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Design of CPW FED UWB Antenna with Multiple Narrow Circular Slots

K. Madhu Sudhana Rao, M.V.S. Prasad

***Abstract:** In this paper, a planar waveguide fed patch antenna is designed, simulated and validated with the fabricated prototype for ultra-wide band (UWB) applications. The typical antenna has its operating frequencies in the allowed UWB region with the appreciable bandwidth. The antenna is simulated in commercially available Computer Simulation Technology (CST) software and analyzed using the simulated and measured return loss/reflection coefficient (RC) plots along with the respective radiation pattern plots.*

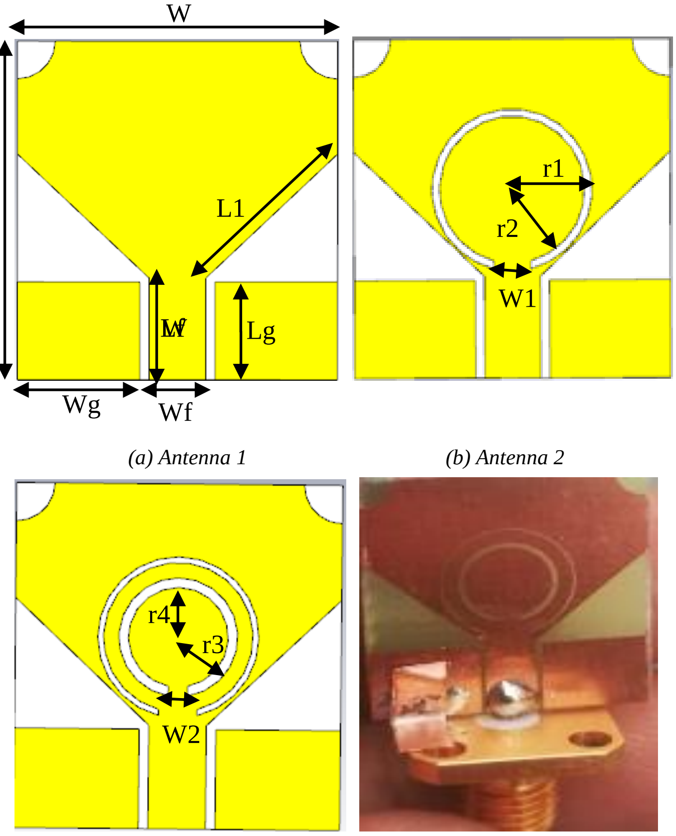
***Index Terms**: UWB, Antenna, CST Studio Suite, Return Loss, VSWR and Radiation patterns.*

I. INTRODUCTION

The UWB technology is the latest revolution. This also happens to be the reason for many inventions in wireless communications [1-7]. With the ever-increasing wireless devices in commercial and civil applications, it has been challenging to antenna engineers to design antenna. It is always a tedious task to design the radiating system in an environment which is heavily adulterated with electromagnetic interference [3-5]. Hence the design should have both notch band features along with resonance characteristics. In this paper, such a design of antenna is proposed and thoroughly analyzed for its UWB characteristics. The antenna validation is carried out using the fabricated prototype and the measured results. The basic geometry is further modified with introduction of slots with narrow width resulting in an abrupt change in the radiation features of the antenna. The introduction of slots and the resultant effect are also discussed in this paper. Further, the paper discussion is presented in four Sections. The proposed geometries of the antenna are presented in the second Section while the simulation and measured results are given in the third Section. The concluding remarks on the work are presented in the fourth Section.

II. ANTENNA DESIGN

The proposed design geometry of the UWB Antenna is presented in this section. The antenna geometry typically consists of a substrate lying between two conducting layers. However, conducting layer is completely etched as the proposed antenna has a coplanar feed system-based technique. For the analysis, three different types of designs



(a) Antenna 1 *(b) Antenna 2*

(c) Antenna 3 *(d) Fabricated prototype*

Fig.1. Antenna Design

Table 1: The dimensions of the proposed antenna

S.no	Parameter	Dimensions (mm)
1	L	18
2	W	17
3	Lf	5.4
4	Wf	3
5	Wg	6.5
6	Lg	4.85
7	W1	2
8	L1	5.5
9	r	2
10	r1	4.2
11	r2	3.9
12	r3	3.1
13	r4	2.6
14	W2	1

are proposed. The outline of all the three types, however remains. This means, the

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K. Madhu Sudhana Rao, Research Scholar, Department of ECE, ANU College of Engineering & Technology, Guntur, AP, India.

K. Madhu Sudhana Rao, Department of ECE, KKR & KSR College of Engineering, Vinjanampadu, Guntur, AP, India.

M V S Prasad, Professor, Department of ECE, RVR & JC College of Engineering, Chowdavaram, Guntur, AP, India.

corresponding base design remains unaltered all the three cases of design. Further the description of the geometry is discussed as follows. The case wise antenna design described in three different sub-sections as follows.

Antenna Design 1: the antenna geometry type typically has a V-shape planar conducting plate as radiating patch from two ends. However, the shape is merged with a rectangle at the open V-edge of the patch which are also reflecting the top extreme corners of the surface are etched in semi-circle shape. Finally, after etching, the design looks more like a 2-dimensional cone. This all arrangements forms the radiating patch. On the other side which is referred as the lower side of the planar surface, the corresponding feed system is arranged. The feed system includes two planar conducting sheets are arranged on either side of the lower plane keeping a gap in between through which a rectangular strip runs form the edge of the plane to the tip of the V-shaped surface. The nomenclature of different parts and portions of the geometry and then respective dimensions is given in Table 1.

Typically, the substrate dimensions are represented by length 'L' and width 'W' which are 18 mm X 17 mm respectively. Similarly, the length f the feed plane Lf and the width of the same 'Wf' are 5.4 mm and 3 mm. the corresponding width of the gap between the planes is given by 'Wg'. Accordingly, the dimension 'Wg' is 6.5 mm. the radius of the circle which could form the corner curvature is extended is represented by 'r'. the corresponding dimension is 2 mm. the length of the V-arm is 'L1' which is 5.5 mm. the width of the gap between the strip line and the planar waveguide surface is given by 'W1' which is 2 mm.

Antenna Design 2: the geometry design 2 is incarnated from the design 1, in design referred here carried a circular ring strip line etched in the V-grove. However, the ring referred here is not purely circular as both the ends facing toward planar waveguide strip line is not connected. The circular ring typical observe two circles namely outer and inner circles. The inner and outer circle are represented as r2 and r1 which has dimensions given by 3.9 mm and 4.2 mm.

The etched strip line in shape of a circle resembles a slot which has resonant nature and its resonance features are particularly dependent on the width of the slot represented by (r1-r2). In this case, the slot width is 0.3 mm which is quite narrow and the smallest dimensions in the entire geometry. The slot has both capacitive as well as inductive nature both combinely form a resonant circuit. The final geometry of design-2 is as shown in Fig.1(b).

Antenna Design 3: the design 3 is a further extension to the design 2 which is well discussed above. The design 3 takes the entire geometry described in design 2 along with an additional inner ring slot. As a result, one can witness two slots of same width appearing in the V-grove. The inner circular slot is described in terms of two radii typical called as inner and outer circle radii of the inner circle. These radii are given as 'r3' and 'r4' respectively. The dimensions of 'r3' and 'r4' are 3.1 mm and 2.6 mm. the gap between the two edges separated to resemble a discontinuous circle is represented by 'w2'. The length of 'w2' is 1 mm. the final geometry is described above as design 3 is as shown in Fig.1(c).

III. RESULTS AND DISCUSSION

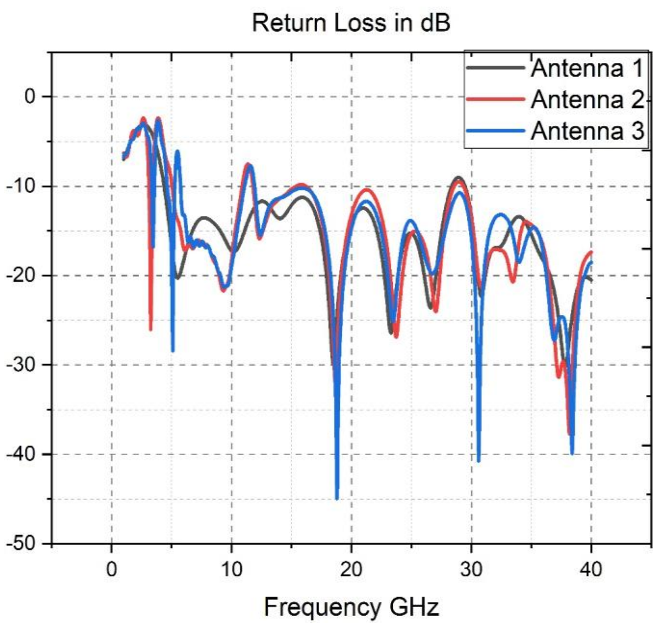
The three types of geometrical shapes are simulated in high end electromagnetic modelling tools. The simulated antenna is solved according to the implemented boundary conditions as per the operation principles of the antenna. While solving, the native solver typically uses mesh system to reach through each and every corner of the radiating system. This allows to have a complete differential model representation of the proposed antenna.

The antenna dimensions were initially chosen to comply with the calculations. Intuitive to the resonant characteristics. further, using the tuning option, the antenna physical parameters like the length, width grove size, and slot widths are thoroughly verified to find the optimal parameters which are listed in the table 1.

The analysis of the antenna is carried out using several radiation and electrical reports generated by the simulation tool. Accordingly, for the study, we have taken reflection coefficient (RC) plots along with VSWR response is obvious according to the RC plots. Hence, here in the study the RC plots alone are used instead of VSWR considering the space constraints. Several resonant frequencies are identified from the corresponding RC plot for which the respective radiation patterns are plotted.

Further once the simulation results are according to the requirements, the prototype of the simulated geometry is fabricated in order to validate the designs.

The simulated return loss and VSWR plots are presented in Fig.2 (a) and (b) respectively for all the three designs. Both the simulated and measured results are in good agreement in terms of resonant frequencies and notch band characteristics of operations and are shown in figure 3 (a) and (b). Both the results expressed excellent UWB characteristics.



(a)

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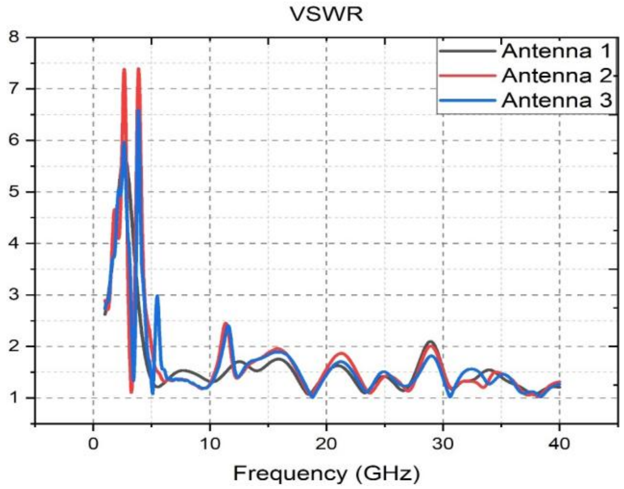
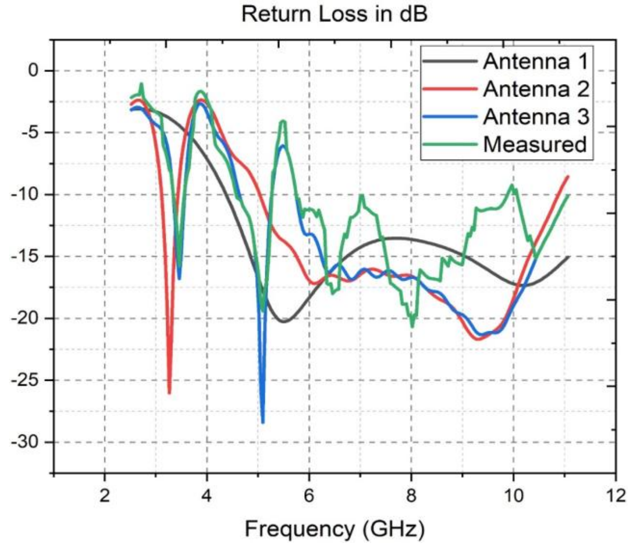
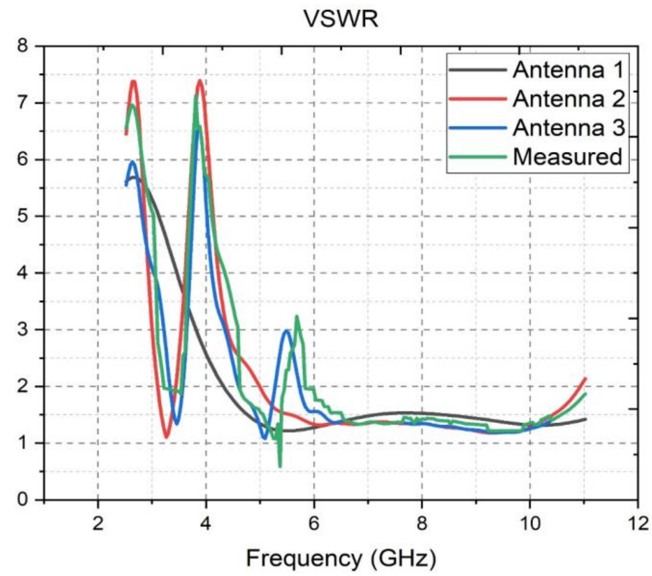


(b)

Fig.2. (a) Reflection coefficient (b) VSWR plot of simulated frequency range from 1-40 GHz



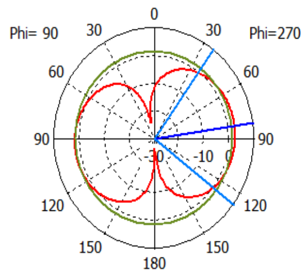
(a)



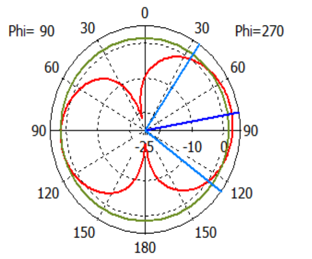
(b)

Fig.3. simulation and measured results of frequency range 3-12 GHz (a) Reflection Coefficient (b) VSWR

Frequencies with respective RC lying below -10 dB are identified as resonant frequencies while the band of frequencies above this level are termed as notch bands. Accordingly, looking at the Fig.2, frequencies like 3.4 GHz, 5 GHz, 6 GHz and 7 GHz are chosen for radiation pattern analysis. Following this simulated radiation patterns are plotted for XY cut as a polar diagram. Both the simulation pattern as well as the measured patterns are used for analysis and presented in fig.3. both the patterns are in good agreement and matching in terms of dips resembling the resonant characteristics and bandwidths. The corresponding radiation patterns are as shown in fig.4(a) – (d) and Fig 4(e)- respectively for simulation and measured patterns. The comparison of proposed antenna with previous literature is represented in table 2.



(a)



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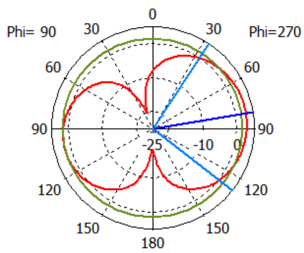

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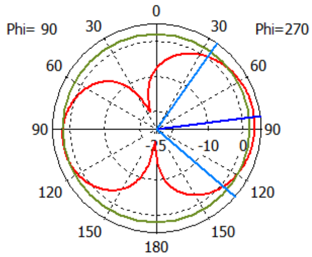

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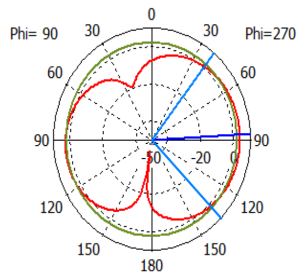

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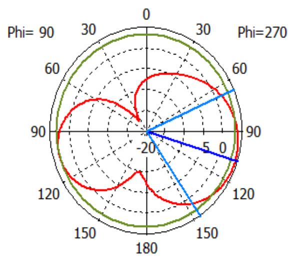

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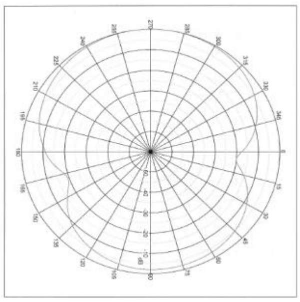

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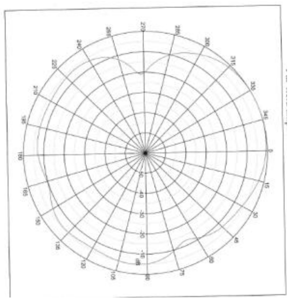

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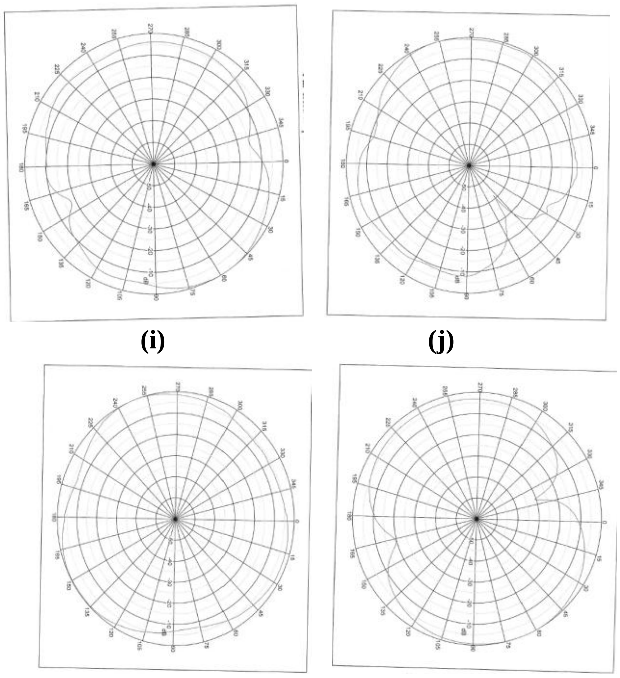

Fig.4. Radiation patterns of simulation Frequencies (a) 3.4 GHz (b) 5 GHz (c) 6 GHz (d) 7 GHz (e) 8 GHz (f) 10.5 GHz and Measured frequencies (g) 3.4 GHz (h) 5 GHz (i) 6 GHz (j) 7 GHz (k) 8 GHz (l) 10 GHz

Table 2. Comparison of proposed antenna with Literature

Reference	Antenna Purpose	Antenna size (mm3)	Operating frequency (GHz)	BW (GHz)	Applications	Gain (dB)
Ref [8]	UWB	28 x 28 x 1.6	2.7 – 12.55	9.85	UWB	4.5 dbi at 11 GHz
Ref [9]	Triple Band Notched UWB	36 x 32 x 0.813	2.7 – 13.45 (3.15 – 4 5.7 – 6.3 7.9—8.6)	8.5	UWB	3 dbi average gain except notch bands
Ref [10]	UWB	32.5 x 10 x 1.6	3.01-10.75	7.74	UWB	3.5 dbi
Ref [10]	Single Notch UWB	32.5 x 10 x 1.6	2.37-2.53 3.22-10.82		Bluetooth, UWB	3.9 dbi at 10.5 GHz
Ref [11]	Single UWB antenna	4 x 4.5 x 0.863 (no on-body) 4 x 3.5 x 0.201 (on body)	7.5 – 8.5 7.5 – 8.45	1 0.95	Wireless binaural hearing aids	
Ref [12]	Dual band UWB	25 x 25 x 1.6 (2.4 -2.484) (2.635-2.66)	2-12	10	S-DBM, Wibro, WPAN, CMMB	
Ref [13]	UWB	19.2 x 28.8 x 1.6	3.4 -14	10.6	UWB	6 dB at 9.02 GHz
Ref [14]	UWB	25 x 20 x 1.6	2.51 -16.48	13.97	UWB	5.271 dbi at 9 GHz
Ref [15]	UWB	30 x 27 x 0.8	3.62-11	7.38	UWB	7.9 dBi at 9.5 GHz
Ref [16]	Four notch UWN	26 x 30 x 1.6	3.17 – 11 (2.7-3.54) (4.7–5.25) (5.5-6.12) (7.6-9.1)	4.43	UWB	4.4 dBi at 11 GHz
Ref [17]	Triple Notch UWB	20 x 20 x 0.787	2.49-19.41 (3.1-3.89) (4.8-6.19) (7.3-7.86)	14.32	UWB	6vdBi at 17 GHz
Ref [18]	Single Band notch	30 x 31 x 1.5	2.4-11 (2.48-3.1)	7.98	Blue tooth, UWB	6.1 dBi at 4 GHz
Proposed antenna	Dual notch Band	18 x 17 x 0.8	3.1-11 (3.67-4.7) (5.2-5.9)	7.9	UWB	3.2 dBi average gain

IV. CONCLUSION

The UWB antenna with CPW feed systems is simulated and validated using the prototype developed. The multiband characteristics are evident from the RC reports which are having similar radiation patterns. The planar circular narrow slots are more useful to increase the inductive nature of the system while the width of the slot has a capacitive effect. The current distribution typically modified resulting in a null in the radiation pattern with the introduction of circular slots.

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