Enhanced Frequency Reconfigurable Antenna for LTE Implementations

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Abstract - The design is focused on fabrication and testing of frequency reconfigurable antenna designed to operate in LTE and Wi-Fi implementations. The reconfigurable mechanism is governed by three PIN diodes and the operating bandwidth (1.38 GHz - 3.24 GHz) is efficiently controlled by diode’s different operating states. The antenna’s working principle is elucidated with the reflection coefficient, VSWR, gain and directivity characteristics. The antenna exhibits a maximum gain of 2.23 dBi and the VSWR of less than 1.5 throughout the bandwidth. The ON and OFF conditions of the diode go well with the desired operation and it does not induce the cross polarization. This work aims to design the simulations which are conceded using ANSYS HFSS full wave EM simulator and the measurements are in accordance with the simulated one.

Keywords - Reconfigurable antenna, PIN Diode, Varactor diode, Microstrip antenna.

1. Introduction
The day-to-day need for smart devices increases as the customer need increases. So, the modern telecommunication industry has to be developed accordingly. There are many applications where each application required different operating frequency. Segregating antennas for each application makes the device complicated and large in size. Thus, the key requirement of modern devices is to design a single antenna capable of operation at different frequencies. To meet this requirement a reconfigurable antenna is designed which will be operating at different frequencies (1.38 GHz to 3.24 GHz). This can be achieved using diodes. There are various types of reconfigurations such as polarization reconfiguration, radiation reconfiguration, frequency reconfiguration and compound reconfiguration. The frequency reconfiguration is followed to improve the gain and efficiency. When compared with multiband and wideband antennas, frequency reconfigurable antenna operates more efficiently at user desired frequency band and also it operates without disturbing the other bands of the antenna. The reconfigurable operation can be achieved using different techniques such as introducing slots and switches in the antenna’s radiating element. The switches can be of different types such as varactor diode, PIN diode, MEMS switches, RF switches, etc. In this presented work, frequency reconfiguration is achieved using PIN diodes.

There are many reconfigurable works available in the literature and are summarized as follows. In this proposed antenna frequency reconfigurability is achieved by using six RF PIN diodes with double slot is placed at various position on ground side [1]. The proposed antenna has loop antenna and monopole antenna. The Antenna system exhibits wide multiband operation with good radiation pattern [2]. The slot type micro strip antenna is used for narrowband-to-narrowband frequency reconfiguration. In second configuration planar monopole and slot antenna is used for wideband and narrowband, followed by the wideband to narrowband frequency reconfiguration is obtained. In third configuration the band notched frequency obtained by using tunable electromagnetic band-gap (EBG) [3]. Three resonant modes of tri - band is produced due to rectangular cut off introduced on a substrate of monopole antenna which is printed on a substrate [4]. Proposed structure can operate in three states based on the PIN diodes condition [5]. Proposed system consists of miniaturized feeding–point in broadband planar dipole with four arms. It can be used in the tracking devices [6]. PIN diodes are used to redirect the current flow, by this method antenna will attain the reconfigurability [7]. The antenna exhibits better performance in terms of current distribution and return loss by using diode as switch [8]. The proposed
system consists of slot antenna has five RF PIN diodes to achieve frequency reconfigurability [9]. The proposed antenna frequency is controlled by a single DC voltage applied on varactors, by varying capacity of varactor, frequency also varied [10]. Using lumped elements like PIN diodes the reconfigurability is attained [11]. The proposed system consists of an inverted-L antenna sporting three tunable BST capacitors for desired operating frequency [12]. The reconfigurable circular patch antenna is proposed. The different types of geometrical shapes have been proposed for designing reconfigurable antennas [13]. The proposed antenna works in different frequencies and adequate gain is obtained depending on the changes in lumped element switch implemented in the radiating patch. In this paper, reception apparatus with single reconfiguration highlight is applied. The diodes are inserted in the middle of patches for reconfiguration. The diode is enacted through the exchanging condition. This paper is organized as follows, the evolution, results and the last section presented the conclusion and future work.

2. Proposed Antenna Design

The antenna is planned with different patches joined as a solitary fix as shown in Figure 1. The component of the substrate is 60 mm x 60 mm. The substrate is FR4 with the dielectric steady of 4.4 and thickness of 1.6 mm. The patch design is chosen such a way that each diode is placed can opt for radiation under various switching conditions. The noise that are created during the active condition of the diode can be reduced by using the patch placed at the other end of diode. So, the current from the diode can make the patch to radiate to gain maximum efficiency. The material can be effectively accessible for manufacture and has points of interest when contrasted with other material. Halfway ground is applied for improving radio wire execution. The present streams from the fix to the substrate. The fix and substrate interfaces through bordering fields.

![Fig. 1: Proposed Antenna Schematic](image1)

Antenna design is printed on low-cost FR-4 epoxy substrate with dimension (Length (Ls) and Width (W)) 60x60x1.6 mm³ and halfway ground plane is printed on the bottom surface as shown in Figure 1. The dimensions of the proposed antenna. Three slots are created and diodes D1, D2 and D3 are inserted in slots. The antenna dimension is -17x3 mm². The radius of the circle connected to diode 1 is 1 mm. The dimension of the rectangles connected to diode 1 and 2 are -9x3 mm² and 3.9x2 mm². The partial ground is of dimension (Length (Lg) and Width (W)) -17x60 mm². The antenna structure consists of waveguide feed with the impedance of 50Ω. Three lumped element switches give eight operating conditions when the diode state is varied. 1N 4007 is used for the antenna and the equivalent circuit is shown in Figure 2.

3. Results and Discussion

![Fig. 2: Equivalent circuit of the diode](image2)

The reflection coefficient of antenna simulated is shown in Figure 3 with 8 operating modes. For the condition in which all the three diodes are in OFF condition, frequency shifts from 1.38 GHz - 3.18 GHz with better return loss-
18.32 dB. The maximum gain attained is 1.98 dBi. The VSWR obtained is 1.94. For the condition in which all the three diodes are in ON condition, the frequency shifts from 1.4 GHz - 3.24 GHz with better return loss -21.06 dB. The maximum gain attained is 1.95 dBi. The VSWR obtained is 1.53.

Table 2 summarized different combinations of the diode and its gain and reflection coefficient. In all the cases, the antenna exhibits acceptable bandwidth and average gain of 2 dBi. This represents the antenna can radiate its power better in particular direction and it exhibits less reflection power for better performance of antenna.

![D1 ON D2, D3 OFF](image1)

![D1, D2 ON D3 OFF](image2)

Fig.4: Simulated Radiation

For the condition in which D1 diode is in ON condition and diodes D2 and D3 are in OFF condition, frequency shifts from 1.35 GHz - 3.10 GHz with the better return loss -24.49 dB. The maximum gain attained is 2.23 dBi. The VSWR obtained is 1.13. The condition in which diodes D1 and D2 are in ON condition and D3 is in OFF condition, frequency shifts from 1.35 GHz - 3.14 GHz with better return loss -28.26 dB. The maximum gain attained is 2.21 dBi. The VSWR for the condition in which diode D1 is in OFF condition and D2 and D3 are in OFF condition, frequency shifts from 1.38 GHz - 3.24 GHz. VSWR obtained is 1.68. For condition in which diode D1 and D2 are in OFF condition and diode D3 is in ON condition, frequency shifts from 1.38 GHz - 3.24 GHz with better return loss -18.88 dB. The maximum gain attained is 1.97 dBi. The VSWR obtained is 1.93. For the condition in which two diodes D1 and D3 are in ON condition and diode D2 is in OFF condition, frequency shifts from 1.39 GHz - 3.24 GHz with return loss -19.32 dB. The maximum gain attained is 1.97 dBi. The VSWR obtained is 1.9. For the condition in which diodes D1 and D3 are in OFF condition and diode D2 is in ON Condition, frequency is obtained at 1.45 GHz with the reflection coefficient of -41.09 dB. The maximum gain attained is 1.98 dBi. The VSWR obtained is 1.5. This represents antenna can radiate its power better in particular direction and it exhibits less reflection power for the good performance of antenna.

The radiation pattern for all eight conditions applied is presented in 2D plane is shown in Figure 4. It can be observed that radiation in E-plane and H-plane is similar for all conditions. Both planes are directional in all cases.

The gain is measured from the electrical efficiency and antenna’s directivity. The power gain of antenna is given as ratio of radiation intensity of antenna to radiation intensity of isotropic antenna. Figure 4 shows simulated radiation pattern of designed antenna at resonant frequencies selected between 1.38 GHz and 3.24 GHz. Omnidirectional radiation patterns are found in X-Y and Y-Z planes.

As already discussed, the purpose of the paper provides the design of frequency reconfigurable antenna. Continuous tunability is obtained with the help of three PIN diodes placed on the specific antenna locations. It is also observed that implementing the diodes doesn’t affect antenna radiation characteristics.

4. Conclusion

The antenna exhibits an average gain of 1.97 dBi throughout operating bandwidth i.e., from 1.38 GHz to 3.24 GHz. The return loss, VSWR and gain are measured for the fabricated antenna. Finally found in the paper, all the results are in line with the simulated results and hence the proposed antenna is the potential candidate for the implementation in LTE and Wi-Fi applications.

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