American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-10, pp-118-126
www.ajer.org
Research Paper Open Access

Designing and Analysis of Microstrip Patch Antenna for Wi-Fi Communication System Using Different Dielectric Materials

Raja Rashidul Hasan[1], Md. Moidul Islam[2], Kazi Saiful Islam[3], Md. Mostafizur Rahman[4], Md. Tanvir Hasan[5]

[12345]*(Electrical and Electronic Engineering, American International University-Bangladesh, Bangladesh)*

ABSTRACT : *Wireless communications has become very popular now-a-days. Wireless communication and networking system has become an important area for research in academic and industrial institutes. Wires provide less free space and non-mobility, thus indoor wireless communication system takes interest. Microstrip patch antennas has low weight and low profile, conformability, easy and cheap fabrication costing, that's why it has been widely used in a various useful applications now a days. Microstrip patch antenna is designed for Wi-Fi communication which operates using 2.4 GHz frequency band. This research paper represents the effort of designing and performance analysis of microstrip patch antenna for Wi-Fi communication system. The main objective of this paper is to design and observe the performance of the designed microstrip patch antenna using different dielectric materials. Better performance is observed for FR4. For FR4 the return loss, S_{11}isobtained -11.4 dB at 2.4 GHz, this indicates the return loss is much lower comparing to the other dielectric materials used in this research. Also VSWR is found 1.74 which is desirable. In this paper we also observed and analyzed the radiation pattern of far field region, gain, radiation efficiency and total efficiency for different dielectric materials.*

Keywords – *Wi-Fi communication system, Microstrip patch antenna, Return loss, Far field, Different dielectric materials.*

I. INTRODUCTION

Technology is making rapid progress and is making many things easier. As the innovative thinking of persons is increasing day-by-day, new methods for wireless communication have been evolved of which our present topic Wi-Fi is the most accepted technology. Wi-Fi allows to connect to the internet from virtually anywhere at speeds of up to 54Mbps.The computers and handsets enabled with this technology use radio technologies based on the IEEE 802.11 standard to send and receive data anywhere within the range of a base station.

Antenna is the most important equipment for wireless communication systems which is used for both transmitting and receiving electromagnetic waves. Microstrip antennas are relatively inexpensive to manufacture and design because of the simple two dimensional physical geometry. They are usually employed at UHF and higher frequencies because the size of the antenna is directly tied to the wavelength at the resonant frequency. With the development of MIC and high frequency semiconductor devices, microstrip has drawn the maximum attention of the antenna community in recent era. In spite of its various attractive features like, light weight, low cost, easy fabrication, conformability on curved surface and so on, the microstrip element suffers from an inherent limitation of narrow impedance bandwidth.

We focused on improving the performance of Wi-Fi communication by designing of a microstrip patch antenna [3]. To increase the performance of a microstrip patch antenna there are several methods like increasing the thickness of substrate, using low dielectric substrate, using of various impedance matching and feeding techniques [4].

Microstrip patch antenna consists of a conducting patch of any planar or non-planar geometry on one side of a dielectric substrate with a ground plane on other side. It is a popular printed resonant antenna for narrow-band microwave wireless links that require semi-hemispherical coverage. Due to its planar configuration and ease of integration with microstrip technology, the microstrip patch antenna has been heavily studied and is often used as elements for an array [5].

This research paper is organized as follows: Section II explains the structure and design specifications of a microstrip patch antenna. Section III describes the simulations of designed device. Analysis of the simulations for the designed microstrip patch antennas are described in this section. This paper ends with a conclusion in Section IV. CST Microwave Suite simulation results show better performance in terms of return loss, radiation efficiency and total efficiency.

II. STRUCTURE AND DESIGN SPECIFICATIONS

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 as shown in Fig 1. The patch is generally made of conducting material 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].

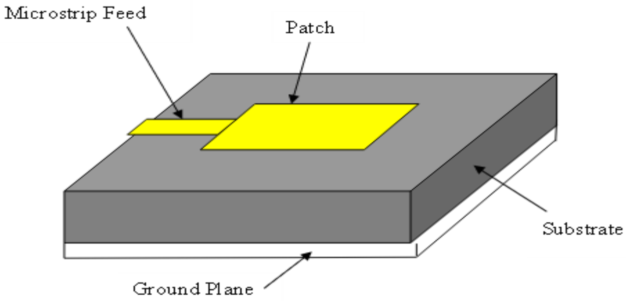


Figure 1: Structure of Patch antenna [8].

Different materials are used in different layer in the antenna. In substrate layer different dielectric substrate materials are used. Copper is used in ground plane, patch and microstrip line. In this research different dielectric materials were used for specific cut-off frequency to analyze the performance of the antenna for Wi-Fi application. Table I shows the name of the layers and materials used in the microstrip patch antenna. In simulation software materials with loss effect were selected to get practical simulated results.

Table I: Name of the layers and materials used in the layers of a microstrip patch antenna.

Layer Name	**Material Name**
Microstrip Line	Copper
Patch	Copper
Substrate	Dielectric substrate materials
Ground plane	Copper

Table II shows the list of the dielectric materials used in this research purpose to analyze the performance of the antenna for 2.4 GHz.

Table II: List of different dielectric materials used in this research and their dielectric constants.

Name of the dielectric materials	**Dielectric constants (ε_r)**
FR4	4.3
RTDuroid 5880	2.2
Arlon Di 522	2.5
Taconic RF 35P	3.5
Bakelite	4.8
Dupont-951	7.8

The essential parameters require designing Microstrip Patch Antenna are:

Frequency of operation (*fo*): The resonant or cut-off frequency of the antenna must be selected appropriately. Wi-Fi communication system uses 2.4 GHz frequency. Thus the designed antenna must be able to operate at this frequency [6].

Dielectric constant of the substrate (ε_r): Six different dielectric materials were used in this research. Name of the dielectric materials and their dielectric constants are mentioned in table. A substrate with a high dielectric constant has been selected since it reduces the dimensions of the antenna [6].

Height of dielectric substrate (*h*): For the microstrip patch antenna used in Wi-Fi communication system should not be bulky. Hence, the height of the dielectric substrate used to design the antenna is 1.5 mm [6].

Calculation of effective dielectric constant, ε_{reff}: Effective dielectric constant, ε_{reff} can be calculated from the below equation.

$$\varepsilon_{reff} = \frac{\varepsilon_{r+1}}{2} + \frac{\varepsilon_{r-1}}{2}[1 + 12\frac{h}{w}]^{1/2} \quad (1)$$

Calculation of the width of the patch, W: The width of the patch can be calculated from the below equation.

$$W = \frac{c}{2f_o\sqrt{\frac{[\varepsilon_r+1]}{2}}} \quad (2)$$

Calculation of the length of the patch, L: The effective length of the patch can be calculated from the below equation.

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{reff}}} \quad (3)$$

The length extension can be calculated from the below equation.

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\ (\frac{W}{h}+0.264)}{(\varepsilon_{reff}-0.258)\ (\frac{W}{h}+0.8)} \quad (4)$$

The actual length of the patch can be calculated from the below equation.

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

Calculation of the length of the ground plane, L_g: The length of the ground plane can be calculated from the below equation.

$$L_g = 6h + L \quad (6)$$

Calculation of the width of the ground plane, W_g: The width of the ground plane can be calculated from the below equation.

$$W_g = 6h + W \quad (7)$$

Calculation of the length of the feed line, L_f: The length of the feed line can be calculated from the below equation.

$$L_f = \frac{\lambda_o}{4\sqrt{\varepsilon_r}} \quad (8)$$

$$\text{Where, } \lambda_o = \frac{c}{f_o} \quad (9)$$

Calculation of the width of the feed line, W_f: If Z_c= 50 Ω, the width of the feed line can be calculated from the below equation.

$$Z_c = \frac{120\pi}{\sqrt{\varepsilon_{reff}}[\frac{W_f}{h}+1.393+0.667\ ln(\frac{W_f}{h}+1.444)} \quad (10)$$

Calculation of the gap of the feed line, G_{pf}: The gap of the feed line can be calculated from the below equation.

$$G_{pf} = \frac{4.65x\,10^{-9}xC}{f_o\sqrt{2\varepsilon_{reff}}} \quad (11)$$

In fig. 2 parameters required to design microstrip patch antenna are identified.

\\

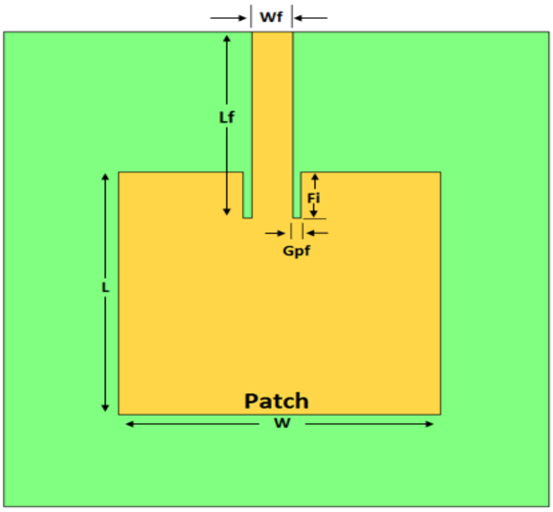


Figure 2: Parameters of microstrip patch antenna.

III. SIMULATIONS AND ANALYSIS

Microstrip patch antenna was designed in CST Microwave Suite for 2.4 GHz resonant frequency for different dielectric materials. Then the performance for different substrate materials were compared to observe for which materials the designed antenna performs better. All the simulations were done by CST Microwave Suite. Parameters were calculated individually using the equations and different dielectric constants. Table III shows the values of the parameters for different dielectric materials used in this research.

Table III: Values of different parameters of microstrip patch antenna for different dielectric materials for 2.4 GHz.

Expression	Substrate Materials					
	FR4	**RTDuroid 5880**	**Arlon Di 522**	**Taconic RF 35P**	**Bakelite**	**Dupont-951**
L (mm)	29.7786	41.3484	38.8568	32.9573	28.2022	22.1492
W (mm)	38.3934	49.4106	47.2456	41.6667	36.7013	29.7957
L_f (mm)	15.07	21.069	19.7642	16.7038	14.2636	11.1893
W_f(mm)	3.0389	4.9284	4.2525	3.5613	2.7796	1.7867
Fi (mm)	11.0213	14.5014	13.7273	11.9577	10.5556	8.7202
G_{pf}(mm)	0.20558	0.283	0.2663	0.22679	0.19507	0.1547
h (mm)	1.6	1.6	1.6	1.6	1.6	1.6
M_t (mm)	0.1	0.1	0.1	0.1	0.1	0.1

Fig. 3 shows the designed microstrip patch antenna for 2.4 GHz using 6 different dielectric materials.

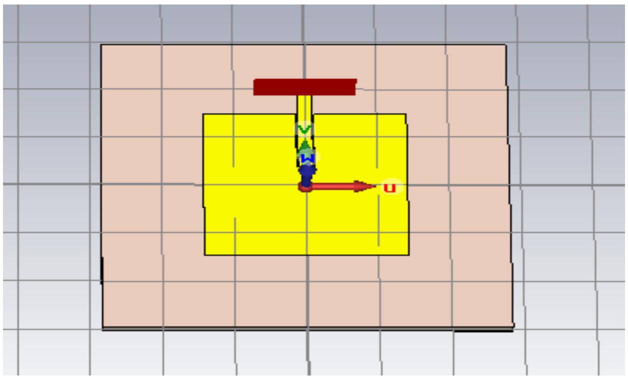


Figure 3: Designed microstrip patch antenna in CST Microwave Suite.

A. Performance of the antenna for FR4:

Fig. 4 shows of the designed microstrip patch antenna using FR4 substrate material. Fig. 5 shows the s-parameter graph for FR4. S-parameter represents how much power is reflected from antenna and is known as reflection coefficient or return loss. In the figure the value of S11 parameter is -11.401291 dB at 2.4 GHz, which is better for antenna performance. The less the value of S11 is, the better the performance.For better performance of microstrip patch antenna the value of return loss or S_{11} parameter should be less than -10 dB.

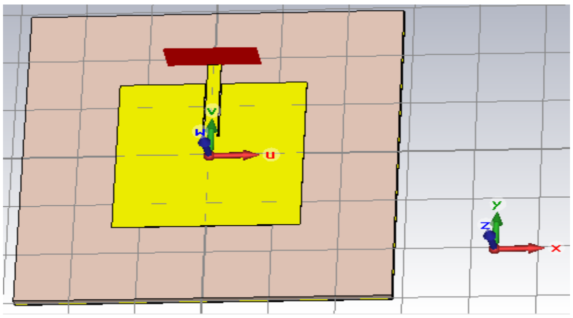


Figure 4: Designed microstrip patch antenna for FR4.

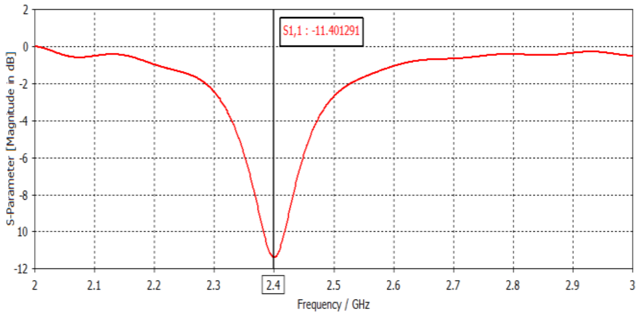


Figure 5: Return loss for FR4.

Fig.6 shows the far field region. In the figure the total efficiency and radiation efficiency are mentioned. From the figure it can be seen that the directivity is in Z-axis on the XY plane. At 2.4 GHz the radiation efficiency is -2.763 dB and total efficiency is -3.305 dB, which is better for the performance of antenna. Directivity is 6.316 dBi. The top red color shows the radiation. Radiation increased from green to red in Z direction. Fig.7 shows the far field polar view. According to the figure at 2.4 GHz angular width of half power beam is 94.4^0 and side lobe level is -13.1dB.

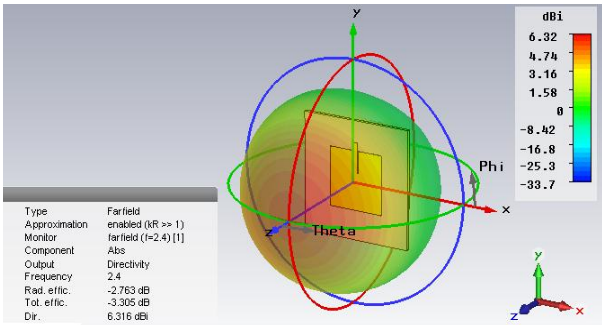


Figure 6: Far field region for FR4.

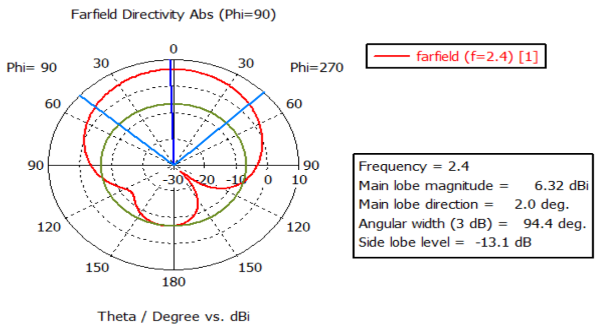


Figure 7: Far field in polar view for FR4.

B. Performance of the antenna for RTDuroid 5880:

Fig. 8 shows the designed antenna for RTDuroid 5880. Fig.9 shows the s-parameter graph for RTDuroid5880. According to the figure the value of S11 parameter is -8.3849 dB at 2.4 GHz. The value of return loss is less for better performance.

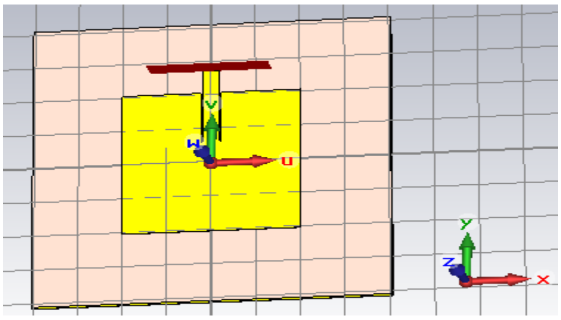


Figure 8: Designed microstrip patch antenna for RTDuroid 5880.

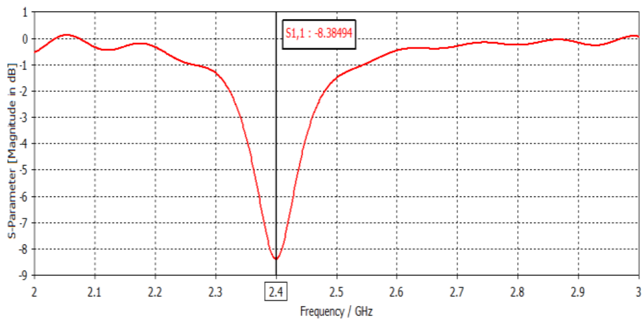


Figure 9: Return loss for RTDuroid 5880.

Fig.10 shows the far field region. According to the figure the directivity is in Z-axis on the XY plane. At 2.4

GHz the radiation efficiency is-0.8413 dB and total efficiency is -1.731 dB, which is better for the performance of antenna. Directivity is 7.559 dBi. Radiation increased from green to red in Z direction.Fig.11shows the far field polar view. According to the figure at 2.4 GHz angular width is 81.1^{0} and side lobe level is -19.6 dB.

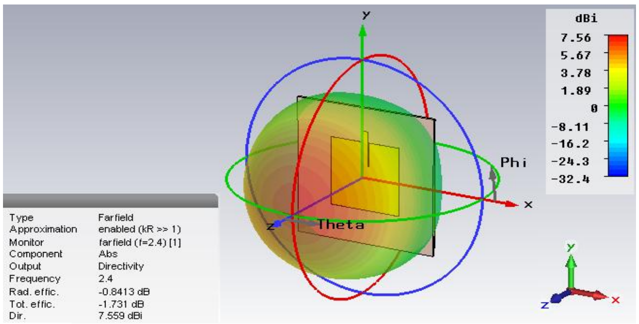


Figure 10: Far field region for RTDuroid 5880.

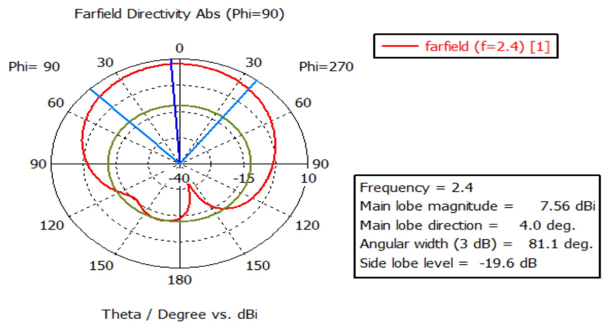


Figure 11: Far field in polar view for RTDuroid 5880.

C. *Performance of the antenna for Arlon Di 522:*

Fig. 12 shows the designed antenna for Arlon Di 522 dielectric material. Fig.13 shows the return loss graph for Arlon Di 522. In the below figure the value of S11 parameter is -9.5806 dB at 2.4 GHz.

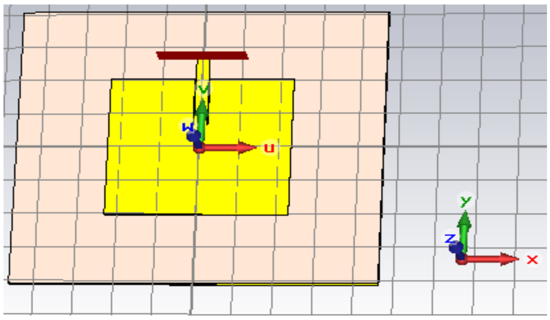


Figure 12: Designed microstrip patch antenna for Arlon Di 522.

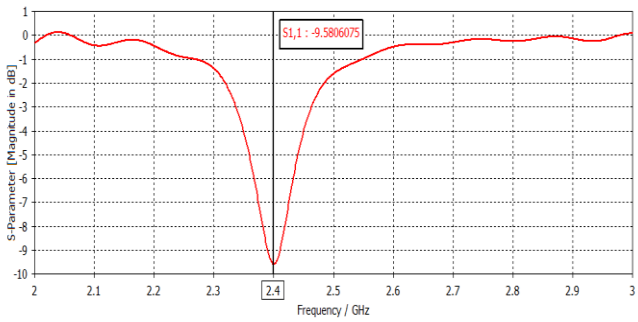


Figure 13: Return loss for Arlon Di 522.

Fig. 14 shows the far field region. From the figure it can be seen the total efficiency and radiation efficiency. According to the figure directivity is in Z-axis on the XY plane. At 2.4 GHz the radiation efficiency is -0.7555 dB and total efficiency is -1.580 dB, which is better for the performance of antenna. Directivity at 2.4 GHz is 7.899 dBi. Fig. 15 shows the far field polar view. From the figure we can measure angular width and side lobe level. At 2.4 GHz angular width is 80.3^{0} and side lobe level is -18.8 dB.

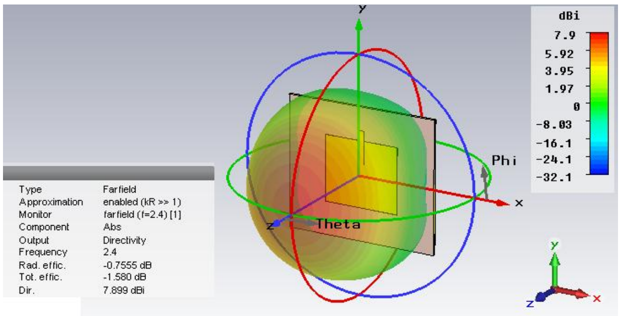


Figure 14: Far field region for Arlon Di 522.

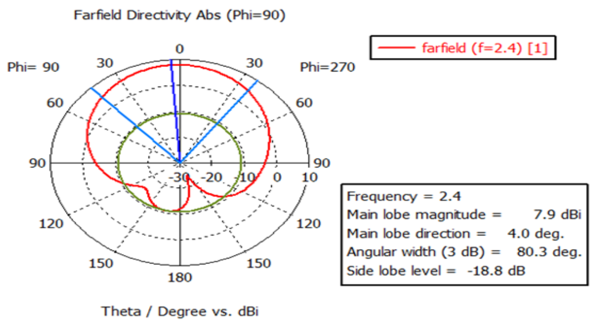
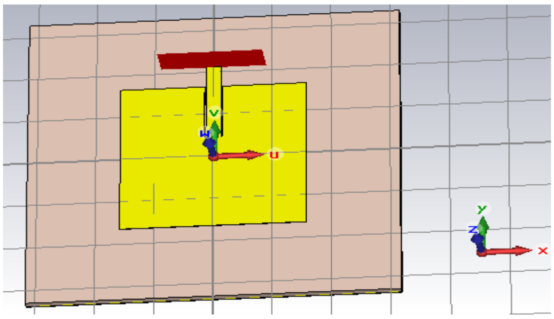


Figure 15: Far field in polar view for Arlon DI 522.

D. *Performance of the antenna for Taconic RF 35P:*

Fig. 16 shows the designed antenna for Taconic RF 35P in substrate layer. Fig. 17 shows the return loss graph for Taconic RF 35P. The value of S11 parameter is -6.4270911 dB at 2.4 GHz.



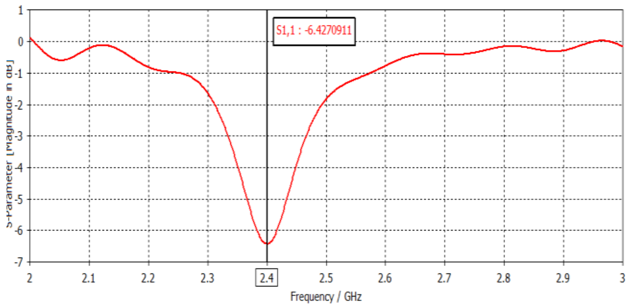
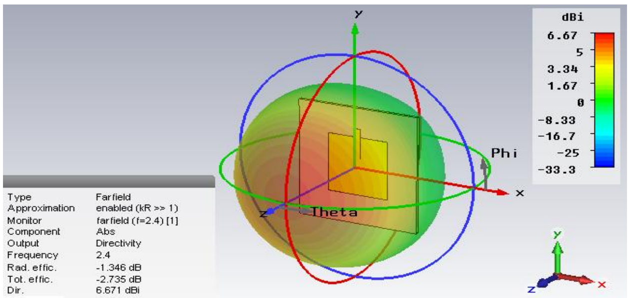


Figure 16: Designed microstrip patch antenna for Taconic.

Figure 17: Return loss for Taconic RF 35P.

Fig. 18 shows the far field region. According to that figure the directivity is in Z-axis on the XY plane. At 2.4 GHz the radiation efficiency is -1.346 dB and total efficiency is -2.735 dB, which is better for the performance of antenna. Directivity is 6.671 dBi. Fig. 19 shows the far field polar view. At 2.4 GHz angular width is 90.8^0 and side lobe level is -15.6 dB.



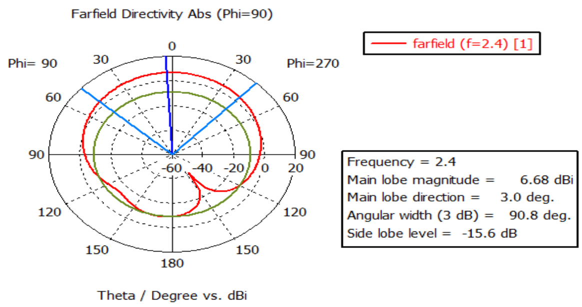
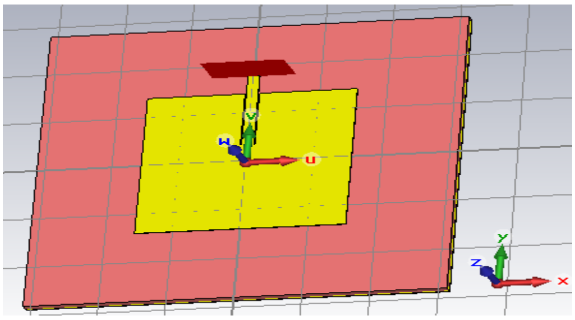


Figure 18: Far field region for Taconic RF 35P.

Figure 19: Far field polar view for Taconic RF 35P.

E. Performance of the antenna for Bakelite:

Fig. 20 shows the designed antenna for Bakelite substrate material. Fig. 21 shows the return loss graph for Bakelite. According to the below figure the value of S11 parameter is -7.7358 dB at 2.4 GHz. The performance for bakelite is very poor.



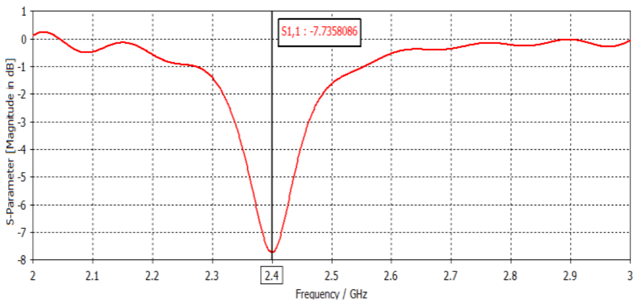


Figure 20: Designed microstrip patch antenna for Bakelite.

Figure 21: Return loss for Bakelite.

Fig. 22 shows the far field region. In fig. 16 the directivity is in Z-axis on the XY plane. At 2.4 GHz the radiation efficiency is -0.7625 dB and total efficiency is -1.871 dB, which is better for the performance of antenna. Directivity is 6.481 dBi. Radiation increased from green to red in Z direction. Fig. 23 shows the far field polar view. According to the figure at 2.4 GHz angular width is 95.7^0 and side lobe level is -11.9 dB.

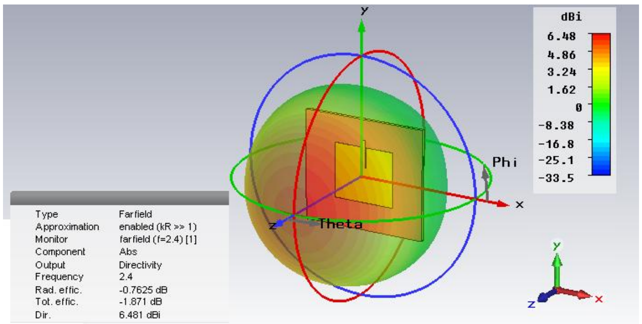


Figure 22: Far field region for Bakelite.

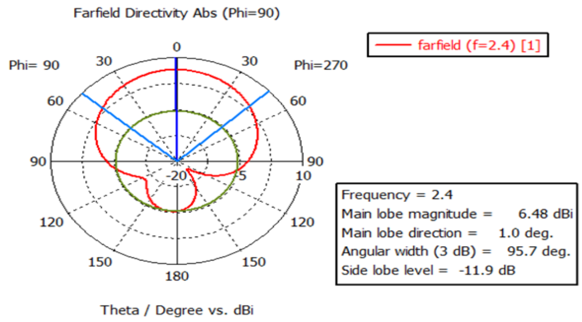


Figure 23: Far field polar view for Bakelite.

F. Performance of the antenna for Dupont-951

Fig. 24 shows the designed antenna for Dupont-951 in substrate layer. Fig. 25 shows the return loss graph for Dupont-951. According to the below figure the value of S11 parameter is -10.768469 dB at 2.4 GHz.

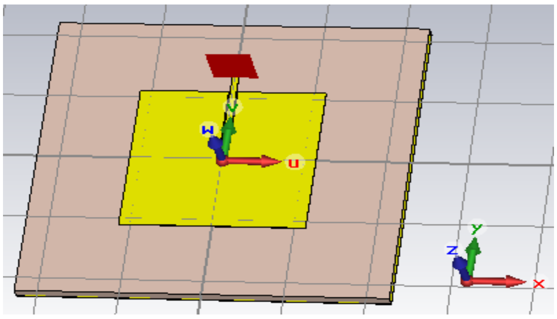


Figure 24: Designed microstrip patch antenna for Dupont-951.

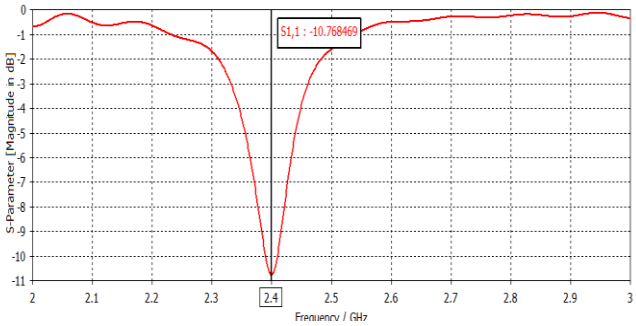


Figure 25: Return loss for Dupont-951.

Fig. 26 shows the far field region. From the figure it can be seen that that the directivity is in Z-axis on the XY plane. At 2.4 GHz the radiation efficiency is -1.068 dB and total efficiency is -1.940 dB, which is also better for the performance of antenna. Directivity at 2.4 GHz is 5.565 dBi. Figure 27 shows the far field polar view. At 2.4 GHz angular width is 100^0 and side lobe level is -7.7 dB.

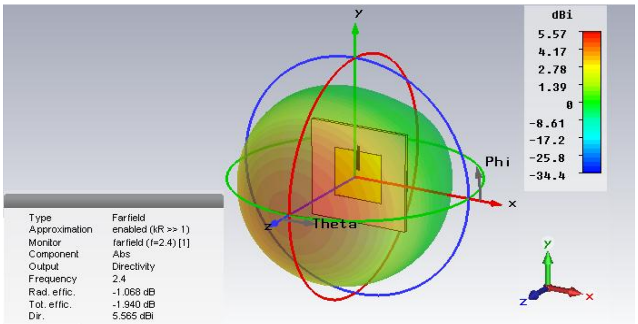


Figure 26: Far field region for Dupont-951.

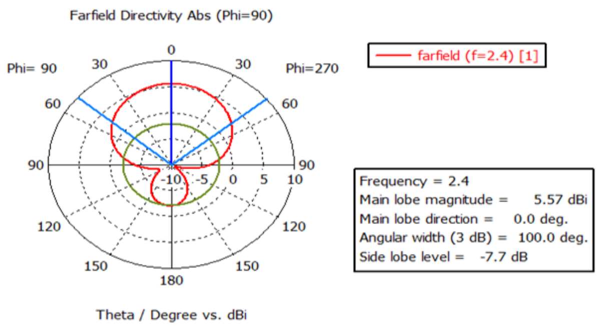


Figure 27: Far field polar view for Dupont-951.

Table IV shows the performance analysis of the designed 2.4 GHz microstrip patch antenna for all the 6 dielectric materials used in this research. From the above table we can see that the highest value of return loss or reflection coefficient is 11.4 dB for FR4, which it better for performance. Also highest total efficiency is achieved for FR4 which is -3.30 dB and radiation efficiency is -2.76 dB. So the best performance of microstrip patch antenna at 2.4 GHz is achieved for FR4 dielectric material. If FR4 is used as substrate material in the microstrip patch antenna it will give the best performance comparing to the other 6 dielectric materials.

Table IV: Performance analysis of the designed microstrip patch antenna for different dielectric materials at 2.4 GHz

Parameters	Substrate Materials					
	FR4	RTDuroid 5880	Arlon Di 522	Taconic RF 35P	Bakelite	Dupont- 951
Dielectric Constant	4.3	2.2	2.5	3.5	4.8	7.8
Resonant Frequency (GHz)	2.4	2.4	2.4	2.4	2.4	2.4
Return Loss (dB)	-11.4	-8.38	-9.58	-6.43	-7.74	-10.8
Side Lobe (dB)	-13.1	-19.6	-18.8	-15.6	-11.9	-7.7
Gain (dB)	3.55	6.72	7.14	5.33	5.72	4.50
VSWR	1.74	2.23	1.99	2.83	2.39	1.81
Directivity (dBi)	6.32	7.56	7.90	6.67	6.48	5.57
Radiation Efficiency (dB)	-2.76	-0.84	-0.76	-1.35	-0.77	-1.1
Total Efficiency (dB)	-3.31	-1.73	-1.58	-2.74	-1.87	-1.9

IV. CONCLUSION

Microstrip patch antenna is widely used in mobile communication, Wi-Fi and WiMAX communication sectors. To develop the communication, several things need to be consider and they are minimize the cost, weight, power consumption and profile of antennas which are capable of maintaining high performance over a wide spectrum of frequencies which was the goal in our work. For designing and analysis of microstrip patch antenna for Wi-Fi communication here different dielectric materials like FR4,RTDuroid 5880,Arlon Di 522,Taconic RF 35P,Bakelite and Dupont-951 were used in substrate layers. By analyzing the performance of the designed microstrip patch antenna for all the six different dielectric materials, better performance was observed for FR4 at 2.4 GHz resonant frequency. The value of return loss was better for FR4 substrate material at 2.4 GHz. Total efficiency and radiation efficiency is also higher for FR4.If FR4 is used in the substrate layer better return loss, radiation efficiency and total efficiency will be observed. Thus FR4 is very suitable for designing this type of antenna for Wi-Fi application.

REFERENCES

[1] *Microstrip Patch Antenna for 2.4GHzWireless Applications*, International Journal of Engineering Trends and Technology (IJETT) Volume 48-August 2013.

[2] *Antenna Theory: Analysis and Design*, Constantine A. Balanis, 3rd Edition 2005.

[3] Yahya S. H. Khraisat (2012) Design of 4 Elements Rectangular Microstrip Patch Antenna with High Gain for 2.4 GHz Applications. *Modern Applied Science* .**6**(1), 68-74.

[4] G. Sharma, D. Sharma and A. Katariya (2012) An Approach to Design and Optimization of WLAN Patch Antennas for Wi-Fi Applications. *IJECCT*,**2**(2),18-23.

[5] Indrasen Singh, Dr. V.S. Tripathi, *Microstrip Patch Antenna and its Applications: A Survey*, Indrasen Singh et al, Int. J. Comp. Tech. Appl., Vol 2 (5), 1595-1599.

[6] Joshua Madhukar Singh, Mayank Mishra, Prafull Sharma, *Design & Optimization of Microstrip Patch Antenna.*

[7] Escortradarforum.com, 'Kustom Falcon HR & Raptor RP-1 - Escort Radar Forum', 2015. [Online] Available: http://escortradarforum.com/forums/showthread.php?t=9611. [Accessed: 08- July- 2015].

[8] Dakir, R. et al. 'Rectangular Planar Antenna Using U-Slot For Bandwidth Improvement'. *Electrical and Electronic Engineering* 3.4 (2013): 118-121. Web. 4 Oct. 2015.