aligned} E(x, y, z, t) &= \text{Re}[E(x, y, z)e^{i\omega t}] \\ H(x, y, z, t) &= \text{Re}[H(x, y, z)e^{i\omega t}] \end{aligned} \right\} \tag{2}$$

Using and the identity $\text{Re}[Xe^{i\omega t}] = \frac{1}{2}[Xe^{i\omega t} + X^*e^{-i\omega t}]$ equation (1) can be rewritten as;

$$S = \frac{1}{2} \text{Re}[E \times H^*] + \frac{1}{2} \text{Re}[E \times H e^{i\omega t}] \tag{3}$$

Hence, the time average Poynting vector can be written as [4], [1]:

$$S_{av} = \frac{1}{2} \text{Re}[E \times H] \quad Wm^{-2} \tag{4}$$

The factor 1/2 appears because the E and H fields are peak values and not rms.

This research aims to compare the effects of changing resonant frequency and height of substrates in the design and implementation of a circular microstrip patch antennas adaptable to microwave frequencies.

3. CIRCULAR PATCH AND FIELD CONFIGURATION

The mode supported by the circular patch antenna can be found by treating the patch, ground plane and the material between the two as a circular cavity. The radius of the patch is the only degree of freedom to control the modes of the antenna [2]. The antenna can be conveniently analyzed using the cavity model [5], [4]. The cavity is composed of two electric conductors at the top and the bottom to represent the patch and the ground plane and by a cylindrical perfect magnetic conductor around the circular periphery of the cavity. The

dielectric material of the substrate is assumed to be truncated beyond the extent of the patch [5].

The field configuration within the cavity can be found using the vector potential. The magnetic vector potential A_z must satisfy, the homogeneous wave equation [2]:

$$\nabla^2 A_z(\rho, \phi, z) + k^2 A_z(\rho, \phi, z) = 0 \tag{5}$$

whose solution is written as:

$$A_x = B_{mnp} J_m(k_\rho \rho') [A_2 \cos(m\phi') + B_2 \sin(m\phi')] \cos(k_z z') \tag{6}$$

with constraint equation of

$$(k_\rho)^2 + (k_z)^2 = k_r^2 = \omega_r^2 \mu \epsilon \tag{7}$$

The electric and magnetic fields are related to the vector potential A_z by [2]:

$$E_\rho = -j \frac{1}{\omega \mu \epsilon} \frac{\partial^2 A_z}{\partial \rho \partial z} \quad H_\rho = \frac{1}{\mu} \frac{1}{\rho} \frac{\partial A_z}{\partial \phi} \tag{8a}$$

$$E_\phi = -j \frac{1}{\omega \mu \epsilon} \frac{1}{\rho} \frac{\partial^2 A_z}{\partial \rho \partial z} \quad H_\phi = -\frac{1}{\mu} \frac{\partial A_z}{\partial \rho_x} \tag{8b}$$

$$E_\rho = -j \frac{1}{\omega \mu \epsilon} \left(\frac{\partial^2}{\partial z^2} + k^2 \right) A_z \quad H_z = 0 \tag{8c}$$

These are subjected to the boundary conditions of [2], [5], [4]:

$$\begin{aligned} E_\rho(0 \leq \rho' \leq a, 0 \leq \phi' \leq 2\pi, z' = 0) &= 0 \\ E_\rho(0 \leq \rho' \leq a, 0 \leq \phi' \leq 2\pi, z' = h) &= 0 \\ H_\phi(\rho' = a, 0 \leq a, 0 \leq \phi' \leq 2\pi, 0 \leq z' \leq h) &= 0 \end{aligned} \tag{9}$$

The primed coordinates ρ', ϕ', z' are used to represent the fields within the cavity while $J_m(x)$ is the Bessel function of the first order.

$$k_\rho = X'_{mn} / a \tag{10a}$$

$$k_z = \frac{p\pi}{h} \tag{10b}$$

where $m = 0, 1, 2, \dots$, $n = 1, 2, 3, \dots$ and $p = 0, 1, 2, \dots$



X'_{mn} represents the zeroes of the derivative of the Bessel function $J_m(x)$ and they determine the order of the resonant frequencies. The resonant frequencies of the cavity, and thus the microstrip antenna are found using (7) and (10). For typical microstrip antennas, the substrate height is very small, the fields along z are essentially constant ($p = 0$ and $k_z = 0$). Therefore the resonant frequencies for the TM_{mn0} modes can be written as [5], [4]:

$$(f_r)_{mn0} = \frac{1}{2\pi\sqrt{\mu\epsilon}} \left(\frac{X'_{mn}}{a} \right) \quad (11)$$

The field radiated by the circular patch can be found by using the Equivalence principle whereby the circumferential wall of the cavity is replaced by an equivalent magnetic current density radiating in free space. Based on cavity model and assuming a TM_{110}^z mode field's distribution beneath the patch, the normalized electric and magnetic fields within the cavity for the cosine azimuthal variations can be written as [2], [3]

$$E_p = E_\phi = H_z = 0, \quad E_z = E_o j_1(kp^1) \cos \phi^1 \quad (12a)$$

$$H_p = j \frac{E_o}{\omega\mu^o} = \frac{1}{p} j_1(kp^1) \sin \phi^1,$$

$$H_\phi = j \frac{E_o}{\omega\mu^o} j_1(kp^1) \cos \phi^1 \quad (12b)$$

Where $\phi^1 = \partial / \partial p$ and ϕ^1 is the azimuthal angle along the perimeter of the patch.

Based on (12a) evaluated at the electrical equivalent edge of the disk ($p^1 = a_e$), the magnetic current density can be written as [2], [3]

$$M_s = -2 \hat{n} \times E_a / p^1 = a_e = a_\phi 2E_o J_1(ka_e) \cos \phi^1 \quad (13)$$

Since the height of the substrate is very small and the current density of (6) is uniform along the z direction, we can approximate (13) by a filamentary magnetic current of [2]:

$$I_m = hM_s = \partial_\phi 2hE_o J_1(ka_e) \cos \phi^1 = \partial_\phi 2V_o \cos \phi^1 \quad (14)$$

where $V_o = hE_o J_1(ka_e)$ at $\phi^1 = 0$. The microstrip antenna can now be treated as a circular loop. And using the radiation equations we can write [2], [3]

$$E_r = 0 \quad (15a)$$

$$E_\theta = -j \frac{k_o a^e V_o e^{-jk_o r}}{2r} \{ \cos \phi j_{102} \} \quad (15b)$$

$$E_\phi = j \frac{k_o a^e V_o e^{-jk_o r}}{2r} \{ \cos \theta \sin \phi j_{02} \} \quad (15c)$$

$$J_{102}^1 = J_o(k_o a^e \sin \theta) - (k_o a^e \sin \theta) \quad (15d)$$

$$J_{02} = J_o(k_o a^e \sin \theta) + (k_o a^e \sin \theta) \quad (15e)$$

where a_e is the effective radius. The fields in the principal planes reduces to [2]:

$$E - plane (\phi = 0^\circ, 180^\circ, 0^\circ \leq \theta \leq 90^\circ)$$

$$E_\theta = j \frac{k_o a_e V_o e^{-jk_o r}}{2r} \{ j_{102}^1 \} \quad (16a)$$

$$E_\phi = 0 \quad (16b)$$

$$E_\phi = j \frac{k_o a_e V_o e^{-jk_o r}}{2r} \{ \cos \theta j_{02} \} \quad (16c)$$

4. DESIGN ANALYSIS OF CIRCULAR PATCH MICROSTRIP ANTENNA

4.1 Circular Patch Radius and Effective Radius

Since the dimension of the patch is treated a circular loop, the actual radius of the patch is given by [2]:

$$a = \frac{F}{\left\{ 1 + \frac{2h}{\pi\epsilon_r F} \left[\ln \left(\frac{\pi F}{2h} \right) + 1.7726 \right] \right\}^{1/2}} \quad (17)$$

$$F = \frac{8.791 \times 10^9}{f_r \sqrt{\epsilon_r}}$$



Equation (17) does not take into consideration the fringing effect. Since fringing makes the patch electrically larger, the effective radius of patch is used and is given by [2]:

$$a_e = a \left\{ 1 + \frac{2h}{\pi \epsilon_r a} \left[\ln \left(\frac{\pi a}{2h} \right) + 1.7726 \right] \right\}^{1/2} \tag{18}$$

Hence, the resonant frequency for the dominant TM_{110}^z is given by [2]:

$$(f_r)_{110} = \frac{1.8412 v_0}{2 \pi a_e \sqrt{\epsilon_r}} \tag{19}$$

where v_0 is the free space speed of light.

4.2 Conductance

The conductance due to the radiated power of the circular microstrip patch antenna can be computed based on the the radiated power expressed as [2]:

$$P_{rad} = |V_0|^2 \frac{(k_0 a_e)^2}{960} \int_0^{\pi/2} [J_{02}'^2 + \cos^2 \theta J_{02}^2] \sin \theta d\theta \tag{20a}$$

equation (20a) can be further broken down to:

$$P_{rad} = |V_0|^2 \frac{(k_0 a_e)^2}{960} \left\{ \left[1 - \frac{3}{2^3} \alpha^2 \sin^2 \theta + \frac{1}{3 \times 2^3} \alpha^4 \sin^4 \theta - \frac{7}{12 \times 2^{10}} \alpha^6 \sin^6 \theta \right] + 0.333 \left[1 - \frac{3}{2^3} \alpha^2 \sin^2 \theta + \frac{1}{3 \times 2^3} \alpha^4 \sin^4 \theta - \frac{7}{12 \times 2^{10}} \alpha^6 \sin^6 \theta \right] \right\} \tag{20b}$$

Where $V_0 = h E_0 J_1(k a_e)$, $\alpha = k_0 a_e$ and $k_0 = \frac{2 \pi f_r}{v_0}$

$$\tag{21}$$

k_0 is the free space phase constant. The conductance across the gap between the patch and the ground plane at $\phi^z=0^\circ$ is given as [2]:

$$G_{rad} = \frac{(k_0 a_e)^2}{480} \int_0^{\pi/2} [J_{02}'^2 + \cos^2 \theta J_{02}^2] \sin \theta d\theta \tag{22}$$

Equation (22) further reduces to:

$$G_{rad} = \frac{(k_0 a_e)^2}{480} \left\{ \left[1 - \frac{3}{2^3} \alpha^2 \sin^2 \theta + \frac{1}{3 \times 2^3} \alpha^4 \sin^4 \theta - \frac{7}{12 \times 2^{10}} \alpha^6 \sin^6 \theta \right] + 0.333 \left[1 - \frac{3}{2^3} \alpha^2 \sin^2 \theta + \frac{1}{3 \times 2^3} \alpha^4 \sin^4 \theta - \frac{7}{12 \times 2^{10}} \alpha^6 \sin^6 \theta \right] \right\} \tag{23}$$

G_{rad} accounts for radiation and dielectric losses and are expressed as [2]:

$$G_c = \frac{\epsilon_{mo} \pi (\pi \mu_0 (f_r)_{110})^{-3/2} [(k a_e)^2 - m^2]}{4 h^2 \sqrt{\sigma}} \tag{24}$$

$$G_d = \frac{\epsilon_{mo} \tan \delta}{4 \mu_0 h (f_r)_{110}} [(k a_e)^2 - m^2] \tag{25}$$

where G_c is the conductance due to conduction losses, G_d is the conductance due to dielectric losses and f_r is the resonant frequency of the dominant mode. The total conductance can be expressed as

$$G_t = G_{rad} + G_c + G_d \tag{26}$$

The conductivity of the substrate, $\sigma = \frac{G_l}{A}$, and skin dept,

$$\delta = \sqrt{\frac{2}{\omega \mu_0 \sigma}} \tag{27}$$

4.3 Directivity

For all antennas the directivity is one of the most important figures -of -merit, and is given as [2];

$$D_0 = \frac{U_{max}}{U_0} = \frac{4 \pi U_{max}}{P_{rad}} \tag{28a}$$

Considering the electric field from (15), the maximum radiation intensity and radiated power in (20), the directivity of a single slot may be written as [2]:

$$D_0 = \frac{(k_0 a_e)^2}{120 G_{rad}} \tag{28b}$$



This directivity is not strongly influenced by height of substrate as long as it is maintained electrically small. It is a function of patch radius.

4.4 Resonant Input Impedance

The input impedance of a circular patch at resonance is real and the input power is independent of the feed point position on the circumference [2]. Taking the reference of the feed point at $\phi' = 0^\circ$, the input resistance at any radial distance

$\rho' = \rho_0$ from the center of the patch can be written as [2]:

$$R_m(\rho' = \rho_0) = \frac{1}{G_t} \frac{J_m^2(k\rho_0)}{J_m^2(ka_e)} \quad (29)$$

For the circular patch antenna, the resonant input resistance with an inset feed is [2]:

$$R_m(\rho' = \rho_0) = R_{in}(\rho' = a_e) \frac{J_m^2(k\rho_0)}{J_m^2(ka_e)}$$

$$R_m(\rho' = a_e) = \frac{1}{G_t} \quad (30)$$

where the radial distance is given as:

$$\rho = \frac{2(2a)}{\lambda} \quad (31)$$

For thick elements (substrate), reactance may be significant and needs to be taken into account in impedance matching and in determining the resonant frequency of a loaded element. [5]

4.5 Quality Factor

The quality factor is a figure of merit that is representative of the antenna losses. Typically there are radiation, conduction (ohmic), dielectric and surface wave losses. The summation of which gives the total quality factor Q_t , which is influenced by all these losses.

$$Q_t^{-1} = Q_{rad}^{-1} + Q_c^{-1} + Q_d^{-1} + Q_{sw}^{-1} \quad (32)$$

For very thin substrates, losses due to surface waves (Q_{sw}^{-1}) are very small and can be neglected.

For such substrates ($h \ll \lambda_0$) and may be represented as

$$Q_c^{-1} = h\sqrt{\pi f \mu \sigma} \quad (33)$$

$$Q_d^{-1} = \frac{1}{\tan \delta} \quad (34)$$

$$Q_{rad}^{-1} = \frac{2\omega\epsilon_r}{h\left(\frac{G_{rad}}{2a}\right)} \left(\frac{a}{2}\right) \quad (35)$$

Tan δ is the loss tangent of the substrate material, σ is the conductivity of the conductors associated with the patch and ground plane and $G_t/2a$ is the total conductance per unit length of the radiating aperture. G_{rad} is usually the dominant factor since it is inversely proportional to the patch height.

5. PROGRAM DESIGN AND SIMULATION

The program written in FORTRAN using WATFORT g77 compiler was developed based on equations (17) to (35). The program was run on the DOS mode and results exported to Microsoft word. The main program reads in the microstrip parameters then determines the ideal radiation characteristics.

5.1 Input Parameters

ϵ_r = dielectric constant of substrate

f_r = resonant frequency of substrate

h = height of substrate

v_0 = Speed due to free space = 3×10^{10} cm/s

μ_0 = Permittivity due to free space = $4\pi \times 10^{-3}$ H/cm

5.2 Output Parameters

a = The radius of patch

a_e = The effective radius of patch

G_{rad} = Conduc tan ce between gap and ground

G_d = Conduc tan ce due to dielectric

G_t = Total conduc tan ce

D_0 = Directivity of slot ($\phi = 0^\circ$)

$R_{in}(\rho' = \rho_0)$ = Re sonant input resis tan ce ($\phi = 0^\circ$)

Q_c^{-1} = Quality factor due to conduction (Ohmic) losses

Q_d^{-1} = Quality factor due to dielectric losses

Q_{rad}^{-1} = Quality factor due to radiation (space wave) losses

The radius of patch is obtained from equation 17. The effective patch radius is given in equation 18. Radiation power is given in equation 20. Radiation conductance is given in equation 23.

The voltage across gap is $V_0 = hE_0 J_1(ka_e)$ (for $\theta = 90^\circ$).



Conductivity of the substrate and the skin depth are given in equation 27. The resonant frequency is given in equation 19. Conductance due to radiation loss of equation 24 is:

$$G_c = \frac{\epsilon_{mo} \pi (\pi \mu_0 (f_r)_{10})^{-3/2}}{4h^2 \sqrt{\sigma}} [(ka_e)^2 - m^2].$$

The total conductance is given in equation 26. The directivity of a slot is given in equation 28. The resonant input impedance is given in equation 30. The total radial distance is given in equation 31 and the quality factors are given in equations 33, 34 and 35.

In an earlier research on the design and implementation of circular microstrip patch antenna, a similar program was run alongside manual computation to compare for efficacy and also to determine the parameters for the other three substrates [7]. The parameters - viz - radius, effective radius, conductance of slot, conductance between gap and ground, conductance due to conduction, conductance due to dielectric, total conductance, directivity of slot, resonant input resistance, quality factor due to conduction, quality factor due to dielectric, quality factor due to radiation of a circular patch microstrip patch antenna using different substrates were first determined using the same resonant frequency and at the same substrate height. These parameters were then considered under a different resonant frequency and height.

Table 1: Comparison of Computed Parameters of Some Selected Substrates at the Same Frequency and Height

($f_r = 10.0e9$, $h = 0.1$ cm)

Characteristics	Silicon $\epsilon_r = 11.80$	Duroid $\epsilon_r = 2.20$	GaAs $\epsilon_r = 12.90$	InP $\epsilon_r = 112$
A	0.2478	0.5421	0.2374	0.2419
a_e	0.2561	0.5960	0.2449	0.2498
G_1	0.0007155	0.002227	0.0006607	0.0006845
G_{rad}	0.0007155	0.002227	0.0006607	0.0006845
G_c	1.8092×10^{-10}	1.5429×10^{-10}	1.8423×10^{-10}	1.8275×10^{-10}
G_d	3.1565×10^{-13}	2.6855×10^{-13}	3.2145×10^{-13}	3.1885×10^{-13}
G_t	0.0007155	0.002227	0.0006607	0.0006845
D_o	3.3507	5.8305	3.3187	3.3325
R_{in}	1433.34	386.62	1552.20	1498.15
Q_c^{-1}	0.01174	0.009841	0.01196	0.01186
Q_d^{-1}	2.0488×10^{-5}	1.7175×10^{-5}	2.0869×10^{-5}	2.0698×10^{-5}
Q_{rad}^{-1}	7.8587×10^{-16}	2.7417×10^{-15}	7.2311×10^{-16}	7.5037×10^{-16}


Table 2: Effect of Variation of Resonant Frequency on Performance (GaAs: $\epsilon_r = 12.90$, $h = 0.10$ cm)

Characteristics	@ 10.0GHz	@ 45.0GHz
A	0.2374	0.05079
a_e	0.2449	0.05448
G_1	0.0006607	0.0006619
G_{rad}	0.0006607	0.0006619
G_c	1.8423×10^{-10}	4.4201×10^{-13}
G_d	3.2145×10^{-13}	7.7083×10^{-16}
G_t	0.0006607	0.0006619
D_o	3.3187	3.3193
R_{in}	1552.20	1518.42
Q_c^{-1}	0.01196	0.002605
Q_d^{-1}	2.0869×10^{-5}	4.5465×10^{-6}
Q_{rad}^{-1}	7.2311×10^{-16}	3.5164×10^{-15}

Table 3: Effect of Variation of Substrate Height on Performance (GaAs: $f_r = 10.0$ GHz, $\epsilon_r = 12.90$)

Characteristics	@ 0.10 cm	@ 0.20 cm
A	0.2374	0.2336
a_e	0.2449	0.2451
G_1	0.0006607	0.0006614
G_{rad}	0.0006607	0.0006614
G_c	1.8423×10^{-10}	4.5760×10^{-11}
G_d	3.2145×10^{-13}	1.5964×10^{-13}
G_t	0.0006607	0.0006614
D_o	3.3187	3.3191
R_{in}	1552.20	1550.50
Q_c^{-1}	0.01196	0.005927
Q_d^{-1}	2.0869×10^{-5}	2.0689×10^{-5}
Q_{rad}^{-1}	7.2311×10^{-16}	1.4954×10^{-15}



6. DISCUSSION OF RESULTS

From earlier researches and also from Table 1, GaAs with a patch radius of 0.2374cm, has the smallest radius compared to other chosen substrates, which made it to be the best in miniaturization. Its high input impedance implies that loading effect will be minimal. However, it has the least radiation conductance, which implies that its radiation is least when compared to the other substrates primarily because it suffers the highest losses due to radiation conductance (Q_{rad}), which is the dominant loss for thin substrates. This makes it a prime choice for Bluetooth application. Indium Phosphide closely trails Gallium Arsenide. Duroid exhibited the best conductance (0.002227 S) thereby yielding a high radiation due to the high fringing effects. It also showed the best directivity and the least losses due to radiation conductance (Q_{rad}). However, these advantages are at the expense of an enlarged patch radius and a reduced input resistance which translates to increased in loading effects. This makes it useful in high frequency mobile telecom. The stability feature of Silicon makes it suitable for patch antenna construction.

Table 2 showed that patch radius decreases as the required resonant frequency increases (0.2374cm at 10.0GHz and 0.05079 cm at 45.0GHz for GaAs). Directivity was seen to increase with resonant frequency, but at the expense of increase in conduction and dielectric losses. Radiation losses were observed to have reduced with increase in resonant frequency, which translates to the slight increase in the radiation conductance.

Table 3, showed that as the substrate height increases, the physical patch radius decreased, but the effective radius increases. This increase in effective radius implies that there is an increased fringing (radiation). It was also deduced that directivity increases with increase in substrate height, but at the expense of loading effect. A lower radiation conductance loss was observed at higher substrate height, but at the expense of increasing losses due to surface wave.

7. SUMMARY AND CONCLUSION

This research aims to compare the effects, on performance, of changing resonant frequency and height of substrates in the design and implementation of a circular microstrip patch antennas adaptable to microwave frequencies. Computations and simulations using a program developed in FORTRAN were done based on the cavity model. Alongside these, other parameters viz actual and effective patch radii, conductance, directivity, input resistance

and quality factor, which dictate the ultimate performance of the antenna were also determined.

Deductions were made on results obtained for different substrates. It was observed that patch radius decreases as the required resonant frequency increases (0.2374cm at 10.0GHz and 0.05079 cm at 45.0GHz for GaAs). Directivity was seen to increase with resonant frequency, but at the expense of increase in conduction and dielectric losses. Radiation losses were observed to have reduced with increase in resonant frequency, which translates to the slight increase in the radiation conductance.

It was also observed that as the substrate height increases, the physical patch radius decreased, but the effective radius increases. This increase in effective radius implies that there is an increased fringing (radiation). It was also deduced that directivity increases with increase in substrate height, but at the expense of loading effect. A lower radiation conductance loss was observed at higher substrate height, but at the expense of increasing losses due to surface wave.

REFERENCES

- [1] Akande S. F. (2003) VHF/UHF Communications. A Postgraduate Course in the Department of Physics, University of Jos. Unpublished
- [2] Balanis C.A(1982) Handbook of Microstrip Antennas. John Wiley and Sons New York.
- [3] Burkholder, R and Lundin, T. (2006). Antenna and Radiation Pattern. IEEE. Transactions on Antennas and Propagation, 53(2):
- [4] Gonca, C. (2005) Design, Simulation and Tests of Low-cost Microstrip Patch Antenna Arrays for the Wireless Communication Turk J Elect Engin, 13 (1)
- [5] Richards, W.F. (1988) Microstrip Antennas. Theory, Application and Design. Van Reinhold NY.
- [6] Wikipedia (2011) [www.http.wikipedia](http://www.wikipedia) The free on-line encyclopedia.htm
- [7] Kwaha, B. J., Inyang, O. N and Amalu, P. (2011) The Circular Microstrip Patch Antenna – Design and Implementation. International Journal of Research and Reviews in Applied Sciences. ISSN: 2076-734X, EISSN: 2076-7366. Volume 8, Issue 1 (July, 2011)