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MODIFIED PLUS SHAPED CIRCULAR SLOTTED UWB MICROSTRIP PATCH ANTENNA FOR WIRELESS APPLICATIONS

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Abstract: In this article a modified plus shaped circular slotted ultrawide band (UWB) microstrip patch antenna for wireless applications is designed and developed. The design process is carried out by taking rectangular patch antenna of size 21 x 15 x 1.6 mm^3 with resonant frequency 4.5 GHz as the basic design to achieve and optimize the proposed antenna. The proposed design gives a close approximation of the ultrawide band range from 3.05 - 10.5 GHz and resonates at 4.5 GHz with -10 dB simulated return loss and bandwidth of around 99.33% (3.05 - 10.5 GHz) of UWB range. Antenna design simulation is from HFSS software, fabricated on FR-4 substrate of ε_r=4.4, height h=1.6 mm and tangent loss δ=0.01. The fabricated antenna is measured using Agilent E8362B vector network analyzer and an isolated anechoic chamber setup. The optimized, simulated and measured results like return loss S_{11}, VSWR, radiation pattern and gain are analyzed and validated for close approximation. The presented antenna can be utilized for various wireless applications like 3.6 / 4.9 / 5 / 5.9 GHz WiFi, 3.41 / 3.49 GHz LTE, 3.5 / 5.5 GHZ WiMAX, 4.2 - 4.4 GHz Radio Altimeter, 5.2 / 5.8 GHz WLAN, 7.05 - 7.075 GHz Satellite Radio Uplink, 5.15 - 5.35 GHz HiperLAN and 3.3 / 3.4 GHz 5G applications.

***IndexTerms* - Patch, HFSS, UWB, S_{11}, VSWR, FR-4**

I. INTRODUCTION

Wireless communication is a rapidly growing field for information exchange and become the integral part of modern-day lifestyle. The advances in wireless communication developed many useful wireless appliances like smart phones, Worldwide Interoperability for Microwave Access (WiMAX), Wireless Local Area Network (WLAN), Wireless Fidelity (WiFi), Bluetooth, Global System for Mobile Communication (GSM), Long Term Evolution (LTE) and many more [1, 2]. Wireless communication uses UWB technology for more advantages like less power requirement, increased operating speed, less interference, and high resolution. Designing an antenna to these systems to determine the performance in terms of efficiency, data transfer rate and compactness is a big challenge. A compact antenna with good radiation pattern, less cross polarization, and wide bandwidth has one of the research issues for wireless applications like portable devices, remote sensing, and radars. Many antennas have been developed and implemented for UWB range from 3.1 GHz to 10.6 GHz [3, 4]. In recent time antenna design on fractal theory has become more popular due to advantages like miniaturization, wide band operation, and repeatability. Fractal shapes are more attractive in reducing the antenna size using space filling, self-similarity and self-similarity properties. Generally, we need specific antenna for specific application. Consider Bluetooth operates 2.4 GHz, and WIMAX at 5.2 GHz. Hence, we use different antennas for both of them, and may use an array of antennas to obtain required gain and directivity. So, it is necessary to replace different antennas for different applications with a single antenna for almost all the wireless applications. Design of ultra-wideband, high gain and precise antenna to cover most of the ultra-wideband wireless applications is the objective of this work. Simultaneous bandwidth enhancement and reduction of antenna size is the major design consideration of the proposed work.

Bandi Alekhya et al. [4] proposed the design of millimetre-wave reconfigurable antenna for 5G applications. The overall dimension of the antenna is 30 mm × 23 mm, meets 98% efficiency. The measured and simulated results are very close to each other, suitable for 5G devices. The proposed antenna finds its useful in wearable WBAN applications. The designed antenna 1 provides bandwidth of 94.17% from 4.13 - 11.48 GHz and the antenna 2 provides 98.22% from 3.57 - 10.46 GHz maintaining VSWR<2 and moderate level of gain.

Nagabhushana H M et al. [2] presented a novel S shaped wide band patch antenna with split ground for digital multimedia broadcasting and LTE applications. The proposed antenna of 30 mm x 34 mm x 1.6 mm is developed using FR-4 substrate on a split or defected ground. The tested and simulated results are parallel to each other. suitable for digital multimedia broadcasting and LTE. The designed antenna provides the wide frequency range from 3.38 – 7.3 GHz with VSWR<2 and appreciable level of gain.

Harikrishna Paik et al. [5] explains a miniaturized fractal antenna with square ring slots for ultrawideband applications. The designed antenna shows excellent performance with return loss below −10 dB in the wide operating band of 4.2 GHz to 13.6 GHz. The antenna characteristics are optimized to achieve ultra-wideband characteristics.

Modified plus shaped circular slotted microstrip patch antenna is proposed in this work. The shape of the antenna is evolved from several iterations on the basic rectangular patch of size 21 x 15 x 1.6 mm. The designed structure is simulated with HFSS software, fabricated using FR-4 substrate of $\varepsilon_r = 4.4$, height h = 1.6 mm and tangent loss 0.01. The fabricated antenna is measured using Agilent E8362B vector network analyzer and an isolated anechoic chamber setup. The optimized, simulated and measured results of return loss, VSWR, gain and radiation pattern are analyzed and validated for close approximation.

II. PROPOSED ANTENNA DESIGN

The proposed antenna is developed with five iterations as represented in the figure 1. Optimal results were achieved in the 5th iteration. The designed structure is simulated with HFSS simulator, fabricated on FR-4 substrate of $\varepsilon_r = 4.4$, height h = 1.6 mm and tangent loss $\delta = 0.01$.

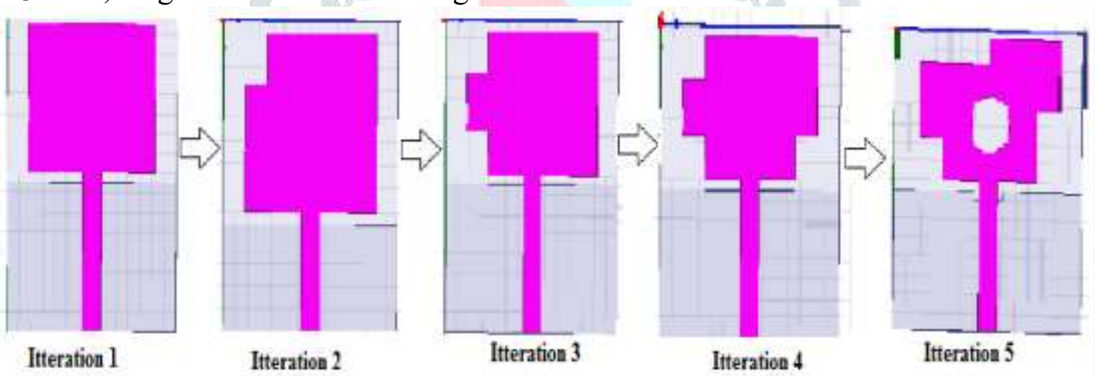

Figure 1: Evolution of the antenna

Fabricated antenna is tested using Agilent E8362B vector network analyzer and an isolated anechoic chamber setup. The optimized, simulated and measured results like S_{11}, VSWR, radiation pattern and gain are analyzed and validated for close approximation. The patch and ground surface of the patch antenna with complete dimensions are depicted in the figure 2. Detailed dimensions of the patch, substrate, feed, slots and ground structure are tabulated in the table 1. The reduction in the size of antenna is about 41.38% by etching slots on the patch and ground surface. The optimized structure of the proposed design gives a close approximation of the ultra-wideband range from 3.05 GHz - 10.5 GHz. The optimal design of the modified plus shaped circular slotted microstrip patch antenna has the following dimensions. The slot lengths $L_1 = 5.5$ mm, $L_2 = 2.5$ mm, $L_4 = 4.5$ mm, $L_3 = 5.5$ mm, $L_6 = 7.5$ mm, $L_5 = 3.5$ mm, radius of the circle R = 3 mm, feed length $L_f = 16$ mm, feed width $W_f = 3$ mm, substrate width $W_s = 28$ mm, substrate length $L_s = 32$ mm and height of the substrate h = 1.6 mm.

Figure 2 Patch view and Ground of the antenna

Table 1: Dimensions of the Antenna

Parameter	**Specifications**	**Dimensions (mm)**
Patch	Rectangle (Basic Patch)	21 x 15
	Three Rectangular Slots on the patch	Slot 1 = 5.5 x 2.5
		Slot 2 = 5.5 x 4.5
		Slot 3 = 3.5 x 7.5
	Circular Slot on the Patch	3 mm (Radius)
Feed	Microstrip Line feeding	3 x 16
Substrate	FR4(ε_r = 4.4, δ = 0.01)	28 x 32 x 1.6
Ground Plane	Partial Ground	28 x 15
	Slot on the Ground Plane	2 x 4
Overall Size(Before Slotted)	1259 mm^2	Reduction in Size 41.38%
Overall Size(After Slotted)	521.01 mm^2	

The partial ground [6] dimensions with length L_g = 15 mm and width W_g = 28 mm and a small rectangular slit on the ground plane 2 x 4 mm is etched to match the impedance. The radiation mechanism and resonance has been analyzed in both numerically and experimentally to study the impact of various antenna parameters on its performance. The parametric study is also conducted to finalize the antenna. The tested radiation patterns of the antenna are studied to meet its applications in compact wireless devices. Dimensions of the ground plane are not much affecting the resonant frequency but helps in impedance matching.

III. RESULTS AND DISCUSSIONS

The designed antenna gives an ultra-wideband frequency from 3.05 GHz - 10.5 GHz with 99.33% efficiency. The simulation results of radiation pattern, return loss, gain, VSWR and the surface current distributions are represented from the figures 3 to 10.

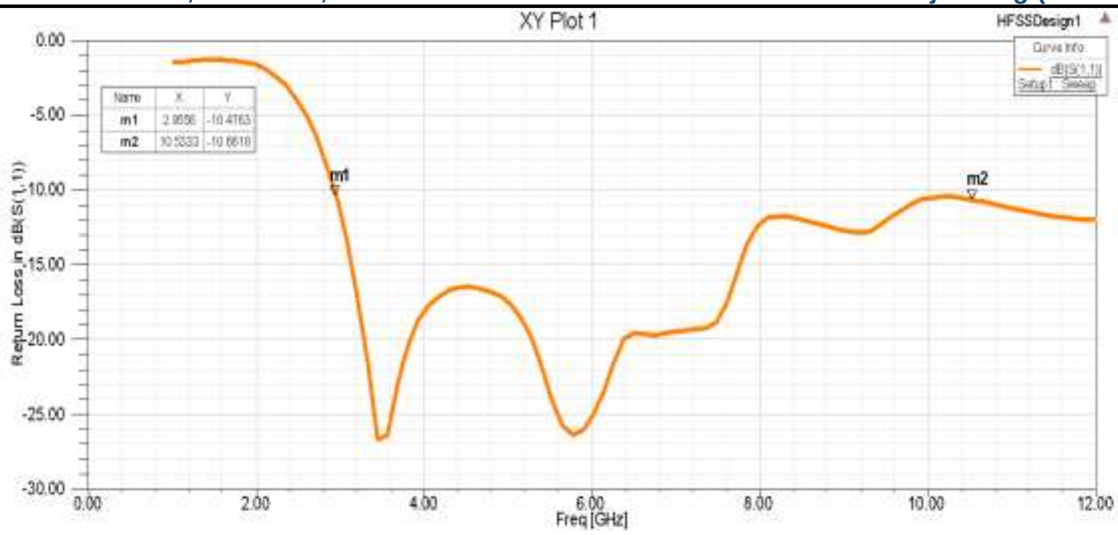

Figure 3: Simulation result of return loss

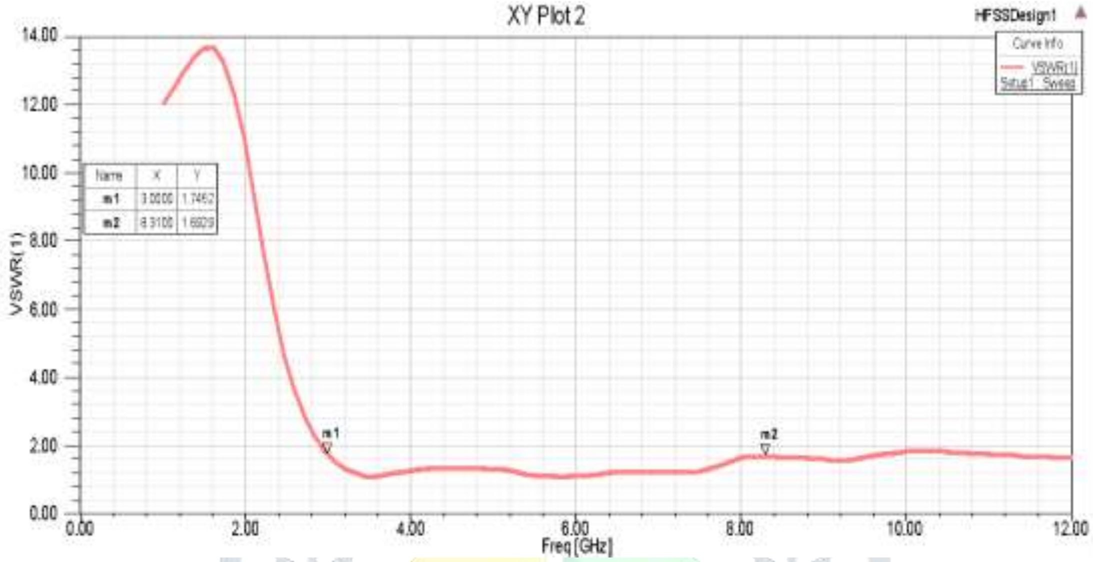

Figure 4: Simulation result of VSWR

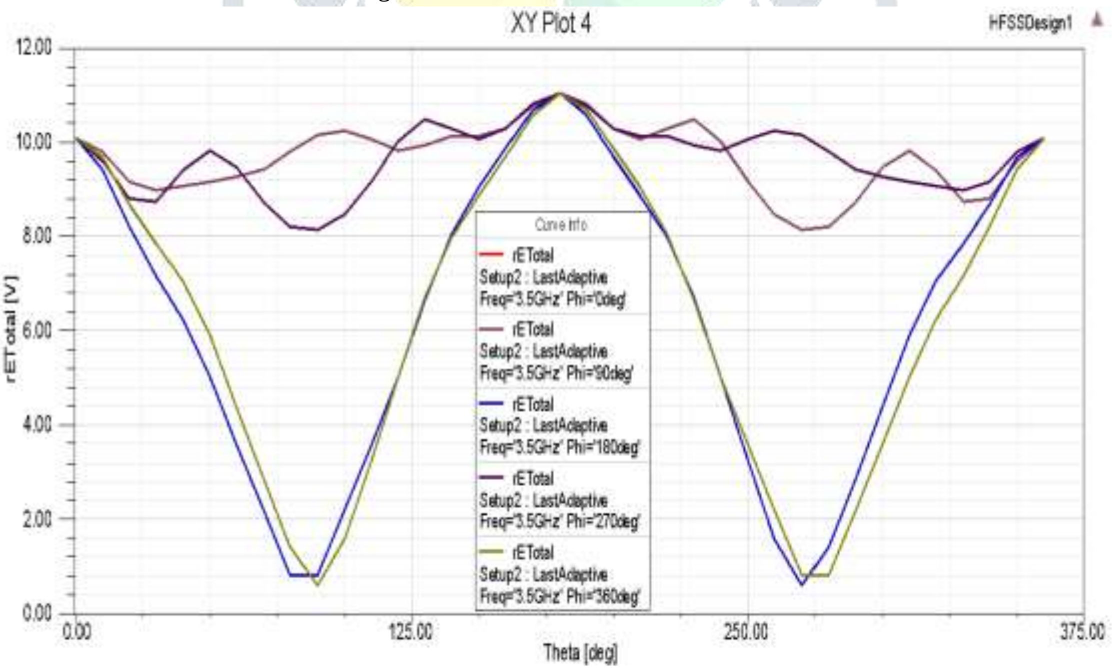

Figure 5: Simulation result of gain at 3,5 GHz

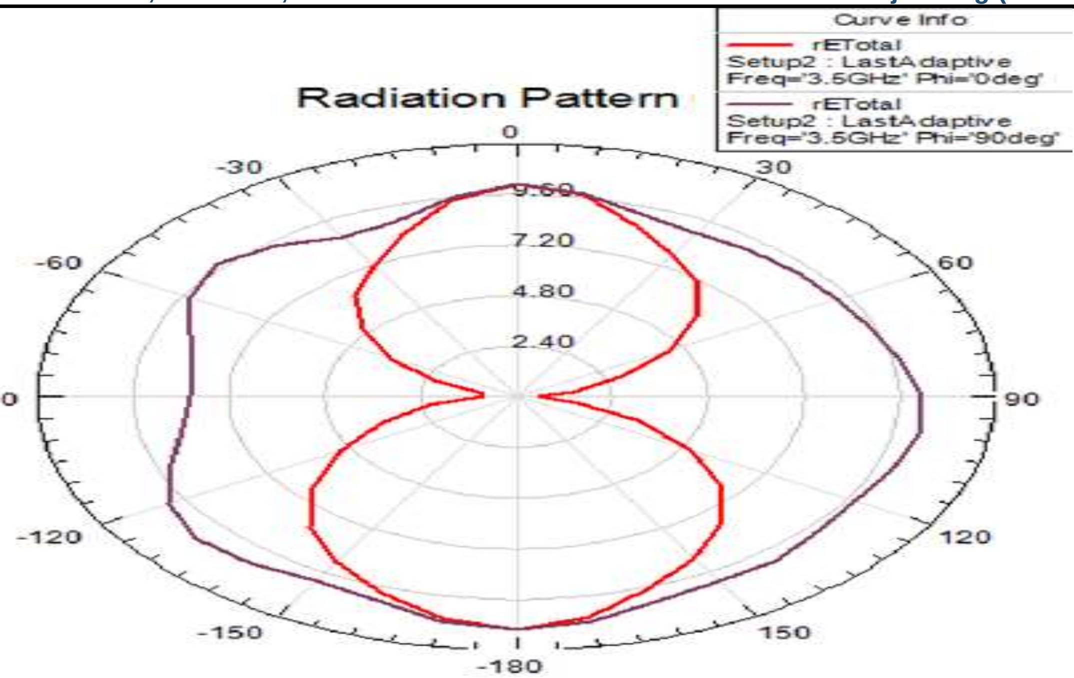

Figure 6: Simulated radiation pattern at 3.5 GHz

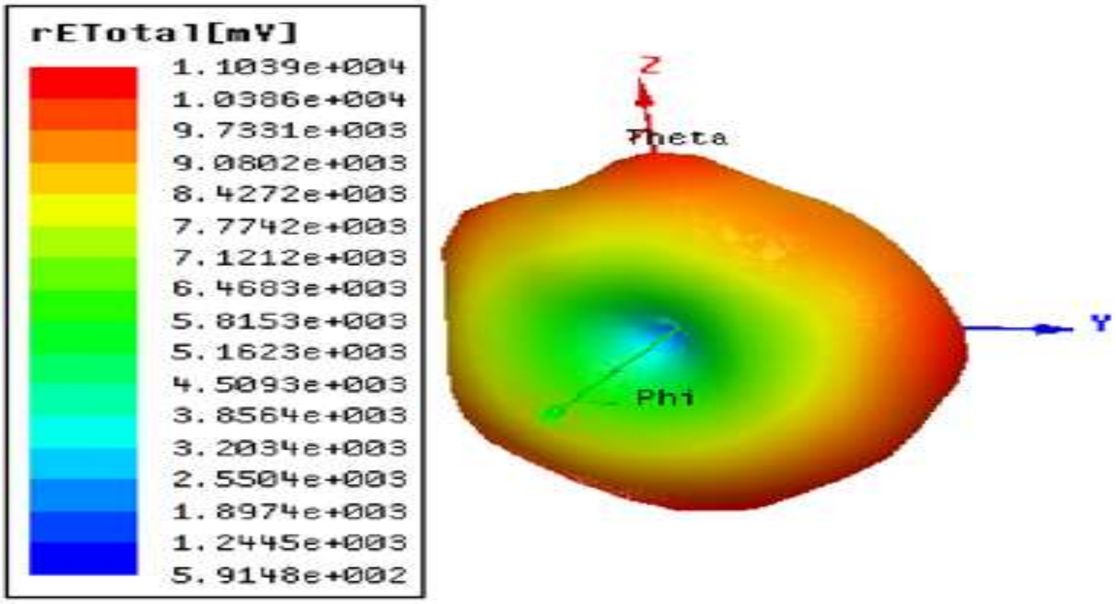

Figure 7: 3-D Simulated plot of radiation pattern

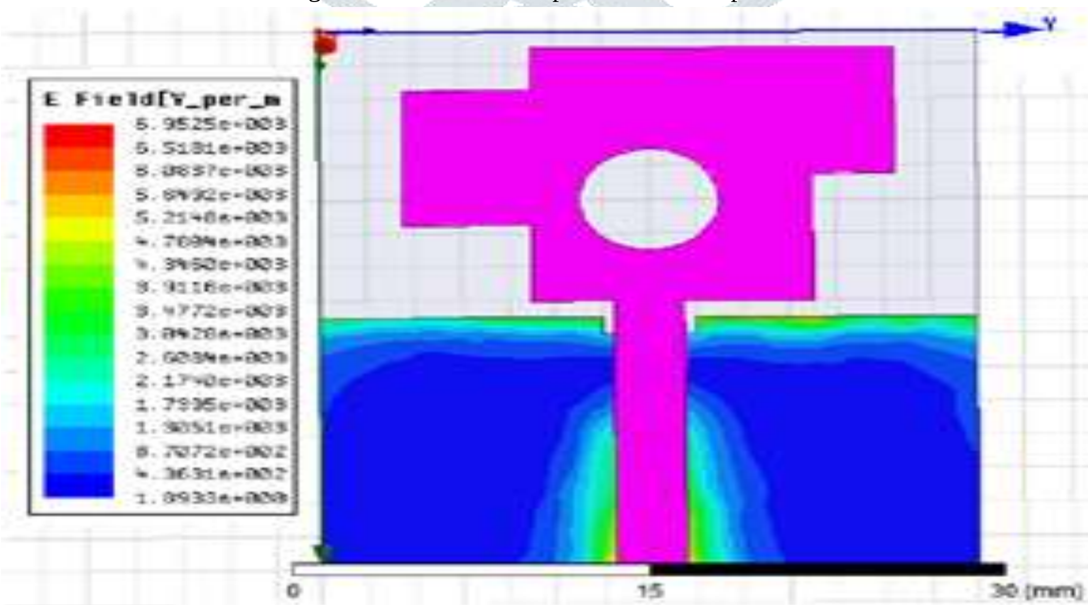

Figure 8: Electric field distribution

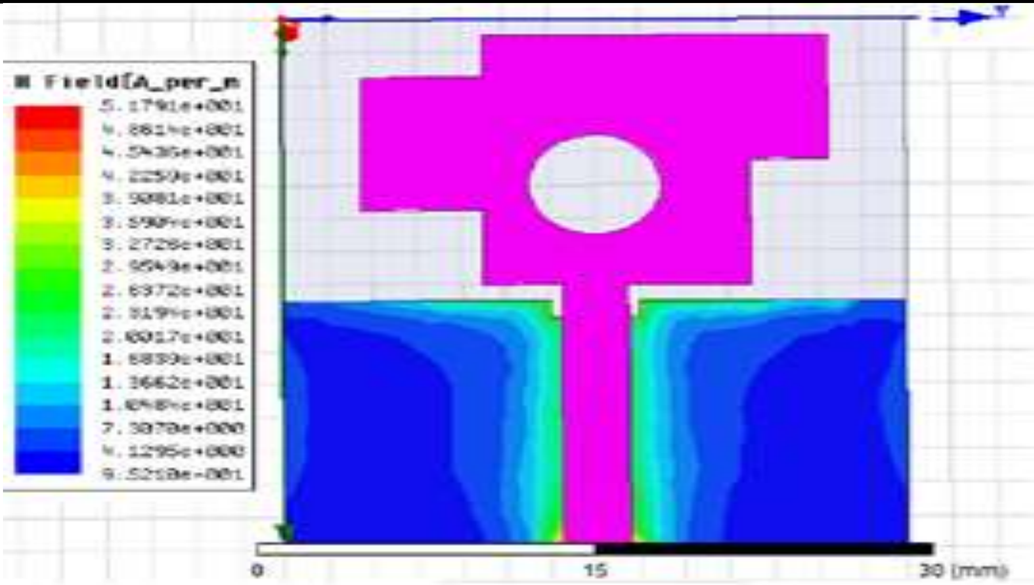

Figure 9: Magnetic field distribution

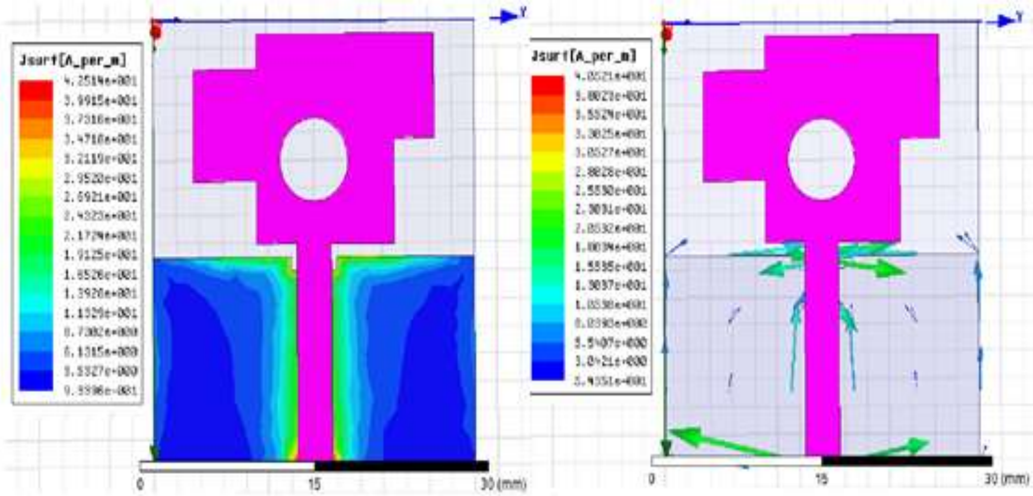

Figure 10: Surface current density distributions

The optimized antenna is fabricated on FR-4 substrate using mechanical milling or photolithography method. Measurement of the designed antenna is carried out using Agilent E8362B vector network analyzer and anechoic chamber. Return loss and VSWR are measured with Agilent E8362B vector network analyzer, radiation pattern and gain are measured in an anechoic chamber. The measured results are represented from the figures 11 to 14. We can notice the bandwidth ranging from 3.05 GHz to 10.5 GHz in this design.

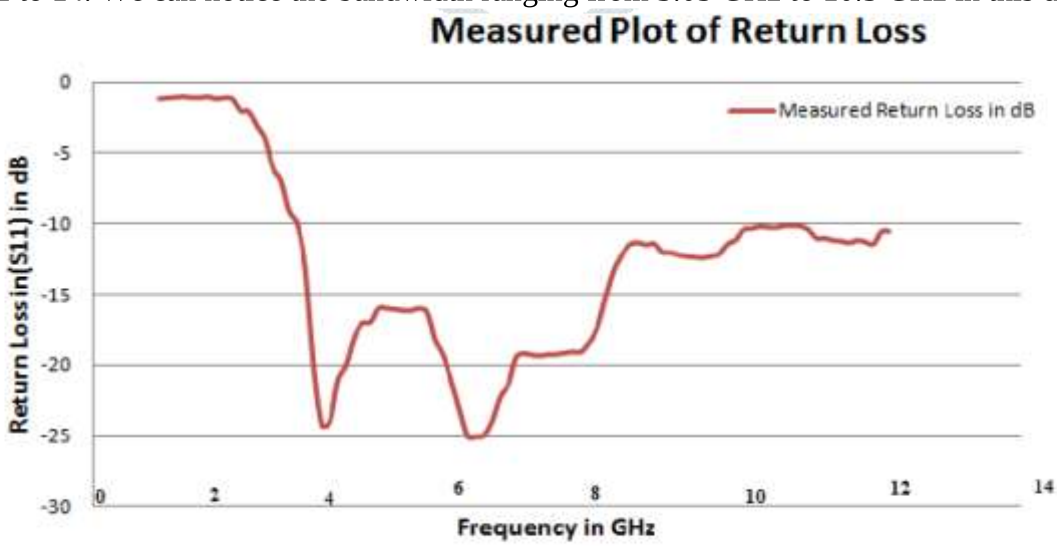

Figure 11: Measured plot of return loss

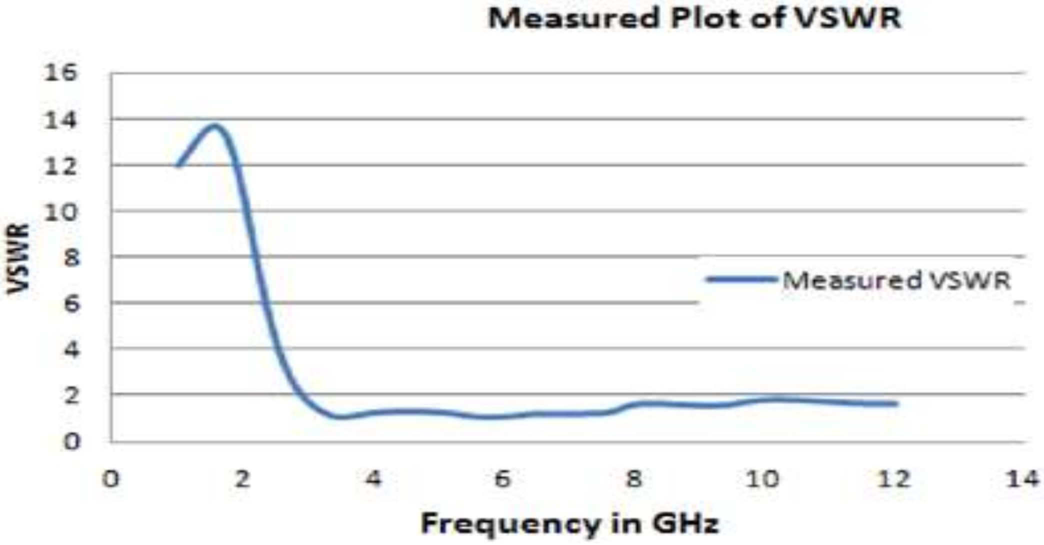

Figure 12: Measured plot of VSWR

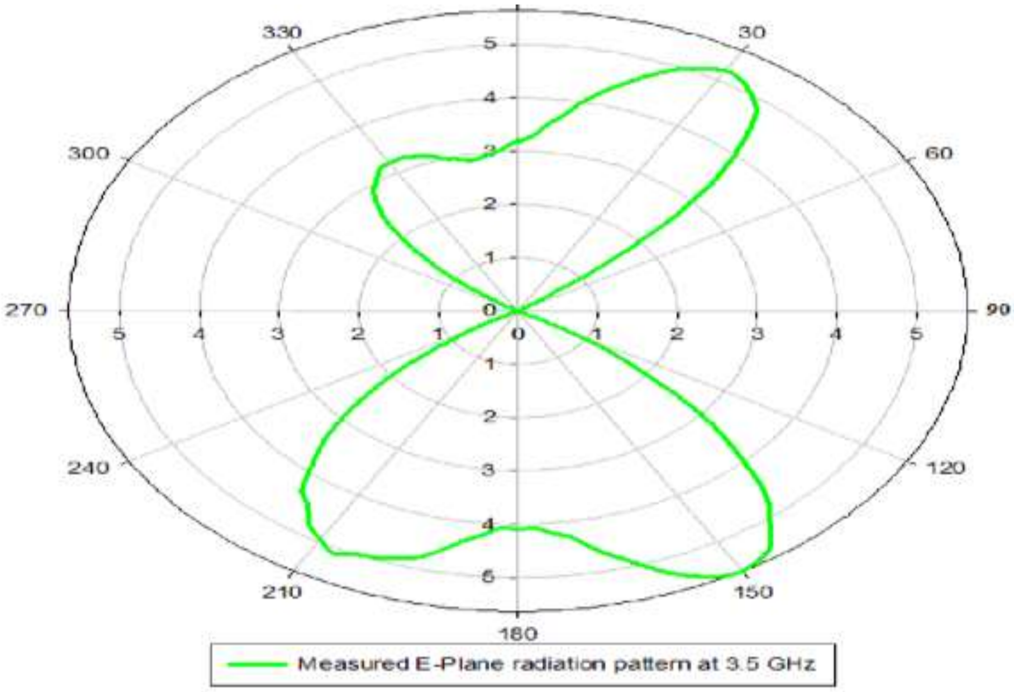

Figure 13: Measured plot of radiation pattern at 3.5 GHz

The simulated and measured values of return loss are in close agreement with each other as depicted in the figure 14.

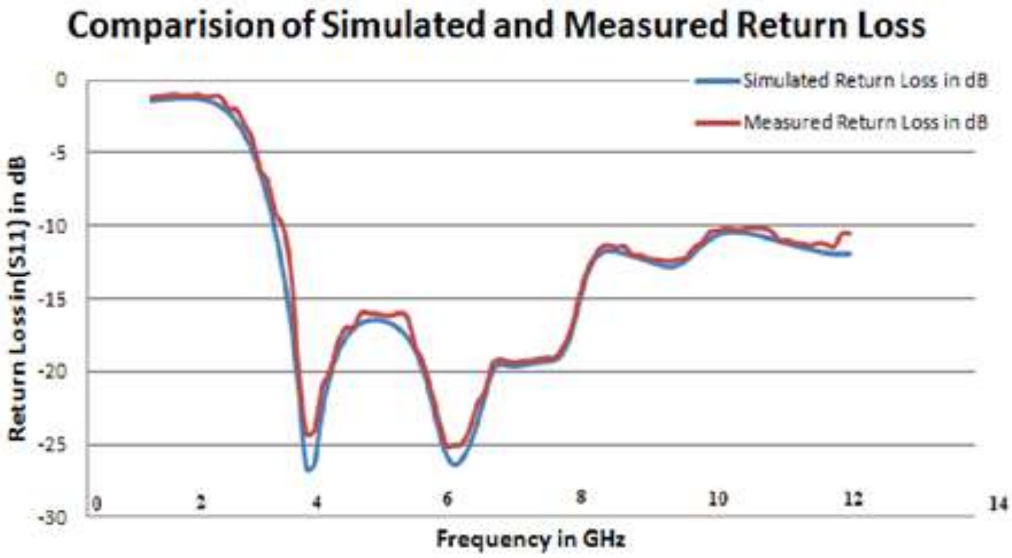

Figure 14 Comparison of simulated and measured return loss in dB

Final fabricated antenna is shown in the figure 16.

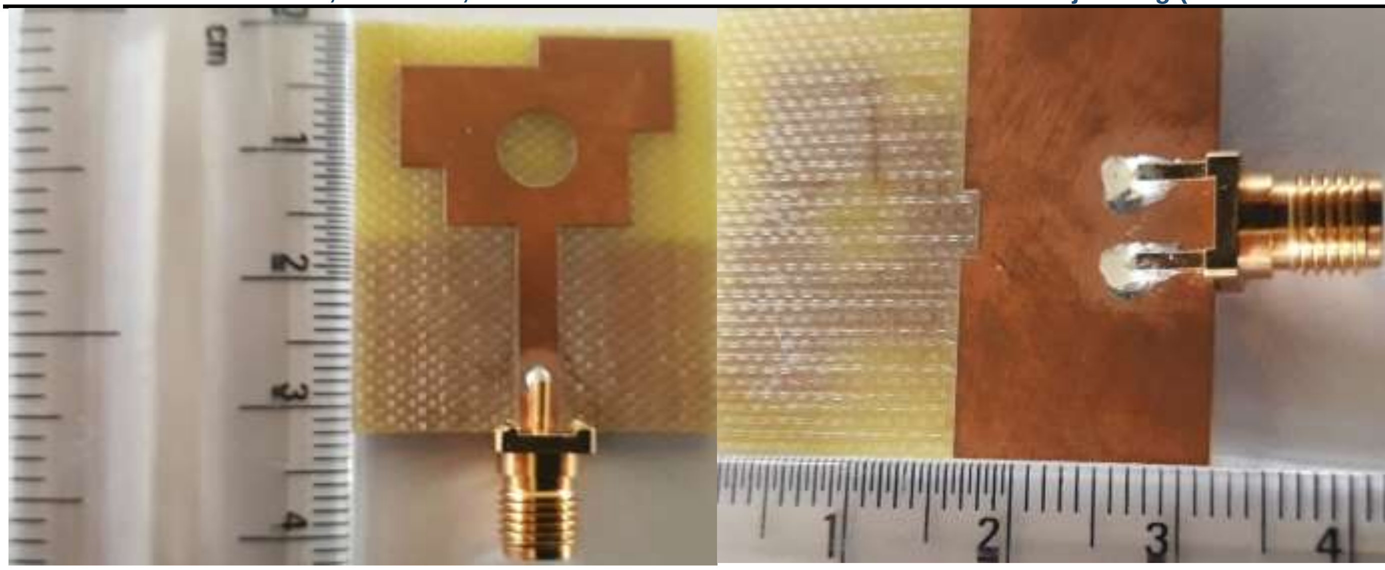

Figure 16 Final fabricated antenna patch and ground view

IV. CONCLUSION

A compact modified plus shaped circular slotted microstrip patch antenna is designed with resonance overlapping concept and defected ground. The designed antenna is more compact and derived from a basic rectangular patch of size 21 x 15 x 1.6 mm^3 through five iterations. Simulation is carried out using HFSS simulator, fabricated on FR-4 substrate with $\varepsilon_r = 4.4$, height 1.6 mm and tangent loss 0.01. The measurement of the antenna parameters is with Agilent E8362B network analyzer and an anechoic chamber setup. The measured and simulated results are analyzed and validated for close approximation. The radiation concept and resonance are studied in both virtually and experimentally to analyses various parameters of the antenna. The specifications of the ground plane will not vary the resonances but finds its use in impedance matching. The measured gain is around 8.1 dBi. The bandwidth of the measured value is at 99.33% (3.05 to 10.5 GHz). The proposed antenna can be utilized for 3.6 / 4.9 / 5 / 5.9 GHz WiFi, 3.41 / 3.49 GHz LTE, 3.5 / 5.5 GHZ WiMAX, 4.2 - 4.4 GHz Radio Altimeter, 5.2 / 5.8 GHz WLAN, 7.05 - 7.075 GHz Satellite Radio Uplink, 5.15 - 5.35 GHz HiperLAN, 3.7 - 4.2 GHz C-Band and 3.3 / 3.4 GHz proposed 5G applications.

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