Power System Technology
ISSN:1000-3673
Received: 16-04-2025 Revised: 05-05-2025 Accepted: 22-07-2025

Novel-shaped Frequency Reconfigurable Antenna for Wireless Networks

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Abstract— This Novel-shaped Frequency Reconfigurable Antenna (FRA) is introduced in this study for wireless network applications. High Frequency Structure Simulator (HFSS) is used to design and optimize the FRA. The FRA is designed on an FR-4 epoxy substrate with relative permittivity of 4.4. The designed FRA has small dimensions of 30x16x1.6 mm^3. The designed FRA has three different operating stats, at (1)2.45 GHz (Bluetooth), 5.48 GHz (WLAN), (2)3.38 GHz (5G – n78), (3)6.10 GHz (Wi-Fi 6E) which can be accessed by optimal placing of RF PIN diode on the FRA design. The antenna can be used in WiMAX, WLAN, 5G, and 6GHz wireless networks applications.

Keywords—Frequency Reconfigurable antenna, PIN diode, Bluetooth, WLAN, WiMAX, 5G

I. INTRODUCTION

As result of fast enhancement in wireless communication system, the demand of antenna which can work on multi-frequency bands for different applications has become necessary. A multi-band antenna can operate on multiple frequencies. But Modern communication devices still need an antenna that can change its operating frequency from one to another, ensuring the good performance of antenna. So, for this purpose the Frequency Reconfigurable antenna is preferred. Frequency reconfigurable antenna has ability to change

Received: 16-04-2025 *Revised: 05-05-2025* *Accepted: 22-07-2025*

their operating frequency in disciplined and reversible manner in accordance with user's requirements.

Now, Frequency reconfiguration on antenna can be done by using switching elements like PIN diode, varactor diode, RF MEMS switch, and tunable materials [1]. The reconfiguration of frequency is mainly executed by electrical and physical switching technique [2]. But one of the most used switching technique for frequency reconfiguration is electrical switching technique in which PIN diode is mostly used because it provides fast switching as compared to other switching elements.

In [3], Tri-band FRA is discussed for wireless applications. The designed FRA operates at Wi-Fi, WLAN and WiMAX applications using one PIN diode. In [4], C-shaped FRA is described for wireless applications. The designed FRA is suitable for Bluetooth, WLAN, WiMAX applications. In [5], F-shaped FRA is discussed for ISM / WiMAX applications. The designed FRA operates at 2.4 GHz and 3.5 GHz applications using one PIN diode. In [6], F-shaped FRA is designed for WLAN, WiMAX, C-band and Sub-6 GHz wireless communications. In [7], Frequency and Pattern reconfigurable monopole antenna is designed for ISM band applications in which reconfiguration is executed using two PIN diodes which are mounted on antenna.

In [8], A compact Hook-shaped FRA is designed for 5G applications. In [9], Th-shaped multi-band antenna is described for wireless applications with using one PIN diode. In [10], Y-shaped monopole FRA is designed using one PIN diode. In [11], S-shaped FRA is described using three PIN diode for frequency reconfiguration for WiMAX and WLAN applications. In [12], I-shaped FRA is discussed using one PIN diode for frequency reconfiguration for WiMAX and WLAN applications. In [13], Epsilon-shaped multiband FRA is designed for wireless applications. In [14], A compact E-shaped monopole FRA is designed for wireless communications with using two PIN diodes for reconfiguration. In [15], Hexa-band FRA is discussed using three PIN diodes for wireless communication application. In [16], F-shaped multi-band switchable antenna is discussed using two PIN diodes for Wi-Fi, 3G advanced, WiMAX and WLAN wireless applications.

Now, as compared to above papers, the proposed design of FRA is much smaller in size and uses two PIN diodes for reconfiguration. At simulation time PIN diode is realized by using its lumped RLC components values.

II. ANTENNA DESIGN

The geometry and design of proposed FRA is provided in this section. In order to achieve the reconfiguration of frequencies, the equivalent Lumped RLC circuit of PIN diode is used at the simulation time. This proposed FRA design allow antenna to work at various wireless network frequencies by accessing ON and OFF state of PIN diodes.

A. *Antenna Design and Geometry*

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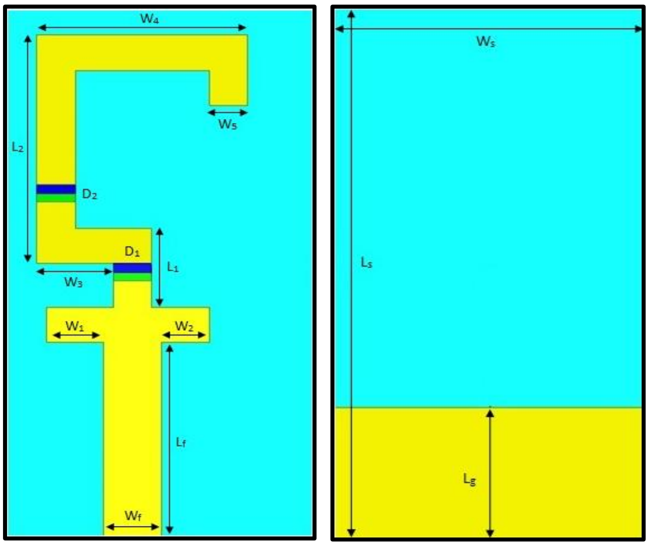
The FRA is designed on a substrate FR-4 epoxy which has relative permittivity of 4.4 and loss tangent 0.02. As shown in Figure 1, The Designed FRA has dimensions of 30x16x1.6 mm^3. Figure 1(a) shows antenna's front view, which depicts the radiating surface of antenna. Figure 1(b) shows antenna's back view, which depicts the ground plane of antenna.

As shown in Figure 1, the proposed FRA design consists of two PIN diodes for the frequency reconfiguration. For the placing of PIN diodes, distance of 1 mm is given between two patches.

A partial ground plane is used in antenna design to enhance the performance of FRA. The length of partial ground plane is measured 7.5 mm.

To achieve impedance matching and to activate antenna, proposed FRA is fed by 50Ω microstrip line with 3 mm width.



(a) (b)

Figure 1. Geometry of Antenna (a) Front view (b) Back view

In Table 1, the dimensions of the proposed FRA are shown.

TABLE 1. THE DIMENSIONS OF PROPOSED FRA

Parameter	Value (mm)
Ws	16
Ls	30
Wf	3
Lf	11
Lg	7.5

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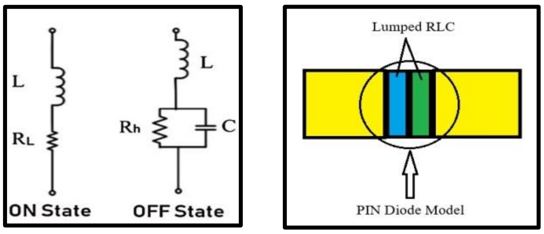
W1	3
W2	2.5
L1	4.5
W3	4
L2	13
W4	11
W5	2

B. *Switching Technique*

In this proposed FRA, Infineon technology's BAR50-02V PIN diodes are used at design and simulation time. As shown in Figure 2(a), PIN diode has two states ON and OFF. To use a pin diode corresponding RLC combination of pin diode is used while implementing pin diode in software. So, the equivalent Lumped RLC circuit of PIN diode is shown in Figure 2(a).

At ON state of diode, it has inductor (L) and resistor (R) in series. At OFF state of diode, it has parallel configuration of resistor (R) and capacitor (C) connected in series with inductor (L). The RLC parameter of BAR50-02V PIN diode is given in Table 2.



(a) (b)

Figure 2. (a) Equivalent RLC circuit and (b) PIN diode model in HFSS

In Table 2, the RLC parameter values of BAR50-02V PIN diode are shown.

TABLE 2. RLC PARAMETERS VALUES

BAR50-02V PIN diode states	Resistor (R) Ω	Inductor (L) nH	Capacitor (C) pF
ON	3	0.6	-
OFF	5k	0.6	0.15

III. RESULTS AND DISCUSSION

The proposed FRA is designed and simulated on HFSS 15 software. Boundary conditions are also used to derive performance parameters of antenna like, Return loss, VSWR, Gain, Radiation pattern etc.

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A. Return Loss and VSWR

Figure 3 describes the simulated S11 or return loss of each switching states. Also, Table 3 depicts the return loss value derived at each state of switching conditions.

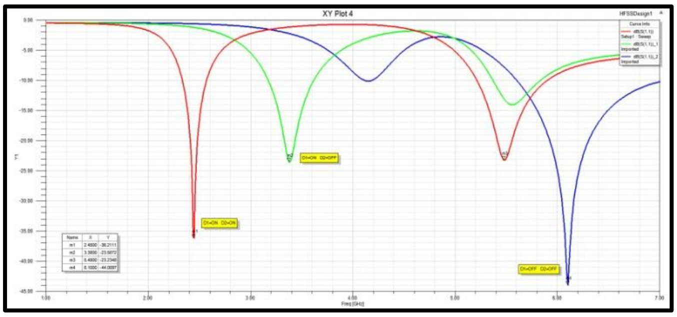

Figure 3. Simulated Return loss values at each switching states

TABLE 3. S11 AT EACH SWITCHING STATES

Marker	**Diodes condition**	**Resonant frequency**	**Return loss**
m1	D1,D2 = ON	2.45 GHz	-36..21 dB
m2	D1 = ON, D2 = OFF	3.38 GHz	-23.58 dB
m3	D1,D2 = ON	5.48 GHz	-23.23 dB
m4	D1,D2 = OFF	6.10 GHz	-44.01 dB

Figure 4 describes the simulated VSWR of each switching states. Also, Table 4 depicts the VSWR value derived at each state of switching conditions.

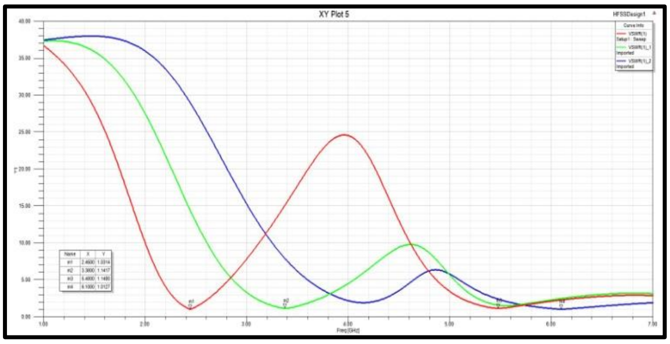

Figure 4. Simulated VSWR values at each switching states

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TABLE 4. VSWR AT EACH SWITCHING STATES

Marker	Diodes condition	Resonant frequency	VSWR
m1	D1,D2 = ON	2.45 GHz	1.03
m2	D1 = ON, D2 = OFF	3.38 GHz	1.14
m3	D1,D2 = ON	5.48 GHz	1.14
m4	D1,D2 = OFF	6.10 GHz	1.01

B. *Impedance matching*

Figure 5 describes the simulated impedance matching plots of each switching states. Also, Table 5 depicts the impedance value derived at each state of switching conditions.

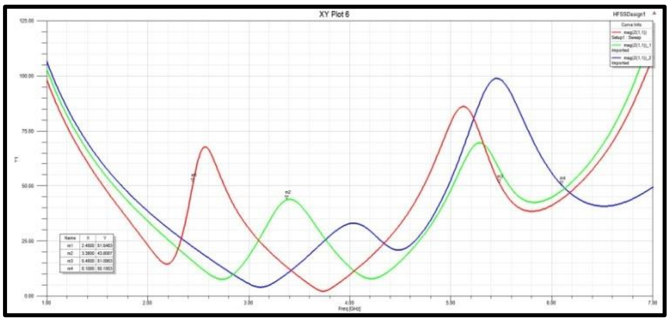

Figure 5. Simulated impedance values at each switching states

TABLE 5. IMPEDANCE AT EACH SWITCHING STATES

Marker	Diodes condition	Resonant frequency	Impedance
m1	D1,D2 = ON	2.45 GHz	51.54 Ω
m2	D1 = ON, D2 = OFF	3.38 GHz	43.80 Ω
m3	D1,D2 = ON	5.48 GHz	51,09 Ω
m4	D1,D2 = OFF	6.10 GHz	50.18 Ω

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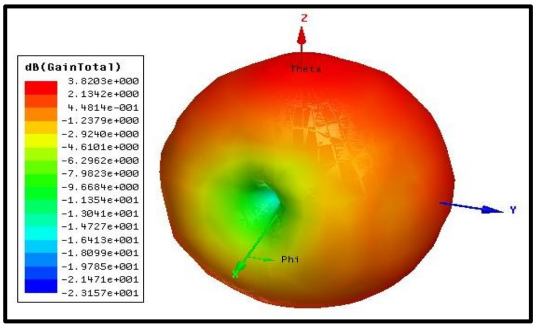
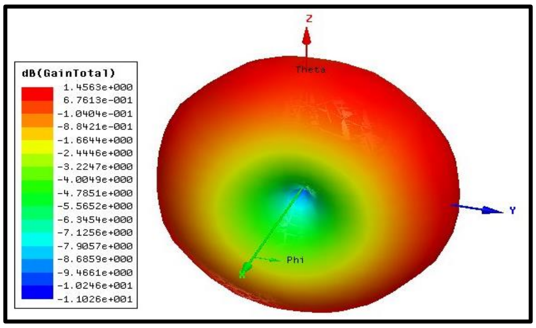
C. Gain and Radiation patterns

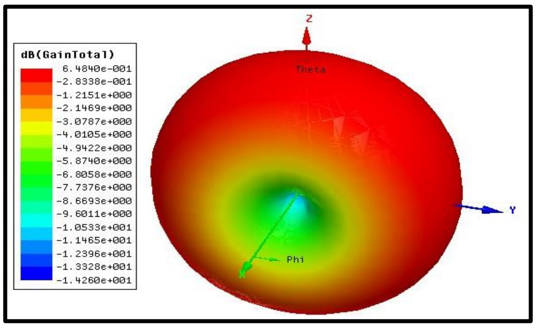
In Figure 6, simulated 3D gain plots of each switching states is shown. Also, Table 6 depicts the gain value derived at each state of switching conditions.



(a)



(b)



(c)

Figure 6. Gain plots at (a) D1,D2 = OFF, (b) D1 = ON, D2 = OFF, and (c) D1,D2 = ON

TABLE 6. GAIN AT EACH SWITCHING STATES

Diodes condition	**Resonant frequency**	**Gain**
D1,D2 = ON	2.45 GHz & 5.48 GHz	6.48 dB
D1 = ON, D2 = OFF	3.38 GHz	1.45 dB

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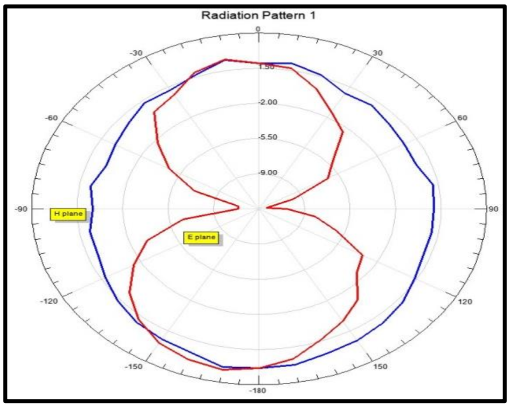
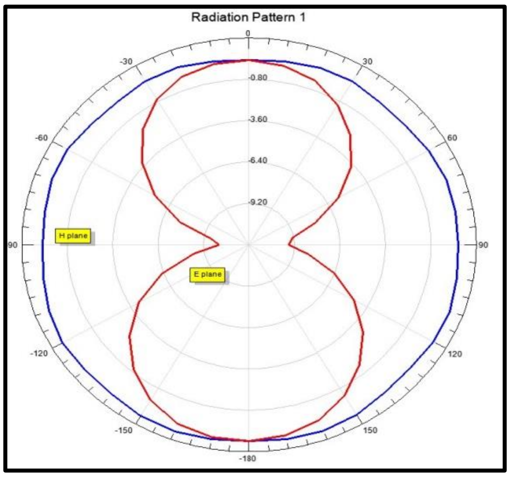
D1,D2 = OFF	6.10 GHz	3.82 dB

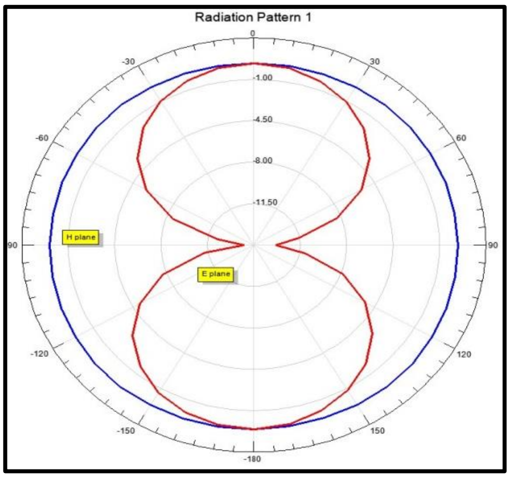
Figure 7 illustrates the 2D radiation pattern plots of each switching states. It is seen form Figure 7 that the eight shape pattern is achieved at each switching state.



(a)



(b)



(c)

Figure 7. Radiation pattern plots at (a) D1,D2 = OFF, (b) D1 = ON, D2=OFF, and (c) D1,D2 = ON

Received: 16-04-2025 *Revised: 05-05-2025* *Accepted: 22-07-2025*

D. Surface current distribution

Figure 8 illustrates the current distribution at each switching states.

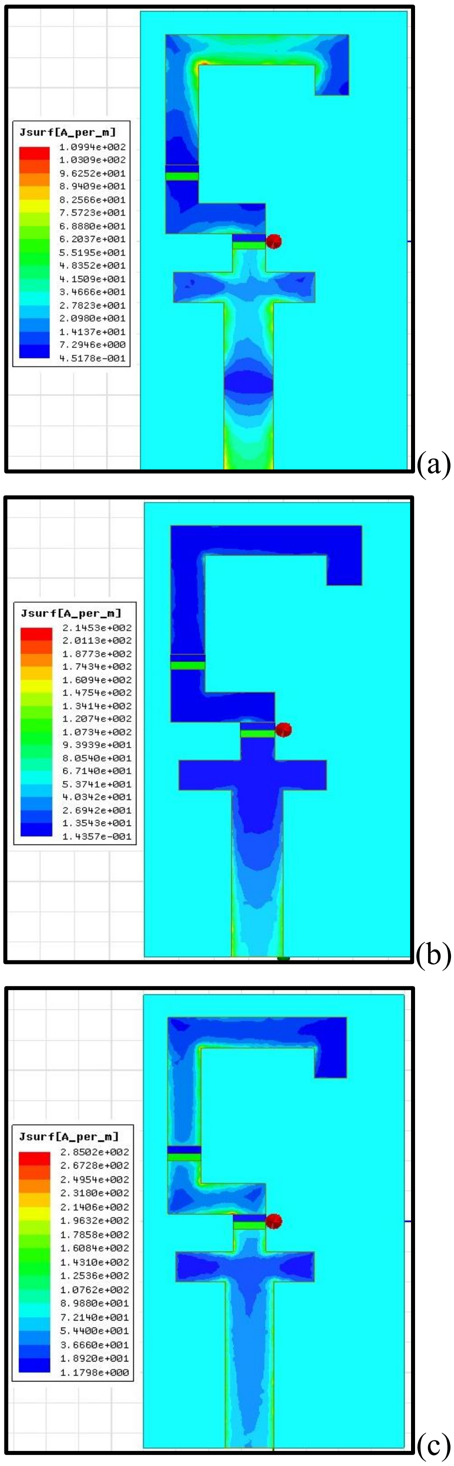


Figure 8. Current distribution plots at (a) D1,D2 = OFF, (b) D1 = ON, D2=OFF, and (c) D1,D2 = ON

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In Figure 3, return loss is below -20 dB for all operating frequencies which indicates a good performance. In Figure 4,and 5 VSWR is near about 1 and thus impedance is matched excellently to near about 50 Ω.

A comparison table is given in Table 7.

TABLE 7. COMPARISON TABLE

Ref.	**Dimensions (mm)**	**Diodes**	**Frequency (GHz)**	**Max. S11 (dB)**	**Min. VSWR**
[3]	33x16x1.6	1	2.4,3.5,5.65	-31.88	1.05
[4]	33x16x1.6	2	3.01,7.71	-36.00	-
[5]	30x33x1.6	1	2.4,3.5	-35.23	-
[6]	40x32x1.6	2	3.8,7.5	-32.92	1.02
[7]	59x39x1.6	2	2.7,3.35,4.3	-31.00	-
Proposed	30x16x1.6	2	2.45,3.38,5.48,6.1	-44.01	1.01

CONCLUSION

The proposed Novel-shaped Frequency Reconfigurable Antenna for wireless networks is presented. The design operates at different frequencies; 2.45 GHz, 3.38 GHz, 5.48 GHz and 6.1 GHz. These frequencies can be achieved by optimal placing of PIN diode on antenna deign.

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