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Conference Paper

Left-Handed Metamaterial Structure for Side Lobe Suppression of Microstrip Array Antenna

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Abstract

In this paper, a Left-handed Metamaterial (LHM) structure is designed for side lobe suppression of a microstrip array antenna at frequency 2.8-3.1 GHz. The LHM structure is placed at the top of the microstrip array antenna with a space or gap between them. Side lobe suppression is very important for Radar system which needs antenna with high performance of its radiation properties. The linier array microstrip antenna consists of 4x1 elements. The simulation result using CST microwave studio shows that the Side Lobe Level (SLL) has been suppressed from -8.93 dB to -15.86 dB at phi = 0 while the measurement result shows suppression from -6.6 dB to -10.75 dB. Both simulation and measurement result shows a side lobe suppression using LHM structure.

Keywords: Left handed metamaterial, side lobe suppression, microstrip array antenna

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1. Introduction

Radar (Radio Detection and Ranging) is a system that can detect an object and therefore needs high accuracy. Antenna as one important part of the Radar system plays an important role for the accuracy of the Radar to detect an object. The antenna exhibits radiation properties such as radiation pattern. The radiation pattern consists of major lobe and side lobes. The main lobe is used to detect an object precisely at a certain coordinate. If the side lobe is too high and has the magnitude almost the same as the main lobe, the radar can false detect the object with wrong coordinate. One method that can increase the accuracy is reducing the Side Lobe Level (SLL) from antenna performance of the radar. High SLL can cause false signal or false detection. There are several techniques that can reduce the SLL, which are Chebyshev [1], Electromagnetic Band Gap (EBG) [2] and Metamaterial (MTM). Electromagnetic Band Gap in [2] has reduced the antenna SLL around 2.5 dB from -12.69 dB to -15.24 dB.

Metamaterial is defined by the permittivity and the permeability of the material. A Material found in nature usually has positive permittivity and permeability, however, metamaterial is defined as engineered material or engineered structure that has negative permittivity with positive permeability or negative permeability with positive permittivity or has both negative permittivity ($\varepsilon < 0$) and negative permeability($\mu < 0$) and called as Left-Handed Metamaterial (LHM). LHM can cause backward wave propagation [3].

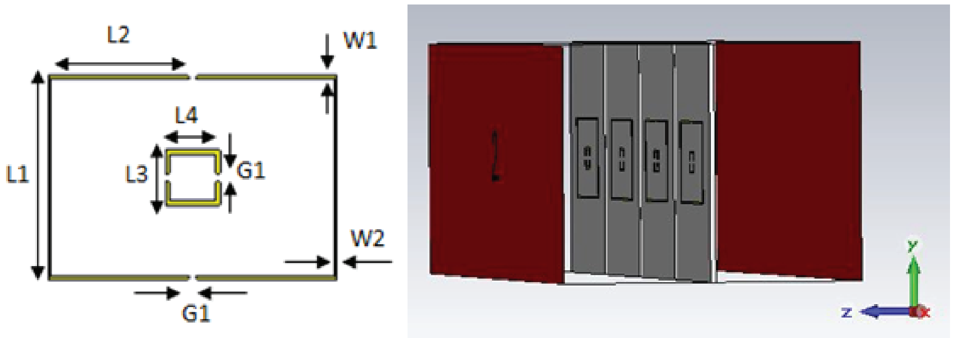

Figure 1: (a) Dimension of the LHM structure, (b) Boundary condition of the LHM structure simulation setup.

Metamaterial has many different structure types like a rectangular, omega or S structure. The omega and the S type are not easy to construct and has a narrow bandwidth [4], while the rectangular structure has broader bandwidth and more easy to construct. Split Ring Resonator (SRR) is also a LHM structure. LHM contains a Split Ring Resonator (SRR) that produce a strong magnetic field [5] causing the permeability negative and a thin wire that cause a negative permittivity, but beside using a thin wire which is hard to apply in this application, the LHM structure can make a CLS (Capacitive Loaded Strip) at the LHM structure that can cause the permittivity to be negative too. LHM structure can also be placed at the top of the array antenna [6] because the negative characteristic can act as lens that can focus the radiation beam. A focus beam can make the main lobe much larger and reduce the size of the side lobe level. In this paper, a microstrip array antenna with LHM structure placed at the top of the antenna is proposed to suppress the side lobe level.

2. Design of Left Handed Metamaterial

The LHM structure is designed using FR-4 substrate with thickness h = 1.6 mm, relative permittivity $\varepsilon_r = 4.6$ and loss tangent 0.025, which is depicted in Fig. 1(a). Variable L, W, and G shows the length, width and gap of the LHM structure dimension. Where, L1 = 26 mm, W1 = 0.5 mm, G1 = 1 mm, L2 = 18 mm, W2 = 0.25 mm, G2 = 1 mm, L3 = 7 mm and L4 = 7 mm.

Simulation of the LHM structure is conducted using CST Microwave studio software. Before starting the simulation, the boundary condition has to be set. The top and bottom of the LHM structure (y-axis) is given Perfect Electric Conductor (PEC), the front and back (z-axis) of the LHM structure is given open add space, the left and right of the LHM (x-axis) is given Perfect Magnetic Condition (PMC). After the boundary condition has been set, the port is given at the z-axis as shown in Fig. 1(b).

Figure 2 shows the result S_{11} of the LHM structure which operates at frequency 2.8–3.1 GHz. The S_{11} is used for calculation to prove the new permeability and the permittivity of the LHM structure.

Formula Nicholson, Ross and Weir (NRW) [7] is used to find the permittivity and the permeability of the LHM structure used in Eq. 1 to Eq. 4:

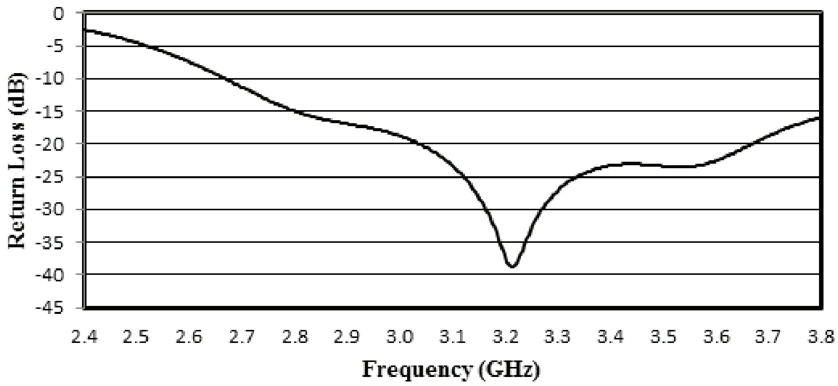

Figure 2: Return loss of the LHM structure.

$$\mu_r = \frac{2 \cdot c \left(1 - v_2\right)}{\omega \cdot d \cdot i \left(1 + v_2\right)} \tag{1}$$

$$v_1 = S_{11} + S_{21} \tag{2}$$

$$\varepsilon_r = \frac{2 \cdot c \left(1 - v_1\right)}{\omega \cdot d \cdot i \left(1 + v_1\right)} \tag{3}$$

$$v_2 = S_{21} - S_{11} \tag{4}$$

Where μ_r is the permeability, ε_r is the permittivity, ω is the frequency in radian, c is the speed of light, and d is the thickness of the substrate. The permittivity and the permeability that has been calculated is plot and shown in Fig. 3. Figure 3(a) shows the negative permittivity of the LHM structure while Fig. 3(b) shows the negative permeability. This means that the structure designed has both negative permittivity and negative permeability and called the LHM structure.

This LHM structure is then applied to microstrip antenna for radar application. Figure 4 shows the exploded view of the microstrip antenna array 4 elements for radar application [5] with the LHM structure. Between the microstrip and the LHM structure is given a space or a gap about 0.05λ.

The simulation result shows that the antenna design with LHM structure can suppress the side lobe level from -8.93 dB to -15.86 dB. This design with simulation result aforementioned is then fabricated to be a prototype.

3. Measurement Result

The LHM structure is fabricated and photo as depicted in Fig.5, the top view and the back view of the LHM structure is the same. The array antenna 4 element with the

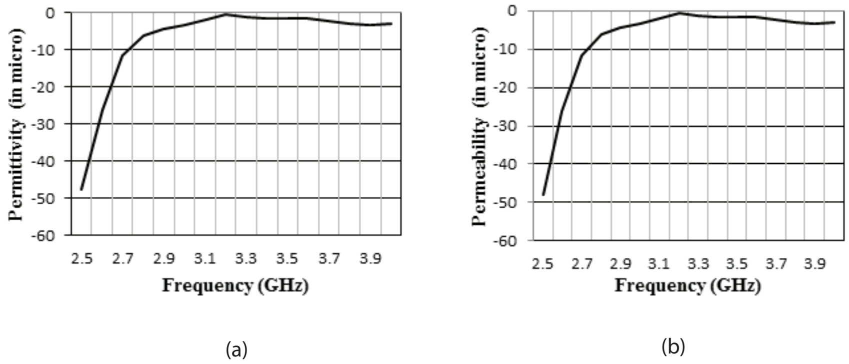

Figure 3: (a) Permittivity, (b) Permeability.

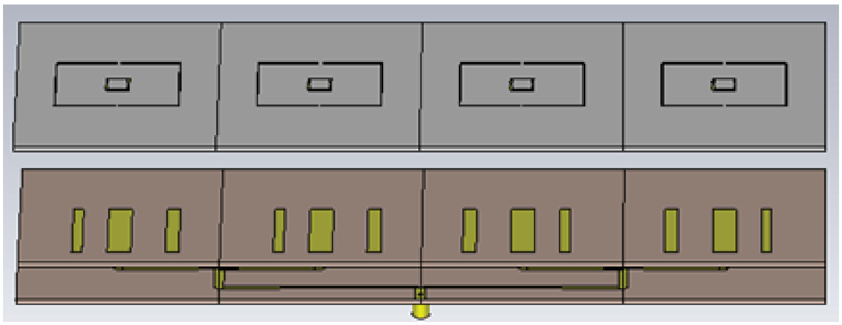

Figure 4: Exploded view of LHM Structure for antenna array 4x1 element.

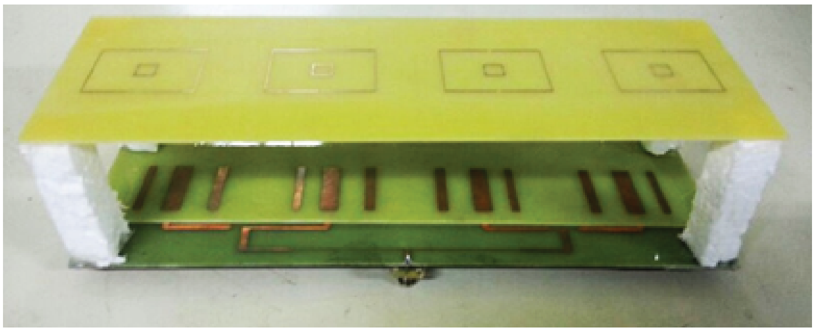

Figure 5: Exploded view of the array antenna 4 element with the LHM structure.

LHM structure has a gap distance of 5 cm. Stereo foam is used to make the gap and support the substrate with the LHM structure on top of the antenna to avoid significant change of the radiation properties if using conductive materials.

The LHM structure with the array antenna 4 elements is measured in anechoic chamber at Electrical Engineering Department, Faculty of Engineering, Universitas Indonesia. Both the simulation and measurement result is plotted in Fig. 6. Although there is a slight difference of peaks and valleys of the S_{11} parameter, the simulation and measured frequency show the same bandwidth of the antenna which is about 320 MHz at $S_{11} \leq$ -10dB.

Figure 7 shows the linear plot of the radiation pattern at phi = 0. The simulated side lobe level from antenna with LHM structure is about -15.86 dB, the measured is about

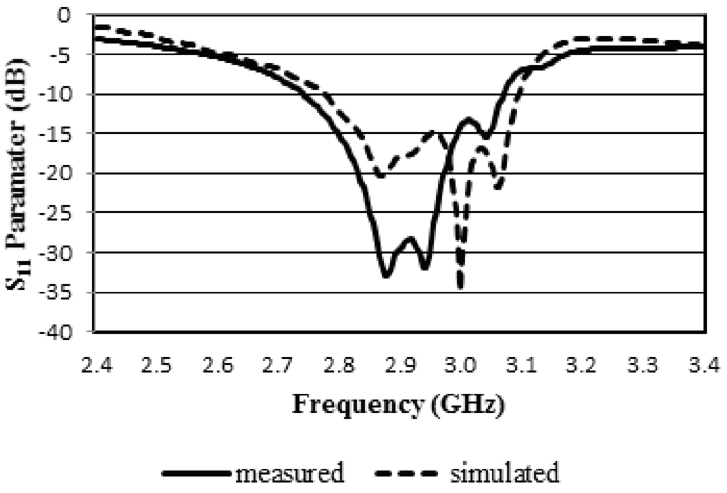

Figure 6: Simulation Result of S_{11} Parameter.

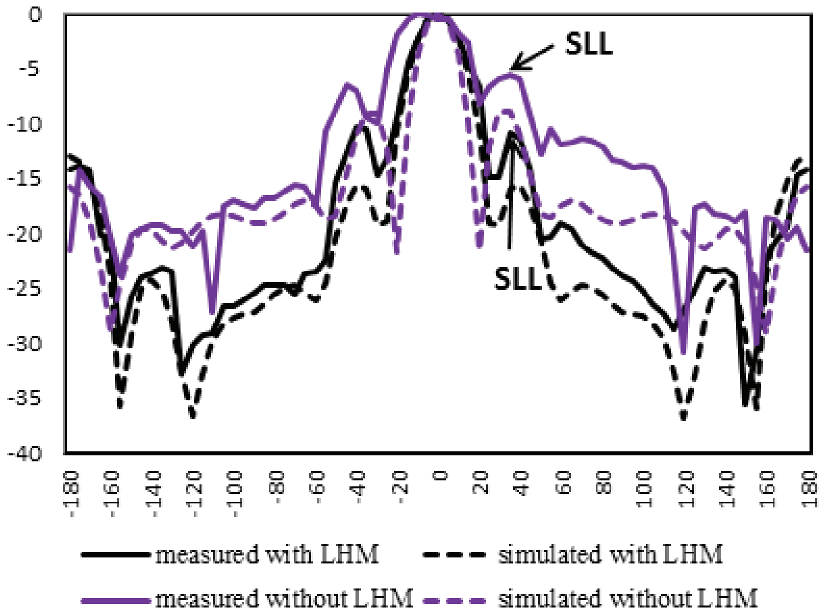

Figure 7: Linear plot at phi = 0.

-10.75 dB. Meanwhile, the simulated SLL without LHM structure is -8.93 dB and the measured is -6.6 dB. So simulation result shows a SLL suppression of 6.93 dB while measurement result shows suppression of 4.15 dB.

The slight difference between the simulation and measurement result is due to the imperfect condition of the antenna fabrication. In microwave, a slight difference of antenna dimensions between design and fabrication can cause shift of results because the impedance of the antenna can be easily influenced and therefore changed.

4. Conclusion

The LHM structure discussed in this paper has both negative permittivity and permeability. The microstrip antenna array 4 elements with a LHM structure can suppress the side lobe level of the antenna with simulation result shows a suppression of 6.93 dB while measurement result shows suppression of 4.15 dB.

Acknowledgement

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References

[1] F. Y. Zulkifli, T. Hidayat, Basari, and E. T. Rahardjo, Sidelobe Level Suppression Using Unequal Four-Way Power Divider for Proximity Coupled Microstrip Antenna, *Asia Pacific Microwave Conference (APMC 2013)*, 1166–1168

[2] M. J. Asghari, F. H. Kashari, A. Malekijavan, and B. Bahirei, Using Mushroom EBG In Microstrip Array Antenna to Reduce Side Lobe Level, *Life Sci J*, **10**, 3s, (2013).

[3] T. J. Cui, D. R. Smith, and R. Liu, in *Metamaterials Theory, Design, and Applications*, Springer, 2010.

[4] W. Wang, Directive Antenna Using Metamaterial Substrates (2004).

[5] C. D. Moss, T. M. Grzegorczyk, Y. Zhang, and J. A. Kong, Numerical Studies of Left Handed Metamaterials, *Prog In Electromagn Res PIER*, **35**, 315–334, (2002).

[6] H. A. Majid, M. KA. Rahim, and T. Masri, Microstrip Antenna's Gain Enchancement Using Left-Handed Metamaterial Structure, *Prog In Electromagn Res M*, **8**, 235–247, (2009).

[7] R. W. Ziolkowski, Design, Fabrication and Testing of Double Negative Metamaterials, *IEEE Trans Antenn Propag*, **51**, p. 662, (2003).