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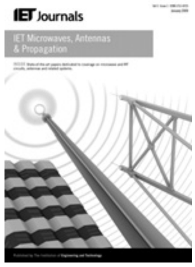

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Ultra-wideband circular slot antenna with reconfigurable notch band function

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Abstract: An ultra-wideband (UWB) antenna is presented whose frequency characteristics can be reconfigured electronically to have either a single- or dual-band notch function to block interfering signals from C-band satellite communications systems, IEEE802.11a and HIPERLAN/2 WLAN systems for example. The proposed antenna is excited using a circular ring resonator fabricated on one side of the dielectric substrate with a circular slot etched on the ground plane. To realise a single- or dual-band notch characteristic the antenna includes a semi-circular parasitic strip located above the circular ring, and a T-shaped stub is located near the inner edge of circular ring. The parasitic strip and T-shaped stub are connected to the circular ring via PIN diodes to give the antenna reconfigurable capability by configuring the PIN diodes in a prescribed combination of ON and OFF states. It is shown that there is virtually no change in the antenna's *E*-plane and *H*-plane radiation patterns for the various PIN diode switching conditions. The proposed antenna's performance has been verified by measurements.

1 Introduction

Ultra-wideband (UWB) technology is now becoming widely used in a variety of applications such as radar, short-range communications and positioning systems. This is because this technology offers advantages of large channel capacity, multipath propagation performance and potential for ultra-low-power implementation of transmitting-only devices. As is the case in conventional wireless communication systems, an antenna plays a crucial role in UWB systems. However, there are more challenges in designing a UWB antenna than a narrow band one. In particular, a suitable UWB antenna should be capable of operating over an ultra-wide bandwidth as allocated by the Federal Communications Commission (FCC), that is, 3.1–10.6 GHz. At the same time, it needs to exhibit satisfactory radiation properties over the entire frequency range. In addition, the antenna needs to be compact in size and cheap to manufacture for consumer electronics applications. To satisfy these requirements, various wideband antennas have been studied [1–5]. However, other narrow band services coexist within the UWB spectra such as C-band (3.7–4.2 GHz) satellite communication systems, and wireless local-area network (WLAN) IEEE802.11a and HIPERLAN/2 systems operating in the 5.15–5.825 GHz band. As a result UWB communication systems are likely to experience unwanted interference from those systems. To overcome this problem agile software-defined radios provide a solution [6] that demands the use of 'smart' reconfigurable antennas capable of cancelling in-band interference. Hence, a UWB antenna with reconfigurable band-rejection characteristics at the WLAN or C-band satellite frequencies is highly desirable.

Recently, UWB antennas that generate band-notch functions have been investigated and successfully implemented by using various techniques; for example, two rectangular parasitic patches are embedded within the antenna's structure in [7], two linear slots are utilised in the Vivaldi antenna in [8], and a slot split-ring resonator was added on the microstrip-fed monopole antenna in [9]. Various other UWB antennas with a notch function have been developed for UWB communication systems [10–12]. A reconfigurable antenna for multiple input and multiple output (MIMO) application has been investigated in [13]. PIN diodes and micro-electro-mechanical systems (MEMS) switches have been employed in antennas to achieve frequency [14–16] or radiation pattern [17] reconfiguration.

In this paper, a novel UWB antenna with reconfigurable notch band capability is presented. The proposed antenna comprises a circular ring radiator on the front side of a dielectric substrate with a circular slot etched on its ground plane. A semi-circular parasitic strip and a T-shaped stub are utilised within the antenna's structure to achieve band rejections at frequency bands of 5.15–5.825 and 3.7–4.2 GHz, respectively. The parasitic strip and the T-shaped stub are connected to the circular ring radiator with PIN diodes. With prescribed switching states of the three PIN diodes the antenna's band notches can be reconfigured as desired. The proposed antenna was designed and fabricated to demonstrate its feasibility. Simulations of the antenna were performed with Ansoft HFSS 10.0 software [18], and the fabricated antenna was measured in the antenna laboratory of the Iran Research Institute for ICT (ITRC).

2 Antenna configuration

The geometry of the proposed circular slot UWB antenna with band-notch function is depicted in Fig. 1. The antenna is located on the *xy*-plane and the normal direction is parallel to the *z*-axis. The antenna's ground plane consists of a circular slot with radius of R and a radiating circular ring resonator on the other side of the dielectric substrate with inner and outer radii of r_i and r_o, respectively. The radiating ring is fed via the 50 Ω feed-line of width $W_f = 3$ mm, as illustrated in Fig. 1*a*. Above the ring is included a parasitic semi-circular annular strip of width w_n whose inner radius is r_n. This strip is employed to reject the frequency band of WLAN systems. Also included is a T-shaped stub near the inner edge of circular ring. The proposed antenna was fabricated on a dielectric substrate FR4 with a relative permittivity (ε_r) of 4.4 and thickness of 1.6 mm. The antenna's ground-plane size is $L_g \times W_g = 45 \times 40$ mm^2.

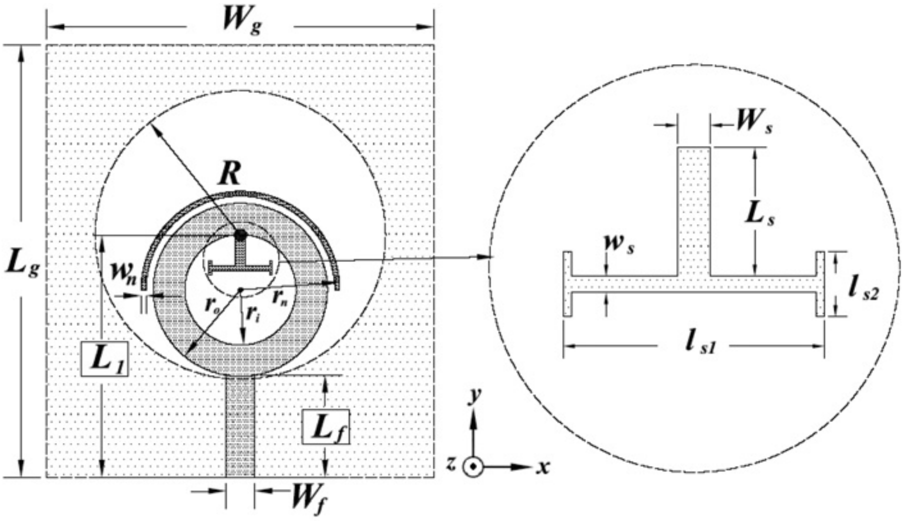
Frequency reconfigurable capability is achieved by using three PIN diode switches integrated within the antenna's structure. Two PIN diodes are located at the ends of the parasitic strip to connect the strip to the circular ring resonator. The third PIN diode connects the T-shaped stub to the circular ring to control the notch band at C-band. The positions of diodes in antenna's structure are shown in the photograph in Fig. 1*b*. For clarity the dc bias to the PIN diodes is not shown.

3 Parametric study of antenna

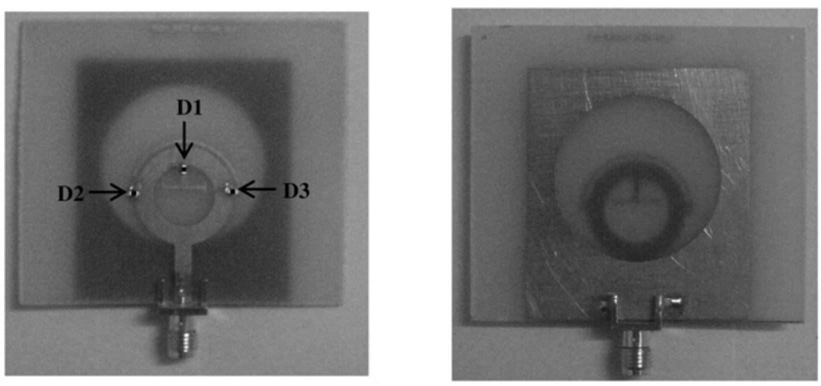
To achieve the desired band-notching characteristics, the effect of the parasitic annular strip and T-shaped stub parameters on the antenna's performance were studied. The simulated voltage standing wave ratio (VSWR) of the antenna for different values of r_n is shown in Fig. 2. This figure shows that by increasing r_n there is no affect on the first band notch located at about 4 GHz, however, the second notch's centre frequency shifts towards the lower-frequency end from 5.49 to 5.02 GHz with variation in r_n from 10.25 to 11.25 mm, respectively, and its corresponding bandwidth increases marginally. In addition, the VSWR increases by about 1 dB, which corresponds to a greater rejection.

Fig. 3 shows the simulated VSWR response of antenna for different values of L_s. It can be observed that the first notch's centre frequency decreases from 4.36 to 3.8 GHz with the increase of the length L_s from 4 to 6 mm, and there is no affect of the length change on the second band notch located at 5.49 GHz. In this case the VSWR also increases by about 1 dB.

The effect of the parameter l_{s1} of the T-shaped stub on the antenna's performance is depicted in Fig. 4. It is clear from



a



b

Fig. 1 *Geometry of proposed reconfigurable UWB antenna*

a Antenna's defining parameters
b Photograph of fabricated reconfigurable antenna

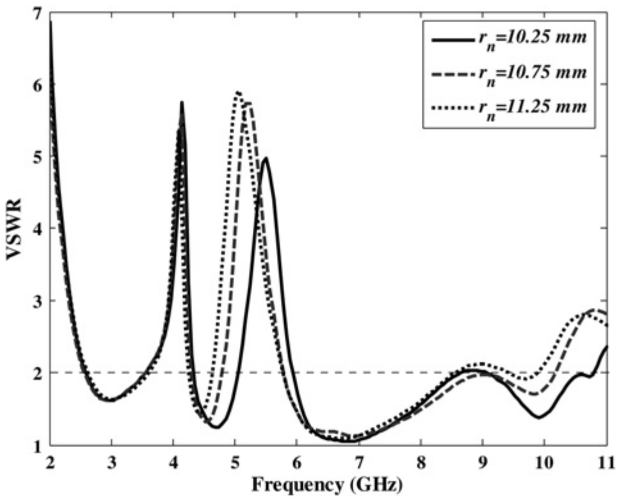


Fig. 2 *Effect of r_n on the antenna's band-notching characteristics*

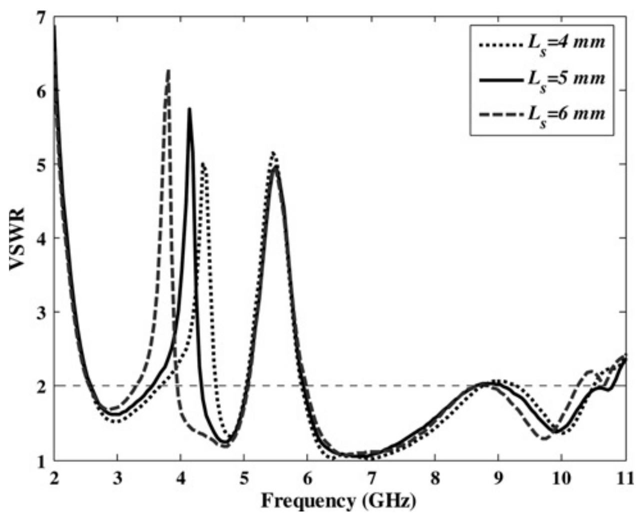


Fig. 3 *Effect of parameter L_s of T-shaped stub on the antenna's band-notching characteristics*

this figure that the first band notch shifts towards the lower-frequency end from 4.56 to 3.74 GHz with an increase in the length of l_{s1} from 6.5 to 8.5 mm. Moreover, it is seen that the length of l_{s1} affects the second notch's

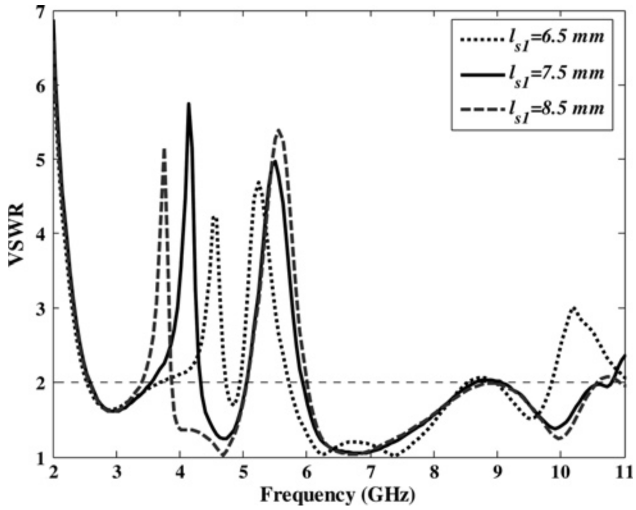


Fig. 4 *Effect of parameter l_{s1} of T-shaped stub on the band-notched characteristics*

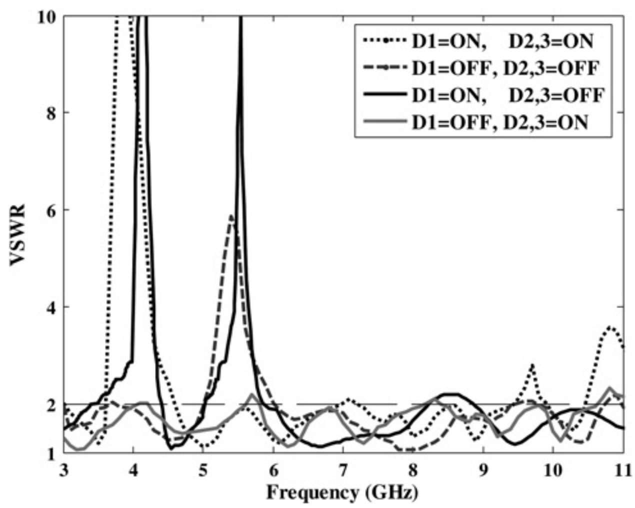


Fig. 5 *VSWR curves of the reconfigurable UWB antenna at different RF switch states*

characteristics in terms of VSWR and centre frequency. The VSWR is degraded by 0.69 and the centre frequency is reduced by 260 MHz. As observed, the filtering function of

Table 1 Dimensions of the proposed UWB antenna

parameter	W_g	L_g	R	r_o	r_i	W_f	L_f	L_1	L_s	W_s	l_{s1}	l_{s2}	w_s	r_n	w_n
value, mm	40	45	15	9	6	3	10.6	25.2	5	1	7	2	0.5	10.25	0.5

Table 2 Summary of results for different configurations of PIN diodes

Status	Switch status			Notched band status			
State	D1	D2	D3	C-band		WLAN	
state 1	ON	ON	ON	✓	GD[a] 3 to −3.6 dB	–	–
state 2	OFF	OFF	OFF	–	–	✓	GD 2.9 to −4 dB
state 3	ON	OFF	OFF	✓	GD 3 to −3.8 dB	✓	GD 2.9 to −3.4 dB
state 4	OFF	ON	ON	–	–	–	–

[a]Gain drop

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the antenna can be tuned by varying the principal parameters of parasitic annular strip and T-shaped stub.

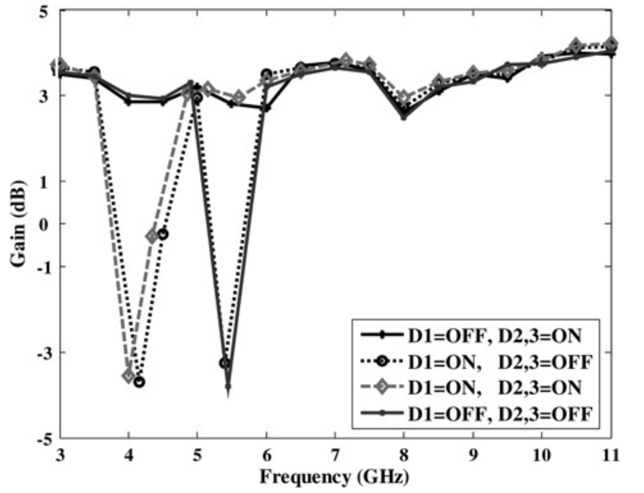

Fig. 6 *Gain of the reconfigurable UWB antenna at different RF switch states*

4 Results and discussions

The proposed antenna in Fig. 1 was fabricated using the optimised dimensions obtained from the above parametric study given in Table 1. The measured VSWR curves of proposed reconfigurable UWB antenna at different radio frequency (RF) switch states were investigated. The antenna's VSWR is shown in Fig. 5, and the summary of results is depicted in Table 2, where it is found that for different states of RF switches the proposed UWB antenna acts as an antenna with none, or single- or dual-band-notched characteristics. Hence, this UWB antenna possesses frequency reconfigurable capability.

The antenna's gain across the UWB band at different PIN diode states is presented in Fig. 6. In the C-band and WLAN frequency band the variation of the antenna gain is shown in Table 2. Thus, the antenna's notch band can be controlled the antenna gain in the C-band or WLAN frequency bands.

The measured radiation patterns of the proposed reconfigurable UWB antenna in the *E*-plane (*yz*-plane) and *H*-plane (*xz*-plane) are shown in Fig. 7 at three different spot frequencies, that is, 3.3, 7 and 10 GHz. It is shown that the radiation patterns are virtually similar for the various

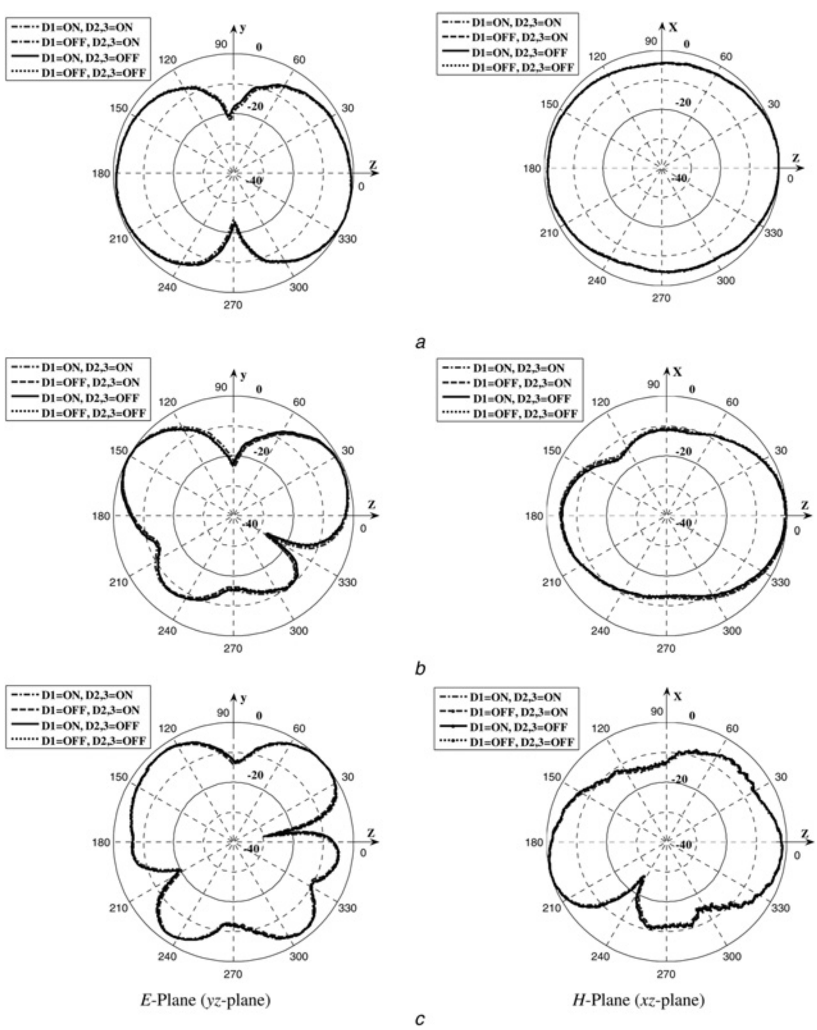

Fig. 7 *Measured E- and H-plane radiation patterns of the proposed reconfigurable UWB antenna at three different spot frequencies*

a $f = 3.3$ GHz
b $f = 7$ GHz
c $f = 10$ GHz

PIN diode switching configurations. It can be observed that the patterns in the *H*-plane are omni-directional as expected, however, the variation in the sensitivity declines at the higher-frequency end of the UWB spectrum. In the *E*-plane, the radiation patterns remain roughly bi-directional at higher frequencies.

5 Conclusion

A simple and effective UWB slot antenna with notch bands is proposed. The antenna is reconfigurable to suppress unwanted interfering signals by using PIN diodes integrated within the antenna configuration. By changing the ON/OFF conditions of the PIN diodes the antenna can be used to generate either a single or dual notch band to isolate and block any interference in the C-band and/or WLAN frequency bands. A parametric study on the antenna was performed for designing the antenna, which was verified experimentally. The antenna radiated essentially omni-directionally in the *H*-plane and bi-directionally in the *E*-plane. In addition, it exhibited approximately a constant gain in the UWB band with the exception at the notched bands.

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