Bandwidth Enhancement of Microstrip Patch Antenna by Using Metamaterial

https://doi.org/10.3991/ijim.v14i01.10618

Huthaifa A. Al Issa, Yahya S. H. Khraisat (✉), Fatima A. S. Alghazo
Al-Balqa Applied University, Irbid, Jordan
`Yahya_khr@bau.edu.jo`

Abstract—In this paper we designed microstrip patch antenna by using metamaterial to improve antenna bandwidth. We inserted Complementary Split Ring Resonator (CSRR) structure between the ground and patch in the substrate. We compared our design with the conventional microstrip patch antenna in point of bandwidth. We obtained bandwidth improvement by 800MHZ. Simulation was obtained by using High Frequency Structure Simulation (HFSS) simulator.

Keywords—Microstrip patch antenna, metamaterial, complementary split ring resonator, bandwidth.

1 Introduction

The idea of Material which is known Left Handed Materials (LHMs) dates back to (1967), when Veselago [1] considered theoretically electromagnetic plane wave propagation in a lossless medium with simultaneously negative real permittivity and permeability at a given frequency. In order to describe a LHM, we need to start with a description of a Right Handed Material (RHM) first. In general, materials have two unique parameters, permeability and permittivity that determine how the material will interact with electromagnetic radiation, which includes light, microwaves, radio waves, even x-rays. A RHM is a material whose permeability and permittivity are simultaneously positive. RHMs are also called Double Positive Material (DPS) in the literature. If the direction of the Electric field (*E*) and the Magmatic field (*H*) are represented by the thumb and the index finger of the right hand respectively, then the middle finger gives the direction of propagation of the wave, if it is placed normal to both fingers. Additionally, in RHMs wave propagation or the energy flow represented by Pointing vector $\boldsymbol{P_{av} = 0.5\, RE}\,[\boldsymbol{E} \times \boldsymbol{H}^*]$ and the phase changes represented by phase constant $(\boldsymbol{K = \omega\sqrt{(\varepsilon)}^{*}\sqrt{(\mu)}}\ )$ are in the same direction as shown in Figure 1. Electromagnetic waves propagation in all known natural materials follows the right hand rule, with positive refractive indexes [2].

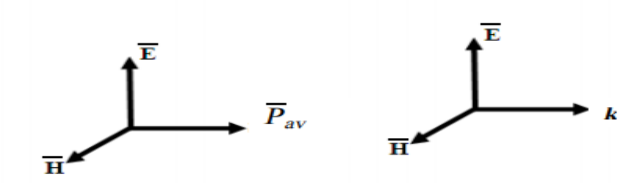

Fig. 1. Wave propagation in right handed medium.

On the other hand, a LHM is a material whose permeability and permittivity are simultaneously negative. LHMs also called Double Negative Materials (DNGs). LHM as defined by Sihvola [3], is an engineered material that does not exist in nature which gains its material properties from its structure rather than inheriting them directly from the material. In such a medium, LHM, if the direction of the electric field (E) and the magmatic field (H) are represented by the thumb and the index finger of the left hand respectively, then the middle finger gives the direction of phase changes of the wave ($\boldsymbol{K = \omega\sqrt{(\varepsilon)}\sqrt[*]{(\mu)}}$) if it is placed normal to both fingers. In a LHM medium the energy flow $\boldsymbol{P_{av} = 0.5\ RE\ [E \times H^*]}$ and the phase changes represented by phase constant ($\boldsymbol{K}$) are in opposite directions (anti-parallel) as shown in Figure 2. Propagation of type is called backward propagation [1].

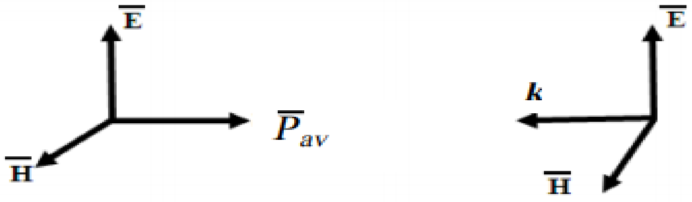

Fig. 2. Wave Propagation in left handed medium.

Considering the effect that the LHM has on the refractive index ($\boldsymbol{n}$) defined by equations (1) to (3):

$$\boldsymbol{n} = \sqrt{(\boldsymbol{\varepsilon}_{\mathbf{r}})} * \sqrt{(\boldsymbol{\mu}_{\mathbf{r}})} \tag{1}$$

where:
$\boldsymbol{\mu_r}$ = Relative permeability of material
$\boldsymbol{\varepsilon}_{\mathbf{r}}$ = Relative permittivity of material
When both permittivity and permeability are negative, thus equation takes the following:

$$\boldsymbol{n} = \sqrt{(-\boldsymbol{\varepsilon_r})} * \sqrt{(-\boldsymbol{\mu_r})} \tag{2}$$

Which reduces to

$$\boldsymbol{n} = \boldsymbol{j}\sqrt{(\boldsymbol{\varepsilon_r})} * \boldsymbol{j}\sqrt{(\boldsymbol{\mu_r})} \tag{3}$$

2 Antenna Design

In order to obtain enhanced characteristics and good performance, the double layered substrate concept is applied to a metamaterial loaded micro strip antenna .Initially micro strip antenna, which is a square patch with a resonant frequency of (2.4)*GHz*, will be designed [4]. Then it will load with a metamaterial Complementary Split Ring Resonator (CSRR) structure between the ground and patch in the substrate. The inclusion of the metamaterial has shown an increase in the bandwidth, but there has to be a tradeoff with the gain, as it was found to reduce, thereby becoming a drawback. Another substrate will then be added over the previous one, which will increase the effective dielectric constant, thereby increasing the gain along with the bandwidth. The effective dielectric constant is found to increases. The substrate used for the second layer, FR4 Epoxy substrate having a dielectric constant of 4.4 that use in the first layer. The height of the substrate selected as 2 *mm* and the dimensions of the substrate to be 50 *mm* which is a square patch with dimensions 25 *mm*. The micro strip feed, which is essentially a micro-strip line, 4.5 mm in length and 2 *mm* thick [5 - 13].

Metamaterial structure chosen is the Complementary Split Ring Resonator (CSRR) as shown in the Figure 3 with the following dimensions: [2]

- $\ell = 2.5mm$
- $c = 0.2mm$
- $g = 0.3mm$
- $d = 0.15mm$

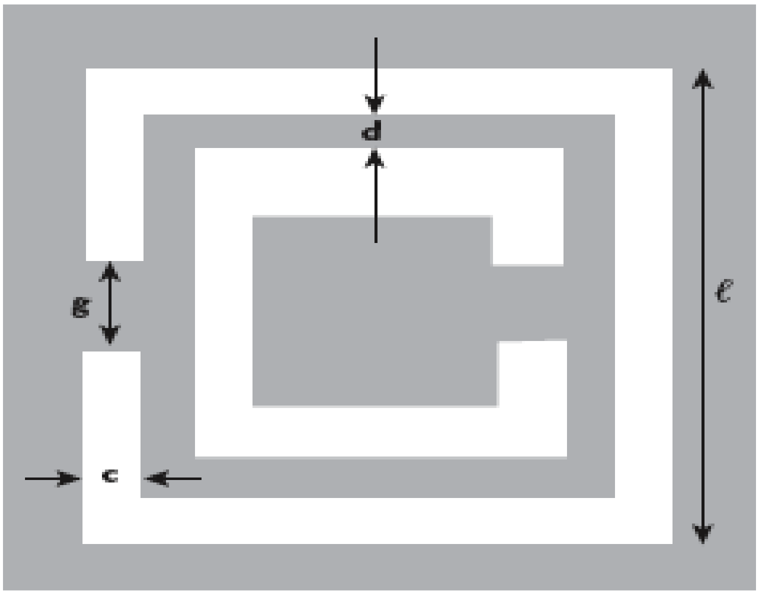

Fig. 3. Unit cell of CSRR.

3 Simulation and Results

The proposed antenna has been simulated by using High Frequency Structure Simulation (HFSS) as shown in figures 4 and 5.

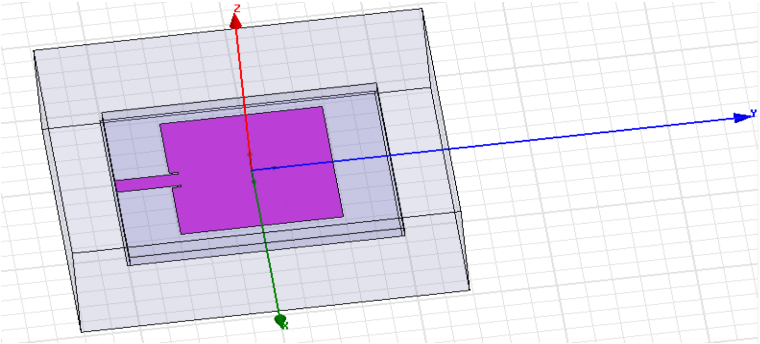

Fig. 4. Microstrip patch antenna design.

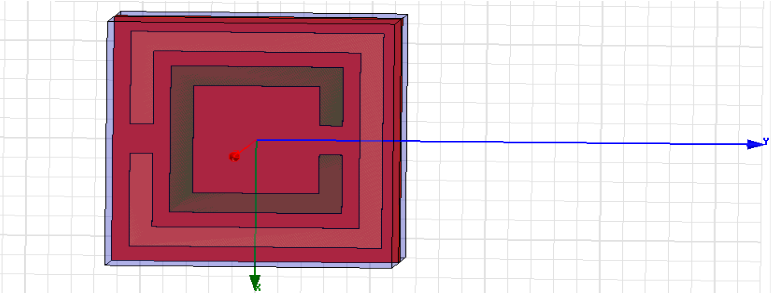

Fig. 5. Metamaterial design.

The comparison of simulated characteristics of patch antenna with and without metamaterial are shown below in figures 6 (a, b), 7 (a, b) and 8 (a, b):

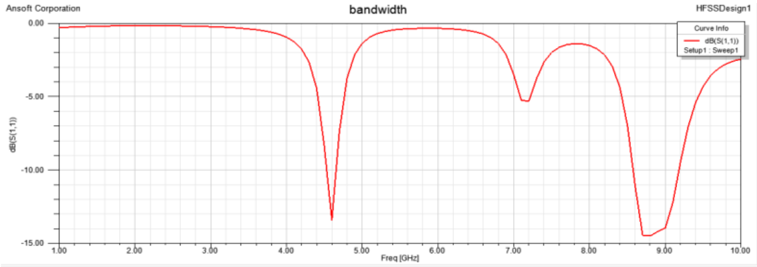

Fig. 6. (a). Simulated bandwidth characteristic of patch antenna

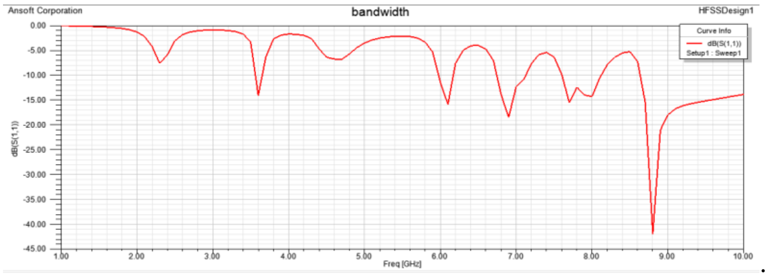

Fig. 6. (b). Simulated bandwidth characteristic of patch antenna with metamaterial.

For antenna without metamaterial we obtained one resonance frequency at 8.8*GHz*. For the design with metamaterial we obtained two resonance frequencies at 4.6*GHz* and 8.8*GHz*. We got an improvement in the gain for 8.8*GHz* by 800*MHz*.

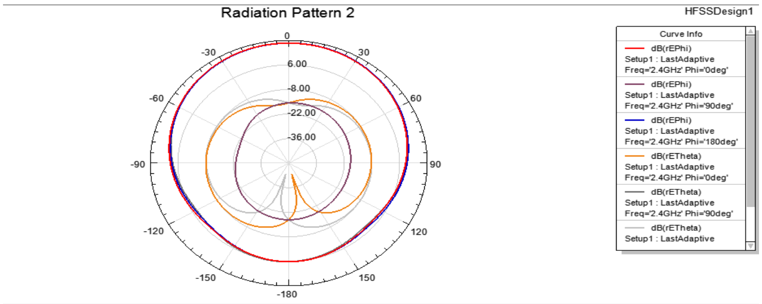

Fig. 7. (a). Simulated radiation pattern characteristic of patch antenna.

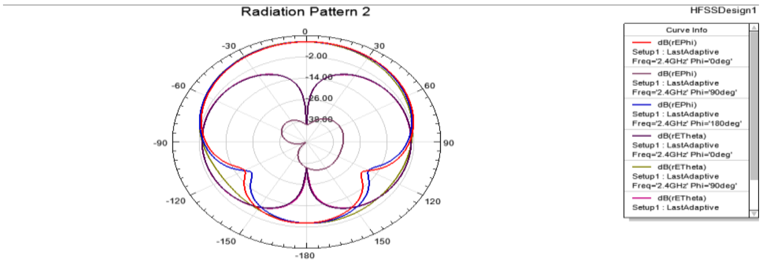

Fig. 7. (b). Simulated radiation pattern characteristic of patch antenna with metamaterial.

We obtained almost the same radiation pattern for both cases.

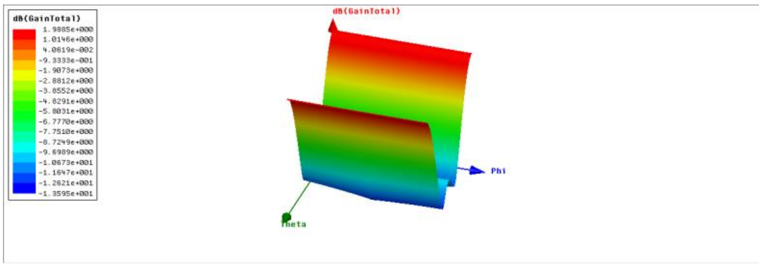

Fig. 8. (a) Simulated gain characteristic of patch antenna

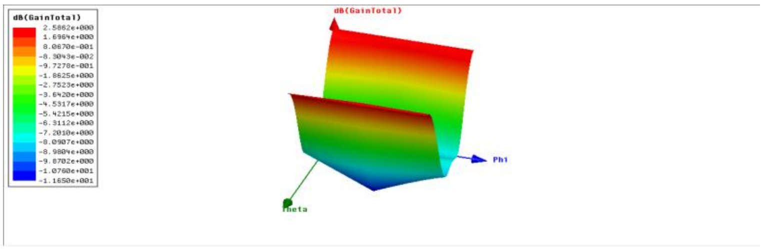

Fig. 8. (b) Simulated gain characteristic of patch antenna with metamaterial.

We observed that we have improvement in the gain for the case of antenna with metamaterial by 1dBi.

As can be seen from the above Figures 8 (a), 8 (b) that the (-10) dB bandwidth is increased with metamaterial. The bandwidth of patch antenna with metamaterial is 800MHz.

4 Conclusion

The main problem in microstrip patch antenna is narrow bandwidth. By using metamaterial we can increase the antenna bandwidth. In this paper we designed microstrip patch antenna by using metamaterial to improve antenna bandwidth. We inserted Complementary CSRR structure between the ground and patch in the substrate. We compared our design with the conventional microstrip patch antenna in point of bandwidth. We obtained bandwidth improvement by 800MHz. Simulation was obtained by using HFSS simulator.

5 References

[1] https://www.ripublication.com/aeee_spl/aeeev4n1spl_14.pdf.
[2] M.A. Wan Nordin • M.T. Islam • N. Misran (2012) A compact wideband coplanar waveguide fed metamaterial-inspired patch antenna for wireless application. https://doi.org/10.1007/s00339-012-7381-9
[3] GoranKiti, Vasa Radoni, and Vesna Crnojevi –Bengin(2012), Soil moisture sensors based on metamaterials, SIST.

[4] Antenna theory analysis and design “(third edition- a john wiley & sons).

[5] Antenna design, simulation and fabrication’ Department of Electronics and Computer Science Engineering Visvesvaraya National Institute of Technology (Deemed University) Nagpur – 440011, ‘2006-2007’.

[6] http://wireless.ictp.it/handbook/C4.pdf.

[7] http://www.rfwireless-world.com/Terminology/Advantages-and-Disadvantages-of- Antenna-types.html.

[8] Microstrip Patch Antenna A Historical Perspective of the Development B. D. Patel H. O. D, E. T Department, College Of Engineering Roorkee,Roorkee, U.A-247667, India.

[9] S Anantha Ramakrishna (2005), Physics of negative refractive index materials, pp 453-467,490-495S. Raghavan and Rajesh Kumar (2013),, An Overview of Metamaterials in Biomedical Applications, PIERS Proceedings.

[10] Nader Enghta, R. W. Ziolkowski (2006) Metamaterials Physics and Engineering Explorations Published by John Wiley & Sons, In, Canada.

[11] Davi Bibiano Brito (2010), Metamaterial inspired improved antenna and circuits, UFRN, pp.19-27.

[12] Adnan Noor (2010), Metamaterial Electromagnetic Absorbers and Plasmonic Structures, pp.42-43.

6 Authors

Huthaifa A. Al Issa received his Bachelor’s and Master’s degrees in Electrical Engineering at the Near East University, Nicosia, Cyprus, in 2003 and 2005, respectively with high honors GPA. He received his Ph.D. degree in Electrical Engineering at the University of Dayton, Dayton, OH, USA, in 2012. He spent two years as an assistant professor in the department of electrical and electronics engineering at Jerash University. Currently, he is an assistant professor in the Department of Electrical and Electronics Engineering at AL-Balqa Applied University. He has been a member of the Jordan Engineers Association (JEA) since 2003.

Yahya S. H. Khraisat received his PH. D. In 1998 from Kiev National Aviation University in Radar Engineering and Navigation. Currently he is a Full Professor in the electrical and electronics engineering department at Al-Balqa Applied University. He has more than 50 publications in antenna design, radar and remote sensing of the atmosphere. He was the dean of Al – Huson University College from September 2013 until September 2016. Currently he is also a member of trustees of Luminance Technical University College, Jordan.

Fatima A. S. Alghazo got her Bachelor degree in Communication and Software Engineering from Al-Balqa Applied University in 2019. Currently working at Jordan University of Science and Technology in scientific research.

Article submitted 2019-04-07. Resubmitted 2019-11-19. Final acceptance 2019-11-23. Final version published as submitted by the authors.