A CPW Fed E-Shaped Reconfigurable Antenna with Frequency Diversity

Ch. Sulakshana and L. Anjaneyulu

***Abstract*—A new CPW fed E-shaped reconfigurable Antenna with frequency diversity is designed and analyzed in this paper. The basic antenna consists of CPW fed E-shaped Patch antenna which operates at 5.8GHz which falls in IEEE 802.11 WLAN/RFID applications. The reconfigurability in frequency is obtained by connecting the switches in basic antenna by use of PIN diodes. By controlling the switches the antenna can be operated at three different frequencies namely 8.5GHz, 6.18GHz and 8.76GHz. The return loss of -28dB, -28.2dB,-33.07dB and -38.17dB are observed at 5.8GHz, 8.5GHz, 6.18GHz and 8.76GHz respectively. Two dimensional radiation patterns with elevation angles, gain, and efficiency of about 70% are also obtained. The compact aperture area of the antenna is 35mm X 30mm. The thickness of the substrate is 1.5mm. The proposed antenna is described and simulated results are illustrated. The results of antenna are simulated by using Zeeland's MOM based IE3D tool.**

***Index Terms*—CPW feed, frequency diversity, patch antenna, reconfigurable antenna.**

I. Introduction

With the enormous development of wireless communication technologies, the use of multiband antennas is increasing to meet different applications in wireless communication like Wi-Fi, Bluetooth, WiMAX, WLAN, and PCS. Hence the topic of reconfigurable antennas is gaining great attention. These antennae are researched extensively and achieved improvements to some extent through the projects like RECAP (Reconfigurable Aperture Program) conducted by DARPA [1]. Intelligent or Smart antennas are suitable for 3G and 4G technologies. The property of these antennas is to respond automatically by changing the radiation pattern, operating frequency to meet large number of wireless services that operate over wide frequency bands. Practically it is not possible to provide one antenna for each of these services. These antennas are replaced by single reconfigurable antenna which satisfies all the services by reconfiguring the operating frequency [2]. It is desirable to combine multiple antenna functions into a single antenna system to reduce antenna dimensions, cost and performance [3]. Due to the additional degree of freedom provided by the reconfigurable antennas, there is increased system performance [4]. The diversity features of reconfigurable antennas are operating resonant frequency, polarization, radiation pattern [5]-[9].

Recently, due to its many attractive features such as wide bandwidth, low cross polarization, radiation loss, less dispersion, uniplanar nature, no soldering point, and easy integration with active devices or monolithic microwave integrated circuits (MMICs), the coplanar waveguide (CPW)-fed antenna has been used as an alternative to conventional antennae for different wireless communication systems [10].

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.

II. Structure and Design of Proposed Reconfigurable Antenna

The geometrical configuration of the proposed CPW fed E-shaped Reconfigurable Antenna is shown in Fig.1. The designed antenna is etched on a single layer of low cost FR4 dielectric substrate which is 35 X 30 mm^2 in dimension. The antenna is symmetrical with respect to the longitudinal direction; whose main structure is an E-shaped Patch and a strip with Co-planar waveguide (CPW) feed line.

The geometrical parameters are adjusted carefully and finally the antenna dimensions are obtained to be W_1 = 30mm, W_2 = 5mm, W_3 = 6mm, W_4 = 8mm, W_5 = 2mm, W_6 = 2mm, W_7 = 1mm, L_1 = 15.3mm, L_2 = 3.6mm, L_3 = 12mm, L_4 = 2mm, d=1.5mm, ε_r = 4.3. The gap spacing between ground plane and CPW feed line is g=0.4mm. The substrate thickness t=1.5mm. The two switches are introduced in the structure namely S_1 and S_2. The switches S_1 and S_2 connect two rectangular patch lines that are present in the E shape as shown in Fig.1. In order to obtain frequency diversity, the two switches are made ON and OFF in four different modes which is given in Table I.

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

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switch exhibits high impedance characteristic and acts as open circuit which implies that there is no connection.

TABLE I: FOUR MODES OF SWITCHES

Case	Switch S1	Switch S2
1	OFF	OFF
2	OFF	ON
3	ON	OFF
4	ON	ON

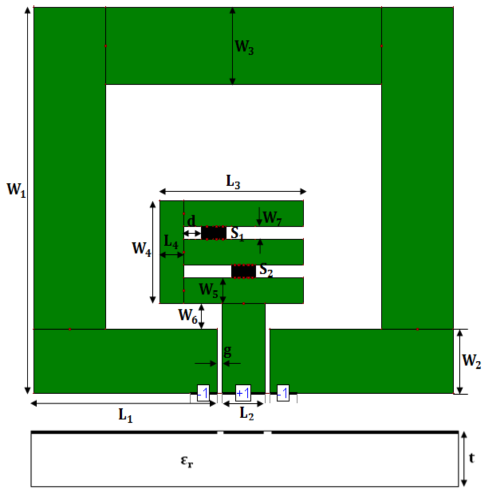


Fig. 1. Geometry of the proposed reconfigurable antenna.

III. INFERENCES FROM SIMULATED RESULTS AND DISCUSSIONS

To investigate the performance of the proposed antenna configurations in terms of achieving the required results, a commercially available Moment Method based CAD tool-IE3D, was used for required numerical analysis and obtaining the proper geometrical parameters in Fig.1.

A. Case 1

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(a) – 4(a). Fig.2 (a) depicts the return loss (dB) versus frequency (GHz). It is observed from figure that a return loss of -28dB at 5.8GHz with -10dB band width of 897MHz is obtained. This antenna is suitable for RFID/IEEE 802.11a WLAN (5.725GHZ-5.875GHz) Applications. Fig.3 (a) depicts the measured radiation pattern which gives E_φ polarization pattern in the elevation cuts (*y–z* plane and *x–z* plane) for the antenna at 5.8GHz. Fig.4(a) depicts the simulated gain (dBi) of the antenna versus frequency (GHz) and radiating efficiency versus the frequency. It is observed that gain of 2.8dBi is obtained and antenna efficiency of about 70% is obtained.

B. Case 2

The S-parameters curve, radiation pattern, antenna gain and efficiency of antenna when switch is S_1 OFF and S_2 is in ON condition are shown in Fig 2(b) – 4(b). Fig. 2(b) depicts the return loss (dB) versus frequency (GHz). It is observed from the figure that the return loss of -28.2dB at 8.5GHz with -10dB band width of 1390MHz is obtained. Fig. 3(b) depicts the measured radiation pattern which gives E_φ polarization pattern in the elevation cuts (*y–z* plane and *x–z* plane) for the antenna at 8.5GHz. Fig. 4(b) depicts the simulated gain (dBi) of the antenna versus frequency (GHz) and radiating efficiency versus the frequency. It is observed that gain of 4.7dBi and antenna efficiency of about 99.88% is obtained.

C. Case 3

The S-parameters curve, radiation pattern, antenna gain and efficiency of antenna when S_1 is ON and S_2 in OFF condition are shown in Fig 5(a)-7(a). Fig.5 (a) depicts the return loss (dB) versus frequency (GHz). It is observed from the figure that the return loss of -33.07dB at 6.18GHz with -10dB band width of 600MHz is obtained. This antenna is suitable for C-band application. Fig.6(a) depicts the measured radiation pattern which gives E_φ polarization pattern in the elevation cuts (*y–z* plane and *x–z* plane) for the antenna at 6.18GHz. Fig.7 (a) depicts the simulated gain (dBi) of the antenna versus frequency (GHz) and radiating efficiency versus the frequency. It is observed that gain of 2.91dBi and antenna efficiency of about 70% is obtained.

D. Case 4

The S-parameters curve, radiation pattern, antenna gain and efficiency of antenna when both the switches S_1 and S_2 are ON are shown in Fig 5(b)-7(b). Fig.5(b) depicts the return loss (dB) versus frequency (GHz). It is observed from the figure that the return loss of -38.17dB at 8.755GHz with -10dB band width of about 1.09GHz is obtained. Fig.6(b) depicts the measured radiation pattern which gives E_φ polarization pattern in the elevation cuts (*y–z* plane and *x–z* plane) for the antenna at 8.755GHz. Fig.7(b) depicts the simulated gain (dBi) of the antenna versus frequency (GHz) and radiating efficiency versus the frequency. It is observed that gain of 5.15dBi and antenna efficiency of about 99.96% is obtained.

E. Effect of Change in Switch Position

The effect of change in switch position is evaluated. By keeping both switches in ON condition, the switch S_1 position is moved from 0.5mm distance which is indicated by 'd' in Fig.1 to 4.0mm and simulated. The corresponding return loss curves are observed and plotted. The change in resonant frequency and return loss for different switch positions are tabulated in Table II and the graph showing comparative curves for the same is shown in Fig.8.

After few repeated simulations using IE3D simulator, it is observed that by increasing distance (d) to 1.5mm the return loss increases to -38dB and it is also observed that there is no change in resonant frequency which is 8.55GHz, and also efficiency in case 4 is increased from 75% to 99%. Hence, d=1.5mm is taken as an optimum value in the geometry.

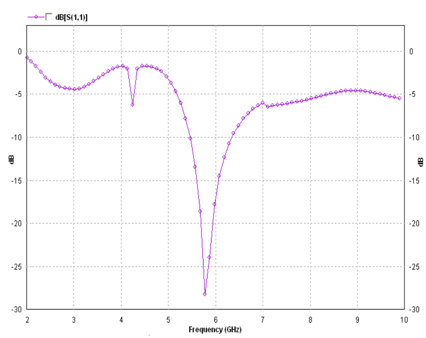


Fig. 2. Simulated return loss of the antenna (a) when both switches are OFF.

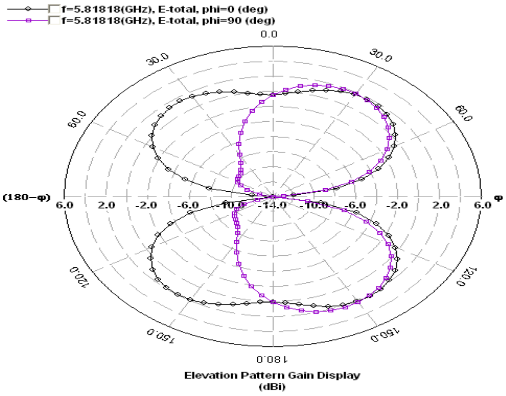
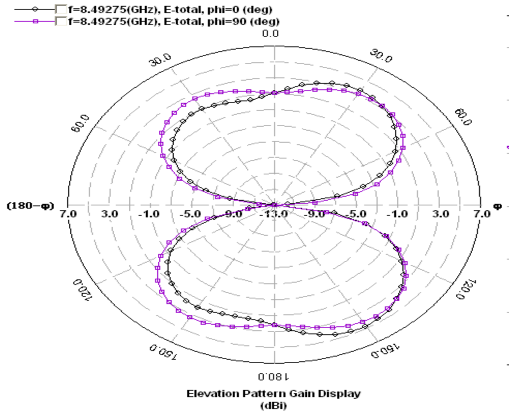


Fig. 3. Simulated radiation pattern of the antenna (a) At 5.8GHz.



(b) At 8.5GHz.

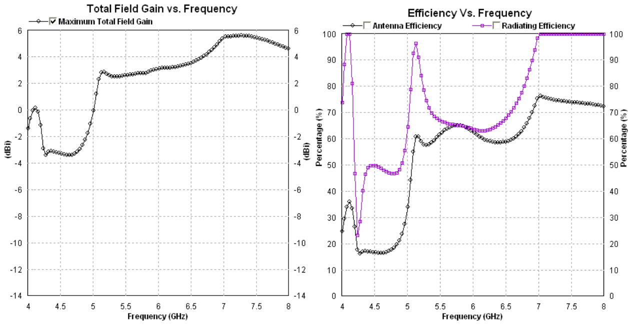
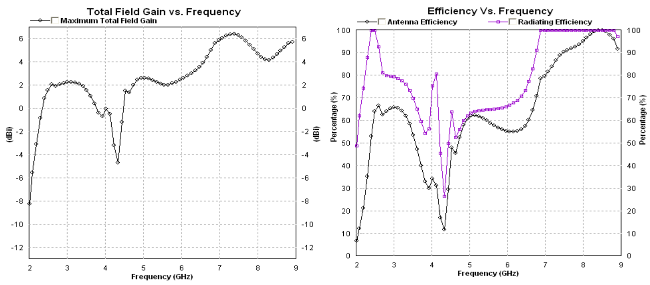


Fig. 4. Gain and efficiency of the antenna (a) when both switches are OFF.



(b) when S_1 is OFF and S_2 is ON.

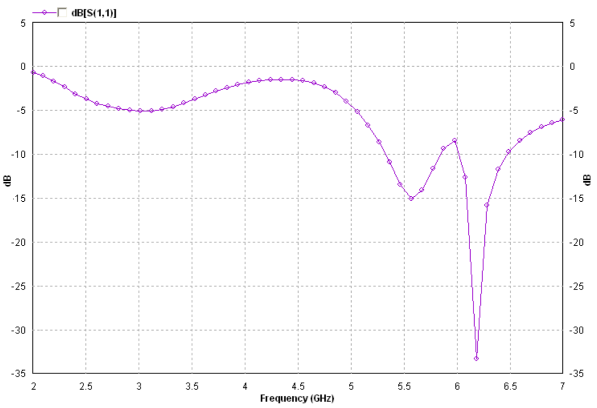
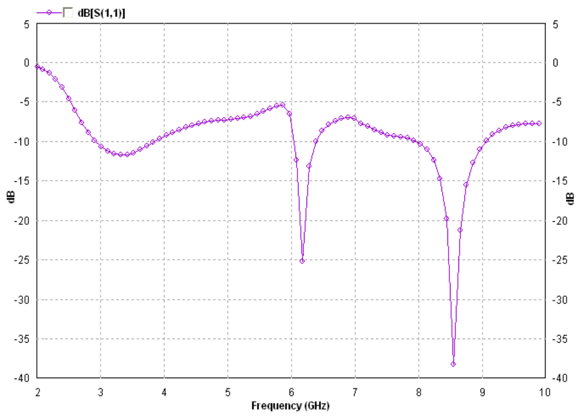
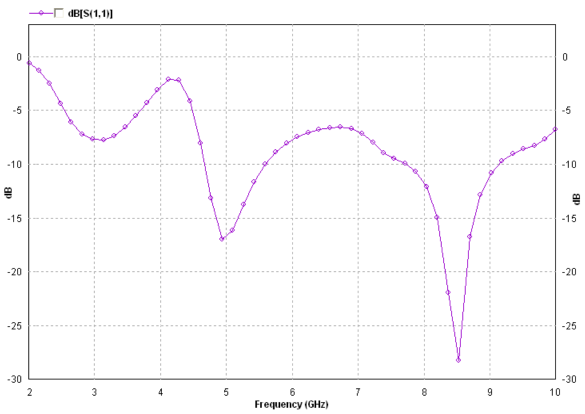


Fig. 5.Simulated return loss of the antenna (a) when S_1 is ON and S_2 is off.



(b) When both the switches are ON



(b) when S_1 is OFF and S_2 is ON.

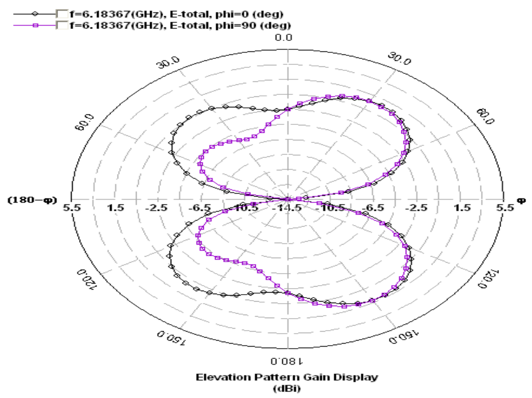


Fig. 6. Simulated radiation pattern of the antenna (a) At 6.18GHz.

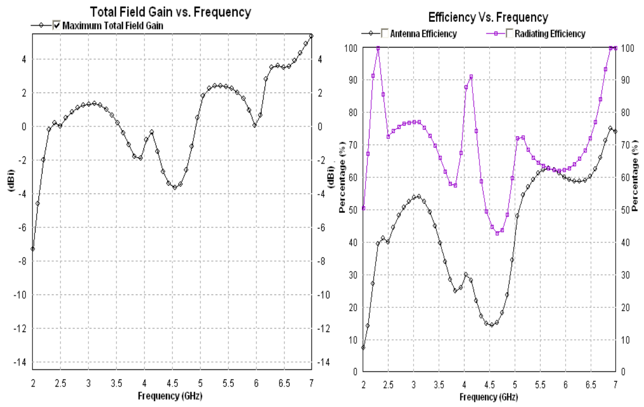
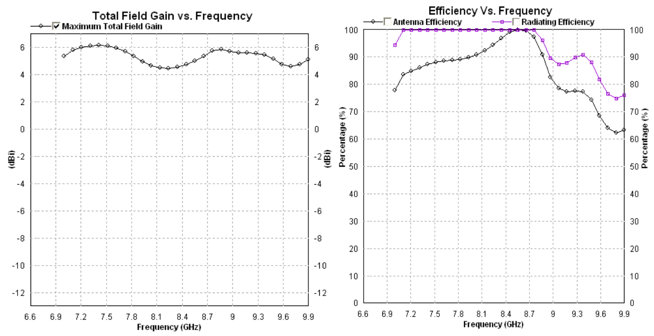


Fig. 7. Gain and efficiency of the antenna (a) when S_1 is ON and S_2 is OFF.



(b) when both the switches are ON

TABLE II: EFFECT OF CHANGE IN SWITCH S_1 POSITION ON RESONANT FREQUENCY AND RETURN LOSS

Distance (d in mm)	Resonant frequency (fr in GHz)	Return loss (S11 in dB)
0.5	8.55	-30.0
1.0	8.55	-32.9
1.5	8.55	-38.3
2.0	8.55	-28.9
2.5	9.28	-23.9

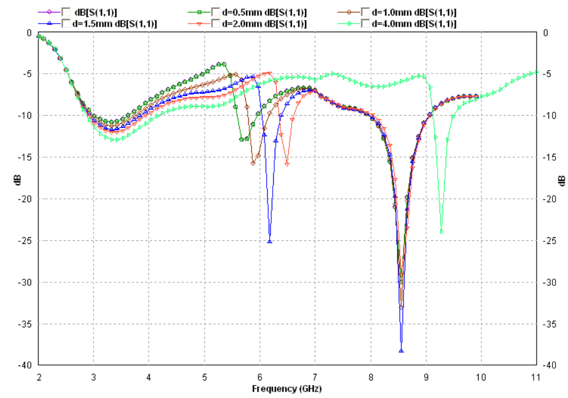
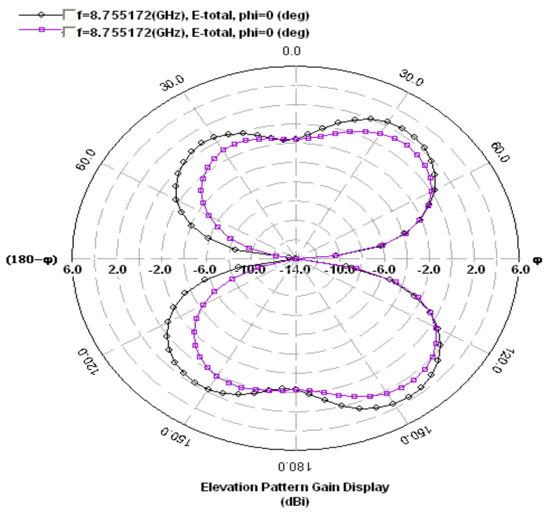


Fig. 8. A comparative graph showing return loss curves for different positions of switch S_1 when both the switches are turned ON.

Finally the results of the proposed reconfigurable antenna are concluded in Table III.

TABLE III: RESULTS

Antenna Parameters	Case1	Case 2	Case 3	Case 4
Return loss (dB)	-28	-28.2	-33.07	-38.2
Operating Frequency (GHz)	5.8	8.5	6.18	8.76
Bandwidth (MHz)	897	1390	600	1090
Antenna Gain (dBi)	2.8	4.7	2.91	5.15
Antenna Efficiency (%)	70	99.88	70	99.96
VSWR	1.09	1.08	1.05	1.03
Application	RFID/WLAN	-	C-Band	-



(b) At 8.5GHz.

IV. CONCLUSION

In this paper, a novel reconfigurable CPW fed E- shaped Patch antenna is presented. This antenna is compact in comparison to existing antennas. It operates at the frequency bands 5.8GHz, 8.5GHz, 6.18GHz and 8.76GHz among which 5.8GHz is found applicable for RFID/IEEE 802.11 WLAN application. This antenna is meeting desired antenna gain and efficiency at different operating frequency bands.

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