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Miniaturised Asymmetrical E-Shaped Patch Antenna With Circular Polarisation

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Abstract- Abstract should be times This paper includes the simulation and design parameter microstrip E-shaped patch antenna, demonstrating different operating frequencies. In this study three unequal resonance arms are fed by probe feed to the folded patch in order to increase the impedance bandwidth. The miniaturisation of the size of patch is done by the application of shorting pins . The performance of broadening the impedance bandwidth is explored by investigating the behavior of surface currents in patch. The tuning resonance ability of antenna is present within the impedance bandwidth by varying the length of unequal resonance arms. For ultra-wideband applications the measured -10 dB impedance bandwidth of fabricated antenna is 76.18% from 3.34 to 7.45 GHz. The size of the antenna is 0.379λ_L × 0.145λ_L × 0.078 $\lambda_{L,}$ where λ_L is wavelength at the lower frequency of measured operating bandwidth in the free space. It is designed by air substrate which has a dielectric constant of 1.0006. In addition to this, parametric studies are done by investigating the effect of different key parameters on obtaining an optimal design of the proposed antenna design.

Keywords – Patch Antenna, E-Shaped Antenna, Co-axial feed Antenna.

I. INTRODUCTION

In Wireless communication and in Global Positioning system Microstrip patch antenna is key building technique since it was first demonstrated in 1986 by Heinrich Hertz and its practical application by Gulielmo Marconi in 1901.Microstrip antenna has a great consideration because of its light Weight,Low profile,Compatibility integration and with other circuits and subsystems, low cost and immunity to multipath interference. Those Microstrip antennas which are having Narrow Impedance Bandwidth various methods have been accomplished to overcome this problem in order to achieve ultra-wideband (UWB) performance. The frequency range of the UWB wireless standard has been allocated from 3.1 to 10.6 GHz[1]. Nowadays a compact Wideband antenna is exclusively accentuated in commercial and military systems. It operates in C-band and partially in S-band which makes it suitable for UWB applications such as Wireless monitoring and home networking.

When the size of the microstrip antenna is reduced then the bandwidth impedance gets reduced. Many techniques have been used to miniaturized the size of the antenna such as meandered patch[2], shorting pin/wall[3-5] , by applying the shorting pin loading technique at microstrip antenna exhibits a quarter-wavelength structure. Also there are several more techniques used to enhance the impedance bandwidth for example: by utilising a thick substrate [6], modification in patch geometric structure like E-shaped patches[7-8] , U-shaped-slot patch[9] . Other useful techniques to improve the impeadance bandwidth are implementation of stacked patch antenna[10], L-probe feed[11], shorted patch[12], shorting pins[13]. In earlier investigations , an E-shaped patch antenna fed by a folded L-shaped probe with unequal arms provides an impedance bandwidth of 19.8% [14]. In asymmetric patch dimensions of 25×27.7 mm^2 , which has been mounted above the ground plane with dimensions of 62.5×100mm^2 , produces three adjacent resonances to achieve a wideband antenna. Also, modified E-shaped patch antennas with unequal resonance arms for producing different resonances have been introduced in [15, 16]. In [16] usage of shorting walls is utilized on asymmetric arms inorder to enhance impedance bandwidth. Recently by introducing the novel feeding method namely folded- patch feed, the impedance bandwidth of patch antenna has been improved[17,18]. An E-shaped patch antenna with folded patch feed is introduced to have an impedance bandwidth of 73.78% [19].

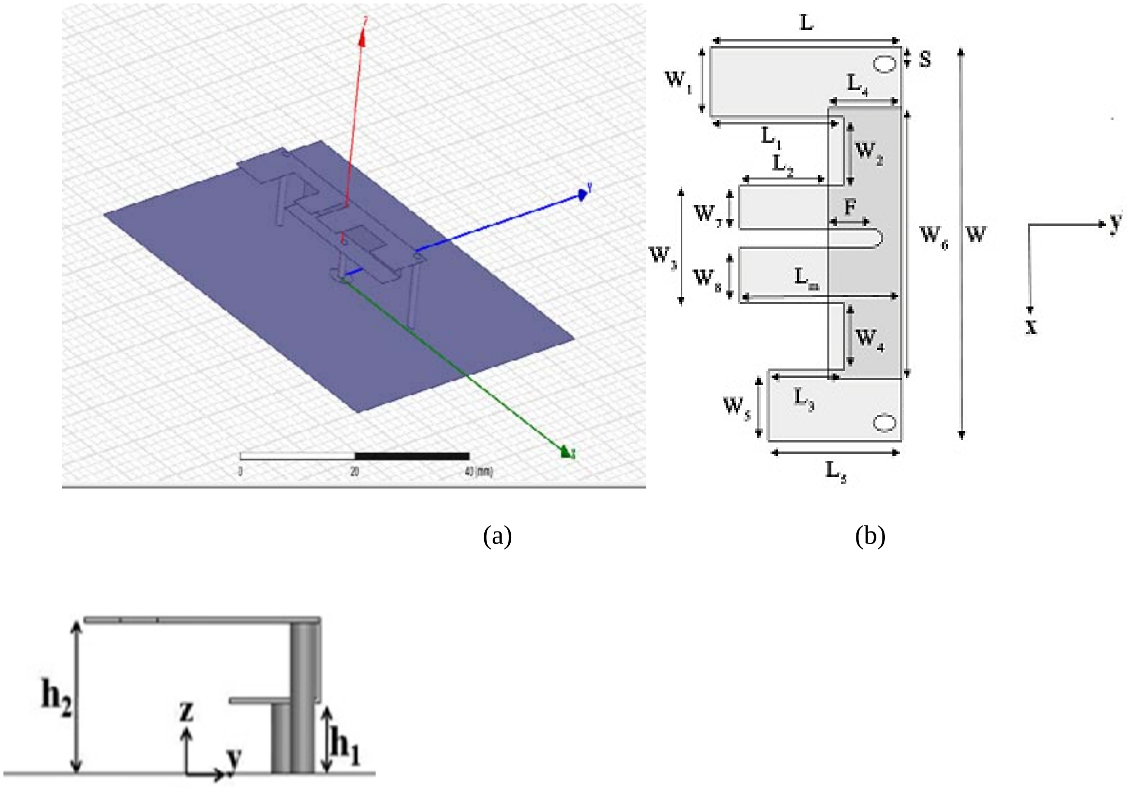
In this article, a probe- fed microstrip patch antenna with an asymmetric rectangular patch based on unequal resonance arms and a folded patch feed to broaden the bandwidth is introduced. It includes impedance badwidth ranging from 3.34to 7.45 GHz for UWB applications. Moreover, two shorting pins are applied in the proposed structure to reduce the size of antenna. Also, the radiation pattern acceptable stability over the frequency band acquired in both E- and H- planes.

Nomenclature
A UWB- Ultra Wide Band
B ESPA- E-Shaped Patch Antenna
C CP- Circular Polarisation

A. Antenna design and structure

In this microstrip antenna coaxial type of feeding is given. Since the coaxial probe feed is easy to fabricate with low spurious radiation related to other feeding methods, it is applied in the structure of the proposed antenna. The microstrip antenna have high Q factors so the probe feeding have lower impedance bandwidth. By increasing the substrates's thickness, the quality factor i.e. Q decreases and consequently the impedance bandwidth enhances. The microstrip antenna which are coaxially fed the substrate thickness is limited by the inductance of feeding coaxial probe, which increases directly with an increment of substrate thickness. To overcome this problem, the folded- patch feed technique with air substrate is introduced [17-20]. In this method, the introduce inductance of probe can be easily decreased by using a shorter coaxial probe.

The configuration of proposed antenna is depicted in Fig. 1. It consists of an E-shaped patch as upper patch, a folded patch feed and shorting pins , which are placed over the ground plane with air substrate. The patch is supported by the coaxial probe and the shorting pins. It is fed by the 50Ω SMA connector with a distance to the Egde of the lower patch (see fig.1).



(a) (b)

(c)

Figure 1:Configurations of the proposed antenna (a) Three-dimensional view (b) Top view (c) Side view

Patch is fed by 50Ω SMA connector wi th a distance to the edge of the lower patch F (fig.1). The probe length by applying folded-patch feed with height h_1, thus the low inductance contributed by the shorter coaxial probe is obtained. The total height (h_2) is 7mm and the length of the probe (h_1) is 3.4mm of the proposed antenna. Therefore a thick antenna without increasing the probe inductance to broaden its impedance bandwidth is achieved. At the edge of asymmetric E-shaped patch two shorting pins are connected between the edges and so the ground plane is result in an increase in antenna's effective electrical length and a decrease in antenna's physical size. Analytically

with a parametric study is used to attain an optimal broadband performance when shorting pins of various diameters at different positions were incorporated. According to the geometric structure of proposed antenna in Fig.1, the optimised diameters of the two pins are 1.4mm for providing the optimum impedance bandwidth. It should be mentioned that the shorting pins make the antenna resonates at a lower frequency compared with antenna without them . Thus, the antenna with an acceptable miniaturization can be achieved.
The asymmetric E-shaped patch with dimensions of 34×13 mm^2 is located at height h_2 from the ground plane .In achieving a wideband width the slot length, width and position plays an significant roles. The asymmetric E –shaped patch produces three resonances, with incorporation of two parallel slots into the upper patch and unequal resonance arms. The width of the slot that's between $\mathbf{w_7}$ and $\mathbf{w_8}$ is 1 mm and the length of that slot is 10mm.Therefore, the wider bandwidth can be achieved. The main advantage of the proposed antenna is its ability in tuning the resonances and the variation of slot's length and arms's length affect tuning of three resonances. By adjusting the longer, middle and shorter arms on upper patch can principally control the first, second and third resonances, respectively, in order to widen the impedance bandwidth of the antenna significantly. As compared with the antennas reported in [17,18] the proposed antenna has a wider bandwidth. This antenna can be made from the single piece of copper plate without the need of soldering the folded part to upper patch .The other advantage of the antenna is that it is simpler and easier fabrication process compared with the similar antennas such as U-shaped –slot and L-shaped slit patch with folded-patch feed technique . The optimum design values are determined with the parametric studies to find out the overall dimensions, slots and arms length. In addition, to choose the proper dimension for an optimal design, the minimum ripples of the gain with in the impedance bandwidth are considered. Several key parameters that help to achieve an optimal design are described in section 4. The dimensions of proposed antenna are given in Table1.

1.2 Tables

Table - 1 Dimensions of proposed antenna (units in mm)

Parameters	Values
W	**34**
W_1	**6**
W_2	**6**
W_3	**10**
W_4	**6**
W_5	**6**
W_6	**23**
W_7	**4**
W_8	**5**
L	**13**
L_1	**9**
L_2	**7**
L_3	**5**
L_4	**5**
L_G	**60**
L_s	**9**
L_m	**11**
h_1	**3.4**
h_2	**7**
W_G	**60**
S	**1.5**
F	**3**
Feed point	**(-0.5,4.5)**

1.3 Simulation and measurements results

Anasoft version 12 High Frequency Structure Simulator Software (HFSS) is used for prediction and optimization of antenna's resonant properties. The design procedure begins with determining the length, width and the of dielectric substance for the given operating frequency . As shown in the Fig.2, the proposed antenna operates from

3.34 to 7.45 GHz and measured -10 dB impedance bandwidth is 76.18%. The measured results are in agreements with the simulation results obtained using a finite ground plane. The proposed antenna has an enhancement of 20% in impedance compared with antenna reported in [17]. The 10% enhancement of bandwidth has also obtained when the slot has been cut in the middle of the arms of folded E-patch antenna. The impedance Anasoft version 12 High Frequency Structure Simulator Software (HFSS) is used for prediction bandwidth of antenna is more than triple of that of the E-shaped patch antenna with unequal resonance arms in [14]. The length, width and total height of patch in terms of wavelength at the lower end of frequency band are $0.379\ _{L}$, $0.145\lambda_L$ and $0.078\lambda_L$, respectively whereas the length of probe is $0.038\lambda_L$ .In comparison with a conventional patch antenna, 78.1% size reduction is achieved by the proposed structure. Also , to highlight the proposed antenna, in comparison with the conventional E-shaped patch antenna which is reported in [7]. In [17], an impedance bandwidth is 32.3% in the frequency range of 2.05-2.84 GHz is obtained with an antenna size of $70\times45\times10$ mm^3 . Thus our design result in 43.88% increases in the frequency bandwidth and 36.93% size reduction.

As per the stimulated gain of proposed antenna in Fig.3, at 7.45 GHz the maximum broadside gain of the antenna within the bandwidth is 8.25 dB. The measured and stimulated radiation pattern in the xz –plane (E-plane) and yz-plane (H-plane) are shown in Fig.4. It has been observed that agreement between the measured and stimulated results are good. The measured and the stimulated radiation patterns in three frequencies within the bandwidth are approximately stable.

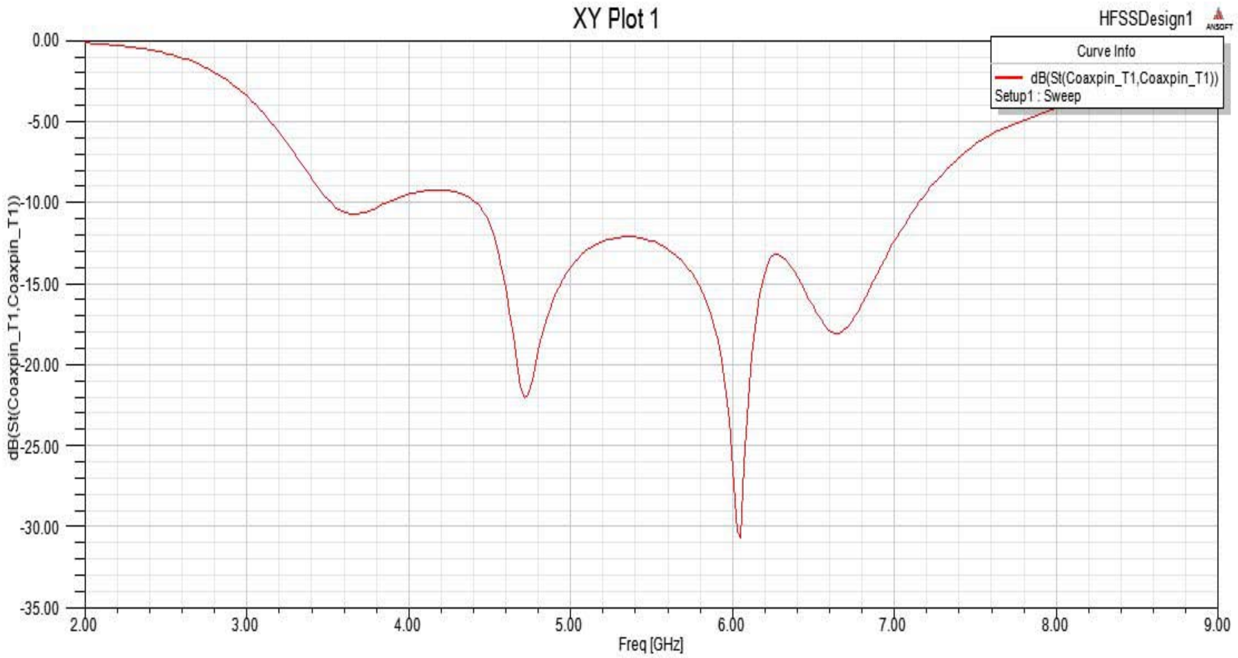


Figure2. Stimulated reflection coefficients of antenna

Also, the radiation patterns are not exactly symmetrical for electric fields in both planes because of its asymmetric structure. On the other hand, the antenna presents good broadside radiation patterns. At the same time, the cross-polarisation radiation is seems to be higher in the E-plane than that of in the H-plane. This is done because of the discontinuity in the structure obtained using the shorting pins and the feed location on the Y-axis. By the introduction of probe feed and shorting pins the asymmetry of the structure can effect on the increase of the contribution of the cross/-polarised radiation. The photograph of fabricated antenna is shown in Fig.11. In Fig.5. surface current distribution on the patch at three frequencies are shown. It is clear that at the first resonance of 4.74 GHz , a typical λ/4 patch antenna is exhibited. The current distribution along y-axis is non-uniform, which is observed with concentration around the slot between the longer arm and middle arm, as shown in Fig.5a. this is due to the asymmetry of the antenna. So, it is concluded that the first resonance corresponds to the longer arm. The second resonance is at 6.13 GHz, where a λ/2 resonant antenna is exhibited. The concentration of current is around the slots of the asymmetric E-shaped patch antenna and on the edges of the folded part, as shown in Fig.5b. So, we can say that the second resonance corresponds to the middle arm. Likewise, the third resonance of 6.73GHz , a $\lambda/2$ resonant antenna is exhibited. As shown in Fig.5c, the distribution of current concentrates on the overall of the folded part specifically on its edges and the area upper the patch which connects to the folded part.

1.4 Discussions on key parameters

In this section, the effects of some key parameters are describe to investigate the performance of the antenna. Fig.6. demonstrate the variation of the probe length (h_1) . It has been observe that as a length h_1 increases, the feed of probe inductance increases, impedance matching deteriorates and consequently the impedance bandwidth decreases. The capacitive effect dominate, when the probe length reduces from an optimised value, which results in worse impedance bandwidth. The antenna's optimum value oh h_1 is 3.4mm. Moreover, the optimised value of h_2 is 7mm for broadening the impedance bandwidth.

The first resonance frequency is mainly determined by length L of the upper patch, as shown in Fig.5a.As seen from Figs 5a and b, it is found that the length of slot L_1 affects the first and second resonances decrease and due to the fact that the current paths at these frequencies increase.

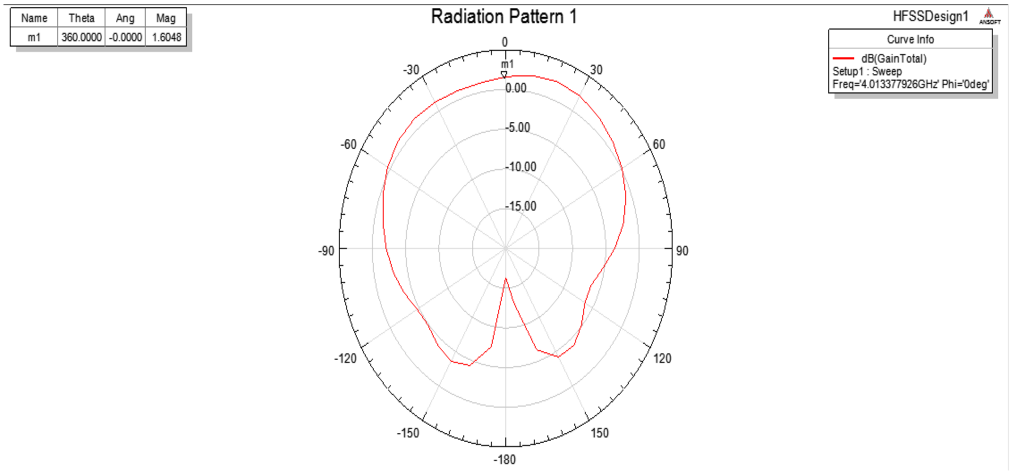


Figure3. Stimulated gain of antenna

Likewise, according to the Fig.8, when the slot length L_3 increases, the second resonance decreases, because the current paths increase. Furthermore, the variations of L_3 have a little effect on the third resonance. Optimum values of values of L_1=9mm and L_3=5mm are chosen for the optimal proposed antenna design.

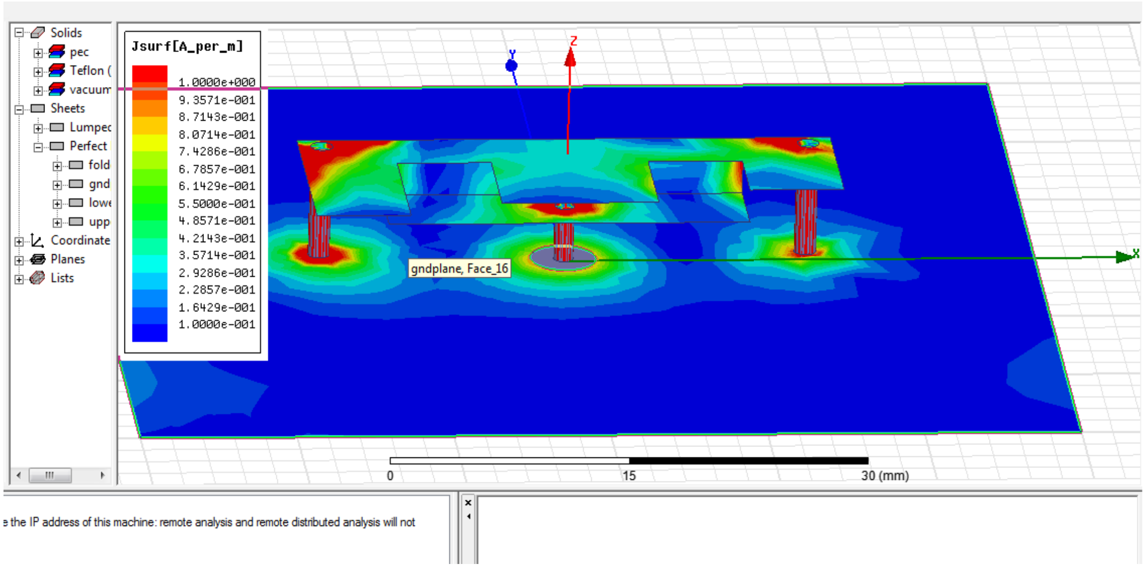


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Figure4. Current distribution of the proposed antenna at different frequencies

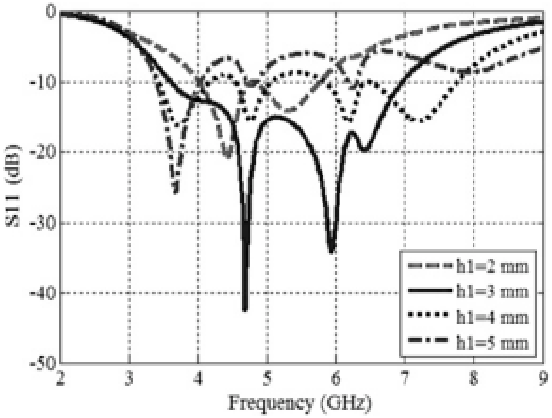

Figure 6 Simulated reflection coefficients for different Lengths for coaxial probe feed

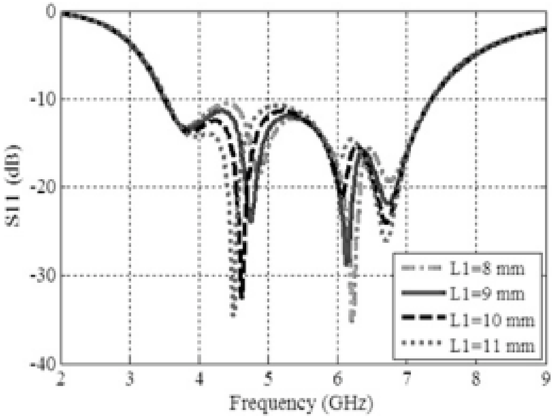

Fig.7. Reflection coefficients for different values of slot length L_1

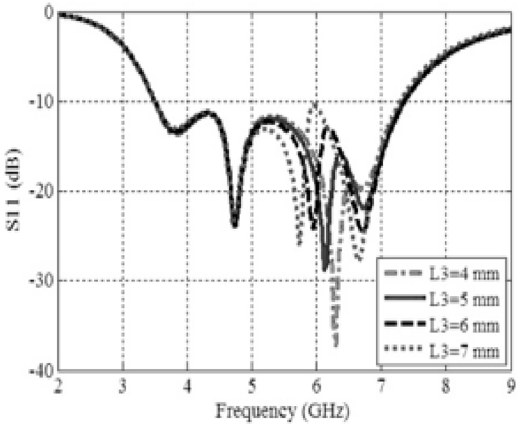

Figure 8 Reflection coefficients for different values length L_3

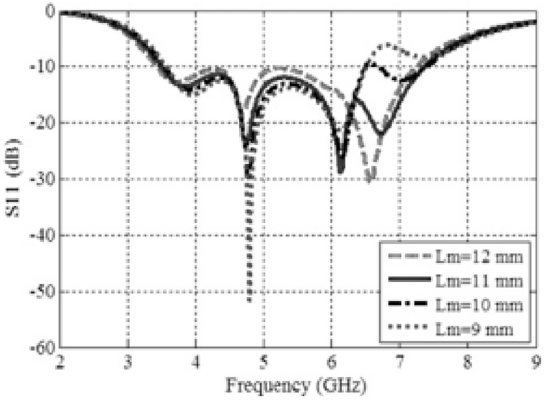

Figure 9 Reflection coefficients for different values of middle arm length L_m

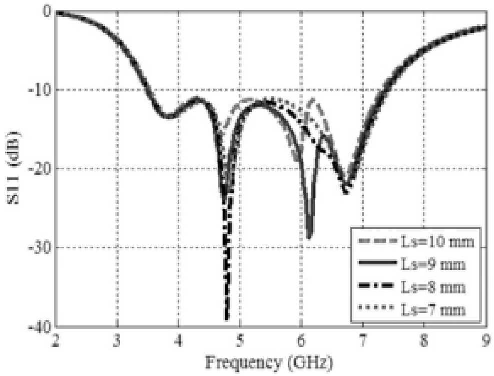

Figure 10 Reflection coefficient for different values of shorter arm length L_s

By the length of middle arm, L_m, of the upper patch the second resonance frequency can be mainly determined. As shown in the Fig.9. with an increase in L_m, the first and third resonance decreases, because the current paths prolong at these frequencies . In Fig. 10. the variations of the shorter arm L_s of the upper patch are shown. With an increase in L_s, as the current paths at these frequencies increase, the first and second resonances mainly decrease. Therefore, it is concluded that the third resonance is mainly determined by L_s .The optimum values for length of the middle and shoreter arms are 11 and 9 mm, respectively to achieve the optimal broadband operations.

ANTENNA DESIGN	**BANDWIDTH**	**POLARIZATION**
Square patch Antenna	**32.5%**	**Linear polarized**
E Shaped patch Antenna	**76.18%**	**Linear polarized**
E Shaped folded patch Antenna	**86.18%**	**Circularly polarized**

The modified E shaped folded patch antenna has an improvement in the bandwidth by 10% then the proposed antenna and 86.18% then the square patch antenna and CP is also achieved for the modified antenna with a axial ratio bandwidth of 2.2GHz and size of the antenna is reduced by 5% then the ESPA

IV.CONCLUSION

In this paper, a microstrip patch antenna with folded patch feed for UWB applications is designed, fabricated and tested to achieve bandwidth of 86.18% in 3.34-7.45 GHz. It consists of an asymmetric E-shaped patch fed by folded patch, which exictes three resonances for broadening the impedance bandwidth. Moreover, two shorting pins are used to reduced the size of an antenna. Impedance bandwidth performance are investigated through examining the behavior of the surface currents on the patch at three resonances. It is observed that the radiation patterns of the proposed antenna are nearly stationary within the bandwidth. An acceptable agreements is obtained with in the measured and simulated results. The effects of different key parameters are investigated to obtain optimised values of the proposed antenna.

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