

Coplanar wave guide fed fork shaped frequency reconfigurable antenna for LTE, WI-FI and WLAN applications

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Abstract

A coplanar wave guide fed fork shaped antenna is designed with reconfigurability for switching between the application bands of LTE, Wi-Fi and WLAN. A novel closed hut shaped ground plane structure is used in the construction of the antenna model for good impedance matching with the feed line. The basic structure of the antenna model is working in the UWB range from 3.1 to 10.6 GHz. The adjacent strips of the monopole consisting of the slots for the placement of PIN diodes. The switching operation of the diodes providing frequency reconfigurability nature in the antenna between LTE (2.1-2.2 GHz), Wi-Fi (2.4 to 2.7 GHz) and WLAN (5.6-5.8 GHz) bands. Antenna is providing peak realized gain of 4.5 dB and efficiency more than 70% in the operating bands. The prototyped antenna is providing excellent measurement results in correlation with simulation results obtained from CST Microwave Studio.

Keywords: Coplanar Waveguide (CPW); Fork Shape; Frequency Reconfigurability; Long Term Evolution (LTE); Wireless Fidelity (Wi-Fi), Wireless Local Areanetwork (WLAN).

1. Introduction

Transmission of information is spread over a large bandwidth with usage of UWB technology of soaring information rate. Allocated by federal communication commission (FCC), the technology is being utilised with unlicensed radio spectrum from 3.1-10.6 GHz. Based on the advent of this, recent UWB technology curiosity in designing wideband antennas has increased, which provides high data rates due to short duration of UWB pulses and is well suited for short distance applications because of its low emission levels [1-3].

UWB antennas are paid more attention because they are integral part of the system itself. The most striking features like Low profile and monopole antennas are the most are widely used antennas for its applications [4]. Omnidirectional radiation from monopole antennas has made it one of the desired UWB applications [5-7]. Several narrowband systems pre-exist like WiMAX, WLAN, X band satellite communication, Hyper LAN etc., around this enormous bandwidth and the UWB communication potentially causes interference to these narrowband systems. As the wireless channels are in very close proximity and co-existing with each other and they are consequently leading to interference among these wireless channels. Suppressing of this interference caused by other undesired sources in any wireless or wired electronic systems is needed [8]. On the other hand, one of the difficult challenges being faced in its realistic appliance is antenna design for UWB applications, which can also be used for avoiding intrusion with other active services that have previously occupied frequency in the UWB [9].

In order to reduce the number of antennas operating at different frequencies a single antenna can be used to operate at different frequencies, such type of multifunctional antennas is called recon-

figurability antennas. There are four types of reconfigurable antennas: frequency, pattern, polarisation, hybrid reconfigurable antennas. Many antennas are designed to operate either as polarisation, frequency, or pattern reconfigurable. [10] Some other designs can achieve two types of reconfigurability which are both frequency and polarisation as proposed in [11]. Patch antennas are prominent for the design of Reconfigurable antennas among other types of antennas. They have the best features of low price, light weight, low profile, compatibility with RF circuitry and simple fabrication [12].

There are many techniques which can be used for reconfigurability in antennas such as using varactor diodes, and PIN diodes [13-14]. To produce a reconfigurable performance and to make a notch at 5-6 GHz MEMS (Micro electro mechanical systems) can also be used [15-16]. In this paper, a design is proposed for the reconfigurable microstrip antenna with the capability of producing switchable single and double notched bands by using PIN diodes. This article presents a novel fork shaped reconfigurable antenna for different wireless communication applications. PIN diodes are used to get the frequency reconfigurability with their switching operation. The design aspects of the antenna model and the results are discussed in the subsequent sections.

2. Antenna geometry

Fig 1 shows the configuration of the proposed reconfigurable antenna and its iterations, which consisting of fork shaped slotted aperture patch on the top side of the model. The antenna which has the compact dimensions of 23X27X1.6 mm printed basically on FR4 substrate with permittivity of 4.4 and loss tangent of 0.02. The strip width and gap of the coplanar waveguide feed are derived using standard design equations for 50-ohm impedance.

Besides, the structure of the antenna is symmetrical respect to the longitudinal direction. Ground plane and radiating patch are printed on same side of the substrate.

Frequency of operating band is taken into the account, while deriving the dimensions of the antenna. A 50Ω CPW line is derived on a substrate with permittivity ϵ_r . Effective dielectric constant is derived using $\epsilon_{eff} = (\epsilon_r + 1)/2$, where ϵ_{eff} is the effective permittivity of the substrate. The dimensions of the antenna are derived from the resonant frequency and effective dielectric constant. PIN diodes D1 and D2 are placed at the slots provided on two adjacent radiating elements as shown in the Fig 1(b). Biasing voltage is applied to the diodes for switching operation. The complete analysis of the reconfigurable antenna with respect to its parameters are simulated with commercial electromagnetic tool of CST microwave studio. The antenna dimensions are presented in the table 1.

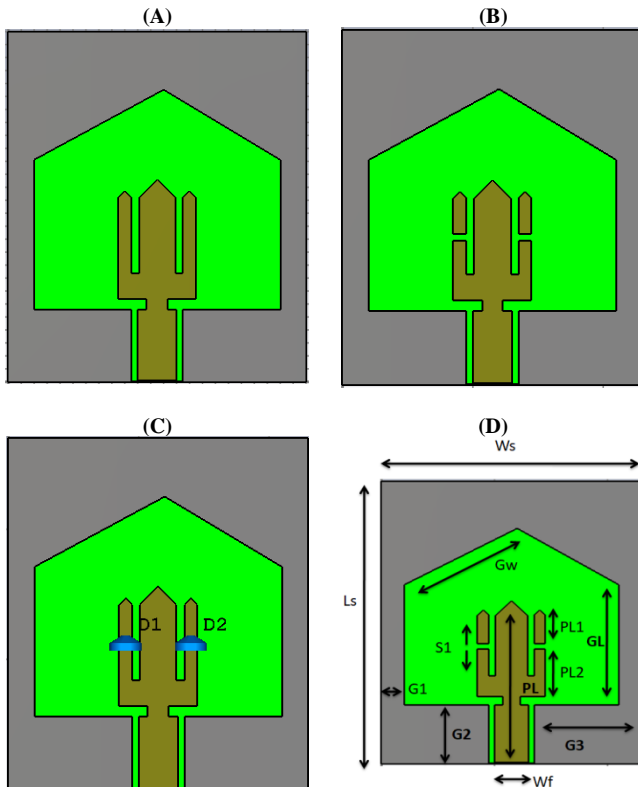


Fig. 1: Antenna Model, (A) UWB Antenna, (B) Reconfigurable Antenna, (C) Reconfigurable Antenna with Diodes, (D) Proposed Antenna Dimensional View.

Table 1: Antenna Dimensions

S. No	Parameter	Dimension in mm	Parameter	Dimension in mm
1	Ws	23	Gw	10
2	Ls	27	GL	11.6
3	Wf	3	G1	2
4	PL	15.6	G2	5.6
5	PL1	3	G3	9.5
6	PL2	5	S1	1

3. Results and analysis

The simulation results of VSWR, gain, efficiency, current distribution and the radiation characteristics are discussed in this section. Fig 2 shows the VSWR curve for the antenna model 1, which is of no slots and the diodes in the structure. The antenna model 1 covering the UWB range of 3.1 to 10.6 GHz with good impedance matching.

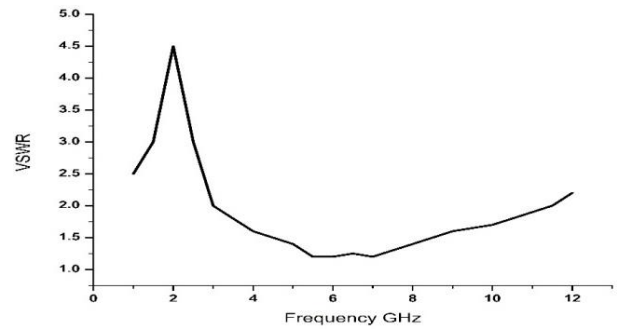


Fig. 2: Frequency vs. VSWR of UWB Antenna.

The modified antenna model of reconfigurable structure shown in Fig 1(d) is analyzed with the diodes switching and the corresponding VSWR characteristics are presented in Fig 3. The range over the antenna is operating with respect to the diodes ON and OFF positions are presented in Fig 3 as well as in Table 2. When diodes are in ON position, antenna is showing maximum bandwidth of 7.1 GHz in the operating band from 3.1 to 10.2 GHz.

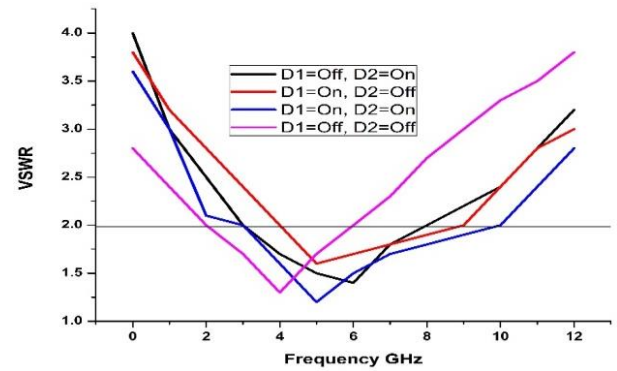
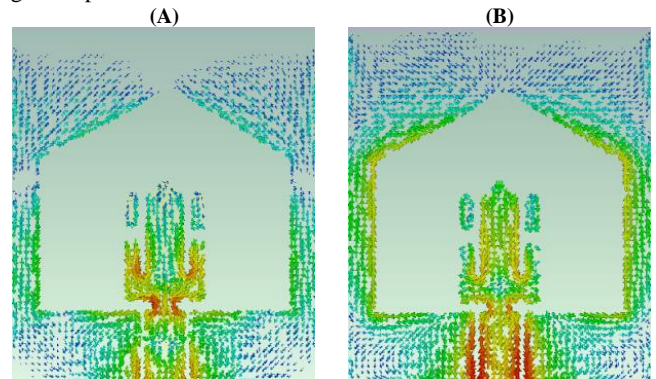


Fig. 3: Frequency vs. VSWR of Proposed Antenna with Diodes Switching.

Table 2: Operating States of the Antenna Model

State	D1	D2	Frequency in (GHz)		Bandwidth in GHz	Peak Realized Gain in dB
			f1	f2		
1	0	0	2	5.9	3.9	4.6
2	0	1	3.1	7.8	4.7	4.5
3	1	0	4.2	9	4.8	4.4
4	1	1	3.1	10.2	7.1	4

The current distribution of the antenna at different operating bands are shown in Fig 4. The surface current distribution at 5.8 GHz is showing more intensity and less at 2.5 GHz. The current distribution is mostly located nearer to the feed line and at adjacent ground plane.



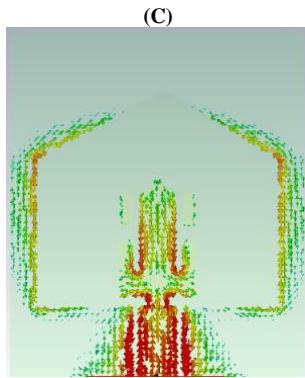


Fig. 4: Surface Current Distribution at 2.5 Ghz, 3.6 Ghz and 5.8 Ghz.

The parametric analysis of the antenna model with respect to the change in width of the feed is presented in Fig 5. For width of the feed 3 mm, antenna is showing optimum performance. The length of the adjacent upper arm PL_1 in the radiating element is varied from 2.4 to 3 mm and the optimum dimension is fixed at 3 mm.

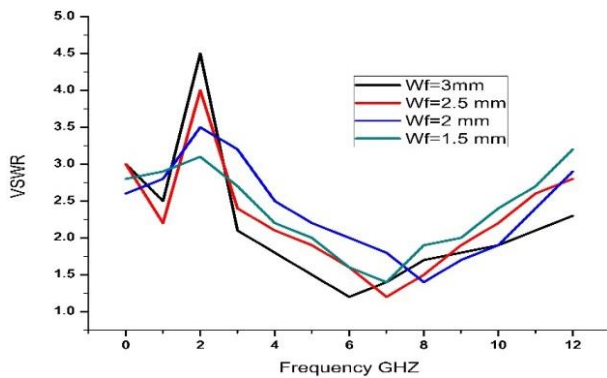


Fig. 5: VSWR For Change Is WF.

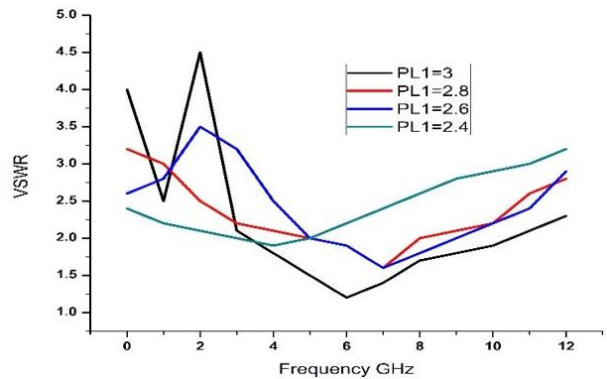


Fig. 6: VSWR for Change in PL_1 .

The gain of the antenna with change in diode switching conditions are presented in Fig 7. As per the operating band in accordance with diode switching the gain is varied and peak realized gain of 4.5 dB is attained. When diodes are in off condition the average gain of 3.6 dB and when diodes are in on condition, an average gain of 3.2 dB is attained in the operating band. The frequency versus efficiency plot is shown in Fig 8 for diodes switching condition. Efficiency more than 70% is attained in the corresponding operating bands as per the switching conditions of the diodes. The far field radiation characteristics of the proposed antenna model at 3.6 GHz and 5.8 GHz are shown in Fig 9 and 10. Omni directional pattern with low cross polarization is obtained in the H-plane and monopole like radiation is obtained in the E-plane for the designed model.

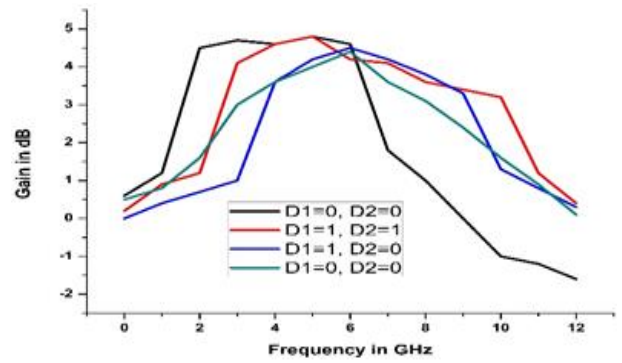


Fig. 7: Frequency vs. Gain.

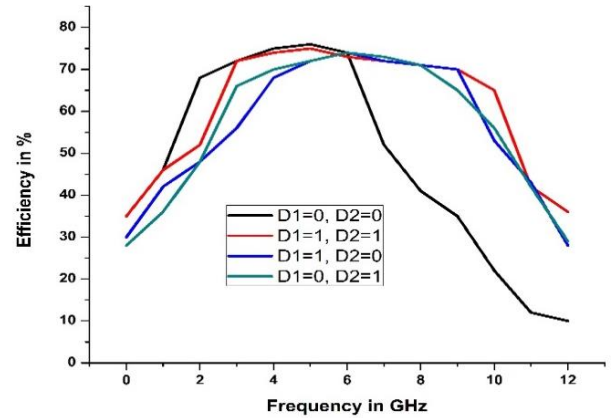


Fig. 8: Frequency vs. Efficiency.

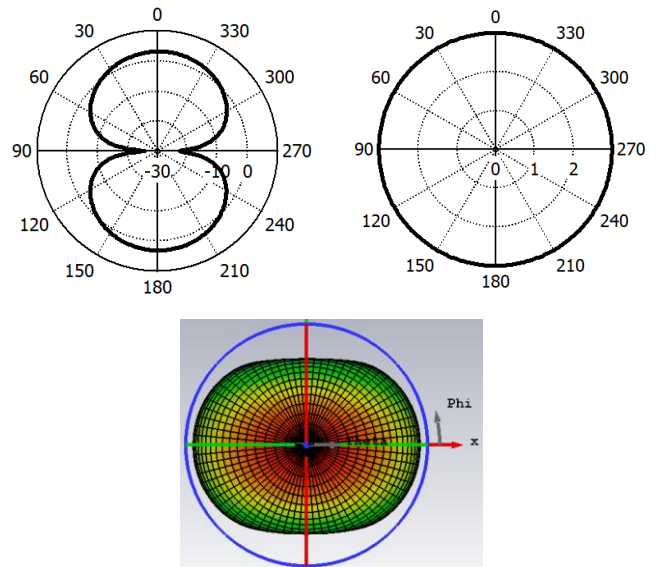
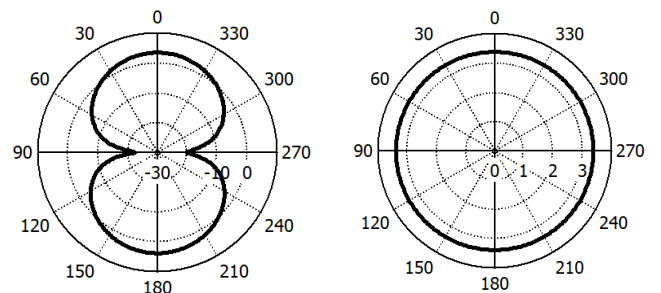


Fig. 9: Far Field Radiation Characteristics in E & H-Fields at 3.6 Ghz.



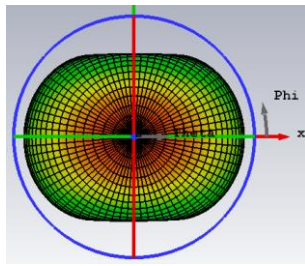


Fig. 10: Far Field Radiation Characteristics in E & H-Fields at 5.8 Ghz.

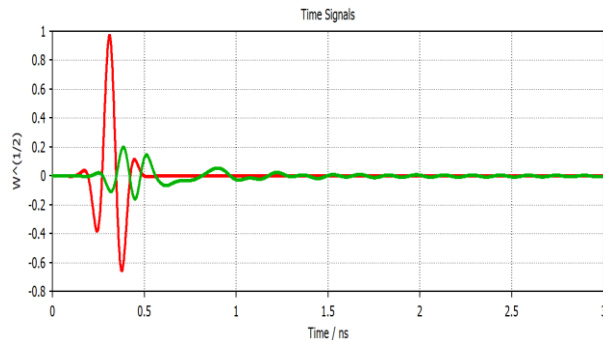


Fig. 11: Time Domain Analysis.

The impulse response characteristics of the antenna with excited signal and input signal is presented in Fig 11. The distortion in the response is due to mismatch in timing. The proposed antenna is prototyped, and the measured results are analyzed for validation. Fig 12 shows the prototyped antenna with PIN diodes and measurement of antenna parameters with Anritsu combinational analyzer. Fig 13 shows the VSWR curve for measured and simulation. The measured results are providing good matching with the simulation results.

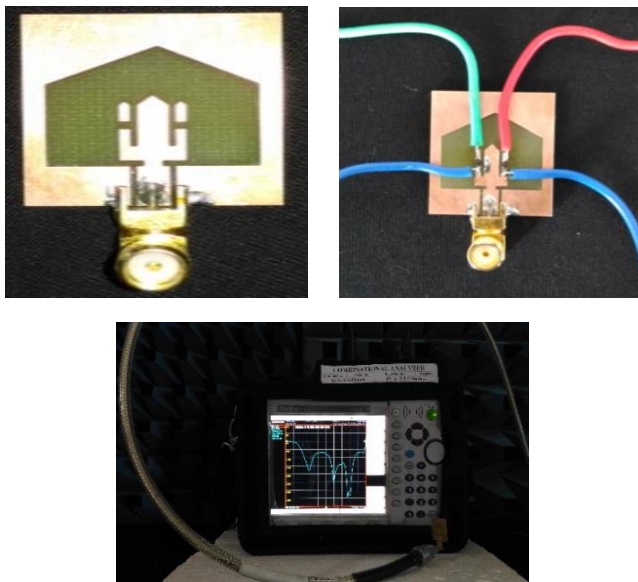


Fig. 12: Prototyped Antenna, (A) Front View, (B) Back View, (C) Measurement of S_{11} on VNA.

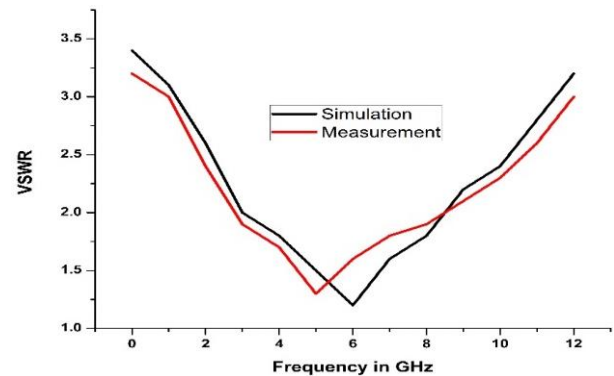


Fig. 13: Measured and Simulated Result of VSWR.

4. Conclusion

A fork shaped monopole antenna is designed for UWB applications and converted it in to frequency reconfigurable antenna to switch between LTE, Wi-Fi and WLAN bands. PIN diodes are used to attain the frequency reconfigurability in the antenna model between LTE (2.1-2.2 GHz), Wi-Fi (2.4 to 2.7 GHz) and WLAN (5.6-5.8 GHz) bands. Omni directional radiation pattern with low cross polarization is obtained in the H-plane and monopole like pattern in E-plane. VSWR < 2 with good impedance matching is attained in the operating bands. The prototyped antenna is giving good matching with simulation results and the designed model is more suitable for desired band of applications with average gain of 4.5 dB and efficiency more than 70%.

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