# Simulation and Evaluation of Circular and Rectangular Microstrip Patch Antenna

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*Abstract* - **This paper discovers the performance evaluation of circular and rectangular patch microstrip antennas. The study concentrates on frequency of 2.4GHz in reference to the Nokia mobile phone characterirstics. The antennas has been designed using three different materials; Perfect Electric Conductor (PEC) for ground plane, Flame Retardant 4 (FR-4) and Taconic RF-30 used as substrate and Copper for the patch. It has been simulated using Computer Simulation Technology (CST) Microwave Studio in CST2009 software. Return loss, input impedance, VSWR and farfield values obtained from simulations of both antennas were compared. The best performance for return loss, impedance Z11, VSWR and farfield out of both antennas was obtained through simulations. Circular patch antenna gave better results in comparison to rectangular patch antenna. The development of circular patch antenna is increasing and the future prospect of this antenna could expand rapidly with the adjustments of the sizes of patch and substrate permittivity selected.**

Keywords – microstrip antenna, performance

## I. INTRODUCTION

An antenna is defined by Webster's Dictionary as "a usually metallic device (as a rod or wire) for radiating or receiving radio waves". The *IEEE Standard Definitions of Terms for Antennas* (IEEE Std 145 -1983) defines the antenna or aerial as "a means for radiating or receiving radio waves" [1]. In other words, the antenna is the transitional structure between free-space and a guiding device. The guiding device or transmission line may take the form of a coaxial line or a hollow pipe (waveguide), and it is used to transport electromagnetic energy from the transmitting source to the antenna or from the antenna to the receiver [2]. Conventional antenna often limits the applications of the antenna since they are governed by the 'right hand rule' which determines the way electromagnetic wave should behave. Their operating mechanism is unique since it involves traditional electric circuit concepts and physical fundamentals associated with electromagnetic waves can be understood if we consider the waves as having optical properties - this is especially true at microwave and millimeter wave frequencies, where the wavelengths involved are very small [3].

Microstrip patch antenna offers the ease of analysis and fabrication, and their attractive radiation characteristics, especially low-cross polarization. The microstrip antennas are low-profile, comformable to planar and non-planar surfaces, simple and inexpensive to fabricate using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and very versatile in terms of resonant frequency, polarization, pattern and impedance.

As the microstrip patch antenna is light weighted and is low in volume, therefore it is suitable for applications such as in mobile phones or any other mobile-related devices. It provides low fabrication cost, hence can be manufactured in large quantities. It also supports both, linear as well as circular polarization. This type of antenna can be easily integrated with microwave integrated circuits (MICs) and capable of dual and triple frequency operations. It is mechanically robust when mounted on rigid surfaces.

Nevertheless, microstrip patch antenna suffers from a number of disadvantages as compared to conventional antennas. Since it has a narrow bandwidth, it also has low efficiency and gain. Furthermore, it has low power handling capacity with extraneous radiation from feeds and junctions.

Circular patch antenna is used due to its size that fits in available space better than a rectangular one. No suitable transmission line model presents itself, and the cavity model must determine the resonant frequency and bandwidth [4].

The rectangular patch is usually designed so that it can operate near a resonance frequency.

## II. METHODOLOGY

The preliminary process of producing these antennas was by choosing a suitable structure. As for this paper, there was no specific structure chosen since it needed to be officiated on the simple-most structure which is the common circular and rectangular patch.

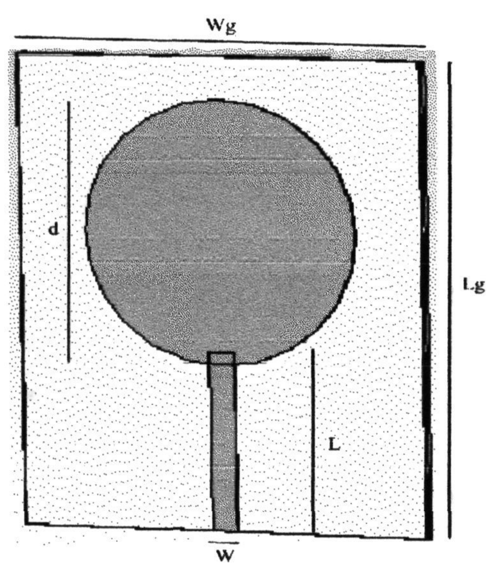


Figure 1: Dimensions of circular patch antenna

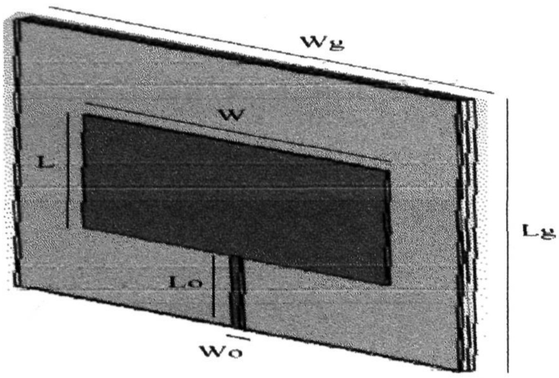


Figure 2: Dimensions of a rectangular patch antenna

The antennas has been designed using three different materials; Perfect Electric Conductor (PEC) for ground plane, Flame Retardant 4 (FR-4) used as substrate and Copper for the patch.

TABLE I
FR-4 SUBSTRATE PROPERTIES

| | |
|---|---|
| Permittivity, $\varepsilon$ | 4.9 |
| Permeability, $\mu$ | 1 |
| Substrate Height, h | 0.8mm |

TABLE II
TACONIC RF-30 PROPERTIES

| | |
|---|---|
| Permittivity, $\varepsilon$ | 4.9 |
| Permeability, $\mu$ | 1 |
| Substrate Height, h | 0.8mm |

Before realising the circular patch microstrip antenna, several calculations needed to be made. The required and suitable dimensions for the antenna were able to obtain using these formulas.

Physical Radius

$$F = \frac{8.79 \times 10^9}{f\sqrt{\varepsilon}} \qquad (1)$$

where

f = resonant frequency
$\varepsilon$ = permittivity of material used

Radius

$$r = \frac{F}{\left\{1 + \frac{2h}{\pi\varepsilon f}\left[ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\right\}^{\frac{1}{2}}} \qquad (2)$$

where

h = height of substrate in cm

Diameter
$$d = 2r \qquad (3)$$

All values of the antenna's dimensions were tabulated in Table I. As for the length and width of the feeder, line calc software was used and the values are tabulated in Table I.

TABLE III
CIRCULAR PATCH MICROSTRIP ANTENNA DIMENSIONS

| Parameters | Dimensions (mm) | |
|---|---|---|
| | Antenna 1 | Antenna 2 |
| Patch radius, $r$ | 33.6 | 21.0 |
| Patch diameter, $d$ | 67.2 | 42.0 |
| Substrate Width, $W_g$ | 60.0 | 60.0 |
| Substrate Length, $L_g$ | 100.0 | 100.0 |
| Feeder length, $L$ | 45.0 | 48.5 |
| Feeder width, $W$ | 6.0 | 6.0 |

There were some calculations to be done before proceeding with the rectangular patch microstrip antenna. Below are the crucial parameters to abide to in order to produce a rectangular patch microstrip antenna.

Patch Width

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r + 1}{2}}} \qquad (4)$$

where
$c$ = speed of light ($3x10^8$ m/s)
$f_0$ = operating frequency in GHz
$\varepsilon_r$ = permittivity of material

Effective Dielectric Constant

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + 12\left(\frac{h}{W}\right)\right)^{-\frac{1}{2}}\right] \qquad (5a)$$

when $\frac{W}{h} < 1$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\left(1 + 12\left(\frac{h}{W}\right)\right)^{-\frac{1}{2}} + 0.04\left(1 - \left(\frac{W}{h}\right)\right)^2\right]$$

when $\frac{W}{h} < 1$

where
h = substrate thickness (0.8mm; as in Table I)
W = width of antenna

Effective Length

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad (6)$$

Length Extension

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (7)$$

Patch Length

$$L = L_{eff} - 2(\Delta L) \quad (8)$$

Patch width value from equation (4) and patch length from equation (8) were substituted in equations (6) and (7) respectively to get the corresponding substrate width and substrate length.

Substrate Width

$$W_g = 6h + W \quad (9)$$

Substrate Length

$$L_g = 6h + L \quad (10)$$

Formulas stated above were used to calculate the initial values of the antenna dimensions with respect to 2.4GHz operating frequency and also FR-4 permittivity as well as its thickness. The calculated results are tabulated as shown below:

TABLE III
RECTANGULAR PATCH MICROSTRIP ANTENNA DIMENSION

| Parameters | Dimensions (mm) | |
|---|---|---|
| | Antenna 3 | Antenna 4 |
| Patch Width, $W$ | 53 | 73.0 |
| Patch Length, $L$ | 25.65 | 31.9 |
| Substrate Width, $W_g$ | 77.4 | 93.5 |
| Substrate Length, $L_g$ | 60.9 | 75.3 |
| Feeder Width, $W_o$ | 1.4 | 4.4 |
| Feeder Length, $L_o$ | 16.4 | 24.0 |

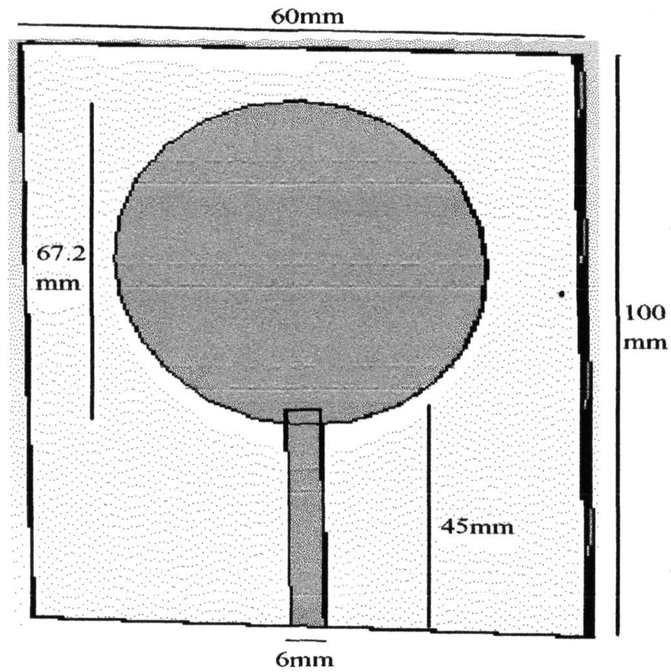

Figure 3: Dimension values of a circular patch antenna

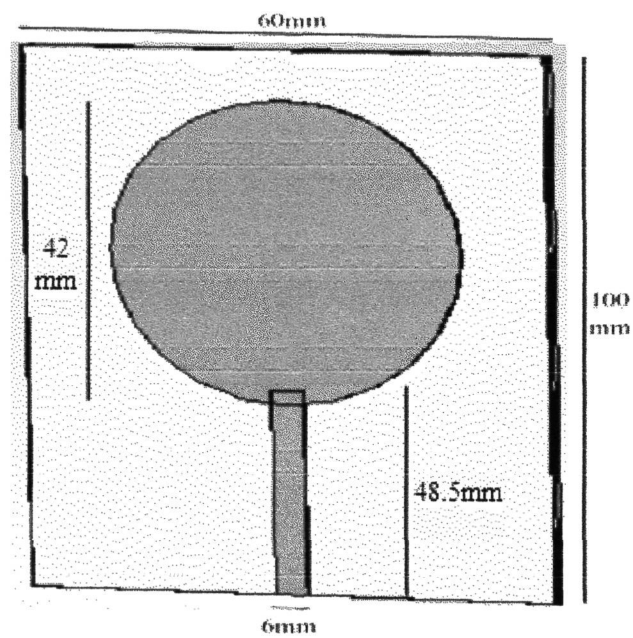

Figure 4: Dimension values of a circular patch antenna

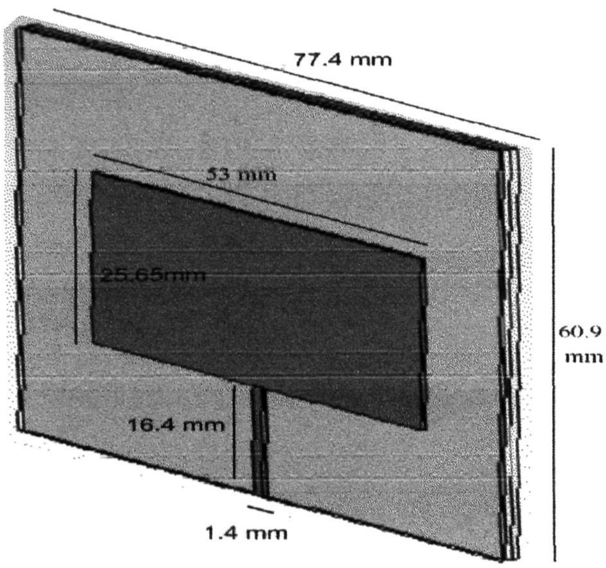


Figure 5 : Dimension values of a rectangular patch antenna

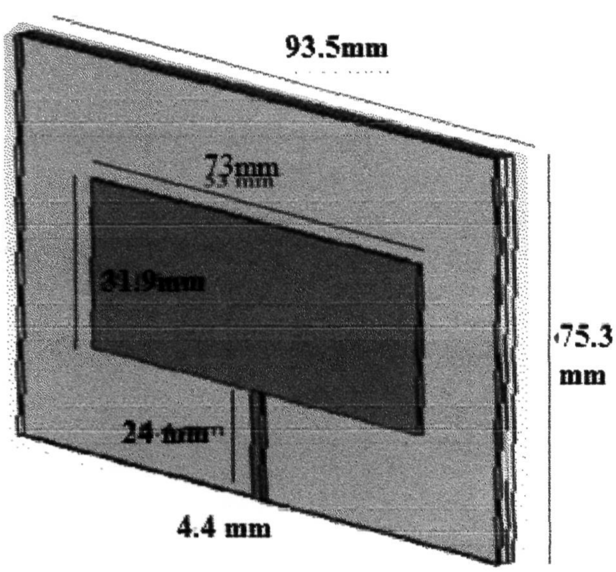


Figure 6 : Dimension values of a rectangular patch antenna

## III. RESULTS AND DISCUSSIONS

TABLE IV
COMPARISON OF CIRCULAR AND RECTANGULAR MICROSTRIP PATCH ANTENNA

| Parameters | Values | | | |
|---|---|---|---|---|
| | Antenna 1 | Antenna 2 | Antenna 3 | Antenna 4 |
| Return Loss, $S_{11}$ (dB) | -19.34 | -12.97 | -16.45 | -12.58 |
| Impedance, $Z_{11}$ (Ω) | 57.01 | 53.28 | 59.71 | 54.99 |
| VSWR (V) | 1.19 | 1.46 | 1.21 | 1.62 |
| Farfield, (dBi) | 5.54 | 7.3 | 3.19 | 7.96 |

The return loss between the antennas was different. Circular patch antenna provides less return loss compared to rectangular patch antenna. As for the impedance value, the approximation for circular patch antenna was closer to the value of expected input impedance, Zo which was 50 ohms. Voltage Standing-Wave Ratio (VSWR) obtained was about the same. The farfield value of the antennas had major difference, whereby the circular patch provides a better farfield plot compared to rectangular patch antenna.

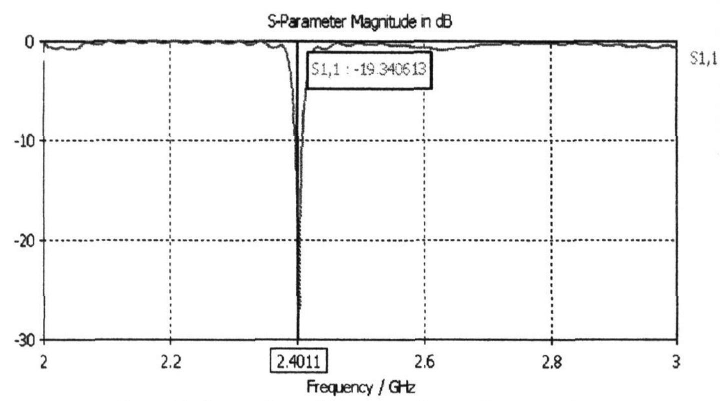


Figure 7 : Return Loss, S11 of circular patch antenna 1

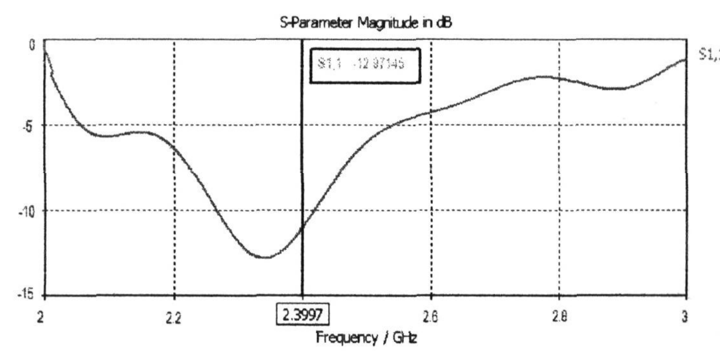


Figure 8 : Return Loss, S11 of circular patch antenna 2

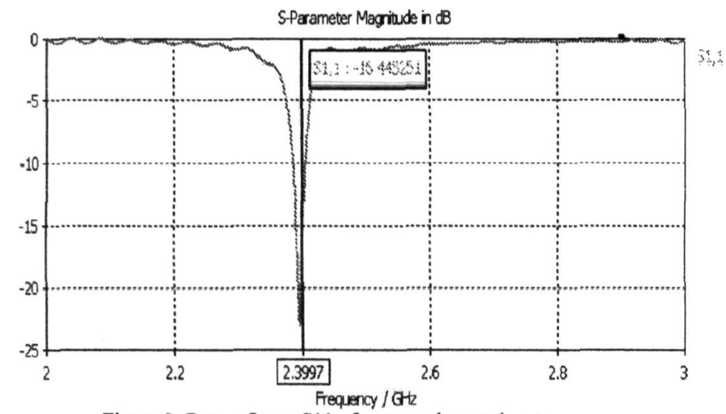


Figure 9: Return Loss, S11 of rectangular patch antenna

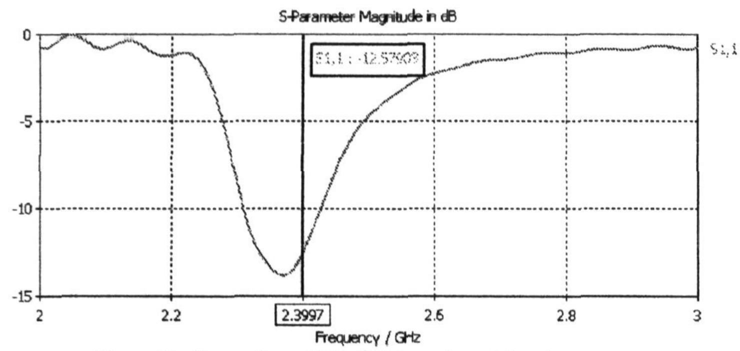


Figure 10 : Return Loss, S11 of rectangular patch antenna

Figure 5 and Figure 6 show the plot of return loss for rectangular and circular patch antennas. With the values of -19.34 and -16.45 from approximation of frequency at 2.4GHz, show that the antennas have a small amount of reflection back to the microstrip. Small value of return loss leads the antenna closely to operate at its maximum power.

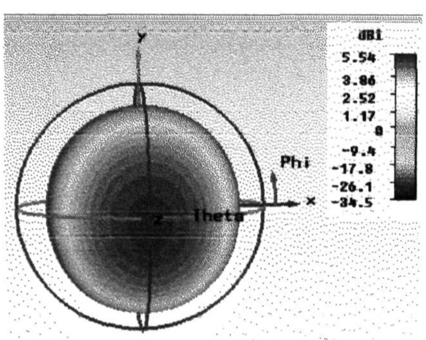


Figure 11 : Directivity radiation of circular patch Antenna 1

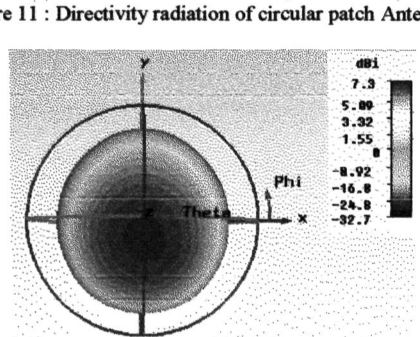


Figure 12 : Directivity radiation of circular patch Antenna 2

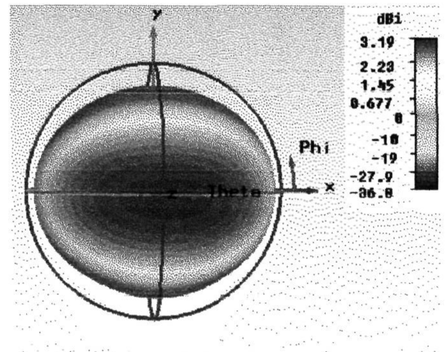


Figure 13 : Directivity radiation of rectangular patch Antenna 3

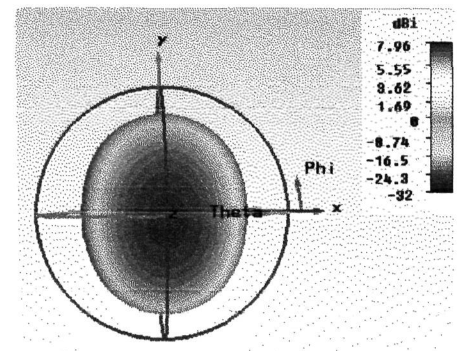


Figure 14 : Directivity radiation of rectangular patch Antenna 4

Figure 11, Figure 12, Figure 13 and Figure 14 respectively shows the farfield generated through the simulation of both type of antennas. The performance of the antenna was based on the outcome of the radiation. The circular patch radiation was more converging whereas the rectangular patch radiation was more diverging. Theoretically, the more converging the directivity, the more excellent the antenna is.

## IV. CONCLUSION

The patch antennas were developed based on the most basic principle of all microstrip patch antennas. With the guidance of written formulas, calculations were made to obtain the required measurements for the antennas' dimensions.

Through the CST simulation, results were obtained. Nevertheless, some adjustments were necessary in order to achieve the 2.4GHz reference frequency. With minor adjustments made, the circular and rectangular microstrip patch antennas were attained.

The simulation results clearly show that the circular microstrip patch antenna was more to the advantage. With the better performance in all aspects; return loss S11, impedance Z11, VSWR and farfield, compared to rectangular microstrip patch antenna, the circular patch also supports the theory written. Theoretically, the existence of circular patch was more applicable and has better performance in comparison to the rectangular patch. This theory was achieved in development of these antennas.

## V. FUTURE DEVELOPMENT

It is recommended that several improvements are to be made in terms of the size of the patch chosen. Since in the advancement of technology era, all electronic-related devices are reducing in size, therefore it is important for the sizes of these antennas to be reduced. The preferred substrate also needs to be wisely selected. The permittivity of the substrate affects the size of the antenna.

## ACKNOWLEDGMENT

Author would like express gratitude to Puan Norhayati Bt. Hamzah for her sincere opinions, guidance and support throughout the project progress. Special appreciation is expressed to author's beloved parents Mohd. Ismail B. Ahmad and Shahroonbee Bt. Noordin and author's friends 'Aisyah Bt. Abdul Razzak, Ahmad Ridhuwan B. Sudin and Tuan Mohamad Izram B. Tuan Soh for their kindness and sincere assistance throughout the whole project. Extended thanks to Noor Irmahani Bt. Mohmad Tahiruddin for her guidance in using the CST2009 Microwave Studio software and Adib B. Othman for his MATLAB programming on rectangular microstrip patch antenna dimensions calculations.

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