# Design Optimization in Patch Feed Line of a Circular Patch Antenna Array

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**Abstract: Circular microstrip patch antennas with discontinuities in their feed line is presented in this paper. The antennas are composed of a radiating patch, and step discontinuities are given in its feed lines to improve the performance. The three circular microstrip planar array antennas through various signal excitation lines are computationally designed, and PCB etched, and their performance is analyzed based on various feed lines. The proposed array antenna operates in the ISM band at 2.45 GHz. The HFSS is used to design and perform the simulations. A prototype of an antenna effective at 2.45 GHz has been PCB etched and verified for concept demonstration. $S_{11}$ [dB] at 2.45 GHz is -21.143 dB for straight feed line, -22.0 dB for one step feed line, and -24.72 dB for two-step feed line. The computational and practical outcomes illustrate that the $S_{11}$ [dB] is enhanced for circular microstrip patch array antennas with two-step feed lines. The simulated and measured scattering parameters and radiation patterns show that they are in good agreement.**

## 1. Introduction

Microstrip patch array antennas which operate in the microwave and mm-wave band are appropriate for 4G and 5G communication systems [1]-[3]. Microstrip patch antenna has been emphasized in electronics microwave communications due to its benefits of an easy pattern, low cost, and power requirement at microwave and mm-wave frequencies. The configurations of patch antennas can be attuned to attain bandwidth improvement, optimum gains, and reflection coefficients, for example, by using the patches of different shapes, the patches with different types of shapes, and the patches with various types of modified feed lines. In addition, these antennas can be fabricated using the PCB process. Numerous design methods came into existence to increase the bandwidth of patch antennas by manipulating shape and feeding mechanisms. The most commonly used feed mechanisms at microwave frequencies include microstrip line, coplanar waveguide, coaxial probe, and inserting discontinuities in a feed line that stimulates the patch antenna to enhance the bandwidth [1]–[4]. Previous research studies have proposed many methods to enhance gains or return loss of patch antennas. This paper studies how an array of circular microstrip patches can enhance its broadside gain and appropriate return loss while keeping a low profile. This paper has developed a 2 X 2 circular patch array antenna at 2.45 GHz, with three different types of microstrip lines. Simulations were conducted using the HFSS software, and the patch array antenna was fabricated and experimentally tested. The scattering parameters, gain, and radiation patterns nearly agree with the computational and measured results. The fundamental array elements are shown in Fig. 1. This paper is ordered as follows: Section II briefly reviews the Antenna Array Design. In Section III, Simulation results and experimental validations are compared, and the roles of discontinuities are proposed. Finally, section IV concludes the paper.

***Fig. 1.*** *Microstrip patch array antenna*

## 2. Antenna Array And Feed line Design

Wireless communication networks are emerging quickly, and current wireless services apart from voice and text include multimedia communications, requiring a high bandwidth and data rate. In the case of single patch antennas, characteristics such as high gain, beam scanning, appropriate return loss are possible only when individual patch radiators are combined to form an array [5]-[7]. The patch elements are distributed in a single dimension to form a linear array, in two dimensions to form a planar array, and in three dimensions to form a volume array, and the radiation pattern can be determined from this distribution. The radiation elements' excitations are an essential factor that must be carefully designed for required gains and beam directions. Commonly used feeding methods are parallel and series. The input port and multiple feed lines form parallel feed mechanisms, and every feed line is ended at distinct radiating elements. The series feed consists of continuous transmission lines from which small portions of energy are gradually coupled into the separate element connected along the line by various means of coupling. The feed networks contain specific undesirable characteristics that must be carefully examined to diminish adverse effects on array performance.

The feed line itself is radiated, proper optimization of the feed line is required to achieve appropriate reflection coefficient and gain [8]-[11]. Patch array antennas with steps-in-width display improved performance in associations of reflection coefficient and gained compared to a patch antenna through uninterrupted feed lines. This work examines circular patch array antennas with uninterrupted feed lines and single and double step feed lines. The circular patch array antennas are designed, computationally investigated, and PCB etched to study and analyze the enactment for three different feed lines [13]-[15]. The exciting E-fields of patch arrays with three different feed lines are shown in Fig. 2, 3, and 4.

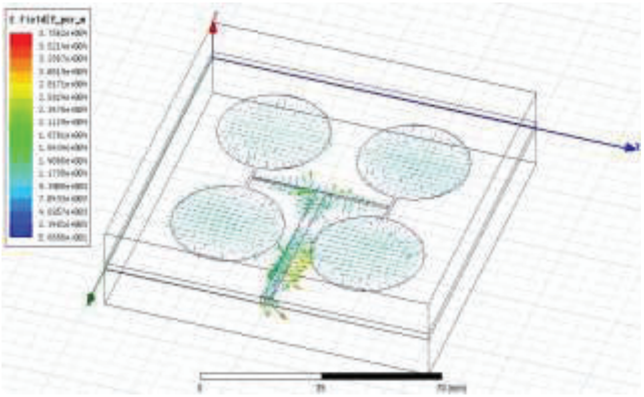

***Fig. 2.*** *Geometry and E-field of a circular planar array - straight excitation line*

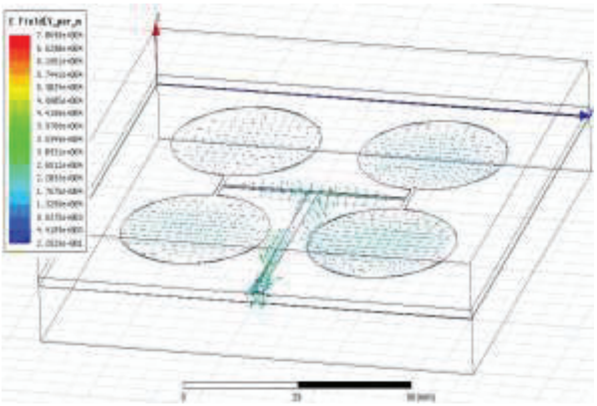

***Fig. 3.*** *Geometry and E-field of a circular planar array - one step excitation line*

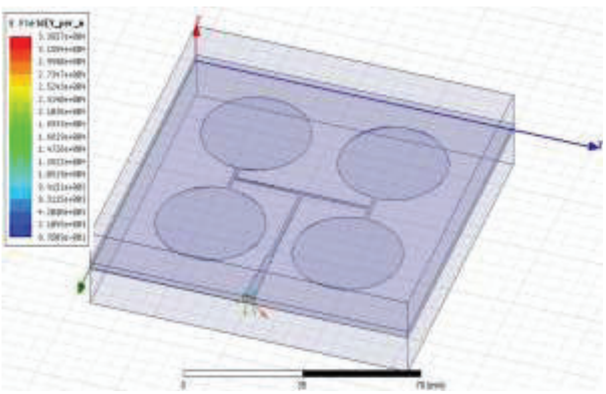

***Fig. 4.*** *Geometry and E-field of a circular planar array - two-step excitation line*

## 3. Computational Simulation Results and Experimental Validations

The circular microstrip planar arrays are simulated on FEM computational simulation, and PCB etched on FR4 substrate. The circular patch array with the uninterrupted feed line, one-step feed line and two-step feed line are shown in Fig. 5, 6 and 7. The output factors like reflection coefficient, Voltage Standing Wave Ratio and radiations were analyzed. Figures 8, 9 and 10 show the $S_{11}$ [dB] versus frequency. The $S_{11}$ [dB] versus frequency plot shows that it is better for a circular patch array antenna with a two-step feed line as equated to a patch array with an uninterrupted and one-step feed line. For an array of circular microstrip patches, the simulated $S_{11}$ [dB] is -21.14 dB, -22.0 dB and -24.73 dB at 2.45 GHz for no step excitation line, single-step excitation line and double step excitation line, respectively. The experimental results for $S_{11}$ [dB] versus frequency for circular patch array with uninterrupted excitation line, one-step excitation line and two-step excitation lines are shown in Fig. 11, 12 and 13. The measured $S_{11}$ [dB] of a circular patch array with an uninterrupted excitation line is -13.77 dB at 2.71 GHz, with one step excitation line is -17.65 dB at 2.71 GHz and with two-step excitation line is -19.99 dB at 2.34 GHz. The $S_{11}$ [dB] for a microstrip patch array with a two-step excitation line is approximate at frequency 2.34 GHz, which is near the requisite frequency. Computationally simulated results and measured results approximately validate each other. The minor deviation is witnessed among the experimental required and simulated operating frequencies. This may be due to imprecision in the manufacturing process and measurement errors. Table 1 shows the circular microstrip patch array antennas with the single patch [16].

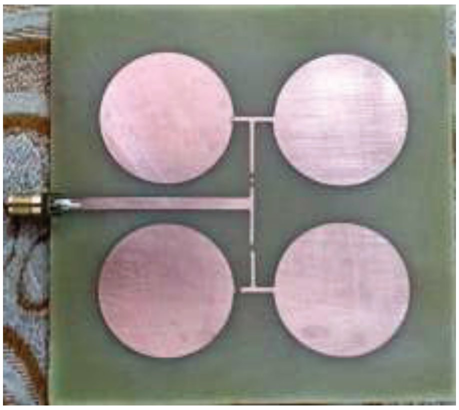

***Fig. 5.*** *PCB circular patch array - straight excitations*

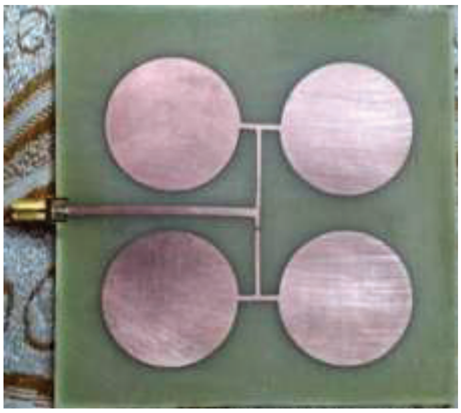

***Fig. 6.*** *PCB circular patch array – one step excitations*

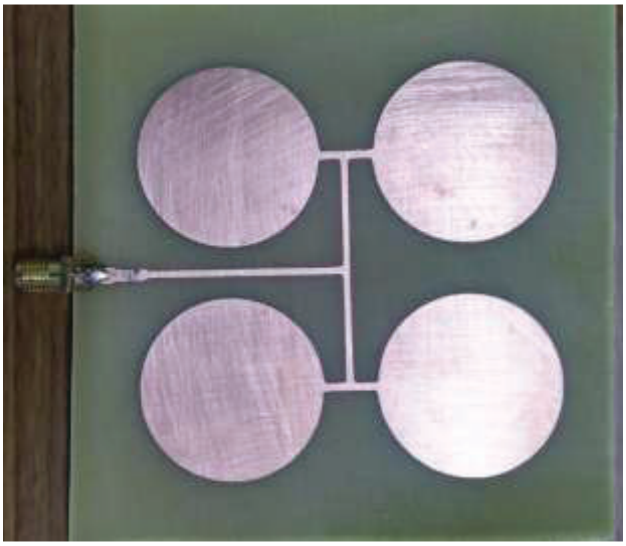

***Fig. 7.*** *PCB circular patch array – two steps excitations*

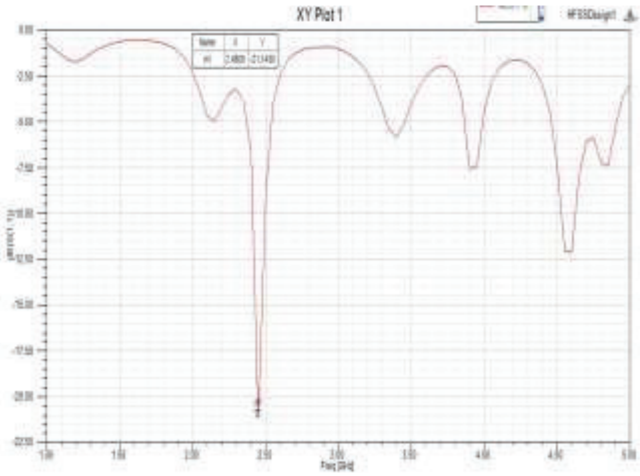


***Fig. 8.*** *$S_{11}$ [dB] circular microstrip array – straight feed line*

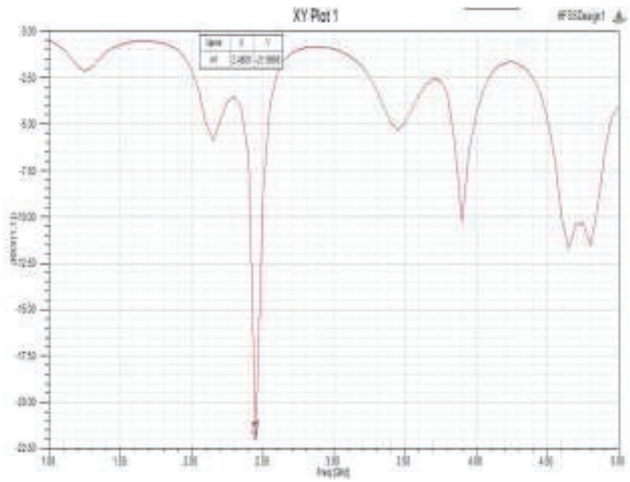


***Fig. 9.*** *$S_{11}$ [dB] circular patch array – one step excitations*

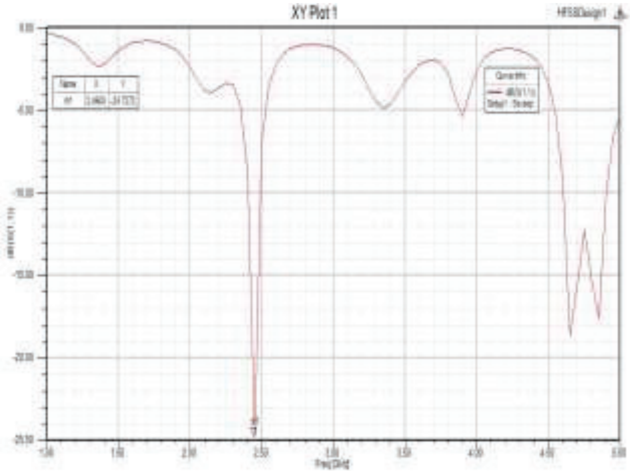


***Fig. 10.*** *$S_{11}$ [dB] circular patch array – double step excitations*

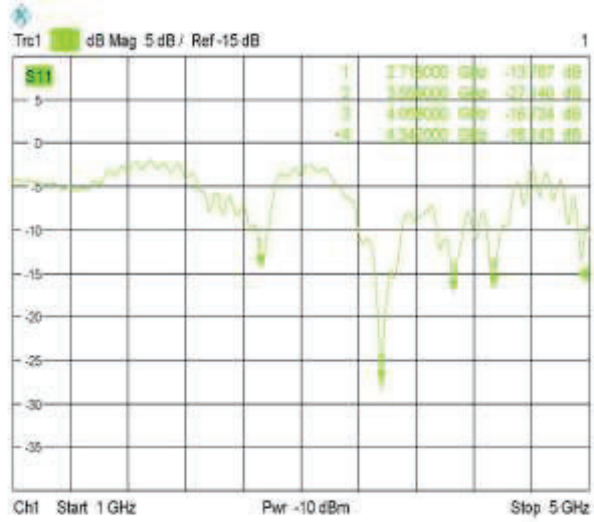


***Fig. 11.*** *$S_{11}$ [dB] circular microstrip array – uninterrupted feed line*

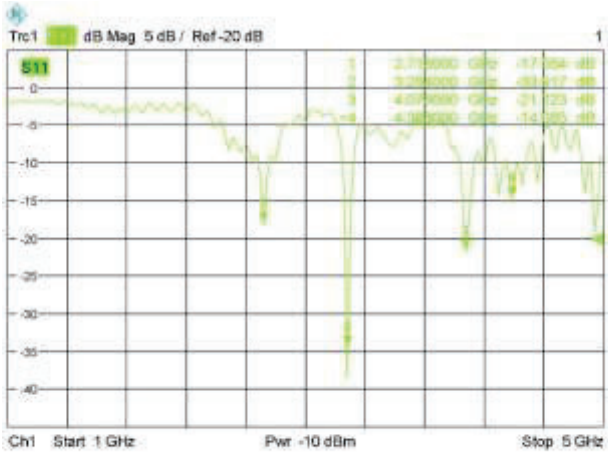


***Fig. 12.*** *$S_{11}$ [dB] circular microstrip array – one step excitation line*

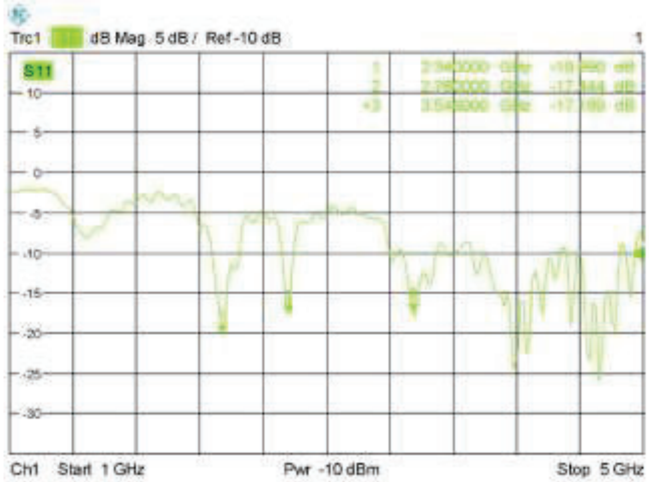


***Fig. 13.*** *$S_{11}$ [dB] circular microstrip array – two Step excitation line*

TABLE 1A: ESTIMATES OF A PATCH AND CIRCULAR PATCH ARRAY - COMPUTATIONAL AND EXPERIMENTAL RESULTS.

| $S_{11}$ [dB] | | Single and Circular Array Patch | |
|---|---|---|---|
| | | ***Simulated*** | ***Experimental*** |
| Straight Feed Line | Single | -11.91 dB at 2.3 GHz | -11.77 dB at 2.2 GHz |
| | Array | -21.14 dB at 2.45 GHz | -13.77 dB at 2.71 GHz |
| Single Step Feed Line | Single | -14.32 dB at 2.3 GHz | -10.44 dB at 2.26 GHz |
| | Array | -22.0 dB at 2.45 GHz | -17.65 dB at 2.71 GHz |
| Double Step Feed Line | Single | -15.91 dB at 2.4 GHz | -19.96 dB at 2.395 GHz |
| | Array | -24.73 dB at 2.45 GHz | -19.98 dB at 2.34 GHz |

## 4. Conclusions

This paper presents a circular planar array antenna operating at 2.45 GHz with an uninterrupted excitation line and discontinuities at the feed lines. The effect of discontinuities on the performance of antennas was studied in computational simulations, PCB etching excitation, and experimental validations to investigate the role of step discontinuities in the excitation line. The simulation and the experimental outcomes for the circular patch array antennas disclose the role of excitation lines and lines with two-step discontinuities for circular array antenna shows better results than the one-step feed line and uninterrupted feed line. The multiband and reconfigurable systems are getting popular in this decade[16-18]. In the future, the reported design can be extended in this direction.

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