ISSN: 2278 – 909X
International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE)
Volume 5, Issue 5, May 2016

Effect of Corner Truncation on Microstrip Feed Rectangular Patch Antenna

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Abstract- ***In this paper mode study of microstrip feed rectangular patch antenna is carried out. It was observed that TM10, TM20, TM30, TM02 and TM12 modes were presented. Spurious mode was also found because of microstrip line. It was observed that truncation from the corner changes the resonance frequencies of antenna and surface current distribution.. The antenna was simulated using CST, on FR-4 substrate with relative permittivity of 4.4.***

Keywords—Rectangular Microstrip Patch Antenna (RMPA); Modes.

I. INTRODUCTION

Microstrip patch antenna offers several advantages like low profile, low cost, planar structure and easy integration with printed circuit board.These features make the microstrip antenna very attractive for use in high-speed vehicles, such as missiles, rockets and satellites. But it has some draw back like low gain, low impedance bandwidth and less power handling capability [1-2].The geometry of a microstrip antenna contains conducting patch on the top of a substrate, which is backed by a ground plane. The shape of patch can be arbitrary. But in practice, regular shapes like rectangular, circular and the annular ring are used for easier analysis. In ref. [3-8], dual band and broad band response is realized by cutting slot in side of the patch in appropriate position. Slot in side of the patch reduces the resonance frequency of the higher order modes and fundamental modes also and it also alters the surface current distribution of the modes. In previous articles the feeding technique was coaxial feed. In this work the dimension of the patch is taken as similar to ref [3]. In this paper corner slots are introduced and observed the variation of resonance frequencies of higher order modes.

II. TRANSMISSION LINE MODEL

The physical dimension of the rectangular microstrip patch antenna is calculated by transmission line model. In transmission line model the RMPA can be represented by two slots of width (W) and height (h) separated by transmission line of length (L).The width of the patch can be calculated from the following equation

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

The effective dielectric constant (ε_{eff}) is less than (ε_r) because the fringing field around the periphery of the patch is not confined to the dielectric also speared in the air also.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \qquad (2)$$

Because of fringing field, extension in length and width is given by empirically.

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)(W/h+0.264)}{(\varepsilon_{reff}-0.258)(W/h+0.8)} \qquad (3)$$

$$\Delta W = 1.6\ln(4/\pi) \qquad (4)$$

Effective length (L_e) and effective width (W_e) is given by

$$L_e = L + \Delta L \qquad (5)$$

$$W_e = W + \Delta W(6)$$

The length of the patch is given by

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L(7)$$

Where,

c = speed of light
f_r = operating frequency
ε_{reff} = effective dielectric constant

For a rectangular Microstrip patch antenna the resonance frequency for any TM_{mn} mode is given by

$$f_{mn} = \frac{c}{2\sqrt{\varepsilon_{eff}}}\sqrt{\left[\left(\frac{m}{L_e}\right)^2+\left(\frac{n}{W_e}\right)^2\right]}(8)$$

The width of ground plane is given by

$$W_g = 6h + W \qquad (9)$$

The length of the ground plane is given by

$$L_g = 6h + L \qquad (10)$$

III. ANTENNA CONFIGURATION

The reference antenna which is designed for frequency 2.4 GHz is shown in fig. 1. The substrate used for this design is FR-4 with relative permittivity 4.4, loss tangent 0.02and thickness h=1.6mm. The physical dimension of ground plane (Lg×Wg) is 105×58mm. Given geometry is excited by microstrip line. The length of the feed line is ML=16mm and width MW =3mm. the physical dimension of the substrate is given by Lsub=110mm and Wsub=58mm. These physical dimensions are calculated using transmission line model.

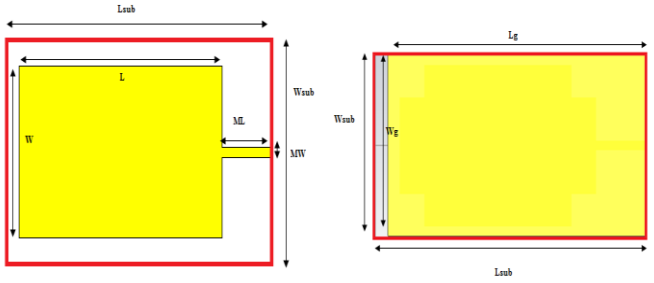

Fig.1. Configuration of reference Antenna with ground plane

IV. Mode Analysis

(A). Reference antenna

It is clear from the figure 2 antenna is resonating at five frequencies. The lowest resonating frequency is 0.89 GHz. This lowest frequency is known as TM10 mode. Other higher order modes generated by patch are TM20, TM30, TM02, and TM12. Resonance curve of antenna is shown in figure 3.Figure 4 shows the surface current distributions of various modes.

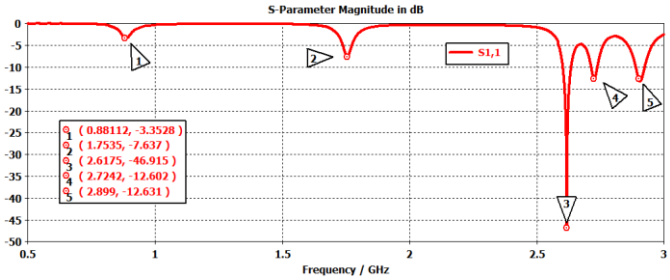

Fig.2. Return loss vs Frequency of reference antenna

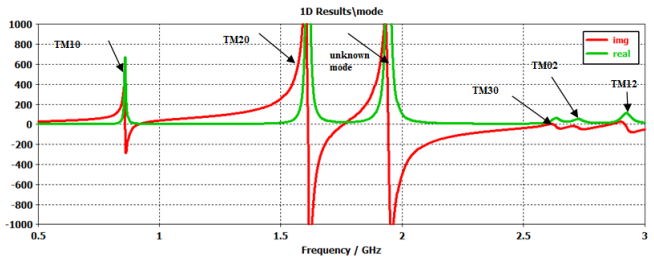

Fig.3. Resonance curve of reference antenna

It is clear from the figure 4 excited modes are TM10, TM20, TM30, TM02 and TM12. But from the resonance curve one unknown mode is found. That unknown mode is spurious mode generated by microstrip line. Figure 4 (a) shows the current distribution of TM10. For TM10 mode surface current shows one half wave variations along L, and no variation along W. Figure4 (b) shows the current distribution of the TM20 modethis mode is the second harmonic of the TM10 mode. For TM20 mode two half wave variations along L and no variation along W.Figure 4 (c) shows the current distribution of the TM30 mode this mode is the third harmonic of the TM10 mode. For TM30 mode three half wave variations along the length of the patch and no variation along the width of the patch is observed.Figure 4 (d) shows the surface current distribution of the TM02.For TM20 mode two half wave variations along the width of the patch and no variation along the length of the patch is observed. Figure 4 (e) shows the surface current distribution of the TM12. For TM12 mode one half wave variation along length and two half wave variation along the width if observed.

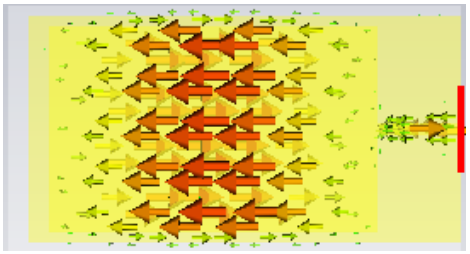

Fig.4(a). Surface current distribution for TM10 mode

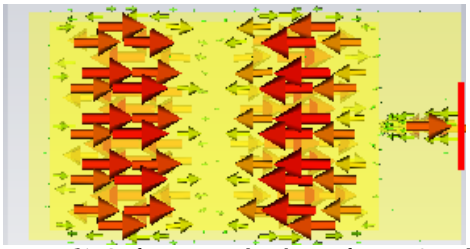

Fig.4(b). Surface current distribution for TM20 mode

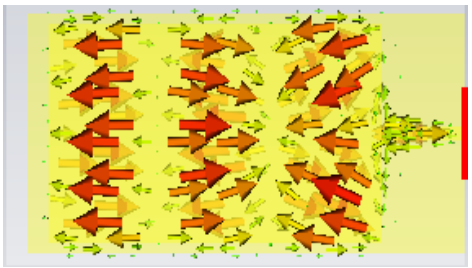

Fig.4(c). Surface current distribution for TM30 mode

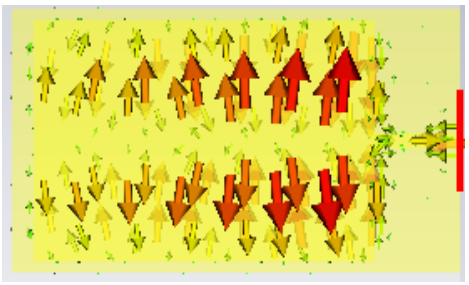

Fig.4 (d). Surface current distribution for TM02 mode

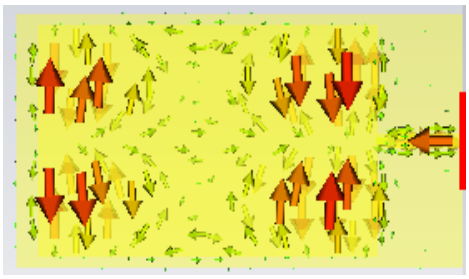

Fig.4(e). Surface current distribution for TM12 mode

(A). Antenna with square slot at corner

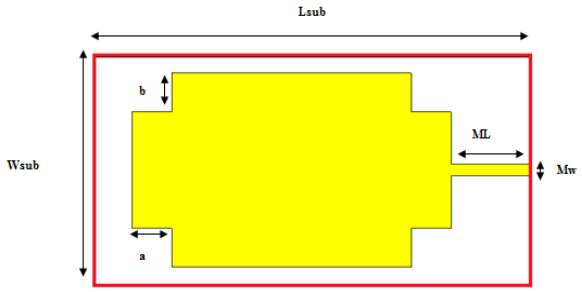

Fig 5. Geometry of antenna with square slot at corner

Geometry of antenna with square slot at corner is shown in figure 5. The length a is varied from 5mm to 15mm. figure 6 the variation of resonance frequencies of different modes. It is observed from resonance curve the resonance frequency of the TM10 mode, shifted right if slot length is varied from 5mm to 15mm. it is clear from the figure 6 TM20 mode is shifted left. Uneven variation is observed for spurious mode while TM30 and TM02 modes areshifted left. TM12 mode is shifted right.

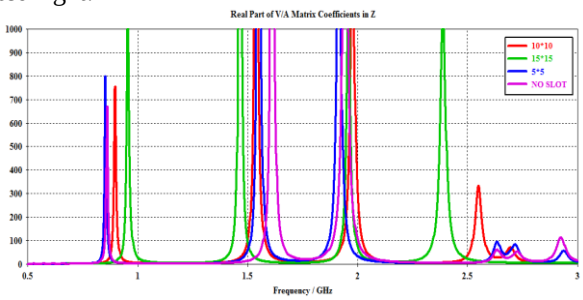

Fig 6. Resonance curve for square slot antenna

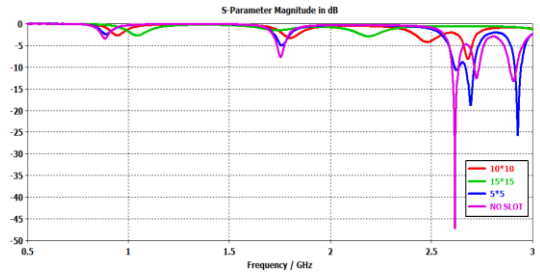

Fig 7. Return loss curve for square slot antenna

Figure 7 shows the variation of return loss. For slot 5mm*5mm TM30 and TM02 modes are mixed and for slot 10*10 both modes are separated

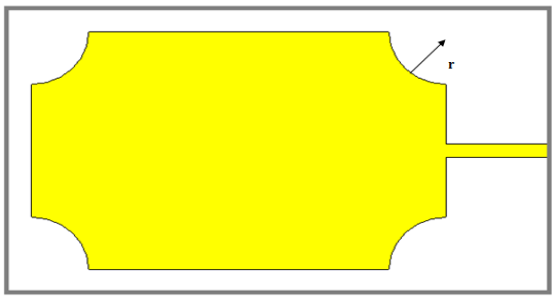

Fig 8. Geometry of antenna with cicular slot at corner

The geometry of microstrip fed patch antenna with circular cut at corner is shown in figure 8 . the dimension of the patch and ground plane are same as reference antenna. The parameter r is varied from 8mm to 11mm.

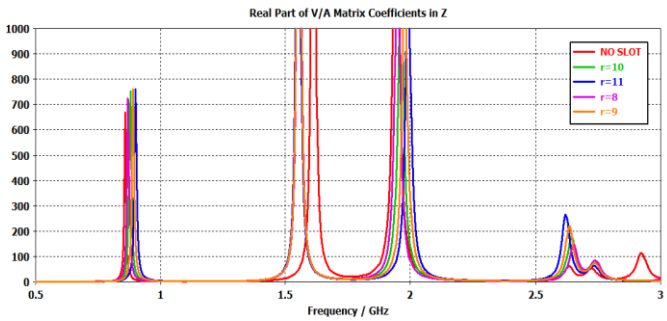

Fig 9 Resonance curve of antenna with circular slot

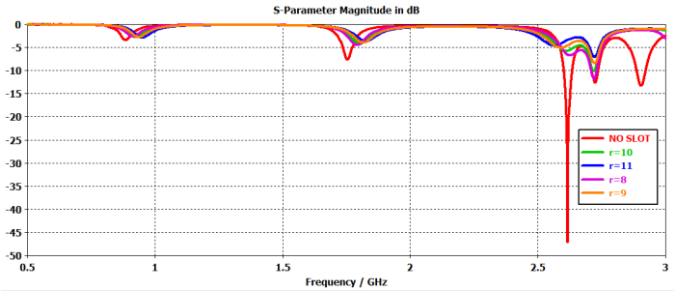

Fig 10. Return loss curve for circular slot antenna

It is observed from resonance curve (figure 9) the resonance frequency of the TM10 mode, shifted right if radius of circular slot is varied from 8mm to 11mm. it is clear from the figure 9 TM20 mode is shifted left for r=8mm then after no variation is observed for other circular slot. Uneven variation is observed for spurious mode while TM30 and TM02 modes are shifted left. TM12 mode is shifted right. Figure 10 shows the variation of return loss.

V. Conclusion

Microstrip feed Rectangular patch antenna has been simulatedusing CST software. Due to excitation various modes are generated such as TM10, TM20, TM30, TM02 and TM12. Due to incorporation of slot current distribution is

altered and mode frequencies are increased or decreased. Theses modes are affected by corner slots.

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