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By I.V.S. Rama Sastry & Dr. K. Jaya Sankar
Auroras Engineering College, India

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I.V.S. Rama Sastry [α] & Dr. K. Jaya Sankar [σ]

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I. Introduction

The microstrip antenna in its simple form cannot satisfy the bandwidth requirements for most wireless communication systems. Antenna plays a vital component in wireless application systems. The microstrip antenna can be used for wireless applications as it has features such as light weight, easily mounted and it is easy to mass production. Although there are many features that suits well for microstrip antenna to be deployed for wireless applications, there is a very serious limitation where it has a very narrow bandwidth. The typical bandwidth of the microstrip antennas is between 1% to 3%.By overcoming this limitation the microstrip antenna can be used to its full potential. An alternative bandwidth enhancement technique is studied and then proposed in order to broaden the bandwidth of the microstrip antenna [1]. The wireless application that is selected to be studied is the Wireless Local Area Network (WLAN) based on the IEEE 802.11b standard. This WLAN band spans from 2.4GHz to 2.48GHz. Inserting slot on ground plane and stacked patch supported by wall, the bandwidth can improve up to 25% without significant change in the frequency [1].

In this paper the bandwidth of RMSA is enhanced by using combination of two techniques, Proximity coupled feed line and adding X slot in the patch.

a) Proximity Coupled Feed

The microstrip antenna consists of a grounded substrate where a microstrip feed line is located. Above this material, there is another dielectric laminate with a rectangular microstrip patch etched on its top surface. There is no ground plane separating the two dielectric layers. The power from the feed network is coupled to the patch electromagnetically, as opposed to a direct contact. This form of microstrip patch is sometimes referred to as an electromagnetically coupled patch antenna.

A key attribute of the proximity-coupled patch is that its coupling mechanism is capacitive in nature. This is in contrast to the direct contact methods, which are predominantly inductive. The difference in coupling significantly affects the obtainable impedance bandwidth, because the inductive coupling of the edge- and probe-fed geometries limits the thickness of the material useable. Thus, bandwidth of a proximity-coupled patch is inherently greater than the direct contact feed patches.

b) Slots in The Patch

Recently, most applications need larger bandwidths, so in these application areas, microstrip antennas' biggest handicap is the narrow bandwidth. Because of this, there are lots of studies going on and various bandwidth enhancement techniques are reported [2]. These techniques to increase bandwidth include introducing multiple resonances into the structure [3]. This may take the form of stacked patches, coplanar parasitic patches, or patches that have novel shapes such as the U-shaped slot patch antenna.Using special feed networks or feeding techniques [4] to compensate for the natural impedance variation of the patch is another method. Etching a slot on the patch is a simple design. This design avoids the use of stacked or coplanar parasitic patches, either of which increases the thickness or the lateral size of the antenna. So, while changing the current distribution on the microstrip patch, by enhancing the impedance bandwidth sometimes more than one resonant frequency is obtained [5]. In this study, slots with various dimensions etched on present rectangular patch antennas in literature are tested and it is seen that their bandwidths can be enhanced by sacrificing a bit from the initial resonant frequencies. The simulation measurement without slots give near resonant frequencies to the experimental results; but all the bandwidths are under 5% and by using the slots with direct contact feeding techniques we can enhance the bandwidth up to 15%.

Author α: Associate professor, Department of ECE, Aurora's Engineering College, Bhongir, Nalgonda district A. P., India. e-mail: sastry_ivsr@yahoo.com
Author σ: Professor & Head Department of ECE, Vasavi College of Engineering , Hyderabad, A. P, India. e-mail: kottaredyjs@gmail.com

II. Design of Proximity Coupled Fed Microstrip Antenna with X-Slot

This section describes the design of Rectangular Microstrip patch antenna (RMSA) to obtain the results at frequency of 2.45 GHz

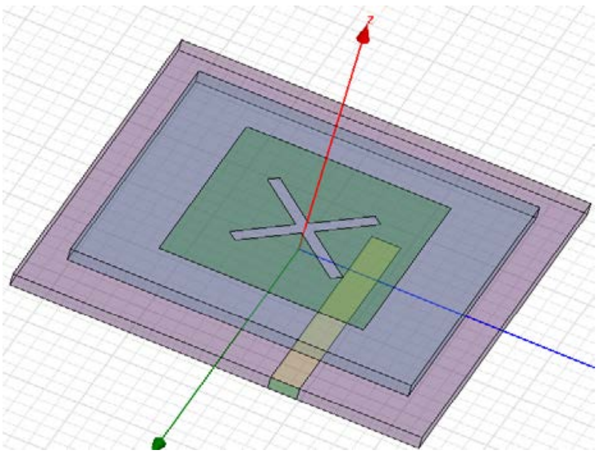

Figure 2.1 : Geometry of Proximity Coupled Fed Antenna with X-Slot

The geometry of proximity coupled microstrip line fed RMSA with X-Slot is shown in figure 1. In the design of RMSA the substrate material Fr4 (Glass-epoxy) with dielectric constant (ε_r) of 4.4 and thickness (h) of 1.60 mm, has been used. The dimensions of RMSA at frequency of 2.45 GHz have been calculated by using Transmission line model [6]. The length (L) and width (W) are calculated as 28.8 mm. A slot of X shape is made on RMSA. The slot length (L_S) is considered as less than $\lambda/4$ and width (W_S) is less than $\lambda/10$.

A 50 Ω. Impedance matching line of $\lambda/4$ length is used as microstrip feed line to couple the power, to RMSA. It is etched on top portion of the bottom substrate material (Fr4). The length (L_f) and width (W_f) of feed line are calculated.

The design of Proximity coupled RMSA with X-slot is simulated with HFSS simulator [7]. To get the satisfied simulation results, the design parameters are optimised. The optimised design parameters of proximity coupled RMSA with X-slot are shown in table 2.1.

Table 2.1 : Optimised design parameters

f_r	ε_r	h	W	L	F_L	F_W	L_W	L_S
2.45 GHz	4.4	1.6 mm	26 mm	24 mm	30 mm	3.4 mm	1.75 mm	17.32 mm

With the above design parameters, the RMSA has been fabricated and tested using network analyzer. From measurement VSWR characteristic is obtained which is shown in figure 3.6 VSWR

a) Photo copies of fabricated RMSA

The fabricated design of proximity coupled RMSA photos are shown in figures

Figure 2.2 : Proximity coupled RMSA with X-slot

Figure 2.3 : RMSA with X-slot (on first substrate)

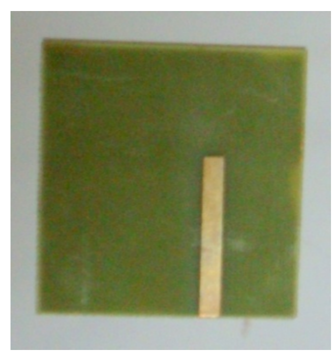

Figure 2.4 : Microstrip feed line (on Second Substrate)

III. Simulation Results

The High Frequency Simulation Software (HFSS) is used to model and simulate the Proximity coupled RMSA. HFSS software [8] is the industry-standard simulation tool for 3-D full-wave electromagnetic field simulation. Using this software, input port impedances, s-parameters, return loss, radiation pattern, etc. are obtained and the results are shown in figures from.

a) Return Loss

Return loss is the difference between forward and reflected power, in dB, generally measured at the

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input to the coaxial cable connected to the antenna. If the power transmitted from the source is P_T and the power reflected back to the source is P_R, then the return loss is given by P_R/P_T. For maximum power transfer, the return loss should be as small as possible. This means that the ratio should be as small as possible, or expressed in d B, the return loss should be as large a negative number as possible. For example a return loss of -40dB is better than one of -20dB.

The designed antenna resonates at 2.45GHz with return losses of -26 dB which is shown in figure3.1 and percentage BW is calculated as 8.17%

- *Bandwidth Calculation*

$$\%BW = \frac{f_2 - f_1}{f_r} \times 100\%$$

$$= \frac{2.4715 - 2.2709}{2.45} \times 100 = 8.17\%$$

Where f_1 and f_2 lower and upper frequencies

b) Voltage Standing Wave Ratio (VSWR)

The most common case for measuring and examining VSWR is when installing and tuning transmitting antennas. When a transmitter is connected to an antenna by a feed line, the impedance of the antenna and feed line must match exactly for maximum energy transfer from the feed line to the antenna to be possible. When an antenna and feed line do not have matching impedances, some of the electrical energy cannot be transferred from the feed line to the antenna. Ideally, VSWR must lie in the range of 1-2 which is achieved in figure 4.4 for the frequency 2.45 GHz, near the operating frequency value.

c) Radiation Pattern

The radiation pattern is a graphical depiction of the relative field strength transmitted from or received by the antenna. Antenna radiation patterns are taken at one frequency, one polarization, and one plane cut. The patterns are usually presented in polar or rectilinear form with a dB strength scale.

Since a Microstrip patch antenna radiates normal to its patch surface, the elevation pattern for $\theta = 0^o$ and $\theta = 90^o$ would be important. Figure 3.10 below shows the gain of the antenna at 2.45GHz for $\theta = 0^0$ and $\theta = 90^o$.

d) Input Impedance

We expect pure real impedance at frequencies where the patch resonates, that is, where the patch is designed to radiate. As a result, the input impedance plot in Fig 3.2 shows that around the desired radiating frequency, sufficient reactance cancellation can only occur inside a narrow bandwidth. In addition, one needs to match the resonant resistance with the characteristic impedance of the feed line. A small antenna can be tuned to resonate with an appropriate addition of reactance, or it can be made to self-resonate so that the reactance cancellation at resonance happens naturally in the antenna structure. Since adding external reactance for this purpose increases the power loss and it also requires extra space, it is advisable to follow the second alternative.

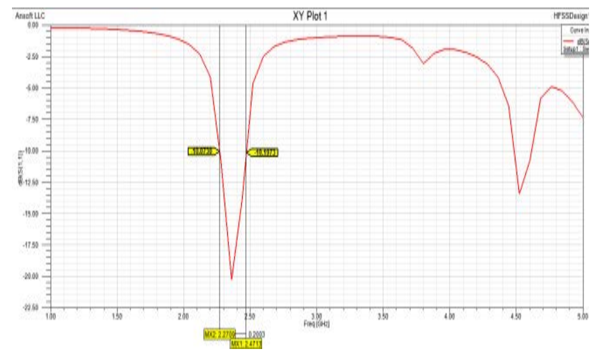

Figure 3.1 : Return loss

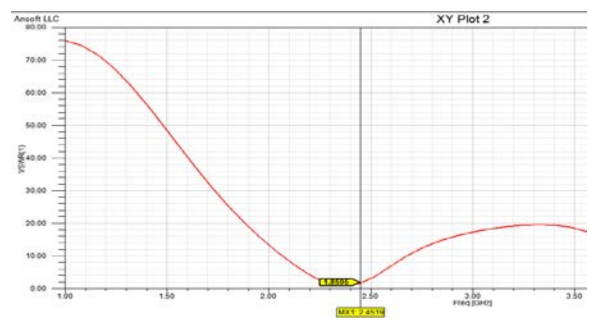

Figure 4.5 : VSWR plot

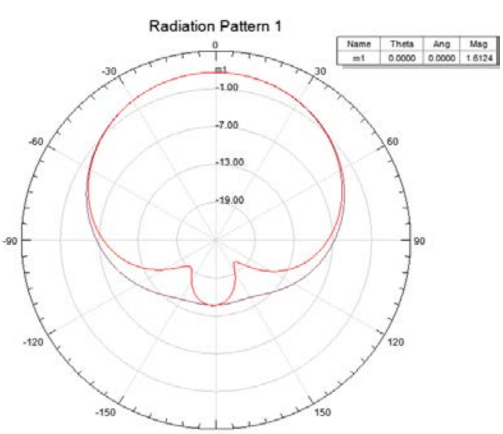

Figure 4.6 : Radiation Pattern

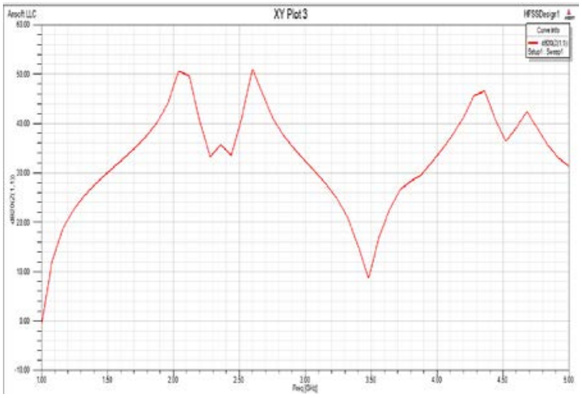

Figure 4.7 : Z-parameter

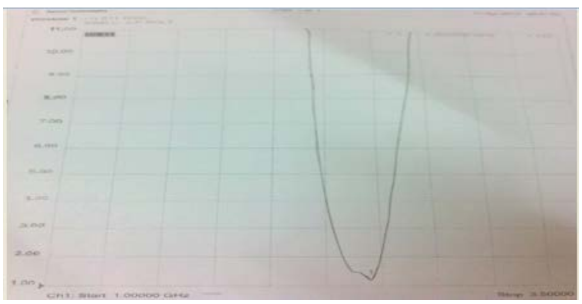

Figure 3.8 : Network Analyzer test result –VSWR Plot

e) Fabricated Antenna Results

The fabricated Proximity coupled RMSA with X-slot is tested with HP Make network analyser. From this test,The VSWR characteristics are obtained. The percenge Bandwidth from VSWR plot is calculated as 7.14% ,

- *Practical Bandwidth Calculation*

$$= \frac{2.5 - 2.325}{2.45} \times 100 = 7.14\%$$

f) BW Comparison

The percentage BWs of Proximity coupled RMSA with X-slot is compared, those values are calculated from HFSS simulation results and Network analyser test.Table 4.1shows comparison of % BW between the simulation and practical results.

Table 4.1 : Simulation & Practical Test Results

Results	**Rectangular MSA(Without X-Slot)**	**Proximity coupled fed Rectangular MSA with X-slot**
Simulation Results	5.68%	8.17%
Practical Results (Network Analyzer Test)	2.4%	7.14%

IV. Conclusion

Proximity coupling and X slot techniques are introduced for improving the BW of RMSA at 2.45GHz. The proposed design of RMSA has been simulated and practically tested with network analyzer. For proposed antenna design, BW of 8.17% is obtained from HFSS simulation, where as from network analyser test the BW of 7.14% is calculated .The bandwidth before adding the slot and the stacked patch was 2.5% whereas after adding the slot and the stacked patch the bandwidth increased. Thus the proposed design is useful for BW enhancement for RMSA, which is required for Wireless LAN applications.

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