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Design Analysis and Performance Assessment of Rectangular Microstrip Patch Antenna for WLAN

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***Abstract*—This paper provides a brief insight into the design aspects of rectangular microstrip patch (RMP) antenna in terms of size and compactness and performance assessment in terms of bandwidth, directivity and gain by using same and different dielectric substrate materials with same and varying thickness of substrate as well as effects of creating a notch on the patch of RMP antenna. Increasing the dielectric constant of substrate material allows small size and compactness of a RMP antenna. But miniaturization comes with a trade-off in bandwidth, directivity and gain. Performance assessment is made by comparing simulated results of RMP antenna for various cases. Gain and Directivity of a RMP antenna decrease with respect to increasing the thickness of dielectric substrate but bandwidth increases. The radiation properties of a notched RMP antenna are obtained and compared with that of a normal RMP antenna. The designed antennas have been characterized using the commercially available software CST and HFSS for the application of WLAN at resonance frequency 2.4 GHz.**

***Keywords*—Rectangular Microstrip patch (RMP) antenna, CST tool, HFSS tool**

I. INTRODUCTION

Microstrip patch antennas are preferred over other antennas in today's modern wireless communication Systems for their compatibility to be fit in Mobile, Aircraft, Satellites, radars and many more applications owing to its very small size. Hence design and development of superior and cost effective microstrip patch antenna has become an active research area. In designing the microstrip patch antenna, selection of dielectric substrate materials and their thickness are the main parameters in terms of size and compactness. A RMP antenna is a popular antenna type, which has proved its worth in size and compactness but compactness comes with a trade-off in bandwidth, directivity and gain.

II. DESIGN ANALYSIS OF A RMP ANTENNA

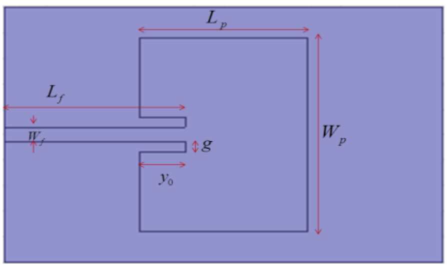

Fig 1: A Rectangular Microstrip Patch (RMP) Antenna

A rectangular microstrip patch (RMP) antenna is designed using a transmission line model. Three parameters required for a design are a resonant frequency, dielectric constant and height of the dielectric substrate material. An inset fed of a rectangular patch antenna is designed to match the patch with a 50Ω microstrip transmission line. The designed RMP antenna structure is shown in figure 1. The calculated parameters are Dielectric constant ε_r = 4.4 (FR-4 epoxy), Resonant frequency = 2.4GHz, Substrate thickness, h = 1.58mm, Effective dielectric constant, = 3.91, Patch width = 38.01mm, Patch length = 28.77mm, Width of 50Ω transmission line = 5.93mm, Length of inset feed = 15.80mm, Inset depth = 9.23mm, Notch width g =1.51mm.

A. S_{11} Plot

The plot of the designed RMP antenna is shown in figure 2.1. The bandwidth of microstrip patch antenna is determined by the return loss graph. The bandwidth of microstrip patch antenna is the frequency range over which return loss or is below -10dB.

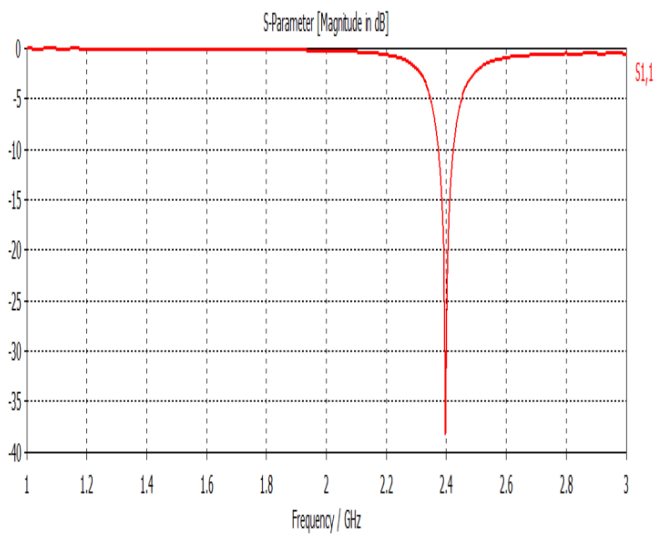

Fig 2.1: S_{11} (Return Loss) Parameter plot of RMP antenna

B. Impedance Matching Plot

The ratio of the voltage to current at the input terminals or Input impedance of antenna at input terminal Z1,1=49.81. Its graph is given in figure 2.2. The value of input impedance is very closed to Z1,1=50.

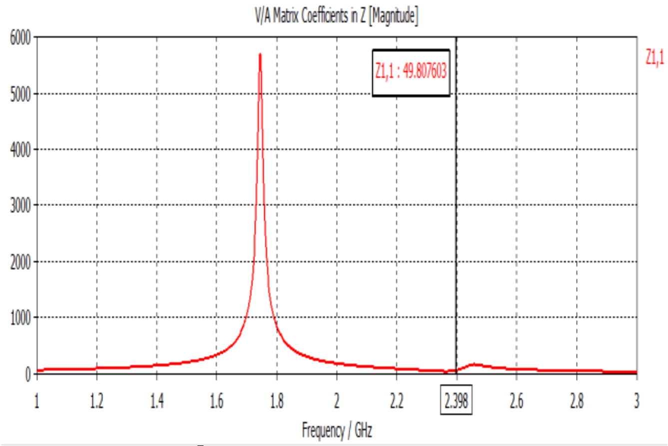

Fig 2.2: Z Plot graph of RMP Antenna

C. *Gain and Directivity*

The designed RMP antenna radiates in broadside direction with gain of 4.67dB and the directivity of 7.06dBi. It has a broad beam width. Gain and Directivity 3D far field plots are given below in figure 2.3 and figure 2.5. Gain and Directivity polar plots are given in figure 2.4 and figure 2.6.

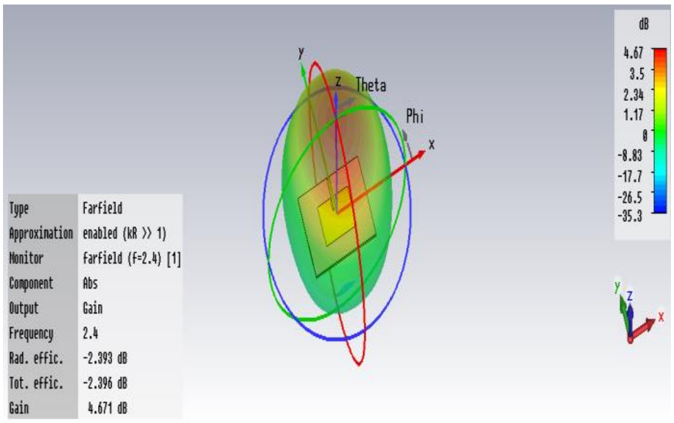

Fig 2.3: Far Field 3D Plot of Gain of RMP Antenna

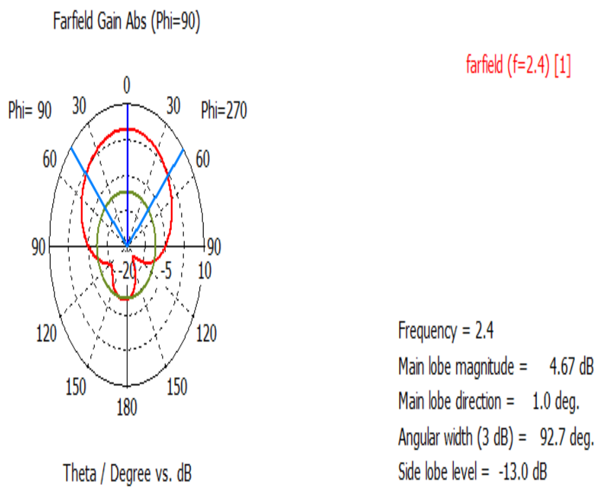

Fig 2.4: Far Field Polar Plot of Gain of RMP Antenna

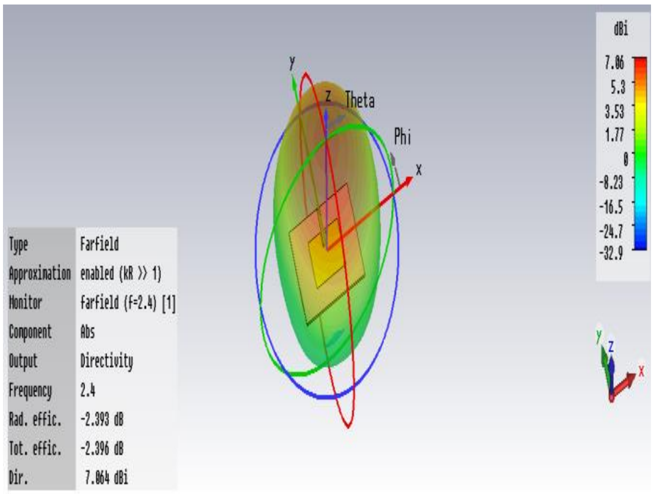

Fig 2.5: Far Field 3D Plot of Directivity of RMP Antenna

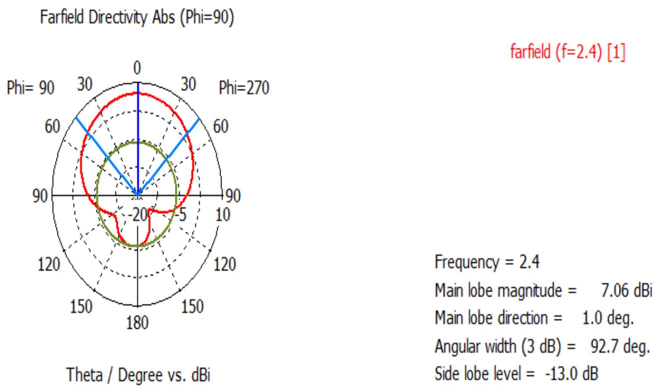

Fig 2.6: Far Field Polar Plot of Directivity of RMP Antenna

III. DESIGN ANALYSIS OF A RMP ANTENNA(DIFFERENT DIELECTRIC THICKNESS H WITH SAME DIELECTRIC MATERIAL)

In a RMP antenna, when the dielectric thickness of substrate varies then the physical dimensional parameters and other parameters are also changed as in table 1. The simulated results using CST are also given in fig. 3.1-3.3.

Table 1: dimensional parameters of a RMP antenna

(different dielectric thickness h and same dielectric material ε_r)

Parameters	h =3.1mm	h =2.35mm	h =1.58mm
Operating frequency (f_r)	2.4GHz	2.4GHz	2.4GHz
Dielectric constant ε_r	4.4	4.4	4.4
ε_{reff}	3.91	3.99	4.09
Patch width (W_p)	38.01mm	38.01mm	38.01mm
Patch length (L_p)	28.77mm	29.12mm	29.42mm
Feed width (W_f)	5.93mm	4.49mm	3.02mm
Feed length (L_f)	15.80mm	15.64mm	15.44mm
Inset feed length (y_0)	10.87mm	11.01mm	11.13mm

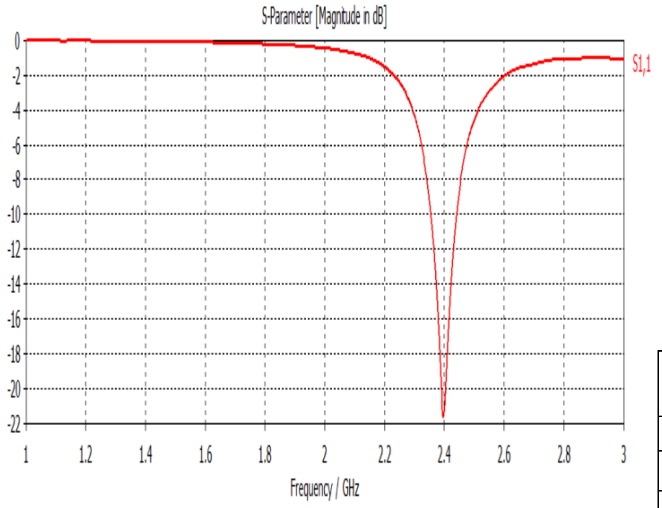

Fig. 3.1 S_{11} Plot of RMP Antenna at h=3.1mm

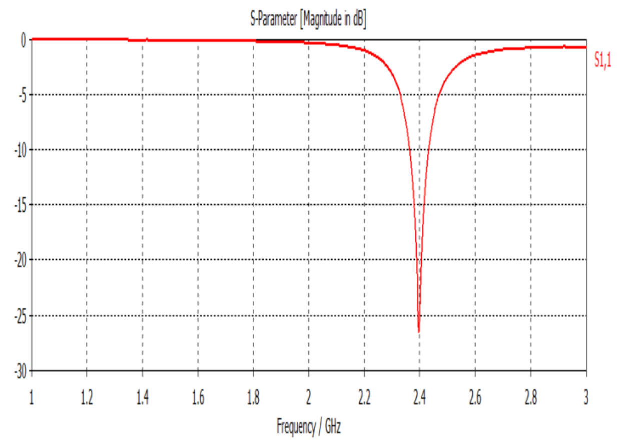

Fig. 3.2 S_{11} Plot of RMP Antenna at h=2.35mm

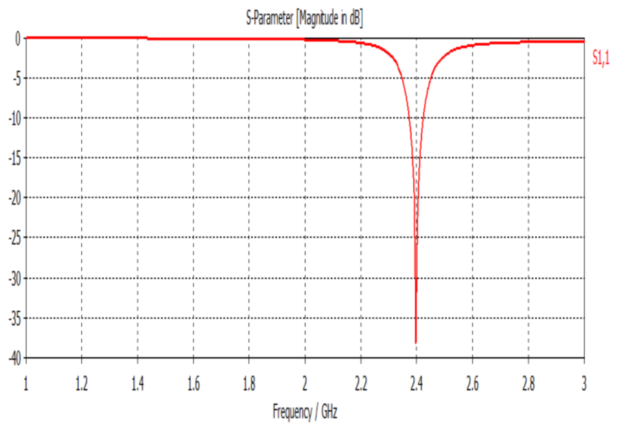

Fig. 3.3 S_{11} Plot of RMP Antenna at h=1.58mm

S_{11} Plot for a RMP antenna for different thickness of same dielectric substrate have different characteristics for different thickness. S-Parameter plot is given for microstrip patch antenna at dielectric thickness h=3.1mm. Here Return Loss is -21.62dB and BW is 3.61%. S-Parameter plot is given for microstrip patch antenna at dielectric thickness h=2.35mm. Here Return Loss is -26.51dB and BW is 2.83%. S-Parameter plot is given for microstrip patch antenna at dielectric thickness h=1.58mm. Here Return Loss is -38.18dB and BW is 2.17%.

IV. Design Analysis of a RMP Antenna(Different Dielectric Materials ε_r at Same Dielectric Thickness h)

In a RMP antenna, when the dielectric materials of substrate varies then the physical dimensional parameters and other parameters are also changed as in table 2. The simulated results using HFSS (High Frequency Structural Simulator) are also given belowin fig. 4.1-4.3.

Table 2: dimensional parameters of a RMP antenna

(different dielectric materials ε and same dielectric thickness h)

Parameters	ε_r =4.4 (FR4-epoxy)	ε_r =2.94(Rogers RT/duroid 6002)	ε_r =2.2(Rogers RT/duroid 5880)
Operating frequency (f_r)	2.4GHz	2.4GHz	2.4GHz
Dielectric constant ε_r	3.1mm	3.1mm	3.1mm
ε_{reff}	3.91	2.69	2.05
Patch width (W_p)	38.01mm	44.50mm	49.38mm
Patch length (L_p)	28.77mm	35.08mm	40.35mm
Feed width (W_f)	5.93mm	7.90mm	9.55mm
Feed length (L_f)	15.80mm	19.06mm	21.79mm
Inset feed length (y_0)	10.87mm	11.29mm	11.96mm

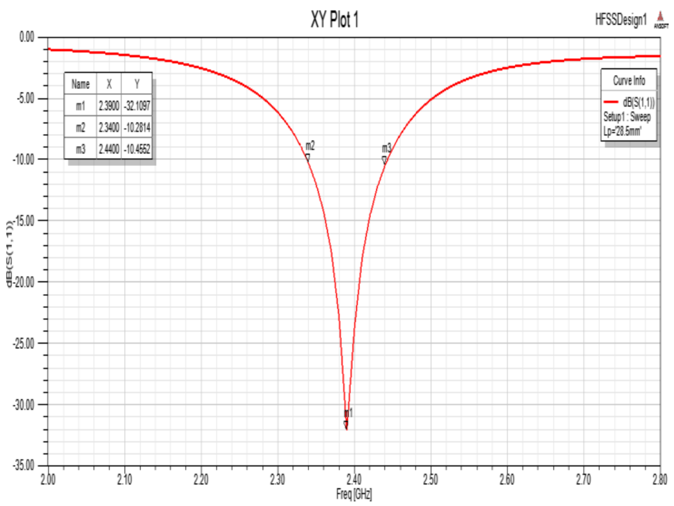

Fig. 4.1 S_{11} Plot of RMP Antenna for ε_r =4.4

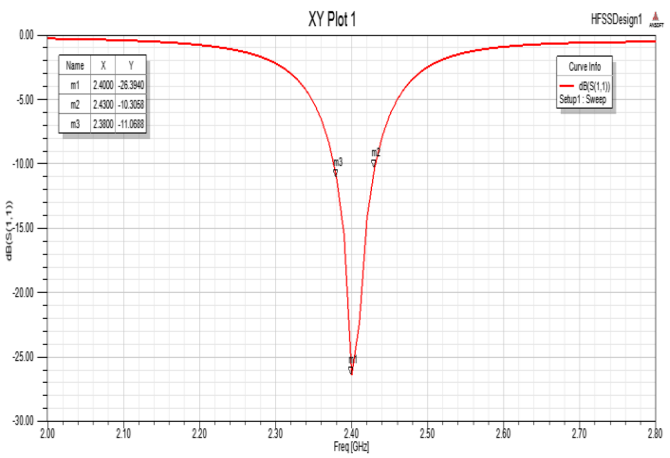

Fig. 4.2 S_{11} Plot of RMP Antenna for ε_r =2.94

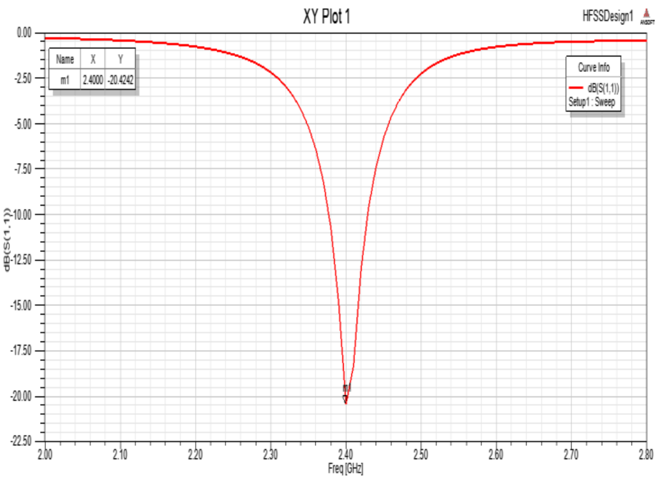

Fig. 4.3 S_{11} Plot of RMP Antenna for ε_r =2.2

S_{11} Plot for a RMP antenna for different dielectric substrate with same thickness have different characteristics for different thickness. S-Parameter plot is given for microstrip patch antenna for dielectric constant=4.4 (FR4-epoxy). Here Return Loss is -32.11dB and BW is 3.75%. S-Parameter plot is given for microstrip patch antenna for dielectric constant=2.94(Rogers RT/duroid 6002). Here Return Loss is -26.40dB and BW is 2.33%. S-Parameter plot is given for RMP antenna for dielectric constant=2.2(Rogers RT/duroid 5880). Here Return Loss is -20.42dB and BW is 2.08%.

V. DESIGN ANALYSIS OF A RMP ANTENNA WITH A NOTCH FOR BW ENHANCEMENT

A RMP antenna with a notch is designed for bandwidth enhancement of antenna. For designing of this RMP antenna transmission line model is used. An inset fed microstrip rectangular patch antenna is designed to match the patch with 50Ω microstrip transmission line. The designed microstrip patch antenna structure is shown in figure 5.1 The substrate used is FR-4 epoxy having dielectric constant = 4.4 and height h=1.58mm. The operating frequency is 2.4GHz. The inset depth and gap width are varied to get the desired results. The width and length of notch are 14mm and 2mm. Effect of the notch on physical parameters of a RMP antenna is given below in table 3.

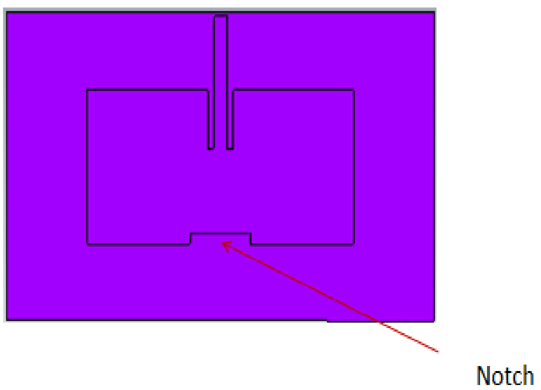

Figure 5.1 A RMP Antenna with a Notch

Table 3 Effect of Notch on Physical parameters of a RMP Antenna

Parameters	Microstrip Patch Antenna	Microstrip Patch Antenna with Notch
Operating frequency (f_r)	2.4GHz	2.4GHz
Dielectric constant ε_r	4.4	4.4
Substrate thickness h	1.58	1.58
Effective dielectric ε_{reff}	4.09	4.09
Patch width (W_p)	38.01mm	62.33mm
Patch length (L_p)	29.42mm	29.20mm
Feed width (W_f)	3.02mm	3.02mm
Feed length (L_f)	15.44mm	25.09mm
Inset feed length (y_0)	11.13mm	11.23mm

A. S_{11} Plot

S_{11} Plot is the simulated result of a RMP antenna with notch using CST as in fig 5.2. The value of S parameter is =-15.48dB. The Bandwidth of a RMP antenna with notch is 2.61%.

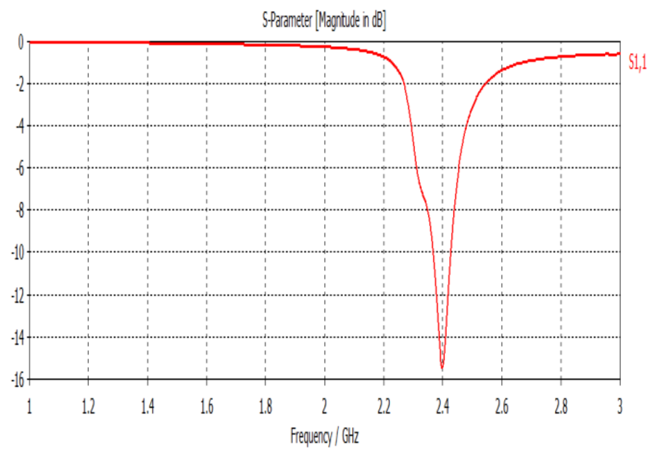

Fig 5.2 S_{11} Plot of RMP Antenna with a Notch

B. Gain and Directivity

The designed antenna radiates in broadside direction with gain of 4.67dB and the directivity of 7.06dBi. It has a broad beam width. Gain and Directivity polar plots are given in figures. A RMP antenna is designed and simulated using CST. The results after simulation are given in fig. 5.3 & 5.4. Thus the designed rectangular microstrip patch antenna with notch provides BW enhancement. Here BW increases 2.08% to 2.61% as in table below.

Parameter	Value
S_{11}	-15.48dB
VSWR	1.3
Gain(dB)	3.91
Directivity (dBi)	6.06
FBW (%)	2.61

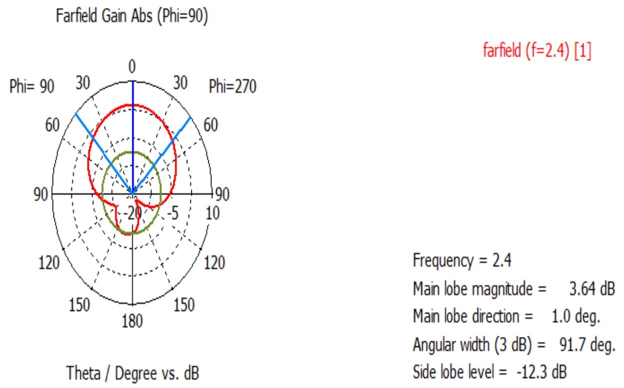

Fig. 5.3 Far Field Polar Plot of Gain of RMP Antenna with Notch

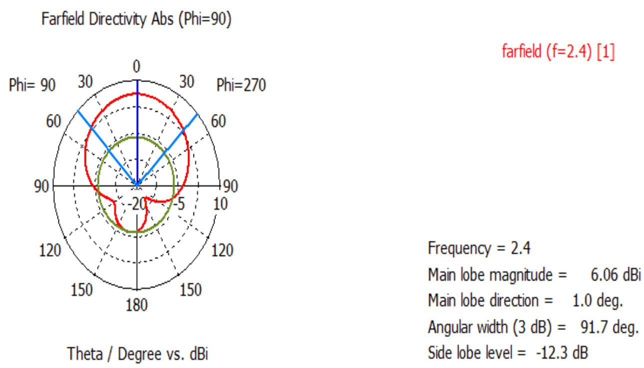

Fig. 5.4 Far Field Polar Plot of Directivity of RMP Antenna with Notch

VI. RESULTS

A. Comparison of Performance and Result of a RMP antenna for different Dielectric constants ε_r at same Thickness h of Substrate

In a RMP antenna, when the dielectric materials of substrate varies then the physical dimensional parameters and other parameters are also changed as in table 4. The simulated result using HFSS (High Frequency Structural Simulator) is given. Plot for RMP antenna for different dielectric substrate with same thickness have different characteristics for different thickness. Plots for all cases are given below in figure 6.1.

Table 4 Simulated results of RMP antenna

(different dielectric constants and same thickness h=3.1mm)

Parameters	ε_r =4.4(FR 4-epoxy)	ε_r =2.94(Rogers RT/duroid 6002)	ε_r =2.2(Rogers RT/duroid 5880)
Return Loss S_{11}(dB)	-32.11	-26.40	-20.42
VSWR	1.051	1.101	1.211
Gain (dB)	4.023	7.579	7.747
Directivity(dBi)	5.989	7.383	7.892
FBW (%)	3.75	2.34	2.08
Efficiency (%)	67.17	97.41	98.16

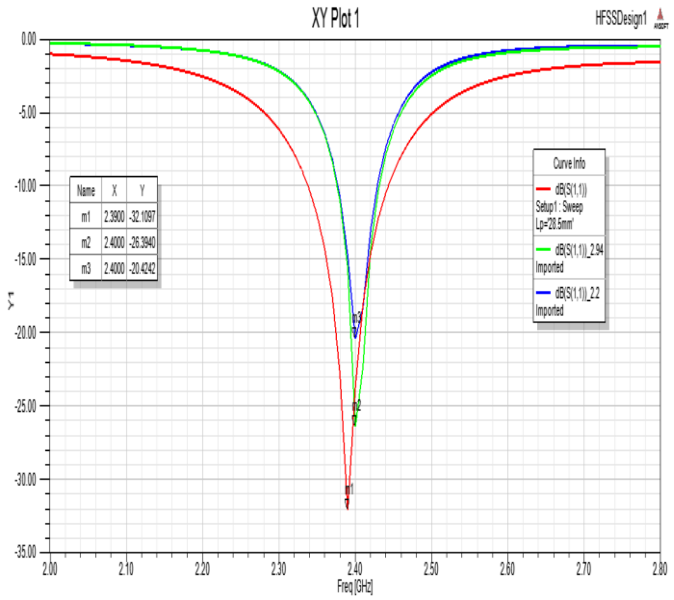

Fig. 6.1 Comparisons between S Parameter

B. Comparison of Performance and Result of a RMP antenna for different Thickness h of substrate at same Dielectric constant ε_r

In a RMP antenna, when the dielectric thickness of substrate varies then the physical dimensional parameters and other parameters are also changed as in table 5. The simulated result using CST is given. Plot for RMP antenna for different substrate thickness with same dielectric constant have different characteristics of a microstrip patch antenna. Plots for all cases are given below in figure 6.2.

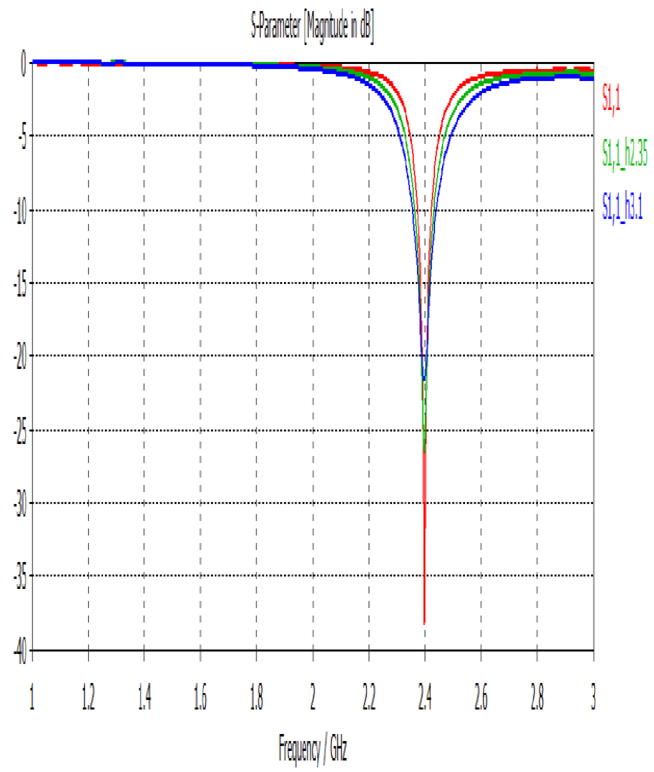

Fig. 6.2 Comparison between S Parameter of RMP antenna

Table 5 Simulated results of RMP antenna

(different thickness of substrate and same dielectric constant)

Parameters	h =3.1mm	h=2.35mm	h =1.58mm
Return Loss S_{11} (dB)	-21.61	-26.52	-38.18
VSWR	1.180	1.099	1.025
Gain (dB)	5.03	5.08	4.67
Directivity (dBi)	6.82	6.95	7.06
FBW (%)	3.61	2.84	2.08
Efficiency (%)	73.75	73.05	66.15

C. Comparison of Performance and Result of a RMP antenna and a Notched RMP antenna

When a RMP antenna is designed with notch then its physical parameters also changed compared to the without notch RMP antenna. The effect of the notch on physical parameters of a microstrip patch antenna is also given in table 6. Simulated parameters of a microstrip patch antenna are also affected. Bandwidth of a notched RMP antenna is greater than bandwidth of a without notch RMP patch antenna. S parameter of a notched and without notch RMP antenna is given below in figure 6.3 & 6.4. Thus the bandwidth of a RMP antenna enhanced using notch in a microstrip patch antenna. The bandwidth of a RMP antenna increases 2.08% to 2.61%.

Table 6 Comparison of Performance of a RMP Antenna and a Notched RMP Antenna.

Parameter	Notched Microstrip Patch Antenna	Microstrip Patch Antenna
S_{11}	-15.48dB	-38.18
VSWR	1.3	1.025
Gain(dB)	3.91	4.67
Directivity (dBi)	6.06	7.06
FBW (%)	2.61	2.08

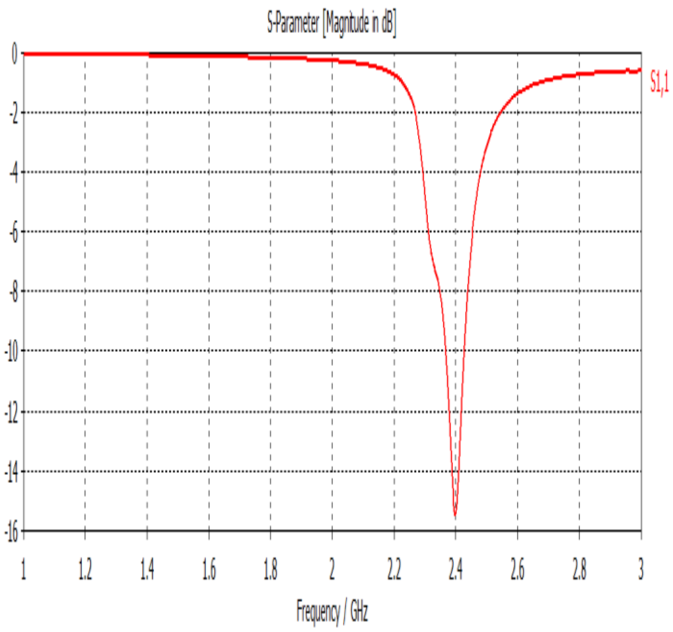

Fig. 6.3 S_{11} Plot of RMP antenna with Notch

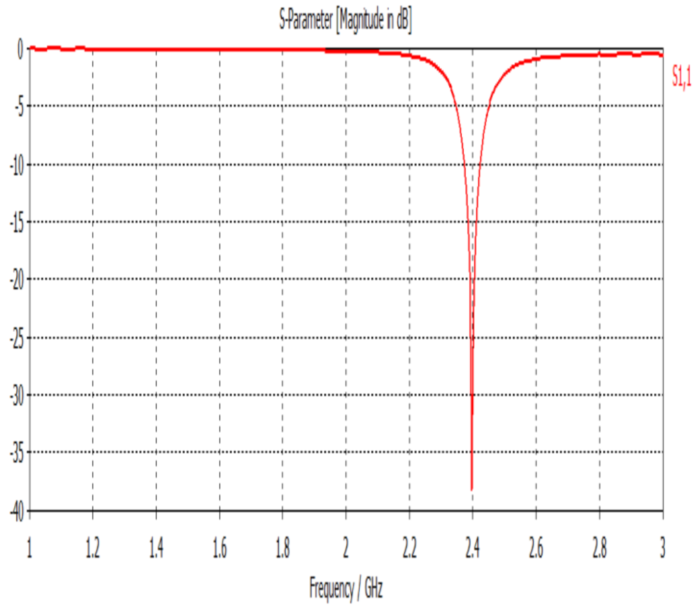

Figure 6.4 S_{11} Plot of RMP antenna without Notch

VII. CONCLUSIONS & FUTURE SCOPE

Increasing the dielectric constant of substrate material allows miniaturization of RMP antenna. But miniaturization comes with a trade-off in bandwidth, impedance and efficiency. The result obtained in simulation proved that the Gain and Directivity of single microstrip patch antenna increase with respect to decreasing the dielectric constant of substrate but FBW (%) decreases. The result obtained in simulation proved that the Gain and Directivity of single microstrip patch antenna decrease with respect to increasing the thickness of dielectric substrate but FBW (%) increases. The result obtained in simulation of the slotted MSPA proved that the FBW(%) increases as compared to MSPA.

Making the slot in a microstrip patch antenna can be used to observe the effect of different dielectric constant. Some optimization technique can be used for getting better results because in this work optimization has done manually. For enhancing the bandwidth, directivity and gain, RMP antenna arrays can be designed by placing same RMP antenna in linear configuration and utilizing power divider circuits.

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