Multilayer Structured Rectangular Microstrip Antenna for ISM Band Applications

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Abstract- In this paper efforts have been made to design and simulate the Multilayer Structured Rectangular Microstrip antenna for ISM Band applications. The shape will provide the bandwidth which is required in various wireless applications like Bluetooth (2.4 GHz-2.484 GHz), RFID (2.4 GHz - 2.5 GHz), and WLAN (3.6 GHz) etc. Coaxial feed technique is used for its simplicity. The performance of the designed antenna is analyzed in terms of Bandwidth, Return loss, Gain, VSWR, Directivity and Radiation Pattern. FR – 4 epoxy substrate has been used, which has dielectric constant of 4.4.

Keywords – *Rectangular Microstrip antenna, High Frequency Structure Simulator (HFSS), coaxial feed technique, Bandwidth.*

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I. INTRODUCTION

A Rectangular Microstrip antenna (MSA) in its simplest form consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. The top and side views of a design antenna are shown in Figure-1and Figure-2.

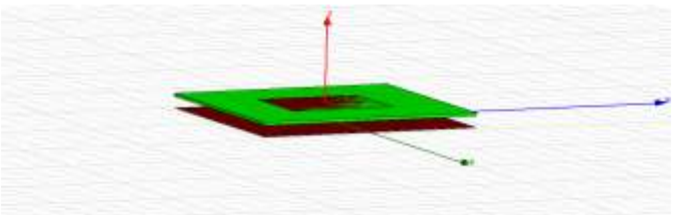

Figure1. The top view of a Multilayer rectangular MSA

Figure2. Side view of MRMSA showing probe feed

However, other shapes, such as the square, circular, triangular, semicircular, sectoral, and annular ring shapes are also used [5]. Microstrip patch antenna consists of a dielectric substrate, with a ground plane on the other side. Due to its advantages such as low weight, low profile planar configuration, low fabrication costs and capability to integrate with microwave integrated circuits technology, the Microstrip patch antenna is very well suited for applications such as wireless communications system, cellular phones, pagers, Radar systems and satellite communications systems [5, 7].

The major disadvantages of Microstrip antennas are lower gain and very narrow bandwidth [1]. The gain and directivity is the issue in fixed wireless local area network (WLAN) application where antenna of high gain and directivity is required [7]. The gain can be increased by using the Microstrip antenna array structure but this again increases the size. Hence the Bandwidth and Gain of Microstrip antenna (MSA) is increased by slightly increasing the dimensions of multilayer structure. The resonant frequency of patch antenna is the function of the length of patch. The two patches have different length so their resonant frequencies are also different. Whole structure resonates at their resultant of resonant frequencies. This increases the bandwidth and gain of MSA. Here FR4 dielectric material is used for its low cost and ease of availability.

II. ANTENNA DESIGN SPECIFICATIONS

Essential parameters for the design of required antenna are as follows:

I] Frequency of operation (f_o): 2.4 GHz.

II] Height of dielectric substrate (h): For the Microstrip patch antenna to be used in cellular phones, it is essential that the antenna is not bulky. Hence, the height of the dielectric substrate is selected as 1.6 mm.

III] Dielectric constant of the substrate (ε_r): The dielectric constant is the ratio between the stored amount of electrical energy in a material and to that stored by a vacuum. The lower the dielectric constant, the better the material works as an insulator and it resists electrons from being absorbed in the dielectric material, creating less loss. FR – 4 epoxy substrate has been used, which has dielectric constant of 4.4.

The basic structure required for antenna design is as follows:

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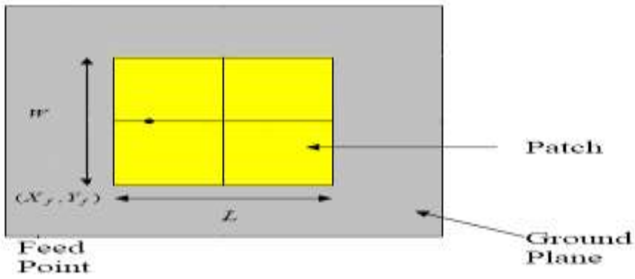

Figure3. Basic structure

Design steps of Multilayer Structured Rectangular Microstrip antenna

Step 1: Calculation of the width of Patch (W):

The width of the Microstrip antenna is given as:

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}} \quad \text{.................................(1)}$$

For c=3*10^8 m/s, f_0 =2.4GHz, ε_r =4.4
Then We get W=38 mm.

Step 2: Calculation of effective dielectric constant (ε_{reff}):

Fringing makes the Microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant given as:

$$\varepsilon_{reff} = \frac{(\varepsilon_r+1)}{2} + \frac{(\varepsilon_r-1)}{2}\left(1+12\frac{h}{w}\right)^{-\frac{1}{2}} \quad \text{..................(2)}$$

For ε_r =4.4 , h=1.6mm, W=38mm

Then We get ε_{reff} =4.085

Step 3: Calculation of Length of Patch (L):

The effective length due to fringing is given as:

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{reff}}} \quad \text{..(3)}$$

For c=3*10^11 mm/s, ε_{reff} =4.085, f_o=2.4GHz

Then We get L_{eff} =30.91 mm

Due to fringing the dimension of the patch increased by ΔL on both the sides given as:

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{eff}-0.258)(\frac{w}{h}+0.8)} \quad \text{......................(4)}$$

For W=38mm, h=1.6mm, ε_{reff} =4.085
Then We get ΔL=0.7388mm

Hence the length the of the patch is:
L= Leff-2ΔL=29.44 mm …………………..(5)

Step 4: Calculation of Substrate dimensions (L_s and W_s):

Ls=L+2*6h Ls = 2*6h + L ……………………….....….(6)
Ls = 2*6(1.6) + 30 = 48.64mm

Ws=W+2*6h Ws = 2*6h + W ……………………….......(7)
Ws = 2*6(1.6) + 38.76 = 57.23mm

Step 5: Calculation of feed point(X_f , Y_f):

The position of the coaxial cable can be obtained by using

$$X_f = \frac{L}{2\sqrt{\varepsilon_{reff}}} = \frac{29.44}{2\sqrt{4}} = 7.36 \cong 7.5 \quad \text{……………..……….(8)}$$

$$Y_f = \frac{W}{2} = \frac{38.76}{2} = 19.38 \quad \text{……………………..…...….....(9)}$$

III. SIMULATION RESULTS OF MULTILAYER STRUCTURED RECTANGULAR MSA

3.1 RETURN LOSS:

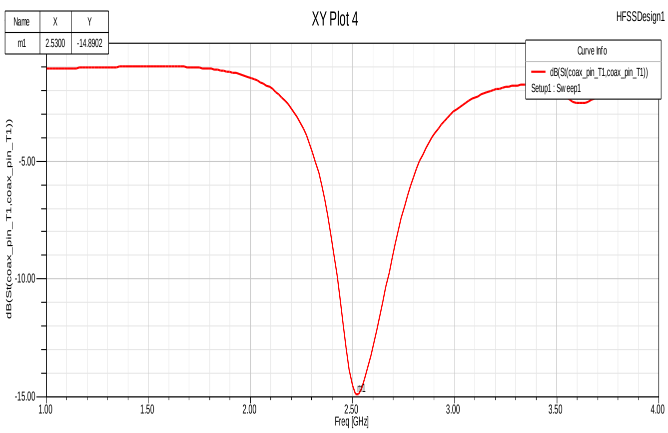

Figure4. Return Loss

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3.2 Bandwidth:

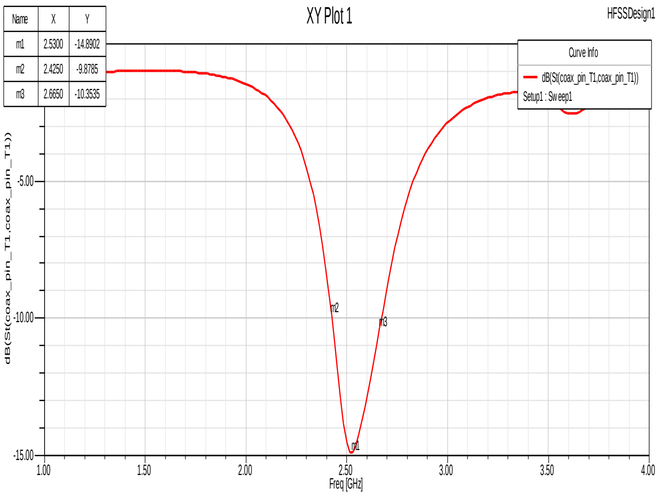

Figure5. Bandwidth

3.3 VSWR:

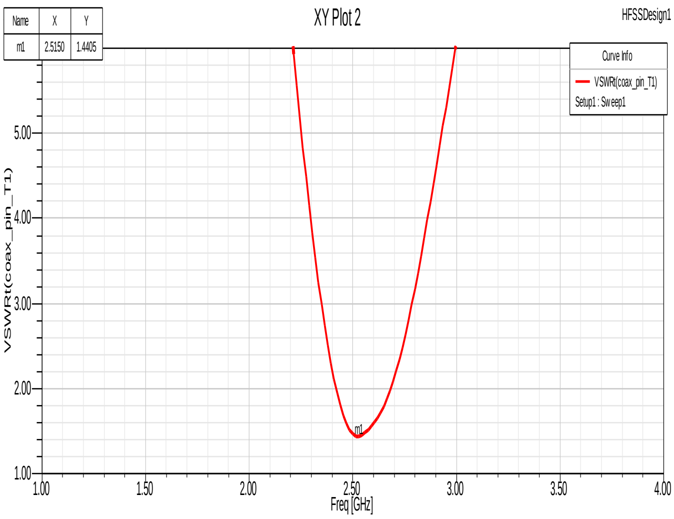

Figure6. VSWR

3.4 Radiation Pattern:

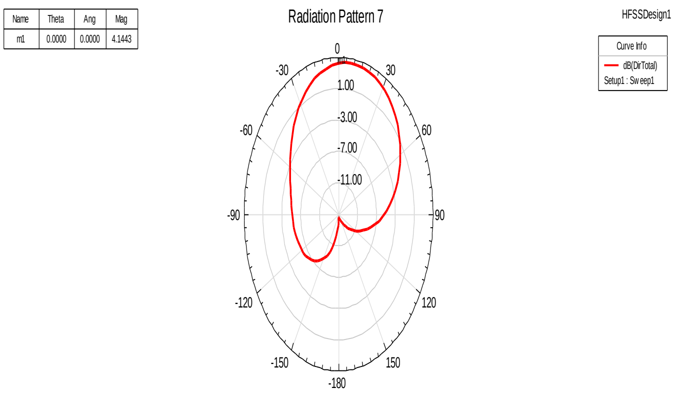

Figure7. Radiation Pattern

3.5 Directivity:

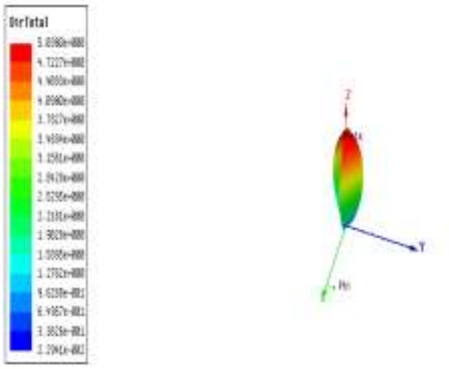

Figure8. Directivity

3.6 Gain:

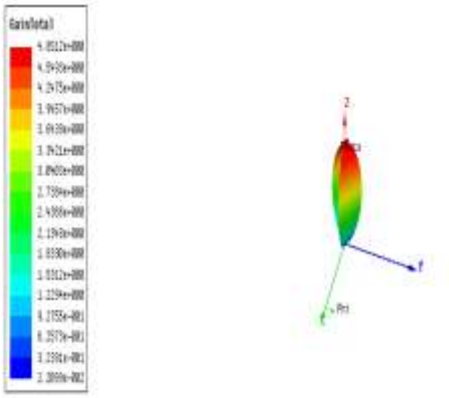

Figure9. Gain

Table No.1 Simulation Results of Multilayer Structured Rectangular MSA with different Parameter:

Parameters	Rectangular MSA	Multilayer Structured Rectangular MSA
Operating Frequency (GHZ)	*2.3900-2.4600*	*2.4250-2.6650*
Return Loss(dB)	-16.1236	-14.8902
Bandwidth (MHZ)	*70*	*240*
VSWR	*1.38*	*1.4405*
Gain (dB)	*5.0*	*4.1443*

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IV. CONCLUSION

Design of Multilayer Structured Rectangular MSA has been simulated using Ansoft HFSS (High Frequency Structure Simulator) software. In this work, the performance of the antenna has been analyzed in terms of Return loss, Bandwidth, VSWR, Gain, Directivity and radiation Pattern. It has been obsereved that, the bandwidth of MRMSA is improved over RMSA. MRMSA is satisfying the requirements of ISM Band applications.

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