Different Effects of Various Types of Substrate in Designing of an Microstrip Patch Antenna for WLAN Application

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Abstract— In the previous two decades the study of microstrip patch antennas has made great impact. Microstrip patch antennas have larger benefits and higher prospects compared with conventional antennas. Various types of dielectric substrates have been used by different researchers to construct microstrip patch antennas. They have used various types of dielectric substrates to fabricate microstrip patch antenna. Therefore, a query arises that which dielectric substrate among the common substrates available gives better performance. So, if the designer has a clear conception about the effect of various substrate material on the performance of microstrip patch antenna, it will become easier to design an antenna for many application. This paper represents that how performance of an inset feed microstrip patch antenna changes with respect to change in substrate material. A comparative study has been performed to know the dielectric properties of three different substrates which affect antenna performance. The reference frequency 2.4 GHz (ISM band) and height of the dielectric substrate 1.5mm taken to design inset feed microstrip patch antenna.

Keywords: Inset Feed, Dielectric Constant, Bandwidth, Return Loss, Gain, Directivity, Radiation Efficiency

I. INTRODUCTION

The basic geometry of a microstrip patch antenna (MPA) comprises of a metallic patch which is printed on one side and a ground plane on another side. The antenna is usually fed either by a strip line or coaxial probe. In the coaxial feed patch antenna, the center conductor is directly connected to the patch and the outer conductor to the ground whereas in the strip line feed patch antenna, energy is coupled to the patch in different ways: by proximity coupling or by direct connection or by aperture coupling. The patch antenna concept was originated in the early 1950s, but there was less improvement for almost two decades, mainly due to its inherent narrow bandwidth. It began to attract the intense attention of the antenna community in the 1970s, as antenna designers beganto appreciate the advantages offered by this type of antennas, which include low profile, mechanically rugged surface and can be shaped and designed to confirm to the curving skin ofa vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated and operated into electronic devices such mobile radio communication equipment's. [2] Commonly made microstrip antenna shapes are square, rectangular, circular and elliptical but any continuous shape is possible and can be created. The rectangular shape of microstrip patch antenna is the widely used of all the types of microstrip antennas that are present. The substrate material, dimension of antenna, feeding technique will determine the performance of microstrip antenna. In the last three decades, many studies have been devoted for improving the bandwidth and other performance characteristics of such type antennas.

II. DESIGN PROCEDURE & SIMULATION OF DESIGNED ANTENNA

A. *Design Procedure:*

The rectangular shape inset feed microstrip patch antenna was selected for analysis as well as to see the effect of various types of substrate in designing of multiband microstrip patch antennas. The platform used to design inset feed microstrip patch antenna is microwave CST studio suite.To design an inset feed microstrip patch antenna the design procedure which is used in my research is discussed below.

Calculation to get the dimension of the patch antenna such as substrate, ground plane, effective dielectric constant, input impedance etc.

By using these parameter, we start for designing a patch antenna in CST microwave studio suite firstly we are drawing a substrate after that ground plane, patch antenna, gap between the patch and microstrip feed and feedline.

The last step involves simulation as well as optimization of patch antenna.

The picture of a microstrip patch antenna with line feed is shown below: -

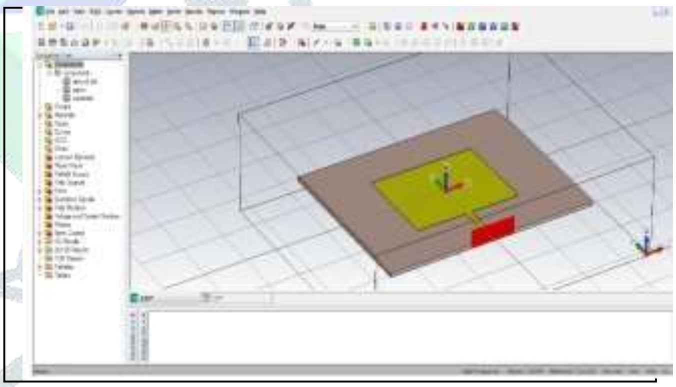

Fig. 1: Excitation of microstrip patch antenna

Step 1: Calculation of the Width (W): The width of the microstrip patch antenna is given as:

$$Width = \frac{c}{2f_o\sqrt{\frac{\varepsilon_r+1}{2}}}$$

Where c = 3.00e+008 m/s

Step 2: Calculation of Effective dielectric constant (ε_{reff}): The effective dielectric constant is calculated by

$$\varepsilon_{eff} = \frac{\varepsilon_R+1}{2} + \frac{\varepsilon_R-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{W}\right)}}\right]$$

Step 3: Calculation of the Effective length (L_{eff}): The effective length is calculated by

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}}$$

Step 4: Calculation of the length extension (ΔL): The length extension is calculated by

$$\Delta L = 0.412\, h \frac{(\epsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\epsilon_{reff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

Step 5: Calculation of actual length of patch (L): The actual length is obtained by:

$$L = L_{eff} - 2\Delta L$$

B. Calculated parameters

To design an inset feed microstrip patch antenna for the reference frequency equal to 2.4GHz, the parameters taken for different substrate is mentioned in the table 1 givenbelow-

Parameters	Substrate Material		
	FR 4 (lossy)	Roggers RT 5880	Arlon AR 600
dielectric constant (εr)	4.3	2.2	6
Width of patch (Wp)	38.3934	49.4106	33.4077
Length of patch (Lp)	29.7786	41.4071	25.2776
Length of feedline (Lf)	15.0597	21.0542	12.7489
Gap between path and feedline (Gpf)	0.20558	0.2827	0.17501
Inset feed point distance (Y0 or Fi)	11.0192	14.5237	9.683
Width of feedline (Wf)	3.137	4.6206	2.1504
Height of substrate (H)	1.5	1.5	1.5
Metal thickness (Mt)	0.12491	0.12491	0.12491

Table 1: List of different parameters of different substrates used for designing of inset feed microstrip patch antenna

C. Simulation Setup and Results

The software used to design and simulate the Microstrip patch antenna is CST Microwave Studio. It is a full-wave electromagnetic test system in view of the methods of moments. It analysis 3D and multilayer structures of general shapes. It has been broadly utilized as a part of the outline of MICs, RFICs, patch antenna, wire antenna, and other RF/wireless antenna. It can be utilized to compute and plot the S11 parameters, VSWR, current distributions and in addition the radiation pattern.

Using the different substrate material means that changing the dielectric constant (εr). Although, there are wide variety of substrate materials have been found which are suitable for designing of microstrip antenna. In this paper different substrate materials like FR 4 (lossy), RT Duroid 5880 and Arlon AR 600 are used whose dielectric constants are 4.3, 2.2, and 6 respectively for the same antenna configuration (fr=2.4 GHz & h=1.5 cm). For different substrate materials the antenna performance parameters determined as resonance frequency, directivity, gain, return loss as well as the dimension of patch of the antenna (length and width of patch). These antennas are designed and simulated by using CST microwave studio. Table 2 shows the antenna parameters variation summary with changing substrate material. From the Table 1&2, it can be said that as dielectric constant (εr) increase the dimension of patch, inset depth (d), Directivity (D) and Gain (G) decreases.

Substrate Material	Resonating Frequencies	Return Loss R (dB)	VSWR	Directivity D(dBi)	Gain G (dBi)
FR 4 (lossy)	2.3604	-19.689	1.23	6.969	6.97
Roggers RT 5880	2.387	-12.70	1.60	8.205	8.21
Arlon AR 600	3.63	-13.70	1.52	6.362	9.34

Table 2: Variation in patch antenna parameters as a function of changing substrate material

Figure 2-4 shows return loss plot of designed microstrip patch antenna using FR 4 (lossy), RT Duroid 5880 and Arlon AR 600 substrates at their resonant frequency.

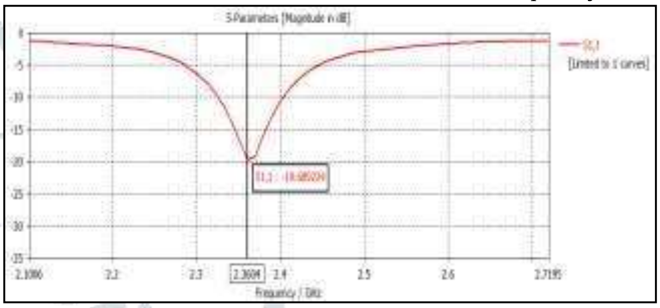

Fig. 2: Return loss of designed microstrip patch antenna using FR4 (lossy) substrate at resonant frequency 2.3604 GHz

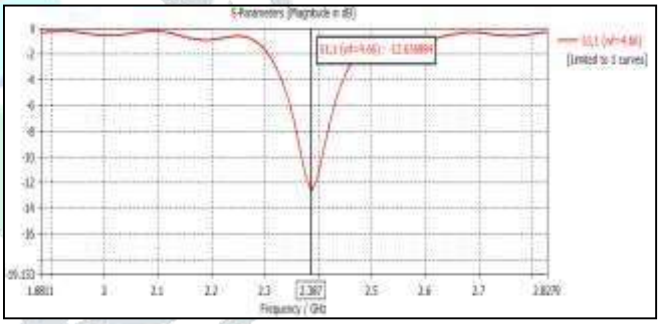

Fig. 3: Return loss of designed microstrip patch antenna using RT Duroid 5880 substrate at resonant frequency 2.387 GHz

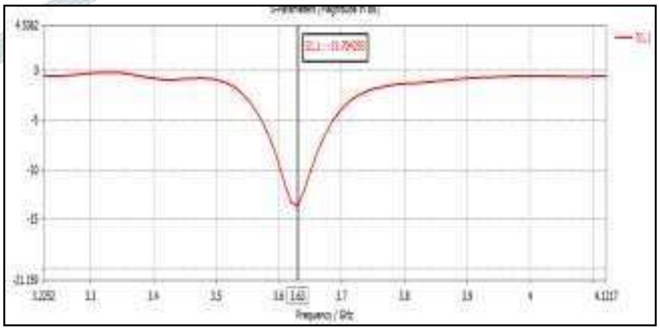

Fig. 4: Return loss of designed microstrip patch antenna using Arlon AR 600 substrate at resonant frequency 3.63 GHz

Ideally, the value of VSWR must lie in the range of 1-2. The value of VSWR achieved for FR 4 (lossy), RT Duroid 5880 and Arlon AR 600 at resonant frequencies 2.3604 GHz, 2.387 GHz, and 3.63 GHz are 1.23, 1.6 and 1.52

respectively. Figure 5-7 shows VSWR plot of designed microstrip patch antenna using FR 4 (lossy), RT Duroid 5880 and Arlon AR 600 substrates at their resonant frequency.

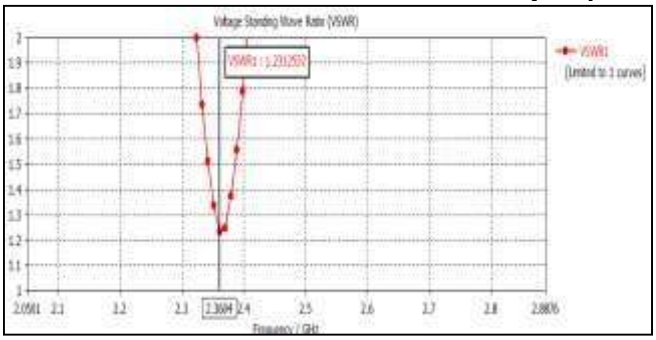

Fig. 5: VSWR of designed microstrip patch antenna using FR4 (lossy) substrate at resonant frequency 2.3604 GHz

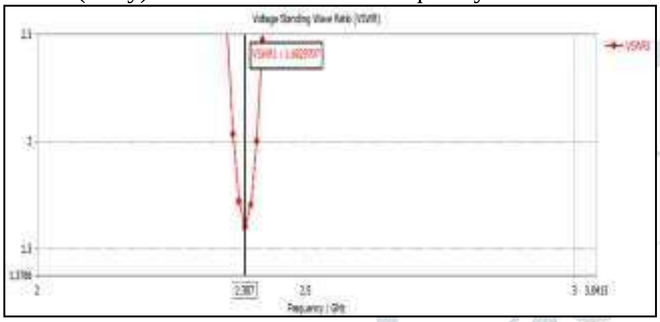

Fig. 6: VSWR of designed microstrip patch antenna using RT Duroid 5880 substrate at resonant frequency 2.387 GHz

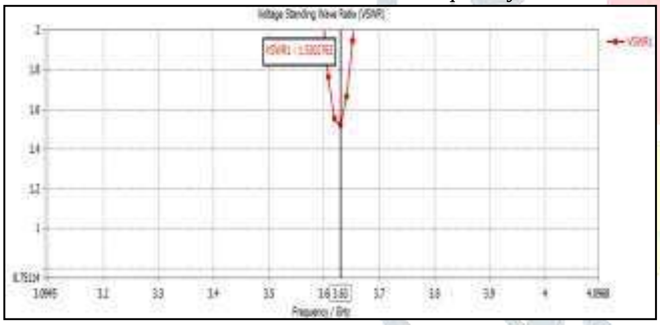

Fig. 7: VSWR of designed microstrip patch antenna using Arlon AR 600 substrate at resonant frequency 3.63 GHz

Figure 8-10 shows 3D radiation pattern of designed microstrip patch antenna using FR 4 (lossy), RT Duroid 5880 and Arlon AR 600 substrates at their resonant frequency.

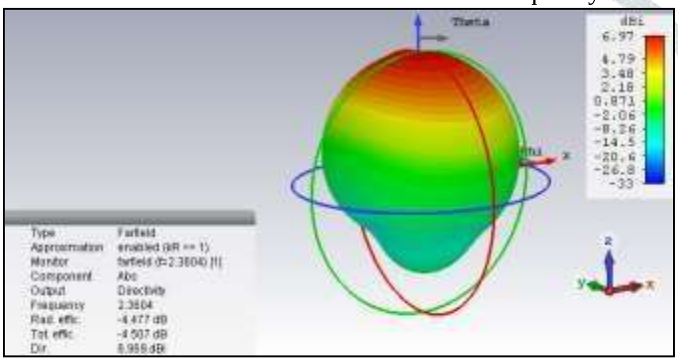

Fig. 8: 3D radiation pattern of designed microstrip patch antenna using FR4 (lossy) substrate at resonant frequency 2.3604 GHz

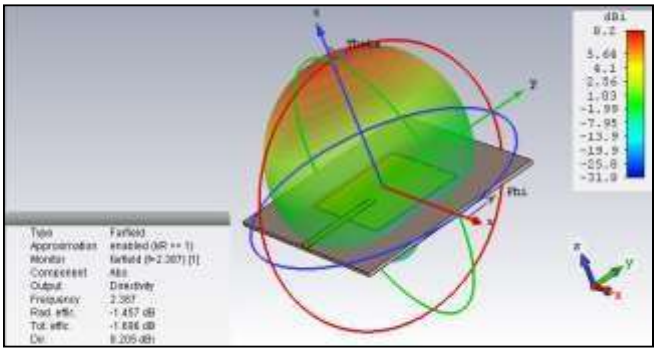

Fig. 9: 3D radiation pattern of designed microstrip patch antenna using RT Duroid 5880 substrate at resonant frequency 2.387 GHz

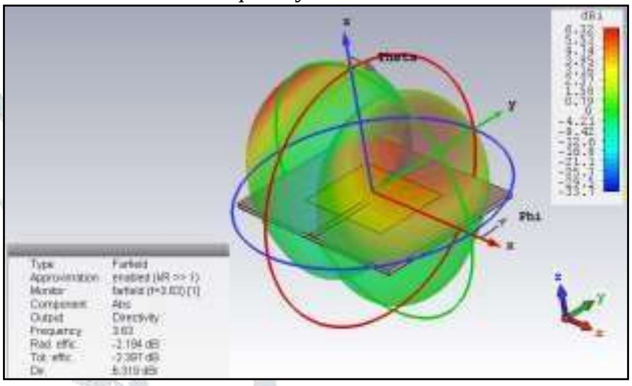

Fig. 10: 3D radiation pattern of designed microstrip patch antenna using Arlon AR 600 substrate at resonant frequency 3.63 GHz

III. Conclusion

The work in this paper was focused on the effect of different types of substrates on designing of an inset feed microstrip patch antenna for WLAN application. In my work the different types of substrate materials like FR 4 (lossy), RT Duroid 5880 and Arlon AR 600 are selected which can operate at the center frequency 2.4 GHz. Antennas designed using FR4 lossy and RT Duroid 5880 substrate are having resonant frequency at 2.3604 GHz and 2.387 GHz respectively, which are close to selected resonant frequency 2.4 GHz but antenna designed using arlon ar 600 substrate having resonant frequency at 3.63 GHz. During my researchI found that with increase in the value of dielectric constant the dimensions of patch, inset depth, directivity, gain decreases and the value of resonant frequency shifted away from selected resonant frequency. Hence proper selection of substrate material plays important role during designing of an inset feed microstrip patch antenna.

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