Comparative study of Rectangular Microstrip Patch Antenna with different materials for UWB Applications

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Abstract

This research paper, presents a comparative study of rectangular microstrip patch antenna with 3 different substrate such as FR-4, CEM-1 and G-10 with a fed through coaxial probe. The antenna with dimension 3.2×3.2 cm (L×W) is fabricated on different substrate materials with substrate height of 0.16 cm is designed and analysed with different parameters. The main goal is to obtain which materials have high directivity with better gain and reduce losses. The results of antenna parameters like VSWR, return loss, gain, and radiation pattern are analyzed on different frequency bands. Simulation is done using SONNET Software.

Keywords *- Microstrip patch antenna; Substrate Material; VSWR; Directivity; Return Loss; SONNET.*

Introduction

In today's world, where the communication has become the necessity, more rightly to be said the antennas are become the essential part of the world because of their undeniable place in the technology of communication systems, the microstrip patch antennas have been the fastest developments in the miniaturization era [1]-[3]. In the past years, the microstrip patch antenna has acquired the popularity in the wireless communication because of its applicable characteristics like small, inexpensive, narrow bandwidth and easy fabrication process. Generally, a microstrip patch antenna consists a patch, substrate, ground plane and feedline [4]. The 8 element microstrip patch antenna array for the 10 GHz with three different kind of materials viz. FR-4, GML 1000 and RT/Duroid 5880, this kind of antenna also shows the good results in comparison to the desirable results and it is very useful for the small area country which required to cover by emission of the microwave beams through the satellite [5]. FR-4, it is a composite material which is composed of woven fibre glass cloth with an epoxy resin binder and it is called flame resistant. FR-4 is mainly used as an electrical insulator which possessing the considerable mechanical strength [6].

Microstrip patch antennas posses many advantages over the standard antennas like lower volume, low price, light weight, low profile, small dimensions, easy fabrication and conformity [7]. The benefits of the UWB (Ultra-Wide Band) technology are less interference, cheap price, high data rate, minimum complexity and protected. The disadvantage of this technology is the requirement for exact time synchronization at the receiver side since the pulse duration in time domain is fraction of nanosecond. It is utilized in many applications such as military communication, radar and imaging in medicine [8].

In this paper we have focused on the performance of the antenna with different material and analysed to select the best on for the UWB applications. We have designed the rectangular shaped antenna and studied the antennas to see the variation in the antenna properties with the different materials.

Methodology

Microstrip patch antenna has a patch which serves as radiating element; dielectric layer as substrate and ground plane for providing isolation between electromagnetic waves [9]. Structural Microstrip Patch Antenna is shown in figure 1.

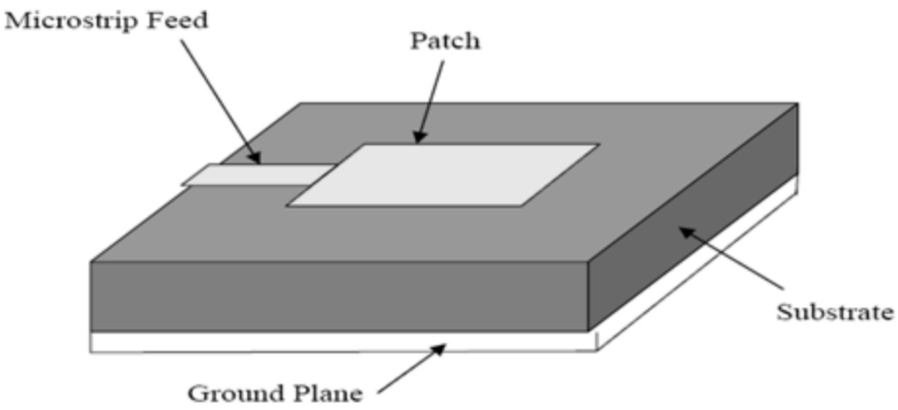

Fig. 1 - Basic Structure of Microstrip Patch Antenna

The proposed Microstrip patch antenna is designed using microstrip line inset feeding technique, because this technique provides a smooth surface to the antenna. The operating frequency to design different antennas is taken as 3.48 GHz, 3.62 GHz and 3.98 GHz simultaneously. SONNET software is utilized to model the proposed antenna. The operating specifications of patch antenna under considerations are its width (W), Length (L), Effective Length (Leff), Patch Extension length (ΔL) and Effective Dielectric Constant (Ereff). These values are calculated using below given equations.

Width:

$$W = \frac{c}{2fr\sqrt{\frac{\mathcal{E}r+1}{2}}}$$

Length:

$$L = Leff - 2\Delta L$$

Patch Length Extension:

$$\Delta L = 0.412h\frac{(\in reff + 0.3)(\frac{w}{h} + 0.264)}{(\in reff + 0.258)(\frac{w}{h} + 0.8)}$$

Effective Length:

$$Leff = \frac{c}{2fr\sqrt{\mathcal{E}reff}}$$

Effective Dielectric Constant:

$$\mathcal{E}reff = \frac{\mathcal{E}r+1}{2} + \frac{\mathcal{E}r-1}{2}\ [1 + 12\frac{h}{w}]\frac{-1}{2}$$

In above equations, resonant frequency of the structure is fr, $\mathcal{E}r$ is the dielectric constant of the substrate material, h is the height and w is the width.

Designing of an Antenna using SONNET

We used the same box dimensions for all the antennas (32×32) mm. Dielectric thickness is 1.6 mm, also the air is 70 cm is same for all the antennas. Design specifications of an Antenna and design parameters for different substrate materials are shown in Table 1 and Table 2 respectively.

Table 1: Design specification of the Antenna

Parameters	**Rectangular (mm)**
Length	19.4
Width	18.5
Substrate Height	0.07
Width of Feedline	6
Height of Feedline	11
Input Impedance	50 Ω
Dielectric Thickness	1.6

Table 2: Design Parameters for different Substrate Material

Design Parameters	**Substrate Material**		
	FR-4	**CEM-1**	**G-10**
Loss Tangent	0.025	0.025	0.025
Dielectric Constant	4.9	4.5	4.8

Geometry of a **Rectangular Microstrip** Antenna is shown in Figure 2. The Patch Antenna is excited using a voltage source connected across the metal patch and the bottom metallic plane of the substrate.

This structure provides maximum radiation in a direction perpendicular to substrate (i.e. broadside) direction and structure under consideration has ideally no radiation in the plane of substrate (i.e. end-fire) direction. The dimensions of the antenna are selected in such a way that it resonates at the operating frequency with a production of real input impedance. In above designed rectangular microstrip patch antenna the length L is to be nearly half of wavelength in the used dielectric medium, width W determines the value of input impedance.

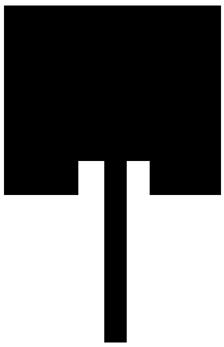

Fig. 2 - Geometry of Rectangular Antenna

Results and Discussion

When the designed antenna is simulated by using the SONNET, the comparison of return loss and VSWR is shown in the figure 3 and 4. From the results obtained the resonating frequency and return loss is different for different materials. The proposed antenna can cover the UWB applications.

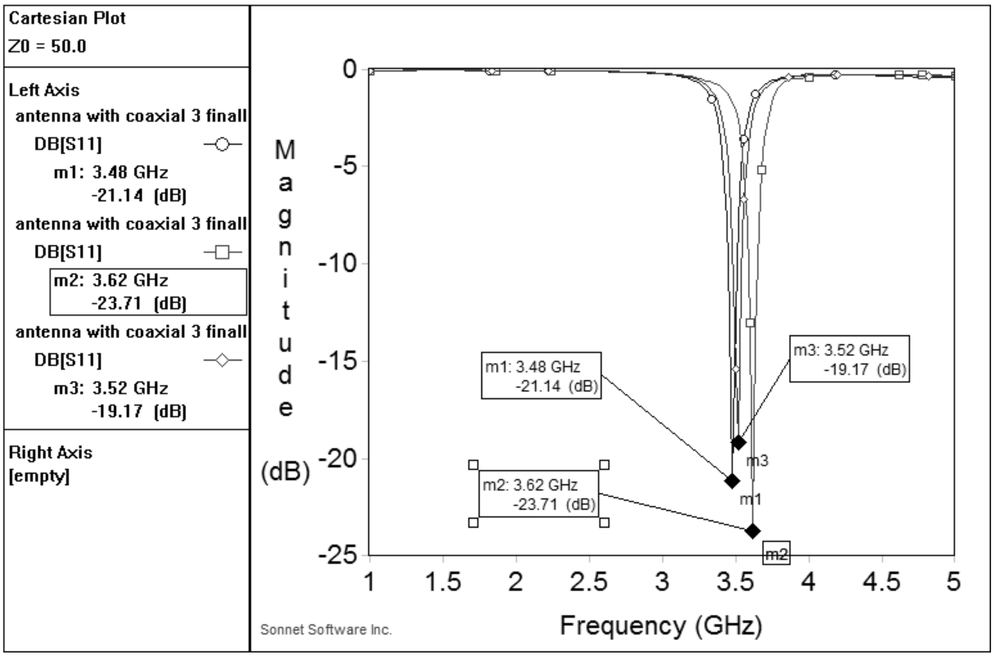

Fig. 3 - Comparison Return loss of Different Materials

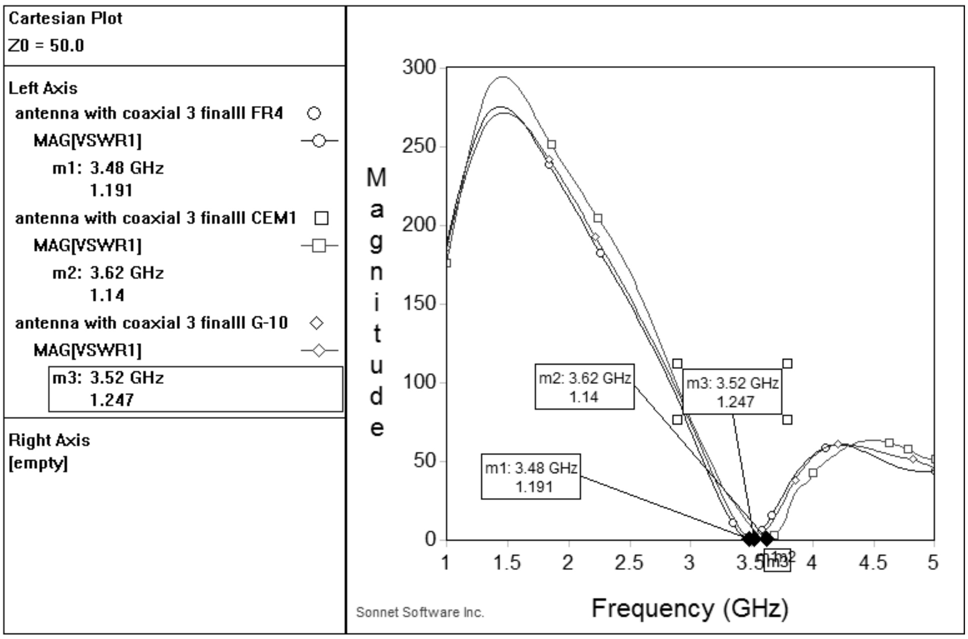

Fig. 4 - VSWR comparison with different materials

Figure 5 shows the Smith chart comparison of FR-4, CEM-1 and G-10 material.

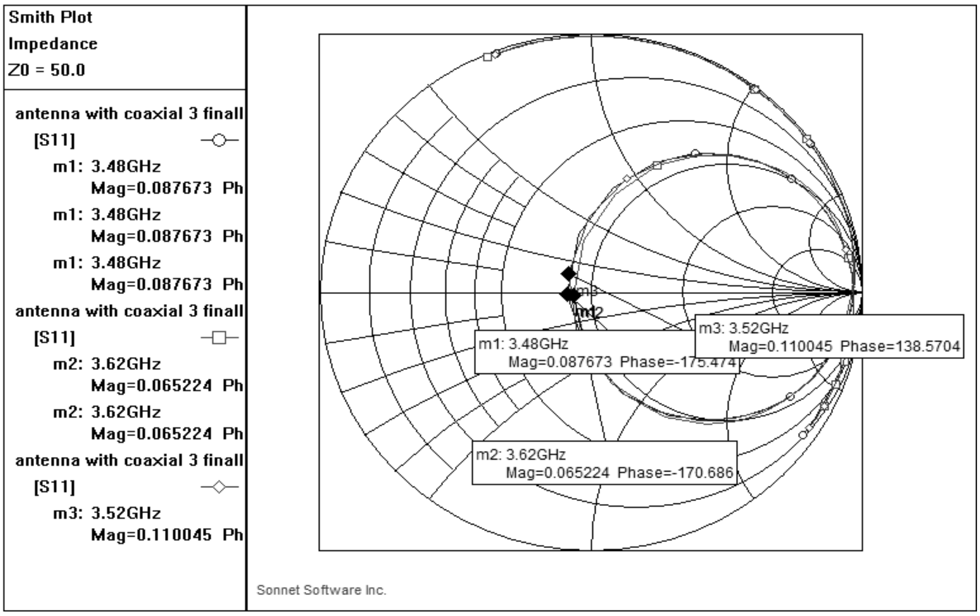

Fig. 5 - Smith Chart comparison with different materials

Figure 6 and 7 shows the current distribution of the proposed rectangular antenna which shows the distribution of the current and far firld distribution of the antenna.

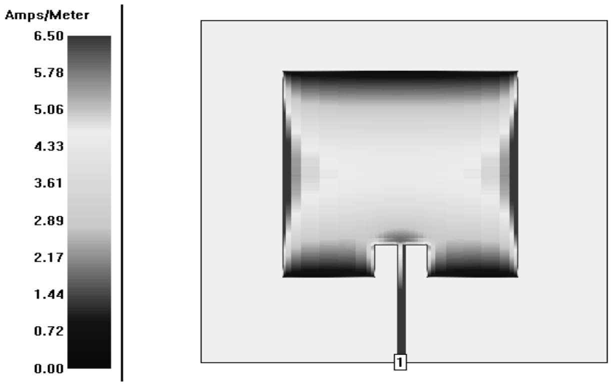

Fig. 6 - Current Distribution of Rectangular Shape Antenna

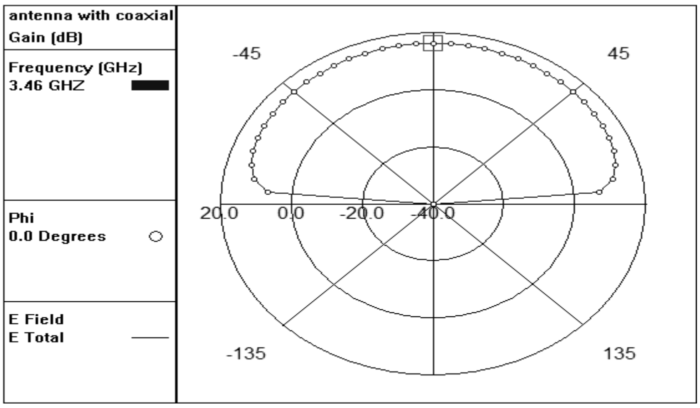

Fig. 7 - Far Field Distribution of Rectangular Shape Antenna

Table 3 shows the comparision of various parameters of antenna for FR-4, CEM-1 and G-10 substrate materials.

Table 3: Comparison of performance parameters

Antenna Parameters	Substrate Material		
	FR-4	CEM-1	G-10
Frequency	3.48 GHz	3.62 GHz	3.52 GHz
Return loss	-21.16 dB	-23.71 dB	-19.16 dB
VSWR	1.191	1.14	1.247
Gain	3.789 dB	3.472 dB	3.304 dB

Conclusion

Observation of the results gained by the simulation of the rectangular antenna can help us to draw some conclusions regarding the design parameters. Table 3 shows the comparison of return loss, gain and VSWR of 3 substrate materials. The materials which have been taken with the different dielectric material. It has been found from the above simulation that the CEM-1 has the good results among the all substrate material for this particular design which is suitable for the UWB applications.

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