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Effect of Rectangular Slots On Printed Antenna for C and X Band Application

Mamatha A G[1], Dr. Pradeep M Hadalgi[2]

[1,2]*Department of Applied Electronics Gulbarga University Kalaburagi, India.*
[1]*Corresponding Email: mamathaprashth80@gmail*

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Abstract: *Planar antennas play an important role in the field of wireless communication to a greater extent since it has been replaced by traditional large antennas. The microstrip antenna is of the compact, low cost antenna. In the present work, rectangular slots are embedded on a printed antenna (microstrip antenna) using quarter wave transformer feed. The effect of rectangular slots near the radiating edge of printed antenna is observed. The antenna is showing triple band in nature i. e frequency f_1 = 6.46 GHz, f_2 = 8.54 GHz and f_3 = 9.65 GHz with return loss R_1 = - 16.93 dB, R_2 = -13.2 dB and R_3 = -11.31 dB. High frequency structure simulator is used to simulated the antenna design. The simulated antenna is fabricated using low cost substrate FR_4 and experimental results is carried out using the vector analyzer model MS2037C/2. The printed antenna is compared with the simulated and experimental results and it is observed that the antenna is showing good return loss, bandwidth, VSWR and gain.*
Keywords*: FR_4 ; HFSS; Rectangular slots and Triple band.*

I. Introduction

In wireless communication, transferring data is the major role for both transmission and reception. If the data has to be transmit for multiple outputs, then more number of antennas are required hence to overcome the space limitation multiband antenna can be adopted. Bandwidth improvement can be achieved by embedding slots, introducing shots, DGS, metamaterial and EBG structures etc. along with multiple resonance. One of the simple and easy fabricating technique is slot loading [1][2].

The microstrip antenna [3] by adjusting dimensions of patch and feed a dual band frequency which is operating in 2.3 GHz and 3.5 GHz is observed. The antenna has good return loss of -20.00 Db and -16.90 Db with good gain of 3.612 DB and 1 DB found a long term evolution and broad band application is obtained. A circular microstrip antenna [4] for Wi-Fi application is designed by using circular patch with quaterwave transformer feed. The antenna is embedded with the defective ground structures in the form of square split rings. Antenna is resonating at three different frequencies with highest bandwidth of 14%. A dual band [5] microstrip antenna with microstrip feed line for wearable and ISM band application is proposed and analyzed by loading rectangular slots on the patch and the results obtained obeys the specific absorption rate limit too hence it is can also be used for flexible antenna. The rectangular microstrip [6] patch antenna using FR4 substrate with thickness 1.6mm is showing multiband resonance for the application of wireless local area network. The antenna is showing gain of 3.12 Db and the design is simulated using high frequency structure simulator. A U shaped [7] slot using Rogger Duroid 5880 substrate for X band application is designed. Three rectangular slots are loaded and the antenna is simulated using HFSS software and results in single band in nature with good gain of 7.07 dB. Embedding EBG structures [8] and partial ground planes for a microstrip slot antenna a high gain with good directivity and bandwidth are obtained. The antenna is simulated using CST software and for each stage the current distribution is analyzed. A stair shaped [9] with circular slots microstrip antenna is simulated using HFSS software with FR4 substrate which results a resonating frequency 8 GHz with good return loss and gain for x band application. Design of microstrip antenna [10] with the rectangular slots embedded in the form of inverted U shaped using FR4 substrate which results in the resonating frequency of 5.6 GHz for the WLAN application. The antenna is designed using HFSS software for good gain, VSWR, impedance bandwidth and return loss with good radiation pattern

It is observed from the literature review the printed antenna with DGS, EBG structures and partial ground techniques are implemented to achieve higher impedance bandwidth more than 10%. But in the present work the antenna with impedance bandwidth more than 10% is achieved using simple slot loading technique. The proposed work is done by loading rectangular slots on the patch using FR4 as a dielectric substrate and antenna is simulated using HFSS software results in triple band in nature with a gain of 5.28 dB at 9.9 GHz and impedance bandwidth of 11.6 % at 6.46 GHz is achieved.

II. Basic Antenna Design

The basic printed antenna is designed for 3.5 GHz frequency with the dimensions 8 cms x 4 cms x 0.16 cms. Width and length of the patch along with the quarter wave transformer feed line dimensions are tabulated in table 1. The structure of the basic microstrip antenna with dimensions of patch and feed line is shown in the figure 1 and the fabricated basic(conventional) antenna using FR4 substrate is shown in the figure 2.

Table 1: Antenna Design Parameters.

Parameters	Dimensions
Width of the patch Wp	2.64 cms
Length of the patch LP	2.04 cms
Width of the substrate Ws	4 cms
Length of the substrate Ls	8 cms
Width of the quarter wave length Wtf	0.05 cms
Length of the quarter wave length Ltf	1.09 cms
Width of the feed Wf	0.3 cms
Length of the feed Lf	2.18 cms

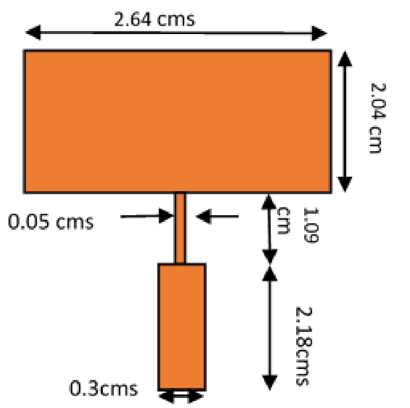


Figure. 1 Basic printed antenna structure.

Figure 2. Prototype of the basic antenna.

III. Proposed Antenna Design

Rectangular slots are embedded on the rectangular patch near the radiating edge of the antenna. The length of the slots A= B= 1.7 cms with width of 0.05 cms. Slots B = C = D = E = F = G = H = I = J = K = 0.6 cms length and 0.05 cms width. The structure of the proposed antenna is shown in the figure 3.

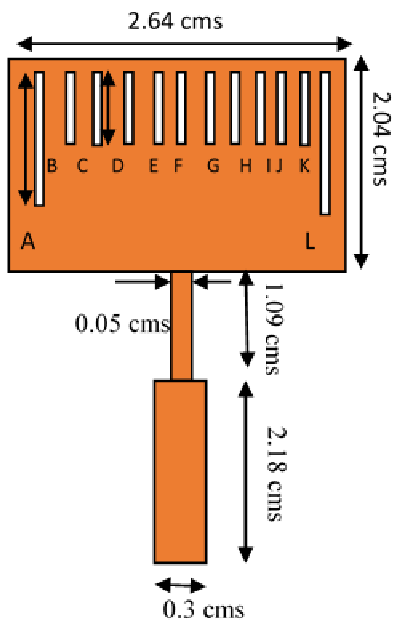


Figure 3: Structure of the proposed antenna

Figure 4. Prototype of microstrip antenna with slots

IV. Results and Discussions

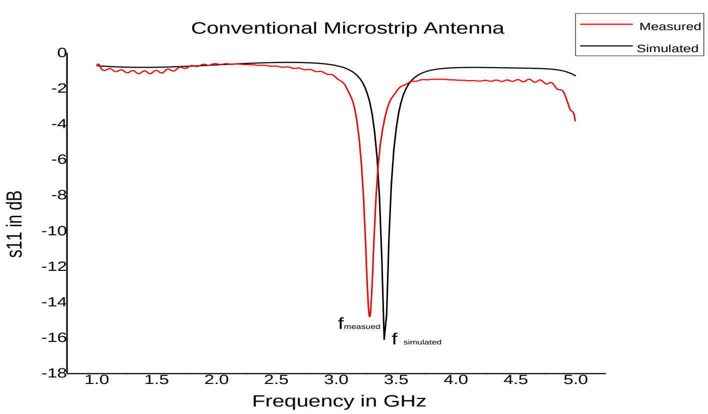


Figure 5: Frequency versus s11 graph of basic antenna

The basic printed antenna is designed for 3.5 GHz. The simulated frequency is compared with the measured frequency are shown in figure 5. The simulated frequency is 3.4 GHz with return loss -16.08 dB and measured frequency is 3.3 GHz with -14.72 dB return loss. The basic printed antenna has narrow band with single resonant frequency, to overcome this limitation slot loading technique is implemented. Hence multiband as well as improvement in the parameters characteristics are observed.

The impedance bandwidth of the microstrip antenna is calculated by the equation (1),

$$\text{Impedance Bandwidth} = \frac{f2-f1}{fc} x100 \text{ --------(1)}$$

Where the f_1 = Lower frequency, f_2 = Upper frequency and f_c = Resonating frequency.

The simulated bandwidth is (3.44-3.35) GHz is 2.64 % and the measured bandwidth is (3.31-3.22) GHz 2.73%.

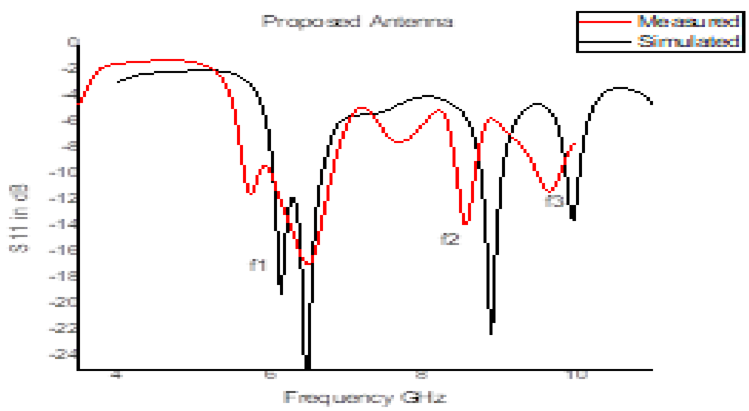


Figure 6: Frequency versus s11 graph of proposed antenna

When the rectangular slots are embedded on the patch the microstrip antenna radiates in three different frequencies (measured) f_1 = 6.53GHz, f_2 8.52 GHz and f_3 = 9.67 GHz with return loss -16.75 dB, -13.48 dB and -11.41 dB and simulated frequencies are 6.46 GHz, 8.87 GHz and 9.9 GHz with return loss -23.20 dB, -17.94 dB and -13.61 dB. The difference of 0.07 %, 0.35 % and 0.3 % between measured and simulated results are observed. The compared return loss with frequency graph is as shown in figure 6.

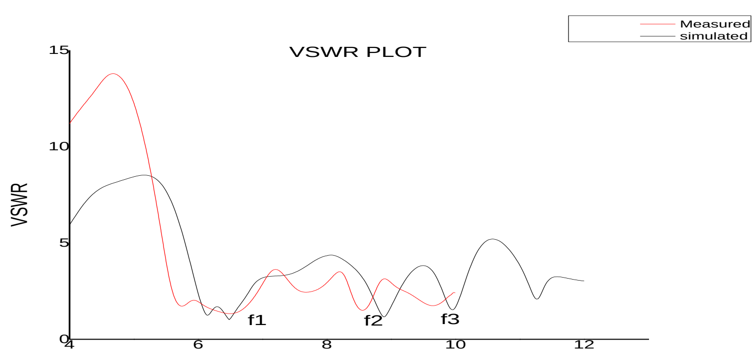


Figure 7: Frequency versus VSWR graph with slots.

The voltage standing wave ratio is the defined as the ratio of transmitted wave to the reflected wave in radio frequency. For the resonating frequencies 6.53 GHz 8.52 GHz and 9.67 GHz the measured VSWR values are 1.35, 1.38 ,1.60 and the simulated values are 1.13,1.12 and 1.52 respectively, the value of VSWR for all the three resonating frequencies are lesser than 2 which shows that the power received is more. The simulated and measured VSWR plots are shown in figure 7.

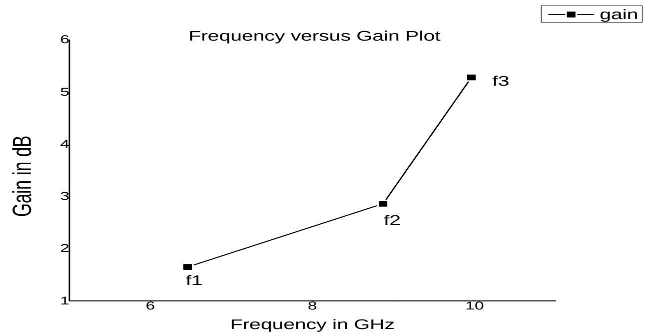
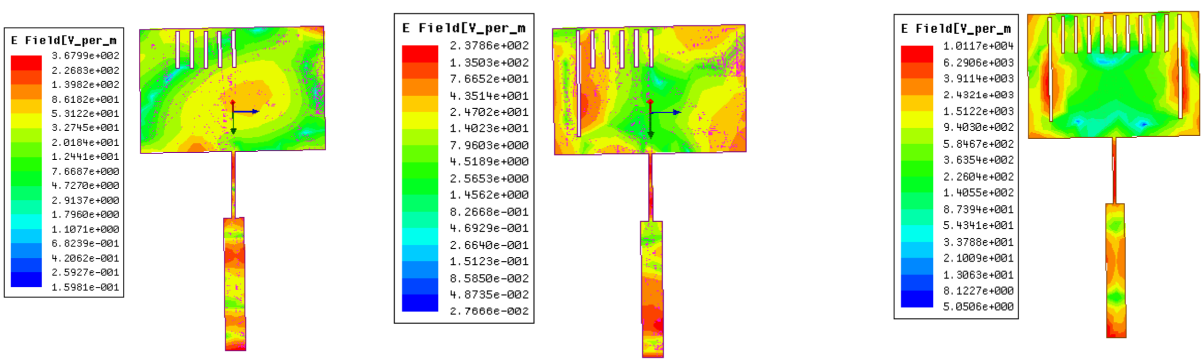


Figure 8: 3D Polar Plot gain with Slot loaded antenna.

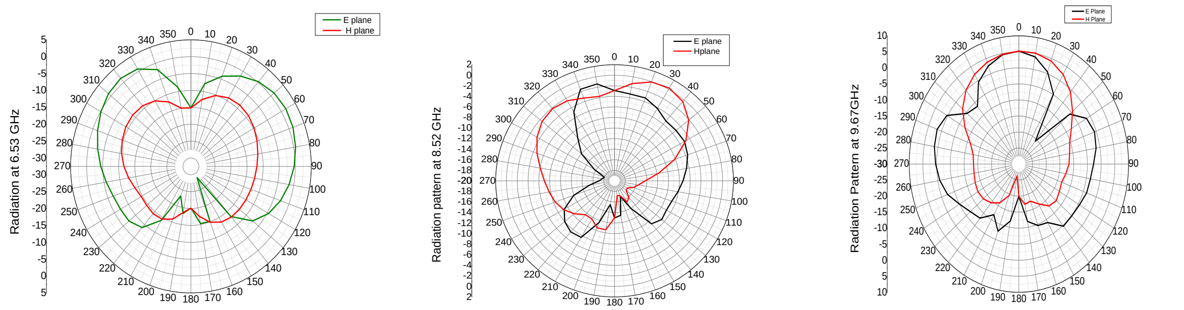
The 3D polar plot gains for three frequencies 6.46 GHz, 8.87 GHz and 9.9 GHz frequency are 1.65 dB, 2.86 dB and 5.28 dB respectively. It is observed that the gain is increased with frequencies.



(a) I Iteration (b) II Iteration (c) III Iteration

Figure 9. (a), (b) and (c) Iterations for antenna design

The proposed antenna is designed in three iterations. For the I iteration five (B, C, D, E and F) rectangular slots are loaded near the radiating edge later in the II iteration rectangular slot A is loaded to improve the current distribution. Further slots G, H, I, J, k and L are loaded in the III iteration. It is observed that the current distribution has increased more in the feed line as well as near the slots in the iteration III as compare to iteration I and II.



(a) Radiation pattern at 6.46GHz (b) Radiation pattern at 8.87GHz (c) Radiation pattern at 9.9 GHz

Figure 10. (a), (b) and (c) Radiation Patterns with E and H plane.

The proposed antenna radiation pattern for frequencies 6.46 GHz, 8.87 GHz and 9.9 GHz with E and H plane are shown in figure10, with simulated impedance bandwidth B_{W1} (6.68-6.04 GHz) = 9.87 %, B_{W2} (9.02-8.76 GHz) = 2.92 % and B_{W3} (9.77-9.48 GHz) = 2.99 % and measured bandwidth B_{W1} (6.80-6.04 GHz) =11.62 %, B_{W2} (8.68-8.43 GHz) = 2.93 % GHz and B_{W3} (10.04-9.86 GHz) = 1.86 %.

V. Conclusion

Rectangular slots embedded on printed antenna is analyzed using FR4 substrate with quarter wave transformer feed. The designed antenna shows triple band in nature as compared with the basic microstrip antenna. The proposed antenna shows impedance bandwidth of 11.62 %, 2.92 % and 1.86 % with gain of 1.65 dB, 2.86 dB and 5.28 dB for the frequencies 6.53 GHz, 8.52 GHz and 9.67 GHz. Since the proposed antenna is resonating between 6.53 GHz to 9.67 GHz it found application in C and X band.

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