COMPLEMENTARY SYMMETRY RECTANGULAR MICROSTRIP ANTENNA FOR TRIPLE WIDEBAND OPERATION

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ABSTRACT

In this work the design and development of a E–slot complementary symmetry rectangular microstrip antenna is presented for triple wideband operation. The antenna has a volume of 80 X 50 X 1.6 mm$^3$ and operates between the frequency range of 3.96 to 11.56 GHz giving a maximum impedance bandwidth of 29.45% with a peak gain of 2.64 dB. The simple modified glass epoxy substrate material is used to fabricate the antenna. The microstripline feed arrangement is employed to excite the antenna. The antenna shows linearly polarized broadside radiation characteristic. The design detail of the antenna is described. The experimental results are presented and discussed. This antenna may find applications for systems in C and X-band of frequencies.

Key words: Microstrip antenna, complementary symmetry, E slot, triple band.

1. INTRODUCTION

In the recent years, the microstrip antennas have become good aids for transmit/receive purpose in modern communication application like WLAN, WiMax and 4G mobile systems, because of their numerous advantages like low profile, low fabrication cost, integrability with MMICs, ruggedness and ease of installation [1]. But an antenna operating at single, dual and triple band is more useful the device for the desired set of frequencies. The broadband antennas are realized by many methods such as, slot on the patch, ground plane arrays, monopoles [2-4], etc. But in this study a simple rectangular microstrip antenna with complementary symmetry E-slots on the radiating patch is used to get triple wideband operation with better gain. This kind of geometry is found to be rare in the literature.
2. ANTENNA DESIGN

The conventional rectangular microstrip antenna (CRMSA) and the proposed E-slot complementary symmetry rectangular microstrip antenna (ECSRMSA) are fabricated on low cost glass epoxy substrate material of thickness \( h = 0.16 \text{ cm} \), loss tangent = 0.01 and \( \varepsilon_r = 4.2 \). The artwork of proposed antennas is sketched using the computer software AUTO CAD to achieve better accuracy. The antennas are etched using the photolithography process.

![Top view geometry of CRMSA](image1)

Figure 1: Top view geometry of CRMSA

Figure 1 shows the top view geometry of CRMSA. The radiating patch of length \( L \) and width \( W \) are designed for the resonant frequency of 3.5 GHz, using the basic equations available in the literature [5]. A quarter wave transformer of length \( L_t \) and width \( W_t \) is used between \( C_p \) along the width of the patch and microstripline feed of length \( L_f \) and width \( W_f \) for matching their impedances. A semi miniature-A (SMA) connector of 50\( \Omega \) impedance is used at the tip of the microstripline to supply the microwave power.

![Top and bottom view geometry of ECSRMSA](image2)

Figure 2: Top and bottom view geometry of ECSRMSA

Figure 2 shows the top and bottom view geometry of ECSRMSA. The complementary symmetry E shaped slot of width 2 mm having upper, middle and lower arm lengths \( L_1, L_2, \) and \( L_3 \) is placed at the middle of the patch. The H shaped slot of width 2 mm having horizontal and vertical arm lengths \( H_h \) and \( H_v \) is placed on the ground plane such that the middle point of this slot coincides with the center of the radiating patch. The dimensions \( L_1, L_2, L_3, H_h \) and \( H_v \) are taken in terms of \( \lambda_0 \), where \( \lambda_0 \) is a free space wavelength in cm corresponding to the designed frequency of 3.5 GHz. Table 1 gives the design parameters of CRMSA and ECSRMSA.
Table 1: Design parameters of CRMSA and ECSRMSA.

<table>
<thead>
<tr>
<th>Antenna</th>
<th>L</th>
<th>W</th>
<th>L₁</th>
<th>W₁</th>
<th>A</th>
<th>B</th>
<th>L₂</th>
<th>L₃</th>
<th>H₀</th>
<th>Hₛ</th>
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<tbody>
<tr>
<td>CRMSA</td>
<td>2.04</td>
<td>2.66</td>
<td>2.18</td>
<td>0.32</td>
<td>1.09</td>
<td>5</td>
<td>8</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CSERMSA</td>
<td>2.04</td>
<td>2.66</td>
<td>2.18</td>
<td>0.32</td>
<td>1.09</td>
<td>5</td>
<td>8</td>
<td>λ₀/14</td>
<td>λ₀/6</td>
<td>λ₀/34</td>
</tr>
</tbody>
</table>

3. RESULTS AND DISCUSSION

Vector Network Analyzer (The Agilent N5230A: A.06.04.32 ) is used to measure the experimental return loss of CRMSA and ECSRMSA.

Figure 3 shows the variation of return loss versus frequency of CRMSA. From this figure it is seen that, the CRMSA resonates at 3.39 GHz of frequency which is close to the designed frequency of 3.5 GHz. The experimental bandwidth is calculated using the formula,

\[
\text{Bandwidth (\%) = } \frac{f₂ - f₁}{f_c} \times 100
\]

where, \( f₂ \) and \( f₁ \) are the upper and lower cut off frequencies of the resonated band when its return loss reaches -10dB and \( f_c \) is a centre frequency between \( f₁ \) and \( f₂ \). The bandwidth of CRMSA is found to be 3.27 %.

Figure 3: Variation of return loss versus frequency of CRMSA

Figure 4: Variation of return loss versus frequency of ECSRMSA
Figure 4 shows the variation of return loss versus frequency of ECSRMSA. It is clear from this figure that, the antenna operates for three bands $BW_1 = 29.49\% \ (3.96-5.33 \text{ GHz})$, $BW_2 = 28.78\% \ (6.87-9.18 \text{ GHz})$ and $BW_3 = 20.92\% \ (9.37-11.56 \text{ GHz})$ for the resonating modes $f_1$, $f_2$ and $f_3$ respectively. The $BW_1$ is due to the fundamental resonance of the patch. The bands $BW_2$ and $BW_3$ are due to the complementary symmetry E slots on the patch. Further it can be noted that the insertion of the H shaped slot on the ground plane, the bandwidth is enhanced in $BW_1$ when compared to the bandwidth of CRMSA. Furthermore, ECSRMSA uses less copper area of 50.02 $\%$ when compared to the copper area of CRMSA by placing slots on the patch and ground plane.

Figure 5: Radiation pattern of CRMSA measured at 3.39 GHz

Figure 6: Radiation pattern of ECSRMSA measured at 4.645 GHz

Figure 5 and 6 show the far field co-polar and cross-polar radiation patterns of CRMSA and ECSRMSA measured in their operating bands. From these figure it is observed that, the patterns are broadsided and linearly polarized. The gain of the proposed antenna is calculated using absolute gain method given by the relation,

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

where, $P_t$ and $P_r$ are transmitted and received powers respectively. R is the distance between transmitting antenna and antenna under test i.e. The peak gain of ECSRMSA measured in $BW_1$ is found to be 2.64 dB with a half power beam width of 51$^0$ this shows directional property of the antenna.

4. CONCLUSION

From this study it is concluded that, ECSRMSA gives triple wide bands with a maximum bandwidth of about 29.45 $\%$ in $BW_1$, a bandwidth of 28.78 $\%$ is obtained in $BW_2$ and 20.92 $\%$ is observed in $BW_3$. The enhancement of bandwidth is caused due to the incorporation of H shaped slot on the ground plane. The antenna exhibits broadside radiation characteristics with a peak gain of 2.64 dB. The proposed antenna uses low cost substrate material with simple design and fabrication. This antenna may find applications for systems in C and X-band of frequencies.
REFERENCES


BIO-DATA

Dr. Nagraj K. Kulkarni received his M.Sc, M.Phil and Ph. D degree in Applied Electronics from Gulbarga University Gulbarga in the year 1995, 1996 and 2014 respectively. He is working as an Assistant professor and Head, in the Department of Electronics Government Degree College Gulbarga. He is an active researcher in the field of Microwave Electronics.