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A Compact Micro Strip-Fed UWB Antenna with Double Band Rejection Using SIR

Abstract: In this research paper, a compact ultra wideband (UWB) antenna with double notch bands using SIR is proposed.Rejection bands around 5.15–5.85 GHz WLAN frequencies are obtained by embedding a step impedance resonator (SIR1) near the radiating patch of the antenna. Furthermore, rejection for the 8.0–8.4-GHz ITU-band frequencies as second rejection band is achieved by placing another SIR near the feed line patch junction of the antenna. Effects of the basic design parameters on antenna band notch characteristics are also examined.

The correlation between the simulated and experimental results shows that the proposed antenna can be efficiently used in ultra wide band applications. The design and functional simulation of proposed antenna is analyzed using HFSSv14 software.

Keywords— Step Impedance Resonator, Ultra Wide band, Wireless Local Area Network

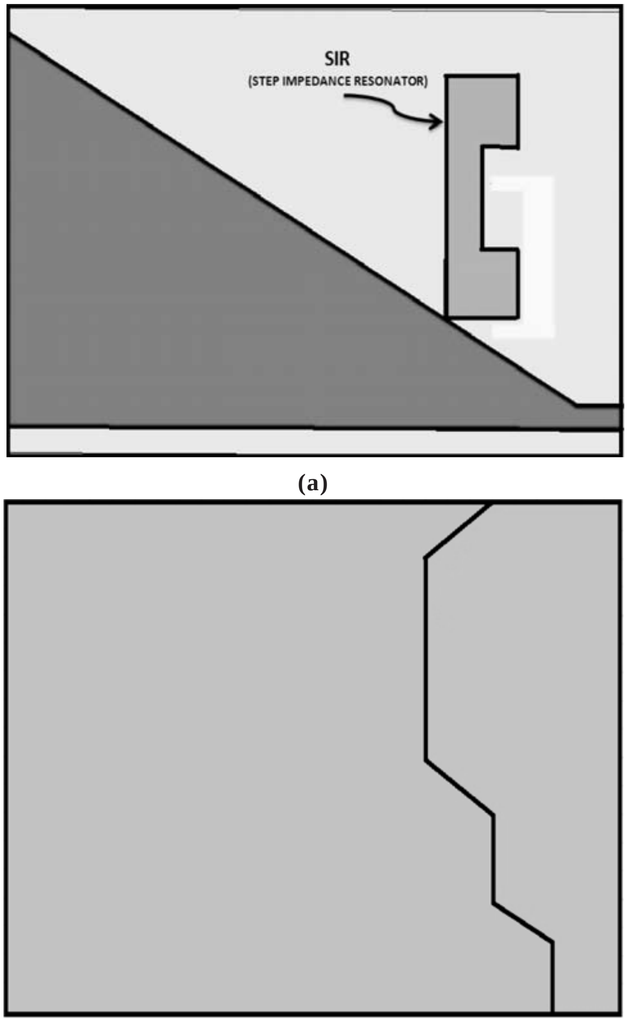
I. INTRODUCTION

In the year 2002, the US Federal Communications Commission (FCC) allocated the ultra-wideband (UWB) spectrum from 3.1 to 10.6 GHz to be used for commercial communication purposes [1]. UWB communication systems can support high data rates with low power consumption and are mainly used for short-range indoor communication systems. Antennas spanning the broad frequency range of 3.1–10.6 GHz are essential components of such UWB systems. Hence, their design problem has become an active topic of research in recent years. In the last decade, several UWB antennas with different shapes have been developed and adopted in practice. Designs of antenna for ultra-wideband applications face many challenges including their radiation stability, impedance matching, small size, less cost of manufacturing, and EMI problems. [2].

For the band rejecting, many methods have been reported. The most popular approach is etching slots on the UWB antenna radiator to achieve notched band performance [3-8]. Various shaped slots can be chosen, such as triangle-shaped, L-shaped, C-shaped, U-shaped slots, etc. The etched slot could be simply modelled as a quarter wavelength or a half wavelength resonator, and the length of the slot can be determined by the notched frequency accordingly. Those designs are with flat skirt characteristics and cannot control bandwidth and ripple because they have one-pole rejection characteristics using one or more resonators. The complementary split ring Resonators (CSRRs) have also been etched on the radiator to obtain notched band characteristics in [9]. A UWB antenna composed of two identical monopoles and a strip bar to achieve a band-notched property was reported in [10]. Similarly, with folded strip configuration, the antenna reported in [11] can achieve a good band-rejection performance. The genetic optimisation algorithm has been successfully brought to design a band-notched UWB antenna in [12]. By adding meander line slot or stubs [13, 14], the UWB filter has shown notched band performance, which is also a promising solution for avoiding interferences in another aspect.

However, most of the proposed antennas and filters mentioned above [3-8, 10–14] have only one notched band concerned, which could not meet the requirement of avoiding multiple-interference caused by the coexisting systems. Different multiple (dual, triple, quadruple) band-notched UWB antenna topologies have also been reported in recent literature [15]–[18]. Use of split-ring resonators (SRRs) and complementary split-ring resonators (CSRRs) to design reconfigurable multiple band-notched UWB antennas has been presented in [19]–[22].

In this paper, we propose a new compact micro-strip fed UWB Antenna with dual band rejection functionality using SIR. SIR has been found advantageous for band rejection. One of the key attribute is that it allows its resonant frequencies to be tuned by adjusting its structural parameters. The SIR can be placed around the radiating patch without degradation on the operation of the main UWB antenna except the band-rejection band without any extra space for adoption.



(a)

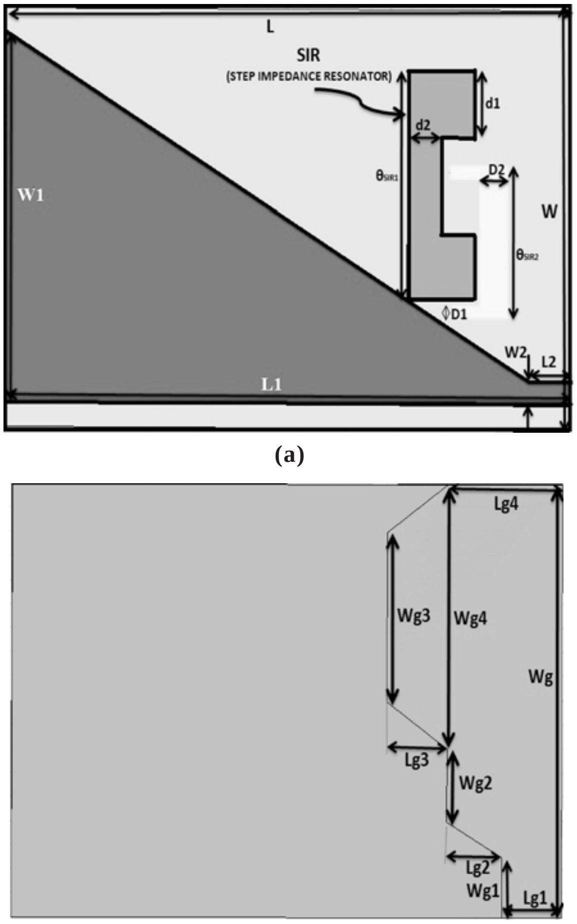
(b)

Fig.1 (a) Top view (b) Bottom view of proposed antenna using SIR

II. METHODOLOGY

The geometries of the proposed antenna are shown in Fig. 1. The antenna radiator is a half-structured bow-tie patch placed on one side of the substrate.

The radiating patch is fed by a 50W micro-strip line of width. The ground plane of the antenna has uneven structure on the other side of the substrate to control the impedance distribution of the antenna.



(a)

(b)

Fig.2 (a) Geometry of patch and substrate (b) Geometry of uneven ground structure

· The width, W and length, L of the patch are calculated by using the transmission line model. The width of the rectangular patch, W is given by using equation

$$W = \frac{c}{2fo\sqrt{\frac{\varepsilon r + 1}{2}}}$$

$$L = \frac{c}{2fo\sqrt{\varepsilon r}}$$

- The effective dielectric constant, can be obtained by using equation -

$$\varepsilon eff = \frac{\varepsilon r + 1}{2} + \frac{\varepsilon r - 1}{2} \left(1 + 12 \frac{h}{w} \right) - 1\ 2$$

- The length extension of the patch, can be obtained by using equation -

$$\Delta L = 0.412\, h \left[\frac{(\varepsilon reff + 0.3)\left(\frac{w}{h} + 0.264\right)}{(\varepsilon reff - 0.258)\left(\frac{w}{h} + 0.264\right)} \right]$$

Parameter	Data(mm)	Parameter	Data (mm)
Length of substrate L	27.5	**Wg2**	3
Width of substrate W	18	**Wg3**	7
Height of substrate h	0.64	**Wg4**	11
Length of patch L1 L2	27.5 2	**Lg1**	3
Width of patch W1 W2	16 1	**Lg2**	2.75
Wg	18	**Lg3**	3
Wg1	2.5	**Lg4**	5.7
θSIR1	10.7697	**θSIR2**	6.67 49
d1	4.34676	**D1**	0.68 014
d2	1.23779	**D2**	1.34 27

- The actual length of rectangular patch, L is calculated by using equation-

$$L = Leff - 2\Delta L$$

where *Leff* is the effective length and is calculated as-

$$Leff = \frac{C}{2fo\sqrt{\varepsilon reff}}$$

- The dimensions of the ground plan may be given as-

$$Lg = 6h+1 \ \& \ Wg = 6h+w$$

The proposed antenna fabricated on 0.64 mm-thick Taconic RF60-A substrate (dielectric constant 6.15, loss tangent 0.0023). Prior to proceeding for full-wave simulations, we make some initial assumptions about band-notch elements. It is non uniform transmission line i.e. as transmission line is in step form having different electrical length and different impedance. Wave cancellation theory [12] states that when two signal having same properties but phase shift of 180° at defined frequency then they cancel out each other at that defined frequency.

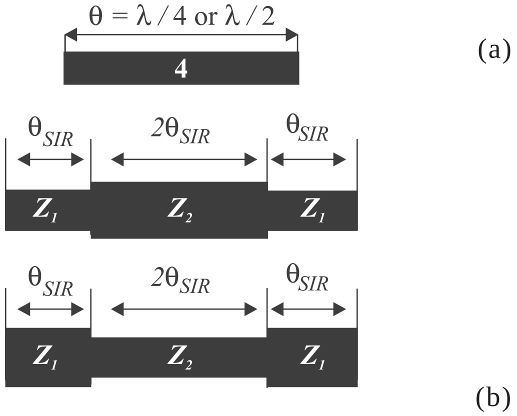


Fig.3 Types of SIR resonator (a) unitary impedance resonator (b) Various SIRs

Now, we attach the first SIR to the basement UWB antenna to obtain a rejection bands. The structure of SIR1 used for this is a series combination structure of different impedance micro-paths, as shown in Fig. 3. The SIR generates the second harmonics according to the difference of the each impedance which results in third rejection band of antenna.

The second harmonics and the length of transmission line can be determined by [9]

$$\mathbf{fs2 = \pi f / (2tan - 1 \sqrt{K})} \quad (1)$$

$$\mathbf{K = Z1/Z2} \quad (2)$$

$$\mathbf{\theta SIR = tan"1\sqrt{K}} \quad (3)$$

According to (1), (2) and (3), the frequency of the second harmonics is two times of the base frequency in unitary impedance resonator. Thus, it is predictable that the second harmonics would be generated at the frequency of

$$f_{s2} < 2 f_0, \text{ when } K < 1$$

$$f_{s2} > 2 f_0, \text{ when } K > 1 \qquad (4)$$

So that we can adjust the 2nd harmonic frequency. The initial length of the SIR (θSIR1*)* is predetermined by the centre frequency of the stop band. The most important design parameters to be decided are gap and *d*1, *d*2 of SIR.

The second SIR2 is embedded on basement UWB antenna to obtain a rejection band centred at ITU 8GHz band.

III. SIMULATION AND RESULTS

Fig. 7 shows the simulations result including return losses (S parameter) of the antenna having multi-band characteristic in the UWB spectrum.

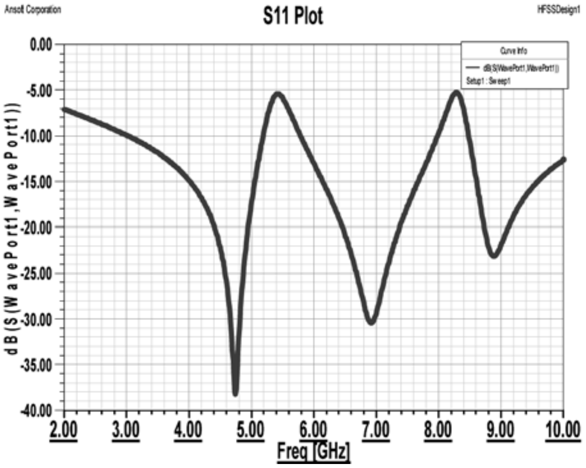


Fig.4. RL Vs frequency curve

From Fig. 4, it is observed that UWB antenna covers total frequency range from 2.8 GHz to 10.8 GHz except two rejection bands ranging from 5.15GHz to 5.9 GHz and 7.9GHz to 8.6 GHz with return loss less than -10 dB. The result shows that the proposed antenna structure efficiently performs over the entire UWB range with low return loss.

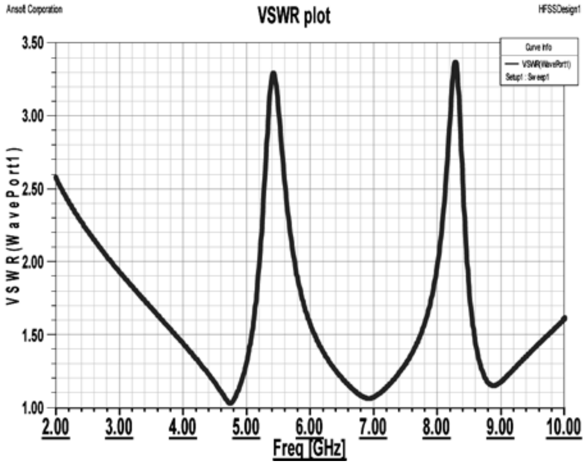


Fig. 5. VSWR Vs frequency curve

Fig. 5 shows the VSWR of the proposed antenna structure with optimized parameters. It is observed from the given Fig. that the simulated VSWR characteristic of the proposed antenna possesses two notch bands for WLAN (5.4 GHz) and ITU (8 GHz).

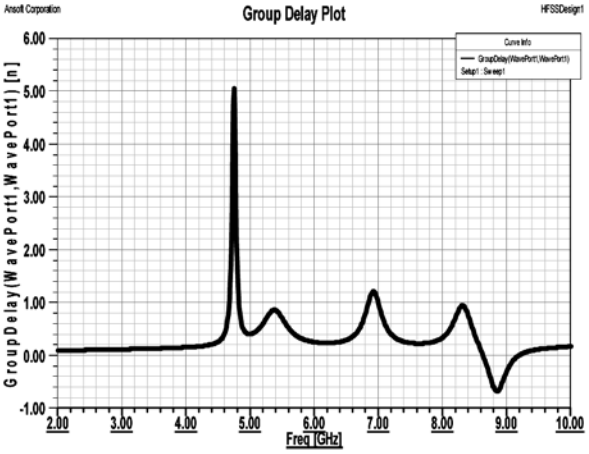
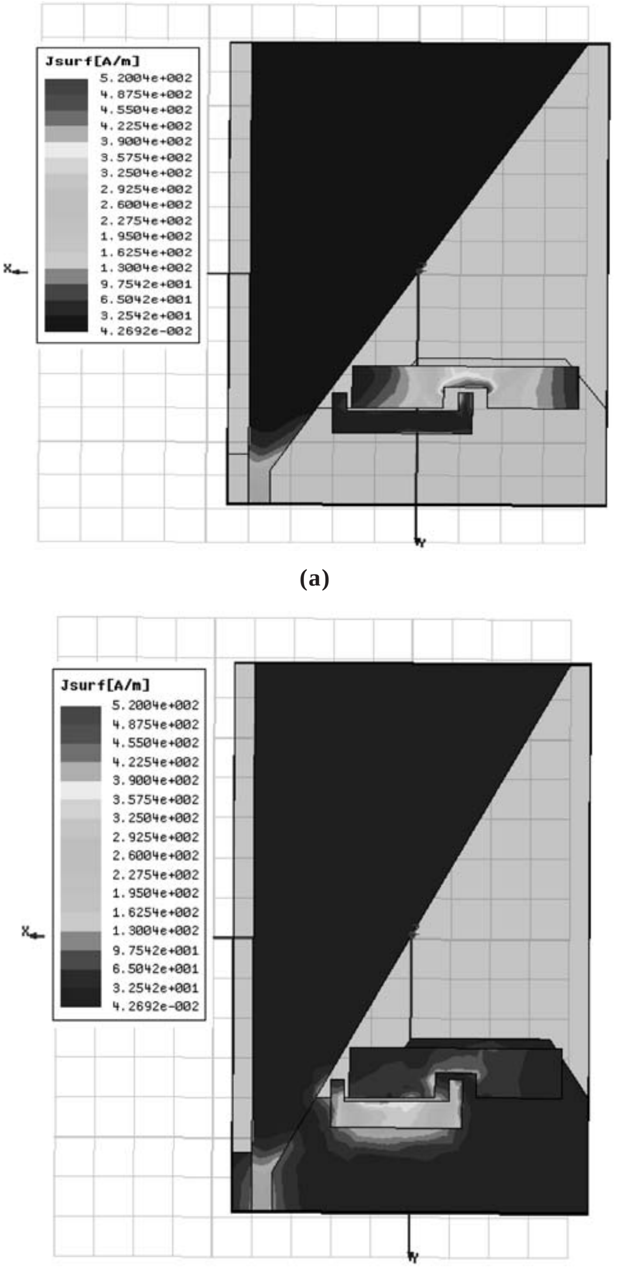


Fig. 6. Group Delay Vs Frequency plot

Group delay is a measure of transit time of a signal through a device versus frequency. Below Fig. shows the group delay Vs freq. curve.

From the Fig. 6, group delay variations of up to 0.5 ns can be observed within the operating bandwidth except rejection bands.

Current distribution at different notch frequency is given below:



(a)

(b)

Fig. 7. Distribution of surface current distribution on the antenna for the three notch frequencies (a) 5.44, (b) 8.28 GHz

From current distribution figures we concluded that SIR1 does not allow current to reach at antenna at frequencies 5.44GHz & 12 GHz and SIR2 plays role to stop current to reach at antenna at frequency 8.28GHz.

EFFECT OF NOTCHED PARAMETERS ON ANTENNA PERFORMANCES

The key parameters are selected to analyse the effects on the band-notched characteristic by considering only one SIR.

- **Effect of Variation of the Geometrical position of SIR**

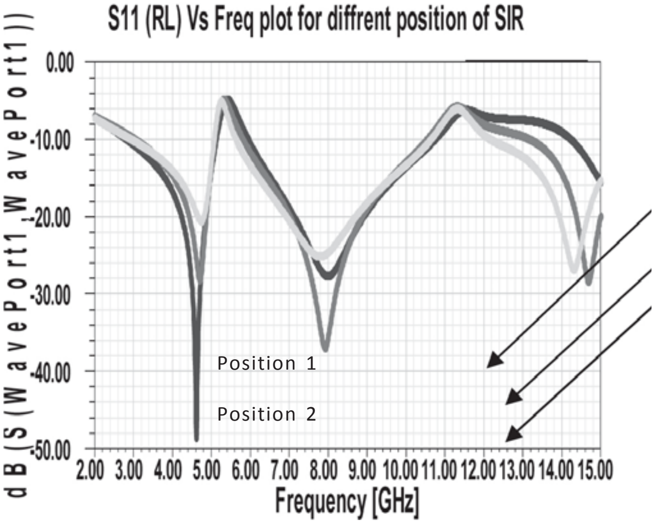


Fig. 8. Plot of position variation of SIR with respect to radiating patch

The plot shown in Fig. 8 gives the comparison of characteristics corresponding to different return losses curves obtained by varying the position of the resonator. The change in the position of SIR causes a variation in the bandwidth of the stop-bands. By positioning SIR in close proximity to radiated patch results in larger bandwidth of the stop-band, while farther positioning results in smaller bandwidth of stop-band.

- **Effect of Variation of Initial Length of SIR**

The plot depicted in Figure 9 shows a comparison of the characteristics to different S11 (RL) curves corresponding to variation in the initial length of the resonator.

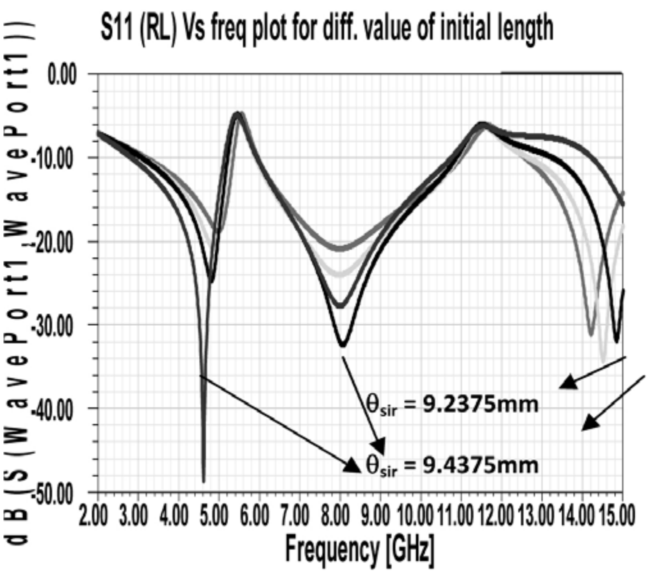


Fig. 9. S11 (RL) Vs frequency curves for different initial lengths of SIR

Fig. shows that the variation in the initial length of SIR causes a change in the center frequency of the stop-band, more is the length of SIR smaller is the central frequency of the stop-band and vice versa.

- **Effect of Variation of d_1, d_2 on the lower frequency of the second rejection band of SIR.**

Fig. 10 shows RL curve corresponding to various widths i.e. d_1 and d_2 of the step impedance resonator It can be observed that an increase in d_1 and d_2 leads to decrement in the bandwidth and vice versa for the proposed antenna.

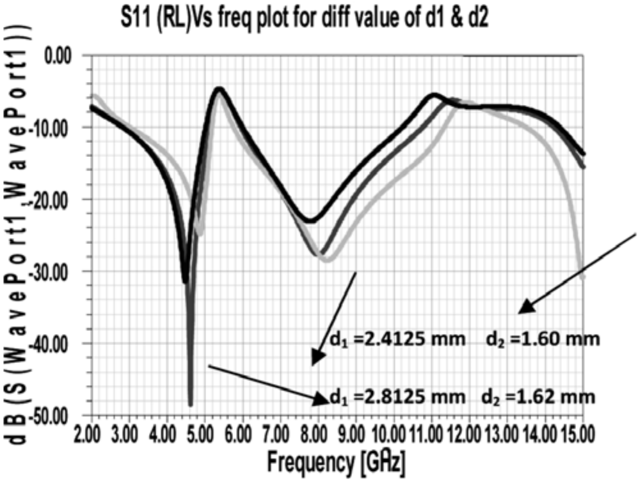


Fig.10 RL vs frequency curves for different width d_1, d_2 of SIR

- **Effect of various Substrate material.**

The curve depicted below in Figure 11 shows the effect of the variation of substrate material of the proposed UWB Antenna structure without any tunning in dimensionals.

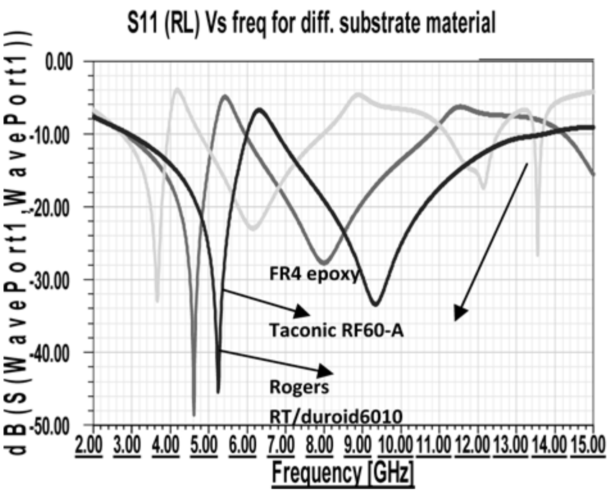


Fig. 11. Effect of various substrate materials of the proposed UWB antenna structure

Fig. 11 shows that in case we use FR4-epoxy dielectric material which has a moderate value of $e_{r,}$ in the substrate, provide us larger bandwidth than that of other two dielectric materials at the cost of Q-factor.

Table 2. Effect of variation of different substrate material

Material	ε_r	tanδ	BW Covered
FR4-epoxy	4.4	0.0200	8.1 GHz
Taconic RF60-A	6.15	0.0028	7.9 GHz
Rogers RT/duroid6010	10.2	0.0012	5.6 GHz

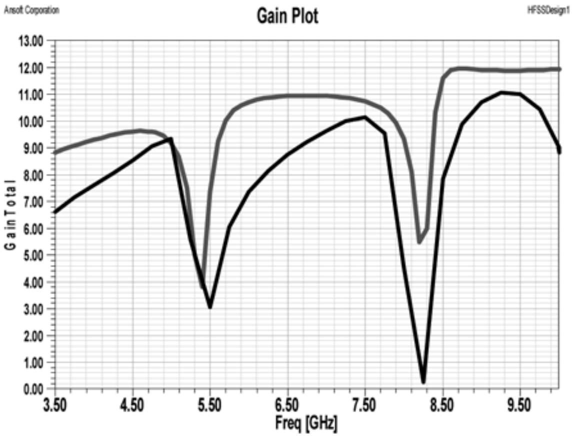


Fig. 12. Comparison of simulated and measured return loss of the proposed UWB antenna

Fig. 12 shows the measured and simulated gain plots of the proposed antenna with single band notch characteristics.

A relatively good trade-off between measurement and simulation can be analyzed. It can also be observed that the input impedance of the fabricated antenna is well matched in the entire UWB band (3.1-10.6 GHz).

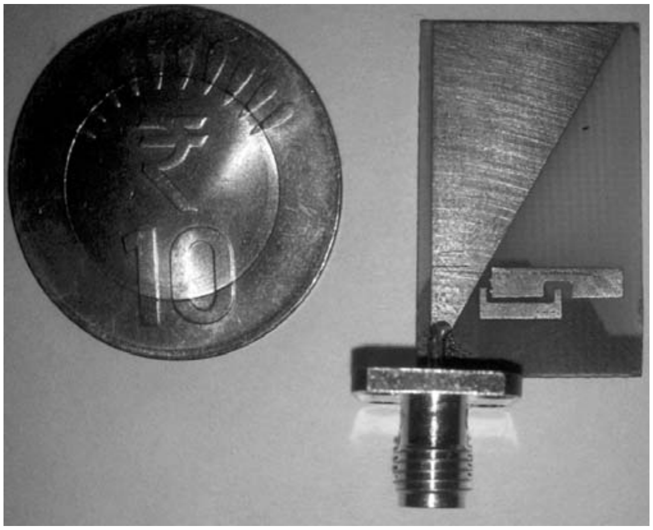


Fig. 13. Fabricated photograph of proposed antenna structure

IV. CONCLUSION

The designed antenna has suitable size and Omni-directional radiation pattern which allow us to use it for UWB applications. Overall, the performance of the antenna meets the desired requirement in terms of return loss and VSWR. The proposed antenna has impedance bandwidth covering the entire UWB range (3.05–10.6 GHz), along with notch-bands in the WLAN (5.15–5.85 GHz) and ITU-band (8–8.4 GHz) frequencies. The design guidelines and relevant equations are described and validated via HFSS simulations. A prototype antenna is fabricated in PCB lab using low-cost Taconic RF60-A substrate. The measurement results of the fabricated antenna exhibit good match with simulation predictions.

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