DOUBLE OCTAGONALSHAPE MICROSTRIP ANTENNA

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Abstract

This paper describes the design, development and experimental results of double octagonal shape microstrip antenna(DOMA) for various applications in high microwave frequency range. A considerable emphasis is placed on the designing of rectangular microstrip antenna through AUTOCAD software and obtaining antenna results on Network Analyzer. The design considerations are given for microstripline feed rectangular microstrip antenna operating at a frequency of 3.7 GHz. In this paper, particular attention is also paid to the measurement of return losses (RL) and bandwidth of the RMSA and DOMA with the help of VSWR for the designed antenna.The impedance bandwidth of DOMAis enhanced from 2.06% to37%. The design procedure and results are presented and discussed.

***Keywords**: Octagonal, Microstrip, VSWR, Patch, Analyzer*

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1. INTRODUCTION

The most popular antenna for communication applications in the category of microwave antennas is microstrip antenna. The microstrip antenna [3, 5-6] is a type of radio antenna with a low profile that can be mounted on a flat surface. These antennas consist of a flat rectangular sheet or "patch" of metal, mounted over a larger sheet of metal called as ground plane. In communication application, only distinct frequency bands may be needed [1] for transmit and receive applications respectively. The wide impedance bandwidth at each operating band is more useful for better communication [2].

2. DESIGNING OF RMA AND DOMA

The conventional RMA is designed for the resonant frequency (fr) of 3.5 GHz using the basic equations available in literature [3, 4]. The geometry of this antenna is as shown in Fig. 1. The antennas are designed by using the following equations.

The patch width W shown in Fig. 1 is given by,

$$W = \frac{c}{2f_r}\sqrt{\left(\frac{\varepsilon_r + 1}{2}\right)} \quad (1)$$

The length of patch is given by,

$$L = \frac{c}{2 f_r \sqrt{\varepsilon_r}} - 2\Delta l \quad (2)$$

Where,

$$\Delta l = 0.412h \frac{(\varepsilon_e + 0.3) + \left(\frac{w}{h} + 0.264\right)}{(\varepsilon_e + 0.258)\left(\frac{w}{h} + 0.8\right)} \quad (3)$$

$$\varepsilon_e = \left(\frac{\varepsilon_r + 1}{2}\right) + \left(\frac{\varepsilon_r - 1}{2}\right)\sqrt{1 + \frac{12h}{w}} \quad (4)$$

The width and length of feed network is designed using the following equations.

If $\frac{w}{h} < 1.52$, Width of feed line is given by,

$$W_f = \frac{8he^{A}}{e^{2A} - 2} \quad (5)$$

Where,

$$A = \frac{Z_0}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right) \quad (6)$$

Length of feed line is given by,

$$L_f = \frac{\lambda_g}{4} \quad (7)$$

Where, λ_g is effective guide wavelength and is given by,

$$\frac{\lambda_0}{\sqrt{\varepsilon_{eff}}} \quad (8)$$

In equation 8 the value of ε_{eff} is given by,

$$\varepsilon_{eff} = \varepsilon_r - \frac{\varepsilon_r - \varepsilon_e}{1 + G\left(\frac{f_r}{f_p}\right)^2} \quad (9)$$

Where

$$G = \left(\frac{Z_0 - 5}{60}\right)^{\frac{1}{2}} + \left(0.004 \times Z_0\right) \quad (10)$$

$Z_0 = 50\ \Omega$ (Characteristic impedance)

The patch is fabricated on a low cost glass epoxy substrate material of thickness h = 1.66 mm and permittivity $\varepsilon_r = 4.4$. In order to get better accuracy, the antennas are presketched using computer software AutoCAD-2012 and are fabricated using photolithography process. The length and width (*L x W*) of the patch is (18.99 *x* 26.92 mm). The length and width of quaterwave transformer $(L_t x W_t)$ is (10.18 x 0.66 mm). The length and width of microstrip feedline$(L_f \, x \, W_f)$ is (10.19 x 3.35 mm) which is as shown in Fig.1.

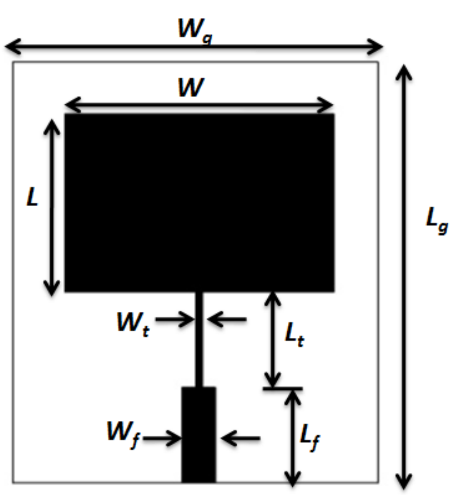

Fig-1: Top view geometry of conventional RMA

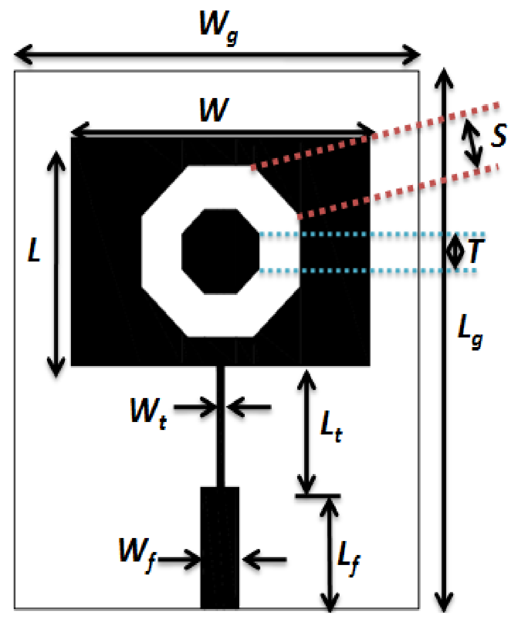

Fig-2: Geometry of DOMA

$$f_p = \frac{Z_0}{2\mu_0 h} \quad (11)$$

$$\mu_0 = 4\pi \times 10^{-9} \quad (12)$$

And

$$\lambda_0 = \frac{c}{f_r} \quad (13)$$

Width of quarter wave transformer is given by

$$W_t = \frac{8he^A}{e^{2A} - 2} \quad (14)$$

Where,

$$A = \frac{Z_1}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}\left(0.23 + \frac{0.11}{\varepsilon_r}\right) \quad (15)$$

$$Z_1 = \sqrt{Z_{in} \times Z_0} \quad (16)$$

$$Z_{in} \cong \frac{\left(120\lambda_0\right)^2 + \left(\frac{377h}{L\sqrt{\varepsilon_r}}\right)^2 \tan^2 \beta l}{240 \times L \times \lambda_0 \times \left(1 + \tan^2 \beta l\right)} \quad (17)$$

$$\beta = \frac{2\pi\sqrt{\varepsilon r}}{\lambda_0} \quad (18)$$

$$l = \frac{L}{2} \quad (19)$$

In equation 17, Z_{in} is the impedance offered by the rectangular patch at the centre point along W of Fig. 1.

Length of quarter wave transformer is estimated using the equations 7 to 13 by replacing Z_0 by $Z_1$and is given by

$$L_t = \frac{\lambda_g}{4} \quad (20)$$

Later, the double octagonal shape slot is etched on the patch plane of conventional RMA as shown in Fig. 2. This antenna is named as double octagonal shape microstrip antenna (DOMA). The dimensions of the slots are taken in terms of λ_0, where $\lambda_0$is the free space wavelength corresponding to the designed frequency of conventional RMA i.e. 3.5 GHz. The side length of outer (S) and inner (T) octagonal shape are 4.22 mm and 2.03 mm keeping the length, width of patch, feed line length and width, quaterwave transformer length and width unchanged.

3. EXPERIMENTAL RESULTS

For the proposed antennas, the impedance bandwidth over return loss less than −10 dB is measured on Agilent Technologies E8363B Network Analyzer operating for the frequency range of 10 MHz to 40 GHz.

The variation of return loss verses frequency of RMA is as shown in Fig. 3. From the figure it is clear that, the antenna resonates at fr_1 = 3.7 GHz of frequency which is very much close to the designed frequency of 3.5 GHz and hence validates the design. From this graph, the experimental impedance bandwidth is calculated using the formula,

$$\text{Impedance Bandwidth } (\%) = \left[\frac{f_2 - f_1}{f_c}\right] \times 100 \qquad (21)$$

Where, f_2 and f_1 are upper and lower cut-off frequencies of the band respectively when its return loss reaches −10 dB and f_c is the centre frequency between f_1 and f_2. The bandwidth of conventional RMA is found to be BW_1 = 2.06%.

Fig. 4 shows the variation of return loss verses frequency of DOMA. The antenna resonates at five distinct bands with resonant frequencies of fr_1 = 3.1 GHz, fr_2 = 3.74 GHz, fr_3 = 6.5 GHz, fr_4 = 8.8 GHz and fr_5 = 10.52 GHz with corresponding impedance bandwidths of BW_1 = 1.2 %, BW_2 = 1.9 %, BW_3 = 0.9 %, BW_4 = 37 % and BW_5 = 12 %.

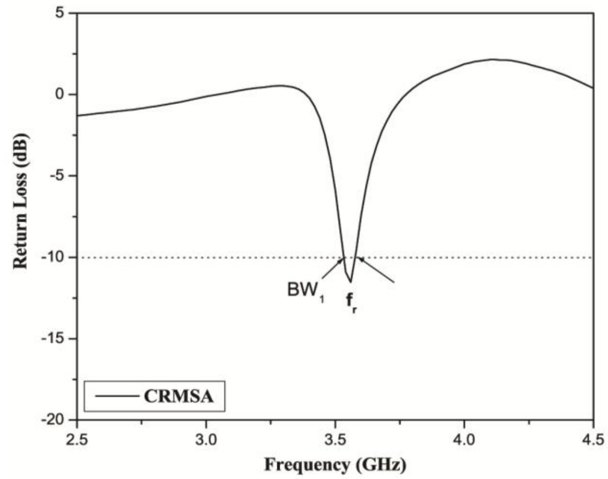

Fig-3: Variation of return loss Vs frequency of CRMA

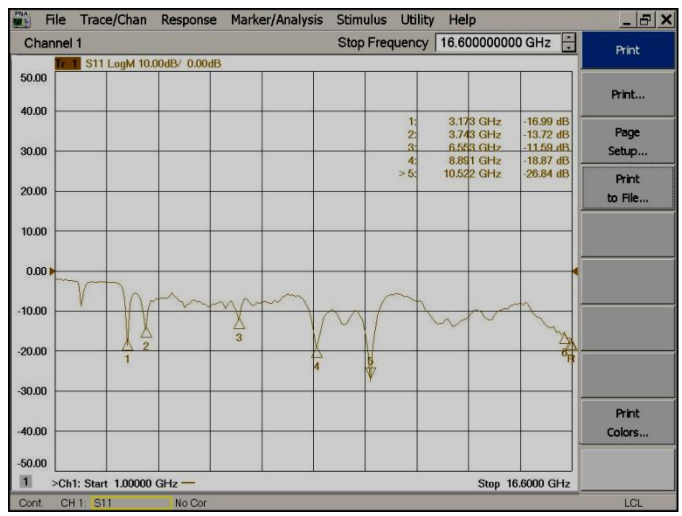

Fig-4: Variation of return loss verses frequency of DOMA

The gains G (dB) of proposed antennas are measured by absolute gain method [5] as given in below equation.

$$(G)\,dB = 10\log\left(\frac{P_r}{P_t}\right) - (G_t)\,dB - 20\log\left(\frac{\lambda_0}{4\pi R}\right) dB \quad (22)$$

Where

P_t– Power transmitted by pyramidal horn antenna,

P_r– Power received by antenna under test (AUT),

G_t– Gain of pyramidal horn antenna,

R – Distance between transmitting antenna and AUT

The gains of conventional RMA is found to be 2.6 dB at 3.7 GHz and for DOMA it is found to be1.6 dB at fr_1 = 3.1 GHz, 1.2 dB at fr_2 = 3.7 GHz, 2.1dB at fr_3 = 6.5 GHz, 3.4 dB at fr_4 = 8.8 GHz and 4.1 dB at fr_5 = 10.52 GHz respectively. Hence the enhancement of antenna gain from 2.6 dBof conventional RMA to 4.1 dB of DOMA is also achieved.

Fig.5 shows the smith chart plot of DOMA and is quite clear that the resonant frequency point are near to the centre impedance point 1 which validates better matching characteristics between input and load.

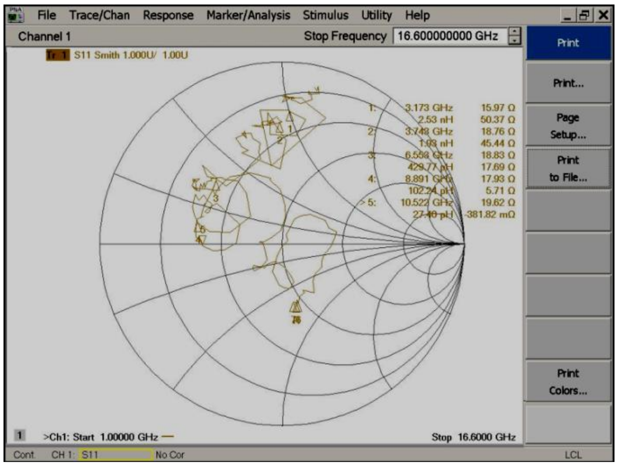

Fig-5: Smith chart plot of DOMA

Fig.6 shows the measured VSWR of 1.33, 1.47, 1.73, 1.27, and 1.08 less than VSWR of 2 at respective resonant frequencies of DOMA signifying less reflected power. Fig. 7 shows the S11 linear magnitude plot where 122.76mU, 202.39mU, 252.37mU, 116.76mU and 39.61mU magnitudes are measured for respective resonant frequencies of DOMA.

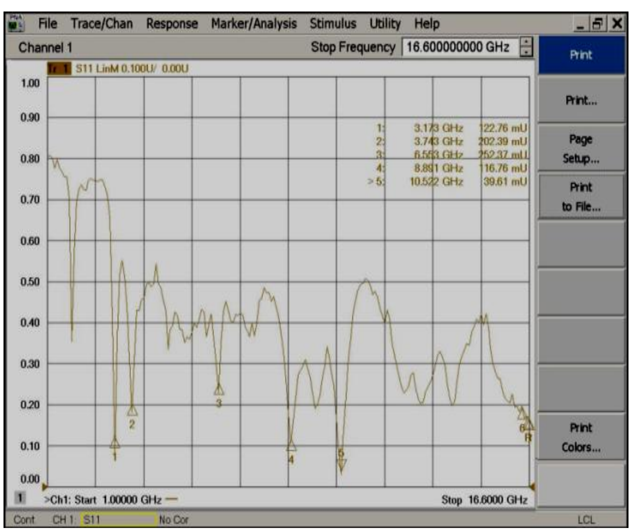

Fig-6: VSWR plot of DOMA

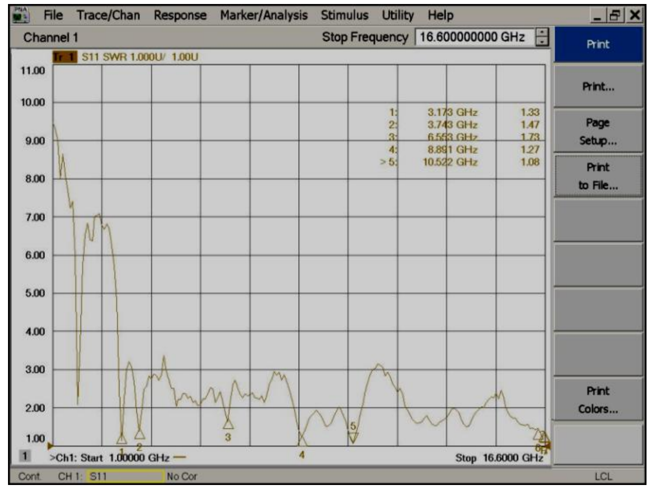

Fig-7: S11 Linear magnitude plot of DOMA

4. CONCLUSIONS

In this paper, the microstripline fed antenna has been designed and proposed. The double octagonal shape slot on the patch plane of rectangular microstrip antenna achieves five different bands with better return loss. The impedance bandwidth is also enhanced from 2.06% to 37% with better gain characteristics i.e, enhances the gain from 2.6 dB to 4.1dB.

ACKNOWLEDGMENTS

Authors thank Prof. M. Kulkarni, Head, Dept of E&CE, National Institute of Technology, Surathkal,Dakshin Kannada, Karnataka, India for providing an opportunity to useand obtain results on Agilent Technologies E8363B Network Analyzer.

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