Study of Miniaturized Patch Microstrip Antenna with Circular Slot and SRR Optimization

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Abstract

In this article, a novel approach on miniaturization of a simple rectangular patch has been discussed. Microstrip feed line has been used to excite the structure at 2.45 GHz. By introducing circular slots in the patch the design has been optimized. The impact on reflection coefficient and overall size due to slots of different radius is studied thoroughly. To achieve better impedance matching and desirable antenna gain, a 3x3 array of Split Ring Resonator (SRR) is introduced at the ground plane. CST MICROWAVE STUDIO is used for the necessary simulation.

1. Introduction

Patch antenna has gained a wide acceptance in the modern wireless communication systems. Consequently, the miniaturization of the radiating element has become an important issue to reduce the volume of the entire communication system. The common method of reducing the microstrip patch size is to utilize a high permittivity dielectric substrate. But, those antennas are more expensive, less radiation efficient and have narrow bandwidth. In order to overcome the above mentioned limitations, a couple of design techniques have already been proposed [1-3]. However, all of these designs have limitation in their design, which are complex in structure and low performance for miniaturization. In this paper, initially, a simple rectangular microstrip patch antenna is designed at 2.45 GHz. Then, circular slots of different radius have been inserted into the patch and it is observed that the operating frequency is shifted up to 2. 229 GHz resulting in reduction of patch size. A 3x3 array of Split Ring Resonator (SRR) is introduced with subsequent miniaturization in patch size. The proposed antenna takes an advantage over previously designed antenna in terms of simplicity in structure and enhanced bandwidth.

2. Antenna Design

There are several methods used in recent research works for obtaining antenna with miniaturized radiating element [4], [5], [6], [10]. A novel approach has been taken in this article. Figure 1 shows the front and back view of rectangular microstrip patch antenna considered initially. The patch has the dimension of (33 mm x 28.5 mm). The substrate used in the design is FR-4, having dielectric constant of 4.4 and loss tangent of 0.009. The dimension of ground plane and substrate is (40 mm x 40 mm x 1.6 mm). The antenna resonates at 2.45 GHz with simple microstrip line feed structure.

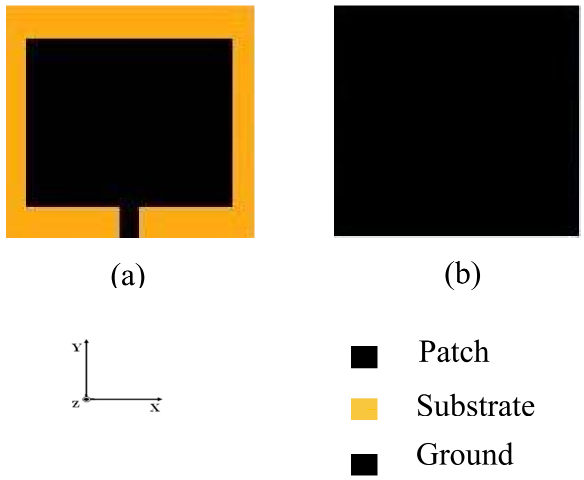


Figure 1. Line Fed Rectangular Microstrip Patch
(a) Front View (b) Back view

In the second prototype, circular slots of radius 2 mm, 3 mm and 4 mm have been introduced and corresponding reflection coefficient and gain of the antenna is observed. It is noted that in case of double circular slots having radius of 4 mm, the antenna operating frequency shifts to 2.229 GHz from its design frequency of 2.45GHz, thereby indicating the patch size reduction. In this prototype, we have observed gain of 0.35 dB and the return loss is -15.87 dB.

In the third antenna prototype, in order to enhance the gain and the impedance matching, SRR structure has been introduced in the ground plane of the radiating element. A unit cell dimension of SRR is given in the following table.

Table 1 Unit Cell Dimension

Parameters	Notation	Value
Outer Ring Length	r_s	12 mm
Split Width	s	0.2 mm
Gap	g	1 mm
Ring Thickness	w	1.5 mm

An array of 9 element square split ring resonators has been introduced to get the optimized output in terms of return loss and gain.

Figure 2(a), 2(b) and 2(c) show the front view of the antenna with double slots for 4 mm radius, a unit cell of SRR dimension and 3x3 SRR array incorporated in the back side of the circular slotted patch respectively.

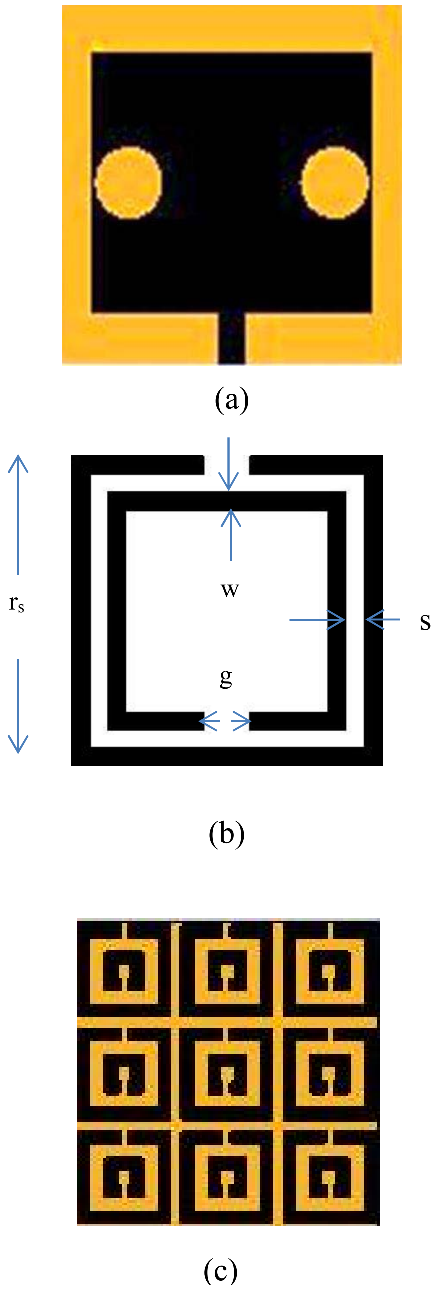


Figure 2. Proposed Antenna Structure (a) Top View (b) Unit Cell Dimension of SRR (c) 3x3 SRR Array incorporation

3. Results and Discussions

The circular slots in a rectangular patch are used in this article in order to get the required minimization in patch element. First of all, a single slot has been cut at the center of the patch. The optimization is done using radius of 2 mm, 3 mm and 4 mm respectively. To obtain more decrease from the resonating frequency position a 2.45 GHz, dual circular slots are used and optimized. Table 2 shows the comparative study of shifting in operating frequency due to incorporation of circular slots.

Table 2 Change in Operating Frequency due to variable radius of circular slots

Type of Patch	Radius of Circular Slot (mm)	Operating Frequency (GHz)	Return loss S_{11}(dB)
Single Circular Slot	2	2.455	-17.36
	3	2.428	-17.71
	4	2.389	-15.71
Double Circular Slot	2	2.443	-19.65
	3	2.389	-18.00
	4	**2.229**	-15.87

Table 3 shows the comparative performance of the antenna in terms of impedance matching and gain because of 3x3 array of Split Ring Resonator (SRR) on the ground plane.

Table 3 Comparisons of S_{11} and Gain for 3x3 SRR Array

Type of Patch	S_{11} (dB)	Gain(dB)
Circular Slotted Patch without SRR	- 15.87	0.35
Circular Slotted SRR loaded Patch	- 23.36	0.65

It is clearly observed from this table, that the antenna gain is enhanced with increase in reflection coefficient. The gain, as depicted in the above table is enhanced by approximately 98% because of SRR implementation.

Figure 3 shows the return loss (S_{11}) shift in resonant frequency from 2.45 GHz towards left indicating the miniaturization of patch element of the microstrip antenna.

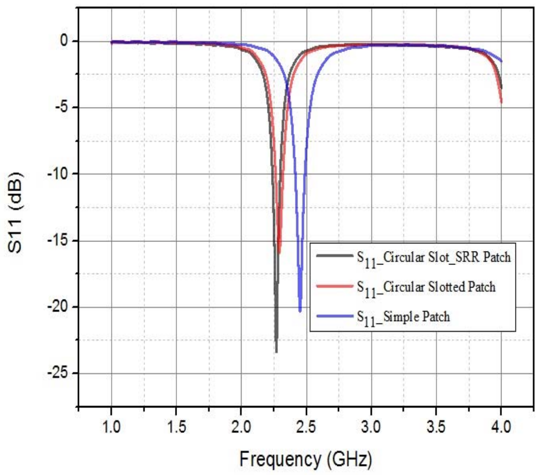
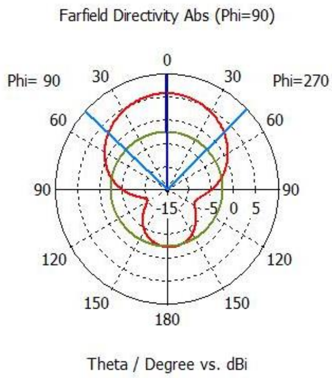
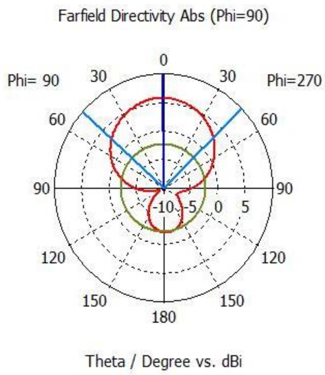


Figure 3. S_{11} Comparison Plot for slot radius of 4 mm

The return loss of the simple patch antenna operating at 2.45 GHz is -20.30 dB. The operating frequency shifted to 2.229 GHz due to the effect of circular slots with acceptable return loss of -15.87 dB and gain of 0.35 dB. The impedance matching is enhanced upto 23.36 dB with antenna gain of 0.65dB using 3x3 SRR array.



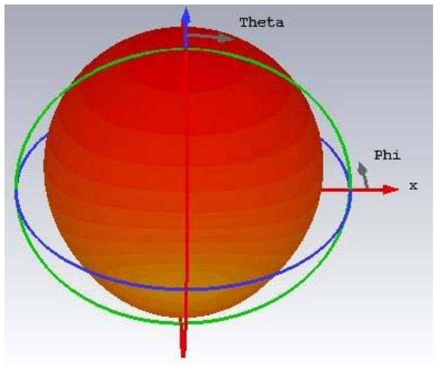
(a)



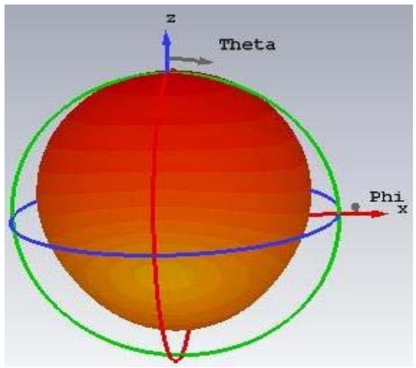
(b)

Figure 4. Directivity Plot (a) Slotted Patch without SRR (b) with SRR

The gain is enhanced almost double as compared to the dual circular slotted patch as shown in Table 2. The far-field directivity and radiation pattern plot of Circular slotted Patch antenna with and without SRR is shown in Figure 4 and Figure 5 respectively.



(a)



(b)

Figure 5. Radiation Pattern Plot (a) Slotted Patch without SRR (b) with SRR

4. Conclusions

In this research, a simple miniaturization technique using circular slotted patch has been discussed. According to the conventional formula of achieving microstrip patch dimension, if the operating frequency increases, the patch size reduces [7-9]. Here, keeping the patch dimension unaltered, the operating frequency decreases upto 220 MHz causing about 9% reduction in patch size with enhanced gain of around 98% by using Split Ring Resonator array.

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