Design & Analysis of Microstrip Patch Antenna Using Different Dielectric Materials for WiMAX Communication System

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***Abstract*—This Paper presents Microstrip patch antenna for WiMAX communication system which operate at 5.8 GHz frequency band. The main objective of this paper is to design and observe the performance of the designed microstrip patch antenna for different dielectric materials. The size of the designed antenna has been also miniaturized. Better performance is observed for FR4 and dupont-951 dielectric material. For FR4 radiation efficiency is-2.776 dB and total efficiency is -3.026 dB at 5.8 GHz, this indicates better performance. And for dupont-951 the return loss is much lower comparing to the other dielectric materials used in this research, which is -16.609 dB. Also for dupont-951 and FR4, VSWR is found 1.35 and 1.7 respectively which is desirable. Also the size of the antenna has been reduced. 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.**

***Index Terms*—Microstrip patch antenna; WiMAX communication; dielectric materials; far field; return losses; Directivity**

I. INTRODUCTION

Day by day our life become easier and comfortable with bless of Technology. Invention increases with the pursue of innovative people. WiMAX is one of the great inventions by those scientists. WiMAX is an acronym meaning “Worldwide Interoperability for Microwave Access” and it is a new in terms of a standard initiative. WiMAX is designed to extend local Wi-Fi network across greater distance. In this paper, our aim is to analyze the performance of an antenna by using dielectric material for using in WiMAX communication application system.

Microstrip antenna was proposed in early 1970 [1][2] and provides a great revolution in the field of antenna design and Research. Nowadays, microstrip patch antenna has become very popular and is widely used in many areas like in mobile communication, Wi-Fi and WiMAX applications. 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 [3]. For designing and manufacturing, Microstrip antenna has low cost because of the simple two dimensional Physical geometry.

To minimize the cost, weight, power consumption and profile of antennas which are capable of maintaining high performance over a wide spectrum of frequencies is the goal to develop the communication System. We focused on improving the performance of WiMAX communication by designing of a microstrip patch antenna. 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 [6].

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 at cutoff frequency 5.8 GHz. Analysis of the simulated results 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 [4].

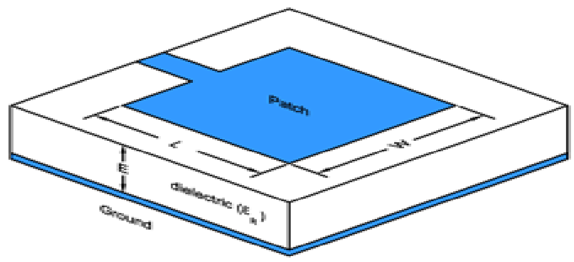

Figure 1. Structure of Patch antenna [3].

In these different layers different materials are used. Copper is used in ground plane, patch and microstrip line. In substrate layer different dielectric substrate materials are used. In this research different dielectric materials were used for specific cut-off frequency to analyze the performance of the antenna for WiMAX application. Table 1 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 II shows the list of the dielectric materials used in this research purpose to analyze the performance of the antenna for 5.8 GHz.

TABLE I.
NAME OF THE LAYERS AND MATERIALS USED

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

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. WiMAX communication system uses 5.8 GHz frequency. Thus the designed antenna must be able to operate at this frequency [6].

Dielectric constant of the substrate (εr): 6 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 WiMAX 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.

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

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

Calculation of the width of the feed line, W_f: IfZ_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.

$$G_{pf} = \frac{4.65x10^{-9}xC}{fo\sqrt{2\varepsilon_{reff}}} \quad (11)$$

III. ANALYSIS OF SIMULATED RESULTS

CST Microwave Suite was used to design microstrip patch antenna for 5.8 GHz resonant frequency using different dielectric materials. Performances for different substrate materials were compared to observe for better performance. Return loss, radiation efficiency, total efficiency, VSWR are the most important factor for the performance analysis of a microstrip patch antenna.

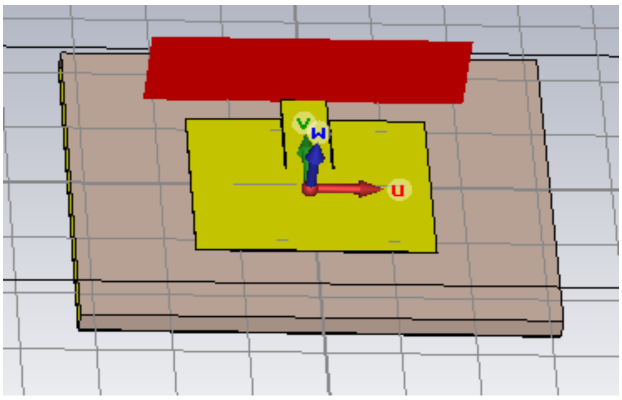

Figure 2. Designed Microstrip Patch Antenna for 5.8 GHz.

A. Performance of the antenna for FR4

Fig. 3 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. The less the value of S_{11} 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. In the figure the return loss is -12.421397dB at 5.8 GHz, which is better for antenna performance.

Fig. 4 shows the far field region. In the figure the total efficiency and radiation efficiency are mentioned. At 5.8 GHz the radiation efficiency is -2.776 dB and total efficiency is -3.026 dB, which is better for the performance of antenna. From the figure it can be seen that the directivity is in Z-axis on the XY plane. Directivity is 6.108 dBi. The top red color shows the radiation. Radiation increased from green to red in Z direction. Fig. 5 shows the far field in polar view for FR4. According to the figure at 5.8 GHz angular width of half power beam is 113.1° and side lobe level is -10.5 dB.

B. Performance of the antenna for RTDuroid 5880

Fig. 6 shows the return loss graph for RTDuroid 5880. According to the figure the value of S_{11} parameter is -9.6935619 dB at 5.8 GHz.

Fig.7 shows far field region for RTDuroid 5880. At 5.8 GHz the radiation efficiency is -0.8192 dB and total efficiency is -1.487 dB, which is better for the performance of antenna. According to the fig. 7 the directivity is in Z-axis on the XY plane. Directivity is 7.282 dBi. Radiation increased from green to red in Z direction. Fig. 8 shows the far field in polar view for RTDuroid 5880. According to the figure at 5.8 GHz angular width is 96.6 ° and side lobe level is -14.7 dB.

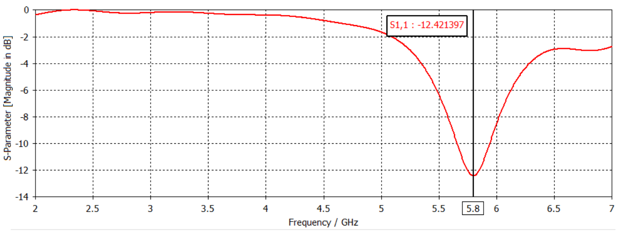

Figure 3. Return loss for FR4.

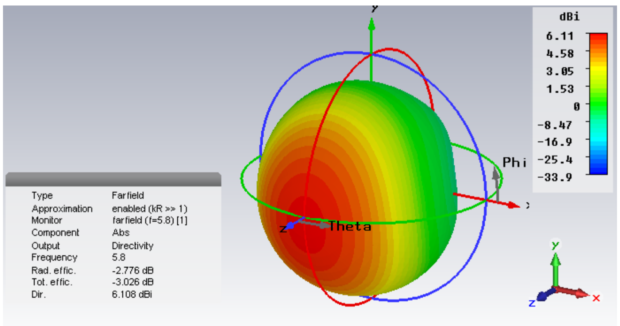

Figure 4. Far field region for FR4.

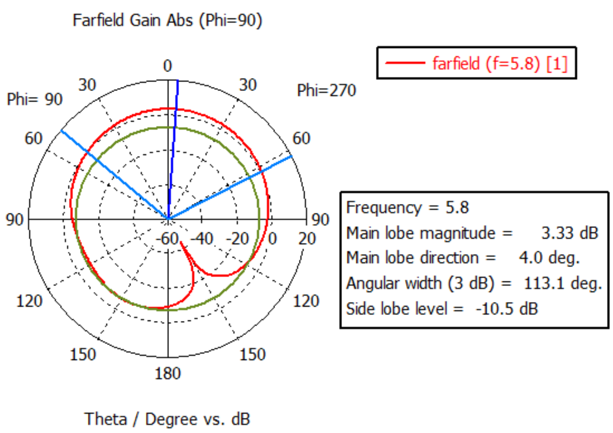

Figure 5. Far field in polar view for FR4.

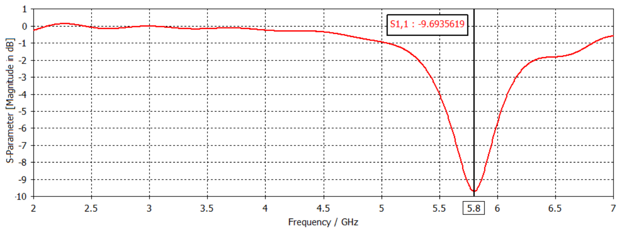

Figure 6. Return loss for RTDuroid 5880.

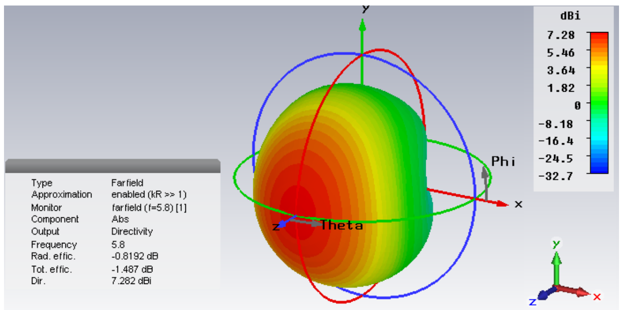

Figure 7. Far field region for RTDuroid 5880.

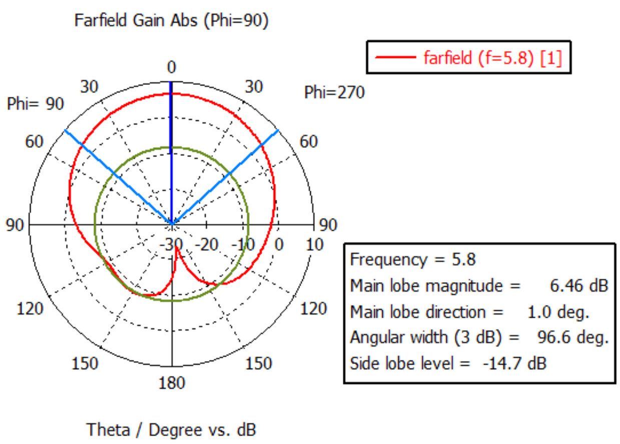

Figure 8. Far field in polar view for RTDuroid 5880.

C. Performance of the antenna for Arlon Di 522

Fig. 9 shows the return loss graph for Arlon Di 522. According to fig. 9, the value of return loss is -13.821792 dB at 5.8 GHz.

Fig. 10 shows the far field region for Arlon Di 522. At 5.8 GHz the radiation efficiency is -1.013 dB and total efficiency is -1.553 dB, which is better for the performance of antenna. According to fig. 10 directivity is in Z-axis on the XY plane. The value of directivity at 5.8 GHz is 7.078 dBi. Fig. 11 shows the far field in polar view for Arlon Di 522. At 5.8 GHz angular width is 94.9 ° and side lobe level is -15.3 dB.

D. Performance of the antenna for Taconic RF 35P

Fig. 12 shows the return loss graph for Taconic RF 35P. At 5.8 GHz return loss is -15.464453 dB.

Fig. 13 shows the far field region. For 5.8 GHz the radiation efficiency is -1.380 dB and total efficiency is -1.640 dB. Directivity is 6.609 dBi. Directivity is in Z-axis on the XY plane. Fig. 14 shows the far field in polar view. At 5.8 GHz angular width is 105.3 ° and side lobe level is -12.4 dB.

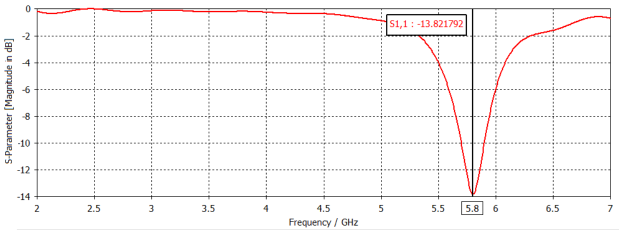

Figure 9. Return loss for Arlon Di 522.

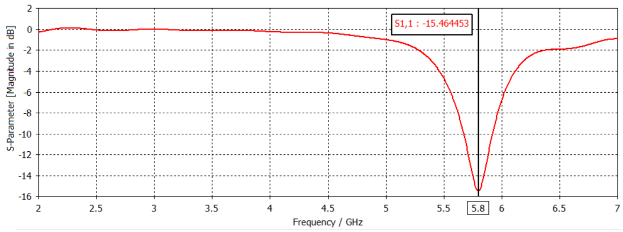

Figure 12. Return loss for Taconic RF 35P.

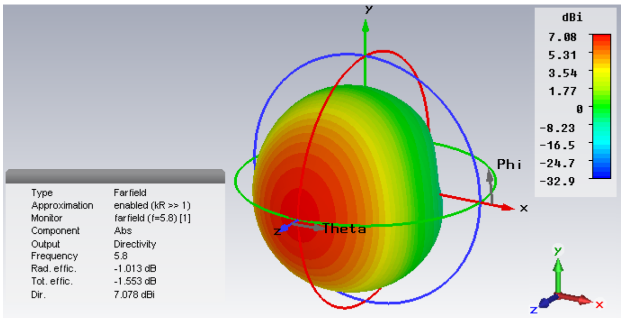

Figure 10. Far field region for Arlon Di 522.

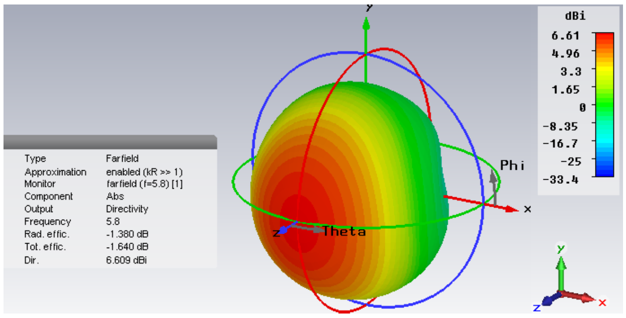

Figure 13. Far field region for Taconic RF 35P.

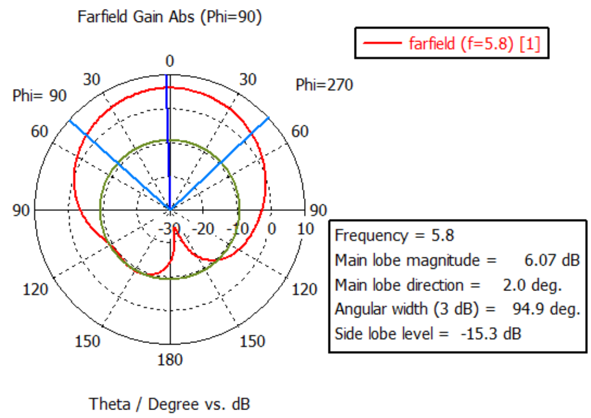

Figure 11. Far field in polar view for Arlon Di 522.

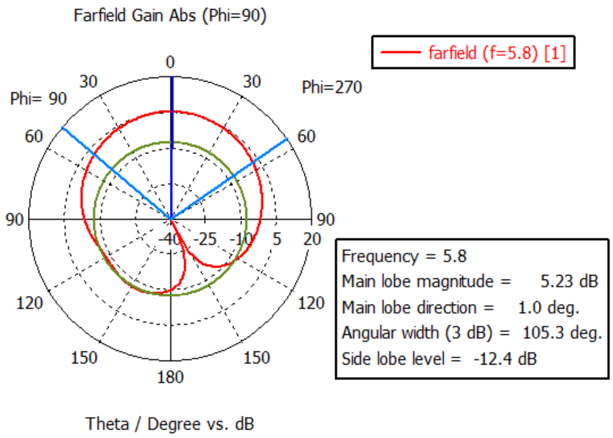

Figure 14. Far field in polar view for Taconic RF 35P.

E. Performance of the antenna for Bakelite

Fig. 15 shows the return loss graph for Bakelite. According to the below figure the value of S_{11} parameter at 5.8 GHz is -14.091718 dB.

Fig. 16 shows the far field region. At resonant frequency the radiation efficiency is -1.382 dB and total efficiency is -1.743 dB, which is better for the performance of antenna. Directivity is 6.023 dBi. Fig. 17 shows the far field in polar view. According to the figure angular width is 108.7^{o}and side lobe level is -11.1 dB at the resonant frequency.

F. Performance of the antenna for Dupont-951

Fig. 18 shows the return loss graph for Dupont-951. According to the figure at 5.8 GHz the value of return loss/ S_{11} parameter is -16.609992 dB.

Fig. 19 shows the far field region. According to the figure at resonant frequency the radiation efficiency is -1.439 dB and total efficiency is -1.944 dB. From the figure it can be seen that directivity is in Z-axis on the XY plane. Directivity at 5.8 GHz is 5.573 dBi. Fig. 20 shows the far field in polar view. From the figure angular width is 105.8^{o} and side lobe level is -9.7 dB at the resonant frequency.

According to Table III that the highest value of return loss is -16.609 dB, which is for Dupont-951. If Dupont-951 is used as substrate material it will give better performance. Also maximum radiation efficiency and total efficiency has been observed for FR4, which also indicates better performance. For FR4 radiation efficiency is -2.776 dB and total efficiency is -3.026 dB. If FR4 is used as substrate material it will also give better performance at 5.8 GHz. So either Dupont-951 or FR4 can be used as substrate material in microstrip patch antenna for better performance at 5.8 GHz.

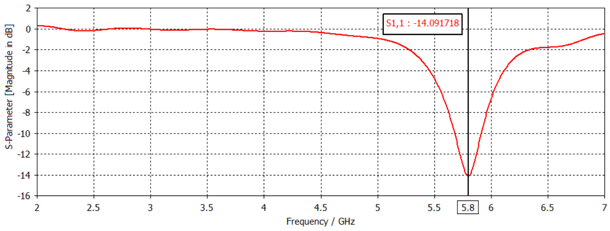

Figure 15. Return loss for Bakelite.

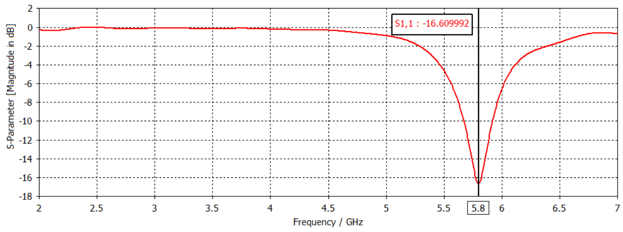

Figure 18. Return loss for Dupont-951.

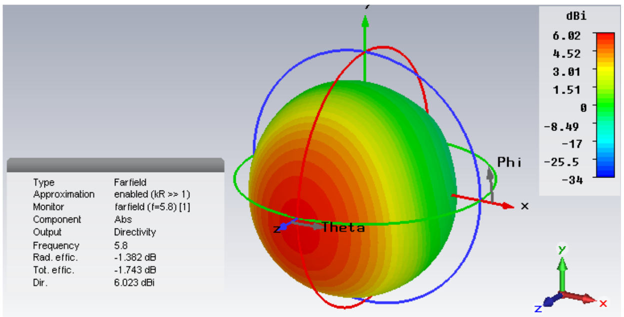

Figure 16. Far field region for Bakelite.

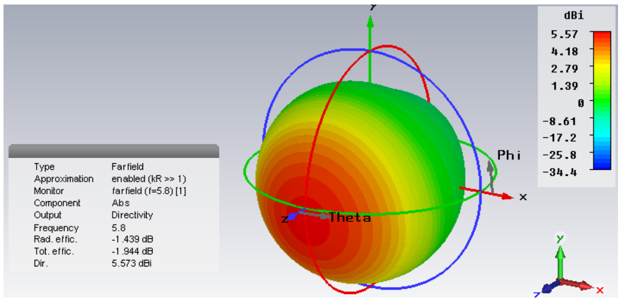

Figure 19. Far field region for Dupont-951.

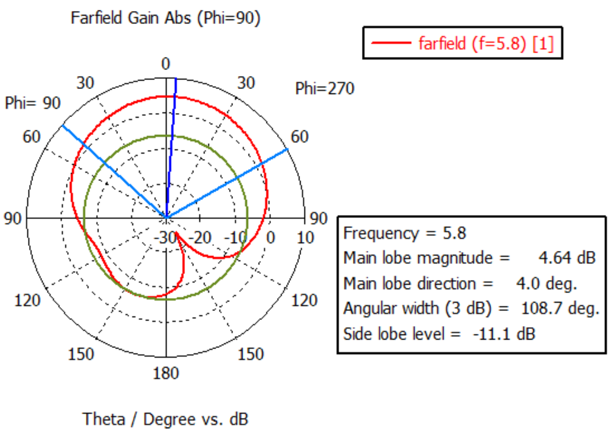

Figure 17. Far field in polar view for Bakelite.

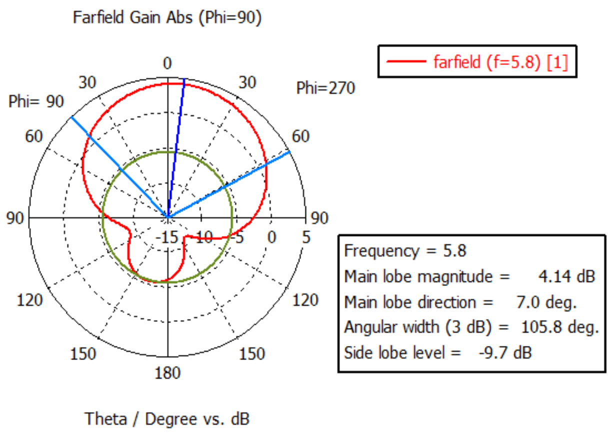

Figure 20. Far field polar view for Dupont-951.

TABLE III.
PERFORMANCE OF THE DESIGNED MICROSTRIP PATCH ANTENNA FOR 6 DIFFERENT DIELECTRIC MATERIALS AT 5.8 GHZ RESONANT FREQUENCY.

Paramet-ers	Substrate Materials					
	FR4	***RTDu-roid 5880***	***Arlon Di 522***	***Taconic RF 35P***	***Bakelite***	***Dupont-951***
Dielec. Constant	4.3	2.2	2.5	3.5	4.8	7.8
Res. Freq. (GHz)	5.8	5.8	5.8	5.8	5.8	5.8
Return Loss (dB)	-12.421	-9.693	-13.821	-15.464	-14.091	-16.609
Side Lobe (dB)	-10.5	-14.71	-15.3	-12.4	-11.1	-9.7
Gain (dB)	3.332	6.462	6.065	5.228	4.641	4.134
VSWR	1.6291	1.9743	1.51149	1.4055	1.4920	1.3467
Directivity (dBi)	6.108	7.282	7.078	6.609	6.023	5.573
Radi. Effic. (dB)	-2.776	-0.8192	-1.013	-1.380	-1.382	-1.439
Total Effic. (dB)	-3.026	-1.487	-1.553	-1.640	-1.743	-1.944

IV. CONCLUSION

Today is the era of wireless communications system. WiMAX communication system is widely used around the world. So the use of microstrip patch antenna is increasing day by day. The designed antenna has been miniaturized. The most important factor for the performance analysis of antenna is return loss, radiation efficiency, total efficiency, VSWR. After analyzing the above factors for the 6 mentioned dielectric materials, better performance at 5.8 GHz resonant frequency was observed for both FR4 and Dupont-951. If FR4 or Dupont-951 is used in the substrate layer, designed microstrip patch antenna will provide better performance for WiMAX communication system.

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