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Controllable Band-Notched UWB Printed Monopole Antenna

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Abstract: A compact ultra-wideband (UWB) antenna with an electronically tunable notched band is proposed for UWB communication applications. The antenna consists of radiating patch, a combination of three circular patches, and a partial ground structure. Moreover, the proposed antenna has a compact volume of 25 mm × 27mm × 0.787 mm realized on a FR4 substrate with a relative dielectric constant of 4.5. The antenna design and the simulation results for radiation pattern and gain are discussed in detail. To obtain reconfigurable notch band, the ring-shaped slot structure was connected with a Varactor diode that have a capacitance varied from 0.63 to 2.67 pF, which achieve a continuous tuning notched band from 5.8 to 8.4 GHz. The frequency characteristics and radiation performance of the proposed antenna are successfully optimized with numerical experimentation techniques using 3D full-wave electromagnetic simulator CST 2014 and Ansoft HFSS that using three dimensional finite difference time domain (FDTD) method and finite integral method (FIM) for verification purposes. The antenna was realized and its performance was measured and compared with the simulated results. Good agreements between the simulated and the measured results are found.
Keywords— UWB antenna, band notched, Patch antenna, Partial ground plane, CST and HFSS

I. Introduction

Recently, a lot of articles have been devoted to the development of the ultra-wide-band (UWB) technology that transmits very low energy levels broadband pulses allowing for short-range high-bandwidth communications and considered to bring a leap in wireless communication technology. Many coplanar waveguide-fed and microstrip-fed antennas have been proposed for UWB applications [1-6]. However, over the designated UWB frequency band, there exist some narrow bands for other communication systems, such as WiMAX (3.3 to 3.6 GHz) and WLAN (5.15 to 5.5825 GHz), which may cause electromagnetic interference with the UWB systems. To overcome problem, UWB antennas with good band rejection performance are desirable. The widely used methods are etching slots on the patch or on the ground plane, such as straight, triangular, C-shaped, H-shaped, U-shaped, and pie-shaped slot [2]-[8]. Another way can be done by added a parasitic elements near the printed monopole which work as filters to reject the limited band or introducing a parasitic open-circuit element, rather than modifying the structure of the antenna like RF PIN diodes [9][10], RF Varactor diode [11] and RF MEMS [6]. High data rate pulsed communication at power levels below the noise floor and co-existence with other communication systems are the key features of the UWB operations. In the recent articles, UWB is supposed to show its mark in places such as portable devices, wireless USB, BAN, Microwave Imaging etc.

In this paper, we propose a new structure of microstrip UWB antenna operating in the frequency range of 3.8 GHz to 15.8 GHz. The structure is simple when compared with available ultra wideband antenna. To obtain the reconfigurable notch band, the ring-shaped slot structure with several switches is added into the patch. Effect of several antenna design parameters on each of the input impedance and the radiation performance are discussed. As an example, the UWB antenna with controllable notch-band extend from 5.25GHz to 6.25GHz is realized and measured. This frequency range is suitable for WLAN applications. Simulations were performed by using CST 2014 Microwave Studio package [12] and HFSS [13]. Both of the monopole patch antenna and that with ring-slot are fabricated using the thinfilm technology and photolithographic techniques in the microstrip Laboratory at the Electronics Research Institute. Their performances were measured using the vector network analyser (Agilent 8719ES).

II. Antenna Design and Discussion

The ultra-wideband monopole antenna that consists of three circular patch integrated with microstrip line fed, while the conductor in the ground plane under the antenna was etched partially is shown in Fig.1 (a). The antenna was realized on the low cost FR4-Epoxy substrate with dielectric constant of 4.5, height of 0.787 mm, and loss tangent of 0.02. With some trials using the CST 2014 simulator, the dimensions were obtained, the notch band can be obtained by a ring-shaped slot on the antenna patch, as shown in Fig. 1. (b). The gray part indicates the partial ground of the antenna and the black part depicts the patch of the antenna and the feed line connected to it. The antenna size in x-y plane is 27.0 mm x 25.0 mm. In this design, three circular patches are combined to form a one patch which is fed by a microstrip line printed on a partial grounded substrate. For this proposed model, the optimization was carried out to achieve good impedance bandwidth.

The proposed antenna model is simulated through the CST Microwave Studio simulator in order to evaluate its performance. A study has been performed for antenna parameters (such as disk radius, slots width, etc.) to find its optimum values. This analysis is done by varying one parameter while maintaining other parameters constant. The impedance matching of the proposed antenna is enhanced by correctly adjusting the dimension of the feeding structure and the patch size. A partial rectangular ground plane that used creates a capacitive load that neutralizes the inductive nature of the patch

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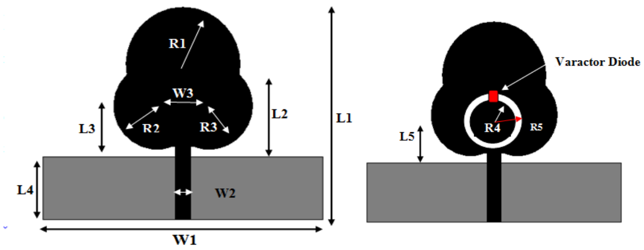
to produce nearly pure resistive input impedance and resulting in bandwidth enhancement.



(a) (b)

Fig. 1 Antenna model, (a) conventional UWB antenna (b) notch-band UWB antenna.

III. Optimized Parameters and Simulation Results

The proposed planar monopole antenna is designed and analyzed using the readymade software package CST and HFSS [21], to solve the electromagnetic wave equations in each of time and frequency domains. Waveguide port is assigned to microstrip feed line for excitation of the antenna. The antenna performance parameters such as gain (E- and H-plane), scatter parameter, return-loss, VSWR and surface electric fields are evaluated using open add space boundary conditions and transient solver

A. The Effect of Radius of Greater Circle (R1)

Fig. 2 shows the simulated return loss S11 of the antenna for different values of R1 while other parameters are fixed. When R1 equal to 5.5 mm, it can ameliorate the return loss up to 10 GHz.

B. The Effect of Radius of Two Smaller Circles (R2)

The radius (R2) of two smaller circles has an important effect on the impedance bandwidth as shown in Fig.3. When R2= 4 mm, it creates more intense resonances and generally decreases the return loss level.

C. The effect of Length of Partial Ground (L4)

The effect of the length of the partial ground (L4) is shown in Fig. 4 while other parameters are fixed. This length have an effect in the frequency ranges below 16 GHz.

D. The Design for Optimized Parameters

The dimensions of the ultra wideband antenna using the optimized parameters are shown in Table 1, where the overall antenna dimension is 27 mm x 25 mm. while the VSWR for this antenna using CST and HFSS is shown in Fig.5.

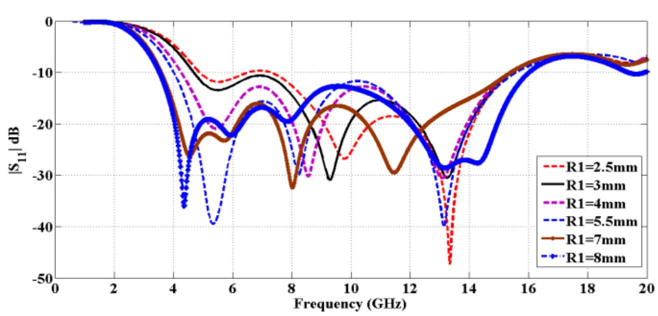


Fig.2 The antenna return loss versus frequency for different values of radius R1

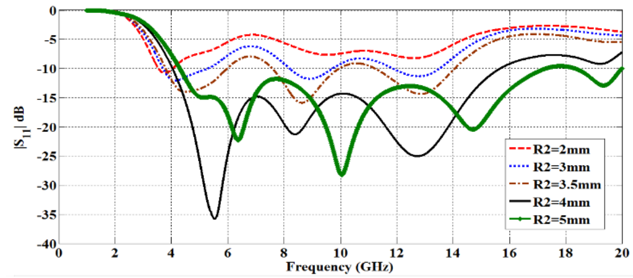


Fig. 3 The antenna return loss versus frequency for different values of radius R2 when (R1=5.5mm).

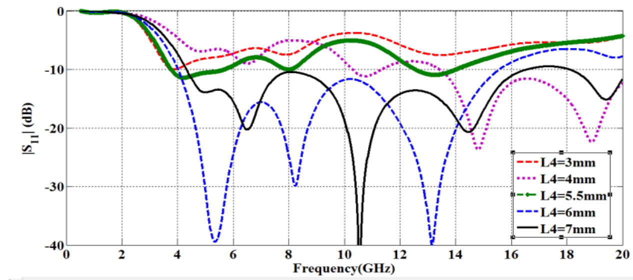


Fig. 4 The antenna return loss versus frequency for different values of length L4.

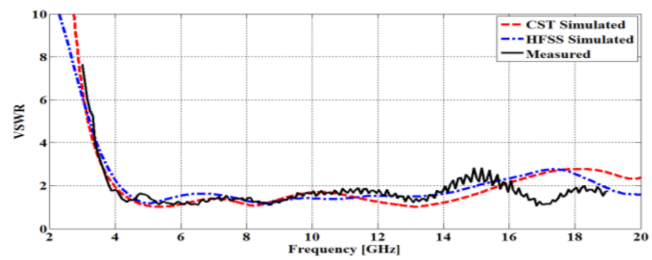


Fig. 5 The antenna VSWR for CST, HFSS and measured

Table 1 Optimized dimensions (in mm) of antenna

W_1	W_2	W_3	L_1	L_2	L_3	L_4	L_5	R_1	R_2
27	1.5	11	2.5	1	0.15	6.1	4.6	5.5	4.1
R_3	R_4	R_5							
4.1	2.7	3.1							

E. *Reflection Coefficient*

The photo of the realized antenna is shown in Fig.6. The comparison between the simulated and measured results of S11 is given in Fig.7, where the return loss (S11) is less than -10dB in the frequency band from 4.5 up to 15.7GHz which give more ultra wideband performance *The VSWR in that band was very good due* to the straight slits especially when the slits were bent, Fig.7.

IV. Implementation of Notched-band

The ultra wideband antennas are essential element in wireless communication system, but due to the interference with other communications systems operated in that band (WiMAX, WLAN, etc.), the UWB antenna with rejection band is preferred. The band-notch antenna can be produced through some

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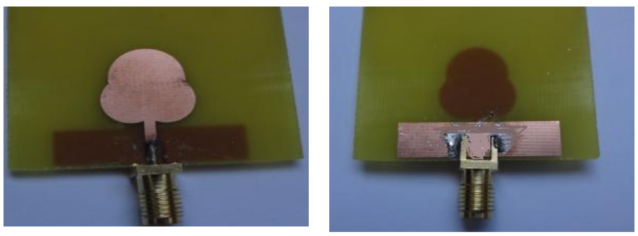
modification of the UWB antenna. Planar printed technology has been used for UWB antenna configurations that based on dipole/monopole configurations [3] and on slot-based antennas [4]. In modem wireless devices planar and printed monopole antennas capable of operating at multiple frequency bands can be employed. The resonant frequencies of this antenna can be reconfigured by using Varactor [13], PIN diodes [11] optical switches [14] and lumped elements [10].



The realized regular UWB monopole

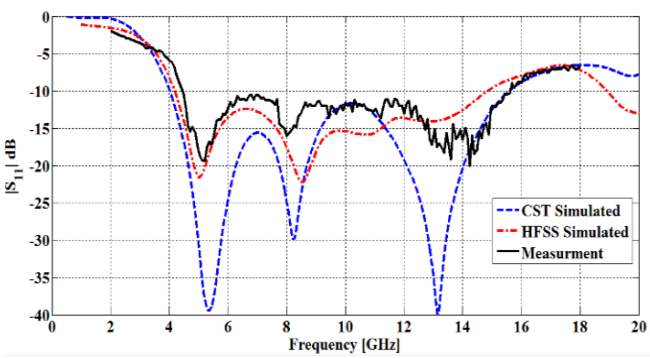


Fig.7 The Simulated and measured Return loss (S11) for the proposed UWBA.

Here, in the present article, a modifications of the layout presented in [4] was done using simulator to produce the required WLAN band-rejection. The simulation results show that the modified configuration remains complaint with the FCC requirements and corroborate the potential of the proposed antenna for UWB applications. By lengthening the microstrip and slitting a slot ring on the radiator, a UWB antenna with band-notched characteristics is achieved. Figure 1(b) shows the geometry and configuration of the band-notched UWB antenna. A new band-notched UWB monopole antenna, is mainly composed of a radiation patch with good radiation performance from 3.8 to 15.8 GHz. In order to obtain a uniform rejection performance over the whole interference band, a new geometry of the proposed frequency-tunable antenna is shown in Fig. 8. It is a planar UWB monopole antenna with notched band that the radiator has a short ring with Varactor diode. To enable tenability of the higher band at 5.8 GHz, a Varactor (SMV 1405-79 [14]) is placed between ring slot and the stem of the radiator. The Varactor is modeled in simulator by a simple circuit, shown in Fig. 9(a), where the parasitic inductance and resistance are L=0.7nH and R=0.8Ω. The Varactor capacitance varies from 2.67 to 0.63 pF for the bias voltage from 0 to 30 V. To provide a dc path for the Varactor, a narrow shaped stub is printed on the same side of the radiator, as shown in Fig. 8. One end of the stub is connected to branch 2 using resistor R1, and the other end is connected to another resistor R2 and then via to the ground. Each of the two resistors are 2.3 kΩ that used with RF choke (ADCH-80A) as Varactor biasing circuit. To prevent short circuit effect between upper and lower side of the patch antenna a SMD coil with 1pH is added to have S.C effect only for DC

bias.

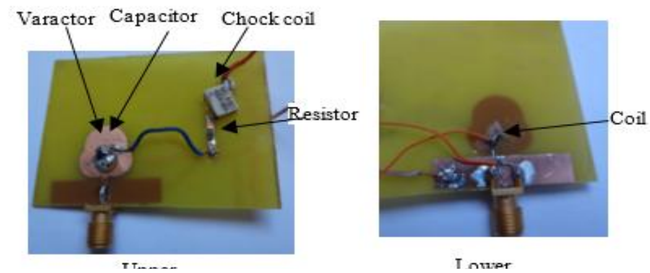


Fig.8 The realized UWB antenna with notched band using Varactor

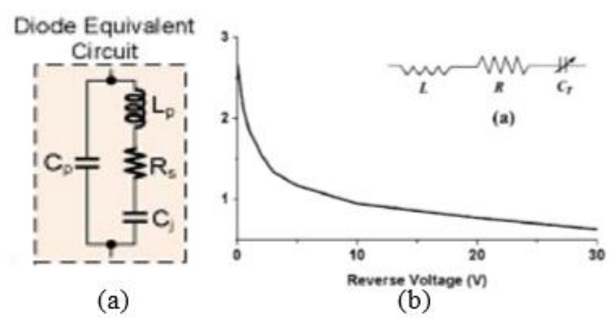


Fig. 9. (a) Simulation model for Varactor and (b) capacitance versus dc bias voltage for Varactor

The antenna with the biasing circuit is studied and optimized using the EM simulation tool CST. The optimized dimensions are listed in Table 1 and used to fabricate the antenna. The simulated and measured S11 of the antenna are shown in Fig. 10. It can be seen that the simulated and measured resonant frequencies agree very well. The discrepancies are mainly due to the: 1) effects of the feeding cable used in measurement; 2) accuracy of the simulation model for the Varactor; 3) use of an ideal model for the resistors in simulation; 4) fabrication tolerances in antenna; and 5) measurement tolerance. An SMD capacitor are connected in parallel with Varactor diode to achieve different capacitance values. With C=1pF, 3pF, 5PF and 7PF, the rejected band are centered at 6.7 GHz, 6 GHz, 5.8 GHz and 5.3 GHz, respectively as shown in Fig. 10. The simulated and measured return losses of the proposed antenna have good agreement with each other, Fig.10. In general, it can be observed that a good impedance matching is obtained in the frequency band 3.8-16.6 GHz. except the stopband. Figure 11 illustrate the current distribution at 5.8GHz, and 8GHz, where 5.8GHz is the center frequency of one of the rejection band. It can be seen that current is concentrated on the resonator edges at 5.8 GHz, so no radiation happened at this frequency. The radiation patterns of the antenna with and without using the biasing circuit have also been studied using simulation. In fact, the biasing circuit has insignificant effect on the radiation patterns, especially at the low frequency, no changes happened for the radiation pattern at higher band. As an example, the radiation patterns of the proposed antenna for each of E-plane (xy-plane) and H-plane (yz-plane) at different frequencies 4, 5, 7 and 12 GHz are shown in Fig. 12. The patterns in the H-plane are quite omnidirectional over the entire UWB frequency range except in the band notched frequency. In the E-plane, the radiation patterns remain roughly a dumbbell shape like a small dipole leading to bidirectional patterns. From Fig. 13 it is clear that the proposed antenna's gain with and without notch have a variation of between 2dBi and 7dBi within the operating frequency band of the antenna. At the pass band, the antenna gain stably varies from 1dB and 5.6 dB. Lower performance for gain has been expected over the stopband. Better antenna performance for practical applications can be attained as a low-loss substrate is used for fabricating the antenna. Therefore, the gain is successfully suppressed (in both E and H planes) at notched frequency (5.8 GHz). Then gain increases slowly as the frequency increases, and the gain is 2 ～ 7dBi. Sharp gain decrease occurs in the vicinity of 5.25 GHz and gain decreases to -0.55dB obviously, which suppresses the interference with WLAN effectively

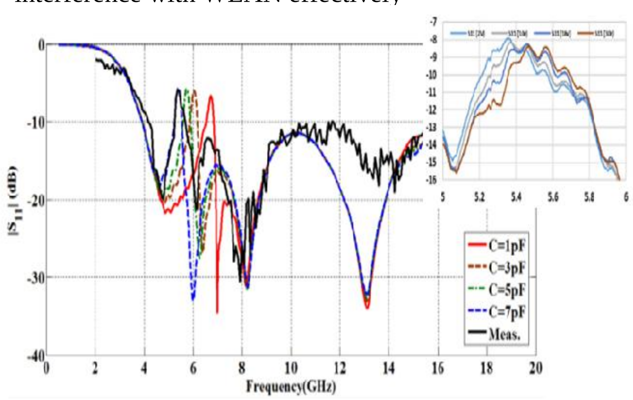


Fig10. Simulated and measured S11 with tunable capacitor

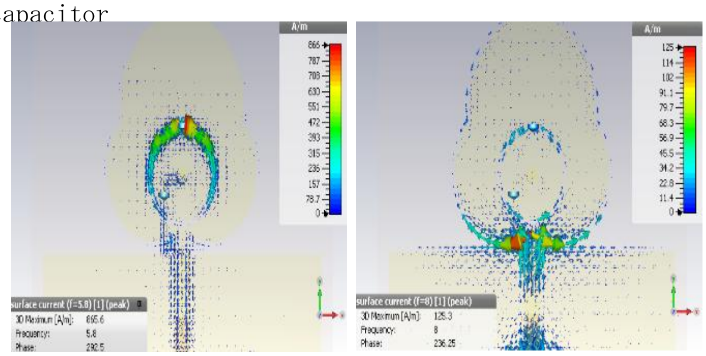


Fig.11 Current distribution for frequency at f= 5.8 and 8 GHz.

V. CONCLUSIONS

In this paper, a new configuration for the UWB antenna with rejection band is simulated and measured. The design and simulation has been carried out by using CST and HFSS software packages. Good results have been found at all UWB frequencies. This antenna is nominated to be applied for the UWB applications, available for wireless systems, and any applications pertained to high resolution screening and extremely high data rate sensors, RFID at 6.5 GHz and satellite applications which require simultaneous transmit/receive functionality at widely separated frequency bands at Ku-band at dual frequencies 11.95GHz as downlink and 14.248GHz as uplink. The proposed antenna can be easily fabricated and used with small portable devices. The proposed antenna has a compact size of 27mm × 25 mm. Using a three combined circular patches, is a novel technique to enhance the antenna properties such as ultra-wide bandwidth, stable pattern, high gain, directional behaviour, and compact size. A Varactor was used for tuning the rejected frequency bands. A simple biasing circuit has been proposed to bias the Varactor. Results have shown that the biasing circuit has little effects on the antenna performance.

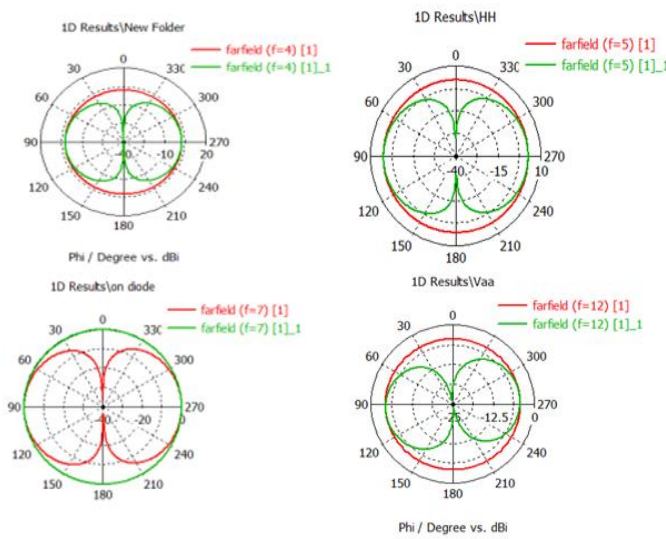


Fig. 12. Simulated radiation patterns in XZ- and XY-planes at Frequencies. = 4, 5, 7 and 12 GHz

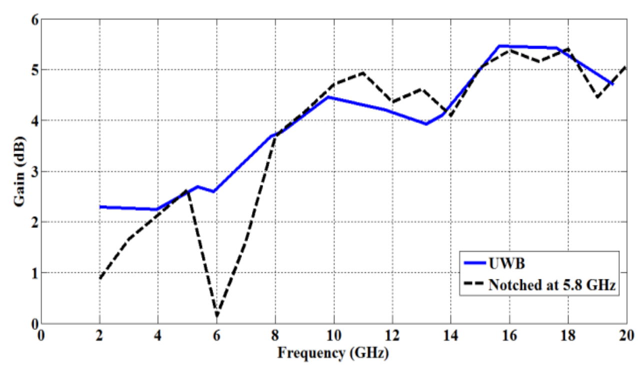


Fig.13 Simulated Antenna Gain of the proposed

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