To Study the Effect of Substrate Material for Microstrip Patch Antenna

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Abstract- *In this paper a rectangular patch antenna with parasitic stubs whose edge have been cut has been proposed. Two slots are used near the feedline . The antenna is designed using HFSS. Different substrate has been used to design the antenna such as Epoxy_kevlar_xy and FR4_epoxy. The effect of change in substrate material on the performance of antenna is studied, in terms of antenna performance parameter like gain, return loss and radiation pattern. It is analysed that antenna performance changes when we vary substrate material.*

Keywords - *Microstrip Patch Antenna, Substrate, Slot, Relative Permittivity, dielectric loss tangent*

I. INTRODUCTION

An antenna is a transducer that is used to transmit or receive electromagnetic waves. A microstrip patch antenna is made up of a radiating patch on one side of dielectric substrate while has a ground plane on the other side [1]. The radiating patch can take any geometrical configuration like square, rectangle, circular, elliptical, triangular etc [2]. The material used for substrate can be dielectric constant in the range of $2.2 \leq \varepsilon_r \leq 12$. A microstrip patch antenna finds huge attention because of several advantages over the conventional antennas. Some of the advantages of microstrip patch antenna are low profile, light weight, low volume and low cost. The substrate provides mechanical strength to the overall antenna design and surface waves also propagate through it. If we change the material of substrate and the thickness of substrate of a microstrip antenna, it changes the system performance by changing the dielectric constant (ε_r). There are wide variety of substrate materials have been found for microstrip patch antenna design with mechanical, thermal and electrical properties which are attractive for use in both planar and conformal antenna configurations. Due to the finite dimensions of the antenna, the fields along the edges undergo fringing. The amount of fringing varies with the antenna dimensions and the height of the substrate. Since waves travel both in air as well as in the substrate, so an effective dielectric constant (ε_{eff}), is introduced for the fringing effects as given in below equation (1) .

$$\in_{reff} = \left(\frac{\in_r + 1}{2}\right) + \left(\frac{\in_r - 1}{2}\right)\left[1 + 12\left(\frac{h}{w}\right)\right]^{-1/2} \qquad (1)$$

Where,

ε_{reff} = Effective dielectric constant

ε_r = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of the patch

The radiation increases with the increase in frequency, lower permittivity and thicker substrate. Cost, power loss and performance are trade-off considerations in choosing the substrate material. There are such materials with dielectric constant higher than 10 [3]. The patch size reduces for higher dielectric constant and it also reduces bandwidth and radiation efficiency. It concludes that the selection of substrate material is an important part of antenna design methodology.

II. RELATED WORK

S.A.Zaidi and M.R.Tripathy designed an E shape microstrip patch antenna [4], at operating frequency of 9.8 GHz. FR4 is used as substrate material & simulated result gain is 4.45 dB. They use Kevlar material with reduced dielectric constant. The antenna is working at a frequency of 10.8 GHz for Kevlar material and total gain of 6.29 dB. In [5] B.Ahmed et. al. shows the effect of various parameters on the performance of microstrip patch antenna. By change in feeding technique, height of substrate and material of substrate authors observed that there is variation patch antenna parameters like gain & return loss . In [6] D.Pavithra and K.R.Dharani studied that substrate material affect the performance parameters such as Return Loss (S_{11}). The patch antenna is designed for 4 different frequencies with FR4 and DUROID-6006. The results represent that for frequencies up to 4GHz FR4 material is convenient. Alak Majumder [7], designed wide band H shaped microstrip patch antenna is working at a frequency of 2.42 GHz and can be used in WLAN applications. Sushila Gupta proposed H- shape antenna [8] using probe fedd technique at frequency 3.42 GHz that is used in WiMax applications. In this paper author used RT Rogers Duroid 5880 as the substrate to study the various parameters like gain, VSWR, return loss etc. Goyal R, Jain Y. K , [9] shows the bow shape microstrip antenna with Benzocyclobuten as a substrate material. The size was reduced upto 40% that of conventional rectangular patch antenna. It operates on Resonant frequency 4.35GHz. The simulated results return loss and radiation pattern are good for Benzocyclobuten material. Awan A H et. al. in paper [10] worked on three different types of materials such as FR4, GML 1000 and RT/Duroid 5880. The designed frequency was 2.5GHz and simulated with HFSS for those materials. Design of 8 element microstrip patch array for 10GHz shows good experimental results as compare to the desirable results. In paper [11] author studied effects of substrate thickness on antenna parameters by changing substrate parameters. The designed frequency was 2.4 GHz.

III. ANTENNA DESIGN AND IMPLEMENTATION

Wideband microstrip patch antenna has been designed by taking a rectangular patch of 20×12mm^2.Upper corner of the patch as well as the stub corner have been cut. Now a T shape slot is applied on the patch as shown in the Fig.1 and the effect of change of substrate like Epoxy_kevlar_xy and FR4_epoxy has been studied. The Table 1 shows the different parameters used to design the antenna. The Table 2 gives material with their different properties.

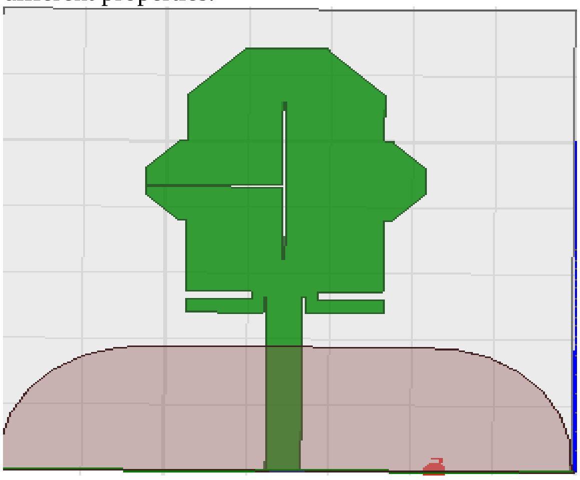


Fig.1: 2D view of proposed antenna

Table 1: Design parameter and corresponding values

Subject	Dimensions
Ground Size	35×9.4mm
Patch Size	20 ×12mm
Substrate Used	Epoxy_kevlar_xy and FR4_ epoxy
Thickness	1.6mm
Stub size	2.6×6 mm^2
Slit size	4×0.6 mm^2

Table 2: Materials used for Substrate

Material	Relative permittivity	Dielectric Loss Tangent
FR4_epoxy	4.4	0.02
Epoxy_kevlar_xy	3.6	0

IV. RESULTS & DISCUSSION

The designed antenna is simulated with help of HFSS. With the edge tapering and by adding parasitic stubs antenna resonates at different frequencies. The graph of return loss for FR4_epoxy and Epoxy_kevlar_xy is shown in Fig. 2. The dotted line shows the return loss for epoxy_kevlar and other is for FR4_epoxy substrate. The designed antenna give different values for both materials. The maximum value of return loss is -31.264 dB at 7.58 GHz for FR4_epoxy and -22.24 dB at 8.01 GHz for epoxy_kevlar_xy.

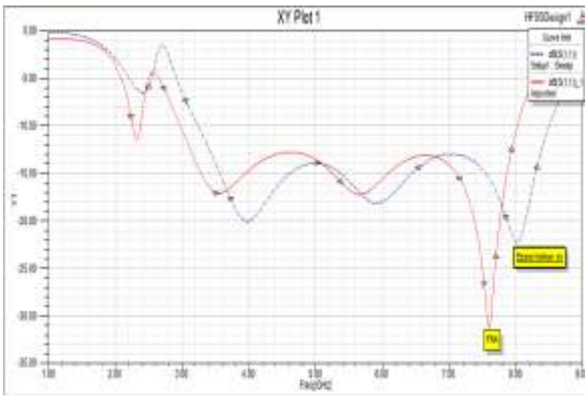


Fig.2: Return loss for FR4_epoxy and epoxy_kevlar_xy substrate

Gain :- In order to study the effect of gain the designed antenna is simulated for different materials of substrate. The gain is 7.96 dB at 5.66 GHz frequency for FR4 epoxy material and 8.45 GHz at 5.90 GHz for epoxy_kelvar_xy material. The thickness of substrate and geometric shape is same for valid comparison of gain. The 3D polar plot of gain for different materials is shown below.

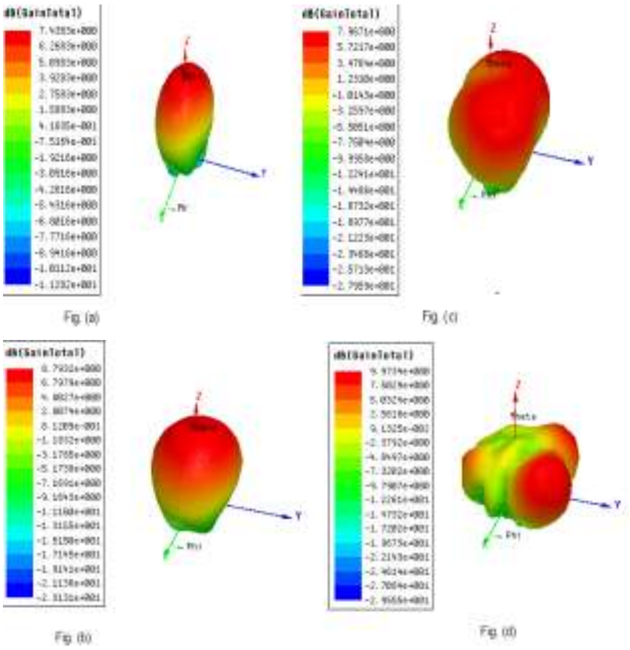


Fig.3: 3D polar plot of gain for designed antenna for FR4 epoxy substrate Fig (a) for 2.30 GHz, (b) for 3.53 GHz, (c) for 5.66 GHz and (d) for 7.58GHz

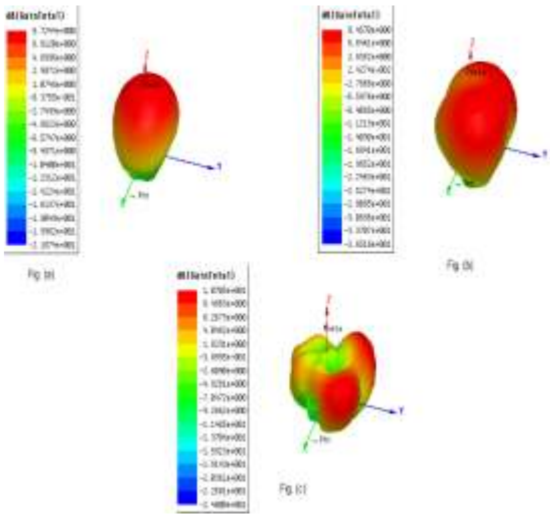


Fig.4: 3D polar plot of gain for designed antenna for Epoxy_kevlar_xy substrate (a) for 3.97 GHz (b) for 5.90 GHz and (c) for 8.01 GHz

Radiation pattern:-

The antenna has been designed to provide uniform radiation patterns on the broadside of the radiating surface. Figures show the 2D plots of the radiation pattern in all the three principle planes for both the corner and the center frequencies. These are obtained at different frequencies.

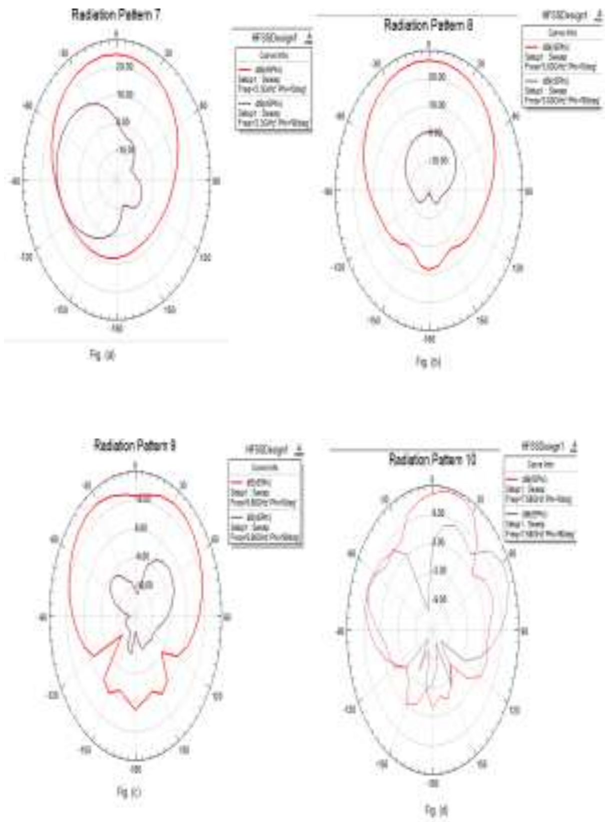
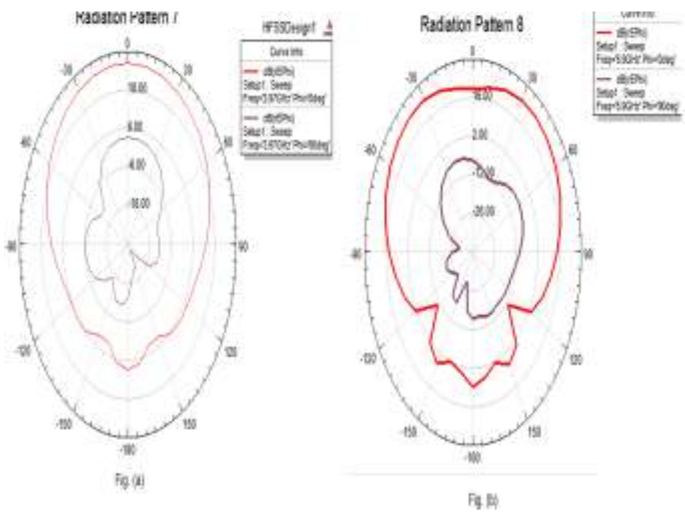


Fig.5: Radiation pattern of designed antenna for FR4_epoxy substrate (a) for 2.30 GHz, (b) for 3.53 GHz, (c) for 5.66 GHz and (d) for 7.58GHz



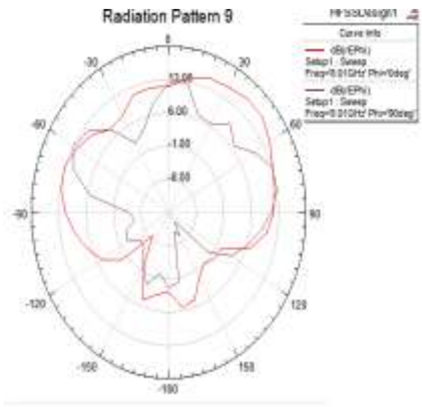


Fig (c)

Fig.6 : Radiation pattern of designed antenna for Epoxy_kevlar_xy substrate substrate (a) for 3.97 GHz (b) for 5.90 GHz and (c) for 8.01 GHz

Table 3: Comparison of performance parameters of antenna using different substrate material

Material	Frequency (GHz)	Return Loss (dB)	Gain (dB)	Efficiency (%)	Band width (GHz)
FR4-epoxy	2.30	-11.404	7.4	1.10	0.12
	3.53	-17.00	8.79	0.989	5.07
	5.66	-17.30	7.96	0.96	5.07
	7.58	-31.24	9.97	0.798	5.07
Epoxy kelvar-xy	3.97	-20.24	8.72	1.02	5.26
	5.90	-18.45	8.45	1.04	5.26
	8.01	-22.24	1.07	1.24	5.26

From the comparison table, it has been concluded that with the decrease in relative permittivity of substrate material performance of antenna can be enhanced. The bandwidth is 5.26 GHz for epoxy_kelvar_xy material and 5.07 for FR4 – epoxy. The overall efficiency also increases with low dielectric constant.

V. CONCLUSION

The performance of microstrip Antenna is effected by its structure and dimensions but the substrate material has also significant role in analyzing antenna performance. When dielectric constant increases then the resonant frequency as well as the bandwidth also decreases. Two material Epoxy_kevlar_xy with dielectric constant 3.6 and FR4 with dielectric constant 4.4 are used for designed antenna to study the effect of substrate material. It has been concluded that when dielectric constant reduces from 4.4 to 3.6 then Bandwidth increases. The efficiency of the antenna also improve with low dielectric constant. The overall performance of the antenna is influenced by substrate material at great extent.

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