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Research paper

Notch Band Switchable Reconfigurable Monopole Antenna with Defected Ground Structure for Wideband Applications

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Abstract

A compact notch band switchable antenna with defected ground structure is proposed in this article. The designed antenna is constructed on FR4 substrate of ε_r=4.4 with overall dimension of 26X24X1.6 mm. The patch consisting of square shaped radiating element with corner truncation at lower edges. Two inverted U-shaped slots are placed on the radiating element to achieve the notch band characteristics in the antenna operating band. The proposed antenna covering operating bands from 3.7 to 7.9 GHz and 11.3 to 20 GHz with impedance bandwidth of 71% and 67% respectively. The antenna providing peak realized gain of 5 dB and efficiency more than 85% in the operating band. The frequency reconfigurable behaviour of the antenna with diodes switching is presented in this article. A perfect correlation between the results on Anritsu combinational analyzer MS2037C and HFSS simulation witness the applicability of this antenna in wideband communication applications.

Keywords: *Defected Ground Structure (DGS), Monopole Antenna, Notch Band, Reconfigurability, Wideband.*

1. Introduction

To allow maximum connectivity in the single wireless platform, a greater number of radios is to be integrated. Extensive research is under way to develop multiple radio mobile platforms such as Mobile Internet Devices, laptops and smart devices to address different wireless services scattered over a wide frequency range. Researches designing multiple band antennas to addresses different wireless communication applications such as GPS, GSM, PCS, UMTS, Bluetooth, LTE, Wi-Fi and WLAN etc [1-6]. These multi band antennas are facing several challenges when more and more wireless services are packed into compact devices [7-8].

A comparison between antenna solutions and wireless mobile platforms provide different characteristics for the analysis. If the number of antennas is used in wireless mobile platform then frequency bands, services and diversity problems should be addressed. When multi band/wide band antennas are used then wireless modules related diversity problems should be addressed. The individual radio performance is excellent with multiple antennas and good with multi band/wide band antennas. But due to insertion losses at front end the receiver sensitivity will be decreased [9-12].

The solution for these problems can be obtained by designing reconfigurable antennas. These reconfigurable antennas have multiple advantages like switching to dedicated bands and reduction of interference etc. The reconfigurable antenna supports only one service at a time with low power consumption at low cost. The reconfigurable antenna usually equipped with switches that are controlled by DC bias signals. By toggling these switches in on and off states, the antenna will be reconfigured to support a dedicated set of operating frequencies. The reconfigurable antennas consist of three types of configurations like frequency reconfigurability, polarisation reconfigurability and hybrid reconfigurability (both frequency and polarisation reconfigurability). Commonly two major types of switches, PIN diodes and RF MEMS are used in the design of frequency reconfigurable antennas for wireless applications [13-18].
In this article, PIN diodes are used to attain frequency reconfigurability. The advantage of PIN diodes includes high power handling capability, very low driving voltage and extremely low cost. Here the switch placement and control/biasing strategies depend on the type of the switch and the topology of the antenna. The DC lines are placed near the radiating elements affected the antenna resonant characteristics.

2. Antenna Structure:

The designed antenna is constructed on FR4 substrate of ε_r=4.4 with overall dimension of 26X24X1.6 mm. The patch consisting of square shaped radiating element with corner truncation at lower edges. Two inverted U-shaped slots are placed on the radiating element to achieve the notch band characteristics in the antenna operating band. The ground plane is partially etched and made defected ground to obtain good impedance bandwidth. The ground plane was selected in fashion with corner truncated orientation on top edges. A 50-ohm input impedance is used at the port to attain good impedance matching. the structure of the antenna is presented in Fig 1. The dimensional characteristics are presented in Table 1.

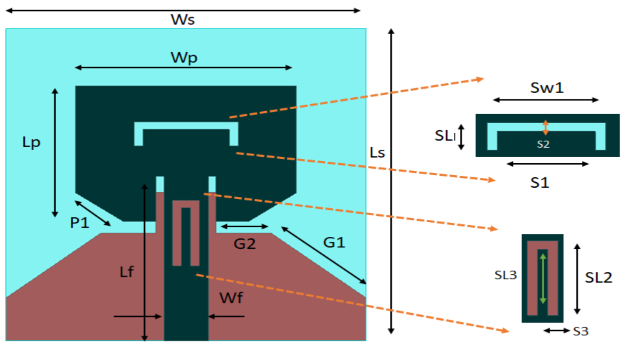


Fig 1:. Antenna Structure

Table 1:. Antenna Dimensions

Antenna Parameter	Ws	Ls	Wp	Lp	Wf	Lf	G1	G2
Dimension in mm	24	26	15.2	9.2	3	13.4	6.6	3.8
Antenna Parameter	P1	S1	S2	S3	SL1	SL2	SL3	Sw1
Dimension in mm	2.4	5.9	0.6	0.3	2	5.8	5.5	7.2

3. Results and Analysis:

The simulation of the designed antenna is carried out with FEM based commercial EM tool HFSS and the reflection coefficient, VSWR, radiation patterns and current distributions are analyzed and presented in this section. The reflection coefficient and VSWR are plotted in Fig 2. The result shows the bandwidth of 4 GHz (4-8 GHz) at fundamental resonant band and 9 GHz (11-20 GHz) at second resonant band. An impedance bandwidth of 80% at first band and 70% at second band is obtained with VSWR of 2:1 ratio and reflection coefficient less than -10 dB.

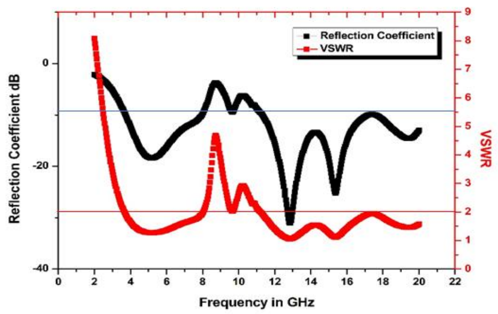


Fig 2. Reflection coefficient and VSWR of the antenna

Parametric analysis with change in width of the feed line 'W_f'and slot length 'S_2' is presented in Fig 3 and 4. The optimum dimension of width of the feed line is fixed to 3 mm and slot length of 0.6 mm after the analysis.

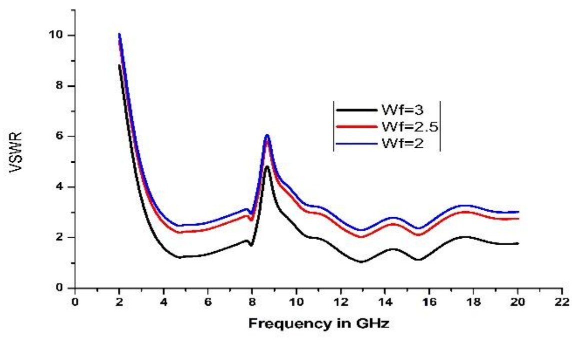


Fig 3:. Parametric analysis for width of the feed 'W_f'

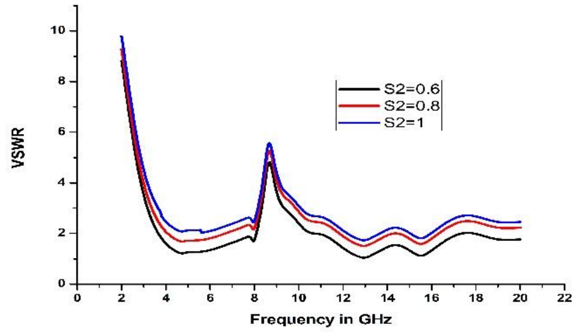


Fig 4:. Parametric analysis for slot length 'S_2'

The radiation pattern of the antenna in three-dimensional view at 5 GHz and 13 GHz are presented in Fig 5. A peak realized gain of 4.51 dB at 5 GHz and 4.99 dB at 13 GHz can be observed from the obtained results. Antenna is radiating like monopole in E-plane and omni directional in H-plane with low cross polarization. Fig 6 shows the evidence for E-plane and H-plane patters in polar coordinates.

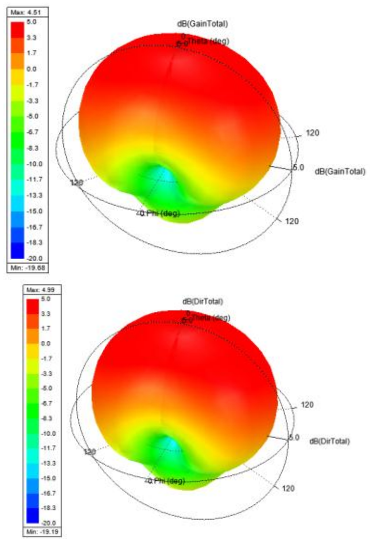
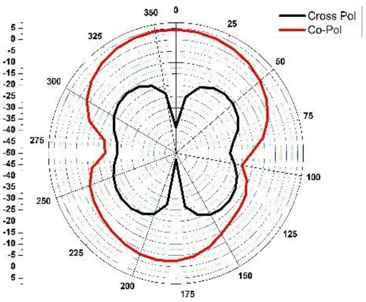
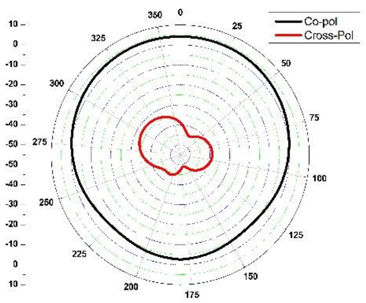


Fig 5:. Radiation pattern in 3D view, (a) At 5 GHz , (b) At 13 GHz





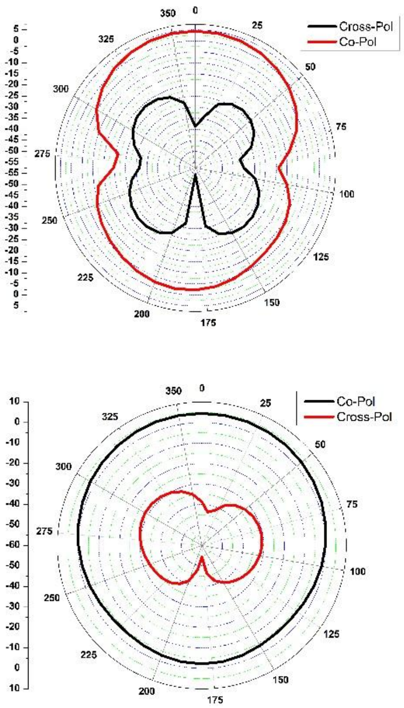


Fig 6. Radiation pattern with Co and Cross Polarization levels, (a) E-Plane at 5 GHz, (b) H-Plane at 5 GHz, (c) E-Plane at 13 GHz, (d) H-Plane at 13 GHz

The designed antenna gain in dB and efficiency in % plot with respect to the frequency of the operation is presented in Fig 7. A peak gain of 4.99 dB is attained with peak efficiency value of 78% from the current model.

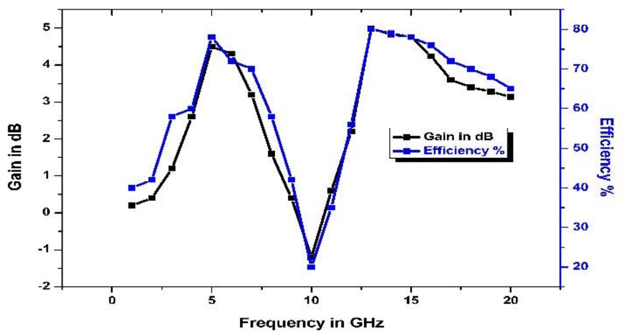
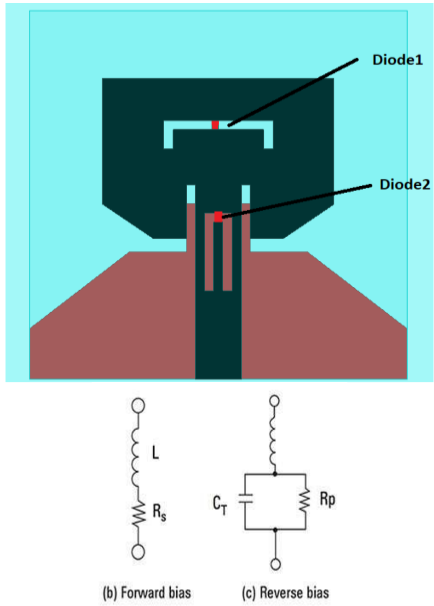


Fig 7:. Gain and Efficiency Vs Frequency

4. Reconfigurability with Diodes:

Two diodes are placed in the slots over the radiating structure as shown in Fig 8 (a). The equivalent circuits for diode on and off conditions are also presented in Fig 8 (b) and 8 (c). The slots are made in the maximum current flowing paths and diodes are connected for frequency tuning. The diodes swithing in the approporiate locations provided the band stopping and band passing characteristics, which inturn controlled the frequency tuning operation.



(a)

Fig 8. Proposed antenna with PIN diodes, (a) Diodes placement, (b) On state, (b) Off sate

The prototyped antenna is tested for its reconfigurable nature by applying bias voltage to the diodes and the corresponding change in reflection coefficient is presented in Fig 9 and 10. A considerable shift in the notch band towards lower frequency band can be observed from the experimented results with change in the capacitance values of the diode. For diode 1, when capacitance is at 0.6 pf a dual notch band characteristic is obtained at 6-6.5 GHz and 8-10 GHz as shown in Fig 9. For the value of 0.4 pf, a notch band is obtained at 6.5-7 GHz. The diode 2 related tuning is presented in Fig 10. When capacitance value is increasing, a shift in the notch band from higher frequency to lower frequency is attained.

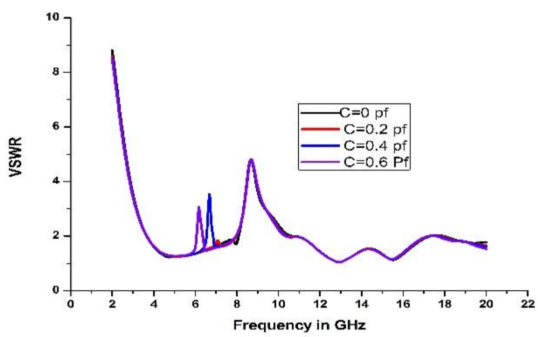


Fig 9:. Switching of Frequency with change in Capacitance at Diode1

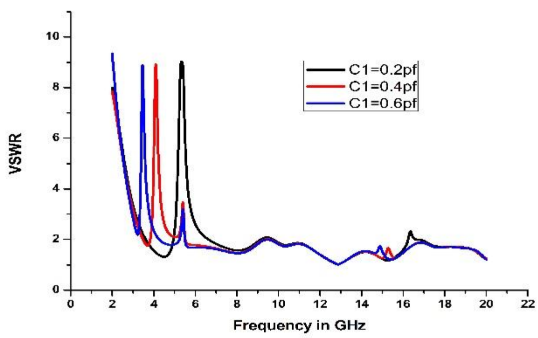


Fig 10:. Switching of Frequency with change in Capacitance at Diode2

The proposed antenna is prototyped on FR4 substrate and the evidence is presented in Fig 11. The diode 1 and 2 are switched between four different conditions and the corresponding VSWR is plotted and presented in Fig 12. It is being observed that the notch band became narrow and it moved to lower frequency bands. When both the diodes are in on condition, the notching occurred at ISM band (2.4-2.5 GHz). When diode is on and diode 2 is off, notching occurred at WLAN (5.6-5.8 GHZ) band. When diode 1 is off and diode 2 is on, notching occurred at Wi-Fi band (3.2-3.6).

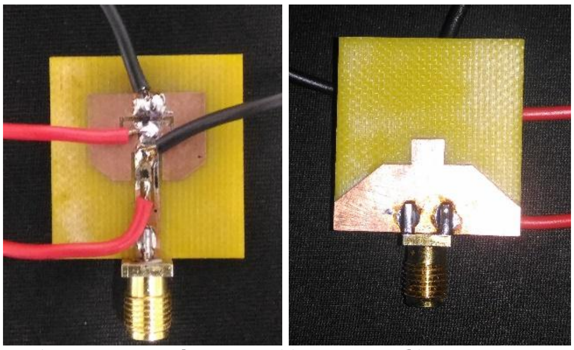


Fig 11. Prototyped Antenna, (a) Top View, (b) Bottom View

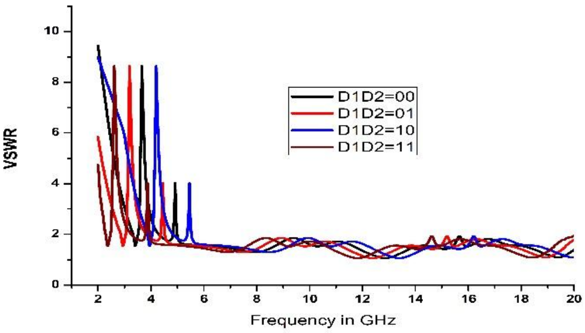


Fig 12:. Measured VSWR for diodes switching conditions

The switching conditions of the diodes providing good shift in the notch band characteristics. The obtained results are supporting the applicability of the antenna model as frequency reconfigurable candidate in desired band of applications.

5. Conclusion:

The designed antenna is operating in the dual band with good impedance bandwidth. The impedance bandwidth attained for the antenna at the resonating frequencies are about 80% and 70% respectively at both the bands. By positioning two PIN diodes on the radiator, the frequency switching is attained. The results of the proposed antenna exhibiting good return loss (S11<-10dB) at operating bands and satisfying the VSWR criteria (VSWR<2). The antenna structure provides the good radiation patterns like omni direction pattern in H-plane with low cross polarization. The reflection coefficient of the proposed antenna is measured using aniritsu MS2027 combinational analyzer and good matching is obtained with simulation.

6. Acknowledgements:

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