DESIGN OF MINIATURIZED TRI-BAND MONOPOLE RECONFIGURABLE ANTENNA

MA.Shahina
Department of Electronics And Communications Engineering(ECE)
Andhra Loyola Institute of Engineering and Technology(ALIET)
Vijayawada, Andhra Pradesh,India.
Email: mullaabdulshahina@gmail.com
D.Prathyusha
Department of Electronics And Communications Engineering(ECE)
Andhra Loyola Institute of Engineering and Technology(ALIET)
Vijayawada, Andhra Pradesh,India.
Email:deeviprathyusha@gmail.com
Sayeeda Fathima
Department of Electronics And Communications Engineering(ECE)
Andhra Loyola Institute of Engineering and Technology(ALIET)
Vijayawada, Andhra Pradesh,India.
Email: fathimasayeeda3@gmail.com
D.Hepzibha Rani
Asst.Prof,Department of Electronics And Communications Engineering(ECE)
Andhra Loyola Institute of Engineering and Technology(ALIET)
Vijayawada, Andhra Pradesh,India.
Email: hepzibharanidasari@gmail.com

Abstract - **In this paper, multiband reconfigurable antenna with three pin diodes is proposed. The proposed antenna is designed with ground asymmetric coplanar strip, build upon flexible polyamide substrate with compact dimensions of 22×19mm and thickness 1.6mm. The investigated antenna structured consists of monopole patch that facilitate operation for wireless LAN application on the other hand inverted L shaped monopole, T shaped monopole and F shaped monopole facilitates for WIFI, WIMAX, 5G NR, BLUETOOTH, GSM& SATELLITE COMMUNICATION. The investigated antenna operates at 2.4GHz, 2.6GHz, 4.1GHz, 5.6GHz, 5.9GHz, 6.4GHz, 8.1GHz-8.3GHz and 8.6GHz with measured impedance bandwidth of 3.02%, 3.7%, 4.3%, 4.8%, 4.9%, 5.3%, 6.0% ,7.2% respectively over these frequency bands. The proposed antenna is tuned at five modes for three pin diodes which includes single-band(5.6GHz), one dual-band(4.1GHz,6.4GHz), two tri-band(2.6GHz,5.6GHz,8.3GHz, &8.6GHz)and one quad band(2.4GHz,5.9GHz,6.4GHz&8.1GHz).The proposed antenna radiates unidirectionally with gain of 4.7dB at 8.1GHz.The antenna exhibits good impedance matching, radiation characteristics and a gain across their operational bandwidth.**

Keywords-Flexible, GACS, reconfigurable, pin diode, multiband, polyamide substrate.

I.INTRODUCTION

With the advancement of wireless communication technology requirement of multiple wireless services in a single device has increased significantly, to meet the demands, a flexible reconfigurable antenna is needed. An antenna is designed which has an ability to switch its characteristics according to the requirements. Such antenna is called a reconfigurable antenna. Reconfigurable antennas are used for different wireless applications that operate in a wide range of frequency as they have proved to be very useful in completing new requirements of the system. This antenna can able to deliver the same performance as that of multiple antennas without increasing the size which would have occurred in case of using multiple antennas. There are three basic types of reconfigurable antennas which includeFrequency, Pattern, and polarization reconfigurable antenna.

Frequency reconfigurable antennas provide frequency tuning overdesired frequency bandsand efficient utilization of spectrum. Pattern reconfigurable antennas direct their radiation pattern towards a desired direction and are a fundamental concept for beam steering in the future mobile networks. Polarization reconfigurable antennas reduce multipath fading, improve the effectiveness in receiving communication signal and reduce co-channel interference. Flexible antenna technology has receivedmuch attention with several research efforts. A Compact GroundedAsymmetric coplanar strip –fed flexible multiband reconfiguration antenna for wireless applications[1]. The flexible reconfigurable antenna has benefits of low cost, optimum efficiency, compact size, unidirectional pattern and flexibility.

Presently,some methods for multiband antenna design include Flexible and compact spiral-shaped frequency reconfigurable antenna for wireless applications[2] a compact triple-band antenna fed by a coplanar waveguide (CPW) a monopole with two F-shaped slot radiators and amicrostrip-fed antenna, a tri-band double-element foldeddipole monopole-fed antenna a monopole antenna fortri-band applications and a compact triple-band double planar inverted-F antenna. However, these models arenot flexible, and they transmit all resonances regardlessof user needs.

Design and fabrication of triple-band folded dipole antenna for GPS/DCS/WLAN/WiMAX applications [3]. Multi band inverted E and U -shaped compact antenna for digital broadcasting, wireless, and sub 6GHz 5G applications[4].Low-profile frequency reconfigurable antenna for heterogeneous wireless systems and innovation in wearable and flexible antennas [5-6]. A multi-band switchable antenna for Wi-Fi, 3Gadvanced, WiMAX, and WLAN wireless applications[7].Compact multiband CPW fed sub 6 GHz frequency reconfigurable antenna for 5G and specific UWB applications[8].

A grounded asymmetric coplanar strip (GACS) is a modification of an ACS. On the back of the substrate, an additionalground plane is used. The bottom ground plane is spaced1.6 mm beneath the top ground to decrease backward radiation. In this article, a compact, flexible multiband reconfigurable GACS-fed antenna that utilizes tri-PIN diodes (SMP1320-079) to realize frequency reconfiguration functionalitythat covers the BLUETOOTH, WIMAX, WIFI, WLAN, 5G NR, GSM & SATELLITE COMMUNICATION.The main motivation forinvestigating this flexible, reconfigurable multibandantennais the high demand for flexible electronics. Flexible substrateantennas (FSAs) are quickly becoming a preferred optionfor flexible displays, smart clothing, wearable computer systems, and applications in wireless sensing, such as healthcare monitoring, surveillance in civil construction, or inclusion in search and rescue satellite networks.

II.EXISTING SYSTEM

In existing system of miniaturized tri-band monopole reconfigurable antenna which covers the modern communication systems for supporting various applications such as WIFI, WiMAX, WLAN, GSM, BLUETOOTH & 5G NR. The three pin diodes are tuned at five modes which include one single-band mode, dual-band mode, two tri-band and one quad-band. The total bandwidth of the proposed antenna is 65.01% and gain is 4.7dB.

III.ANTENNA DESIGN

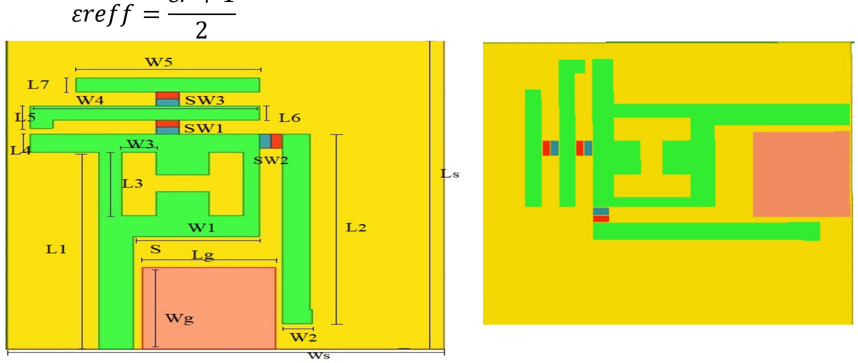
A.STRUCTURE & DIMENSIONS

The geometrical structure of the proposed antenna is depicted in Fig. 1.The compact dimensions of the substrate of the investigated antenna are 22 mm × 19 mm. The proposed antenna is formed on a 1.6-mm-thick flexible polyamide substrate, with εr= 4.3. The proposed antenna includes a monopole patch connected to a 50Ω GACS feedline for better impedance matching patch with H slot in the middle, an inverted L shaped monopole, T shaped monopole and F shaped monopole connected to themonopole patch and three RF pin diode switches are used. Multiband frequency reconfigurable performance is achieved for 5G NR, BLUETOOTH, WIFI, WIMAX & WLAN applications by turning ON/OFF the PIN diodes SW1, SW2 & SW3 respectively.

design equations are below.

$$L = \frac{c}{4f\sqrt{\varepsilon reff}}, W = \frac{c}{2f\sqrt{\varepsilon reff}}$$

$$\varepsilon reff = \frac{\varepsilon r + 1}{2}$$



(a) **(b)**

Figure 1 : Geometrical configuration (a) Top view (b) Bottom view

PARAMETER	VALUE(mm)	PARAMETER	VALUE(mm)
Ls	22	L4	1.3
Ws	19	L5	1
L1	15.8	L6	1
W1	7	W4	10
L2	13.5	W5	10
W2	1.2	H	1.6
L3	4.5	Lf	8.5
W3	1.5	Wf	1.5
Lg	5.8	L7	1
Wg	5.8	S	2.7

Table 1: Dimensions of proposed antenna

B. SWITCHING TECHNIQUES

For switching purpose four pin diodes (SMP1320-079) are used, as they behave like a variable resistor in the radio frequency (RF) range. These pin diodes provide open and the short circuit behaviour at their respective insertion positions, thus vary the effective resonant length of the antenna and hence result in reconfiguration of antenna's operating frequency. The equivalent circuits for both ON and OFF states of a pin diode switches are shown in the Fig.2. For ON state it is simply an RL series circuit, having a low value resistor "RL" and an inductor 'L'. In OFF state it is equivalent to an RLC circuit, having inductor 'L' in parallel with a high value resistor "RH" and a capacitor 'C'. For ON state L= 0.6nH and R=1Ω and for OFF state R=0.1kΩ & C= 0.1pF and L=0.6nH.

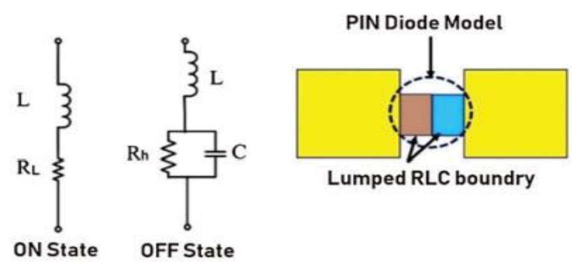


Figure 2:RF pin diode ON/OFF state

IV. RESULTS AND ANALYSIS

Flexible and reconfigurable antenna simulations were performed with Ansys HFSS software. Furthermore, the simulated and measured S11 values were obtained for various switch conditions (SW1, SW2 and SW3), and the surface current distribution was studied at the different operating frequencies to obtain a good understanding of quad-band operation for the presented antenna, as illustrated in Fig. 6. After optimizingthe antenna parameters, an experimental model of the proposed antenna was developed to justify the simulated results.

A. MODE 1(SW1, SW2 & SW3-OFF)

In this mode, the maximum current is concentrated throughout the monopole patch as observed in Fig3(a), and the simulated S11 characteristics of the proposed antenna with PIN diodes SW1, SW2 & SW3 in the OFF state. A single frequency band is observed at 5.6 GHz with a maximum S11 of -18.7dB as observed in Fig4(a). The bandwidth is 6.0%, which is used for WLAN.

B. MODE 2 (SW1-OFF, SW2 & SW3-ON)

In this mode, the maximum current is concentrated throughout the monopole patch, inverted L shaped and T shaped as observed in Fig3(b), and the simulated S11 characteristics of the proposed antenna with PIN diodes SW1-OFF, SW2 & SW3 are in ON state. A dual frequency band is observed at 4.1 GHz & 6.4GHz with a maximum S11 of -13.6dB & -25.5dB as observed in Fig4(b). The bandwidth is 4.3%& 4.9% which is used for 5G NR and WIFI.

C.MODE 3 (SW1-OFF, SW2-ON & SW3-OFF)

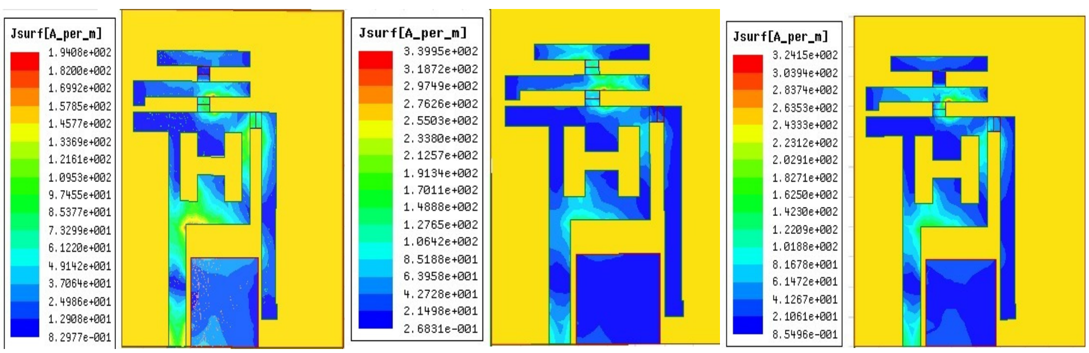
In this mode, the maximum current is concentrated throughout the monopole patch and inverted L shaped as observed in Fig3(c), and the simulated S11 characteristics of the proposed antenna with PIN diodes SW1-OFF, SW2-ON & SW3 in the OFF state. A tri frequency band is observed at 2.6GHz,5.6GHz & 8.6GHz with a maximum S11 of -11.7dB, -14.8dB & -21.1dB as observed in Fig4(a). The bandwidth is 5.3%, 6.0% & 4.3% which is used for WLAN, WIMAX & SATELLITE COMMUNICATION.

D.MODE 4 (SW1-ON, SW2-OFF& SW3-OFF)

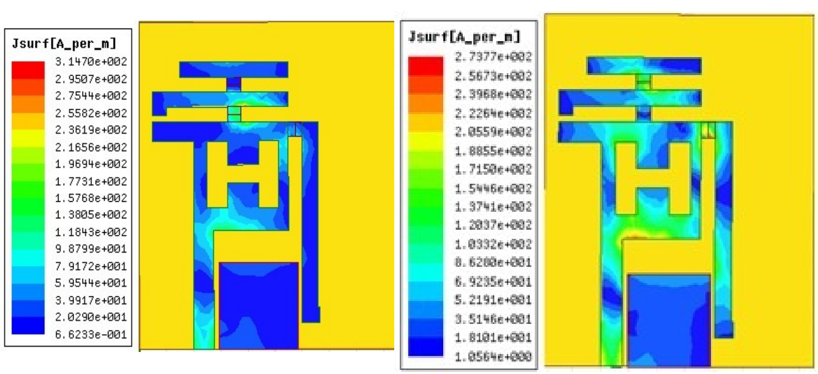
In this mode, the maximum current is concentrated throughout the monopole patch & F shaped as observed in Fig3(d), and the simulated S11 characteristics of the proposed antenna with PIN diodes SW1-ON, SW2 & SW3 are in OFF state. A tri frequency band is observed at 2.6GHz,5.6GHz & 8.3GHz with a maximum S11 of -13.6dB,-19.2dB and -34.7dB as observed in Fig4(b).The bandwidth is 5.3%, 6.0% & 3.7% which is used for WIMAX, WLAN and GSM.

E. MODE 5 (SW1, SW2 & SW3-ON)

In this mode, the maximum current isconcentratedthroughout the monopole patch, inverted L shaped, T shaped and F shaped as observed in Fig3(e), and the simulated S11 characteristics of the proposed antenna with PIN diodes SW1, SW2 & SW3 in the ON state. A quad frequency band is observed at 2.4GHz,5.9GHz, 6.4GHz & 8.1GHz with a maximum S11 of -14.8dB, -14.7dB, -20.3dB and -19.5dB as observed in Fig4(c). The bandwidth is 3.02%, 7.2%, 4.3% & 4.9% which is used for BLUETOOTH, WLAN, WIFI & GSM.



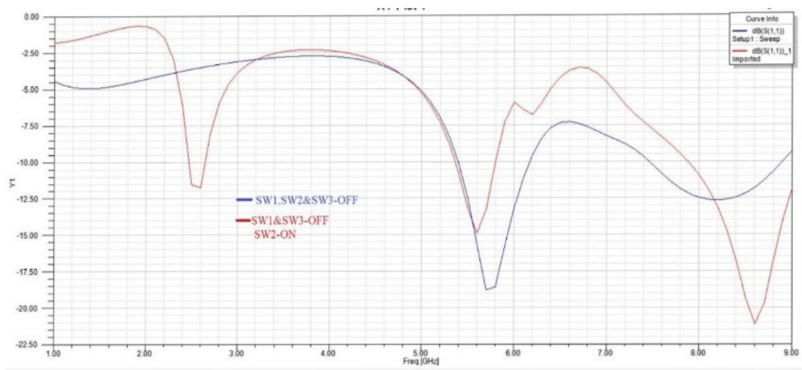
(a) (b)(c)



(d) (e)

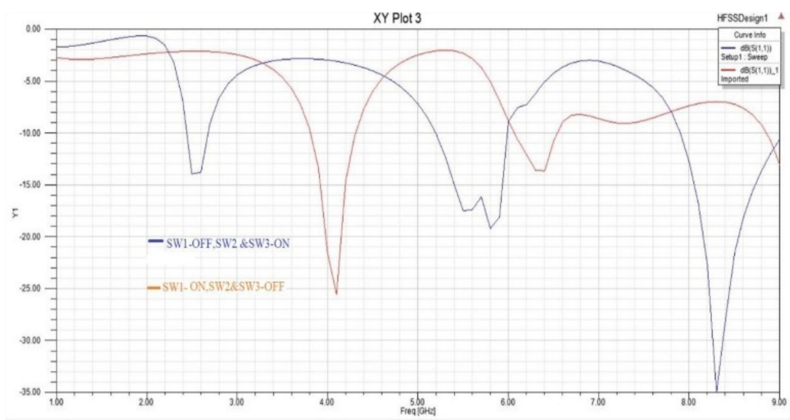
Figure 3: Surface Current distributions of proposed antenna (a) mode 1 (b) mode 2 (c) mode 3 (d) mode 4 (e)mode 5

The surface current distribution on the radiating structure of the antenna at different frequency bands is shown in fig.3 ,the current distribution operate at low concentration for high frequency and more concentrated surface currents are observed for lower frequencies bands. These surface currents indicate that the contributing resonant length for respective frequency decreases as resonant frequency increases, thus proves the inverse relation of frequency with resonant length.



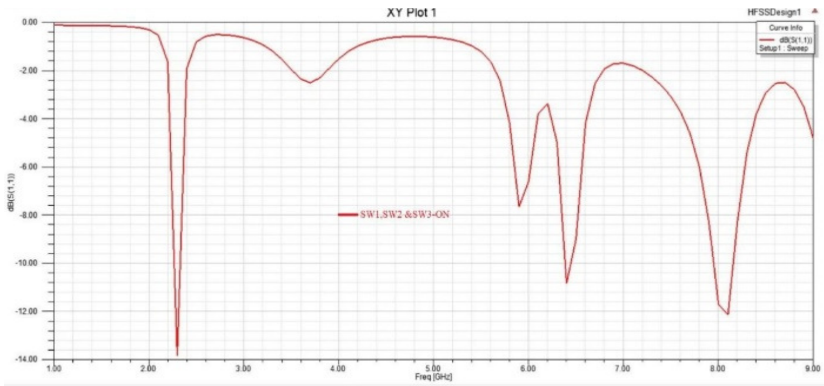
(a)

The simulated return loss of mode 1 and mode 3 of the proposed antenna are depicted in Fig. 4(a) When all switches (SW1 to SW3) are OFF, the proposed antenna operates in MODE 1, covering 5.6 GHz band with maximum return loss of −18.7 dB. In MODE 3 (When SW 1,SW3- OFF,SW2-ON), the presented antenna resonates at 2.6GHz,5.6 GHz& 8.6 GHz with return loss of −11.7dB,-14.8dB and −21.1 dB.



(b)

The simulated return loss of mode 2 andmode 4 of the proposed antenna are depicted in Fig. 4(b) When all switches (SW1–OFF,SW2&SW3-ON) the proposed antenna operates in MODE 2, covering 4.1GHz &6.4 GHz band with maximum return loss of −13.6dB & -25.5dB. In MODE 4 (When SW1-ON,SW2&SW3- OFF), the presented antenna resonates at 2.6GHz,5.6 GHz& 8.6 GHz with return loss of −11.7dB,-14.8dB and −21.1 dB.



(c)

The simulated return loss of mode 5 of the proposed antenna are depicted in Fig. 4(c). When all switches (SW1 to SW3) are ON, the proposed antenna operates in MODE 5, covering 2.4GHz,5.9GHz, 6.4GHz & 8.1GHz band with maximum return loss of-14.8dB, -14.7dB, -20.3dB and -19.5dB.

Figure 4: Reflection coefficients vs frequency for all modes.

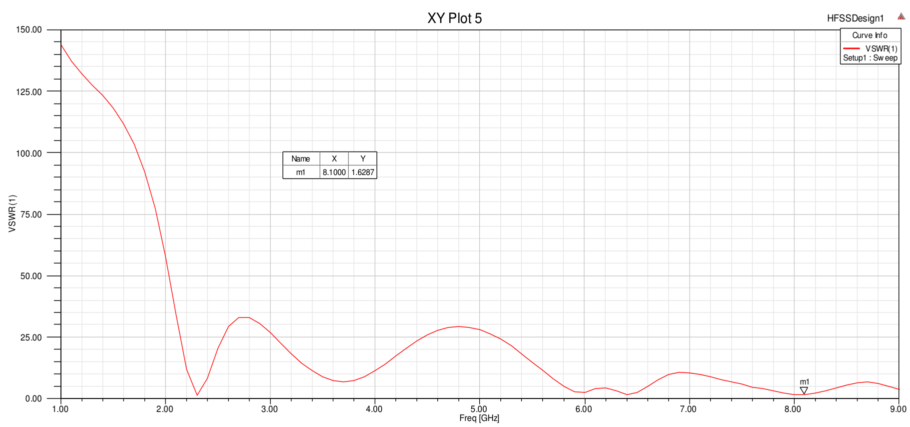


Figure 5 :VSWR vs Frequency

The standing wave ratio for the antenna should be less than 2 for better propagation of the signal. The proposed antenna having the VSWR at 1.62 range of 8.1GHz.

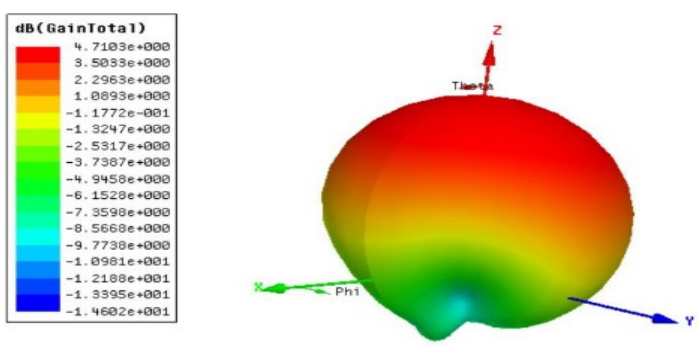


Figure 6 :3D polar plot

The gain of the antenna describes amount of the power transmitted in a direction andusuallyrepresented in dB for proposed antenna having gain of 4.7dB.

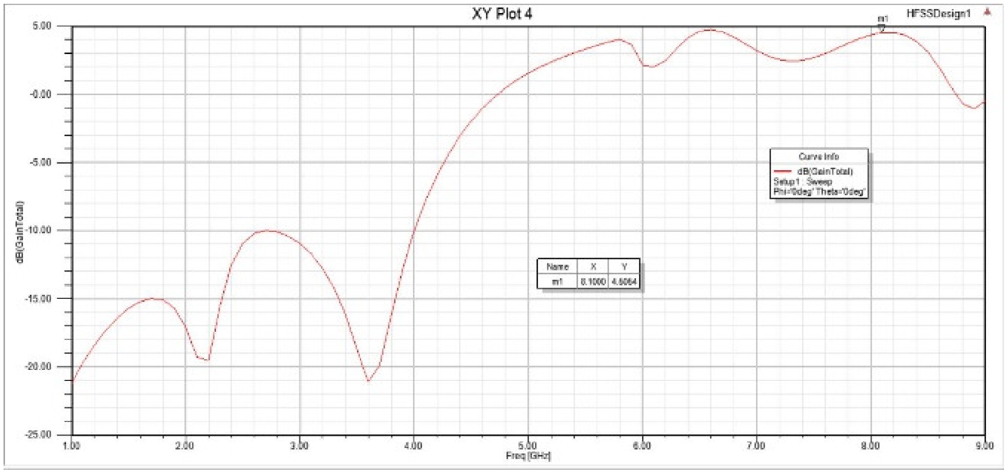
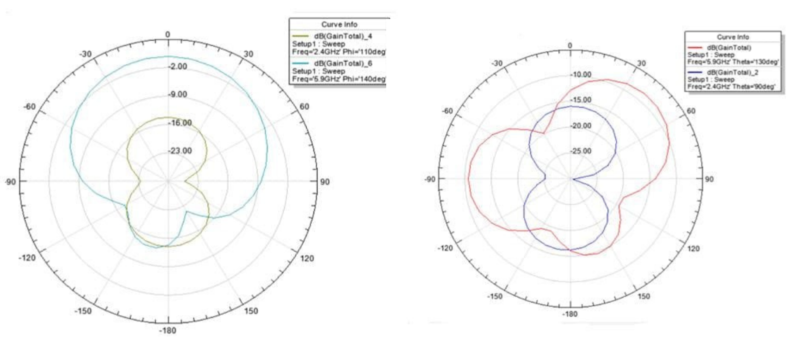
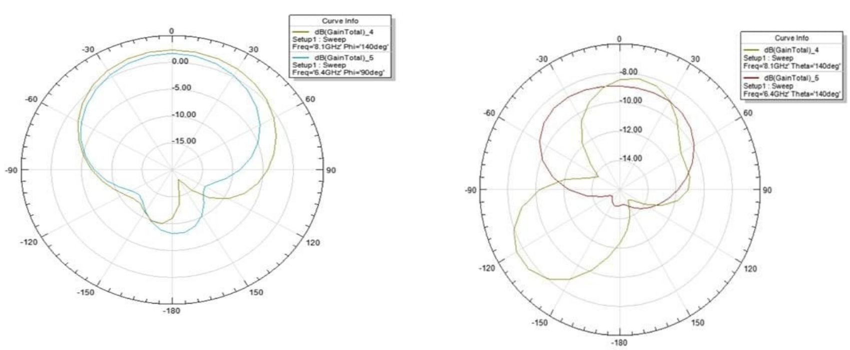


Figure 7: Gain vs Frequency



(a) (b)



(c) (d)

Figure 8: Radiation patterns for mode 5 (a) E plane at 2.4 & 5.9GHz (b) H plane at 2.4 & 5.9GHz (c) E plane at 6.4 & 8.1GHz (d) H plane at 6.4 & 8.1 GHz.

The radiation pattern for proposed antenna is unidirectional at different angles are shown in Fig.8, it shows the multi band reconfigurable antenna has radiation pattern in E & H plane at 2.4GHz, 5.9GHz, 6.4GHz and 8.1GHz. For E plane theta is at 110 degrees and for H plane phi is at 140 degrees.

V.CONCLUSION

A monopole reconfigurable unidirectional antenna is presented. The proposed antenna is appropriate 2.4-Bluetooth, 2.6-WiMAX, 4.1-5G NR,5.6-WLAN,6.4-WiFi and 8.1-GSM.The antenna incorporates a monopole patch, an inverted L-shaped, F-shaped monopole and T-shaped monopole that covers the BLUETOOTH, WLAN, WIFI, WiMAX, 5G NR and GSM frequency band. Three PIN diode are employed to reconfigure the antenna. As result of reconfigurable antenna produce the bandwidth 65.01% and which is applicable for wireless communication system.

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