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RESEARCH ARTICLE

Novel Pentaband Microstrip Antenna for 1 GHz -15 GHz Frequency Range

[1]Ambresh P. A, [2]Sujata A.A, [3]P.V.Hunagund

1. Department of Electronics, Mangalore University, Mangalore, Karnataka (INDIA).
2. Department of Applied Electronics, GulbargaUniversity, Gulbarga-585106.Karnataka (INDIA).
3. Godutai Engineering College for Women, Gulbarga

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***Corresponding Author**

Ambresh P. A

Abstract

A new type of rhombus square shape microstrip antenna (ROSQMA) is designed and developed for various applications in high microwave frequency range. Penta bands are obtained with better gain characteristics. The impedance bandwidth of ROSQMA is enhanced from 2.06 % to 49.4 % by etching rhombus square shape slots along with better return loss characteristics. The design procedure and practical results are presented and discussed.

Introduction

Recently, microstrip patch antennas have been widely used in satellite communications, aerospace, radars, biomedical applications and reflector feeds because of its inherent characteristics such as light weight, low profile, low cost, mechanically robust, compatibility with integrated circuits and very versatile in terms of resonant frequency. In computation 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]. In view of this, the simplest technique of etching slots is designed and fabricated to achieve these requirements.

DESIGN OF ANTENNAS

The antenna design includes, a low cost glass epoxy substrate material of thickness h = 1.66 mm and permittivity ε_r = 4.4 for the proposed antennas. In order to get better accuracy, the antennas are presketched using computer software AutoCAD-2012 and are fabricated using photolithography process.

The conventional RMA is designed for the resonant frequency (f_r) 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,

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

The length of patch is given by,

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

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

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

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

$$\text{if } \frac{w}{h} < 1.52$$

Width of feed line is given by,

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

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

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,

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

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

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

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 feedline *(L_f x W_f)* is (10.19 x 3.35 mm) keeping other dimensions unchanged.

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

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

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

Width of quarter wave transformer is given by

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

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

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

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

$$\beta = \frac{2\pi\sqrt{\varepsilon_r}}{\lambda_0} \qquad (18)$$

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

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

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

Later, the rhombus with square shape slot is etched on the patch plane of conventional RMA as shown in Fig. 2. This antenna is named as rhombus square shape microstrip antenna (ROSQMA). The dimensions of all the slots are taken in terms of λ_0, where λ_0 is the free space wavelength corresponding to the designed frequency of conventional RMA i.e. 3.5 GHz. The side length of square slot A is 7.8 mm and rhombus slot B is 13.46 mm.

I. EXPERIMENTAL RESULTS

For the proposed antennas the impedance bandwidth over return loss less than −10 dB is measured on Agilent Technologies E8363B Network Analyzer (10MHz – 40GHz).

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 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 ROSQMA. The antenna resonates for five different bands with resonant frequencies of fr_1 = 3.7 GHz, fr_2 = 5.4 GHz, fr_3 = 6.9 GHz, fr_4 = 10.7 GHz and fr_5 = 12.63 GHz with corresponding impedance bandwidths of BW_1 = 1.2 %, BW_2 = 3.2 %, BW_3 = 2.3 %, BW_4 = 49.4 % and BW_5 = 32 % with better return loss less than -10dB.

The gains G (dB) of proposed antennas are measured by absolute gain method [5].

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

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 gain of conventional RMA is found to be 2.6 dB at 3.7 GHz and for ROSQMA the gains are, 2 dB at fr_1 = 3.7 GHz, 1.5 dB at fr_2 = 5.4 GHz, 1.6 dB at fr_3 = 6.9 GHz, 8.2 dB at fr_4 = 10.7 GHz and 5.1 dB at fr_5 = 12.63 GHz respectively. Hence the enhancement of antenna gain from 2.6 dB of conventional RMA to 8.2 dB of ROSQMA is achieved.

Fig.5 shows the smith chart plot of ROSQMA and is quite clear that the resonant frequency points are near to the centre impedance point 1 which validates better matching characteristics between input and load. Fig.6 shows the measured VSWR of 1.35, 1.33, 1.06, 1.08, and 1.35 at respective resonant frequencies of ROSQMA which are less than 1.5 signifying less reflected power.

CONCLUSIONS

In this paper, the microstripline fed antenna has been designed and proposed. It is seen that, by using novel rhombus shape slot and square shape slot on the patch plane of rectangular microstrip antenna, pentabands are obtained. Further, the enhancement in bandwidth of rhombus square microstrip antenna is 49.4% better gain characteristics compared to 2.06% of conventional MSA. This technique also enhances the gain from 2.6 dB to 8.2 dB. The proposed antennas are simple, cost effective and may find application in wireless applications in L and X band frequency range.

Fig. 1. Top view geometry of conventional RMA

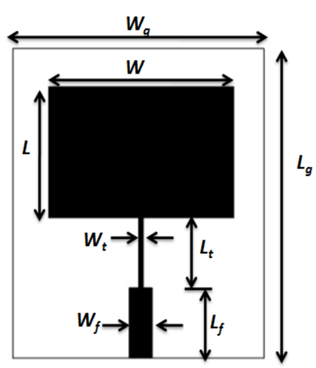


Fig. 2. Geometry of ROSQMA

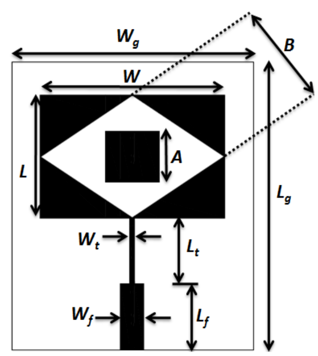


Fig. 3. Variation of return loss Vs frequency of conventional RMA

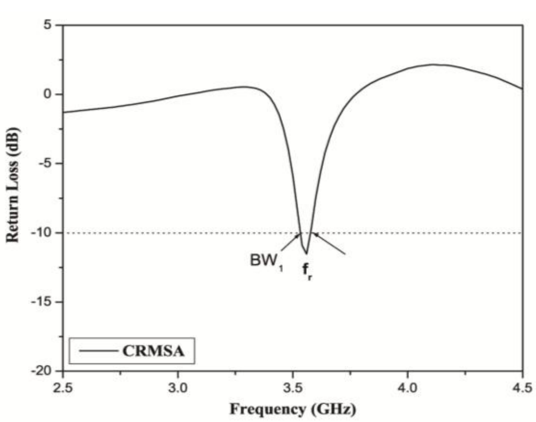


Fig. 4. Variation of return loss verses frequency of ROSQMA

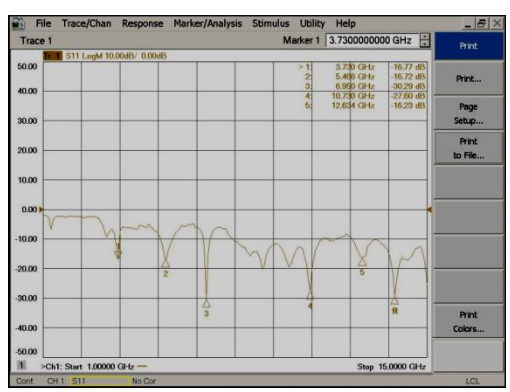


Fig. 6. VSWR plot of ROSQMA

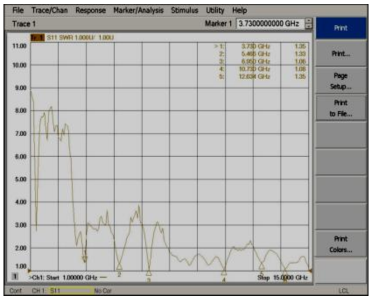
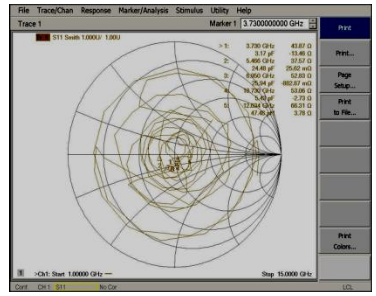


Fig. 5. Smith chart plot of ROSQMA



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