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Miniaturization of Microstrip Patch Antenna Using CSRR

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Abstract: *In this paper a novel structure of metamaterial is proposed in order to miniaturize a rectangular microstrip patch antenna. The metamaterial is composed of two nested split octagons which are located on a 10 mmx10 mm Rogers RT/duroid 5880 with 0.7874 mm thickness and dielectric constant of 2.2. A 3X5 array of such metamaterials is placed on the patch antenna substrate. By using this metamaterial in the antenna structure, the dimension of this proposed antenna is reduced compared to a simple microstrip patch antenna. Simulation results for return loss and radiation pattern of both proposed and conventional antenna are shown and compared.*
Keywords: *CSRR,frequencyMetamaterial,microstrip antenna ,Miniaturization*

I. Introduction

The basic geometry of a microstrip patch antenna(MPA) consists of a metallic patch printed on a grounded substrate. Three commonly used feeding methods are coaxial feed, stripline feed, and aperture-coupled feed. The patch antenna idea was first proposed in the early 1950s, but it was not until the late 1970s that this type of antenna attracted serious attention of the antenna community. The microstrip patch antenna offers the advantages of low profile, conformability to a shaped surface, ease of fabrication, and compatibility with integrated circuit technology, but the basic geometry suffers from narrow bandwidth.

Metamaterials are artificial structures, and their electromagnetic properties dont exist in nature. Employing metamaterials in microstrip antenna substrate will result in the improvement of the antenna parameters like bandwidth, gain, efficiency, etc. Additionally, it is possible to miniaturize the antenna as much as desired with these structures, without dealing with surface waves problems. To date, many different techniques have been proposed, based on the use of metamaterials. Applications of double negative (DNG) and single negative (SNG) metamaterials have been widely studied by some research groups in miniaturization of subwavelength cavities, waveguides , and antennas. [6]This project present the possibility of miniaturization of a rectangular microstrip patch antenna by using a novel structure of metamaterial, which is placed on the substrate[1].

With the advent and popularity of many wireless services, a quandary has arisen in the antenna community about how to develop small antennas that can satisfy the performance requirements for these systems as well as be aesthetically pleasing to the user. It is interesting to note that the latter point is not insignificant. As with the computer industry, mobile communications is very much a customer-driven market and thus the user requests, although technically with little merit, must be addressed. Ideally, an antenna that is unobtrusive and low cost, and can be located within thecasing of the handset would ensure the compactness of the handset terminal and therefore please the users. Microstrip antennas would appear to be possible candidates because of several attractive features, including their low profile, light weight, and ease of fabrication. Unfortunately, most present-day mobile communication systems are in the lower microwave region of the spectrum (less than 3 GHz) where these antennas in their conventional form are too large for wireless communication handsets. Several approaches have been reported to effectively reduce the size of the printed conductor of a microstrip patch antenna,here a new concept,that is the presence of metamaterial is used.[2]

In this paper, we present the possibility of miniaturization of a rectangular microstrip patch antenna by using a novel structure of metamaterial, which is placed on the substrate.[3] First of all, designed a conventional rectangular patch antenna and analysed it. Then the resonance structure of the metamaterial is investigated and analyzed. Then the antenna structure at the presence of this metamaterial in the substrate is investigated and the return loss and radiation pattern of the proposed antenna is compared with the conventional patch antenna with the same dimension.[10]

II. Antenna Design

The most important features considering when designing an antenna are the resonating frequency and selection dilectric substance. All of the parameters in a rectangular patch antenna design (L, W, h, permittivity) control the properties of the antenna. First, the length of the patch L controls the resonant frequency . This is true in general, even for more complicated micro strip antennas that weave around - the length of the longest path on the micro strip controls the lowest frequency of operation.[2]

The width W controls the input impedance and the radiation pattern. The wider the patch becomes the lower the input impedance is. The permittivity (dielectric constant) of the substrate controls the fringing fields - lower permittivities have wider fringes and therefore better radiation. Decreasing the permittivity also increases the antenna bandwidth. The efficiency is also increased with a lower value for the permittivity. The impedance of the antenna increases with higher permittivities. Higher values of permittivity allow a "shrinking" of the patch antenna. Particularly in cell phones, the designers are given very little space and want the antenna to be a half wavelength long. One technique is to use a substrate with a very high permittivity. The height of the substrate h also controls the bandwidth - increasing the height increases the bandwidth. The fact that increasing the height of a patch antenna increases its bandwidth can be understood by recalling the general rule that an antenna occupying more space in a spherical volume will have a wider bandwidth. This is the same principle that applies when noting that increasing the thickness of a dipole antenna increases its bandwidth. Increasing the height also increases the efficiency of the antenna. Increasing the height does induce surface waves that travel within the substrate. Here in this design,ROGERS/RT DUROID 5880 is used as the dielectrin witha thickness of0.7874mm and it is having a dielectric constant of 2.2.

The antenna and metamaterial unit cell are designed and analysed in High Frequency Structure Simulator(HFSS).HFSS is a commercial finite element method solver for electromagnetic structures from Ansys. It is one of several commercial tools used for antenna design, and the design of complex RF electronic circuit elements including filters, transmission lines, and packaging The rectangular patch micro strip antenna for a resonant frequency of 6.0GHz is designed using the traditional equations. Here the dielectric is the ROGERS/RT DUROID 5880. [4]The basic structure of the design is shown in the figure 1. the feeding technique used is the inset feed.by allowing proper frequency sweep the antenna is designed in HFSS and analysed the results. The antenna has a required performance in 6Ghz region with a return loss more than -10dB.

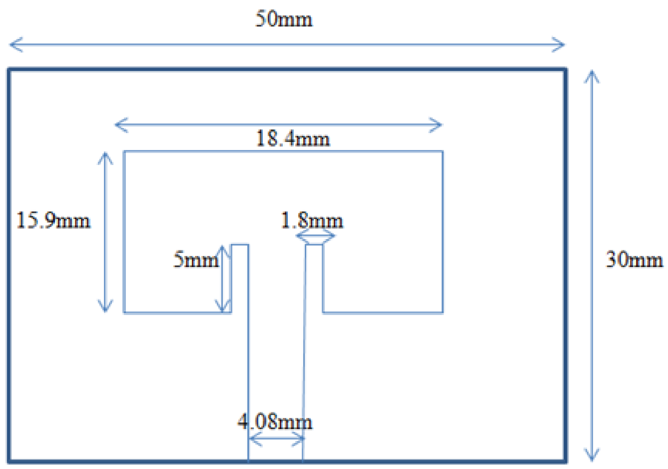

Figure1: Basic structure of conventional rectangular MPA.

The configuration of the novel metamaterial model that is investigated in this paper is shown in Figure 2. As it is seen from the figure 5.5, this metamaterial unit cell is composed of two nested split octagons which are etched on a dielectric substrate. The strip width of each octagon is 0.6mm. The sides of the octagons ,from the outer side to inner side,(S1; S2; S3; S4)are 4.0mm,3.5mm,2.8mm and 2.3mm respectively. Both of the gaps ,g, in the octagon are 0.3mm and distance between octagons, d, is 0.845mm. The relative constitutive parameters of the unit cell ,such as permittivity and permeability are calculated from S parameters by using retrieval method .Here both of the permittivity and permeability parameters are negative in specific frequency band. So this structure shows double negative property and it can be used as a DNG medium.[9].

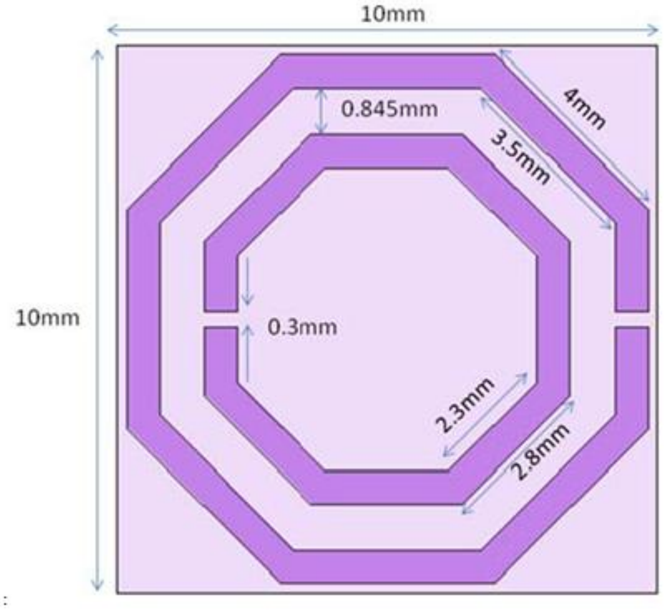

Figure 2: The unit cell structure and its dimensions.

A 3 X 5 array of metamaterial which was described above is placed in the substrate of a patch antenna. The substrate width(Wg) is 50 mm and its length (Lg) is 30 mm. The patch dimensions of this structure, w X l, are 18.4 mm X 15.9 mm. The resonance frequency gets slightly influenced by the physical notch and its corresponding junction capacitance. The resonant input impedance decreases monotonically and reaches zero at the centre as the inset feed point moves from the edge towards the centre of the patch antenna. When the patch antenna is loaded with this metamaterial, its resonance frequency depends on the metamaterial constitutive parameters. It means that the antenna resonates when the constitutive parameters become negative. [5]Therefore the antennas resonance frequency shifts to the metamaterials resonance frequency. In the proposed antenna, it is shown that by loading a conventional rectangular patch antennas substrate with a DNG metamaterial, a sub-wavelength resonant mode on the patch will be excited.[7][8] Also the antenna is simulated by using a small modification, by using a single metamaterial structure .And also the properties of antenna in the presence of a single metamaterial unit cell also studied as in figure3.The presence of metamaterial is considerably reducing the size of the antenna. The antenna is working excellent in the 3.0GHz frequency, here also the conventional antenna is designed for a 6.0GHz and it is resonating at 3.0GHz

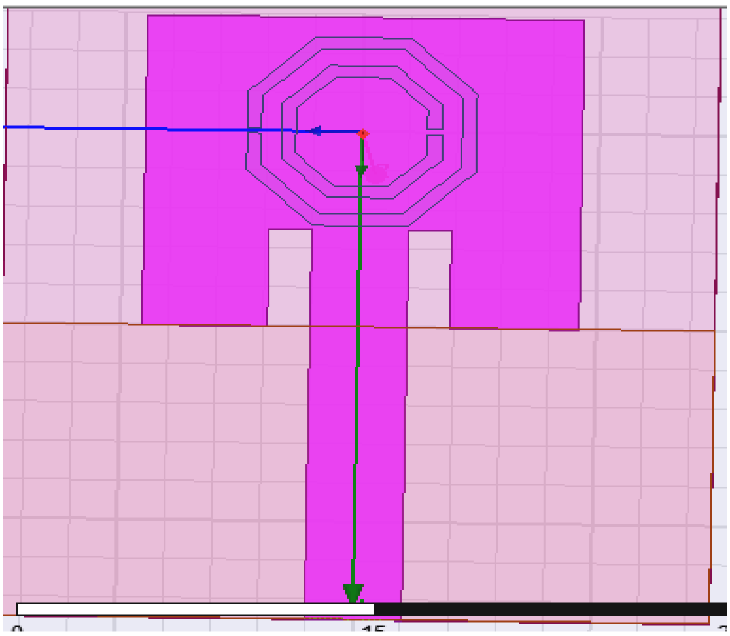

Figure3: Antenna in the presence of single unit cell.

III. Results

Simulation result for return loss plot of the conventional antenna is shown in the figure 4.This antenna is resonating at frequency of 6.0GHz.

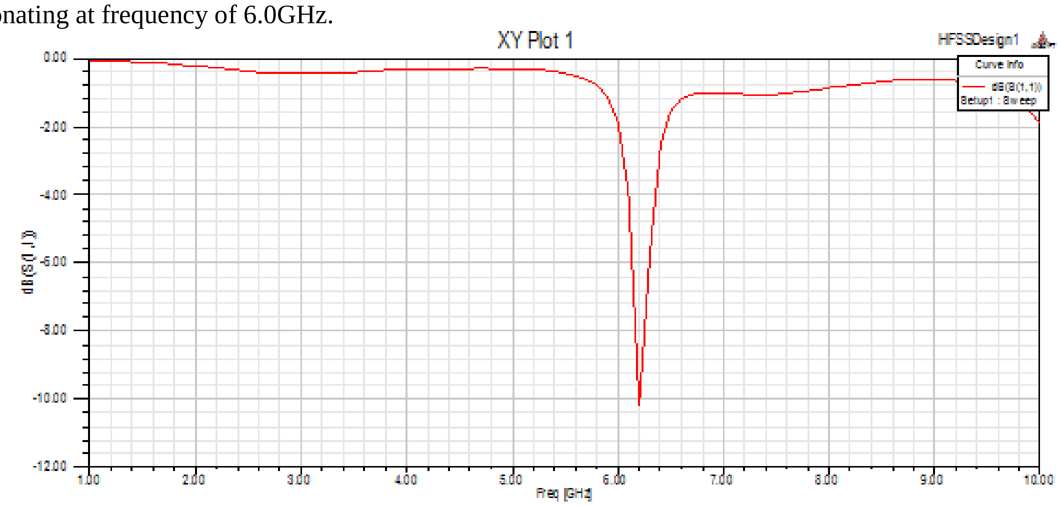

Figure 4: Return loss of conventional antenna.

The resonance frequency of the proposed antenna is 3.0 GHz. By this patch dimension, the conventional antenna resonates at 6.0 GHz. When the metamaterial is incorporated, the antenna resonates at a frequency where the permittivity and permeability are negative. This reduces the resonance frequency of the antenna from 6.0 GHz to 3.0 GHz. By reducing the resonance frequency of the antenna, miniaturization happens, because, the dimensions of the proposed antenna is smaller than a conventional antenna which resonates at 3 GHz as shown in figure5. This miniaturization brings about 50 present size reduction. The dimensions of the proposed patch antenna are as small as 0.273 λ x 0.236λ.

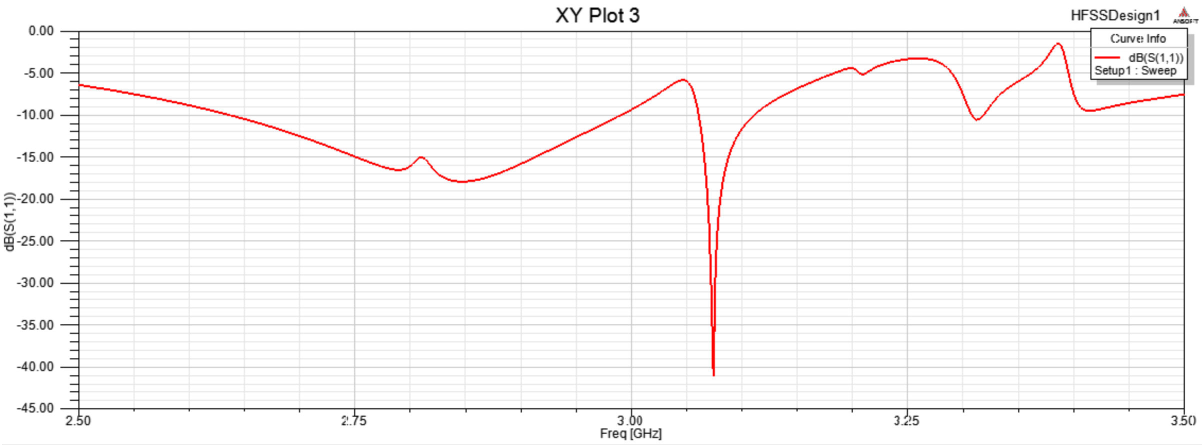

Figure 5: Return loss of proposed antenna

Because these metamaterial structures are narrowband, the bandwidth of the proposed antenna is smaller than the conventional antenna. The -10dB return loss Bandwidth of the proposed antenna, which is standard define for antenna engineering applications, is 0.01 GHz, while the bandwidth of the conventional antenna is 0.18 GHz. The gain of the antenna at frequencies 6.0GHz and 3.0 GHz are 6.53 dB and 4.35 dB, respectively. It shows that by reducing the size of the antenna, its gain decreases. So there is a trade off between gain and size of the antenna.

IV. Conclusion

A miniaturized micro strip patch antenna loaded with a DNG metamaterial was investigated. The overall dimension of the proposed antenna reduced about 50 percent. The location of the operating frequency is tuned effectively by the resonance of the metamaterial; therefore a sub-wavelength resonance was produced by the help of metamaterials. The radiation pattern and gain of the proposed antenna was deteriorated by size reduction. So there is a trade off between size reduction and gain of the antenna[10].

The comparison between the resonance frequency and gain of the conventional antenna and proposed antenna are shown below. The gain of the antenna at frequencies 6.0GHz and 3.0 GHz are 6.53 dB and 4.35 dB, respectively. It shows that by reducing the size of the antenna, its gain decreases

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