COMPARATIVE STUDY OF SLOT LOADED RECTANGULAR AND TRIANGULAR MICROSTRIP ARRAY ANTENNAS

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Abstract

In this paper we have presented the comparative study and theoretical validation of two element slot loaded rectangular microstrip array antenna (TS-RMAA) and two element slot loaded equilateral triangular microstrip array antenna (TS-ETMAA), fed by corporate feed technique illustrating wide band operation. The experimental results reveal that, the impedance bandwidth of TS-RMAA is 6.54% (i.e., 700 MHz) and the impedance bandwidth of TS-ETMAA is 7.35% (i.e., 820MHz). The impedance bandwidth of TS-ETMAA is 1.12 times more than the impedance bandwidth of TS-RMAA. The theoretical impedance bandwidth is determined to compare the experimental impedance bandwidth for validation. The theoretical and experimental impedance bandwidth is in close agreement with each other. The wide band operation of the antenna may find application in communication system.

Keywords: *Array antenna, wide band microstrip antenna, triangular microstrip antenna.*

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1. INTRODUCTION

With the saturation of low frequency bands, the operating frequencies of modern communication systems have risen and planar antennas have become more attractive. Among them, microstrip antennas form a special category on which considerable research work has been conducted. However microstrip antennas inherently have a narrow impedance bandwidth and its enhancement is usually demanded for practical applications. On the other hand, wide band antenna with small physical size and good performance are an oncoming challenge to meet the needs of integration, cost and efficiency of the emerging wireless world.

One of the most attractive features of the equilateral triangular microstrip antenna (ETMSA) is that, the area necessary for the patch becomes about half as large as that of a nearly rectangular or square microstrip antenna designed for the same frequency [1]. In view of this an effort is made to enhance the impedance bandwidth of the antenna by reducing the area of the radiating patch.

2. DESCRIPTION OF THE ANTENNA GEOMETRY

The antennas are sketched by using computer software Auto-CAD and fabricated on low cost glass epoxy substrate material of thickness h =1.66mm and permittivity ε_r = 4.2. The radiating elements of TS-RMAA and TS-ETMAA shown respectively in Fig.1 and Fig.2 are fed by using corporate feed technique.

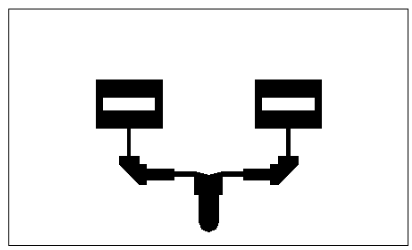

Fig – 1: Designed geometry of TS-RMA

Fig – 2: Designed geometry of TS-ETMAA

This technique has been selected because of its simplicity and it can be simultaneously fabricated along with the antenna elements. In Fig. 1 and Fig. 2 the distance between the two radiating elements D_R is kept at $3\lambda_o/4$ in order to add the radiated power in free space by individual elements to improve antenna parameters. However, the D_R is taken in terms of multiple of half wavelength. But in this case $3\lambda_o/4$ has been selected in order to accommodate corporate feed arrangements between the two radiating elements. The corporate feed arrangement consists of matching transformer, quarter wave transformer, microstrip bend and two way power divider used for better impedance matching between feed and radiating element which reduces the loss in the feed line At the tip of microstrip line feed [2] a 50 Ω coaxial SMA co-axial connector is used for feeding the microwave power.

3. EXPERIMENTAL RESULTS

The impedance bandwidth over return loss less than –10dB for the proposed antennas is measured for X-band frequencies. The measurement is taken on Vector Network Analyzer (Rohde & Schwarz, Germany make ZVK model).

The variation of return loss versus frequency of TS-RMAA and TS-ETMAA is shown in Fig. 3 and 4 respectively. From these graphs the impedance bandwidth is determined by using the equation:

$$\mathrm{BW} = \left[\frac{(f_2 - f_1)}{f_c}\right] \times 100\,\%$$

Where, f_1 and f_2 are the lower and upper cut off frequency of the band respectively, when its return loss becomes –10dB, and f_c is a centre frequency between f_1 and f_2. The experimental result shows the impedance bandwidth of TS-RMAA is 6.54% and the impedance bandwidth of TS-ETMAA is 7.35%.

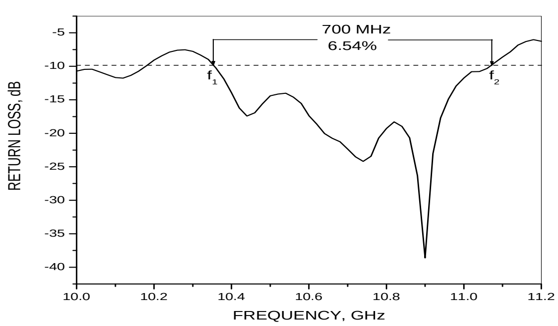

Fig - 3: Variation of return loss versus frequency of TS-RMAA

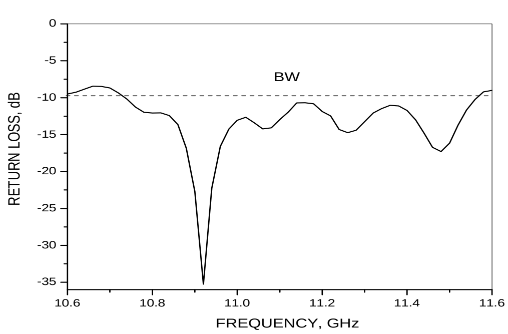

Fig - 4: Variation of return loss versus frequency of TS-ETMAA

4. THEORETICAL RESULTS

The proposed antennas TS-RMAA and TS-ETMAA have been designed for TE_{10} mode.

The expression derived by Girish Kumar and K. P. Ray [3] for the calculation of percentage impedance bandwidth are in terms of patch dimensions and substrate parameters for conventional rectangular microstrip antenna and is given by,

$$\text{Impedance Bandwidth}(\%) = \left[\frac{A \times h}{\lambda_0 \sqrt{\varepsilon_r}}\right] \times \sqrt{\frac{W}{L}} \qquad (1)$$

Where
h = thickness of the substrate
ε_r = relative permittivity of the substrate
W = width of the patch
L = length of the patch
λ_0 = free-space wavelength
A = correction factor

The correction factor 'A' changes as the value of factor $\left[\frac{h}{\lambda_0 \sqrt{\varepsilon_r}}\right]$ changes [4], which is given by;

A = 180 for $\left[\frac{h}{\lambda_0 \sqrt{\varepsilon_r}}\right] \le 0.045$

A = 200 for $0.045 \le \left[\frac{h}{\lambda_0 \sqrt{\varepsilon_r}}\right] \le 0.075$

A = 220 for $\left[\frac{h}{\lambda_0 \sqrt{\varepsilon_r}}\right] \ge 0.075$

In the present investigation the value of correction factor A is taken as 180 because the calculated value of $\left[\frac{h}{\lambda_0 \sqrt{\varepsilon_r}}\right]$ TS-RMAA and TS-ETMAA is lesser than 0.045 determined for the known value of h, λ_0 and ε_r.

Since the expression (1) given by [3] is for single element RMSA. This equation is extended for calculating the impedance bandwidth of RMAAs by multiplying the ratio $\frac{W}{L}$ by n. The extended equation becomes,

$$\text{Impedance Bandwidth}(\%) = \left[\frac{A \times h}{\lambda_0 \sqrt{\varepsilon_r}}\right] \times \sqrt{n \times \frac{W}{L}} \qquad (2)$$

Where, n = number of rectangular radiating patches in RMAAs.

If the radiating elements are equilateral triangular in shape The equation (1) is converted for equilateral triangular microstrip antenna and arrays by replacing the W/L ratio with (n × S_e). The modified equation for ETMA is given by

$$\text{Impedance Bandwidth}(\%) = \left[\frac{A\times h}{\lambda_0\sqrt{\varepsilon_r}}\right]\times\sqrt{n\times S_e} \tag{3}$$

Where, S_e = effective side length of the equilateral triangular radiating patch and

n = number of radiating patches.

In equation (3) the value of S_e is given by the formula [4]

$$S_e = S+\frac{4h}{\sqrt{\varepsilon_e}} \tag{4}$$

Where
S = side length of the equilateral triangular microstrip patch
ε_e = effective dielectric constant

In TS-RMAA and TS-ETMAA the rectangular slots are loaded at the center of the radiating elements The insertion of slot changes the impedance of conducting patch. Therefore for determining the impedance bandwidth of area of slot loaded rectangular and triangular microstrip radiating patches (A_{SP}) and capacitance of the slot (C_S) are taken into consideration. The C_S is calculated with the help of the transmission line model [2]. This analytical technique is based on equivalent magnetic current distribution around the patch edges which is similar to slot antennas.

The change of impedance of patch mainly depends upon the area of slot and its location as the impedance of the patch is non-linear [3]. The effective resonance characteristics due to change of impedance is given by multiplying the ratio W/L by A_{SP} in equation 2 and by S_e in equation 3. Since slots are on the radiating patches separated by the ground plane by substrate of thickness h The slot behaves as capacitor and resonates as secondary resonator to the main patch. The resonance of slot if close to the main patch which causes enhancement in the impedance bandwidth The capacitive associated to the slot is $C_{S.}$ The term C_S is added to equation 2 and 3 to determine total resonance of TS-RMAA and TS-ETMAA. The capacitance parameter C_S associated to the slot is evaluated using the transmission line model [2] given by;

$$C_S = \frac{\Delta l\sqrt{\varepsilon_{eff}}}{c\times Z_0} \tag{5}$$

Where, Δl is the extension length and ε_{eff} is the effective dielectric constant. Hence equation (2) for TS-RMAA becomes,

$$\text{Impedance Bandwidth}(\%) = \left\{\frac{A\times h}{\lambda_0\sqrt{\varepsilon_r}}\times\sqrt{n\times\frac{W}{L}\times A_{SP}}\right\}+C_S \tag{6}$$

And for TS-ETMAA is,

$$\text{Impedance Bandwidth}(\%) = \left[\left(\frac{A\times h}{\lambda_0\sqrt{\varepsilon_r}}\right)\times\sqrt{2\times S_e\times A_{sp}}\right]+C_s \tag{7}$$

Where
n = 2 as proposed antennas consists of two radiating elements.
A_{SP} = area of the slot loaded patch excluding the area of rectangular slot
C_S = capacitance of the slot

The value of A_{sp} in equation (6 and 7) is calculated by using the formula

$$A_{SP} = A_P - A_S \tag{8}$$

Where
A_p = area of patches.
A_s = area of rectangular slots

The value of A_P is for the given antennas are determined using basic formulae for rectangular and equilateral triangular geometries. In the above equation 8, A_S is obtained by the formula;

$$A_S = L_S \times W_S \tag{9}$$

Where
L_S = length of the rectangular slot
W_S = width of the rectangular slot

The impedance bandwidth of TS-RMAA and TS-ETMAA is calculated using the equation (6) and (7) is recorded in Table 1.

5. CONCLUSIONS

From the detailed experimental study it is found that, the proposed antenna TS-ETMAA is quite capable of enhancing the impedance bandwidth by 12.38% and compactness of 10.71% when compared to TS-RMAA. This shows the superiority of ETMSA in enhancing the impedance bandwidth. Experimental impedance bandwidth is verified theoretically. The theoretical and experimental impedance bandwidth is in close agreement with each other. These antennas are simple in their geometries and the feed line can be fabricated along with the radiating patches. Such antennas may find applications in the microwave communication systems.

Table -1: Various antenna parameters

Antennas	Parameters					Impedance bandwidth (%)	
	Minimum return loss in dB	VSWR	HPBW in dB	Gain in dB	Nature of impedance bandwidth	Theoretical	Experimental
TS-RMAA	-38.61	1.02	43.91	4.7	Single band	5.55	6.54
TS-ETMAA	-35.26	1.04	42.34	4.14	Single band	7.12	7.35

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BIOGRAPHIES

Dr. G. M. Pushpanjali, is presently working as an Assistant Professor at Department of Physics, Central University of Karnataka, Gulbarga, India. She is an active researcher in the area of microwave communication and applied electronics with the teaching and research experience of more than 10 years. In recognition she is awarded with best research paper award for her work in antenna design. Along with academics she holds national recognition for social service and welfare.

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