DUAL BAND FREQUENCY RECONFIGURABLE ANTENNA FOR WIRELESS APPLICATION

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Abstract : ***A dual band frequency reconfigurable antenna for wireless application presented in this paper. A square shaped antenna is used as a primary which operates over WLAN band. Further EBG structure embedded near feedline to provide dual band response. Proposed frequency reconfigurable antenna is able to switch between multiple resonant using PIN diodes. Proposed antenna covers WLAN band, WiMAX band and C-band. The proposed antenna is printed on 1.6 mm thick FR-4 substrate with dimension 32x40 mm2. The proposed antenna has broad bandwidth with VSWR < 2. Measured and simulated result of primary antenna is presented and has good agreement of results.***

IndexTerms - *PIN Diode Switches, Multiband Antenna, WLAN Antenna, WiMAX Antenna, EBG Structure.*

I INTRODUCTION

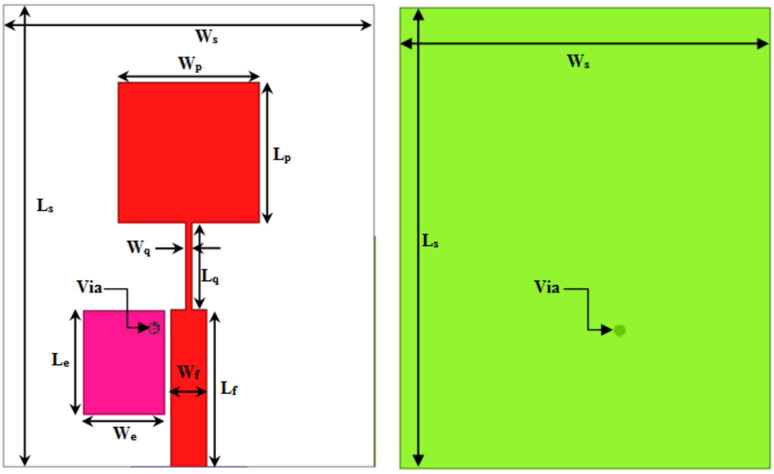
In recent year reconfigurable antennas gain more attention due to their several advantages. They reduce fading effects caused by multipath, increase the system capacity by frequency reuse, provide immunity to interfering signals, increase the communication link quality and reduce co-channel interference, increase bandwidth of the system [1]. Reconfigurable antennas firstly introduced in 1998 [2], in which the functionality of the antenna can be altered by changing their configuration upon request. In this paper a new technique is proposed by the author Elliott R. Brown in which RF MEMS (radio frequency microelectromechanical system) are used as switching element for reconfigurable antenna. RF MEMS has greater performance joint with ultra-low-power dissipation and large-scale integration. Reconfigurable Antenna Challenges for Future Radio Systems [3] presented by Hall P S, Gardner P and et-al shows antenna design and analysis for software defined radio .In this paper cognitive radio system is defined in detail and possible antenna designs are studied, the first design wideband and Omni-directional, feeding a receiver capable of both coarse and fine spectrum sensing over a broad bandwidth. The second antenna is directional and is frequency reconfigurable to select a particular band. Vivaldi Antenna with Integrated Switchable Band Pass Resonator [4] is proposed by M. R. Hamid, Peter Gardner in which a single pair of ring slot resonators is located in the Vivaldi to realize frequency reconfiguration. The proposed antenna is capable of switching six different narrow pass bands within a wide operating band of 1–3 GHz , to achieve this PIN diodes are used with biasing network. The ring slot is placed above circular slot stub and then switches are added, with varies cases of ON OFF condition of the switches different operating frequencies are obtained. A Novel Band-pass Defected Microstrip Structure (DMS) Filter for Planar Circuits [5] is the filter proposed by M. Kazero oni and et-al which shows model of band-pass filter that The BPF has a bandwidth more than 39%and can be used in feeding network of microstrip planar antennas to filter out undesired signals. To achieve Reconfigurability switches are added after detailed analysis and optimization.

Similar approach can be seen in the paper Analysis and circuit modeling method for defected microstrip structure in planar transmission lines by Girdhari Chaudhary et.al [6], in this paper detail analysis and comparison has been done between varies filters and proposed G slot filter for microwave applications. Two port frequency reconfigurable antenna for cognitive radios [6] proposed by F. Ghanem, P.S. Hall and J.R. Kelly, in which simultaneous sensing and communication can be achieved as two different antennas are used for sensing and communication. The decoupling is shown here is below -10 dB as required, otherwise interference will be more. A Reconfigurable Triple-Notch-Band Antenna Integrated with Defected Microstrip Structure Band-Stop Filter for Ultra-Wideband Cognitive Radio Applications [7] proposed by Yigsng Li and et. al where underlay cognitive radio system can use this type of antenna . Defected microstrip structure (DMS) band stop filter (BSF) embedded in the microstrip feed line is used for filtering a particular band of frequency and reconfiguration is done by using PIN diodes. PIFA-Based Tunable Internal Antenna for Personal Communication Handsets [8] proposed by Viet-Anh Nguyen, Rashid-Ahmad Bhatti, and Seong-Ook Park is a very good candidate for cellular phones where the device having different antennas for varies communication services can be replaced by a single antenna. The design uses a varactor diode for smooth and continuous frequency tuning. Frequency reconfigurability by modifying ground geometry also discussed in [9-10]. An dual band antenna with periodic structure discussed in [9], author achieved reconfigurability by applying PIN diode between partial ground and periodic structure. An pixel ground structure for multi frequency reconfigurability presented in [10]. Author achieved multi band frequency response using PIN as RF switch.

In this paper an dual band frequency reconfigurable antenna has been discussed. The reconfigurability achieved by using PIN diode as switch. Frequency reconfiguration depends on the switching state of PIN diode, while switching of diode controlled by applied biasing voltage. The proposed antennas having overall dimensions 32x40 mm2 and fabricated on FR4 substrate with copper on both of it sides. All the simulations have been carried out using Ansoft High Frequency Structure Simulator (HFSS). The designed antenna geometry is simple, compact in size and easily fabricated. The result of this research work has get to solid understanding of how we can understand different approach to accomplish reconfiguration of antenna.

II DESIGN AND ANALYSIS

In this section, design of proposed reconfigurable antenna is presented. The designing of a dual band antenna has been completed in three steps. In the first step, primary antenna is designed, which is a square microstrip patch that operates for single 5.5GHz frequency. In the second step, designing a rectangular shaped EBG structure that operates at the 3.5GHz frequency is designed. In the third step, the design of aimed dual band antenna that resonates at 5.5 GHz and 3.5 GHz will achieve by investigating various parametric analysis. To obtain dual band antenna, designed EBG structure will be implement near the feed line of antenna. The above EBG design connected with the ground with help of metalic copper via of 1mm diameter. The dual band antenna structure has been shown in in Fig.1. Fig. 1(a) shows the top view of proposed antenna and Fig. 1(b) shows the bottom view of the proposed antenna .The antenna is designed on FR4 substrate (thickness = 1.6mm, permittivity = 4.4, loss tangent = 0.02) and antenna is fed with 50Ω microstrip feed line.



(a)Front view (b) Back view

Fig.1. Design and Configuration of dual band Antenna

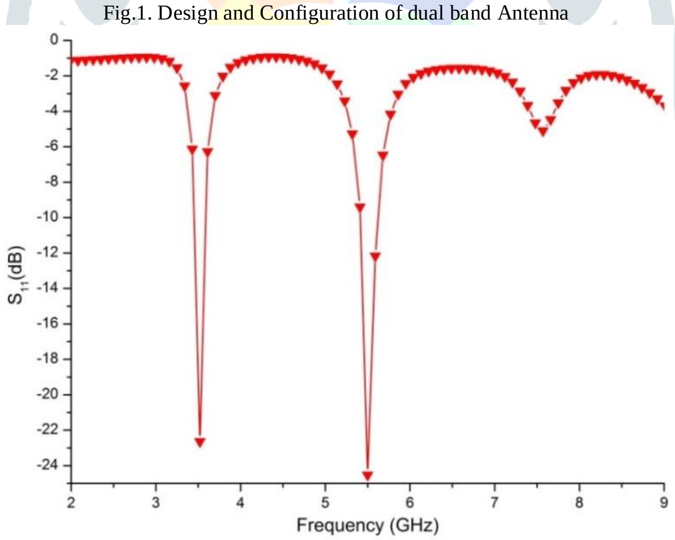


Fig.2. Reflection coefficient vs. frequency for dual band antenna

The proposed antenna shows successful dual band characteristics and bandwidth with VSWR < 2. Fig.2 shows the graphs between S-Parameter (S_{11}) and frequency of dual band antenna. From the graphical representation, one can conclude at frequency of 3.5 GHz, the value of S_{11} (dB) is -23dBand at frequency of 5.5 GHz, the value of S_{11} (dB) is -24.5dB.

To achieve reconfigurabilty initially a U shape slot cut in radiating patch. The length of slot is 26.6 mm and width is 0.5 mm. Now a rectangular parasitic patch designed on the above of the EBG structure. PIN diodes have been used to demonstrate the frequency Reconfigurability. When the parasitic patch and the U shape slot connected or disconnected to the proposed design by switching ON/OFF condition of diodes, the antenna can provide single or dual band characteristics. The reconfigurability of microstrip antenna is controlled by biasing voltage applied to the diodes. The suggested reconfigurable antenna is exhibited in Fig.3. The size of planned antenna is $40x32mm^2$ and all the optimized dimensions have been presented in Table-I.

TABLE I
Optimized Dimensions of Proposed Antenna

Variable	W_S	L_S	W_P	L_P	W_f	L_q
Size (mm)	32	40	12.2	12.2	3.05	7
W_q	L_f	l	L_e	W_e	$W_{parasitic}$	$L_{parasitic}$
0.72	11.8	26.6	10	7	7	4

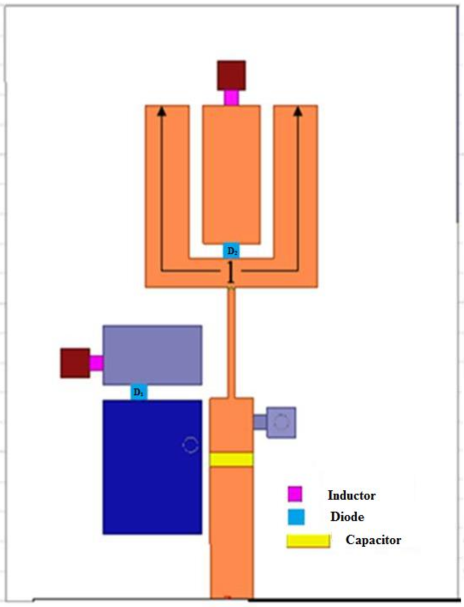


Fig.3. Geometry of proposed frequency reconfigurable antenna

1 RESULT AND DISCUSSION

To obtain dual band frequency reconfigurable antenna, various cases as discussed below in this section are investigated. Various possible configurations of PIN diodes have been presented in Fig.3 and their detailed conditions have been mentioned in Table-II. Various simulations have been performed as discussed below in this section to find the optimum condition for implementing the dual band frequency reconfigurable antenna. For simulation purposes equivalent circuit model has been calculated. The switch ON state is modelled as a serial resistance (R_{on} = 3.5Ω) and the OFF state is modelled as a parallel R-C circuit (R_{off} = 5 kΩ, C_{off} = 0.17 pF). Inductor of 68nH ensures the minimizing coupling with radiating geometry. The simulated S_{11} of the reconfigurable antenna has been displayed in Fig.4.

Table II
Different Diode Configurations

Antenna Configuration	Diode Combination	Resonant Frequency
Case A	D_1 OFF and D_2 OFF	3.5 GHz
Case B	D_1 ON and D_2 OFF	5.3 GHz
Case C	D_1 OFF and D_2 ON	5.5 GHz
Case D	D_1 ON and D_2 ON	5.5 GHz 4.0 GHz

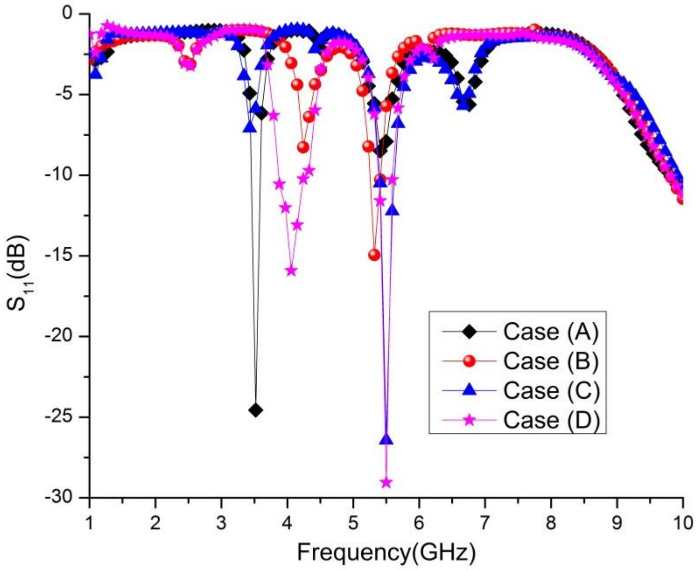
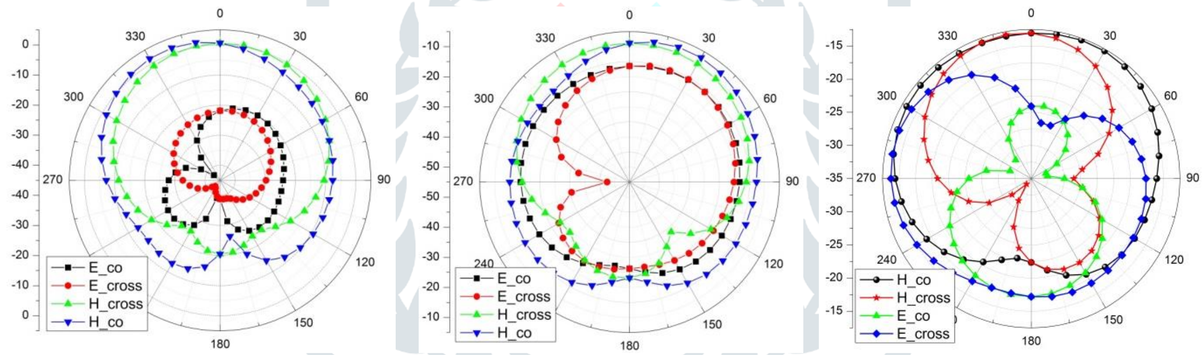


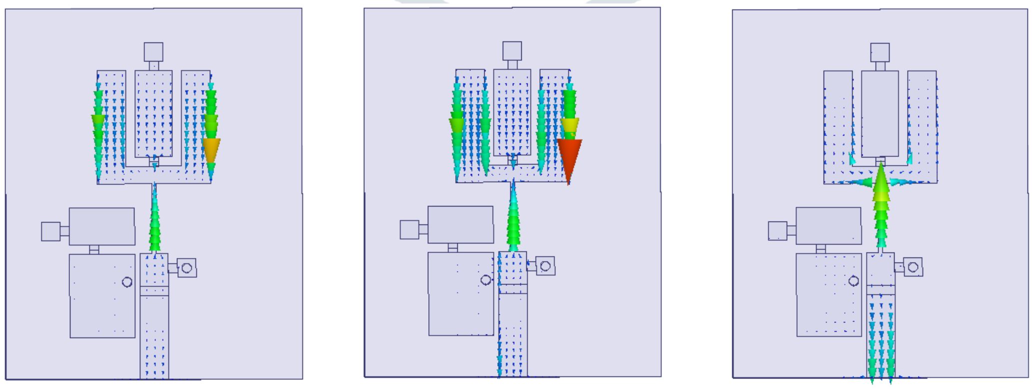
Fig.4. Geometry of proposed frequency reconfigurable antenna

When both diodes are switched off, it means square patch just work as a defected patch. The overall electrical length of the patch decreased so it will not resonant on 5.5 GHz. In the same way parasitic patch is not cone ted to EBG structure. In this case the parasitic patch connected to the EBG structure. This increases the effective electrical length and also improves the coupling. The electric current density elaborates the functioning of slot between the patch very effectively. The maximum current accumulation near the surface of radiating patch that causes antenna to radiate on 5.3 GHz. In case C, the D_2 makes the U slot as a short circuit network. it is seen that antenna when embedded with case C has covered the WLAN band from 5.4 GHz to 5.6 GHz. When the D_2 and D_1 both are on, the antenna covers dual band at 4.0 GHz and 5.5 GHz frequency with a return loss less than 10 dB.



(a) 5.5 GHz (b) 4.0 GHz (c) 3.5 GHz

Fig.5. Radiation pattern of frequency reconfigurable dual band antenna

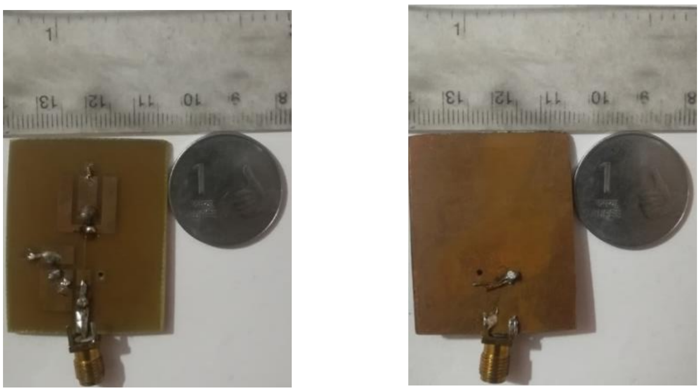


(b) 5.5 GHz (b) 4.0 GHz (c) 3.5 GHz

Fig.6. Vector current distribution of frequency reconfigurable dual band antenna

The compared H-plane & E-plane patterns on 5.5 and 3.5 GHz for co and cross polarizations have been displayed in fig.5. The radiation patterns of the presented design show the acceptable matching results with pass band characteristics. The influence of vector current upon the proposed antenna on numerous frequencies has been obtained in Fig.6. The current distribution is identical at 3.5 GHz, 4.0 GHz and 5.5 GHz frequency which acts like pass band for antenna structure.

The proposed antennas have been fabricated on FR4 substrate with dielectric constant of 4.4. For the reconfigurable antenna RF-switches have been implemented using PIN diodes D_1 and D_2. The biasing network accommodated on the same layer. Fabricated prototypes have been depicted in Fig.7.



(a)Front view (b) Back view

Fig.7. Fabricated prototype of frequency reconfigurable antenna

The fabricated structure has been measured using free-space measurement technique in anechoic chamber. The complete setup used to measure the impedance characteristics of the antenna is depicted in Fig.8.

Fig.8. Measurement setup for antenna measurement

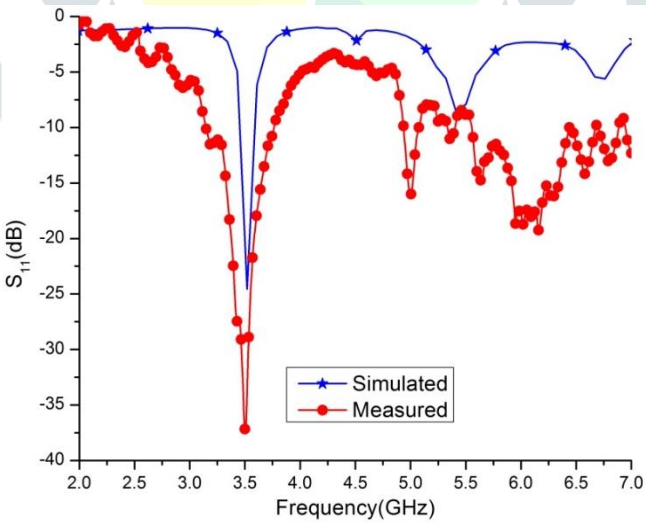


Fig.9. Compared S_{11} for reconfigurable antenna (D1&D2 are off)

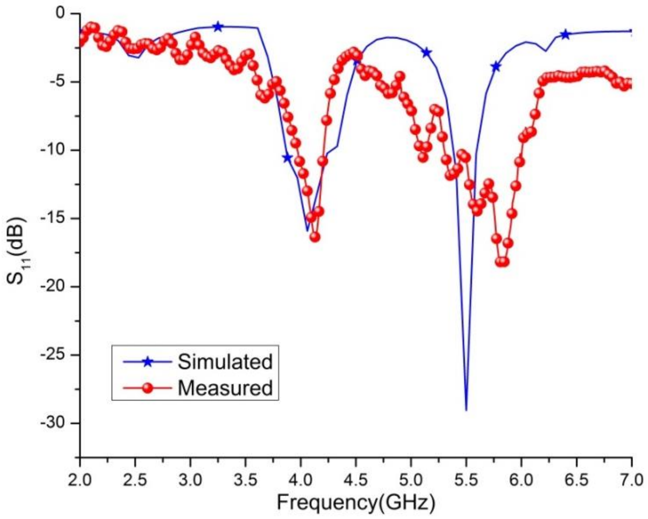


Fig.10. Compared S_{11} for reconfigurable antenna (D1&D2 are on)

Fig.9 and Fig.10 displayed the compared results (measured and simulated) of proposed reconfigurable antenna for S_{11} (in dB). Here only two cases A&D are discussed. Suggested antenna shows the successful good agreement with the simulated results. The conflict between measured result and the simulated result is due to the boundary condition errors during simulation and inaccurate calibration of cable & connectors during measurement. Suggested antenna shows the successful dual band creation and broad bandwidth.

IV CONCLUSIONS

The dual band frequency reconfigurable antenna using PIN diode has been discussed in this paper. The initial design is dual band microstrip antenna. A new and innovative mushroom shaped EBG structure directly connected to the bottom side of the FR4 substrate by copper via. Finally different parameters are optimized to obtain dual band operation at WiMAX and WLAN frequency. The final design is frequency reconfigurable antenna; frequency tuning can be obtained by controlling switching circuits or manually changing the configuration of the RF-PIN diode. For reconfigurability, RF- switch is used when U slot cut into radiated patch and also parasitic patch used with EBG structure. According to the switching states, there are 4 cases where antenna covers the WLAN, WiMAX, C band and broadband communication operating at different frequencies. The antenna is successfully operated over multiple frequency bands and is suitable for multi-function communication applications.

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