Design and Simulation of Microstrip Rectangular Patch Antenna for Bluetooth Application

Tejal B. Tandel , Nikunj Shingala

Abstract — **A design of small sized, low profile patch antenna is proposed for BLUETOOTH applications at 2.4GHz frequency with inset feeding technique. The patch is design with different parameters like return loss, VSWR, directivity along two directions, radiation pattern in 2-D and 3-D, smith cart , impedance matching are simulated using CST Microwave Studio simulation software. Designed antenna is simulated on FR4 substrate with loss tangent tanδ=0.02. The proposed antenna based on co-axial feed configuration has the maximum achievable bandwidth obtained about 818 MHz (2.35-2.44 GHz) at -10 dB reflection coefficient which corresponds to Bluetooth 2.4 GHz frequency band and the maximum achievable directivity is 6.32 dBi. Simulation and measurement results are compared and discussed.**

Index Terms: Transmission line model, CST, S-parameters, VSWR

I. INTRODUCTION

The BLUETOOTH devices technology provides short range of wireless connections between electronic like computers, mobile phones and many others thereby exchanging voice, data and video. The rapid increase in communication standards has led to great demand for antennas with low real estate, low profile and size, low cost of fabrication and ease of integration with feeding network. Microstrip patch antennas are widely used because they are of light weight, compact, easy to integrate and cost effective. However, the serious problem of patch antennas is their narrow bandwidth due to surface wave losses and large size of patch for better performance.

To exchange the data over a short distance communication a wireless technology called Bluetooth is used with in frequency range 2400-2485 MHz. So antenna is an essential device to transmit the data through unguided media. In wireless communication applications the major constraints are size, weight and ease of installation of antennas. These constraints are overcome by using a low or flat profile Microstrip Antenna (MSA). MSA is a simplest configuration of radiating patch of different shapes on one side of dielectric material whose dielectric constant lies in 4< εr <12 and ground plane on the other side. It is a narrow band wide beam antenna [6].

Tejal B Tandel, Electronics and Communication Department, Madhuben and Bhanu bhai Patel Institute Of Engineering, For Studies And Research In Computer And Communication Technology, New V.V. Nagar, Anand, India.

Shingala Nikunj, Electronics and Communication Department, Madhuben And Bhanubhai Patel Institute Of Engineering, For Studies And Research In Computer And Communication Technology, New V.V. Nagar, Anand, India.

The conductors used for patch are generally copper and gold of different shapes. In order to simplify mathematical analysis and to predict patch performance at resonance frequency, conventional shapes like rectangular, square, circular etc. are generally preferred. Excitation of patch is done by using different techniques like inset feed, co-axial feed, aperture coupling etc.

In this paper, a compact size patch antenna is proposed with dielectric substrate as FR4 with εr=4.4 and dimensions are based on resonant frequency. Various attempts are made to adjust the dimensions of the patch to improve the parameters like return loss, VSWR, directivity along θ, Ø directions, radiation pattern in 2-D and 3-D, impedance matching using CST which is a high performance full wave EM field simulator for arbitrary 3D volumetric passive device modelling that takes advantage of the familiar Microsoft Windows graphical user interface. It integrates simulation, visualization, solid modelling, and automation in an easy to learn environment where solutions to your 3D EM problems are quickly and accurate obtained. CST MICROWAVE STUDIO is a full-featured software package for electromagnetic analysis and design in the high frequency range. It simplifies the process of inputting the structure by providing a powerful solid 3D modelling front end. Strong graphic feedback simplifies the definition of your device even further. After the component has been modelled, a fully automatic meshing procedure is applied before a simulation engine is started. There are numerous and well-known methods to increase the band width of the antennas including: the use of the substrate thickness [2], the use of low dielectric substrate [2], the use of various impedance matching and feeding techniques [3]. Since the first practical antennas were developed in early 1970's, interest in this kind of antennas was held in New Mexico [4]. Dual frequency operation of antenna is very necessary in recent wireless communication system for some applications such as GPS, WLAN etc [5].

In transmission line model, the microstrip antenna is represented by two slots of width W and height h, separated by a transmission line of length L. Most of the electric fields are reside in the substrate and parts of some lines are in air. Since microstrip line is a non homogeneous, it cannot support Transverse Electromagnetic Mode (TEM) of transmission and because of phase velocities change in air and dielectric media, it can support quasi-TEM mode only. By considering the fringing effect and wave propagation, effective dielectric constant (εreff) is obtained rather than dielectric constant (εr) whose value is slightly less than εr. The length of the patch is slightly less than λg/2, where λg is guided wavelength in dielectric media (λ0/ *reff*) and λ0 is free space wavelength to support TM10 mode[7].

II. ANTENNA DESIGN

The proposed antenna is designed with the specifications as Resonant frequency (*fo*) = 2.40 GHz, dielectric constant (εr) = 4.4, height (h) = 1.6 mm. The width and effective length of the patch are given by the fallowing formulas [1] and calculated values for above specifications are

Step 1: Calculation of the width (W): the width of the microstrip patch antenna is given by equation as [6]:

$$w = \frac{c}{2 f_o \sqrt{\frac{\varepsilon_r + 1}{2}}}$$

*Step 2: Calculation of effective dielectric constant (**ε_{reff}**):* **e**quation (3.1) gives the effective dielectric constant as [6]:

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

Step 3: Calculation of the effective length (L_{eff}): equation (3.2) gives the effective length as [6]:

$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{reff}}}$$

Step 4: Calculation of the length extension (ΔL): equation (3.3) gives the length extension as [6]:

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

Step 5: Calculation of the actual length of the patch (L): the actual length is obtained by subtracting the length extension from the effective length as:

L = L eff - ΔL

Step 6: Calculation of the ground plane dimensions (L_g and W_g)

The transmission line model is applicable to infinite ground planes only. However, for practical considerations, it is essential to have a finite ground plane. It has been shown in many open literatures that similar results for finite and infinite ground planes can be obtained if the size of the ground plane is greater than the patch dimensions by approximately six times the substrate thickness all around the periphery. Hence, for this design, the ground plane dimensions would be given as:

$L_g = 6h + L$

$W_g = 6h + W$

Patch Dimension:	**Ground Dimension:**
Length (L) = 19.5 mm	Length (L_g) = 39 mm
Width (W) = 23.5 mm	Width (W_g) = 47 mm

With above calculated values the antenna is simulated on FR4 material with loss tangent of 0.02 using CST software. The size of the antenna is 23.5 X 19.5 mm [2], which is suitable for Blue tooth communication. The inset probe can carefully be inserted to reduce the radiation. Figure 1 shows the proposed structure of antenna using CST software.

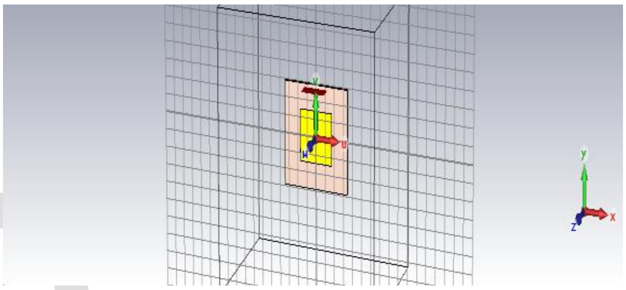

Figure 1.CST Generated Antenna Model

Figure 2 shows the Return Loss (S_{11}) plot of the proposed design. The minimum return loss which we are getting for this design is **-27 dB** for the band centred around 2.4 GHz.

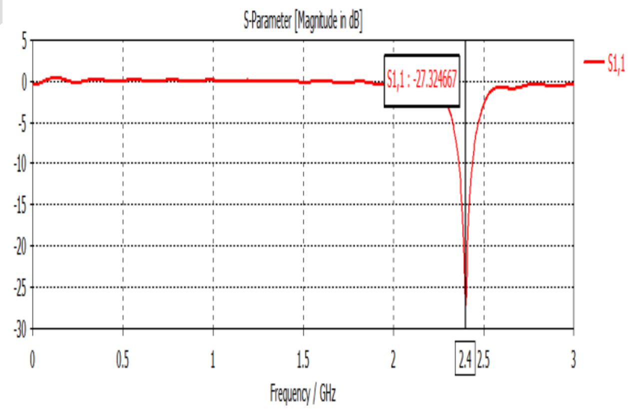

Figure 2. Simulated reflection coefficient [S11] of the proposed microstrip patch antenna

The simulated impedance bandwidth of about is achieved 818 MHz (2.35-2.44 GHz) at -10 dB reflection coefficient (VSWR≤2) shown in figure 3. The reflection coefficient value that is achieved at this resonant frequency is equal to **-27 dB**. This reflection coefficient value suggests that there is good matching at the frequency point below the -10 dB region. It covers the frequency band for the Bluetooth application i.e.. 2.35-2.44 GHz

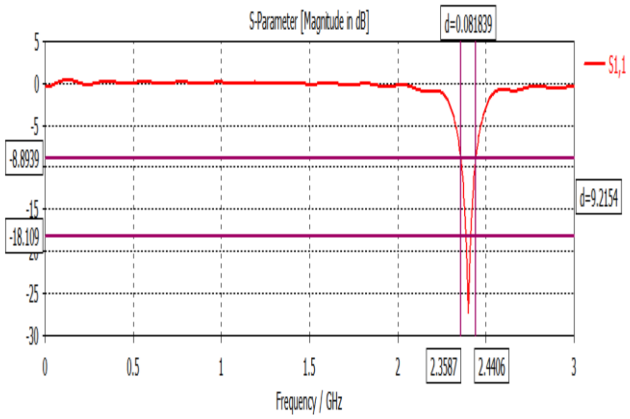

Figure 3 Bandwidth of the proposed design (S_{11} in dB)

Radiation pattern is a graphical depiction of the relative field strength transmitted from or received by the antenna. The antenna should not have the side lobes and back lobes ideally. We cannot remove them completely but we can minimize them. Figure 4 and figure 5 shows the simulated 3-D radiation pattern with directivity of 6.32 dBi and gain 3.62 Db for proposed antenna configuration at the resonating frequency of 2.4GHz.

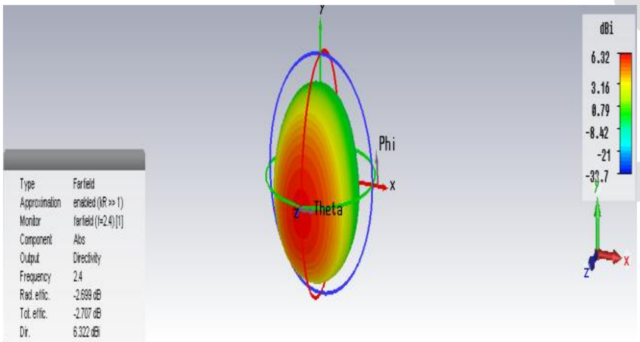

Figure 4 Directivity (3D) of the proposed design

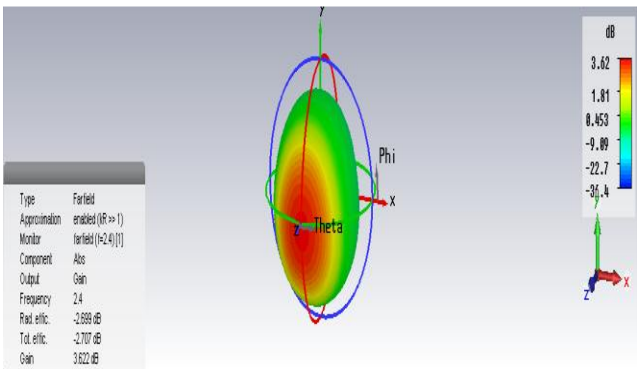

Figure 5 Gain (3D) of the proposed design

Figure 6 show the simulated E-plane (phi=90°, theta=varying) and radiation patterns for proposed antenna configuration at the resonating frequency of 2.4 GHz.

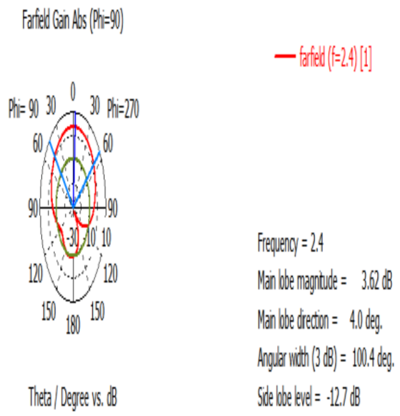

Figure 6 E-plane radiation pattern for fr =2.359 GHz

Figure 7 shows the VSWR (voltage standing wave ratio) plot for the designed antenna. The value of VSWR should lie between 1 and 2. SWR is used as an efficiency measure for transmission lines, electrical cables that conduct radio frequency signals, used for purposes such as connecting radio transmitters and receivers with their antennas, and distributing cable television signals. Here the value of the VSWR for the proposed microstrip patch antenna is 1.089 at the specified resonating frequency. The achieved values of reflection coefficient and VSWR are small enough and frequency is closed enough to specified frequencies bands for 2.4 GHz WLAN application.

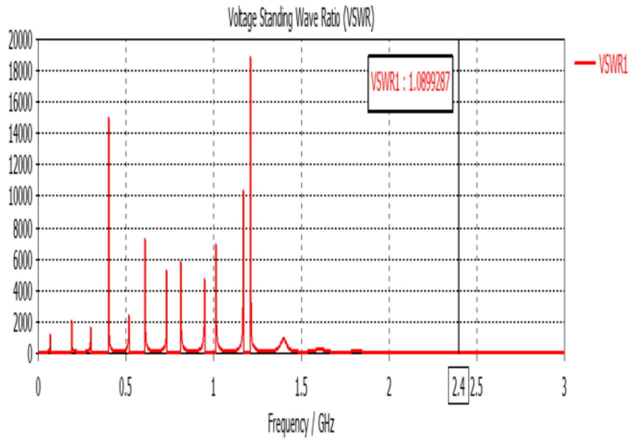

Figure 7 VSWR of the proposed design

Figure 8 shows the smith chart of the proposed antenna. It is a graphical representation of the normalized characteristic impedance. The Smith chart is one of the most useful graphical tools for high frequency circuit applications. The goal of the Smith chart is to identify all possible impedances on the domain of existence o the reflection coefficient.

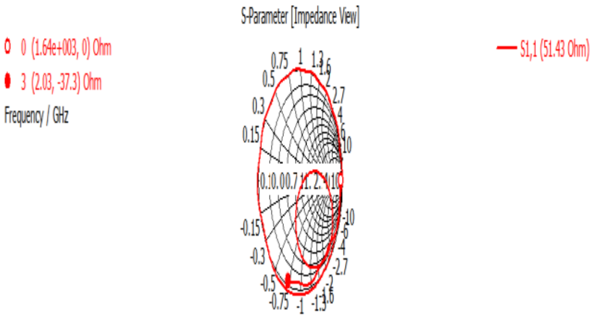

Figure 8 Smith Chart of the proposed design

III. FABRICATION AND TESTING

The transformation of geometric shapes on a mask to the surface of FR4 wafer can be done by using photolithography and the steps involved in this process are wafer clearing, barrier layer formation, photoresist application, soft banking, mask alignment, exposure and development and hard banking. Below Figure 9(a) and (b) shows the ground plane negative of proposed antenna, front photographic views respectively.

Figure 9. (a)Ground plane of the Fabricated MPA

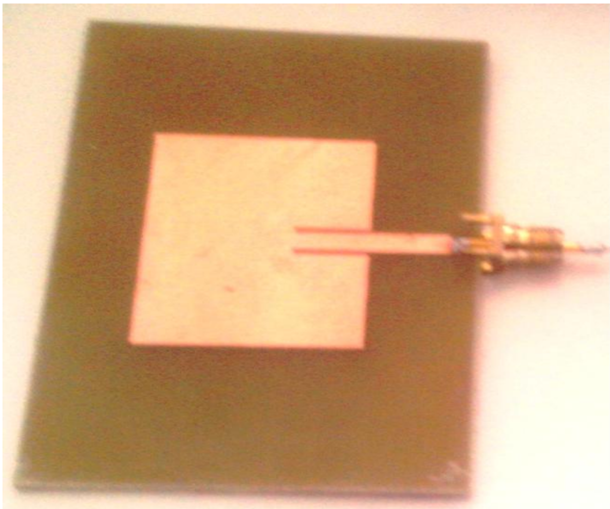

Figure 9 (b) Front View of the Fabricated MPA

The performance of the designed antenna can be understood by measuring parameters like reflection coefficient (S11), VSWR and input impedance (Zin) measurement using Smith Chart. They have been measured by using **N9912A FieldFox Analyzer** model (Up to 3GHz) of Vector Network Analyzer. Figure 10 shows testing of fabricated antenna using Agilent Network Analyzer .

Figure 10 The Set up for the testing of Fabricated MPA

Both Simulated and Fabricated antenna Designs are compared here in Table 5.4. Comparison table shows the change in the results slightly due to fabrication errors, losses due to SMA connector etc.

Table: 1 Comparisons of Simulated & Fabricated Proposed antenna design

Design	Frequency (GHz)	Minimum Return loss in dB
Simulated	**2.35975**	**-27**
Fabricated	**2.48076**	**-18.24**

IV. CONCLUSIONS

This paper presents design procedure of a inset fed microstrip rectangular patch antenna at 2.4 GHz for Bluetooth application. Main parameters such as return loss (S11), input impedance (Z0), gain and radiation patterns have been studied and are agreed with measured results. This antenna can be used for Bluetooth application and it is fully utilizes the entire frequency range 2.35-2.44

GHz. The resonant frequency of proposed antenna is occurred at 2.4 GHz and also VSWR is 1.088 which is < 2.

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Tejal B Tandel is working as assistant professor in electronics and communication department in Madhuben And Bhanubhai Patel Institute Of Engineering For Studies And Research In Computer And Communication Technology, New V.V. Nagar, Anand, India. Her areas of interest are Microwave Engineering, Antenna etc. She has several research papers to her name.

Mr. Shingala Nikunj is working as assistant professor in electronics and communication department in Madhuben And Bhanubhai Patel InstituteOf Engineering For Studies And Research In Computer And Communication Technology, New V.V. Nagar, Anand, India. His areas of interest are image processing, Signal processing, Digital circuits, etc. He has several research papers to his name.