Multi-band Double I-shaped slot Microstrip Patch Antenna With Defected Ground Structure for Wireless Application

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***Abstract*— This paper proposes a design of multiband Double I-shape slot microstrip patch antenna with dumbbell shape DGS (Defected Ground Structure). The antenna structure comprises double I-shape slotted antenna with Dumbbell shape DGS for wireless applications. The antenna is designed by using FR-4 epoxy (Fire Retardent-4) as a substrate and obtained the multiband results at 2.45 GHz, 3.58 GHz, and 5.50 GHz. This antenna structure is further modified by incorporating parasitic elements parallel to the radiating edge of the patch. This modified antenna is resonated at four frequencies at 2.45 GHz, 3.60 GHz, 4.68 GHz and 5.50 GHz respectively and analyzed for the antenna parameter like VSWR, antenna gain, bandwidth, and radiation pattern. HFSS simulation software has been used for designing and simulation of the proposed antenna. HFSS software is used for simulating microwave passive components.**

Keywords*— *DGS, microstrip patch antenna, HFSS

I. INTRODUCTION

Antenna plays a very vital role in the field of wireless communication. Few of them can be enlisted as Parabolic Reflector antenna, Microstrip Patch Antennas, Folded Dipole antenna and Slot antennas. In today's world of wireless communication, Microstrip Patch antennas have proven to be playing a foremost role. A microstrip patch antenna is analogous to a sandwich like structure where a dielectric substrate is sandwiched between two metal layers, out of which one metal layer with a pattern would be referred as a metal patch and other as a layer as a ground plane. Besides the popularity due to low cost and easy manufacturing process, Microstrip Patch Antenna has drawbacks such as narrow bandwidth, low gain, and lower return loss. Although these characteristics can be improvised by implementing few techniques such as Defected Ground Structure. In Defected Ground Structure a ground patch is made defective by etching a simple shape, thereby disturbing the shielded current distribution. Whereas disturbances incorporated in the shielded current distribution in ground plane depends on shape and dimension defected ground structure. Change in current distribution results into controlled excitations and thereby propagating electromagnetic waves through the substrate [1]. A number of Microstrip Patch Antenna with multiband property with various techniques has been proposed in order to achieve multiband frequencies [2][3]. The most popular technique preferred is by incorporating slots and slits on to the surface of metallic patch or on the ground plane etching slots and slits, for example, S-shaped slot [2], U-shaped slot [4], C-shaped slot [5] and T-shaped slot [6] etc.

In this paper, an antenna which has a radiating patch with double I-shape slot and ground plane with dumbbell shape is described. The proposed antenna is further modified by incorporating parallel parasitic element on the radiating side of the patch. In section II, the basic design of proposed Microstrip Patch Antenna and its simulated results has been discussed. Section III deduces the modified structure for the proposed Microstrip Patch Antenna along with simulation results. And simulation results of the antenna proposed and modified antenna has been compared and discussed. Finally, in section IV the paper is concluded.

II. DESIGN OF PROPOSED ANTENNA

Initially, a simple rectangular patch antenna resonating at 2.4 GHz frequency band is designed as shown in figure 1. Due to its low-cost advantage, a substrate used for the proposed antenna is FR-4 i.e. fire Retardent-4 having a dielectric constant of 4.4. The substrate height has been chosen to be 1.6mm and loss tangent value as 0.02. After obtaining simulation the return loss and gain of the proposed antenna are observed. Figure 2 shows the simulated S11 plot for simple rectangular microstrip patch at 2.4 GHz. The polar plot is shown in figure 3.

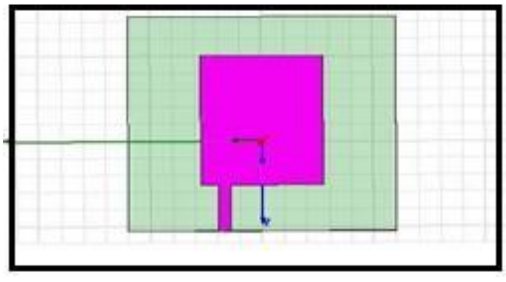

Fig 1: HFSS model of Rectangular microstrip patch antenna

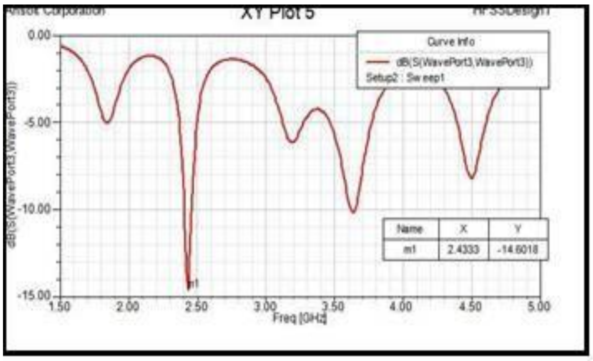

Fig 2: S11 plot of simple rectangular microstrip patch antenna

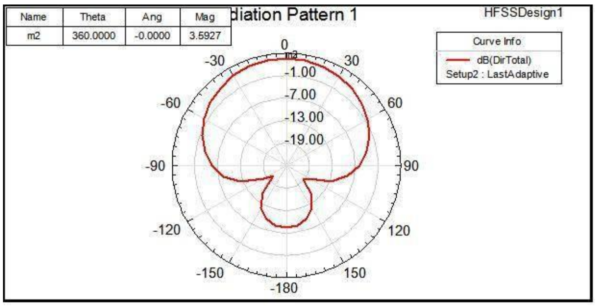

Fig 3: Radiation pattern of simple microstrip patch antenna

The proposed antenna design and simulation of the rectangular microstrip patch antenna is carried out. Fig 2 shows return loss characteristic [S11] dB of the antenna resonating at frequency 2.4 GHz with the gain 3.59 dBi observed from the polar plot of the metallic rectangular microstrip patch antenna.

Furthermore, the antenna is modified by inserting Double I-shape slot on the patch with a dumbbell shape defect in-ground structure as shown in figure 4. Introduction of the double I- shape slot on the radiating patch the results into a division in the path of current and thereby forming current loops and hence the multiband frequency is obtained.

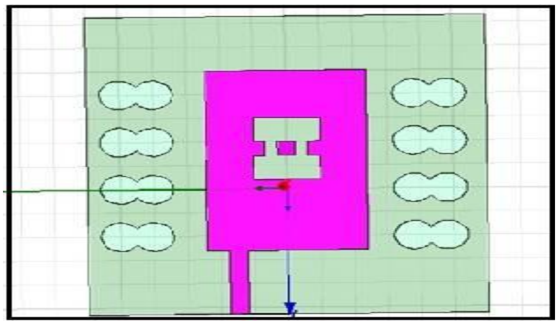

Fig.4: Proposed antenna with double i-shape slot and dumbbell shape DGS

A metal patch of length Lp = 29 mm and Wp = 38 mm is connected to 50-ohm microstrip feed line residing on the top of the substrate and the antenna parameters like return loss characteristic, VSWR characteristic, bandwidth and polar plots are observed.

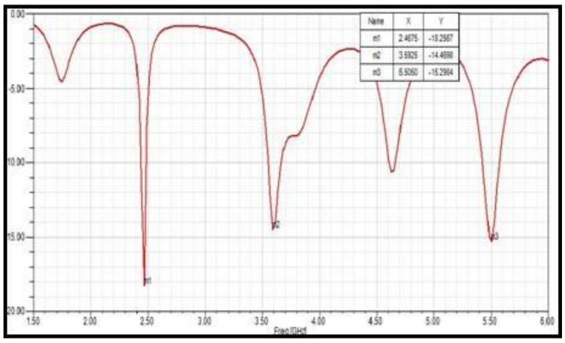

Fig 5: Simulated S11 plot of the proposed antenna with double I-shape slot

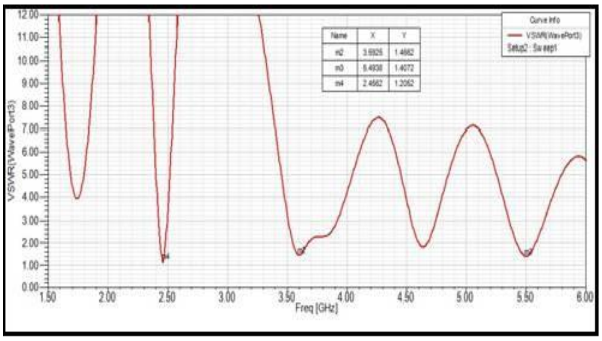

Fig 6: VSWR plot of the proposed antenna with double I-shape slot

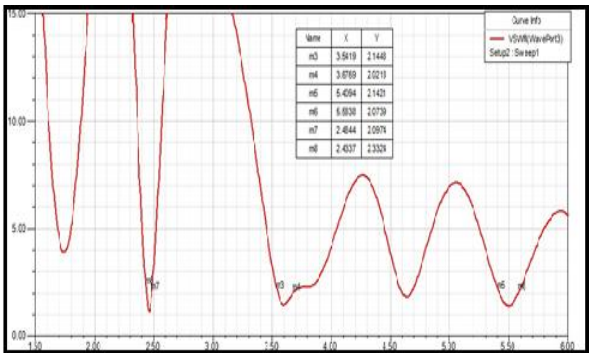

Fig 7: Bandwidth plot for proposed antenna with double I-shape slot

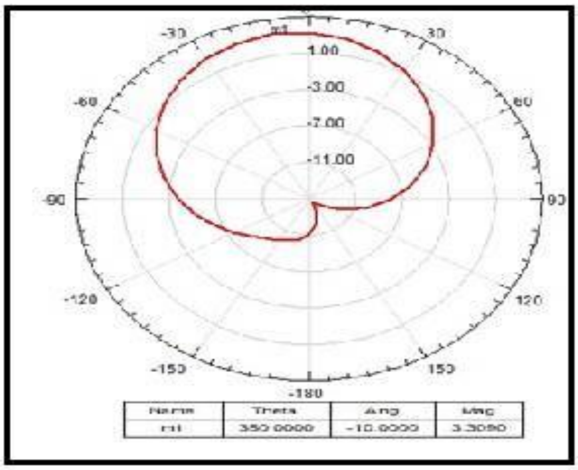

Fig 8: Radiation pattern of proposed antenna

Figure 5 shows the [S11] dB plot i.e. return loss characteristic of the antenna proposed with a double I-shape slot on the patch and dumbbell shape DGS which resonates at three frequency bands 2.45 GHz, 3.58 GHz and 5.50 GHz. Figure 6 illustrates the VSWR plot of antenna proposed which lies between 1 and 2. Figure 7 shows the bandwidth of all the three frequency band which is 54 MHz, 140MHz, and 180MHz respectively with gain 3.32 dBi obtained from the radiation pattern of the antenna proposed as shown in figure 8.

III. MODIFIED ANTENNA DESIGN

The antenna proposed is represented in the figure. 4 is further modified in order that the number of frequency band should be increased along with the improvement in bandwidth and gain. In the modified design of proposed antenna two parasitic elements parallel to the radiating patch has been introduced as depicted in figure 9 and observed the simulated antenna characteristics such return loss, VSWR, bandwidth, and gain of the antenna.

After introducing the two parasitic elements which are act as stub parallel to the radiating patch there is WiMAX improvement in a number of the frequency band and bandwidth and also gain.

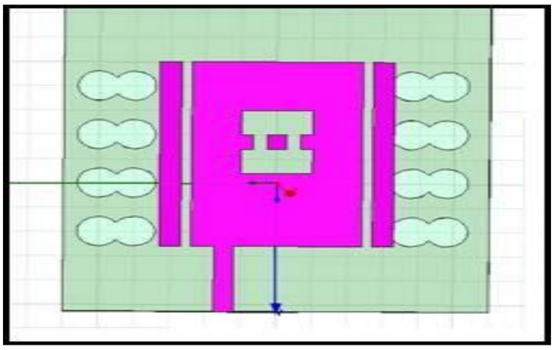

Fig 9: Modified antenna with parallel parasitic elements

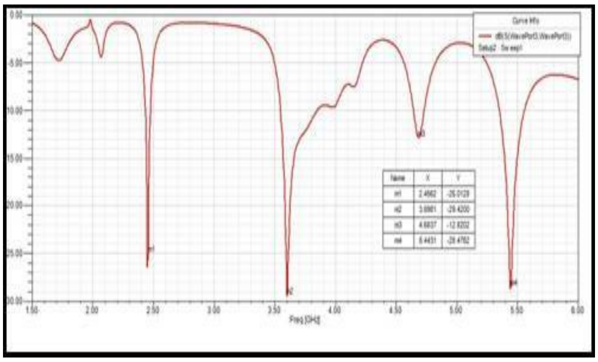

Fig 10: Simulated S11 plot of the modified antenna

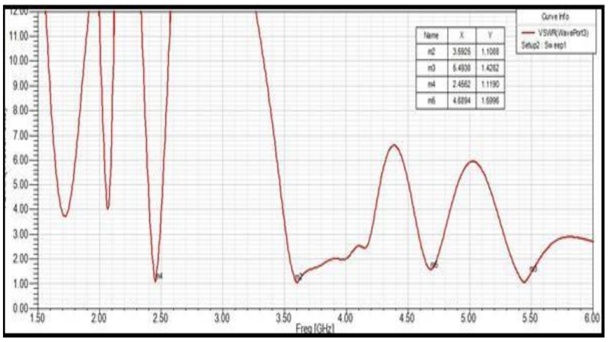

Fig 11: VSWR plot of the modified antenna

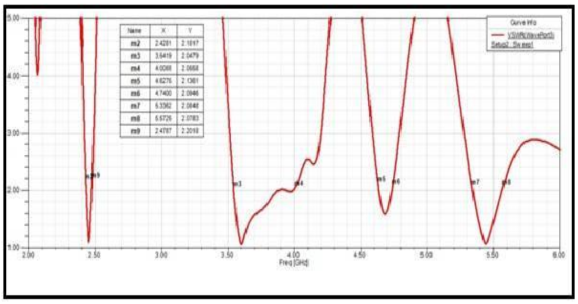

Fig 12: Bandwidth of the modified antenna

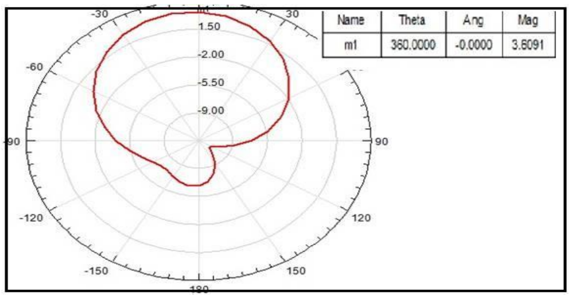

Fig 13: Polar plot of the modified antenna

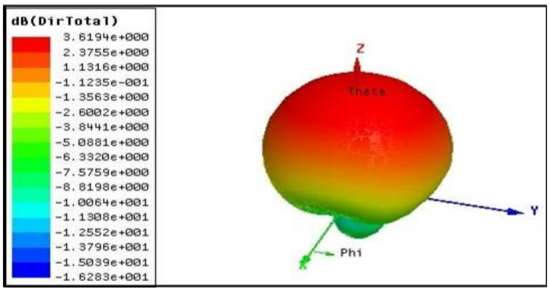

Fig 14: Directivity of the modified antenna

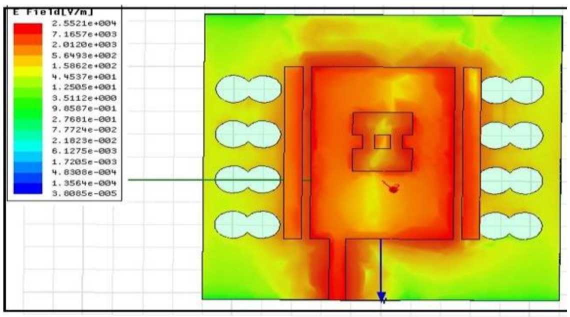

Fig 15: Current distribution of the modified antenna

Figure 9 illustrates the simulated result of the modified antenna, S11 versus frequency indicating four distinct frequency band centered at 2.45 GHz, 3.60 GHz, 4.68 GHz and 5.50 GHz with bandwidth 60 MHz, 500 MHz, 115 MHz and 230 MHz respectively as shown in figure 12. Also, the VSWR (Voltage Standing Wave Ratio) is a ratio of maximum RF voltage value to minimum RF voltage value along the microstrip transmission line ranges from 1 to 2 throughout the desired frequency range shown in figure 11. So the modified antenna structure has more smooth and extra operating frequency band with improvement in gain.

TABLE I. COMPARISON TABLE OF PROPOSED ANTENNA WITH DGS AND MODIFIED ANTENNA WITH PARASITIC ELEMENTS PARALLEL TO PATCH AND DGS

S. N.	Effect of Different type of DGS slot	Freq (GHz)	Return loss (dB)	VSWR	Band width (MHz)	Gain (dB)
1.	Double I shape design without stub parasitic	2.45	-18.28	1.20	54	3.32
		3.58	-14.46	1.46	140	
		5.50	-15.29	1.40	180	
2.	Double I shape design with stub parasitic element	2.45	-25.01	1.12	60	3.61
		3.60	-29.42	1.10	500	
		4.68	-12.82	1.59	115	
		5.50	-28.47	1.42	230	

IV. CONCLUSION

This paper represents the design of new multiband antenna and their analysis for wireless application is presented. This antenna operates with different resonant frequencies which are applicable in wireless communication such as WiMAX (Worldwide Interoperability for Microwave Access) and WLAN (Wireless Local Area Network) and C-band applications. This structure can be modified further to a reconfigurable antenna by connecting switches in a switchable slot.

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