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# Butterfly Shaped Printed Monopole Antenna for Ultra Wide Band Applications

**Vinit Tak, Anurag Garg, Aditya Pareek**

***Abstract:** In this paper, a microstrip line fed butterfly shaped monopole UWB antenna is proposed for wireless applications. The wings of butterfly shaped monopole antenna is formed by adding two rotated ellipse of same radius symmetrically placed about the centre of feeding line. The proposed antenna exhibits impedance bandwidth of 3.1-11.9 GHz which covers the whole ultra-wideband frequency range from 3.1-10.6 GHz. The performance is characterised in terms of VSWR, radiation patterns, impedance bandwidth and gain. The proposed antenna can be used for various UWB applications like high performance in noisy environment, low transmission power, cost effectiveness and large channel capacity.*

***Keywords-** Butterfly shaped monopole antenna, Ultra wide band, microstrip line, impedance, bandwidth*

## I. INTRODUCTION

The ultra-wideband (UWB) antennas are gaining huge attention to the researchers due to several advantages like large bandwidth, low power consumption and high data transmission rate, simultaneously there are various wireless systems that use antennas for transmitting and receiving information such as satellite communication, mobile communication, health care monitoring and many more. For this the size and shape of antennas have been a prominent issue. Microstrip antennas are low profit antennas of small size and weight and easily manufactured with economic considerations. UWB include high data rate, high bandwidth, low power consumption high security. UWB also consist radio communication technology that transmit pulse of very low energy for short duration it also includes less interference and power levels which are comparable to noise levels that is upto -41.3 dBm/MHz they also make the system secure enough because detection of noise signals is difficult, so transmission of extremely short duration pulses makes UWB operation quick and fast enough and enable it for many real time applications. In this paper, the microstrip line fed butterfly shaped printed monopole antenna is designed on flame retardant type-4 (FR-4) dielectric substrate for the performance analysis in terms of antenna parameters for ultra-wideband applications. Stepwise designing of butterfly shaped monopole antenna shown in section II. Simulated and fabricated results have been discussed in section V, section VI, section VII.

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## II. DESIGN OF PROPOSED ANTENNA

The Geometry of Proposed Butterfly shaped antenna is shown in the Fig 1. The desired antenna has been fabricated on FR-4 dielectric substrate, which is one sided copper laminated. The design of proposed antenna occurs various stages which are discussed in this section.

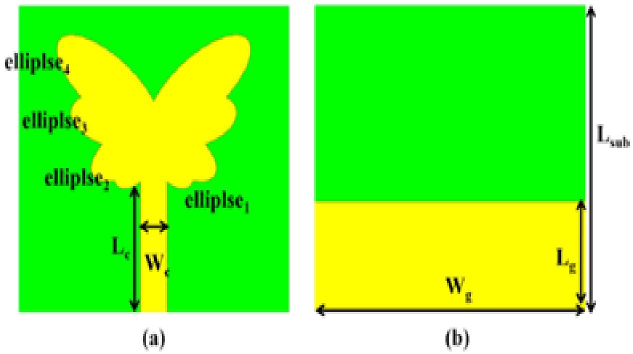


**Fig 1: Geometry of the proposed four arms butterfly shaped UWB antenna**

### A. *Proposed Antenna Design is Categorised in 4 Stages Mainly.*

**Stage 1: -** The wings of butterfly shaped antenna are formed by adding two rotated ellipses of same radius ($rad_i$) symmetrically as shown in Fig 2. In the consecutive of Fig 2(a), a single wing monopole antenna is designed by using rotated ellipses 1. The structure is supplied by a microstrip line, for this feeding purpose the width and length are $W_c$ and Lc taken which provide the suitable matching in terms of impedance. The overall size of the antenna is Lsub × Wg and ground plane size is Lg × Wg. It is resonating at 6.5 GHz and 10.9 GHz and formed a wide impedance bandwidth ranging 5.7-12.4 GHz.

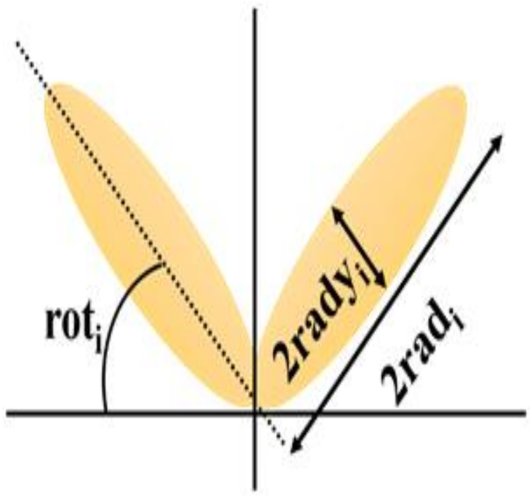


**Fig 2: The implementation of butterfly structure**

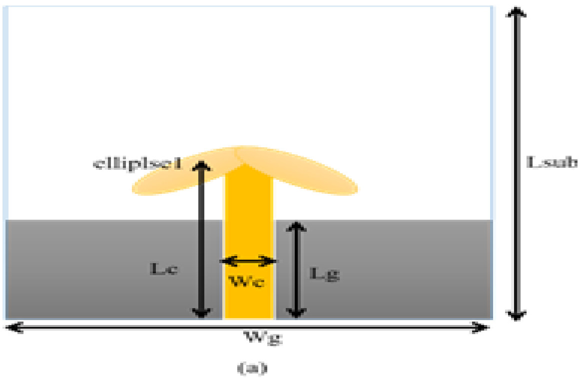


**Fig 2 (a): The implementation of rotated ellipse1 and feeding by microstrip line.**

**Stage 2: -** In Fig 2 (b). the two back rotated ellipses 2 added, the impedance bandwidth is reduced and upper resonance frequency of 10.9 GHz is shifted towards lower frequency side at about 9.6 GHz.

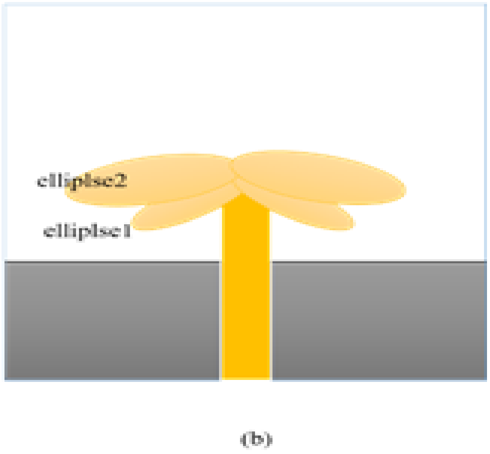


**Fig 2(b): Implementation of two back rotated ellipses 2**

**Stage 3:-** An ellipse 3 is added in Fig 2 (c) try to cover the UWB frequency range. After implementing an ellipse 3, the antenna is resonating at about 5 GHz and 10.1 GHz but the gap between frequencies is large. So, it is difficult to cover the UWB band.

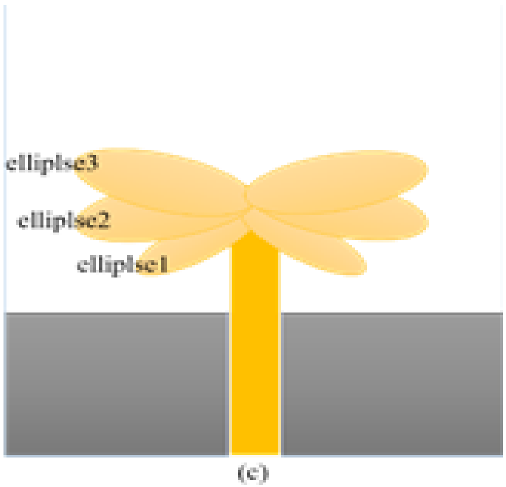


**Fig 2(c): Implementation of ellipses 3**

**Stage 4**: -An ellipse 4 is added in Fig 2 (c) as shown in Fig 2 (d). This structure can be called a butterfly shaped antenna. It provides the triple resonances at about 3.95 GHz, 8 GHz and 10.9 GHz. These three resonances are closely spaced and formed an impedance bandwidth of wide range that is ranging from 3.1 GHz to 11.9 GHz which covers the whole UWB band. The dimensions of the evolution stages of the antenna are summarized in Table 1.

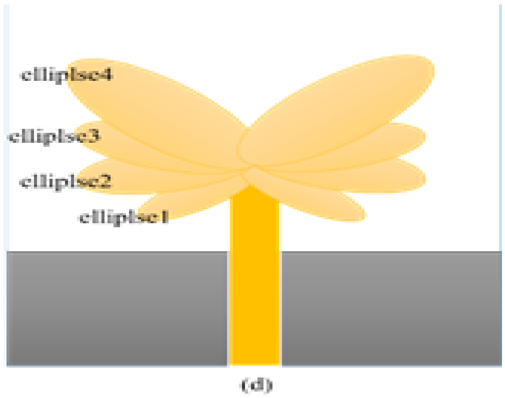


**Fig 2(d): Implementation of ellipses 4**

### *B.* Parameters of microstrip-fed butterfly shaped monopole antenna

For the simulation of desired butterfly shaped monopole antenna, the designing parameters are listed in Table 1

**Table 1: Designing Parameters for the proposed antenna**

| **Parameter** | **Value** |
|---|---|
| Dielectric constant | 4.4 |
| Substrate height | 1.524 mm |
| Ground plane length , Lg | 10mm |
| Ground plane width, Wg | 30mm |
| Feed line width, Wc | 2.9mm |
| Length of feed line, Lc | 16.6mm |
| Length of substrate, Lsub | 28 mm |
| Rad1 (ellipse 1) | 3.35 mm |
| Rady1 (ellipse 1) | 1.8 mm |
| Rot1 (ellipse 1) | -49deg |
| Rad2 (ellipse 2) | 4 mm |
| Rady2 (ellipse 2) | 2mm |
| Rot2 (ellipse 2) | -30deg |
| Rad3 (ellipse 3) | 4.9 mm |
| Rady3 (ellipse 3) | 2.5mm |
| Rot3 (ellipse 3) | 11 deg |
| Rad4 (ellipse 4) | 6.8 mm |
| Ratio4 (ellipse 4) | 2.8mm |
| Rot4 (ellipse 4) | 37deg |

## III. PARAMETRIC ANALYSIS OF SINGLE WING BUTTERFLY MONOPOLE PRINTED ANTENNA

In this section the parametric analysis for single wing butterfly antenna is presented The curve in between reflection coefficient and frequency at different stages is shown below The ellipse 1 radius (rad1), ellipse 1 vertical

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radius (rady1) and angle of rotation from *x*-axis of ellipse 1 (rot1) are taken and the performance is presented in terms of reflection coefficient parameters.

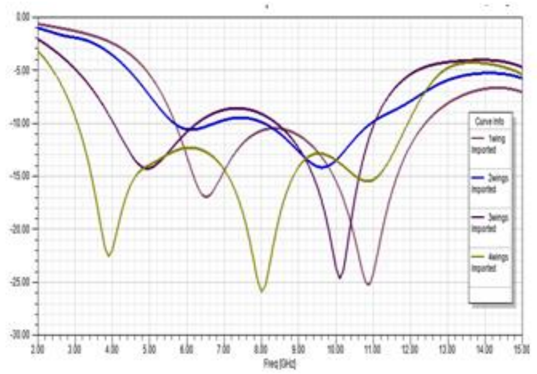

**Fig 3.1: |S11| parameters of the different evolution stages of butterfly shaped monopole antenna**

**a) Effect of radius of ellipse 1 (rad1)**

The variation effect in radius of the ellipse 1 (rad1) is shown in Fig 3.2. If the radius of the ellipse 1 is gradually increased from 3.5 mm to 5.5 mm, the reflection coefficient goes poor. From the results obtained from Fig 3.2, it is observed that at rad1 = 3.5 mm, the antenna provides the best impedance matching. The overall impedance bandwidth at rad1 = 3.5 mm is 5.8-11.3 GHz.

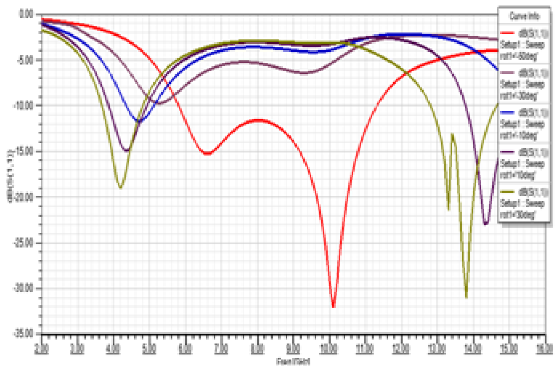

**Fig 3.2: |S11| parameters of variation in radius of ellipse 1 (rad1)**

**b) Effect of vertical radius of ellipse 1 (rady1)**

The variation effect in vertical radius of the ellipse 1 (rady1) is shown in Fig 3.3. When the vertical radius of the ellipse 1 is increased from 1.6 mm to 2.2 mm with a step size of 0.2 mm, the upper edge frequency of the antenna shifted towards upper side while the second resonance frequency affected. Overall the impedance bandwidth of the antenna is enhanced while vertical radius of the ellipse is enhanced. From the results as shown in Fig 3.3, it is observed that at rady1 = 1.8 mm, the antenna provides the best impedance matching.

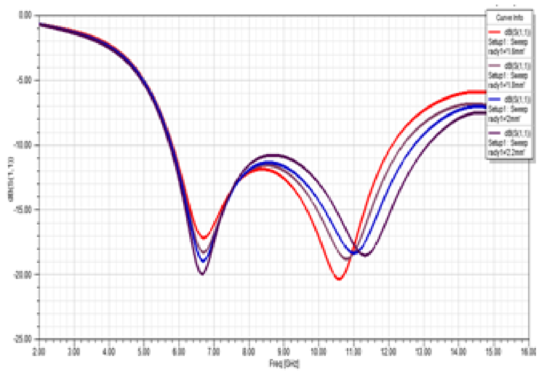

**Fig 3.3: |S11| parameters of variation in vertical radius of ellipse 1 (rady1)**

**c) Effect of rotation angle from x-axis of ellipse 1 (rot1)**

The effect of variation in rotation angle from *x*-axis of ellipse 1 (rot1) is shown in Fig 3.4. When the rotation angle of the ellipse 1 is changes then impedance matching goes worse. From the results as shown in Fig 3.4, it is observed that at rot1 = -50 deg, the antenna provides the best impedance matching

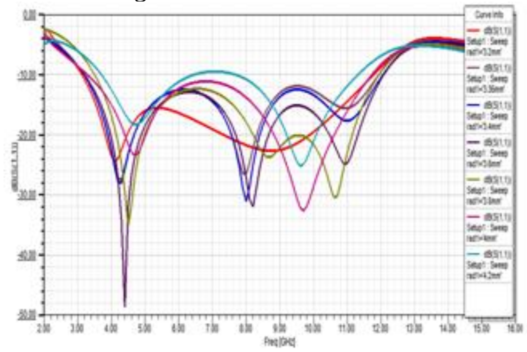

**Fig 3.4: |S11| parameters of variation in rotation axis from *x*-axis of ellipse 1 (rot1)**

## IV. PARAMETRIC ANALYSIS OF FOUR WINGS BUTTERFLY MONOPOLE PRINTED ANTENNA

The parametric analysis of four wings butterfly monopole printed antenna is presented in this subsection. The radius of ellipse 1 (rad1), rotation angle from *x*-axis of ellipse 1 (rot1), radius of ellipse 2 (rad2), rotation angle from *x*-axis of ellipse (rot2), radius of ellipse 3 (rad3), rotation angle from *x*-axis of ellipse 3 (rot3), radius of ellipse 4 (rad4), rotation angle from *x*-axis of ellipse 4 (rot4), are discussed and performance is presented in terms of reflection coefficient parameters. It is also observed that when all four wings are present then the effect of their vertical length ($rady_i$) is negligible and the results are not present here.

**d) Effect of radius of ellipse 1 (rad1) with four wings**

The effect of variation in radius of the ellipse 1 (rad1) with four wing is shown in Fig 4.1. When the radius of the ellipse 1 with four wings is increased from 3.2 mm to 4.2 mm, the reflection coefficient goes worse. From the results as shown in Fig 4.1, it is observed that at rad1 = 3.35 mm, the antenna provides the best impedance matching. The overall impedance bandwidth at rad1 = 3.5 mm is 3.1-11.9 GHz.

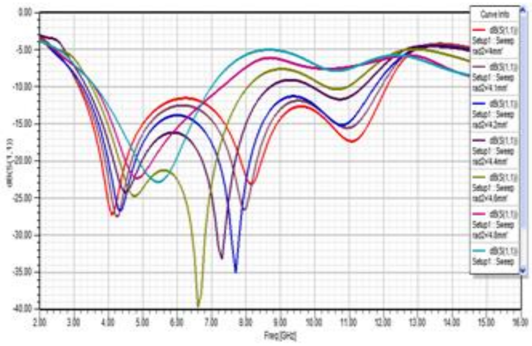

**Fig 4.1: |S11| parameters of variation in radius of ellipse 1 (rad1) with four wings**

### e) Effect of rotation angle from x-axis of ellipse 1 (rot1) with four arms

The effect of variation in rotation angle from *x*-axis of ellipse 1 (rot1) with four arms is shown in Fig 4.2. When the rotation angle of the ellipse 1 is changes from -55 degree to -45 degree with the step angle of 2 degrees then impedance matching goes worse. From the results as shown in Fig 4.2, it is observed that at rot1 = -49 degree, the antenna provides the best impedance matching.

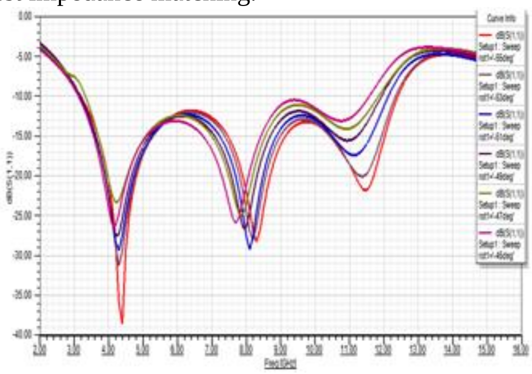

**Fig 4.2: |S11| parameters of variation in rotation axis from *x*-axis of ellipse (rot1)**

### f) Effect of radius of ellipse 2 (rad2) with four wings

The effect of variation in radius of the ellipse 2 (rad2) with four wing is shown in Fig 4.3. When the radius of the ellipse 2 with four wings is increased from 4 mm to 5 mm, the reflection coefficient goes worse and overall impedance bandwidth is reduced. From the results as shown in Fig 4.3, it is observed that at rad2 = 4 mm, the antenna provides the best impedance matching and maximum impedance bandwidth. The overall impedance bandwidth at rad2 = 4 mm is 3.1-11.9 GHz. In addition, it may also conclude that the impedance bandwidth of the butterfly antenna is controllable by the radius of the ellipse 2.

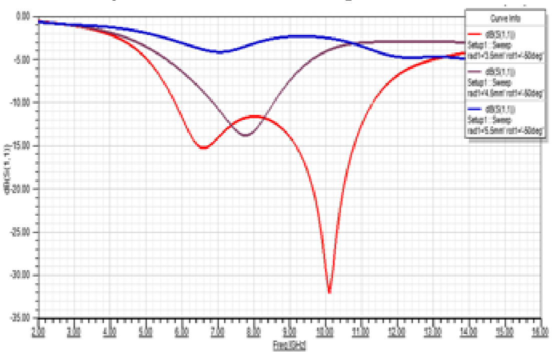

**Fig 4.3: |S11| parameters of variation in radius of ellipse 2 (rad2) with four wings**

### a) Effect of rotation angle from x-axis of ellipse 2 (rot2) with four arms

The effect of variation in rotation angle from *x*-axis of ellipse 2 (rot2) with four arms is shown in Fig 4.4. When the rotation angle of the ellipse 2 is changes from -35 degree to -25 degree with the step angle of 2 degrees then first and second resonances are almost same but upper edge frequency of the antenna changes. From the results as shown in Fig 4.4, it is observed that at rot2 = -31 degree, the antenna provides the best impedance matching.

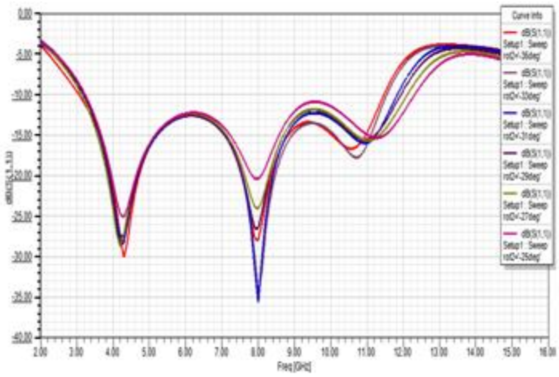

**Fig 4.4: |S11| parameters variation in rotation axis from x-axis of ellipse 2 (rot2)**

### g) Effect of radius of ellipse 3 (rad3) with four wings

The effect of variation in radius of the ellipse 3 (rad3) with four wing is shown in Fig 4.5. When the radius of the ellipse 3 with four wings is increased from 4.6 mm to 5.6 mm, the overall impedance bandwidth is reduced. From the results as shown in Fig 4.5, it is observed that at rad3 = 4.8 mm, the antenna provides the best impedance matching and maximum impedance bandwidth. The overall impedance bandwidth at rad3 = 4.8 mm is 3.1-11.9 GHz.

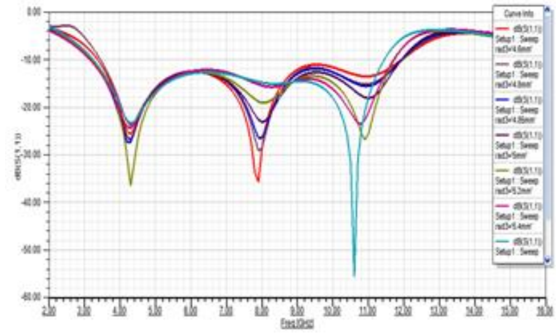

**Fig 4.5: |S11| parameters of variation in radius of ellipse 3 (rad3) with four wings**

### h) Effect of rotation angle from x-axis of ellipse 3 (rot3) with four arms

The effect of variation in rotation angle from *x*-axis of ellipse 3 (rot3) with four arms is shown in Fig 4.6. When the rotation angle of the ellipse 3 is changes from 5 degrees to 15 degrees with the step angle of 2 degrees then mainly first and second resonances are slightly shifted. The lower and upper edge frequency of the antenna is also changes. From the results as shown in Fig 4.6, it is observed that at rot3 = 11 degree, the antenna provides the best impedance matching.

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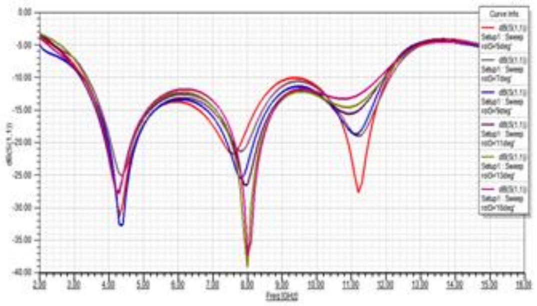

**Fig4.6: |S11| parameters of variation in rotation axis from *x*-axis of ellipse 3 (rot3)**

### b) Effect of radius of ellipse 4 (rad4) with four wings

The effect of variation in radius of the ellipse 4 (rad4) with four wing is shown in Fig 4.7. When the radius of the ellipse 4 with four wings is increased from 5 mm to 7 mm, the overall impedance bandwidth is enhanced. In addition, the lower edge frequency is shifted towards lower frequency side while the upper edge frequency shifted towards upper edge frequency. From the results as shown in Fig 4.7, it is observed that at rad4 = 6.8 mm, the antenna provides the best impedance matching and maximum impedance bandwidth. The overall impedance bandwidth at rad4 = 6.8 mm is 3.1-11.9 GHz.

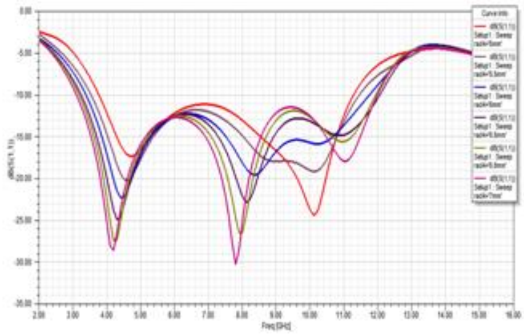

**Fig 4.7: |S11| parameters of variation in radius of ellipse 4 (rad4) with four wings**

### c) Effect of rotation angle from x-axis of ellipse 4 (rot4) with four arms

The effect of variation in rotation angle from *x*-axis of ellipse 4 (rot4) with four arms is shown in Fig 4.8. When the rotation angle of the ellipse 4 is changes from 30 degrees to 45 degrees with the step angle of 3 degrees then mainly first, second and third resonances are slightly shifted towards lower frequency side. From the results as shown in Fig 4.8, it is observed that at rot4 = 37 degree, the antenna provides the best impedance matching and impedance bandwidth 3.1-11.9 GHz.

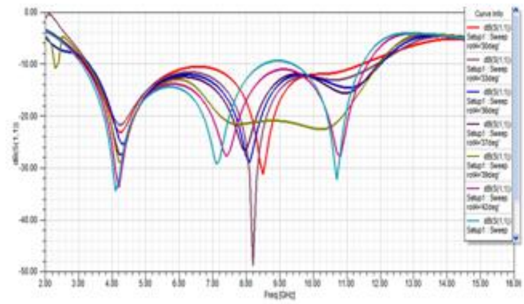

**Fig 4.8: |S11| parameters of variation in rotation axis from *x*-axis of ellipse 4 (rot4)**

## V. SIMULATED RESULTS

In the Fig 5.1, the simulated result of S-parameter (|S11|) against frequency for desired antenna is presented. The observed impedance bandwidth 3.1-11.9 GHz by simulation. It indicates that it is useful for UWB purpose. The obtained value in term of S parameter for butterfly shaped UWB antenna at 4.4 GHz is -37 dB and at 8 GHz is -32.50 dB. In the next sequence in Fig 5.2 voltage standing wave ratio is obtained of about less than 2 in the whole UWB frequency range. The gain against frequency of the butterfly shaped UWB antenna is simulated and realized in Fig 5.3. The gain variation which is realized for this antenna is 1 dBi to 4 dBi lies in UWB band. In the next level Fig. 5.4 shows about the simulated 2D radiation patterns of the compact butterfly shaped UWB antenna at some resonance frequencies lies in UWB frequency range.

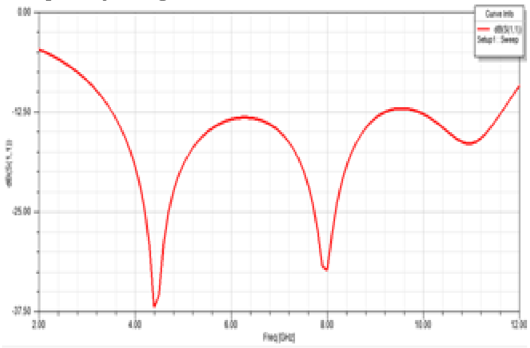

**Fig 5.1: |S11| parameter for four arms butterfly shaped proposed UWB antenna**

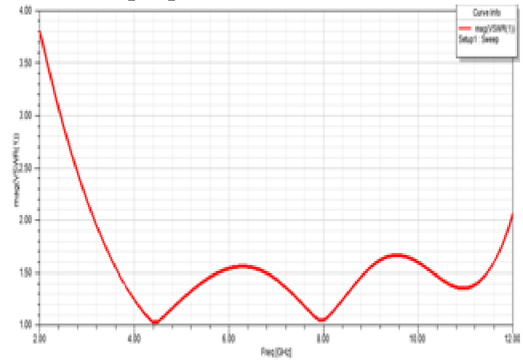

**Fig 5.2: VSWR pattern for the proposed four arms butterfly shaped UWB antenna**

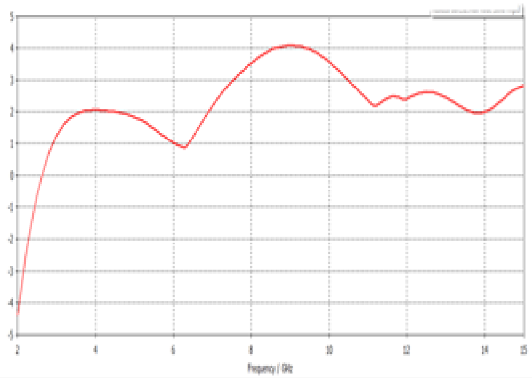

**Fig 5.3: Realized gain pattern for proposed four arms butterfly shaped UWB antenna**

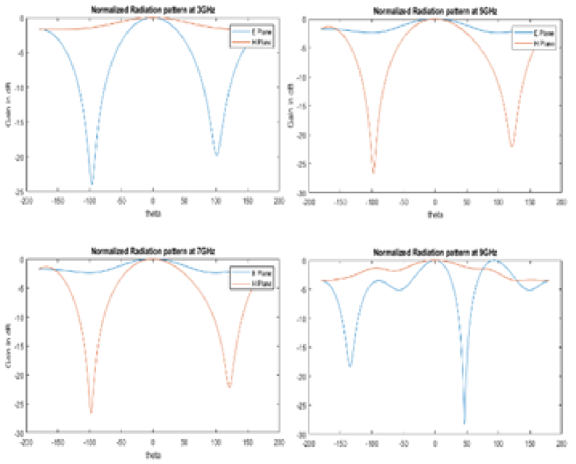


**Fig 5.4: 2D radiation patterns of the proposed four arms butterfly shaped UWB antenna**

## VI. FBARICATED RESULTS AND DISCUSSION

The fabricated structure of the proposed four arm butterfly shaped antenna is displayed in Fig 6.1, The photograph measured result using vector network analyser is displayed in Fig 6.2, the measured $S_{11}$ parameter result shown in Fig 6.3 indicates that the impedance bandwidth is 3.9-14.5 GHz which shows good matching.

**Fig 6.1: Fabricated design of four arm butterfly shaped antenna**

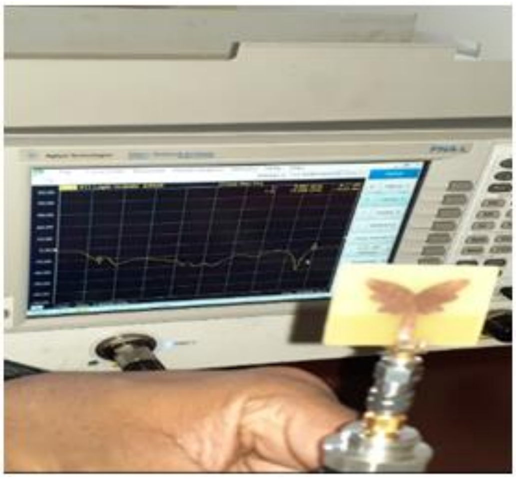

**Fig 6.2 VNA result during testing of proposed antenna**

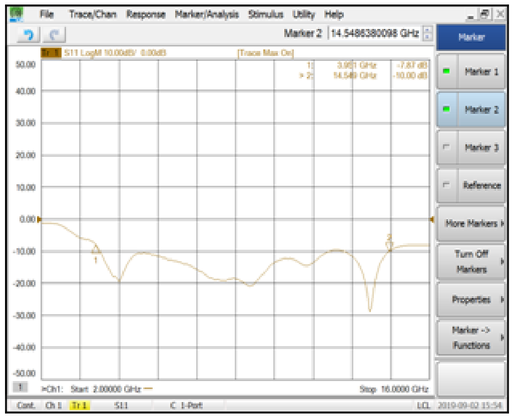

**Fig 6.3: $S_{11}$ parameter result of four arm butterfly shaped antenna**

## VII. EXPERIMENTAL RESULT DISCUSSION

In the given Table 2 Result analysis of simulated and fabricated antenna are summarized.

**Table 2: Discussion of experimental result**

| S.No | Antenna Design | Frequency range covered by Simulated Antenna | Frequency range covered by Fabricated Antenna |
|---|---|---|---|
| 1 | Butterfly shaped Monopole | 3.1-11.9 GHz | 3.9-14.5 GHz |

The above table shows that the fabricated and simulated results are closed enough and matched so the fabricated antenna is suitable for the required purpose for UWB application.

## VIII. CONCLUSION

In this paper, the development of butterfly shaped monopole antenna for UWB application is presented. From the simulation and fabricated result, it can be concluded that the designed butterfly shaped monopole antenna is suitable for the UWB application because the impedance bandwidth 3.1-11.9 GHz is obtained which cover the whole ultra-wideband frequency range that ranging from 3.1-10.6 GHz. The variation in realized gain for required antenna is 1 dBi to 4 dBi which resides in the UWB band so the proposed butterfly shaped monopole antenna is meaningful.

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