A Tunable Microstrip Patch Antenna with Switchable Polarization

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Abstract

A novel reconfigurable microstrip patch antenna with frequency and polarization diversities is proposed. A slot is etched on a patch, and a PIN diode is utilized to switch the slot on and off, which realizes the Frequency diversity characteristic. The polarization diversities among linear polarization (LP), right-hand circular Polarization (RHCP), and left-hand circular polarization (LHCP) are also obtained by switching three PIN diodes on the slot on and off. The antenna design and experimental results are presented.

1. Introduction

Reconfigurable antennas have recently received much attention in wireless and radar communication systems due to their selectivity for operating frequency, radiation pattern and polarization. A Microstrip patch antenna is an attractive candidate to provide reconfigurability with low profile, light weight, conformability, and easy fabrication properties [2].

In this paper, we propose a novel reconfigurable Microstrip patch antenna having frequency and polarization diversities simultaneously. A slot is incorporated into the patch. The frequency diversity characteristic of the antenna is realized by switching a PIN diode on a slot of rectangular patch on and off [1]. The polarization diversity is also obtained by turning two PIN diodes on the slot etched on rectangular patch on and off. The proposed antenna is designed to operate at 11.49 GHz and 12.47 GHz with Linear Polarization by switching a PIN diode on and off and at 13.02 GHz and 13.60 GHz with Left-hand Circular Polarization (LHCP) and Right-hand Circular polarization (RHCP) by switching two PIN diodes on and off . As LHCP and RHCP are time separated there would be no coupling between these two polarizations. The validity of this concept is demonstrated by experimental results with good parameters like return loss, VSWR both in LHCP and RHCP.

2. Antenna Design

The geometry of the proposed reconfigurable Microstrip patch antenna with a slot is illustrated in Fig. 1. The structure of this antenna is simple and compact. The outer dimension of this antenna is just 10.35mm X 8.07mm. A single-fed rectangular patch is constructed on GML low cost laminate of dielectric substrate polyester/resin. The parameters of this substrate are as follows:

Substrate : GML1000 laminate
Dielectric Constant ε_r : 3.2
Loss tangent (Tan δ) : 0.004
Thickness : 0.762mm

Table 1.1 Optimized Dimensions for proposed antenna

Parameters	**Optimized dimensions**
Width of patch	10.35 mm
Length of patch	8.07 mm
Width of transition line	4.98 mm
Length of transition line	0.8 mm
Width of Feed line	1.8 mm
Length of Feed line	10 mm

To obtain the diversity characteristic of the proposed antenna, three PIN diodes are used. PIN diode 1 is

inserted into the slot offset from the center at (-1.7, 1.3) and PIN diodes 2 and 3 are placed in the slots at points (-1.1, 2) and (0,-2). The diode '1' is kept in such a way that its positive terminal is faced towards the center of the patch. And second diode '2' is kept so that its negative terminal is faced towards the center of the patch. As shown in figure. This is to achieve ON and OFF states for both the polarization diversity. Here in IE3D software tool there is no facility to implement switches and diodes. So an approximation is made that the switch is simply be represented by a metal which is soldered in the place. The simulation of ON and OFF states is simple a metal simulating the piece of metal. The feed here used is Microstrip line feed with a quarter-wave transformer to achieve impedance matching of dimensions as given in Table 1.1.

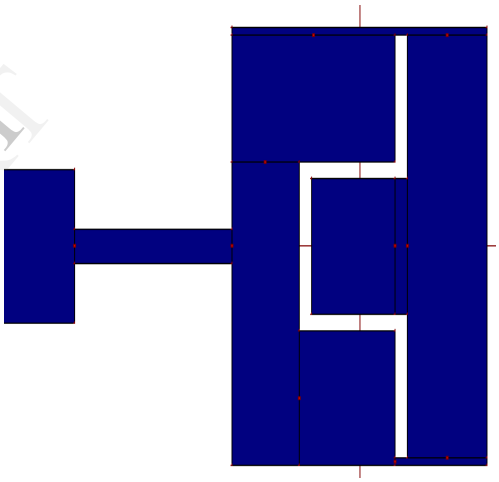
Table 1.2 Dimensions of Slot in patch

Strip 1	Length=3.4 mm
	Width=0.4 mm
Strip 2	Length=3.02 mm
	Width=0.4 mm
Strip 3	Length=3.2 mm
	Width=0.4 mm
Strip 4	Length= 3.02 mm
	Width= 0.4 mm
Strip 5	Length= 3.4 mm
	Width= 0.4 mm

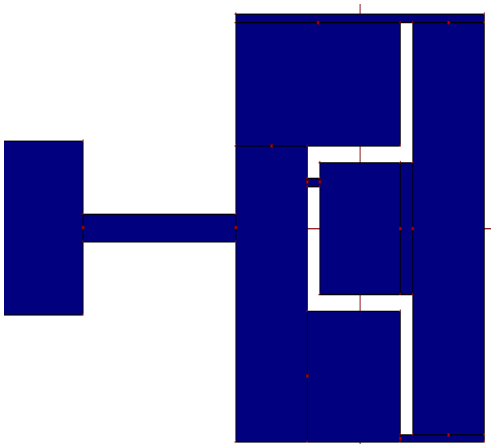
Frequency diversity is achieved to control the electrical length. When all the diodes are off, the current on the patch have to flow around the slot, and this antenna (denoted as antenna I) basically operates at a resonant frequency of 11.49GHz. Therefore antenna resonant at a low frequency. If diode 1 is turned on but diodes 2 and 3 are off, the current can flow through the diode, and the current path becomes shorter so that the antenna has a higher resonating frequency. As a result this antenna, denoted as antenna II, resonates at a higher frequency of 12.47 GHz and exhibits an LP characteristic. In the case of the proposed antenna with diodes 1 and 2 on but diode 3 off, LHCP, denoted by antenna III, can be excited at around 13.02 GHz. When diodes 1 and 3 are on but diode 2 is off, RHCP, denoted by antenna IV, can be obtained at 13.60 GHz.

3. Antenna Operational Mechanism

In this there is no need of power divider and two or three feeds. We can achieve polarization diversity with single feed itself; this is main advantage of this antenna. As this antenna is reconfigurable it as two slightly different structures. In one structure it radiates Left Handed Circular Polarization and in other form it radiates Right Handed Circular Polarization. So separate explanation have given for both RHCP and LHCP antennas clearly. Here polarization diversity is achieved by two pin diodes by making ON one diode and other OFF. When we give input voltage the diodes have different dc voltages on their two sides. If a negative voltage is supplied, diode 2 is turned ON and second diode 3 is turned OFF and it is reversed for +ve voltage. By making diodes '1' and '2' ON and diode '3' OFF the diode radiates left handed circular polarization and when '2' is OFF and '1' and '3' are ON the antenna radiates right handed circular polarization.

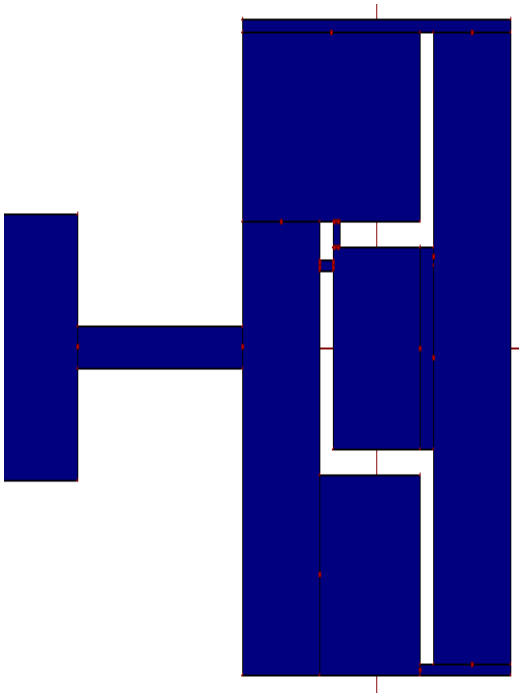


(a)

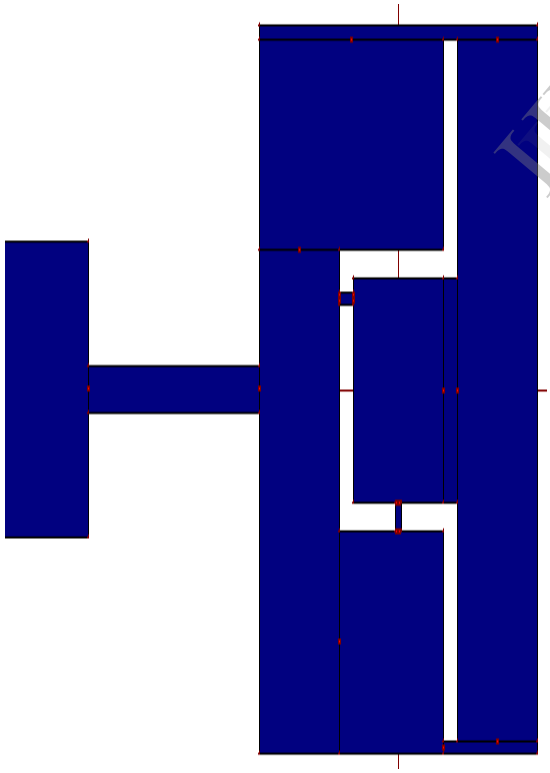


(b)

Figure 1 show Frequency reconfiguration antenna with PIN diode 1 as (a) OFF (b) ON



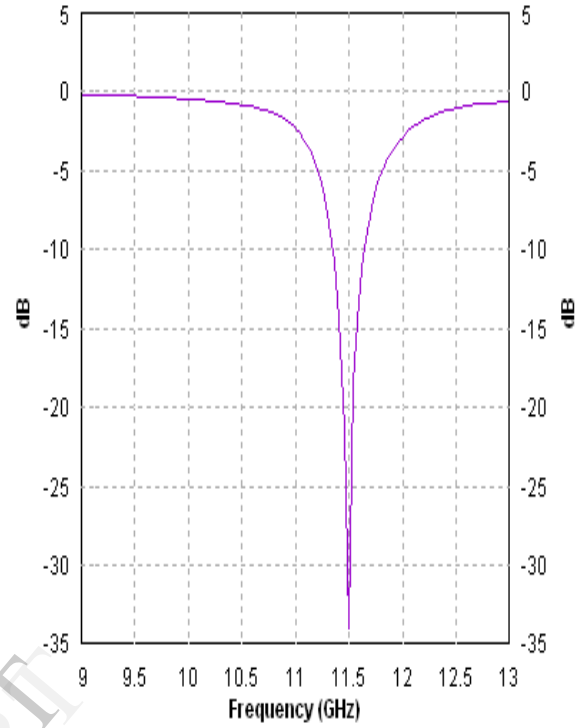
(a)



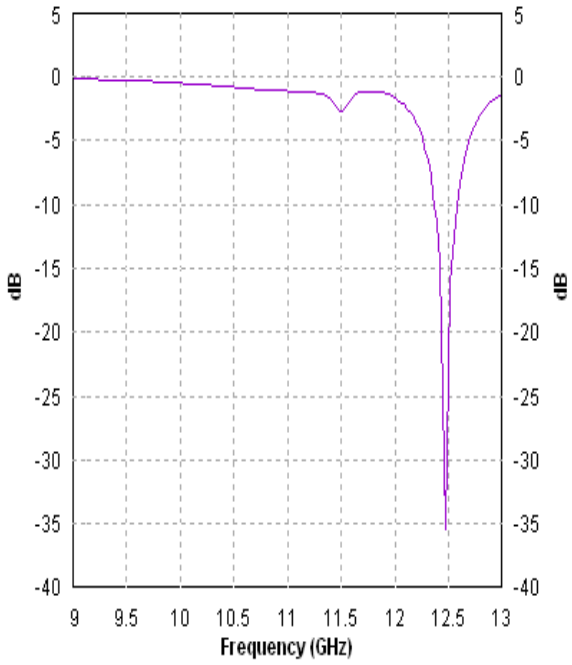
(b)

Figure 2 show Polarization diversity antenna with PIN diode 1 as ON and: (a) Diode 2 ON and diode 3 OFF; (b) Diode 2 OFF and diode 3 ON.

4. Experimental Results:

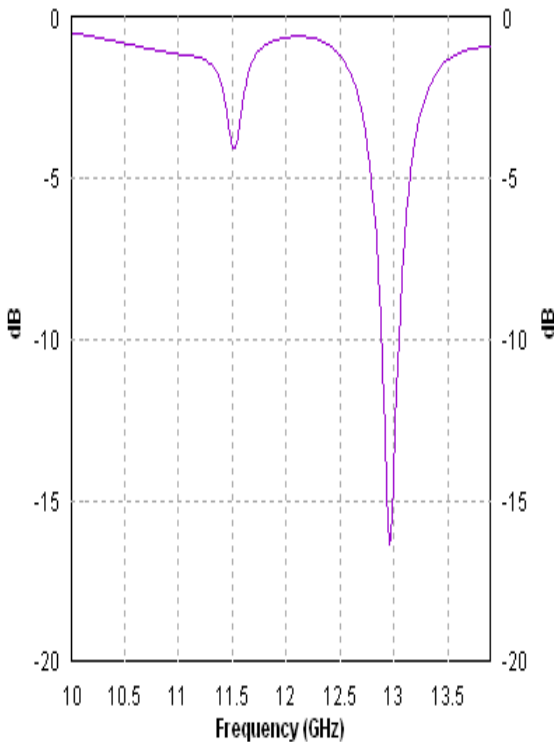


(a)RL=-33.99 at 11.49

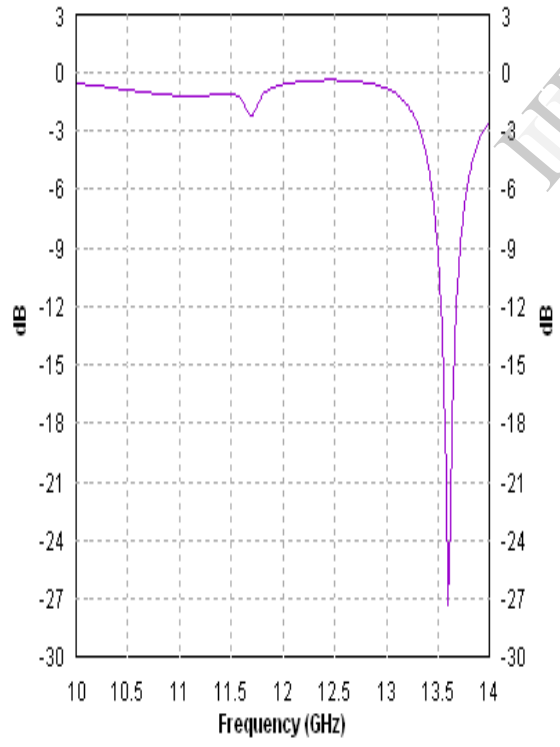


(b) RL=-35.49 at 12.47GHz

Figure 3 Return Loss for frequency reconfiguration antenna with LP (a) Diode 1 OFF (b) Diode 2 ON



(a) RL=-16.87 at 13.03 GHz



(b) RL=-27.28 at 13.6 GHz

Figure 4 Return loss for Polarization diversity antenna with diode 1 ON and (a) Diode 2 ON and Diode 3 OFF (b) Diode 2 OFF and Diode 3 ON

Frequency:	12.995 (GHz)
Incident Power:	0.01 (W)
Input Power:	0.0096484 (W)
Radiated Power:	0.00643122 (W)
Average Radiated Power:	0.00051178 (W/s)
Radiation Efficiency:	66.6558%
Antenna Efficiency:	64.3122%
Total Field Properties:	
Gain:	4.84888 dBi
Directivity:	6.76595 dBi
Maximum:	at (25, 170) deg.
3dB Beam Width:	(46.12, 131.938) deg.
Theta Field Properties:	
Gain:	4.69562 dBi
Directivity:	6.61269 dBi
Maximum:	at (25, 190) deg.
3dB Beam Width:	(40.2749, 48.1189) deg.
Phi Field Properties:	
Gain:	2.54337 dBi
Directivity:	4.46044 dBi
Maximum:	at (0, 110) deg.
3dB Beam Width:	(0, 0) deg.

Left-Hand Circular Field Properties:	
Gain:	4.31968 dBi
Directivity:	6.23675 dBi
Maximum:	at (35, 130) deg.
3dB Beam Width:	(55.0269, 80.4859) deg.
Right-Hand Circular Field Properties:	
Gain:	4.13959 dBi
Directivity:	6.05665 dBi
Maximum:	at (35, 300) deg.
3dB Beam Width:	(58.3535, 81.6477) deg.

Figure 5 Frequency properties of antenna III when diodes 1 and 2 are ON and diode 3 is OFF

From above frequency properties it is clear that antenna will operate in LHCP and RHCP as the gain is not equal. When the gain of LHCP properties is more than its RHCP properties means antenna is Left-Handed Circular polarized (antenna III). Similarly if the gain of RHCP properties is more than LHCP properties means antenna is Right-Handed Circularly Polarized (antenna IV). While when both the gains (LHCP gain and RHCP gain) are equal, the antenna linearly polarized (antenna I and antenna II).

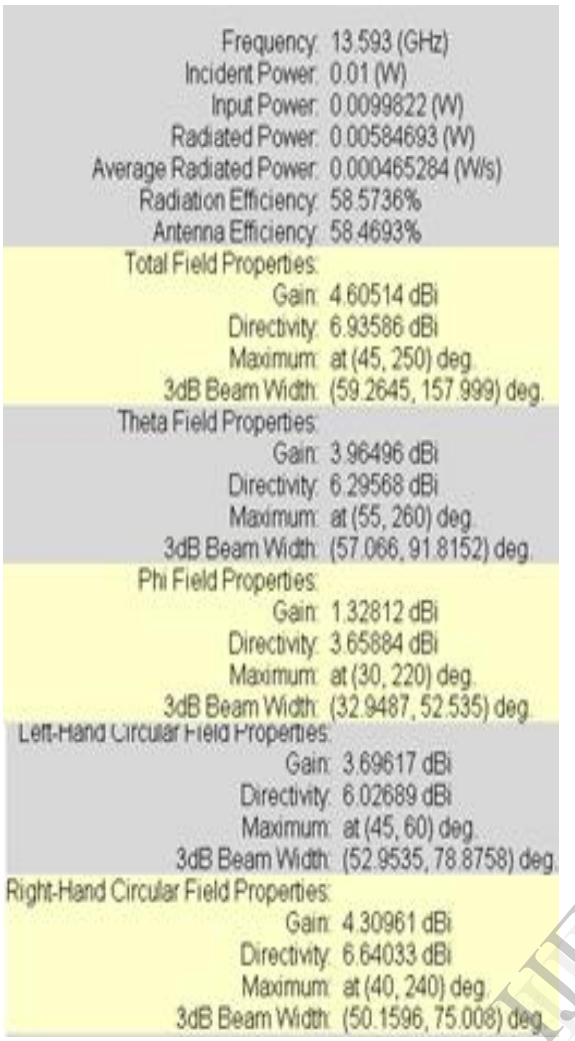


Figure 6 Frequency properties of polarized antenna IV when diodes 1 and 3 are ON and diode 2 is OFF

5. Conclusion

A novel reconfigurable microstrip patch antenna with frequency and polarization diversities has been designed. The frequency diversity characteristic of this antenna is realized by turning a PIN diode located offset to the center of the slot inserted into a microstrip patch on and off. The polarization diversity is also obtained by switching two PIN diodes on the slot parallel to the feed line of the patch opposite to each other on and off. The designed antenna satisfies the 10 dB return loss requirement and also polarization diversity (LP, LHCP and RHCP).

6. Application

The X band and Ku-Band defined by an IEEE standard for radio waves and radar engineering with frequencies that ranges from 8.0 to 12.0 GHz and 12.0 to 18.0 GHz, respectively [10]. The X band is used for short range tracking, missile guidance, marine, radar and air bone intercept. Especially it is used for radar communication ranges roughly from 8.29 GHz to 11.4 GHz. The Ku band [11] is used for high resolution mapping and satellite altimetry. Especially, Ku-Band is used for tracking the satellite within the ranges roughly from 12.87 GHz to 14.43 GHz. In this paper the microstrip patch antenna is designed for use in X band. The results obtained provide a workable antenna design for incorporation in a satellite TV. Recently the Direct broadcast satellite (DBS) system uses the upper portion of the Ku band.

7. References

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