Frequency Reconfigurable Microstrip Patch Antenna for Wireless Communication

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ABSTRACT
Modern communication devices support several applications which requires several antennas operating at different frequencies on a single device. Therefore, using multiple antennas on the single devices is not possible. Hence there is need for integration of a single antenna that can operate at different frequencies which can support several applications in a single device. In this paper reconfiguration is achieved with the aid of PIN diodes located on two U-slots on the main antenna radiating patch. Since the resonance frequency is inversely related to the size of the radiating patch, The PIN diodes are switch ON and OFF to progressively activate the radiating patch which consequently produce dual band frequencies at F1 (2.5847 and 5.189 GHz), F2 (4.2271 and 5.2051 GHz) and F3 (3.2051 and 4.7138 GHz). Only simulated results of reflection coefficient and radiation pattern are presented. The antenna is a potential candidate for Wireless local Area Network (WLAN) (5.2 GHz) and Fifth Generation (5G) 2.5 GHz applications
Keywords: *Antenna · Reconfigurable · PIN diodes*

1. INTRODUCTION

An antenna is an electromagnetic device used to receive or transmit electromagnetic wave. Patch antennas are commonly used in modern communication because of their light weight, low profile, inexpensive and easy to fabricate. It has an application in satellite communications, aircraft and various military purpose [1]. Modern communication devices like smart phones, computers and others support several applications which requires several antennas operating at different frequencies on a single device. Therefore, using multiple antennas on that device is not possible because it accommodates much space, high cost and un-reliable. Hence there is need for integration a single antenna that can operate at different frequencies which can support several applications in one device. Therefore, frequency reconfiguration method is a simple idea that can resolve this issue, where an antenna is design with a reconfiguration mechanism to change it is operating frequency dynamically. Reconfigurable antennas are antennas that has capability of modifying their properties such as frequency, polarization and radiation pattern dynamically in controlled and reversible manner [2], [3]. Frequency reconfigurable antennas are the antennas that have capability of modifying their operating frequency dynamically by increasing or decreasing the dimensions of the antenna physically or electrically using radio frequency (RF) switches, impedance loading or tunable materials [4].

The frequency reconfigurable antennas are useful in a situation where several communication systems needed to be integrated in a single device, so the idea of a single antenna with a multiple operating frequencies is deployed instead of fabricating a multiple antenna on a single device [5]. There is different switching mechanism being used to achieved frequency reconfigurable such as PIN diode, varactor, field effect transistors

(FETs) and the radio frequency microelectromechanical systems (RF MEMS). Pin diodes are commonly used by many researchers because of its low cost and easy to fabricate [6], [7]. In [8], patch antenna with serpentine cantilever beam is designed. U-shaped slot is also presented on the patch. The radio frequency microelectromechanical systems (RF MEMs) switch was presented on the slot in order to achieved the configuration of the antenna. As the state of switch is changed, the dimension of the antenna is also changed. And the antenna is capable to modify its frequency up to three frequency bands. The antenna has a complex structure and the radio frequency microelectromechanical systems (RF MEMs) switch is difficult to fabricate. Also in [9], microstrip patch antenna is designed with two L-shaped slot on the patch. Two PIN diodes was presented on the slot. As the state of the PIN diode change, the dimension of the antenna is also changed so that the frequency of the antenna will change dynamically. About nine frequencies reconfigurable is achieved. The position of the transmission line of the antenna is difficult to obtain, since the transmission line is not at the middle. In [10], microstrip patch antenna designed with a parasitic patch located at the top of the patch. Three PIN diodes presented between the actual patch and the parasitic patch in order to connect the two patches. As the state of the PIN diode change, the effective length of the patch will change and the antenna will modify its frequency. This antenna reconfigures only one frequency that is from 2.2GHz to 2.45GHz. In [11], the patch antenna with concept enable by adhesive polyimide tape was designed. The antenna can switch from a conventional patch to monopole-like antenna with minimal actuation complexity. The antenna reconfigured its frequency form 2.1GHz to 2.4GHz. The antenna has a complexity in reconfigure its frequency because no active components used in order to increase or reduce the size of the patch. In [12], planar antenna with narrow and ultra-wide (UWB) bands was designed. Its ground plane made of nickel-titamin with shape memory alloy (SMA) is also presented. The antenna operates at flat condition with frequency of 1.16GHz. Upon bending the SMA ground plane at an angle of 200° with a transformation temperature of 66°C. The same antenna operates over 3.4GHz to 10.2GHz UBW range, this is due to the SMA phase transformation via resistive heating and cooling. The antenna has no sources of heat, hence, it is difficult for the SMA to bend. In this paper, a microstrip strip patch antenna with frequency reconfigurability features is proposed. Two U-shaped slots was presented to separate the three patches and six PIN diodes were used to modified the size of the radiating patches in order to obtain various frequency bands knowing fully that resonant frequencies are dependent of the patch sizes. Three configurations of dual bands are obtained by proper switching combinations of F1, F2 and F3 switches. This antenna has a simple structure and also have an application in WLAN and future generation. Section II discusses the design methodology and approach, section III discusses the simulated results and analysis while section IV concludes the paper with references.

2. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Figure 1. The antenna is design on lossy Flame Retard-4 (FR-4) substrate with permittivity of 3.4 with tangential loss of 0.025 and thickness of 1.6 mm. The antenna is fully grounded with substrate material dimension of Ws x Ls x Hs. The switches are placed on the two slots to progressively increase the size of the radiating patch. The antenna is fed via an inset transmission line of size Wt x Lt. The patches are separated by slot s with three switches S1, S2 and S3 in each slot which must be on same diode state (0 0 0) or (1 1 1).
The equations (I) and (ii) used in the design to match the impedance of this antenna;

$$Z_0 = \frac{87}{\sqrt{\varepsilon_r + 1.41}}\, In\left[\frac{5.98h}{0.8W_f}\right] \quad (1)$$

$$L_f = \frac{\lambda_g}{4} \quad (2)$$

In order to achieve the frequency reconfigurability, three PIN diodes were presented on every slots. And all the design and simulation was done using Computer Simulation Technology (CST) software 2019.
The dimensions of the antenna are presented in table 1 below.

Table 1: Dimension of the proposed antenna

Parameters	Ws	Ls	h	Wp	Lp	W1	L1	W2	L2	W3	L3	Wy	Ly	Wf	t
Dimension (mm)	46.5	48.1	1.6	34.9	24.3	25.9	15.7	22.9	14.3	12.9	7.9	4.0	15.6	3.0	0.035

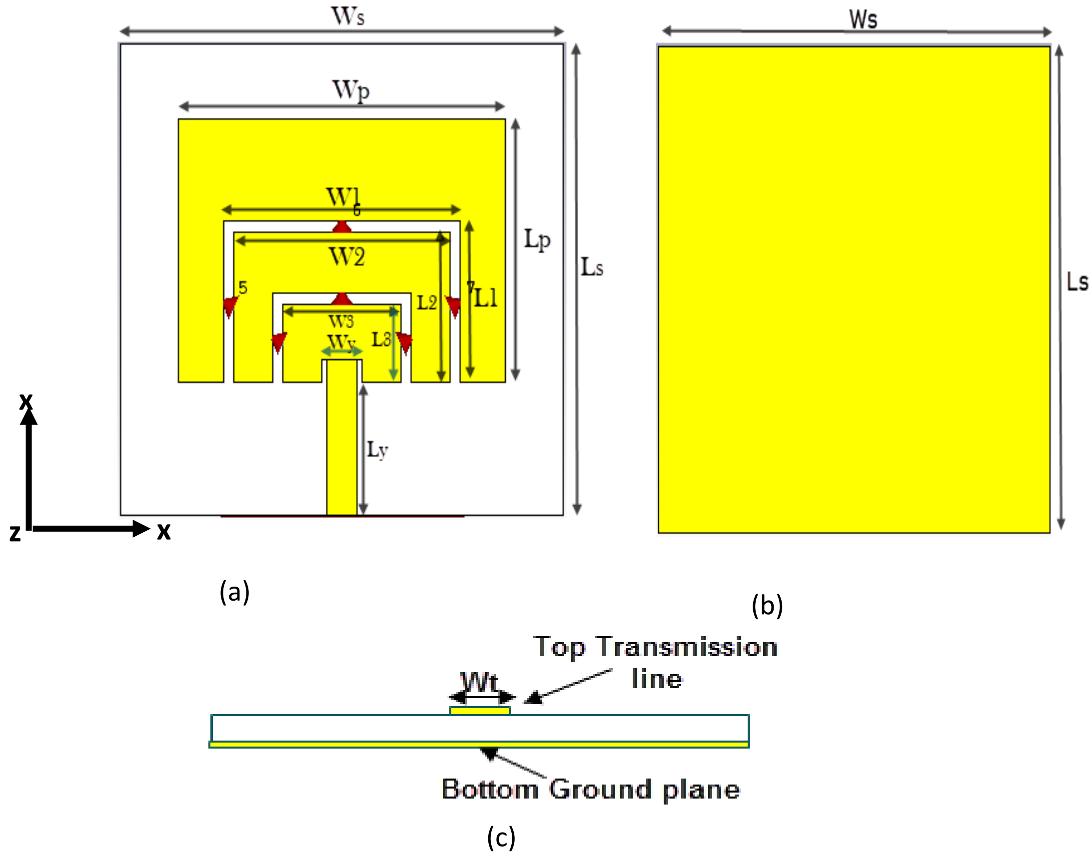

Figure 1: Geometry of the proposed antenna (a) Front view (b) Back view (c) Side view

3. Result Discussions

The simulated reflection coefficients (S11) dB of the antenna for various switch configurations is shown in figure 2. It can be observed that two dominant modes for each configuration can be seen. Different frequency configurations are discussed in Table 2.

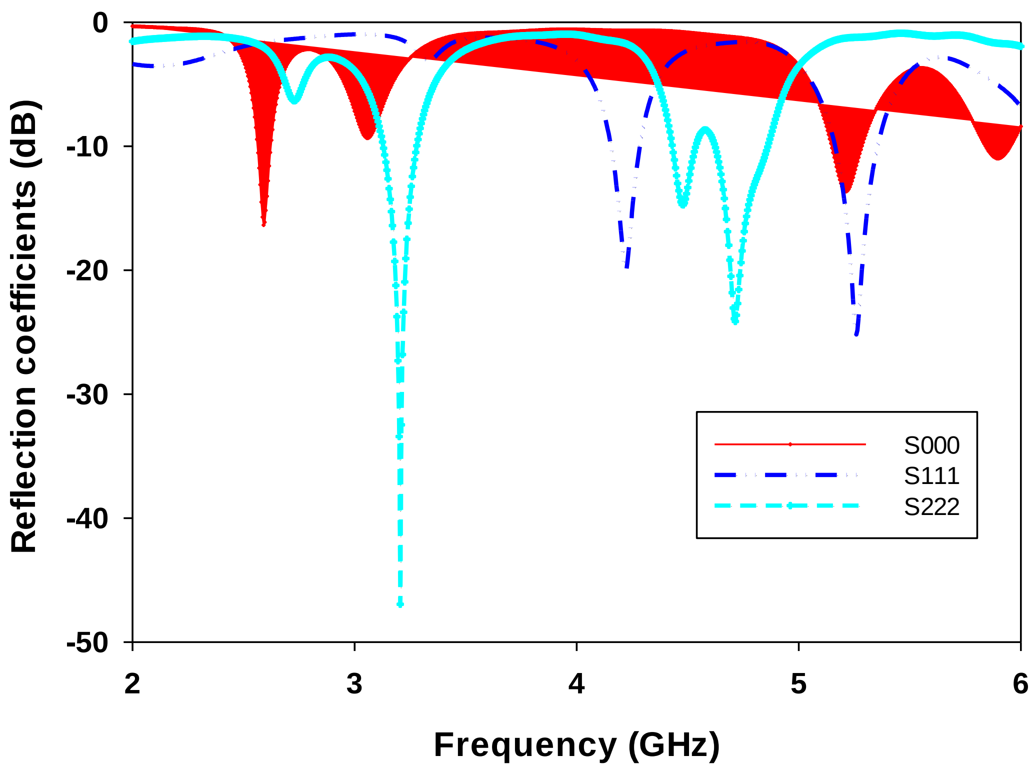

FIGURE 2: Simulated result of the antenna.

From the above S11 result, S000 is represented by F1 and this is when all the switches are in OFF state where only small patch is resonated. S111 is represented by F2 and this is when the first three switches are in ON state, so the small patch and the middle patch are resonated. S222 is represented by F3 and this is when all the switches are in ON state, so all the patches are resonated. After all the patches are simulated, six frequency bands were achieved by varying the states of the PIN diodes presented on the slot. It is clear that when all the PIN diodes (S1-S6) are in OFF state, its only patch (W3 x L3) that resonate with resonance frequency at 2.587GHz (WiMAX) and 5.189 GHz (WLAN). However, when PIN (S1, S2, and S3) are in ON state while PIN (S4, S5 and S6) are in OFF state. Resonating patch (W2x L2) is activated where the two patches resonated and the results are 4.2271GHz and 5.2051GHz respectively. Lastly when all the PIN diodes are in ON state, all the patches will resonate and the results obtained are 3.2051GHz and 4.7138GHz. All the results obtained have a return loss of -10dB.

Table 2: Switch configuration and frequencies achieved

Switch Configuration	Diode states						Resonance Frequency (GHz)	Band
	S1	S2	S3	S4	S5	S6		
F1	0	0	0	0	0	0	2.5847 and 5.189	Double
F2	1	1	1	0	0	0	4.2271 and 5.2051	Double
F3	1	1	1	1	1	1	3.2051 and 4.7138	Double

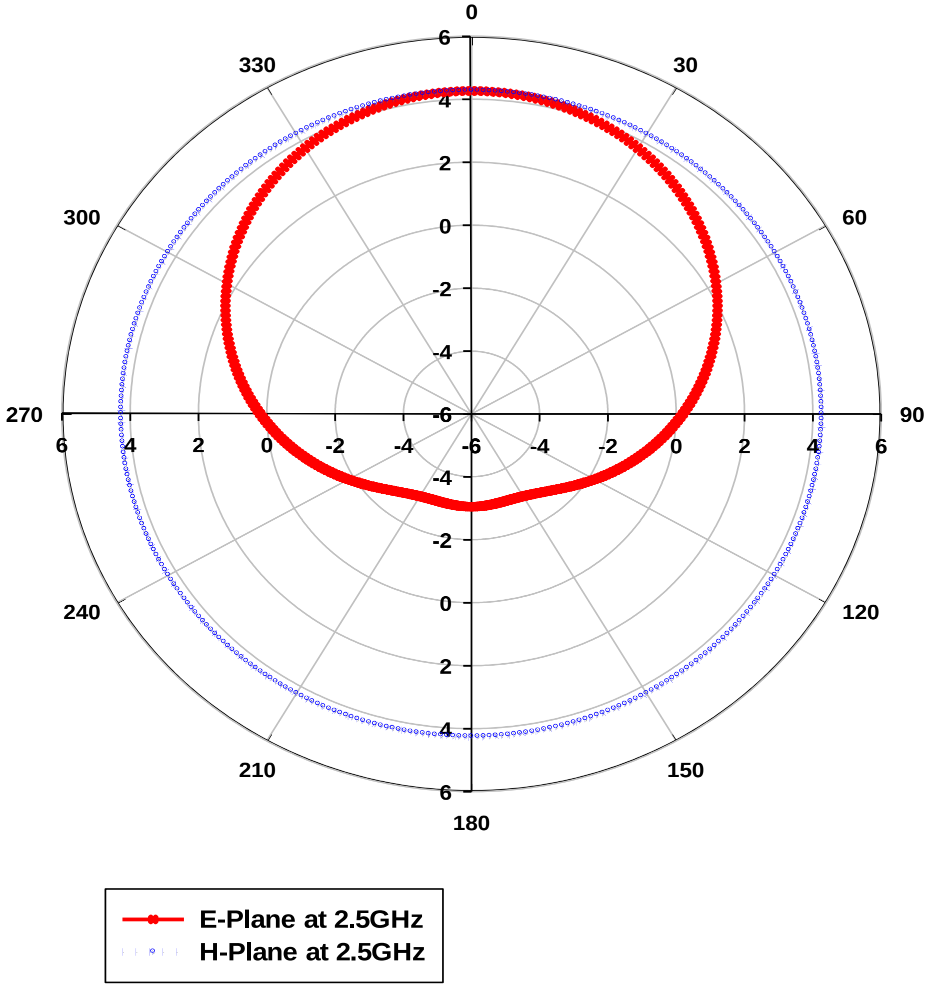

Figure 3. Directivity radiation pattern of the antenna

4. CONCLUSION

A frequency reconfigurable microstrip patch antenna with two U-shaped slots has been designed. By producing six PIN diodes at the slots, the antenna is capable to change its frequency up to six bands dynamically. All the return losses of the frequencies are less than -10dB which indicate that the antennas have a good impedance matching. To design an antenna with more than two patches ahead of the radiating patch for future work or to fabricate the propose design as future work.

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