Single-Feed C-shaped Microstrip Antenna with Co-axial Feed for Tri-band Applications

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ABSTRACT
In this paper, a compact circular shaped microstrip monopole patch antenna is presented. The proposed antenna comprises a plane of three circles coincides with each other C-shaped rectangular slot element with another inverted C-shaped shaped rectangular slot introduced inside circular patch which offer tri band. The impedance bandwidth can be tuned by changing the ground plane geometry parameters (length and/or its width). The overall size of the antenna is 26mm×22mm×0.8mm including finite ground feeding mechanism. The antenna operates in tri bands which are 5.9-6.1 GHz, 7.2-7.4 GHz and 9.1-9.3 GHz. Stable Omni-directional radiation patterns in the desired frequency band have been obtained. The proposed geometry was practically realised and tested its parameters. Measured data fairly agree with the simulated results.

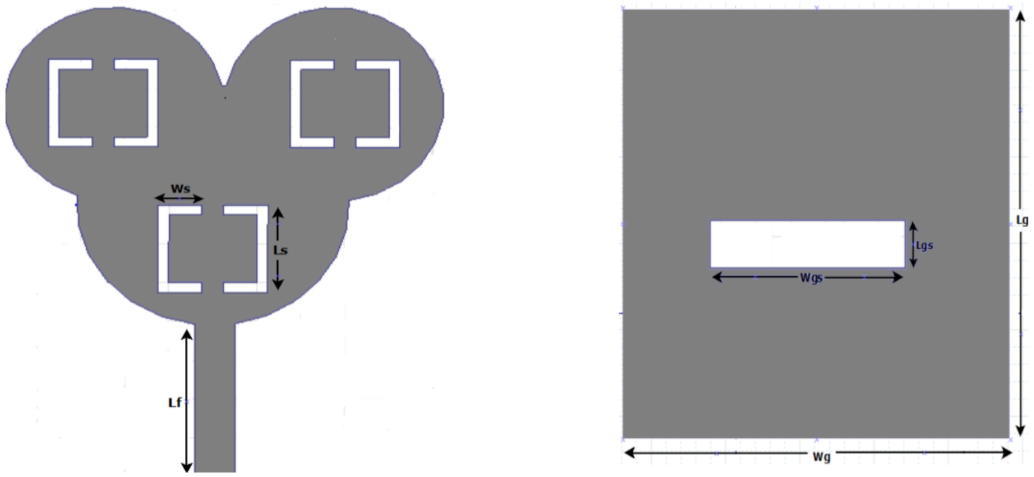
Keywords
Microstrip Antenna, Finite Ground, and Monopole Antenna.

1. INTRODUCTION
With rapid development of microstrip antenna it has been found that, study of microstrip antenna with symmetrical feed line technique are good candidates for multi-bands applications. A patch antenna with return loss up to -33dB in the frequency range of 2.4 GHz to 2.5GHz (ISM band) and VSWR less than 1.5 was reported in [1]. With further study and optimization of dual band microstrip antenna [2] it has been found that the return loss for dual band frequency at 2.4GHz is -43dB and at 3GHz is -27dB. To get compact size and maintaining optimum performance of antenna for multiple bands i.e., dual band, triple band antennas etc., various shapes of antenna was integrated [3]. As suggested in [4], introducing slot into patch (L-Shape) increases the impedance bandwidth up to 13%. To enhance bandwidth further various shapes like L-shape, U-shape etc., slots were introduced to obtain bandwidth up to 42% [5, 6]. On the other hand [7] and [8] proposed bandwidth enhancement techniques that use photonic band gap structure and wideband stacked microstrip antennas, respectively. By introducing stacked microstrip antenna bandwidth and gain was enhanced. While Designing of symmetrical microstrip antenna, it has been found that microstrip antenna has narrow Bandwidth [9], Asymmetrical position of patch antenna on ground affect the performance of antenna that is to enhance bandwidth it was also found that asymmetrical position of slot on patch affects performance of antenna [10] that is asymmetrical L-shape, U-shape position of slot on patch affects the performance. In another study [10, 11] reported asymmetrical L-shaped slot on patch antenna for UWB application with acceptable return loss that is -10dB and peak gain of 2.2 to 6.1 dBi for operating bandwidth 3.01-11.30 GHz frequencies.

The microstrip patch antenna is a good candidate for multi-frequency. The common methods for achieving multi-frequency performances are as follows: 1) using several different resonant modes of a single microstrip patch; 2) changing surface instantaneous current distributions of resonance modes by loading or etching slot on a single patch [9]–[11]; 3) utilizing multiple microstrip patches on the single-layer substrate.

In this paper we proposed a c-shaped microstrip antenna fed co-axial feed with two c-shaped slots printed on dielectric substrate (pl. ref. Figure 1). The proposed antenna offers multi-bands (tri) operations. Design and optimization procedure of the proposed antenna is presented in Section 3. Section 4 presents the validation of the fabricated prototype and discussions on the measured results are also presented there. Finally, conclusions of this study are presented in Section 5.

2. ANTENNA GEOMETRY
Figure 1(a) shows the top view of the basic geometry of proposed circular monopole antenna for tri bands operation and its ground plane (bottom view) is shown in Figure 1(b).The antenna is symmetrical with respect to the longitudinal direction. Substrate used for the design is FR4 with dielectric constant of 4.4, and thickness of 0.8mm. A tri-band circular shaped antenna with three circle of C-shaped slot resonator (Figure 1(a)), where a pair of C-shaped slot facing each other are placed on each circular microstrip patches fed by a line feed. The feed line width is 1.8 mm. The rectangular ground plane with length L_g=21mm and width W_g =22mm, the ground plane has rectangular slot of length L_{gs}=2.3 mm and width W_{gs}= 11 mm. The detailed optimization procedure of the proposed antenna and its optimum dimensions, and characteristics are presented in Section 3. All the parameters of the geometry are indicated in Figure 1 (a).



(a)Top view (b) Ground

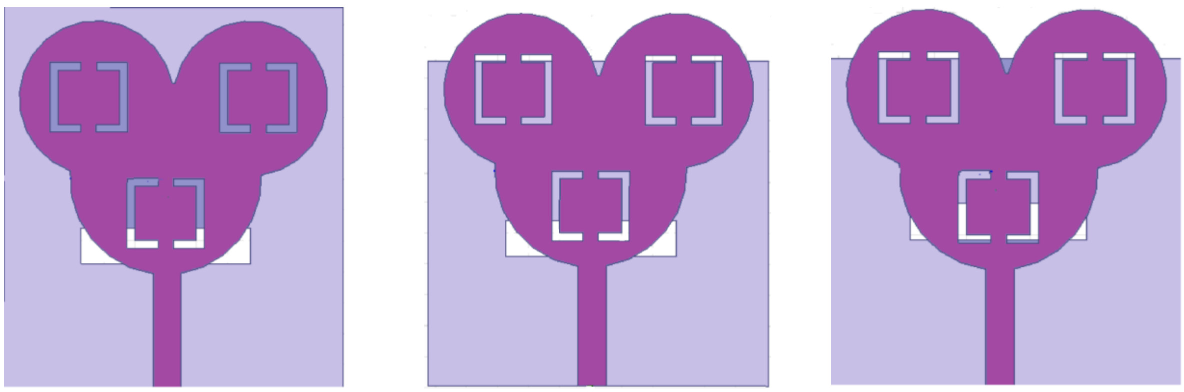
Figure 1: Geometry of proposed CPW-fed monopole antenna.

3. GEOMETRY OPTIMIZATION AND DISCUSSIONS

In this section parametric study is conducted to optimize the proposed antenna. The key design parameters used for the optimization are dimension of C-shape, gap between to C-shape patch and dimension of ground plane (length and width of C-slot. The detailed analysis of these parameters is investigated in the following paragraphs of this section.

4. SIMULATION SET-UP

As showed in Figure 2, ground plane of the geometry is varied to see its effect on the performance of antenna. For this, ground plane is changed to different shape. Initially, the ground plane is kept for entire plane that is type-1. After simulation it found that, only first band is available for type-1. We consistently changed ground plane radius, for this we obtained second, and third band (type-2). Further we introduced c-slot into ground plane to get tri band as presented in Figure 2(type-3). So, the finalized ground planes shape to get tri bands.



a) Type 1 b) Type 2 c) Type 3

Figure 2: Variation in number of steps in the staircase profile of ground.

From Figure 2(c) it may be noted that ground plane dimensions are finalized to get tri bands. Further we changed Length (L_{gs}) and width (W_{gs}) of rectangular slot on ground plane (L_{gs}), length of C-shape(s) and gap between C-shape patch (d). Figures (3), (4) and (5) show return loss characteristics plots of this study. From these figures it may be noted that the tri bands can be obtained for W_g= 21mm.The finalized dimensions obtained from these parametric studies are presented in Table 1.

Table 1: Optimized dimensions of the proposed geometry.

Parameter	L_g	W_g	L_{gs}	W_{gs}	L_s	W_s	L_f
Unit(mm)	22	21	2.3	11	3.5	2	7.9

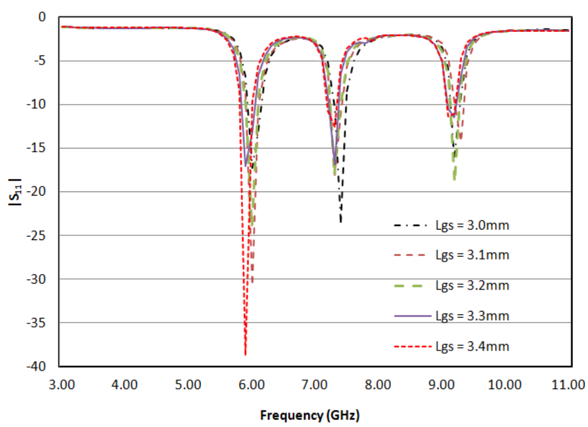


Figure 3: Return loss vs. frequency plot for variation in length of rectangular slot of ground (L_{gs}).

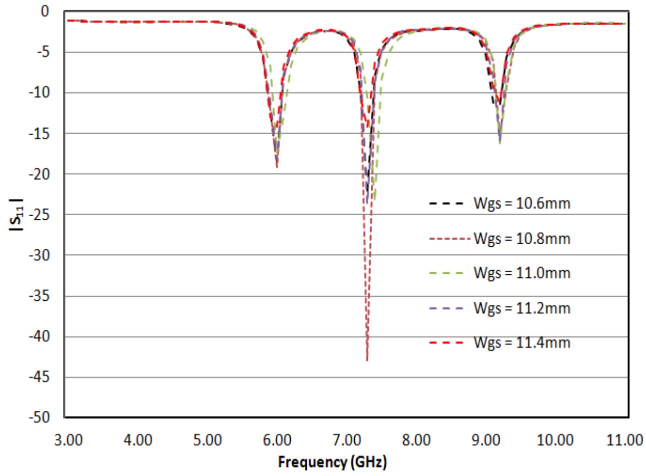


Figure 4: Return loss vs. frequency plot for variation in width of rectangular slot of ground (W_{gs}).

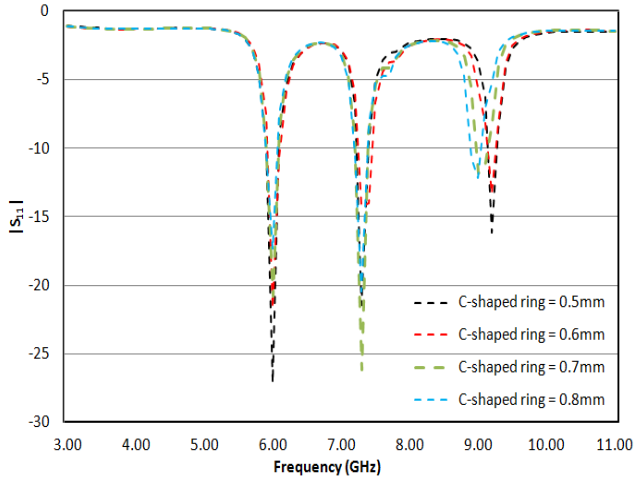


Figure 5: Return loss vs. frequency plot for variation in length of U-shaped patch (s).

5. EFFECT C-SLOT GEOMETRY

To study the effect of C-shape slot dimensions on the antenna performance, its dimension values i.e., L_{gs} , W_{gs} and C-slot are varied. Initially, length (L_{gs}) and width (W_{gs}) of rectangular slot on ground plane. Length is varied from 3.0mm to 3.4mm in steps of 0.1mm. Similarly width is varied from 10.6mm to 11.4mm in steps of 0.2mm.Keeping dimension of patch constant. The effects of variation of this study are presented in Figure 3 and Figure 4 respectively. From Figure 3, it may be noted that the tri bands with return loss less than -30dB for 5.9-6.1 GHz, 7.2-7.4 GHz and 9.1-9.3 GHz. Further we simulated for different dimension of C-slot on patch keeping L_{gs} and W_{gs} constant. In this range having return loss less than -35dBm for all tri bands with lower cut-off frequency remains nearly constant whereas upper cut-off frequency varies slightly i.e., impedance bandwidth varies with respect to this parameter.

The geometry shown in Figure 1 with its optimized dimensions presented in Table 1was fabricated and tested. The substrate used for the fabrication is the FR4 glass epoxy with dielectric constant of 4.4, and thickness of 0.8mm. A photograph of the fabricated prototype and S11 measurement setup is shown in Figure 4(a) and its S11 measurement graph shown in Figure 4(b).

From Figure 5 it may be noted that the proposed antenna is having operating frequency range from 3GHz to 11 GHz with three operating bands located at 5.9-6.1 GHz, 7.2-7.4 GHz and 9.1-9.3. Radiation patterns of the geometry are presented at various frequencies in the band of operation (Figure 6) to demonstrate that the patterns are nearly stable across the bands of operations.

E-plane and H-plane radiation Pattern of proposed antenna is presented in Figures 7(a)-(c) at 3.4 GHz, 6.0sGHz, 8.0 GHz and 9.0 GHz respectively

6. EXPERIMENTAL RESULTS AND DISCUSSIONS

The geometry shown in Figure 1 with its optimized dimensions presented in Table 1was fabricated and tested. The substrate used for the fabrication is the FR4 glass epoxy with dielectric constant of 4.4, and thickness of 0.8mm. A photograph of the fabricated prototype is shown in Figure 6(a) and its S11 measurement setup is shown in Figure 6(b). Return loss measurement is presented in Figure 6(c) and VSWR measurement is presented in Figure 6(d). The measured results fairly agree with the simulated values.

From Figure 5 it may be noted that the proposed antenna is having operating frequency range from 3 GHz to 11 GHz with three operating bands located at (5.9-6.1 GHz), (7.2-7.4 GHz) and (9.1-9.3GHz). Radiation patterns of the geometry are presented at various frequencies in the band of operation (Figure 7) to demonstrate that the patterns are nearly stable across the bands of operations.

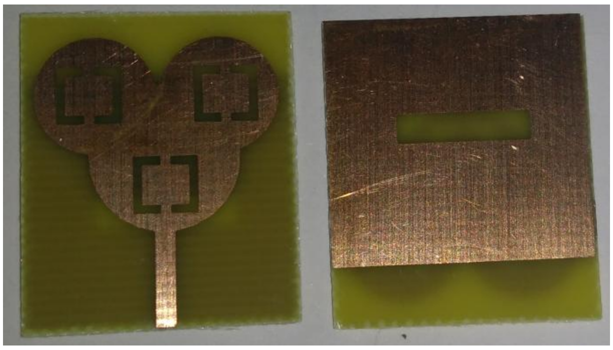


Figure 6(a): Fabricated Prototype

Figure 6(b): S_{11} Measurement Setup

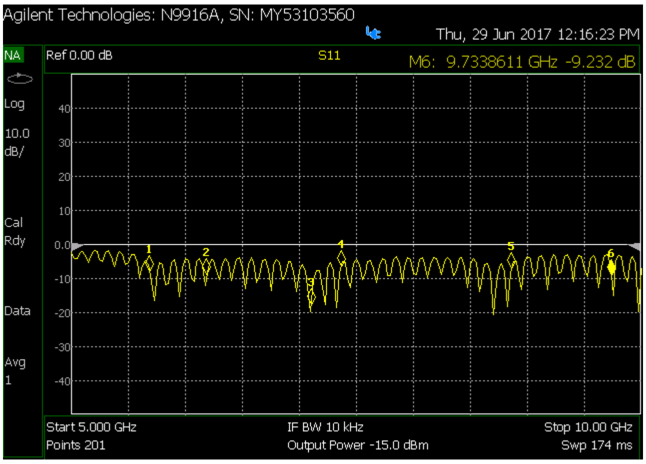


Figure 6(c): S_{11} Tested result

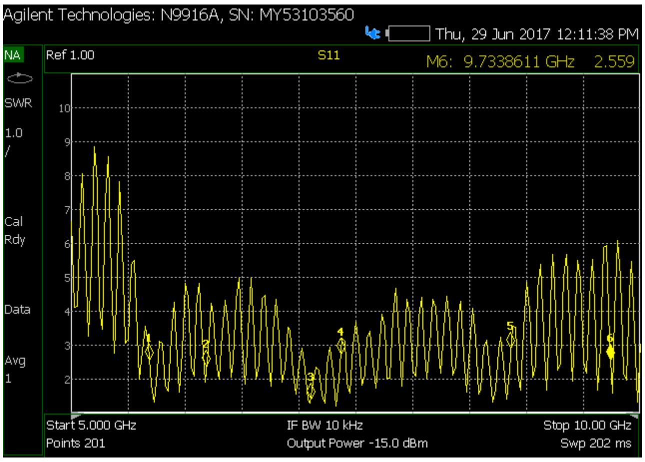
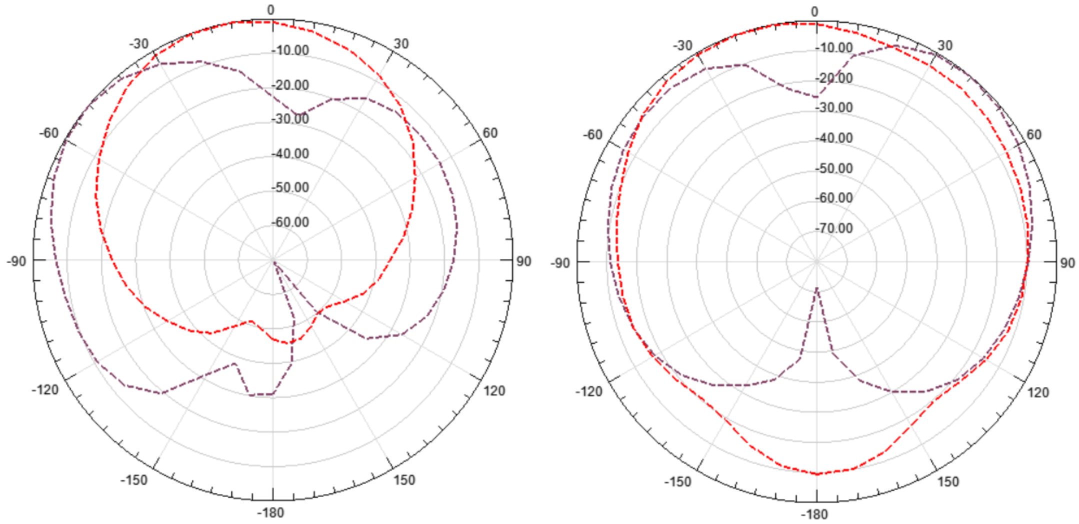
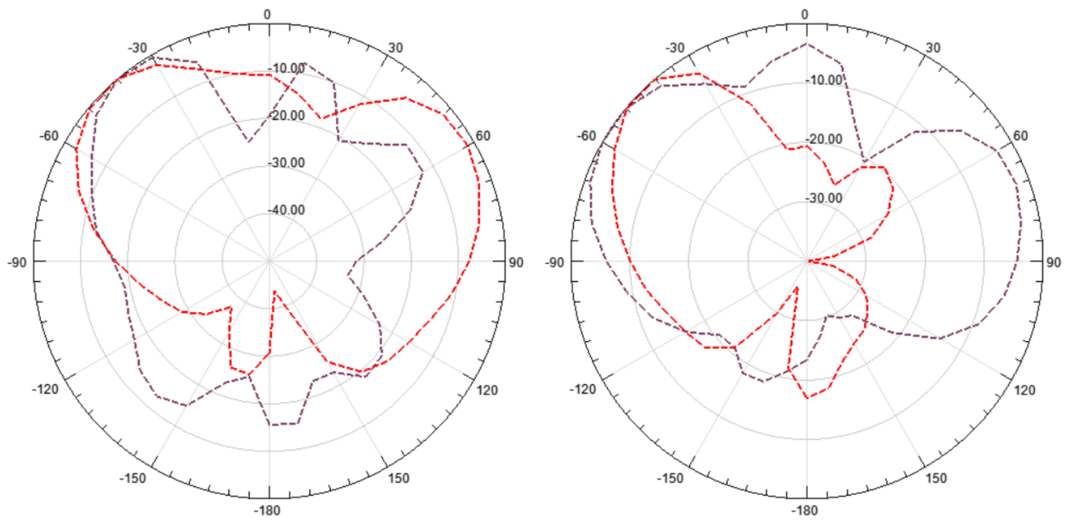


Figure 6(d): VSWR Tested result

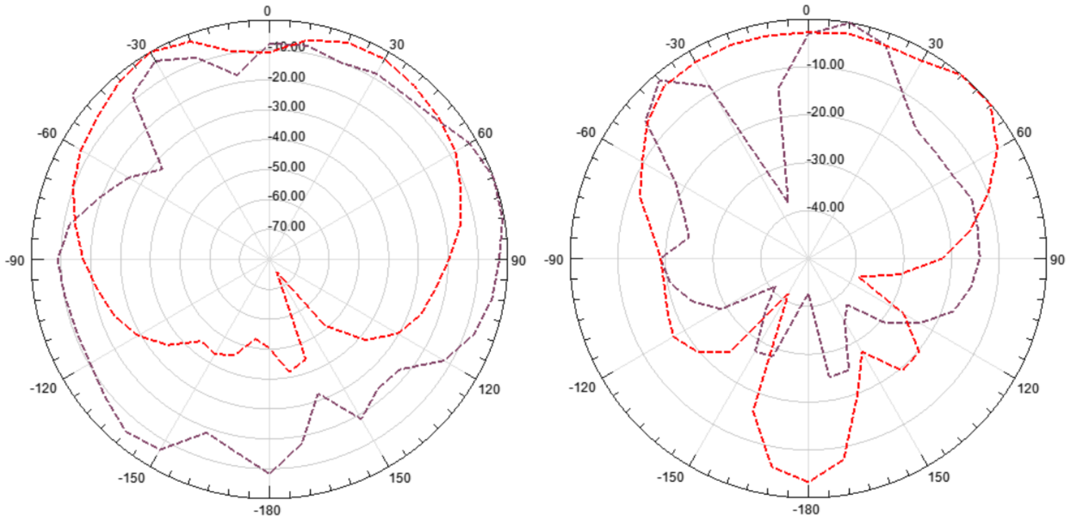
Fiure (6): Fabricated Protype Tested Results



(a) E- and H-plane patterns at 6.0 GHz



(b) E-and H-plane patterns at 7.1 GHz



(c) E-and H-plane patterns at 9.0 GHz

Figure 7: E-and H-plane radiation patterns at various frequencies throughout the band of operation.

7. CONCLUSION

The design optimization of a c-shape patch with finite ground plane antenna has been presented. It has been shown that, with correct selection U-shape dimensions on patch and shape of ground plane, a tri-band frequency response can be achieved. With this antenna, we obtained tri bands at 5.9-6.1 GHz, 7.2-7.4 GHz and 9.1-9.3.The proposed antenna has been analyzed using a HFSS simulator and tested with network analyzer. This C-slot microstrip antenna is practical solution for tri- band application.

8. REFERENCES

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