Design and Implementation of Microstrip fed E–Shaped Defected Microstrip Surface Printed Monopole Antenna for Ultra Wideband Applications

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Abstract : This paper introduces the Printed Monopole Antenna (PMA) with E – shaped patch to enhance the bandwidth for Ultra wideband (UWB) applications. The conventional PMA is designed with a centre frequency of 6.77 GHz. The patch of conventional PMA is modified using three rectangular slots etched on patch, the slot dimensions are varied, moved to form different patterns and finally for E – shape the band width has been enhanced to cover UWB (3.1 GHz to 10.6 GHz) and excellent broadside radiation. The dimension of the E – shaped patch is finalized through optimization. The proposed PMA is designed and simulated using High Frequency Structure Simulator (HFSS). The conventional PMA and proposed PMA have been fabricated using commercially available low-loss dielectric material FR4 with dielectric constant 4.4. The conventional PMA and proposed PMA's parameters is measured using vector network analyzer (VNA) and its radiation pattern is measured in anechoic chamber. The simulated and measured results were almost similar.

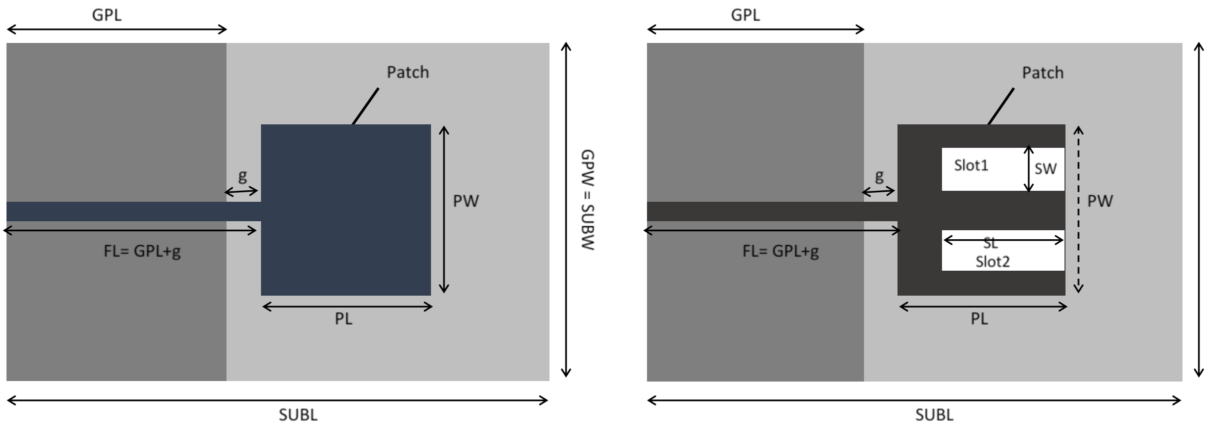
***IndexTerms* - Printed Monopole Antenna, Defected Microstrip Surface, Ultra-wide band, Vector Network Analyzer.**

I. INTRODUCTION

The modern Personal Area Network (PAN) wireless communication applications with high data transmission rate needs an antenna with simple and compact to cover UWB band. The PMA have many attractive features such as simple configuration, low profile, compact size, large bandwidth and low fabrication cost, relative wide band width with near Omni-directional characteristics, high radiation efficiency and low power operation. The enhancement of bandwidth is a challenge to avoid the number of antennas used for separate applications instead; a single antenna can resonate at multiple frequencies and can be used to cover multiple bands. Detailed experimental study on CDM antennas including some new configurations an experiments have been carried out on various planar monopole antennas such as circular, elliptical, rectangular, square, and hexagonal disc monopoles. An elliptical disc with ellipticity ratio 1.1 provides a bandwidth ratio of more than 1: 10.7 for VSWR < 2 [1]. A compact wideband planar monopole antenna of dimension 40X40mm^2 is etched on to a substrate of permittivity $\varepsilon_r = 4.5$ and of thickness 0.508mm, achieves S_{11} below -10 dB from 1.2GHz to 3.5GHz for future mobile device is reported [2]. The US-Federal Communication Commission (FCC) has approved the ultra-wideband (UWB) communication system of the frequency range from 3.1 to 10.6 GHz for commercial UWB applications in 2002. [1-2], this has increased the demands on the UWB systems has attracted many research groups to work on antenna to satisfy the UWB band requirements with different antenna designs [3-4].

A circular disc monopole with a radius of r=10 mm and a 50 microstrip feed line are printed on the same side of the FR4 substrate dielectric substrate and the conducting ground plane with a length of L=20mm covers the frequency band from 2.8 GHz to almost 10 GHz is presented [5]. A new compact and microstrip-fed ultra-wideband (UWB) monopole antenna provides impedance bandwidth 2.9 GHz to 12.1 GHz for VSWR < 2. By by inserting inverted-U shaped slot rejects the band 4.9 GHz to 6 GHz is reported [6] A novel antenna topology based on the Printed tapered monopole antenna (PTMA) for ultra-wideband (UWB) wireless body area network (WBAN) applications. The effect of bandwidth of an antenna in the presence of a human arm and the pulse distortion of a modulated Gaussian pulse is investigated, based on measured S_{21}-parameters observed that, there is a small acceptable influence on the matching of the antenna and that the pulse distortion is low. The presence of an arm results in a poorer but still acceptable matching. It lies below -7dB, simulated between 2.7 and 7.9 GHz and measured between 2.8 and 7.5 GHz is reported [7]. Two novel designs of planar elliptical slot antennas are Printed on a FR4 dielectric substrate and fed by either microstrip line or coplanar waveguide with U-shaped tuning stub, the elliptical/circular slots have been demonstrated to exhibit an ultra wideband characteristic and Presented up to cover the bandwidth from 3.5GHz to 12.5 GHz [8]. A printed ultra wideband (UWB) antenna suitable for multiband orthogonal frequency division multiplexing (MBOFDM) UWB is designed using FR-4 substrate. An examination of the effects of ground plane dimensions on antenna properties such as gain, bandwidth and radiation pattern is made and the antenna covers a wide band from 3.1 GHz to 11.2 GHz. The gain remains same for smaller ground plane and variations approach ±2 dB for wider and ±3.5 dB for longer ground planes [9]. The printed monopole antenna with satire case and circular slot has a wide frequency bandwidth of 8.4 GHz starting from 3 GHz up to 11.4 GHz for a return loss S_{11} of less than -10 dB and gain flatness over the frequency range is reported [10]. A compact rectangular monopole with an equal-width ground Plane, which improve its radiation performance and decrease its size. The feeding structure composed of a trident-shaped strip and a tapered impedance transformer is used results, VSWR less than 2, is from 2.75 to 16.2 GHz with a ratio of about 5.9:1 is reported [11]. A compact printed ultra wideband (UWB) monopole antenna with dual band-notched characteristics is presented. By inserting two I-shaped notches in both sides of the microstrip feed line on the ground plane, T-shaped stubs in the radiation patch and a modified G-slot defected ground structure in the feeding line operates over the frequency band between 2.8 and 11.8 GHz of one notch frequency band at 3.3–3.8 GHz (Wi-MAX band) and the other at 5.1–6 GHz (WLAN band) has been reported [12]. A complex E-shaped printed monopole antenna for MIMO application to resonate at 2.4, 5.4 and 5.8 GHz is reported [13]. A novel compact ultra-wideband (UWB) printed monopole loaded with a dielectric resonator (DR) antenna is proposed. The antenna consists of a microstrip fed monopole printed on a substrate with a truncated ground plane loaded with a DR. The bandwidth is enhanced by making an inner groove inside the DR and controlling the slot width of the truncated ground has been reported 3.6 to 11.2 GHz [14].

A printed regular hexagonal slot antenna with a hexagonal stub fed by a coplanar waveguide line has been considered for ultra wide bandwidth. By inserting C-shape slot within the exciting stub as well as a couple of Z-shape open circuit stubs symmetrically inserted at the edge of the slot to obtain dual band WLAN and WiMAX rejection is reported [15]. The methodology is based on applying the modified rational function model with passive components which are determined using vector fitting (VF) approaches. One of the key advantages of the proposed modeling method is the reduced complexity of the circuits describing the UWB network, which generally improves the robustness of the data fitting process. Simulation results show that this methodology is effective over the UWB bandwidth of 3.1 to 10.6 GHz frequency range [16]. An Ultra-Wide Band (UWB) patch antenna designed with Finite Element Method (FEM) based on high frequency electromagnetic simulation software achieved Return loss is obtained below -10 dB from 8.39 to 9.7 GHz. It has achieved stable radiation efficiency 84% with gain 3.81 dB and 4.25 dB in the operating frequency band [17]. The antenna with square patch and four capacitive coupled feeds used for impedance bandwidth enhancement. The feeds are formed by a vertical isosceles trapezoidal patch and a horizontal isosceles triangular patch has been reported as gain varies from 3.91 to 10.2 dB for port 1 and from 3.38 to 9.21 dB for port 2, with a 3-dB gain bandwidth of 107% [18]. A multilayer broadband microstrip antenna is designed using FR4 substrate. The ground plane is defected with different shapes to improve the bandwidth and to cover the multiple bands, up to 129% bandwidth improvement is achieved [19]. The plus shaped structure is realized by combining two rectangular shaped planar monopole printed patches to achieve UWB and reported 3 to 10 GHz frequency band [20]. Double circular shaped monopole antennas with different type of feedings are used to achieve directional radiation characteristics and high front to back lobe ratio (F/B) for different applications.



(a) (b)

Figure.1. Schematic diagram of a conventional and modified printed monopole antenna, considering parameters as PL=9.8, PW=13.32, g = 5.2, FW= 3, FL= GPL = 10.43, GPW = SUBW = 23.73, SUBL = 34.16, h = 1.575, SL = 3, SW = 8.5. (all dimensions in mm) ε_r = 4.4. (a) Conventional PMA, (b) Proposed PMA

The designed antenna covers an ultra-wideband (3.3 GHz-10.6 GHz) and a part of the license free super wideband (10.6 GHz-20 GHz) is reported [21]. A compact antenna for TV WSDs was designed with a dimension of $0.37\lambda l \times 0.06\lambda l \times 0.001\lambda l$ and achieves impedance bandwidth from 474 to 1212 MHz. The characteristic mode analysis (CMA) used to understand physical insight of antennas, by optimizing the dimension different impedance band width is obtained [22]. An UWB-MIMO antenna with frequency selective surface (FSS) decoupling structure is used for antenna system miniaturization and integration with silicon substrate of dimension of 38.2 × 26.6 × 0.4 mm3. For an array achieve high isolation between antennas, six meta-material FSS units are employed in the middle of array and isolation is less than −16 dB over the entire UWB frequency band [23].

II. ANTENNA CONFIGURATION

The conventional printed monopole antenna (PMA) has been designed as per the design guidelines [5] with a centre frequency (f_0) = 6.77 GHz. The dimension of patch (12X16) mm^2 with thickness of 0.03 mm, the dielectric substrate FR4 epoxy with ε_r = 4.4, and thickness h =1.575 mm is considered. The S_{11} of conventional antenna is above -10dB for the frequency ranges from (4.07 -5.89) GHz and (9.08 – 9.73) GHz among UWB (3.1 - 10.6) GHz. The PMA is fed by microstrip line and its length and width are chosen to match the 50Ω impedance as shown in Fig.1 (a). In the proposed PMA, two symmetrical rectangular slots of size (2X12.5) mm^2 with thickness 0.03 mm are etched on conventional patch as DMS elements to form E-shape is shown in Fig. 1 (b). The proposed E-shape PMA simple, compact in size and covers the entire UWB range. These DMS elements dimensions are decided through optimizations. The optimization involves, the position of DMS slot are varying along X and Y axis, varying length, and varying width. Finally the two slots are decided through observing both the S_{11} as well as radiations characteristics. The dimension of proposed PMA configuration is given in Fig. 1 caption.

III. RESULTS AND DISCUSSION

The conventional PMA is designed using commercially available low-loss dielectric material FR4 with ε_r = 4.4 and thickness h = 1.575 mm to resonate at 6.77 GHz. The conventional PMA shows reflection coefficient well below the -10 dB over the impedance bandwidth (3 – 10.8) GHz to covers the entire UWB, but for the frequency ranges (4.07 -5.89) GHz and (9.08 – 9.73)

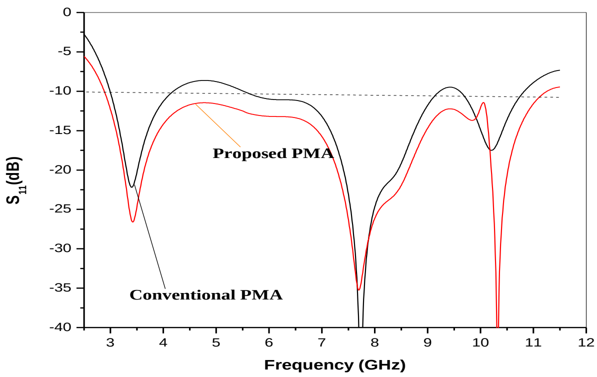


Figure-2: Simulated return loss characteristics of conventional and proposed PMA configurations

GHz shows the reflection coefficient above -10 dB, hence the conventional PMA is not covering these two wide notches. In order to make the antenna to cover the entire UWB range, the two rectangular slots of size (2 X 12.5) mm^2 with thickness 0.03mm are etched on the patch, which pulls the reflection coefficient to below -10 dB and covers the entire UWB range. The reflection coefficient of conventional and proposed MPA is shown in Fig. 2. The impedance of conventional PMA is varies over the resonating frequency range (3 – 9.23) GHz there by two wideband notches of frequency ranges (4.07 -5.89) GHz and (9.08 – 9.73) GHz are reporting above-10 dB. The DMS slot on patch compensates the shift in S_{11} for the two bands to below -10 dB to cover entire is shown in Fig. 2. The proposed PMA widens the impedance bandwidth (2.8 – 11.7) GHz, approximately 26%

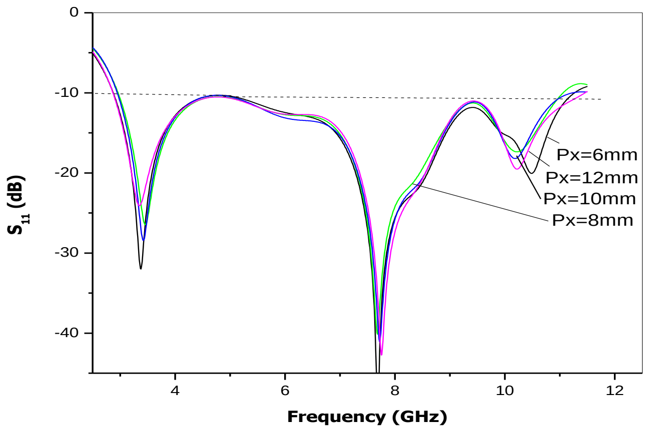


Figure-3: Simulated return loss characteristics with single slot of size (2 X 12.5) mm^2 varying the position along X-axis.

bandwidth enhancement is achieved. The bandwidth increases due to E-shape etching in the patch; this is because of many reasons, etched E-shape increase the electrical path on the patch and strengthens the current distribution. The other reason is that, the slots add their own resonances to enhance the bandwidth and hence the bandwidth is increased to cover the UWB band (3.1 to 10.6) GHz.

The Fig. 3 shows the reflection coefficient due to one slot etched on patch of arbitrary size (2 X 12.5) mm^2 with thickness 0.03mm and is varied along the X-axis in steps of 2 mm and very small notch or it touches exactly at -10 dB from 4.3 GHz to

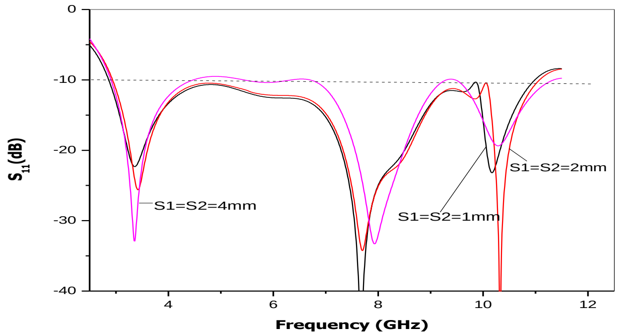
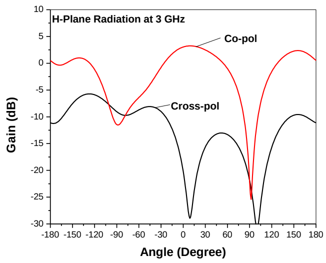


Figure-4: Simulated return loss characteristics with two slots and varying the width of the slots simultaneously.

almost 5 GHz.



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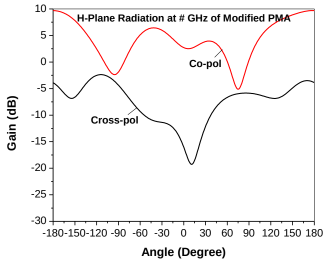

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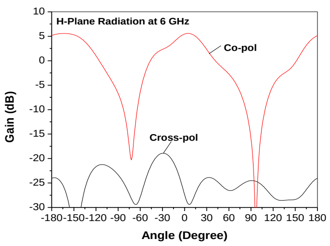

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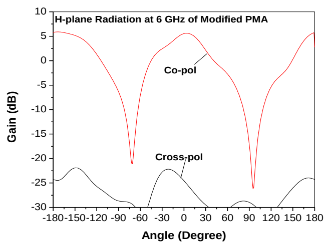

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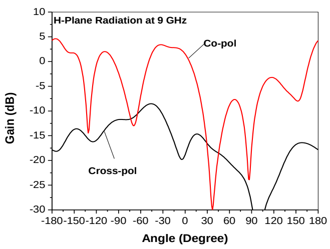

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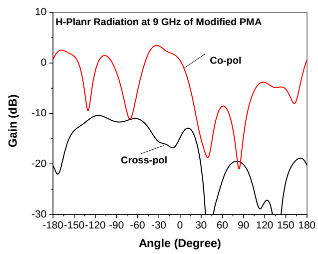


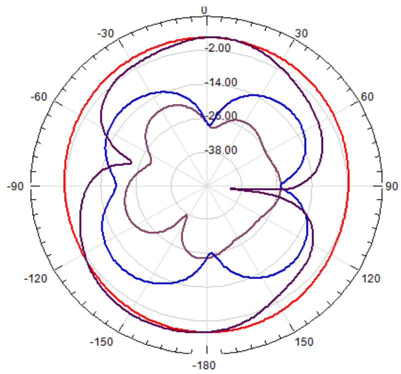
(f)

Figure-5: Simulated radiation characteristics of conventional and modified PMA (a) Conventional PMA at 3 GHz (b) modified PMA at 3 GHz (c) Conventional PMA at 6 GHz (d) modified PMA at 6 GHz (e) Conventional PMA at 9 GHz (f) modified PMA at

To overcome the reflection coefficient exactly at -10 dB, another slot is etched on the patch and varying the width of both the slots simultaneously and their return loss characteristics is shown in Fig. 4. The etched two slots on patch is again above -10 dB, when both slots widths are optimized and optimized S_{11} is shown in Fig. 4. The S_{11} plot exactly at -10 dB at 10.3 GHz and 10.4 GHz for S1 = S2 = 1 mm and S1 = S2 = 1 mm respectively. The two symmetric slots of size (2 X 12.5) mm^2 at position (6, 0, 1.63) and (10, 0, 1.63) the reflection coefficient is well below -12 db from 2.7 GHz to 11.3 GHz shown in Fig. 2 and achieved a coverage bandwidth of 8.6 GHz.

The Fig. 5(a) and (b) shows the radiation characteristics of conventional and modified PMA at 3 GHz. The conventional PMA shows a positive gain over -40^0 to $+60^0$ with peak gain of 3.5 dB, but in modified PMA gain has improved up to 4.5 dB with a wider angular coverage from -80^0 to $+70^0$and the positive peak gain varies over the coverage angle. Better radiation characteristics obtained at 6 GHz shown in Fig. 5(c) and (d). The conventional PMA reported 5 dB peak gain over $\pm 50^0$, but modified PMA also reported 5 dB over $\pm 45^0$ with reduced cross-pol when compared to conventional PMA at 6GHz. Fig. 5(e) and (f) shows the radiation characteristics of conventional PMA and modified PMA at 9 GHz. The conventional PMA shows two peak gains at -120^0 to -100^0 and -60^0 to 30^0 with peak gain 2 and 3 respectively; whereas modified PMA shows same angular coverage with peak gain 2.3 and 3.3 respectively.

The Fig. 6 shows the simulated radiation patterns at 3 GHz, 6 GHz and 9 GHz.



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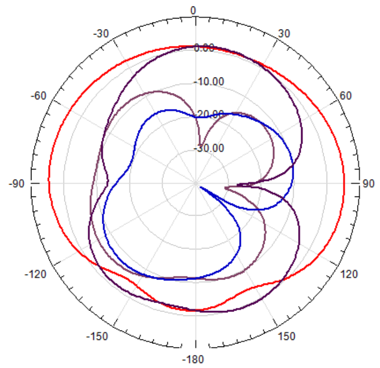

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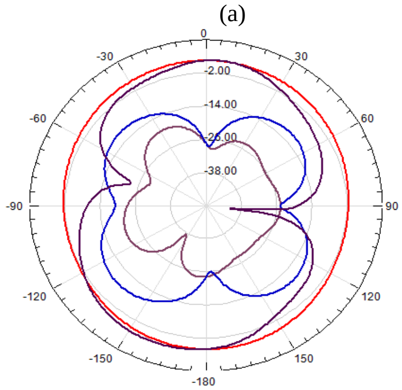

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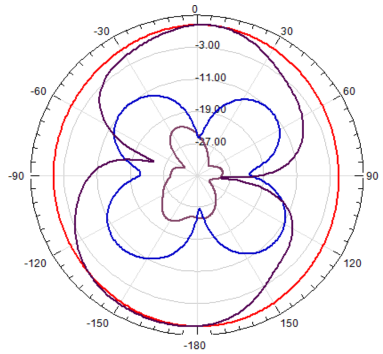

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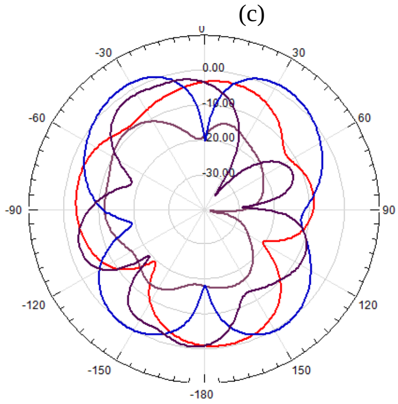

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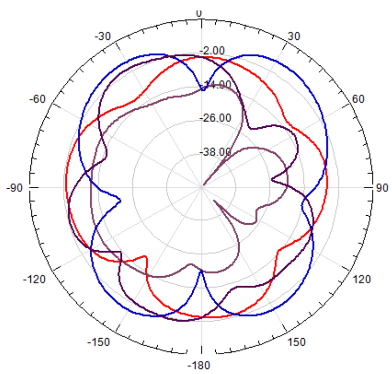


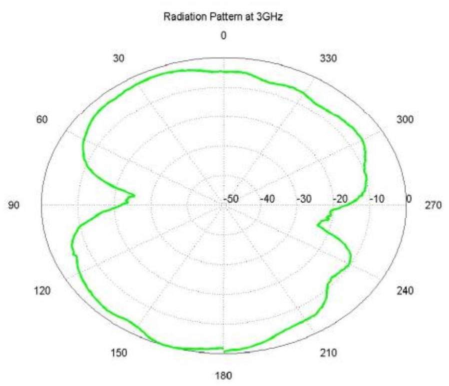
(f)

Figure-6: Simulated Radiation pattern of conventional and modified PMA. (a) (b) at 3GHz, (c) (d) at 6 GHz, (e) (f) at 9 GHz

IV. PROTOTYPES AND EXPERIMENTAL VERIFICATION

The prototypes of conventional and proposed PMAs are fabricated using commercially available FR4 substrate with ε_r=4.4. The prototypes are measured using Agilent Technologies, N5230A vector network analyzer and in an automatic anechoic chamber.

The Figure-7 and Figure-8, shows the measured radiation patters at 3 GHz, 6 GHz and 9GHz. The radiation pattern of H-plane and E-plane are shown separately. It is observed that, there is good agreement obtained between the simulation and measured plots.



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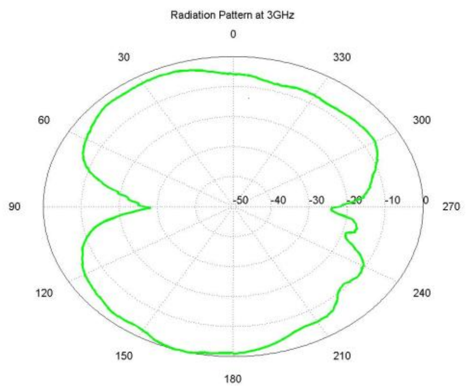

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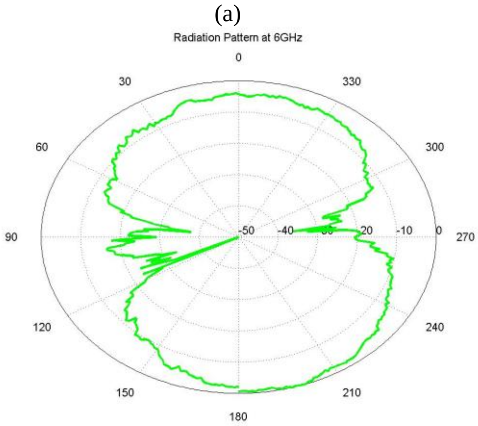

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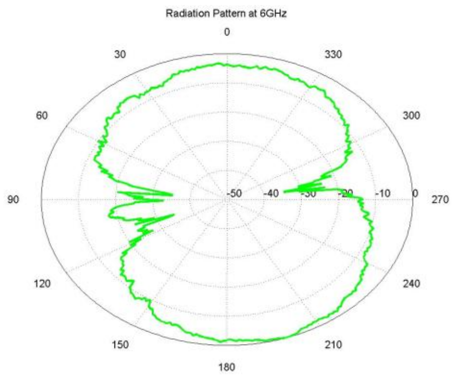

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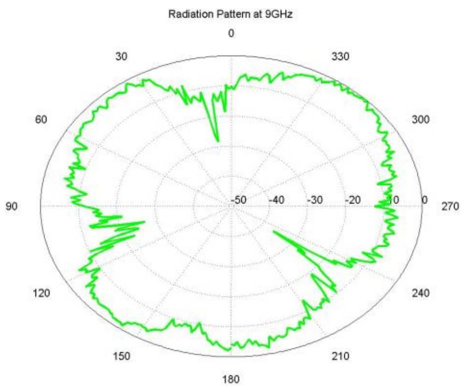

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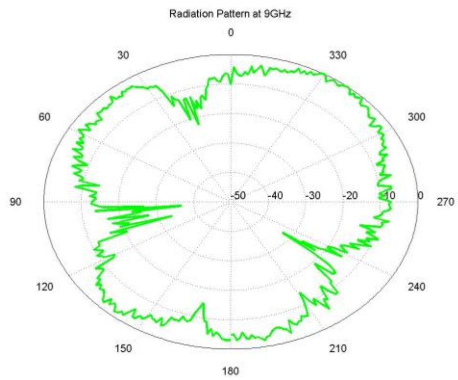
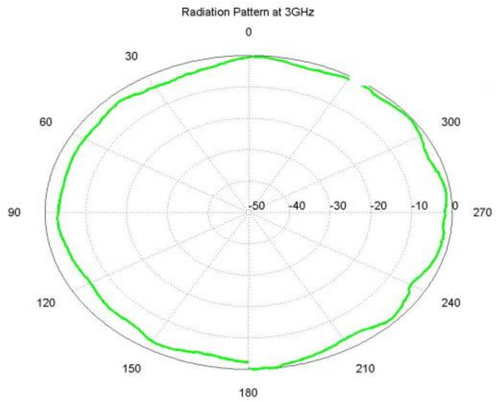
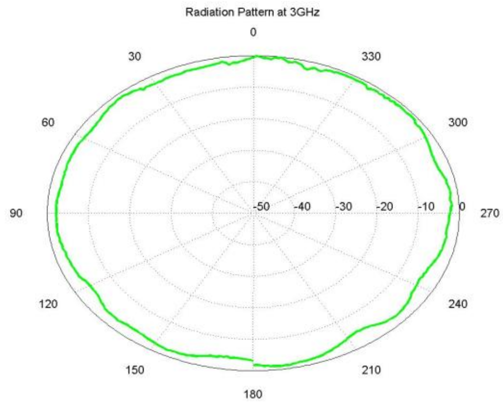


(f)

Figure.-7: Measured elevation plane radiation pattern of conventional and modified PMA. (a) (b) at 3GHz, (c) (d) at 6 GHz, (e) (f) at 9 GHz



(a)



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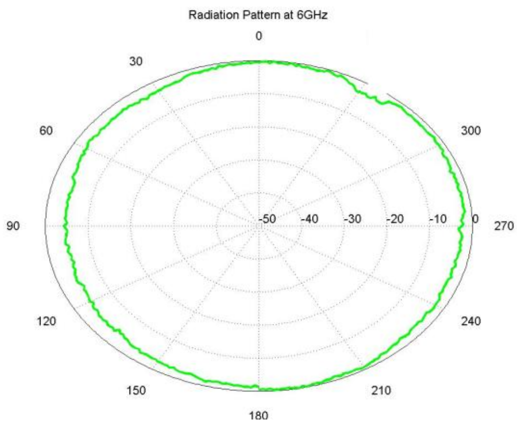

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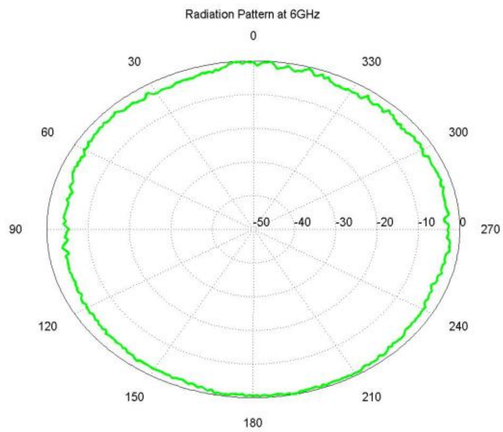

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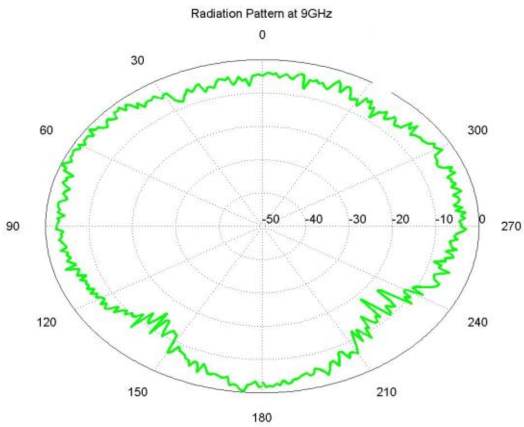

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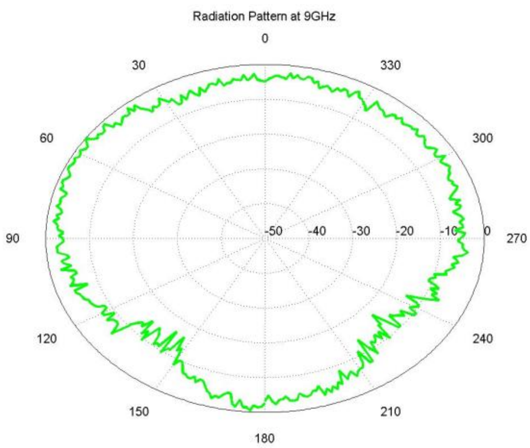
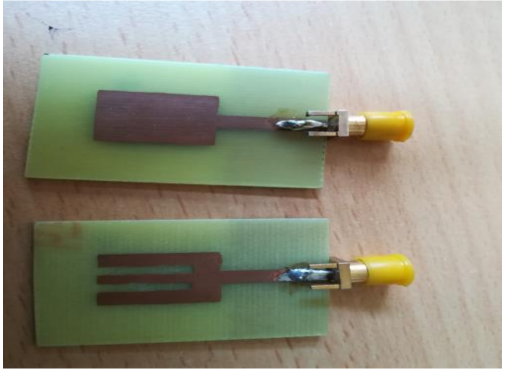


(f)

Figure-8: Measured Azimuthal plane radiation pattern of conventional and modified PMA. (a) and (b) at 3 GHz, (c) and (d) at 6 GHz, (e) and (f) at 9 GHz

The Figure-9(a) shows conventional and modified fabricated antennas, the Figure-9(b) S_{11} measurement setup (Vector Network Analyzer) and the Figure-9(c) shows Anechoic chamber for measuring radiation characteristics.




(a) (b)

(c)

Figure-9: Measurement Setup. (a) Fabricated Antennas, (b) S11 Measurement using VNA (C) Radiation measurement in anechoic chamber

V. CONCLUSION

An E-shaped Printed Monopole Antenna (PMA) with microstrip feed is proposed for covering UWB band. The conventional PMA covers the UWB range with two wide notches for the frequency ranges from (4.07 -5.89) GHz and (9.08 – 9.73) GHz. The conventional PMA's patch is defected with E-shape, which pulls the return loss of two wide notches to below -10 dB there by modified PMA covers entire UWB range with an average gain of 4 dB. The PMA's are fabricated and measured using VNA and anechoic chamber. The simulated and measured plots are well matched.

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