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Circularly Polarised Rectangular Micro-strip patch Antenna using Meta-material

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ABSTRACT: In this paper, a circularly polarized rectangular micro-strip patch antenna using unit cell of meta-material structure is presented. Since micro-strip patch antenna is a low profile antenna having low power, efficiency bandwidth etc. With the use of meta-material its improved performance is achieved. The antenna consists of a rectangular, slotted patch radiator, a single rectangular ring cell and a coaxial feed using FR-4 substrate. Plots of different parameters like Gain, Return Loss, & VSWR are analysed across the frequency band of 3.6-4.8 GHz. Desired patch antenna design is initially simulated by using Ansys HFSS Simulator and patch antenna is realized as per design requirements.

KEYWORDS: microstrip patch antenna, meta-material, hfss.

I. INTRODUCTION

There is a growing demand for compact microstrip patch antennas in the rapidly changing scenario of wireless and mobile communication to simultaneously access the multimedia information. The micro-strip antennas are low profile, comformable to planar and nonplanar surfaces, simple and inexpensive to fabricate using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and very versatile in terms of resonant frequency, polarization, pattern, and impedence. These antennas can be mounted on the surface of high performance aircraft, spacecraft, satellites, missiles, cars, and even handheld mobile telephones.

These antennas need the features such as high gain, high directivity, and large bandwidth to achieve faster data transfer rates. Antenna researchers are striving hard to design substantially diminutive antennas according to the progressively reducing size of the communication devices and handheld equipments. Micro-strip patch antennas have greater perspective due to their low profile, light weight and low cost. Moreover, the performance of these antennas (bandwidth and gain, multi-band characteristics, miniaturization, etc.) can be enhanced by using the state-of-art techniques such as making the slots inside the patch, meandering, stacking, use of high permittivity substrates, shorting pin etc. On the other hand the above mentioned techniques have certain limitations. A narrow bandwidth and low gain are main drawback of this antenna. Higher bandwidth is desired in various applications such as remote sensing, biomedical, mobile radio, satellite communications etc. In order to improve the bandwidth, intensive research has been carried out and several techniques are proposed.

However, most of these antenna designs are either too complex or impractical for practical applications in GHz frequency range. The difficulty in designing a simple and compact antenna with broadband or multiband functions is still a challenge for engineers since the complexity and size of the antenna's structure is reduced and the operating frequency bands increase. As mentioned earlier, there is extensive literature that presented the design of broadband rectangular microstrip antennas. However, previous studies have not included the effect of very high operating frequency in the procedure which increases chances calculation error in the model.

II. META-MATERIAL

In 1967 Victor Veselago speculated about the existence of meta-materials, these are artificial metallic structures having simultaneously negative permittivity (ε) and permeability (μ), which leads to negative refractive index. Due to negative index it supports backward waves i.e. inside Meta-material phase velocities and group velocities are anti parallel. Meta-material doesn’t obey Snell’s law, Doppler effect, Vavilov-Cerenkov radiation etc. No other material in

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the world shows the above properties like Meta-material. Due to these unusual properties Meta-material can change the electric and magnetic property of electromagnetic wave passing through it and because of these reasons when Meta material is used in the fabrication of microwave components and antennas the required properties can be enhanced. Also miniaturization in the size of the component is possible as the structural cell size of Meta-material is less than one fourth of the guided wavelength.

Using this Meta-material antenna the demerits of ordinary patch antenna like low gain and efficiency can be overcome and is useful in the field of wireless communication. The rationale behind the work is that small planar antennas are proposed using DNG (Double Negative) Meta-materials. The double negative property is being obtained by introducing unit cell structure. An unit cell consists of micro-strip gaps whose behaviour is equivalent to the combination of series capacitors and shunt inductors respectively. And this negative permittivity and permeability leads to negative refractive index due to this it exhibits unusual properties compared to readily available materials. Due to the unusual properties of the Meta-materials by using a single unit cell the antenna. This antenna has better VSWR, gain and radiation efficiency compared to an ordinary patch antenna. Meta-material is the only material (artificial) in the world which exhibits simultaneously negative permittivity and permeability which leads to negative refractive index.

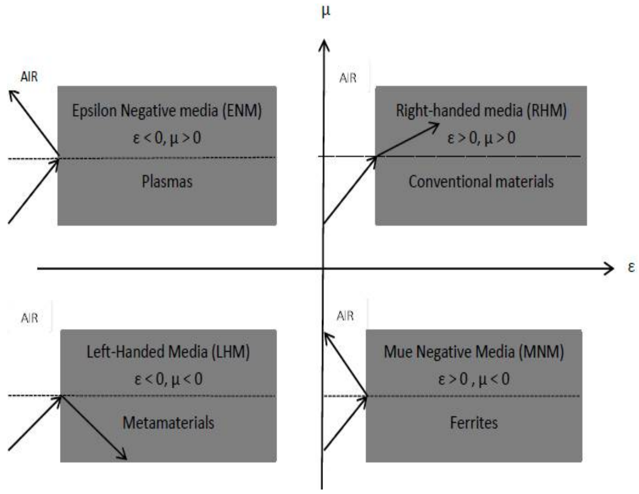

Fig.1. μ-Ɛ Space

Electromagnetic properties are the effect a material has on the electric and magnetic field of a wave, which is determined by the material's permittivity and permeability respectively. The four possible combinations of permittivity and permeability are shown in above fig. When the wave incident from air to plasmas and ferrites it gets reflected so the wave attenuates. But in case of conventional materials and meta-materials positive and negative refraction takes place respectively and wave propagates. Materials that reside in quadrant I, II and III are known to exist in nature, however naturally occurring materials with negative permittivity and negative permeability have not yet discovered.

Negative refraction can be achieved when both μr and Ɛr are negative, as described in the following equation-

$$
\begin{aligned}
n &= \sqrt{(-\varepsilon_r)(-\mu_r)} \\
&= \sqrt{\varepsilon_r(e^{-j\pi})\mu_r(e^{-j\pi})} \\
&= \sqrt{\varepsilon_r\mu_r}(e^{-j\pi})^{1/2}(e^{-j\pi})^{1/2} \\
&= \sqrt{\varepsilon_r\mu_r}(e^{-j\pi/2}e^{-j\pi/2}) \\
&= -1\sqrt{\varepsilon_r\mu_r} < 0
\end{aligned}
$$

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III. ANTENNA DESIGN

Below fig. shows a cross-sectional view of proposed rectangular slotted patch radiator using rectangular ring unit cell.

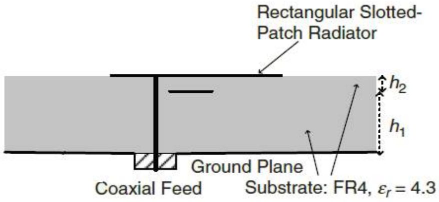

Fig.2. Cross-sectional view

In the proposed antenna design, the rectangular, slotted patch antenna over the unit cell of meta-surface is used.

Based on the simplified formulation that has been described, a design procedure is outlined which leads to practical designs of rectangular micro-strip antennas. The procedure assumes that the specified information includes the dielectric constant of the substrate (Ɛr) the resonant frequency (fr) and the height of the substrate h in order to determine length(L) and width(W) of the patch.

1. Width can be calculated as-

$$W = \frac{1}{2f_r\sqrt{\mu_0\epsilon_0}}\sqrt{\frac{2}{\epsilon_r+1}} = \frac{\upsilon_0}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}}$$

2. Length is given by-

$$L = \frac{1}{2f_r\sqrt{\epsilon_{\text{reff}}}\sqrt{\mu_0\epsilon_0}} - 2\Delta L$$

   where ΔL is extended length due to fringing effect

3. Ɛreff is given by-

$$\epsilon_{\text{reff}} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2}$$

4. ΔL is given by-

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{\text{reff}}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{\text{reff}}-0.258)\left(\frac{W}{h}+0.8\right)}$$

S. No.	Antenna Dimensions	Values
1.	Dielectric constant(Ɛr)	4.3
2.	Width(W)	21.9357mm
3.	ΔL	2.08506mm
4.	Leff	0.0190mm
5.	Ɛeff	3.5164mm
6.	Length(L)	15.65mm

Table1. Antenna dimensions

Antenna dimension values mentioned in above table are the calculated values by using above equations.

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IV. SOFTWARE USED

In this proposed work desired patch antenna is designed and simulated by using software Ansys HFSS. HFSS is a commercial finite element method solver for electromagnetic structures from Ansys. The acronym originally stood for high frequency structural simulator. 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. It was originally developed by Prof. Cendes and his students at Carnegie Mellon University.

The finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. It is also referred to as finite element analysis (FEA). It subdivides a large problem into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function.

V. SIMULATION RESULTS

In this section improved results of patch antenna using rectangular ring unit have been simulated and presented.

S. No.	Parameters	Values	Optimized Values
1.	Ground Plane	X=60mm Y=88mm	X=60mm Y=88mm
2.	Substrate1, Substrate2 height	3.2mm, 1.6mm	3.2mm, 1.6mm
3.	Slot radius	0.5952mm	0.5952mm
4.	Length of rectangular ring- Inner ring(S1), outer ring(Lu)	7.46mm, 8.96mm	7.46mm, 8.96mm
5.	Width of rectangular ring- Inner ring(Sw), outer ring(Wu)	0.85mm, 5.6mm	0.85mm, 5.6mm
6.	Length of Patch(L)	15.65mm	18.5mm
7.	Width of Patch(W)	21.9357mm	18.5mm

Table2. Designing parameters of antenna using unit cell of meta-material

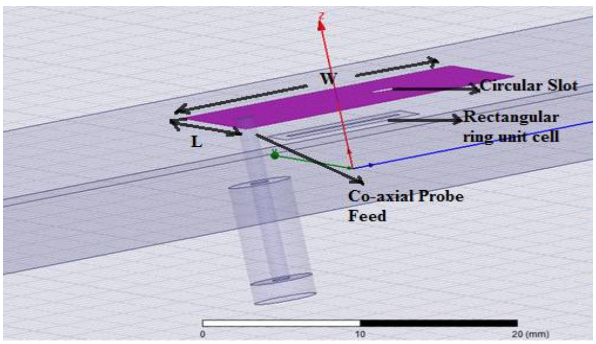

Fig.3. Side view of patch antenna over single unit cell

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In Fig 3, side view of antenna is shown , here we use coaxial type feeding to excite the antenna.

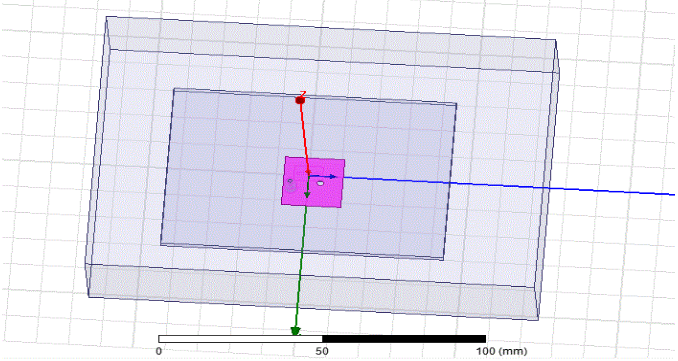

Fig.4. Top view of Patch antenna with single unit cell of meta-material

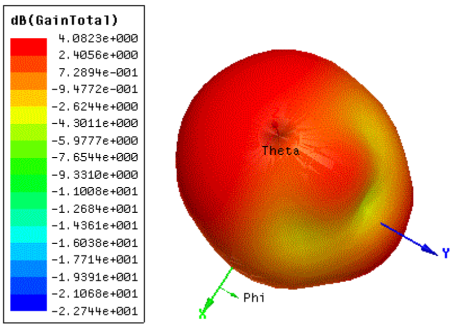

Fig.5. Gain of meta based patch

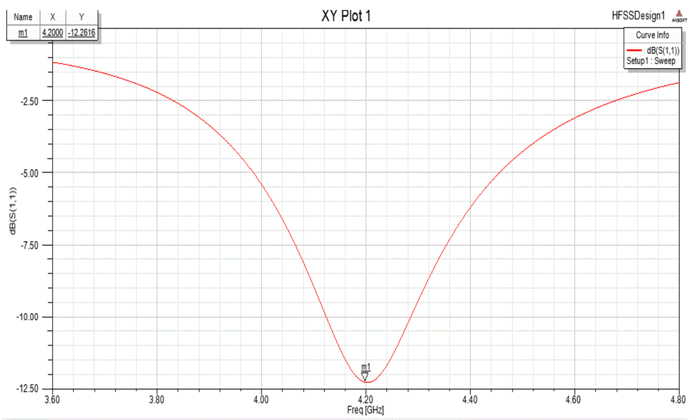

Fig.6. Return Loss Plot

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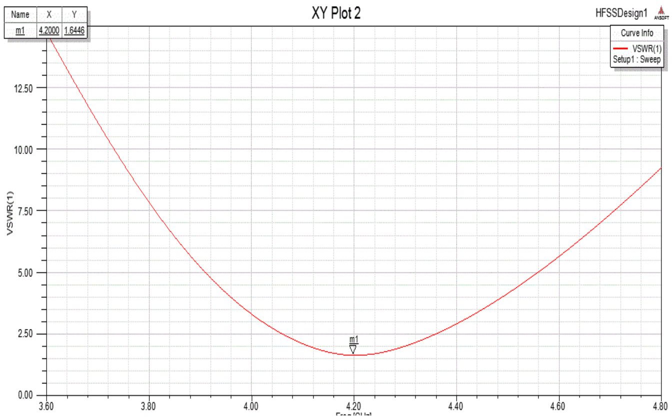

Fig.7. VSWR Plot

A patch antenna miniaturization technique using meta-material is proposed at 4.2 GHz resonating frequency. Gain, Return loss, VSWR characteristics are observed for the proposed antenna configuration by and depicted in Figures 3, 4 & 5. VSWR values obtained at resonating frequencies is 1.40 which is very much nearer to ideal value 1. From figure 6: percentage bandwidth observed at -10 dB return loss for the band is 3.75%. The proposed antenna is a good candidate for mobile application.

VI. Conclusion

This paper presents a rectangular micro-strip patch antenna having FR-4 as substrate using single rectangular unit cell of meta-material that exhibits negative permittivity as well. as negative permeability, and hence referred as double negative materials. In this work, various parameters like vswr, gain, return loss are acheived with improved performance. These meta-material are not usually found in nature, these are man-made structures that possess sub-wavelength dimensions.

In this work, much improved performance in terms of gain is achieved by using unit cell. Other several radiation characteristics can also be improved by using meta-surface of 3X3 or 7X7 rectangular unit cells. This meta-surface can be any form of structures that are generally designed by meeting requirements of the proposed antenna.

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