Design a Switchable Band Notch Π-Slot Reconfigurable Antenna for Ultra Wide Band Applications

Salah Mahdi*, Haydar Malik Al-Tamimi *'Ph.D(Lecturer)

Abstract

Square patch frequency and radiation reconfigurable microstrip antenna design is proposed for Ultra Wide Band application. The notch band function was created by embedding a Π-slot within the radiator patch that has a small size (24 × 23) mm printed over a FR-4 substrate with relative dielectric constant of 4.3, and thickness of 1 mm. A microstrip line feeds the designed antenna. To satisfy the UWB frequencies the length ground plane has been reduced. The finite ground plane is printed on the lower side of dielectric substrate. The simulating process and performance estimation of the designed antenna was achieved by using the electromagnetic simulator, Computer Simulation Technology Software. Simulation results indicate that the designed antenna has an effective bandwidth, for $|S_{11}| \leq -10$ dB, extending from approximately (3.7 to 8) GHz and (8.8 to 10.75 GHz), with a switchable notch band performance in the (5.15 and 5.825 GHz).

Keywords: Reconfigurable, Π-slot antenna, microstrip, UWB.

* University of Technology

Introduction

Ultra-wideband (UWB) technology have received much interest because the requirement of transmitting information at high transmission rates in the modern communication applications [1, 2]. The (UWB) technology has been used for many applications, for instance, sensing and military applications, radar, etc [3]. So, there are many brilliant antenna designs in the current literature on UWB systems, which is used to satisfy the overall UWB frequencies [4-6]. In addition to a number of researches about the bandwidth enhancement techniques for the UWB antennas [7-8].

Within the large band of the UWB technique, there aresome bands which have been applied for a long period of time, suchas worldwide interoperability for microwave access (WiMAX) [9],wireless local area networks (WLAN) [10]. To reduce the interference effect, the traditional methodis to add narrow band-stop filter. This will increase the complexity of the design antenna. So, a lot of notch band technique for the UWB antennas havebeen proposed to solve this problem [11-14]. However, the proposed antenna was a printed reconfigurable square patch antenna consist of a Π-slot with a switchable single band-notch is designed as shown in Figure 1. The notch band function was done by etching a single Π-shape slot in the square patch.

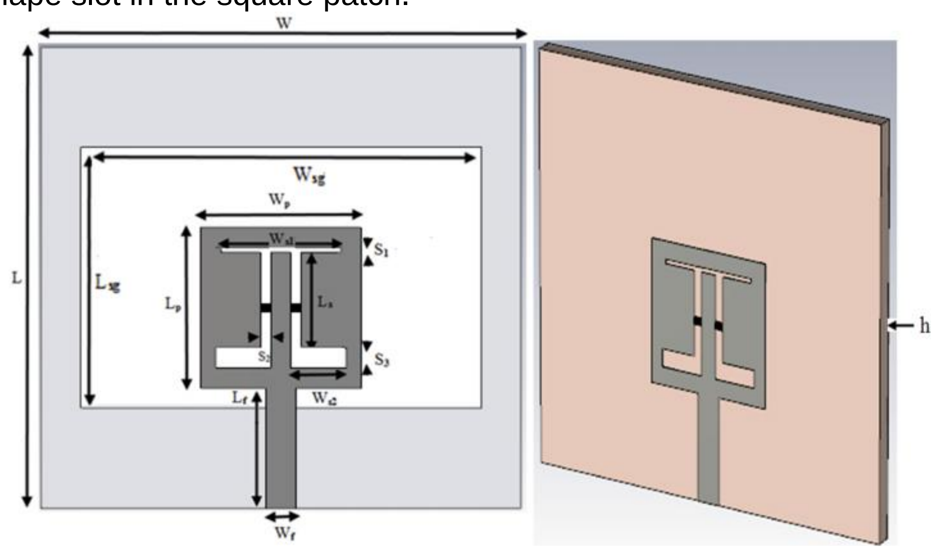


Figure 1: Switchable band notch Π-slot reconfigurable antenna

Inserting a small Π-narrow slot within the square patch of the presented antenna will change the current flow on the metallic patch, at the notch band frequencies, the major current flows will be steered nearby the inserting slot, with an oppositely directions around the slot boundaries. Therefore, the required notch frequency band can be produced. Figure 2 shows the current distribution for the term when all switches are on or off states.

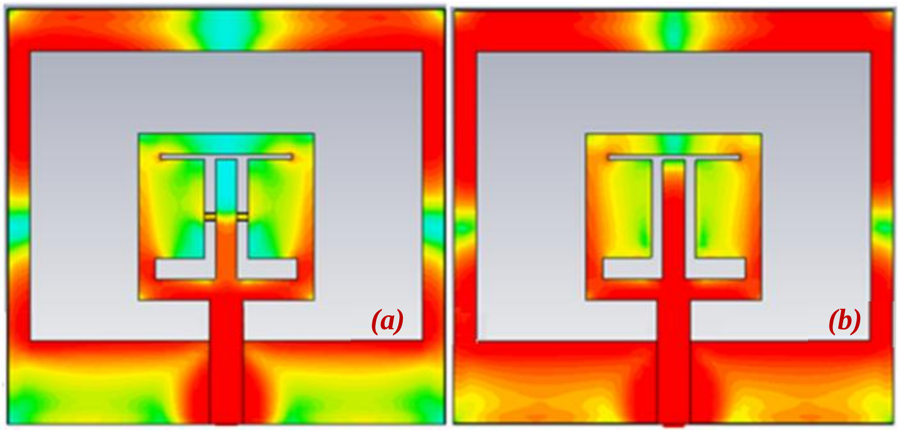


Figure 2: The surface current distribution on the proposed reconfigurable antenna (a) all switches are on (b) all switches are off

Antenna Structure

The geometrical simulation of the offered square reconfigurable antenna is shown in Figures 1. The suggested square patch can radiates within the UWB frequency band. It has a small size of (24 × 23) mm, and it is fed by (50 Ω) microstrip feed-line printing above FR4 substrate with dimensions (W & L), and thickness (h) equal to (1) mm with a relative permittivity (4.3). The UWB characteristic is achieved by optimizing the parameters (Wp and Lp) of the patch and the parameters (Wsg and Lsg) of the ground plane.

The notch band function in the proposed antenna has been done by embedding a Π-slot into the square patch. A positive-intrinsic-negative (PIN) diode is used across the Π-slot to control the occurrence of the notch band. When the PIN diodes are on, the Π-slot changes to a smaller Π-slot with a couple L-slots, furthermore, by transforming to the new shape, an additional frequencies are stimulated, hence the notch band will canceled and the entire band will be performed to cover the

UWB frequency band. Once the PIN diode turned off, the notch band will be created. Also, according to which one of the two switches, the radiation field will steer to a specific direction. The optimum values for each parameter has shown in Table 1.

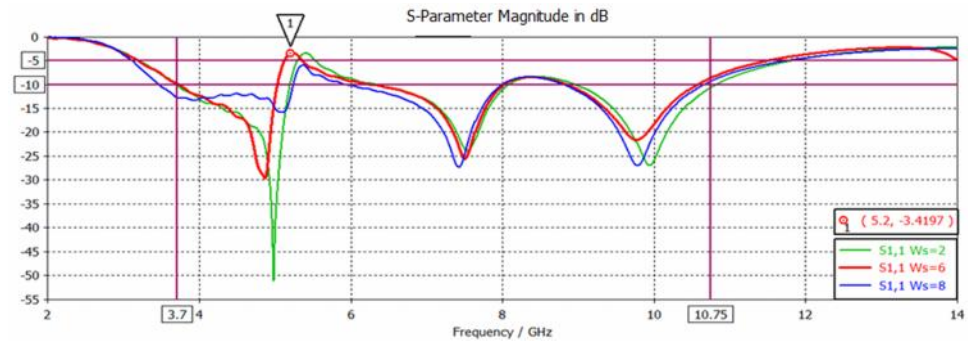
Table 1: The parameter list of the proposed antenna

Parameters	W	L	h	W_{sg}	L_{sg}	W_p	L_p	W_f
Values / mm	24	23	1	20	13	8	8	1.5
Parameters	L_f	S_1	S_2	S_3	W_{s1}	W_{s2}	L_s	
Values / mm	6	0.25	0.5	1	6	2.75	4.75	

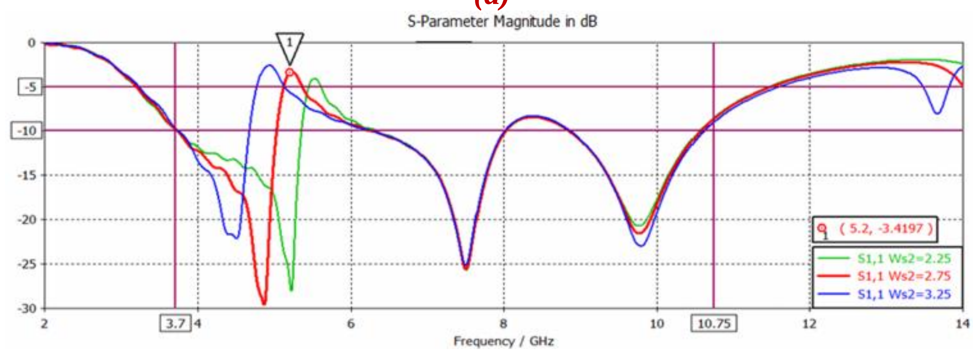
All the parameters of the designed reconfigurable antenna have an effect on the antenna performance. However, the main effect on the notch band characteristics was done by the shape, location and the size of the embedded slots, because at the notch band frequencies, the current flows around these embedded slots has the major effect with an oppositely directions nearby the slot boundaries. So, the preferred attenuation close to the notch band frequencies can be created.

To examine the width (S1, 2, 3) and length (WS1, 2 and LS) parameters, many antenna designs for the same proposed antenna with different values for (S1, 2, 3, WS1, 2 and LS) parameters has been designed.

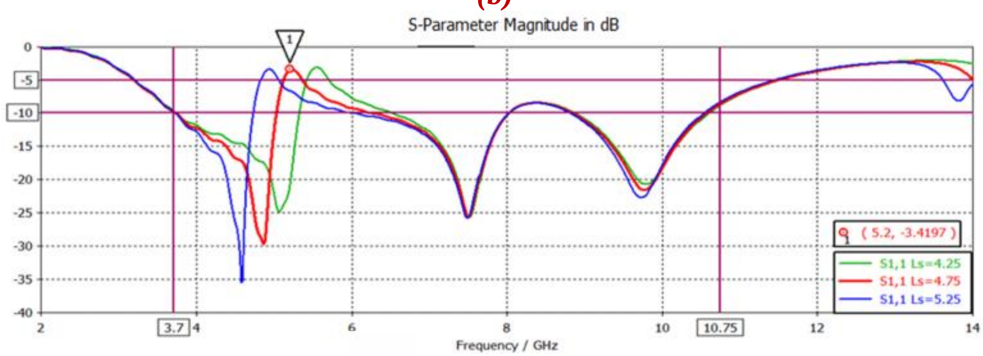
Figure 3 (a) shows the minor effect of the Ws1. The suitable value for this parameter will be used to cover the notch band. In Figure 5 (b) different value to the WS2 has been taken, and the most appropriate value for this parameter will be very suitable for the (5.2, 5.8) GHz notch bands. On the other hand, the parameters (LS) have a considerable effect on the notch band characteristics. As shown in Figures 5 (c) the presented reconfigurable antenna design with a different values to the (LS) parameter will be taken to get the best value for the (LS) parameter according to the notch band efficiency.



(a)



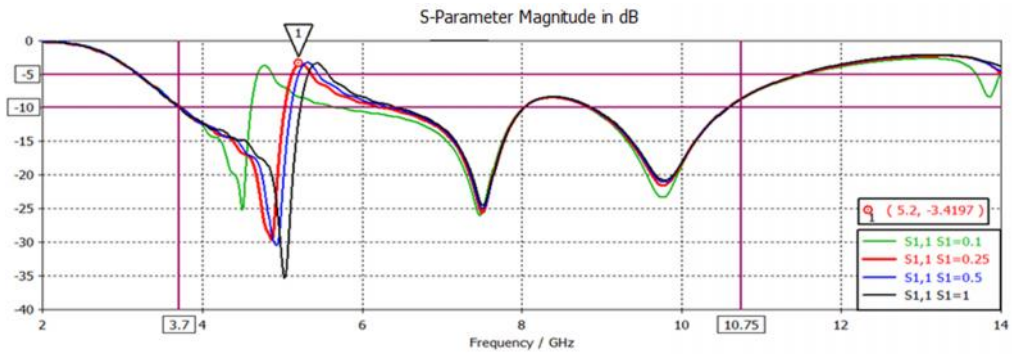
(b)



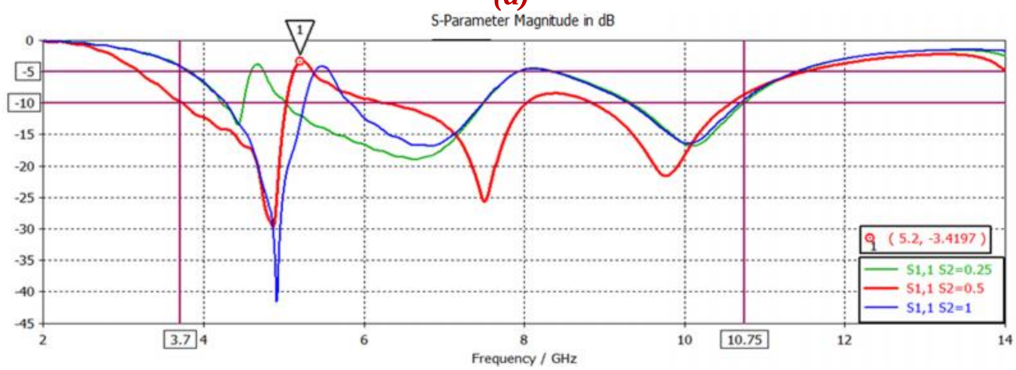
(c)

Figure 3: The simulated $|S_{11}|$ results with a various values to the slot length (WS1,2 and LS) parameters for the designed reconfigurable antenna
(a) WS1 (b) WS2 (c) LS

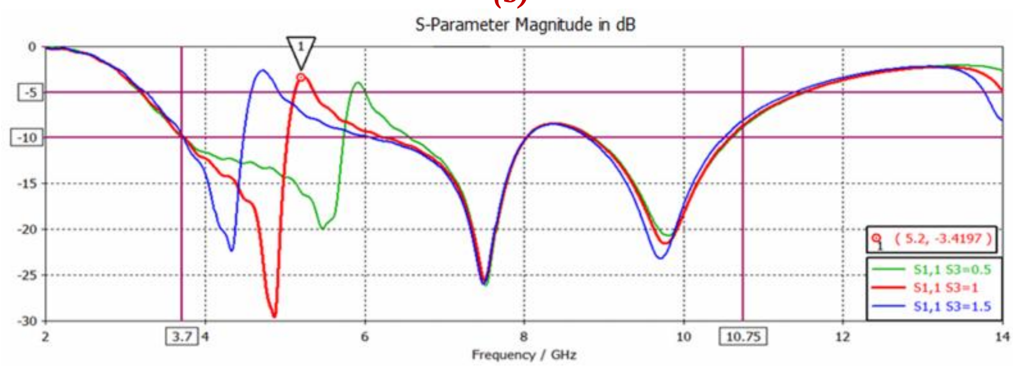
Furthermore, Figure 4 (a, b and c) shows another effects due to the values of the (S1, 2, 3) separately, and it is clear to notice the most important values to the performance of (5.2 and 5.8) GHz notch band.



(a)



(b)



(c)

Figure 4: The simulated $|S_{11}|$ results with a various values to the slot width (S1,2,3) parameters for the designed reconfigurable antenna (a) S1 (b) S2 (c) S3

The parameter values has been chosen according to this results, to satisfy the better notch band performance for the suggested reconfigurable antenna.From the previous Figures of the simulated $|S_{11}|$ with a different values for a specific parameters, which has a sufficient effect on the notch band characteristics, it is very clear to conclude that, the parameters above have the major effect among the rest parameters on the notch band properties.

Simulation and Measurement Results

Simulated results obtained for the proposed reconfigurable antenna shows an effective radiation performance to the (UWB) technique, also it has a desirable frequency notch band behavior in the frequency band (5-6) GHz. Which are used to minimize the interference effect between UWB technique and other communication applications Figure 5 shows the simulated $|S_{11}|$ with various Switching States.

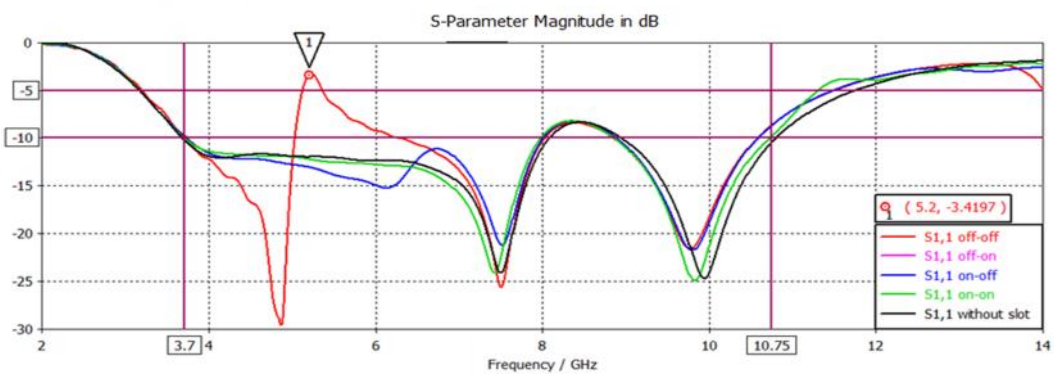


Figure 5: The simulated $|S_{11}|$ result with varying switching states for the reconfigurable antenna

The presented antenna can radiate within the frequencies of (3.7 to 8) GHz and (8.8 to 10.75 GHz) with a switchable notch band performance in the (5.15 and 5.825 GHz) for the (IEEE 802.11a). Therefore, this antenna is suitable for UWB communication applications in addition to reducing the interference effect with (WLAN) systems.

The overall results of the proposed reconfigurable antenna are summarized below:

Table 2: The Π-slot switchable notch reconfigurable antenna results

	Switch States	Operating Frequency	Gain	Directivity	Main lobe Direction	Null Direction	Angular width
1	on-on	3.7 -8 & 8.8-10.85 GHz	3.18 dB	3.656 dBi	219^0 - 321^0	90^0	109.2^0
2	off-off	3.7-8 & 8.8-10.75 GHz with 5.2 and 5.8 Notch Band	3.122 dB	3.613 dBi	219^0 - 321^0	90^0	113^0
3	off-on	3.7-8 & 8.8-10.75 GHz	3.215 dB	3.737 dBi	320^0	70^0	59.9^0
4	on-off	3.7-8& 8.8-10.75 GHz	3.215 dB	3.737 dBi	220^0	100^0	59.9^0

The simulated radiation patterns for the x-y plane of the proposed antenna are shown in Figure 6.

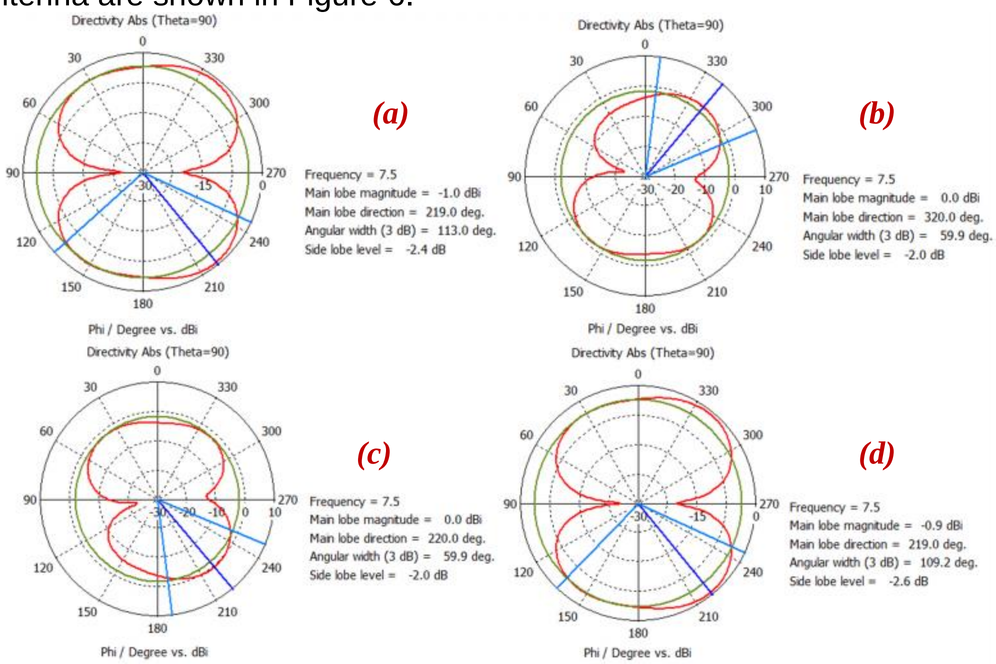


Figure 6: The simulated radiation patterns with varying switching states for the proposed reconfigurable antenna (a) off-off (b) off-on (c) on-off (d) on-on

Conclusions

The previous results show the following conclusions:

- The offered antenna has a very small size (24×23) mm and presenting a frequency band of (3.7 to 8) GHz and (8.8 to 10.75 GHz) with a switchable notch band function in (5.2 and 5.8 GHz) as seen in the previous results, these benefits are made the presented antenna a suitable reconfigurable design to the UWB technique.

- All the parameters of the proposed antenna have an effect on the performance of the proposed antenna, some of these parameters may have the most considerable effects. Specially, the dimensions of the square patch, the dimension of the ground slot and the height (h) of the substrate.

- According to which one of the two PIN switches is on, the radiation field will steer to a specific direction.

- The major effect for the shape, location and the size of the embedded slots on the notch band characteristics, because at the notch band frequencies, the current flows nearby these embedded slots has the major effect with an oppositely directions around the slot boundaries. So, the preferred attenuation close to the notch band frequencies can be created. So, the notch band performance is generally produced by the position, width (S1, 2, 3) and length (WS1, 2 and LS) of the Π-shaped slot.

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تصميم هوائي بخاصية التشكيل المتغير ذو شق بشكل ⊓ متحكم بحزم الترددات الغير مرغوب فيها للتطبيقات واسعة النطاق الترددي

صلاح مهدي* د.م. حيدر مالك التميمي*

المستخلص

هوائي بشكل مربع متغير التردد والأشعاع تم أقتراحه للتطبيقات واسعة النطاق الترددي. خاصية إلغاء الترددات الغير مرغوبة تم تكوينها من خلال إضافة شق بشكل ⊓ضمن الجزء المشع في الهوائي والذي أبعاده (24 × 23) ملم وتم طباعته على قاعدة من نوع FR-4مع ثابت العزل الكهربائي النسبي 4.3، وسمك 1 ملم. ولتلبية ترددات UWB تم تقليل طول الجزء السالب المطبوع على الجانب السفلي من القاعدة العازلة. تم التحقق من عملية النمذجة وتقدير أداء الهوائي باستخدام برنامج محاكاة الكهرومغناطيسية، برنامج تكنولوجيا المحاكاة الحاسوبية. تشير نتائج المحاكاة أن تصميم الهوائي لديه عرض نطاق ترددي فعال يمتد من حوالي (3.7-8) غيغاهرتز و(8.8-10.75 غيغاهرتز)، مع القدرة على إلغاء الترددات الغير مرغوبة ضمن (5.15 و 5.825 غيغاهرتز).

*الجامعة التكنولوجية