Simulation and Comparison of different dielectrics in S-band antenna

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Abstract—As the communication technology is thriving day by day, the number of satellites is shooting up in a faster rate. S-Band antennas have profound applications especially in the field of medical, military, mobile and satellite communications and their utilization has become diverse because of small size and light weight. S-band antennas are very versatile in terms of resonant frequency, polarization, radiation pattern and impedance at the particular shape. This paper elucidates the aspects related to the design and simulation of s-band antenna using microstrip patch. The metallic patch has different configurations such as square, rectangular, circular, dipole or elliptical. When compared to other shapes, Circular patch antenna is widely used since they provide larger Gain with higher bandwidth. First, the dimensions are mathematically calculated and electromagnetic model of circular patch antenna has been simulated using CST Software. Finally, comparison of various parameters of antenna for different dielectrics has been analysed.

Keywords—Microstrip Antenna, Circular Patch, S-Band, Different Dielectrics, Bandwidth, Gain, Directivity.

1 INTRODUCTION

S Band Antenna has frequency range of 2-4GHz and is less susceptible to rain fading.2.4GHz is selected as resonant frequency because it has longer range. Microstrip Antenna is a semi directional radiator using a flat metal strip mounted over a ground plane. Because, it has Low profile ,low cost and portability. Circular patch antenna is preferred because it occupies lesser space. Gain and bandwidth obtained is higher.

This paper demonstrates the concept of designing a microstrip antenna based on liquid substrate. This work suggested an advantage of owing synthesized dielectric constant by mixing diverse liquids. The demonstrated antenna is designed in the UHF band for receiving the digital broadcasting TV. [1]. In this paper they built an innovative circular patch antenna that resonated at 2.34 GHz using3D printing technique, using a new material to the subject which is Acrylonitrile Butadiene Styrene (ABS) as the substrate of the antenna, the cost can be greatly reduced. This antenna is designed on an ABS substrate with dielectric constant 2.74. The whole designation of the antenna is by using Computer Simulation Technology (CST) software [2]. The design and realization of a coastal radar antenna that works on S-Band frequency was demonstrated. The microstrip antenna had been fabricated using FR-4 epoxy substrate with 4.6 dielectric constant and a thickness of 1.6mm [3]. A Microstrip antenna for radar application has been done and conventional shapes like Rectangular, Triangular and Circular Microstrip patch antenna are designed and analysed. The antenna is designed to resonate at X-band frequency. The substrate used by the antenna is the low cost FR4 (Flame Retardant) Epoxy. The Ansoft HFSS (High Frequency Structural Simulator) Version 12 software is used to analyse the results of different shapes of Microstrip patch antenna [4]. This paper presents the comparative study of the Microstrip Patch Antennas which are useful for the wireless application. The antenna performance parameters such as Reflection coefficient and Gain along with their practical usability in the wireless applications are analysed. Most of the antennas discussed are simulated on the FDTD and FEM based methodology [5]. This paper describes various techniques for improving the bandwidth of antenna. There are several techniques used for this purpose like introducing air gap in between substrate and the ground plane, using thick substrate, low dielectric constant of the substrate, multilayer substrates, stacked patch antenna, co-planar with parasitic element and artificial dielectrics. Finally, these techniques are analysed to determine the efficient method [6].

2 ANTENNA DESIGN CONSIDERATION

To design a circular patch antenna the input parameters are

- Resonant frequency (f_r)
- Dielectric constant of substrate (ε_r)

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- Height of substrate (h)

Dielectric materials	Dielectric constant (ε_r)	Radius of patch (mm)	Ground plane dimensions (mm)
FR4	4.3	17.3	40*40
Quartz	3.75	18.4	42*42
RogersRO4350B	3.66	18.7	43*43
Polycarbonate	2.9	20.94	48*48
Oil	2.33	23.2	52*52

Table 1: Antenna Parameters for different dielectrics

The radius of patch is given by

$$a = \frac{r}{\sqrt{\{1 + \frac{2h}{F\epsilon_r\pi}\left[\ln\left(\frac{\pi F}{2h}\right) + 1.7726\right]\}}}$$

where,

$$F = \frac{8.791 \times 10^9}{f_r\sqrt{\epsilon_r}} = 1.7664$$

The length and width of ground and substrate plane is given by

Lg= 6*h+2*a

Wg=6*h+2*a

Substrate: FR4, Resonant frequency of 2.4GHz, dielectric constant of 4.3 and Dielectric height of 1mm then the following were obtained.

The radius of patch a=17.3 mm,

Lg=Wg =40.6 mm.

3 ANTENNA PARAMETERS

Likewise, for other four different dielectric materials the parameters are obtained with frequency of 2.4 GHz and dielectric height of 1mm and is illustrated in the table shown below.

4 CST SOFTWARE

Many simulation software is available to acquire the antenna parameters like SWR, Radiation pattern, Impedance, Gain etc. CST Studio Suite is a high-performance 3D EM analysis software package for designing, analysing and optimizing electromagnetic (EM) components and systems. Electromagnetic field solvers for applications across the EM spectrum are contained within a single user interface in CST Studio Suite.

CST Studio Suite is used in leading technology and engineering companies around the world. It offers considerable product to market advantages, facilitating shorter development cycles and reduced costs. Simulation enables the use of virtual prototyping. Device performance can be optimized, potential compliance issues identified and mitigated early in the design process, the number of physical prototypes required can be reduced, and the risk of test failures minimized.

One key strength of CST STUDIO SUITE is the ability to link multiple simulations with different solvers into a single workflow with System Assembly and Modeling (SAM). This is complemented by new features for EM/circuit co-simulation and the Hybrid Solver Task providing bidirectional solver coupling between the Time Domain and Integral Equation Solvers–a major step forward for hybrid simulation.

5 SIMULATION PROCESS

Simulation of s-band antenna using CST software consists of following steps:

- Creating the project template.
- Creating a geometrical structure of an antenna.
- Setting waveguide port.
- Obtaining far field patterns.
- Determine Radiation pattern, directivity and VSWR.
- Determine Bandwidth and f/b ratio.

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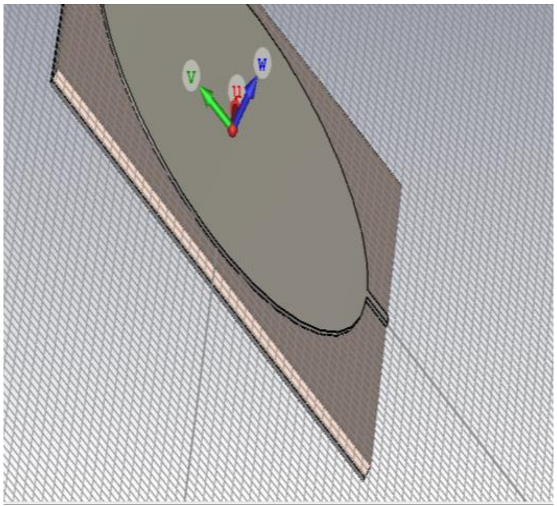

Figure 1: Side view of antenna

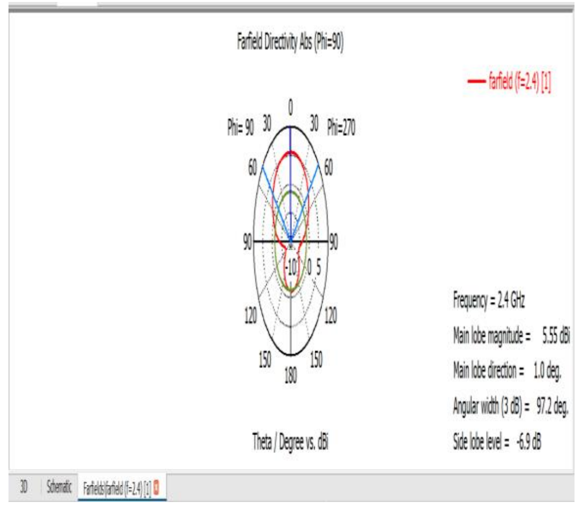

Figure 3: Directivity

6 SIMULATION RESULTS

6.1 3D Radiation pattern (FR4)

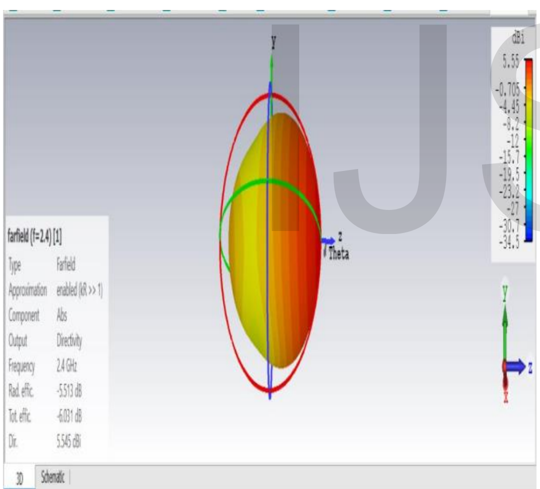

Figure 2: 3D Pattern

6.2 Directivity (FR4)

Directivity is the measure of the concentration of an antenna's radiation pattern in particular direction. Directivity is expressed in dB. The higher the directivity, the more concentrated or focussed is the beam radiated by an antenna.

6.3 S-parameter plot (FR4)

The -3dB line which cuts the curve is considered to determine the lowest and highest cut off frequency. The difference between highest and lowest cut off frequencies gives the antenna bandwidth (ie) Bandwidth = fH – fL

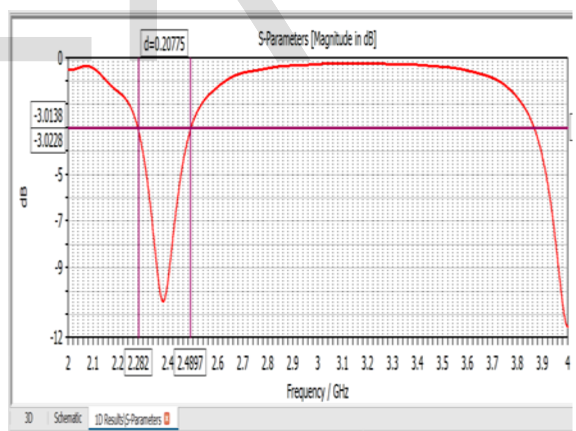

Figure 4: S Parameter Plot

6.4 VSWR plot (FR4)

The Voltage Standing Wave Ratio (VSWR) is an indication of the amount of mismatch between an antenna and the feed line connecting to it. The range of values for VSWR is from **1 to ∞.** A VSWR value under 2 is considered suitable for most antenna applications.

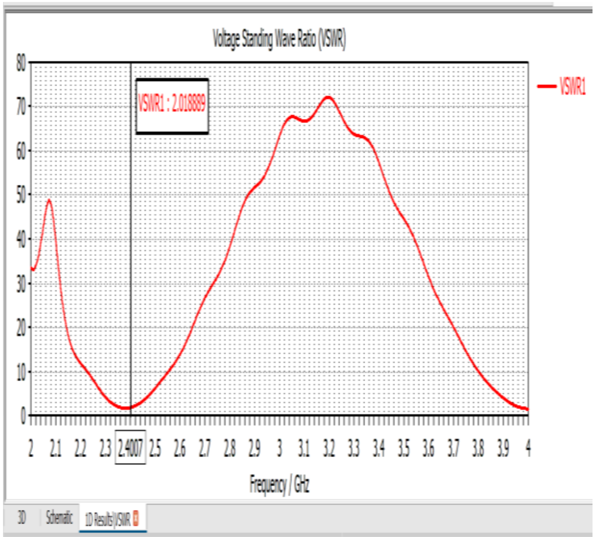

Figure 5: VSWR Plot

6.5 Impedance plot (FR4)

Impedance relates the voltage and current at the input to the antenna. Impedance matching is required for the maximum efficiency.

ZL=Z0(mostly 50 ohm).

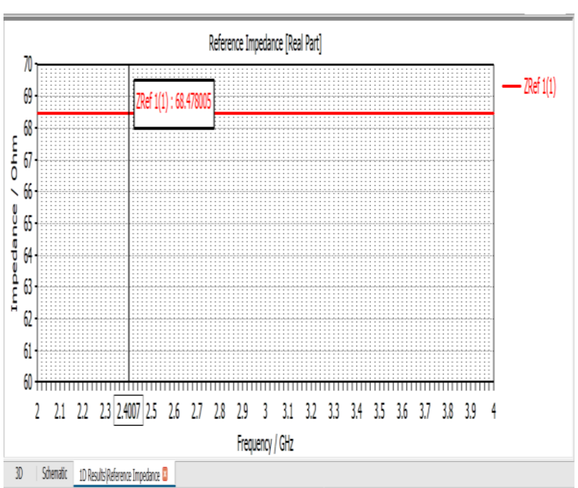

Figure 6: Impedance plot

6.6 Front to Back Lobe Ratio:

The Front to Back Ratio (F/B Ratio) of an antenna is the ratio of power radiated in the front/main radiation lobe and the power radiated in the opposite direction.

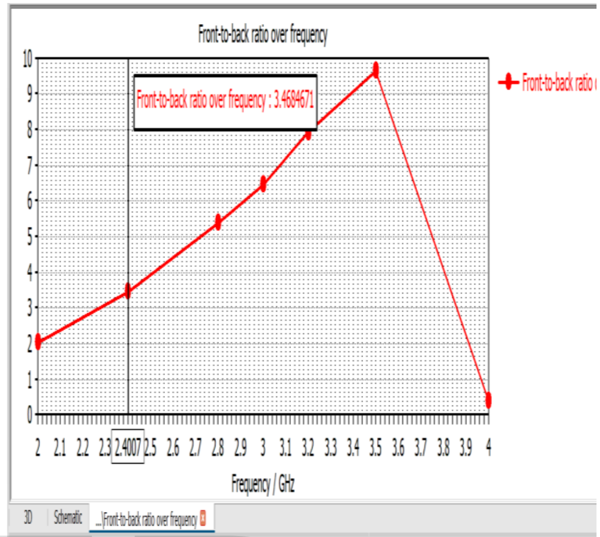

Figure 7: F/B Ratio plot

7 COMPARATIVE ANALYSIS

Thus, comparative analysis is performed for different dielectric materials and antenna parameters for each material is obtained which is shown in the above table.

Dielectric materials	Directi-vity (dBi)	Band-width (MHz)	VSWR	Imped-ance (Ohm)	FBR
FR4	5.55	207.75	2.01	68.48	3.47
RogerRO4350B	5.92	110.82	4.15	61.75	4.28
Quartz	5.82	82.04	4.71	73.29	4.24
Polycarbonate	6.45	171.4	5.09	82.95	5.79
Oil	6.85	11.36	3.59	88.60	7.39

Table 2: Comparison of different dielectrics

8 CONCLUSION

This project illustrates the design and simulation of microstrip antenna in S band (2.4GHz) with different dielectric materials which is mainly used for satellite communication. This project mainly focuses on the antenna parameters like Bandwidth, VSWR, Directivity, Gain, Impedance and FBR. It is used to determine the cost effective and efficient method which gives higher efficiency and also reduced size so that it can be easily used in spacecrafts. The use of FR4 type of material shows that the results produced is better than other dielectric materials. In future the efficient method can be implemented and used in space-crafts so that information from satellites can be tracked and used for several purposes.

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