DOI: 10.21917/ijct.2010.0025

SIMULATED CHARACTERISTICS OF PATCH ANTENNA LOADED WITH SRRs

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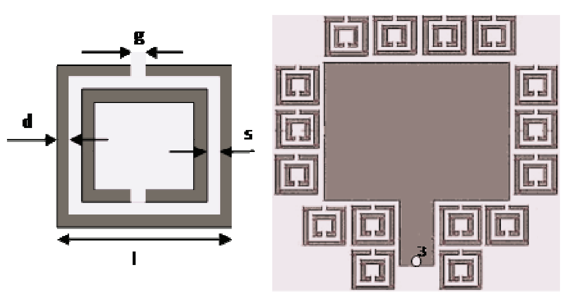
Abstract
This article investigates, from electromagnetic simulation, the effects on gain and efficiency of a patch antenna loaded with split ring resonators. It is observed that it leads to lowering of resonant frequency; some mismatch resulting in a slight degradation of the impedance bandwidth and improvement of gain and efficiency.

Keywords:
Patch Antenna, Split Ring Resonator (SRR).

1. INTRODUCTION

The microstrip antenna has become popular due to many favourable characteristics like ease of fabrication, light weight, conformability etc. On the other hand, limitations also exist in forms of low bandwidth, surface-wave losses etc. Scientific efforts to minimize such detrimental limitations are continuously on. The radiation efficiency of patch antennas is reduced due to surface wave loss [1]. This article proposes use of split ring resonators (SRRs) to enhance the efficiency of the patch antenna. A MoM based commercial package *IE3D*™ verifies the proposed arrangements.

2. PROPOSED STRUCTURAL ARRANGEMENT



(a)

Fig.1. (a) SRR Schematic Layout, (b) SRR around the edges of the patch antenna and feed-line

Media with microstructure inclusions having controllable electromagnetic parameters and high dispersion are known as Electromagnetic metamaterials. The left-handed (LH) materials [2] composed of electrically small unit cells, exhibiting backward wave propagation belong to this category. Usually, these are realized with electrically small resonant elements such as split rings resonators (SRRs) [3]-[4]. SRR (Fig. 1a) are known to behave as artificial magnetic plasma [5]-[6], when they intercept the propagating fields. In a patch antenna, surface waves propagate along the substrate. Hence, for maximum interaction the SRRs shall be along the substrate and be designed to exhibit negative permeability within the desired operating bandwidth, so as to obstruct the propagating surface waves. So, it is proposed to place the radiating patch within a ring of SRRs (Fig. 1b). Also, another nomenclature with SRRs along the microstrip feed-line (Fig. 3) is proposed.

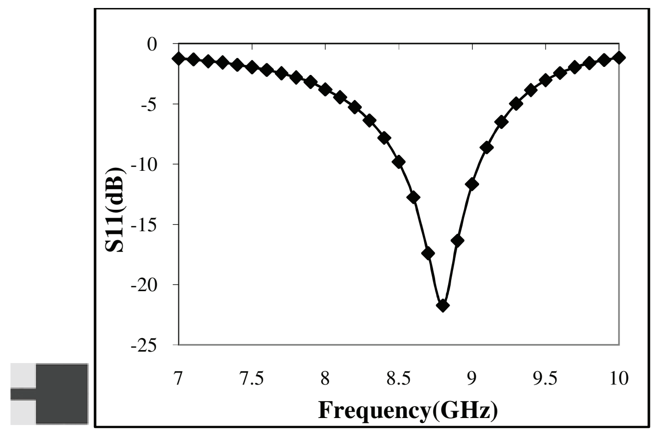


Fig.2. Edge-fed patch antenna and its S_{11} variation with frequency

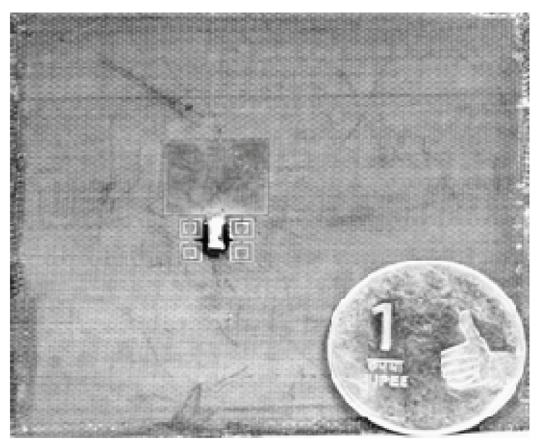
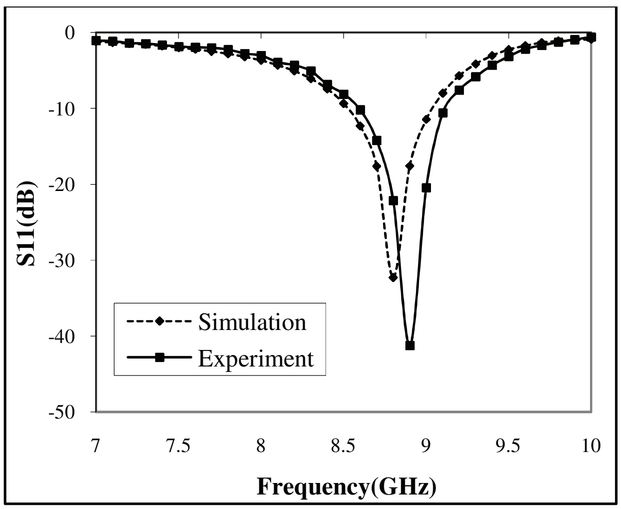
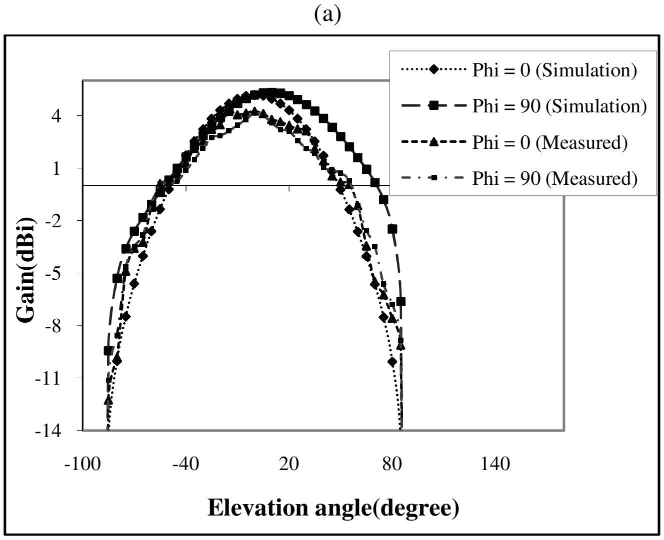


Fig.3. Fabricated prototype of the Antenna with SRR along the microstrip feed

The two proposed antennas with SRR as well as a simple edge-fed patch antenna are simulated using *IE3D*™. A prototype of the 2nd structure is fabricated and tested. The design process started with simulation using Method of Moment (MoM) based commercial electromagnetic solver IE3D. First a simple program is written to determine the patch dimensions, based on the standard procedures for microstrip antenna [1] to obtain the desired resonant frequency. These dimensions are then implemented in IE3D. Then the dimensions are fine tuned using the available optimization procedure in IE3D. Thus a simple microstrip antenna is first generated. Then this structure is re-simulated by loading it with SRRs on its periphery. Because of the loading it gets detuned. So, again the optimization procedure in IE3D is used to bring the resonant frequency back to that of the simple patch antenna, as closely as possible. The same procedure is also adopted for the structure with SRR alongside the microstrip feed-line.



(a)



(b)

Fig.4. Simulated and measured results of the SRR Feed along patch antenna: (a) S-Parameter variation; (b) Elevation

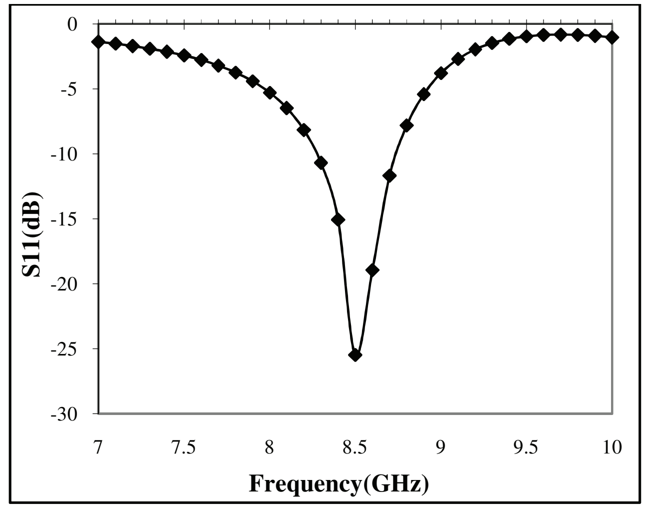


Fig.5. Simulated S-Parameter of the Antenna loaded with a ring of SRR

3. RESULTS AND DISCUSSIONS

A rectangular patch with dimensions 10.7 mm x 13.1 mm edge fed with a 5mm x 2.4mm microstrip line on a substrate of ε_r = 2.4 and 1.5875 mm thickness was simulated using *IE3D*™. It was observed that it would radiate at 8.8GHz with a S_{11} of -21.74dB over a 0.5GHz bandwidth with a linear gain 5.116 dBi, radiation efficiency 75% and linear directivity 8.129 dBi.

A second simulation was done by placing 2 SRRs on each side of the microstrip feed-line. It was observed that the resonant frequency is pushed up to 8.9GHz with a better matching (S_{11} = -41.25 dB). The linear gain and efficiency improved to 5.32dBi and 81% respective. On the hind side, the bandwidth decreased to 5.6% from 6.2%.

In the third simulation the radiating patch and the microstrip feed were surrounded with 16 numbers of SRR's ($l = 3mm$ and $d = s = g = 0.33mm$.) around their edges (Fig. 1b). It was found that the fundamental resonant frequency shifted down to 8.5 GHz with a return loss of -25.48 dB. Here the 5.514 dBi linear gain, 83% radiation efficiency and 8.08dBi directivity.

The downward shift in frequency indicates possibility of size reduction of the antenna. The shift can be due to weak coupling between the radiating patch and the SRRs. Due to this detuning, mismatch at the band-edges increase, resulting in lowering of the bandwidth. However, the matching improves at the centre frequency due to suppression of surface waves and consequent improvements in the linear gain and radiation efficiency. Obviously, the presence of the metallic SRRs around the radiating patch, distorts the pattern a bit resulting in marginal decrease of the linear directivity.

In the same process, simulation was done for two other frequencies of 1.8 GHz and 2.4 GHz. The split rings were scaled in proportion to the patch length at each of these frequencies. In other words, first the ratio of the SRR side lengths (outer ring length: inner ring length) was determined for the 8.8 GHz antenna. Then the ratio of the outer ring length to the patch length was determined for this antenna. These two ratios were kept constant for the antennas at other two frequencies. Then the patch lengths at 2.4 GHz and 1.8 GHz were determined. Using these lengths and the ratios the ring-length was determined. Following same procedure, the ring width and gap widths were also determined for the rings loading the other two antennas of 2.4 GHz and 1.8 GHz. The performance characteristics at the three frequencies of 8.8 GHz, 2.4 GHz & 1.8 GHz for the 3 configurations in each frequency are compared in Table 1.

Table.1. Comparison of Characteristics of Antennas (**A1:** l = 10.7 mm, w = 13.1 mm; **A2:** l = 39.78 mm, w = 33.9 mm; **A3:** l = 53.29 mm, w = 45.19 mm)

Antenna Type		**Resonant frequency in GHz**	**S_{11} in dB**	**Gain dBi**	**% BW**	**% η**
Simple patch	A1	8.8	-21.74	5.116	6.2	75
	A2	2.4	-19.12	4.836	3.2	73
	A3	1.8	-15.28	4.43	2.85	70
SRR along the feed of patch	A1	8.9	-41.25	5.32	5.6	81
	A2	2.6	-37.21	5.173	3	78
	A3	1.8	-29.83	4.92	2.54	74
SRR around edges of the patch	A1	8.5	-25.48	5.51	5.2	83
	A2	2.2	-23.53	5.132	2.78	78
	A3	1.68	-20.38	4.892	2.63	72

4. CONCLUSION

This paper proposed configurations to improve the performance of patch antenna using SRRs. Electromagnetic simulation showed that the gain and radiation efficiency of such a structure can be improved, while there shall be marginal degradation in bandwidth and directivity as well as a small downward shift of resonant frequency.

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