Bandwidth Enhancement of Microstrip Patch Antenna by Using Metamaterial

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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 \( \mathbf{P}_{av} = 0.5 \mathbf{R} \mathbf{E} \times \mathbf{H}^\ast \) and the phase changes represented by phase constant \( \mathbf{K} = \omega \sqrt{\varepsilon / \mu} \) 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].
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 magnetic 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 \( \mathbf{K} = \omega \sqrt{\varepsilon_r} \sqrt{\mu_r} \) if it is placed normal to both fingers. In a LHM medium the energy flow \( P_{av} = 0.5 \Re\{\mathbf{E} \times \mathbf{H}^*\} \) and the phase changes represented by phase constant \( \mathbf{K} \) are in opposite directions (anti-parallel) as shown in Figure 2. Propagation of type is called backward propagation [1].

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

\[
n = \sqrt{(\varepsilon_r)} \times \sqrt{(\mu_r)}
\]

where:

\( \mu_r = \) Relative permeability of material

\( \varepsilon_r = \) Relative permittivity of material

When both permittivity and permeability are negative, thus equation takes the following:

\[
n = \sqrt{(-\varepsilon_r)} \times \sqrt{(-\mu_r)}
\]

Which reduces to

\[
n = j\sqrt{(\varepsilon_r)} \times j\sqrt{(\mu_r)}
\]
2 Antenna Design

In order to obtain enhanced characteristics and good performance, the double layered substrate concept is applied to a metamaterial loaded microstrip antenna. Initially, microstrip 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 increase. 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 microstrip feed, which is essentially a microstrip 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]

- l = 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.](image1)

![Fig. 5. Metamaterial design.](image2)

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](image3)
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.

We obtained almost the same radiation pattern for both cases.
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

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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.

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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.