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Controllable WLAN Band Rejection of Ultra Wideband Monopole Antenna Using PIN Diodes and Two C-Shaped Conductor

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ABSTRACT

In this paper, an ultra wideband circular printed monopole antenna is presented. The antenna performance will be studied using the two readymade software package IE3D and CST. The regular monopole antenna will be tuning by adding two C-shaped conductor near the antenna feeder to control the rejection band inside the WLAN frequency range (5.15-5.825GHz). The simulation results using the two software packages will be compared to each other. An empirical formula for the variation of the rejection band frequency against the mean length of C-shaped conductors is derived. The effect of the variation of the C-shaped conductor mean lengths on the center frequency of the rejection band will be discussed. The WLAN band rejection will be controlled by using two groups of PIN diodes. The circuit will designed on RT/Duriod substrate (ε_r=2.2, h=1.57 mm, $\tan\delta$ = 0.00019), where the simulations results using IE3D and CST are in good agreement with measurement results.

Keywords: Ultra wideband antenna, monopole, PIN diodes, WLAN, band Rejection, switchable

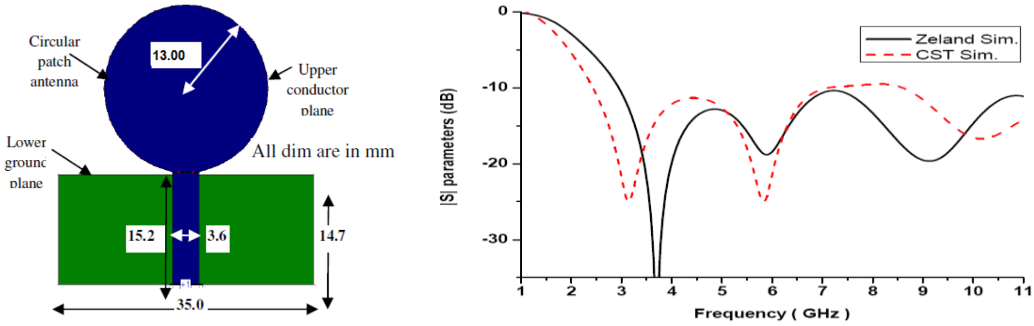
I. INTRODUCTION

The Ultra wideband antennas (UWBA) that operate in the frequency band 3.1–10.6 GHz have many challenges such as achieving wide bandwidth, reducing cost and size. This demand greatly attracted towards printed monopole antennas [1], due to their features such as; small size; low cost; light weight; simple structure; wide impedance bandwidth; easy fabrication; easy integration with other microstrip circuits, added to the gain and group delay that are expected to be constant [2, 3] over the operating bandwidth. There are many planar UWBA such as circular, square, triangular, and elliptical [4–8]; coplanar waveguide ultra wideband antenna (CPW-UWBA) and double sides printed antennas with a little higher gain [9-10]. The UWBA frequency range overlapped with lower and upper WLAN bands of 5.15–5.35 GHz and 5.725–5.825 GHz. Since the power level of these bands is about 70 dB higher than that of UWBA, so it causing signal distortion and loss of sensitivity. To avoid the potential interference, some UWBA antennas having a frequency band notch function were designed [11-14]. Some techniques have been recommended to achieve UWBA with band notch such as; loading a pair of symmetrical open-ended slits on the radiating patch [15-16]; inserting a pair of symmetrical parasitic strips [17]; embedding a $\lambda/4$ resonant circuit on the feed line [18]; use of U-slot in the circular monopole patch antenna [19] and use of radiating patch with W- and Π-shaped slot cut inside in the conductor sides [20]. In fact, the uses of a lot of slots on the antenna metal sides make some deviations especially on each of the antenna gain and the radiation pattern.

In this article, a circular monopole antenna that was previously described in [19] without U-slot will be used with adding dual C-shaped conductors near to the microstrip line feed. This construction will have less effect on both of antenna gain and radiation pattern. The variation of the C-shaped conductor length can be controlled with using two groups of PIN diodes [21]. The rejection frequency band can be controlled with the ON/OFF states of these PIN diodes.

II. CIRCULAR MONOPOLE ULTRA WIDEBAND ANTENNA

A circular monopole UWBA is designed on RT/Duriod (ε_r=2.2, h=1.57 mm, $\tan\delta$=0.00019); which is based on previous work of one of the author [19]. The circular antenna radius is 13.0 mm, while the partial ground plane is 14.9x35.0 mm and the microstrip feed line is 3.6 mm, Fig.1 (a). The antenna was simulated using the IE3D and the CST readymade software packages; where the antenna return loss (S_{11}<-10dB) overall the operating band for both simulators, Fig.1 (b). The deviation between performances of both simulators is due to different numerical techniques that the simulator based on it, which are method of moment (MoM) and finite difference time domain (FDTD), respectively. The CST simulator is the suitable especially for big structures. The difference in performance appears especially at the low frequency, where the number/wavelength ratio is smaller.



(a) (b)

Fig. 1: The monopole circular UWBA antenna and its response

The antenna achieves an ultra-wide band that extends from 2.23-11 GHz for IE3D software and from 3.1-11GHz for CST software package. Figure 2 illustrates the current density distribution, where the radiation is happened around the circumference edges of the circular monopole antenna and also around the edges of the antenna feeder and the edges of the partial ground plane.

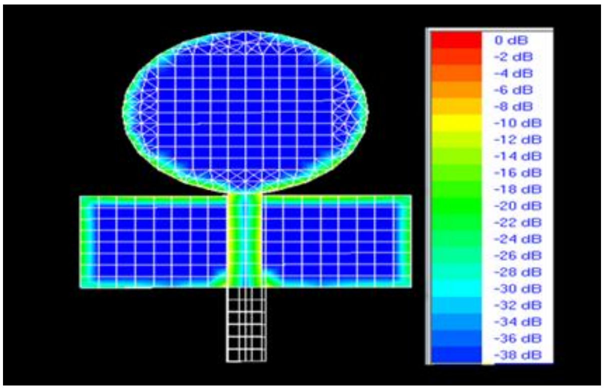


Fig. 2: The current density distribution of the monopole UWBA antenna

III. CIRCULAR MONOPOLE ULTRA WIDEBAND ANTENNA WITH REJECTION BAND

The above antenna is used and a two additional C-shaped conductor with specified length is added near to the antenna feeder on the upper layer above the partial ground plane to control the rejection for the WLAN applications; Fig.3. It found that; the frequency of the band rejection is inversely proportional to the length of the C-shaped conductors, Fig.4. As the C-shaped conductor mean length varied from 23 to 20 mm, the notch frequency will be varied from 5.15-5.84 GHz which covers the WLAN frequency band (5.15-5.825GHz), Fig.4. Figure 5 illustrates the variation of the rejection frequency against the variations of C-shaped conductor mean length.

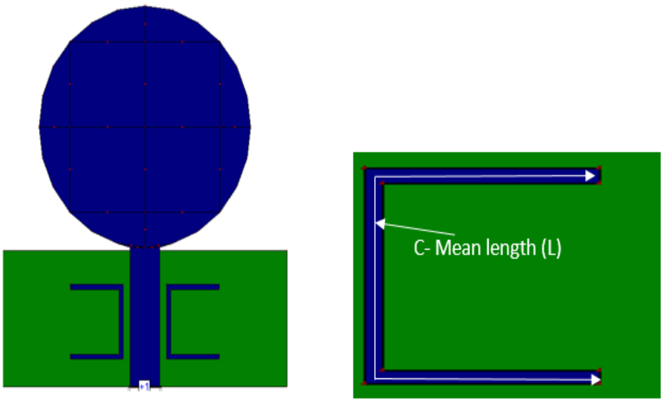


Fig.3: The UWBA antenna with rejection band using two C-shaped conductor

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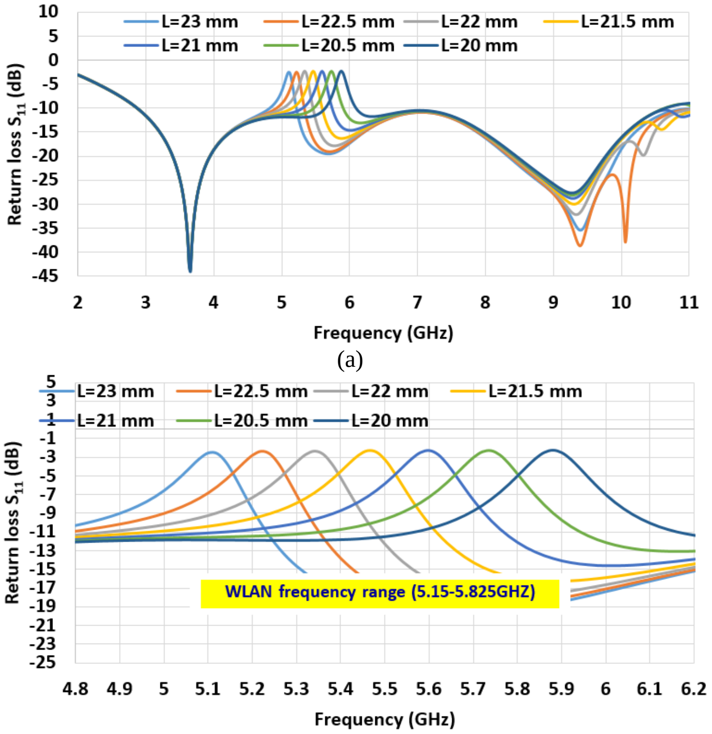


(a)

(b)

Fig.4: The Variation of the return loss of antenna for different values of C-shaped conductor

The variations of the rejection frequency against the C-shaped conductor mean length is converted with the help of Excel software to an imperial formula based on polynomial equation of second order as:

$$F_{notch} = 13.673 - 0.5039 * L + 0.0057 * L^2 \qquad (1)$$

Where F in GHz represents the frequency of the rejection band and L in mm is corresponding to C-shaped conductor mean length.

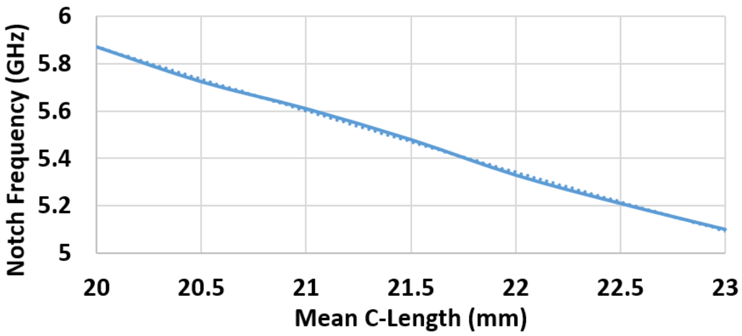
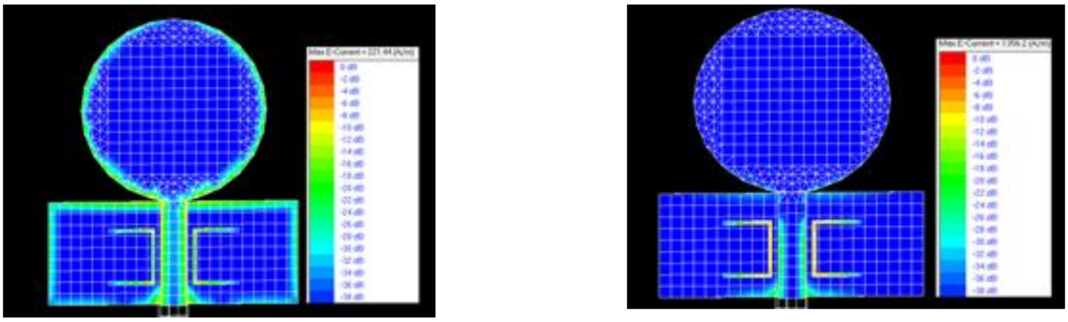


Fig. 5: The variation of the rejection band frequency against the C-shaped conductor mean length (mm)

The effect of the C-shaped conductor on the current density distribution for the modified antenna is given for two frequencies inside and far from the rejection band. So the current distribution for a frequency of F = 5.0 GHz which is outside the rejection frequency band is shown in Fig.6 (a), where; the current is mainly distributed around the circular edge of the antenna and around the edges of the C-shaped conductors as happened in the regular monopole antenna, previously shown in Fig.2. At the frequency, F = 5.87 GHz; which is inside the rejection band, the current is distributed around the edges of the C-shaped conductors only and nearly no current has been distributed around the edges of the circular monopole patch antenna, so the monopole antenna have no radiation at this frequency which means it have a good rejection band, that will not interfered with the WLAN frequency band range (5.15-5.825GHz).

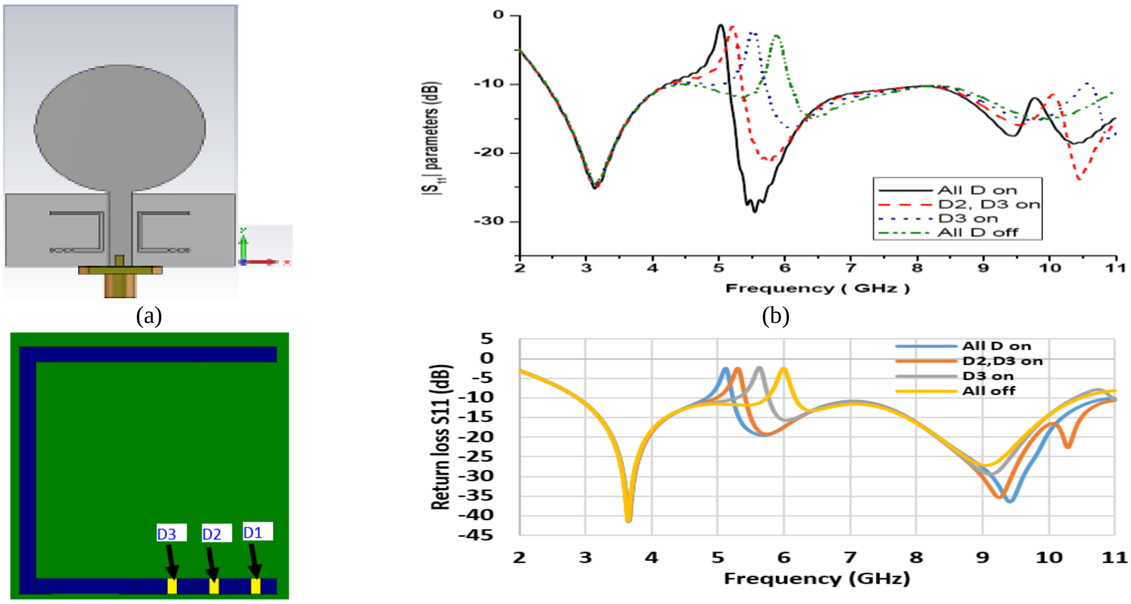


(a) (b)

Fig. 6: The currents density distribution at (a) F= 5.0 GHz, (b) F=5.87

IV. MEAN LENGTH VARIATIONS USING THREE PIN DIODES

Two groups, each of three PIN diodes D3, D2 and D1 are used to control the variation of the C-shaped conductors mean length. The mean length of the C-shaped conductors can be controlled using the ON/OFF states of the PIN diodes. Figure 7 illustrate such variation using the IE3D and CST readymade software packages. Table 1 illustrate the different states for the diodes groups and the corresponding notch frequency and also the value of the return loss at this frequency which is less than -3dB for all cases. The deviation between the two simulators for the notch frequency is due to the different numerical analysis which is the simulators is based on it.



(a) (b)

(c) (d)

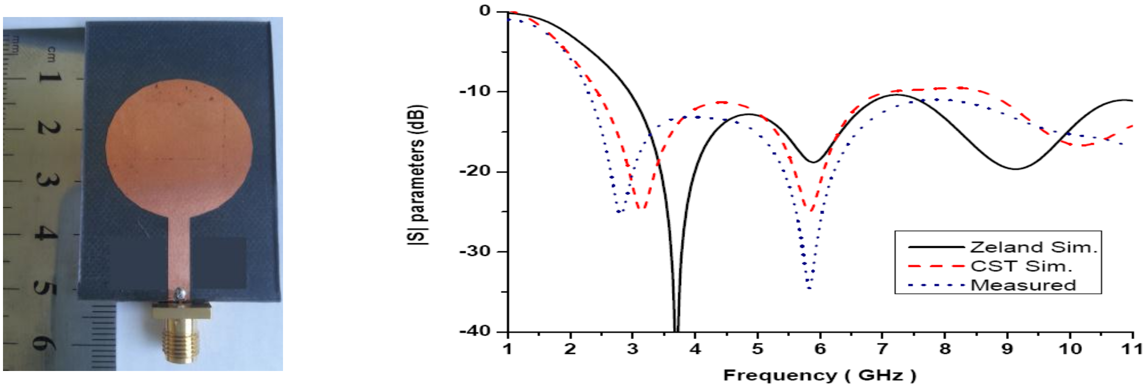
Fig.7: The PIN diodes positions and it's ON/OFF state effect on the notch frequency for the IE3D and CST software packages

Table 1: Diodes group ON/OFF states and its corresponding notch frequency

D1 group	D2 group	D3 group	IE3D Zeland		CST	
			F_{notch} (GHz)	$\|S_{11}\|$ (dB)	F_{notch} (GHz)	$\|S_{11}\|$ (dB)
Off	Off	Off	5.98	-2.41	5.88	-2.86
Off	Off	On	5.62	-2.26	5.52	-2.18
Off	On	On	5.30	-2.32	5.21	-1.59
On	On	On	5.12	-2.45	5.03	-1.28

V. EXPERIMENTAL RESULTS AND DISCUSSION

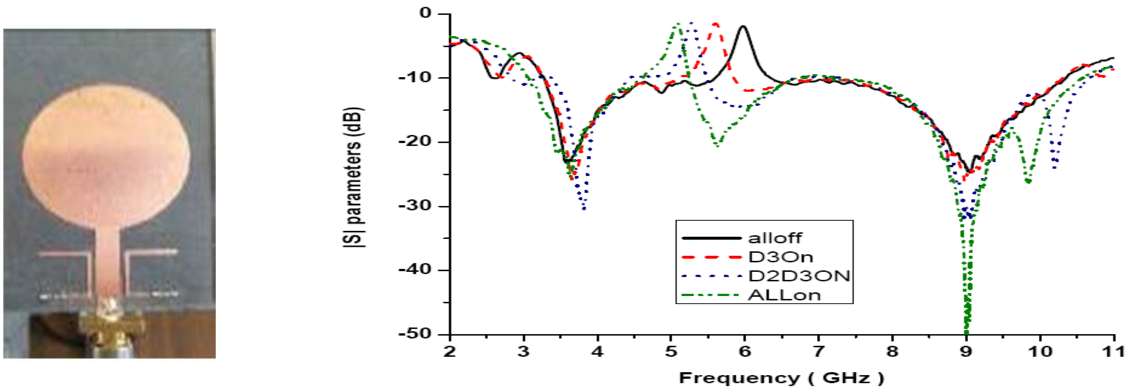
To verify the concept that was described above, two microstrip antennas were fabricated on Roger RT/Duriod 5880 substrate (ε_r=2.2, h=1.57 mm, tanδ = 0.00019) using thin-film technology and photolithographic technique. The measuring results were obtained using Agilent N9918A Vector Network Analyzer at Electronics Research Institute. The measured and simulated return loss (S_{11}) for the regular monopole antenna is shown in Fig. 8, where it is less than -10dB overall the ultra-wideband frequency range (3.1GHz-10.6GHz).



(a) (b)

Fig. 8: (a) The circular UWBA antenna (b) Comparison between the measured and simulation results.

The photo of the realized modified monopole antenna by adding C-shaped conductors and PIN diodes is shown in Fig. 9. The effect of the ON/OFF states of the PIN diodes on the antenna return loss (S_{11}) is shown in Fig.10, where the rejection frequency is moved according to the diodes states. The data is summarized in Table 2. Good agreement is observed between the measured and the simulation results with little variation which is attributed to the tolerance in fabrication and mismatching in soldering of PIN diodes and SMA Connectors. The variations between the IE3D and CST simulators results with the realized monopole antenna with C-shaped conductors' results are not exceed 90 MHZ for the locations of the rejection frequency inside the WLAN band.



(a) (b)

Fig. 9: The measured results of PIN diodes positions and it's ON/OFF cases effect on the notch frequency.

Table 2: Diodes group ON/OFF states and its corresponding measured notch frequency

D1 group	D2 group	D3 group	Measurements	
			F_{notch} (GHz)	$\|S_{11}\|$ (dB)
Off	Off	Off	5.97	-1.85
Off	Off	On	5.6	-1.43
Off	On	On	5.27	-1.35
On	On	On	5.08	-1.37

VI. CONCLUSION

A regular circular monopole antenna is used to achieve the ultra-wide band antenna with rejection band by adding two C-shaped conductors beside the antenna feeder on the upper plane. The effect the C-shaped conductors mean lengths on the rejection band frequencies inside the WLAN band is studied. A two readymade software packages IE3D and CST were used to verify the antenna performance. The current distribution for both the regular antenna and the modified antenna with rejection band is given. It is found that, as the C-shaped conductor mean length varied as the rejection band frequency can be controlled especially in the WLAN frequency (5.15-5.84GHz). The WLAN band rejection was controlled by using two groups of PIN diodes where each group is consisted of a there diodes D3, D2, D1. Both the regular and the modified ultra-wide band antenna are designed on RT/Duriod substrate (ε_r=2.2, h=1.57 mm, tanδ = 0.00019). It is found by controlling the ON/OFF states of the PIN diode, the rejection band can be controlled especially in the WLAN band frequency range. Both of the two antennas are fabricated, the PIN diodes are soldered, and then both antennas were measured. The measured results are in good agreement with the simulated results with a little deviation in the WLAN band which attributed to tolerance in fabrication and mismatching in soldering of PIN-diodes and SMA connectors.

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