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Quad Band U-Slot Microstrip Antenna for C, X and Ku Band Wireless Applications

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Abstract

The primary aim of this work is to design a quad band microstrip antenna with U slot that is able to transmit at a target frequencies spanning over C, X and Ku band. The proposed antenna design has a return loss below -22dB and voltage standing wave ratio (VSWR) value below 1.5 at all four resonant frequencies of 5.8GHz, 8.25GHz, 9.85GHz and 13.95GHz. Furthermore, the impedance of the proposed antenna varies closely around 50ohms at all resonant frequency which is a desirable feature for multiband operation. The bandwidth limits of the designed antenna at various resonant frequencies are found to be 5.2-5.5GHz, 7.7-8.5GHz, 9.75-10GHz and 13.75-14.10GHz. The efficiency calculated is high up to 95% compared to other design.

Keywords: VSWR, Quad band, patch antenna, U slot antenna, Radiation pattern, return loss, C band, Ku band

1. Introduction

Micro strip antennas find widespread use in many contemporary wireless communication devices, on account of its low profile structure, robustness and ease of fabrication in a pcb substrate [8, 9]. In majority of applications, microstrip antennas are operated at their fundamental mode to achieve a broadside radiation pattern. The 3dB bandwidth of standard micro strip antenna is quite narrow and found to be 3% of its resonant frequency. One of the popular methods to enhance the bandwidth of the micro strip antenna is to incorporate a U-slot on its metal patch layer as proposed in [2, 6]. However, the U-slot technique was studied only at the fundamental mode of the patch [2].

Ahmed Khidre et al., proposed a wideband dual-beam U-Slot microstrip antenna in which a coaxial-fed rectangular patch is printed over a RT Duroid substrate and a U-slot is cut on the patch's surface. The other side of the substrate is coated with metal, which is the ground plane of the antenna. The antenna has 11.3% bandwidth (5.17–5.81 GHz) and exhibit dual radiation beams and single resonant frequency of 2.4 GHz [9]. Realized gain of the forward beam is 7.92 dBi at the center frequency, whereas it is 5.94 dBi for the backward beam. The difference between both beam's maxima is less than 2 dBi across the entire bandwidth.

Amit Kumar Gupta et al., proposed a dual E-shaped antenna designed by cutting four notches in the rectangular shaped micro strip antenna [10]. It is observed that the antenna operates in three different frequency bands with bandwidths of 6.55%, 7.012% and 34.60% of resonant frequency. The bandwidth of the antenna is between 1 to 5 GHz with a gain of 6dBi.

2. Proposed Design

In this work, an analysis of U-slot patch antenna excited at the higher order mode is presented. The U-slot inclusion on the patch's surface introduces asymmetry, which affects the radiation characteristics, such as pattern symmetry, pattern stability and the direction of the beams. It should be noted that that optimization and parametric study are needed for the U-slot parameters to acquire a wide bandwidth.

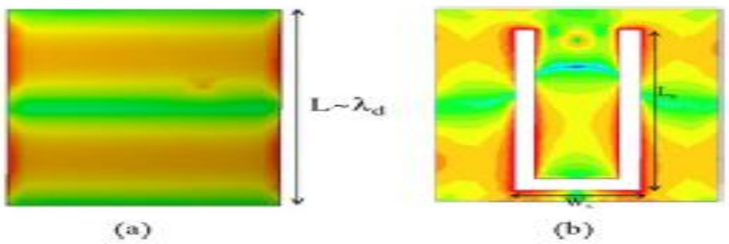

Figure 1: (a) a plain rectangular patch; (b) U-slot micro strip Patch antenna at the higher order

A. Geometry of U-Slot Microstrip Patch Antenna

The proposed antenna geometry is shown in below diagram, where a coaxial-fed rectangular patch is printed over a Rogers RT\ Duroid substrate of thickness h = 3.175 mm and permittivity Er = 2.2. A U-slot is cut on the patch's surface, which is mounted over the substrate of size L x W = 67x74 mm.

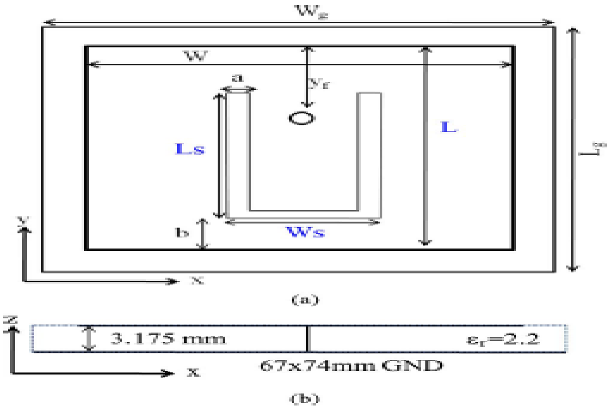

Figure 2: Geometry of the proposed U-slot micro strip antenna: (a) top view; (b) side view

The dimensions of the antenna that give a broad impedance bandwidth are listed in Table I, which are obtained via iterative process. Figure 2 and 3 shows the basic structure of proposed antenna with U-shaped slot etched on the patch layer in HFSS simulation environment.

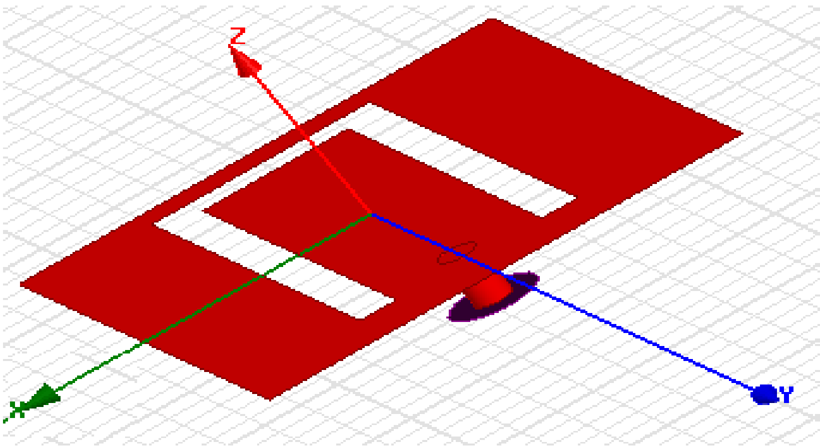

Figure 3: Etching U-Slot on the metal patch in HFSS

B. Parametric Study

The parameters that have critical influence on the antenna performance are: L, W, Ls and Ws. To study their effects on the antenna performance, parametric study is carried out on the parameters mentioned above, using the full wave simulator Ansoft HFSS. Final optimized parameter that represents the position of the U-slot on the rectangular patch which controls the separation between multiple resonances are given in table 1.

Table 1: Dimensions of Proposed U-Slot Microstrip Antenna.

Parameter	**L**	**W**	**Ls**	**Ws**	**a**	**b**	**yf**
Units (mm)	34	27	28.25	12	2	2	5.5

C. 3D Structure of proposed antenna

Figure 4 shows the U-slot micro strip patch antenna along with Rogers RT Duroid substrate of thickness h = 3.175 mm. The position and dimension of slot width determines the resonance frequencies of the structure.

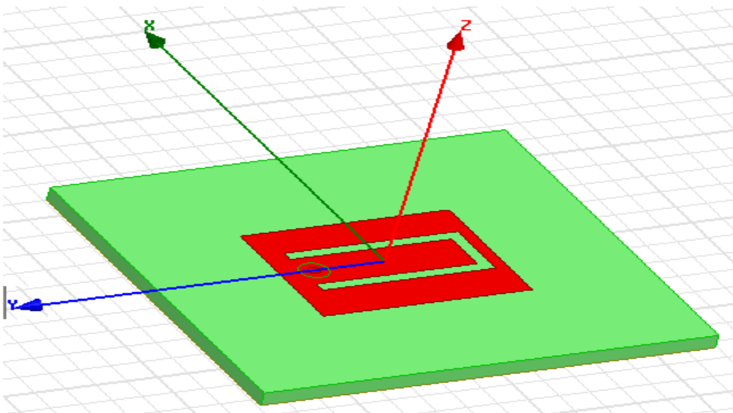

Figure 4: U-slot patch antenna with Base substrate

3. Performance Analysis

The proposed antenna structure is fed by a coaxial probe as it can be easily fabricated and has low spurious radiation. The performance of the proposed antenna is analyzed using HFSS 3D solver tool and the results are presented below.

A. Return loss

The return loss curve is obtained by plotting s11 of an antenna vs frequency of excitation. The frequency at which the return loss dips to a minimum value (below -15dB) is considered to be the resonant frequency of the antenna. This return loss value is taken to be the key performance parameter of this work and the antenna dimensions are optimized through several iterations to achieve a reflection coefficient of at least -20 dB at all the four resonant frequencies. Figure 5 shows the Frequency vs Return loss plot and also S_{11} value for frequencies 5.35GHz, 8.25GHz, 9.85GHz, and 13.95GHz respectively.

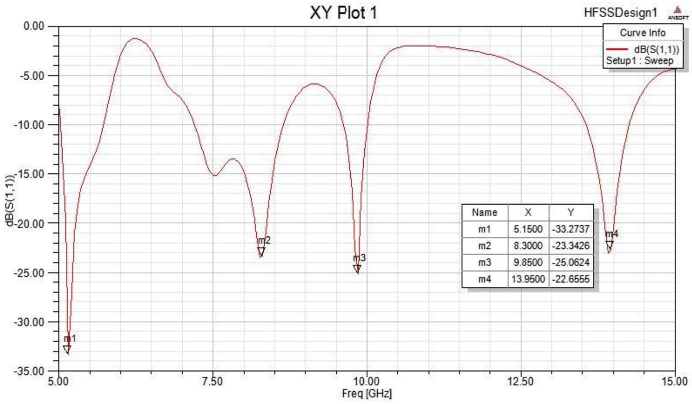

Figure 5: Return loss Vs Frequency

Bandwidth of an antenna is defined as the range of frequencies for which the VSWR value of the antenna remains lower than 1.2 or 1.3. Type and thickness of substrate material, dimension and shape of patch are few factors that determine the bandwidth of microstrip antennas the operating bandwidths can be easily obtained using the above graph and it turns out to be 5.2 - 5.5GHz, 7.7-8.75GHz, 9.75-10GHz and 13.15-14.10GHz. The bandwidth is often expressed in terms of fractional bandwidth (FWB) which is defined as the ratio of the difference frequency between -3dB points divided by the center frequency.

B. Frequency vs Impedance

A poorly matched antenna will not radiate power. This can be somewhat alleviated via impedance matching, although this doesn't always work over a sufficient bandwidth. But the proposed antenna has an impedance close to 50 ohms at all resonant frequencies eliminating the need for matching network. Figure 6 show that the impedance value of the antenna reaching around 50 ohms at resonant frequencies (5.8Ghz, 8.25Ghz, 9.85Ghz, 13.95Ghz) which is the optimum impedance requirement for typical RF applications.

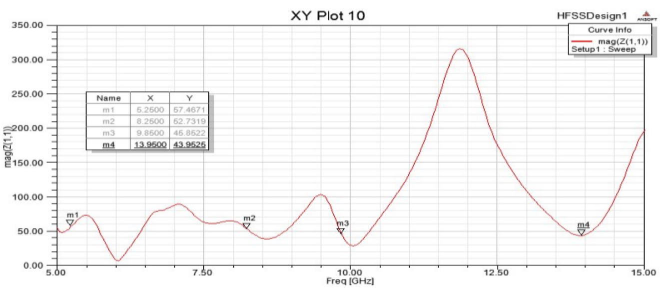

Figure 6: Impedance curve vs Frequency

C. 2D Radiation pattern of the proposed antenna

Radiation pattern of an antenna is usually obtained by measuring the received signal strength over various angular positions. This signal variation as a function of the arrival angle is observed in the antenna's far field region. Each angle is differentiated with various colors Figure 7 shows the rectangular radiation pattern obtained by plotting Theta(deg) against directive gain(dB) for first resonant frequency.

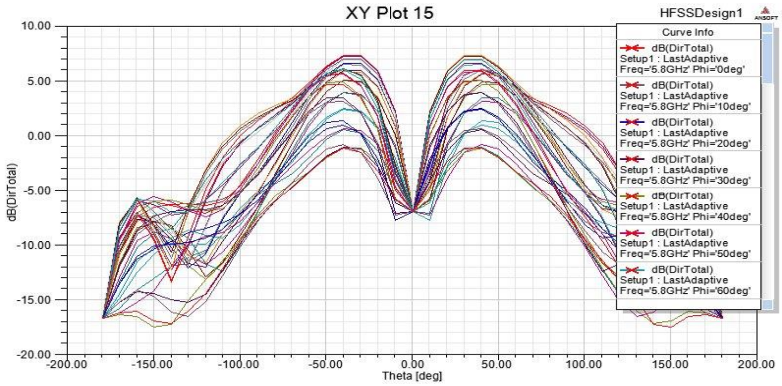

Figure 7: Radiation patterns of 5.8Ghz

Similarly figure 8, 9 and 10 shows the rectangular radiation pattern plotted at other resonant frequencies 8.25Ghz, 9.85Ghz, and 13.95Ghz respectively.

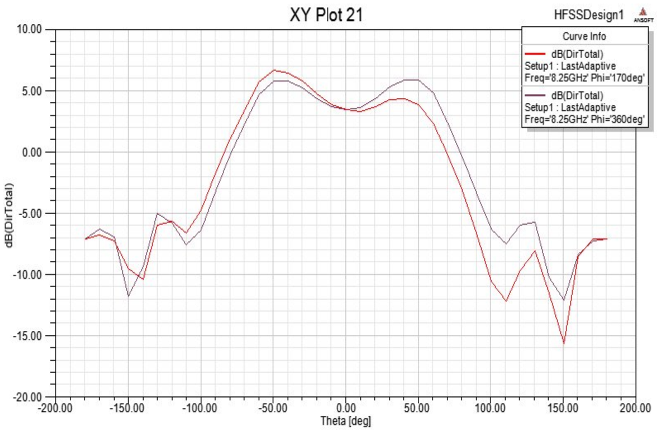

Figure 8: Radiation pattern at 8.25 GHz

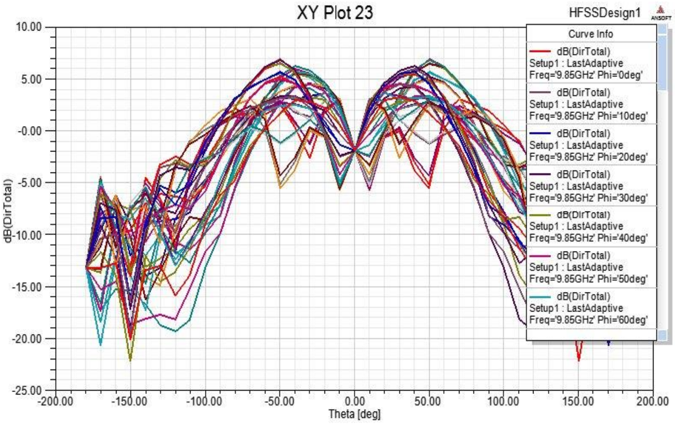

Figure 9: Radiation pattern at 8.25 GHz

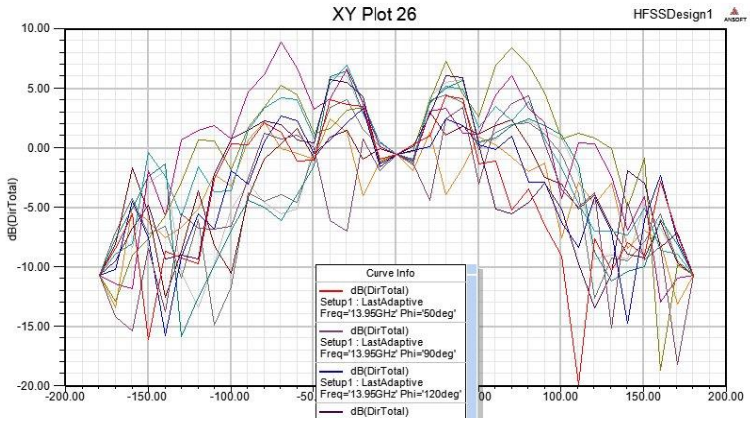

Figure 10: Radiation patterns at 13.95Ghz

D. 3D Radiation pattern

The three dimensional radiation pattern of an antenna is a plot of energy radiated per unit solid angle. 3D radiation pattern helps to analyze beam pattern of an antenna and is usually measured only at Fraunhofer's region. It is a key parameter as it shows the antenna's directivity as well as gain at various points in space and also beam width. Figure 11 shows the 3D radiation pattern along with antenna Gain. The maximum gain of the proposed antenna is observed to be 7dBi.

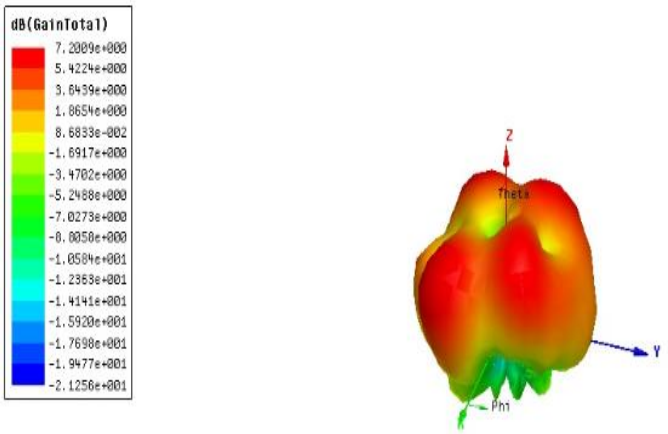

Figure 11: 3-D Radiation pattern of proposed antenna

4. Conclusion

In this paper, design and analysis of a quad band U-slot antenna is discussed. From the simulation results, it is found that the antenna provides a multiband resonance at 5.8GHz, 8.25GHz, 9.85GHz, 13.95GHz. The major performance improvement obtained in our work compared to other similar works found in the literature is that the proposed design has a return loss well below -22dB for all the four resonant bands. Hence it could be a better choice for multiband operations with lower radiation loss

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