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A DOUBLE E SHAPED MICROSTRIP PATCH ANTENNA FOR MULTIBAND APPLICATIONS

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Abstract

This paper presents a dual band Compact double E shaped Microstrip Patch antenna with enhanced gain for Worldwide Interoperability for Microwave Access (WI-MAX), Universal Mobile Telecommunication Systems (UMTS) and Satellite applications. The modified E shaped patch antenna is designed using CADFEKO and the results of return loss, Voltage Standing Wave Ratio (VSWR), gain of the proposed antenna are compared with a conventional E shaped patch antenna. The results show that the double E shaped wideband patch antenna has an impedance bandwidth of 10.7 % with a return loss of -13.6dB, -12.4 dB, -12.1dB and -14.2dB at resonant frequencies of 1.96 GHz, 3.62 GHz, 5.76 GHz and 6.82 GHz, whereas a conventional E shaped patch antenna operates at 2.5 GHz, 3.4 GHz and 5.5 GHz with a return loss of -16 dB each and impedance bandwidth of 10.6 %. Both the antennas uses Coaxial Probe feeding technique and Flame Retardant 4 (FR-4) as the substrate material with a thickness of 2.87 mm. A parametric study has been done so as to understand the effect of each parameter to obtain a better performance and optimised results.

Keywords:

Double E Shaped Patch Antenna, WIMAX, Dual band, CAD FEKO

1. INTRODUCTION

Antenna serves as the base of any wireless communication standard. The wide range of wireless communication standards and its various applications demands the need of compact multiband antennas [1-3]. The use of separate antennas for each system makes the design very expensive thereby increasing the number of antennas. This has been overcome by using the multiband behaviour in antennas [4-5]. As the device size of the wireless communication is being reduced, the antennas used in such devices should also be compact. Microstrip patch antennas are widely considered to be satisfying both these criterions.

Microstrip patch antenna was first proposed by Deschamps. A microstrip patch antenna in its simplest form consist of a radiating patch made of copper on one side of the dielectric substrate and a Perfect Electric Conductor (PEC) ground plane on the other side as shown in Fig.1 [6-8]. Such antennas are more preferred in wireless communication since they can be printed onto a circuit board. Other advantages of such antennas include low cost, easy fabrication, multi band behaviour, cost effective manufacturing etc. They also suffer various drawbacks like narrow bandwidth, low Gain, surface waves etc [9-11].

The bandwidth limitation is usually overcome by various techniques like using air substrate[3], cutting slots in the patch [12-13], using stacked patch antenna [6], increasing the thickness of the substrate[3,6] etc. Among all these techniques cutting slots in the patch is attractive due to the reason that it maintains the thin profile characteristics of the patch. Some of the commonly used patch shapes using slots are U shaped patch antenna, V shaped patch antenna, H shaped patch antenna etc.

The shape of an E shaped patch antenna resembles the letter ‘E’ and hence its name. In order to design an E shaped patch, two parallel slots are introduced into a rectangular shaped patch antenna resulting in a dual band antenna [14-16]. The slot length and width are two important parameters that determine the performance of the E shaped patch antenna. A parametric study is done to determine the length and width of the slots so as to obtain optimal performances for the antenna. The feed point is placed close to the tip of the centre arm.

In this paper a modified compact E shaped patch antenna with enhanced gain has been proposed, by in cooperating another identical E shape adjacent to the first E shaped patch. The proposed antenna operates at multiple frequencies of 1.96 GHz to 6.82 GHz making it suitable for WIMAX, UMTS and Satellite applications. The proposed antenna provides an impedance bandwidth much better than a conventional E shaped patch. Both the structures were simulated using an Electro Magnetic (EM) simulator, CAD FEKO. The paper is organized as follows. Section 2 describes the geometry of the antennas, section 3 discusses the various results and section 4 provides the conclusion.

The Fig.1(a) shows the basic structure of a rectangular shaped patch and Fig.1(b) shows its equivalent circuit given by cavity model theory. The equivalent circuit consist of an inductor L and a capacitor C. The current gets distributed from the feeding point to the edges of the patch and the length of the current path determines the value of capacitance C.

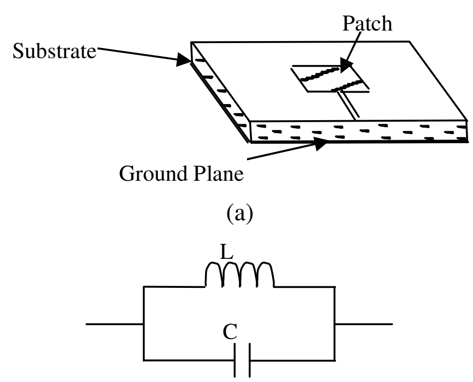
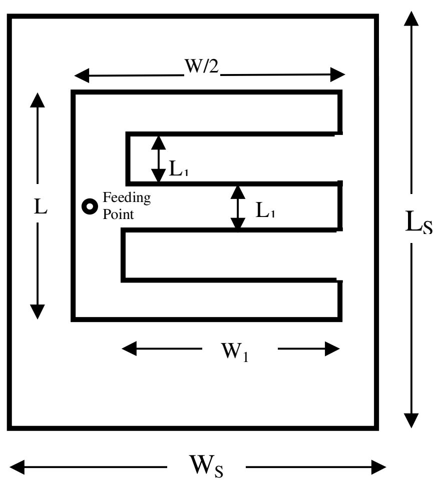


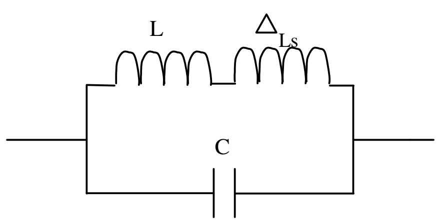
Fig.1(a). Conventional Microstrip patch antenna, (b). Equivalent Circuit

2. ANTENNA DESIGN

The microstrip patch antenna has been designed using transmission line modal. The Fig.2(a) shows the top view geometry of the conventional coaxial probe fed E shaped patch antenna operating at WI-MAX frequencies (2.5 GHz - 2.69 GHz, 3.2 GHz - 3.8 GHz and 5.2 GHz - 5.8 GHz) and Fig.2(b) shows the equivalent circuit for an E shaped patch antenna. When slots were introduced into the radiating patch, the current flows normally at the middle part of the patch indicating a simple LC circuit whereas towards the edges, the current gets distributed and takes a longer path around the slots which can be considered as equivalent to an inductance ΔL. Fig.2(c) shows the geometry designed using CAD FEKO by placing two rectangular shaped slots of length W_1 = 17 mm and width L_1 = 8 mm so that both this slots lie at symmetrical distance from the length of the patch.



(a)



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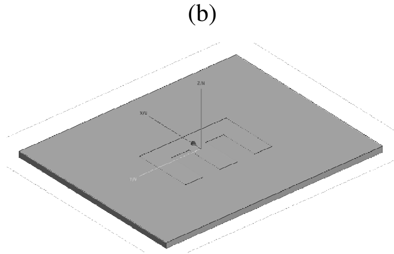
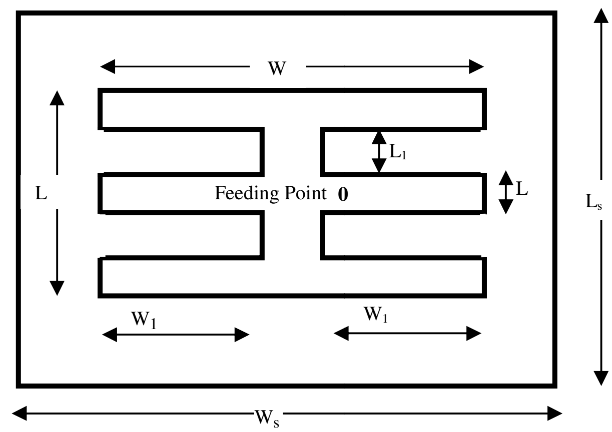


(c)

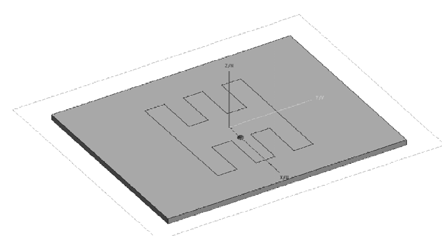
Fig.2(a). Top view of the E shaped Patch, (b). Equivalent circuit of E shaped patch, (c). Geometry designed using CADFEKO

The antenna has been designed on an FR4 substrate with a dielectric constant of 4.4. The dimension $L_S \times W_S$ is 50 mm × 80 mm with a thickness of 2.87 mm. A microstrip patch of length L_p = 25 mm and width W_p = 40 mm is used for this design given by the equations for the design of a conventional rectangular shaped Microstrip patch antenna. The design specification of this E shaped patch is given in Table.1.

The Fig.3(a) shows the top view geometry of the proposed antenna using coaxial probe feed technique and Fig.3(b) shows its design using CADFEKO software. A symmetrical E shaped patch is placed close to the conventional E shaped patch resulting in a double E shaped antenna operating at WI-MAX, (3.2 GHz - 3.8 GHz, 5.2 GHz - 5.8 GHz), UMTS (1920 MHz - 2170 MHz) and INSAT Satellite Communication transmit Frequencies (6.725 GHz - 7.025 GHz) with an improved bandwidth. The feed position is optimized so as to obtain better impedance matching at the resonant frequencies which is then connected to a 50 Ω SMA connector. The radius of the feed of the coaxial probe connector is 0.5 mm and is present towards the corner of the E shaped patch.



(a)



(b)

Fig.3(a). Geometry of the proposed modified E shaped antenna, (b). Geometry designed using CADFEKO

Table.1. Dimensions of the proposed antenna

Parameters	Value (mm)
Length of patch (L)	40
Width of Patch (W)	50
Length of substrate (Ls)	80
Width of substrate (Ws)	100
Height of substrate (Hs)	2.87
Length of slits1 (L_1)	8
Width of slits1 (W_1)	17

3. RESULTS AND DISCUSSION

The simulation of both the antenna geometries is done by using CADFEKO software version 5.5. The variation of return loss with frequency of both the antenna is shown in Fig.4. Return loss indicates the amount of power that is lost to the load and does not return as reflection. The E shaped patch resonates at frequencies of 2.52 GHz, 3.4 GHz and 5.5 GHz each at a return loss of -16 dB making it suitable to operate in the WI-MAX range whereas the double E shaped patch operates at 1.96 GHz, 3.62 GHz, 5.76 GHz and 6.82 GHz each with a return loss of -13.6 dB, -12.4 dB, -12.1 dB and -14.2 dB respectively making them suitable for WIMAX, UMTS and INSAT frequencies. The bandwidth is calculated at these frequencies where return loss falls below -10 dB. The bandwidth of the conventional E shaped patch is 450 MHz whereas it is 480 MHz for the proposed antenna.

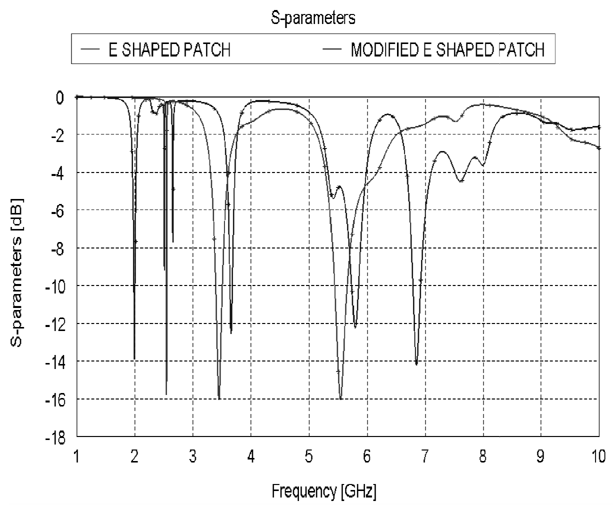


Fig.4. Comparison of return loss of E shaped patch antenna and modified E shaped patch antenna

The VSWR indicates the amount of mismatch between the antenna and the transmission line. VSWR should always be a positive real number between 1 and 2. The VSWR graph of the conventional E shaped patch and the proposed E shaped patch is shown in Fig.5.

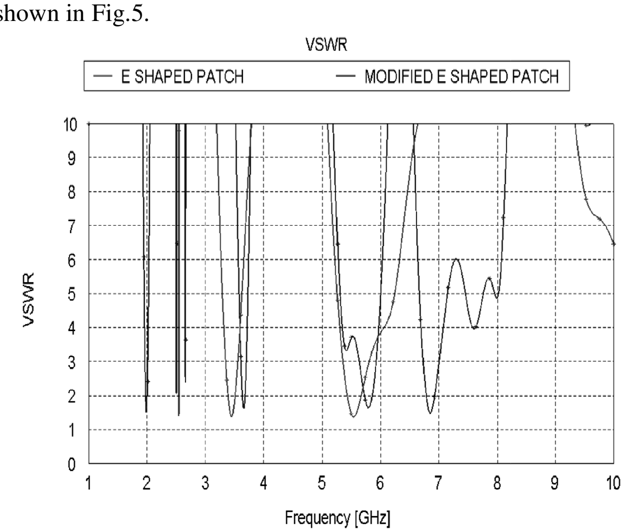
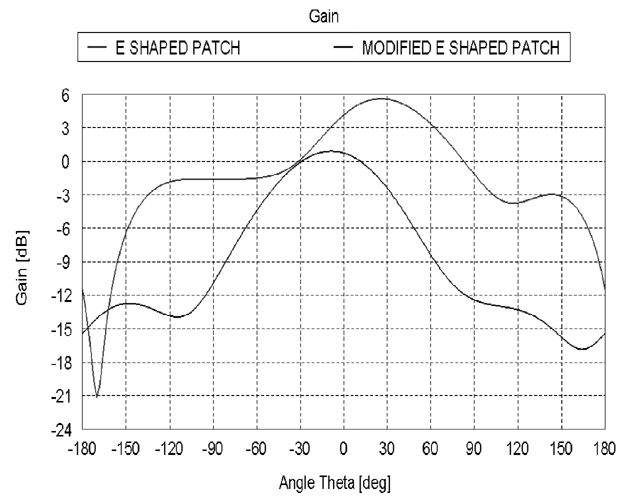
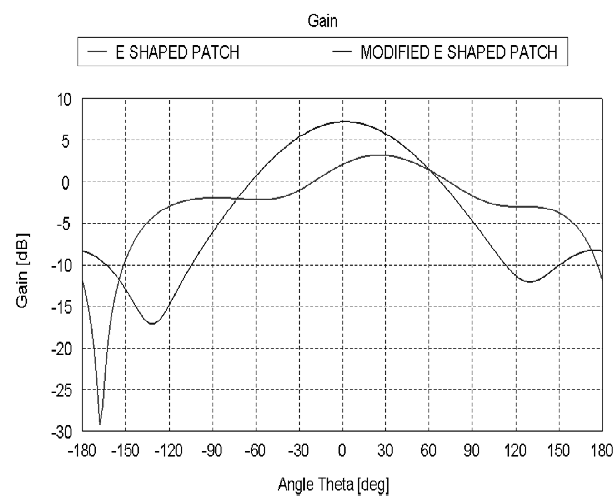


Fig.5. Comparison of VSWR of E shaped patch antenna and modified E shaped patch antenna

The Fig.6(a) shows the gain plot of the conventional E shaped patch and the proposed antenna at a frequency of 2.4 GHz with $\theta = 0^\circ$ and $\varphi = 90^\circ$ whereas Fig.6(b) shows the gain plot at 1.94 GHz. It is observed that a maximum gain of 2.4 dB is obtained for the conventional E shaped patch whereas it increases up to 6.3 dB when symmetrical E shape is plotted adjacent to the E shaped patch.



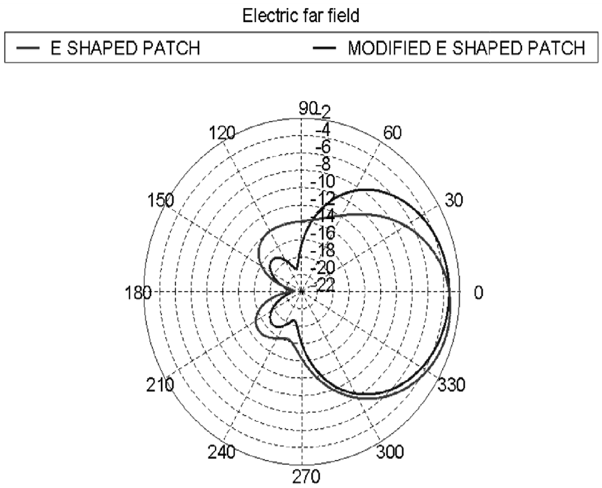
(a)



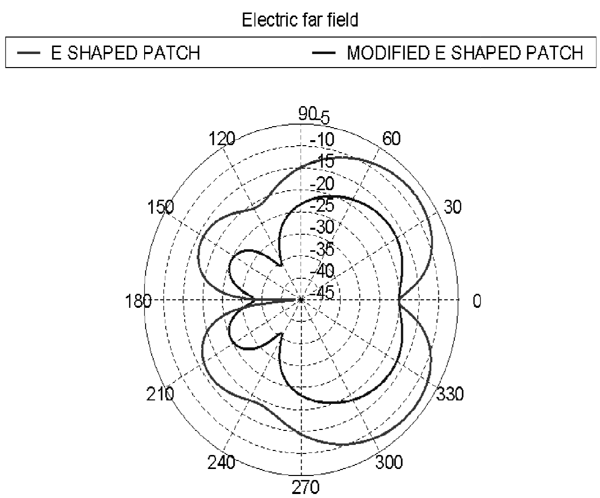
(b)

Fig.6. Gain plot of E shaped patch and modified E shaped patch: (a) at 2.4 GHz (b) at 1.94 GHz

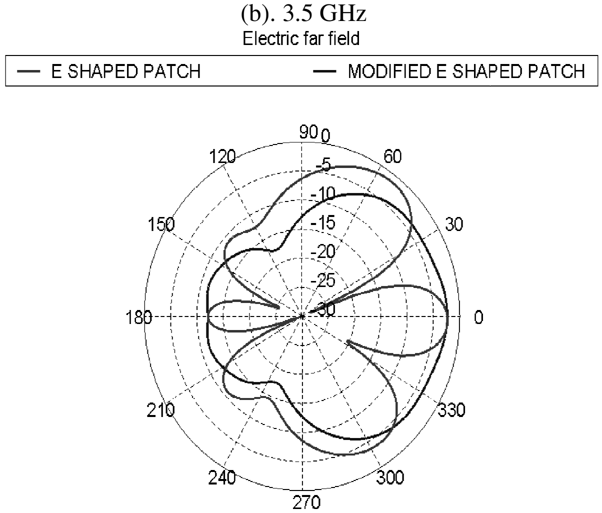
Since the patch antenna radiates normal to the patch the radiation pattern for $\theta = 0^\circ$ and $\varphi = 90^\circ$ would be very important. The 2D radiation plot in E plane and H plane of the proposed antenna at 2.48 GHz is given by Fig.7(a) whereas Fig.7(b) shows the 2D radiation pattern plot at 3.5 GHz and Fig.7(c) shows the radiation pattern plot at 5.7 GHz. The 3D radiation pattern plots of these frequencies is shown in Fig.8(a) to Fig.8(c). The radiation pattern is omni-directional at lower frequencies in the YZ plane that varies directionally when the frequency is increased. The radiation pattern in the XZ plane consists of major lobes and minor lobes.



(a). 2.48 GHz

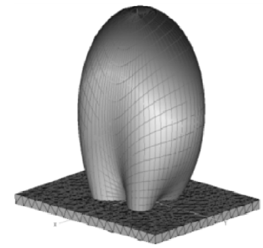


(b). 3.5 GHz

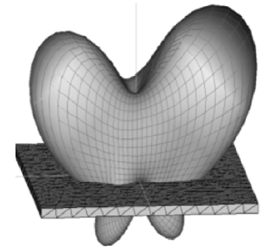


(c). 5.7 GHz

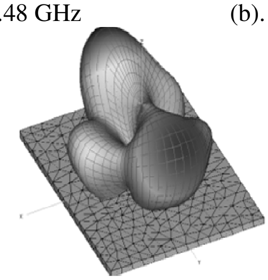
Fig.7. Comparison of 2D plot of E plane and H plane radiation patterns of proposed antenna



(a). 2.48 GHz



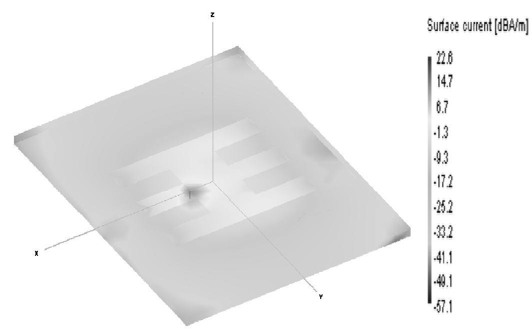
(b). 3.5 GHz



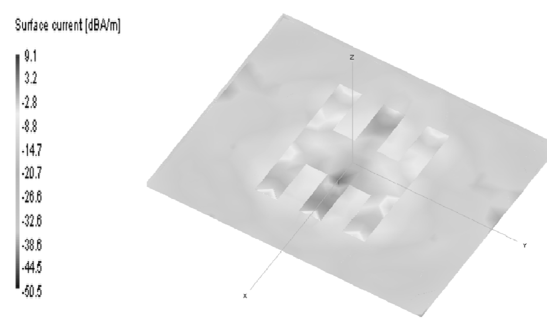
(c). 5.7 GHz

Fig.8. Comparison of 3D plot of radiation patterns of proposed antenna

The Fig.9(a) shows the current distribution of the proposed antenna at 1.9 GHz whereas the Fig.9(b) shows the current distribution at 6.82 GHz. Corresponding values of Surface currents in db are indicated as labels.



(a). 1.9 GHz



(b). 6.82 GHz

Fig.9. Current distribution of proposed antenna

The Table.2 shows the comparison of antenna parameters of the proposed E shaped patch and the conventional E shaped patch antenna.

Table.2. Comparison of antenna parameters of E shaped patch and modified E shaped patch

Antenna Parameters	E Shaped Antenna	Modified E Shaped Antenna
Resonant Frequency (GHz)	2.52, 3.4, 5.5,	1.96, 3.62, 5.76, 6.82
Return Loss (dB)	-16, -16.1, -16	-13.6, -12.4, -12.1, -14.2
VSWR	1.2	1.2
Gain (dB)	2.4	6.3
Bandwidth (MHz)	450	480
Impedance Bandwidth (%)	10.61	10.7
Miniaturization (%)	52.72	73.59
Application	WIMAX	UMTS WIMAX INSAT SATELLITE

4. PARAMETRIC STUDY

4.1 EFFECT OF FEED POINT LOCATION

Feed point has a crucial role in designing the performance of a patch antenna. Table.3 shows the variation of return loss with frequency for different feed point locations. It is observed that more bandwidth is obtained when the feed point location is varied along the *x* axis.

Table.3. Variation of Return loss with feed point location

Sl. No	Feed point location (X,Y)	Resonant Frequency (GHz)	Return Loss (dB)	Bandwidth (MHz)
1	(18,17)	2.04	-13.7	310
		3.64	-22.3	
		4.1	-13.6	
2	(10,0)	1.9	-17	480
		6.8	-23	
		8.1	-23	
3	(0,12)	3.7	-24	110

4.2 EFFECT OF LENGTH OF THE SLOTS

The Table.4 shows the effect of slot length on antenna parameters. The length of slots is varied from 10 mm to 20 mm keeping the width to be constant. It was observed that the bandwidth increases first and then starts decreasing. As the length of slits increases, the antenna resonates at multiple frequencies. This is shown in Fig.10.

Table.4. Effect of length of slots on antenna parameters

Sl. No	Length of Slots (mm)	Width of Slots (mm)	Resonant Frequency (GHz)	Return Loss (dB)	Bandwidth (MHz)
1	10	8	2.0	-14.3	280
			5.6	-19.2	
2	15	8	2.00	-24.9	560
			2.8	-11.9	
			5.6	-14.1	
			6.9	-14.5	
			8.2	-11	
3	20	8	2.4	-18.4	390
			5.2	-11.2	
			7.5	-15.4	

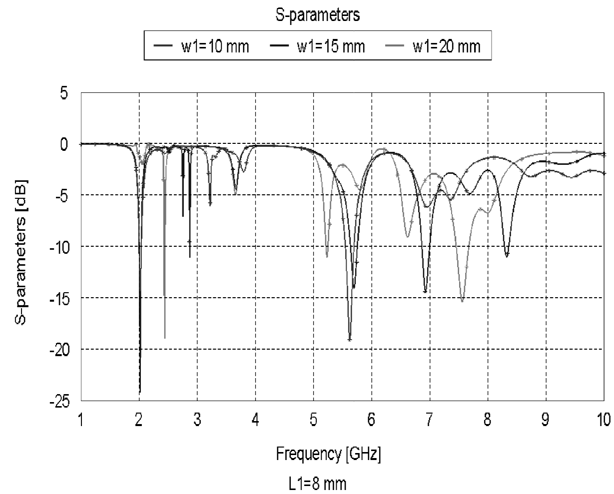


Fig.10. Variation of return loss for different slot lengths

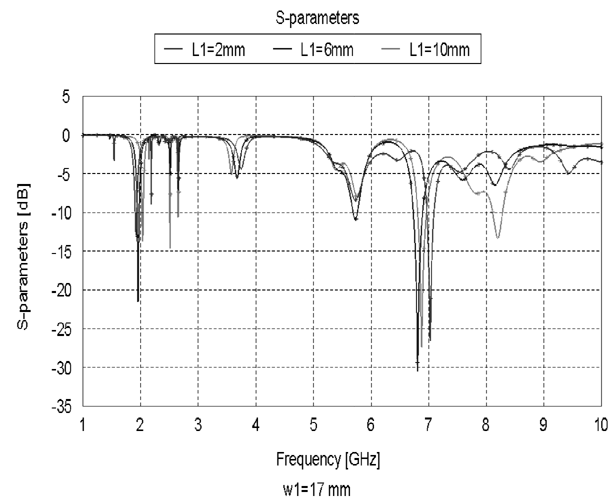


Fig.11. Variation of return loss for different slot widths

4.3 EFFECT OF WIDTH OF SLOTS

The width of slots is varied from 2 mm to 10 mm with an increment in steps of 4 mm. As the width of slits increases the overall bandwidth of the proposed antenna increases. Table.5 shows the effect of width of the slots on the bandwidth of the antenna. The antenna radiates at multiple frequencies when the width of the slots increases. Fig.11 shows the variation of return loss with different slot widths.

Table.5. Effect of width of slots on antenna parameters

Sl. No	Length of Slots (mm)	Width of Slots (mm)	Resonant Frequency (GHz)	Return Loss (dB)	Bandwidth (MHz)
1	17	2	1.89	-13	250

			7.04	-26	
2	17	6	1.9	-20	470
			5.7	-11	
			6.8	-30	
3	17	10	2.00	-13.9	620
			2.52	-26	
			5.65	-14	
			5.83	-16	
			6.1	-31	

5. CONCLUSION

In this paper a double E shaped Microstrip patch antenna on an FR4 substrate has been obtained and simulated. The proposed antenna has a compact size of 50 mm × 40 mm and is simple in its design and fabrication with a bandwidth of 480 MHz and a gain of 6.3 dB. All the results have been obtained using CAD FEKO software version 5.5. A Parametric study has been conducted with the results indicating that the antenna operates better in the resonating frequencies. The proposed antenna also has sufficient gain of 6.3 dB suitable for wireless communication systems. The newly designed E shaped patch is better than a simple E shaped patch or a conventional microstrip patch in terms of bandwidth of operation or gain. Future work on enhancing the bandwidth of the structure can be done by increasing the thickness of the substrate and at the same time the gain should be of acceptable limit.

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