Miniaturised multiband e-shaped structure microstrip antenna for satellite communication

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Abstract. Microstrip antenna technology has been designed of an E-Shaped antenna structure for Ku-band satellite communication application such as broadcasting, remote sensing and space communication. The proposed E-Shaped structure antenna is used to operate the frequency bands, 2.39 GHz and 2.44 GHz with a return loss less than -20.4 dB. The concept of microstrip based lossy characteristics impedance; hence the effect of high frequency is included in the procedure The proposed E-Shaped structure has been designed with dielectric FR4 epoxy substrate of dimension (60mm X 50mm), dielectric constant $\varepsilon_r$ =4.4 and height = 1.8mm and it is fed by coaxial cable 50 Ω matching impedance with the bandwidth of 480 MHz and 640 MHz. The Proposed E-Shaped structure which operates the resonating frequencies in various wireless communication and satellite communication applications. The proposed antenna structure parameters have been analyzed and simulated by using HFSS tool. The simulated results for the proposed antenna are in good results for VSWR, radiation pattern, Gain, Return Loss and Efficiency.

Keywords: E-Shaped, Ku-Band, VSWR, Gain and Efficiency

1. Introduction

Nowadays the microstrip patch antennas have demand for various structures have increased tremendously for various applications [1]-[3]. Microwave and RF design engineers for extensive research on compact microstrip antenna design. One of the most suitable applications to support high mobility satellite communication devices is the compact microstrip antenna such as VSAT systems [3]-[6]. Ku-band frequency in the range of 12-18 GHz is one of the most preferred choices in VSAT system [7]-[8]. During disasters, VSAT is one of the best emergency communication backup systems.

Microstrip patch antenna is 3D dimensional planar antenna configuration. It has all the advantages of a printed circuit board, but are not limited to easy to design, easy to manufacture and low cost. These antenna structures posses several disadvantages even though they have several advantage [9]-[10]. The disadvantages are low bandwidth, low gain and low efficiency. In order to overcome these disadvantages several researchers are in progress and hence make full use of advantages such as ease in design, ease in manufacturing, and low cost in manufacturing these compact in microstrip antennas.

The methods by which the microstrip patch antennas are fed, categorized into conducting material and non-conducting material [11]-[12]. The electromagnetic field coupling, while
non-conducting is conducting via transmission of power from microstrip line and radiating patch. Microstrip line, coaxial probe (both conducting scheme), aperture coupling (both non-conducting) are the most popular fed techniques used [13]-[14].

By cutting a notch in a rectangular microstrip patch antenna, an E-Shaped antenna structure is designed. The application such as broadcasting, remote sensing, aeronautical radio navigation and mobile satellite can be achieved by using the proposed antenna in this paper [15]-[16].

2. Antenna Design Methodology

The transmitter covers the frequency band for 2.39 GHz and 2.44 GHz to get access the connection varies from one region to another region for demanding bandwidth. By increasing substrate thickness includes the patch shape designing an E-Shaped have been applied for several techniques to enhanced the bandwidth. E-Slot patch antenna provides good bandwidth while compared to the other slot patch antenna structure. The dimensions are rectangular patch, slots of E-Shaped patch and feed point position are the important parameters involved in the antenna design process. Smart antennas are used at the base station radiates wireless networks with narrow beams serve different users are also known as adaptive antennas.

Smart antennas require higher data rate, compact size, data secured transmission, low power consumption to enhance the bandwidth for optical and microwave frequencies. The fringing effect undergoes the edges of the patch depends on dimensions of the patch, thickness and substrate of the materials. The smart antenna structure are used in WLAN application for lower and higher bands of frequencies.

To design E-shaped structure using rectangular microstrip patch antenna has been designed based on the designing procedure. The length and width of the antenna dimensions are calculated by using following equation.

\[ W = \frac{v_o}{2f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \]  

\[ \varepsilon_{eff} = \frac{\varepsilon_r + \frac{1}{2} + \frac{\delta}{w}}{\varepsilon_r + \frac{1}{2}} \]  

\[ \Delta L = 0.421h \left( \frac{\varepsilon_r + 0.3}{\varepsilon_{eff} + 0.36} \right) \left( \frac{w}{h} + 0.264 \right) \]  

\[ L = \frac{1}{2f_r \varepsilon_{eff} \sqrt{\mu_o \varepsilon_o}} - 2\Delta L \]  

Here, \( W \) is the width of the patch  
\( v_o \) is the speed of light in a vacuum  
\( \varepsilon_r \) is the dielectric constant of the substrate  
\( f_r \) is the resonant frequency  
\( \varepsilon_{eff} \) is the effective dielectric constant  
\( \Delta L \) is the extension in length  
\( H \) is the thickness of the substrate  
\( L \) is the length of the patch

The Proposed antenna is used for the substrate has been designed, simulated and analyzed by using the software. The proposed antenna is presented for which showing the results can be operated at the resonant frequency band for 2.39 GHz and 2.44 GHz. Based on the designed
E-Shaped structure is an improvement of bandwidth is expanded from 2.39 GHz and 2.44 GHz and also similar parameters such as $S_{11}$, Return loss and VSWR also improved. The antenna design methodology is shown in Figure 1.

**Figure 1.** Flow Chart of Design Methodology

The proposed of the E Shaped antenna is designed and implemented is shown in Figure 2.

**Figure 2.** Proposed E-Shaped Antenna
Antenna impedance is used to measure as return loss (or) VSWR with the help of network analyzer. Anechoic chamber is used to measurement for antenna gain and radiation patterns. Microstrip patch antennas are used to improvement of broadcasting for increase the bandwidth, increase the substrate thickness, various impedance matching, various feeding techniques and different slots.

Microstrip Patch Antennas have been applied a large number set of frequency for various wireless applications. The finite difference time domain methods are usually transformed into discrete finite difference equations. The system of the difference equations, both of the electric and magnetic field components are obtained. The final design a thick dielectrics and E-Shaped patch geometry.

Probe feed and slot dimensions were optimized by using HFSS simulation. The mainly advantages of patch antenna include weight is light in nature; Cost is very low in nature and ease to fabrication to analysis the radiation pattern. The mainly drawback of patch antenna is the power handling capacity is very low, gain is moderate and bandwidth is narrow in nature.

Edge currents flowing around the slots and around the patch are created by the lower and higher resonant frequencies respectively. Microstrip line strategy is anything but difficult to manufacture. In this coordinating should be possible more by controlling the inset position. It looks like expansion of the fix in light of the fact that a directing strip is joined to the fix. Hindrance of this technique is substrate thickness increment, deceptive radiation and surface wave expands which cutoff the data transmission.

Linear equation is used to solve the method of moment’s techniques. Basically the patch antenna is used to convert the electric field into matrix solutions.

\[ L(s) = \frac{f}{S} \quad (5) \]

\[ L \quad \text{---- Linear operation} \]
\[ S \quad \text{---- Substrate} \]
\[ f \quad \text{---- Operating frequency} \]

In order the matrix equation, the unknown frequency is defined as the sum of set of known independent frequency

\[ R = \sum_n \alpha u \quad (6) \]
\[ \alpha \quad \text{---------- Unknown amplitude} \]
\[ u \quad \text{---------- Unknown frequency} \]

\[ \sum_n \alpha u = R \quad (7) \]

\[ L \quad \text{-------- Length of the Patch} \]

The proposed antenna is popular radar frequency used in defence, weather monitoring, traffic control, tracking, vehicle speed control, missile, broadcasting and various purposes. The patch antennas are designed with different structure by using different feeding techniques. Normally, feeding techniques can be classified into two, there are conducting and non-conducting.

The conducting technique is nothing but the power is fed directly to the patch with the help of microstrip line. The non conducting technique is nothing but the electromagnetic fields are completed with the microstrip antenna and radiating path due to power is transferred between them. In this paper the proposed antenna are used for microstrip line feeding techniques. FR4 substrate has a wide variety of electrical and mechanical application is commonly used for PCB board.

Copper is one of the materials referred for FR4 substrate thickness can be varied both of
them separately. The proposed of the rectangular patch shaped antenna is designed and implemented is shown in Figure 3.

![Rectangular Patch Antenna with E-Shaped Structure](image)

**Figure 3.** Rectangular Patch Antenna with E-Shaped Structure

### 3. Results and Discussion

The rectangular patch with E-Shaped structure have designed parameters is shown in Table 1. This structure is fed by microstrip line feeding techniques. The calculated parameters are transferred to the software for simulation FR4 substrate with dielectric constant is used to design the E-Shaped structure antenna is shown in Table 2.

**Table 1. Parameters of Antenna Design**

| S.No | Design Parameters     | Range            |
|------|-----------------------|------------------|
| 1    | Antenna Dimension     | 60mm*50mm        |
| 2    | Width                 | 37.39mm          |
| 3    | Length                | 28.85mm          |
| 4    | Dielectric Substrate  | FR4              |
| 5    | Substrate Thickness   | 1.8mm            |
| 6    | Impedance             | 50 ohm           |
| 7    | Frequency Bands       | 2.39GHz and 2.44GHz |

**Table 2. Parameters of Rectangular Patch and E-Shaped Antenna**

| Parameters       | Rectangular Patch | E-Shaped |
|------------------|-------------------|----------|
| Resonant Frequency | 2.39 GHz          | 2.44 GHz |
| Bandwidth        | 480 MHz           | 640 MHz  |
| Return Loss      | -19.5 dB          | -20.4 dB |
| VSWR             | 1.98              | 1.88     |
| Gain             | 7.72 dB           | 7.82 dB  |

As indicating in the results the operating frequencies of the proposed antenna comply with the Ku-band. The $S_{11}$ parameter of the E-shaped antenna structure is shown in Figure 4. From the Figure 4, shows the parameter for the original air gap substrate and the optimized proposed
antenna.

The frequency band is used for E-shaped structure antenna in the range from 2.39 GHz and 2.44 GHz. The gain of the proposed antenna is 7.72 dB and 7.83 dB are shown in Figure 5. The VSWR of the proposed antenna is 1.98 and 1.88 is shown Figure 6. The E-field and H-field radiation of the E-Shaped Structure antenna is shown in Figure 7.

![Figure 4. S11 Parameter of the Proposed Antenna](image)

The output gain of the E-Shaped structure antenna is 7.72 dB and 7.82 dB at resonant frequencies in the range from 2.39 GHz and 2.44 GHz respectively.

![Figure 5. Gain of the Proposed Antenna](image)

The return loss of the proposed antenna is -19.5dB and -20.4dB at resonant frequencies in the range from 2.39 GHz and 2.44 GHz respectively.
Figure 6. VSWR of the Proposed Antenna

The VSWR of the E-Shaped structure antenna is 1.98 and 1.88 at resonant frequencies in the range from 2.39 GHz and 2.44 GHz respectively.

Figure 7. Radiation Pattern of E-Plane and H-Plane

The Radiation pattern of the proposed antenna is good results both the E-field and H-field at resonant frequencies in the range from 2.39 GHz to 2.44 GHz respectively.

Figure 8. Antenna and Radiation Efficiency of the Proposed Structure

From the Figure 8, shows that the antenna and radiation Efficiency of the proposed E-shaped
structure antenna is 80%

![Figure 9](image)

**Figure 9.** Gain and Efficiency of the Proposed Structure

From the Figure 9, shows that the Gain and Efficiency of the proposed antenna is 80% for Ku-band applications in the proposed E-Shaped structure

![Figure 10](image)

**Figure 10.** 3-D pattern of the Proposed Antenna

From the Figure 10, shows that the Radiation pattern of the proposed antenna is good performance of the antenna parameters.

4. Conclusion

The proposed E-Shaped structure antenna is used for the operating frequencies of 2.39 GHz and 2.44 GHz for Ku-band and provides good results in terms of bandwidth. The implementation will be simple and effortless if the procedure proposed in this paper can be applied to the wireless applications. The simulation results get good return loss, gain, VSWR, bandwidth and directivity has also been presented. The proposed antenna can effectively covers the GSM and wireless applications. The simulated results for the proposed antenna are in good results for VSWR is 1.88, Good Radiation Pattern, Gain is 7.82 dB, Return Loss is -20.4 dB and Efficiency is 80%.

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