International Journal of Emerging Engineering Research and Technology
Volume 2, Issue 9, December 2014, PP 18-23
ISSN 2349-4395 (Print) & ISSN 2349-4409 (Online)

Comparative Study of Microstrip Antenna for Different Subsrtate Material at Different Frequencies

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Abstract: *Limitations of microstrip antenna such as low gain, low efficiency and high return loss can overcome by selecting proper substrate materials. Permittivity of substrate is critical parameter in controlling band width, efficiency, and radiation pattern of patch antenna. In this paper, comprehensive study of effects of various dielectric materials on performance parameters of patch antenna is studied at different frequencies. Antennas are designed for different frequencies with two different substrate materials viz. FR4 and DURIOD. Finally the comparison is shown. Ansys HFSS (High Frequency Structure Simulator) is used for design simulation.*

Keywords: *FR4, DUROID-6006, HFSS, patch.*

1. Introduction

The rising importance of wireless communication and multimedia services increasing the efforts to the design and implementation of microstrip patch structures. A patch antenna is advantageous because of its low cost, small size, ease of fabrication, and can easily be integrated into many commercial transceiver systems. Microstrip antenna elements radiate efficiently as devices on microstip printed circuit boards. The microstrip patch antenna is an excellent candidate for portable wireless devices**.**

As patch antenna establishes its physical attributes on a dielectric substrate having effective electrical and magnetic properties, so selecting a correct substrate is important as well. The change in substrate material will effects the performance of the antenna in all aspects as per the output parameters are concerned. Thick substrates are desirable for better antenna performance. But thick substrates have dielectric constant in the lower end of the range. This is due to larger bandwidth, better efficiency, and loosely bound fields for radiation into space but results in large element size. With the increase in frequency, lower permittivity and thicker substrate, the radiation increases. Cost, power loss and performance are trade-off considerations in choosing the substrate material. There are such materials with dielectric constant higher than 10. The patch size is smaller for higher dielectric constant. However, higher dielectric constant also reduces bandwidth and radiation efficiency. However it concludes that selection of substrate material is an important part of antenna design methodology.

2. Basic Structure

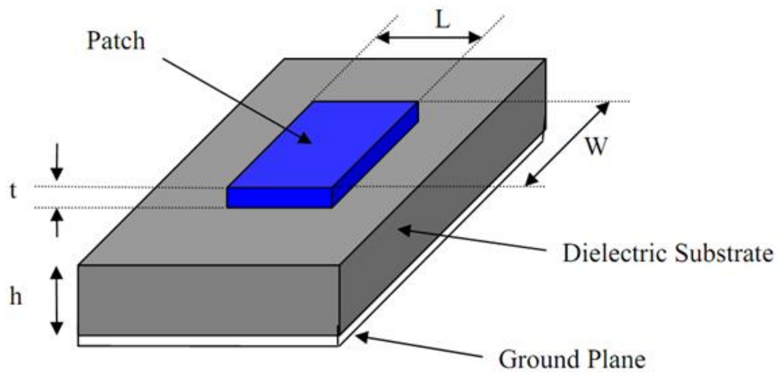

Fig1. *Structure of Microstrip Antenna*

In its most basic form, a Microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which also has a ground plane on the other side as shown in Figure 1. The patch [2] is generally made of conducting materials such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

2.1 Literature Review

Deschamps first proposed the concept of the MSA in 1953. However, practical antennas were developed by Munson and Howell in the 1970s **[1,2,3]**. The numerous advantages of MSA, such as its low weight, small volume and ease of fabrication using printed-circuit technology, led to the design of several configurations for various applications. With increasing requirements for personal and mobile communications, the demand for smaller and low-profile antennas has brought the MSA to the forefront **[1]**.

Goyal R *et al.*[7] put forward the bow shape microstrip antenna having Benzocyclobuten as a substrate material. It was a rectangular patch antenna but the size was reduced upto 40% that of conventional rectangular patch antenna. Resonent frequency was found 4.35 GHz when tested experimentally. Antenna with Benzocyclobuten material shows good results for return loss and radiation pattern.

Awan,Munir *et al.* [8] exploited this feature and worked on three different types of materials viz. FR4, GML 1000 and RT/Duroid 5880. Antenna was designed for 2.5GHz and simulated with those materials. Simulation software HFSS has been used. Design of 8 element microstrip patch array for 10GHz shows good experimental results as compare to the desirable results. 10GHz X-Band antenna is useful in small countries where the small area is required to cover by emission of microwave beams through satellite. This patch antenna with narrow beam-width of approximately 20 deg to 365 deg are required to complete the satellite communication coverage.

Rathi V *et al.* [9] has worked on effects of substrate thickness on antenna parameters. The designed frequency was 2.4 GHz. They have studied different properties by making changes in substrate parameters.

Chen,W *et al* [10]. has made an attempt to answer questions like i) how does the impedance of antenna changes with change in substrate thickness. ii) how does the impedance bandwidth of antenna changes with change in substrate thickness. iii) what is the effect of feed location on impedance bandwidth. Numerical results are presented to show the clear effects of each parameter.

Singh and Tripathi V. L *et al.*[11] worked on two layer conventional substrate with different permeability and different height. The designed frequency is 2.4GHz. The slot antenna fabricated on reactive impedance substrate (RIS). The final optimized structure exhibits an axial-ratio bandwidth of about 15% and impedance bandwidth better than 10%.

2.2 Antenna Design

In order to identify and verify the improvement for rectangular structure in microstrip antenna, the conventional Microstrip antenna design method is used [1].

Design Steps:

Designing the patch antenna is to employ the following formulas as an outline for the design procedures.

i. Width (W)

$$W = \frac{c}{2f_r\sqrt{(\frac{\varepsilon_r+1}{2})}} \qquad (1)$$

Where

c - free space velocity of light, 3×10^8 m/s

f_r - frequency of operation

ε_r - dielectric constant

ii. Effective Dielectric constant (εreff)

$$\varepsilon_{\mathrm{reff}} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{w}\right]^{\frac{-1}{2}} \qquad (2)$$

Where;

ε_r - dielectric constant

h - Height of dielectric substrate

W - Width of the patch

iii. Effective Length (Leff)

$$L_{\mathrm{eff}} = \frac{c}{2f_r\sqrt{\varepsilon_{\mathrm{reff}}}} \qquad (3)$$

Where;

c - Free space velocity of light, 3 x 108 m/s

f_r - frequency of operation

ε_{reff} - effective dielectric constant

iv. Patch Length Extension (Δl)

$$\Delta L = 0.412h\,\frac{(\varepsilon_{\mathrm{reff}}+0.3)(\frac{w}{h}+0.264)}{(\varepsilon_{\mathrm{reff}}-0.258)(\frac{w}{h}+0.8)} \qquad (4)$$

v. Actual Length of Patch (L)

$$L = L_{\mathrm{eff}} - 2\Delta L \qquad (5)$$

3. ANTENNA MODELING

In this paper, rectangular patch antenna have been designed using HFSS. The substrate materials are FR4 and DURIOD. Antenns are designed for different frequencies viz. 2.4GHz, 3GHz, 3.5GHz, 4GHZ. To calculate antenna dimensions by conventional method we need to provide some data like substrate height, its dielectric constant etc. Table No.1 Shows modeling of antenna for different frequencies using two substrate materials. FR4 has dielectric constant of 4.4 where as the DUROID-6006 has dielectric constant of 6.

Table1. *Dimensions of an Antenna with Different Substrates*

Substrate Material	Frequency	Dimensions	
		Width (W)	Length (L)
FR4	2.4 GHz	38.03 mm	29.46 mm
	3.0 GHz	30.42 mm	23.45 mm
	3.5 GHz	26.08 mm	20.02 mm
	4.0 GHz	22.82 mm	17.43 mm
DUROID-6006	2.4 GHz	33.40 mm	25.26 mm
	3.0 GHz	26.72 mm	20.11 mm
	3.5 GHz	22.90 mm	17.15 mm
	4.0 GHz	20.04 mm	14.93 mm

4. RESULT COMPARISON

Table2. *Result comparison of Designed Frequency and Simulated Frequency.*

Material	Designed Frequency	Simulated Frequency
FR4 (εr=4.4)	2.4 GHz	2.33 GHz
	3.0 GHz	2.91 GHz
	3.5 GHz	3.35 GHz
	4.0 GHz	3.83 GHz
DUROID-6006 (εr=6)	2.4 GHz	2.23 GHz
	3.0 GHz	2.89 GHz
	3.5 GHz	3.33 GHz
	4.0 GHz	3.80 GHz

After modeling of antenna, the structure is designed in HFSS software and results are obtained for return loss and radiation pattern.

TableNo.2 shows the designed frequency and the frequency obtained from HFSS simulator.

Frequencies obtained by using FR4 material are closer to the designed frequency.

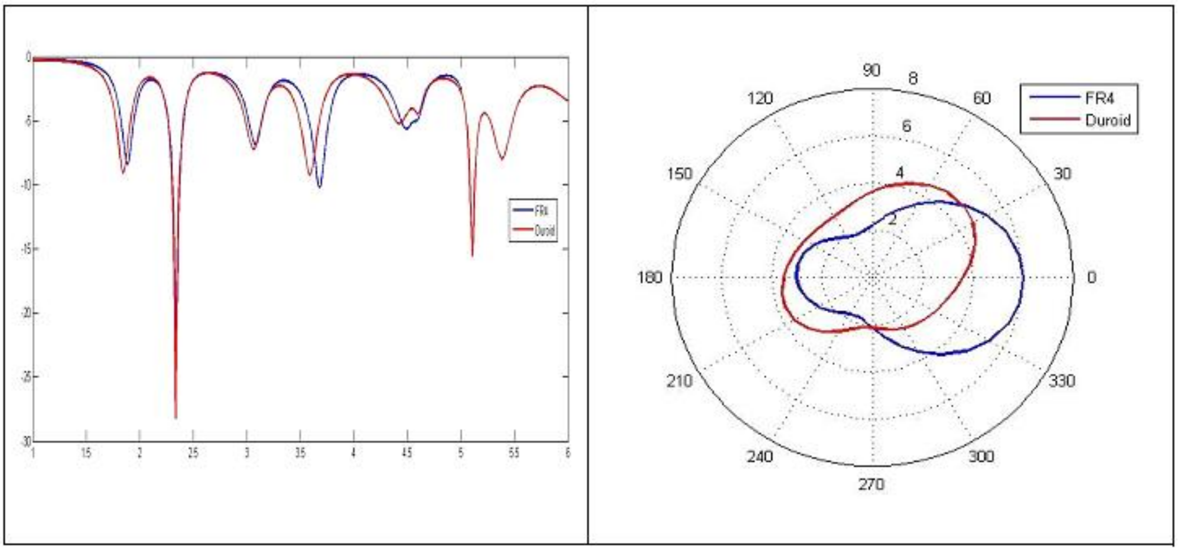

Fig2. *Return Loss (S11) and Radiation Pattern at 2.4 GHz*

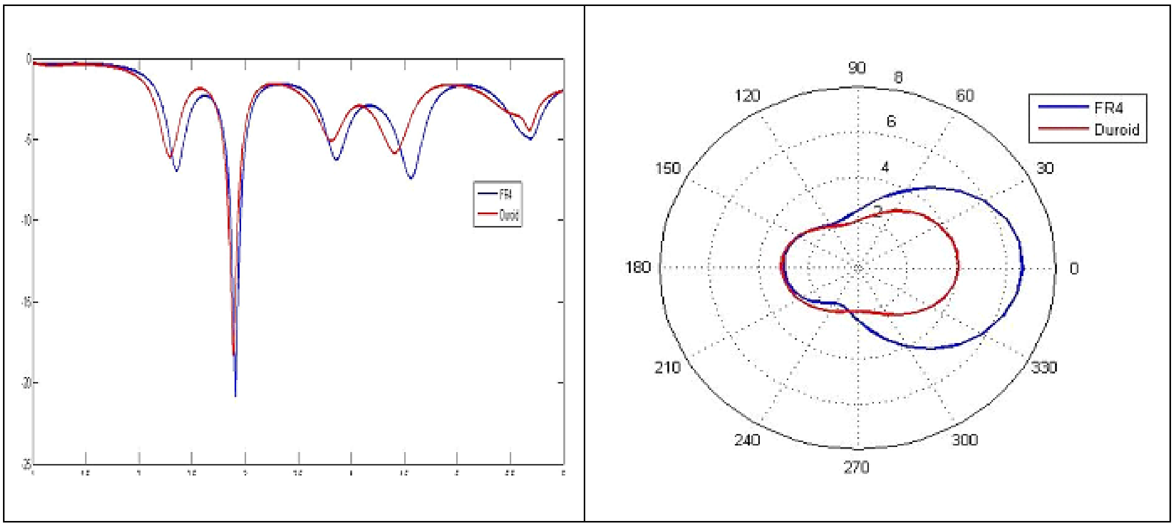

Fig3. *Return Loss (S11) and Radiation Pattern at 3GHz*

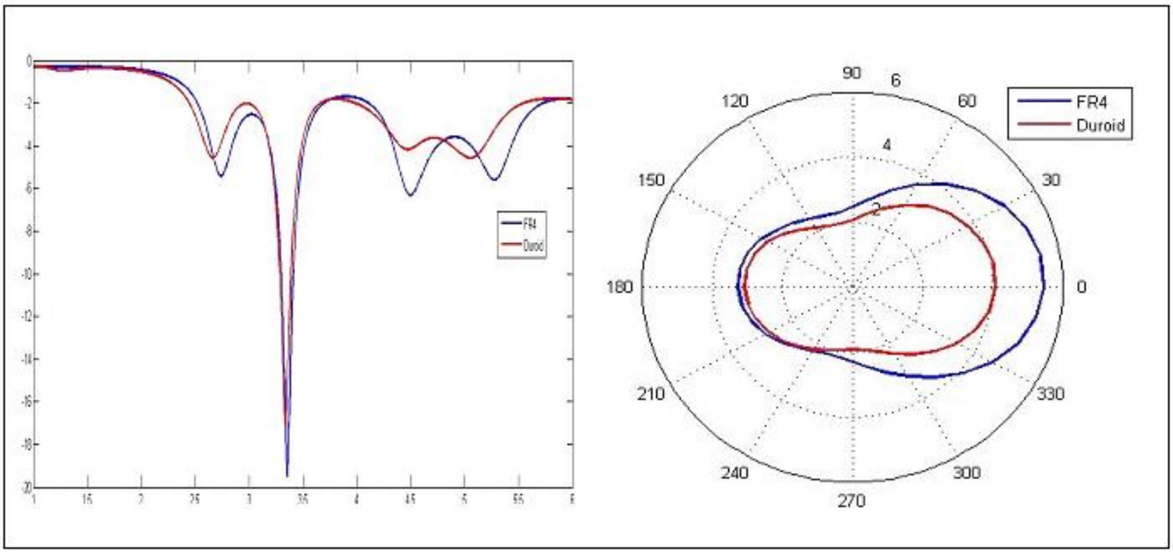

Fig4. *Return Loss (S11) and Radiation Pattern at 3.5GHz*

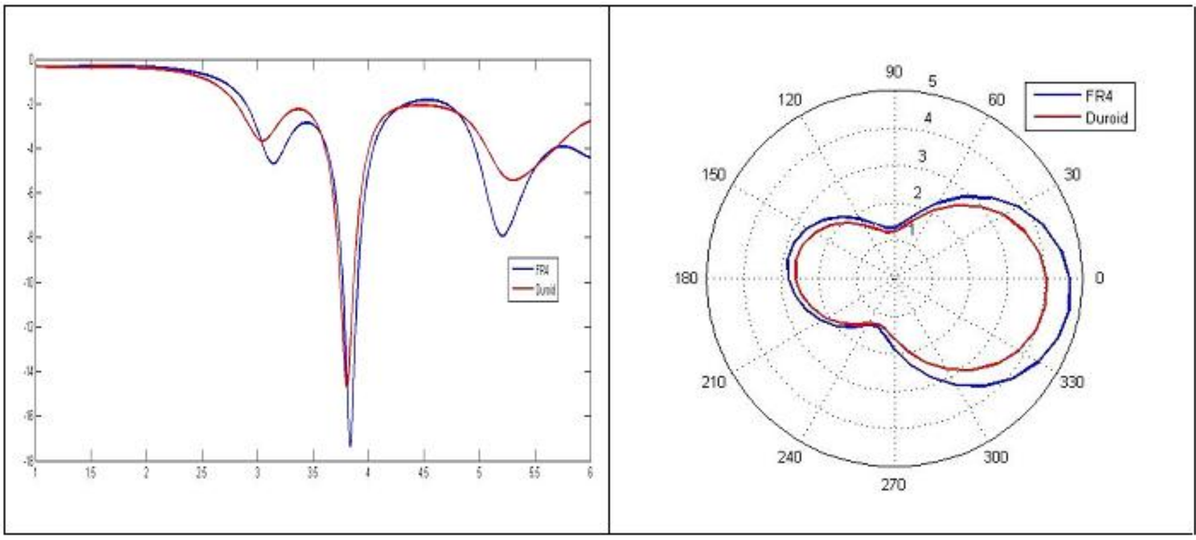

Fig5. *Return Loss (S11) and Radiation Pattern at 4GHz*

5. CONCLUSION

The performance of microstrip Antenna is mainly depend on its structure and dimensions but the substrate material shows significant role in performance parameters such as Return Loss (S11). The rectangular patch antenna is designed for 4 different frequencies with two FR4 and DUROID-6006. The result shows that FR4 material is quite suitable for frequencies up to 4GHz. The reflection at the source and axial directivity of the antennas designed by FR4 is better than antennas designed by using DUROID-6006.

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