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A Metamaterial Microstrip Patch Antenna WithL-Shaped Uniform Impedance Resonators for Wireless Application

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Abstract: *In this paper, ametamaterial microstrip patch antenna is put forwarded. The compressed antenna is suitable for the IEEE 802.16 authorized standard band. The High frequency structure simulator is used for simulating this antenna. The simulated result showed that it resonated at the frequency of 2.4GHz, which is widely known as Mobile Wi-Fi application. It had a good return loss of >-20dB, and an optimal gain. The VSWR obtained in the order of< 2.The total dimension of this antenna is (10×10×1.6)mm^3 and so that the fractional bandwidth attained is about 27%.These features makes the microstrip patch antenna desirable for the IEEE802.16 application. Here the proposed antenna achieved the metamaterial effect at the resonated frequency, which helped in size reduction and enhanced properties of the antenna.*
Index Terms: *Microstrip , resonator, microstrip feed, bandwidth, resonant frequency.*

I. Introduction

THE rapid development of technology in wireless communication makes it important to have the microwave components in miniature size for various practical mobile applications. By the evolution of lightweight, low profile, flush-mounted and single-feed antennas, the wireless communication gets swiftly increased. Also, there is an possibility of integrating multiple RF modules of various frequencies into single piece of an equipment.In the antenna area there is an burgeoning developments toward electromagnetic (EM)metamaterials which have intrigued a great impetus and a renewed interest [1-7]. Because of low profile, light weight,easy fabrication, low cost and compatibility with the integrated circuittechnology in practice, the microstrip patch antenna has been prefferd choice. Thus the circularlypolarized (CP) microstrip antenna satisfies the above mentioned properties in which it posses additional advantagesof imposing less strict restrictions on orientation of the transmitterand receiver and mitigative multi path effects. A survey of recentliterature indicates that the CP antennas were used for bandwidth enhancement by using left handed (LH) metamaterialtransmission line (TL) [8] and reactive impedance substrates [9],respectively, CP antennas with gain and directivity enhancement [10-13], omnidirectional radiations [14-16] and even dual-band or multi-frequency operation with radiation pattern selectivity and polarization diversity [16-20].Among them, the multiband antennas [16-20] with one or moreCP bands have generated much attention Becauseof the multifunctional systems which exhibit the benefits of high stability, reliability and integrity, the multiband antennae with one or more CP bands has been generated great interest. some of these antennae were cramped to mushroom structure due to the provision of shorted LH stub inductor through drilling viaholes, in spite of small layout at the lowest resonant mode and decent CP radiation performances with good axial ratios [16-19]. In this case, large currents have been concentrated around the vias which are lossy conductors, provoking desirable losses in thestructure. Consistently, by some order of percentages, the antenna's gain and radiation efficiency gets debased.

The microstrip patch antenna was analysedby using the HFSS simulator Which works on the principle of Finite Element Method. Due to the affordable cost, small size, good efficiency, the designed antenna is suitable for the mobile applications.

II. Descriptions And Design Procedures Of The Antenna Design

A. Microstrip Patch Antenna

A Micro strip patch antenna consists dielectric substrate, the ground plane and the thin square patch which resides in between the substrate and ground plane. The rectangular patch antenna has been the elementary patch antenna layout. The conducting material used for designing the patch is copper or gold. On dielectric substrate, the radiating patch and feed line have been conventionally photo engraved. The radiating patch is cropped at its edges to form aS-shaped patch on the top side of the substrate, which comprises of two L-shape resonators on either side of the patch. figure1 shows the above described antenna.

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B. Design Formulae

The dimension such as length and width of the patch is L=W=10mm.Figure 1 shows the sides on the top, left and right of the patch is etched in such a way that it forms a S-shaped patch.

The feedline used here is the microstrip feed structure. The microstrip fed patch antenna comprises of two L shaped resonators [12], which is of uniform in size at the either sides of the patch. The sides of the square patch is deliberated by using the formula given below,

$$L= (c/(2f_r\sqrt{\varepsilon_{eff}})-2\Delta L \qquad (1)$$

where c = free space velocity ,
f_r = resonant frequency,
ε_{eff}= effective dielectric constant.

The height of the substrate is chosen as 0.8mm. Since due to small size of the height of the substrate, the surface waves are avoided[8]. There is not much loss in the radiation, since due to the absence of surface waves.

C. Structure of the Proposed Antenna

The proposed s- patch antenna is designed using the cheap, easily available and widely used substrate Flame Retardant4 (FR-4). It has the dielectric constant (ε_r) of 4.4. The desirable substrates for the efficient antenna performance are the lower end range substrates, with greater thickness. But all these will constitute a larger element size. By considering the factors like compact element size, and increased performance of the antenna, FR4 substrate is choosed, since it possess the intermediate substrate dielectric constant value 4.4 ($2.2\leq \boldsymbol{\varepsilon_r = 4.4}\leq 12$).

Figure 1 shows the structure of the put forwaded s-patch antenna.The structure consist of two L-shaped resonators with equal length and width on both sides. The length of the resonator is taken as 3.5mm and the width to be 1.2mm. The height of the feedline ΔL was taken as 4.5mm and the feedlline width has been deliberated as 1mm.

The structure was simulated using a finite ground below the patch. At the height of -0.8mm it has been positioned, that is at the bottom side of the substrate. The grey part in the above mentioned figure constitute the ground plane.

III. Simulated Results And Discussions.

D. Return loss

Measurement of energy returned in the transmission line has been mentioned as return loss. Hence it has been observed that the simulated S_{11} (dB) characteristics -30 dB.Figure 2 shows the simulated result. It was found that it resonated at the frequency of 2.4GHz. this made the designed s-shaped antenna suitable for wi-fi application. Recently there is a wide concentration of designing RF antennas in a miniaturized size , which will be compatible for wireless mobile applications.

Keeping this consideration as a main theme, this antenna was proposed using the special concept of miniaturization technique, called the Metamaterial concept. This gives arises to new functionalities and properties in the structure. Negative refraction is the core concept of metamaterial. Achieving this feature from a normal substrate is a new feature and property of that material used. This helps in achieving new functionalities like negative permeability and negative permittivity values in a conductor.

E. Analysis of the proposed antenna

HFSS is a high-performance full-wave electromagnetic (EM) field simulator For arbitrary 3D volumetric passive devicemodelling, HFSS has been recognised as a high-performance full-wave electromagnetic (EM) field simulator which has the advantage of the familiar Microsoft Windows graphical user interface. It integrates Simulation,visualization, solid modelling, and automation in an easy-to-learn environment has been integrated in which the solutions to your 3D EM problems were swiftly and accurately procured.

Ansoft HFSS works on the principle of Finite Element Method (FEM), adaptive meshing, andbrilliant graphics which propounded unparalleled performance and insight to all of your 3D EM problems.The parameters such as S-Parameters, Resonant Frequency, and Fields have been deliberated by using this simulator.

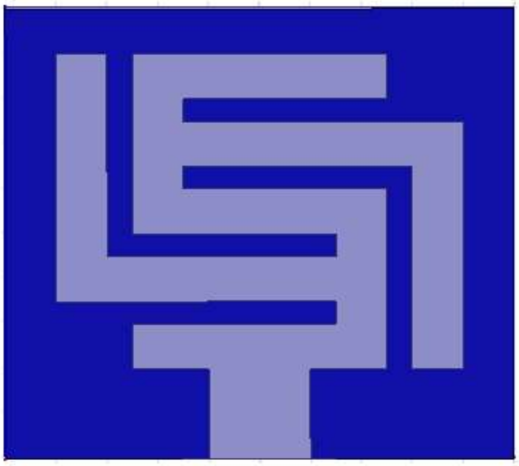


Fig. 1. Structure of the proposed S-shaped microstrip patch antenna.

Figure 1 shows the simulated structure. Figure 3 shows the 3D radiation pattern of the simulated antenna. The resonant frequency of the antenna should be selected properly. The high data rate wireless networking systems for future wireless communications are Wifi .

Hence in the suitable frequency range, this antenna should operate. The resonant frequency of the put forwadedantenna is 2.4 GHz, which will be used by systems for future wireless mobile communications, Wi-fi, and Bluetooth.

The fractional bandwidth of the put forwaded antenna has been deliberated as 13%. The guided wavelength of the antenna isfound to be 73.78mm is achieved from the simulated band of 2.4GHz.

Figure 6 shows the VSWR of the put forwadedantenna. It is evident from the result that the VSWR obtained was approximately 1.06, which is less than 2, at the resonant frequency.

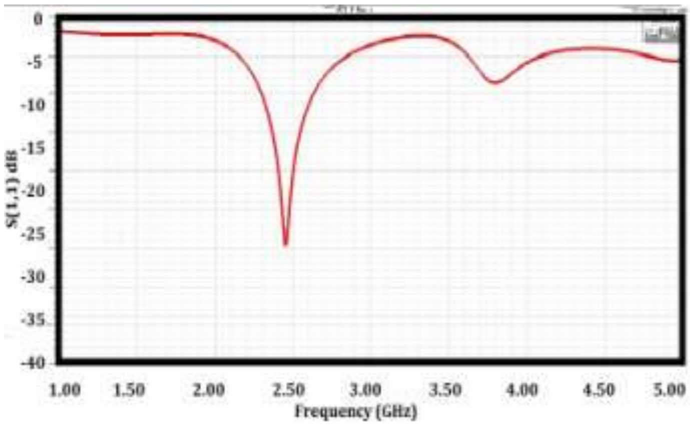


Fig. 2. Simulated result of the proposed microstrip patch antenna, simulated using HFSS simulator. It shows that it achieved a RL = -30dB.

The current distribution of the put forwaded antenna is obtained by accounting the optimal design parameter values at frequency 2.4 GHz. It is seen that the maximum radiation is possible at the corresponding frequency owing to the currentdistribution all over the edge and at the centre portion of the patch.The microstrip patch proposed was exited with the full port impedance of 50Ω. The bottom plane is the ground plane for a microstrip transmission line.

Here a microstrip transmission line has been used for the design of the antenna. It was etched to form complementary split ring resonators (CSRR's) .These rings encourages the metamaterial effect to be produced in the structure. The bottom plane with CSRR's is shown in figure 4.

Figure 5 shows the gain of the antenna. The maximum far-field occurs at θ=90,and φ=0. It is plotted in the figure 8 & 9. The VSWR, voltage standing wave ratio, is an optimal factor in deciding the performance of the antenna.

The VSWR of the proposed microstrip antenna has been found as 1.06, which is < 2. Hence this serves as an optimum condition in deciding the performance of the antenna. It is plotted in figure 6. The directivity of an antenna is an important factor, which decides the radiation at a particular direction. It is plotted in the figure 7.

The antenna designed was considered to be very small when compared with the normal size of the antenna for the resonant frequency f_c = 2.4GHz. A size reduction of 53.8% was achieved in the designed microstrip patch antenna. The electrical length of the antenna has been deliberated as ($0.135\lambda_g \times 0.135\lambda_g$). The E-field pattern and the H-field pattern are shown in figures 8 and 9, respectively.0.472565W was the deliberated radiated power of this antenna. The antenna which is proposed was given an input power of 1W, and the power accepted was 0.535096W. The radiation efficiency of the MSP antenna at the resonant frequency has been calculated as 88%. The peak directivity value was obtained as 0.035.The impedance value on the ring is calculated from the above formula is said to be 0.578Ωs.

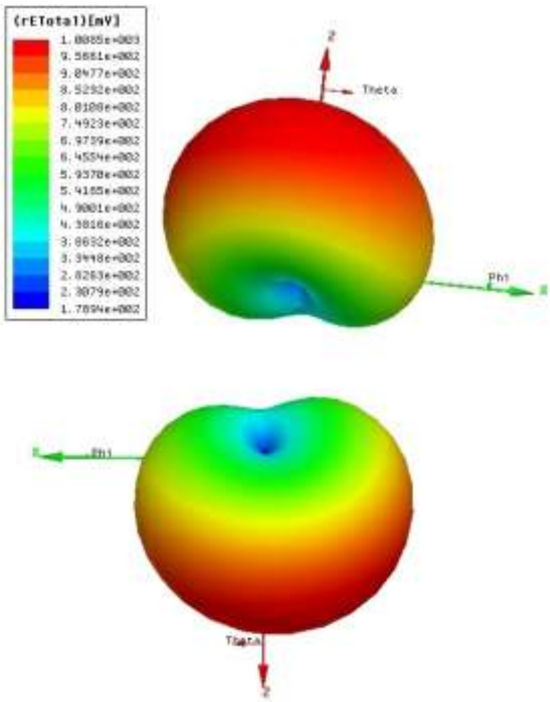


Fig. 3. 3Dpolar plot of the proposed microstrip patch antenna.

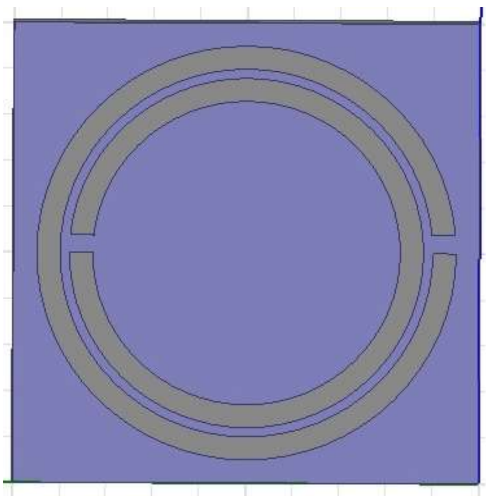


Fig. 4.Bottom Plane of the proposed microstrip patch antenna, which is loaded with CSRR's.

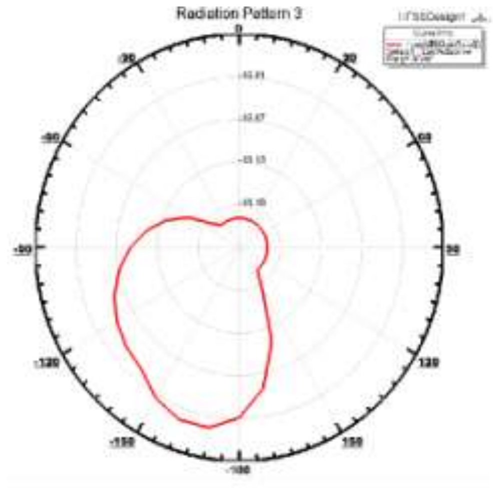


Fig 5. Gain plot using HFSS

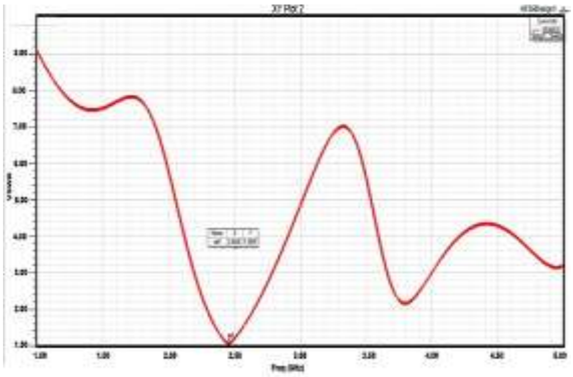


Fig. 6.VSWR measurement plot of the proposed microstrip patchantenna

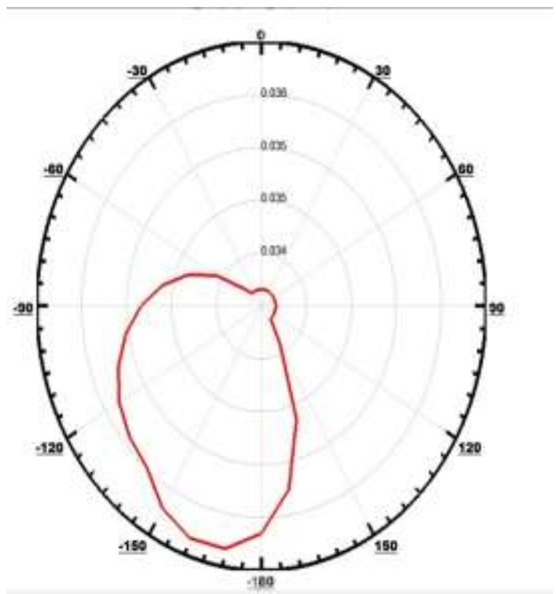


Fig 7.Directivity plot of the proposed antenna.

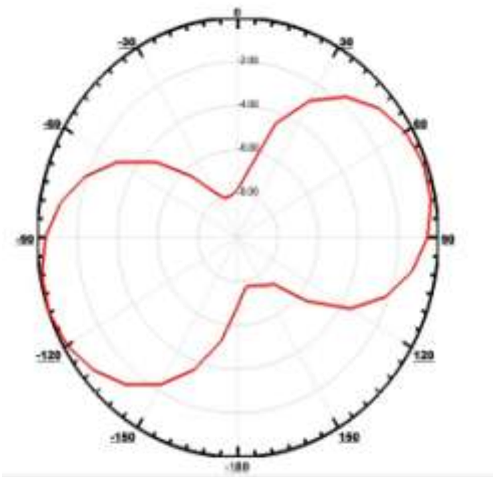


Fig. 8.E-Field polar plot of the proposed microstrip patch antenna.

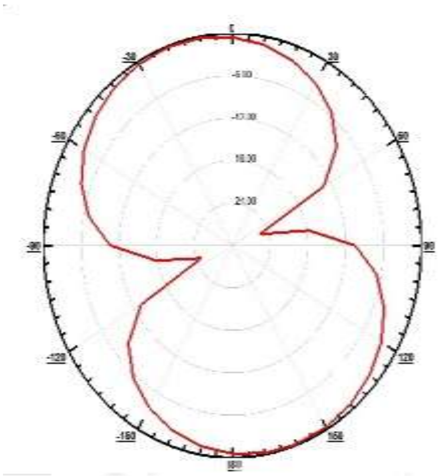


Fig.9. H-field polar plot of the proposed microstrip patch antenna.

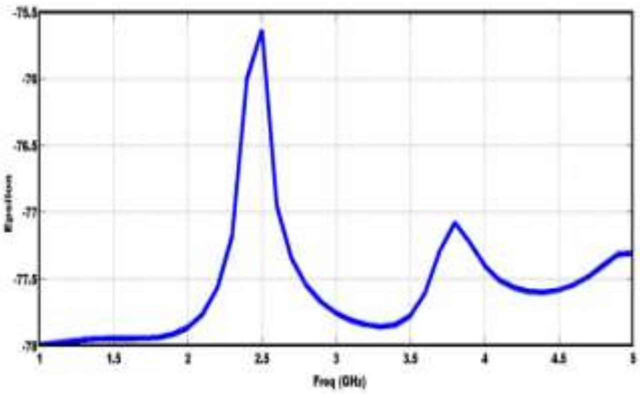
The miniaturization in this paper is achieved by using the metamaterial concept. The metamaterial is a concept where negative media with either negative values of permittivity or permeability or both is achieved in a substrate. Here the proposed structure is analyzed for the negative values. The negative effects is achieved using a pair of CSRR's in the ground plane of the microstrip line[18-20].

The value of refractive index for the negative media is determined to be -1, which represents the negative media. The negative epsilon and negative mu(permittivity and permeability ,respectively) values are determined to be -1.73 and -0.578, respectively.

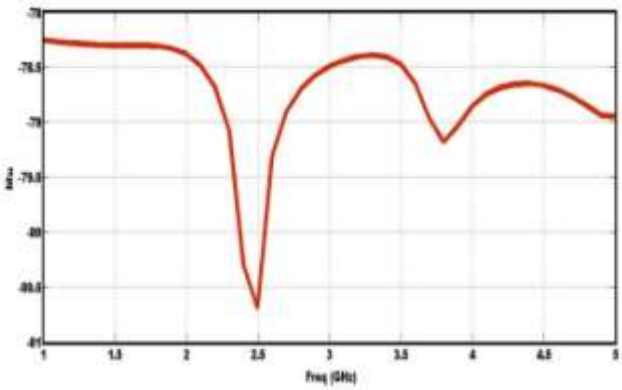
From the determined values it is observed that both the permittivity and permeability achieves the negative property of the corresponding material.

To still more elaborate the evidence for achieving the metamaterial effect in the put forwaded antenna, the S-matrix values were derived and the parametric analysis was done using MATLAB. The results were plotted in figure 10.

From the results it is evident that the permittivity and permeability values are achieved at the simulated band. The results discussed here stands as a proof that the proposed microstrip antenna has achieved the metamaterial effect.



(a)



(b)

Fig.10. Metamaterial Effect of the proposed microstrip patch antenna, (a) negative permittivity, (b) negative permeability at the desired frequency of operation.

IV. Conclusion

A microstrip s-shaped patch with two L-shaped resonators on either sides of the patch is put forwaded in this paper. It was analyzed that the designed patch antenna had a good performance.The fractional bandwidth (FBW) and the guided wavelength of the transmission line from the simulated result has been observed as 13% and 73.78mm. At the resonant frequency 2.4GHz,The VSWR of the antenna is achieved < 2 which is an optimum condition for a good antenna. The electrical size of the structure put forwarded was found to be ($0.135\lambda_g\times 0.135\lambda_g$). The maximum size reduction of the put forwaded antenna was achieved as 53.8% , for the resonant frequency. The put forwaded antenna had an overall size of (10*10*1.6)mm^3 and was simulated using the FEM based HFSS simulator. Hence, from the simulated result, it is evident that the put forwaded microstrip patch antenna is suitable for the wireless mobile application which has the wireless standard of IEEE 802.16, Wi-fiand Bluetooth application.

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