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Design and Analysis of a Connected E-Shape and U-Shape Dual-Band Patch Antenna for WLAN Application

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Abstract

This paper represents a numerical simulation of connected E-shape and U-shape for WLAN application. In this paper, dual operation E-shape and U-shape Patch Antenna is fed by transmission line. The objective in this design is to obtain the enhancement in bandwidth (BW) for WLAN applications over the frequency band (2 to 6 GHz).The proposed antenna is designed on two-layer, one FR4 substrate and another ground plane with an area of 33 mmx42 mm. The dual operation frequencies are 2.66 GHz and 5.72 GHz. In addition, the antenna has achievable return loss, radiation pattern and also bandwidths within the 6dB return loss bandwidth. It is observed that the impedance bandwidth can be expanded by using FR4 substrate. Furthermore, this antenna provides a stable radiation pattern across the operating bandwidth.

Keywords: *Patch antenna, Connected E-shape& U-shape, Dual-Band, WLAN, Radiation pattern, GEMS Software.*

1. Introduction

Microstrip patch antennas have been widely studied and commonly used as a promising candidate in wireless applications, due to their attractive characteristics, such as low profile, light weight, low cost, ease of fabrication and good conformability with integrated circuits. It is well known that the limited bandwidth is an intrinsic drawback of a patch antenna. Many efforts have been made during the past few decades and several effective methods have been proposed, such as using thick substrate with low dielectric constant [1], parasitic patch loading on the same layer with the main patch [2], stacked multilayer patches [3], chip resistor loading [4] U-slot (or double U-slot) [5] and E-slot [6] etched on the patch, and L-probe feeding [7].However, it's still a difficulty to achieve such broadband on a miniaturized single layer patch, especially when the thickness of the substrate is reduced, as the bandwidth always decreases as the total thickness is reduced [8].The previous reported broadband is usually achieved when a relatively thick substrate, more than 0.07λ, is used. Recently, authors investigated the application of the connected U-shape & E-shape Design patch antenna to wireless local area net-works (WLAN) operating in the 2.40-2.48 GHz & 5–6 GHz [9] and successfully developed several antennas suitable for high-speed (IEEE 802.11a,54 Mb/s)WLANs and other similar wireless communication systems[10]. This proposed antenna is designed to suit wireless network adaptor cards for notebook computers in the PC (also known as Card Bus or PCMCIA) format.

In this paper, bandwidths of return loss characteristic for the dual band are 15.452 % and 4.04 % respectively. This proposed patch antenna has less area but still covers the WLAN frequency bands that are of practical interest. Many designs of single and dual band microstrip patch antenna with triangular, square and circular using E-slots and U-slots have been reported [11][12].For the numerical analysis we consider the substrate permittivity of the antenna is ε_r =4.4 (FR4) with substrate thickness 1.1mm and feed by a 50 Ω microstrip line

The paper is divided as follow: Section 2 discusses the antenna design and structure; Section 3 presents antenna design procedure; Section 4 explains the simulation result of the antenna; Section 5 conclusions; Section 6 future works of the paper.

2. Antenna Design & Structure

In this paper several parameters have been investigated using GEMS (General Electromagnetic Solver) version 7. The design specifications for the proposed antenna are:

- The dielectric material selected for the design is FR4.
- Dielectric constant 4.4
- Height of substrate (h) = 1.1 mm.

The antenna is fed by 50Ω microstrip line, through a quarter-wavelength transformer for impedance matching. The main advantage of using transmission line feeding is very easy to fabricate and simple to match by controlling the inset position and relatively simple to model. The proposed antenna has one U-shape and one E-shape and one bridge to connect both shape as shown in Fig.1 and detail dimensions is given in Table-1 Proposed antenna generates dual bands at 2.66 GHz and 5.72 GHz with simulated impedance bandwidth of 15.452% and 4.04%.

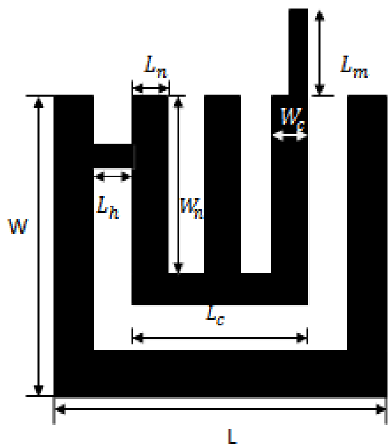

Fig.1: Structure of U-shape & E-shape Design

Table 1: Dimensions of the proposed antenna (Unit: mm)

L	W	L_h	W_h	L_n
42	33	4	3.5	5
W_n	L_m	W_m	W_c	L_c
20	8	2	5	23

3. Antenna design procedure

This section describes the approach of designing a patch antenna using connected set of U-slot and E-slot techniques to adapt the structure to the desired interest operating frequency. The proposed antenna consists of a ground plane, a printed patch and a microstrip feeding line. The most important parameters that affect the antenna performance, such as impedance bandwidth, gain and efficiency are described in this section.

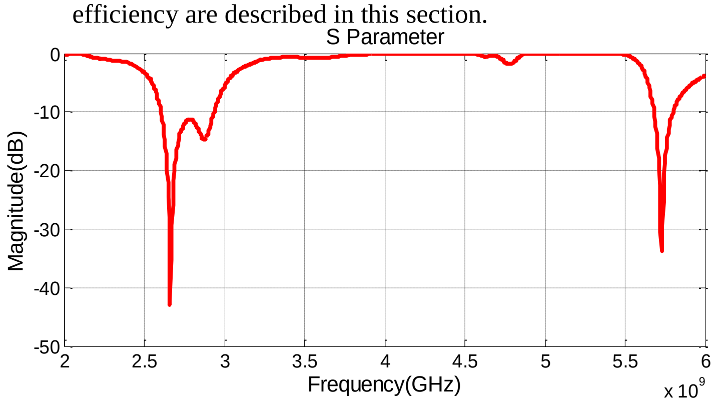

Fig.2: Return loss of Connected E-Shape & U-Shape Design

A connected microstrip E-shape and U-shape patch antenna has been designed with over all dimensions 33mm x 42 mm and height of 1.1 mm. Dual operation E-shape and U-shape Patch Antenna feed by transmission line is presented. In the following Fig.2 we analysis the return loss and then analysis the improved bandwidth using this connected set of E-shape & U-shape.

Antenna bandwidth=$\frac{f_2-f_1}{\sqrt{f_1 f_2}}\times 100\%$

The value of f1 and f2 were taken at –6dB or 6% from the transmitted power.
At 2.66 GHz return loss bandwidth=15.452%
At 5.72 GHz return loss bandwidth=4.04%
So, the bandwidths of the dual band are 15.452% and 4.04% respectively.

3.1 The Effect of Changing Width of W_h

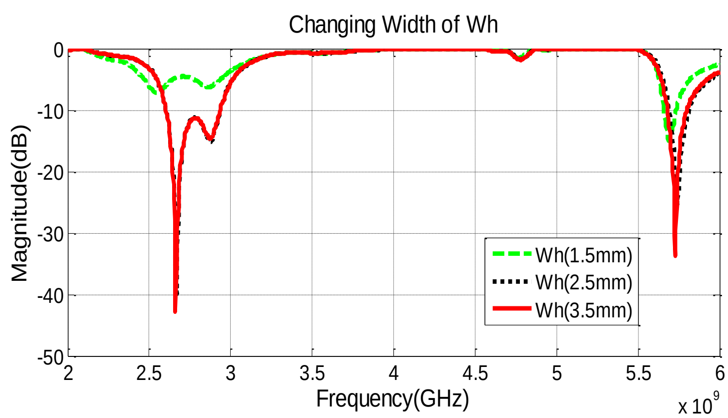

Fig.3: The variation of the (W_h) parameter on the return loss response

Table 2: Return loss and Bandwidth for the variation of the (W_h) parameter

Bridge Width(W_h)	Return loss Magnitude(dB)	Bandwidth
1.5mm	-7.216dB&-15.07dB	4%&2.695%
2.5mm	-40dB & -25.44dB	15.424%&4.03%
3.5mm	-42.88dB&-33.72dB	15.452% & 4.04%

Fig.3 shows the simulation results of the E-shape and U-shape based on the variations of the value of width (W_h). When we use width of the bridge 3.5 mm then bandwidth will increase. And resultant return loss magnitude of the 3.5mm width is higher than the 2.5mm width. Return loss magnitude higher negative means less return loss. Higher bandwidth means it is applicable for wide range frequency area. Therefore choosing the width of 3.5 mm will give the best response.

3.2 The Effect of Changing Substrate Height (h)

Fig.4 shows the simulation results of the E-shape and U-shape based on the variations value of substrate height (h). It is clear from the figure that the resultant return loss magnitude of the 1.1mm substrate height(h) is higher than others. When Substrate height (h) is 1.1 mm then bandwidth will increase not only for 2.66GHz but also for 5.72 GHz. So, choosing the value of the substrate height of 1.1mm will give the best response.

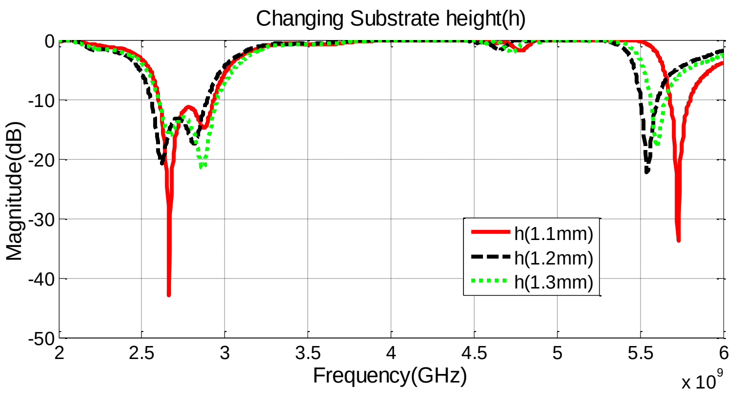

Fig.4: The variation of the of substrate height (h) on the return loss response

Table 3: Return loss and Bandwidth for the variation of the Substrate height (h)

Substrate height(h)	Return loss Magnitude(dB)	Bandwidth
1mm	-21dB & -27.97dB	16.33% & 3.244%
1.1mm	-42.88dB&-33.72dB	15.452% & 4.04%
1.2mm	-20.7 dB & -22.32dB	16.6% & 3.605%

3.3 The Effect of Changing Position of the Width (W_h)

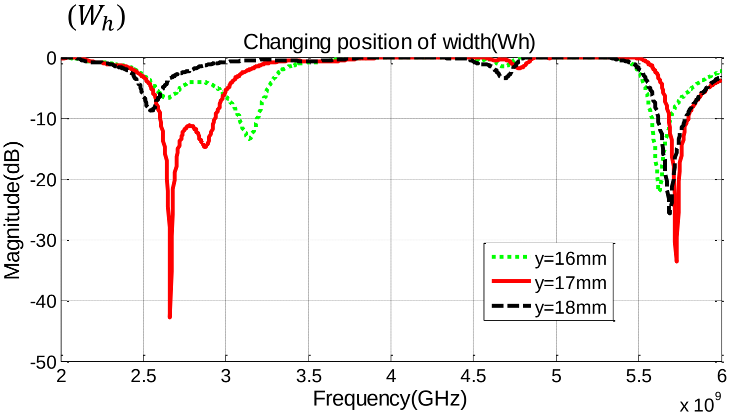

Fig.5: The variation of the position of the width (W_h) on the return loss response

Fig.5 shows the simulation results of the E-shape and U-shape based on the variations of the position of the width (W_h). It is clear from the figure that the resultant return loss magnitude for the position of the width(y=17mm) is higher than others and bandwidth will increase at that position. Therefore choosing the value of the position of the width of y=17mm will give the best response.

Table 4: Return loss and Bandwidth for the variation of the position of the width (W_h)

Position of width(W_h)	Return Loss Magnitude(dB)	Bandwidth
Y=16mm	-13.46 dB & -22.23 dB	8.3258% & 4.2%
Y=17mm	-42.88dB&-33.72dB	15.452% & 4.04%
Y=18mm	-8.84 dB & -25.74dB	4.197% & 5.289%

3.4 Changing Effect of substrate dielectric constant (ε_r)

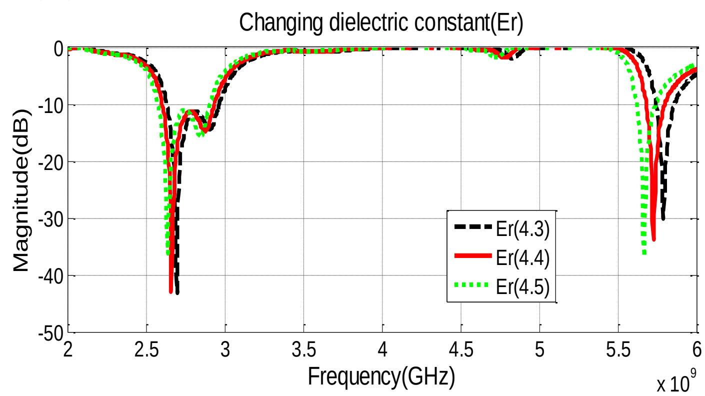

Fig.6: The variation of the of substrate dielectric constant (ϵ_r) on the return loss response

Fig.6 shows the simulation results of the E-shape and U-shape based on the variations of the value of substrate dielectric constant (ϵ_r). Here the dielectric constant is 4.4 then impedance bandwidth is increased for both 2.66 GHz and 5.72 GHz. The resultant return loss magnitude is higher than others for substrate's dielectric constant 4.4. So, choosing the dielectric constant of 4.4 will give the exact response.

Table 5: Return loss and Bandwidth for the variation of substrate's dielectric constant (ε_r)

Dielectric Constant(Er)	Return loss Magnitude(dB)	Bandwidth
4.3	-43.26dB & -30.1dB	15.43% & 3.978%
4.4	-42.88dB&-33.72dB	15.452% & 4.04%
4.5	-36.28dB & -36.82dB	15.486% & 4.03%

4. Simulation Result:

The radiation patterns at the centre frequencies 2.66GHz, and 5.72GHz of WLAN applications are plotted as shown below-

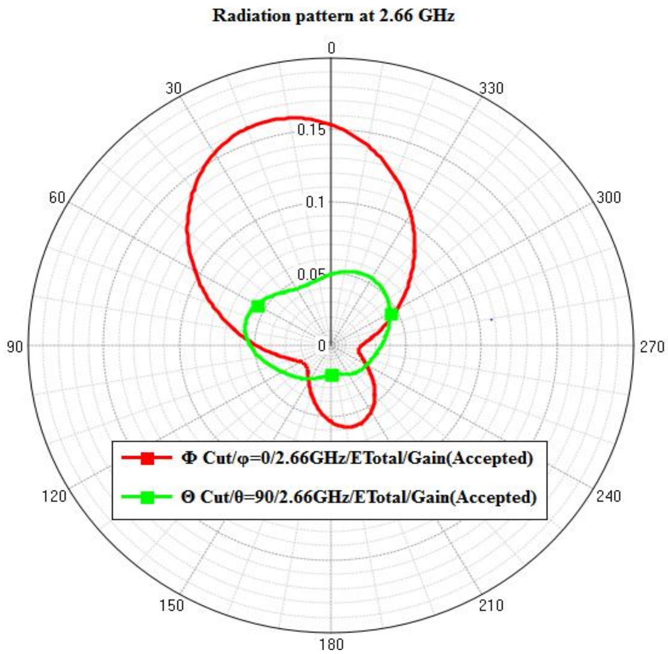

Fig.7: E-plane and H-plane at 2.66 GHz

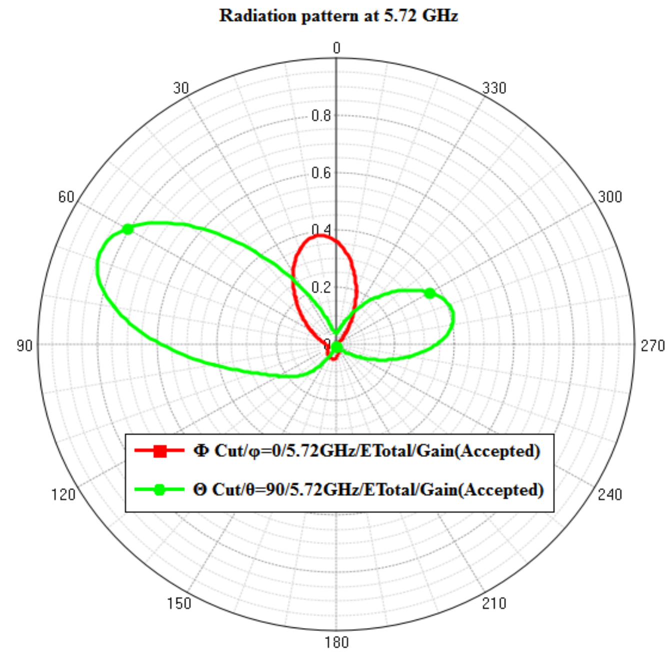

Fig.8: E-plane and H-plane at 5.72 GHz

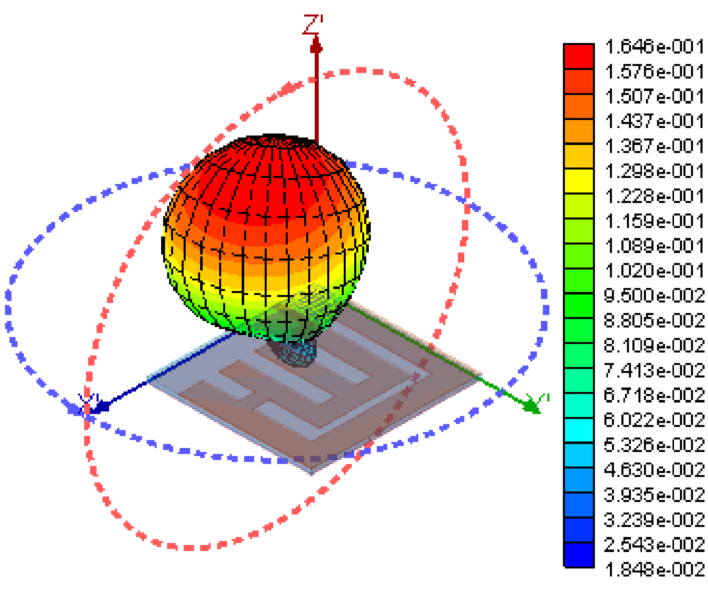

Fig.9: Gain at 2.66 GHz in 3D view with main design

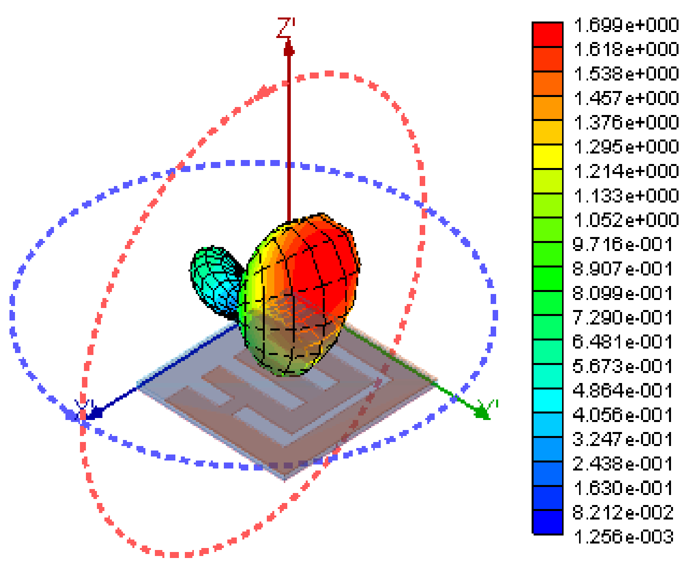

Fig.10: Gain at 2.66 GHz in 3D view with main design

5. Conclusion

Connected E-shape and U-shape patch antenna is investigated and successfully simulated in this paper, the simulated return loss and radiation pattern showed well performance for the dual band at 2.66 GHz and 5.72 GHz, the impedance bandwidths for the dual band are 15.452% and 4.04%. The design shows suitable characteristic for dual-band operations**.** Using this Connected E-shape and U-shape patch antenna, bandwidth can be improved at two different frequencies at 2.66 GHz and 5.72 GHz for wireless LAN application. It can be concluded from the above results that, designing a proper feed network and impedance matching are very important parameters in microstrip patch antenna design. Also choosing a proper position for terminating the feed line affects the overall performance of the antenna.

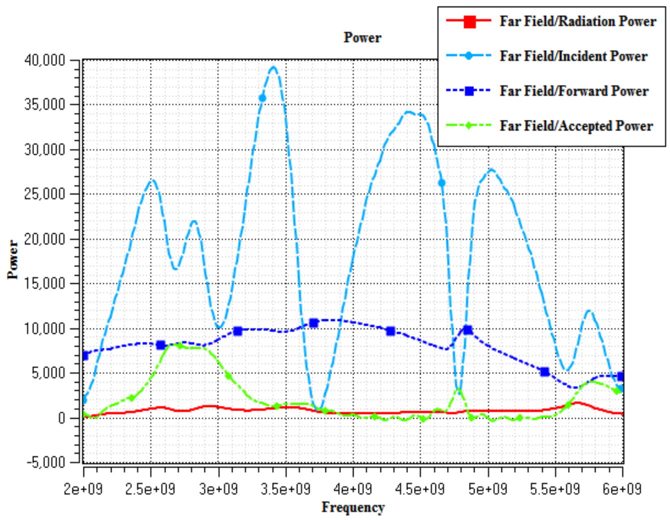

Fig.11: Power measurement of a connected E-shape & U-shape Microstrip patch antenna

6. Future work

Different types of feed methods affect the performance of an antenna. In this paper, microstrip line feed is chosen. In the future study we would like to look at how other types of feed network will affect the performance of microstrip antennas as compared to the microstrip line feed.In this paper bandwidth is not too much at 5.72 GHz.The performance of bandwidth will be increased by using Proximity Coupled Feed.

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