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DESIGN OF SLOTTED MICROSTRIP ANTENNA FOR WI-MAX APPLICATION

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Abstract--- *Microstrip patch antennas are very strong candidates for use in various communication applications. In this paper slotted multiband microstrip antenna for Wi-MAX (Wireless interoperability for Microwave access) is presented and parameters like voltage standing wave ratio, Return loss, gain, Directivity are analyzed. Here we report the investigation on slotted multiband microstrip patch antenna for Wi-MAX and other wireless application using probe feed technique. Analysis is done on the two different substrate that is the FR-4 and RT Duroid 5880 with dielectric constant 4.3and 2.2 respectively. The antenna is simulated using CST (Computer Simulation Technology) microwave studio v2011. Here the antenna radiate at 3.6GHz and other frequency band. This can be used in Wi-MAX and other wireless application.*

Keywords---Wi-MAX, multiband microstrip antenna, VSWR, Return loss

I. INTRODUCTION

An antenna is a device which converts electric powers into electromagnetic wave and vice versa.[2] There are many types of antenna are available in the market but because of the various advantages of microstrip antenna we selected the microstrip patch antenna.[6] Microstrip antenna consists of very small conducting patch, ground plane and substrate, in which substrate is sandwiched between the ground plane and the radiating patch.[4] The concept of microstrip patch antenna was developed during the revolution in electronics circuit miniaturization and large-scale integration in 1970s.[2] Because of the various disadvantage of the other conventional antenna like bulkiness, cost etc. microstrip patch antenna comes into the picture and it has advantages like low cost, light weight and also these antennas are integrated with microwave integrated circuits .[7] The telemetry and communication antenna used onboard missiles need to be thin and conformal.[10] They are often in the form of microstrip patch antenna. Another very important and essential application of microstrip patch antenna is in satellite communication.[5] Typically the microstrip patch antennas are characterized by their length, width, gain and radiation patterns etc.[8] Various parameters of the microstrip patch antenna and their design considerations are discussed in the subsequent sections. Section II describes the introduction to microstrip patch antenna. Section III describes the design consideration and the design specification. Next section IV describes the simulation results and comparison of the simulation results for two different substrate i.e. FR-4 and RT Duroid and in last section V gives the conclusion.

II. MICROSTRIP PATCH ANTENNA

The radiating metallic patch can be designed of any shape theoretically, but mostly conventional shape likes circular and Rectangular is used [1]. Some of the other configurations used are complex for analysis and it requires very large numerical calculations. In its most common form, a microstrip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side.[4] It is illustrated below in figure 1.

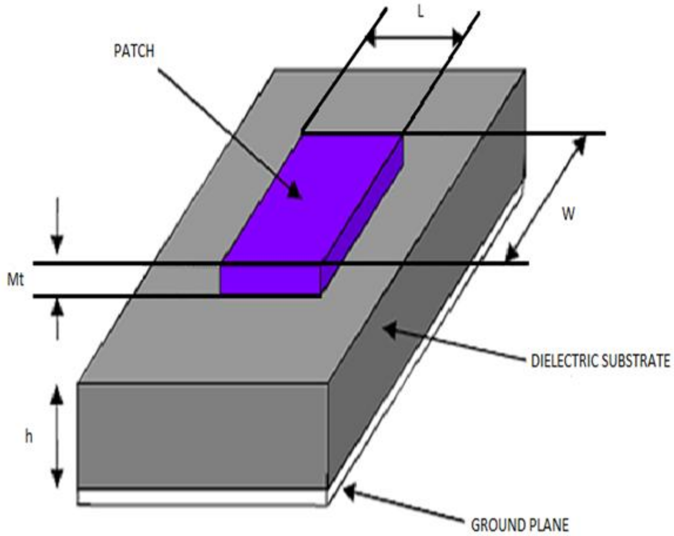

Figure 1: Structure of microstrip patch antenna

The patch is usually made of conducting radiating materials such as gold, copper etc.[3] and it can be of any possible shape. The Radiating metallic patch and the probe feed lines are usually photo etched on the dielectric substrate. Microstrip patch antenna radiate mainly because of the fringing fields effect between the patch edge and the ground plane.[10] For a rectangular patch, the length L of the patch is usually $0.3333\lambda 0 < L < 0.5\ \lambda 0$, where $\lambda 0$ is the free space wavelength. The patch is selected to be very thin such that $t \ll \lambda 0$ (where t is the thickness of patch). The height h of the dielectric substrate is usually $0.003\ \lambda 0 \leq h \leq 0.05\ \lambda 0$. The dielectric constant of the substrate (εr) is typically in the range $2.2 \leq \varepsilon r \leq 12$.[1]

III. DESIGN SPECIFICATION AND PROCEDURE

A. Design Specification

Mainly there are three important parameters which are to be considered carefully for the designing of a slotted rectangular microstrip patch antenna for various communication application.[1]

- Resonant Frequency (f_r): The Mobile Communication Systems (Wi-MAX) uses the frequency range from 2100-5600 MHz [6]. Hence the antenna designed must be able to operate for this frequency range. The default resonant frequency chosen for this research design simulation is 3.67 GHz.

- Dielectric constant of the substrate material (ε_r): The dielectric material chosen for this design is RT Duroid and FR-4 which has dielectric constants of 2.2 and 4.3 respectively.

- Height of dielectric substrate (h): For the Microstrip patch antenna to be used in communication system, it is very essential that the antenna is kept light and compact in size [7]. Hence, the height of the dielectric substrate is chosen as 3.048 mm.

Hence, the design specification for the mentioned design are chosen as fr=3.6 GHz, $\varepsilon_{r(RT\ Duroid)}=2.2$, $\varepsilon_{r(FR\text{-}4\ )}=4.3$ and h=3.048mm

B. Design Procedure

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

$$W = \frac{c}{2 * f_r}\sqrt{\frac{2}{\varepsilon_r + 1}}$$

By substituting C = 3×10^8 m/s, εr = 2.2 and fr = 3.6 GHz, it can be easily determined that W = 0.0323 m = 32.3 mm and if εr = 4.3 than W= 0.0251 m=25.1 mm.

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

$$\varepsilon_{reff} = \frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_{r-1}}{2}\sqrt{1+12\frac{h}{w}}$$

By substituting ε_r = 2.2, W = 32.3 mm and h = 3.048 mm, it can be determined that ε_{reff} = 2.476 and for ε_r = 4.3, W = 25.1 mm we get ε_{reff} = 5.236.

Step 3: Determination of the effective length (L_{eff})
The effective length is given by

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

By substituting ε_{reff} = 2.476, c = 3×10^8 m/s and f_r = 3.67 GHz, it can determined that L_{eff} = 26mm and for FR-4 we get L_{eff} =17.86mm.

Step 4: Determination of the length extension (ΔL)
The length extension may be given by

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

By substituting ε_{reff} = 2.476 and other corresponding value it can be determined that ΔL = 1.4986 mm.

Step 5: Determination of actual length of patch (L):
The actual length is obtained by using expression

L = L_{eff} - 2ΔL

By substituting L_{eff} =26mm and ΔL = 1.4986 mm, the actual length can determined as L =23 mm and for L_{eff} =17.86mm and ΔL = 1.313 mm, the actual length can determined as L =15.23 mm

From the above mathematical calculation, the patch Parameters has been calculated for the substrate RT Duroid with dielectric constant 2.2. In similar manner the patch parameters are calculated for the substrate FR-4 with dielectric constant 4.3 by using the above equations. Here we have used h=3.048. The results are summarized in table 1 given below.

Table 1: Comparison of patch parameter for different Substrate material

Patch Parameter	RT Duroid($\varepsilon_{r=2.2}$)	FR-4($\varepsilon_{r=2.2}$)
Length(L)	23	15.23
Width(W)	32.3	25.1

From the above one can say that the substrate with low dielectric constant leads to a larger size of antenna. So that design for the microstrip antenna mostly substrate with higher dielectric constant is chosen.

IV. DESIGN & SIMULATION RESULTS

Here the slotted MSTPA is simulated using two different substrate i.e. RT Duroid and FR-4 and the result is simulated using CST(Computer Simulation Technology) microwave studio version 2011 and using CST antenna parameter like Return loss(S_{11}), Bandwidth(MHz),gain and VSWR(Voltage Standing Wave Ratio) are analyzed. Slot is introduce in the forth quadrant. Figure below shows the coaxial fed slotted microstrip patch antenna using CST microwave studio.

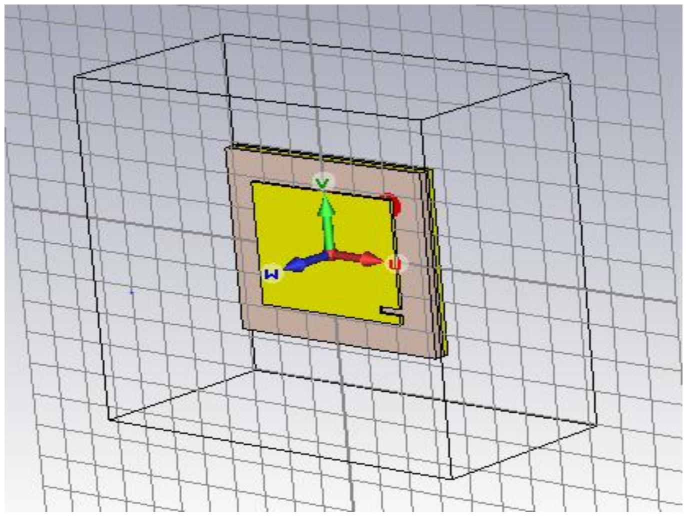

Figure 2: Slotted MSTPA designed using CST

A. Return Loss

For obtaining the results a frequency range of 2.0GHz to 6.0GHz is chosen. The resonant frequency is selected as the one at which the return loss has minimum value also the bandwidth can be determined from the return loss plot or the VSWR plot. The bandwidth of the antenna is said to be that range of frequencies over which the return loss (S_{11}) is greater than -10.0 dB (-10.0 dB corresponds to a VSWR of 2 which is an acceptable figure) as shown in figure 5. For the substrate RT Duroid (ε_r = 2.2) return loss of -38.74 dB is obtained at the resonant frequency. It can be seen that for the substrate FR-4 the return loss is of -39.49dB is obtained at the frequency 3.64GHz.For both the substrate the return loss Vs frequency graph is given below.

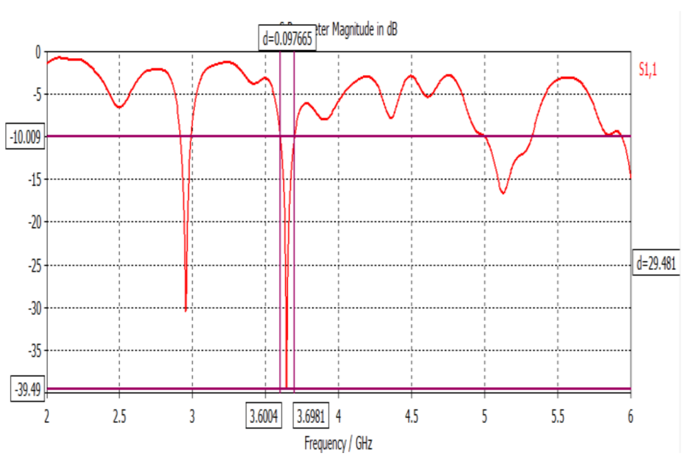

Figure 3: Return loss Vs Frequency graph for FR-4

Figure 3 shows that the proposed slotted antenna using FR-4 substrate is resonates at three different band of frequency i.e. 2.95GHz, 3.64GHz and 5.128GHz and the corresponding return loss is -30.0dB,-39.49dB and -16.60dB respectively.

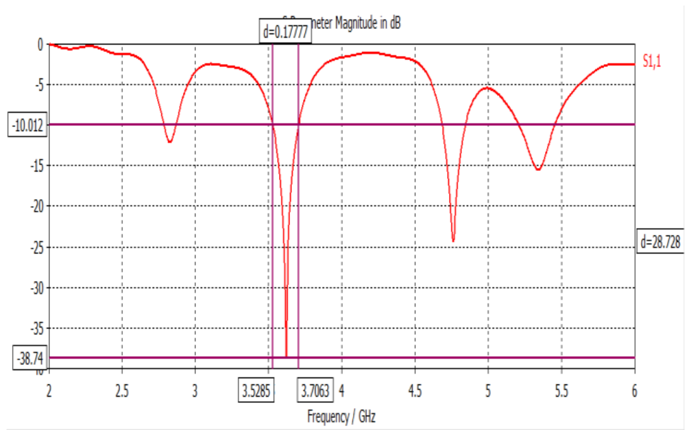

Figure 4: Return loss Vs Frequency graph for RT Duriod

Above figure 4 shows the return loss Vs frequency graph for the rectangular patch antenna with substrate RT Duroid. From the above figure one can say that the antenna will resonates at four different band of frequency i.e. 2.828, 3.62, 4.76, 5.34GHz with return loss -12.13dB, -38.74dB, -24.39dB, -15.57dB respectively.

B. VSWR

VSWR plot for both the RT Duroid and FR-4 substrate is given below.

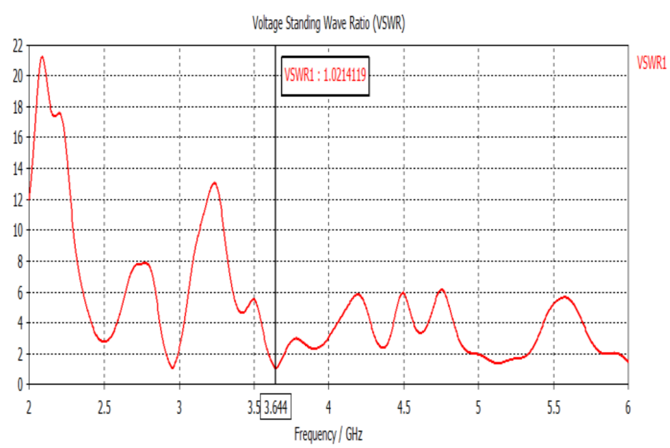

Figure 5: VSWR plot for the substrate FR-4

Here in both the figure 5 and figure 6 measure line is shows for the resonate frequency and which is used for the Wi-MAX (Wireless interoperability for Microwave Access) and other wireless application because the proposed antenna is resonate at multiband of frequency.

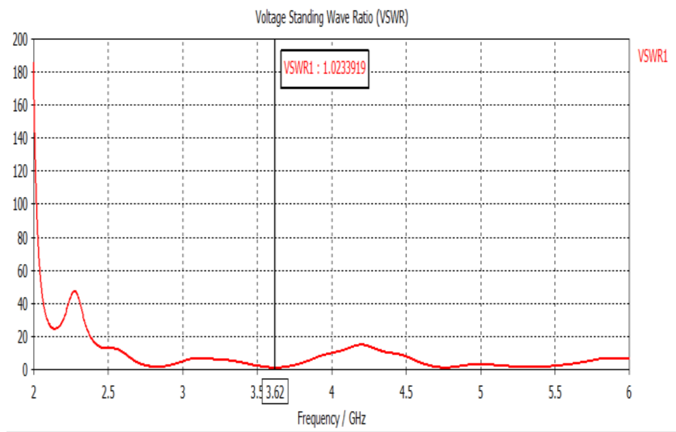

Figure 6: VSWR plot for the substrate RT Duroid

Figure 5 show that slotted antenna using FR-4 has a good impedance match at 3.64GHz because the VSWR for that is 1.021 and which is very good. Also from the figure 6 we can say that antenna has a good impedance match at 3.62 GHz because the VSWR for that is 1.0233.

Table II: Comparison of Simulation result for Slotted MSTPA Using different dielectric substrate material

Patch Paramet er	Return Loss S_{11} (dB)	VSWR	Band width (MHz)	Gain (dB)	Directi vity (dBi)
FR-4 (ε_r = 4.3)	-39.49	1.0214	97.66	2.114	5.351
RT Duroid (ε_r = 2.2)	-38.74	1.0233	177.77	8.123	8.246

V. CONCLUSION

Here the proposed Slotted microstrip patch antenna is designed and simulated using CST Microwave studio. The analysis is carried on two different substrate namely FR-4 epoxy and RT Duroid whose permittivity varies. Coaxial feeding technique is used as the antenna provides acceptable return loss , Gain, VSWR, Bandwidth etc. In this proposed model multiband is obtained for the antenna in which the substrate is chosen as RT Duroid gives better efficiency in term of return loss , Gain, Bandwidth when compared to antenna designed using FR-4 epoxy because RT Duroid has a low loss tengent as compared to FR-4. The antenna will resonates at multiband of frequency which includes our research work frequency 3.6GHz and also because of the multiband response it is applicable to Wi-MAX and other wireless application.

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