Design and Performance analysis of Microstrip Patch antenna for C band applications

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Abstract *- A microstrip feed compact rectangular microstrip antenna designed in CST 2016 has been proposed and presented in this paper. The proposed microstrip patch antenna design has been devised using woven fiberglass cloth substrate (FR4) having depth of 0.157 cm with a dielectric constant of (Ɛr= 4.4) and loss angle of 3.18 degree. The ground, patch and feedline are of copper material having conductivity and resistivity of 5.67×10^8 S/m and 1.69×10^{-7} Ω-m, respectively. A rectangular slot has been cut in the upper rim of the patch to stint the resonant frequency. A small rectangular slot has been added within the patch to increase the bandwidth performance of the antenna. The antenna patch size after slotting has been abridged by 10.12% when compared to a conventional rectangular shaped microstrip patch antenna with a maximum bandwidth of 2.65 GHz and return loss of -60.29 dB. A broad scrutiny of the return loss pattern (dB), directive gain (dB), performance efficiency and directivity (dBi) of the insinuated antenna design has been tendered in this paper. The simple structure and low profile characteristics of the proposed antenna design make it easy to fabricate and employable in the field of wireless communication system. The proposed antenna is capable of operating in the C band having frequency range of 4 GHz – 8 GHz. The input impedance of antenna is 49.96 ohms which meticulously matches with the input impedance of SMA cable having impedance of 50 ohms. This leads reduction in reflection coefficient. The proffered antenna has the capability of being suitably deployed for ISM band, maritime military systems, maritime communications, SAR communications, aeronautical military systems, land military systems and aeronautical communications.*

Keywords — *Directivity, FR4, Gain, Microstrip Antenna Radiation pattern, VSWR.*

I. Introduction

The microstrip antenna elements emanate EM waves proficiently as devices on the microstrip (PCB) printed circuit boards. The microstrip antenna comprises of an emanating conducting patch on one face of a dielectric substrate with an incessant conducting layer adhered to the opposite side of the substrate which forms a ground plane. The patch and ground are usually made of material such as copper or gold and different type of shapes can etched [1]. A patch antenna is an antenna having narrow bandwidth and wide-beam of radiation fabricated by photo etching technique on the dielectric substrate [2]. The microstrip patch antenna emanate because of the collection of opposite charges forming fringing fields between the patch edge and the ground plane. For optimum antenna performance efficiency, a thick layer of dielectric substrate which must have low dielectric constant is considered necessary since this offers better proficiency, better radiation and larger bandwidth [3]. But this methodology leads to bulky profile antennas. The researchers are working on different alternate methods to formulate the size of compact antenna. This can be attained by reducing the thickness of substrate and increasing the dielectric constant of the substrate which in turn decrease the performance proficiency of the microstrip patch antenna as well as narrow bandwidth [4]. The elements of facets of a microstrip antenna hinge on the resonant frequency and value of the dielectric constant [5]. Since microstrip antenna has limitation of narrow bandwidth, many methods have been recommended for attaining the large bandwidth. These methods contain: using parasitic elements either in same layer or in stacked layer, reduced ground and skimmed patch [6][7]. The dielectric substrate plays a substantial role in the design and structural behaviour of microstrip antennas. In the proposed paper, the woven fiberglass cloth substrate (FR4) has been chosen as substrate whose dielectric constant is 4.4. FR-4 glass epoxy is a prevalent and multipurpose thermoset plastic with good mechanical toughness to weight ratio. The FR-4 is most generally used as an electrical insulator having significant mechanical and thermal strength. It has an extensive variability of applications [8]. A patch antenna supplies a maximum directive gain of 6-9dBi. The impedance of a resonant micro strip antenna is from 150 to 400ohms and the coveted impedance is 50ohms [9]. The investigation of microstrip antennas has made significant development nowadays. The microstrip antennas have more benefits. They are lighter in volume and weight having low fabrication cost and conformity. The microstrip antennas also offers dual bandwidths, circular polarizations, multi frequency operations, frequency agility, feed line flexibility, beam scanning omnidirectional patterning. In this paper the microstrip patch antenna, types of microstrip patch antenna, different types of feeding methodologies and their applications has been discussed and compared with other conventional antennas [10]. The most significant application of microstrip antenna is in GPS systems. It is also used in mobile communications; RFID; TAGS and Wi-Fi applications [11].

II. Design Overview

To design a microstrip patch antenna, we have to choose the resonant frequency and a dielectric medium for which antenna is to be designed [12]. The parameters to be calculated are as under [13].

A. Width of patch:

The width of the patch is calculated using the formula:

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\epsilon_r + 1}} \qquad (1)$$

B. Thickness of patch:

The thickness of the patch is calculated using the formula:

$$h \leq 0.3 \times \frac{c}{2\pi\sqrt{\epsilon_r} f_r} \qquad (2)$$

C. Effective dielectric constant:

The effective dielectric constant is given by the formula:

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left\{ \begin{matrix} \left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}} \\ +0.04\left[1 - \frac{w}{h}\right]^2 \end{matrix} \right\}, \frac{w}{h} < 1 \qquad (3)$$

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2}\left\{\left[1 + 12\frac{h}{w}\right]^{\frac{-1}{2}}\right\}, \frac{w}{h} \geq 1 \qquad (4)$$

D. Length of patch:

The actual length, L of the patch is using the following formula:

$$L = \frac{\lambda_g}{2} - 2\Delta L \qquad (5)$$

E. Length extension:

To determine the length extension, we use this formula:

$$\Delta L = 0.412h\left[\frac{(\epsilon_{eff} + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\epsilon_{eff} - 0.258)\left(\frac{w}{h} + 0.8\right)}\right] \qquad (6)$$

$$\lambda_g = \frac{\lambda}{\sqrt{\epsilon_{eff}}} = \frac{1}{\sqrt{\epsilon_{eff}}} * \frac{c}{f_r} \qquad (7)$$

where c is the velocity of light.

The fig. 1 (a), fig. 1 (b) and fig. 1 (c) illustrates the geometry of the propounded antenna. The fig. 1 (a) represents the side view of the designed antenna. The fig. 1 (b) represents the top view of the designed antenna. In the propounded antenna design, the FR-4 (Flame Retardant) substrate of dielectric constant value of $\mathcal{E}_r$= 4.4 and thickness 0.157 cm has been used. The arrangement of substrate, patch, feed line and ground are shown in fig. 1 (a). The copper material is used for ground and patch. The propounded microstrip antenna design has a compact area of 32.01 × 21.86 mm^2. The rectangular patch of thickness 0.02 mm has been deposited on the substrate. The input to the antenna is provided through SMA connector via feedline of dimensions 2.72 x 5.60 mm2. The microstrip feedline provides proper impedance matching of the antenna with SMA connector which ensures that the maximum power is delivered to antenna for radiation with minimal reflection losses from antenna towards the SMA connector. The antenna has input impedance of 49.96 Ω which closely matches with the 50 Ω impedance of SMA connector. The thickness of the substrates, feed line, patch and ground are given in Table I. The antenna has been designed and simulated by using CST Microwave Studio 2016.

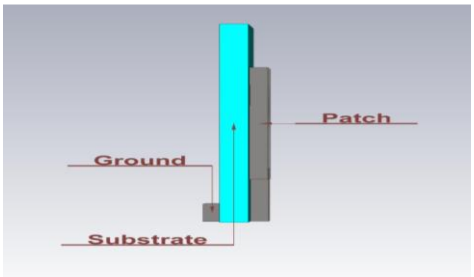

Fig. 1 (a) Lateral view of the propounded antenna design.

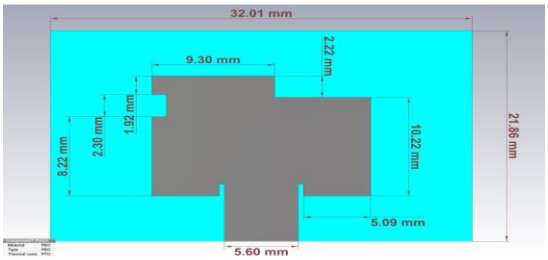

Fig. 1 (b) Top view of the propounded antenna design

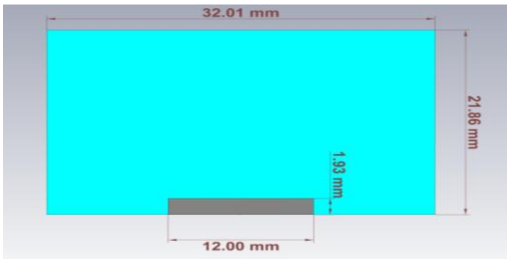

Fig. 1 (c) Spinal view of the propounded antenna design.

III. TABLE I

ANTENNA DIMENSIONS

Antenna Dimensions	Value (mm)
Thickness of patch	0.02
Thickness of substrate	1.57
Thickness of ground	0.02

IV. SIMULATED RESULTS

The recital of the antenna design has been perceived in terms of return loss (dB), gain (dB), directivity (dBi), resonant frequency (GHz), bandwidth (GHz), VSWR and input impedance (ohms). The return loss plot of the propounded antenna is shown in fig. 2. It has been scrutinized that the propounded antenna has resonant frequency of 5.54 GHz with the corresponding return loss of -60.29 dB. The bandwidth of propounded antenna is 2.65 GHz in the frequency range of 4.74 GHz – 7.40 GHz. It has been examined that antenna has gain and directivity of 3.3 dB and 3.08 dBi correspondent to the resonant frequency of 5.54 GHz as shown in fig. 3 and fig. 4, respectively. It has been observed that antenna has E-field and H- field intensity of 18.04 dBV/m and -33.48 dBA/m respectively at resonant frequency of 5.54 GHz as shown in fig. 5 and fig. 6. It has been also analysed that the VSWR of the propounded microstrip antenna design lies below the maximum tolerable value of 2 within the operating frequency range of antenna as shown in fig. 7. The fig. 8 illustrates the Smith chart plot of the propounded antenna. It has been examined from the smith chart that the propounded antenna has impedance of 49.96 Ω which closely matches with desired port impedance of 50 Ω.

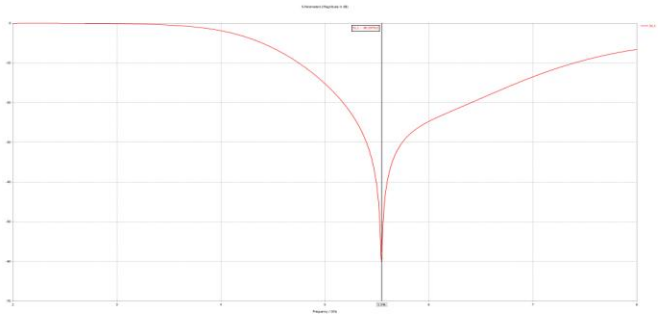

Fig. 2(a) Return loss (S11) showing resonant frequency of antenna design.

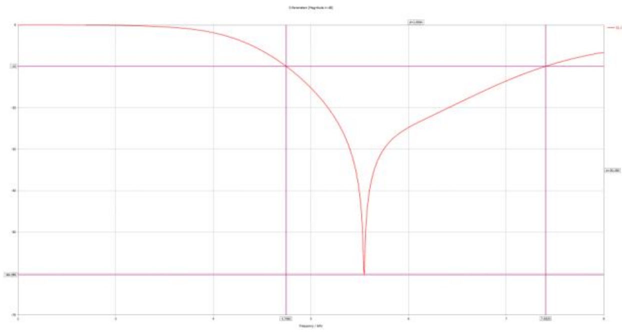

Fig. 2(b) Return loss plot (S11) showing bandwidth of antenna design.

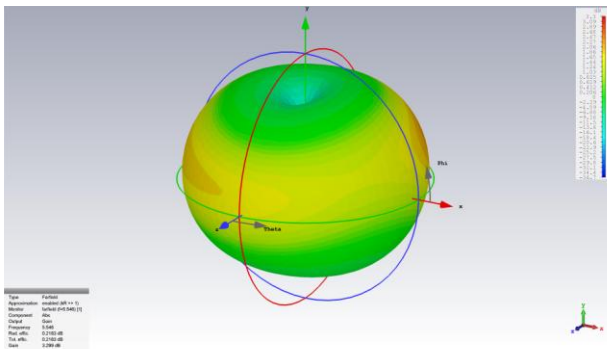

Fig. 3 Gain of antenna @ 5.54 GHz in CST 2016.

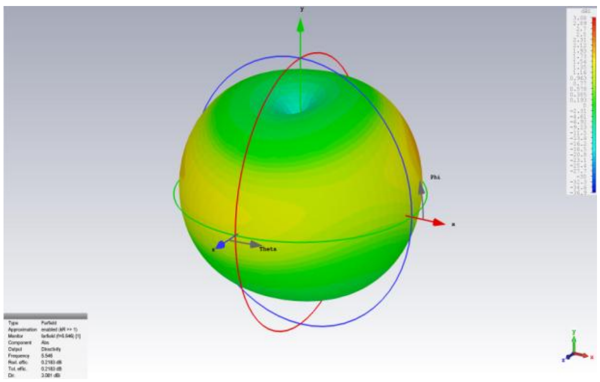

Fig. 4 Directivity of antenna @ 5.54 GHz in CST 2016.

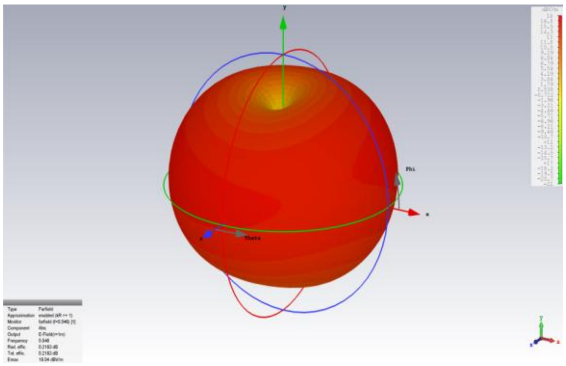

Fig. 5 E-field plot of antenna @ 5.54 GHz in CST Microwave Studio

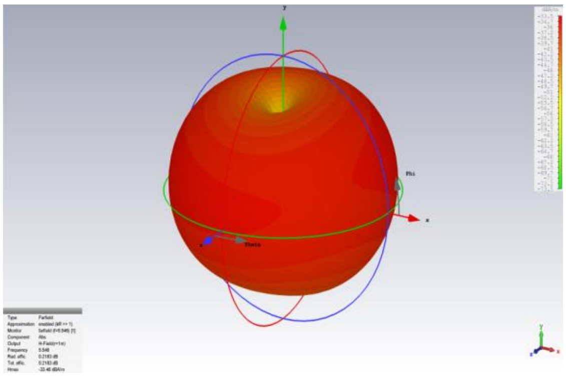

Fig. 6 H-field of antenna @ 5.54 GHz in CST 2016.

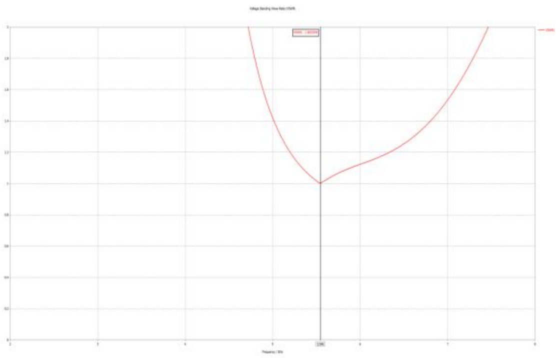

Fig. 7 VSWR of the simulated antenna in CST 2016.

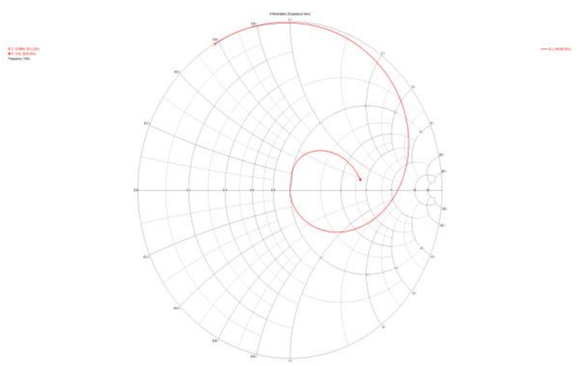

Fig. 8 Smith chart of the antenna design.

V. Conclusion

In this paper a rectangular microstrip antenna for C band applications has been proposed and designed using CST Microwave Studio 2016 software. It has been examined that the antenna is resonant at a frequency of 5.54 GHz with a return loss of -60.29 dB. The impedance bandwidth of antenna is 2.65 GHz ranging from 4.74 GHz to 7.40 GHz. The gain and directivity obtained at resonant frequency is 3.3 dB and 3.08 dBi respectively. The antenna has impedance of 49.96ohms, which makes it is easy to connect a 50ohms transmission line to antenna to reduce impedance mismatching losses. The VSWR value at resonant frequency is less than the maximum tolerable value (i.e. 2). The antenna design can effectively be employed for C band applications like aeronautical communications, aeronautical military systems and land military systems (5.45 GHz - 5.48 GHz), SAR communication (5.48 GHz - 5.68 GHz), inductive applications (5.73 GHz - 5.9 GHz), broadcasting (5.9 GHz - 5.95 GHz), maritime communications, maritime military systems (6.2 GHz - 6.5 GHz) and ISM band (5.13 GHz) [14].

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