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Circular Shaped Ultrawide-Band Antenna for Wireless Communication

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***Abstract*—** This paper presents the design of (UWB) antenna with asymmetrical U-Slot, operating in the microwave band of (3.5-15) GHz. This design permits its applications in various sectors, such as wireless communications, radar systems, and remote sensing. The antenna is covering bandwidth of (11.5) GHz with gain of (6.298) dB at (14.25) GHz. The substrate used is (FR4 Epoxy) of (ε_r=4.4), loss tangent of (0.02), and thickness of (1.575) mm. The extensive bandwidth of the antenna makes it operate in both the C-Band and X-Band. Overall, the design of this (UWB) antenna aims to provide a high-performance antenna that can operate over a wide frequency range, making it suitable for various applications.

***Keywords*—** U-Slot, Ultra-wide band, C-Band, finite ground

I. Introduction

For today's scenario in the growing and developing world, technology plays a very crucial and pivotal role. Especially in the mobile applications, the basic antenna which is usually used is the patch antenna. Also the microwave band can be used for mobile applications and some other wireless communications. The humanity or the mankind needs a technology that can change the way of living and uplift the lifestyle. Most of the devices are fabricated in such a way that they can provide much higher throughput and standards. To fetch such requirements, patch antenna has been used because of its feasible structure, low profile and easy fabrication. Generally, traditional and conventional methods which were used to design the patch antenna suffered from narrow frequency band which is basically a few percent of a whole. On the same way, if we discuss about the ongoing and present work which exist between these days, we can find core difference in terms of bandwidth, return loss and some more antenna parameters.

In order to sustain and support high frequency bands, few novel methods are adopted to enhance bandwidth of patch antennas. One method is to design slots which can provide better resonances for bandwidth enhancement. One more method which is feasible to increase bandwidth is to increase the depth of substrate by decreasing the value of (Dielectric Constant). Every substrate used in the designing of the patch antenna has a parameter called as (Dielectric Constant). So, for pertaining excellent bandwidth you must decrease the value of (Dielectric Constant). Another method is to introduce half ground in the schematic design. Feeding methods do provide great results in antenna bandwidth. There are several feeding methods that are as microstrip line, coaxial probe, inset feeding, proximity coupled technique, aperture coupled etc. Out of all these methods, the feeding which is implemented to provide best results for antenna bandwidth is microstrip line feeding. In addition, if we introduce different sort of shapes to the antenna, it can also enhance bandwidth [2]-[3].

Shorting pins are also an effective way to increase the antenna bandwidth, it seems to act like an input or the feed which provides magnificent results. As these elements add more stability to the antenna design allowing to have resonant bands respectively. Following it up parasitic patches can also increase the antenna bandwidth. In this design an asymmetrical (U-Slot) antenna with a finite ground plane is designed to achieve increased bandwidth compared to traditional antenna designs. The asymmetrical (U-Slot) provides a wider bandwidth, while the finite plane helps to improve the impedance matching of the antenna, leading to a broader frequency response [10].

The motivation for designing an asymmetrical (U-Slot) antenna with a finite ground plane is to achieve increased bandwidth, compact size, improved radiation efficiency, low cross-polarization, and ease of integration [1]. These benefits make this type of antenna particularly suitable for applications where performance and size are critical factors. This paper is divided into four sections. In second section of the paper antenna implementation is described or executed. The outcomes of the paper are explained in third section of the paper. Conclusion of the work is given in the fourth section of the paper.

II. Antenna Design

This provided section is devoted to the antenna design of microwave range, that is from (3.5 GHz to 15 GHz) respectively.

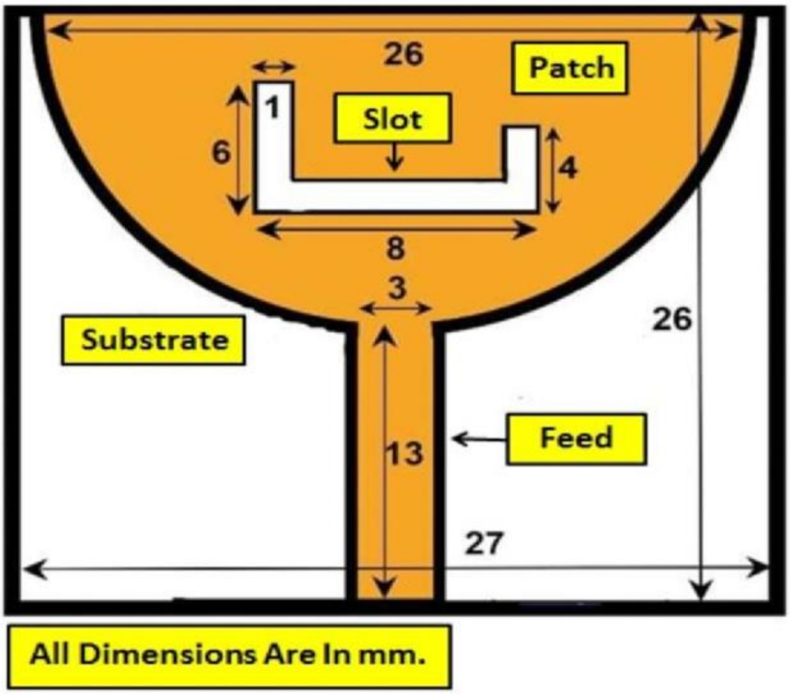

Fig. 1 Antenna design with its dimension

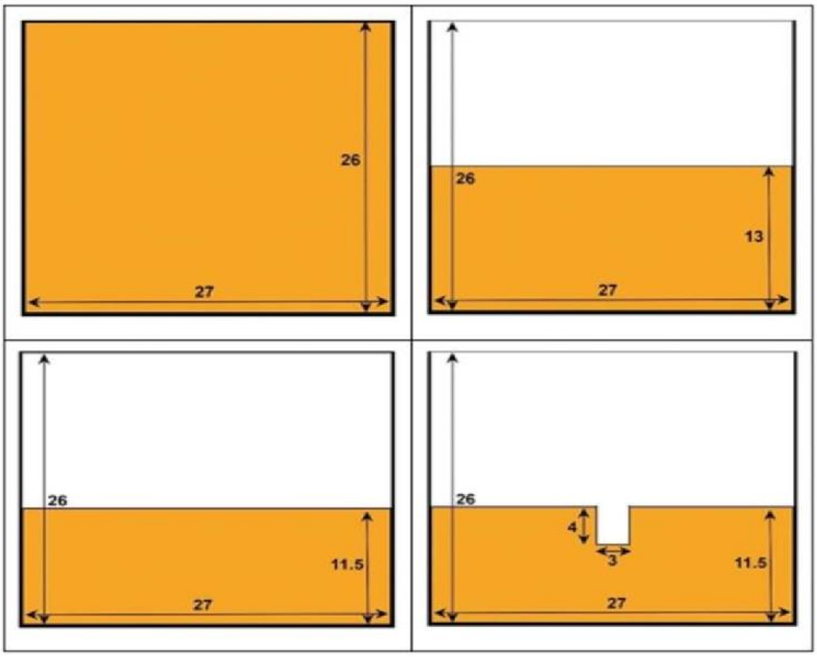

Fig. 2 Iterations in Ground

$$[a = \left\{\frac{F}{\sqrt{1+\left(\frac{2h}{F\pi\varepsilon_r}\right)\left[ln\left(\frac{\pi F}{2h}\right)+1.7726\right]}}\right\}] \text{------------------------(1)}$$

where

$$[F = \left\{\frac{8.791\times10^9}{fr\times\sqrt{\varepsilon r}}\right\}]$$

The given equation denotes a as the radius of the circular patch antenna or h is the height of the substrate respectively, axes and plane. All these configurations are carried out in the microwave band ranging from (3.5-15) GHz. As we assigned proper material to the ground, few modifications were carried out. Normally the dimensions of the ground is always taken same or equal to the substrate, but in some cases, if we want to carry out bandwidth enhancement, we have to reduce the length of ground. The spectrum bandwidth of this designed antenna covers frequencies from (3.5-15) GHz which can be further used for C-Band and X-Band applications respectively [5]-[6]. The modifications carried out made this patch antenna to work like (UWB) (Ultra-Wide-Band) antenna due to radiating in more than one particular band. The parameter like wide bandwidth made this designed patch antenna applications quite better while performing such modifications. The best merit or the advantage is that with the extent of wide bandwidth, the designed patch antenna uses less power as it suffers low interference respectively. Also, the effective radius of the patch antenna is given by [12-15]

$$[a_{eff} = \left\{a\times\sqrt{1+\left(\frac{2h}{\pi a}\right)\left[ln\left(\frac{a}{2h}\right)+1.7726\right]}\right\}] \text{--------------------(2)}$$

The semi-circular patch antenna is fabricated with a relative ground thickness. The substrate used is (FR4 Epoxy) with the value of relative dielectric constant of (4.4) and loss tangent of (0.02) respectively [16]. The feeding is provided through microstrip line feeding by providing the excitation through lumped port respectively. Proper implementation of the radiation box is also being provided for the necessary radiation along with proper boundaries assigned to the patch as the perfect electric. Relative slots of typical length and width is being deducted to provide the asymmetrical (U-Slot) in the designed patch. Equal slot width is also being provided wherever the slots are introduced with a typical value of width (1mm). The ground which is fabricated is being assigned the material which is perfect electric. The position and the coordinates of the line feed is implemented in such a way that it should be symmetrical.

The proposed (UWB) patch antenna is implemented using four basic iterations. The first antenna involved full traditional ground consisting of equivalent size of the substrate. In the second process, the reduction of the ground to half is carried out as relative increase in antenna bandwidth is observed. But we intend to go for more modifications by reducing the ground to a more bit by value shown in the third antenna. The bandwidth achieved using such iteration gave us the idea to implement some more changes. And we hereby, subtracted and created a slot from where the feed line is driven to the designed patch antenna [4]. The relative rectangular slot of dimensions (4 mm × 3 mm) got truncated from the ground itself to provide the desired results. The final alterations that we have carried out can be seen in the fourth iteration respectively.

III. Simulated Results

A brief study has been carried out to find the optimum solution for the designed patch antenna. It is being noted that, while changing and altering the length of ground causes few desirable results respectively. dB. Although some portion of this curve is below (0) dB line ranging from (5-9) GHz, it means during these intervals, the antenna is rejecting this band and passing other residual and remaining bands of typically (7.5) GHz. As it can be understood and very clear, that every device made or constructed cannot behave ideally in every interval of time or frequency. At one spot of time, practicality will strike and hence such results can be seen respectively.

In the above figure, we can visualize that we are having the optimum solution in the IV Iteration due to which Gain of the designed patch antenna is having its maximum magnitude and value respectively. The modifications carried on the Ground is analyzed deeply giving the best response in the carried iteration **[7]-[8].** As we deducted some portions of ground described in the final iteration gave the peak value of the Gain respectively.

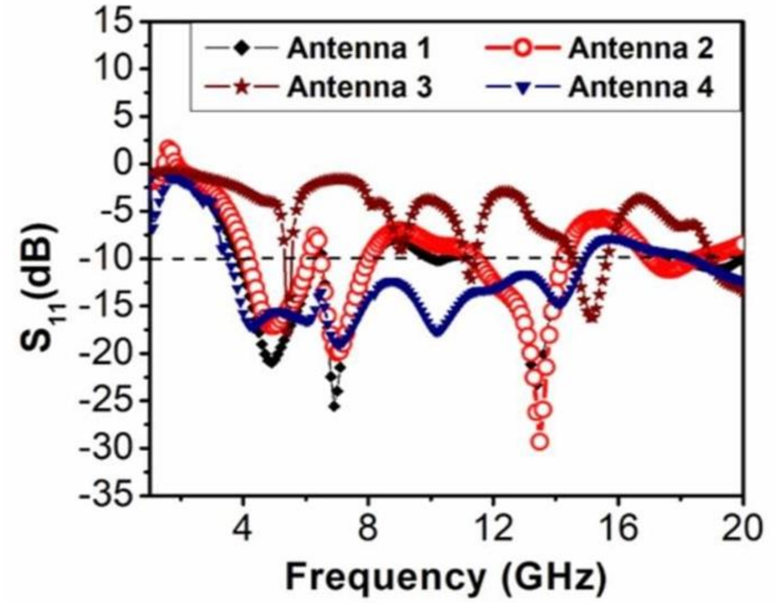

Fig. 3 Parametric analysis in terms of return loss for different iterations in Ground

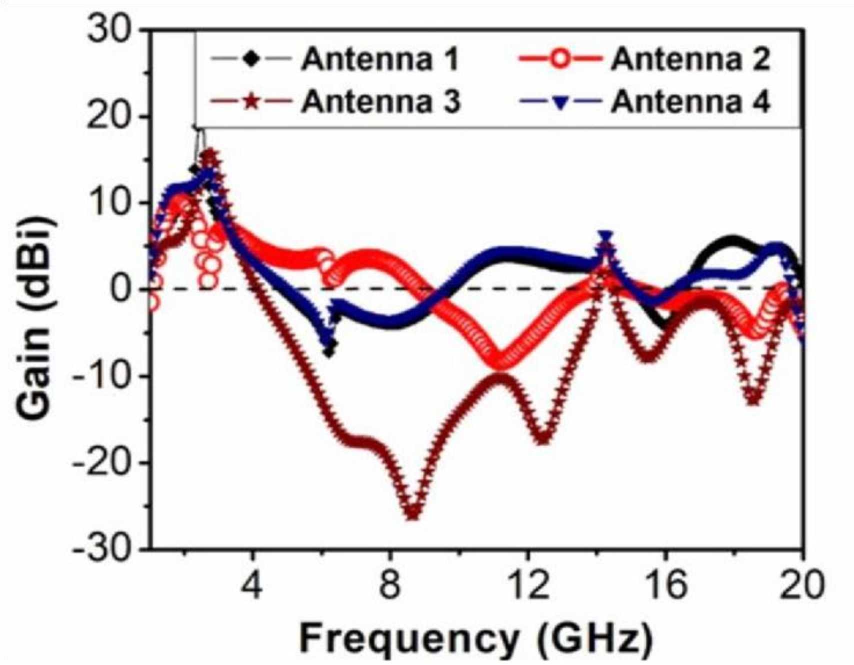

Fig. 4 Parametric analysis in terms of gain for different iterations in Ground

The Gain is having its peak value of **(**6.298 dB) at the frequency of (14.25) GHz by keeping the values of (θ= 90°) and (φ=90°) respectively [9].

In the given figure stated above, we can analyze that out of four demonstrated iterations, we are getting our best result in terms of Antenna Bandwidth by providing the Ground Length of (11.5) mm by also inducing a Rectangular Slot of dimensions (4 mm × 3 mm) from where the excitation and input is being driven to the designed patch antenna in (IV Iteration) respectively. The first antenna was carried out on full traditional ground, where the length and width of the ground were exactly equal to the substrate. The maximum gain achieved during this iteration was found to be (5.9) dB. In the second case, the length of the ground was reduced to half of length of substrate and was found to provide Gain of (6) dB. The third case provided here is constituted by reducing the length of the ground exactly of the length of the feed given to the antenna. Therefore, the gain achieved during this cycle attain its peak value of (6.08) dB. The reason of not choosing this curve as the best one is that, its majority of the portion is below the (0) dB line. In the last and final iteration, we provided a slot at the ground, which is known as defective ground, where the value of peak gain is (6.298) dB. Although some portion of this curve is below (0) dB line ranging from (5-9) GHz, it means during these intervals, the antenna is rejecting this band and passing other residual and remaining bands of typically (7.5) GHz. As it can be understood and very clear, that every device made or constructed cannot behave ideally in every interval of time or frequency. At one spot of time, practicality will strike and hence such results can be seen respectively. In the above figure, we can visualize that we are having the optimum solution in the IV Iteration due to which Gain of the designed patch antenna is having its maximum magnitude and value respectively. The modifications carried on the Ground is analyzed deeply giving the best response in the carried iteration [7]-[8]. As we deducted some portions of ground described in the final iteration gave the peak value of the Gain respectively. The Gain is having its peak value of (6.298 dB) at the frequency of (14.25) GHz by keeping the values of (θ= 90°) and (φ=90°) respectively [9].

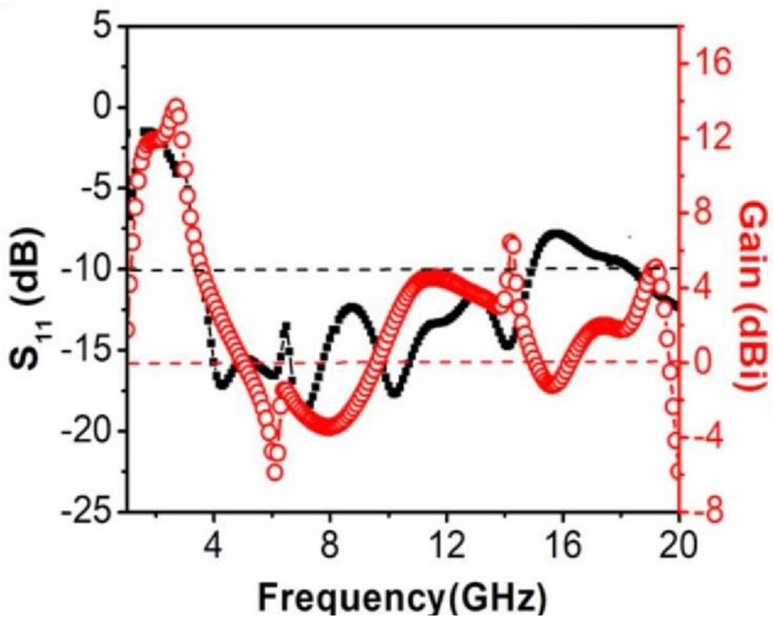

Fig.5 Return loss and gain of the proposed antenna

Fig.5 represents the combined plot for return loss and gain for the final designed antenna. In a given direction, the phase and amplitude of the Co- polarization and Cross-polarization components are entirely depicted in Figure 6 or 7. In (Fig. 6) we can analyze the value of (Gain Theta) at two certain values of ($\boldsymbol{\theta} = \mathbf{0}$°) or ($\boldsymbol{\theta}$=$\mathbf{90}$°) and similarly for

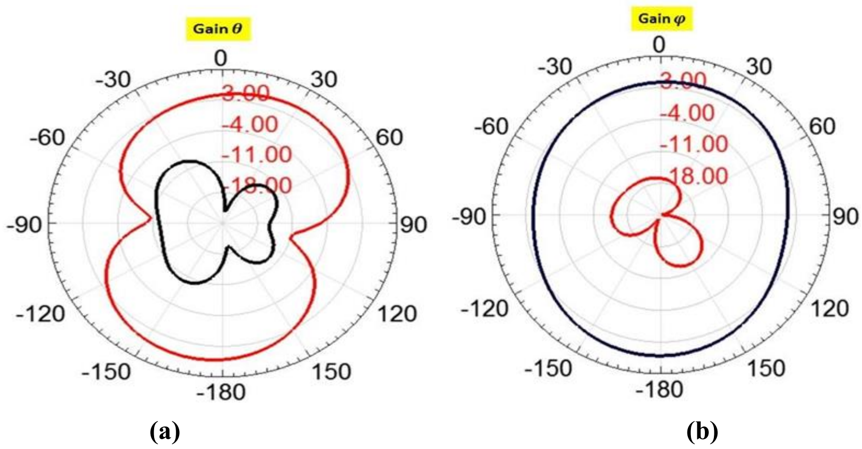

Fig.6 Radiation pattern in theta and phi plane at 5GHz

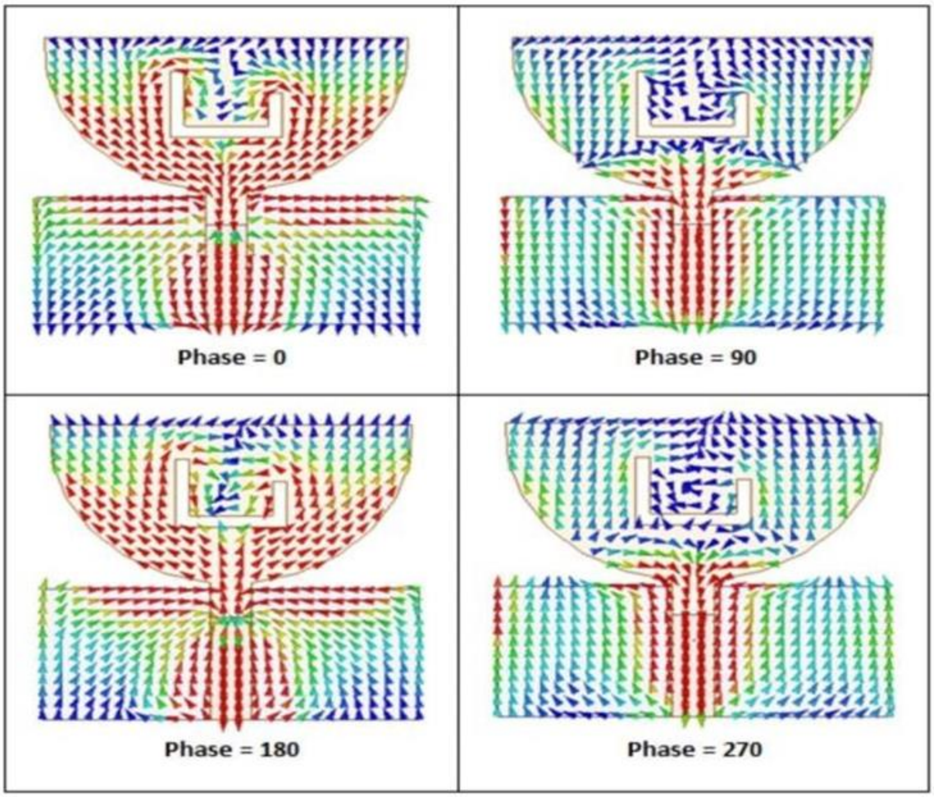

Fig.7 Surface Current distribution at 5GHz

(Gain Phi) where the principal values of it are plotted at the intervals of ($\boldsymbol{\varphi}$ = **0**°) or ($\boldsymbol{\varphi}$ =**90**°) respectively. From the graph, it is shown that Cross-polarization level is low respectively.

In the above figure, implementation of the current density distribution is carried out for the four phases (0°, 90°, 180° and 270°). From the demonstrations, it can be observed that the maximum distribution is constrained at the feed from where the input is being driven into it. At phases (0 and 180), the maximum distribution is along the feed and as well as at the slotted region, while at phases of (90 and 270) is having the portion during these two phases are having uniform distribution across the edges respectively.

IV. Conclusion

In this paper, the main goal was to design an antenna which can operate in multiple or can also work in various microwave bands. The (Bandwidth) of this designed antenna is 11.5 GHz with a peak Gain of 7.2dB. After varying few elements like Feed Width and Ground Length, it was observed that by keeping relative (Feed Width) of 3mm and (Ground Length) of 11.5 mm reducing it more than half along with a rectangular slot gave the best possible results. With these enhancements, the designed antenna can be implemented in multiple bands which can be used in a large domain [13]-[14].

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