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Microstrip Patch Antenna Using Metamaterial-based RIS-Structures

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ABSTRACT
The paper presents the design of a microstrip patch antenna using metamaterial with reactive impedance surface (RIS) structures. Microstrip patch antenna has been prime in wireless communication and the requirement for wide bandwidth has always been a need in it. Using the metamaterial-based structure with RIS, the patch can achieve more VSWR bandwidth. The antenna features a single one-layer low-cost substrate fire retardant type-4 glass epoxy ($\epsilon = 4.3$). The edge fed rectangular patch consists of a shifted transmission line feed and the bottom consisting of the RIS structure with a 7×6 array of 6mm*8mm patches with an alternative spacing of 0.7mm and 1mm in between. RIS structure reduces coupling between the ground plane and patch which results in extended bandwidth. The antenna provides a wide bandwidth of VSWR<3 from 1.8GHz to 5.9GHz which covers both the 2.4GHz and 5GHz WI-FI band with a peak gain of 5.4dBi. The antenna designed was simulated, fabricated and tested.

Keywords-Fr4-Epoxy, Metamaterial, Microstrip Patch, Reactive impedance surface, WLAN.

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I. INTRODUCTION

Microstrip patch antennas are widely used in wireless communication for both voice and data communication. The advantage of size, weight, and cost makes it more corporate but as like every other antenna it also comes with some limitations i.e. wide bandwidth, low gain, and efficiency. The paper presents work done for overcoming these limitations. MSA has resonant nature which limits its impedance bandwidth [1-3].

A metamaterial is one of a material which was engineered in labs, with better electromagnetic mechanical traits such that is not available in nature. Using the new frontier modern aid of designing using computer-aided-engineering (CAE) it has given RF a new building block. Designing microwave passive components using the metamaterial structures has enabled a wide range of application such as miniaturization, extending bandwidth as presented in this paper herein. An antenna designed for Bluetooth, WiMAX, WCDMA operating from 1920 to 2170 MHz widely uses metamaterial structures for its characteristics [4,5].

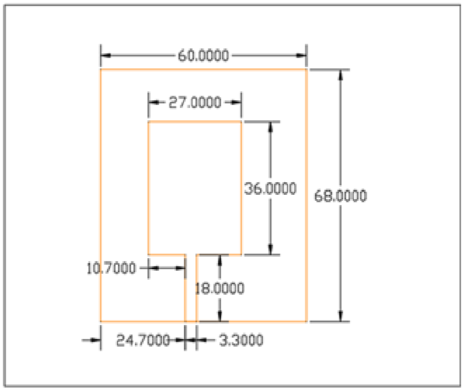
Improving the performance of the passive component novel metamaterial structures like reactive impedance surface (RIS), split ring resonators (SRRs), partial reflective surface (PRS) and electromagnetic bandgap (EBG) have been developed in recent years [6,10]. For extending bandwidth and maintain good radiation gain over the operating range, RIS structures are preferred [11,12].

RIS structure consists of simple pattern distribution of patches resulting in improvement of impedance bandwidth. For miniaturizing, composite-split-ring-resonator (CSRR) structures are designed on the patch along with substrate and ground plane [13]. For circular polarization, the chiral patterned metamaterial structure was proposed [14]. This method works so effectively for the patch and also keeps up the overall radiation performance.

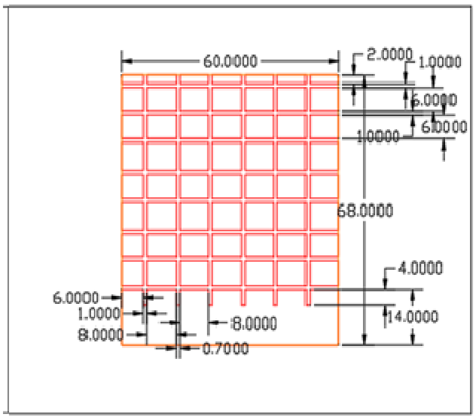
In this paper, a metamaterial inspired single layer patch antenna with RIS surface is designed and fabricated. The antenna configuration in the ground is done by etching strip gaps to construct small periodic metallic patches, forming a RIS structure. The antenna patch on top has a shifted transmission line to excite it with the input port. The antenna designed is detailed in the following sections consisting of antenna geometry, its simulation and results using High-Frequency Structure Simulator (HFSS) software and fabricated antenna with test results and working of it using a WIFI radio.

II. ANTENNA GEOMETRY

Numerous designs of patch antenna are constructed over the years to enhance the performance. The paper presents work done on the patch antenna in enhancing the performance by keeping the size compact and cost low. The prime aim of the design was to widen the bandwidth while keeping the radiation performance satisfying.



(a) Top View



(b) Bottom View

Fig. 1 Antenna Geometry

Figure 1 and 2 shows the geometry of the metamaterial-based patch antenna. The antenna is proposed with compact size and using low-cost substrate Fr4 Epoxy. As shown in the figure the dimensions of the patch are miniaturized to 60mm×68mm. The transmission line to the patch is kept shifted in the top side. The feed line is kept shifted as it generating more resonance area on one side, resulting in wider VSWR bandwidth. Shifting the line towards left or right does not matter, as it is all about creating a larger area on either of the side.

The Bottom side shows periodic patch structure of 6mm×8mm separated by strip lines of 1mm and 0.7mm respectively. The array of patches structured in this pattern creates reactive impedance on the surface. Thus, VSWR bandwidth increase as reactive impedance does. The small patches and the gap in between create capacitance, while the substrate permittivity and thickness create inductance. Depending upon the configuration and its combination resonant frequency can be generated.

III. FABRICATION AND MEASUREMENTS

The patch antenna was simulated in HFSS software to analyze the EM fields on the structure and was fabricated on Fr4 Epoxy sheet of relative dielectric constant, $\epsilon r \approx 4.3$ as shown in figure 2.

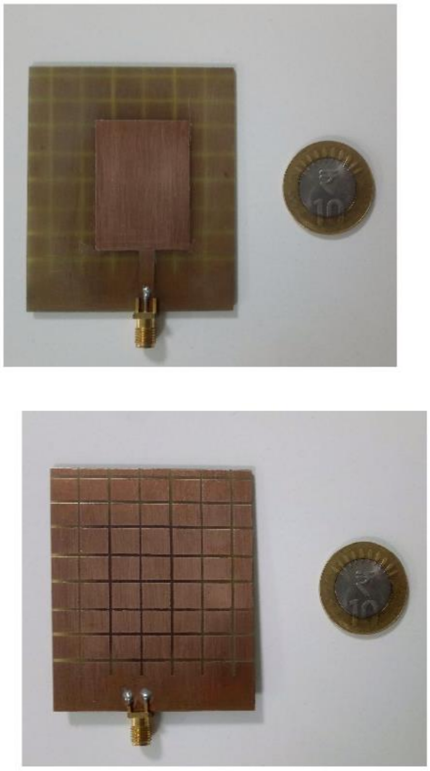


Fig. 2 Fabricated Antenna

The antenna results in extended bandwidth if the resonant frequency of the ground RIS structure is kept higher than that of the patch. Due to this, the magnetic energy gets stored in the ground surface which recoups for the electrical energy. This produces extra resonances in lower frequencies which results in an increase in bandwidth. The VSWR bandwidth of the proposed antenna was compared with the original fabricated antenna as shown in figure 3.

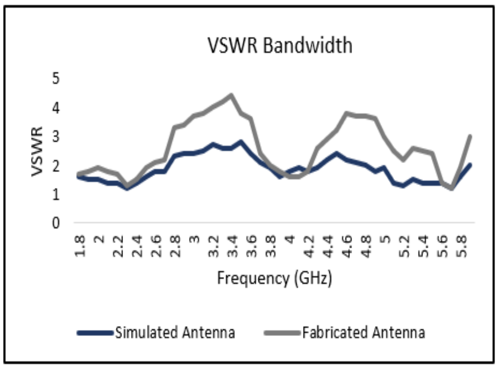


Fig. 3 The plot shows the VSWR of the simulated and fabricated antenna

The antenna's reflection coefficient S11 parameter was measured using Keysight FieldFox RF Analyzer N9913A as shown in figure 4.

Fig. 4 S_{11} Parameter measurement

The gain of the antenna over the VSWR bandwidth ranging above 1.3dBi, with a peak gain of 5.4dBi at 5.25GHz as shown in figure 5.

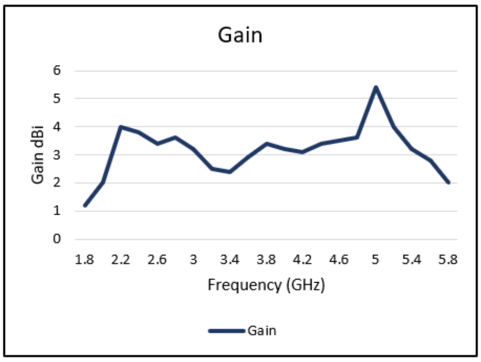


Fig. 5 Gain of the antenna

IV. CONCLUSION

The microstrip patch antenna using metamaterial based RIS structure is designed. This setup improves the bandwidth of the antenna. The antenna results in the VSWR bandwidth from 1.8GHz - 5.9GHz in simulation, while when fabricated and measured it resulted in a triple band; 1.8GHz -2.6GHz, 3.7GHz - 4.4GHz, 5.1GHz - 5.9GHz. The antenna offers a peak gain of 5.4dBi and ranging above 1.3dBi over the band. The proposed antenna can be used in many wireless communication applications

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