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Bandwidth Enhancement of Compact Circular Slot Antenna for UWB Applications

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Abstract- In this paper the compact circular slot antenna suitable for UWB applications is presented. The bandwidth enhancement technique introduced in this design is using modified patch and ground plane of the antenna with ring and circular shaped slots on the patch.The diagonal cuts at the top corners and the rectangular slots can increase the bandwidth of antenna. The proposed antenna is excited with a simple 50- microstrip line. The simulated and measured results indicate that the proposed antenna with dimensions of 30mm (Wsub) x 50mm (L_{sub}) x 1.6mm (H) has a large bandwidth over the frequency band from 2.75 GHz to 20 GHz with VSWR less than 2.The presented results also depict the radiation behavior which exhibit good radiation pattern, and impedance bandwidth over the entire band of operation.

Keywords: *microstrip antenna, return loss, UWB antenna.*

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Sonalika P. Kulkarni [α] & Veeresh G. Kasabegoudar [σ]

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I. Introduction

With the rapid development of wireless communication systems and increase in their applications, compact and wideband antenna design has become a challenging topic [1]. Printed slot antennas are widely used in a variety of communication systems because wide-slot antennas have two orthogonal resonance modes, which are merged to create a wide impedance bandwidth [2]. Thus, printed slot antennas have recently received a great deal of attention from researchers. As is well known, an antenna with various shapes such as circle [3], ellipse [4], and triangle [5] were reported for wide bandwidth. Each slot shape requires a feed stub of appropriate shape. An optimum impedance bandwidth can be obtained by the coupling between the feeding structure and the slot.There are some more methods of Bandwidth of antenna Increases Like bandwidth of a dual patch antenna is improved by etching dummy EBG pattern on the feed- line [6]and proximity coupled feed and aperture coupled feed methods are used [7].The slots etched on the ground plane and split square ring slots etched on the patch has been designed with wide bandwidth and minimal return loss characteristic for UWB applications [8].The new method of enhancing the bandwidth of a proximity coupled microstrip patch antenna using an integrated impedance matching network (IMN) is presented [9].

Patch antenna possesses many advantages such as low profile light weight small volume and compatibility with monolithic microwave integrated circuits (MMIC) and MIC. The narrow bandwidth is the major obstacle in wide application for the micro strip antenna [10]. Basically, the maximum achievable data rate or capacity for the ideal band-limited additive White Gaussian noise (AWGN) channel is related to the bandwidth and the signal-to-noise ratio through Shannon-Nyquist criterion [12].

$$C = B \log_2 (1 + SNR) \qquad (1)$$

Where C denotes the maximum transmit data rate, B stands for the channel bandwidth, and SNR is the signal-to-noise ratio. From this principle, the transmit data rate can be enhanced by increasing either the bandwidth occupation or the transmission power.

In this article, we report a technique to enhance the bandwidth using a microstrip-fed planar circular disc monopole. The circular disc monopole with a 50-Ω microstrip feed line is fabricated on the FR4 substrate. To improve the bandwidth, we modified the original ground plane to be T-shaped with diagonal cuts at the top corners and rectangular slots on the body with the ring and slot introduced in the patch of the antenna. Applications of corner cut technique have been previously employed to improve the impedance bandwidth for microstrip patch antennas [4– 6]. The preliminary simulation results of our proposed antenna are compared with the measured ones. Following this introduction, the rest of the paper is organized as follows.

The detail of the antenna design and preliminary results from simulations are described in Section 2, and Section 3 presents the modifications done to achieve UWB operation. Experimental validation and discussions are presented in Section 4 followed by conclusions of the work carried out in Section 5.

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II. Basic Antenna Geometry

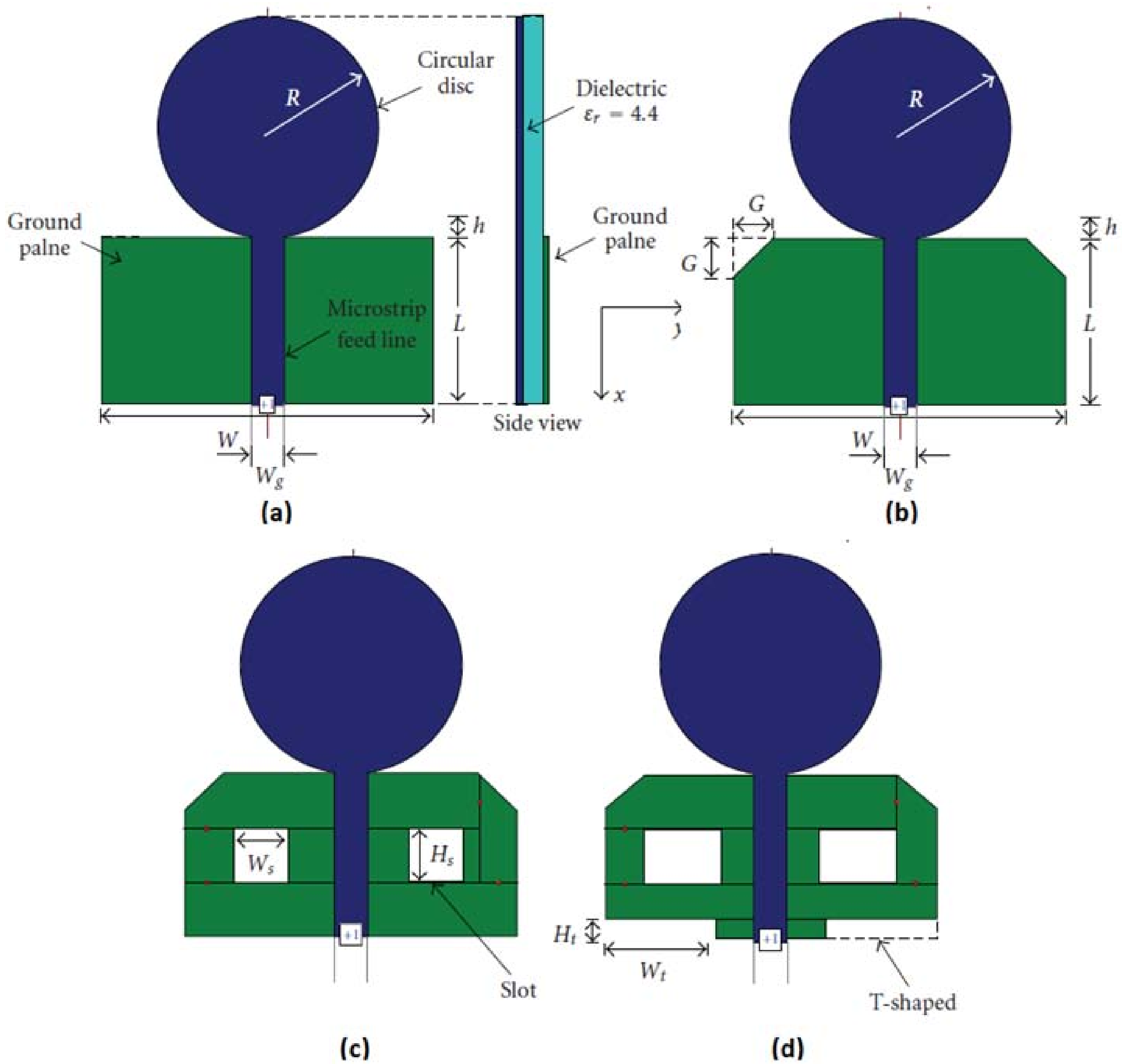
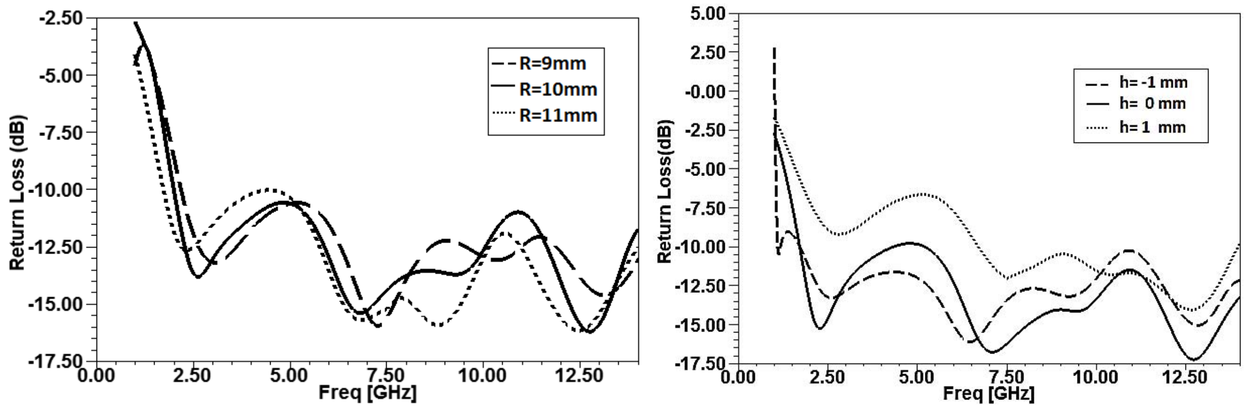


Figure 1: Geometries of the circular microstrip antennas (a) original shape, (b) with diagonal edges, (c) with slots, and (d) with T-shaped cut on the ground plane

The geometry of the proposed antenna is shown in Figure 1.The proposed antenna, with overall dimensions of only 30x41mm^2 is fabricated on a FR4 substrate with a relative permittivity of 4.4 and a thickness of 1.6 mm. On one side of the substrate, two ring-shaped slots are etched to create a relatively wide frequency band since the larger inverted slot affects the lower frequency mode, while the smaller one influences the higher frequency mode. Moreover, at the end of the feed line, a rectangular conducting patch is applied to create a good impedance matching for the proposed antenna to attain the bandwidth enhancement for the UWB applications. By properly varying the lengths of L and W, a wider impedance matching is achieved. To investigate the performance of the proposed antenna, the electromagnetic simulation software Ansoft HFSS is used for parameter studies and other parameters are also described in Figure 1.Unlike most of the ultra-wideband printed antennas which have partial or defected ground planes (DGS) for ultra-wide bandwidth enhancement, this antenna has a full ground plane.

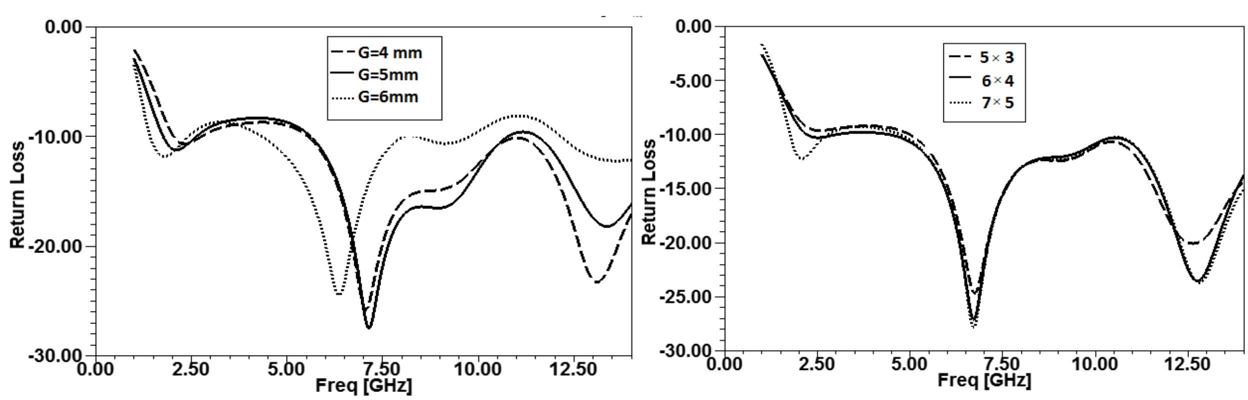


(a) (b)

Figure 2: Return losses as functions of (a) disc radius R and (b) vertical gap

In order to increase the impedance bandwidth, two C-shaped slots are inserted in the ground plane of the designed antenna as shown in Figure 1.The slotted ground planes that provide one more resonance is shown in Figure 2.The monopole antenna with slotted ground plane has wider impedance matching in comparison to the same antenna without slot in ground plane. The Results in Figure 2indicate the varying radius values increase the impedance bandwidth of the antenna and for this we have chosen the 10mm radius for optimum impedance bandwidth.

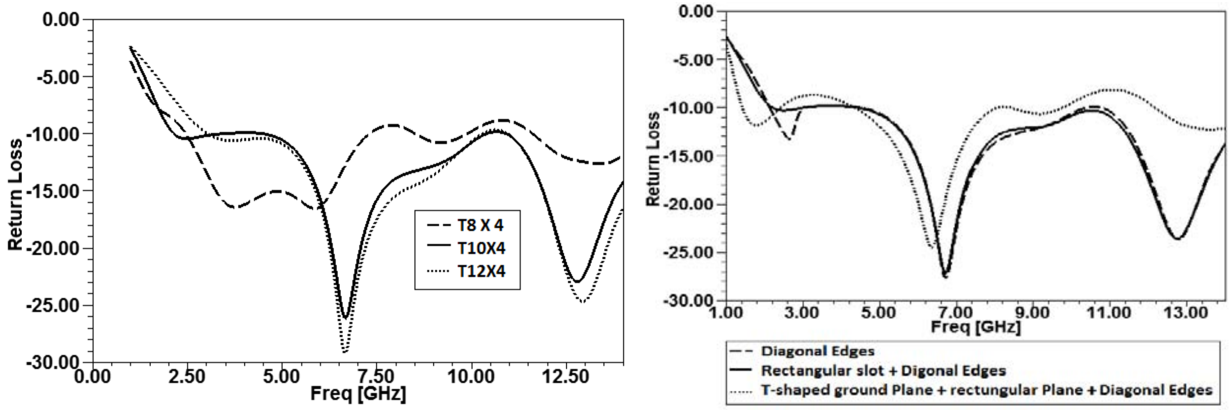
While the next parameter for selection of the gap (G) between the ground planes of the UWB antenna with respect to the feed line of the UWB antenna. Whenever the *h* is positive the bottom of the disc is at the higher level than the top of the ground plane. The same can be said for the negative value of *h* in the opposite direction. The results of the return loss and bandwidth as a function of the parameter h are shown in Figure 2(b).By analysing the *h* parameters we select it is zero value for the good frequency resonance. Later the length of the ground plane of the UWB antenna is analysis on the basis of parametric study. The length equal to L=15 mm for the high impedance bandwidth of the antenna. Second, the length of the ground plane affects the impedance matching more significantly at higher frequencies than at lower frequencies as shown in Figure 3.



(a) (b)

Figure 3: (a) Return losses as a function of the parameter G associated with the removed area on the ground plane. (b) Return loss (Γ) of antenna with slot dimension

In this study, a change in the dielectric constant leads to a shift in the characteristic impedance of the feeding strip from 50 ohm [13]. The corner cut used here plays an important role in balancing resistive part and reactive part which affect the impedance matching shown in Figure 3(a). Triangle slot at the Ground plane of the antenna increases radiating edges which results in improved bandwidth [14]. A parametric analysis for the effect of the position of rectangular slot with respect to the ground plane on the return loss is shown in Figure 3(b).



(a) (b)

Figure 4: (a) Return losses of antenna as a function of T-shaped cut dimension (b) Comparison of return lossless of all three antennas shown in Figure 1(i.e., Figures 1(b), 1(c), and 1(d))

As it could be observed from Figure 4, at each frequency band the surface current is concentrated around different part of the slots, indicating that the slots functioned as band stop filters to reject each target band. In order to further improve the overall bandwidth, rectangular-shaped slot in the patch is incorporated. The return loss of the antenna in Figure1 (d) Shown in Figure 4(b).Fig illustrates the return loss for different values of slot width and with different parameters of antenna. It is seen that the bandwidth is dependent on the width of the rectangular slot. In order to achieves to highest bandwidth of UWB antenna the rectangular slots, T-shaped slots and the Corner cut slots are introduced in the UWB antenna. A Comparison among the Antennas with modified dimension of ground plane is shown in Figure 4.

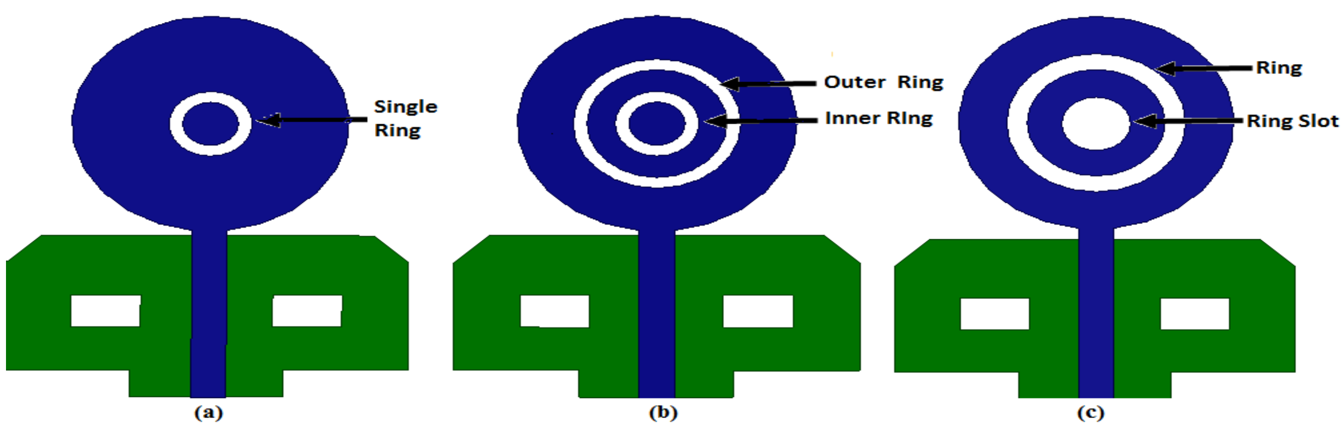
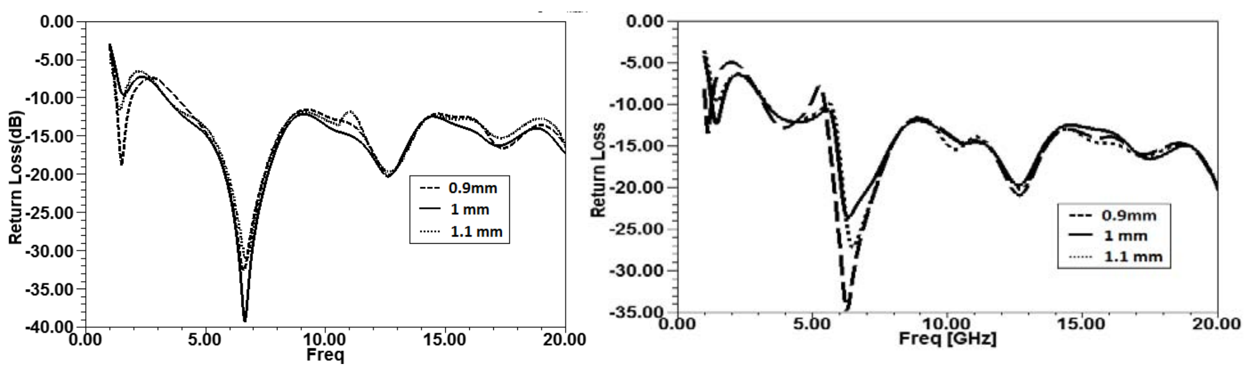


Figure 5: Different Ring Structure (a) Single Ring (b) Inner and outer ring (c) Single ring with slot antennas

III. Antenna Modifications with Ring slot

For more increasing the impedance bandwidth of the antenna the ring type structure enter in the patch of the UWB antenna. In the first UWB antenna, single ring slot insert in the patch of UWB antenna which shown in Figure5. And figure 6(b) shows the two ring structure insert in the patch antenna. Due to insertion of slot in the Patch of the antenna which results shown in Figure 6 and the proposed antenna structure which shown in Figure 5(d) which insert one slot and one Ring structure shaped slot in the patch of UWB antenna.



(a) (b)

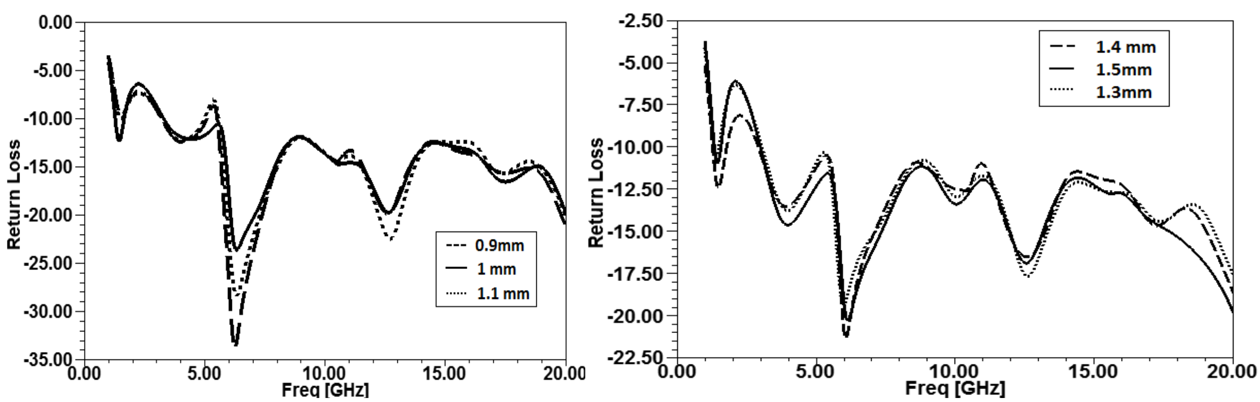
Figure 6: (a) Return loss of antenna with Single Ring dimension b) Return loss of antenna with inner Ring dimension

To meet the required objectives, some geometrical alterations have been made in the antenna when compared to the conventional micros trip patch antenna. By varying the radiuses of the ring in the patch of UWB antenna is shown in Figure 7.

The comparison over the different slot of the antenna shown in Figure 5 over the bandwidth and return loss and gain frequency shown in Table 1. Fractional bandwidth is also calculated and gain of the UWB antenna is also shown in Table 1.

Table 1: Comparison of the ring and round circular slot on antenna parameters

Sr. No.	Types	Resonance Frequency	Return Loss(dB)	VSWR	Bandwidth (MHz)	% BW	Gain (dB)
1	Single Ring	6.6	-39.32	1.05	1670	143%	3
2	Two Rings	6.2	-23.16	1.15	1680	144%	4.3
3	Two Ringswith Slot	6.6	-20.19	1.21	1710	149%	4.4s

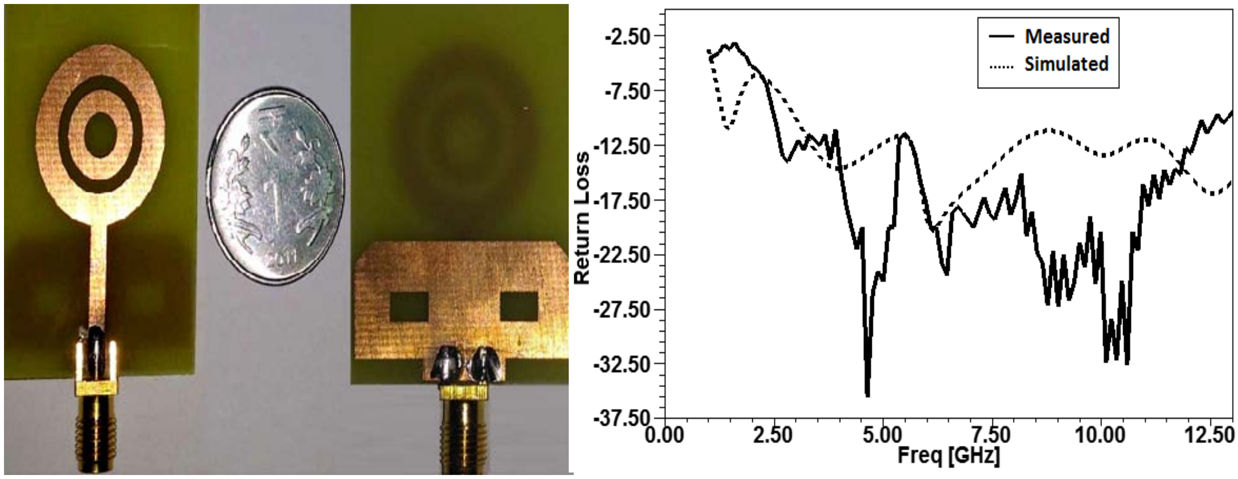


(a) (b)

Figure 7: (a) Return loss of antenna with outer ring dimension (b) Return loss of antenna with single ring dimension with slot antenna

IV. Results and Discussions

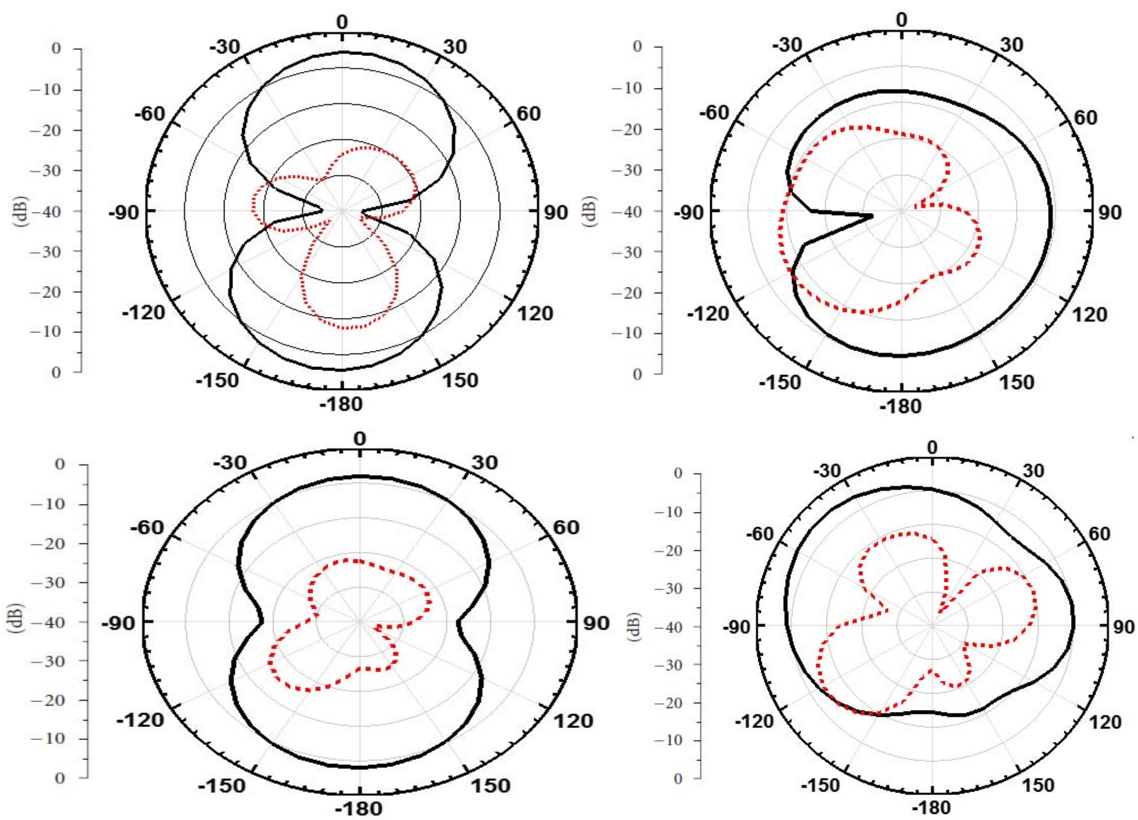
The comparison between the simulated results using commercial high frequency structure simulator (HFSS) and the results from the measurement of the fabricated antenna using a ROHDE N SCHWARZ ZVL Vector Network Analysers is shown in Figure 8(b). The measured result is relatively close to that obtained from simulation. The discrepancy of the return loss at the first resonant frequency would be caused by the size difference of the circular discs [17–19] between the simulation model and the fabrication as mentioned in the previous section.



(a) (b)

Figure 8: (a) Prototype of fabricate Antenna (b) Comparison of simulated and measured return loss of antenna

Antenna radiation patterns demonstrate the radiation properties on antenna as a function of space coordinate. For a linearly polarized antenna, performance is often described in terms of the E and H-plane patterns [8].



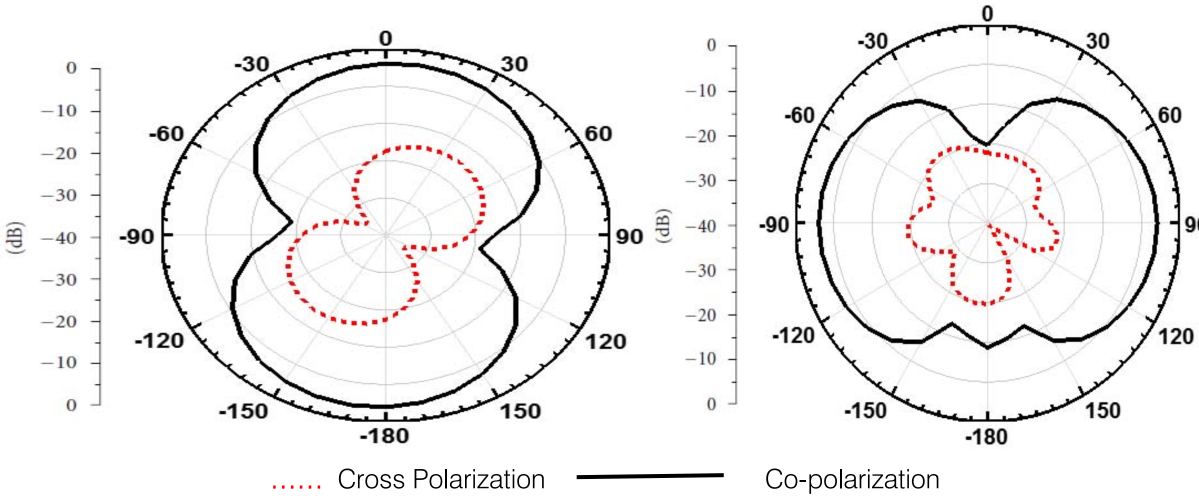


Figure 9: Simulated far-field radiation patterns; *(left)* H (x-z)-plane and *(right)* E (y-z)-plane at (a) 3.24 (b) 4.22, and (c) 9.12 GHz

The electric field (E) and magnetic field (H) planes at different frequencies are shown in Figure 9. It is obvious that the antenna behaves like a typical monopole antenna that acquires Omni-directional pattern in the lower frequencies and quasi Omni-directional pattern in the higher ones. It is known that a conventional thin patch antenna with a full ground plane is inherently narrow band. Thus, to achieve a very wide bandwidth, several bandwidth enhancement techniques, such as inclusion of multiple resonators [13], slots [15], and parasitic element [16] are applied.

The 10 dB return loss bandwidth is indeed slightly decreased (4.2 to 9.3 GHz) compare to the flat one. This shows that the antenna is relatively robust against the physical deformation. The peak gain of the antenna is shown in Figure 10.

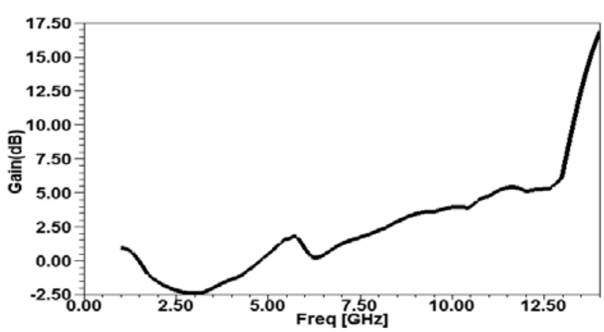


Figure 10: Simulated gain of the antenna vs. frequency

V. Conclusions

In this paper, a compact small square monopole antenna suitable for UWB applications has been investigated and presented. By inserting the ring shaped structure and circular slot on the patch of antenna which resulted in the good impedance bandwidth. The length of the ground plane at the bottom layer and the position of the slot with respect to the ground plane play a great role in optimizing the return loss, and the antenna radiation parameters. The radiation patterns of this antenna show good omni-directional performance throughout the UWB frequency range and positive gain. Because of its simple structure, compact size, and good performance the proposed antenna is expected to be a good candidate in various UWB systems.

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