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A Novel Rectangular Microstrip Patch Antenna for S - Band Frequency Applications

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Abstract **- A microstrip patch antenna has the ability of polarization diversity. So, it has become an essential antenna for antenna designers. The dielectric loading of the antenna has an impact on the radiation pattern, impedance and the bandwidth. Maximum directive gain is obtained by a single patch antenna. In communications and radar applications, it becomes an important element since it has a scope of a wide variety of design. This paper proposes a design, analysis and simulation of a rectangular microstrip patch antenna for operating in single and dual S band frequencies with center and off-center feeds using ADS software which can be used for the applications such as IRNS, GSM850, GSM900, DCS, PCS, UMTS, WWAN.**

Keywords: Microstrip Patch antenna, Rectangular Patch, ADS

I. INTRODUCTION

A. Microstrip Antenna

A microstrip antenna is a constructed using a conducting patch etched on a ground plane which is separated by a dielectric substrate. The radiation in microstrip antenna occurs due to the fringing fields that is present between the patch edge and the ground plane [1]. Compared to conventional microwave antennas, the characteristics of Microstrip antennas depend more on their physical parameters [2]. Higher bandwidth, better efficiency and lower quality factor Q is obtained by using low dielectric constant. Increased radiated power is possible with a lesser value of dielectric constant which in turn increases the fringing field at the edges of the patch.

II. MICROSTRIP PATCH ANTENNA

A Microstrip Patch antenna is a combination of a radiating patch on one side of a dielectric substrate and a ground plane on the other side [2], as shown in Figure 2.1

Copper or Gold is used as the conducting material to form a patch . The feed lines are typically photo etched on the dielectric substrate.

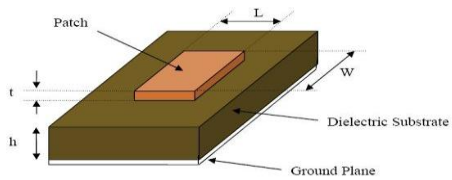

Figure 2.1 Structure of a Microstrip Patch Antenna

The different types of patch are square, rectangular, circular, triangular, and elliptical or some other common shape [3], as shown in Figure 2.2.

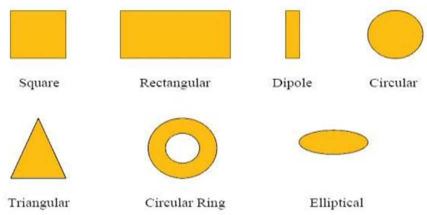

Figure 2.2 Types of microstrip patch elements

III. FEED TECHNIQUES OF PATCH ANTENNA

Microstrip patch antennas can be fed by either contacting or non-contacting method [4]. The RF power is fed straightforwardly to the radiating patch via a connecting element such as a microstrip line, in the contacting method. In the non-contacting scheme, electromagnetic field coupling is done to transmit power between the radiating patch and the microstripline .

A. Microstrip Line Feed

The periphery of the Microstrip patch is directly linked to a conducting strip [5] as shown in Figure 3.1.

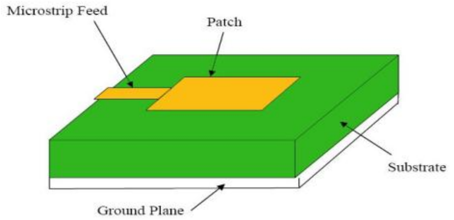

Figure 3.1 Microstrip Line Feed

B. Coaxial Feed

As seen in the Figure 3.2, in a coaxial feed the interior conductor of the coaxial connector extends all the way through the dielectric and it is soldered to the radiating patch, and the external conductor is coupled to the ground plane [6] .

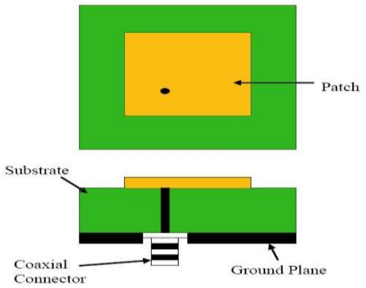

Figure 3.2 Coaxial Feed Rectangular Microstrip Patch Antenna

C. Aperture Coupled Feed

In this type of feed technique, a slot or an aperture etched on the ground plane couples the patch and the feed line as shown in Figure 3.3.

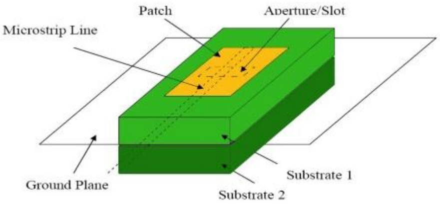

Figure 3.3 Aperture-coupled feed

D. Proximity Coupled Feed

As shown in Figure 3.4, two dielectric substrates are used such that the feed line is sandwiched between them so that the superior substrate contains the radiating patch. Hence this type of feed technique is also called as the electromagnetic coupling scheme.

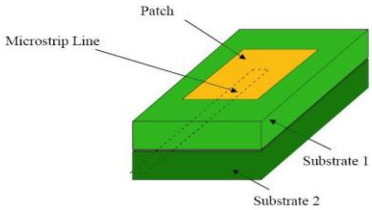

Figure 3.4 Proximity-coupled Feed

IV. ANALYTICAL METHODS OF INVESTIGATION OF PATCH ANTENNAS

A. Transmission Line Model

Compared to other methods, transmission line method is the simplest method. Though it has a better physical insight, it offers only a lesser accuracy [7]. This model predicts the input parameters of the rectangular patch antennas. Here, a rectangular patch radiator is considered as a strip line resonator which does not contain any transverse field variation. It is a known fact that the main mode of propagation in a strip line is the transverse electric magnetic (TEM) mode which has a insignificant deviation of fields in the transverse path.

The microstrip antenna is constructed by two slots of width W and height h that is detached by a transmission line of length L. From figure 4.l it is seen that, largely the electric field lines dwell in the substrate and very few of the electric lines in air. This makes the propagation of TE mode impossible in a transmission line [8]. Fringing fields at the boundary of the patch are not restricted to the dielectric substrate but also extend in the free space.

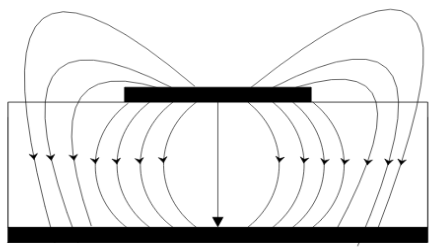

Figure 4.1 Electric field lines

B. Cavity Model

The cavity model is used since the field deviations along the radiating boundaries are ignored in the transmission line model. Here, the interior part of the dielectric substrate is designed as a cavity.

The cavity is encircled by the electric walls on the top and bottom, with the magnetic fields present surrounding the cavity. As the microstrip patch is energized, the allocation of charges occurs not only on the superior and inferior patch surfaces, but also on top of the ground plane surface as shown in figure 4.2

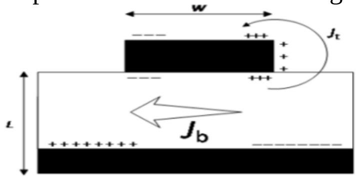

Figure 4.2. Charge distribution and current density creation on microstrip patch antenna

V. NUMERICAL METHODS OF INVESTIGATION OF PATCH ANTENNAS

A. MOM- Methods of Moments

In this method the patch is modelled considering the surface currents. Here a matrix which can be easily solved by a computer is obtained from testing and basis functions.

B. FEM-Finite Element Method

In this method, the area of interest is separated into a number of finite surfaces. These units can be of any distinct geometrical structures such as triangles, tetrahedral etc. Which depends on whether the arrangement is planar, 2D or 3D.

C. FDTD-Finite Difference Time Domain method

The solution is calculated utilizing the spatial and time grid for electric and magnetic fields. Differential form of the Maxwell's equations is used in this method.

VI. DESIGN PROCEDURE

Step 1: The width of the patch is designed (W_p), using the formula [9],

$$W_p = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

Where, c= velocity of light=3×10^8m/s
f_r= resonance frequency
ε_r=dielectric constant

Step 2: The Effective dielectric constant is calculated using the formula [9],

$$\varepsilon_r^{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[\frac{1}{\sqrt{1 + \frac{12h}{W_p}}}\right] \quad (2)$$

Step 3: The Effective length of patch is calculated using the formula [9],

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_r^{eff}}} \quad (3)$$

Step 4: Calculation of length extension uses the formula [9],

$$\Delta L = 0.412h\frac{(\varepsilon_r^{eff} + 0.3)(\frac{W_p}{h} + 0.264)}{(\varepsilon_r^{eff} - 0.258)(\frac{W_p}{h} + 0.8)} \quad (4)$$

Step 5: Actual length of patch is calculated using the formula [9],

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

Step 6: calculation of inset depth is done using the formula [9],

$$Z_o = Z_{in}\cos^2(\frac{\pi d}{L_p}) \quad (6)$$

Where,
Z_o = Characteristics impedance
Z_{in} = input impedance
d = inset depth/notch depth/gap depth

VII. SIMULATION RESULTS

A. Design Specifications for Single Band Operation with center feed.

- f_o= 2.4 GHz
- ε_r = 3.4
- h = 60 mil

Other Parameters for the design are as follows

- μ_r = 1
- Mesh density = 30 cells/wavelength
- Arc Resolution = 45degrees
- Sweep type = Adaptive

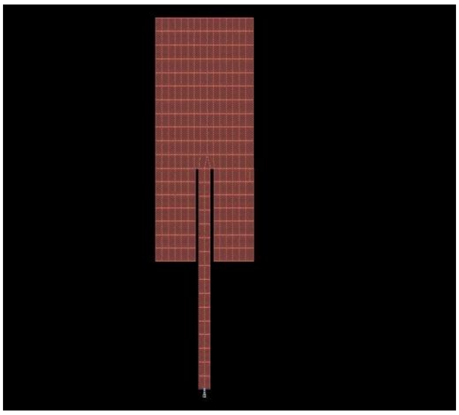

Fig.7.1 ADS mesh pattern for Single Band Rectangular microstrip patch antenna

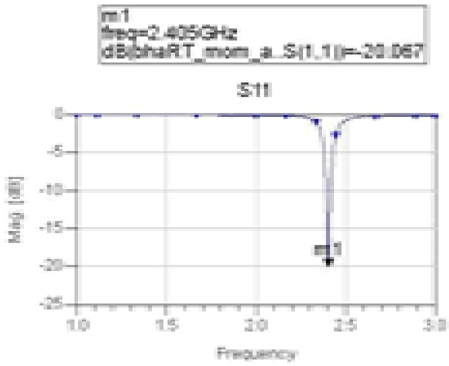

Fig.7.2 Plot for Return loss Vs Frequency

The Simulation results shows that the antenna works in the designed single resonant frequency of 2.435 Ghz in the S Band frequency range.

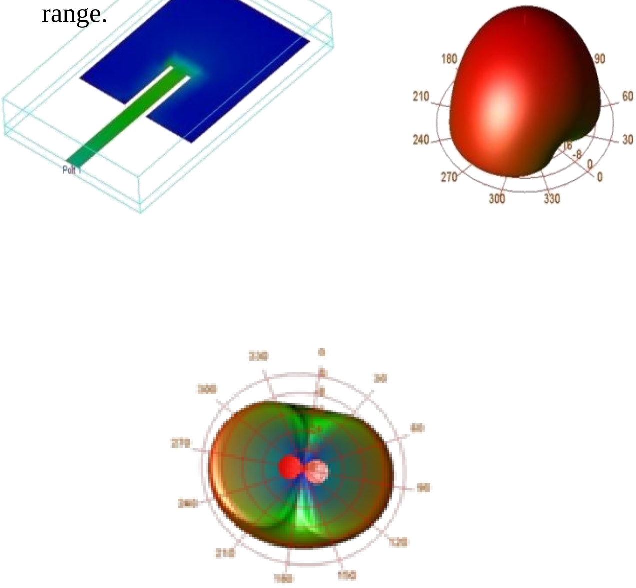

Fig. 7.3 3-D Visualization and Radiation pattern for Single Band Rectangular microstrip patch antenna

B. Design Specifications for Dual Band Operation with Off - Center feed.

The essential parameters for the design are given below,

- f_o= 2.4 and 2.8 GHz
- ε_r = 3.55
- h = 60 mil

Other Parameters for the design are as follows

- Mesh density = 30 cells/wavelength
- μ_r = 1
- Arc Resolution = 45degrees
- Sweep type = Adaptive

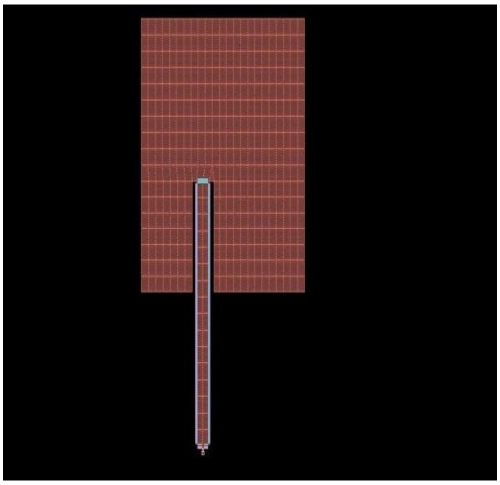

Fig.7.4 ADS mesh pattern for Dual Band Rectangular microstrip patch antenna

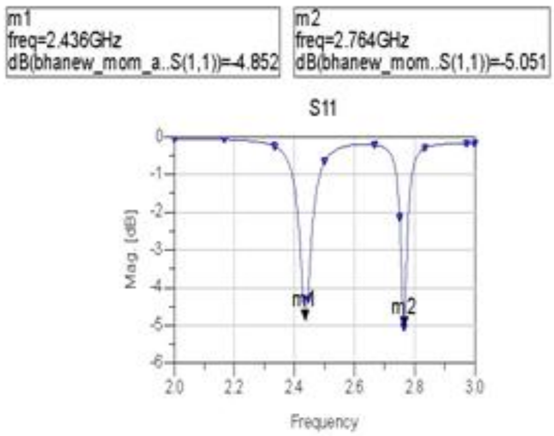

Fig.7.5 Plot for Return loss Vs Frequency

The Simulation results shows that the antenna works in the designed dual frequencies of 2.436 Ghz and 2.764 Ghz in the S Band frequency range.

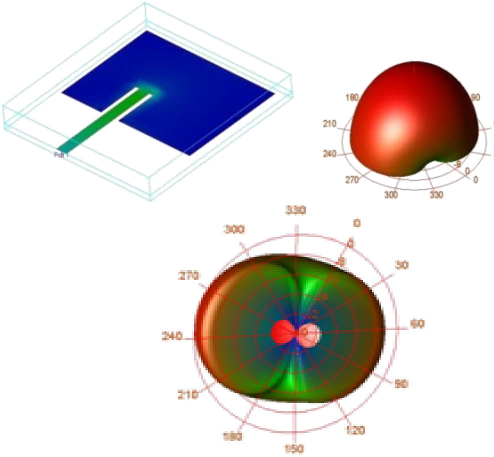

Fig. 7.6 3-D Visualization and Radiation pattern for Dual Band Rectangular microstrip patch antenna

VI CONCLUSION

The design, simulation and investigation of Rectangular Microstrip Patch Antenna for a single resonant frequency of 2.4 Ghz with a centre feed and dual frequencies of 2.4 Ghz and 2.8 Ghz with an off - center feed has been done and the simulation results show that the antenna is perfectly operating in the designed frequencies of S Band. The design of the antenna can be further implemented to be used in S band frequency applications such as Indian Regional Navigational Service(IRNS) etc.

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