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Design and Performance Analysis of Rectangular Microstrip Patch Antenna using Metamaterial Structure for Improved Radiation

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***Abstract*— There is an increase in demand for microstrip antennas with improved performance for wireless communication applications because of their planar structure, low profile, and light weight, moderate efficiency and ease of integration with active devices. In this paper, general property of rectangular micro-strip patch antenna is explained with metamaterial structure like return loss, bandwidth, directivity and gain. Comparison of return loss, bandwidth & gain of the micro-strip patch antenna at a frequency of 2GHz with and without metamaterial structures will be provided using the design tool Ansoft HFSS.**

***Keywords*—** A*rray antenna; corporate-series feed array; corporate feed array; microstrip antenna; series feed*

I. INTRODUCTION

Now a day, the growth in communication systems requires the development of less expensive, minimal weight, low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. The key features of a microstrip antenna such as relative ease of construction, light weight, low cost and either conformability to the mounting surface or, an extremely thin protrusion from the surface make them prominent in the use of wireless applications such as satellite communication, radar, medical applications, etc. [1]. This antenna renders all of the advantages of printed circuit technology. The limitations of microstrip antennas are narrow frequency band and disability to operate at high power levels of waveguide, coaxial line or even strip line. Therefore, the challenge in microstrip antenna design is to increase the bandwidth and gain [2]. Different array configurations of microstrip antenna can give high gain, wide bandwidth and improved efficiency. The distribution of voltages among the elements of an array depends on feeding network. Suitable feeding network accumulates all of the induced voltages to feed into one point [3]. The proper impedance matching throughout the corporate and series feeding array configurations provides high efficiency microstrip antenna [4]. Power distribution among antenna elements can be modified by corporate feed network. The corporate feed network can steer beam by introducing phase change [5]. The choosing of design parameters (dielectric material, height and frequency, etc is important because antenna performance depends on these parameters. Radiation performance can be improved by using proper design structures [6]. The use of high permittivity substrates can miniaturize microstrip antenna size [7]. Thick substrates with lower range of dielectric offer better efficiency, and wide bandwidth but it requires larger element size [8]. Microstrip antenna with superconducting patch on uniaxial substrate gives high radiation efficiency and gain in millimeter wave lengths [9]. The width discontinuities in a microstrip patch reduces the length of resonating microstrip antenna and radiation efficiency as well [10]. Different radar systems such as synthetic aperture radar (SAR), shuttle imaging radar, remote sensing radars, and other wireless communication systems operate in L, C and X bands. Microstrip antenna is the first option for this high frequency band such as X-band due to its low cost, light weight, and hardiness [11].

In this article, the unusual properties of metamaterial are utilized in a microstrip patch antenna to enhance the performance of the antenna at 2GHz. Section II gives the antenna design. The simulation results are discussed in section III.

II. MICROSTRIP PATCH ANTENNA DESIGN WITH METAMATERIALS

A. Metamaterial loaded around the patch

The rectangular microstrip patch antenna is incised on FR4 epoxy substrate of dielectric constant 4.4 and height 1.57mm. The suggested design consists of rectangular split ring (SRR) metamaterial loaded on the microstrip patch antenna as shown Fig. 1 below

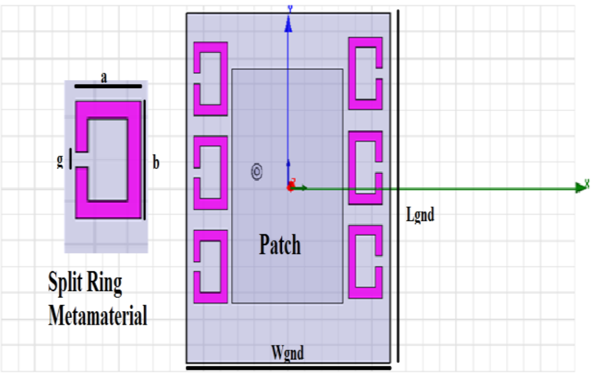


Fig.1. Split Ring Metamaterial loaded microstrip patch antenna simulated using HFSS

The dimension used for the designing the patch is mentioned in Table. 1

TABLE.1. ANTENNA SPECIFICATIONS

Parameter	Dimension	Units
Dielectric constant	4.4	
thickness	1.57	mm
Operating frequency	2	GHz
Length of patch (L)	34.3	mm
Width of patch (W)	44.2	mm
Length of SRR (a)	10	mm
Width of SRR (b)	14	mm
Gap (g)	2	mm
No. of SRR units used	06	

As seen in Fig. 1 six in-plane metamaterials are incised in the vicinity of the radiating patch to obtain the efficient antenna performance. The antenna is designed to resonate at 2GHz. A 50 Ω co-axial feeding is used to excite the antenna.

B. Metamaterial loaded below the patch

The rectangular microstrip patch antenna is incised on FR4 epoxy substrate of dielectric constant 4.4 and height 1.57mm. The suggested design consists of rectangular split ring (SRR) metamaterial loaded at height of 0.5mm below the microstrip patch antenna as shown Fig. 2 below

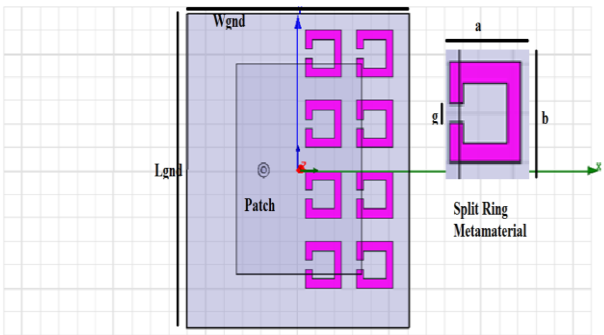


Fig.2. Split Ring Metamaterial loaded below the microstrip patch antenna simulated using HFSS

As seen in Fig. 2 eight SRR metamaterials are loaded below the radiating patch and its effects on the performance of the antenna are studied.

III. SIMULATION RESULTS AND DISCUSSION

A. Metamaterial loaded around the patch

The antenna was designed and simulated using design tool Ansoft HFSS. The return loss is the primary parameter in the analysis of an antenna. The rectangular microstrip patch antenna without metamaterial is designed to resonate at 2 GHz as shown in Fig. 3

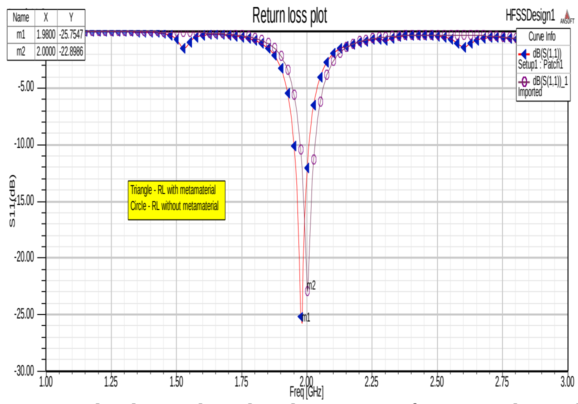


Fig.3. Simulated return loss plotted using HFSS for rectangular patch antenna with and without metamaterial.

As seen in Fig. 3, the return loss is slightly increased to from -24dB to -22dB with metamaterial. This is due to interaction of the radiating patch with the split rings.

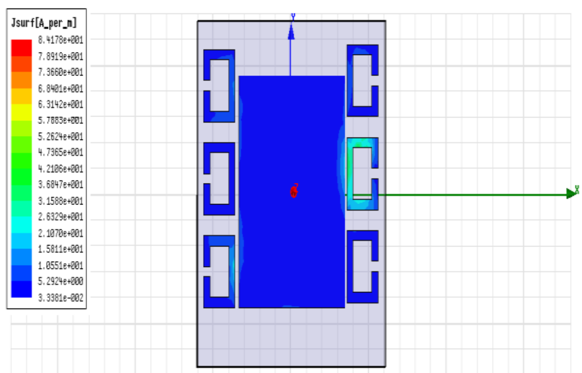
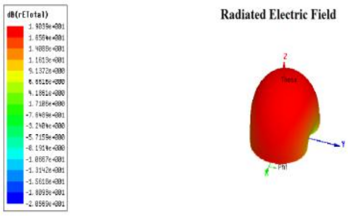


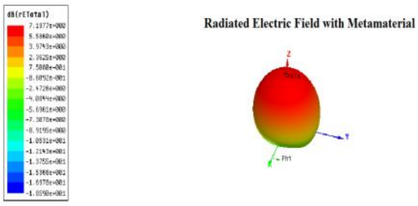
Fig.4. Simulated surface current plot for antenna with metamaterial.

As seen in Fig. 4 significant current is induced in the split rings from radiating patch.

The rE plot simulated using HFSS as shown in Fig. 5 gives the radiated electric field which is multiplied by the radial distance ‘r’.



(a)



(b)

Fig.5. Simulated radiated electric field as a function of the radial distance r (a) without metamaterial (b) with metamaterial

As seen in Fig. 5 the when split rings are placed around the radiating patch the electric field radiated is increased up to 7dB from 1dB. Thus, the radiation efficiency of an antenna is increased by significant amount.

B. *Metamaterial loaded below the patch*

The return loss plot for microstrip patch antenna with and without SRR metamaterial loaded below the patch is presented in Fig. 6

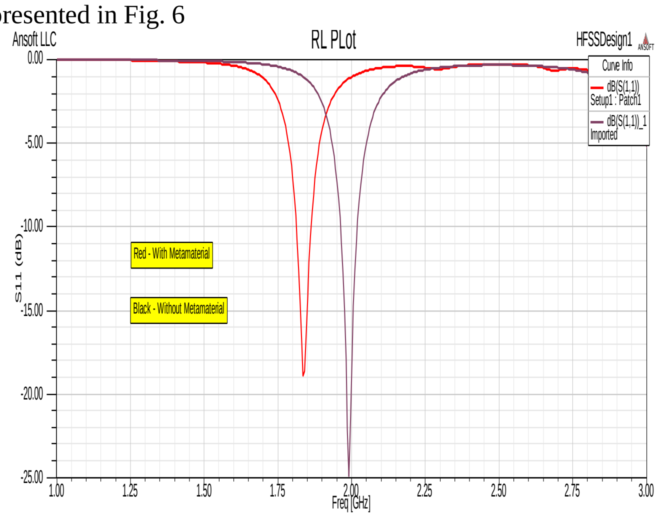


Fig.6. Simulated return loss plotted using HFSS for rectangular patch antenna with and without metamaterial loaded below the patch

As seen from Fig. 6 when the rectangular patch antenna is loaded with SRR metamaterial at a height of 0.5mm below the patch there is a shift in the resonant frequency from 2GHz to 1.8GHz thereby demonstrating the potential for size reduction of the microstrip patch antenna.

IV. CONCLUSION

In this paper, we propose a novel technique to improve the radiation efficiency of the microstrip patch antenna by incising the split ring metamaterial of proper dimension in the vicinity of the radiating patch. By doing so, it is found that the return loss is slightly shifted below and the radiated electric field as a function of the radial distance is significantly increased from 1 dB to 7 dB thus improving the radiation efficiency. Also, it was observed that the antenna showed potential for miniaturization when the metamaterials are loaded below the patch. In future, the designed antennas can be fabricated and tested in real time environment.

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