Industrial Engineering Journal
ISSN: 0970-2555
Volume : 52, Issue 5, No. 5, May : 2023

A MULTIBAND FREQUENCY RECONFIGURABLE MICROSTRIP PATCH ANTENNA FOR WIRELESS APPLICATIONS

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Abstract
Reconfigurable design of microstrip patch antenna has a wide range of wireless applications. The paper introduces a multiband frequency reconfigurable microstrip patch antenna, using a PIN diode is proposed. By adjusting the bias conditions of the embedded PIN diodes, various frequency band operations can be performed. Application of the technique can be useful in the HF band. The antenna features a simple geometrical configuration, with a compact lightweight, good electrical performance, and the proposed antenna will be designed using a simple technique. The antenna design, simulation, optimization, and results are presented by using CST software.
Keywords:Patch Antenna, PIN diode, Reconfiguration, Multiband

Introduction
Reconfigurability
Advancements in wireless communication require the integration of multiple radios into a single platform. Several reconfiguration techniques have been proposed since the rise of reconfigurable antennas. Reconfigurable antennas are all antennas in which the frequency and radiation pattern can be changed reversibly and in a controlled manner [1].
Reconfigurability can be achieved by the use of RF switches, varactors, diodes, or tunable materials and provides a dynamic response. They normally differ from the smart antennas because the reconfiguration mechanism lies inside the antenna. The main advantage of the reconfigurable antenna is here multiple antennas can be replaced by a single reconfigurable antenna and they have a diverse feature that includes resonant frequency, polarization, and radiation pattern[2].

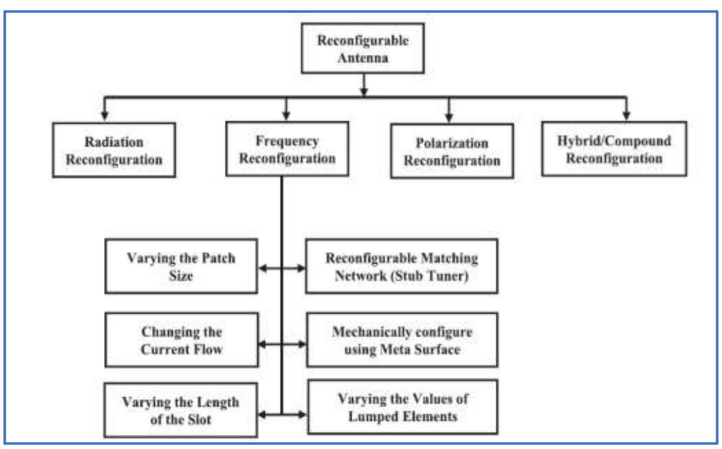

Figure 1Reconfigurability Types

SwitchingTechniques
Dynamic tuning can be achieved by manipulating a specific switching mechanism, controlling electronic, mechanical, physical, or optical switches. Electronic switches are the most popular for

Industrial Engineering Journal
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making reconfigurable antennas because of their efficiency, reliability, and ease of integration into microwave circuits[3].

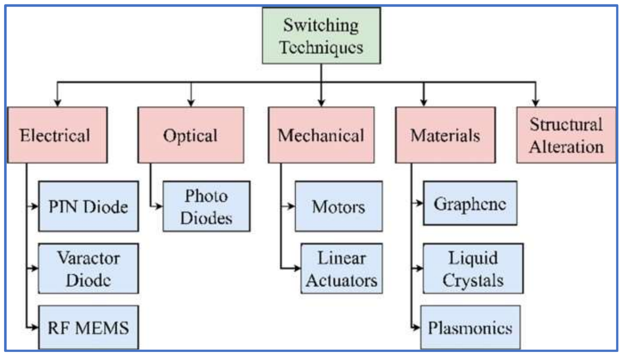


Figure 2Switching Techniques

Applications

Different applications of the reconfigurable antenna are wireless sensing, MIMO, cognitive radio, and on-body networks, for WLAN band rejection. It also provides multiple wireless sensing applications, millimeter-wave communication applications, and terahertz communication applications.

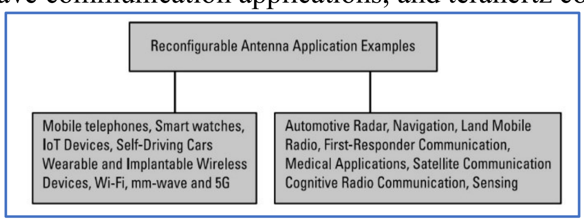


Figure 3 Applications

Related works

For a long time,have been many techniques for altering the current flow on an antenna, using mechanically movable parts, phase shifters, attenuators, diodes, tunable materials, or active materials [1]. The antenna with a simple geometric configuration consisting of a triangular monopole antenna with three stubs achieves wideband, narrowband, dual-band, and tri-band modes of operation [4]. Polarization Agility achieved with A Novel Reconfigurable Microstrip Patch Antenna with in Two Switchable Frequency Bands presented with a PIN diode[5]. Has-san Tariq Chatta presented a simple and Frequency reconfigurable patch antenna with a bias tee, integrated DC line for wire-less LAN applications in 2018[6]. The concept of a reconfigurable ultra-wideband (UWB) mmWave/THz microstrip antenna using a novel gold radiating patch with two PIN diodes on a benzocyclobutene (BCB) polymer is presented[7].

Muhammad Kamran Shereen presents a novel combo-reconfigurable architecture for the frequency and radiation patterning of a novel antenna system for future fifth-generation (5G) millimeter-wave mobile communication [8]. Design of reconfigurable antenna by capacitive type RF MEMS switches for 5G applications presented by K. GirijaSravani in 2020[9]. A very comprehensive review of Reconfigurable Antennas for 4G and 5G Wireless Communications was presented by Arpit Jain in 2021[10]. A similar way two band two mode patch antenna with on-/off-body WBAN communications presented by JinpilTak[11].Chatta presented dynamic changing frequency agility with Patch Antenna for a 4G LTE Application[12].In 2021 Mahmoud Al Ahmad presents how can be a compact singlevaractor diode used to achieve frequencyreconfigurable[13]. Rajesh Kumar Singh proposed a novel reconfigurable microstrip-fed patch antenna withpolarization agility in either of two bands[5].

Reconfigurable antenna design

To design a reconfigurable microstrip patch antenna with Frequency Reconfigurability in two switchable bands, a conventional patch antenna at the operating frequency of 6 GHz is designed first by using standard formulas given in[4]. An additional small rectangular patch is then connected to Proposed work of the main patch. With this additional patch, the frequency can be increased or decreased from the reference frequency.

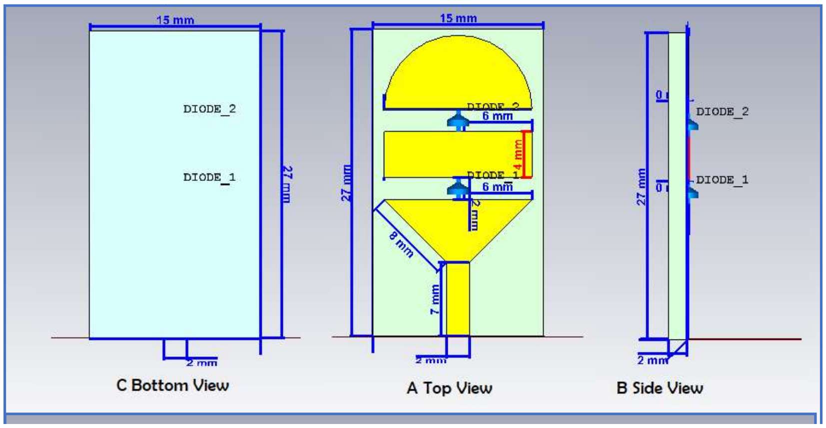


Figure 4Design iteration of the proposed Antenna: (a) Antenna 1 (b) Antenna 2 (c) Antenna 3

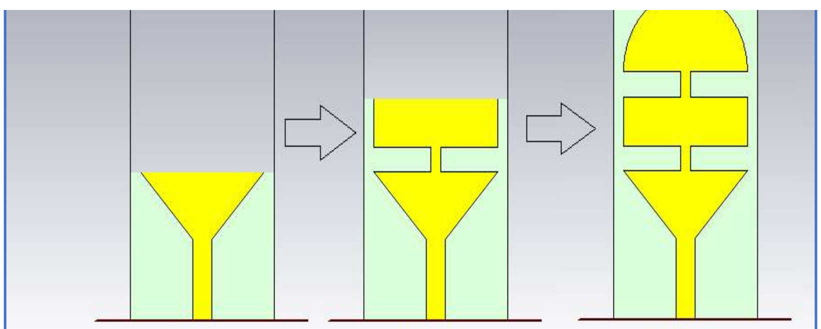


Figure 5Geometrical configuration (A) top-view, (B) bottom-view, and (C) side view

Three design iterations proposed a figure 5. With change will result in a shift in return loss, and working band operation. This frequency shift depends on various parameters, such as the length of the additional section. A parametric analysis is performed by simulating and optimizing these parameters in CST (Computer Simulation Technology — Microwave Studio) version 2019. A noticeable change in frequency is observed by varying the width of the additional patch.

Figure 4. presents the top, bottom, and side view of the systematic geometry of the proposed frequency reconfigurable antenna. An FR4-epoxy dielectric ($\varepsilon r = 4.4$, $\tan \delta = 0.002$, $h = 1.6$ mm) is used as the antenna substrate.The FR-4 substrate is commercially available, which makes the designof the antenna more affordable and feasible The antennastructureof the size 15*27 mm^2 consists of different radiating patches. A gap between two patches is used to achieve reconfigurability byplacing two diodes D1 and D2 through biasing states.

TABLE I. ANTENNA DIMENSIONS

Dimension (mm)	Parameter
AW= 15.03	WIDTH
AL= 27	LENGTH
SH= 1.6	SUBSTRATE HEIGHT
h= 0.035	PATCH HEIGHT
WP3= 2	WIDTH OF DIODE
LP3= 12	HEIGHT OF TRIANGLE
GH= 0.035	GROUND HEIGHT
D1= 2	FIRST GAP
P2_L= 4	LENGTH OF PATCH 2
CH= 0.035	COPPER HEIGHT
D2= 2	SECOND GAP
AL_G= 27	GROUND HEIGHT

PIN diode as a switching element

Infineon series PIN diode used here. The analogous circuit of the PIN diode (BAR64-02V-SC79) switching circuit is shown in Fig.6. For simulation the PIN diode in the ON condition is represented with a 2.1 Ω resistance whereas, in the OFF condition, it is a parallel combination of 4kΩ resistor and a 0.17 pF capacitor[14].

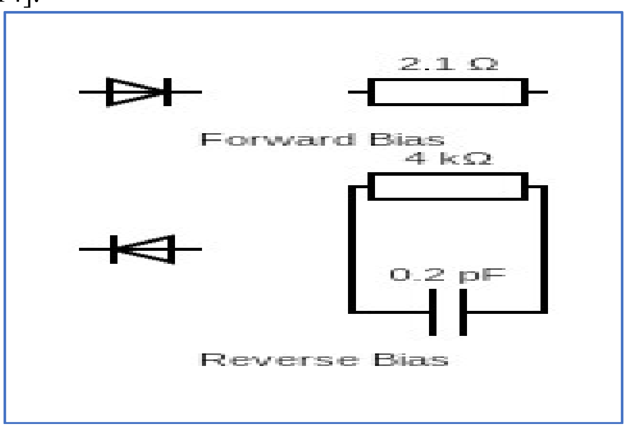


Figure 6Equivalent circuits of BAR 64 PIN diode in forward and reverse

Results & discussions

Working mechanism and parametric analysis

Working Mechanism

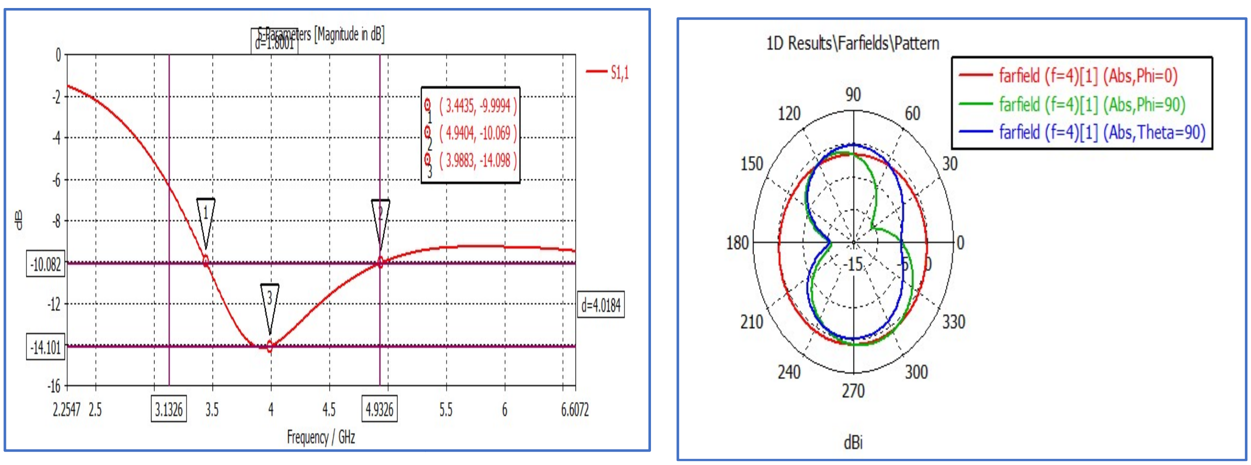
The proposed design operates in three states listed in Table 2. Switching among three operating states is carried out using two PIN diodes named D1 and D2 shown in Fig. 4. These diodes are placed in the rectangular ring slot at the optimum position on the ground plane. The equivalent circuit of the diode in ON and OFF states is shown in Fig. 2(a). Reflection coefficients S11 for all the presented cases are simulated and described below.

TABLE II. OPERATING STATES OF THE PROPOSED ANTENNA.

OPERATING STATES	DIODE STATE	FREQUENCY (GHz)	BW (GHz)
STATE-1	D1 OFF, D2 OFF	4	1.8
STATE-2	D1 ON, D2 OFF	3.13	0.76
STATE-3	D1 ON, D2 ON	2.78	0.55
		6.77	1.42

State-1 (D1 OFF & D2 OFF)

The first case presents a situation where all the switches are in 'OFF' states. The simulated results of the reflection coefficient S11 in dB are shown in Fig. 7. From the results, the proposed antenna covers the following areas 4GHz for 4G LTE wireless band for our criteria of S11 < −10 dB is getting around -14db. The
result shows that the antenna structure has VSWR in the range of 1.45 with a radiation efficiency is



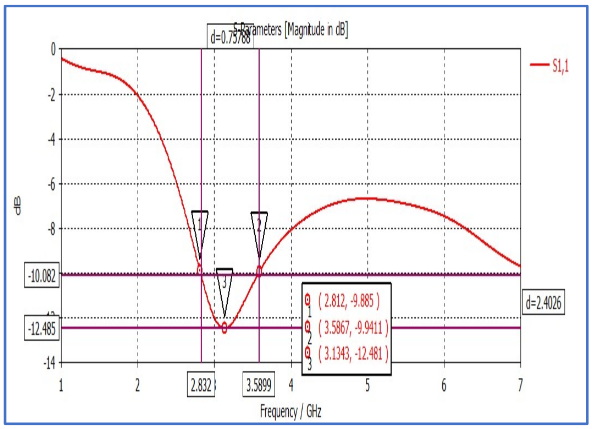
around

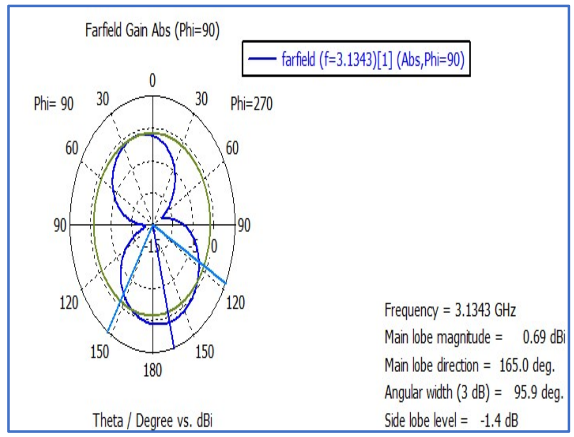
Figure 7State-1 S11 graph & Radiation Pattern

70%. The far field radiation pattern for both the E-plane and H-plane is shown in figure 7

State-2 (D1 ON& D2 OFF)

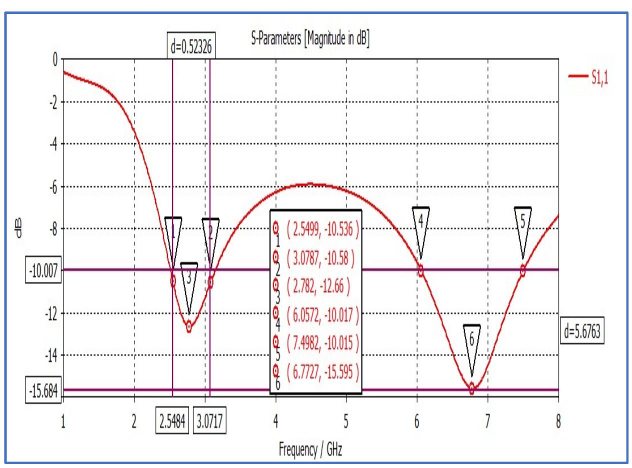
The second case presents a situation where the D1 diode is in an 'ON' condition and diode D2 is in an 'OFF' state. From the results, the proposed antenna covers the following areas of the reflection coefficient S11 in dB are shown in Fig. 8. From the results, it is obvious that the proposed antenna covers 3.13GHz for the 3G LTE wireless band for our criteria of S11 < −10 dB is getting around -12db. The result shows that the antenna structure has VSWR in the range of 1.92 with a radiation efficiency of around 76%. The far field radiation pattern for both the E-plane and H-plane is shown in figure 8.





State-3 (D1 ON & D2 ON*)*

The first case presents a situation where all the switches are in 'ON' states. From the results, the proposed antenna covers the following areas of the reflection coefficient S11 in dB are shown in Fig. 7. From the results, it is obvious that the proposed antenna covers two wireless bands 2.8GHz and 6.77GHz. For our criteria of S11 < −10 dB is around -12db and -15db respectively. The result shows that the antenna structure has VSWR in the range of 1.56 and 1.35 for both bands. With radiation, efficiency is around 75%. The far field radiation pattern for both the E-plane and H-plane showed in figure 8.



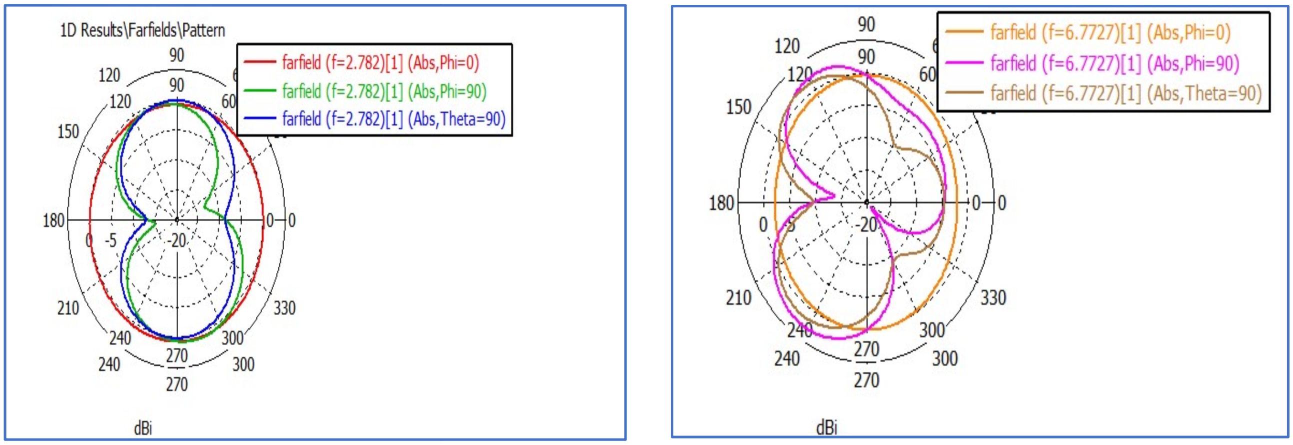


Figure 8. State-3 S11 graph & Radiation Pattern

Parametric Analysis

In this section, a parametric analysis of the main parameters of the proposed antenna is presented, which mainly affects the resonance frequency band of the antenna. The first one is the width of the triangular patch length, i.e., WP3, and the second one is the length of the second rectangular patch i.e., P2_W. The parametric analysis is performed on the antenna to show the frequency reconfiguration propertyof the proposed antenna. For analysis of the effect of both the parameters, i.e., WP3 and P2_W, on the performance of the antenna, only one parameter is varied, and all the others remain uninterrupted.

Rectangular Patch Width(WP3)

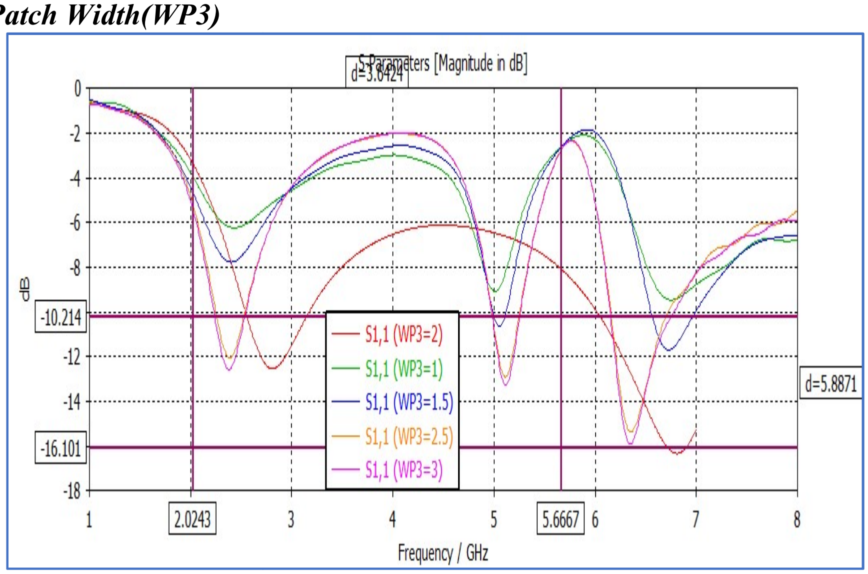


Figure 9S11 graph for different WP3 parameter value(1,1.5,2.5,2,2.5,3)

Figure 10 shows the return loss of the antenna for different values of the width of the triangular main patch(WP_3).As the WP_3 value increases, thelower frequency of the operating band shifts towards the upper side, thereby reducing the operatingbandwidth of the antenna and also return loss increase proportionally. At the same time, with an increasein the value of WP_3, the impedance matching improves.

Rectangular Patch Length(P2_W)

Figure 11 shows the return loss of the antenna for different values of second rectangular patch length varies from 3mm to 9mm . As P2_W increases, thelower frequency of the operating band shifts towards the lower side, At the same time, with an increasein the value of W S1, the impedance matching improves till P2_L = 7.8 mm getting -20db of return loss.

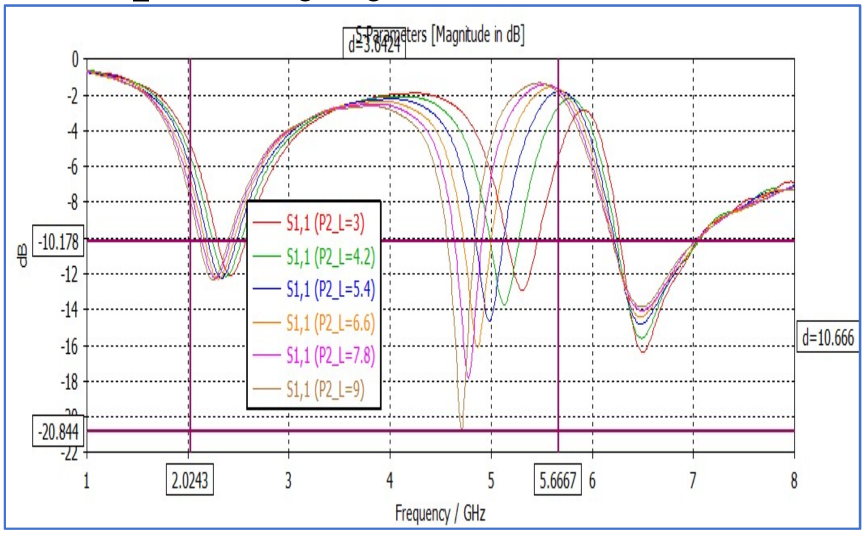


Figure 10S11 graph for different P2_L (Second patch lengthvaries) parameter value(3,4.2,5.4,6.6.,7.8,9)

A comparative study of the proposed antenna performances with similar antennas published inrecent literature is illustrated in Table 3. One can see that the proposed antenna has advantages likecompact size with fewer switches to control more bands over previous reference designs.

TABLE III. COMPARISON WITH PREVIOUSLY PUBLISHED WORKS

References	**Number of switches**	**Number of bands**	**Size(mm^2)**	**Publication Year**	**Substrate**
[15]	4	3	32 * 82	2017	FR4
[16]	4	3	90 * 30	2018	FR 4
[17]	7	2	84 * 84	2018	FR 4
This Work	2	4	27 * 15	2023	FR 4

Conclusion

Different parameters such as Return Loss, Gain, VSWR, Bandwidth, etc. are determined. The optimized performance of the proposed reconfigured antenna structure will be based on Return Loss. Appreciable gain and radiation characteristics have been observed over the entire operating range. The proposed design is best suited for modern wireless applications, requiring multiband antennas. Our method presents a method to accomplish frequency reconfigurability through PIN diode which can be further improved through material changes and optimization. Future work will be based on the improvement of parameters, including a greater number of bands of an antenna.

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