DESIGN AND ANALYSIS OF E-SHAPED PATCH ANTENNA TOWARDS ENHANCED GAIN AND WIDEBAND WIRELESS COMMUNICATION

Gaytri Malviya[1], Yogesh Patidar[2], Ajay Kumar [3], Vimla Agriya[4]

[1,3,4] Research Scholar, School of Engineering and Technology, Vikram University Ujjain, MP, India
[2]Assistant Professor, School of Engineering and Technology, Vikram University Ujjain, MP, India

ABSTRACT

This study presents the design and analysis of an E-shaped patch antenna with dual slots on a Microstrip Substrate Antenna (MSA). The design incorporates bimodal resonant performance by exciting nearby resonant frequencies. The calculation of antenna gain involves parameters such as antenna width, length, dielectric height, dielectric constant, and orientation angle. The study explores the impact of varying dielectric materials (glass, FR4, vacuum, RT5880, Mica, SiO2) and different heights on the antenna's gain. The results indicate that the antenna achieves significant gains for specific frequencies, demonstrating its potential for widespread wireless communication applications. The designed E-shaped patch antenna exhibits promising characteristics for pervasive wireless communication. Through systematic analysis, the study identifies optimal configurations for maximum gain by considering dielectric materials and substrate heights. The antenna's wideband performance, characterized by low Voltage Standing Wave Ratio (VSWR) and effective band notch filtering, makes it suitable for diverse frequency ranges. Future recommendations include exploring cascaded configurations and antenna array techniques to further enhance gain, responsiveness, and stability at high frequencies.

Keyword: *Microstrip Antenna, E-shaped Patch Antenna, Bimodal Resonance, Dielectric Material., Wideband Communication*

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1. Introduction

E-shaped patch antenna is designed by cutting two parallelslots on the patch surface of MSA. for producing double current pathsin patch it should be exciting the nearby resonant frequencies. Fig 4.1 demonstrates the equivalent circuits of bimodal resonant performance for E-shapedpatch antenna.

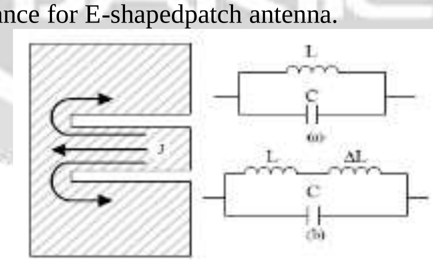

Fig.1 Equivalent circuit of E shape MSA

2. Method for Calculation of gain

The maximum gain of antenna is nothing but directivity of antenna. The gain of antenna is depends upon many parameter like width of antenna , length of antenna, height of dielectric, dielectric constant, orientation angle of antenna.The maximum directive gain or directivity of MSA can be calculated by

$$D = 0.2W + 6.6 + 10\log\left(\frac{1.6}{\epsilon_r}\right) \text{ dB} \quad (4.4)$$

The equation clearly denote that larger width and length of antenna gives more gain. If the height of antenna is increasing then surface wave start to generate and losses in antenna increased so the gain of antenna decrease. The dielectric constant of microstrip antenna is called effective dielectric constant. Effective dielectric constant is depends upon dielectric constant and W/h ratio.

$$\varepsilon_{reff} = \frac{\varepsilon+1}{2} + \frac{\varepsilon-1}{2}\left(1+12\frac{h}{w}\right) \quad (4.5)$$

Changing in dielectric constant affect in changing length and width of microstrip antenna which change the gain of antenna.
we analyse the gain of MSA for six different dielectric glass, fr4, vacuum, RT5880, Mica, Sio2, with four different height(h) 3mm, 5mm, 7mm, 10mm. Table 5.1 shows the variation in gain as dielectric constant and height changes. The Fig. 1 shows the best plot between Gain and frequency with dielectric glass at height of 7mm. The plot clearly shows that the antenna achieve maximum gain 18 db at 11 GHz. Antenna has gain above 5db for frequency range 10.4 – 11.4 GHz.

Table 1 variation in Gain as dielectric constant and height changes

Mica			Glass		FR4		Sio2		RT5880		Vacuum	
h	Gain	f	Gain	F	Gain	F	Gain	f	Gain	f	Gain	f
3mm	8.5	9. 6	6	10	8	10	6	10	4	8	11	11.2
5mm	8.5	10	7	8	20	9.8	13	9	6	8	9.5	10
7mm	9	10	18	11.2	5	8	9	8	7	8.6	15	2.4
10mm	7.5	10	10	7.8	10.5	10.4	8	10	6	6	17.5	12

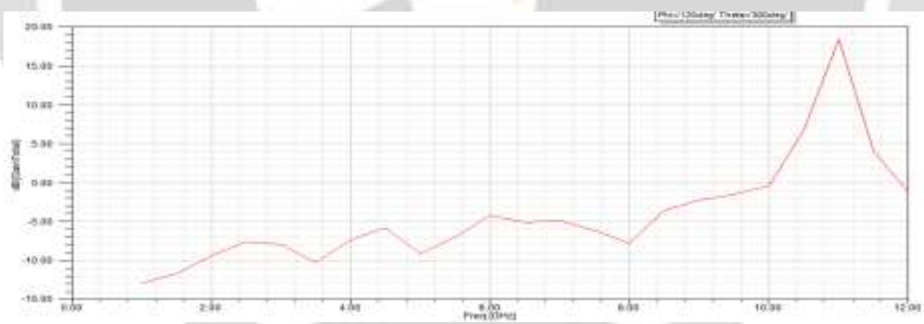

Fig. 2. Gain versus frequency plot for Glass material

For the height of dielectric 3 mm, the antenna attain max gain 6 db at frequency 10 GHz. The antenna also attain a significant gain 5 db at frequency 9.2 GHz. For height of glass dielectric = 5mm, the antenna attain maximum gain 6 db at frequency 8 GHz and 7.5 db at 8.2 GHz. For dielectric glass with height h = 10mm, the antenna attain max gain 10 db at 7.8 GHz. Antenna achieve significant gain 9.2 db and 8.2 db at frequency 8.4 GHz and 9.2 GHz. The gain of antenna is constant from frequency 10.4 to 12 GHz.

Fr4 consider as second dielectric substrate to analyse the gain of antenna.The Fig. 2 shows the plot of gain Vs frequency with height of 5mm dielectric FR4 substrate. As far as the gain is concern the above design is the best design because antenna attain 20 db gain at frequency 9.8 GHz as we increase the height of Fr4 dielectric from 3mm to 5mm.

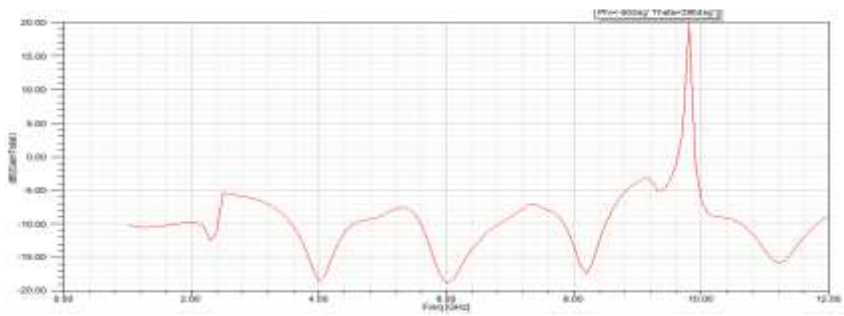

Fig. 3. Gain versus frequency plot for FR4 material

Fr4 with height of dielectric 3mm, the antenna attain max gain 8 db at 10GHz. When we increase the height of fr4 material to 7mm, the antenna achieve max gain 5 db at frequency 7.8 GHz. The gain is above 0 db between 6 GHz to 8.8 GHz. Fr4 with height 10 mm the antenna achieve max gain of 11 db at frequency 10.2 GHz. The antenna has significant gain of 5db in the range of 7.6 GHz to 12 GHz.

Vacuum dielectric constant is equal to 1 is taken as third dielectric substrate to analyse the gain of Microstrip Antenna. We consider vacuum as dielectric with different dielectric height of 3mm, 5mm, 7mm and 10mm and plot the different graph between gain and frequency. The Fig. 5.3 below is plot of Gain Vs frequency for h= 3mm which clearly shows that the antenna achieve max Gain 11db at frequency range 10.8 GHz to 12 GHz. At lower frequency 1.3 GHz antenna have significant gain of 6 db.

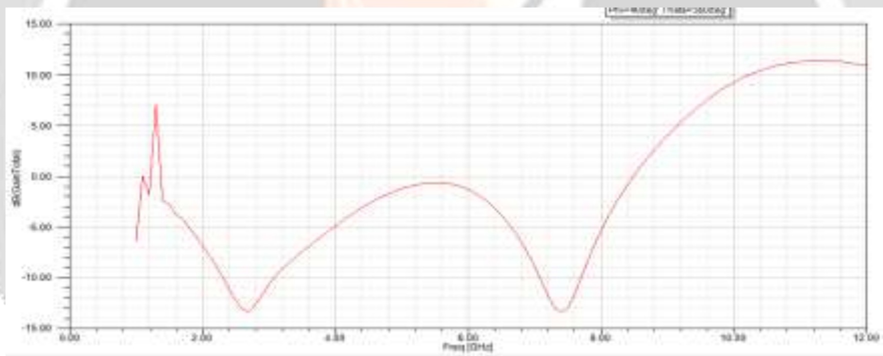

Fig. 4. Gain versus frequency plot for vacuum

As we increase the height of dielectric 5mm, Antenna achieve max gain of 9.5 db at frequency 10 GHz and have significant gain 5 db between 8.4 to 12 GHz. For height of substrate 7mm,Antenna achieve highest gain 15 db at lower frequency 2.4 GHz. Antenna has significant gain of 9 db between 9 to 12 GHz, For 10mm height of dielectric constant. Plot clearly shows that antenna achieve 10 db gain at frequency 1 GHz and after that the Gain increasing with frequency and achieve max gain 17.50 db at frequency 12 GHz.

When we replace mica as a substrate for antenna, the simulation results shows that antenna achieve maximum gain 9db for height of substrate equal to 7mm at frequency 10 GHz. It also achieve significant gain 8.5db for height 3mm and 5mm. When we replace silicon dioxide as dielectric the simulation result clearly shows that antenna achieve maximum gain 13db for height 5mm at frequency 9Ghz. Antenna with dielectric constant RT5880 achieve maximum gain 17.5db at frequency 12 GHz.

3. VSWR analysis

As far as the microstrip antenna is consider the VSWR analysis is very much important. It measure the amount of reflection at the port. The Fig. of VSWR Vs frequency shows the amount of reflection at various frequency. For best performance of antenna VSWR should be between 1< VSWR < 2. VSWR is important parameter for analyse the band notch characteristic of antenna, for band reject or band notch characteristic the VSWR should be as high as possible. we analyse the VSWR pattern for all dielectric Glass, Fr4 and vacuum with three different height of dielectric 3mm, 5mm, 7mm and 10 mm.The Fig. 5.4 shows the plot of VSWR Vs frequency for dielectric glass with height 10mm. The Fig. 4 clearly shows that for entire range of frequency of operation from 1 GHz to 12 GHz the VSWR is always less than 1.8. this exhibit the property of ultra wide band microstrip antenna.

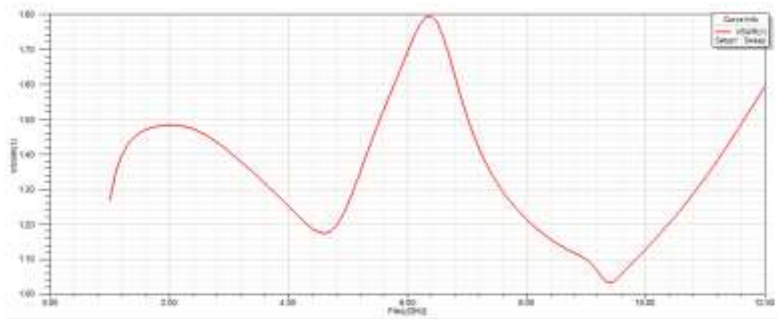

Fig. 5. VSWR Versus frequency plot for Glass material

For glass dielectric with height 3mm, The antenna attain minimum VSWR =1, at 9.4 GHz. It means if we give frequency 9.4 GHz at input port of antenna, then there is no reflection at input port. For Glass dielectric with height of 5mm. The VSWR is less than 2 for frequency range 6.8 GHz to 11.2 GHz and 2.8 GHz to 4.6 GHz. For dielectric Glass with height 7mm, antenna has VSWR less than 2 for a wide range of frequency from 1.1 GHz to 9.4 GHz.

Table 2 variation in VSWR as height changes for Glass material

Height of dielectric(h)	VSWR (1<VSWR<2)
3mm	1GHz to 2 GHz & 10 GHz to 12 GHz
5mm	1 GHz to 2.4 GHz & 6.8 GHz to 9 GHz
7mm	1.2 GHz to 9.4 GHz & 9.6GHz to 10.7 GHz
10mm	1GHz to 12 GHz

The Fig. shows the plot of VSWR Vs frequency for fr4 dielectric for height 7mm.The plot shows that the design antenna is wide band antenna which has VSWR less than 2 for wide range of frequency from 1 GHz to 10 GHz. For fr4 material with dielectric height 3mm, very few range of frequency VSWR is less than 2.

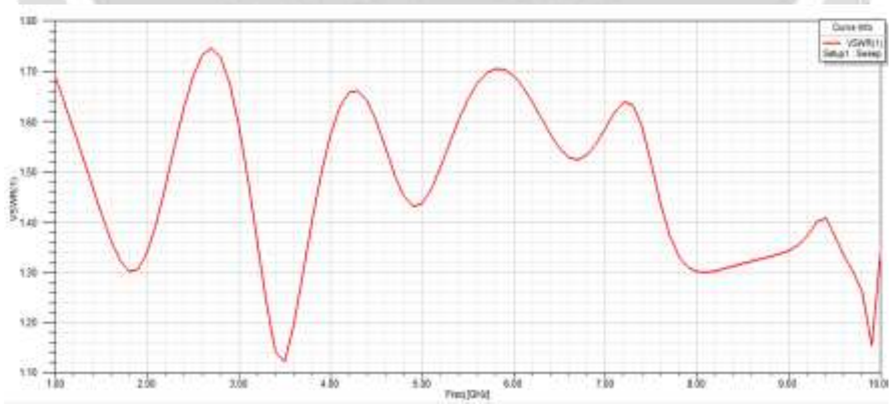

Fig. 6 VSWR versus frequency plot for FR4 material

For the high frequency 10 GHz to 12 GHz the range of VSWR is less than 2. For fr4 material with height 5mm. The Fig. clearly shows that the VSWR is less than 2 for frequency 1.4 GHz to 6.2 GHz and another band 7.4 GHz to 12 GHz. The VSWR has its highest value 3.70 at 1 GHz. For fr4 dielectric with height 10mm.The plot shows characteristic of wideband antenna which has VSWR less than 2 for entire range of frequency of operation from 1 GHz to 12 GHz.

Table 3 Variation in VSWR as height changes for FR4 material

Height of dielectric(h)	VSWR (1<VSWR<2)
3mm	9.8GHz to 12GHz
5mm	1.4 GHz to 6.4 GHz & 7.4 GHz to 12 GHz
7mm	1GHz to 12 GHz
10mm	1 GHz to 12 GHz

Fig. 6 shows the plot of VSWR Vs frequency for vacuum dielectric with height 7mm. The plot has highest VSWR 155 at frequency 1.2 GHz which shows the clear rejection of signal at 1.2 GHz. Antenna accepting the frequency from 1.6 GHz to 12 GHz.

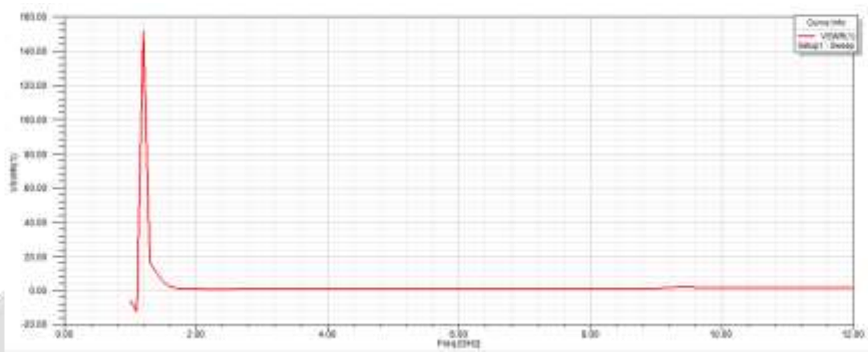

Fig.7 VSWR versus frequency plot for vacuum

For vacuum dielectric with height 3mm. The plot shows the characteristic of band notch filter. Antenna is clearly rejecting the band from 1GHz to 1.4 GHz and accepting from 1.6 GHz to 8 GHz. For vacuum with height 5mm. The device has excellent characteristic of band notch filter. Antenna has VSWR 40 at frequency 1.4 GHz and less than 2 for 1.6 GHz to 12 GHz.Antenna accepting the signal from 1.6 GHz to 12 GHz and rejecting the signal at frequency 1.4 GHz.

Table 4 Variation in VSWR as height changes for vacuum

Height of dielectric(h)	VSWR (1<VSWR<2)
3mm	1.6GHz to 8GHz
5mm	1.6GHz to 12 GHz
7mm	1.6GHz to 12 GHz
10mm	1.6 GHz to 10 GHz

When we replace dielectric with RT5880 with height 3mm the result shows the multiband operation and minimum VSWR is 1.10 at 4.7GHz. for height of dielectric 5mm VSWR is minimum 1.10 at 4.8 GHz. Result shows the VSWR less than 1.5 from 9 GHz to 12 GHz.when we increase the height from 5mm to 7mm the minimum VSWR is 1.10 at 4.8 GHz. For height 10mm VSWR is less than 1.5 from 3 GHz to 12 GHz.

When we replace dielectric with sio2 with height 3mm the result shows that very less part of VSWR plot lies below 1.5 which is not a good for matching purpose. For height 5mm VSWR less than 1.5 from 8 GHz to 12 GHz. The minimum VSWR result shows 1.15 at 3.6 GHz. When we increase the height from 5mm to 7mm, the result shows the VSWR is less than 1.4 for 4.6 GHz to 9.4 GHz. result shows the minimum VSWR 1.15 at 6.4 GHz. for height of dielectric 10mm VSWR is less than 1.5 from 2.8 GHz to 12 GHz. Minimum VSWR 1.4 at 6.8GHz.

When we replace dielectric from sio2 to mica with height 3mm the result shows minimum VSWR 1.15 at 3 GHz. For height of dielectric 5mm result shows minimum VSWR 1.5 at 11.6 GHz. The VSWR less than 1.4 from 7.4

GHz to 12 GHz.for height of dielectric 7mm and 10mm the result shows the VSWR less than 1.5 from 4.9 GHz to 8.14 GHz and 2.2 GHz to 12 GHz. For height 10mm minimum VSWR 1.026 at 5.6 GHz.

4.Return loss (S_{11}) analysis

The return loss of antenna determine by parameter S_{11}. The S11 denotes the amount of power reflecting at input port of antenna. For best performance of antenna the S11 should be below -10 db. The Fig. 8 shows the plot of return loss Vs frequency for fr4 dielectric with h= 7mm. The antenna is match with entire range of frequency from 1 GHz to 12 GHz because the S_{11} is less than -10 db for entire range of frequency band. This design is wideband antenna design. For fr4 material with dielectric height 10mm, The plot shows the characteristic of wideband antenna which has S_{11} less than -10db for entire range of frequency of operation from 1 GHz to 12 GHz.

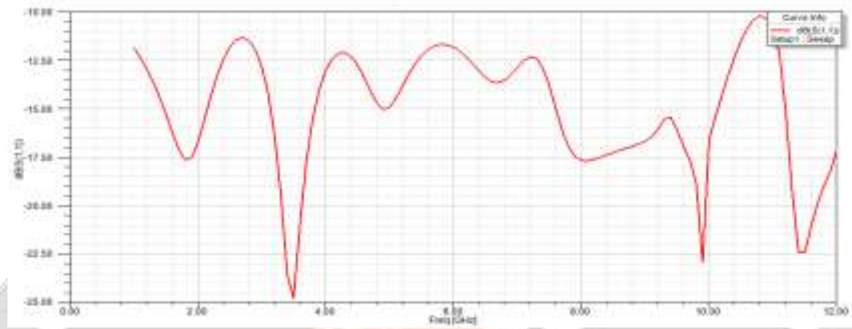

Fig.8 Return loss versus frequency plot for Glass material

For fr4 dielectric with height 3mm. The plot clearly shows the minimum S11 -18 db at 3.5 GHz and -20 db at 11.4 GHz. For fr4 material with h= 5mmThe S_{11} is less than -10db for wide range of frequency band from 1 GHz to 6.4 GHz and 7.2 GHz to 12 GHz.

Table 5 Variation in return loss as height changes for Glass material

Height of dielectric(h)	Return loss S11<-10db (frequency range)
3mm	2GHz – 5.8 GHz 9.8 GHz to 12 GHz
5mm	1GHz – 6.4 GHz,& 7.6 GHz – 12 GHz
7mm	1 GHz – 12 GHz
10mm	1 GHz – 12 GHz

The Fig. 9 shows the plot of return loss Vs frequency for glass material with dielectric height 10mm. The plot shows the characteristic of ultra wide band antenna. The S_{11}< -10db for entire range of frequency from 1 GHz to 12 GHz. The minimum value of S_{11} is -26db at frequency 8.8 GHz.

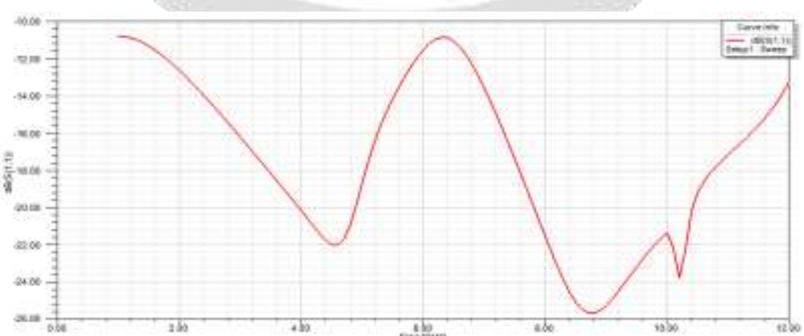

Fig. 9 Return loss versus frequency plot for fr4 material

For glass material with dielectric height 3mm. The plot has S_{11}< -10db for range of frequency 10 GHz to 12 GHz. For glass material with dielectric height 5mm. The return loss less than -10db for frequency 2.6 GHz to 4.8 GHz and 7.2 GHz to 9.6 GHz which is characteristic of dual band antenna. For glass material with dielectric height 7mm, The return loss less than -10db for 1 GHz to 5.5 GHz. The minimum return loss - 37db antenna achieve at frequency 7.2 GHz.

Table 6 Variation in return loss as height changes for FR4 material

Height of dielectric(h)	Return loss S11<-10db
3mm	10 GHz to 12 GHz
5mm	1 GHz to 4.8 GHz & 7.2 GHz to 9.6 GHz
7mm	1 to 5.4 GHz & 5.8 to 9.2 GHz
10mm	1 GHz to 12 GHz

5. Conclusion

Micro strip antennas have become a rapidly growing area of research. Their potential applications are limitless, because of their light weight, compact size, and ease of manufacturing. One limitation is their inherently low gain and narrow bandwidth. However, recent studies and experiments have found ways of overcoming this obstacle. A variety of approaches have been taken, including modification of the patch shape, experimentation with substrate parameters. We here design simple and low costlier patch antenna for pervasive wireless communication by using different dielectric and different height of substrate. The transmission line model seems to be the most instructive in demonstrating the bandwidth effects of the changing the various parameters. When the proposed antenna is design with fr4 substrate with height 5mm the antenna achieve maximum gain of 20db at frequency 9.8 GHz.The VSWR for proposed antenna design is significantly low for glass dielectric with height 10mm, and with fr4 material with height 7mm & 10mm respectively. For this design the VSWR is below 2 for entire range of frequency of operation from 1GHz to 12GHz & for these design Antenna works as wide band antenna. The proposed antenna design also exhibit excellent band notch characteristic if we replace dielectric for vacuum with height 7mm. The antenna attain VSWR 155 at frequency 1.2 GHz which clearly rejected the 1.2 GHz and accept all other frequency in range of operation.

6. References

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