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DESIGN AND EVALUATION OF HEXABAND MICROSTRIP ANTENNA

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ABSTRACT

This paper demonstrate simple, low cost Hexaband microstrip antenna with suitable feeding technique and dielectric substrate for applications in GHz frequency range. The optimum design parameters of the antenna are selected to achieve the improved bandwidth, high gain as well as best possible characteristics such as better radiation pattern, low SWR etc. Designed antenna achieved a bandwidth of 46 % resonating at six different bands between L to K_u band frequency ranges. Effect of slot on the patch is studied experimentally for enhancing the bandwidth. Designed antennas are suitable for L to K_u-band applications of wireless systems. Details of antenna design and results are discussed.

Keywords- Microstrip antenna, Quad band, Rhombus, VNA, Bandwidth.

INTRODUCTION

Modern wireless communication system requires low profile, light weight, high gain and simple structure antennas to assure reliability, mobility and high efficiency characteristics. Hence microstrip antennas (MSAs) are most widely used due to their attractive features such as light weight, low volume, ease in fabrication and low cost [1]. The demerits of the MSA are its narrow bandwidth and low gain and high SWR [1-2] which restricts their many useful applications.

Different design configurations of microstrip antenna can give high gain, wide bandwidth and improved efficiency. With suitable feeding network which accumulates all of the induced voltages to feed into one point [3]. The proper impedance matching throughout the corporate and series feeding array configurations provides high efficiency microstrip antenna [4]. Power distribution among antenna elements can be modified by feed network. The feed network can also steer beam by introducing phase change [5]. The desirable design parameters (dielectric material, height and frequency etc) are important because antenna performance depends on these parameters. Radiation performance can be improved by using proper design structures [6]. The use of high permittivity substrates can also miniaturize microstrip antenna size [7]. Thick substrates with lower range of dielectric offer better efficiency and wide bandwidth but it requires larger element size [8]. Microstrip antenna with superconducting patch on uniaxial substrate gives high radiation efficiency and high gain in millimeter wave lengths [9]. The width discontinuities in a microstrip patch reduces the length of resonating microstrip antenna and radiation efficiency [10].

Antenna Geometry

Microstrip patch antennas consist of very thin metallic strip (patch) placed on ground plane where the thickness of the metallic strip is restricted by $t << \lambda 0$ and the height is restricted by

$0.0003\lambda 0 \leq h \leq 0.05\lambda 0$. The microstrip patch is designed so that its radiation pattern maximum and is normal to the patch. For a rectangular patch, the length L of the element is usually $\lambda_0/3 < L < \lambda_0/2$. The design work is carried out using computer software AutoCAD-2012 and the antennas are fabricated on low cost glass epoxy substrate material of thickness h = 0.16 cm and permittivity ϵ_r = 4.4. Figure 1 show the geometry of conventional rectangular microstrip antenna (CRMA) designed for the frequency of 3.5 GHz using the equations available in the literature [1]. The antenna is fed by using microstripline feeding with 50Ω connector connected to the strip of the patch and also to the ground. Figure 1 consists of a radiating patch of length and width (L x W) of the patch are (18.99 *x* 26.92), quarter wave transformer of length and width are (L_t x W_t) is (10.18 x 0.66 mm) used between the patch and 50 Ω microstripline feed of length and width. (L_f x W_f) is (10.19 x 3.35 mm) while keeping other dimensions unchanged. At the tip of microstripline feed, a 50 Ω coaxial SMA connector is used to feed the microwave power.

Figure 2 shows the geometry of two slot rhombus shape (TSRSP) on patch. The dimension of TSRSP shown in Fig. 2 remains same as that of rectangular patch and feed line as shown in Fig.1, but two rhombus shaped slot which are placed horizontal on patch are etched on the patch plane of CRMA as shown in Fig. 2. Hence, this antenna is named as two slot rhombus shape patch (TSRSP). The dimensions of all the slots are taken in terms of λ_0, where λ_0 is the free space wavelength. The side length SL_1 is 6.25mm equal on all sides. The horizontal and vertical slot lengths (L_1 and L_2) slots are 9.6 mm and 13.5 mm.

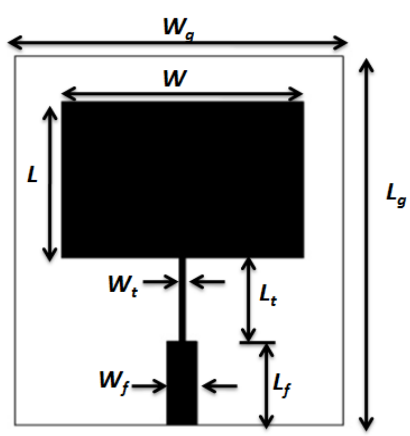

Figure 1: Geometry of CRMA

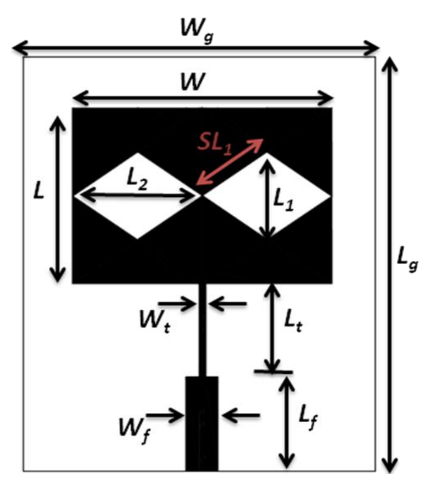

Figure 2: Geometry of TSRSP

Experimental Result Evaluation

The impedance bandwidth over return loss less than -10 dB for the proposed antennas is measured for L to K_u-band microwave frequencies. The antenna measurements are taken on Agilent Technologies E8363B Network Analyzer. The variation of return loss versus frequency of CRMA is as shown in Fig. 3. From the figure it is clear that, the antenna resonates at f_{r1} = 3.6 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 practical bandwidth is calculated using the formula,

$$BW = \left[\frac{f_H - f_L}{f_C}\right] \times 100\% \qquad (1)$$

Where, f_H and f_L are the upper and lower cut-off frequency of the band respectively when its return loss becomes -10dB and f_c is the center frequency between f_H and f_L.

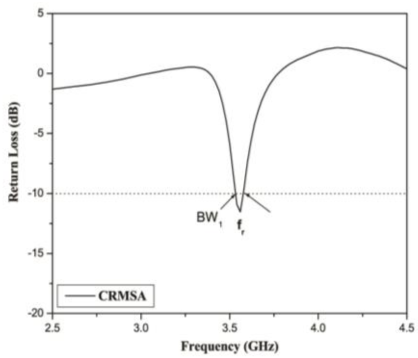

Figure 3: Variation of return loss Vs frequency of conventional RMA

Figure 4 shows the variation of return loss versus frequency of TSRSP. The antenna resonates for six different band of frequencies, fr_1=2.63 GHz, fr_2 = 3.464 GHz, fr_3 =5.70 GHz, fr_4 = 9.70 GHz, fr_5 = 12.634 GHz and fr_6 = 14.230. The respective bandwidths at fr_1, fr_2, fr_3, fr_4, fr_5 and fr_6 are 1.43 %, 2.07 %, 4.1 %, 46 %, 32% and 39 %. The return loss (RL) at different resonant frequencies are -18.02 dB at 1.8 GHz, 14.73 dB at 3.4 GHz, -15.07 dB at 5.7 GHz, -24.09 dB at 9.7 GHz, -18.48 dB at 12.63 GHz and -29.90 dB at 14.23 GHz (L to K_u band).

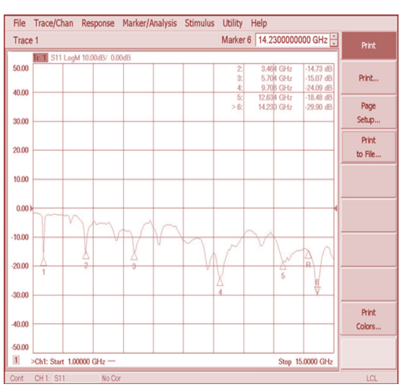

Figure 4: Variation of return loss Vs frequency of TSRSP

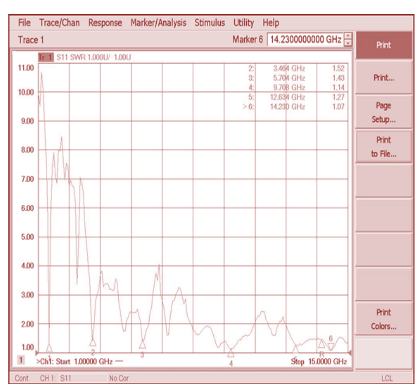

Figure 5.SWR characteristics of TSRSP

Fig.5 shows the measured VSWR of 1.3, 1.52, 1.43, 1.14, 1.27 and 1.07 at all respective resonant frequencies of TSRSP and found that VSWR of TSRSP is less than 1.5 signifying less reflected power. Fig.6 shows the smith chart plot of TSRSP 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.

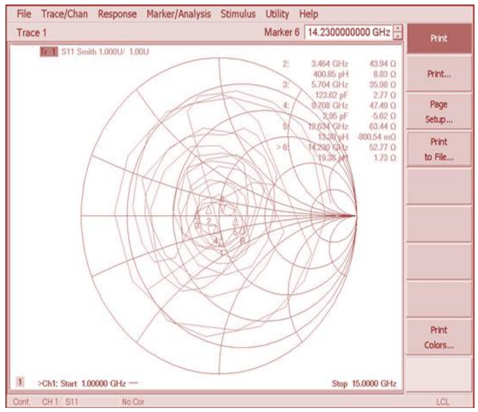

Figure 6: Smith chart plot of TSRSP

For the calculation of gain of antenna under test (AUT), the power transmitted 'P_t' by pyramidal horn antenna and power received 'P_r' by AUT are measured independently [11]. With the help of these experimental data, the maximum gain G (dB) of CRMA in BW_1 is calculated using the equation (3).

$$(G)dB = 10\ \log\left(\frac{P_r}{P_t}\right) - (G_t)dB\ -\ 20\log\left(\frac{\lambda_0}{4\pi R}\right)dB \qquad (3)$$

Where, λ_0 is the operating wavelength in cm and R is the distance between the transmitting and receiving antenna. The gain of CRMA is found to 2.3 dB. The gains of TSRSP is measured for all resonant frequencies and are found to be 2.6 dB, 3.1 dB, 3.8dB, 6.3dB, 4.2 dB and 5.2 dB respectively. The maximum gain is found to be 6.3 dB for 9.708 GHz.

CONCLUSION

In this paper, the evaluation of microstripline fed antenna has been made. It is seen that, by using rhombus shape slot on the patch plane of microstrip antenna, hexabands are obtained. Further, the enhancement in bandwidth of rhombus shape microstrip antenna is 46%, 39 % and 36 % with better gain characteristics compared to 2.06% of conventional MSA. This technique also enhances the gain from 2.06 dB to 6.3 dB. The proposed antennas are simple, cost effective and may find application in wireless applications in L to K_u band frequency range.

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