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The Influence of Metamaterials In Controlling an Antenna

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ABSTRACT

One of the applications of metamaterials is in the manufacture of perfect lenses, which can focus light on a single point and increase data storage capacity. An antenna is a device designed to convert electrical current into free electromagnetic waves in the air. This article also discusses how metamaterials can be used to improve antenna performance in wireless communications. By taking advantage of the unique properties of metamaterials, antennas can convert electrical signals into electromagnetic signals with higher efficiency.

Keywords: *Metamaterial, Antenna, Wave*

1 Introduction

Materials can be interpreted as a form used to produce new things, or it can also be referred to as raw materials for a product. Matter is something that is composed or made up of Matter Based on these two definitions, we can conclude that materials are made up of different materials that are used to produce more useful products and finished products. Materials generally have pure or impure properties and include living and inanimate objects Therefore, materials can be considered physical substances. Based on its physical properties, materials can be used to create or make something that has certain benefits.(Stocks, 2016)

Another disii metamaterial is a material that has negative conductivity and magnetic permeability. Furthermore, the ability to modify properties contained in a material that is able to produce properties that have not yet been formed in nature are sometimes referred to as metamaterials. What can be interpreted as, metamaterials are technology to arrange materials with properties that do not exist in nature, these properties include permittivity and magnetic permeability, which has the power to manipulate the waves that are formed and change the structure that will be emitted. In other words, magnetic permeability is a constant that describes the strength of the magnetic field and magnetic induction in a medium, while permittivity is a parameter that measures the response of a medium to electrical energy when exposed to an electric field.

An example of the application of metamaterials is the use of perfect lenses. The complete lens is a negative index metamaterial plate with a constant thickness. As an illustration, compare the perfect lens to the use of a laser to record data on a digital video disc. A regular DVD can only hold one or a duo of 4 GB viidos> however, with the perfect lens, a DVD can hold up to 1000 videos of the same size. This is because this lens only collects light at one point. If it is a thin film with a negative refractive index value, then the bias property is a creeping wave and forms a shadow from the beginning.

So what is the difference between materials and metamaterials ?

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The difference between materials and metamaterials lies in their properties and structure. Here are the main differences between materials and metamaterials:

1. Physical Properties: Natural materials have naturally occurring physical properties, such as dielectric properties and limited permeability. On the other hand, metamaterials have physical properties that do not necessarily exist in nature, such as the value of permittivity and negative permeability.
2. Structure: Natural materials are made up of naturally formed internal structures, such as the arrangement of atoms and molecules. Metamaterials, on the other hand, are made of small form structures engineered in such a way that they have the desired properties.
3. Composition: Natural materials are made from naturally occurring materials, such as metals and plastics. Metamaterials, on the other hand, are made with composite materials such as metals and plastics.
4. Applications: Natural materials have limited applications, such as use in materials engineering technology. Metamaterials have wider and more innovative applications, such as use in materials engineering technology, sound wave processing, energyless cooling, and wave transformation at terahertz frequencies.

In synthesis, natural materials have naturally occurring physical properties and naturally formed internal structures, while metamaterials have physical properties that do not yet exist in nature and geometric structures that are engineered to have the desired properties.
An antenna is a man-made device to convert electrical current into free electromagnetic waves in the air. The antenna functions in emitting and receiving these waves in accordance with the purpose and benefits of the antenna. With the presence of antennas, signal strength can change for the better with long and high distances and frequencies.

2 Research Methodology

Metamaterials are man-made materials that have a geometric structure built from microscopic materials that can be engineered. The goal is for the new material to be able to direct light, sound, and (other waves) in a useful way. Metamaterials are made by humans with a negative index so that scientists are also familiar with the term Left Handed (LH), Negative Index Material (NIM) or Double Negative (DNG)(Vivek Prakash Yadav, Praveen Kumar Sharma, Dr. L Solanki, 2020).
Light cannot be absorbed by metamaterials because it has a negative index and cannot be reflected, but this light can be deflected through certain objects. All properties of light that interact with common materials will be reversed if light interacts with metamaterials (Fabiana Meijon Fadul, 2019).

$$n = \pm\sqrt{\varepsilon_r \mu_r}$$

This equation is used to describe the refraction of light and is best explained by Snell's law, which applies to the case of objects in the air.

$$n \sin \theta d = n' \sin \theta b$$

n is an air refractive index
n' is the value of the object's bias index.
θd is the large angle of air formed
θb is the large bias angle of the object
$\theta b = \sin^{-1}\left(\frac{n}{n'} \sin \theta d\right)$

The equation to calculate the properties of a material obtained from parameter measurements can use the equation that has been formulated by Nicolson, Ros, and WeirParameter S or scattering parameter represents the linear characteristics of radio frequency (RF) printed circuit board (PCB) components. The parameter matrix depicts the changes in the waves reflected and transmitted with respect to the incoming waves on the N-port PCB components. The relationship between the S parameter and the properties of the material (permittivity and permeability) using the NRW method involves repeated reflections from waves passing through the boundary plane of air and the material(Patel, 2008).

Waves passing through air-matter will be reflected and waves passing through air-matter will also be reflected. This process will occur continuously so that it is able to emit waves in the direction of the material and will stop if the source of wave excitation is exhausted.

Antenna pattern reinforcement or to test and measure antenna performance is used basic antenna parameter elements so that the antenna transmitting power ratio increases in a certain direction. The alternating current will accelerate the free charge in the wire to generate an alternating electromagnetic field so that an antenna can perform properly. And the radiation characteristics of an antenna are described by the radiation pattern that is often known as the far field.

Antennas that do not have connecting wires are called wireless which is an important element in a communication.electromagnetic waves will always be emitted and received by the antenna and will convert electrical signals (voltage/current) into signals that can be used in communication. The signal emitted by the transmitting antenna will be picked up by the receiving antenna. (Tiwery & Corputty, 2018)

An antenna is a device that can be used as a transmitter and receiver of radio waves. There are various types of antennas, one of which is a microstrip antenna. Microstrip antennas have several advantages including easy manufacturing, low price and small dimensions. However, this antenna has weaknesses, namely Bandwidth narrow and Gain the small ones. (Supriadi et al., 2021)

Global system for mobile communication is a digital mobile technology communication. GSM technology is often used in mobile communications, especially mobile phones, this technology utilizes microwaves and signal transmission that is divided by time. GSM is the global standard for mobile communications as well as the most widely used mobile technology. (Tiwery & Corputty, 2018)

3 Results and Discussion

3.1 Antenna

An antenna is a means or device that converts electrical signals (voltage/current) into electromagnetic signals, one of which is a microstrip antenna. Antennas with small dimensions, light, and thin so that they are easy, cheap, and flexible are known as microstrip antennas. One form of microstrip antenna is a circular patch microstrip antenna. The following is a picture on a microstrip antenna

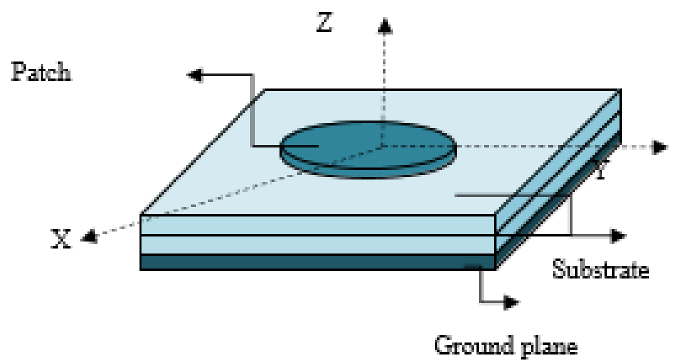

Figure 1. Antenna

1. Parch (conductor) functions to radiate electromagnetic waves located at the very top of an antenna.
2. A substrate made of dielectric material serves to limit the radiating element with the ground plane as well as as a channel for electromagnetic waves.
3. The ground plane functions as a reflector to reflect electromagnetic signals

The equation for calculating antenna dimensions is as follows:

which patch finger : $\alpha = \frac{f}{\left\{1+\frac{2}{\pi \varepsilon r f}[\ln\left(\frac{\pi f}{2h}\right)+1{,}7726]\right\}^{\frac{1}{2}}} f = \frac{8{,}794x10^{9}}{frx\sqrt{\varepsilon_r}}$

Substrate length: $L_g = 6h + \alpha$

Substrate width: $W_g = 6h + \frac{\pi}{2}\alpha$

Feedline length: which one $L_f = \frac{1}{4}\lambda d \lambda d = \frac{\lambda 0}{\sqrt{\varepsilon_r}} \lambda 0 = \frac{c}{fr}$

Feedline width: $w_f = \frac{2h}{\pi}\left\{B - 1 - \ln(2B - 1) + \frac{\varepsilon_{r-1}}{2\varepsilon_r}[\ln(B-1) + 0{,}39 - \frac{0{,}61}{\varepsilon_r}]\right\}$

which $B = \frac{60\pi^2}{Z0\sqrt{\varepsilon_r}}$

3.2 Metamaterials

Metamaterial is a word that comes from Greece and is a combination of "meta" and "material", where is "meta" refers to Something that beyond the normal meaning, changing, transforming, or forward. It is an artificial material that Aims to reach physical properties that are not found on natural materials. Metamaterial terms Introduced by Rodger M. Walser in University of Texas at Austin in 1999 (Fabiana Meijon Fadul, 2019)

Metamaterials (MTMs) are engineered materials with unusual electromagnetic (EM) properties that are not found in natural materials. Metamaterials are also called engineered composite materials. This is an amazing discovery of modern science and has managed to fascinate researchers. In recent decades, research on EM-MTMs for use in the microwave region has attracted great interest from researchers. There are different types of metamaterials, such as single negative (SNG), double negative (DNG), and double positive (DPS).

3.3 Properties of metamaterial properties

The properties of this matematerial are as follows:

Maxwel equation

$\nabla \times E = -j\omega H\mu$

$\nabla \times H = j\omega\varepsilon E$

where E and H are the vectors of electric and magnetic field strengths, respectively; ε and μ are material permittivity and permeability; ω is the frequency of the angle.

$$E = E_{0^{e^{(-jkr+j\omega t)}}}$$

$$H = H_{0^{e^{(-jkr+j\omega t)}}}$$

To evaluate the properties of materials, the general definition of the Poynting power density vector S, which is subdivided into time e + jωt and space component e−jkr. The real part of the Poynting S vector, which determines the energy flow, is represented by the following formula:

S= 1E × H

For field waves, the electric field E and the magnetic field H are defined by

$$k \times E = \omega\mu H$$

$$k \times H = -\omega\varepsilon E$$

For homogeneous media, ε and μ are simultaneously positive. In this medium, E, H, and k form a triad of orthogonal vectors of the right circulation. Therefore, it is also defined as a right-handed medium (RHM), where S, k have the same direction and electromagnetic waves can propagate within it.

In this case, the ε and μ values are negative at the same time; so, Equation, can be rewritten as:

$$k \times E = -\omega\ |\mu|\ H\ ;$$
$$k \times H = \omega\ |\varepsilon|\ E$$

The classification of metamaterials is determined based on the value of permittivity (ε) and permeability (μ). Find that there are materials, namely materials which include the following:

3.3.1 DPS Material

These materials are located in the first quadrant and have positive parameters of ε and μ, Therefore, these materials are called double positive materials (DPS) or right-handed materials (RHM). These materials are found in nature, such as dielectric materials through which electromagnetic waves propagate. A double positive material is a material that is ε and μ both positive ($\varepsilon > 0$, $\mu > 0$). This type of material has a positive refractive index and waves propagate forward according to the rules of the right hand. (Nur, 2022) (Adiwiguna et al., 2019).

3.3.2 ENG

Materials These materials are located in the second quadrant, the parameter is negativeThe metamaterial Epsilon (engs) is a material with negative permittivity and positive magnetic permeability ($\varepsilon < 0 > 0$). Therefore, this material is called negative epsilon material (ENG). For example, plasma. These materials create shunt inductance and radiation patterns due to the electric current within the material. The TL unit cell model is based on a combination of shunt capacitance and series inductance (Nur, 2022) (Adiwiguna et al., 2019)

3.3.3 DNG Material

The material is in the third quadrant. Double negative materials (DNGs) have negative permeability and negative permittivity, and materials with ε and μ less than zero ($\varepsilon < 0 > 0$, $\mu < 0$) are called mu-negative materials. For example, the characteristics of gyrotropic materials at certain frequencies ("Electromagn. Appl.," 1989).

3.4 Types of Metamaterial

3.4.1 Electromagnetic (EM) Metamaterials

Electromagnetic (EM) metamaterials consist of traces and particles in a dielectric matrix. This EM metamaterial refractive index is zero or negative. Applications such as stereo beams, antenna domes, modulators, lenses, microwave couplers, and bandpass filters use these materials extensively.

3.4.2 Photonic Metamaterials

Photonic metamaterials have a zero refractive index, and these metamaterials are the latest research area in the field of optics. Photonic metamaterials are artificially created periodic sub-wavelength structures designed to interact with optical frequencies.

3.4.3 Acoustic Metamaterials

Two or three different materials with different mass densities and bulk modulus make up acoustic metamaterials. This type of metamaterial has a negative effective mass density and a negative bulk modulus.

3.4.4 Mechanical Metamaterials

Mechanical metamaterials are engineered composite metamaterials that are made up of different types of mechanical properties. This metamaterial has a negative Poisson ratio, negative modulus, zero shear modulus, and friction properties (Ashby, 2010).

3.5 Application of Metamaterial

The Application is as follows:

3.5.1 Metamaterials as absorbers

Metamaterial absorbers (Landy et al., 2008) is a type of metamaterial structure designed to efficiently absorb electromagnetic radiation such as light. Metamaterial absorber applications include use in transmitters, photodetectors, sensors, spatial light modulators, infrared enclosure, wireless communications, and photovoltaics and thermal photovoltaics.

3.5.2 Metamaterials as Super Lenses

Super lenses are lenses that use metamaterial structures that exceed the diffraction limit. The diffraction limit is a feature of conventional lenses and microscopes that limits the subtlety of the resolution. The rapid wave passes from memory, which is a non-propagation component, not transmitted. Matemateria1 as a cloak. Steering, the object remains in the specified position, but the incoming wave is guided around the object without being affected by the object itself.

Metamaterials open up the possibility of designing sensors with a certain sensitivity. Metamaterials provide the tools to significantly improve the sensitivity and resolution of sensors. Metamaterial sensors are used in agriculture, biomedicine, etc. In agriculture, sensors are based on resonant materials and use SRR to improve sensitivity. Wireless strain sensors are widely used in biomedicine. Nested SRR-based strain sensors are developed to improve sensitivity.

3.5.3 Metamaterials as Phase Comparators

DPS has a conventional positive refractive index, while DNG has a negative refractive index. Both plates have an impedance that is adapted to outdoor areas (such as open spaces). In this configuration, the desired monochromatic field wave is emitted. As these waves travel through the first plate of material, there is a phase difference between the outgoing and incoming surfaces. As the wave travels through the second plate, the phase difference is significantly reduced and equalized. Therefore, when the wave leaves the second plate, the total phase difference is.

3.5.4 Metamaterials in Antenna Design

The metamaterials layer is used ti improve the radiation and matching properties of electrical and small magnetic dipole antennas. The power emitted is amplified by metamaterials. Ninety-five percent of the 350 MHz input radio signal is emitted by modern metamaterial antennas, i.e. experimental metamaterial antennas that are only one-fifth their wavelength. Patch antennas have increased directivity due to metamaterial enclosure.

4 Conclusion

An antenna is a means or device that converts electrical signals (voltage/current) into electromagnetic signals, one of which is a microstrip antenna

Metamaterial is a word that originated in Greece and is a combination of "meta" and "material", where "meta" refers to something that goes beyond the meaning of normal, changing, transforming, or advancing

- Types of metamaterials
    1. Electromagnetic (EM) Materials
    2. Photonic Metamaterials
    3. Acoustic Metamaterials
    4. Mechanical Metamaterials
- Application of Metamaterials
    1. Metamaterials as absorver
    2. Metamaterials as super lenses
    3. Metamaterials like robes
    4. Metamaterials as sensors
    5. Metamaterials as Phase Compensators
    6. Metamaterials as antenna designers

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