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REGULAR ARTICLE

Two PIN Loaded Inverted *L* Slot Embedded Polarization Reconfigurable Antenna for WLAN Applications

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A simple and compact polarization reconfigurable patch antenna design is proposed to operate in WLAN band at a resonant frequency of 2.4 GHz. This antenna consists of a rectangular patch placed on an FR4 substrate. A rectangular slot is cut in the rectangular patch. Two L shaped microstrip strips are placed inside the slot and joined together at the centre of the rectangular patch by inverting the L shaped microstrip. There are three different methods of achieving the reconfigurability namely electrical, mechanical and optical. This proposed structure uses electrical reconfiguration technique. This proposed antenna structure uses PIN diodes for achieving the polarization reconfigurability because of its ease in biasing. Two PIN diodes both being placed on the inverted L shaped structure in order to achieve the polarization modes and these PIN diodes are used to connect this microstrip with the rectangular patch. By switching these two PIN diodes for various biasing conditions, four different polarization modes namely two linear polarization (LP) modes, one Left Hand Circular polarization (LHCP) and one Right Hand Circular polarization (RHCP) mode is achieved. The antenna produces simulated gain of around 1.5416 dB for LP1 mode at 2.41 GHz, 1.7175 dB for LP2 mode at 2.45 GHz, 1.6062 dB for RHCP mode and 1.5922 dB for LHCP mode both at 2.4 GHz. The antenna structure is simulated using Ansys HFSS.

Keywords: Reconfigurable, WLAN, PIN diode, Linear polarization, Circular polarization.

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1. INTRODUCTION

To meet the operational demand in changing scenarios of wireless communication, the reconfigurable antenna plays a vital role as its characteristics like frequency, polarization and radiation properties can be dynamically varied to maximize the antenna performance. Based on the characteristics that are varied, the reconfigurable antennas are categorized as frequency reconfigurable, polarization reconfigurable and pattern reconfigurable. Losses due to polarization mismatch incur several problems and hence to mitigate these effects, polarization reconfigurable antennas are widely used.

Implementing a cognitive radio system by using a frequency reconfigurable sensing antenna with mechanical reconfigurabillty technique is presented in [1]. Different types of reconfiguration namely frequency reconfiguration, pattern reconfiguration, polarity reconfiguration can be obtained by different methods say electrical, optical, physical and material change [2]. A frequency reconfigurable antenna for 4G LTE frequency bands can be designed using a *L* shaped strip [3]. In [4] a dual layer antenna containing breach truncated circular metal radiator for polarization reconfiguration is discussed. Polarization reconfigurabitlity can be achieved using simple mechanical tactile switches on H shaped slot is presented in [5] whereas [6] discusses about a frequency reconfigurable antenna design using mechanical stepper motors. Though the mechanical methods can be used for polarization and frequency reconfigurability, implementing these mechanical methods with external motors finds quite difficult and incurs additional frictional loss and hence the electrical reconfigurability using PIN diodes [16] have been elated. Dual reconfgurability achievement using PIN diodes for wireless communications has been presented in [7] with dual ports and [8] with single port. In [9-10] the polarization reconfigurability using truncations and slots [13, 14] are presented. Introducing slots to achieve

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multiple wireless bands [11] and a simple rectenna for energy harvesting is discussed in [12]. Numerical analysis for different substrates on a microstrip patch is discussed in [15]. The impact of PIN diodes in achieving polarization reconfigurability for multiple wireless bands is presented in [16] and [17] presents an idea about beam forming antenna arrays with high gain for space applications.

2. DESIGN AND SIMULATION

2.1 Proposed Antenna Geometry

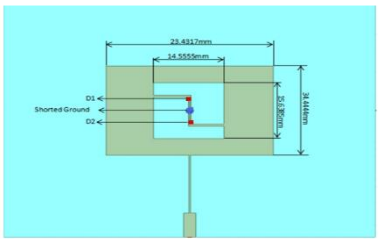

Fig. 1 – PIN Loaded Inverted L Slot Antenna

The structure of the proposed PIN loaded inverted slot antenna model is presented. The model is designed on FR4 substrate of size 38 mm × 38 mm × 1.6 mm having a permittivity of 4.4 and loss tangent (ζ) of 0.002. The antenna consists of a rectangular patch with a rectangular shaped slot cut from the rectangular patch. One L shaped strip and another inverted L shaped strip are joined together at the exact symmetric center of the rectangular slot with a shorted ground in order to achieve polarization diversity. The dimensions of the rectangular patch along with the slot dimensions simulated using HFSS are shown in Fig. 1.

The polarization reconfigurability is achieved by electrical means in which two pin diodes (NXP BAP50-03, 50 mA and 50 V) are exactly fixed in the terminal end of the L arm. The diodes exhibit a series resistance of 5 Ω under ON condition with an inductance of 1.8 nH similarly the diodes exhibit a 500 kΩ resistance under OFF condition with a shunt capacitance is 0.35 pF. The equivalent circuit diagram for the PN diodes under ON and OFF condition is presented in Fig. 2.

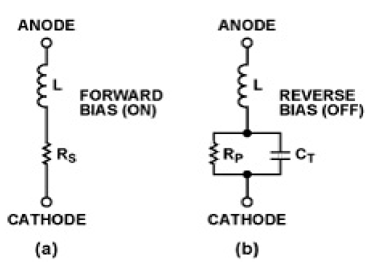

Fig. 2 – Equivalent Circuit of PIN diode (a) forward bias, (b) reverse bias

Where L is the inductance, R_s is the forward bias resistance, R_p is the reverse bias resistance and C_T is the reverse bias capacitance. The PIN diodes are excited using an external DC bias circuit.

2.2 Modes of Polarization

This antenna produces four modes of polarization for varying conditions of PIN diode and is tabulated.

Table 1 – Polarization modes based on diode condition

Modes	*D1*	*D2*	Excitation	Band	Polarization
1	OFF	OFF	Port 1	1	0° (LP)
2	ON	ON	Port 1	2	90° (LP)
3	ON	OFF	Port 1	3	RHCP
4	OFF	ON	Port 1	3	LHCP

Table 1 clearly depicts that the proposed PIN loaded inverted *L* antenna operates at three different bands and produces three different polarization states. Under no DC bias condition, both diodes (D1, D2) are in OFF mode which makes the antenna to behave like a normal rectangular patch tending to resonate at band 1 (2.41 GHz) achieving Linear Polarization (00). The antenna produces another Linear Polarization (900) mode resonating at 2.45 GHZ frequency when both the diodes (D1, D2) are turned ON with an external DC bias. When positive DC bias is applied to diode D1, and negative bias to diode D2, the diode D1 is forward biased and diode D2 is reverse biased making the upper L shaped strip line to be in contact with the center patch. This technique tends the antenna to resonate at 2.4 GHZ producing RHCP signal.

Similarly, when positive DC bias is applied to diode D2, and negative bias to diode D1, the diode D2 is forward biased and diode D1 is reverse biased making the lower L shaped strip line to be in contact with the center patch and resonates at 2.4 GHZ producing LHCP signal.

3. RESULT AND DISCUSSION

This section discusses about the reflection coefficient and the radiation pattern characteristics of the proposed antenna for all the modes of operation.

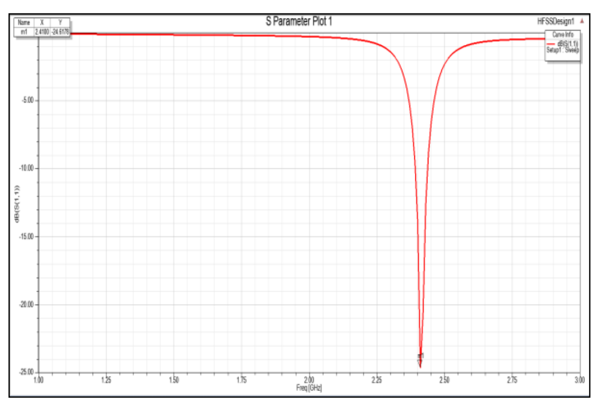

Fig. 3 – Reflection Coefficient of Mode-1 (Linear Polarization)

The reflection coefficient characteristics of the antenna at mode-1 (LP) is shown in Fig. 3 and the return loss is – 24.6178 dB. Fig. 4 shows the radiation pattern with 1.5416 dB at 00 at a resonant frequency of 2.41 GHz.

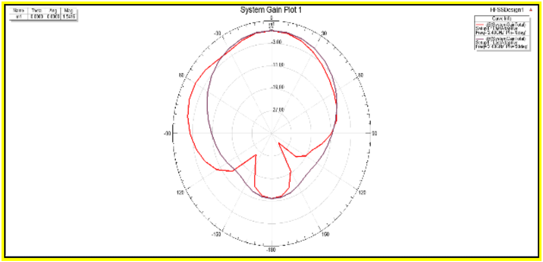

Fig. 4 – Radiation pattern of Mode-1 (Linear Polarization)

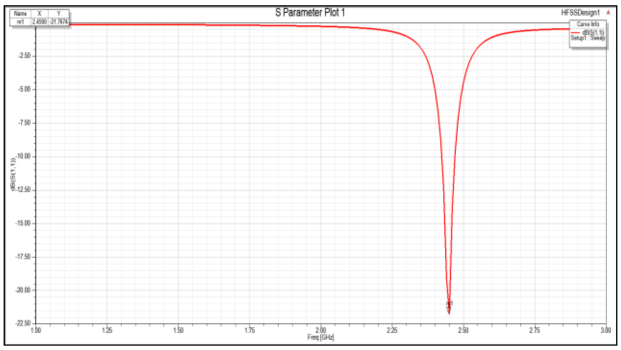

Fig. 5 – Reflection Coefficient of Mode-2 (Linear Polarization)

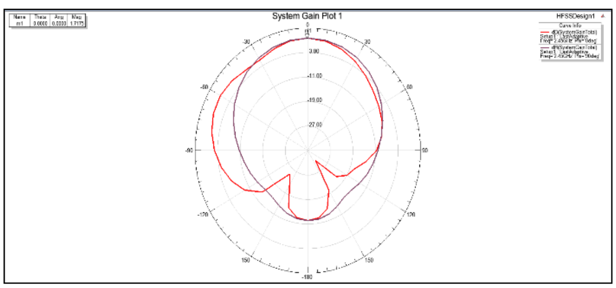

Fig. 6 – Gain Plot of Mode-2 (Linear Polarization)

Fig. 5 shows the reflection coefficient characteristics of – 21.7674 dB and Fig. 6 represents the gain characteristics with a gain of 1.7175 dB respectively for the resonant frequency 2.45 GHz at 900.

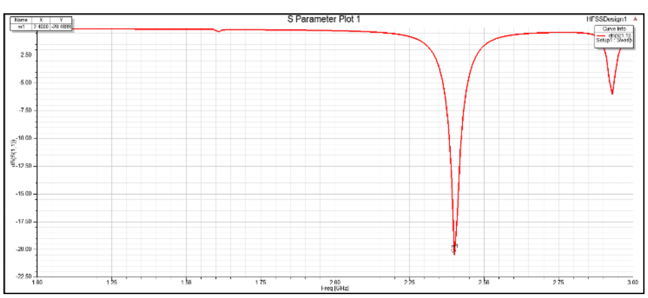

Fig. 7 – Reflection Coefficient of Mode-3 (Right Hand Circular Polarization)

The Right Hand Circular Polarization of the antenna achieves – 20.4899 dB return loss and a gain of 1.6062 dB at a resonant frequency of 2.40 GHz and is presented in Fig. 7 and 8 respectively.

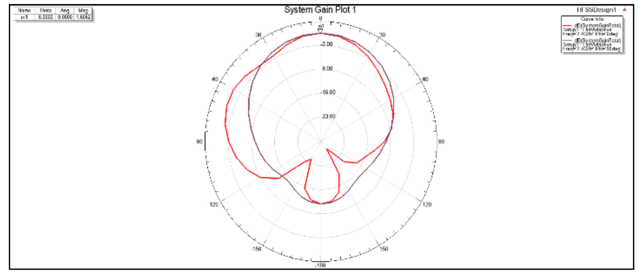

Fig. 8 – Gain Plot of Mode-3 (Right Hand Circular Polarization)

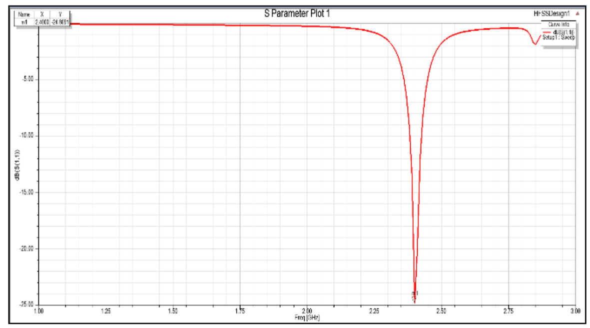

Fig. 9 – Reflection Coefficient of Mode-4 (Left Hand Circular Polarization)

The Left Hand Circular Polarization of the antenna achieves – 24.8091 dB return loss at a resonant frequency of 2.40 GHz.

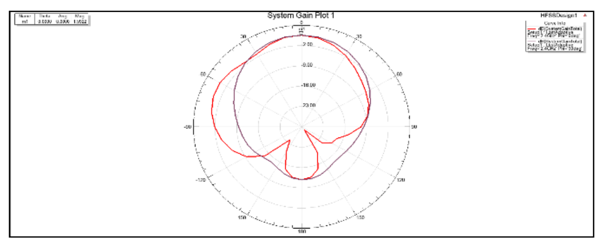

Fig. 10 – Gain Plot of Mode-4 (Left Hand Circular Polarization)

Fig. 10 represents the gain of the proposed antenna with 1.5922 dB at a resonant frequency of 2.40 GHz.

4. CONCLUSION

A simple polarization reconfigurable antenna with an embedded inverted L strip loaded with PIN diodes for reconfiguration is proposed. This antenna is fabricated on a low cost FR4 substrate. This antenna structures gives four different polarizations with two PIN diodes only. It also gives good return loss and gain for all the polarization modes resonating in 2.4 GHz band and hence it is suitable for WLAN applications.

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Поляризаційна реконфігурована антена для додатків WLAN з двома PIN-кодами та перевернутим *L*-слотом

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Запропонована проста і компактна конструкція патч-антени з реконфігурацією поляризації для роботи в діапазоні WLAN на резонансній частоті 2,4 ГГц. Ця антена складається з прямокутної накладки, розміщеної на підкладці FR4. У прямокутній накладці вирізається прямокутна проріз. Дві *L*-подібні мікросмужки розміщуються всередині слота та з'єднуються разом у центрі прямокутної накладки шляхом інвертування *L*-подібної мікросмужки. Існує три різні методи досягнення реконфігурації, а саме електричний, механічний та оптичний. Ця запропонована структура використовує техніку електричної реконфігурації. Ця запропонована структура антени використовує PIN-діоди для досягнення можливості реконфігурації поляризації через її легкість у зміщенні. Два PIN-діоди, обидва розміщені на перевернутій L-подібній структурі для досягнення режимів поляризації, і ці PIN-діоди використовуються для з'єднання цієї мікросмужки з прямокутним патчем. Перемикаючи ці два PIN-діоди для різних умов зміщення, досягається чотири різних режими поляризації, а саме два режими лінійної поляризації (LP), один режим лівої кругової поляризації (LHCP) і один режим правої кругової поляризації (RHCP). Антена створює імітований посилення приблизно 1,5416 дБ для режиму LP1 на 2,41 ГГц, 1,7175 дБ для режиму LP2 на 2,45 ГГц, 1,6062 дБ для режиму RHCP і 1,5922 дБ для режиму LHCP на 2,4 ГГц. Структура антени моделюється за допомогою Ansys HFSS.

Ключові слова: Реконфігурація, WLAN, PIN-діод, Лінійна поляризація, Кругова поляризація.