Three Different Compact Elliptical Slot Ultra -Wide band Antennas for Wireless Communication Applications

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Abstract —From this current paper, 3 separate elliptical slotted ultra- wide band (UWB) antennas are being proposed. These antennas have been designed with a standard PCB design process to be capable of integrating with radiofrequency or microwave circuitry. Two designs were presented in which the initial design comprised a half circular ring radiator and the remaining one considers a half elliptical ring radiator. The third design of the radiator is in the shape of a crescent. The impedance bandwidth of all these presented antenna designs varies from 2.5GHz and reaches to 14GHz with a S11 less than -10GHz. Here, every proposed antenna design also has a consistent radiation pattern across its frequency band of interest. The performance of the antenna is impressive for lower band frequency in UWB system, which differs in a range of 3.1GHz to 5.1GHz. Across the whole frequency band the antenna shows a 10db return loss bandwidth. The antenna is fabricated on RT-duroid substrate and fed with 50 Ω coupled tappered transmission line.

Index Terms—Printed Ckt. Board (PCB), crescent, elliptical, slot antenna, Ultra-wideband (UWB) Antenna, circular ring

I. INTRODUCTION

In nation-wide communication of the modern times, these ultra-wideband systems having a wide frequency allocation (3.1GHz to 10.6GHz) has gained a lot of interest [1]. As the antenna of the UWB system is a pivotal part which has consistent (stable) and Omni-directional radiation pattern, High radiation efficiency, low profile, constant gain and low group delay thus, having many applications [2]. The antenna is constructed using various structures including one, which is based on printed monopole antenna (PMA) having advantages of ease of integration, ease of manufacturing, light weight and inexpensiveness. In general, PMA configurations consist of microstrip-fed structure or an elliptical or circular coplanar waveguide (CPW) fed slot [3]. By making certain slots in ground plane these structures are to be modified into multiband antennas. We can add one more band to the antenna's bandwidth range by making this slot. These device structures exhibiting this behaviour are known as Band-Notch slot antennas [2]. For making a multiband antenna, in [4] a Hexogonal and Octagonal slot, in [5] elliptical slot and in [6] a cone slot is to be incised on the ground plane. By making using of a square ring resonator, the band-notch behaviour can be upgraded as shown in [7] and [8].

Low profile, easy manufacturing, light weight and a broad frequency bandwidth, due to these appealing benefits, printed slot antennas are now considered for application in UWB systems. Antenna can be made either by making use of a DGS and CPW feeding structure [9]-[11] or a microstrip line [12]-[15]. Round-corner rectangular-slot antenna is to be etched into a substrate of dimensions 68 mm × 50 mm is useful for obtaining a 6.17GHz frequency 10dB bandwidth [1]. To improve the bandwidth of microstrip line-fed wide slot antenna, a fork like tuning-stub is employed. A bandwidth of 1.1 GHz (1.821 to 2.912 GHz) was produced and a gain variation lower than 1.5 dBi (3.5 to 5 dBi) across the whole operational band. A bandwidth of 60% can be produced by a Coplanar Wave Guide (CPW) fed square-slot with a broadened tuning stub [14]. The proposed antenna of dimensions 72mm × 72mm and also its gain in the operational band has a range of 3.75 to 4.88dBi. A CPW fed rectangular-slot antenna having a substrate with dimensions 100 mm × 100 mm is able to contribute a bandwidth of 110% and a gain which varies from 1.9 – 5.1dBi [15]. The bandwidths of the antennas have been proven that they couldn't cover the entire FCC specified UWB frequency band 3.10 – 10.60 GHz. Furthermore, the antenna's size is not sufficiently small. Considering the report given by FCC in 2002 [16], there has been a noticeable interest in UWB systems and their application particularly in personal wireless communication. Currently for different UWB applications, we are discussi ng about two innovatively designed printed crescent or circular or elliptical slot antennas are presented and are being fed by microstrip line. The results of both simulation and experiment are in good agreement. And also both have proved that the presented antennas are capable of showing UWB characteristic with almost omni-directional patterns of radiation across the whole bandwidth. In addition, these antennas are of a smaller size than those presented in [17]-[19].

Antenna is a fundamental component for the effective performance of UWB systems. The demand for antenna designers has notably increased to design smaller components with wider bandwidth and also high speed,

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high data rate wireless transmission. Many aspects to be observed in designing the UWB antenna which include ultra-wideband performance of the impedance matching, i.e. good Omni-directional radiation pattern, stable gain and small size. In comparison to patch antennas, slot antennas hold better properties like having a wide impedance bandwidth, good isolation and low copper loss. The principal reason to consider slot antennas is to increase the impedance bandwidth and the widened elliptical slot serves this very purpose.

Every simulation mentioned in this paper was performed with Ansoft HFSS package in which the Finite Element Method (FEM) Technique is used for electromagnetic computation [20].

II. Antenna Geometry

If we have the values of the substrate parameters f_o, h and ε_r, we can use the transmission line model to measure the length and width of antenna (size). The range of frequencies for UWB communication systems varies from 3.1GHz to 10.6GHz. FR4 Epoxy and RT-Duroid of dielectric constants 4.4 and 2.2 respectively are the materials chosen for the design and the resonant frequency is set at 2.8GHz for our design. The length, width and height of the dielectric substrate are selected as 1.575mm, 0.78mm and 1.6mm respectively.

III. Elliptical Slot Antenna with Circular Radiator

TABLE I: OPTIMIZED DIMENSIONS OF CIRCULAR RADIATOR PARAMETERS IN MM

Device Sides	L	W	L1	W1	S
Measurement (mm)	45	45	12.4	3	1.4
Device Sides	R1	R2	B	A	D
Measurement (mm)	4.5	11	19	9.6	31.2

Fig. 1 shows the geometrical configuration of the Circular radiator elliptical slot antenna. RT5880 substrate (thickness h = 1.575 mm, tan δ = 0.0009 and ε_r = 3.38) was used to design and construct the antenna. An elliptical slot is to be etched in to the ground plane of the circuit board of the antenna which also constitutes a microstrip line having a half circular-shaped ring stub for exciting. The elliptical area of the slot is 2A x 2B mm^2. A microstrip line of 50 Ω impedance (Length L = 10mm and Width W = 4.3mm) is used for exciting the antenna. From Fig. 1, we see that the radiator is a half circular-shaped radiator. The inner and outer radii (R1 and R2) along with extrusion depth (S) are the only required parameters for the radiator. A full-wave Electromagnetic simulator was utilized for an optimization process because of the stability of substrate at high frequencies. The process resulted in the following optimized dimensions mentioned in Table I.

A. *Design of Elliptical Slot Antenna with Circular Radiator*

Area of the circular radiator =

$$\left(\frac{\pi R_2^2 - \pi R_1^2}{2}\right) - \left(2 \times S \times (R_2 - R_1)\right)$$
$$= 143.5014$$

Area of the etched ground

$$\pi(2A)(2B) = 2293.0286$$

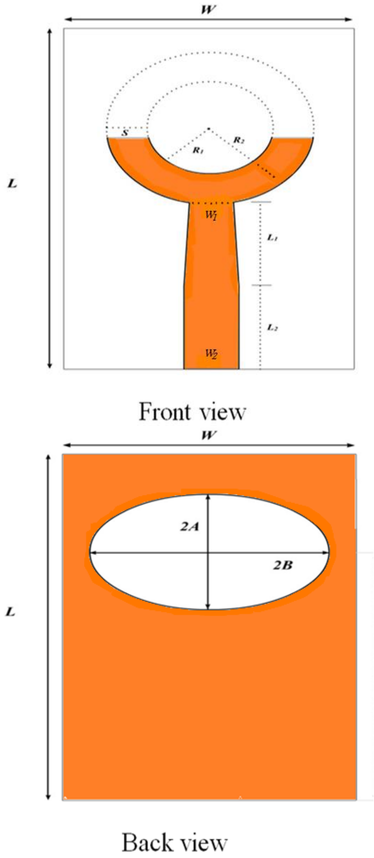


Fig. 1. Geometrical configuration of the elliptical slot antenna with circular radiator (front and back view)

B. *Simulation Results*

Ansoft HFSS was utilized to create the simulation of the antenna and the results obtained are shown below.

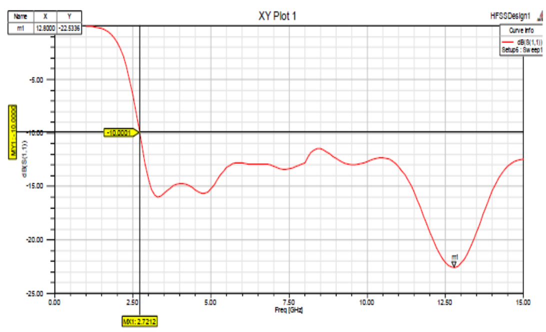


Fig. 2. S11 curve of the circular radiator elliptical slot antenna

The measured values of the S11 in the simulation has been plotted against the frequency of proposed circular radiator antenna as represented in Fig. 2. As per the resulting data we observe that the value of return loss is -23.53dB at 12.8GHz and range between 2.72 GHz to 15GHz, it is below -10dB with both HFSS. It covers entire UWB range.

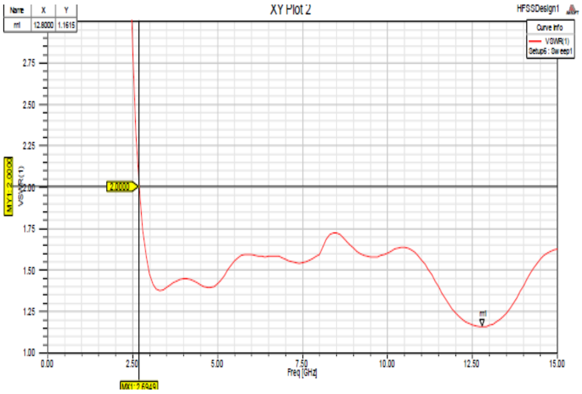


Fig. 3. VSWR of circular radiator elliptical slot antenna.

The VSWR at less than 2 during the range between 2.72 GHz to 15 GHz is shown in Fig. 3.

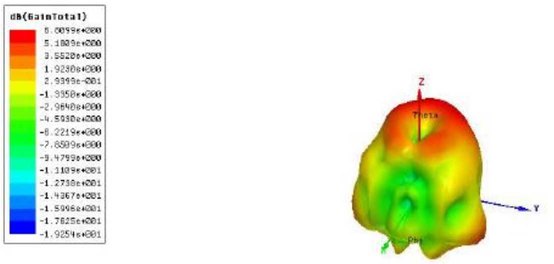


Fig. 4. Gain of circular radiator elliptical slot antenna

Fig. 4 the obtained gain curves in boresight ($\theta = \pi$) angle. It is obvious that the antenna gain is nearly stable across the entire frequency band calculated as 6.809dB.

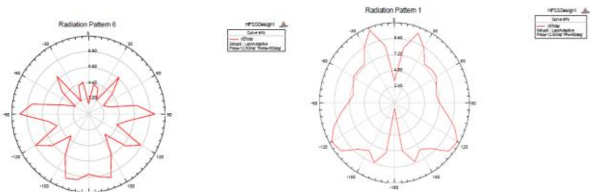


Fig. 5. E-plane & H-plane radiation patterns.

C. Measured Results

Fig. 6.a shows the prototypes of the fabricated microstrip antenna that operates at UWB range

Fig. 6 a. Fabricated Elliptical slot antenna with circular radiator.

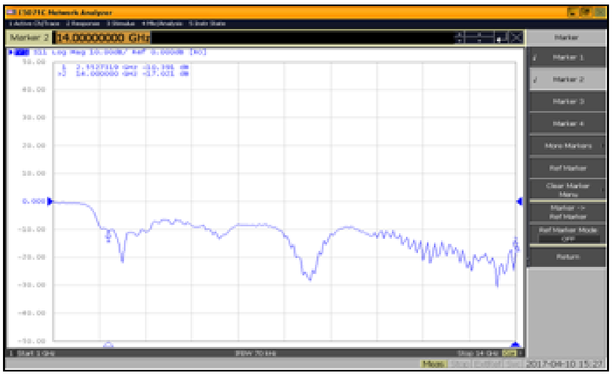


Fig. 6 b. Measured Return loss Curve of the Elliptical slot antenna with circular radiator.

The E5071C vector network analyzer has been used to measure the return losses of the three antennas. The graph of simulated and calculated return loss has been plotted. The Table IV represents the 10 dB bandwidths of the three antennas. Return Loss of circular radiator is figure 6.b. It is obtained as -10.33dB at 2.55GHz and -17.02dB at 14.00GHz and also covers UWB range and VSWR is measured as 1.88 at 2.55GHz and1.33 at 14.00 GHz shown in Fig. 7.

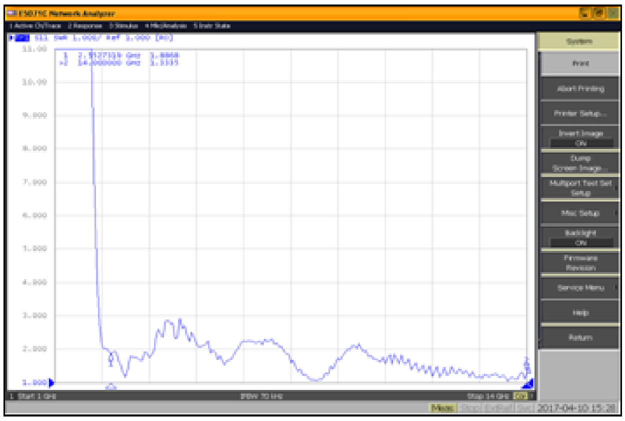


Fig. 7. Measured VSWR of the proposed antenna design.

IV. Elliptical Slot Antenna with Crescent Radiator

Here is a prototypical design for the second antenna namely the elliptical slot antenna with crescent radiator has been presented in Fig. 8. A microstrip line of impedance 50 Ω (length L = 45 mm, width W = 45 mm) along with a tapered line (length L1, width W1) have been used for exciting the antenna. A crescent-shaped ring stub is used as the radiator which has 3 dimensional measurements: Inner and Outer radii (R1 and R2) and also its Extrusion depth (S). A full-wave Electromagnetic simulator was utilized for an optimization process which has resulted in the following optimized dimensions formatted in Table II.

A. Design of Elliptical Slot Antenna with Crescent Radiator

Intersection diameter h = 2r - S = 15.35

Area of the crescent radiator

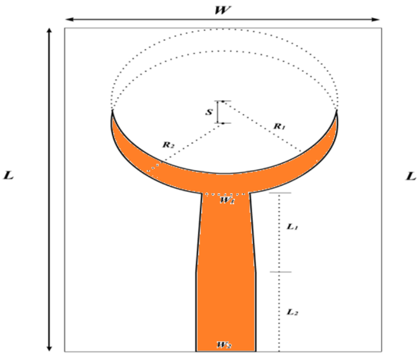
$$= \pi r^2 - 2r^2 \cos^{-1}\left[1 - \frac{h}{2r}\right] + 2\sqrt{rh - \frac{h^2}{4}}\left(r - \frac{h}{2}\right)$$

$= 144.041$

Area of the etched ground = $\pi(2A)(2B) = 2293.0286$

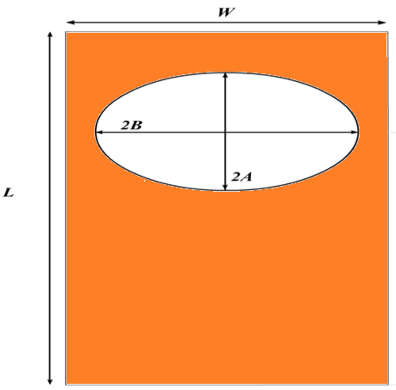
TABLE II: OPTIMIZED DIMENSIONS OF PROPOSED CRESCENT RADIATOR PARAMETERS (UNITS: MM)

Device Sides	W.	L.	W_1.	L_1.	S.
Measurement (mm)	45	45	3	12.5	6.65
Device Sides	R_1.	R_2.	A.	B	D
Measurement (mm)	11	11	9.5	20	31.2



Front view

(a)



Back view

(b)

Fig. 8(a): Front-View: Geometry and configuration of the proposed Elliptical slot antenna with crescent radiator. (b): Back View: Geometry and configuration of the proposed Elliptical slot antenna with crescent radiator.

B. Simulation Results

Fig. 9 and Fig. 10 depict the reflection coefficient of designed antenna with the dimension of table II. From the figure, the antennas bandwidth is acquired as 11dB over the whole UWB range. Simulated return loss curve obtained by HFSS shows that the antenna exhibits a bandwidth of 11GHz (from 2.6 GHz to 13.6 GHz) which covers the entire UWB range.

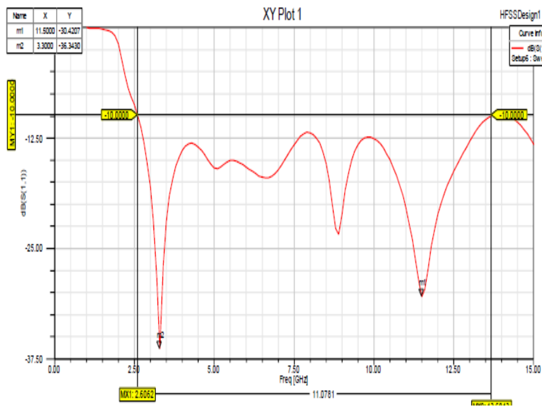


Fig. 9. Reflection coefficient S11 of the proposed antenna design.

Return loss is -36.3430dB at 3.3GHz and range between 2.6GHz and 13.684GHz i.e., 11.0781 GHz band width lies below -10dB 13.684 GHz lies below 2 (see Fig. 11)

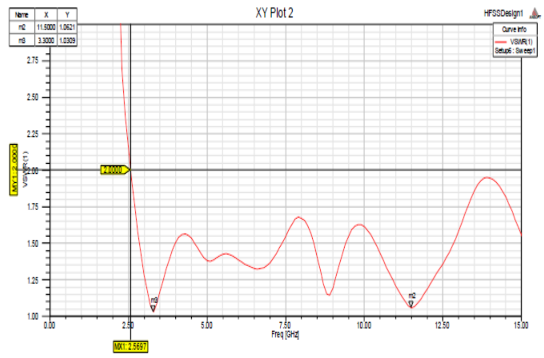


Fig. 10. VSWR of the proposed antenna.

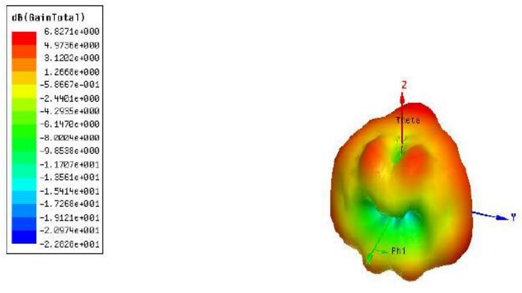


Fig. 11. Gain of the designed device.

The maximum gain of proposed device is 6.8271dB.

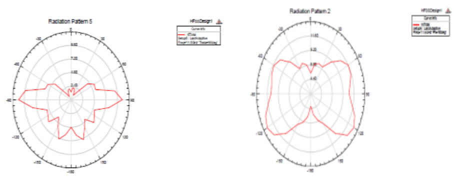


Fig. 12. E-plane & H-plane radiation of device.

Fig 12 depicts the radiation pattern at distinct frequencies for the E-& H-planes simulations. It has to be taken into account that this antenna manifests donut shaped radiation patterns and good Omni-directional radiation patterns in E- & H-planes respectively.

C. Measured Results

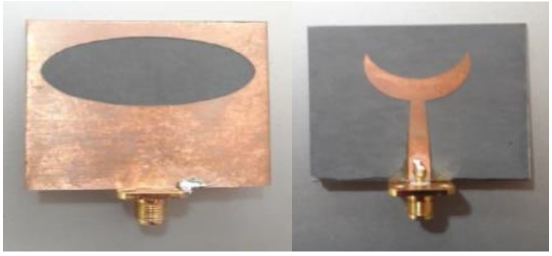


Fig. 13. Fabricated elliptical slot antenna with crescent radiator.

An E5017 vector network analyzer was used to calculate the return losses of the three antennas(see Fig. 13). A return loss curve has been plotted for the elliptical slot antenna with crescent radiator which is shown in Fig. 14 and its bandwidth has been compared with the different antennas in Table IV. Return Loss as is-16.42dB at 13.38GHz and -51.12dB at 7.8GHz and the range between 2.72 GHz to 13.68 GHz, it is below -10dB (see Fig. 15).

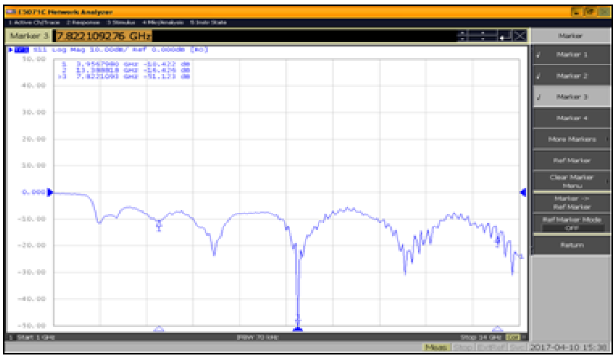


Fig. 14. Measure S11 of the proposed device.

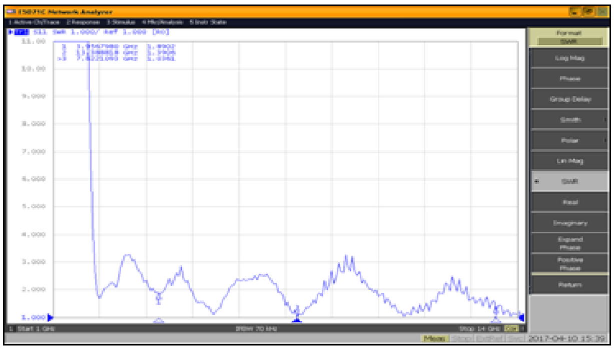


Fig. 15. Measured VSWR of the proposed antenna design.

VSWR is 1.28 at 13.38GHz and 1.54 at 7.8GHz.

V. Elliptical Slot Antenna with Elliptical Radiator

Fig. 16 illustrates the geometrical layout of elliptical slot device with an elliptical radiator. For the excitation of the antenna, a half elliptical-shaped ring stub has been incorporated into in its design, which has five dimensional measurements: The outer major diameter (Rx), inner major diameter (Rxi), outer minor diameter (Ry), inner minor diameter and its extrusion depth (S). Electromagnetic simulator was utilized for an optimization process which has resulted in the following optimized dimensions formatted in Table III.

A. Design of Elliptical Slot Antenna with Elliptical Radiator

Area of the elliptical radiator

$$\frac{4\pi R_x R_y - 4\pi R_{xi} R_{yi}}{2} = 619.96$$

Area of the etched ground

$$\pi(2A)(2B) = 2293.0286$$

TABLE III: Optimized Dimensions of Proposed Elliptical Radiator Parameters (Units: mm)

Parameter	W	L	W_1	L_1	S	D	R_x	R_y	R_{xi}	R_{yi}	A	B
Value (mm)	45	45	3	12.4	1.4	31.2	11.68	10.5	3.43	7	9.6	19

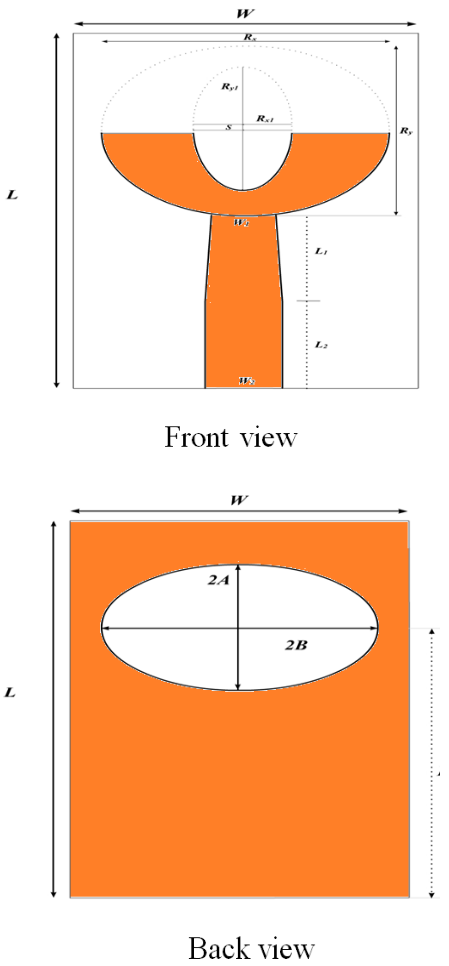


Fig. 16. Front-View and back-view: Geometry of the elliptical slot antenna with elliptical radiator

B. Simulation Results

Return loss as is-23.5336dB at 12.8GHz and lies below -10dB range between 2.72 GHz and 15 GHz. (see Fig. 17-Fig. 18).

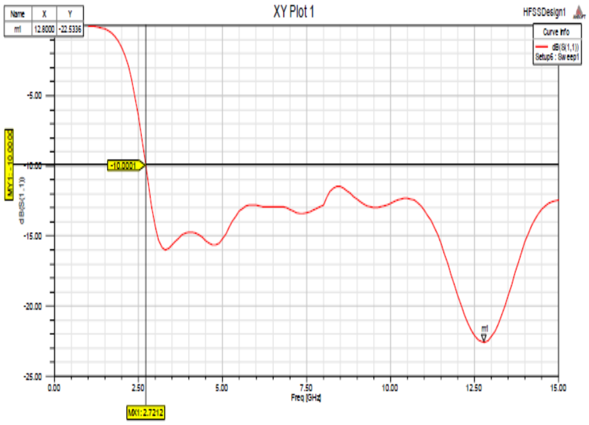


Fig. 17. S11-Reflection coefficient of the proposed device.

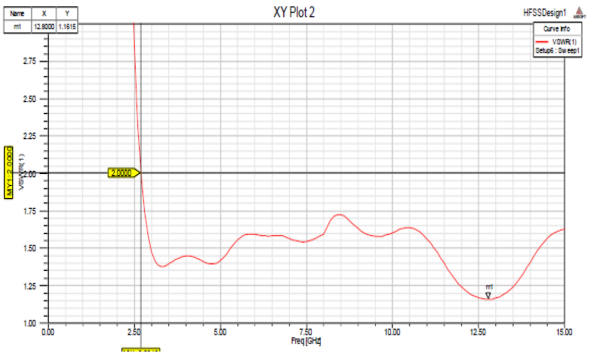


Fig. 18. VSWR of the proposed device.

The measured gains of the elliptical slotted device with elliptical radiator antennas are depicted in Fig. 19. It is observed that the measured maximum gain of this antenna is 5.62 dB (see Fig. 20).

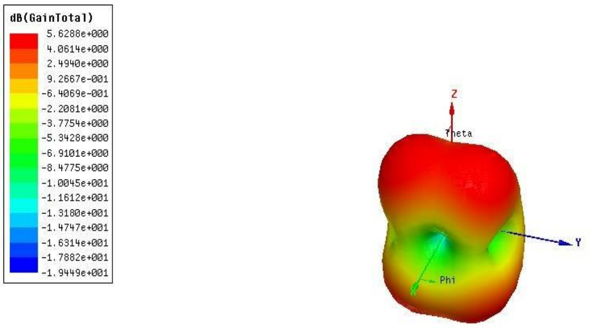
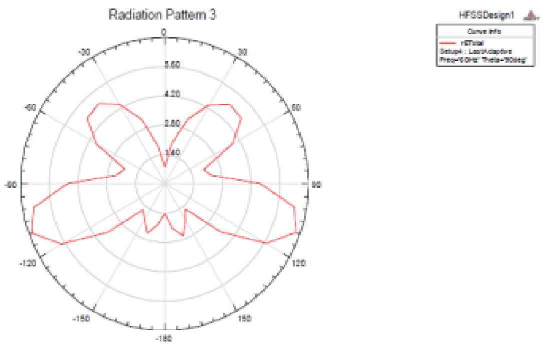


Fig. 19. Device gain.



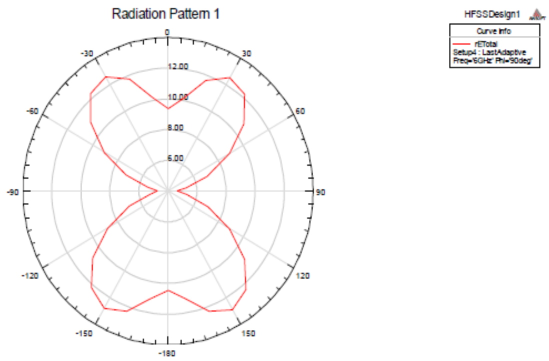


Fig. 20. Simulation radiation pattern results for proposed antenna E & H-planes.

C. *Measured Results*

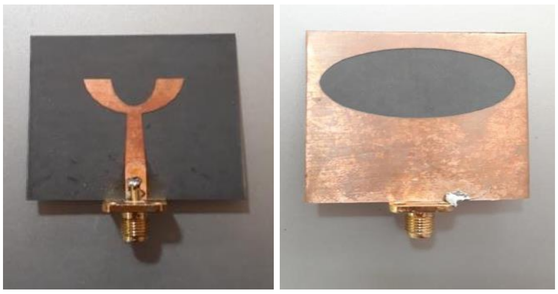


Fig. 21. Fabricated elliptical slotted antenna with elliptical radiator.

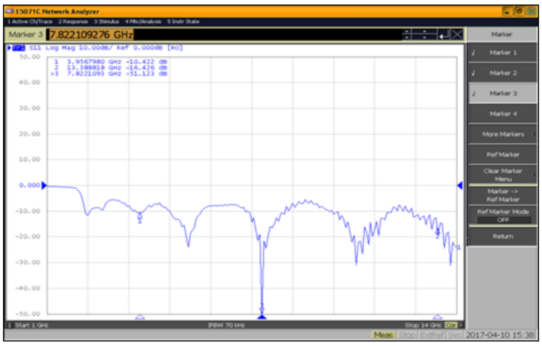


Fig. 22. Measured S11 of the Elliptical slotted antenna with elliptical radiator.

The return losses of the Elliptical slot antenna with Elliptical radiator were determined using an E5071C vector network analyzer. The return loss curves obtained by the simulation are represented in Fig. 17. The 10 dB bandwidths of the 3 antennas are formatted in Table VI.

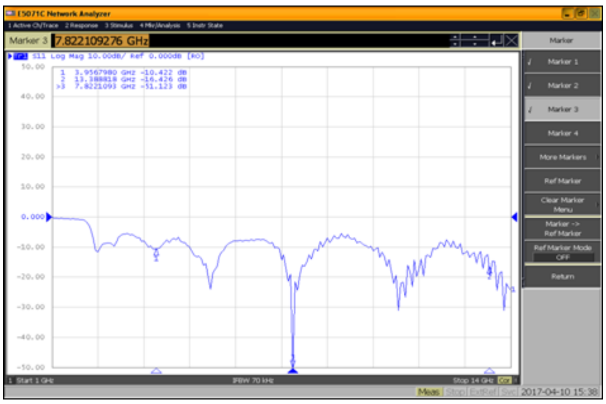


Fig. 23. VSWR of the elliptical slot antenna with elliptical radiator.

Antenna Resonated at -10.42dB at 3.95GHz,-51.12 dB at 7.02GH and -16.42dB at 13.38GH(see Fig. 21- Fig. 23).

VSWR image of Elliptical Slot elliptical radiator antenna < 2.

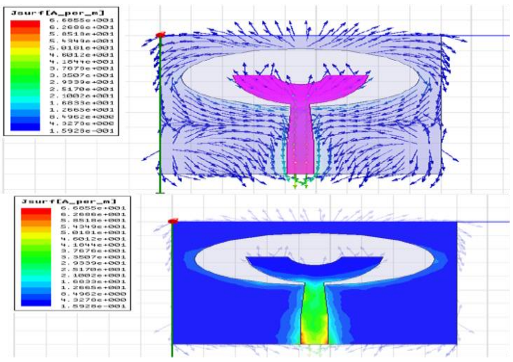
TABLE IV: COMPARISON BETWEEN ALL 3 TYPES OF ANTENNAS

Elliptical Slotted Antenna	Band width (GHZ)	Return loss (dB)	VSWR	GAIN (dB)
With Circular Radiator (€r=3.38 & h=1.575mm)	2.5 to 14 (11.5GHZ)	<- 10dB	< 2	6.80
With Crescent Radiator (€r=3.38 & h=1.575mm)	3 to 14 (11GHZ)	<- 10dB	< 2	6.82
With Elliptical Radiator (€r=3.38 & h=1.575mm)	2.5 to 14 (11.5GHZ)	<- 10dB	< 2	5.62

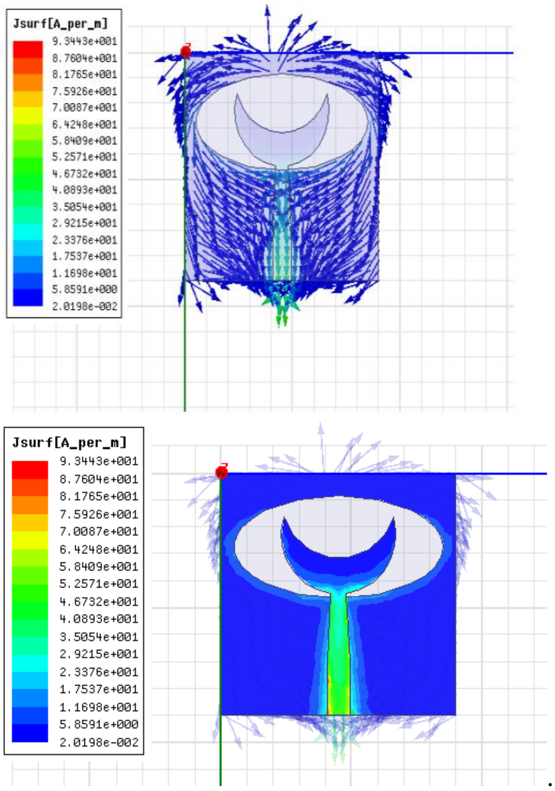
VI. CONCLUSION

We have explored the various techniques to design an elliptical slot antenna with 3 separate radiators. Through the basis of the discussed processes, a compact antenna was developed which has an extensive return loss of 10dB and bandwidth widely ranging from 2.75GHz to over 11GHz (up to 14GHz. The antenna exhibits directive properties to be specific it provides a gain more than 3dB across the necessary UWB range. Through some experiments it has been inferred that the antenna can transmit narrow pulses with no distortion. 3 prototypical antennas have been presented for UWB application.

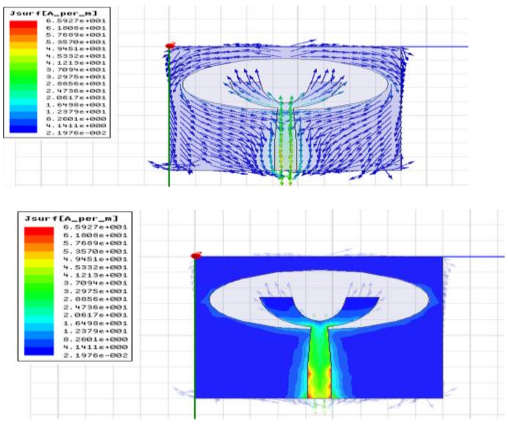
APPENDIX A
CURRENT DISTRIBUTION OFELLIPTICAL SLOT ANTENNA WITH CIRCULAR RADIATOR



APPENDIX B
CURRENT DISTRIBUTION OFELLIPTICAL SLOT ANTENNA WITH CRESENT RADIATOR



APPENDIX C
CURRENT DISTRIBUTION OFELLIPTICAL SLOT ANTENNA WITH ELLIPTICAL RADIATOR



CONFLICT OF INTEREST

We are declaring that there are no conflicts between the corresponding author and co-author.

AUTHOR CONTRIBUTIONS

The first author K. S Chakradhar conducted the research; and analyzed the data to this work, simulated the proposed antenna using Software, conducted Experimental set up for measuring the results, the co author Dr. V. Malleswara Rao examine the simulation and mesured results and wrote the paper. Both authors had approved the final version.

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