

Design and Simulation of Microstrip E-shaped Patch Antenna for Improved Bandwidth and Directive Gain

Prof. Jaikaran Singh ^{#1} Prof. Mukesh Tiwari^{#2}, Ms. Neha Patel ^{#3}
Assoc.Professor, ECE & M.Tech Scholar (DigitalComm.)
Shri Satya Sai Institute of Science & Technology,
Sehore (M.P) India

Abstract—Despite the many advantages of microstrip patch antennas, they do have some considerable drawbacks. One of the main limitations with patch antennas is their inherently narrowband performance due to its resonant nature. With bandwidth as low as a few percent; broadband applications using conventional patch designs are limited. So for the antenna miniaturization and bandwidth improvement E-shaped microstrip patch antenna used.

In this paper, authors cover two aspects of microstrip antenna designs. The first is the analysis of single element narrowband rectangular microstrip antenna which operates at the central frequency of 6.5GHz. The second aspect is the analysis and design of slot cut E-shaped microstrip antenna. The simulation process has been done through high frequency structure simulator (HFSS). The properties of antenna such as bandwidth, return loss, VSWR has been investigated and compared between a single element rectangular and E-shaped microstrip antenna.

Keywords—Rectangular Microstrip antenna, E-shaped Microstrip antenna, HFSS, Bandwidth, return loss, VSWR.

Introduction

Microstrip patch antennas have drawn the attention of researchers over the past few decades. However, the antennas inherent narrow bandwidth and low gain is one of their major drawbacks [1, 2]. This is one of the problems that researchers around the world have been trying to overcome. Throughout the years, authors have dedicated their investigations to creating new designs or variations to the original antenna that, to some extent, produce wider bandwidths.

In the present paper E-shaped microstrip patch antenna analysed and compared with rectangular patch antenna. The substrate material mainly used for design technique is Rogers TMM 4(tm) with $\epsilon_r=4.5$. The software tool HFSS is used because it is a high performance full wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device modelling. It integrates simulation, visualization, solid modelling, and automation in an easy to

learn environment where solutions to your 3D EM problems are quickly and accurate obtained [3].

Rectangular Microstrip patch antenna

Microstrip patch antennas are increasing in popularity for use in wireless applications due to their low-profile structure. Therefore they are extremely compatible for embedded antennas in hand-held wireless devices such as cellular phones, pagers etc. The most commonly employed microstrip antenna is a rectangular patch as shown in Fig. (1) The rectangular patch antenna is approximately a one-half wavelength long section of rectangular microstrip transmission line. When air is the antenna substrate, the length of the rectangular microstrip antenna is approximately one-half of a free-space wavelength. As the antenna is loaded with a dielectric as its substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases.

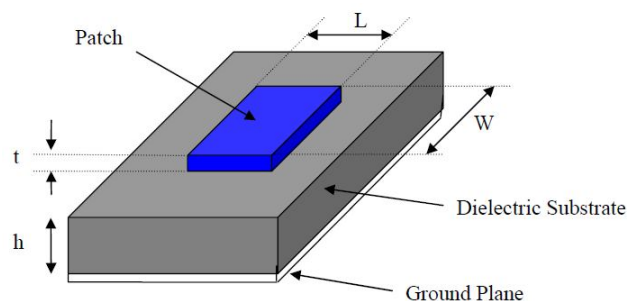


Fig. 1 Microstrip antenna

Feeding Technique

There are many configurations that can be used to feed microstrip antennas. The four most popular are the microstrip line, coaxial probe, aperture coupling, and proximity coupling. This paper uses microstrip line feeding

technique. In this type of feed technique, a conducting strip is connected directly to the edge of the Microstrip patch as shown in Figure 2. The conducting strip is smaller in width as compared to the patch and this kind of feed arrangement has the advantage that the feed can be etched on the same substrate to provide a planar structure

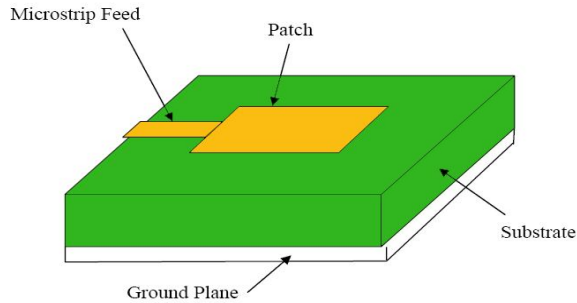


Fig 2. Microstrip Line Feed

Methods of Analysis

There are many methods of analysis for microstrip antennas. The most popular models are the transmission line model, cavity model, and full wave model.[9]The transmission-line model is the easiest of all, it gives good physical insight, but is less accurate and it is more difficult to model coupling. Compared to the transmission-line model, the cavity model is more accurate but at the same time more complex. However, it also gives good physical insight and is rather difficult to model coupling, although it has been used successfully. In general when applied properly, the full-wave models are very accurate, very versatile, and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements, and coupling. However they are the most complex models and usually give less physical insight.

In this paper, we begin with the transmission-line model because it is easier to illustrate. For a microstrip line shown in Figure 3, typical electric field lines are shown 4. This is a nonhomogeneous line of two dielectrics; typically the substrate and air. As can be seen, most of the electric field lines reside in the substrate and parts of some lines exist in air. As $w/h \gg 1$ and $\epsilon_r \gg 1$, the electric field lines concentrate mostly in the substrate. Fringing in this case makes the microstrip line look wider electrically compared to its physical dimensions. Since some of the waves travel in the substrate and some in air, an effective dielectric constant ϵ_{eff} is introduced to account for fringing and the wave propagation in the line.

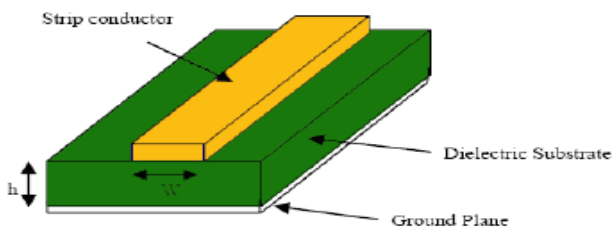


Fig 3. Microstrip Line

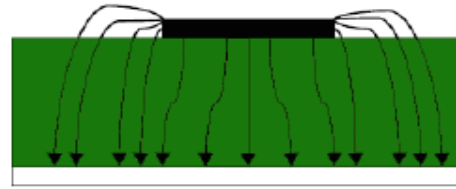


Fig 4. Electric Field Lines

Rectangular Microstrip patch Antenna Design

Calculation of the Length Extension (ΔL):

The Length of the Microstrip patch antenna is given by equation

$$\Delta L = 0.412h \frac{(\epsilon_{reff} + 0.3) \left(\frac{W}{h} + 0.264 \right)}{(\epsilon_{reff} - 0.258) \left(\frac{W}{h} + 0.8 \right)}$$

Calculation of the width (W):

The width of the Microstrip patch antenna is given by equation

$$W = \frac{c}{2f_0 \sqrt{\frac{(\epsilon_r + 1)}{2}}}$$

Calculation of Effective dielectric constant (ϵ_{eff}):

$$\epsilon_{reff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left[1 + 12 \frac{h}{W} \right]^{-\frac{1}{2}}$$

Calculation of the Effective length (L_{eff}):

$$L_{eff} = c / 2f_0 \sqrt{\epsilon_{reff}}$$

Calculation of the resonant length of patch (L):

$$L = L_{eff} - 2 \Delta L$$

In this design, selected three parameters are: Resonant Frequency (f_r) = 6.5 GHz, Dielectric constant (ϵ_r) = 4.5, Height of the dielectric substrate (h) = 1.50 mm.

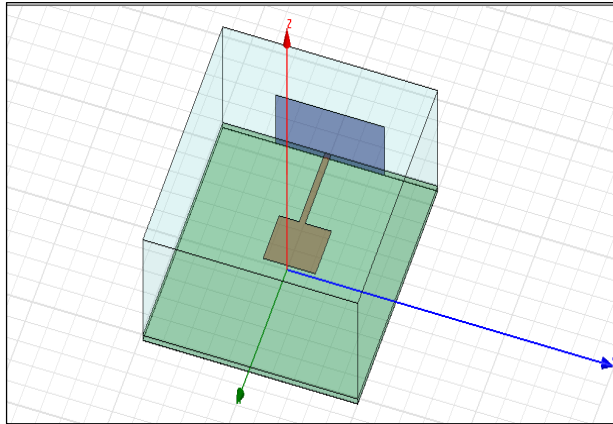


Fig. 5 Rectangular microstrip patch antenna

As shown in figure 5, microstrip line type feeding mechanism used. It is also possible to determine the length and width of quarter wave length long line (branch line) of the patch and the main feed line's length and width to ensure matching. The main feed line is of 50Ω characteristic impedance. The quarter wave length long line is used between main feed line and patch for impedance matching. The characteristic impedance of branch line is calculated as

$$Z_{\lambda/4} = \sqrt{Z_0 Z_e}$$

Z_0 – characteristic impedance of main feed line (50Ω)

Z_e – impedance at patch edge

So for the rectangular Microstrip patch antenna the parameters are

Resonating frequency $f_r = 6.5$ GHz

Patch width $W = 24$ mm

Patch length $L = 22$ mm

Branch line length $q_w = 24.05$ mm

Substrate height $h = 1.50$ mm

Relative permittivity $\epsilon_r = 4.5$

Width of main feed line = 2.75 mm,

Length of main feed line = 15 mm

E-shaped Microstrip patch antenna Design

The E-shaped microstrip antenna [4] consists of an E shaped patch; supported on a grounded dielectric sheet of thickness h and dielectric constant ϵ_r . An E-shaped microstrip patch antenna, shown in figure 6

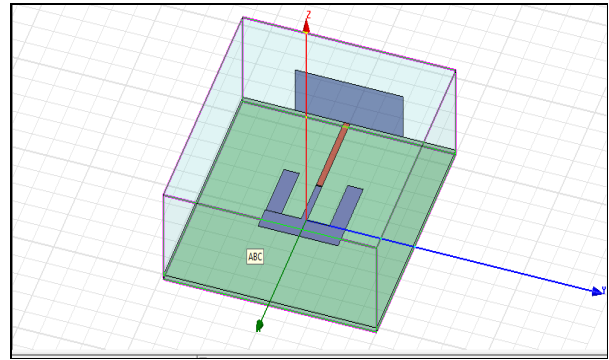


Fig. 6 E-Shaped microstrip patch antenna

The E-shaped Microstrip patch antenna the parameters are

Resonating frequency $f_r = 6.5$ GHz

Patch width $W = 37$ mm

Patch length $L = 35$ mm

Branch line length $q_w = 24.05$ mm

Substrate height $h = 1.50$ mm

Relative permittivity $\epsilon_r = 4.5$

Width of main feed line = 2.75 mm,

Length of main feed line = 15 mm,

Side slot length $L_s = 25$ mm,

Side slot Width $W_s = 7.2$ mm,

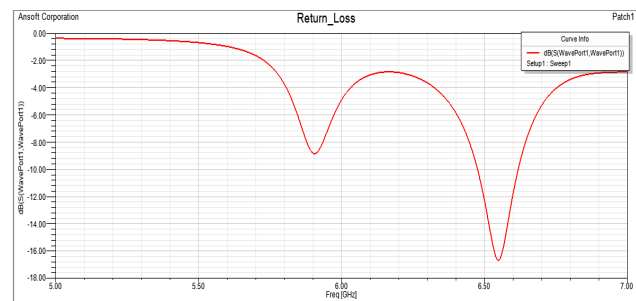
Middle slot length $L_m = 21$ mm,

Middle slot width $W_m = 2.75$ mm

Results

The simulated result of S_{11} scattering parameter (return loss) of single element rectangular microstrip antenna is presented in figure 7. From the figure, the antenna has almost 6.5GHz resonant frequency and it has 50MHz bandwidth at -15 dB (the difference of 6.57 GHz and 6.52 GHz) and it has -16.70 dB return loss. The simulation result for VSWR is shown in the figure 8. The value of VSWR at 6.5GHz resonant frequency is 1.34. The simulation result for Gain (dB) is shown in the figure 9. The measured Gain is 2.65dB. This Patch Antenna is simulated by HIGH FREQUENCY STRUCTURE SIMULATOR (HFSS) software.

Fig. 7 Return loss for Rectangular patch antenna



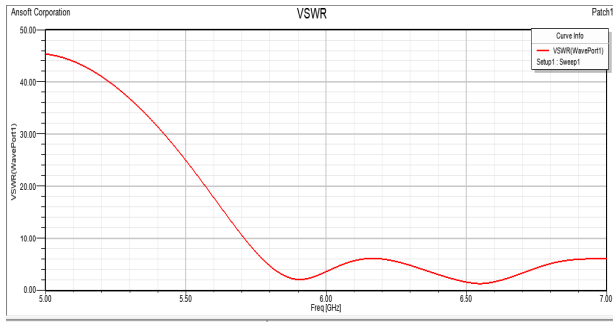


Fig. 8 VSWR for Rectangular patch antenna

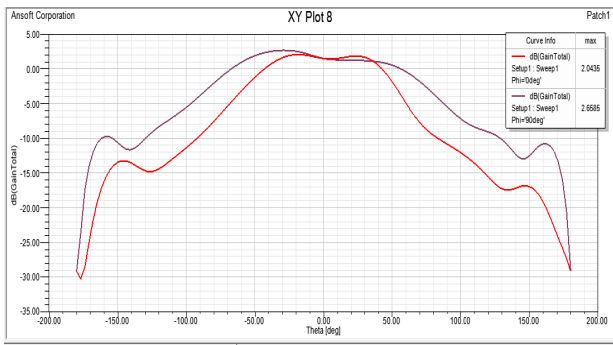


Fig. 9 Gain for Rectangular patch antenna

The simulated result of S11 scattering parameter (return loss) of E-shaped microstrip antenna is presented in figure 10. From the figure, the antenna has almost 6.7GHz resonant frequency and it has 440MHz bandwidth at -15 dB (the difference of 7.03 GHz and 6.59 GHz) and it has -34.28 dB return loss. The simulation result for VSWR is shown in the figure 11. The value of VSWR at 6.5GHz resonant frequency is 1.03. The simulation result for Gain (dB) is shown in the figure 12. The measured Gain is 5.52dB.

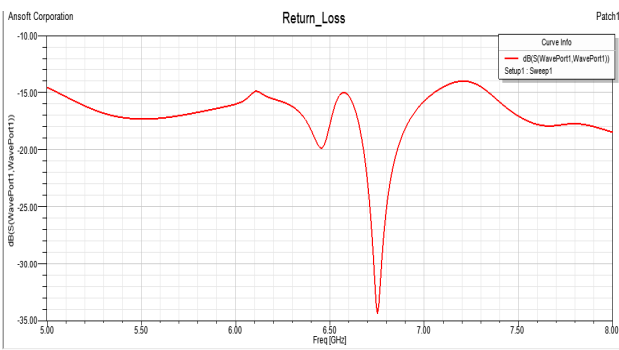


Fig. 10 Return loss for E-shaped patch antenna

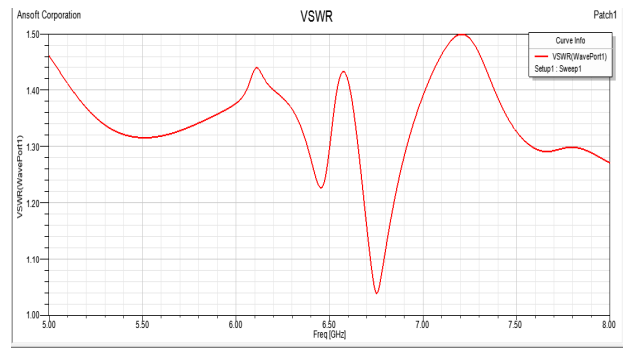


Fig. 11 VSWR for E-shaped patch antenna

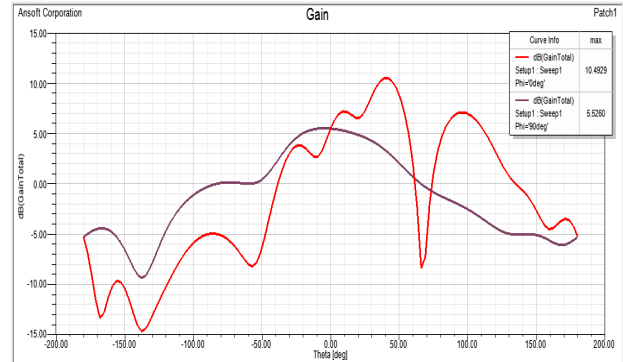


Fig. 12 Gain (dB) for E-shaped patch antenna

Table 1. Comparison between Rectangular and E-shaped microstrip patch antenna

Parameters	Rectangular patch	E-shaped patch
Resonant frequency	6.5GHz	6.7GHz
Bandwidth	50MHz	440MHz
Return loss(dB)	-16.70	-34.28
VSWR	1.34	1.03
Gain(dB)	2.65	5.52

Conclusion

In this paper, we have investigated the enhancement of the Rectangular Microstrip Patch Antenna performances using new E- Shaped patch. The main concern is to study the bandwidth improvement of the microstrip antenna. Rectangular microstrip antenna and E-shaped microstrip antenna have been designed and simulated using high frequency structure simulator (HFSS). The E-shaped patch antenna enhances bandwidth 440MHz, gain 5.52dB and good return loss (S11 parameters) of -34.28dB is achieved compare to rectangular microstrip patch antenna.

References

- [1] J Constantine A. Balanis; Antenna Theory, Analysis and Design, John Wiley & Sons Inc. 2nd edition. 1997.
- [2] Garg, R and Ittipiboon, A; "Micro strip Antenna Design Handbook", Artech House, 2001.
- [3] www.AnsoftHFSS.com
- [4] F. Yang, X. -X. Zhang, X. Ye, and Y. Rahmat-Samii, "Wide-Band E Shaped Patch Antennas for Wireless Communications," in IEEE Trans. Antennas Propagation, vol. 49, no. 7, pp. 1094-1100, July. 2001.
- [5] S. K Satpathy, Vijay Srinivasan, K P Ray and G Kumar, "Compact microstrip antennas for personal mobile communication", IEEE proc.pp. 245-248, 1998.
- [6] Kuo, J.S. and K.L., Wong, 2001. "A compact microstrip antenna with meandering slots in the ground plane", Microwave and Optical Technology Letters 29(2), pp. 95-97.
- [7] Sze, J.Y. and K.L., Wong, 2000. "Slotted rectangular microstrip antenna for bandwidth enhancement", IEEE Transactions on Antennas and Propagation 48, pp. 1149-1152.
- [8] Sudhir Bhaskar & Sachin Kumar Gupta, "Bandwidth Improvement of Microstrip Patch Antenna Using H-Shaped Patch", publication in the "International Journal of Engineering Research and Applications (IJERA)" Vol. 2, Issue 1, Jan-Feb.2012, pp.334-338
- [9] J. R. James and P. S. Hall, Handbook of Microstrip Antennas, Vols. 1 and 2, Peter Peregrinus, London, UK, 1989.