LEFT-HANDED METAMATERIAL INCORPORATED WITH MICROSTRIP ANTENNA

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

FEBRUARY 2010

To my beloved father and mother for their understanding and support throughout my quest in completing my Master

ACKNOWLEDGEMENT

First of all, thanks to our creator for the continuous blessing and for giving me the strength and chances in completing this project.

Special thanks to my project supervisor, Associate Prof. Dr. Mohamad Kamal A. Rahim, for his guidance, support and helpful comments in doing this project.

My family deserves special mention for their constant support and for their role of being the driving force towards the success of my project. My friends deserve recognition for lending a helping hand when I need them. I would also like to thank the wonderful members of P18; Dr Thelaha Masri, Mr. Mohd Nazri A Karim, Mr. Osman Ayop, Mr Farid Zubir, Mrs. Maisarrah Abu, and my middle east friends; Mrs. Mai Abdul Rahim, Mr. Alii, Mr. Hassien, Mr. Hithem, Mr. Akram, Mr. Suhil and Mr. Kusay, who have also been extremely kind and helpful throughout my stay. “We don’t remember days, but we remember moments” and my moments with these guys are very fruitful during my study in UTM.

My sincere appreciation also goes to everyone whom I may not have mentioned above who have helped directly or indirectly in the completion of my project.

ABSTRACT

Left-handed metamaterial (LHM) is an artificial material where the permittivity and permeability are simultaneously negative at a certain range of frequency. One of the unique properties of the LHM is its negative refraction index which produces focusing effect to the wave propagating through the LHM. With this unique property, the LHM structures are used to increase the low gain of the microstrip antenna. In this work, an LHM structure consists of a modified split ring resonator (MSRR) and two capacitance loaded strip (CLS) is proposed. The MSRR has four slots in the middle of the structure which create wider range of negative permittivity and permeability. The MSRR exhibits negative permeability while the CLS exhibits negative permittivity. The well-known modified Nicolson-Ross-Wier (NRW) approach has been used to determine the values of permittivity and permeability. Parametric study on the parameters of the LHM has been carried out. The gap between the CLS – MSRR, the MSRR length and the CLS width show strong influence to the resonant frequency and the range of negative permittivity and permeability. A series of LHM structures are then incorporated with different antenna type such as single patch antenna, linear polarized 2x2 array patches antenna and circular polarized 2x2 array patches antenna at operating frequency of 2.4 GHz. The simulation and measurement results such as return loss, bandwidth, gain, half power beamwidth and radiation pattern are analyzed. The gain of the antennas increased upto 4 dB while the half power beamwidth decreased upto 37 % and became directional. The bandwidth of the antennas also increased upto 60 %.

ABSTRAK

Metabahan tangan kiri (LHM) adalah satu bahan buatan yang mana kebolehtelusan dan kebolehtelapan bahan itu adalah negatif pada julat frekuensi. Salah satu sifat unik LHM adalah indeks pembiasan negatif yang menghasilkan kesan fokus terhadap gelombang yang melalui LHM. Dengan sifat unik ini, LHM digunakan untuk mengatasi gandaan rendah pada antena mikrojalur. Struktur LHM yang terdiri daripada satu penyalun cincin terpisah (MSRR) yang telah dimodifikasi dan dua kapasitans jalur muatan (CLS) dicadangkan. MSRR mempunyai empat celahan di pertengahan struktur dan ia mewujudkan julat kebolehtelusan dan kebolehtelapan negatif yang lebih luas. MSRR mempamerkan kebolehtelapan negatif sementara CLS mempamerkan kebolehtelusan negatif. Pendekatan terkenal Nicolson-Ross-Wier (NRW) yang dimodifikasi telah digunakan untuk menetukan nilai kebolehtelusan dan kebolehtelapan. Kajian parametrik pada parameter LHM telah dilakukan. Lebar celahan antara CLS - MSRR, panjang MSRR dan lebar CLS menunjukkan pengaruh yang kuat kepada frekuensi resonans dan julat kebolehtelusan dan kebolehtelapan negatif. Satu rangkaian struktur LHM kemudiannya digabungkan dengan beberapa jenis antena seperti satu antena tampal, 2x2 antena tampal tatasusun linear berkutub dan 2x2 antena tampal tatasusun berkutub bulat beroperasi pada frekuensi 2.4 GHz. Hasil keputusan dari simulasi dan pengukuran seperti kehilangan balikan, lebarjalur, gandaan, lebaralur setengah kuasa dan corak sinaran dianalisis. Gandaan antena meningkat sehingga 4 dB manakala lebaralur setengah kuasa menurun sehingga 37 % dan menjadi terarah. Lebarjalur antena juga meningkat sehingga 60 %.

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LIST OF SYMBOLS

E	-	Electric Field
H	-	Magnetic Field
D	-	Electric Flux Density
B	-	Magnetic Flux Density
ρ	-	Charge Density
S	-	Poynting Vector
P_0	-	Power Flow
ε	-	Permittivity
μ	-	Permeability
ε_r	-	Relative Permittivity
μ_r	-	Relative Permeability
n	-	Refractive Index
c	-	Speed of Light
ω	-	Radian Frequency
ω_p	-	Plasma Radian Frequency
k	-	Complex wavenumber
f	-	Frequency
λ	-	Wavelength
ξ	-	Damping Coefficient
Z	-	Impedance
β	-	Propagation Constant
σ	-	Conductivity of Metal
η	-	wave Impedance
T	-	Transmission Coefficient
Γ	-	Reflection Coefficient
υ_p	-	Phase Velocity

f_{pm}	-	Magnetic Plasma Frequency
f_{pe}	-	Electric Plasma Frequency
S_{11}	-	Return Loss
S_{21}	-	Insertion loss
d	-	Thickness of the slab (LHM)

LIST OF ABBREVIATIONS

DNG	-	Double Negative
LHM	-	Left Handed Metamaterial
NRI	-	Negative Refractive Index
NRW	-	Nicolson-Ross-Weir
TW	-	Thin Wire
SRR	-	Split Ring Resonator
MSRR	-	Modified Split Ring Resonator
CLS	-	Capacitance Loaded Strip
FSS	-	Frequency Selective Surface

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Recently, there have been frequent study and research by researchers around the world regarding the left handed metamaterial that contradict with a lot of the physics law. The unusual characteristics of these materials have yet to be found in any natural material and are considered as a new material studied in the 21st century.

Left-handed metamaterial (LHM) is an artificial material (periodic metallic structure) where the permeability and permittivity were simultaneously negative at a certain range of frequency [1]. Before venturing deeper into this topic, a brief look into the material terminology would help in understanding this peculiar artificial material. Figure 1.1 shows the terminology of the materials.

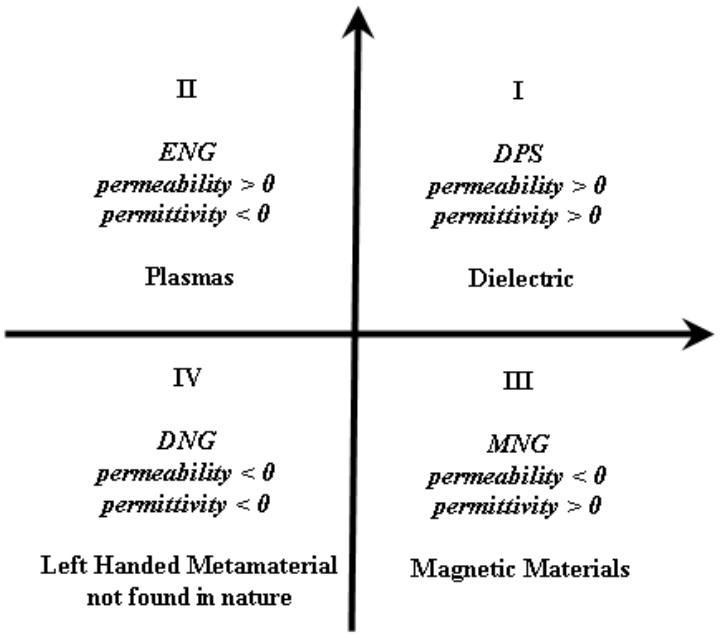

Figure 1.1: Different type of material

From the figure, the material terminology is divided into 4 groups. Group I shows the Double Positive (DPS) material which have positive value of permittivity and permeability. Almost all existing materials are DPS material and one of the examples is dielectric. For group II, Epsilon Negative (ENG) material has only permeability in positive value but the permittivity is negative. On the other hand, group III represents Miu Negative (MNG) material which is opposite of ENG material where the value of permittivity is positive and the value of permeability is negative. Lastly, the group IV shows the Double Negative (DNG) material and also known as Left Handed Metamaterial (LHM). This material has both permittivity and permeability in negative value. The works in this thesis focus on group IV material where the value of the permittivity and permeability are negative.

Left Handed Metamaterial has a few unique and unusual properties due to negative value permittivity and permeability of the structure itself. Therefore, a fair amount of explanation has to be presented in order to showcase this newly discovered material. Their properties are discussed in chapter 2. One of the unique properties of Left Handed Metamaterial is negative refraction which will produce the focusing effect. With this property, LHM will be used to focus the radiation of an antenna thus should increased the gain of the antenna.

1.2 Problem Statement

The study of the Left-Handed Metamaterial is carried out due to escalating interest in this unique material and its immense potential in various applications.

The material with negative value of permittivity and permeability is not found in nature. By applying the concept, theory and design of the Left-Handed Metamaterial, the material with negative value of permittivity and permeability can be created artificially.

Microstrip antenna suffered low gain. A comment technique to overcome this drawback is using array of patch antenna. However, this technique has drawbacks which are high feed network losses and produce mutual coupling [2]. Another method to overcome this disadvantage is by using the Left Handed Metamaterial. The integration of the Left Handed Metamaterial with the microstrip antenna will increased the gain of the microstrip antenna. With this feature, the antenna that integrates with the Left Handed Metamaterial structure can be used for longer range point to point or point to multipoint wireless communication or to extend wireless coverage.

1.3 Scope of Research

The main scopes of the research are:

i. Study the Left-Handed Metamaterial and microstrip antennas.
ii. Design, simulate and analyze Left-Handed Metamaterial using Computer Simulation Technology (CST) CAD tools.
iii. Simulate the Left-Handed Metamaterial incorporate with the single patch, 2x2 array patch and circular polarized 2x2 array patch microstrip antenna.
iv. Measurement the Left-Handed Metamaterial incorporate with the single patch, 2x2 array patch and circular polarized 2x2 array patch microstrip antenna.

v. Analyze and compare the results between simulation and measurement.
vi. Thesis write up.

1.4 Objective of Research

The main objectives of this research are:

i. To study, design, simulate and analyze the new structure of Left-Handed Metamaterial.
ii. To simulate, fabricate and measure the Left-Handed Metamaterial incorporated with the single patch microstrip antenna, 2x2 array patch microstrip antenna and 2x2 array circular polarized patch microstrip antenna.
iii. To compare and analyze the behavior and properties of the microstrip antennas incorporate with Left Handed Metamaterial.

1.5 Organisation of Thesis

Chapter 1 discusses the brief introduction of Left Handed Metamaterial, the problem statement, the objective and scope of the research as well as the organization of the thesis.

Chapter 2 explains the basic concepts and theories of the Left Handed Metamaterial. The unique properties of this material are elaborated thoroughly in this chapter.

Chapter 3 discusses on the design of the Left Handed Metamaterial using Computer Simulation Technology (CST) and MathCAD software. For the completeness of the thesis, the design equation of the single patch microstrip

antenna, 2x2 array patch microstrip antenna and 2x2 array patch circular polarized microstrip antenna are also presented.

The simulation and measurement results of the Left Handed Metamaterial incorporated with the antenna are discusses in Chapter 4.

In Chapter 5, the results of the antennas with and without Left Handed Metamaterial are analyzed in terms of return loss, gain, directivity, half power beam width and others antenna's parameters. The results are presented in a form of tables and graphs.

Lastly, Chapter 6 concludes the finding of the project, key contributions and recommendations for future research.

In addition, the list of references and appendices were listed at the end of this thesis.