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Metamaterial Inspired Dual Band Antenna

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Abstract- In this paper, a dual-band microstrip patch antenna is designed and analyzed using metamaterial. The proposed antenna is tuned to work at two resonating frequencies in the frequency range from 1GHz to 5GHz. The antenna characteristics are studied before and after inclusion of metamaterial .we have also introduced Nicolson Ross-Weir method (NRW) method to achieve effectively the double- negative properties of the proposed metamaterial structure. The proposed rectangular microstrip patch antenna operates at the resonant frequency of 3.7GHz with a return loss of -37.24 dB.In addition to rectangular microstrip patch's fundamental resonance; the additional resonance is obtained at 3.45GHz with a return loss of -36.4dB. To satisfy the demand of commonly used wireless communication systems, the metamaterial structure with microstrip patch antenna is designed with enhanced characteristics and exhibits dual bands. Hence the proposed antenna shows good results and can be effectively utilized for WLAN and RF-ID applications and mobile communication.

Keywords: *Metamaterial, SSRR, Microstrip patch antenna, Negative Refractive Index, Finite Element Method*.

I. INTRODUCTION

A microstrip antenna is one of the most commonly utilized printed antennas. The antennas are the basic elements of any communication wireless system; their roles are to transmit or receive electromagnetic waves. The microstrip antennas have many advantages low cost, compact, easy to manufacture, and can have a miniaturized structure. Tremendous research is being carried out in the field of antennas in order to design compact, smart, and low cost and multi-band antennas to cater the needs of rapidly expanding the wireless industry. Metamaterials have emerged out as a promising solution. Metamaterial inspired antenna consists of a unit cell or a few metamaterial unit cells for performance enhancement of antenna was studied by Si et al. [1].

Metamaterials are artificial materials exhibit the properties of either negative permittivity or permeability. If both negative permittivity and negative permeability happen at the same time, then the composite exhibits an effective negative index of refraction. The metamaterial was first proposed theoretically by Veselago in 1968 [2]. The inclusion of metamaterial in the design improves the characteristics of a microstrip patch antenna due to these exceptional properties. Metamaterials and its utilization for antenna's techniques were identified [3], [4], and [5]. We proposed a microstrip patch design antenna using metamaterial to obtain dual bands. The square split ring resonator and rectangular microstrip patch antenna are designed using the FR-4 substrate with dielectric constant 4.5. The antenna characteristics are studied before and after inclusion of metamaterial, the rectangular microstrip patch antenna operates at the resonant frequency of 3.7GHz. After including SSRR with two rings at an appropriate place, the proposed SSRR antenna induces a new resonant frequency of 3.45GHz. The proposed metamaterial structure exhibits both negative permittivity (ε_r), negative permeability (μ_r) which indicates double negative characteristics of the metamaterial structure. Dual-band antennas have attracted much research attention in the field of wireless communication, radio frequency identifications, and microwave energy harvesting since they reduce the number of antennas and space usage [6]. This new proposed antenna design may find use in a variety of applications including in satellite communications and mobile communications systems.

II.DESIGN AND ANALYSIS OF MICROSTRIP PATCH ANTENNA WITH METAMATERIAL STRUCTURE

Microstrip patch antenna with proposed metamaterial structure is given in Fig.1.The microstrip patch antenna dimensions for the frequency of 3.7 GHz, length L = 14mm and width W = 20mm are determined. The SSRR inspired antenna is Placed on FR4 substrate with dielectric constant ε_r = 4.5 and a thickness of 1mm.

The dimension of the patch is 14× 20 mm^2. To excite the patch Inset feed is used and Inset cuts are made in the patch to match the antenna resistance antenna to the feed resistance. Where W_f and L_f are the Width and length of the feed line that can be seen in Figure 1. The length (L_s) of the external ring is 5mm and width (W_s) of the external ring is also 5mm The SSRR is placed near the patch antenna placed over FR4 substrate. Electromotive force is induced due to electromagnetic inductive coupling in the rings which results in current flow around the SSRR rings which produces an additional resonance due to the inclusion of SSRR.

Table 1. Depict the various dimensions of the proposed SSRR loaded microstrip patch antenna.

Table 1. Dimensions of the proposed microstrip patch antenna with SSRR loaded.

Parameter	Dimension (mm)
L	28
W	36
L_P	14
W_P	20
g	1
L_f	11
w_f	3
L_S	5
W_S	5

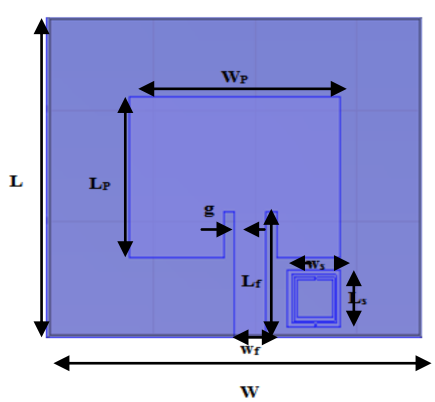

Fig 1: Microstrip patch antenna with metamaterial

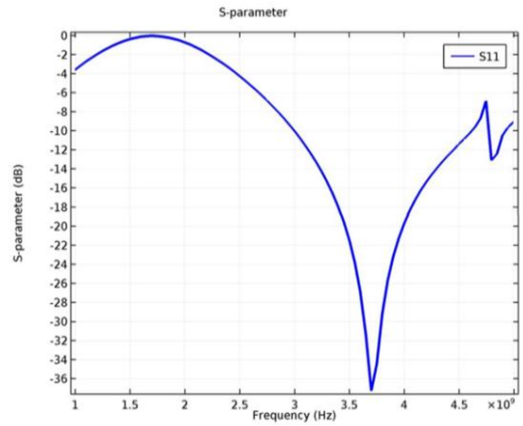

Fig.2: Return Loss *S*11 of Microstrip patch antenna without metamaterial

The design starts with conventional patch antenna and simulated results in a fundamental resonance frequency of 3.7 GHz with a return loss of -37.24 dB and simulated results of Return Loss S_{11} of Microstrip patch antenna Without Metamaterial as shown in Fig.2.The metamaterial cover incorporated with patch antenna is shown in Fig.3. The SSRR structure is placed in adjacent to the rectangular patch produce yield another frequency of 3.45 GHz. the SSRR loading not only enhances the basic resonance frequency 3.75 GHz with a return loss of -29.7 dB but also adds another resonance frequency at 3.45GHz with a return loss of -36.4dB as shown in Fig.4.

In this work, Nicolson-Ross-Weir (NRW) method has been used to obtain the value of permittivity, Permeability and refractive index. The effective metamaterial characteristics are extracted by the Nicolson-Ross-Weir (NRW) method and it is mathematically represented by the following equations [7].

$$\varepsilon_r = \frac{2}{jk_0 t}\frac{(1-(S_{11}+S_{21}))}{(1+(S_{11}+S_{21}))} \quad (1)$$

$$\mu_r = \frac{2}{jk_0 t}\frac{(1-(S_{21}-s_{11}))}{(1+(S_{21}-S_{11}))} \quad (2)$$

$$n = -\sqrt{\varepsilon_r \mu_r} \quad (3)$$

Where ε_r, the effective permittivity, μ_r, the effective permeability, and t = 1mm: The substrate thickness, and n refractive index, k_0 wave number. S_{11}: The reflection coefficient, S_{21} : The transmission coefficient. The scattering parameters S_{11} and S_{21} of the metamaterial are obtained by the following equations [8]

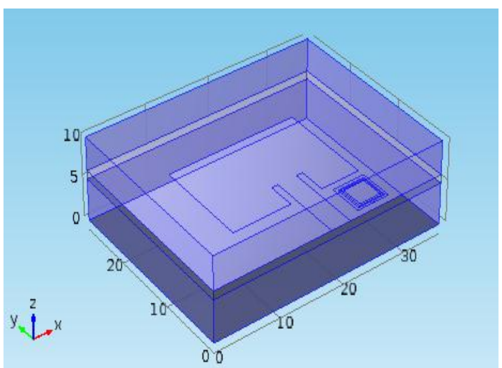

Fig 3: Microstrip patch antenna Incorporated with metamaterial.

Where: S_{11}: The reflection coefficient at the input port 1.S_{21}: The transmission coefficient at the output port 2. Where, E_c is the computed electric field on the port consists of the excitation along with the reflected field, E_1 the electric fields on ports 1, E_2 the electric fields on ports 2. dA_1 and dA_2 are the cross-section of the port 1 and port 2.

The proposed metamaterial structure exhibits both negative permittivity (ε_r), negative permeability (μ_r) as shown in fig.5. and in fig .6. Which indicates double negative characteristics of the metamaterial structure. The refractive index of the proposed SSRR loaded antenna as shown in fig. 7

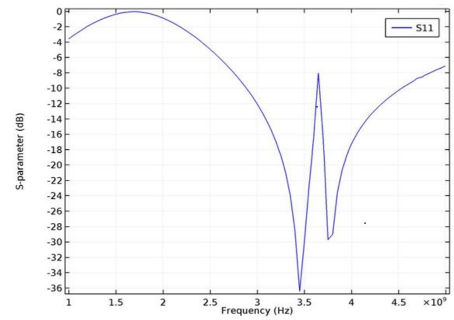

Fig 4: Return Loss S_{11} of Microstrip patch antenna with metamaterial

$$S_{11} = \frac{\int_{port1}((E_c - E_1).E_1^*).dA_1}{\int_{port1}(E_1.E_1^*).dA_1} \quad (4)$$

$$S_{21} = \frac{\int_{port2}(E_c.E_2^*).dA_2}{\int_{port2}(E_2.E_2^*).dA_2} \quad (5)$$

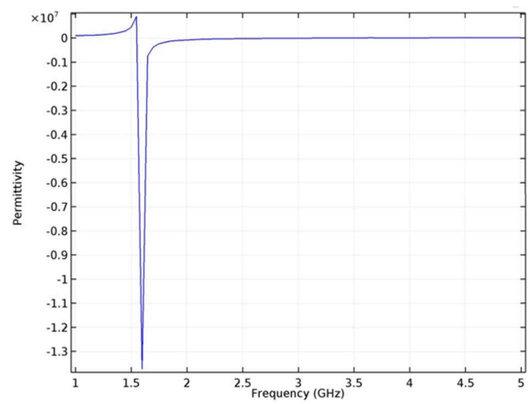

Fig.5: Negative Permittivity of the Proposed SSRR loaded antenna

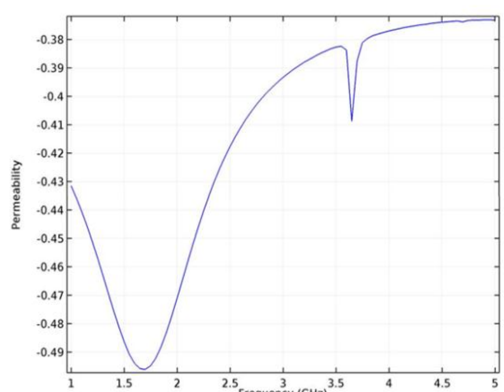

Fig.6: Negative Permeability of the Proposed SSRR loaded antenna

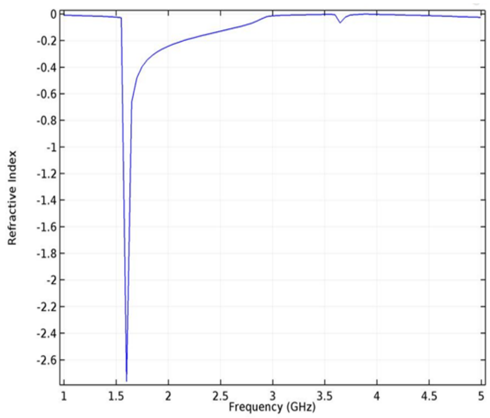

Fig.7: Refractive Index of the proposed SSRR loaded antenna.

Table 2. Shows the Simulated results of the proposed microstrip patch antenna with and without metamaterial structure.

Table 2. Simulated results of the proposed microstrip patch antenna with and Without metamaterial structure.

Proposed Antenna	Resonant Frequency (GHz)	Return Loss (dB)
Without metamaterial structure.	3.7	-37.24
With metamaterial structure.	3.45 3.75	-36.4 -29.7

III. RESULTS AND DISCUSSION

The performance of the proposed antenna is found by simulating the Metamaterial Inspired Dual Band Antenna with COMSOL Multiphysics 5.1 which is based on the finite element method (FEM).From Table 2. The simulated data exhibit dual bands with resonance frequency at 3.45GHz and 3.75GHz with −36.4 dB and -29.7dB respectively. The 3.75GHz resonance frequency is due to the rectangular inset fed microstrip antenna, whereas 3.45GHz resonance frequency is due to the coupling between the rectangular microstrip patch antenna and metamaterial. We have obtained the double negative characteristics as the permittivity, permeability is negative, and the refractive index is negative by Nicolson-Ross-Weir method (NRW) which ensures metamaterial characteristics.

In our proposed model the simulated results have a good agreement for the various wireless communication applications. This proposed antenna can be effectively utilized for WLAN and RF-ID applications and also it is a good aspirant for Wi-MAX and mobile communication.

IV. CONCLUSION

In the present work , as per the simulated data exhibit dual bands with resonance frequency at 3.45GHz and 3.75GHz with −36.4 dB and -29.7dB respectively. The 3.75GHz resonance frequency is due to the rectangular inset fed microstrip antenna, whereas 3.45GHz resonance frequency is due to the coupling between the rectangular microstrip patch antenna and metamaterial.. The effective double negative characteristics of the metamaterial structure are used to obtain a compact antenna. For current wireless communications, these frequency ranges are the best. Patch antennas based on metamaterials offer many benefits, miniaturization is very convenient to use in wireless networks. Hence, further research work can be carried out in a bigger scale and can be applied at various sectors.

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REFERENCES

[1]. Si, L.-M., H.-J. Sun, Y. Yuan, and X. Lv, “CPW- fed compact planar UWB antenna with Circular disc and spiral split ring resonators,” PIERS Proceedings, 502–505, Beijing, China, March 23–27, 2009.

[2]. V. G. Veselago, “The electrodynamics of substances with simultaneously negative values Of ε and μ,” Soy. Phys. Usp., 10,509–514, 1968.

[3]. V. I. Slyusar, “Metamaterials on Antenna Solutions,” in Proc. International Conference on

[4]. Antenna Theory and Techniques, 19-24, 6-9 Oct 2009.

[5]. .R. Ziolkowski, “Metamaterial-Based Antennas: Research and Developments,” IEICE Trans Electron, 89, 9, 1267-1275, Sep 2006.

[6]. .S. B. Jacob and U. P. Khot, “Frequency- Tunable Metamaterial for Microstrip Patch Antenna,” in proc. IEEE Conference on circuits, systems, communication and information technology application(CSCITA),2014,DOI:10.1109/CSCITA.2014.6839258, pp. 195- 200, 2014.

[7]. Si, L. M., W. Zhu, and H. J. Sun, “A compact, planar, and CPW-fed metamaterial-inspired dualband antenna,” IEEE Antennas Wireless Propagation. Letters, Vol. 12, 305–308, 2013.

[8]. Jayant G. Joshi, Shyam S. Pattnaik, Swapna Devi and Mohan R. Lohokare, Bandwidth Enhancement and Size Reduction of Microstrip Patch Antenna by Magnetoinductive Waveguide Loading, Wireless Engineering, and Technology, 2(2), 2011, 37-44.

[9]. Yang Liu, Yitung Chen, Jichun Li, Tzu-Chen Hung, Jianping Li, "Study of energy absorption on solar cell using metamaterials”, Solar Energy 86 (2012) 1586–1599.

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