Design and Implementation of Circularly Polarized Equilateral Triangle Microstrip Antenna with Improved Bandwidth for Wireless Applications

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Abstract
The triangular geometry of the microstrip triangular patch antenna one of the most common shape finds its application in wide frequency range from lumped circuit elements to recent trend wireless antennas. In this paper a novel design, implementation and testing of dual feed triangular microstrip patch antennas with tip truncation and triangular slot is proposed to achieve circular polarization, to increase the axial ratio bandwidth. The proposed antenna structure uses Tip-truncating to improve bandwidth [2] and by cutting a small equilateral triangular slot near the vertex of radiating patch antenna to provide both LHCP and RHCP to double the impedance and bandwidth with improved gain at frequency 1.3 GHz.

Keywords
Equilateral Triangle Microstrip Antenna, Circular Polarization, Bandwidth, Frequency

I. Introduction
The designs of dual feed microstrip antennas for Circular Polarization (CP) are usually achieved by truncating corners of a patch, cutting a diagonal slot in the square or circular patches,[2] protruding or inserting a pair of symmetric perturbation elements at the boundary of a circular patch. Presently, typical designs of circularly polarized triangular microstrip antennas are using a nearly equilateral-triangular patch or an equilateral-triangular patch with a slit inserted at the patch edge. An ordinary microstrip antenna offers narrow bandwidth [6]. There are many techniques to improve bandwidth which are quite complex. An alternative way consists in the use of specially shaped patches with slits and the rectangular patches with slot. We have considered the slotted tip-truncated equilateral triangular patch because it has a smaller patch size [7] at a given frequency, as compared to square and circular microstrip antennas, and has a good CP operation [5]. It is shown that by embedding a small equilateral triangular slot near the modified vertex of a tip-truncated equilateral triangular microstrip antenna, [1] an impedance and AR bandwidth enhancement of about two times can be achieved. With the above design method, the frequency ratio can also be increased by adjusting the size and position of loaded holes, which means a dual-band CP patch antenna can be obtained.

II. Antenna Design Configuration
A Dual feeding is applied to the radiating patch (instead of single feed) at the points A and B. A equilateral triangular slot of side length b is inserted at the upper radiating triangular patch at the height of h1 from the bottom side of the patch, Axial Ratio bandwidth is improved two times [2]. Also, by further selecting a proper slot length and feeding the patch at a suitable position (by optimization ). By applying two near-degenerate orthogonal resonant modes of equal amplitudes and 90± phase difference, a circular Polarization operation can be obtained [1]. As depicted in fig. 1

By feeding at position at point B,( right-hand CP) operation is obtained [1] and by feeding the patch at point A (the mirror image of point B with respect to the centreline of the triangular patch) a left-hand CP is achieved .

A. Design Equations

1. Calculation of the Width (W)
The width of the triangular Microstrip patch antenna is given by [6]

\[
W = \frac{c}{2f_{r}\sqrt{\varepsilon_{r}}} \frac{(\varepsilon_{r} + 1)}{2}
\]

where \( f_{r} \) = resonant frequency
\( \varepsilon_{r} \) = Dielectric constant of the substrate

2. Calculation of Effective Dielectric Constant (\( \varepsilon_{ref} \)): [6]

\[
\varepsilon_{ref} = \varepsilon_{r} + 1 + \frac{\varepsilon_{r} - 1}{2} \left[ 1 + \frac{12h}{W} \right]^{-\frac{1}{2}}
\]

3. Calculation of Effective Length (\( L_{ref} \))
The effective length is calculated from the known frequency to which antenna is to be designed and dielectric constant of material

\[
L_{ref} = \frac{c}{2f_{r}\sqrt{\varepsilon_{ref}}}
\]

4. Calculation of Length Extension (\( \Delta L \)):
The extension length due to fringing field effect [8] in the radiating patch is calculated given by [6]
\[
\Delta L = 0.412h + 0.3 \left( \frac{W}{h} + 0.264 \right) \\
\varepsilon_{\text{eff}} = 0.258 \left( \frac{W}{h} + 0.8 \right)
\]

5. Calculation of Actual Length (L):
From the fringing length the actual length of the patch is calculated given by [6]
\[ L = L_{\text{eff}} - 2\Delta L \]

B. Design Parameters
Let a be the side length of the equilateral triangular MSA and the used substrate material is (Epoxy/Glass)FR4. The various parameters used for the design of the antenna Resonant frequency = 1.1GHz, Relative Permittivity = 1, Total height = 15mm, Dimension of the patch = 98mm, Substrate thickness = 0.8mm, Length of the ground plane = 100mm, Width of the ground plane = 100mm, Length of the feed line = 8mm. Depending on the frequency of operation and dielectric constant of the material to be used substituting it the various parameters are calculated from the formula[6] given above.
The designed layout of designed antenna using IE3D with the above parameters is shown in fig 2. IE3D is a powerful full-wave EM design package for all aspects of high frequency applications. It is based upon 3D integral equation, method of moment for high accuracy and high efficiency full-wave EM simulations. It is not just for planar structures, it can also handle full-3D structures elegantly.

III Simulation Results and Measurements
The antenna resonates at 1.2 GHz with Circular polarization. This antenna has a bandwidth of approximately 66 MHz i.e. from 1.1 GHz to 1.6 GHz. The simulated radiation pattern is achieving a gain 4.4 dB shown in fig (3). The Antenna radiates in both Right handed and Left handed circular Polarization with its dual Feed excitation. On the same operating frequency overlapping of the information signal is miniaturized using this left and right handed polarization. In fig. 4, the simulated antenna at 1.2 GHz radiates with circular polarized omnidirectional Pattern is shown.

Fig. 2: 2D View of Designed Antenna using IE3D Software

Fig. 3: 3D Radiation Pattern of Designed Antenna

Fig. 4: Two Dimensional (Circular) Radiation Pattern of Designed Antenna

The antenna resonates at 1.1 GHz and shows -32.5 dB in fig. (5) for feeding point 1 and -30 dB for feeding point 2 which satisfies the requirement of achieving a value less than -10 dB which states that the matching between the source and the load is acceptable.

Fig. 5: Return Loss of the Proposed Antenna

The simulated result of the antenna in fig. 6 shows that the Voltage Standing Wave Ratio (VSWR) is reaching 1 at the Frequency excitation of 1.14 GHz indication no reflection from the load (designed antenna).
The Impedance matching is achieved by matching the characteristic impedance of the cable with the load (designed antenna) satisfying the 50 ohms impedance matching as shown in fig. 7.

**IV. Simulated Result Values**

The software has yielded results to us as below:

- **VSWR = 1.12**
- **Gain of the antenna = 4.41996dB**
- **Directivity of the antenna = 6.47957dB**
- **Radiation efficiency = 78.0%**
- **Antenna efficiency = 76.3369%**
- **Bandwidth of the antenna = 66MHz**

**V. Antenna Fabrication and Testing**

The proposed work of the two layer fabricated antenna using FR4 (Epoxy/Glass) as a dielectric substrate is shown in fig. 8. A thin layer of Copper is Photo etched above the dielectric which radiates the fringing field. The Radiating element is excited using coaxial connector at the two Dual Feed points which are clearly shown.

![Proposed Fabricated Antenna (Top View)](image)

**VI. Fabricated Antenna Results**

**A. Return Loss**

The Fabricated antenna under test resonates at 1.1GHz and shows -32.5dB which satisfies the requirement of achieving a value less than -10dB which states that the matching between the source and the load is acceptable.

![Return Loss Output Measured from Fabricated Antenna](image)

**B. VSWR Measurement**

The Fabricated result of the antenna shows that the Voltage Standing Wave Ratio (VSWR) is 1.35 at frequency 1.1GHz which clears that the antenna is radiating the feed power effectively.
C. Impedance Measurement
The smith chart in fig. 12, displays the plot of impedance matching nearly of 50Ω between the coaxial connecting stub and the radiating patch antenna. The Antenna will radiate effectively only when there is proper impedance matching between them.

D. Bandwidth Improvement
The Bandwidth of the antenna depends on the wide frequency range at which antenna radiates [8]. The Table 1 shows the desired value of VSWR for the designed antenna over different range of frequency. Where the VSWR at the input terminal is unity at the range of designed frequency indicates impedance matching.

Table 1: Result of Proposed Antenna with Desired VSWR for Different Frequency Range

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>VSWR</th>
<th>Return loss(dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>1.0</td>
<td>-32dB</td>
</tr>
<tr>
<td>1.4</td>
<td>1.1</td>
<td>-25dB</td>
</tr>
<tr>
<td>1.6</td>
<td>1.2</td>
<td>-22dB</td>
</tr>
</tbody>
</table>

VII. Conclusion
The various aspects associated with the design of a Equilateral Triangle Microstrip patch antenna with IE3D simulation procedures are explained and the design process were carried out results. With the help of the simulation result we have been able to fabricate the antenna and test the antenna using a vector network analyzer and It is observed that the measured result’s are in good agreement with the simulated results.

References

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