 ISSN: 2454-4248
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A Novel Multi-Band Patch Antenna on Metamaterial Substrate for Ku band applications

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Abstract— In this paper, a metamaterial based compact multiband microstrip antenna is proposed which can give high gain and directivity. Metamaterial are periodic structures and have been intensively investigated due to the particular features such as ultra-refraction phenomenon and negative permittivity and/or permeability. A metamaterial based microstrip patch antenna with enhanced characteristics and multi band operation will be investigated in this work. The multiple frequency operation will be achieved by varying the capacitance of the metamaterial structure with the help of metallic loadings placed in each metamaterial unit cells. The potential impacts will be miniaturization, reduced cost and reduced power consumption since multiple antennas operating at different frequencies are replaced by a single antenna which can operate at multiple frequencies. The proposed microstrip patch antenna will have its frequencies of operation in the Ku band. The proposed structure is simulated using HFSS.

Keywords- *Bandwidth, Metamaterial, Microstrip patch, permittivity, directivity and gain component;*

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I Introduction

Wireless applications different antennas are required for different applications [1]. This increases the size of the wireless communication. Also high gain and high bandwidth is needed in any communication systems. To achieve all these features simultaneously in a single device, the concept of metamaterial are used along with microstrip antenna (MSA) [2]-[3].During the past ten years great interest in the research of metamaterial has been observed. Metamaterial are artificially invented materials that show the properties which are not detected in naturally occurring materials. Metamaterial exhibits negative permittivity and/ or negative permeability. Metamaterial is a combination of “meta” and “material”,meta is a Greek word which means something beyond, altered, changed or something advance [4]. Metamaterial or left handed materials (LHM) are manmade artificial materials, whose permeability and permittivity are simultaneously negative. The negative refraction has been proven by [5], and the backward wave propagation has been verified by [6].After Veselago, Pendry proposed that long metallic wire lattices had effectively negative permittivity and split ring resonator had effectively negative permeability in specified frequency band and later Smith made the first experimental realization of left handed material [7]. The Metamaterial or left handed material is a combination of thin wires and split ring resonators (SRR). Many new structures have been proposed for LHM such as Omega shape, spiralmulti split, fishnet and S-shape they exhibit the properties of a LHM [8-10]. In the recent years, for microwave applications Metamaterial have been studied. To improve the performance of antenna in the microwave range of frequencies several works have been aimed.

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II.BASIC MICROSTRIP PATCH ANTENNA

The potential target of our research is an antenna suitable for satellite communication applications, thus we have selected as operating frequency band the Ku-band. More specifically the conventional patch antenna that will be used to evaluate the proposed metamaterial-inspired patch antenna was decided to operate at 14 GHz. The evaluation process will be based on the comparison of the characteristics and the performance metrics between the conventional (reference) and the metamaterial antenna. The conventional antenna should have a simple design for easy simulation and implementation. For this reason, a simple rectangular patch antenna has been adopted to be the reference conventional patch antenna design. This antenna has been modeled using an HFSS simulation software package. A microstrip patch antenna is one of the most commonly utilized printed antennas. It consists of a radiating patch on one side of a dielectric substrate and a ground plane on the other side. An MSA can be of any shape, but rectangular shape MSA is most commonly used. Microstrip patch antenna, in their most basic form, benefits from their low profile, low cost, simplicity, and omnidirectional radiation pattern. The detailed design specifications and performance characteristics of the conventional patch antenna are given bellow:

A rectangular patch is used with size 3.3mm X 4.34mm long, fed by a microstrip line this penetrates inside the patch via a notch in order to achieve the proper matching (Figure1). The substrate is FR4, 0.34 mm thick dielectric plate with ε_r equal to 4.4 and operated with operating frequency is 21 GHz.

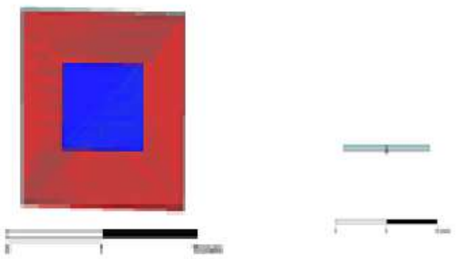


Figure1. conventional microstrip patch antenna

Dimensional view of conventional microstrip patch antenna as shown in Figure1 and simulated results of microstrip patch antenna without metamaterial as shown in Figure 2.

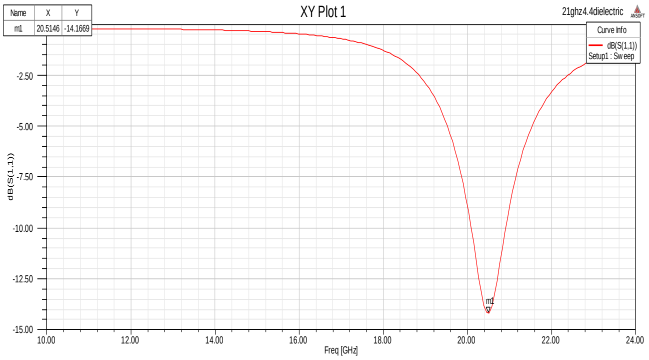


Figure2.Simulation of Return Loss S11 of Microstrip Patch Antenna without Metamaterial.

The disadvantages of Microstrip Patch Antenna are:-

- Limited bandwidth (usually 1 to 5%).
- Low gain.
- Low power handling.

To overcome this drawback metamaterial plays an important role.

III.PROPOSED METAMATERIAL PATCH ANTENNA

Metamaterials are artificial materials synthesized by embedding specific inclusions in host. The idea of metamaterial was first proposed theoretically by Veselago in 1968[11]. The negative permittivity was demonstrated and theorized with an array of metallic wires in 1996 by Pendry[2]. The structure had plasma frequency and thereby negative permittivity in the microwave regime. The structure of negative permeability was demonstrated and theorized in 1999 with split ring resonator (SRR) structure. The negative index of refraction existed in the region where both the real parts of the electric permittivity and magnetic permeability were simultaneously negative, typically in a structure composed of SRRs and metallic wires.

Metamaterials[12-15] exhibit exceptional properties not readily observed in nature. The inclusion of metamaterial in the design improves the characteristics of a microstrip patch antenna due to these exceptional properties. The first results of emission in metamaterial demonstrated, under proper conditions the energy radiated by a source embedded in a slab of metamaterial, concentrated in a narrow cone in the surrounding media. Metamaterial and its utilization for antenna's techniques[16-21] were identified such as improvement of bandwidth, gain miniaturization, directivity and reduction of mutual coupling between elements in an antenna array. Enhanced bandwidth, high gain and high directivity were achieved using a metamaterial layer either as substrate or superstrate.

IV.METAMATERIAL SSR STRUCTURE

The split ring resonator (SRR) structure as shown in Figure3 is the metamaterial substrate used as a superstrate on the microstrip patch for tuning. The outer ring of the structure measures 1.1 mm in length as well as the width. Similarly, the inner ring measures 1mm in length and width. Each microstrip patch has three SSR structure placed on it and then the antenna is simulated. The loadings placed in the SRR structure are small square measuring 0.12 mm each which helps in tuning. In conventional microstrip patch antenna, to achieve multiband operation different antennas are required.

In proposed metamaterial based multiband MSA, even a single patch out of the four patches in can be used. The design of Metamaterial Based Microstrip Antennas is done in three parts: first the conventional MSA is simulated and the reconfigurability is tested, then the antenna is tested with metamaterial superstrate to have increase gain and bandwidth then the individual patches with metamaterial are simulated to test the multiband operation.

The proposed design of multiband microstrip patch antenna covers Ku band in electromagnetic spectrum. To increase the gain and bandwidth, metamaterial is added to the antenna. The base patch of microstrip antenna includes main radiator and four sub-patches placed on FR-4 substrate with relative permittivity =4.4 and height of a substrate *h* =0.35mm. The metamaterial substrate is placed on top of this patch leaving an air gap of 0.1mm. Software used for simulation of antenna design is HFSS. It supports Momentum as well as FEM mode of simulation. As already stated, single slotted patch is sufficient enough for the multiband operation. Further (using patch 2) simulation shown only with one MSA is shown in Figure3.

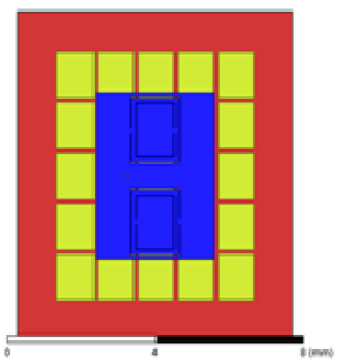


Figure3. Proposed metamaterial SSR structure.

V.RESULTS

The results of the proposed metamaterial SSR structure simulation return loss results are shown in the Figure 4. This figure shows proposed antenna resonate at multiband frequencies are12.12Ghz with -12.64dB,14.23Ghz with -18.38dB and 15.10Ghz with -19.58dB.

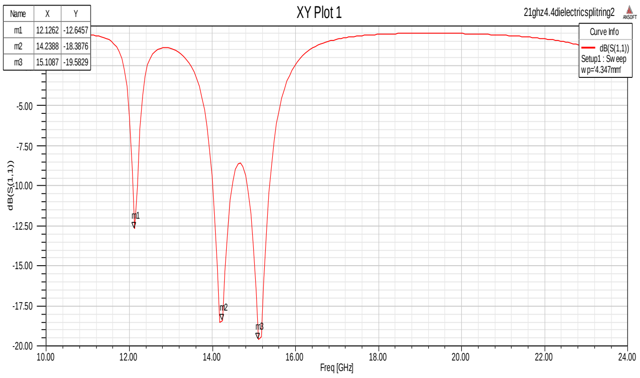


Figure4. Return loss of proposed metamaterial SSR structure

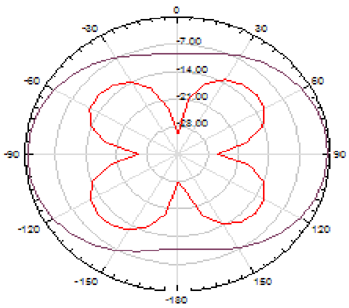
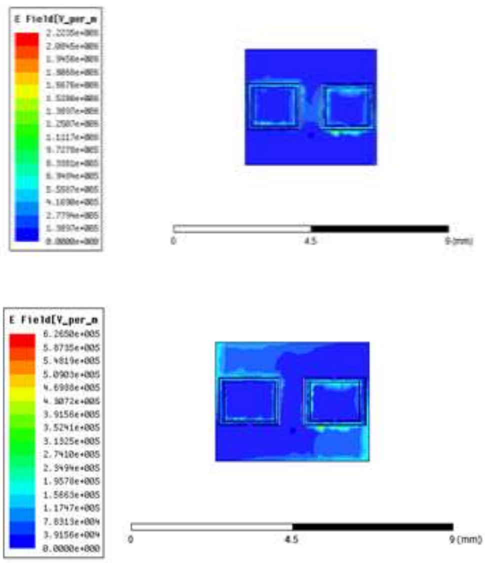
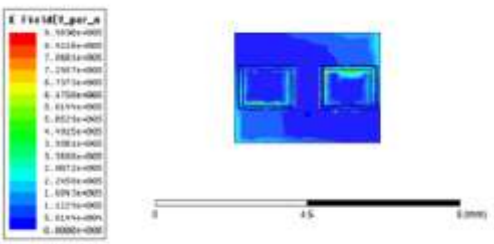


Figure5. Radiation pattern of proposed metamaterial SSR structure.

The E-field current distribution of metamaterial SSR structure microstrip patch antenna for different frequency bands if shown Figure6.



a).E-Field current distribution at 12.12Ghz b).E-Field current distribution at 14.23Ghz



c).E-Field current distribution at 15.10Ghz

Figure6. E-Field current distribution of proposed metamaterial SSR structure at multiband frequencies.

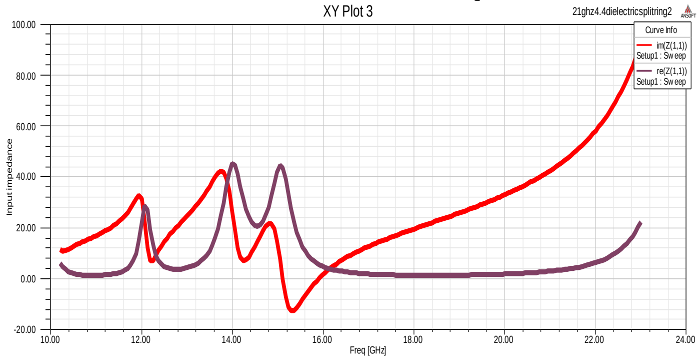


Figure7. Input impedance of proposed metamaterial SSR structure.

VI.Conclusion:-

The design suggested for a multiband metamaterial microstrip patch antenna for satellite communication systems. The proposed microstrip antenna patch antenna with metamaterial gives a multiband operation, covering the frequency range of Ku band as compared to conventional microstrip patch antenna. By analyzing the simulation result, it is found that the directivity is also increased. Further the size of antenna is also reduced. Such a compact multiband microstrip antenna can be used for all the wireless applications thus saving space and cost.

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