A CPW fed H-Shaped Reconfigurable Patch Antenna

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***Abstract*— In this paper a novel frequency reconfigurable CPW fed H-shaped patch antenna is designed. The basic antenna consists of CPW fed two H-shaped patches which operates at 2.48GHz. The basic antenna is suitable for IEEE 802.11 b WLAN (2.4GHz - 2,484GHz) application. The reconfigurability in frequency is obtained by connecting two switches in basic antenna by use of MEMS. By controlling the switches the antenna can be operated at three different frequencies namely 4.39GHz, 12.84GHz and 12.58GHz. The effect of antenna length, size, substrate, thickness, shape has been evaluated and obtained good and acceptable 2D Radiation Pattern in elevation plane, gain, and efficiency. The proposed antenna is described and simulated results are illustrated using Method of Moments based IE3D commercial software.**

Keywords—Patch Antenna, Reconfigurable Antenna, CPW feed, Frequency Diversity

I. Introduction

Now a day's radioelectronic systems employ multiple antenna systems. Intelligent smart or adaptive antennas are the most suitable for today's wireless communication systems especially third and fourth generation systems. Instead of having multiple antennas switched into multiple transceivers covering different frequency range, a single multi-band tunable antenna set would provide size reducing and minimize product complexity. Hence the topic of reconfigurable antennae is gaining great attention. As more wireless services are becoming more common, the available radio spectrum is decreasing. Hence, it is not practical to dedicate one antenna to each service; many of these services are on at a time, while others may be required to be on all the time. Many services means many antennas, and many standards means that more antennas are needed in conventional case of multiple antennas while reconfigurable antennas use single antenna [1].

Antennas that can intentionally and reversibly change the distribution or character of their performance-governing electromagnetic fields are said to be reconfigurable antennas. These antennas effectively allow the antenna volume to be reused as an antenna in a different form and this helps in miniaturizing the entire device size [2]. Reconfigurable Antennas commonly adapts their properties to achieve selectivity in frequency, bandwidth, radiation pattern and polarization. These antennas are capable of multi-band operation, adaptive beamforming, jamming/interference mitigation, polarization diversity, low observability, and direction of arrival estimation [3]. Reconfigurable patch antennas are considered as promising paradigm for generating several antenna modes using a single reconfigurable structure. The attraction of reconfigurable antennas leads its introduction to applications such as military, besides commercial applications. Reconfiguration of an antenna can be achieved through an intentional dynamic redistribution of the currents of the antenna's aperture. These changes are enabled through various mechanisms such as switching, material tuning, and structural modifications [4]. The switching technology can be implemented using PIN diodes, FETs which are classified as solid state switches. There are several advantages of RF-MEMS over solid state switches, such as lower power consumption, on resistance, insertion loss, parasitic capacitance and manufacturing cost, higher isolation, and better intermodulation due to their linearity. Advantages of using solid-state switches over RF-MEMS include faster switching speeds, high-power handling, and low voltage drive [5].

Recently, the coplanar waveguide (CPW)-fed antenna has been used as an alternative to conventional antennae for different wireless communication systems due to its many attractive features [8]. Miniaturization always indicates scientific progress. So efforts are always directed towards reducing the size of the antenna. Another major drawback that prevails in the present antenna systems is the frequency of operation. It is very important that the frequency of operation of the antenna falls in the specific area of application.

The proposed reconfigurable antenna attempts to address these problems. In this paper, a brief description of frequency reconfigurable antenna which includes antenna design and geometrical layout is presented in section II and finally the simulation results of return loss, radiation pattern, antenna gain and efficiency are given in section III. Simulations are carried out using Zeeland's 'Method of Moments' based commercial IE3D (Integral Equation 3-Dimensional simulator). IE3D simulator is preferred than other RF CAD tools because of its high efficiency, high accuracy and low cost with windows based graphic interface that allows interactive construction of 3D and multilayer metallic structures as a set of polygons.

The geometrical configuration of the proposed reconfigurable CPW fed patch antenna is shown in Fig.1. The designed antenna is etched on a single layer of FR4 dielectric substrate which is 36 X 45mm^2 in dimension. The antenna is symmetrical with respect to the longitudinal direction, whose main structure is a H-shaped patch with Co-planar waveguide (CPW) feed line.The geometrical parameters are adjusted carefully and finally the antenna dimensions are obtained as L_1=20mm, L_2=1.5mm, L_3=2mm, L_4=22mm, L_5=3mm, L_6=8mm, L_7=2mm, L_8=1mm, W_1=36mm, W_2=5mm, W_3=9mm, W_4=5mm, W_5=6mm, W_6=14mm, W_7=4mm, ε_r=2.2. The thickness of the substrate is h=1.6mm.

II. STRUCTURE AND DESIGN OF PRPOSED RECONFIGURABLE ANTNENNA

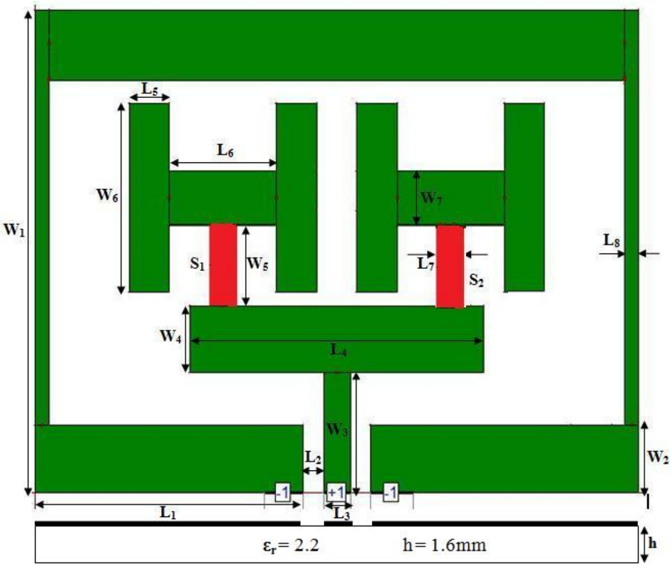

Figure 1. Geometry of the proposed Reconfigurable Antenna

Keeping switches in the structure means placing connection. Two switches are introduced in the structure namely S_1 and S_2 as shown in Fig.1. In order to obtain frequency diversity, the two switches are made ON and OFF in four different modes namely:

TABLE I. MODES OF RECONFIGURABLE ANTENNA

Mode	Switch S_1	Switch S_2
1	OFF	OFF
2	ON	OFF
3	OFF	ON
4	ON	ON

The ON and OFF conditions of switches are realized by forward and reverse biasing of PIN diodes. Ideally, when a forward bias is applied to make the switch ON, the switch would have low impedance characteristic, acts as short and the current can flow through the diode. On the other hand, when a reverse bias is applied to make the switch OFF, the switch exhibits high impedance characteristic and acts as open circuit which implies that there is no connection.

III. DESIGN METHODOLOGY AND INFERENCES FROM SIMULATED RESULTS AND DISCUSSIONS

In order to achieve the required results a commercial CAD tool-IE3D (Integral Equation 3-Dimensional simulator) is used. IE3D is based on MoM's boundary element method (BEM). In Moment's method, first a circuit is divided into small subsections. One sub section is taken at a time and calculate the electric field generated everywhere by the current at one section. Place current on all subsections simultaneously and adjust those currents so that total tangential Electric field goes to Zero. Once the Current distribution is obtained, the S parameters follow immediately. BEM creates a mesh like structure over the modeled surface. These meshes are further modeled as matrices which are solved numerically. This is done using "Green's Functions". Green's Functions consist of source and field patches which form the matrix. Green's Functions are integrated over either or both source and field patch if the model is uniform throughout. This is called "Galerkin's Method". IE3D breaks down the structure to be modeled into numerous meshes whose co-ordinates are modeled as a matrix. It calculates the analytical integral over all these meshes by filling the matrix elements for every single frequency.

Due to the time constraints MoM is not being used. However, MoM analysis would give more accurate results compared to other numerical methods. The primary simulation results of IE3D are the S-parameters. The S-parameters can optionally be converted into a spice net list. The spice net list could be imported into a spice simulator for time-domain simulation. The other simulation results are radiation pattern, antenna and radiating efficiency, antenna gain, directivity and axial ratio.

A. Simulated Results

The S-parameters curve, radiation pattern, antenna gain and efficiency of antenna when both the switches S_1 and S_2 are in OFF condition are shown in Fig 2-4, the results when S_1 ON and S_2 OFF are shown in Fig 5-7, the results when S_1 OFF and S_2 ON are shown in Fig 8-10 and finally the results when S_1 and S_2 are in ON condition are shown in Fig 11-13.

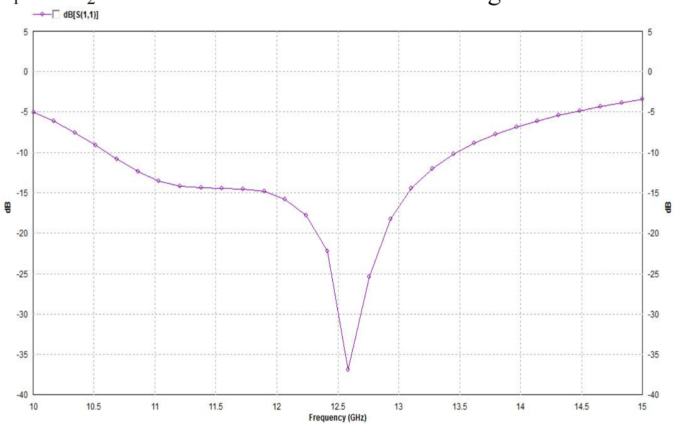

Figure 2. Simulated Return loss of the Antenna when both switches are OFF

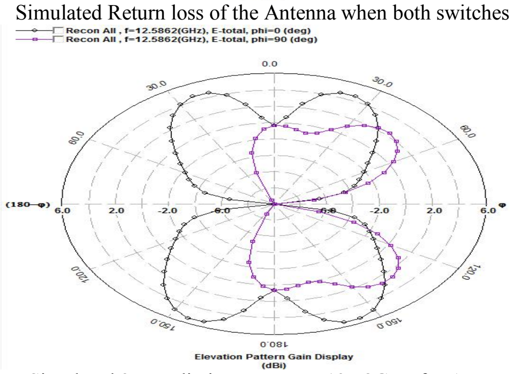

Figure 3. Simulated 2D Radiation pattern at 12.58GHz for Antenna when both switches are OFF.

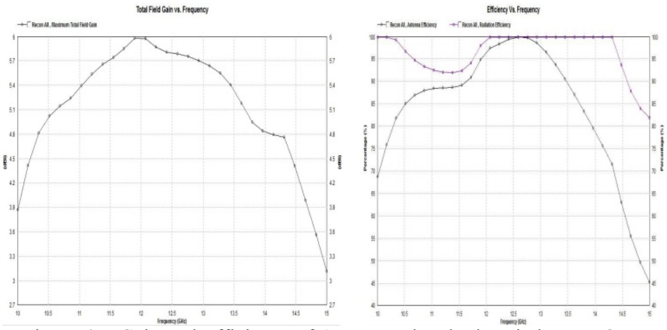

Figure 4. Gain and Efficiency of Antenna when both switches are OFF.

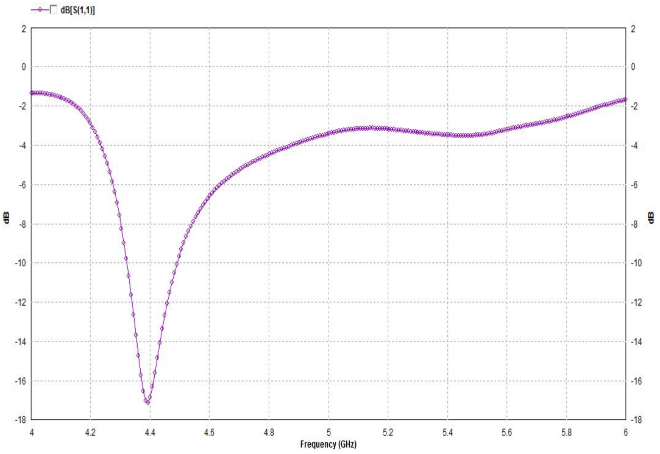

Figure 5. Simulated Return loss of the Antenna when S_1 ON and S_2 OFF

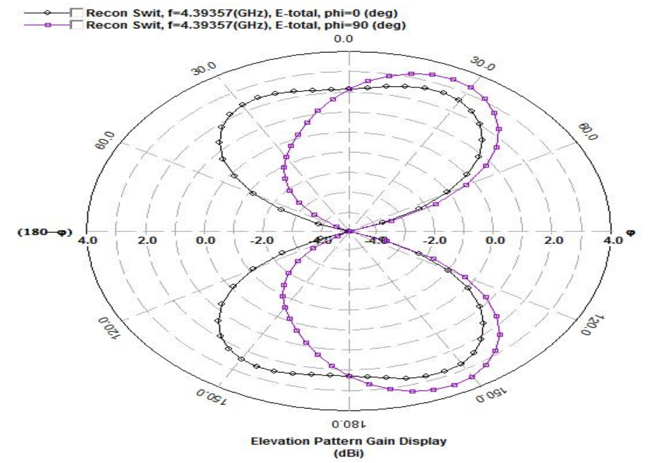

Figure 6. Simulated 2D Radiation pattern at 4.39GHz for Antenna when S_1 ON and S_2 OFF

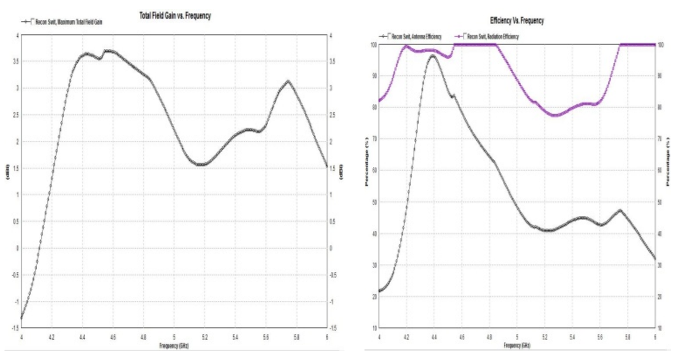

Figure 7. Gain and Efficiency of Antenna when S_1 ON and S_2 OFF

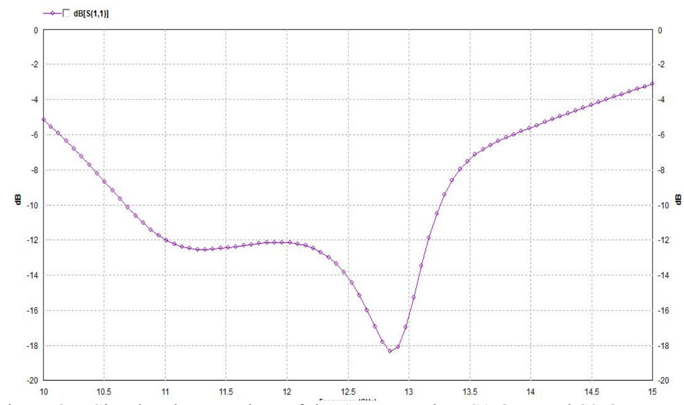

Figure 8. Simulated Return loss of the Antenna when S1 OFF and S2 ON

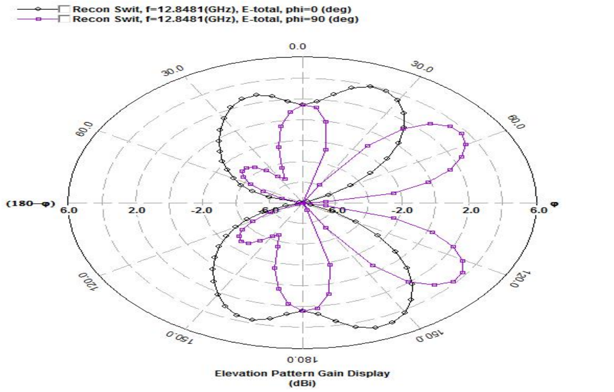

Figure 9. Simulated 2D Radiation pattern at 12.84GHz for Antenna when S_1 OFF and S_2 ON

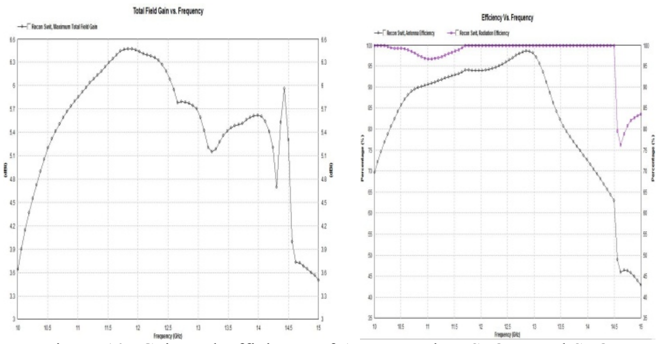

Figure 10. Gain and Efficiency of Antenna when S_1 OFF and S_2 ON

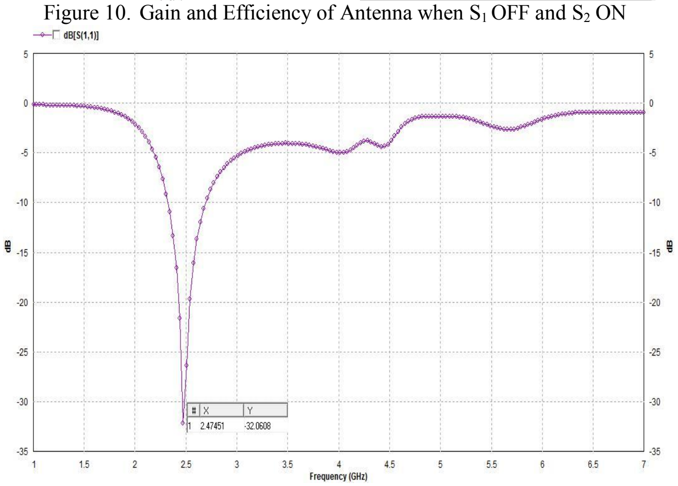

Figure 11. Simulated Return Loss when both switches are ON

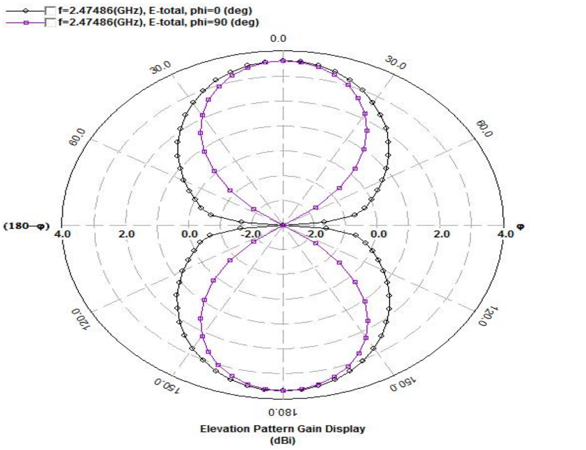

Figure 12. Simulated 2D Radiation pattern at 2.47GHz for Antenna when both switches are ON

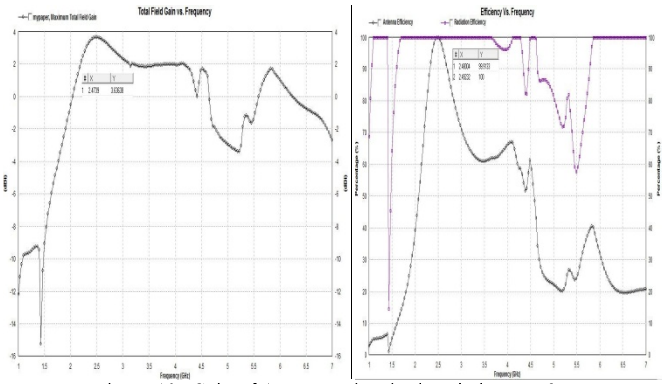

Figure 13. Gain of Antenna when both switches are ON

B. Discussions

In Mode 1 the antenna has a return loss of -36.51dB at 12.58GHz with -10dB band width of 2.88GHz is obtained. In Mode 2 the antenna has a return loss of -17.13dB at 4.39GHz with a bandwidth of 168MHz. In Mode 3 the proposed antenna has a return loss of -18.31dB at 12.84GHz with -10dB impedance bandwidth of 2.57GHz and finally in Mode 3 the given antenna has the return loss of -32.08dB at 2.47GHz with a bandwidth of 371MHz. In this mode antenna is suitable for IEEE 802.11 b WLAN Application. The application band is 2.32GHz-2.69GHz.

The measured radiation patterns which gives E_φ polarization pattern in the elevation cuts (*y–z* plane and *x–z* plane) for the antenna at 12.58GHz, 4.39GHz, 12.84GHz, 2.47GHz are shown in Fig 3, Fig 6, Fig 9, and Fig 12. The gain of 5.8dBi, 3.6dBi, 5.8dBi and 3.6dBi is observed at 12.58GHz, 4.39GHz, 12.84GHz, and 2.47GHz respectively. It is observed that antenna has 100% efficiency at all the resonant frequencies. Finally the VSWR values at all resonant frequencies from Mode 1 through Mode 4 are 1.03, 1.32, 1.28, and 1.05 respectively. The VSWR value is below 2 for all the four operating frequency bands which is closer to ideal value which is 1.

TABLE II. RESULTS

Antenna Parameters	Mode 1	Mode 2	Mode 3	Mode 4
Return Loss	-36.51dB	-17.13dB	-18.31dB	-32.08dB
Operating Frequency	12.58GHz	4.39GHz	12.84GHz	2.47GHz
Bandwidth	2.87GHz	168MHz	2.57GHz	371MHz
Antenna Gain	5.79	3.59	5.77	3.63
Antenna Efficiency	100%	97%	100%	100%
VSWR	1.03	1.32	1.28	1.05

IV. CONCLUSION

In this paper, a novel reconfigurable CPW fed H-shaped Patch antenna is presented. This antenna is compact in comparison to existing antennas. It operates at the frequency bands 12.58GHz, 4.39GHz, 12.84GHz, and 2.47GHz among which 2.47GHz is found applicable for IEEE 802.11 b WLAN application. This antenna is meeting desired antenna gain and efficiency at different operating frequency bands.

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