Simulation and Analysis of Rectangular Micro-Strip Patch Antenna for 1.9 GHz using IE3D

Dishant Shah, Hardik Aboti, Chirag Joshi, Vidya Sawant

***Abstract*— A coaxial probe fed rectangular micro-strip patch antenna using glass epoxy dielectric was designed and simulated using IE3D software. The antenna design operates at frequency of 1.9GHz and is suitable for GSM applications for DECT (Digital European Cordless Telephone). Emphasis was on designing and analyzing the rectangular patch so as to improve its directivity and hence causing less danger from harmful radiations while communicating on a wireless handset. Initially the design was simulated using a silicon dielectric substrate and later using glass epoxy substrate in order to improve its results significantly and to reduce the fabrication cost.**

***Index Terms*— Micro-strip Antenna, Glass Epoxy, IE3D, GSM-DECT.**

I. INTRODUCTION

A micro-strip patch antenna consists of a very thin metallic patch placed a small fraction of a wavelength above a conducting ground-plane. The patch and ground-plane are separated by a dielectric. The patch conductor is normally copper and can assume any shape, but simple geometries generally are used and this simplifies the analysis and performance prediction. The patches are usually photo etched on the dielectric substrate. The substrate is usually non-magnetic. The dielectric constants of the substrate are normally in the range of $2.2 < \varepsilon_r < 12$, which enhances the fringing fields that account for radiation, but higher values may be used in special circumstances. Due to its simple geometry, the rectangular patch is the most commonly used micro-strip antenna. It is characterized by its length L, width W and thickness h, as shown in Figure 1.

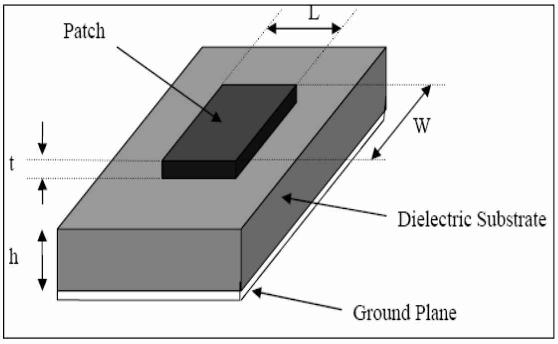

Figure 1. The patch antenna with dimensions

The simplest method of feeding the patch is by a coplanar micro-strip line, also photo etched on the substrate. Coaxial feeds are also widely used [1]. The inner conductor of the coaxial-line (sometimes referred to as a probe) is connected to the radiating patch, while the outer conductor is connected to the ground-plane, as shown in Figure 2.

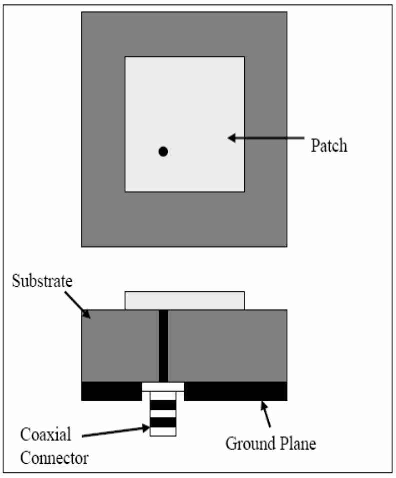

Figure 2. The Co-axial Probe Feed Technique

II. THE PROBE FEED PATCH ANTENNA

The first design step wass to choose a suitable dielectric substrate of appropriate thickness. Many manufacturers offer suitable substrates in various thicknesses and in a variety of claddings. For this antenna, bandwidth and radiation efficiency considerations dictate that the antenna be fabricated on a relatively thick substrate of low relative permittivity. The dielectric loss is proportional to the loss tangent, and values less than about 0.005 are suitable. Conductor losses are not a problem at this frequency, as the skin depth is about 2 μm for copper at 2.0 GHz [2]. The arrangement of a rectangular shaped microstrip antenna is given in Figure 1& 2. It consists of patch, substrate,ground plane and feeding point.

A patch is a two dimensional antenna element, which in this case is rectangular in shape. It is of a very thin thickness (t) of metallic strip on top of a material known as the substrate with thickness h (h « λo), usually $0.003\lambda_o \le h \le 0.05\lambda_o$, where λo is free space wavelength above a ground plane. For rectangular patch, the length L of the element is usually $\lambda_o/3 < L < \lambda_o/2$ [3]. The strip (patch) and the ground plane are separated by a dielectric (substrate). Micro-strip antennas have a very high antenna quality factor (Q). This factor represents the losses associated with the antenna and a large quality factor leads to narrow bandwidth and low efficiency. Quality factor can be reduced by increasing the thickness of the dielectric substrate.

Manuscript received March,2014.
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But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. This surface wave contribution can be counted as an unwanted power loss since it is ultimately scattered at the dielectric bends and causes degradation of the antenna characteristics. However, surface waves can be minimized by the use of photonic band gap structures .Other problems such as lower gain and lower power handling capacity can be overcome by using an array configuration for the elements.

III. FEEDING TECHNIQUE

There are many configurations that can be used to feed micro-strip antennas. The four most popular feeding are the micro-strip line, coaxial feed, aperture coupling and proximity coupling. The feeding technique we are using here is coaxial probe feeding.

IV. ANALYSIS AND PARAMETERS FOR ANTENNA DIMENSIONS

Three commonly used method of analysis for calculating microstrip antenna parameters are transmission line model, cavity model, and full wave analysis. It is useful to model the microstrip antenna as a transmission line. This model is the simplest of all and it gives good physical insight. It represents the MSA by two slots of width W and height h, separated by a transmission line of length L. The microstrip is essentially a non homogeneous line of two dielectrics, typically the substrate and air.The length and width of rectangular patch antenna are calculated from below equations [4]. Where c is the velocity of light, ε_r is the dielectric constant of substrate.

1: **Calculation of the Width *(W)*:** The width of the Micro-strip patch antenna is given by equation as:

$$W=\frac{c}{2f[(\varepsilon_r+1)/2]^{1/2}} \qquad (1)$$

2: **Calculation of Effective dielectric constant (ε_{reff}):** The following equation gives the effective dielectric constant as:

$$\varepsilon_{reff}=\frac{(\varepsilon_r+1)}{2}+\frac{(\varepsilon_r-1)}{2}[1+10h/W]^{1/2} \qquad (2)$$

3: **Calculation of the Effective length (L_{eff}):** The following equation gives the effective length as:

$$L_{eff}=\frac{c}{2f_0(\varepsilon_{reff})^{1/2}} \qquad (3)$$

4: **Calculation of the length extension (ΔL):** The following equation gives the length extension as:

$$\frac{\Delta l}{h}=0.412\frac{(\varepsilon_{reff}+0.300)(W/h+0.262)}{(\varepsilon_{reff}-0.258)(W/h+0.813)} \qquad (4)$$

5: **Calculation of actual length of patch (L):** The actual length is obtained by the following equation:

$$L = L_{eff} - 2\Delta L \qquad (5)$$

6: **Calculation of the ground plane dimensions (L_g and W_g):** Ideally the ground plane is assumed of infinite size in length and width but it is practically impossible to make a such infinite size ground plane, so to calculate the length and width of a ground plane following equations are given as:

$$L_g = L + 6h \qquad (6)$$

$$W_g = W + 6h \qquad (7)$$

7: **Determination of feed point location (X_f, Y_f):** A coaxial probe type feed is to be used in this design. The center of the patch is taken as the origin and the feed point location is given by the co-ordinates (X_f, Y_f) from the origin. The Feed point must be located at that point on the patch, where the input impedance is 50 ohms for the resonant frequency. Hence, a trial and error method is used to locate the feed point. For different locations of the feed point, the return loss (R.L) is compared and that feed point is selected where the R.L is most negative.

V. DESIGN CONSIDERATION

To achieve the requirements, the rectangular microstrip antenna is designed to operate at 1.9GHz as center frequency. The Co-axial probe type feeding technique is used and analysis is carried out by transmission line model [5]. The design parameters for the patch using glass epoxy as a dielectric material having ε_r=4.2 (loss tangent=0.0005), h=1.6 mm for a operating Frequency of 1.9 GHz is given in the table below:

Dimension of Rectangular Microstrip Patch Antenna	**Notation**	**Calculated Value**
Width	W	49 mm
Effective dielectric constant	ε_{reff}	3.56
Effective length	L_{eff}	39.814 mm
Length extension	ΔL	0.757 mm
Actual Length	L	38.3 mm

Table 1. Dimensions of the proposed patch

VI. SIMULATION AND RESULTS

The proposed rectangular micro-strip patch antenna (RMSA) with dimensions given above in table 1 was simulated using Zealand's IE3D evaluation software version 12.30 as shown in figure 3 using glass epoxy which is Teflon based, micro-strip board with dielectric constant 4.2 and the substrate height is 1.6 mm, and loss tangent is 0.005 is considered [4]. The patch size of (38.3mmX49mm) is calculated and simulated. The properties of antenna such as bandwidth, S-Parameter, VSWR has been investigated and compared between different optimization scheme and theoretical results. The patch was simulated for many different feed point locations (X_f, Y_f). Results for the feed point (6.85, 1.8) gave satisfactory results with return loss or S_{11} is -22.3 dB and VSWR of about 1.3 at frequency of 1.866GHz (~1.9GHz).

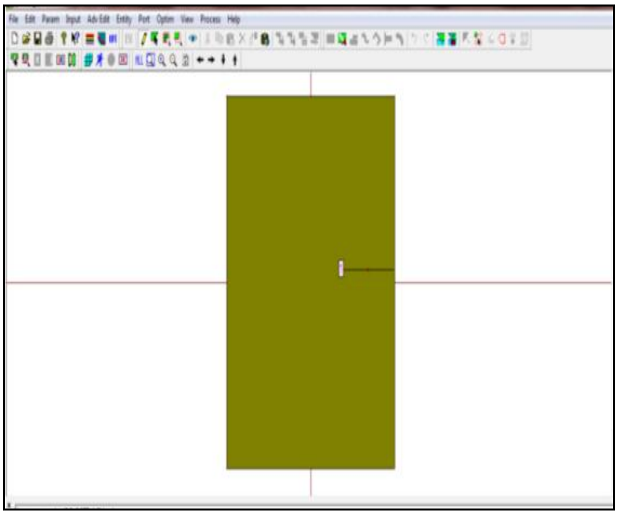

Figure 3- The Proposed patch Antenna

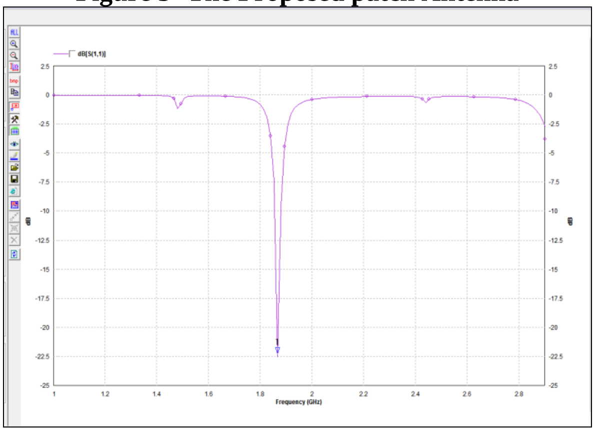

Figure 4- RL Curve

The Return loss of the antenna obtained is -22.3dB at the center frequency of 1.866 GHz, which indicates that 9 % of the power is reflected and 91 % of the power is transmitted. VSWR parameter of a patch antenna indicates how well is the antenna matched with the feed. VSWR result obtained from the simulation is 1.3 at 1.866GHz which implies proper matching at the intended frequency.

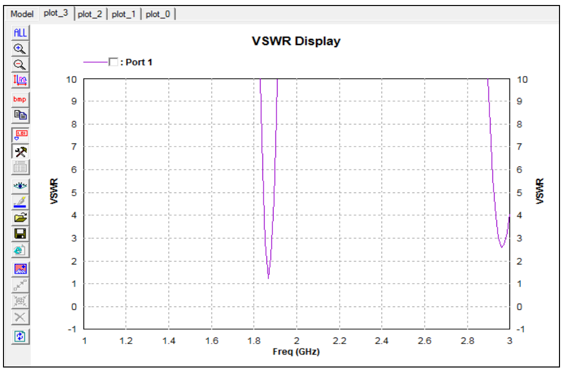

Figure 5- VSWR plot

Figure 6 shows the input impedance plot of the simulated antenna which gives a impedance value of 50Ω at 1.866GHz which shows that impedance matching is achieved at this feed point location and hence reflections are negligible which eliminates standing waves, with maximum power coupled and radiated from the antenna.

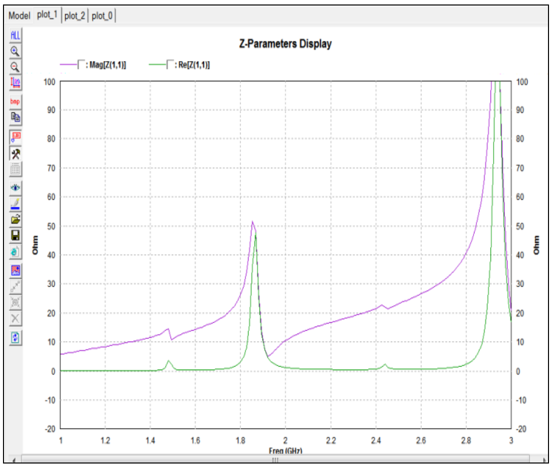

Figure 6- Z parameter plot

The Smith chart plot shown in figure 7 indicates good impedance matching at the desired frequency of 1.866 GHz which lies within the unity circle.

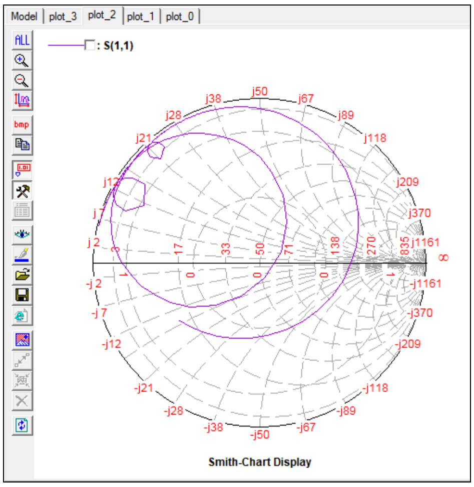

Figure 7-Smith Chart plot

The 2D and 3D radiation patterns of the simulated anteena is obtaines as shown in figure 8 and 9. The radiation pattern shows that the energy is radiated away from the antenna and so this radiation does not harm humans who communicate through the wireless handset.

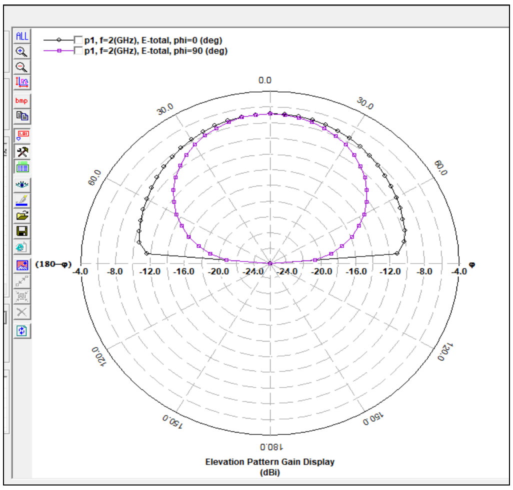

Figure 8- 2D polar plot

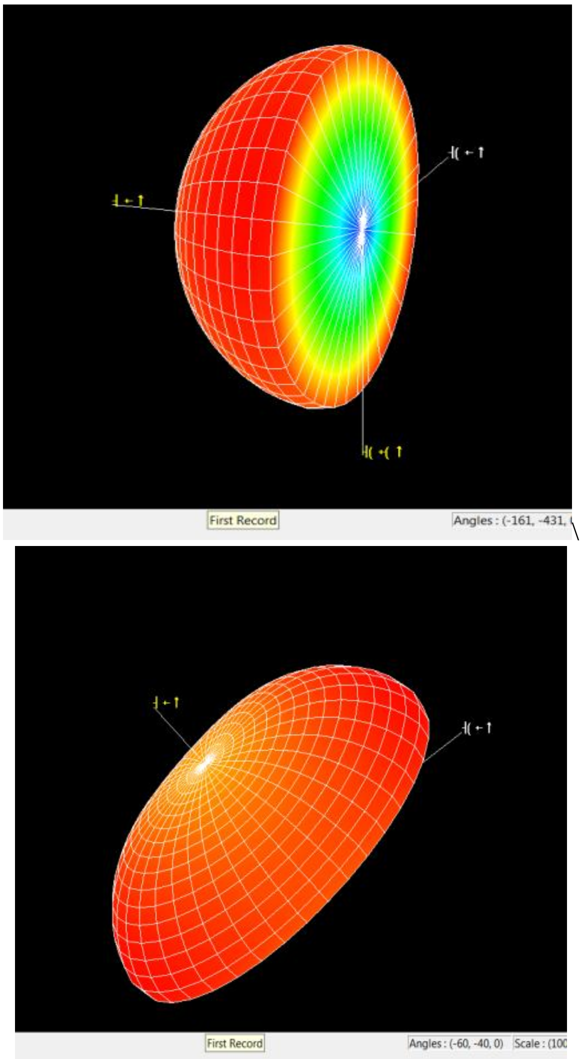

Figure 9-3D Radiation Pattern

VII. CONCLUSION

In this paper, the design of a rectangular patch antenna for 1.9GHz frequency was presented. The results for the proposed antenna above shows that the coaxial probe fed rectangular microstrip patch antenna can be used for applications in cordless handset and for cellular application in the GSM band for DECT. The resonance frequency of the simulated patch is 1.866 GHz. The proposed antenna gave a -10dB bandwidth of 22MHz from 1.878 GHz-1.856 GHz around the certer frequency of 1.866GHz. The simulated results show that the rectangular microstrip patch antenna will be compact and low cost solution for cell phone applications in GSM band. Also since glass epoxy is used as the dielectric substrate, the cost of fabrication of the antenna would be less.

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