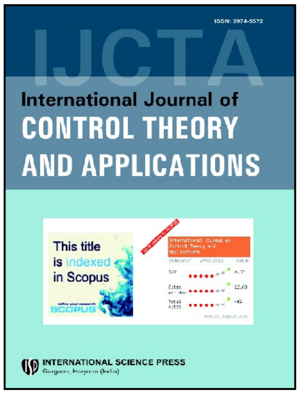

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A Compact CPW-Fed Monopole Antenna using Slotted CSRRs for UWB Applications

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Abstract: A compact CPW-Fed monopole antenna using slotted CSRRs with dual band-notched characteristics is analyzed and presented. To achieve dual band-notch characteristics in UWB against neighbourhood interfering bands, the slotted complementary split ring resonators (CSRRs) are used. The analysis of the proposed antenna is integrated with CSRRs etched on the radiating patch and dual CSRRs etched on the ground. The design antenna is fabricated using a Rogers RT/duroid 5880 substrate with surface area 30x30mm^2, thickness of 0.8mm and relative directivity constant of 2.2.The proposed antenna shows its impedance bandwidth that covers the ultra-wide band which is spread across 3.1 to 10.6 GHz for VSWR ≤ 2 with dual band notches of 3.3 to 3.7 GHz and 5.15 to 5.825 GHz to mitigate the interference from existing Wi-MAX and WLAN bands which makes the antenna a suitable model for desired applications. The antenna design, geometrical parameters and simulations have been carried out by using the HFSS tool. Details of the design steps, parametric studies and measured results of the antenna are presented in this paper.

Keywords: CPW-fed UWB antenna, band-notched characteristics, CSRRs, HFSS.

I. INTRODUCTION

Ultra-wide band technology is a rapid growing field in communication systems because of attractive features such as high speed data rate, increased communication security, simple hardware configuration and low power consumption. It has wide range of applications like sensor networks, radar location tracking, cancer sensing and other commercial applications. The US Federal Communication Commission (FCC) approved the ultra-wide band (UWB) spectrum operating in the band of 3.1 to 10.6 GHz with a -10 dB bandwidth greater than 500MHz that is unlicensed in Feb 2002 for commercial communication purposes [1-2]. In this unlicensed frequency band designated by FCC, there exists other wireless communication systems such as IEEE 802.16 Wi-MAX system operating in the frequency band of 3.3 to 3.7 GHz and the IEEE 802.11a WLAN system operating in the frequency band of 5.15 to 5.85 GHz [3-5]; thus the UWB system is prone to be under interference with the Wi-MAX and WLAN systems.

A feasible way to solve this problem is to design UWB antennas with band-notched characteristics. Several antenna design methods have been developed to overcome the interference problem using band-notched characteristics [6-10].Among these methods, embedding a slot in the feeding line [11-12], or etching different shapes of slots in the radiating patch or in the ground plane of the antennas is most often used [13-18]. Other methods have also been investigated, for instance using parasitic elements, folded strips and resonated cells to the antennas [19-21]. Use of split-ring resonator (SRR) and its complementary SRR structure (CSRR) as shaped-slot and/or shaped-conductor to produce notches at desired frequencies [22-26].

So in this design, a simple and compact CPW-Fed monopole antenna using slotted CSRRs is introduced. The CSRRs are etched on the radiating patch and dual CSRRs etched on the ground plane to obtain dual band-notch characteristics. All the design parameters are related to create band rejection. The CSRRs are made of two rectangular split-ring slots to perform the characteristics of metamaterials. The rectangular CSRR-shaped slot rings length is smaller than a half wave length at resonant frequency. This leads to achieve dual band-notch characteristics that cover Wi-MAX and WLAN bands. However, the position of the slotted CSRRs plays an important role in order to suppress the interference from the existing Wi-MAX and WLAN bands of the proposed antenna. Details of the design steps, simulation and measured results of the proposed antenna are presented and analyzed.

II. ANTENNA DESIGN

The proposed antenna design is fabricated using a Rogers RT/duroid 5880 substrate with surface area 30x30mm^2, thickness of 0.8 mm and permittivity of 2.2 as shown in Figure-1(a). It consists of a radiator combining a semi-circular and rectangular patch as well as an edge-curved ground plane. The patch was fed using 50 ohm feed line with edge-curved ground plane printed on the same side of the Rogers RT/duroid 5880 substrate. The dual band-notch characteristics are obtained by etching the CSRRs in the radiating patch and by etching a CSRRs pair in the ground plane. The parameters of the final design antenna are listed in Table-1.The optimized dimension of the slotted CSRRs having SL1=8mm, SW1=10mm, SL2=6mm, SW2=8mm, S1=0.5mm and G1=3mm which creates a notch in the existing Wi-MAX and WLAN bands is depicted in Figure-1(b).

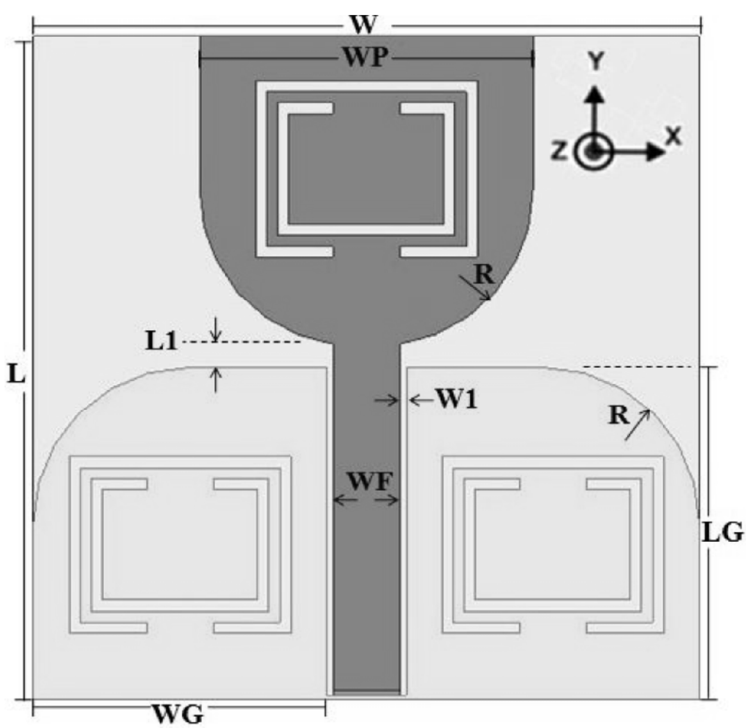


Figure 1: Geometry of the CPW-fed UWB antenna (a) proposed model

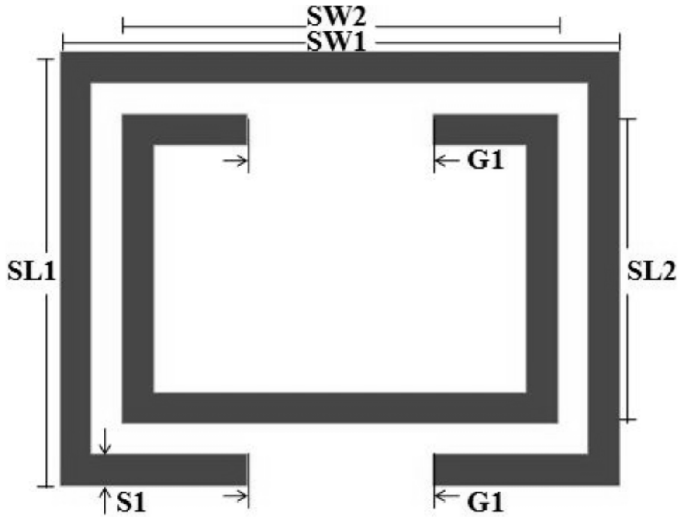


Figure 1 (b): Geometry of the slotted CSRRs

Table 1
Design parameters of the proposed antenna

Parameter	*L*	*W*	*WP*	*L1*	*W1*	*WF*	*R*	*LG*	*WG*
Dimension (mm)	30	30	15	1	0.3	3	7	15	13.2

The geometries of the antenna design that are involved in the evolution process are shown in Figure-2 and its corresponding simulated return loss curves are set in Figure-3.The design procedure begins with the simple basic CPW-fed monopole anenna; Ant#1, that consists of a radiator combining a semi-circular and rectangular patch as well as an edge-curved ground plane.As shown in Figure-3(blue color), this design is showing an ultra wide band behaviour (S11d"10dB) from 2.4 to 14.4 GHz with resonant frequency centered at 12.9 GHz.Next, a pair of slotted CSRRs cut has been introduced in the ground plane (Ant#2) to create a single notched band from 3.3 to 3.7 GHz to eliminate interference from the Wi-MAX band are shown in Figure-3 (pink color).

Similarly, by etching CSRRs at the middle position of the radiating patch as shown in Ant#3, an ultra wide band behaviour from 2.3 to 14.8 GHz with a single notched band is achieved from 5.1 to 6.4 GHz with a bandwidth of 1.3 GHz which will suppress the interference from WLAN band as shown in Figure-3 (green color).A way to suppress the interference from the existing Wi-MAX and WLAN bands, desired dual band notches of 3.3 to 3.7 GHz and 5.1 to 6.3 GHz has been obtained by etching CSRRs in the radiating patch and by

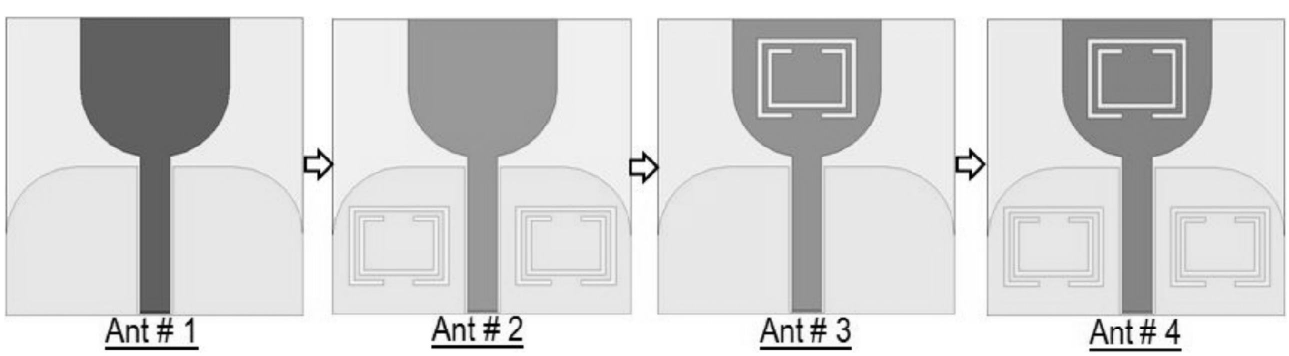


Figure 2: Evolution stages of the proposed antenna

etching dual CSRRs in the ground plane as shown in Ant#4 i.e. proposed antenna.Finally, the proposed antenna could operate from 2.23 to 14.95 GHz, which covers bandwidth requirement of UWB frequency band, for VSWR<2 and also has two notched stop bands for rejecting licensed bands such as Wi-MAX and WLAN, respectively which is clearly shown in Figure 3 (solid red color).

The VSWR characteristics for the evolution stages of antenna design are compared in Figure-4.The VSWR is less than 2 (VSWR<2) in the proposed frequency band of operation.

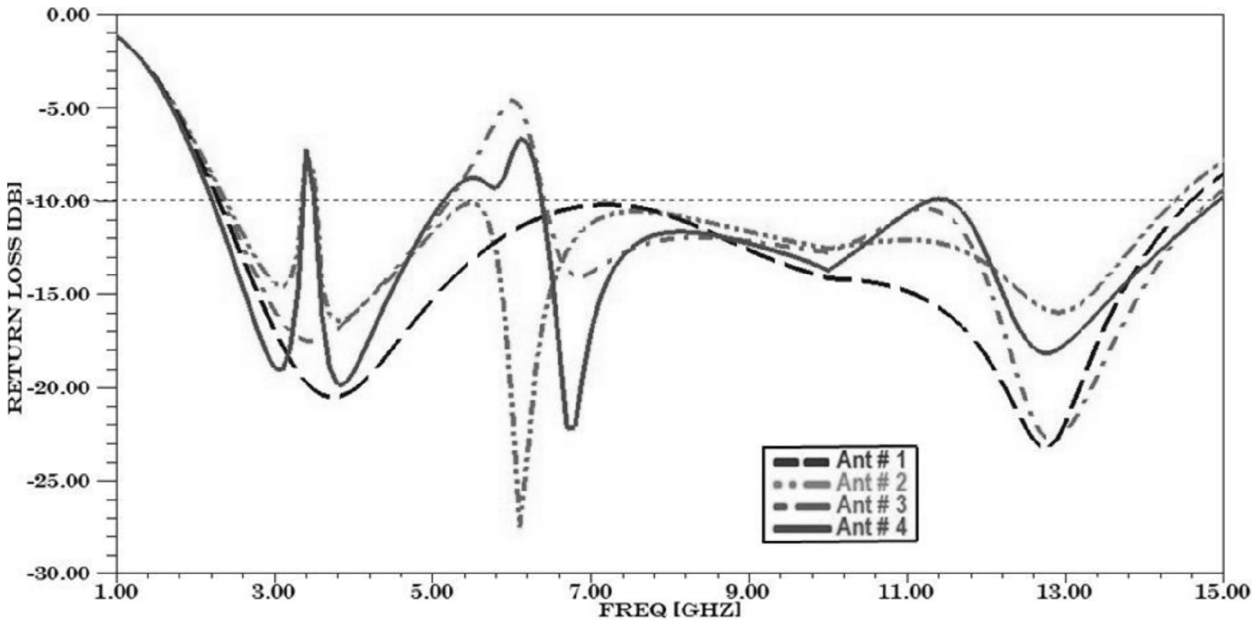


Figure 3: Simulated return loss curves for the evolution stages of antenna design

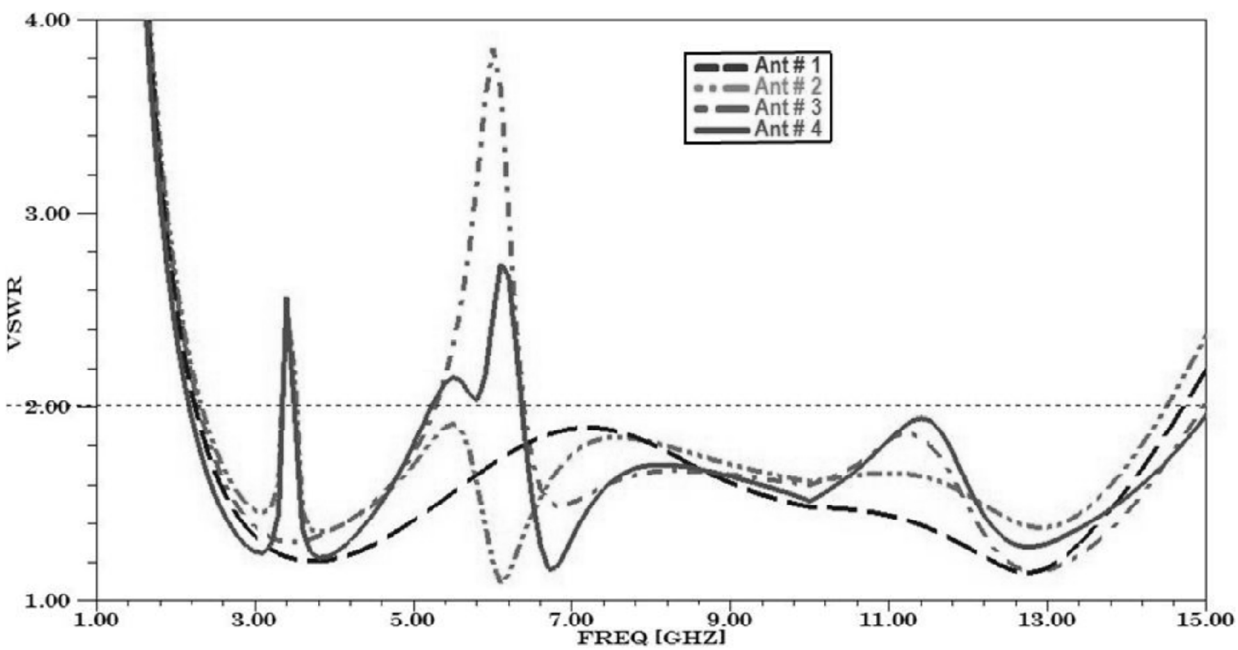


Figure 4: Simulated VSWR for the evolution stages of antenna design

The parametric analysis of the proposed antenna is carried out with respect to the slotted CSRRs in the patch and ground plane.This is executed in order to observe the effects of design parameters, which are detailed as follows.

Figure 5(a) shows the simulated S-parametes of the antenna for different values of external ring length SL1.As the value of SL1 is varied, the desired S-parameters are obtained with improved bandwidth by choosing the value of SL1 is 8 mm which is clearly evident from the figure. Figure 5(b) gives the simulated S-parameters of the antenna with respect to width of external ring SW1.As value of SW1 is slightly increased the notched band shifts towards right.The notched band is seen with 10mm, which is desired.

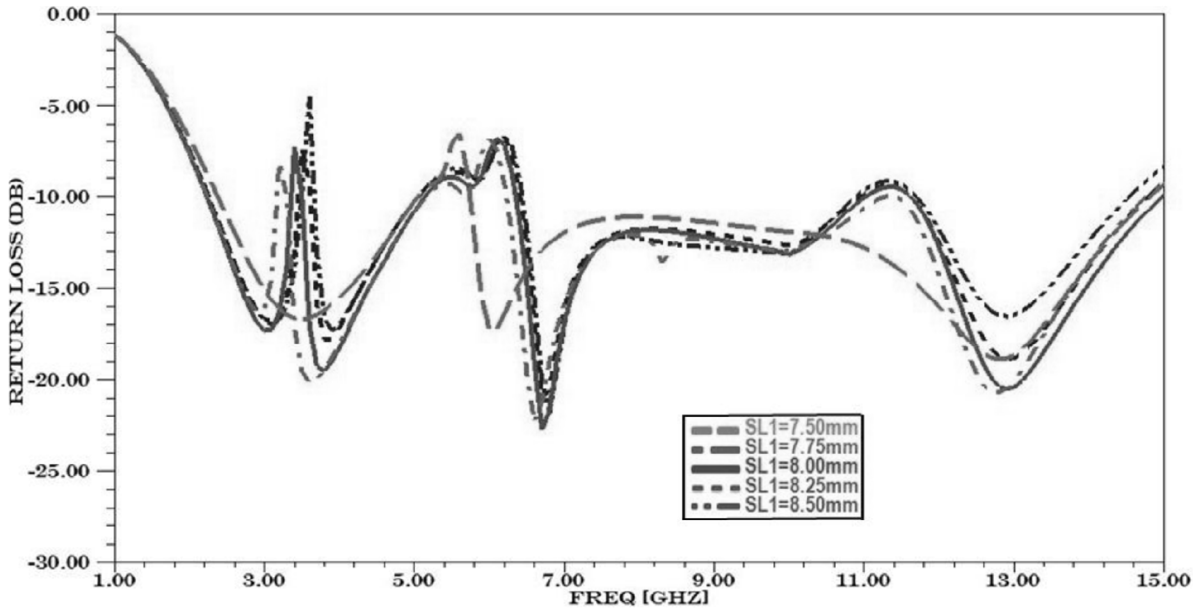


Figure 5(a): Simulated S11 with variation in SL1

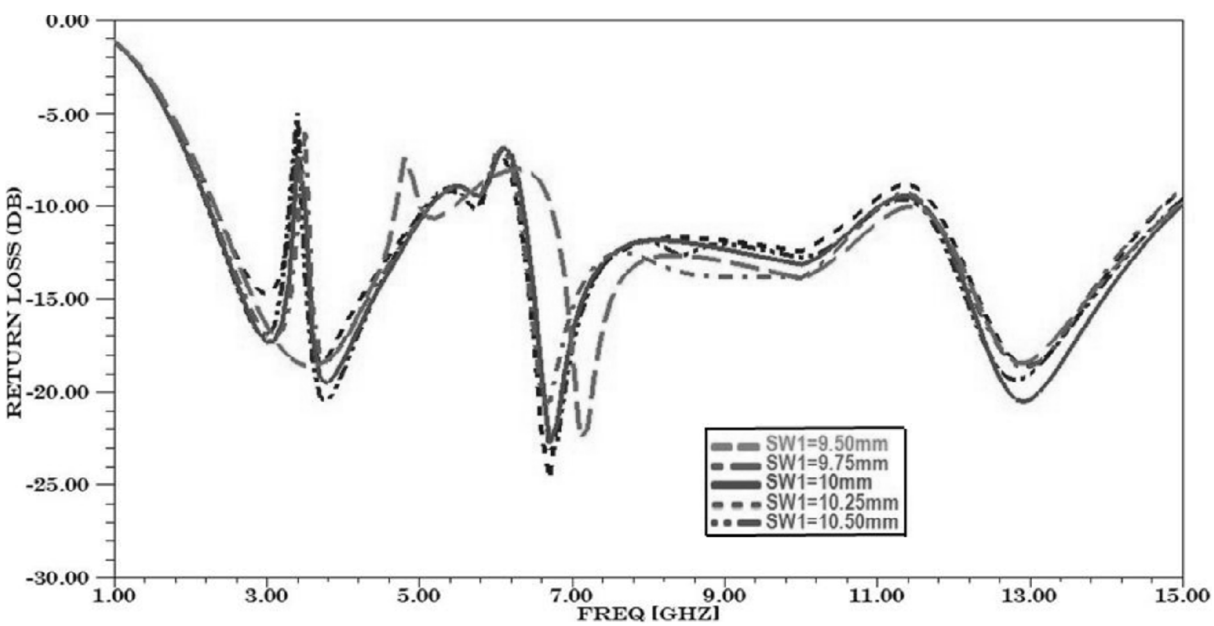


Figure 5(b): Simulated S11 with variation in SW1

Figure 5(c) shows the gap among the two edges of the slotted rings for different values of G1.The resonance of the eliminated bands switches from lower frequency up to a definite value, since the values of G1 rise. Hence, 3mm is the optimized value.Figure-5(d) shows the simulated S-parameters for different values of the slot width i.e.S1, which is the thickness of the CSRR. It is found that the resonance of the band-notched shifts towards left. For the desired performance the value of S1 is set equal to 0.5mm.The simulated reflection coefficient values of the proposed antenna for different feed line widths (Wf) are shown in Figure-5(e).The eliminated Wi-MAX and WLAN bands are acquired, when the width of the feed line is 3mm.Otherwise, the eliminated bands are shifted on lower frequency or higher frequency using 1.5mm, 2mm, 2.5mm, 3.0mm and 3.5mm.

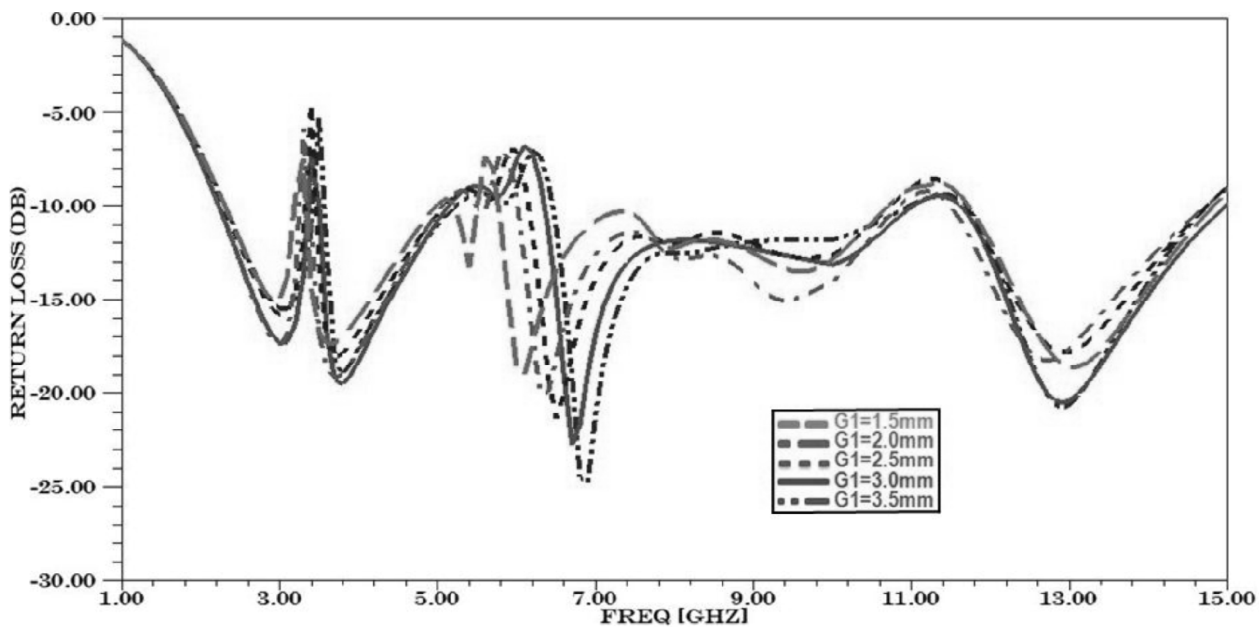


Figure 5(c): Simulated S11 with variation in split ring gap G1

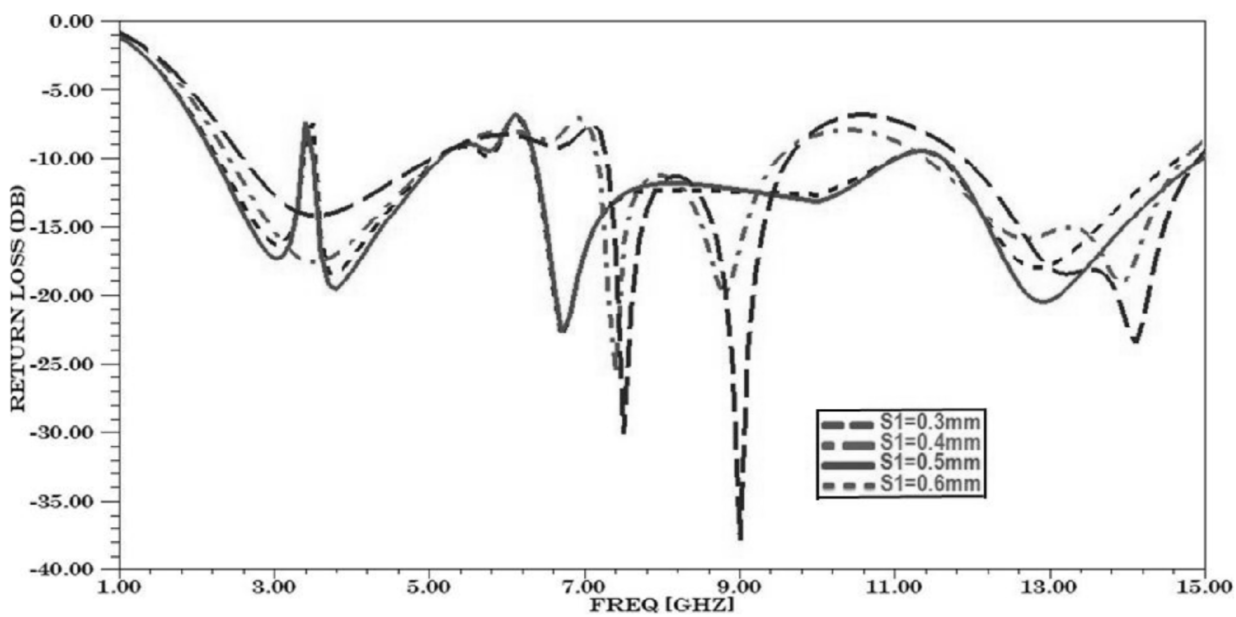


Figure 5(d): Simulated S11 with variation in S1

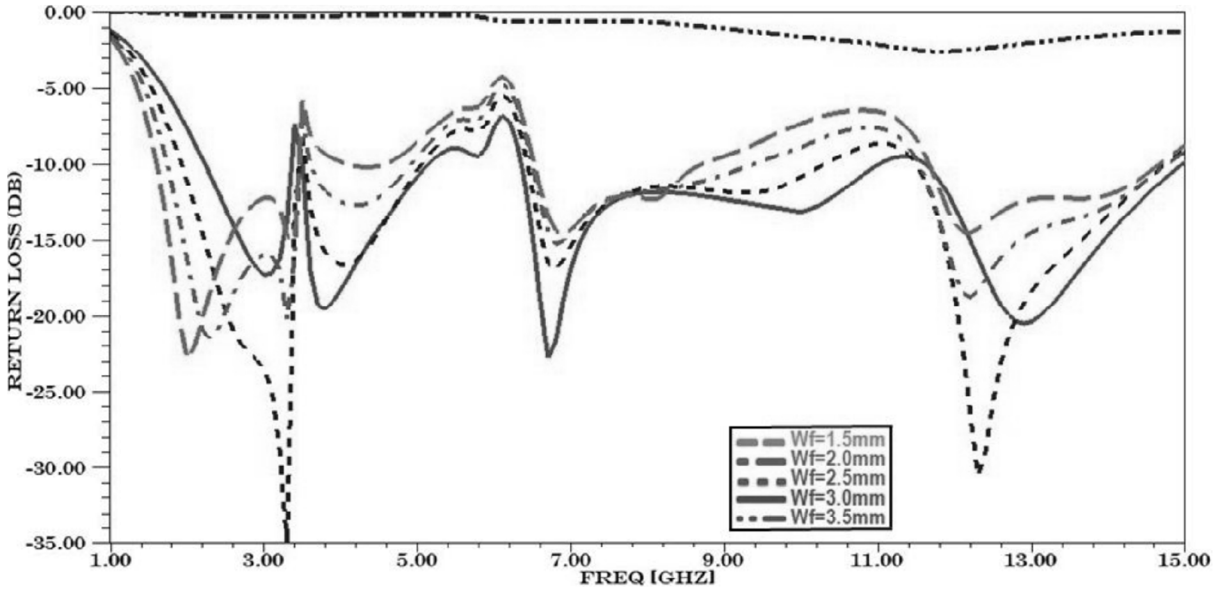


Figure 5(e): Simulated S11 for different values of the feed line width (Wf)

Figure 6 shows the simulated surface current distribution of the proposed antenna at the center of the two notched frequencies i.e. 3.4 GHz and 5.6 GHz. The large current distribution is indicated in red and small one is in blue. It is observed that the surface current at 3.4 GHz is highly concentrated around dual slotted CSRRs in the ground plane and the feeding line, while the current flow is weak around the slotted CSRRs in the radiating patch. This explains why the slotted CSRRs in the radiating patch have little effect on the UWB antenna performance across most of its operating frequency range as shown in Figure-6(a).The simulated current distribution at 5.6 GHz in Figure 6(b) shows around the feeding line as well as slotted CSRRs in the radiating patch. This clearly shows the positive effects of the slots upon obtaining the dual band-notched characteristics.

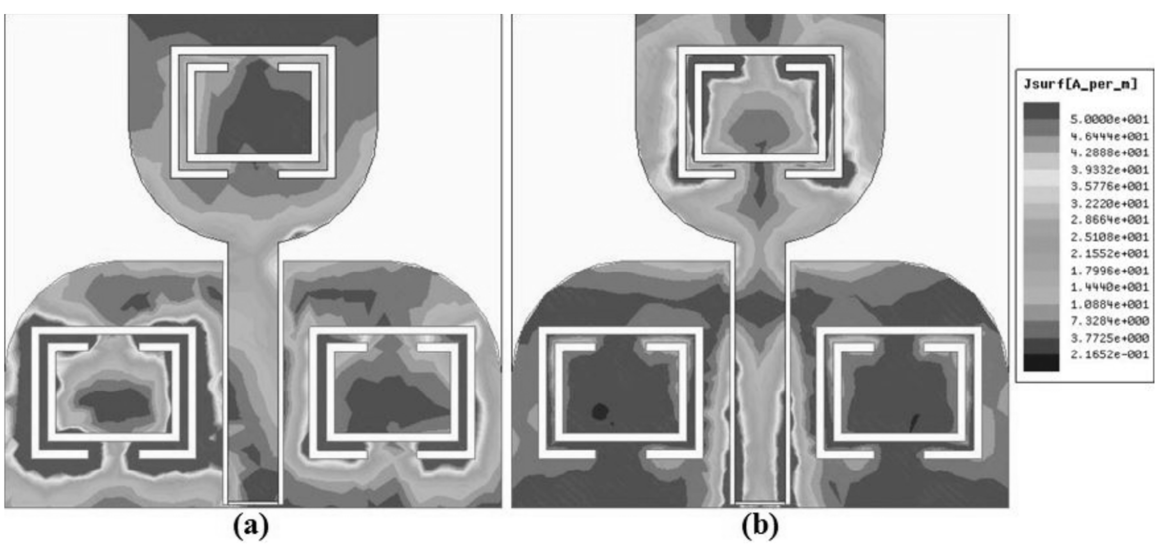
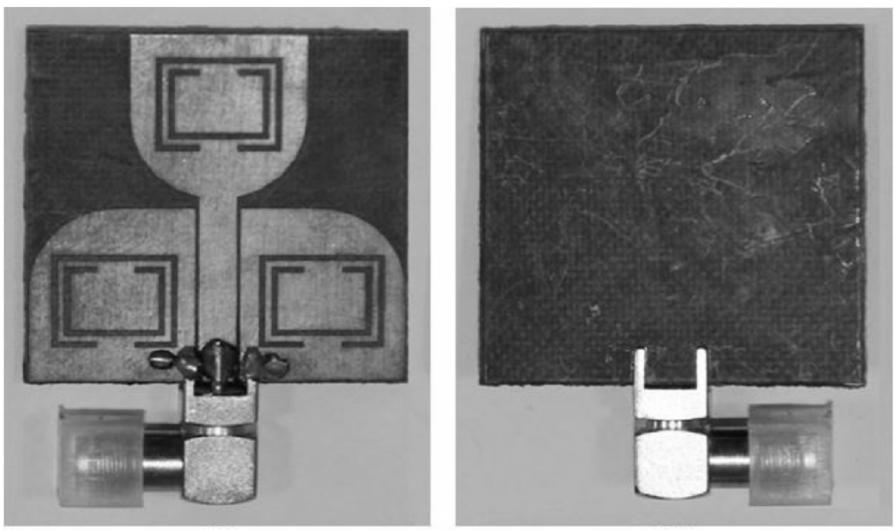


Figure 6: Simulated surface current distribution of antenna at (a)3.4 GHz (b)5.6 GHz

III. RESULTS AND DISCUSSION

The prototype of the proposed antenna is fabricated and measurements are carried out by using R & S ZNB 20 Vector Network Analyzer. The proposed antenna is fabricated on one side of the Rogers RT/duroid 5880 substrate with a thickness of 0.8 mm and relative dielectric constant of 2.2. Figure 7 shows a photograph of the fabricated prototype along with the measured return loss curves. It is been noticed that the proposed antenna is showing estimated results when compared with the simulated results obtained from the HFSS tool. Antenna is rejecting proposed bands and passing the other bands as per the specifications. However, the fabrication tolerances and poor quality of sub miniature version A (SMA) connector would cause slight variation between the simulated and measured results.

The simulated 2-D radiation patterns of the proposed antenna at specific frequencies of 3.0GHz, 3.7GHz, 6.7GHz and 10GHz in E-plane (xz-plane) and H-plane (yz-plane) as shown in Figure-8.It is noticed that the radiation pattern in magnetic (H) plane are Omni directional at lower frequencies and nearly Omni directional at



(i) (ii)

Figure 7(a): Photograph of the fabricated proposed antenna (i) front view (ii) back view

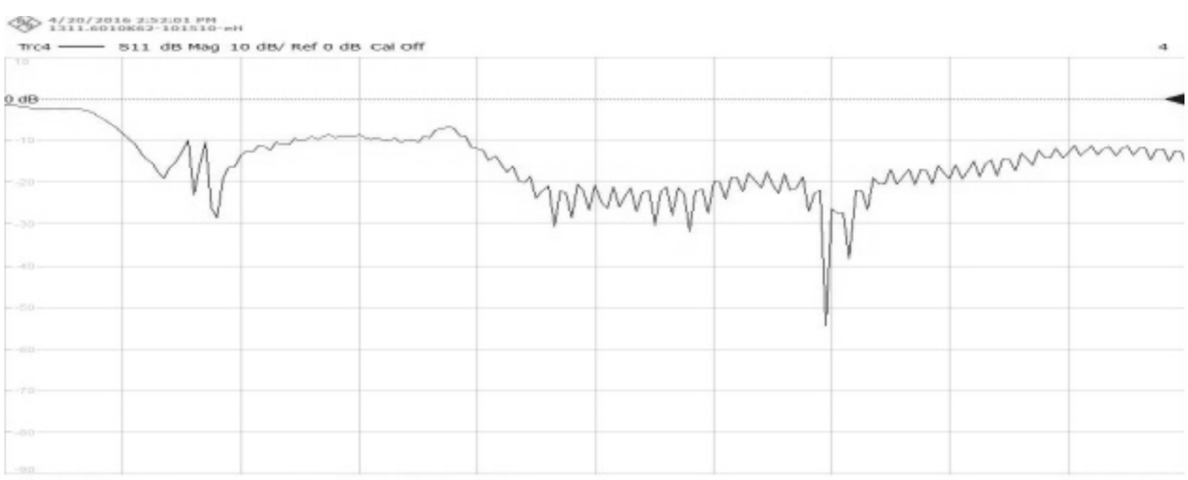


Figure 7(b): Measured S11 of the proposed antenna on ZNB 20 VNA

higher frequencies while the radiation pattern in electric (E) plane are bidirectional or dumb bell shape, which is important for wireless communication systems. However, these radiation patterns at higher frequencies deteriorate. Figure 10 give the gain characteristics of the Antenna with respect to frequency. The gain pattern shows that the antenna has a stable gain over the entire frequency operating band except at notched bands where sharp dips are observed.

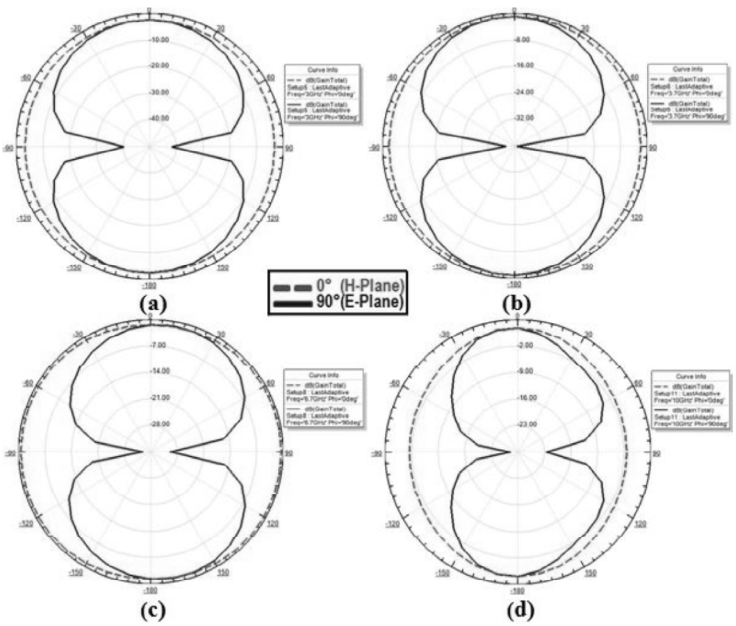


Figure 8: Simulated 2-D Radiation patterns at: (a) 3.0 GHz (b) 3.7GHz (c) 6.7GHz (d) 10 GHz

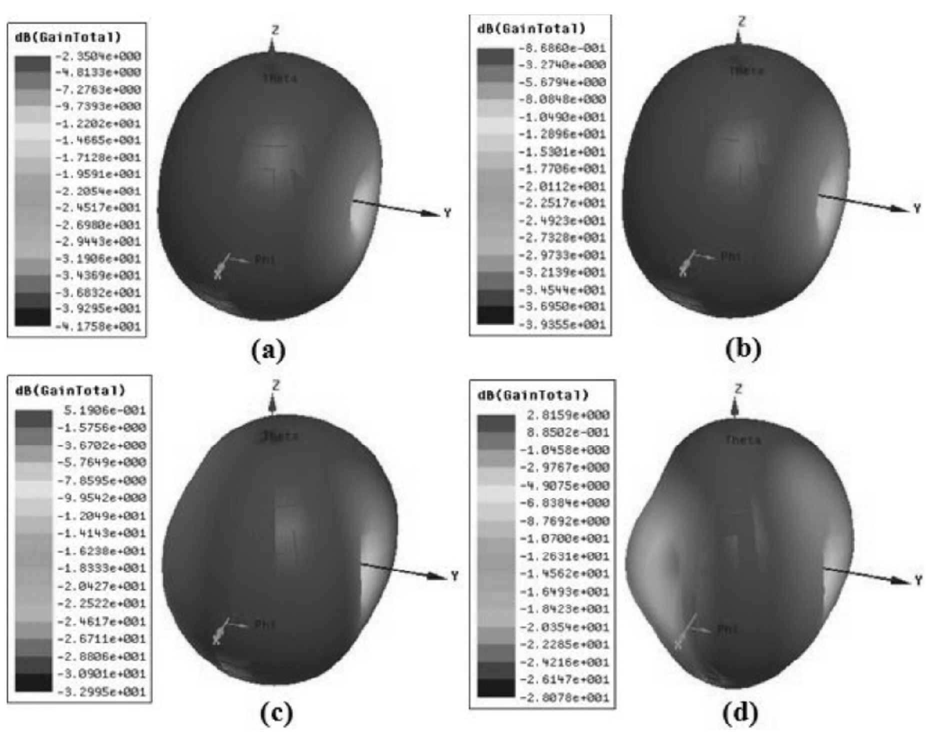


Figure 9: Simulated 3-D Polar plots at: (a) 3.0 GHz (b) 3.7 GHz (c) 6.7 GHz (d) 10.0 GHz

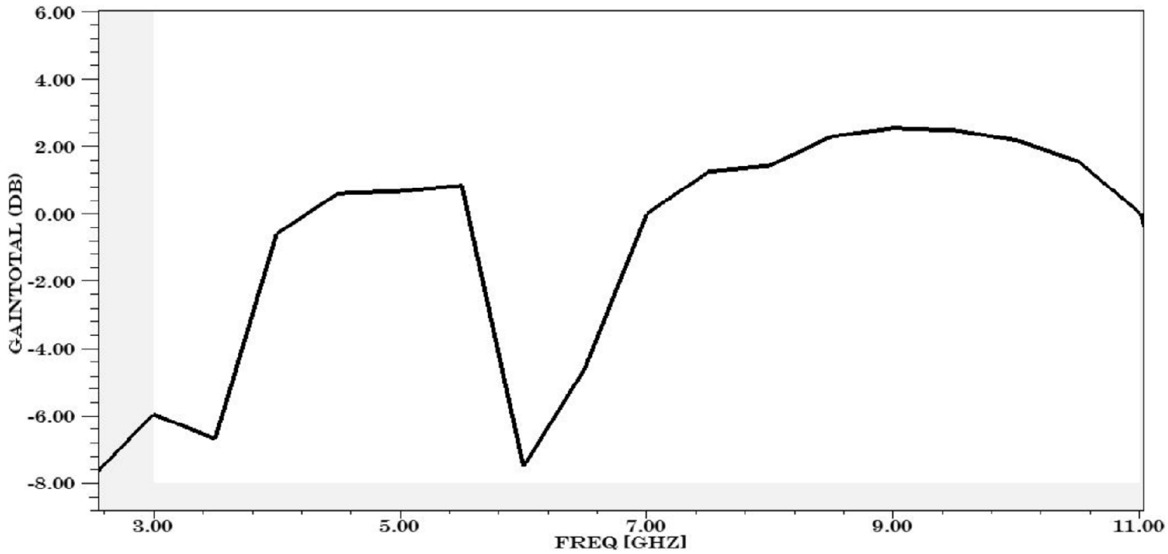


Figure 10: Simulated Gain versus Frequency plot of proposed antenna

IV. CONCLUTION

A compact CPW-Fed monopole antenna using slotted CSRRs with dual band-notched characteristics is designed and presented. Proposed antenna is prototyped on Rogers RT/duroid 5880 substrate and tested on ZNB 20 VNA. Both simulation and measurement results are showing good agreement with each other. The proposed antenna shows good radiation performance with acceptable gain over the desired frequency bands and at notch band antenna is showing poor gain. Further the proposed antenna can be used to notch the desired bands and applicable for wireless communication applications.

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