Special Issue of First International Conference on Innovations in Engineering Sciences (ICIES 2020)

Performance Analysis of Slotted Monopole Antenna with Pin Diodes for Wireless Applications

Chetan S[1],Dr. Chandrappa D N[2], Poojashree G[3],
[1]Assistant Professor, Department of E&CE, SJMIT, Chitradurga ,India.
[2]Professor and Head, Department of E&CE, PESITM,Shivamogga ,India.
[3]Student, Department of E&CE, SJMIT, Chitradurga, India,
chetan.s@sjmit.ac.in[1], chandrappadn@pestrust.edu.in[2], poojashreeg1999@gmail.com[3]

Abstract

This paper deals with Performance Analysis of slotted monopole antenna with pin diodes for wireless applications. The antenna is designed on a 1.6 mm thick FR4 substrate with the dielectric constant (ε_r) of 4.4. Antenna is electrically reconfigured incorporating pin diodes as switching elements to tune desired frequency and to achieve frequency reconfigurability. The antenna parameters like return loss, bandwidth, radiation pattern, directivity and gain are simulated and characterized in this paper. The proposed antenna covers resonating frequencies ranging from the 3.7-13.4GHz. The proposed microstrip monopole frequency reconfigurable antenna can be considered as electrically small, low weight, low profile. The design and analysis of the proposed antenna is accomplished through HFSS EM simulator.
Keywords: Pin diode, HFSS, Monopole

1. Introduction

Modern wireless system structures usually have more than one standard in order that they require modern-day antenna structures with multiple skills and capabilities without enlarging occupied volume. The reconfigurable antenna becomes a popular answer as it presents variety in antenna performance to fulfill various communication necessities and reduce the interference [1]. Single antenna can be used for multipurpose application by way of changing their parameter which includes frequency, pattern or polarization [2]. With multiband capability, reconfigurable antennas can make use of extra efficaciously radio frequency spectrum, facilitating a better get right of entry to wireless services in modern radio transceivers [3].

Responding to the ever-increasing antenna bandwidth needs, significant effort is currently under way to improve multiband antennas. For all of these applications, frequency reconfigurable multiband antennas are attractive where it is advantageous to have a single antenna which can be dynamically reconfigured to transmit and/or receive on multiple frequency bands.For these structures, mainly planar designs are chosen because of their added benefit of small scale, low cost of manufacture and conformability. PIN diode design and manufacturing technology for RF circuits has had a substantial positive effect on the frequency reconfigurable antennas [1]. For an antenna reconfigurable for frequency[2],the challenging task is to connect the radiating elements together, such that the resulting module will have desired operating frequency bands, or in other words to determine which switches to turn ON / OFF, so that a specific set of elements will be active to make the structure operating at desired frequency bands.In this paper , an attempt was made to integrate the technique of electrical reconfigurability to decide the RF switches to be

made ON / OFF to make the antenna resonate at specified frequencies. The formulations produced are measured and are observed with satisfactory results.

2. Problem formulation

A performance analysis of slotted monopole antenna with pin diodes for wireless applications is designed on a substrate of FR4 dielectric material with thickness of 1.6mm and dielectric constant (ε_r) of 4.4[4]. The size of the substrate is 40X47mm. The radiating element constitutes two monopole arms associated with two radiating patches. The design on the bottom side having partial ground plane with 40X10mm with two inverted F shaped slots. The radiating elements which are fed with a 50Ω- microstrip feed line with the length of 12.5 mm and width of 3.3 mm below the microstrip feed line [6]. Two pin diodes have been deployed between the two arms and the associated radiating patches to attain the frequency reconfiguration on biasing them to ON/OFF. The proposed antenna operates at a frequency range 3.7-13.4GHz providing multiband operations.

The proposed antenna is designed and simulated in HFSS EM simulator and observed with acceptable parameters to accomplish frequency reconfigurability with multiband operations. The rest of the research work is organised in the following section. In section 3, the designed antenna geometry specification, in the section 4, the simulation and results, in section 5, the paper is concluded.

3. Antenna geometry and design procedure

Fig 1 shows the geometry and Table 1 gives dimensions of the proposed. The antenna consists of radiating patches incorporated with PIN diodes o the top plane, partial and truncated ground plane on bottom, The patch is designed on a 1.6mm thick FR4 substrate (with dielectric constant =4.4 and loss tangent =0.019). In order to obtain the monopole characteristics and better gain the ground as been truncated with two inverted F shaped slots[6].
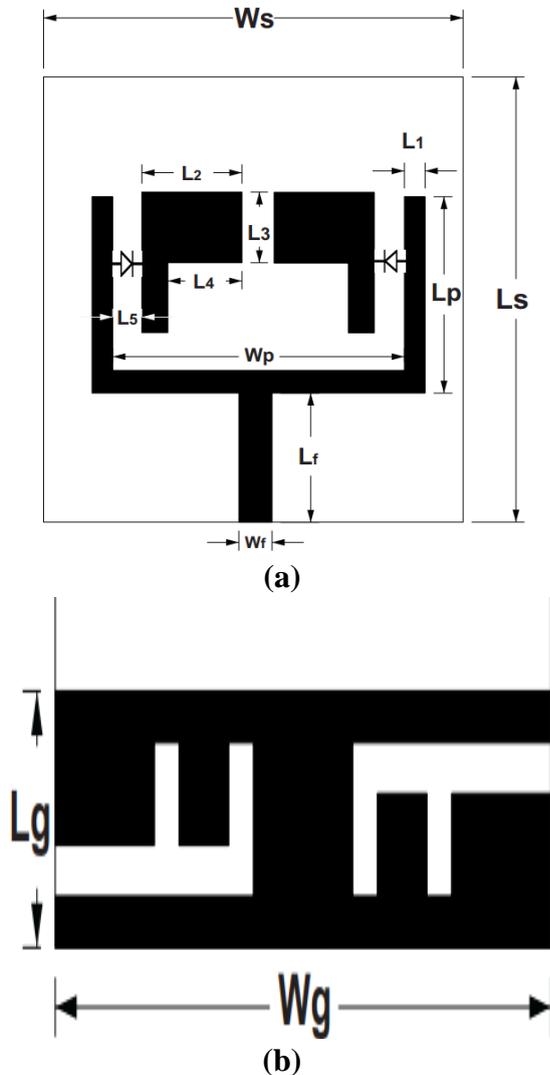

(a)

(b)

Fig.1. Proposed antenna design (a)Front view (b)Rear view

A. Formulation

To design the conventional patch antenna following formulae were used:

- To find the width of the patch,

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

Where C=3x10 m/s, fr = Resonating frequency and ε_r= Dielectric constant.

$$\Delta L = 0.412h\frac{(\varepsilon_{reff}+0.3)\left(\dfrac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\dfrac{W}{h}+0.8\right)} \qquad (2)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left(1+12\frac{W}{h}\right)^{0.5} \qquad (3)$$

$$L_{eff} = \frac{C}{2f_r}\sqrt{\frac{2}{e_{ref}}} \quad (4)$$

The proposed antenna is fed with Microstrip feed line with a line impedance (Z_0) of 50Ω. Equation (6) and (7) showthe formulas for feeder length and width.

- The 50 Ω microstrip line feed is designed by calculating the values of W/h ratio for the known values of characteristic impedance Z0 and ε_r. The design equations are [8]

$$\frac{W_f}{h} = \left(\frac{ge^A}{e^{2A}-2}\right)(5)$$

for

$$\frac{W_f}{h} = \frac{2}{p}\left[B-1-h(2B-1)+\frac{e_f-1}{2e_f}\{\ln(B-1)+ \right.$$
$$\left. 0.39-\left(\frac{0.61}{e_r}\right)\}\right] \quad (6)$$

for $\dfrac{W_f}{h} > 2$

Where, $A = \dfrac{Z_0}{60}\sqrt{\dfrac{e_r+1}{2}} + \dfrac{e_r-1}{e_r+1}\left(0.23+\dfrac{0.11}{e_r}\right)(7)$

and $B = \dfrac{377p}{2Z_0\sqrt{e_r}}$

- To design the Length (L_g) and width (W_g) of ground plane:

The length and width of a substrate is equal to that of the ground plane. The length of a ground plane (L_g) and the width of a ground plane (W_g) are calculated using the following equations.

$$Lg = 6h + L \,(9)$$

$$Wg = 6h + W \:(10)$$

B. Design of PIN diode

The pin diode was modelled using lumped element s in HFSS. The corresponding circuit was shown i

n Fig.2 for both ON state (Forward bias) and OFF state (Reverse bias).
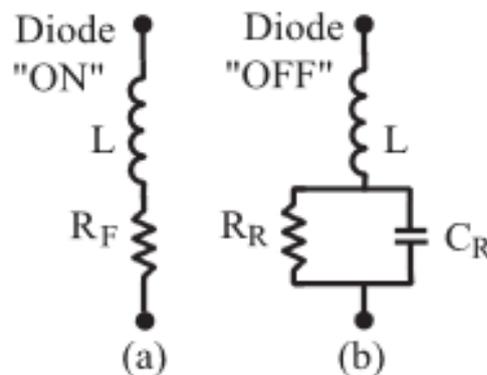

Fig.2. RF PIN diode (a) Equivalent circuit model for 'ON' configuration. (b) Equivalent circuit model for 'OFF' configuration.

The simulation model with switching diode parameter is selected from the pin diode BAP6502115. The design of the RF pin diode in provides a Forward resistance of RF=1 for the ON state and a parallel circuit with capacitance of CT=0.5pF and resistance of RR=20 K for off state. The L stands for the slight inductance of lead. The following figure 2(a) and figure 2(b) respectively represent the electrical countepart and the ANSYSHFSS model for the proposed RF switch.To mount the switches at the right position within the framework, a 2 mm long slot is reserved as shown in Fig. l. The effective length of the monopole antenna is calculated using the transmission line model principle. The lumped elements have negligible effects on the output of the antenna, since the antenna impedance is much lower than the RLC circuit impedance [7].

Table 1.Dimentions of the proposed antenna

Parameter	Dimensions in mm	Parameter	Dimensions in mm
Wp	26	L1	2
Lp	19	L2	10
Ws	40	L3	7.3
Lf	12.5	L4	8
Wf	3.3	L5	2
Lg	10	-	-
Wg	40	-	-

4. Simulation and results

The proposed antenna for performance analysis of slotted monopole antenna with pin diodes for wireless applications [9] is designed and analyzed

using the Finite Element Method (FEM) used in HFSS to solve the equations of electromagnetic waves in time and frequency domains.To solve the EM wave or Maxwell equation in the time and frequency domain, the proposed compact dualarm reconfigurable microstrip planar monopole with truncated ground plane for c, x and ku band applications is constructed and simulated using the EM simulator which is HFSS v 15.0.

Lumped port is assigned to the microstrip line for excitation of the antenna. Return loss, gain, radiation pattern and current distribution were analysed in this design. For perfect impedance matching, the reactance should be negligible and impedance should be 50 Ω.The simulation is done with respect to four switch states .state A, state B, state C and state D. State A considered to be the condition when both pin diodes in OFF condition, state B represents pin diode 1(the left side of from top view of Fig (1) is OFF and pin diode 2 is ON, state C represents pin diode 1 is ON and pin diode 2 is OFF and State D represents both pin diodes are in ON condition.

Table 2. Performance analysis of proposed

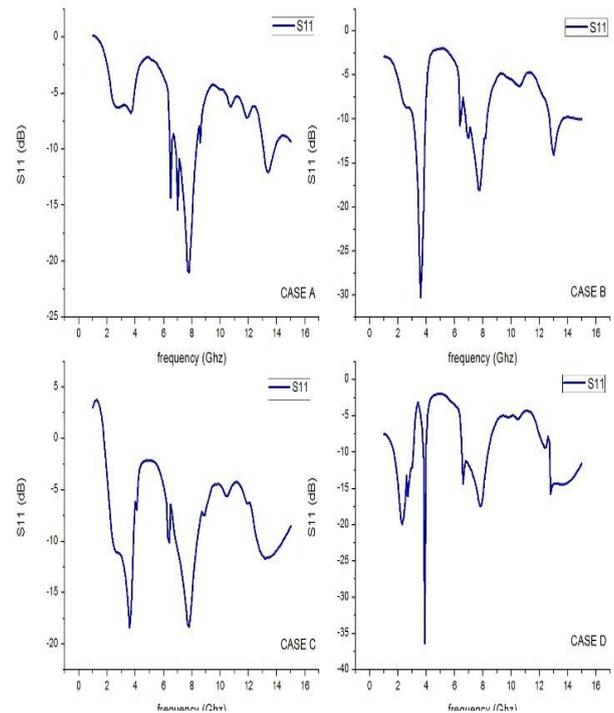| case	Freq (Ghz)	Return Loss(dB)	BW(Ghz)	gain
A	6.5	-14.3347	0.1	1,9516
	7.8	-21.0096	1.5	
	13.4	-12.0146	0.8	
B	3.6	-30.2324	0.8	1.3915
	6.4	-10.6984	0.1	
	7.8	-18.0673	1.4	
	13.0	-14.0545	0.9	
C	3.6	-18.3976	1.4	6.9698
	7.8	-18.3322	1.5	
D	2.3	-19.9936	1.3	9.3063
	3.7	-36.4085	0.2	
	7.8	-17.4239	1.8	

Fig.3. S11 parameter analysis for all four cases where in graph CASE a, CASE B, CASE C and CASE D.

The S11(Return loss) characterization for the proposed antenna for all the four observed cases has been depicted in above fig 3.the antenna shows feasible frequency shift from case to case with acceptable results. The detailed description is as follows.

- S11 Parameter analysis for Case A

When the PD1, PD2 both are ON the proposed antenna operates in triple band frequency mode 6.5, 7.8 and 13.4 in GHz with the return loss of -14.3,-21.0 and -12.0 in dB, respectively. The proposed antenna has the maximum bandwidth of 0.1, 1.5 and 0.8 in GHz .respectively with the gain of 1.95 dB.

- S11 Parameter analysis for Case B

When the PD1 is OFF and PD2 is ON the proposed antenna operates in quad band 3.6, 6.4 ,7.8 and 13.0 in GHz with the return loss of -30.2, -10.6, 18.0 and -14.0 in dB ,respectively. The proposed antenna has the maximum bandwidth of 0.8, 0.1, 1.4 and 0.9 in GHz, respectively with the gain of 1.39 dB.

- S11 Parameter analysis for Case C

When the PD1 is ON and PD2 is OFF the proposed antenna operates in dual band 3.6 and 7.8 in GHz with the return loss of -18.3 and -18.3 in dB, respectively. The proposed antenna has the maximum bandwidth of 1.4 and 1.5 in GHz, respectively with the gain of 6.96 dB.

- S11 Parameter analysis for Case D

When the PD1, PD2 both are OFF the proposed antenna operates in triple band 2.3, 3.7 and 7.8 in GHz with the return loss of -19.9,-36.4 and -17.4 in dB, respectively. The proposed antenna has the maximum bandwidth of 1.3, 0.2 and 1.8 in GHz, respectively with the gain of 9.30 dB.

The antenna's calculated radiation patterns at resonant frequencies on the E plane and H plane are shown in Fig.4. The results show reasonable omnidirectional radiation patterns. The omnidirectional antenna is capable of transmitting in all the desired directions with equal intensities.
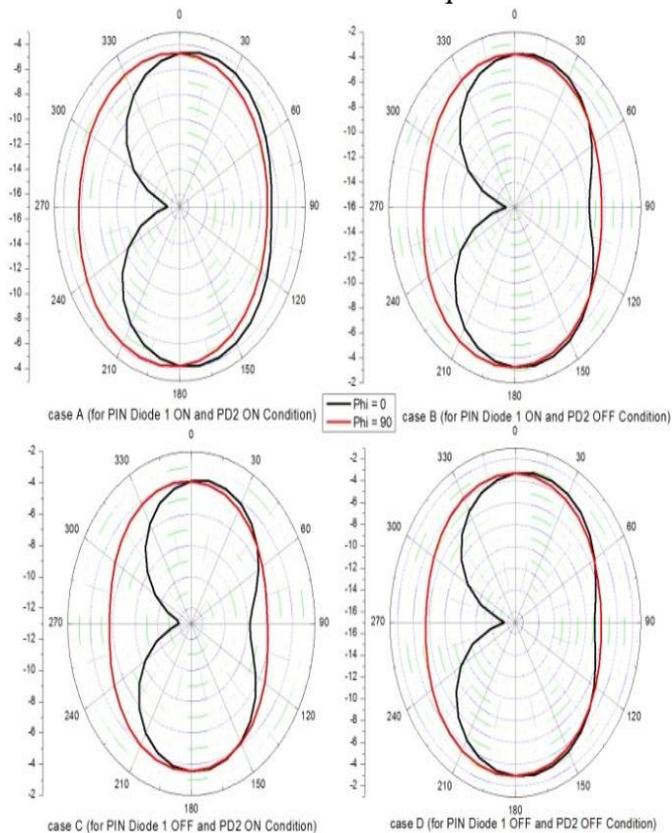

Fig.4. Radiation patterns for proposed antenna for all cases (A, B, C and D)

The 3 D view of a gain total in all the directions is shown in Fig .6. The observed 3-D radiation patterns for all the 4 views were plotted. The pattern of radiation is the relative distribution of

the radiated power in function of direction. In thefarfield area, the pattern of radiation is usually determined.
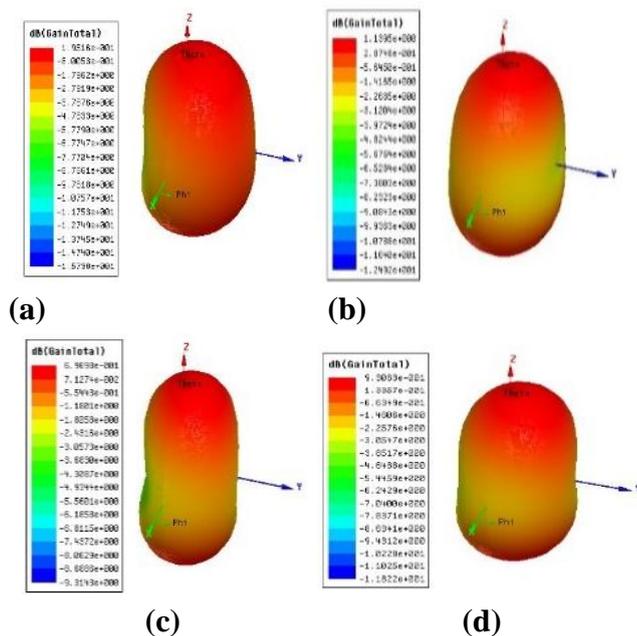

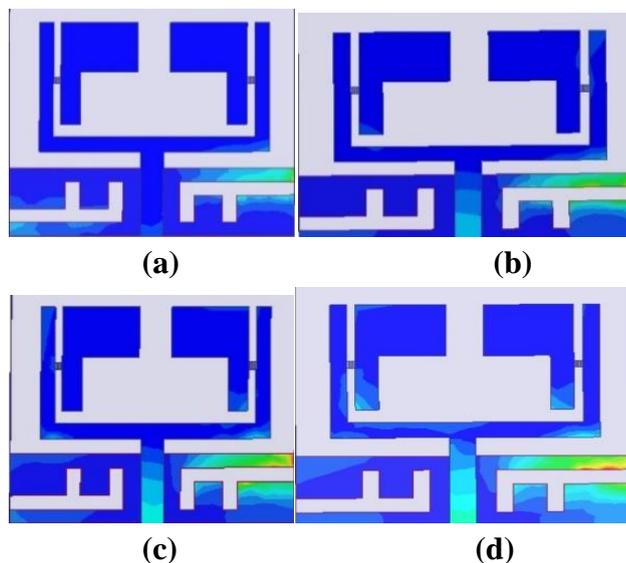**Fig.5. 3D-Radiation patterns for all the four cases were shown in (a)case A, (b)case B, (c)case C, (d)case D**

Fig.6. Surface current distribution for all the four cases were shown in (a)case A, (b)case B, (c)case C, (d)case D

Conclusion

In this paper, performance analysis of slotted monopole antenna with pin diodes for wireless applications is designed and optimized in HFSS. The proposed antenna exhibited characteristics of frequency reconfigurability to operate in multifrequency and multiband by changing the state of RF PIN diodes. The proposed antenna is simple to design and fabricate and exploits two PIN diodes for switching in to different bands. The proposed antenna covers a wide 3.7-13.4GHz frequency range. The antenna is showing the omnidirectional radiation pattern with monopole character, better impedance matching and satisfactory gain is achieved with tunable frequencies for various wireless applications.

References

Journals

[1]. S. Yang, C. Zhang, H. K. Pan, A. E. Fathy, and V. K. Nair, Frequency reconfigurable antennas for multiradio wireless platforms,‖ IEEE Microw. Mag., vol. 10, no. 1, pp. 66–83, Feb. 2009.

[2]. FCC Spectrum Policy Task Force, Washington, DC, ―Report of the Spectrum Efficiency Working Group,‖ Tech. Rep., 2002

[3]. T. Wu,R.L.Li, S. Y. Eom, S. S.Myoung, K. Lim, J. Laskar, S. I. Jeon, and M. M. Tentzeris, ―Switchable quad-band antennas for cognitive radio base station applications,‖ IEEE Trans. Antennas Propag., vol. 58, no. 5, pp. 1468–1476, May 2010.

[4]. R. Panda, A. S. Ram Saladi, R. S. Kshetrimayum, "A Compact Printed Monopole Antenna for Dual-band RFlD and WLAN Applications," Radioengineering, Volume 20, Issue No 2, June 2011.

[5]. Aghda, M. R., M. R. Kamarudin, and H. U. Iddi, "M-Shape Surrounded With Ring-Patch Wide-band Monopole Printed Antenna," Microwave and Optical Technology Letters, Volume 54,Issue No 2, 482-486, January 2012

[6]. Iddi, H. U., M. R. Kamarudin, T. A. Rahman, and R. Dewan, "Design of dual-band B-shaped monopole antenna for MTMO application," 2012 IEEE Antennas and Propagation Society International Symposium (APSURSl), Volume I, Issue no.2, 8-14, July 2012

[7]. Sun, x.L., Cheung S.W., Yuk T.I, "Dual-Band Monopole Antenna With Frequency-Tunable Feature for WiMAX Applications," Antennas and Wireless Propagation Letters, IEEE, Volume. 12, no., pp.100, l03, 2013.

[8]. W.N.W., Abidin, Z.Z., "Dual-wideband G-shaped slotted printed monopole antenna for WLAN and WiMAX applications," RF and Microwave Conference (RFM), 2013 IEEE International, Volume 225, Issue No 227, 9-11, Dec

[9]. Ajit. Roy, S. Anand, P. Kumar Ch,P. P. Sarkar, S. Bhunia, "Compact Multi-Frequency Patch Antenna With Spur-Lines for WLAN/WiMAX Applications,"]JECT Volume5, Issue Spl 2, January - March 2014 . 2013.

[10]. Soloni, H. S. Rajappa and D. N. Chandrappa, "Design and analysis of multiband reconfigurable microstrip patch antenna with switchable element," 2017 International Conference on Advances in Computing, Communications and Informatics (ICACCI), Udupi, 2017,pp.288-293.

[11]. R. Khan, A. A. Al-Hadi and M. Elahi, "Design of circular and pyramidal shape reconfigurable UWB monopole antennas for cognitive radio applications," 2016 IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE), Langkawi, 2016, pp. 282-285

[12]. Ozbakis, S. Okuyucu, M. Secmen and K. Yegin, "Multi-band frequency tunable LTE antenna for mobile phone applications," 2017 Progress In Electromagnetics Research Symposium - Spring (PIERS), St. Petersburg, 2017, pp. 939-943.

[13]. B. Ijaz, A. Iftikhar, K. S. Alimgeer, M. S. Khan and R. Shubair, "A Frequency Reconfigurable Dual-Band Monopole Antenna for Wireless Applications," 2018 International Symposium on Networks, Computers and Communications (ISNCC), Rome, 2018, pp. 1-5.