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Reconfigurable Filtering-Antenna with triple Band Notches for UWB Applications

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Abstract:

A new compact topology of filtering-antenna for Ultra-wide band (UWB) medical applications is proposed. The new design consists of modified monopole antenna integrated with band rejection structures. The band rejection structures are based on defected microstrip structure (DMS) and two double split ring resonators (DSRR). The DMS is introduced in the middle feed line of the antenna de-sign to produce band rejection for X-Band satellite downlink satellite communication band (7.1-7.9 GHz), and the two DSRR are placed above the antenna ground plane to create dual band notches for WiMAX (3.3–3.7 GHz) and Hiper LAN2 (5.47–5.73 GHz). The frequency reconfiguration feature is obtained by employing a PIN diode switches in the band rejection structures. The new design exhibits wide impedance band width covering the 10dB impedance bandwidth (IBW) of (3.1-10.6 GHz) with high selectivity triple band notches, uniform omnidirectional patterns and peak realized gain of 5.3dB.

Keywords: A Filtering Antenna, Band Notches, UWB Applications.

I. INTRODUCTION

In modern radio technologies, Ultra-wideband (UWB) technology is required as its an unique advantages such as broad impedance bandwidth (IBW), high data rate for, low power consumption, , strong immunity against fading, multiple access capabilities, effectively reducing the multipath effects and low cost flexible transceiver communication link [1]. Therefore, the UWB has been used with various recent applications such as wireless communications (e.g. Radio frequency identification, locating and consumer electronics), radar communications (especially in the military applications) [2] and medical engineering [3]. Fig 1 shows UWB system which consists of a radar sensor for detecting the heart and breath rates. This sensor transmits pulses into the target and then receives the reflected pulses from the target which consists of the information of the heart and breath characteristics [4].

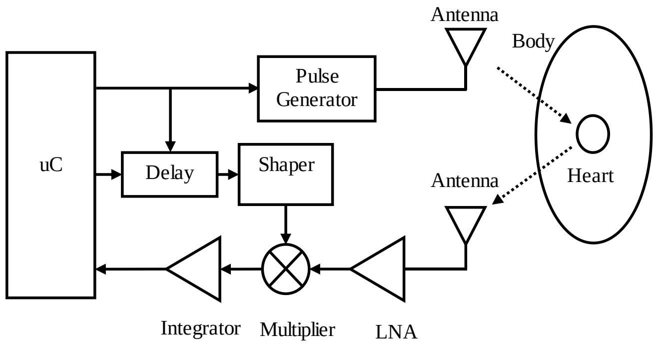


Fig 1: UWB system for radar sensor [4]

A several of challenges cope the continuous development in UWB technology, the important one of these challenges, The UWB antennas must have several features to be suitable for use in UWB technology such as transmit signals with assuring the efficiently and accurately. In addition, the challenge of extending the IBW to be suitable for UWB applications with ensuring that the entire 10 dB IBW of 110% (3.1-10.6 GHz) is covered [5], [6]. challenge in UWB is achieving a wide frequency bandwidth more than to cover The omnidirectional radiation pattern is important for UWB antennas to improve power radiating and receiving functions [7]–[10]. UWB antenna should have a good gain, which contributes to improve the directivity.

Usually the UWB technologies are affected by interference problem with several narrowband frequency systems attributes to their broader IBW, some of these systems are the X-Band satellite downlink frequency band for satellite communication of (7.1-7.9 GHz), world interoperability for microwave access (WiMAX) with frequency range of (3.3–3.7 GHz) and Hiper LAN2 with frequency range of (5.47–5.725 GHz) and [11]–[13]. Therefore, it is desirable to integrate a bandstop filter in the UWB system to mitigate these interfering signals thus reducing the interference influences. Fig 2 presents a typical UWB block diagram at receiver system. The UWB spectrum is received by the UWB antenna and then unwanted signals are filtered by the band stop filter after passing through the low noise amplifier and mixer.

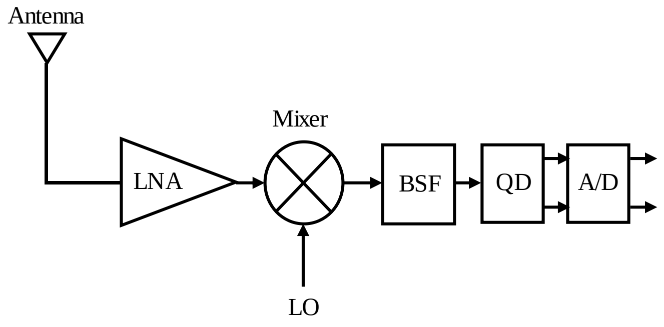


Fig 2: Block diagram of a UWB receiver system [14]

The traditional UWB systems are quite large in structure size, expensive and losses associated between the filter and antenna which attributed to the UWB antenna and filter are designed in separate model [24]. To overcome these drawbacks the filter is inserted into the microwave antenna to realize a single design and then provides the both functions (frequency filtering and radiating) simultaneously. Several techniques have been used in [15], [16] to integrate the filter structure in the main UWB antenna design to reject the unwanted responses at different frequencies. However, integrating a band stop filter in the UWB system increases loss, complexity, cost and weight.

Recently, reconfigurable filtering-antennas have been one of the major interesting research subjects due to their involvement in modern technologies such as radar including Unmanned Airborne Vehicle (UAV) radar, smart weapon protection, cellular radio system, aircraft, satellite and mobile communication, microwave imaging which needs flexibility to support several standards (Such as., Bluetooth, UMTS, DSRC, WiMAX, WiFi), mitigate strong interference signals and cope with the change according to the condition of environment [17]. Therefore, to achieve frequency reconfiguration by using PIN diode employed in the design.

Microstrip structure techniques have attracted considerable interest to achieve stopband characteristics because of their advantages such as miniaturize size, easy to fabricate, lightweight, cost minimization, ease of integration with any microstrip planar structure. Several microstrip structure techniques have been used such as defected ground structures (DGS), defected patch structure (DPS), resonant stub structures (RSS) beside the feedline, coupled line resonator (CLR), nonuniform stub resonator (NSR) and electromagnetic band gap structures (EBG) [18]–[25]. For flexibility and multifunctional operation some researchers tend to produce triple band notches using different technique such as defected ground structure and split ring resonator [26], and complementary split-ring resonators (CSRRs) [27]. In [28], the triple band notches created by using inverted L-shaped stubs. Electric ring resonator is used to produce triple band notches as presented in [29]. However, most of these techniques produce wide rejected band, that leads to reject needed frequencies, thus producing sufficient band notch characteristics is a challenging issue. Furthermore, most reported studies have fixed operating frequency band whether the interfering signal exists or not, which may reduce the UWB system performance. Therefore, reconfigurability property is becoming important to cope with the changing environmental condition. In addition, the rejected band structures on the ground plane and the radiated patch influence the characteristics of radiation.

In this paper, a modified monopole antenna integrated with a band rejection structures to form the proposed filtering-antenna is presented. Two techniques based on defected microstrip structure (DMS) and two double split ring resonator (DSRR) are integrated with the antenna design. The DMS is embedded in the feedline of the antenna design and the two DSRR are placed above the antenna ground plane to create triple band notches. PIN diodes are employed in the band rejection structures to achieve frequency reconfiguration. The new integration using DMS and DSRR provides stable omnidirectional azimuth pattern, and controllable band notches which are sufficient to remove unwanted signals and keep wanted signals.

II. FILTERING-ANTENNA DESIGN

The proposed filtering-antenna is modeled in Computer Simulated Technology (CST) using Roger 5880 substrate materials with a 2.2 dielectric constant or permittivity and 0.787 mm thickness. The circular disc of monopole which has 7.7 mm radius is printed on the same side of the substrate along with microstrip feed line of 50 ohms. The dielectric substrate has a dimension of 40 × 30 mm2. The band rejection structures are based on defected microstrip structure (DMS) and two double split ring resonators (DSRR) as shown Fig 3. The embedded DMS in the feedline of the monopole antenna design is used to produce band rejection for X-Band satellite downlink satellite communication band (7.1-7.9 GHz). While a two DSRR is printed above the ground plane of the designed monopole antenna which is used to produce a dual band notches for WiMAX (3.3–3.7 GHz) and HiperLAN2 (5.47–5.725 GHz) [11]–[13], [30].

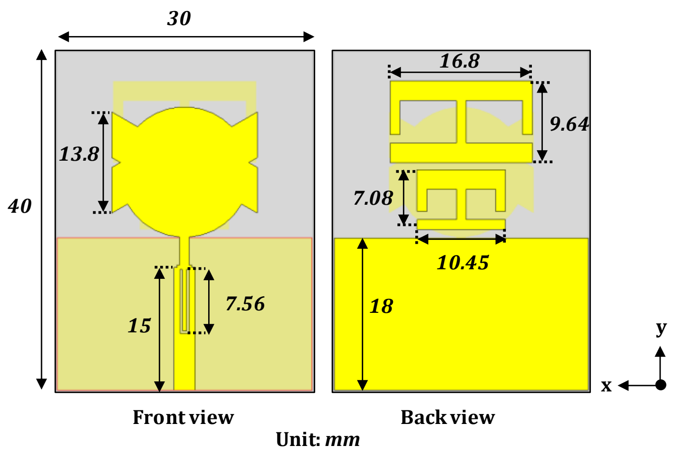
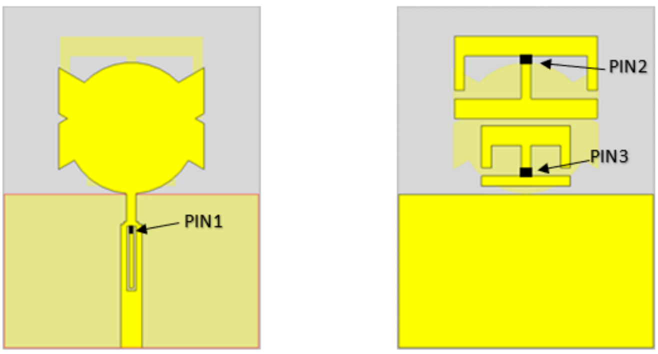


Fig 3: Design structure of the proposed filtering-antenna

III. RECONFIGURABILITY CONFIGURATION

By employing three PIN diode switches in the band notch structures as shown in Fig 4, the proposed design is capable of operating at eight modes as illustrated in Table 1. The PIN diode behaves as a variable resistor which has an ON/OFF operated states [31]. Theoretically, each one of the these two states has an equivalent RLC circuit. For the ON state which acts as forward biased, the currents pass through due to the low resistance which is considered as a short circuit. However, for the OFF state which acts as zero or reversed biased, the flow of the current is blocked due to the parallel combination of large resistance and capacitance. Practically, the PIN diode have well-known values for the RLC elements which are given in the standard datasheet of the PIN diode for both ON/OFF state. In order to achieve the feature of frequency reconfiguration, the BAP64-02 Silicon PIN diode is used. A CST software is used to model the BAP64-02 PIN diode for simulation by using the condition of RLC lumped elements networks. Fig 5 demonstrates the RLC equivalent circuits for both ON/OFF states along with the required values of Pin diode BAP64-02 [32]. To control the PIN diode state, it is required to change the RLC lumped elements network conditions in accordance with equivalent circuit of RLC for both ON/OFF states.

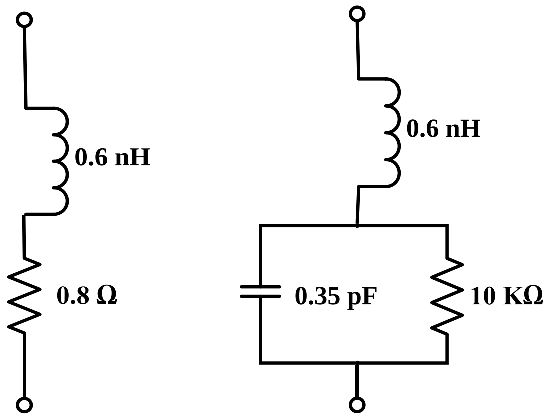


Front View Back View

Fig 4: Structure of the reconfigurable triple band notch filtering-antenna using PIN diode switches

Table 1: Operating modes of the design shown in Fig 4

Mode	PIN1	PIN2	PIN3	X-Band	HiperLAN2	WiMAX
1	ON	ON	ON	>-10 dB	>-10 dB	>-10 dB
2	ON	ON	OFF	>-10 dB	>-10 dB	<-10 dB
3	ON	OFF	ON	>-10 dB	<-10 dB	>-10 dB
4	ON	OFF	OFF	>-10 dB	<-10 dB	<-10 dB
5	OFF	ON	ON	<-10 dB	>-10 dB	>-10 dB
6	OFF	ON	OFF	<-10 dB	>-10 dB	<-10 dB
7	OFF	OFF	ON	<-10 dB	<-10 dB	>-10 dB
8	OFF	OFF	OFF	<-10 dB	<-10 dB	<-10 dB

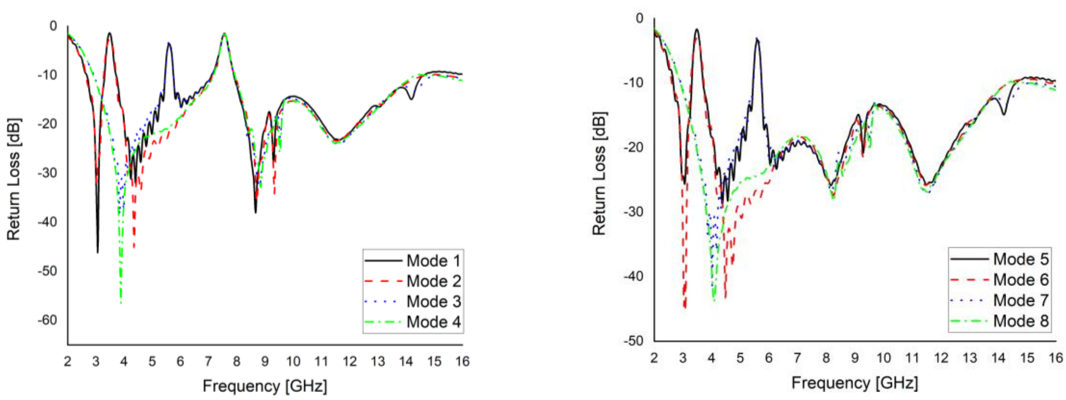


(a) (b)

Fig 5: The equivalent circuit RLC of the BAP64-02 PIN diode at (a) ON and (b) OFF states.

IV. RESULTS AND DISCUSSIONS

From the simulated results in Fig 6, the proposed design produces frequency band width from 2.65 GHz to 14.5 GHz. The rejected band structures produce triple band notch at WiMAX band from 3.3 GHz to 3.7 GHz, HiperLAN2 from 5.47 GHz to 5.73 GHz and X-band from 7.1 GHz to 7.9 GHz. the PIN switches provide the reconfigurability feature where the PIN 1 controls the band notch of the X-band, PIN 2 controls the band notch of the WiMAX band and PIN 3 controls the band notch of the HiperLAN2 band.



(a) **(b)**

Fig. 6: (a) The return loss of the proposed filtering-antenna design for (a) Mode: 1-4), z) Mode: 5-8

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Fig 7 illustrates the simulated realized gain of the designed filtering-antenna with triple band notches. The gain of the designed filtering-antenna with two DSRR and DMS is more than 1 dB and peak gain of 5.27 dB over the UWB operating band. However, the gain is significantly reduced to less than -0.8 dB at the band notches frequencies which means that there is no power transmitted at the band notches frequencies, thus the proposed design produces high level of rejections to these frequencies. It can be observed that the proposed antenna gain is gradually increased and enhanced towards the upper frequencies for entire IBW of UWB (3.1 -10.6 GHz). Noteworthy, this phenomenon is one of monopole antenna properties. Fig 8 demonstrates the simulation results of the radiation patterns of the proposed antenna design at different frequencies (2.5 GHz, 6.5GHz, 9.5 GHz, and 13.5GHz). It can be observed that the proposed design shows an omnidirectional radiation pattern in the H-plane and conical in the E-plane.

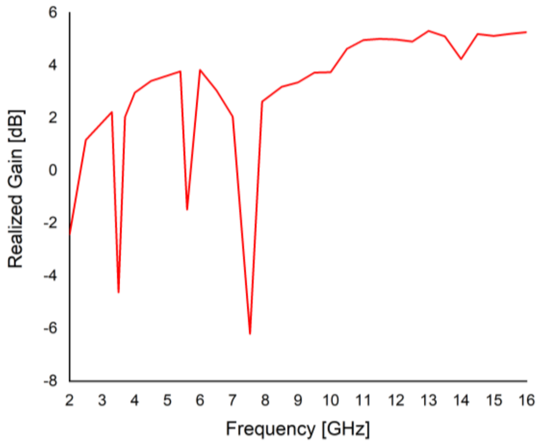

Fig. 7: The realized gain of the proposed filtering-antenna

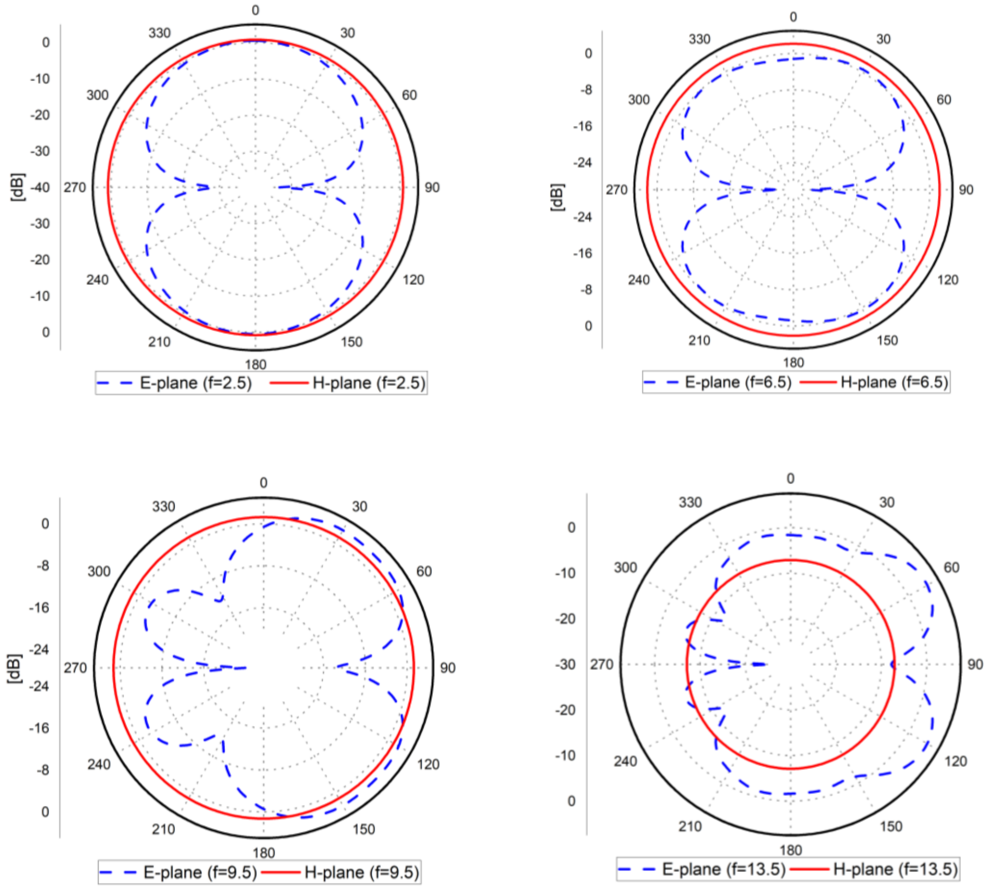

Fig. 8: The radiation pattern of the proposed filtering-antenna.

V. CONCLUSION

A modified UWB monopole antenna integrated with simple and novel technique to achieve triple band notches has been reported. The two DSRR above the ground plane of the antenna and the defected microstrip structure (DMS) provide triple band notches. The created notch position is tuned by varying the length of DMS and DSRR. By employing a PIN diode which acts as switches in the DSRR and in the DMS, the frequency reconfiguration feature is achieved. The results demonstrate that the proposed design of filtering-antenna provides wide impedance bandwidth with reconfigurable triple band notches to filter out WiMAX, HiperLAN2 and X-band frequencies. Therefore, the proposed filtering-antenna design is a good candidate for modern UWB medical applications.

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