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Performance analysis of metamaterial antennas based on variations in combination and radius of hexagonal SRR

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ABSTRACT

The low antenna performance is a concern for researchers to overcome in modern technology. As an effort to overcome this problem, the application of the metamaterial structure to the antenna was carried out to increase the antenna parameters. This study aims to analyze the effect of antenna performance due to the influence of variations in the combination and radius of the SRR hexagonal metamaterial. The research was conducted in a simulation, starting with designing the antenna structure with the metamaterial of two rings into a resonator with a radius variation of 2.5 mm and 2.7 mm, then combining one to four hexagonal SRRs. The results showed that the highest antenna performance was obtained from a combination of four hexagonal SRRs for a radius of 2.7 mm with parameter values in the form of return loss -38.95 dB, a bandwidth of 7.88 GHz at a working frequency of 1.12 – 9.00 GHz and a gain of 5.92 dBi.

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1. INTRODUCTION

Microstrip antennas have several advantages compared to conventional microwave antennas. However, microstrip antennas present several disadvantages such as limited bandwidth, low gain, and reduced radiation power [1-4]. Several innovations have been made to overcome these problems, including implementing metamaterial structures into antenna objects [5, 6]. The application of metamaterials to improve antenna parameters in the last decade [7-10].

Metamaterials are artificial periodic structures consisting of structural elements with negative of permittivity and permeability that carry sub-wavelengths at certain resonant frequencies [11, 12]. Metamaterials can be applied in sensing antennas because they offer high miniaturization which makes them highly sensitive to environmental changes and also shows their suitability for sensing materials including solid dielectrics [13-15]. The type of metamaterial structure used is a split ring resonator (SRR). Various types of metamaterial structures have been developed, such as square, circular, rod, and other SRR structures [16-21]. The hexagonal SRR structure metamaterial will be used in this research because it is rarely found. In addition, the hexagonal structure has the potential for greater resonance [22-24]. This research aims to analyze the comparison of antenna performance from the influence of the metamaterial structure implemented by varying the amount of unit and SRR radius.

2. RESEARCH METHODS

Based on Figure 1, this research will begin with a literature study regarding the basic properties of metamaterials and studying the concept of microstrip antennas. Then identify and start designing a hexagonal metamaterial structure in the form of an SRR and its application in microstrip antenna applications using CST Studio Suite software. The simulation identifies metamaterial properties by analyzing S-parameter data from the simulation results to obtain refractive index values through computation using Matlab software. After that, redesign the shape of the hexagonal structure whose metamaterial properties have been identified into an antenna application with a combination of the SRR-H structure, then start the simulation with the Start Simulation command in the CST menu. Data analysis and interpretation of simulation and experimental results were obtained in the form of antenna parameter values such as return loss, VSWR, gain, and directivity.

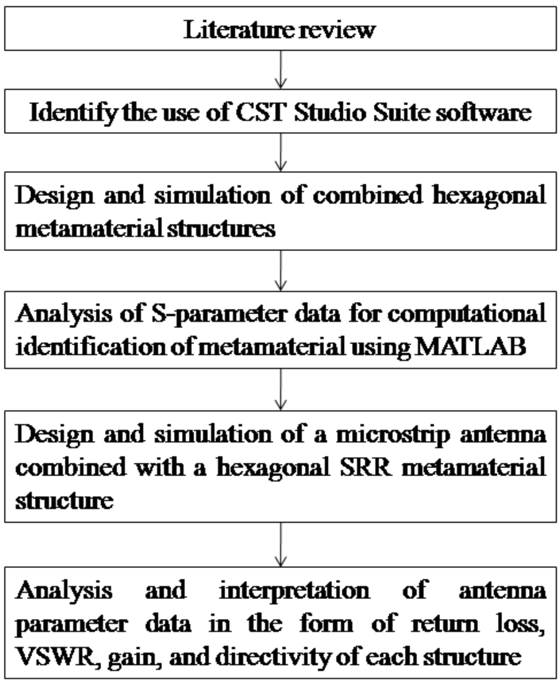
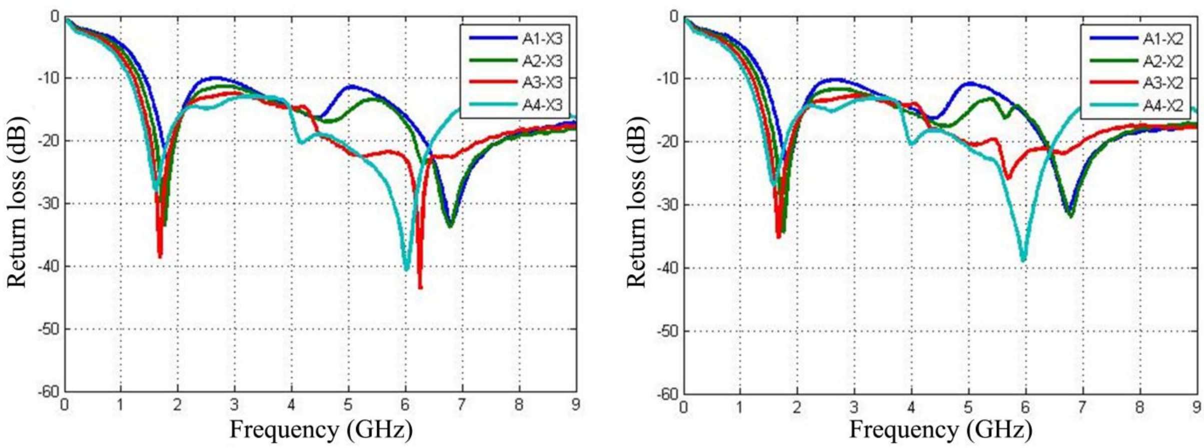


Figure 1. Research flow.

3. RESULTS AND DISCUSSIONS

The metamaterial structure that has been implemented on the antenna object has a very significant influence. Antenna performance becomes more varied with the presence of metamaterial structures. Figure 2 (a) and (b) shows the antenna return loss with various combinations of one (A1), two (A2), three (A3), and four (A4). Apart from that, the SRR radius is also varied by 2.5 mm and 2.7 mm.



(a) (b)

Figure 2. Return loss for various combinations of radii (a) 2.5 mm and (b) 2.7 mm.

The significant change in return loss explains that the antenna is more sensitive in the presence of metamaterial [13]. By varying the combination of metamaterials, the resulting differences are visible as shown in Figure 2. In addition, by varying the SRR radius, the antenna return loss only experiences small changes in the resonance frequency. The highest antenna performance results from a combination of four hexagonal SRR metamaterials of radii 2.5 mm and 2.7 mm which are respectively -41.21 dB and -38.95 dB at a resonant frequency of 6 GHz. However, at a resonant frequency of 1.75 GHz, the highest return loss is produced by an antenna with a combination of three hexagonal SRR metamaterials.

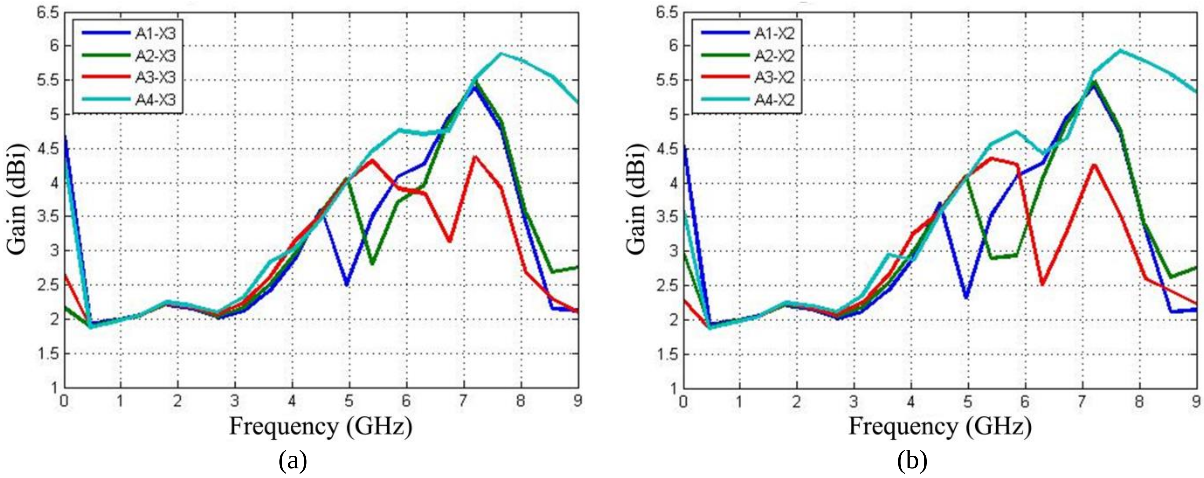


Figure 3. Antenna gain for various combinations of radii (a) 2.5 mm and (b) 2.7 mm.

Another parameter of the antenna that can determine whether the antenna's performance is good or not is the gain. These parameters are generated based on the influence of bandwidth and return loss [25]. The implementation of metamaterials in the antenna provides clear differences in gain with variations in combination and SRR radius (see Figure 3). The highest gain resulted from a combination of four metamaterials of radii 2.5 mm and 2.7 mm, respectively 5.81 dBi and 5.92 dBi at a frequency of 7.67 GHz. Gain results from the largest bandwidth from 1.12 – 9.00 GHz and the highest return loss.

4. CONCLUSION

The combined metamaterial structure antenna of one to four hexagonal SRRs produces an increase in antenna parameters with an average increase of 30% in return loss and 10% in gain. The highest parameters are produced by a metamaterial antenna combining four hexagonal SRRs with a radius of 2.7 mm with a maximum return loss value of -38.95 dB, a bandwidth of 7.88 GHz in a working frequency of 1.12 – 9.00 GHz, and a gain of 5.92 dBi.

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