A Bandwidth Reconfigurable Planar Antenna for UWB-Applications

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Abstract. A reconfigurable planar antenna design bandwidth operating in ultra wide band (UWB) applications with compact dimensions of (50 × 25× 1) mm^3 is proposed. The switching capability is achieved by using a two PIN diodes F-shaped slot and a two narrow vertical slot. A defected ground structure is used to improve a range of frequency from 0.83 GHz to 5.24 GHz with an impedance bandwidth of 4.41 GHz. Moreover, the flow of current within the patch's radiation is controlled via pair of PIN diodes situated at the centre with in the patch in the F-shape slot. A retractable patch antenna design is offered, and the bandwidth re-configurability is attained by manipulating the operational states of the PIN diodes. As result, we get a reconfigurable Circular Polarization (CP). Furthermore, the proposed antenna demonstrated an efficiency of 88.55% infrequencies operating at 3 dB Axial Ratio (AR) bandwidths. All achieved results shows that our antenna design is working much with 5G and UWB application.

1 Introduction

Nowadays, antennas play a big role in transmission and reception of electromagnetic signals in communication systems. In recent years, the demand for data, voice and video communication data, with the increasing emergence of high-tech devices and equipment using the receiving and transmitting antenna such as satellite, mobile communication, WLAN/WiMAX and RFID communication, has increased. The designed antenna can serve either as transmitting or receiving antenna device according to the antenna action mechanism. There are four types of antennas: reconfigurable frequency antennas [1-3], reconfigurable direction figure antennas [4-5], reconfigurable multi-method hybrid antennas and reconfigurable polarized antennas. For our case, we are interested in the polarized reconfigurable antennas which allow us to control the characteristics of polarization of the radiators. These types of antennas enable us to shift regulate linear polarizations, left-hand circular polarization (LHCP), right-hand circular polarization (RHCP) and any other type of elliptical polarizations [6–9]. The antenna is considered as a transmitter in the case RF energy is radiated, while it is regarded as a receiver when RF energy is captured in the developed overall system. This will allow for a better understanding of the role and the scope of UWB devices. However, the spectrum resource of the frequency occupation for modern wireless technology of communication is increasingly restricted [10-11]. To this end, there's an increasing demand for antennas to achieve a wide band expansion and to more compatible with applications using UWB technologies as detailed in IEEE 802.15.6 standard [12-13], and compared to the other narrow frequency ranges in [14-16].

In our paper, a reconfigurable bandwidth antenna for UWB applications, namely WLAN/WiMAX, is proposed. A design utilizing the reconfigurable technique is implemented to make the method switches among four different impedance bandwidths, by changing the PIN diodes states to accomplish the re-configurability.

This article is divided into three sections. We will start with the design proposed antenna geometry. The second section, we will examine and discuss the influence of F-shaped slot controlled by using two PIN diodes on the antenna performance and the simulation study of the left and the right circular polarization. Finally, the last section presents radiation properties with the CP-Sense and its effects

2 Theory

This subsection is introduced to outline the fundamental and basic antenna properties that facilitate the understanding of any antenna. By varying the antenna's form, the antenna's performances are legitime to be altered and varied. It is important to note that the characteristics of the proposed antenna pertaining to gain, bandwidth, polarization, and efficiency are not related to the use of the antenna either when transmitting or receiving. In most study cases, the bandwidth is constrained by the input impedance and the pattern of the radiation of the considered antenna. The bandwidth

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of the antenna extremely depends upon the specific investigated application. For the antennas for which the bandwidth is below -10 dB, the antenna indicates a good matching design. The coefficient of reflection at the first interface between sections of the transmission line with and without the specimen is defined as:

$$\Gamma = (Z_{ant} - Z_0)/(Z_{ant} + Z_0) \quad (1)$$

Here

$$\Gamma(s) = \Gamma e^{-2\gamma s} = \rho_\tau e^{j(\theta t - 2\beta\sigma)} \text{ and } \Gamma_\tau = \rho_\tau e^{j\theta} \quad (2)$$

We define the "Return Loss" as follows;

$$RL = 20Log10(\Gamma) \quad (3)$$

The SWR or the Standing Wave Ratio as well as the reflection coefficient translates the impedance adaptation between two elements is therefore equal to

$$SWR = (1 + |\Gamma|) / (1 - |\Gamma|) \quad (4)$$

The bandwidth of an antenna therefore defines the frequency range in which the reflection coefficient is less than ≤ -10 dB. We then speak of absolute bandwidth for an S11≤ -10dB. Fig. 1 shows the S11 parameter of an antenna as a function of frequency and highlights the bandwidth for an S11 ≤ -10dB.

$$BP = \Delta F = f_2 - f_1 \quad (5)$$

The bandwidth of an antenna is often expressed in terms of the bandwidth relative to the resonant frequency.

$$BP\ (\%) = \Delta F / f_{res} * 100 \quad (6)$$

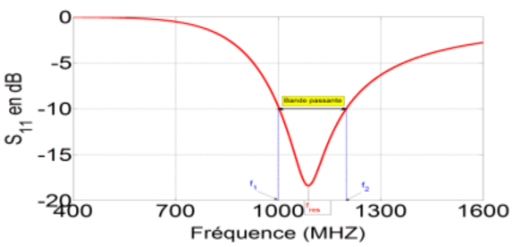


Fig.1. | S11 | of an antenna in dB as a function of the frequency

As shows Fig 2, the design construction two narrow vertical slots and an F-shaped slot either. It is cut from an FR4 substrate with relative permittivity 4.4; its thickness is 1 mm, and it has a global dimension of (25x50) mm^2 with ground dimension of (25x50) mm^2. The design antenna is built with a rectangular radiation patch with an F-shaped slot, two narrow vertical slots, a ground plane, and a microstrip feed line. Two PIN diodes are connected in the middle of the F-slot. Furthermore, the two PIN diodes Micro semi MPP4203 [17] are used as switches. We switch the working state of two PIN diodes to see the evolutionary frequency response of the reflection bandwidth ARBW of -10 dB. An electromagnetic simulator named High Frequency Structure Simulator (HFSS) for the design and the optimization of our proposed antenna. Finally, the used parameters are Ls=50 mm, Ws=25 mm, Lg=30 mm, L1=8 mm, L2=1 mm, L3=1.5 mm, L4=14 mm, L5=1.5 mm, W1=1.3 mm, W2=1.5 mm, W3=1 mm, W4=17 mm, W5=0.2 mm

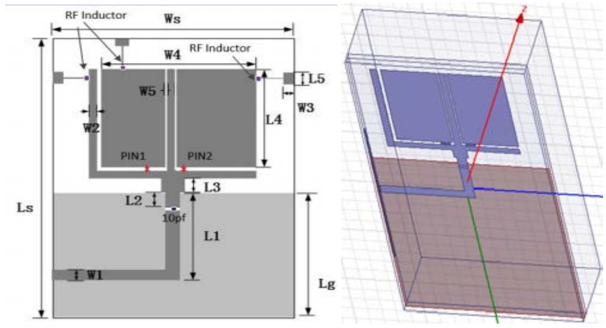


Fig.2. Structure of the proposed antenna

3 Results With Discussions

Fig 3 shows the evolutional frequency response for the proposed antenna by manipulating between the states of two PIN diodes. To illustrate, in Mode One when the two PIN diodes are off, the distribution of the surface current primarily flows along the F-shape that is like a type of monopole antenna. The antenna generates one resonant frequency and has two impedance bandwidths ARBW of -10 dB. The large band moves from 0.92 GHz to 5.2 GHz while the narrowband move from 5.35 GHz to 6.25 GHz. In Mode Two, the left PIN diode is switched on and the right one is switched off. This mode also has two ARBW of -10 dB. The large band moves from 1.2 GHz to 5.21 GHz means while the second one moves from 5.24 GHz to 6.06 GHz. In Mode Three, the right PIN diode is switched on and the left one is switched off. This mode only has one large impedance bandwidth that is 4.41 GHz. As for Mode four, both diodes are turned on. It has two ARBWs of -10 dB, the large band of 3.98 GHz and the narrowband of 0.8 GHz. As we can see, all modes have almost the same impedance bandwidth with different resonance frequencies, which give us the opportunity to use this antenna configuration in multiple applications. Besides, we notice that mode three performed better at the impedance bandwidth's frequency that is 4.41 GHz. Indeed, we believe that configuration antenna can work with specific wireless band, such as RFID, WLAN, WIMAX, LAN, UWB, and mobile communication

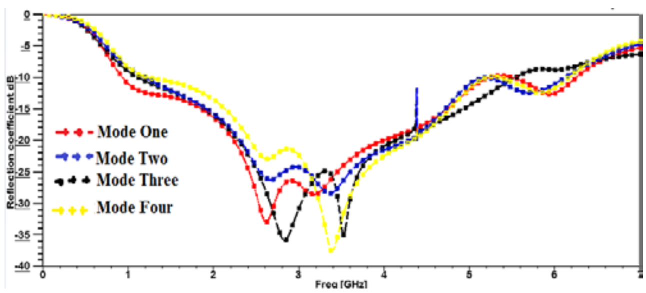


Fig.3. Coefficients of Reflection of the proposed antenna.

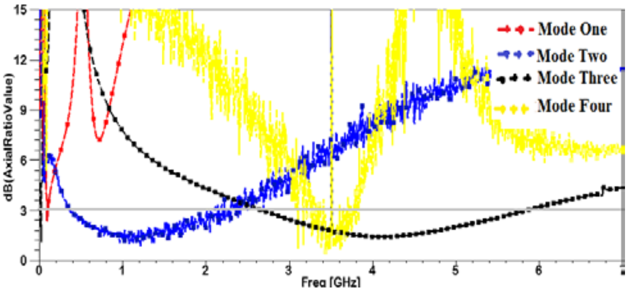


Fig.4. ARs of the proposed antenna.

Fig 4 presents the simulation result of the 3 dB Axial Ratio (AR) bandwidths for different state of two PIN diodes at 3.5 GHz. However, the first mode has no detectable 3dB AR bandwidth. Mode two shows that the simulated 3 dB AR bandwidths cover the frequencies band from 0.25 GHz and at 2.2 GHz. Mode Three, the response of 3 dB AR bandwidths covers a large band of frequencies from 2.24 GHz to5.8 GHz with 88.55%. But for the fourth mode, the3 dB AR band width covers a narrow band from 3.02 GHz to 3.82 GHz with 23.39%. The several 3dB AR bandwidths range from narrow-band to a wide-band with 23.39% to 88.55% respectively. In fact, those results confirm that our proposed antenna for several wireless communication such as fourth generation (4G), WLAN, WiMAX, and satellite communication technology without interference. Besides it has the capability to switch easily between all mentioned wireless communications. In addition, this configuration has the suppleness to perform in different bands

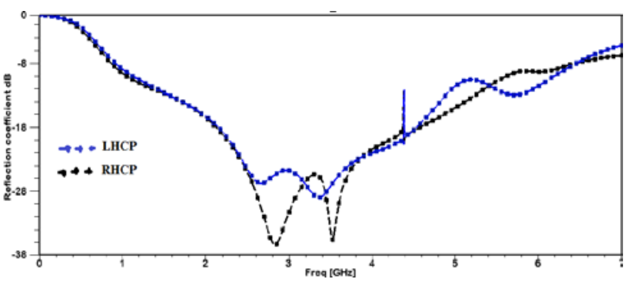


Fig.5. Reflection coefficients for the right and left circular polarization of the proposed antenna.

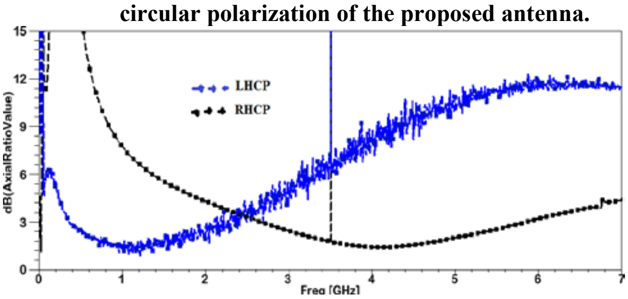
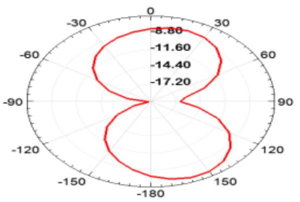


Fig.6. ARs of the antenna for the left and right circular polarization.

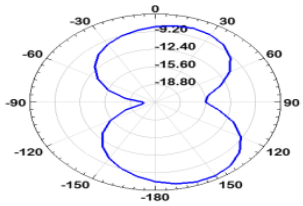
Fig 5 shows the frequency response of the reflection bandwidth ARBW of -10dB for both the left and the right circular polarization. We observe that both polarizations have almost the same bandwidth with little change. Besides, we can see that the right polarization has a good adaptation of the antenna with two resonances frequencies, which is better comparing to the left polarization. But when we examine the simulation result of the 3dB AR bandwidths in the Fig 6, we see that the left polarization has a response from 0.25 GHz to 2.21 GHz. On the other hand, we see that right polarization perform from 2.24 GHz to 5.8 GHz; therefore, we can say that right polarization complements the left polarization.

The simulation radiation patterns in the four different modes are shown in Fig. 7. The radiation patterns for the first three modes are almost unchanged in these states. The proposed antenna does not have an omnidirectional radiation, so they are not shown for brevity. It can be seen that the cross-polarization level is very small. It is also observed that the frequency characteristics are maintained in these states. However in the last mode, we see that the main lobe is directed in the same area.

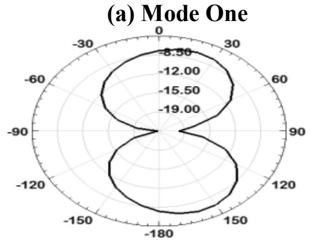
In Fig 7 (e) the simulation of radiation patterns, we noted that radiation of left and right polarization has a little difference regarding the position of lobes. The right one is oriented toward the right area, but the left is oriented toward the left area



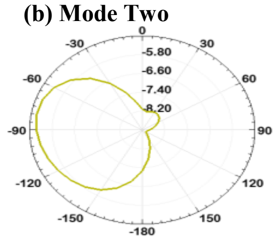
(a) Mode One



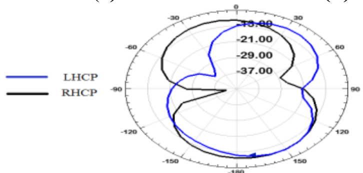
(b) Mode Two



(c) Mode Three



(d) Mode Four

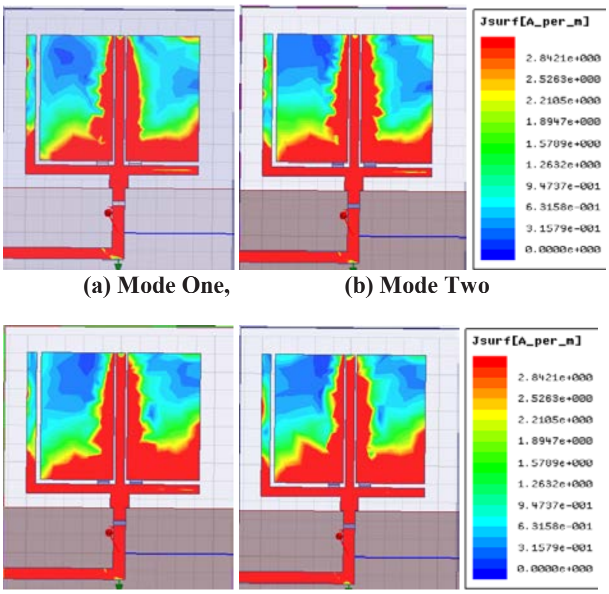


(e)The left and right circular polarization

Fig.7. Radiation patterns of the proposed antenna

4 Surface Current Distribution

The surface current distribution of different frequencies for different state of two PIN diodes at 4.5 is simulated, as shown in Fig. 8. Notice that most of the surface current extend from the bottom to the middle and the edge of the patch, the current with larger intensity located in a two narrow vertical slot in the middle of the patch as shown in Fig. 8 (a). Mode Two shows that most of the surface current extend from the middle in two narrow vertical slots of the patch, and the feeble current placed in the edge of the lift PIN diode of the patch as shown in Fig. 8 (b). Mode Three, as shown in Fig. 8 (c), shows that the surface current spread from the bottom to the middle in a narrow vertical slot and edge of the right PIN diode of the patch. Mode four, as shown in Fig. 8 (d), illustrates that the surface current spread from the bottom to the middle in a narrow vertical slot and edge of two PIN diodes of the patch.



(a) Mode One, **(b) Mode Two**

(c) Mode Three **(d) Mode Four**

Fig.8. Surface current distribution at 4.5GHz.

5 Performance Comparison

The table 1 and Fig 9 highlight a comparison between our proposed antenna with other reconfigurable antennas. In other words, we compared our proposed antenna's performance with other antennas in terms of break gain response and −10 dB reflection bandwidth as well. We have noted that our proposed antenna has scored the highest gain results in comparison to other antennas. On another hand; we can see that our simulation result has a good response, particularly when we observe the resonance frequency move to 4.41 GHz. The results of working with several modes show that the presented antenna has a good isolation at the operating bands with multiple resonances and the antenna gain.

Table1.A performance comparison of circularly polarized antennas

Ref.	Size (mm3)	Description	Band with (GHz)	ECC
This work	50 × 25× 1	Reconfigurable Planar Antenna	0.83-5.24	-38 dB
[18]	66×83×0.39	CP Using The Proposed DR	2.44-5.88	-33 dB
[19]	19× 19 ×1.6	Circular Monopole Antenna	4.36-6.06	-35 dB
[20]	49.4×49.4×1.9	E-shaped Fractal DGS	3.23-3.65	-29 dB
[21]	26×22×0.21	Microstrip Antenna Array	5.65–5.9	-34dB

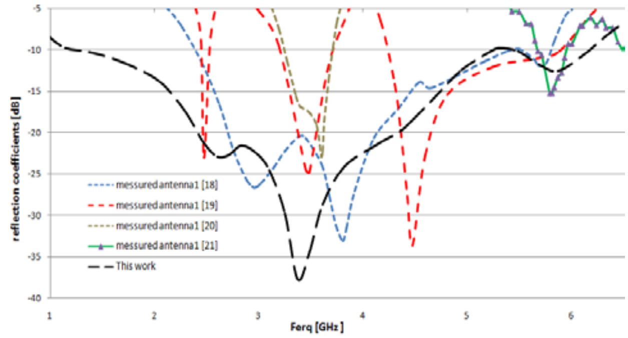


Fig.9. Comparison of reflection coefficients for polarized antennas..

Relying on results from table 1 and Fig 9, we observe that our design have a huge band that can attain to 4.41 GHz with gain -38 dB, whereas other published works antennas do not exceed 3.44 GHz according to previous works [18], particularly when we compared the band of our antenna with that previous works [19], [20] and [21] that the band reaches to 1.7 GHz, 0.42 GHz and 0.25 GHz respectively. It is can be clearly noticed that the proposed design has a wide large band compared to all the previous works and the highest gain value. Therefore, the proposed structure can be used for certain practical applications using an UWB technology that has a requirement compatible with its characteristics and performances.

6 Conclusion

A reconfigurable bandwidth- antenna composed of a radiation patch that is rectangular and of a rectangular patch and an f shaped slot that is faster to a micro strip feed-line with a truncated ground plane of an FR-4 substrate is proposed. The results indicate that by manipulating the diodes states, the bandwidth frequency characteristics of the proposed antenna can be reconfigured to a wider band. The antenna's impedance bandwidth is a huge band that can attain to 4.41 GHz ([0.83-5.24] GHz) with gain -38 dB. These promising findings come as result of experimenting with different states of PIN diodes. We have observed, too, that resonance frequency in the narrow-band and wide-band covers all UWB frequencies band which makes the proposed antenna compatible to use in various wireless communication systems. Moreover, it can be used for wireless technology, such as WLAN, satellite communication, WiMAX, and fourth generation (4G) technology.

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