Design of Reconfigurable Multiband Microstrip Patch Antenna Array for Wireless Applications

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Abstract

In the recent year, a modern technology of wireless communication, reconfigurability acquires a great attention due to its flexibility to operate with distinct frequencies with the same hardware. This paper proposes a new re-configurable multiband microstrip patch antenna array with size 120mm.x60mm. The antenna design is carried out on FR-4 (Fire Retardant 4) substrate with thickness 1.6mm and loss tangent is 0.02. The dielectric constant for the substrate is 4.4. In the proposed antenna design a fractal structure is used with defected ground structure (DGS). Four switches using pin diodes are connected on the double I-shape slot which is employed on radiating patch for multiband results. When all diodes are ON state, then antenna resonated at 3.53 GHz and 5.53 GHz frequencies. When two switches kept ON and two switches kept OFF, then antenna works at 3.55 GHz, 3.95 GHz, 4.62 GHz and 5.13 GHz. When first two switches kept OFF and other two switches kept ON then it works at 3.95 GHz, 5.14 GHz and 5.51 GHz respectively. This antenna is applicable for Bluetooth, WiMax, WLAN and C-band applications.

Keywords: array, re-configurable, microstrip, Pin diode, WiMAX,

1. Introduction

In the modern era of technology, a re-configurable multiband micro-strip patch antenna achieves a great attention due to its re-configurable ability in the same hardware, fast switching, multifunctrional operational capabilities [1]. For wide-band and multiband reconfiguration, inverted T-slot is on radiation patch and E-slot in the ground plane is describe; which is applicable for WiMax, C-band, X-band and fixed satellite communication[1]. A C-slot patch antenna with dual band element for reconfiguration of wide-band and multiband is implemented by using pin diode as switches [2]. A reconfigurable patch antenna using a single substrate and no ground plane operated as a single band for 3.5 GHz WiMax and dual band for 2.4 GHz and 5.2 GHz WLAN application [3]. Also, by incorporating two parallel slots on the radiating patch which introduces inductive effect, are controlled by two switches and reconfiguration is obtained for single band 2.4 GHz and multiband at 2.4 GHz and 5.8 GHz [4]. The permitivity of the substrate affects the size and performance of the antenna [4]. A U-shaped slot with short end and L-shaped slot with open end are etched in ground plan to realize dual band operation , and also by inserting two pin diode as a switches , easy reconfigurablility for three frequency bands i.e. 2.3 GHz LTE, 4.5 GHz ATM fixed service and 5.8 GHz WLAN is achieved [5]. An antenna with center patch known as driven patch and six adjacent microstrip patches as sub-patches using a shorting pin as a switchable element is investigated for practical applications like C-band, WiMAx WLAN and much other system [6]. A reconfigurable U-slot fractal antenna using FR-MEM switches instead of PIN diode to reduce insertion loss and excellent isolation is applicable in wireless communication [7]. For the smaller antennas the radiation resistance decreases and hence stored reactive energy increases which result in poor radiation efficiency [7]. Therefore fractal is very important in adjusting electrical length of the antenna [7].

In this paper, a re-configurable multiband microstrip patch antenna is described. Section II employs the antenna design, Section II comprises of Simulation and result and discussion. Section IV comprises a conclusion.

2. Antenna Design

In the proposed antenna design FR-4 epoxy is used as a substrate which is having a thickness of 1.6 mm with dielectric constant of 4.4. A metal patch of length 26mm and width 38 mm is connected to 50 ohm feed line. The microstrip line 1:2 power divider is used to feed the two antennas and hence the line width is adjusted according to power division.

The radiating patch Incorporated with double I-shape slot for obtaining multiple frequency bands also the square shape fractal geometry is included on the radiating patch for adjusting the electrical length of the microstrip patch antenna array. Two slots parallel to the radiating patch are added to avoid the leaky radiation which results in undesired resonance frequencies.

For enhancement of bandwidth a dumbbell shape defect is employed in ground structure. By introducing DGS in microstrip patch antenna, there is an increase in capacitance and inductance which influence the input impedance and current flow of antenna and thus result in improvement of gain of antenna with respect to given resonance frequency.

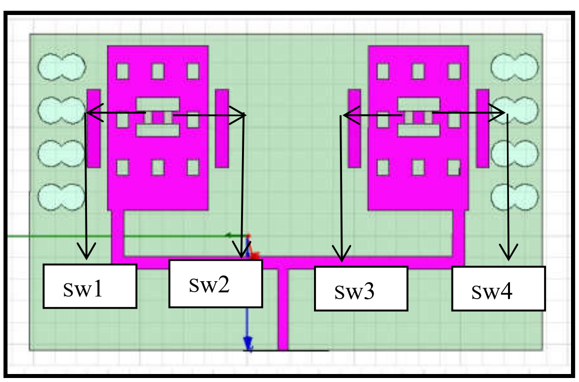

Fig 1: proposed design of reconfigurable microstrip patch antenna array

Four pin diodes as switches are incorporated in the proposed antenna structure to achieve reconfigurability in resonant frequency. The proposed antenna design is as shown in figure 1. When the switches are in ON state, the current will flow through the switch shortening hence increasing the resonance frequency [7]. When switches are in OFF state, current flows around the slot resulting in lower resonance frequency.

3. Simulation Results and Discussion

The proposed has been simulated in three conditions of the switches the first condition is when all the switches are off conditions. The second condition is when all switches are ON and third condition is when two switches kept ON and two switches are kept OFF. When the switch is in off condition, the pin diode operates in reverse bias condition and it behaves like open circuit. And when the switch is in ON condition, the pin diodes operated in forward condition and behave like short circuit and current starts flowing in the radiating patch.

Case I- When all switches off

When all the four switches are kept OFF means the pin diodes are operating in reverse bias and open circuit is formed. The current flows around the patch. The proposed antenna design when all switches are OFF is as shown in figure 2.The proposed antenna is simulated using HFSS.

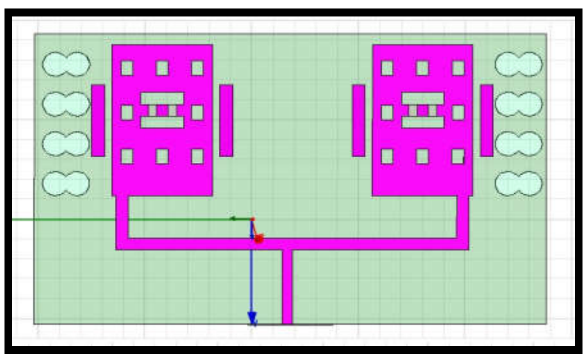

Fig 2: proposed antenna design when all the switches are kept OFf

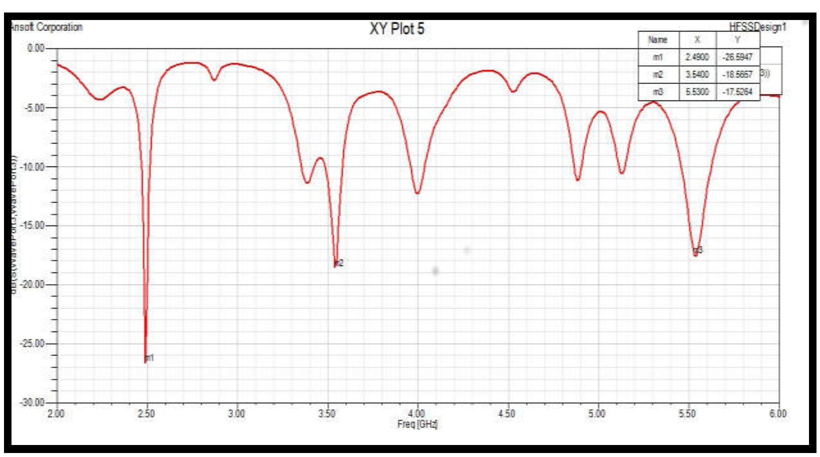

Fig 3: S11 plot of proposed antenna when all the switches are kept off

Figure 3 shows the simulated s11 plot when all the switches are kept OFF. From the S11 plot the proposed antenna resonated at 2.48 GHz 3.54 GHz and 5.53 GHz respectively with return loss -26.59,-18.56 and -17.52 dB respectively. The return loss lies below -10 dB which implies that there is good matching taken place between transmitter and receiver.

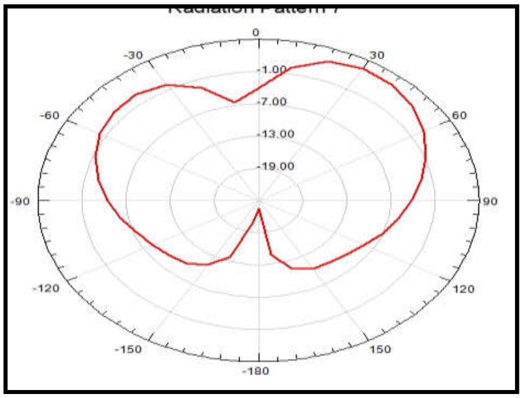

Fig 4: radiation pattern of proposed antenna when all the switches are kept off

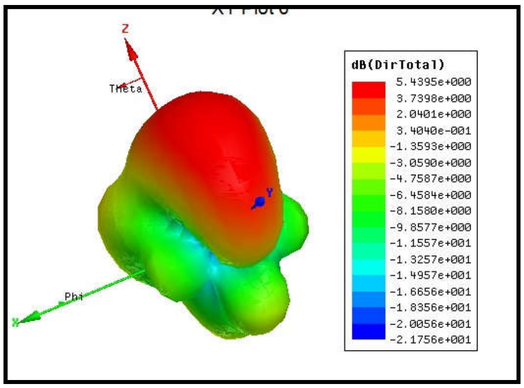

Fig 5: 3-d gain plot of proposed antenna when all the switches are kept off

Figure 4 comprised the radiation pattern also figure 5 comprises the gain plot of the proposed re-configurable multiband microstrip patch antenna array. From figure the simulated gain of the proposed antenna is 5.4 dB.

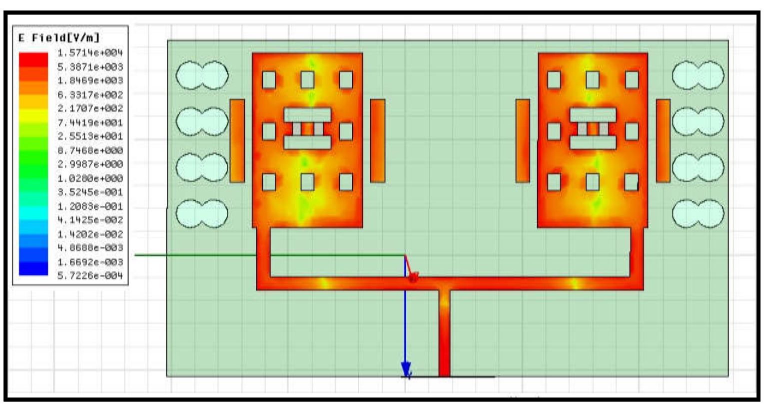

Fig6: E-field of proposed antenna when all the switches are kept off

Figure 6 shows the E-field plot of the proposed antenna. From figure, it seems the current is flowing around the patches when pin diodes are in reverse bias condition.

Case II- When all switches kept ON

When all the four switches are kept ON means the pin diodes are operating in forward bias and closed circuit is formed. The current flows through the patch. The proposed antenna design when all switches are ON is as shown in figure 7.The proposed antenna is simulated using HFSS.

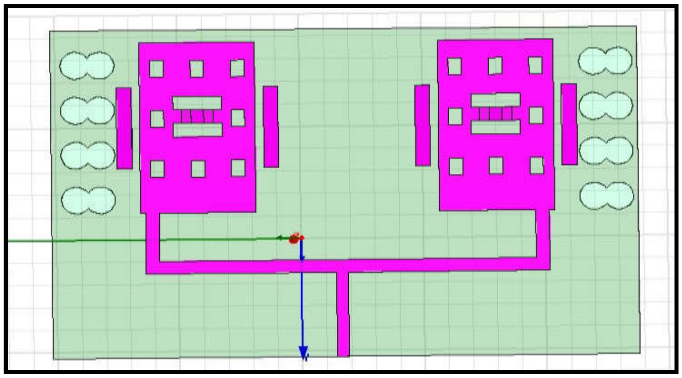

Fig 7: proposed antenna design when all the switches are kept ON

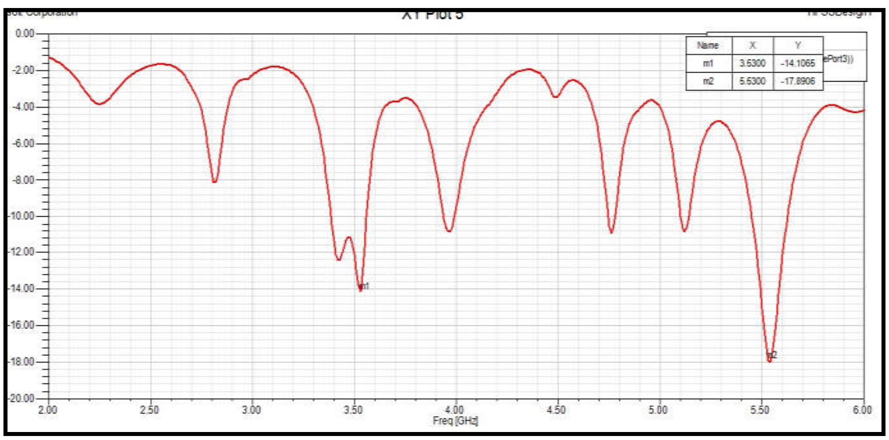

Fig 8: S11 plot of proposed antenna when all the switches are kept on

Figure 3 shows the simulated s11 plot when all the switches are kept ON. From the S11 plot the proposed antenna resonated at 3.53 GHz and 5.53 GHz respectively with return loss -14.10 and -17.89 dB respectively. The return loss lies below -10 dB which implies that there is good matching taken place between transmitter and receiver.

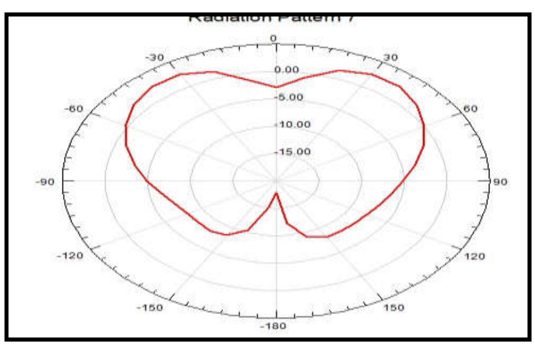

Fig 9: radiation pattern of proposed antenna when all the switches are kept on

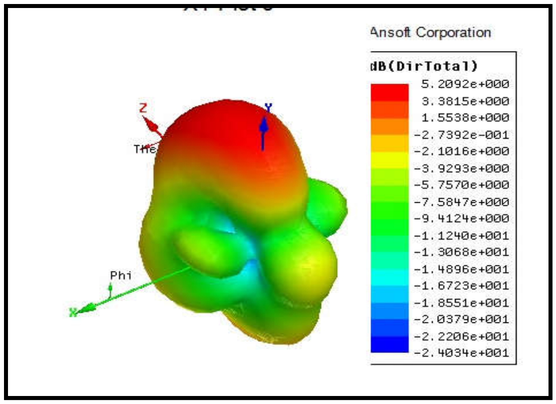

Fig 10: 3-d gain plot of proposed antenna when all the switches are kept on

Figure 9 comprised the radiation pattern also figure 10 comprises the gain plot of the proposed re-configurable multiband microstrip patch antenna array. From figure the simulated gain of the proposed antenna is 5.20 dB.

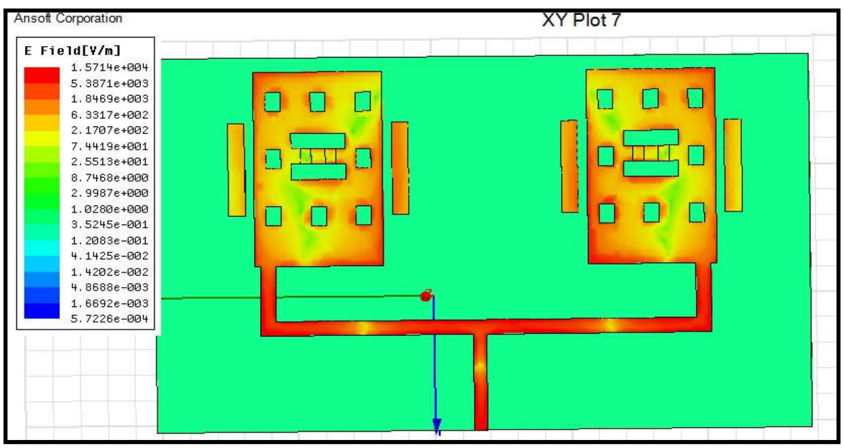

Fig 11: E-field of proposed antenna when all the switches are kept on

Figure 11 shows the E-field plot of the proposed antenna. From figure, it seems the current is flowing through the patches when pin diodes are in forward bias condition.

Case II- When Two switches ON and two switches OFF

When two switches i.e. Switch 1 and switch 2 are kept ON means the pin diodes are operating in forward bias and closed circuit is formed. And two switches i.e. Switch 3 and switch 4 are kept OFF imply pin diodes are operating in reverse bias condition hence creating a open circuit. The current flows through patch incorporating switch 1 and 2 as well as current flow around the patch incorporating switch 3 and 4 The proposed antenna design when all switches are ON is as shown in figure 7.The proposed antenna is simulated using HFSS.

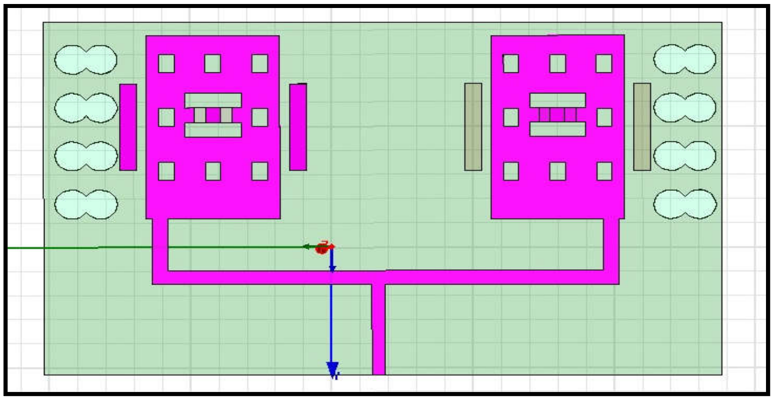

Fig 12: proposed antenna design when two switches are kept ON and two switches are kept OFF

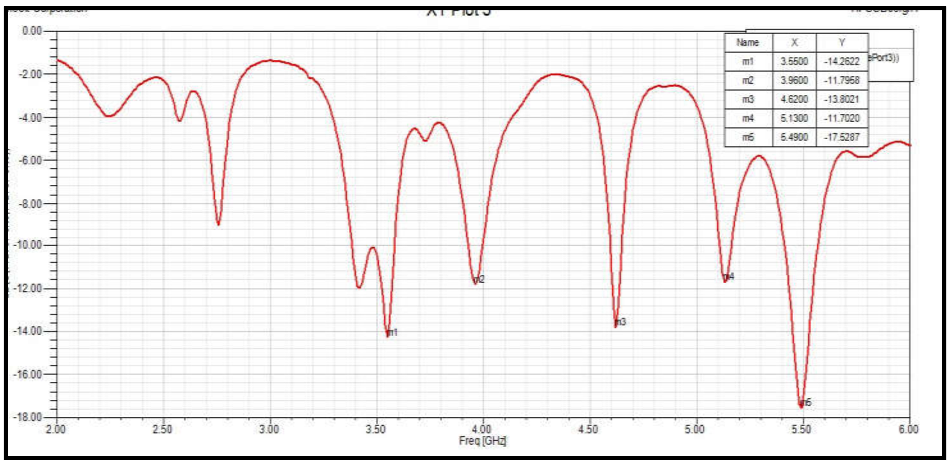

Fig 13: s11 plot of proposed antenna design when two switches are kept ON and two switches are kept OFF

Figure 13 shows the simulated s11 plot when two switches are kept ON and two switches are kept OFF. From the S11 plot the proposed antenna resonated at 3.55 GHz, 3.95 GHz, 4.62 GHz and 5.13 GHz respectively with return loss -14.26, -11.79, -13.80 and -11.70 dB respectively. The return loss lies below -10 dB which implies that there is good matching taken place between transmitter and receiver.

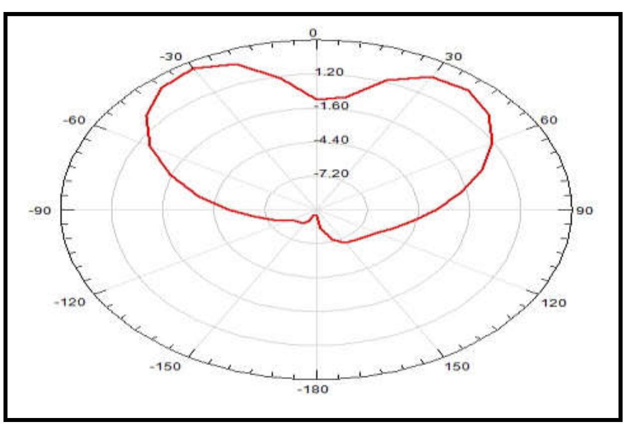

Fig 14: radiation pattern of the proposed antenna design when two switches are kept ON and two switches are kept OFF

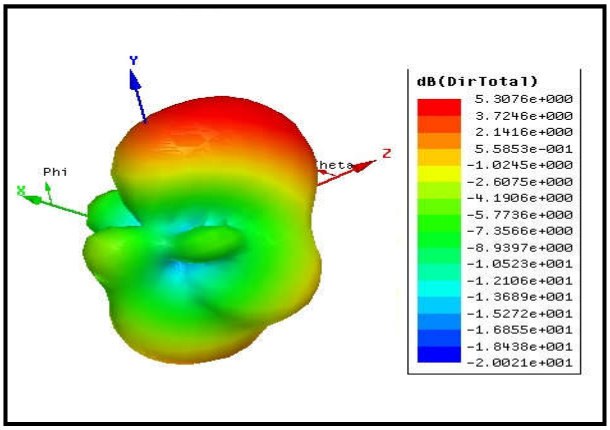

Fig 15: 3-d gain plot of the proposed antenna design when two switches are kept ON and two switches are kept OFF

Figure 14 comprised the radiation pattern also figure 15 comprises the gain plot of the proposed re-configurable multiband microstrip patch antenna array. From figure the simulated gain of the proposed antenna is 5.30 dB.

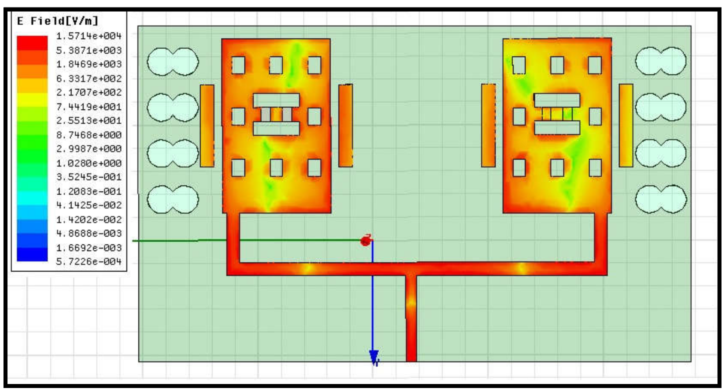

Fig 16: E-field of the proposed antenna design when two switches are kept ON and two switches are kept OFF

Figure 11 shows the E-field plot of the proposed antenna. From figure, it seems the current flows through patch incorporating switch 1 and 2 as well as current flow around the patch incorporating switch 3 and 4 of the proposed antenna design.

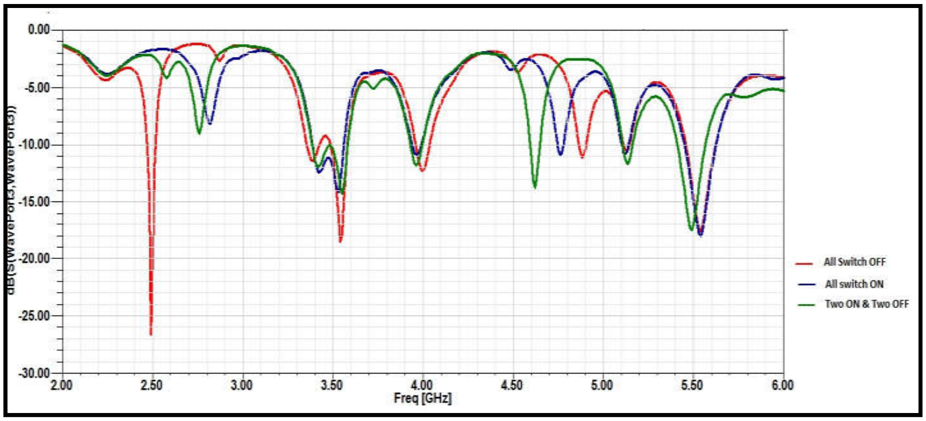

Fig 17: combine s11 plot for all the three cases of the proposed antenna design

From figure 17 i.e. Combine s11 plot of the proposed re-configurable multiband microstrip patch antenna array, it can be conclude that the proposed antenna design covers the frequency range of 2.4 GHz up to 5.53 GHz for re-configurable operation which is applicable in wireless communication, Below table shows switching configuration and its resonance frequency with vswr , bandwidth and gain of the proposed antenna.

Table showing all three conditions of proposed antenna

Sr.no	Switch Conditions	Freq (GHz)	Return loss(dB)	VSWR	Bandwidth (MHz)	Gain (dB)
1.	All Switch ON	3.53	-14.10	1.49	190	5.2
		5.53	-17.89	1.28	200	
2.	Two Switch ON and Two Switch OFF	3.55	-14.26	1.48	210	5.3
		3.95	-11.79	1.72	100	
		4.62	-13.80	1.51	60	
		5.13	-11.70	1.70	70	
3.	All Switch OFF	2.48	-26.59	1.09	60	5.4
		3.54	-18.56	1.29	240	
		5.53	-17.52	1.30	190	

From above table it is observed that for case I when both the switches are ON state, the antenna resonated at frequency 3.53 GHz and 5.53 GHz with bandwidth 190 MHz and 200 MHz respectively and gain is 5.2 dB. For case II i.e. when two switches kept ON and two switches kept OFF then antenna resonated at four frequency bands that are 3.55GHZ, 3.95Ghz, 4.62 GHz and 5.13 GHz with bandwidth 210 MHz, 100Mhz, 60 MHz and 70 MHz respectively with gain 5.3 dB. For case III, when all switches kept OFF the antenna resonated at 2.48 GHz, 3.54 GHz and 5.53 GHz with bandwidth 60 MHz, 240 MHz and 190Mhzrespectively with gain 5.4 dB.

4. Conclusion

In this paper a reconfigurable multiband microstrip patch antenna array is presented to enhancement to gain and bandwidth parameter. The proposed antenna resonated at frequency ranges from 2.48 GHz to 5.53 GHz with higher gain. It is applicable for Bluetooth, WI-Max and WLAN and it is also applicable for high power consumption applications such as satellite applications.

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