A Reconfigurable Ultra-Wideband (UWB) Antenna with Single Band-Rejection

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***Abstract*—In this paper, a reconfigurable ultra-wideband (UWB) antenna with WLAN band-rejection is presented. The proposed antenna operates in the ultra-wideband frequency band from 2.99 – 10.82 GHz with band- rejection of 5.00 – 5.85 GHz. The structure of the antenna is simple octagon-shaped radiating patch and half ground plane with dimension of 30 x 40 mm^2. Bandstop elements (inverted U-shaped slot) are integrated into the structure of the antenna to achieve WLAN band-rejection. Band-rejection reconfigurable capability are achieved by placing RF switches at the slot. By configuring the switch in the ON and OFF modes, two reconfigurable states are realized which are WLAN band-rejection during ON states and full UWB frequency spectrum during off states. The proposed antenna shows a wide impedance bandwidth with sharp rejection at the WLAN band and provide multi-function antenna due to its reconfigurable characteristics. The performance was analyzed in terms of reflection loss, VSWR, gain and radiation pattern. Simulation and measurement result have achieved a good agreement.**

***Index Terms*—Band-rejection; Reconfigurable; Switch; Ultra-wideband (UWB).**

I. INTRODUCTION

Since 2002, US Federal Commission Communication (FCC) released unlicensed ultra-wideband (UWB) frequency spectrum from 3.1 – 10.6 GHz for commercial communication applications UWB antenna have received a lot of attentions. About 110% fractional bandwidth have been allocate for this system [1]. UWB technology offers numerous advantages such as high data rate transmission , compact size , low cost to manufacture and low power consumptions[2]. In particular, UWB antenna should be able to operate over an ultra-wideband frequency spectrum (3.1–10.6 GHz) and display a good radiation properties over entire band to fulfill requirement by FCC. To meet these requirement printed monopole antenna have been studied due to its wide impedance bandwidth, easy to fabricate and low profile [3-4].

However, several narrow band services coexist within the UWB spectrum which is wireless local-area network (WLAN) IEEE802.11a systems operating in 5.15-5.85 GHz. As a result, UWB system will be likely experience potential electromagnetic interference (EMI) with these narrowband systems. Therefore, to avoid or filter the interference UWB antenna needs to be integrated with bandstop element to introduced band-rejection at the desired frequency. Recently, UWB antenna with band-rejection functions have been studied and implemented by various methods; for examples, complementary split ring resonators (CSRRs) have been etched in the circular patch to generate band-rejection[5] inserting various shape into the antenna structure such ad J-shaped slot are loaded into the radiating patch [6]. Half-wavelength and a quarter wavelength slot are embedded in the ground plane of UWB slot antenna to obtain dual band notched[7]. In [8] capacitively-loaded loop resonators (CLL) are inserted near to the feed band to obtain band-rejection properties. However, most of the antenna are used only for UWB antenna band rejection. We need to redesign the antenna whenever we need antenna that can cover full cover frequency band from 3.1-10.6 GHz[9]. To overcome this problem, reconfigurable technique are apply to achieved multi-function antenna as in [2][9].

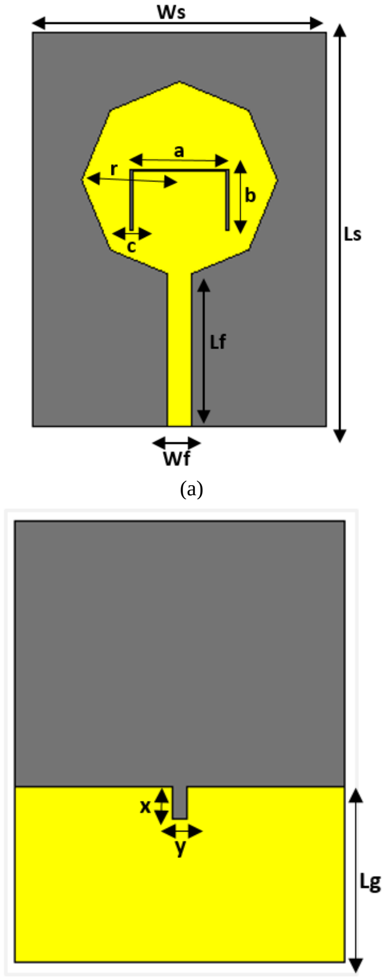
In this paper, an octagon-shaped patch with half ground are design to get UWB frequency spectrum with bandwidth of 113% from its center frequency. Then inverted U-shaped slot is etched in the radiating patch as bandstop element to generate WLAN (5.15 -5.85 GHz) band-rejection. The proposed antenna are simulated using CST Microwave Studio to get optimum value for the best performance. Then, antenna performance are verified by measurement.

II. ANTENNA CONFIGURATION

The geometry of the antenna is shown in the Figure 1. The antenna designed on the Rogers 5880 substrate with dielectric constant of 2.2, loss tangent of 0.00009 and thickness of 0.787mm.The overall dimension the antenna is 40 x 30 x 0.787 mm^3. The structure of the antenna consists of octagon-shape radiating patch, inverted U-Slot that etched on the radiating patch and partial ground plane. 50Ω microstrip feedline with dimension of L_f x W_f is used to fed the antenna. The radiating patch and partial ground plane are formed in the copper layer with dimension of r and length of L_g respectively. List of dimensions and parameters of the antenna is shown in the Table 1.

Table 1
Dimensions and parameters of the antenna

Parameter	Dimension(mm)	Parameter	Dimension(mm)
L_s	40	x	3
W_s	30	y	1.2
L_f	18	a	10
W_f	4.4	b	6
L_g	16	c	0.2



(a)

(b)

Figure 1: The configuration of the antenna (a) top view (b) bottom view

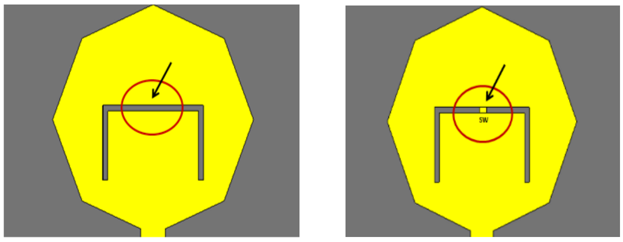
Inverted U-shaped slot in etched in the radiating patch to obtain band-rejection characteristics. Total length of the slot L_p= (a + b) that can be empirically predicted by the following formula [10] :

$$fnotch = \frac{c}{4Lp\sqrt{\frac{1+\varepsilon r}{2}}} \quad (1)$$

where: f_{notch} = Center frequency of the rejected band
c = Velocity of the light in free space
L_p = Length of the slot
εr = Dielectric constant

Center frequency, f_{notch} and impedance bandwidth of the rejected band can be controlled by altering dimension of the inverted U-shaped slot placed in the radiating patch. Interference will happen in the notched frequency band which is 5.1-5.85 GHz (WLAN band) by adjusting parameters of the inverted U-shaped slot that caused antenna to be non-responsive at the frequency.

To achieve reconfigurability an ideal switch (SW) is integrated into the antenna as shown in Figure 2. Small patches are used to represent the switch to alter and control the total length of the slot during the ON and OFF mode. Two reconfigurable states can be obtained by configuring the ON and OFF states. In this design antenna works as UWB antenna with band-rejection during ON mode while during OFF mode antenna will be function as fully cover UWB antenna frequency band[11].



(a) (b)

Figure 2: Switch integrated into the antenna (a) On mode (b) Off mode

III. SIMULATION AND MEASUREMENT RESULT

The structure of the UWB antenna with WLAN band-rejection have been optimized to achieve optimum result of WLAN band-rejection and good radiation pattern using EM simulation tool, CST Microwave Studio. After that, the antennas have been fabricated using LPKF machine.

Parameters and dimensions of the band-rejection element are optimized to achieve optimum result in rejecting WLAN band. Optimization analysis is crucial in order to avoid electromagnetic interference between narrow bands communication systems and UWB systems for a good performance and increasing the level of power of emission[12].

Figure 3 represent VSWR parametric result of different length of the slot (*a*) while maintaining the value of *b* = 6mm for WLAN band. Value of *a* have been used are 6mm, 8mm, 10mm and 12mm. As the length increase, band-rejection of the antenna is shifted from 6.30 – 6.96 GHz to 4.41 – 5.42 GHz. It show that the band is shifting from higher frequency to the lower frequency when the length of *a* is varied from 6mm to 12 mm. The optimum value of *a* from this parametric study is 10 mm because it has desired notch band from 5.00 – 5.85 GHz (WLAN band).

Figure 4 shows the effects of the different values of width inverted U-shaped slot(*c*) to the performance of the antenna. Values of c that have been are from 0.2 mm to 2.2 mm. It can be seen that increasing width of the slot will result broadening bandwidth of the rejected band.

During the optimization of parameter of band-rejection element it has been observed that bandwidth of the antenna is maintained from 2.99 – 10.82 GHz significantly.

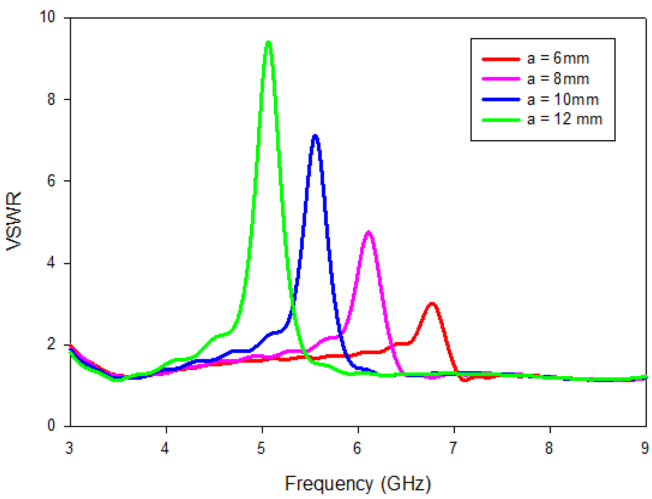


Figure 3: VSWR of the antenna with variation values of *a*

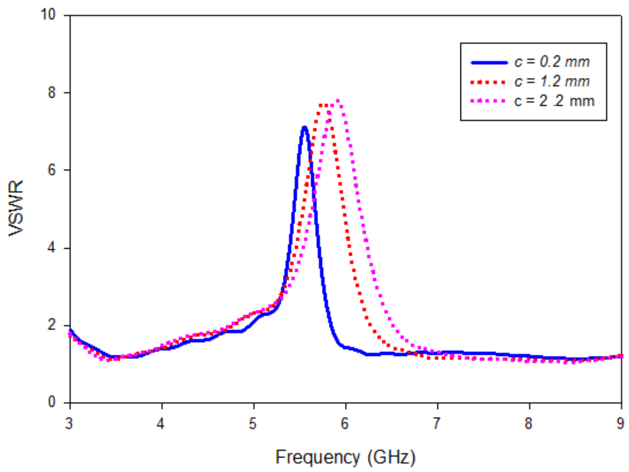


Figure 4 : VSWR of the antenna with variation values of *c*

Simulated and measured reflection loss of the antenna for different state of the switch are presented in the Figure 5 and 6. Reconfigurable technique is achieved by using an ideal switch which is represented as copper stripline which are same in the previous work [4-5]. Two reconfigurable states are achived by controlling the activation of the switch which are UWB with single band-rejection and full cover of UWB frequency band.

Band-rejection in the 5.00 – 5.85 GHz (WLAN band) are generated during ON states. During this mode we can see that S_{11} of the rejected band are above -10dB which means all signal are reflected back and return loss is really high at the WLAN band. During the OFF states UWB frequency band that allowed by FCC 3.07 – 10.77 GHz are operated.

The measured UWB frequency band are slightly shifted about 33 MHz to the higher frequency from the simulated result during ON mode.Meanwhile in the OFF states it can be seen that mesured UWB frequency band are shifted to the higher frequency compared to the simulation which is about 23 MHz with resonant frequency of 3.29 – 10.94 GHz. Despite of the frequency shifting for both states, both antenna are satisfied -10dB reflection coefficient to fulfill FCC condition for UWB applications with 3.32 – 11.24 GHz (ON mode) and 3.29 – 10.94 GHz (OFF mode).

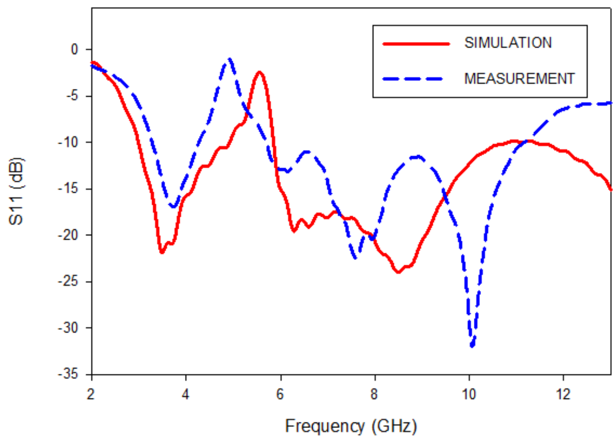


Figure 5 : S_{11} of the antenna during ON mode

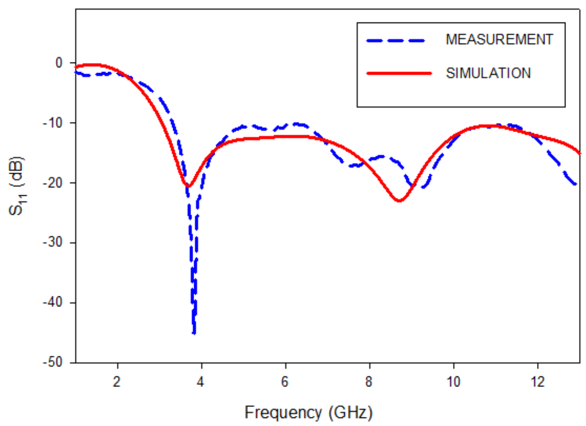


Figure 6 : S_{11} of the antenna during OFF mode

The gains of switchable dual-band antenna are represented in the Figure 7. From the figure it shows that the antenna has a variation of gain throughout the operating band. The gains of the antenna vary from the 2.26 to 5.76 dBi. At the band-rejection region during ON states gain of the antenna are lower compared to the gains during OFF states. It shows that during ON state signal are reflected back at that frequency.

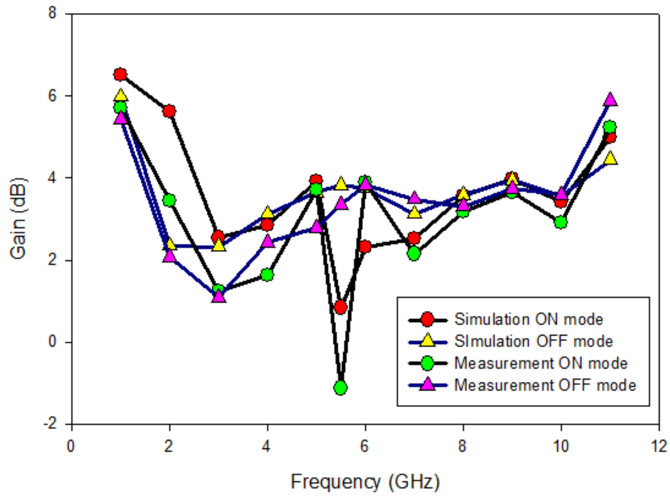
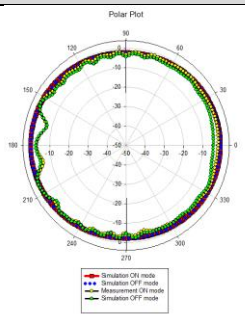
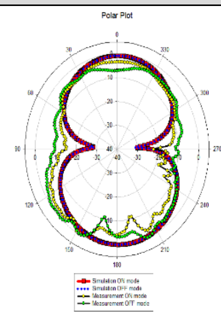
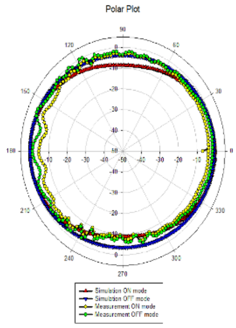
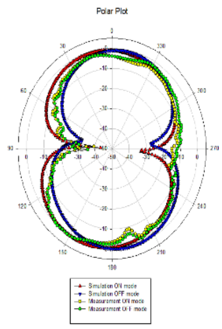
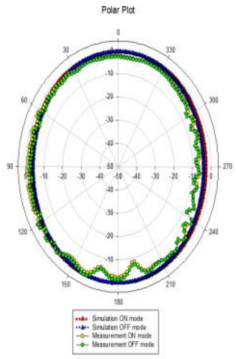
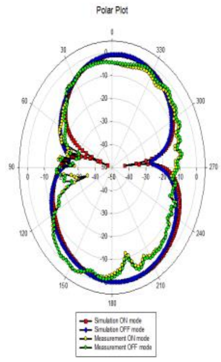
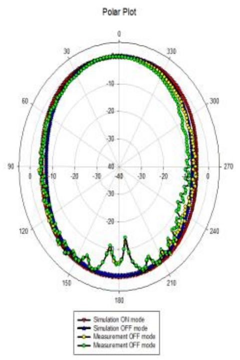
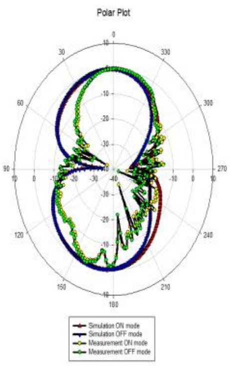


Figure 7: Simulated and measured antenna gain during ON and OFF mode

The simulated and measured radiation pattern in the Phi=90 (yz-plane) and Phi=0 (xz-plane) during the different mode of the switches are shown in Table 2 at three different frequencies which are 4GHz, 5.5GHz, 6GHz and 8GHz. It can be seen from the radiation pattern proposed antenna are radiated in the onmi-directional during ON and OFF mode.

Table 2
Radiation pattern of the proposed antenna

Frequency (GHz)	Phi = 0	Phi = 90
4		

Frequency (GHz)	Phi = 0	Phi = 90
5.5		
6		
8		

IV. CONCLUSION

A reconfigurable UWB antenna with WLAN band-rejection are presented in this paper. The antenna shows a good reflection loss within the UWB frequency spectrum are 3.32 – 11.24 GHz including WLAN band-rejection. Band-rejection are generated by inverted U-shaped slot etched in the radiating element. The performance antenna is then verified by experiment. Despite frequency shifting, simulated and measured result have met a good agreements. The antenna is radiated in omnidirectional during the ON and OFF mode. Proposed antenna is a good candidate for UWB multi-function communications applications.

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