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Design of Reconfigurable UWB Microstrip Patch Antenna along with Defected Ground Structure (DGS)

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Abstract - *Cognitive radio is an advance and intelligent network technology, which is used to detect available channels to enable adaptive transmission of communication signals concurrently and enable efficient use of radio spectrum. The potential solution to this problem is to use reconfigurable antennas where resonant frequency, radiation pattern and polarisation can be altered using solid-state devices. This paper proposes a frequency reconfigurable UWB antenna design with switchable frequency band characteristics from Single Frequencies radiator to Ultra-Wideband(UWB) frequency radiator and vice versa by the means of two p-i-n diode S1 and S2 as switches in the frequency range from 3 GHz to 12 GHz. The antenna utilizes a centre feed transmission line that creates the desired matching across the tunable frequency band. The rectangular patch antenna is reconfigurable in three radiating modes: UWB radiator (with diode S1 ON and S2 in the OFF state) in the range 7.25 to 11.81 GHz, 4.24 GHz radiator (with all diodes are in the ON state) and multiple single frequencies radiator (with all diodes in the OFF-state) are reported. The ANSYS HFSS software is utilised for design simulation and the result obtained is showing that by the help of two p-i-n diodes as switches 9 different transmission frequencies can be used to implement applications like Fixed Satellite Communication and Aeronautical Radio Navigation.*

***Key Words*: UWB Antenna, Reconfigurable, p-i-n diode, ANSYS HFSS, Reflection Coefficient, Cognitive Radio**

1. INTRODUCTION

Today's, Communication networks are governed by Fixed Spectrum Access (FSA) policy, where multiple parts of the spectrum are allotted to multiple users and no unintended user can use the licensed bands. But, with rapidly improving wireless communications and increasing demands for more and more operating frequency bands, the radio spectrum has become scarce and congested. However, sometimes the licensed operating frequency region is idle most of the time because of intermittent use of assigned spectrum range. To efficiently use the available spectrum band and to reduce the spectrum congestion, cognitive radio networks (CRNs) based on Dynamic Spectrum Access (DSA) are used [1].

Antennas which have reconfigurability can provide the solution to the aforementioned problem by covering various wireless frequencies for different applications. Therefore by altering the operating frequency, efficient use of radio spectrum can be enabled for cognitive radio applications. The rectangular patch antenna which has a lightweight and planar structure can be utilised for ease and low-cost design. To achieve desired functionality p-i-n diode, varactor diode and FET devices are used, because of higher switching speeds p-i-n diodes are preferred over the others [3],[6]-[8].

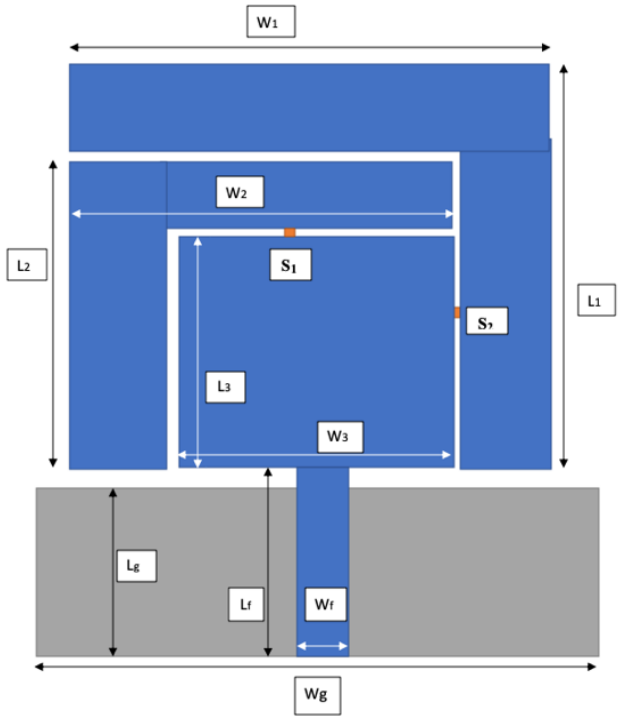


Fig -1 : Reconfigurable UWB Antenna Proposed Design

A reconfigurable antenna design which has been proposed in [2] uses three different reverse L-shaped patches that are separated by 1mm gaps are used. The antenna is fed at one corner of the smallest patch through a transmission line of 9mm length and other two patches are parasitically

fed using energy given to this smaller patch. PIN diodes are placed in the slots present in between the patches. With the help of two PIN diodes as switches, multiple operating frequencies are obtained in the 4 GHz - 8.3 GHz and two independent DC supplies are used for biasing PIN diodes. Antenna design is simulated using HFSS software with the dimensions given in table -1. Many more frequencies are identified in our design as compared to the design proposed in [2] because of the use of technologies like Defected Ground Structure (DGS) and Ultra-Wideband(UWB) to get higher bandwidth than obtained by the previous design.

We are presenting a design of three patches which are interconnected by two diode switches to obtain required reconfigurability and reflection coefficient.

1.1 Defected Ground Structure (DGS)

Defects introduced in the ground plane of a Monolithic microwave integrated circuit (MMIC) design are referred to as Defected Ground Structure. This defected disturbs the current distributions present in the ground plane which changes the transmission line parameters like resistance, inductance, capacitance and conductance.

1.2 Ultra-Wideband (UWB)

UWB is a radio technology which is used for short-range, high bandwidth communication utilising a large portion of radio spectrum for transmission of huge information in short duration of time. It has many applications like radar tracking, data collection etc.

2. ANTENNA DESIGN

Designing of antenna starts with the selection of substrate material. The material FR4 (flame retardant) is used as substrate, having a relative permittivity of 4.4. There are two types of patches in the antenna design one which is being actively fed is called driven patch and the other two are parasitic wing patches with pin diode used to obtain frequency reconfiguration. The block diagram of the antenna design is given in figure 1.

There is two orange coloured p-i-n diodes present named S1 and S2. The substrate has a thickness of 2mm and the other dimensions are present in Table I. 50 ohm transmission line is providing required feeding. Equations of design are given as Equation (1), equation (2), equation (3) and equation(4).

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r+1}} = \frac{v_0}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}} \quad (1)$$

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \quad (2)$$

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \quad (3)$$

$$L = \frac{1}{2f_r\sqrt{\epsilon_{reff}}\sqrt{\mu_0\epsilon_0}} - 2\Delta L \quad (4)$$

L1	13.55 mm	Lf	8.016 mm
L2	9.356 mm	Wf	2.016 mm
L3	6.184 mm	Lg	7.56 mm
W1	18.26 mm	Wg	28.66 mm
W2	13.04 mm	W3	9.128 mm

Table 1: Dimensions of Antenna

3. SIMULATION AND RESULTS

ANSYS High Frequency Simulation Software(HFSS) is used for simulating the design of the proposed antenna. Figure 2 contains the Top view of the proposed structure. Reconfigurability of the antenna is achieved by using two switch S1 and S2 which are incorporated between the driven and parasitic patch.

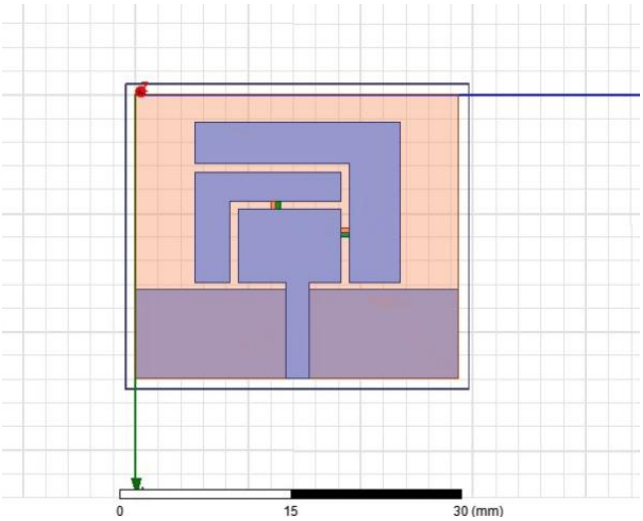


Fig - 2: Top view of proposed Antenna Design

Figure -3 contains the ON and OFF state switch model for the PIN diode. When the PIN diode is in ON state a resistor and an inductor combination comes in series as a circuit model whereas in the OFF state a parallel

combination of a resistor and a capacitor in series with an inductor works as equivalent circuit model.

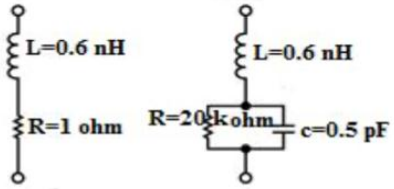
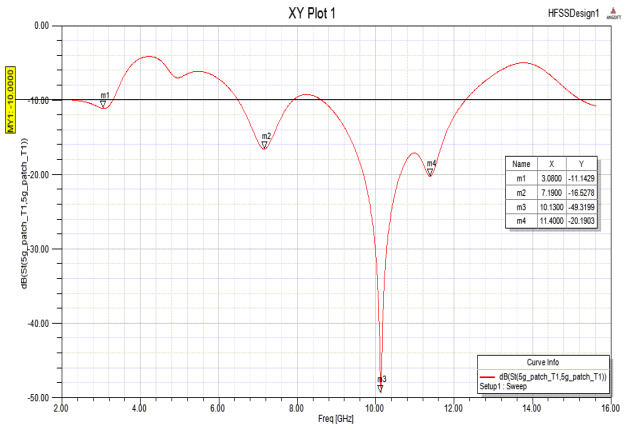
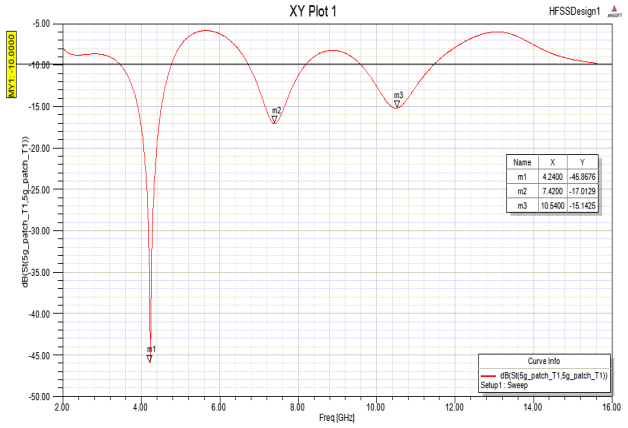


Fig -3: On and off-state circuit model of PIN diode switch

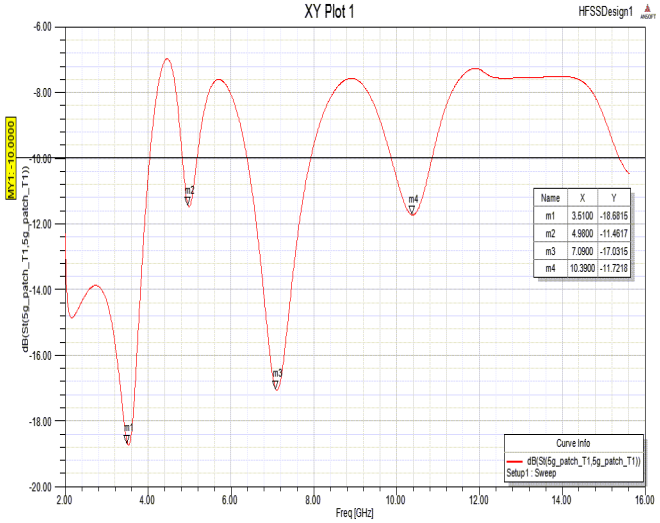
Figure 4 represents the result of the reflection coefficient at different switching conditions. When all the switches are in OFF state the transmit frequency can be any one of four frequencies i.e. 3.08 GHz, 7.19 GHz, 10.13 GHz and 11.4 GHz with a return loss of -11.1429 dB, -16.53 dB, -49.32 and -20.19 dB respectively as shown in Figure 4 (a). When both the switches are in 'ON' state the transmit frequency can be at three frequencies i.e. 4.24 GHz, 7.42 GHz and 10.54 GHz with the return loss of -45.87 dB, -17.01 dB, and -15.14 dB respectively as shown in figure 4 (b). When S1 is in 'OFF' state and S2 in 'ON' state the transmit frequency can be at four frequencies i.e. 3.51 GHz, 4.98 GHz, 7.09 GHz and 10.39 GHz with the return loss of -28.68 dB, -11.46 dB, -17.03 dB and -11.72 dB respectively as shown in figure 4 (c).



(a) All switches are in the 'OFF' state.



(b) All switches are in 'ON' state.



(c) S1 is in 'OFF' state and S2 is in 'ON' state

Fig -4: Simulated return loss plot **(a)** all switches are in 'OFF' state **(b)** all switches are in 'ON' state and **(c)** S1 'OFF' and S2 'ON'.

When S1 is in 'ON' state and S2 in 'OFF' state the transmit frequency can be used for the single frequencies or band of frequencies i.e. 3.94 GHz, 8.01 GHz and 10.88 GHz with the return loss of -10.97 dB, -24.146 dB and -27.12 dB respectively as shown in figure 5. It can also be used for band of frequencies in the range of (7.25 GHz – 11.81 GHz) in this range of frequencies antenna will going to working in UWB spectrum with a bandwidth of 4.56 GHz.

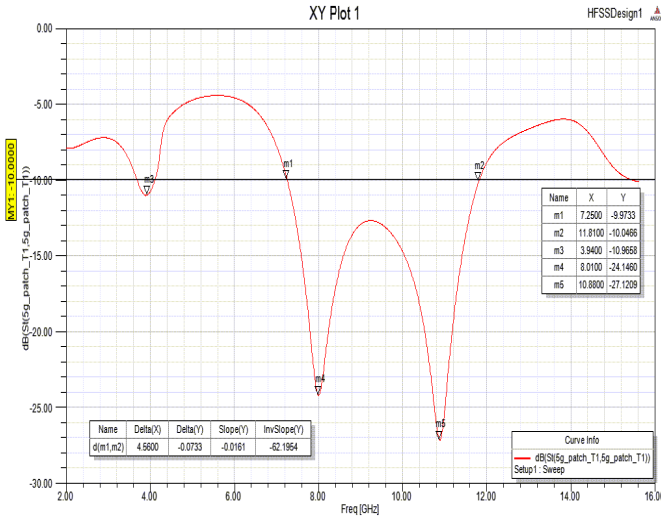


Fig -5 : S1 is in 'ON' state and S2 is in 'OFF' state (UWB Range)

The reflection coefficient results of the proposed design of the antenna in which it is resonating along with different switch state are summarised in Table II.

SWITCH CONDITION	TRANSMIT FREQUENCY
All Switches are OFF	3.08 GHz, 7.19 GHz, 10.13 GHz,11.4 GHz
All Switches are ON	4.24 GHz, 7.42 GHz, 10.54 GHz
S1 is ON and S2 is OFF(UWB)	3.94 GHz, 7.25 – 11.81 GHz, 8.01 GHz, 10.888 GHz
S1 is OFF and S2 is ON	3.54 GHz, 7.09 GHz,10.39 GHz

TABLE II - Transmitting frequencies for different switch positions.

In Figure 6 current distribution is shown for the Switches position being in 'ON' state.

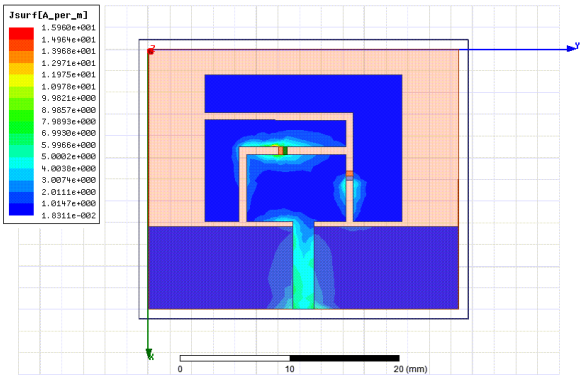


Fig -6: Current distribution on the proposed antenna

4. CONCLUSION

ANSYS HFSS simulation software is used for designing of this proposed patch antenna design. Two switches are successfully used to achieve the desired reconfigurability at multiple frequencies and also demonstrated the UWB nature of the proposed antenna design. Reconfigurability over a range of 3 GHz to 12 GHz with extremely good reflection coefficient. The frequency versus reflection coefficient results is in coherence with the wireless applications for which antenna is designed for. The antenna can be utilised for Fixed Satellite Communication, Radar applications and Radio Aeronautical Navigation.

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