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Analysis and Design of Microstrip Patch Antenna for 2.4GHz ISM Band and WLAN Application

Anushree Arun, Anurag Singh

Department of ECE, SRM University Modinagar

Abstract*: In this paper, a high gain rectangular patch antenna is presented for S-band application. The dimensions of rectangular patch antenna are optimized to obtain the desired result and coaxial feed is used to improve the gain and surface wave excitation. The proposed antenna is simulated at resonance frequency of 2.4 GHz. FR4 glass epoxy substrate with thickness of 1.6mm is used in this design. The simulated design exhibits high gain of 6.9dbi and reflection coefficient is below -17db in the entire range of operation and designed antenna can be used for ISM (industrial, scientific and medical) band and WLAN applications. It also exhibits qualities like low profile, low cost, easy fabrication and good isolation. Themicrostrip patch antenna is designed by using Ansoft HFSSV13 simulation software.

***Keywords** – Microstrip patch antenna, high gain, radiation pattern, S-band application.*

1. INTRODUCTION

In this utterly materialistic world, communication plays a major role in human lives. Communication system is most relied upon on daily basis, thus, making antennae as a vital part of this structure[1]. The patch antenna has low profile, easy maintenance, low cost and can be used for several wireless applications but it has some critical limitations such as low gain, low bandwidth. Several techniques are discussed in the literature to overcome these disadvantages.

RF signal traveling on a conductor are transformed into an electromagnetic guided wave in free space and vice versa, using this device. Antennas lye in the category of frequencydependent devices. Each and every antenna being designed for a certain frequency band, rejects signals beyond that operating band. On that ground, they can be considered as bandpass filters and transducers. Along with this, an antenna in advanced wireless system is actually designed to optimize or emphasize the radiation energy in one directions and suppress the same in others. In today's world, these devices play an essential role in wireless communication systems [2]. Due to its various advantages, microstrip patch antennas are more popularly used in different handheld communicating devices [3].Patch antenna is simple to fabricate and easy to modify and customize [4].According to [5] the substrate material plays significant role determining the size and bandwidth of an antenna. While increasing the dielectric constant decreases the size but lowers the bandwidth and efficiency of the antenna. Whereas, while decreasing the dielectric constant increases the bandwidth but with an increase in size. Some research papers reviews are mentioned below. In [6] antenna is feed using microstrip feeding technique and simulated using IE3D software The antenna shows single band bandwidth of 2 GHz for the working band of 4-6 GHz. The proposed antenna is useful for IEEE 802.11 WLAN standards in the 5.2/5.8 GHz band and WiMAX standards in the 5.5 GHz band. In [7] defected ground plane is designed in the form of an L shaped slot and the rectangular parasitic patches and diagonal cuts at top corners can increase the bandwidth. For the first and second resonant frequencies Return losses of −17dB and −30 dB respectively, can be achieved when the diagonal cut is at optimum value. In [8] circular patch antenna is made with a defect in ground plane. In [9] antenna operating at 2.4 GHz frequency band for WLAN applications uses rectangular slot in the ground plane is located at different locations in the bottom of the substrate are taken into consideration and results of optimized patch antenna were obtained . Return loss improvement is from -17.72dB to -26.92dB. Gain improvement is from-5.1dB to -5.9 dB.There are many feeding techniques in a microstrip patch antenna. The most famous feeding techniques employed in the are: coaxial probe, feeding technique with microstrip line and aperture or proximity coupling methods. [10] Apart from these, some other techniques are discussed in the literature like metamaterials, zero refractive index, superstray, etc.

A microstrip patch antenna design consists of two sides: on one side is the dielectric and other side is the ground plane. Copper and gold are usually used to make the conductors of patch which can attain any shape. Albeit, mostly regular shapes are used for ease of analysis and performance prediction. The radiating elements is photo etched to the feed lines on the dielectric substrate. Rectangle, ellipse, square, circle, or other irregular shapes are some shapes of the radiating patch. But most commonly used shape is rectangular due to its fabrication and simplification of analysis. [11]

A microstrip patch antenna best fits for wireless communication because it possess qualities such as its light weight and low planer configuration. The spacing between the patch and its ground plane is the impedance bandwidth of a patch antenna.

Patch arrays tend to provide higher gain than a single patch. Such an array of patch antenna is a simplified way to make a phase array of antenna with dynamic beam forming ability.

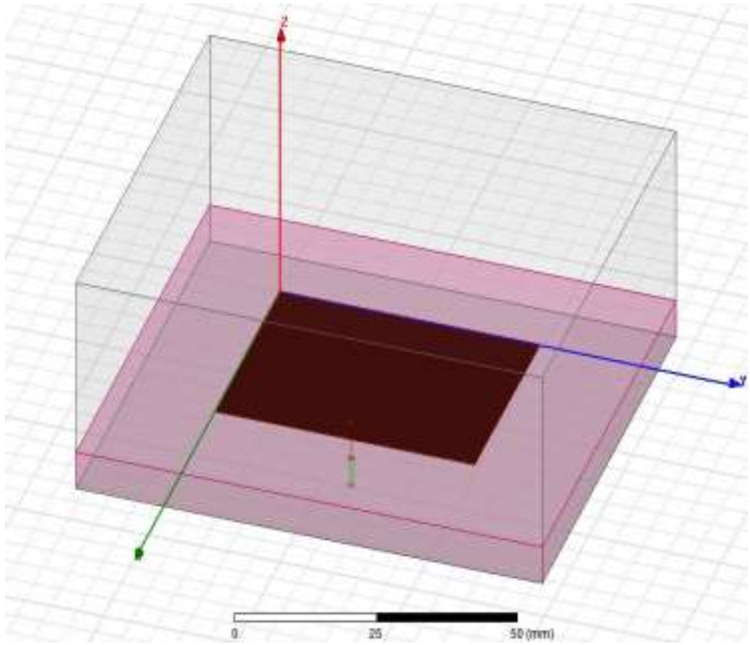

Fig.1 proposed antenna layout

In this paper, we simulate a microstrip patch antenna with optimized coaxial feed. We thereby, improve the gain and current distribution respectively. The designed antenna operates at 2.4 GHz frequency and uses FR4 glass epoxy as a substrate. The inustrial, scientific and medical (ISM) bands are operated at the frequency range 2.4GHZ for the respective purposes. The antenna being designed for 2.4 GHZ, can be used for various applications like WLAN, Wi-Fi family of standard (802.11) and Bluetooth short range wireless application.

2. ANTENNA DESIGN AND SIMULATION

One side being patch and the other side beingground plane, the designed antenna is double side printed, Various feeding techniques can be used to feed the patch antenna. The antenna is fed using a microstrip feed line because it is one of the simplest method to fabricate. The material used for substrate formation is FR-4 Epoxy and its dielectric constant is 4.4. We have the following parameters:

- Frequency of operation fo = 2.4 GHz
- Dielectric constant of the substrate εr = 4.4
- Height of dielectric substrate h = 1.6 mm

1. Width calculation (W)

$$W = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

2.Effective dielectric constant calculation (εreff)

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

3. Effective length calculation (Leff)

$$L_{eff} = \frac{C}{2 f_r \sqrt{\varepsilon_{reff}}}$$

` (3)

4. Length extension calculation (ΔL)

$$\frac{\Delta L}{h} = 0.412 \frac{\left(\varepsilon_{reff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{reff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \quad (4)$$

5. Actual length of patch calculation (L)

L = Leff - 2ΔL (5)

6. Ground plane dimensions calculation (Lg and Wg)

Exclusively for infinite ground planes, transmission line model is applicable, but for practical considerations finite ground plane is required. Same results for finite and infinite ground plane are obtained if, in case of infinite ground plane the size of the ground plane around the periphery is greater than six times thickness of substrate. Hence, the dimensions of ground plane for proposed design would be given as:

Lg= 6h + L =37.9 mm
Wg= 6h + W =47.63mm

A microstrip line or rectangular feed is used for the feeding method. It can be easily fabricated and will match with the patch being a conducting strip smaller in width than the patch antenna. Microstrip line feed have three positions such as inset feed, center feed and outset feed. Our proposed antenna design uses center feed technique which gives excellent match with the patch and also in performance.
Patch Parameters:

Length of Substrate: 76mm

Width of Substrate: 88mm

Height of substrate: 6.7mm

Length of patch: 37mm

Width of patch: 49mm

3. SIMULATION RESULTS AND DISCUSSION

3.1 Return Loss
The diminution of power due to the discontinuity of transmission linein the signal reflected or returned is termed as Return Loss. It can be expressed as,

RL= -20 log [Ł]
It is evident in fig.1 that the proposed antenna has -17.7 db return loss.

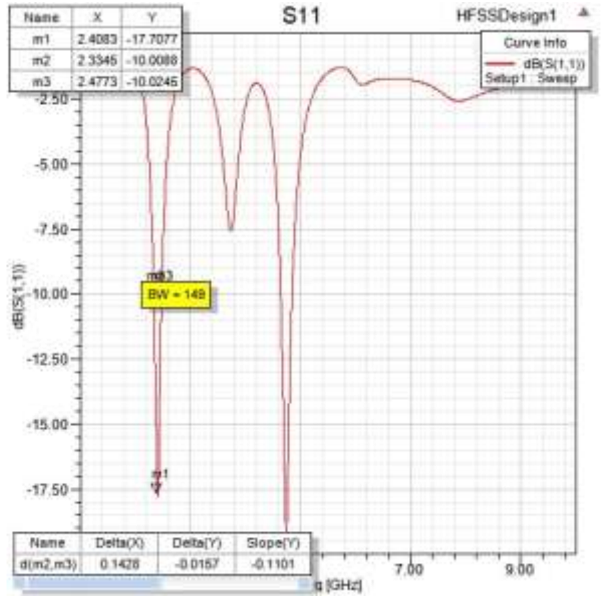

Fig 1. Reflection coefficient of antenna

3.2 Gain

Gain is described as the ratio of radiation field intensity of test antenna to that of the reference antenna. It is evident in fig.2 that the proposed antenna has 6.9 db gain.

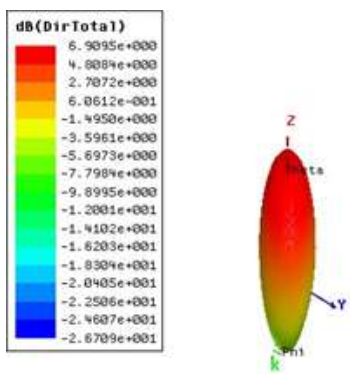

Fig.2. simulated 3D gain of antenna

3.3 Voltage Standing Wave Ratio (VSWR)

The measurement of the incongruity between the load and the transmission line is defined as the Voltage Standing Wave Ration. In an ideal case the value of VSWR is unity and for better matching is 1.6 at 2.4GHZ, 1.3 at 6.1GHZ.

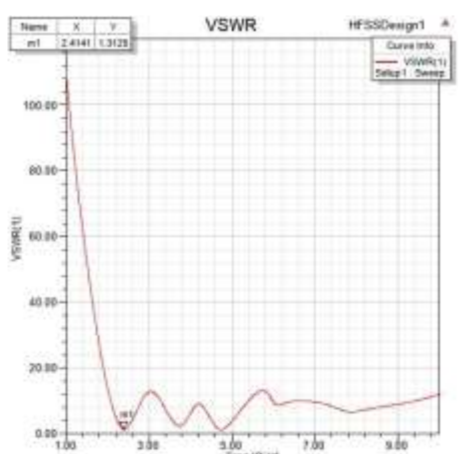

Fig.3 VSWR Curve

3.4 Radiation Pattern

Radiation pattern is depicted in a graphical representation of the electromagnetic power distribution in free space

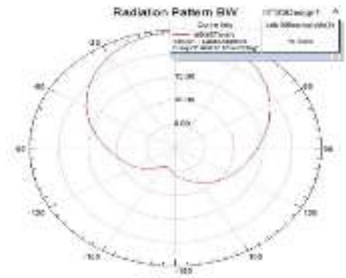

Fig.4 Radiation pattern of E-Field

Conclusion

A high gain rectangular patch antenna is presented for S-band application. The proposed antenna is simulated at resonance frequency of 2.4 GHz.The simulated design exhibits high gain of 6.9dbi and reflection coefficient is below -17db in the entire range of operation and designed antenna can be used for directive and secure applications.

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