OCTAGON SHAPED SLOT LOADED RECTANGULAR MICROSTRIP MONOPOLE ANTENNAS FOR MULTI-BAND OPERATION AND VIRTUAL SIZE REDUCTION

M. Veereshappa¹ and Dr. S. N. Mulgi²

¹Department of Electronics, L.V.D. College, Raichur: 584 101, Karnataka, India
²Department of PG Studies and Research in Applied Electronics, Gulbarga University, Gulbarga 585 106, Karnataka, India

ABSTRACT

This paper presents the design and development of octagon shaped slot loaded rectangular microstrip monopole antenna for multi-band operation and virtual size reduction. The antenna operates for eight bands of frequencies in the frequency range of 1 to 16 GHz. If the radius of complimentary circular slot inside the octagonal is changed from 0.6 cm to 0.5 cm, the antenna operates for five bands of frequencies without changing the nature of monopole radiation characteristics. The antenna gives maximum virtual side reduction of 62% and highest gain of 11.86 dB. The proposed antennas are investigated experimentally and may find application in microwave communication systems.

Keywords: microstrip antenna, monopole, octagonal slot, omnidirectional, virtual size

1. INTRODUCTION

Emerging trends in microwave communication systems often require antennas with compact size, simple in design, low manufacturing cost and capable of operating more than one band of frequencies. Owing to its thin profile, light weight, low cost, planar configuration and easy fabrication, the microstrip antenna is the better choice for these requirements. Number of investigations have been reported in the literature for dual, triple, and multiband operation [3-6]. Design and analysis of octagon shaped hybrid coupled microstrip antenna for multiband operation [7], octagonal microstrip antenna for RADAR and spacecraft applications [8], CPW-feed octagon shaped slot antenna for UWB application [9], bandwidth enhancement of wide slot antenna fed by CPW and microstripline [10] etc. The designs of single feed equilateral triangular microstrip antennas with a virtual size reduction up to about
22% by embedding cross slots on radiating patch [11], a square-ring microstrip antenna with truncated corners shows 19% virtual size reduction [12], double C-slot microstrip antenna is designed and simulated to have a gain of 6.46 dBi and gives a virtual size reduction of 37% [13], slotted rectangular microstrip antenna has been designed to achieve maximum virtual size reduction around 50% [14] etc have been found in the literature. In this paper a simple technique has been demonstrated to construct the monopole antennas for multi-band operation, large virtual size reduction and high gain by loading octagon shaped slot on the patch and changing the radius of circle inside the octagonal slot.

2. DESIGN OF ANTENNA GEOMETRY

The art work of the proposed antenna is sketched by using computer software Auto-CAD to achieve better accuracy and is fabricated on low cost FR4-epoxy substrate material of thickness of \( h = 0.16 \) cm and permittivity \( \varepsilon_r = 4.4 \).

Figure 1 shows the top view geometry of octagonal shaped slot loaded rectangular microstrip antenna (OSLRMA). In Fig.1 the area of the substrate is \( L \times W \) cm. On the top surface of the substrate a ground plane of height which is equal to the length of microstripline feed \( L_f \) is used on either sides of the microstripline with a gap of 0.1 cm. On the bottom of the substrate a continuous ground copper layer of height \( L_f \) is used below the microstripline. The OSLRMA is designed for 3 GHz of frequency using the equations available for the design of conventional rectangular microstrip antenna in the literature [2]. The length and width of the rectangular patch are \( L_p \) and \( W_p \) respectively. The feed arrangement consists of quarter wave transformer of length \( L_t \) and width \( W_t \) which is connected as a matching network between the patch and the microstripline feed of length \( L_f \) and width \( W_f \). A semi miniature-A (SMA) connector is used at the tip of the microstripline feed for feeding the microwave power. In Fig.1 octagon shaped slot is loaded on rectangular patch of vertices X. Further a circle of radius \( R \) is loaded inside octagon slot.

![Fig: 1 Top view geometry of OSLRMA](image-url)
Figure 2 shows the geometry of modified octagonal shaped slot loaded rectangular microstrip antenna (MOSLRMA). In this figure the radius of circle inside the octagon and is taken as 0.5 cm.

The other geometry of Fig. 2 remains same as that of Fig.1. The design parameters of the proposed antenna is shown in Table 1

<table>
<thead>
<tr>
<th>Antenna parameter</th>
<th>L in cm</th>
<th>W in cm</th>
<th>L_p in cm</th>
<th>W_p in cm</th>
<th>L_f in cm</th>
<th>W_f in cm</th>
<th>L_t in cm</th>
<th>W_t in cm</th>
<th>X in cm</th>
<th>R in cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions</td>
<td>8.0</td>
<td>5.0</td>
<td>2.34</td>
<td>3.04</td>
<td>2.48</td>
<td>0.3</td>
<td>1.24</td>
<td>0.05</td>
<td>0.714</td>
<td>0.6</td>
</tr>
</tbody>
</table>

3. EXPERIMENTAL RESULTS

The antenna bandwidth over return loss less than -10 dB is tested experimentally on Vector Network Analyzer (Rohde & Schwarz, Germany make ZVK model 1127.8651). The variation of return loss verses frequency of OSLRMA is as shown in Fig. 4. From this graph the experimental bandwidth (BW) is calculated using the equations,

$$ BW = \left[ \frac{f_2 - f_1}{f_c} \right] \times 100 \% \tag{1} $$

were, $f_1$ and $f_2$ are the lower and upper cut of frequencies of the band respectively when its return loss reaches – 10 dB and $f_c$ is the center frequency of the operating band. From this figure, it is found that, the antenna operates between 1 to 16 GHz and gives eight resonant modes at $f_1$ to $f_8$, i.e. at 1.12, 1.29, 2.01, 4.89, 6.29, 7.41, 8.99, and 15.53 GHz. The magnitude
of experimental -10 dB bandwidth measured for \( \text{BW}_1 \) to \( \text{BW}_8 \) by using the equation (1) is found to be 50 MHz (4.48%), 50 MHz (3.90%), 50 MHz (2.51%), 80 MHz (1.63%), 80 MHz (1.26%), 330 MHz (4.46%), 1.62 GHz (17.25%), and 5.32 GHz (40.06%) respectively.

The resonant mode at 1.12 GHz is due to the fundamental resonant frequency of the patch and others modes are due to the novel geometry of OSLRMA. The multi mode response obtained is due to different surface currents on the patch. The fundamental resonant frequency mode shifts from 3 GHz designed frequency to 1.12 GHz due to the coupling effect of microstripline feed and top ground plane of OSLRMA. This shift in fundamental frequency gives a virtual size reduction of 62.66% which is 12.66% large compared to the literature value [14].

Figure 4 shows the variation of return loss verses frequency of MOSLRMA. It is seen that, the antenna operates for five bands of frequencies \( \text{BW}_9 \) to \( \text{BW}_{13} \). The magnitude of these operating bands measured at \( \text{BW}_9 \) to \( \text{BW}_{13} \) is found to be 210 MHz (17.28%), 140 MHz (2.90%), 410 MHz (5.56%), 1.76 GHz (18.96%), and 5.40 GHz (40.60%) respectively. The resonating modes \( f_1, f_2, \) and \( f_3 \) of \( \text{BW}_1, \text{BW}_2, \) and \( \text{BW}_3 \) of Fig.3 are merged together into single band \( \text{BW}_9 \) as shown in Fig.4. Further from Fig.4 it is clear that, the MOSLRMA is capable of widening its operating bands when compared to the operating bands of OSLRMA. The resonant mode at 1.12 GHz is slightly shifts towards higher frequency side at 1.14 GHz resulting a virtual size reduction of 62%.
The gain of the proposed antennas is measured by absolute gain method. The power transmitted ‘\(P_t\)' by pyramidal horn antenna and power received ‘\(P_r\)' by antenna under test (AUT) are measured independently. With the help of these experimental data, the gain (G) dB of AUT is calculated by using the formula,

\[
(G) \text{ dB} = 10 \log \left( \frac{P_r}{P_t} \right) - (G_t) \text{ dB} - 20 \log \left( \frac{\lambda_0}{4\pi R} \right) \text{ dB}
\]

(2)

Where, \(G_t\) is the gain of the pyramidal horn antenna and \(R\) is the distance between the transmitting antenna and the AUT. Using equation (2), the maximum gain of OSLRMA and MOSLRMA measured in their operating bands is found to be 9.57, 11.86 dB respectively. It is evident that, the MOSLRMA is capable of giving larger gain when compared to the gain of OSLRMA.

The co-polar and cross-polar radiation pattern of OSLRMA and MOSLRMA is measured in their operating bands. The typical radiation patterns measured at 4.83 GHz and 7.27 GHz are as shown in Fig 5 to 6 respectively. The obtained patterns are omnidirectional in nature.

**Fig: 5** typical radiation pattern of OSLRMA measured at 4.83 GHz

**Fig: 6** typical radiation pattern MOSLRMA measured at 7.27 GHz
4. CONCLUSION

From the detailed experimental study, it is concluded that, the OSLRMA excited through microstripline feed has been designed for multi-band operation. The antenna operates for eight bands of frequencies in the frequency range of 1 to 16 GHz and gives virtual size reduction of 62.66%. If radius of circle inside the octagonal slot is varied from 0.6 cm to 0.5 cm the antenna operates for five bands of frequencies in which magnitude of each operating bands are enhanced compared to operating bands of OSLRMA. The MOSLRMA also enhances the gain when compared to the gain of OSLRMA. In both the cases the antenna gives omnidirectional radiation characteristics. The proposed antennas are simple in their design and fabrication and they use low cost FR4 substrate material. With these features the proposed antennas may find application in microwave communication systems operating in the frequency range of 1 to 16 GHz.

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REFERENCES