Frequency Reconfigurable Pentagon Patch Antenna Using PIN Diode for Wireless Applications

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Abstract – **A new design of a frequency reconfigurable pentagon patch antenna for wireless communications is presented in this paper. Four PIN diodes, BAR63-02V, have been used on the ground plane to achieve the desired reconfigurability. The proposed patch antenna having dimensions of 26mm x 15mm has been designed using CST Microwave. The antenna is alimented by coaxial-probe and Rogers 3003 has been used as a substrate. Center frequencies are 2.44 and 4.52 GHz in operating Mode M1, 2.83 and 7.11 GHz in operating Mode M2, 2.68 and 4.66 GHz in operating Mode M3, 3.24 and 6.19 for operating Mode M4, 3.32, 6.32 and 6.62 GHz for operating Mode M5.**

Keywords – **Patch antenna, Reconfigurable antenna, Pentagon, Radiation pattern, S_{11} parameter, PIN diode.**

I. INTRODUCTION

Printed antennas are very suitable and effective for design requirements, especially because of their low profile and wide bandwidth. In recent years, reconfigurable patch antennas are widely used in modern wireless communication systems due to the interest to cover a lot of standards such as GSM, LTE, ISM, WIFI and WLAN [1]-[2]. There are several technical posibilities to make reconfigurable antenna such as the use of active component as PIN diode, RF-MEMS and varactor for the electrical type [3]-[4], there are also the insertion of photoconductors for optical transmission [5], and finally, there is configurability type with mechanical modification in the antenna design known as physical configurability [6]. Several techniques as RF MEMS and PIN diodes are used for making the antenna reconfigurable in frequency or in polarization or in radiation pattern [1]-[2]. In literature, many reconfigurable antennas are designed using these different techniques. In [7], PIN diodes were used to cover 4G LTE applications. In [8], three PIN diodes were inserted to cover Wi-Fi and WiMAX of electromagnetic spectrum. In [9], the authors designed a frequency- and pattern-reconfigurable wideband slot antenna for the frequency bands 3.4–3.8 GHz and 3.7–4.2 GHz, respectively. The authors in [10] incorporated three PIN diodes to cover wireless communication, UMTS/IMT-2000 and ISM band. In [11]-[12], frequency reconfigurable antenna is achieved by changing the operating states of the PIN diodes. In [13], a pattern-reconfigurable planar fractal antenna and its characteristic-mode analysis was presented. In [14], a frequency reconfigurable antenna system with a directional selectivity was presented, the reconfiguration radiation characteristics was controlled through a mobile phone and a microcontroller. In [15]-[16], the authors designed radiation pattern reconfigurable antenna. In [17], the authors presented a polarization reconfigurable antenna at 2.4-2.57 GHz band. Paper [18] presented a switchable multiband microstrip coplanar antenna. The authors in [19] designed a novel antenna with reconfigurable patterns using H-shaped structures. In [20], reconfigurable antennas were also shown.

In [21], the authors designed omnidirectional microstrip patch antenna with reconfigurable pattern and polarization. In this paper, we present a frequency reconfigurable pentagon patch antenna for wireless communications. BAR63-02V PIN diodes are used in ground plane for switching between different operation modes. For reasons of low cost, manufacturing and better performance of return loss S_{11}, Rogers 3003 is the chosen substrate and DGS are applied to the ground plane for bandwidth and gain enhancement [22]-[23].

II. PIN DIODE RF SWITCHES

Infineon BAR63-02V PIN diodes were chosen for the frequency reconfiguration, due to its suitable isolation. The equivalent circuit of this PIN diode matches to an inductance L, for both states of the switch. In OFF state capacitor C_T is parallel with resistance R_p and in ON state L is in series with a resistance R_s as shown in Fig. 1.

Based on datasheet of BAR63-02V diode provided by the manufacturer, the parameter values of this PIN diode are: L=0.6 nH, R_s =1.2 Ω, C_T = 0.3 pF, R_p =15 KΩ [17].

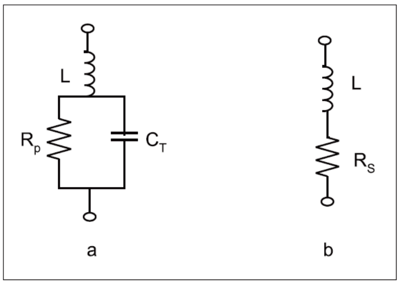

Fig. 1. RLC equivalent circuit of PIN diode: (a) OFF state, (b) ON state.

III. PROPOSED RECONFIGURABLE PENTAGON PATCH ANTENNA DESIGN

The proposed pentagon patch antenna is shown in Fig. 2. The optimal dimensions of the proposed antenna are shown in

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Table I. The parameters were calculated using Table II [24]. A defected ground structure (DGS) with six slits for bandwidth enhancement is used as ground plane. Four BAR63-02V PIN diodes have been applied as the RF-switches in these slits of the ground plane to achieve frequency reconfiguration (Fig. 3). The antenna is designed with Rogers 3003 substrate with relative permittivity ε_r of 3 and thickness of 0.75 mm.

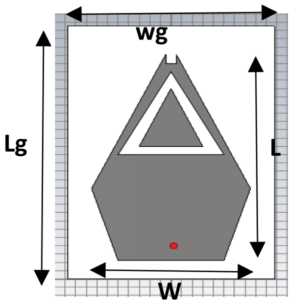
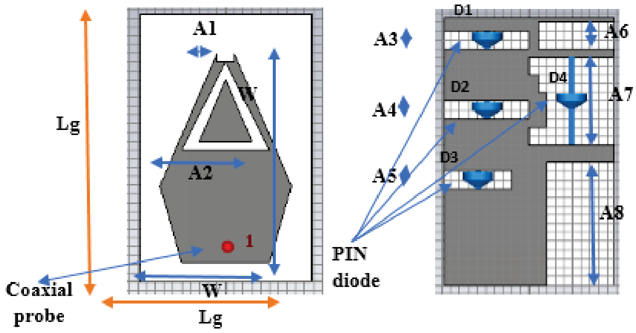


Fig. 2. Geometry of proposed pentagon patch antenna with CST microwave.



(a) (b)

Fig. 3. Geometry of proposed reconfigurable pentagon patch antenna: (a) Front view, (b) Ground plane.

TABLE I
PENTAGON PATCH ANTENNA PARAMETERS

Parameters	Values [mm]
w_g	30.5
L_g	19.5
L	15
W	26
A_1	2
A_2	10.0
A_3	2
A_4	2
A_5	2
A_6	3
A_7	5
A_8	7

TABLE II
ANTENNA PARAMETERS EQUATIONS

Antenna parameters	Equations
Effective width antenna (W)	$W = \frac{1}{2fr\sqrt{\mu_o\varepsilon_o}}\sqrt{\frac{2}{\varepsilon r+1}}$
Dielectric constant (ε_{eff})	$\varepsilon_{eff} = \frac{\varepsilon r+1}{2}\frac{\varepsilon r-1}{2}\left[1+12\frac{h}{w}\right]^{-\frac{1}{2}}$
Extending length (ΔL)	$\frac{\Delta L}{h} = 0.412\frac{(\varepsilon eff+0.3)(\frac{W}{h}+0.264)}{(\varepsilon eff-0.258)(\frac{W}{h}+0.8)}$
Length (L)	$L = \frac{1}{2fr\sqrt{\varepsilon eff}\sqrt{\mu_o\varepsilon_o}} - 2\Delta L$
Effective length antenna (L_{eff})	$L_{eff} = L+2\Delta L$

IV. SIMULATED RESULTS

The proposed antenna is designed and simulated using CST Microwave and the PIN diodes have been modelled as an RLC equivalent circuit.

Table III shows five operating modes of PIN diodes. Alter these modes changes the current distribution in the defected ground plane, in which the resonant frequency will be changed.

TABLE III
PIN DIODES OPERATING MODE

Mode M1	D1 : ON D2/D3/D4 : OFF
Mode M2	D1: ON D2: ON D3/D4: OFF
Mode M3	D1/D2/D3/D4: ON
Mode M4	D1: OFF D1: OFF D2: ON D4: OFF
Mode M5	D1: OFF D1: OFF D2: OFF D4: ON

A. S_{11} and VSWR Parameters

The obtained S_{11} and VSWR for all operating mode are presented in Figs. 4 and 5, respectively.

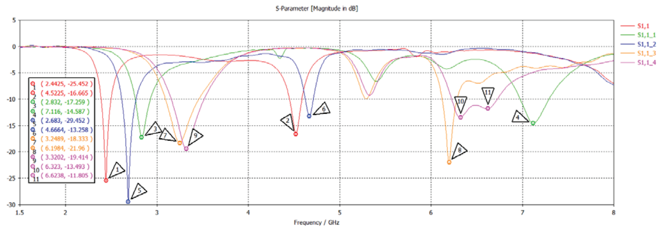


Fig. 4. Return loss for different configuration of PIN diodes according to Table II.

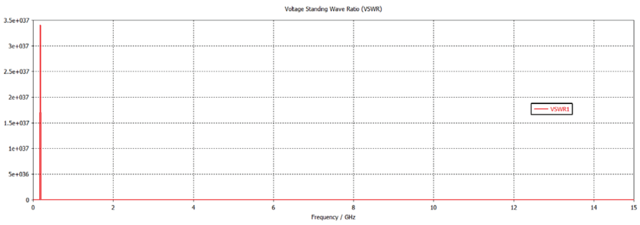


Fig. 5. VSWR results for the different PIN operating modes.

The resonant frequencies and bandwidth of different operating PIN diode modes are given in Table IV.

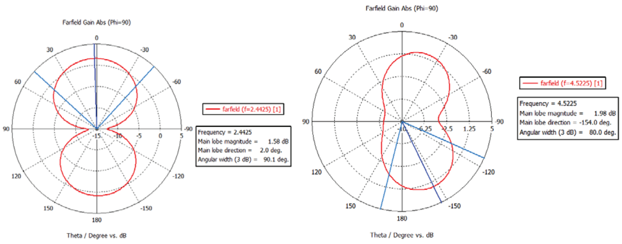
TABLE IV
RESONANT FREQUENCIES AND BANDWIDTH OF DIFFERENT PIN DIODE MODES

Modes	Obtained frequencies GHz	S11 dB	Bandwidth MHz
Mode 1	F1 = 2.4425 F2 = 4.52	-25.45 -16.66	110 130
Mode 2	F1 = 2.83 F2 = 7.11	-17.25 -14.58	160 230
Mode 3	F1 = 2.68 F2 = 4.66	-29.45 -13.25	160 91
Mode 4	F1 = 3.24 F2 = 6.19	-18.33 -21.96	360 160
Mode 5	F1 = 3.32 F2 = 6.32 F3 = 6.62	-19.44 -13.49 -11.80	360 500 500

The return loss values obtained for all the above five modes is well below -10 dB mark and the VSWR is less than 2, which is the radiation condition of the patch antennas. The frequency bandwidths is sufficient for wireless communications applications as WIFI (2.4 GHz), ISM band (2.4-2.4853) GHz, TD-LTE (3.4-3.8 GHz).

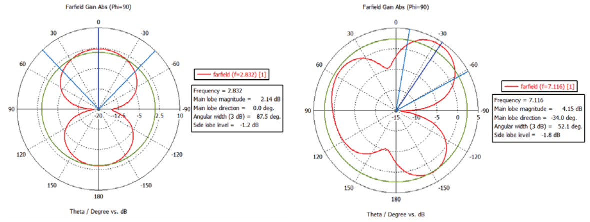
B. Radiation Pattern

The comparison between radiation patterns for all the five operating modes of diodes, in the 2-D plane are shown in Figs. 6, 7, 8, 9 and 10, respectively. As can be observed the patterns are omnidirectional and similar for all the obtained frequencies.



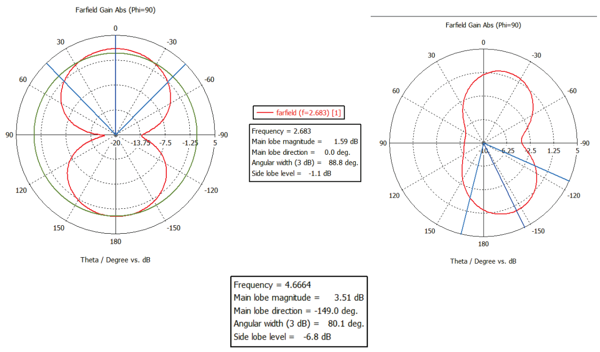
(a) (b)

Fig. 6. (a) and (b): E-plane and H-plane for M1 operating mode at frequencies F1 and F2.



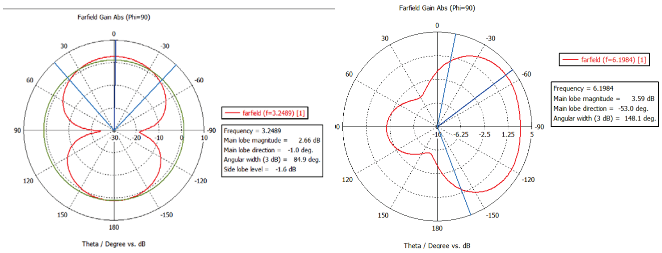
(a) (b)

Fig. 7. (a) and (b): E-plane and H-plane for M2 operating mode at frequencies F1 and F2.



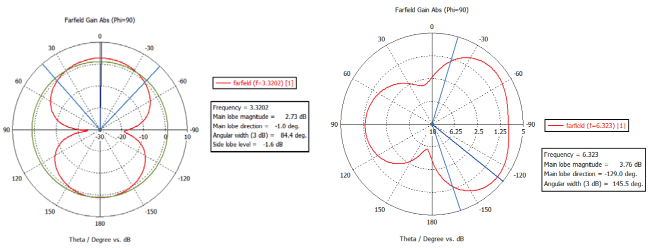
(a) (b)

Fig. 8. (a) and (b): E-plane and H-plane for M3 operating mode at frequencies F1 and F2.

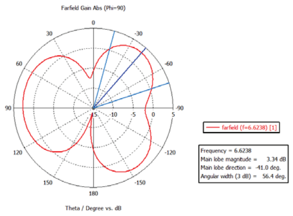


(a) (b)

Fig. 9. (a) and (b): E-plane and H-plane for M4 operating mode at frequencies F1 and F2.



(a) (b)



(c)

Fig. 10. (a), (b) and (c): E-plane and H-plane for M5 operating mode at frequencies F1, F2 and F3.

C. Gain

The gain obtained for the five PIN diode modes respectively is presented in Fig. 11. The maximum value is 4.93.

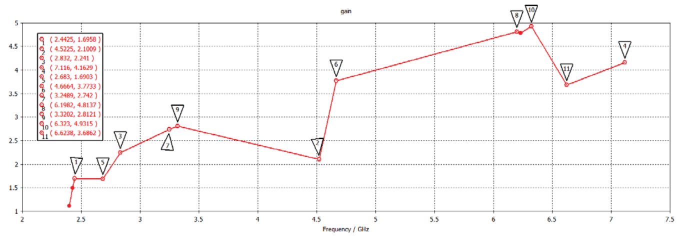
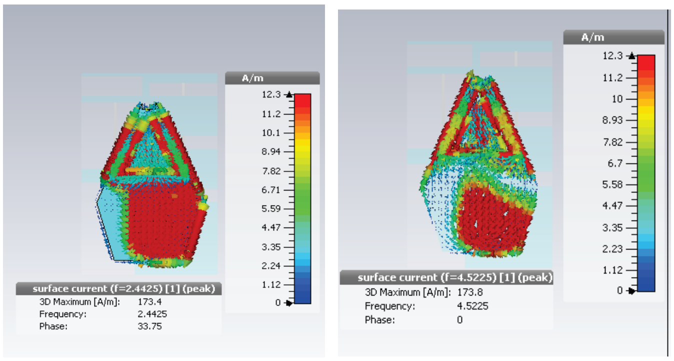


Fig. 11. Gain of proposed reconfigurable patch antenna.

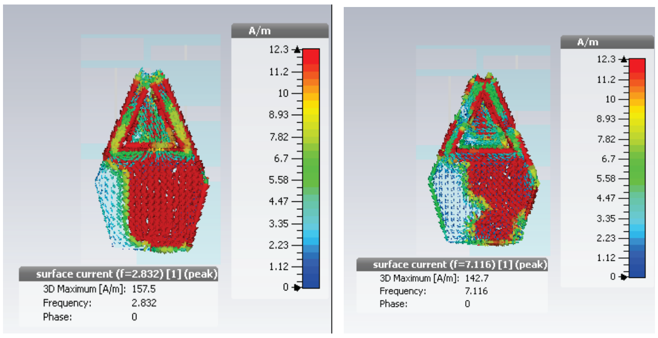
D. Surface Current Distribution

Figs. 12-16 show the surface current density for all operating PIN diode modes. It can be seen that the surface current is more intense at the right and front sides of the patch.



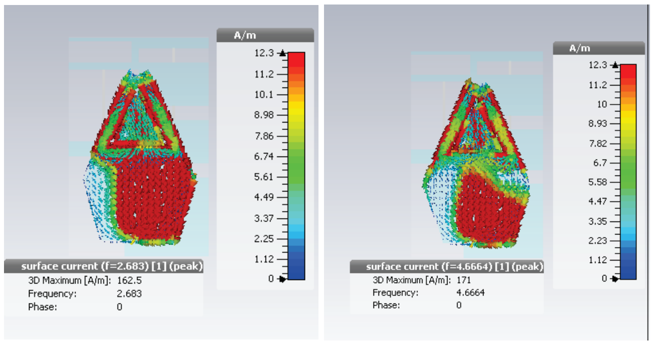
(a) (b)

Fig. 12. Surface current distribution at frequencies of M1 operating mode.



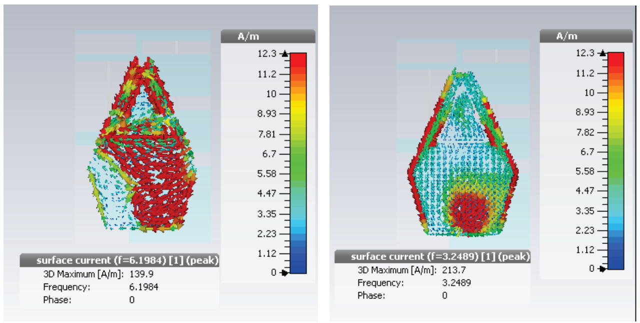
(a) (b)

Fig. 13. Surface current distribution at frequencies of M2 operating mode.



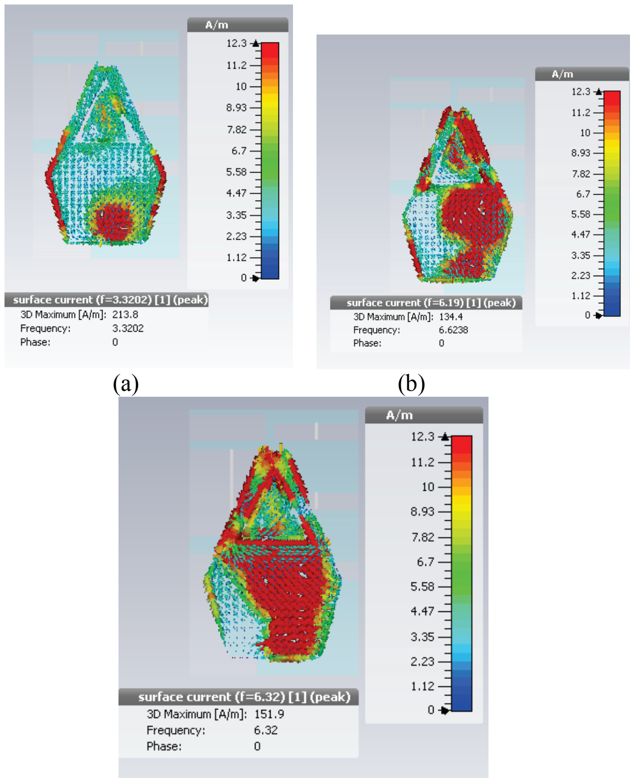
(a) (b)

Fig. 14. Surface current distribution at frequencies of M3 operating mode.



(a) (b)

Fig. 15. Surface current distribution at frequencies of M4 operating mode.



(c)

Fig. 16. Surface current distribution at frequencies of M5 operating mode.

III. CONCLUSION

In this paper, a reconfigurable pentagon patch antenna is designed for wireless communications. Frequency reconfigurability is achieved with the use of four BAR63-02V PIN diodes in the ground plane. Simulated results show that the proposed antenna has the capability to change its frequencies between WIFI (2.4 GHZ), ISM (2.4-2.4853) GHz and TD-LTE (3.4-3.8 GHz), etc. The return loss obtained for each resonant frequency is bellow -10dB which is very satisfactory and confirms the good influence of our proposed antenna. The proposed antenna produces a stable radiation pattern, the maxim gain obtained is 4.9 and an optimal bandwidth for all the operating modes of PIN diodes, to make itself suitable for application in a wireless communication application.

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