A Compact UWB U-Shaped Slot MSA with B and Dispensation Characteristic for Communication

Mukesh Kumar and Rajesh Purohit

Abstract--- A compact and simple design of Ultra Wideband antenna with band dispensation characteristic is presented in this paper. The size of proposed antenna is 35 mm x 30 mm. The proposed antenna has wide frequency spectrum from 1.5 GHz to 10.9 GHz which covers the complete Ultra Wideband (UWB) range with VSWR less than 2, except for the frequency band 5.14 GHz-5.85 GHz which is allocated for IEEE802.11a WLAN (Wireless Local Area Network) systems. By etching a U-shaped slot and a line slot in rectangular radiating patch, the band rejection for WLAN is created to avoid interference. Parametric study of different shape has been carried out with HFSS simulation software. Simulated results of antenna such as return loss, VSWR, radiation pattern has satisfactory values within desired frequency band**.**

Keywords--- Ultra Wideband (UWB) Antenna, VSWR, Band-Notch Characteristic, U-Shaped Slot, WLAN (Wireless Local Area Network)

I. INTRODUCTION

Since the approval for commercial use of Ultra Wideband (UWB) ranging from 3.1 GHz – 10.6 GHz by the Federal Communications Commission (FCC), researchers interest moved towards development of compact UWB antennas both academic and industrial communities of telecommunication. Because of wide bandwidth, high speed data rate and excellent immunity to multipath interference of the UWB technology, it is used in the wireless communication, radar, remote sensing and imaging systems. The FCC allocated a bandwidth of 7.5GHz, i.e. from 3.1GHz to 10.6 GHz for UWB applications [1]. One of the key issues in UWB communication system is the design of a compact size and wide band antenna including the UWB performances with impedance matching, radiation stability and the low manufacturing cost for consumer electronics applications [2]. A conventional microstrip antenna exhibits the inherent drawback of narrow impedance bandwidth [3]. Numerous techniques have been developed to broaden the bandwidth of UWB antennas such as parasitic elements placed around the patch, aperture coupled patch, two stacked patch and use of thick substrate with low permittivity [4].

UWB antennas exhibits wide bandwidth ranging from 3.1 GHz to 10.6 GHz, a narrow frequency band of 5.15 GHz - 5.825 GHz has been reserved for IEEE802.11a WLAN system which causes interference with UWB systems. Therefore, a band stop filter would be required to reject this limited bandwidth but it will increase complexity and cost of UWB systems. Many UWB antennas have been attempted to overcome this problem using frequency band rejected function design to eliminate filters [5].

In this paper a simple and compact UWB antenna with band dispensation characteristic is proposed. The band-rejection operation is achieved by cutting a U-shaped slot and a line slot in the radiating patch. The antenna has operating bandwidth of 1.5 GHz -10.9 GHz with VSWR < 2, except the band of 5.14 GHz - 5.85 GHz for WLAN systems. The band rejection feature of antenna can minimize the interference between UWB system and WLAN system. In section II the antenna details are presented. The antenna parameters like return loss, VSWR,

Mukesh Kumar, Institute of Engineering, Jk Lakshmipat University, Jaipur
Rajesh Purohit, Institute of Engineering, Jk Lakshmipat University, Jaipur

radiation characteristics are analyzed using HFSS simulation software and results are discussed in section III. Also the parametric study of width and length of U-slot and patch is discussed. The concluding remarks presented in section IV.

II. ANTENNA DESIGN

In figure 1 a simple rectangular microstrip patch antenna is constructed with low cost FR4 epoxy dielectric substrate with relative permittivity ε_r = 4.4 and thickness h = 1.6 mm. The substrate has compact area of 35 mm x 30 mm. The radiator is fed with a microstrip feed line of 50 Ω characteristic impedance with 2.2 mm width. The various optimization parameters of antenna are W = 35 mm, W_1 = 11 mm, W_2 = 2.2 mm, L = 30 mm, L_1 = 10.5 mm, L_2 = 8.2 mm and L_3 = 6.5 mm. The antenna resonant at 3.5 GHz and 9.32 GHz. The proposed antenna provides bandwidth from 1.5 GHz to 10.9 GHz which covers the complete UWB but does not provide dispensation to reduce interference with WLAN systems. A U-shaped slot etched on the radiating patch as shown in figure 2 to create band dispensation for WLAN frequency range. The dimensions of slot are W_3 = 7 mm and L_4 = 6 mm with thickness of 0.5 mm. The presence of U-shaped slot on radiating patch creates a band dispensation which is nearly close to the frequency range of WLAN systems. For further improvement in band rejection range a line slot etched on radiating patch near to U-shaped slot as shown in figure 3 having length L_5 = 4 mm and W_4 = 0.75 mm. The final design parameters are also shown in tabular form in table 1.

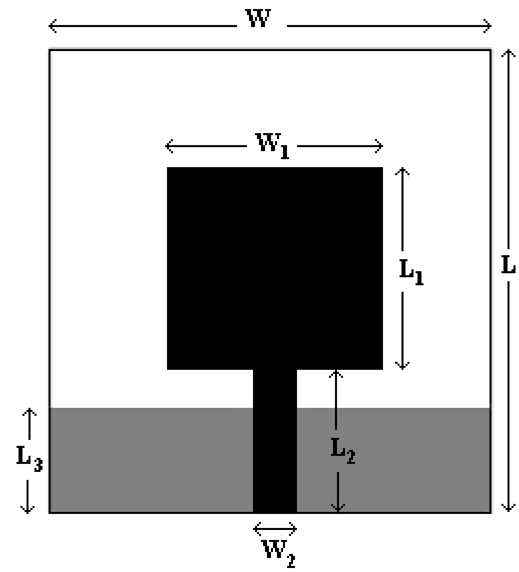

Fig. 1: Geometry of Rectangular Microstrip Patch Antenna

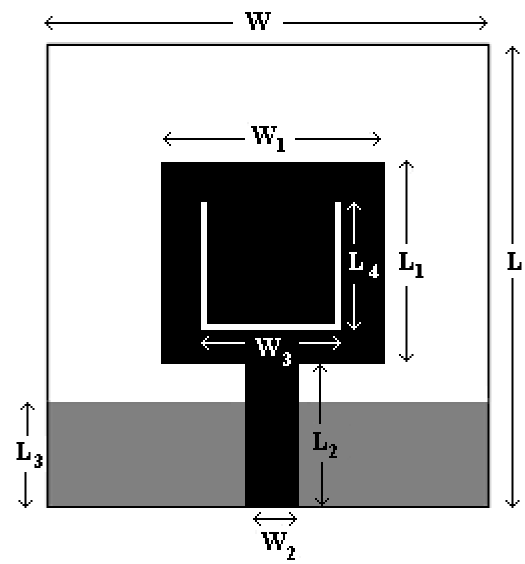

Fig.2: Geometry of Rectangular Patch Antenna with U-Shaped Slot

The final design shown in figure 3 resonates at two frequencies 4.01 GHz and 9.1 GHz which may vary by varying width of patch and gap between the patch and ground plane.

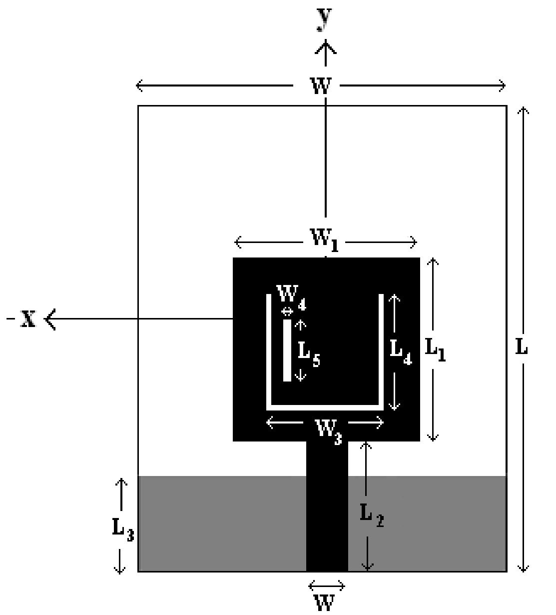

Fig. 3: Geometry of Rectangular Patch Antenna with U-Shaped and Line Slot

Table 1: Design Parameter of Final Antenna

Parameters	Dimensions (mm)
W	35
W_1	11
W_2	2.2
W_3	7
W_4	0.75
L	30
L_1	10.5
L_2	8.2
L_3	6.5
L_4	6
L_5	4
Thickness of U-slot	0.5

III. Parametric Study

The parameters such as ground length L_3, width W_4 of line slot and position of line slot are studied to see the influences on the performances of the antenna by using the software HFSS. The UWB frequency band can be controlled by proper selection of ground length L_3. It is seen that by embedding partial ground UWB characteristic is obtained. As we decrease L_3 from 30 mm to 6.5 mm a 1.5 GHz - 10.9 GHz UWB is achieved as shown in figure 4.

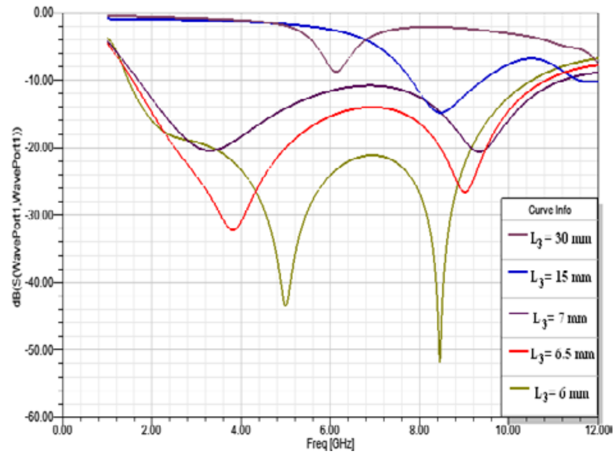

Fig. 4: Effect on Return Loss on Reducing L_3 without Slot

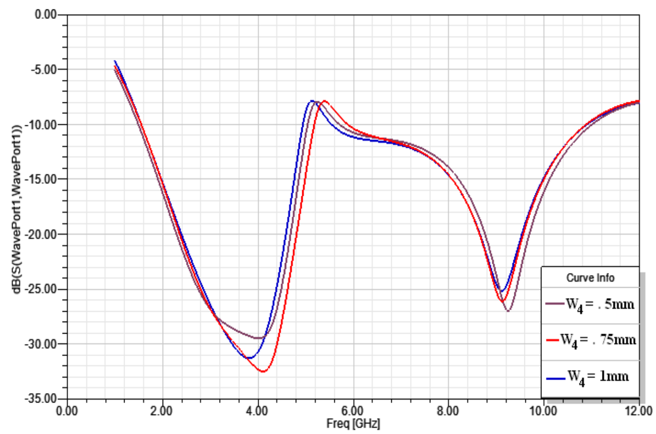

Fig. 5: Effect on Return Loss of Line Slot Width Variation

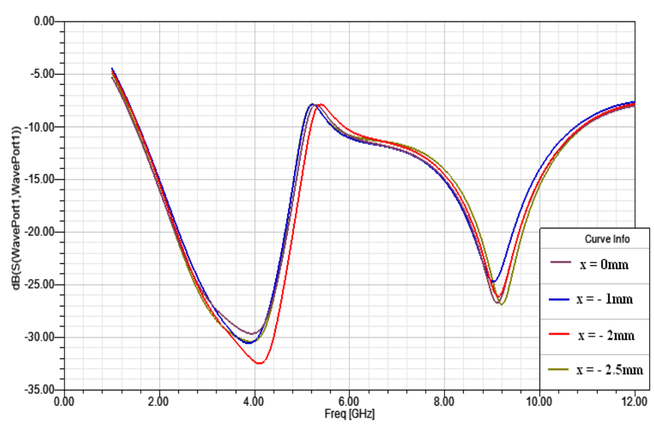

Fig. 6: Effect on Return Loss of Line Slot Position Variation

Figure 5 shows the antenna with different W_4 of the line slot width while the location of slot is fixed. As W_4 increases from 0.5 mm to 1 mm, the notched band of 5.14 GHz – 5.85 GHz is resulted with W_4 = 0.75 mm.

Figure 6 shows the return loss of the antenna with different line slot location as the width W_4 of slot is fixed. As the line slot moves in –x direction from 0 to -2 mm notch band of 5.14 GHz to 5.85 GHz is achieved.

IV. RESULTS

The performance of proposed antenna was optimized and simulated with aid of HFSS software. The simulated return loss of antenna without slot, with U-shaped slot and with U-shaped and line slot are compared in figure 7. First, the antenna without slot is satisfied with impedance bandwidth of UWB band 3.1 GHz - 10.6 GHz. The antenna has the notch band covered 5.01 GHz – 5.56 GHz with U-slot. In addition, the antenna with u-slot and line slot has an improved notch band of 5.14 GHz – 5.85 GHz. The proposed antenna has operating frequency range from 1.5 GHz to 10.9 GHz as shown in figure 7. The fractional bandwidth of antenna is 149.9%. Figure 8 shows VSWR of proposed antenna which is less than 2 for entire operating bandwidth except the range 5.14 GHz - 5.85 GHz. The antenna has excellent impedance matching at resonance frequencies 4.01 GHz and 9.1 GHz using microstrip line feed.

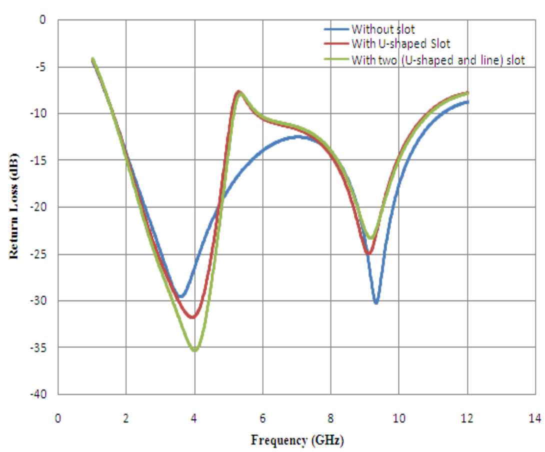

Fig.7: Return Loss of Antenna Without Slot, with U-Shaped and Line Slot

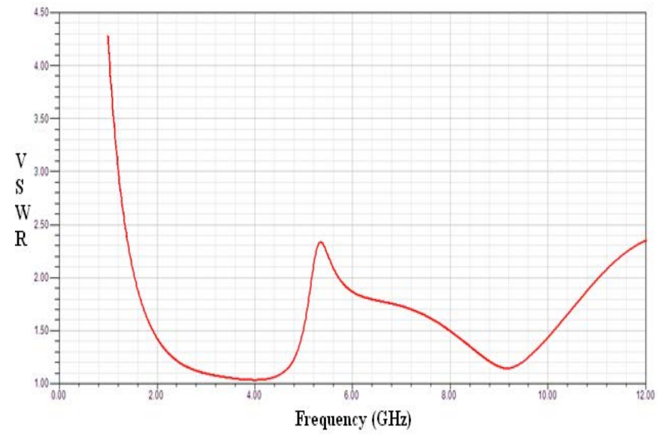

Fig. 8: VSWR vs. Frequency for Proposed Antenna

Far field radiation characteristics of antenna also studied. Figure 9 and 10 show simulated radiation patterns at two frequencies 4.01 GHz and 9.1 GHz. The radiation pattern looks like a dumbbell shaped structure. The radiation patterns of antenna have omni-directional property at both resonant frequencies. This also implies that a large and uniform coverage for UWB system operation can be attained with our design and can be used for broadcasting purpose.

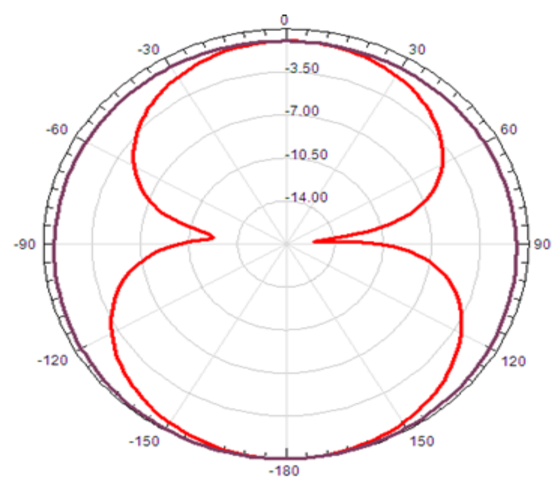

Fig. 9: Radiation Pattern at Resonance Frequency 4.01 GHz

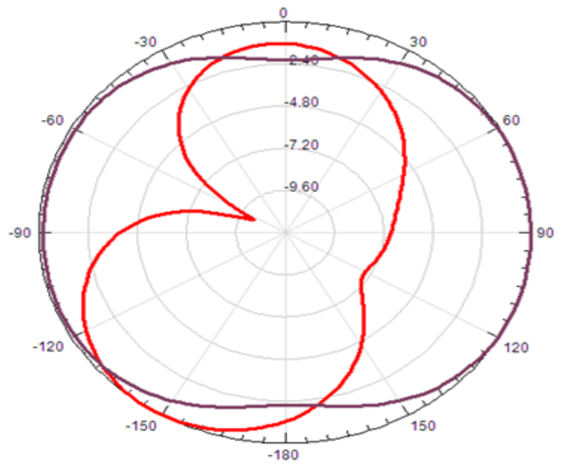

Fig. 10: Radiation Pattern at Resonance Frequency 9.1 GHz

Figure 11 shows the relation between $(f_{un}-f_{ln})/f_o$ (ratio of notch bandwidth to resonant frequency) i.e. frequency ratio, and x/λ (ratio of line slot position to guide wavelength). The graph is plotted by varying position of line slot keeping slot width and length constant at W_4 = 0.75 mm and L_5 = 4 mm respectively. The figure 12 shows the relation between the frequency ratio $(f_{un}-f_{ln})/f_o$ (ratio of notch bandwidth to resonant frequency) and W_4/λ (ratio of line slot width to guide wavelength). The graph is plotted by varying width of line slot keeping slot position and length constant at x = -2 mm and L_5 = 4 mm respectively.

When the position of line slot is changes from x = 0 to x = -2.5 mm keeping width constant, the frequency ratio first increases and then decreases. Similarly when width of line slot changes from W_4 = 0.5 mm to W_4 = 1 mm keeping position constant, the frequency ratio first increases and then decreases. From this analysis we conclude that when the position of line slot is changed with respect to centre of substrate or width of line slot is changed keeping position constant, gap between U-slot and line slot reduced. Due to reduction in gap between U-slot and line slot both figure 11 and 12 shows similar behavior.

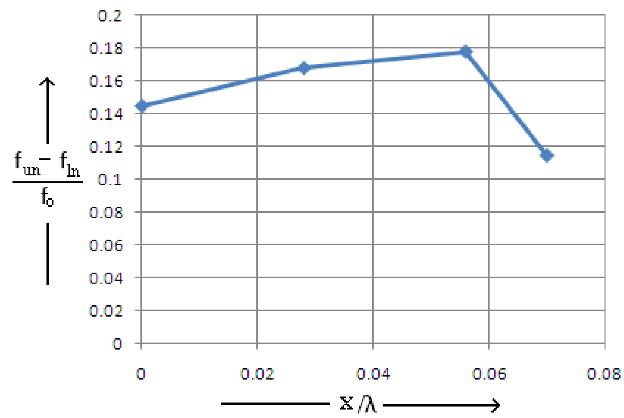

Fig. 11: Relation Between $(f_{un}-f_{ln})/f_o$ and x/λ

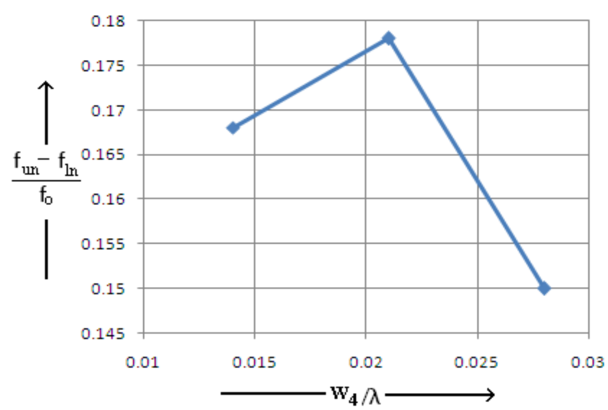

Fig. 12: Relation between $(f_{un}-f_{ln})/f_o$ and W_4/λ

V. CONCLUSION

In this paper, a compact UWB antenna having frequency band from 1.5 GHz - 10.9 GHz which covers the complete UWB range with frequency band dispensation from 5.14 GHz to 5.85 GHz is presented. To achieve band dispensation a U-shaped slot and a line slot plays an important role, avoiding interference at frequency range 5.14 GHz-5.85 GHz. The proposed antenna shows omni-directional radiation pattern. The VSWR and return loss of antenna has satisfactory values within operating frequency band. The antenna can be used for different applications under FCC rules and regulations, a band-stop characteristic introduced to antenna to prevent it from interference to IEEE802.11a WLAN (Wireless Local Area Network) system. The antenna can be used in weather radar systems, satellite communication systems etc.

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