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UWB Filtenna with Electronically Reconfigurable Band Notch using Defected Microstrip Structure

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Abstract
A new design of filtenna with electronically reconfigurable band notch for ultra-wideband (UWB) applications is presented. The filtenna is designed based on modified monopole antenna integrated with resonant structure. To produce wider bandwidth with better return loss and higher frequency skirt selectivity, the monopole antenna is modified using microstrip transition in the feedline and block with a triangular-shape slot on each side of the circular patch. The resonant structure is about U-shaped slot defected on the feedline to achieve band notch characteristic. The position of the created band notch is controlled by optimizing the length of the U-shaped slot. By using a PIN diode switch inserted in the U-shaped slot to achieve reconfigurability feature. The experimental results show that the proposed design exhibits a wide bandwidth ranging from 3.0 to 14.0 GHz with reconfigurable band notch at 5.5 GHz (WLAN), and omnidirectional radiation pattern. Therefore, the proposed design is a good candidate for modern UWB applications.

Keywords: *filtenna, filtering-antenna, notch filters, reconfigurable antenna, ultra-wideband antenna*

1. Introduction

Early ultra-wideband (UWB) technology was limited for U.S government and military including communications and radar applications [1]. In 2002 the Federal Communication Commission (FCC) has issued the UWB to be used for radar, data communication and safety application at a frequency range from 3.1 to 10.6 GHz [2]. The antenna is a main element in the UWB systems to transmit and receive signals. The circular monopole antenna is considered for UWB systems due to its advantages as wide bandwidth, omnidirectional radiation pattern and low profile which are suitable for UWB applications [3]. However, the narrow band technologies such as WLAN cause interference problem into the UWB technology [4], which leads to degrade the performance of the receiver in the UWB system [5]. Thus, the conventional UWB system is integrated with a bandstop filter in separated model from the antenna to remove undesired signals. However, integrating the bandstop filter in a separated model from the antenna increases the losses, weight, complexity and cost. Therefore, most researchers tend to integrate a resonant structure in the antenna to create band notch and filter out undesired signals. The antenna with filtering function property is known as filtering-antenna or filtenna. Recently, the filtenna with reconfigurability feature has been used in different technologies such as radar system, cellular radio system, satellite communications, aircraft, Unmanned Airborne Vehicle (UAV) radar, mobile, microwave imaging and smart weapon protection, that require multifunction operation to support many standards andreduce interference signals [6, 7].

Filtenna has several advantages such as miniaturize the size, simplify the design, reduce the losses and multifunction operation [8]. Thus, there is a growing interest to integrate resonant structures in the antenna design using different techniques. Most researchers used microstrip structures to construct the filtenna such as introducing different forms of slots or structures on the radiating patch of the antenna design [9-12]. Another technique by introducing notch structure in the ground plane [13]. However, introducing a resonant structure in the radiation patch or the ground plane may reduce the performance of the antenna [14]. By incorporating active components into the resonant structure to achieve frequency reconfiguration. In [15, 16], a switch was employed in the defected patch structure to switch ON

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and OFF the created band notch. In [17], the switch was employed in the defected ground structure to control (ON/OFF) the band notch. However, incorporating active component in the radiation patch or in the ground plane may affect the antenna performance due to the biasing network.

From the literature, it can be noted that most researchers tend to use microstrip structure techniques due to their attractive advantages such as low in manufacturing cost, easy to fabricate, and easy to integrate with any planar structure. However, previous topologies produced the band notch using resonant structures in the radiating patch or in the ground plane which may influence the performance of the antenna. In this paper, a modified printed monopole antenna is designed to achieve wide impedance bandwidth. U-shaped slot is inserted in the feedline to provide band notch characteristics with high selectivity. Integrating the band rejection structure in the feedline contributes to miniaturize the design, avoid the leakage through the ground plane, and provide stable omnidirectional azimuth pattern. The produced band notch is tuned by adjusting the dimensions of the U-shaped slot. The created band notch is electronically controlled using BAP64-02 PIN diode.

2. Antenna Design

The simulated using Computer Simulation Technology (CST) is used to simulate the proposed design. Substrate with a relative permittivity of ε_r = 4.3 and thickness of h = 1.6 mm is used. Simulated structure of the proposed filtenna is shown in Figure 1. Regarding the modification of the UWB monopole antenna by producing a simple microstrip transitions between the feedline and the patch, the return loss of the planar monopole can be improved as explained in details in [18]. Furthermore, the return loss at higher frequencies is improved by placing a block with triangular shape slot on each side of the circular patch.

3. Filtenna Design and Configuration

A resonant structure is integrated into the antenna design to produce band notch characteristic and filter out unwanted signals. The resonant structure is about U-shaped slot defected in the feedline of the antenna design. The antenna provides the radiating function and the U-shaped slot provides the filtering function. The U-shaped slot is designed at resonant frequency of 5.5 GHz with length of a quarter of the wavelength [19]. The U-shaped slot influences the behavior of the current flow in the feedline, which creates the band notch.

Figure 2 shows the simulated surface current distribution at 5.5 GHz. It can be observed that the current is more concentrating around the edges of the U-shaped slot and flows with the same amount in opposite directions, which cancels each other and leads to produce high attenuation, thus the antenna does not radiate and, therefore band notch is created [20]. Figure 3 shows the proposed filtenna with PIN diode switches. The PIN diode switch is placed in the U-shaped slot, which acts as a variable resistor with two operating status (ON/OFF) [21]. The operating modes of the PIN diode can be 303odeled by RLC circuit which consists of low resistance that allows the current to pass through the PIN diode and acts as short circuit in the ON state, while it consists of parallel capacitance and large resistance that block the flow of the current through the PIN diode and acts as open circuit in the OFF state. Figure 4 shows the equivalent RLC circuit of the BAP64-02 with the required values [22].

4. Results and Discussions

Figure 5 shows the simulated return loss of the proposed design with and without U-shaped slot. It can be seen that the proposed design without U-shaped slot has a wide bandwidth from 3.0 to 14.0 GHz, while the proposed antenna with U-shaped slot has the same bandwidth with band notch from 5 to 6 GHz at ls = 8.2 mm. Also, it can be seen that the position of the created band notch is controlled by optimizing the length of the U-shaped slot.

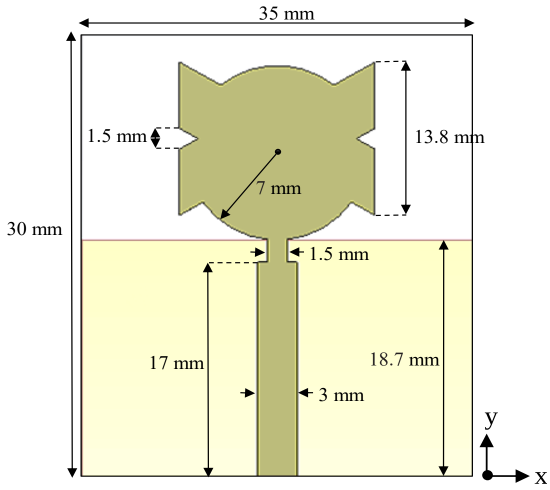


Figure 1. Simulated structure of the modified UWB monopole antenna

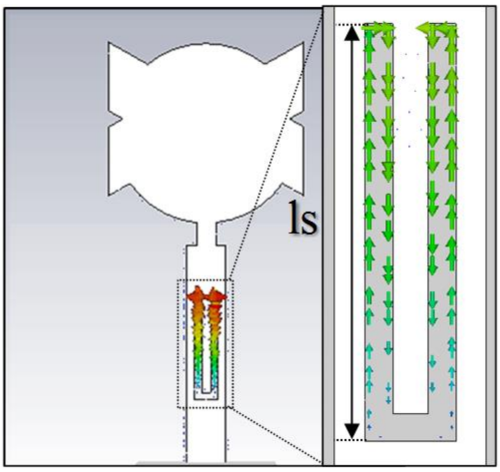


Figure 2. Simulated surface current distribution at 5.5 GHz

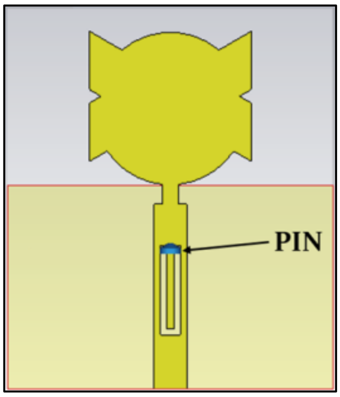
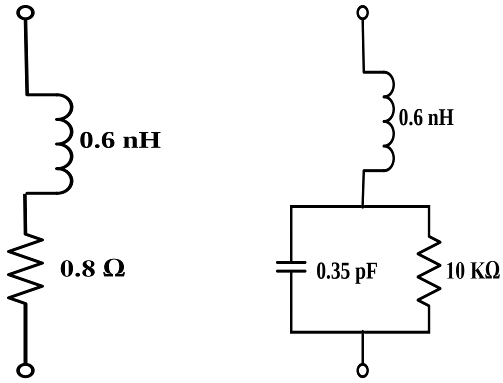


Figure 3. Proposed filtenna with PIN diode switch



(a) (b)

Figure. 4. RLC equivalent circuit of the BAP64-02 PIN diode at (a) ON and (b) OFF states

Figure 6 shows the simulated and measured return loss of the proposed filtenna using PIN diode switch. The results show a good agreement between the simulation and measurement where the proposed filtenna at the OFF state has a bandwidth from 3.0 to 14.0 GHz, while at the ON state it has the same bandwidth with band notch at 5.5 GHz. However, the return loss of the measured band notch is decreased compare to the simulated one which is mainly due to the current limit of the PIN at the ON state [23]. Moreover, the performance of the PIN diode switch BAP64-02 decreases at higher frequencies (more than 2 GHz) as studied in [24]. Therefore, to investigate and demonstrate the reconfigurability feature using active component, PIN diode BAP64-02 (from NXP) is chosen.

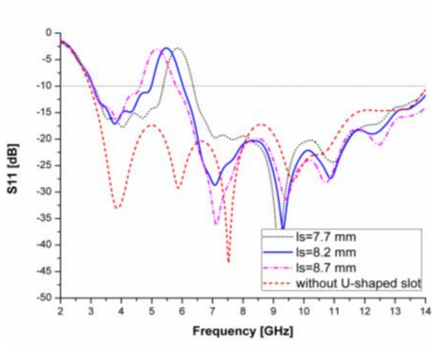


Figure 5. Simulated return loss of the proposed design

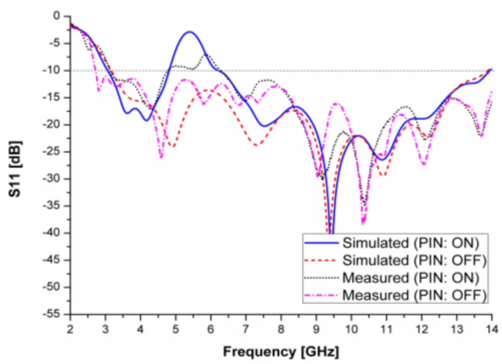


Figure 6. Simulated and measured return loss of the proposed filtenna using PIN diode switch

Figure 7 shows the gain of the proposed design, it can be seen that the proposed design with U-shaped slot has a gain more than 1.0 dB with a peak value of 4.46 dB. Also, the results show that the proposed design with U-shaped slot has the same gain. However, the gain at the band notch frequency is less than -5 dB, which means that the proposed design provides a good rejection to the WLAN frequency band at 5.5 GHz. It can be observed that the gain is increasing gradually by increasing the frequency, which is one of the monopole antenna's characteristics.

Figure 8 illustrates the measured radiation patterns of the proposed filtenna in short circuit case at several frequencies, including the co-polarization (co-pol) and cross polarization (x-pol) in the H-plane and E-plane. However, there are nulls appeared in the measured radiation pattern due to the loss tangent of the substrate and fabrication tolerances [25].

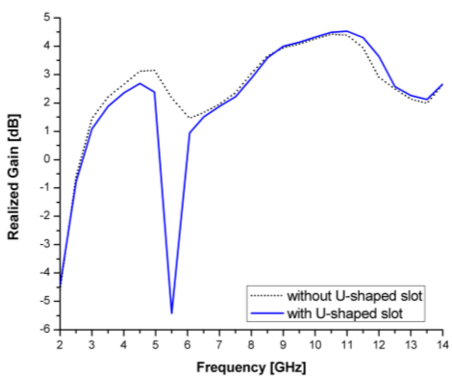


Figure 7. Realized gain of the proposed design with and without U-shaped slot

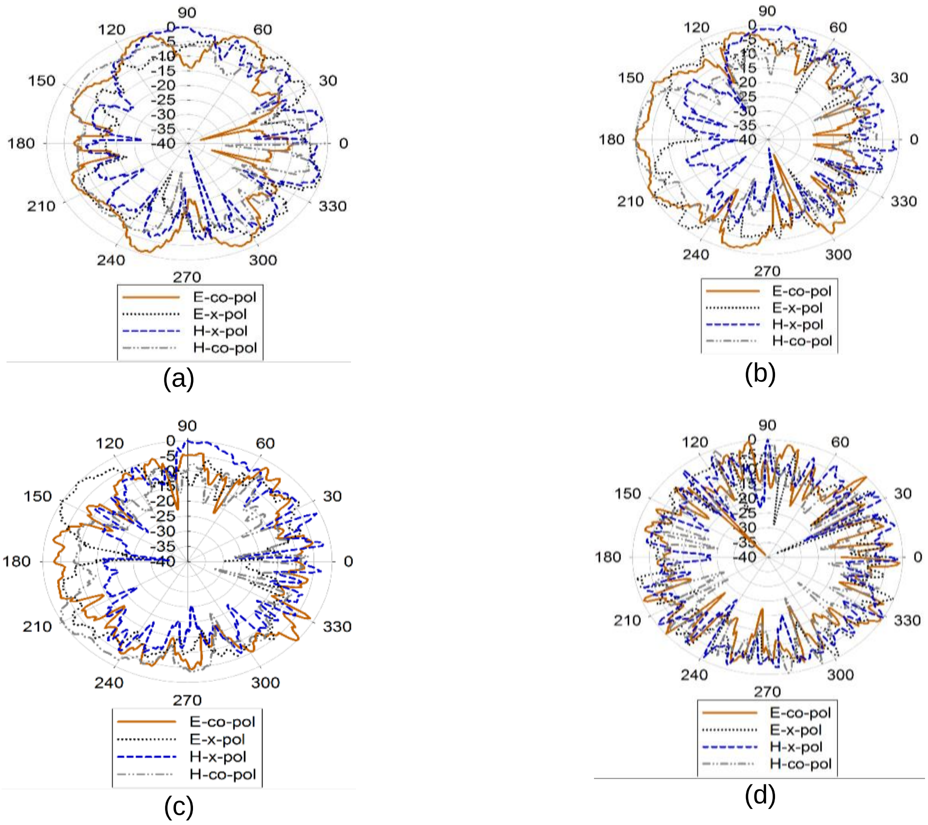


Figure 8. Measured radiation patterns of the proposed filtenna at
(a) 4 GHz, (b) 7 GHz, (c) 9 GHz and (d) 11 GHz

5. Conclusion

An integrated filtenna with reconfigurable band notch for UWB applications is designed and developed. By using microstrip transition in the feedline, and block with a triangular slot on each side of the circular patch to produce wide bandwidth with better return loss and high frequency skirt selectivity. The band notch is created by defecting a U-shaped slot on the feedline. By changing the length of the U-shaped slot, the position of the created band notch is controlled. The created band notch is electronically controlled ON and OFF by using a PIN diode switch employed in the U-shaped slot. The simulated and measured results show a good agreement, where the proposed design provides wide bandwidth which covers the UWB bandwidth from 3.1 to 10.6 GHz with reconfigurable band notch at 5.5 GHz, peak realized gain of 4.56 dB and omnidirectional radiation pattern.

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