FREQUENCY RECONFIGURABLE METAMATERIAL RESONANT ANTENNA

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To my beloved parents: Hon. Engr. Mustapha Alkali Gajibo and mothers Hajja Yagana Mustapha and Hajja Safiya Tijjani.

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ABSTRACT

New paradigm has been engineered to exhibit reverse electromagnetic properties. Novel composite and micro-structured materials (metamaterials) have been designed to control electromagnetic radiation. Such substances have been called as Left Handed Material (LHM) with simultaneous negative or positive permittivity, permeability and refractive index or mixed positive and negative. This engineered paradigm was be used to implement the proposed antenna. The proposed frequency reconfigurable metamaterial antenna is a coplanar waveguide (CPW)-fed matamaterial antenna using an epsilon negative transmission line. The resonance frequencies are reconfigured and also reconfiguration from narrow to wideband was also implemented. The reflections coefficient, bandwidth and surface current of the designed antenna were studied and analyzed. The antenna configuration consist of a signal patch, coplanar ground planes, microstip lines (switches) for varying or selecting frequencies. The switches connect the signal patch with the coplanar ground plane to realize increase in inductance L_L, which is proportional to the length of the patch, where the switch is located. Since it is very difficult to realize large inductance in microstip lines, a coplanar waveguide was used. The shunt capacitor C_R, is obtained from the coupling between the signal patch. Reconfigurability functionality was realized with the help of switches (microstrip lines) incorporated into the antenna. The narrow to wideband configuration is realized by selecting various combinations of those switches. A measured radiation efficiency of more than 70% and gain greater than 1dB was obtained for the narrowband configuration. On the other hand, a measured radiation efficiency of more than 80% and gain greater than 1dB was obtained for the wideband configuration. Computer Simulation Technology (CST) microwave studio was employed as the simulation tool and measurement of the result were obtained via Vector network analyser (VNA).

ABSTRAK

Paradigma baru telah untuk mempamerkan sifat-sifat elektromagnet balikan. Komposit novel dan bahan bahan mikro-struktur tela dirancang utuk mengawal sinaran elektromagnet. Bahan bahan tersebut telah dipanggil sebagai metabahan tangan kiri (LHM) dengan ketelusan negatif atau positif serantak, keboleh telapan dan indeks pembiasain atau positif dan negatif campuran. Paradigma teraka bentuk ini telah digunakan untuk melaksanakan ialah antena metabahan frekuensi boleh konfigurasi semula yang dicadangkan ialah antena metabahan sesatah pandu gelombang (CPW) menggunakan garis transmisi negatif epsilon. Frekuensi gema dikonfigurasi semula dari sempit ke jalur lebar. Pantulan pekali, lebar jalur dan arus permukaan antena yang dirangcang telah diteliti dan diabalisis. Konfigurasi antena terdiri daripada isyarat tampal, satah bumi sesatah dan garis mikrojalur (suis) untuk membezakan atau memilih frekuensi. Suis menghubungkan antara isyarat tampal dengan satah bumi sesatah untuk merealisasikan peningkatan dalam aruhan L_L, yang berkadar kepada panjang tampal, dimana suis ditempatkan. Oleh sebab sukur untuk merealisasikan aruhan besar dalam garis mikrojalur, pandu gelombang sesatah ttelah digunakan. Kapasitor pengalih C_R, diperoleh daripada pengganding di antara isyarat tampal. Fungsi kebolehkonfigurasi telah direalisasi dangan bantuan suis-suis (garis mikrojalur), digabungkan ke dalam antena. Pengkonfigurasian sempit ke jalur lebar direalisasi dengan memilih pelbagai kombinasi suis-suis tersebut. Kecekapan pengukuran sinaram melenihi 70% dan gandaan melebihi 1dB telah diperoleh untuk konfigurasi jalur sempit. Pada masa yang sama, kecekapan pengukuran sinaran melebihi 80% dan gandaan melebihi 1dB telah diperoleh untuk konfigurasi jalur lebar. Gelombang mikro teknologi simulasi computer (CST) telah digunakan sebagai peralatan simulasi dan dapatan pengukuran telah diperoleh melalui penganalisis jaringan vector (VNA).

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CHAPTER 1

INTRODUCTION

1.1 Background of study

The evolution of metamaterial is from naturally occurring electromagnetic materials. A number of procedures were established in order to extract or combine useful substance from natural occurring ones. This is done by either splitting, combining, restructuring or rearranging their particles. This ability shown or developed by man to create or manipulate a naturally existing substance to form a new structure is an extraordinary achievement in human history.

Manipulation or tempering with the structural properties of these substances yields an unusual properties which could be desirable for a certain applications.

1.2 Prolem statement

In the modern world where technology has advanced and progressed, the demand for portable multi-functional mobile communication devices is at high rise. Antenna as a front component is required to have a wideband, good radiation performances and in some cases ability to switch operating frequency. The reconfigurable characteristics of antennas are very valuable for many modern wireless communication and radar system applications, such as object detection, secure communications, multi-frequency communications, vehicle speed tests and many more. Besides, the reconfigurable antenna can also operate within multiple systems by just using a single antenna. For example, a single antenna can be used for both WLAN 2.4 GHz and 5.8 GHz by reconfiguring their dual-band operation.

The ideology of using metamaterial for antenna design seems to be profitable in bid to achieve these desires because of its advantage in size reduction. The exotic property of CRLH unit cell that allows merging of independent resonant modes on a single pass-band is exploited. Furthermore, since the zeroth order mode of the CRLH unit cell supports an infinite wavelength, then a more compact size of the antenna can be realized with smaller footprint so that it can be integrated into small and compact size wireless devices.

1.3 Research Objectives

With the recent advancement in technology as mentioned earlier, devices tend to become even more and more smaller. In addition to that, more functionalities are integrated into these devices. These additional functionalities increases the complexity of these devices and give rises to the need for such devices to operate under various frequencies. It is not practical to have a separate antenna for each function or application on a device, instead, the idea of a single compact antenna with the ability to operate in different circumstances or for various applications in such device is being examined. Metamaterial is used in order to gain the compactness required but these devices.

Therefore the objectives of this project are summarized as follows:

- To design and simulate frequency reconfigurable metamaterial antennas.

- To integrate frequency reconfigurability into the antennas with the help of ideal switches.

- Fabricate the frequency reconfigurable antennas

- To compare and characterized the performance of the simulated and fabricated antennas.

1.4 Scope of Works

This project will focus on the study of frequency reconfigurable metamaterial antenna with more emphasis on its performance properties such as impedance bandwidth, gain and directivity under different selected frequencies.

•The first part involves obtaining the metamaterial antenna design structure and study the various characteristics and performance as listed above.

•The second part involve the realization of the frequency reconfigurability and carry out similar study on its characteristics and performance.

•The final part involves fabrication and testing of the antenna to ascertain the result.

Computer simulation tool (CST-MW studio) will be used for result simulation and Vector Network Analyzer (VNA) and Anechoic Chamber for results measurements.

1.5 Project Report Outline

Chapter 1 introduces metamaterial from antenna's point of view, it further elaborated or gave overview of the project work, problem statements, objective and scope of project.

In chapter 2, the basics of metamaterials, the unusual properties of metamaterials such as negative permittivity and permeability and the left handed phenomenon have been discussed. Also previous work done on metamaterials in relation to frequency reconfigurable antennas were discussed and summarized.

Chapter 3 discusses details on methodology and the flow of the project work. Here, more details were given on the structure of the antenna. In addition, detailed fabrication and measurements process used were discussed.

Chapter 4 describes the configurations and operating principles of the antenna. It discussed more on the narrowband and wideband operations. It compared Simulated and measured results such as S_{11} and radiation patterns of the two. It gave insight of the current distribution in the various configurations.

Chapter 5 concludes the project report and gives recommendations for future work.

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