

LEFT-HANDED METAMATERIAL INCORPORATED WITH CIRCULAR POLARIZED MICROSTRIP ANTENNA

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1. Introduction

Left-Handed Metamaterial (LHM) is an interesting material to be investigated where this artificial material has several unique properties such as the backward wave and the negative refraction. The history of LHM was started from Veselago when he made a theoretical speculation of this artificial material that exhibit negative permittivity and negative permeability. Thirty four years later, on 2001, Smith made the first prototype structures of LHM [3] where the LHM is a combination of Split Ring Resonator (SRR) and thin wire (TW). One of the unique properties of LHM is negative refraction which will produce the focusing effect. With this property, the focusing affect of LHM made a low gain antenna becomes directive and have an increment of gain [1 and 2].

This paper discussed and analyzed the properties of the 2x2 array patch circular polarized microstrip antenna with and without the LHM structure. The designed LHM is a combination of a modified SRR and capacitance loaded strip (CLS). The LHM and antenna is designed to operate at 2.4 GHz. The negative permittivity and negative permeability of the simulated LHM structures is presented. The results show that the gain of the antenna increased and it also change the polarization of the 2x2 array patch circular polarized microstrip antenna to a linear polarized antenna after the integration with the LHM.

2. Design and Simulation of LHM

Figure 1 illustrates the LHM structure where it is a combination of a modified (SRR) and two (CLS). The modified SRR will produce magnetic material-like responses and exhibit the negative permittivity and the CLS will produce strong dielectric-like responses and exhibit the negative permeability [4 and 5].

The simulation of LHM has been done using Computer Simulation Technology (CST) software. Perfect magnetic conductor (PMC) boundary condition is set on the left and right faces of the block in x-axis and perfect electric conductor (PEC) boundary condition is set on the top and bottom of the block in the y-axis. The E- field of the incident wave is polarized along y-axis while the H-field of the incident wave is polarized along x-axis and the wave propagates in z direction [6]. Figure 2 illustrated the simulated structure. The LHM structure is patterned on a FR4 board with a thickness of 1.6 mm. The relative permittivity of the FR4 board is 4.7 and its tangential loss is 0.019. The structure has an air gap of 8 mm on both flanks the substrate.

The S-parameters that is obtained from the simulation were then exported to the MathCAD. Nicholson, Ross and Wier (NRW) approach [5] is used to determine the permittivity, ϵ_r and permeability, μ_r of the LHM structure and the results is shown in figure 3. The equations used to determine the ϵ_r and μ_r are [5]:

$$\mu_r \approx \frac{2}{jk_0d} \frac{1-V_2}{1+V_2} \quad (1.0)$$

$$\varepsilon_r \approx \frac{2}{jk_0d} \frac{1-V_1}{1+V_1} \quad (1.1)$$

Where; k_0 = Wave number
 d = Thickness of slab

$$V_1 = S_{21} + S_{11} \quad (1.2)$$

$$V_2 = S_{21} - S_{11} \quad (1.3)$$

From Figure 3, the range of the negative permittivity and negative permeability ($-\varepsilon$ and $-\mu$) starts from 2.11 GHz to 2.7 GHz. A circular polarized microstrip antenna was then designed to operate at the frequencies where the value of permittivity and permeability are negative. The circular polarized microstrip antenna is designed to operate at 2.4 GHz. The circular polarization can be obtained by slight modification to the patch where the patch corner is trimmed as shown in Figure 4. The antenna has a bandwidth of 6.4 % from 2.326 GHz – 2.48 GHz. The result of the radiation pattern is shown in Figure 6 where the directivity of the antenna is 9.826 dBi with the total efficiency of 42.3 % at 2.4 GHz. The 3 dB half-power beam-width in the E-plane is 61.3° and at the H-plane is 57.1° . The LHM structure is placed in front of the microstrip antenna with a distance of 12.5 mm as shown in Figure 5. The result of the return loss, S_{11} shows that the antenna has two band of frequencies which from 2.3 GHz to 2.38 GHz and 2.42 GHz to 2.5 GHz. At 2.4 GHz, the radiation pattern shown in Figure 7 indicates that the directivity of the antenna is 10.39 dBi with a total efficiency of 29 %. The 3dB half-power beam-width of the antenna in E-plane is 50.7° and in H-plane is 47.5° . The simulation of the microstrip antenna with LHM structure shows an encouraging result. The LHM act as focusing device where the gain of the antenna increases up to 0.5 dB while the 3dB half-power beam-width become narrow.

3. Measurement of LHM

The fabrication is done using the same board properties (FR4 board) as in the simulation. Both the microstrip antenna with and without LHM structure were measured and operating at 2.4 GHz. The measured return loss, S_{11} shows a good agreement between the microstrip antenna with and without integration of LHM structure where both are below -10dB. The measured radiation patterns of the microstrip antenna without and with the LHM structure are shown in Figure 8 and Figure 9. Figure 8 shows that the 3 dB half-power beam-width is 48° in E-plane and 62° in H-plane while the cross polarization of the antenna is 2 dB which is acceptable for a circular polarized antenna. Figure 9 shows that the 3 dB beam-width of the antenna with LHM is 40° in E-plane and 42° in H-plane while the cross polarization of the antenna is 7 dB. The measured radiation pattern shows that an improved of gain up to 4 dB occur in E-co and H-co but the gain reduced up to 1 dB in E-cross and H-cross. The introduction of the LHM structure to a circular polarized antenna affects the polarization of the antenna and turns it to a linear polarized antenna where the cross polarization of the antenna is below 3 dB.

4. Conclusion

From observation, the radiation pattern of circular polarized microstrip antenna integrated with LHM structure has an improved gain compared to the gain of the circular polarized microstrip antenna without LHM structure. An improvement of the gain by 0.5 dB in simulation and 4 dB in measurement is obtained when LHM is placed in front of the circular polarized microstrip antenna. The 3 dB half-power beam-width (HPBW) of the circular polarized microstrip antenna with LHM structure is narrower than the HPBW of the circular polarized microstrip antenna. This shows that

LHM can be a focusing device where the beam become narrow and the gain increased. However, the gain increments only occur in E-co and H-co while it decreases in E-cross and H-cross and it also change the polarization of the antenna from circular to linear polarized where the cross polarization of the antenna is larger than 3 dB. This shows that this kind of LHM structure is not suitable to be used for a circular polarized type of antenna where the LHM will change the polarization of the antenna.

Acknowledgments

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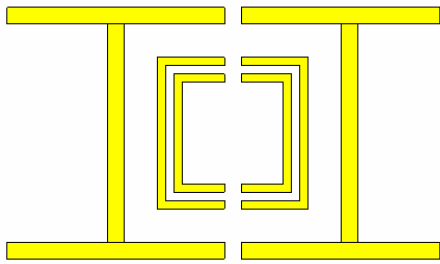


Figure 1: LHM structure consist of SRR and CLS

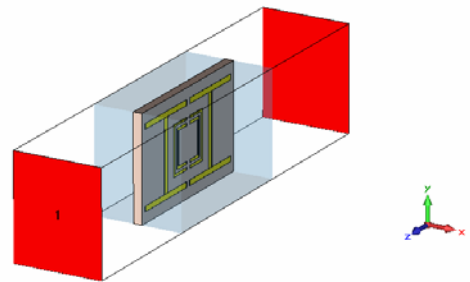


Figure 2: Boundary condition for simulation setup

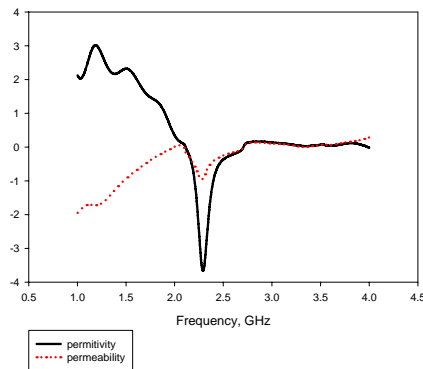


Figure 3: Value of ϵ_r and μ_r of the single cell with 8 mm air gap

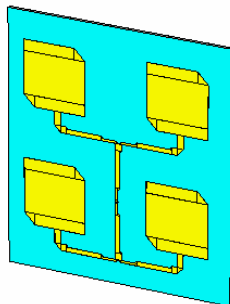


Figure 4: Circular polarized microstrip antenna

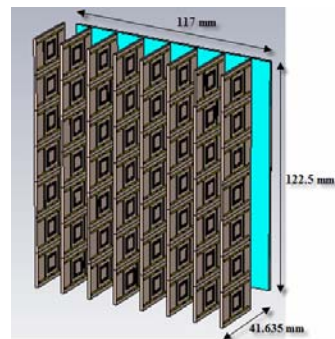


Figure 5: Circular polarized microstrip antenna integrated with LHM structure

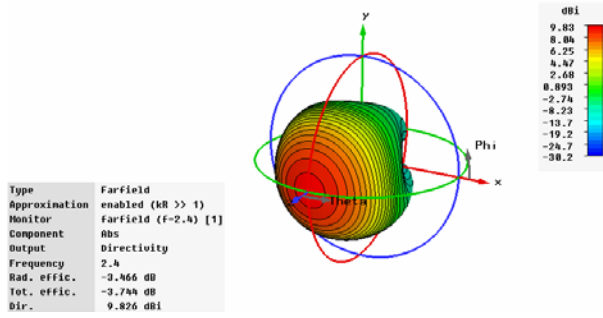


Figure 6: Radiation pattern of circular polarized microstrip antenna

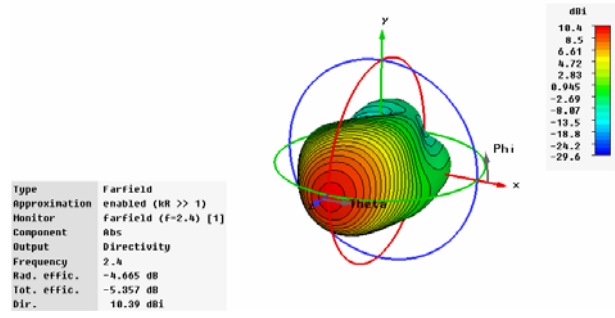


Figure 7: Radiation pattern of circular polarized microstrip antenna with LHM structure

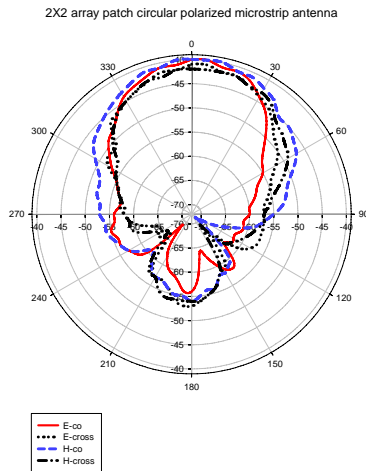


Figure 8: Measured radiation pattern of circular polarized microstrip antenna

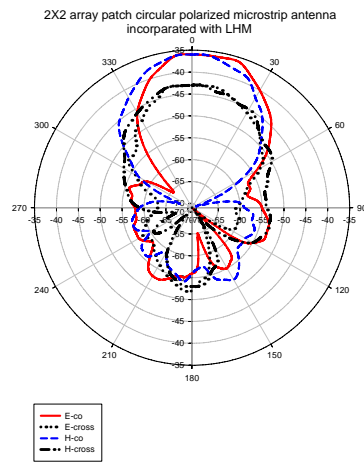


Figure 9: Measured radiation pattern of circular polarized microstrip antenna with LHM structure

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