

Design of E shaped Patch Antenna for UHF Application and its SAR Estimation

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Abstract— In this article, a microstrip antenna with E shaped patch is discussed. This antenna is designed to operate at a frequency of 2.2GHz on a FR-4 Substrate. The proposed antenna is designed for UHF application like mobile communication. The dimension of the proposed antenna is $32 \times 30 \times 1.6 \text{ mm}^3$. Two equal size cuts are being introduced to implement the E shape. The proposed antenna by embedding two equal sized cuts in the rectangular patch to get E shaped patch is used to cover the application of Mobile communication in UHF band. The Voltage Wave Standing Ratio (VSWR) is further calculated which is nearly equal to 1.2, much less than the specified value. Further, the Specific Absorption Rate (SAR) of the proposed antenna is found out. Average SAR value for this proposed design appears to be 0.8 W/Kg , which is also far less than the prescribed value by Telecom Engineering center (TEC) of 1.6 W/Kg .

Index Terms—Microstrip Antenna, UHF, VSWR, SAR, TEC, HFSS, Radiation Pattern.

1 INTRODUCTION

The demand for Wireless Communication is growing day by day. To have an effective and efficient communication, the antenna to be used at the transmitter and receiver must be accurately designed. An antenna is an electrical device that converts the electrical waves into radio waves and vice versa. Design of an antenna is very important in the field of communication. Micro-strip antenna also known as patch antenna, is one such category of antenna that is useful in today's world. The idea of microstrip antenna was first introduced in 1950, however it was successfully implemented in 1970 after the development of PCB technology. Nowadays patch antenna are widely used in communication because of their simplicity in design, light weight, low profile, low cost and superior portability.

1.1 Principle of Microstrip Antenna

An individual microstrip antenna consist of a patch of a metal foil on the surface of a PCB with metal foil as a ground plane on the other side of the board. The antenna is usually connected to the transmitter or receiver through microstrip transmission lines as shown in the Fig 1. Micro-strip patch antennas are very versatile in terms of impedance matching and resonant frequency [1].

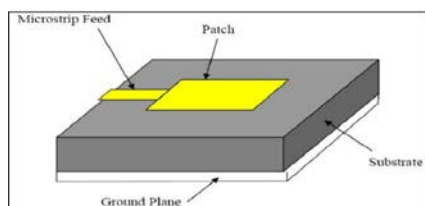


Fig 1. Basic Patch Antenna Structure

In fact, this antenna is a resonant structure with high quality factor [2]. Effective resonance can be achieved easily by varying the length and width dimensions of a patch, by using high dielectric substrate, the bandwidth can be increased [2]. One of the de-merit of a patch antenna is its low bandwidth [3]. For

most of the practical applications, the size of the patch should be as low as possible [4]. Currently there are many methods to reduce the size of patch antenna viz, Cutting of Slots, slits, increase in height of substrate [5]. It is seen that the length of the patch is basically responsible for resonating frequency and the impedance matching happens due to the width [6]. In the proposed design we have introduced the cuts on patch of the equal length. This proposed design aims at using a line feed rather than co-axial feed due to its simplicity in design. The antenna performance can be measured in terms of its radiation pattern, return Loss, Voltage standing wave ratio (VSWR), Gain, Directivity and its radiation efficiency [8]. Finally, we have found out the Specific absorption ratio (SAR) value for this implemented design to check whether this design is hazardous or not to the human beings in practice.

1.2 Proposed Design

The proposed antenna is designed on FR-4 (Flame retardant) substrate as it is readily available, cheaper than other substrate like RT/Duroid-5580. As per the survey done for the various substrates [9]. FR-4 was found to be suitable for cellular applications.

2 DESIGN CONSIDERATION

2.1 E shape Patch Antenna

The proposed E shaped patch antenna is shown in the Fig.2 The substrate so chosen is FR-4 which is discussed earlier. The dielectric constant for this substrate is taken to be as 4.4 while the loss tangent is 0.025. The substrate is placed exactly over the ground plane. Hence the X and Y co-ordinates of the ground plane and the substrate are same. The thickness of the patch and that of the ground plane is 0.1mm. Lossy copper is used for the patch and the ground plane.

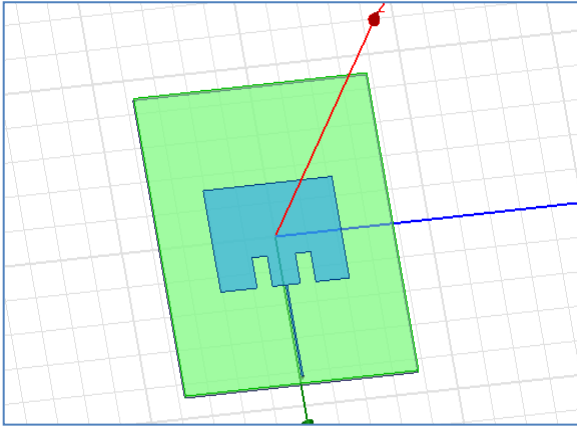


Fig. 2 E shaped antenna

Microstrip feed length and its width are decided with respect to the impedance matching of 50 Ohm to radiate the maximum power as per the maximum power transfer theorem.

This E shaped antenna structure was implemented in HFSS 13 provided by ANSYS.

2.2 Design Equations

The E shaped antenna was designed with the help of the below set of equations.

1. Width of Patch (W_p) : The width of the patch [8] is given by

$$W_p = \frac{C}{2fr} \sqrt{\frac{2}{\epsilon_r + 1}} \quad (1)$$

fr: Resonating frequency

C : Velocity of the Light

ϵ_r : Relative permittivity of the substrate.

2. Effective Permittivity of the Microstrip antenna [8] is given by

$$\epsilon_{eff} = \frac{\epsilon_r + 1}{2} + \frac{\epsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + 12 \frac{h}{W_p}}} \right) \quad (2)$$

h: Height of the substrate.

3. The actual length of the patch (L_p) [8] is given by

$$L = L_{eff} - 2\Delta L \quad (3)$$

$$L_{eff} = \frac{C}{2fr\sqrt{\epsilon_{eff}}} \quad (4)$$

L_{eff} : effective length of the patch.

ΔL : Fringing length.

4. Fringing Length (ΔL) [6] is given by

$$\frac{\Delta L}{h} = 0.412 \left(\frac{(\epsilon_{eff} + 0.3)}{(\epsilon_{eff} - 0.258)} \right)^{\frac{1}{4}} \left(\frac{\frac{W_p}{h} + 0.264}{\frac{W_p}{h} + 0.8} \right) \quad (5)$$

5. Ground/Substrate Dimensions are given by

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

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

L_g : Length of the ground plane
 W_g : Width of the ground plane.
 L_p : Length of the patch.
 W_p : Width of the patch.

3 RESULTS AND DISCUSSIONS

The proposed E shaped microstrip antenna was designed and simulated in HFSS 13 provided by ANSYS. The High Frequency Structure Simulator is a commercial finite element method solver for electromagnetic structures. The other simulation softwares like CST, ZELAND IE3D are also available. HFSS is being used in our design as the results are almost similar to that of the practical design.

3.1 Return Loss

Return loss is the loss of power in the signal returned/reflected by a discontinuity in a transmission line or optical fiber. The return loss for the proposed design is shown in Fig. 3

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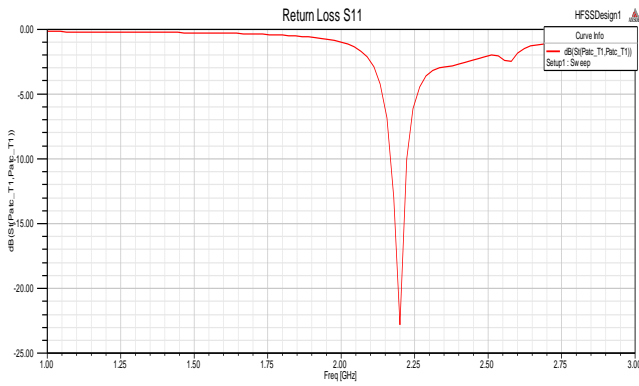


Fig. 3 S11 Parameter

S11 parameter for the proposed E shaped antenna in HFSS comes out to be -22.7dB which is very good.

3.2 Voltage Wave Standing Ratio

VSWR (Voltage Standing Wave Ratio), is a measure of how efficiently radio-frequency power is transmitted from a power source, through a transmission line, into a load. VSWR measures these voltage variances. It is the ratio of the highest voltage anywhere along the transmission line to the lowest.

Mathematically, VSWR is the voltage ratio of the signal on the transmission line.

$$VSWR = \frac{V_{Max}}{V_{Min}} \quad (8)$$

Where V(max) is the maximum voltage of the signal along the line, and V(min) is the minimum voltage along the line.

The VSWR of the proposed antenna is shown in the Fig. 4 as

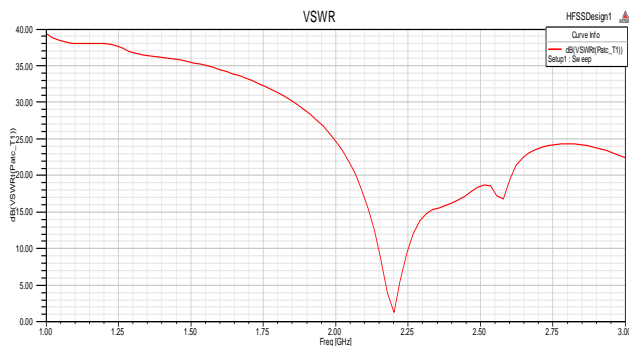


Fig.4 VSWR

The VSWR for the proposed E shaped antenna is 1.2360 and is practically accepted.

3.3 Radiation Pattern.

The directional quality of the antenna is best viewed by means of a radiation pattern. The radiation pattern basically gives directional (angular) dependence of the strength of the radio waves from the antenna. The 3D radiation pattern for the proposed design is as shown in the Fig. 5 as

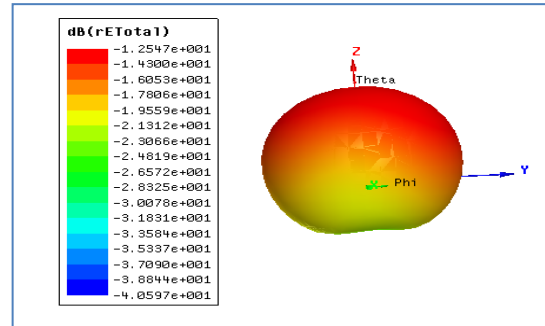


Fig. 5 3D Radiation Pattern

Study of 3D radiation pattern is not recommended as it is tedious and it leads to complex analysis. To avoid such complications, we use 2D polar plots of the radiation pattern.

The 2D radiation pattern for the proposed antenna design is shown in the Fig. 6 as

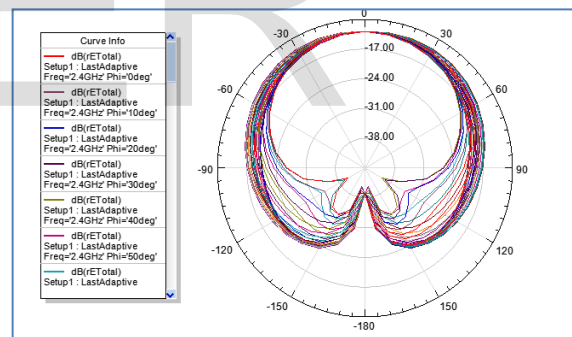


Fig. 6 2D Radiation Pattern

3.4 Current Distribution.

The current distribution for the antenna indicates the amount of current flowing through the antenna. For an antenna the current distribution is generally expressed in terms of the Surface current density (J). The surface current density is actually the amount of current flowing over a unit area. The surface current density for the proposed antenna is shown in Fig. 7 as

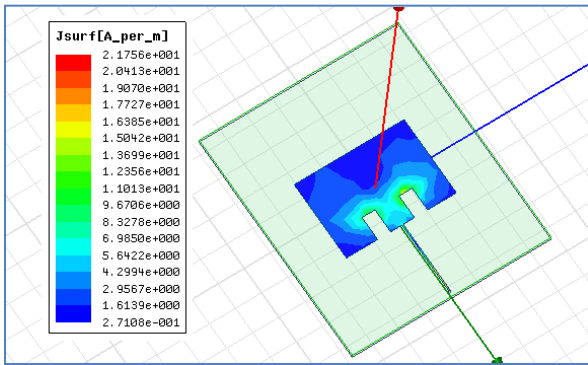


Fig.7 Current Density (Jsurr) for Proposed antenna

Table 1. Maximum SAR values for different Countries

Country	Association deciding SAR	Value of SAR
United States	FCC (Federal Communications Commission)	1.6 Watts per kilogram (W/kg)
European Union	CENELEC (European Committee for Electrotechnical Standardization)	2.0 Watts per kilogram (W/kg)
India	TEC (Telecom Engineering Center)	1.6 Watts per kilogram (W/kg)

3.5 Specific Absorption Ratio

Specific absorption rate (SAR) is a measure of the rate at which energy is absorbed by the human body when exposed to a radio frequency (RF) electromagnetic field; although, it can also refer to absorption of other forms of energy by tissue, including ultrasound. SAR is defined as the power absorbed per mass of tissue and has units of watts per kilogram (W/kg). SAR is usually averaged either over the whole body, or over a small sample volume (typically 1 g or 10 g of tissue). The value cited is then the maximum level measured in the body part studied over the stated volume or mass.

SAR for electromagnetic energy can be calculated from the electric field within the tissue as

$$SAR = \frac{\sigma \times E^2}{m_d} \tag{9}$$

$$IncidentPowerDensity = \frac{E^2}{377} \tag{10}$$

- 6: sample electrical conductivity.
- E: RMS electric field.
- Md: Mass of the Tissue.

When measuring the SAR due to a mobile phone the phone is placed against a representation of a human head (a "SAR Phantom") in a talk position. The SAR value is then measured at the location that has the highest absorption rate in the entire head, which in the case of a mobile phone is often as close to the phone's antenna as possible. Measurements are made for different positions on both sides of the head and at different frequencies representing the frequency bands at which the device can transmit. Depending on the size and capabilities of the phone, additional testing may also be required to represent usage of the device while placed close to the user's body and/or extremities. Various governments have defined maximum SAR levels for RF energy emitted by mobile devices as shown in the Table 1 as

The average SAR field for the proposed antenna was simulated in HFSS. It was seen that the average SAR value for the proposed antenna was 0.92 W/Kg, which is very less than that of the maximum value of 1.6W/kg. Hence the designed antenna is not at all hazardous to use it practically. The average SAR Field is shown in the Fig. 8 as

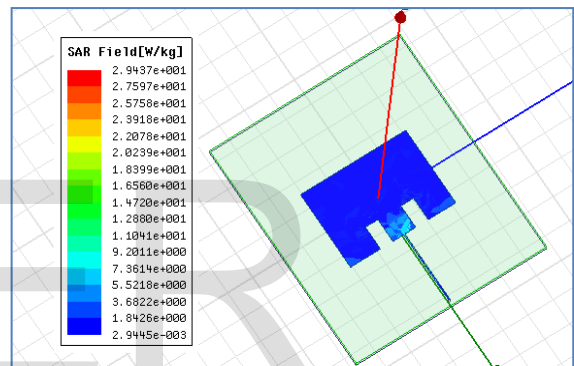


Fig.8 Average SAR for the Proposed Antenna

4 CONCLUSIONS

In this paper we have implemented an E shaped Microstrip antenna which operates at 2.2 GHz. This antenna can be used in the ultra high frequency application like cellular communication. The results for this antenna are implemented successfully in HFSS. The return loss for this proposed antenna is -22.7 dB which is quite good. The VSWR for this designed antenna is 1.2 which is practically acceptable as well. The 3-D radiation polar plot is plotted as well. To avoid the complexity, 2D polar plot for the radiation pattern is simulated as well. The gain for this antenna was found to be 3.65dbi which is the expected value of gain for any Microstrip antenna. The incident power to this antenna was 9.9mW; the radiated power by this antenna was 4.2mW. Hence the efficiency for this proposed design was around 43 percent. Further the average SAR value for this design was calculated which comes out to be 0.92W/Kg, which is much less than the maximum allowable SAR limit provided by TEC as 1.6W/Kg. The gain and hence the efficiency of the antenna can be increased further by using EBG (Electro-magnetic Band gap) structured substrate.

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