SLOTTED LOG PERIODIC FRACTAL KOCH ANTENNA FOR ULTRA HIGH FREQUENCY DIGITAL TELEVISION APPLICATION

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A thesis submitted in fulfilment of the
requirements for the award of degree of
Master of Philosophy

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

MAY 2018

Specially dedicated to my beloved parent, Radziah Long and Mohd Yaziz Ahmad
my supportive husband, Muhammad Ridduan Ramli
my siblings, Syazwan, Syuhada and Syazana
with love for their prays and encouragement.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious and the Most Merciful. Alhamdulillah, all praise to Allah for all strength and His blessing in completing in this study.

Special appreciation goes to my supervisor, Prof Dr. Mohamad Kamal A. Rahim for his supervision and constant support. His invaluable help of constructive comments and suggestion have contributed to the success of this study. Not forgotten, appreciation to my Co-supervisor, Dr. Farid Zubir for his support and knowledge regarding this research.

To my colleagues at P18 members, Saidah, Afifah, Izni, Nazirah, Hafizah, Jannah, Arrauzah, Fatin, Raimi, Ezwan, Amerul, Azfar, Syazwan and Murtala for their sharing knowledge and ideas which helping me a lot. Without their help and support this study will be much harder.

My special thanks to my dearest parents, my lovely family members and my close friends who give their unconditional support, love and prayers throughout my entire journey. My deepest appreciation to my husband, Muhammad Ridduan Ramli for his understanding, moral support and endless love that are the key of my strength to complete the study.

My sincere appreciation also goes to everyone whom I may not have mentioned above who have helped directly or indirectly in the completion my project. Thank you for all your kindness and generosity.

ABSTRACT

The Ultra High Frequency (UHF) band has long been used for voice, data and video communications. For the terrestrial television broadcasting, the lower frequency band of the UHF is used which ranges between 470 to 890 MHz. The conventional UHF antennas for receiving TV signals are quite large. One method that can be utilized is by using a compact and directional antenna that can be easily fabricated. The geometry used in this antenna design is Koch curve fractal structure. The advantage of using fractals in designing the antenna is to minimize the antenna size. The Log Periodic Antenna (LPA) is chosen because it had a wide bandwidth. This thesis describes the design of the planar fractal Koch antenna with slots for the UHF band. Four different iterations which is 0^{th} iteration, 1^{st} iteration, 2^{nd} iteration and series iteration have been designed and simulated. The simulation process was done using Computer Simulation Technology (CST). The antenna has been fabricated on the Flame Retardant 4 (FR4) laminate microstrip board with dielectric constant of 5.4 and thickness of 1.6 mm. The simulation results show that the Koch curve technique can be used to minimize the length of the arm LPA, but the lower frequency tends to shift to the higher frequency as the number of iterations increases. Thus, a slot is introduced at each of the element of the Log Periodic Antenna in order to avoid the lower designed frequencies from shifting to higher band. A 28.7% reduction of the antenna size has been achieved by using slotted fractal Koch technique at the 2^{nd} iteration. All antennas have been tested and measured in terms of reflection coefficient, radiation pattern and its realized gain. The simulation and measurement results have been compared and analyzed. A good agreement was achieved with reflection coefficient, S_{11}< -10 dB for the entire UHF digital television band frequency design, directional radiation patterns with beamwidth of 75°, wide bandwidth up to 95% and an average gain of 6 dBi along the frequency range. This proposed antenna suitable for the intended application.

ABSTRAK

Jalur Frekuensi Ultra Tinggi (UHF) telah lama digunakan untuk komunikasi suara, data dan video. Untuk penyiaran televisyen terestrial, jalur frekuensi rendah UHF yang digunakan adalah antara 470 hingga 890 MHz. Kebanyakan antena konvensional UHF yang telah digunakan untuk menerima isyarat televisyen agak besar saiznya. Salah satu dari kaedah untuk memenuhi permintaan ini adalah dengan menggunakan antena kompak dan berarah. Geometri yang digunakan dalam reka bentuk antena ini adalah struktur fraktal lengkuk Koch. Salah satu kelebihan menggunakan fraktal dalam mereka bentuk antena adalah untuk mengecilkan saiz antena. Antena log berkala (LPA) dipilih kerana ia boleh menghasilkan jalur lebar yang lebih luas. Tesis ini menerangkan reka bentuk fraktal Koch dengan gabungan slot untuk antena frekuensi UHF. Empat rekabentuk yang berbeza seperti iterasi 0, 1, 2 dan sesiri telah direka dan disimulasi. Proses simulasi telah dilakukan dengan menggunakan perisian Teknologi Simulasi Komputer (CST). Rekabentuk yang diperoleh dari simulasi telah difabrikasikan dengan substrat bahan rencat nyala 4 (FR4) dengan pemalar dielektrik 5.4 dan ketebalan 1.6 mm. Hasil simulasi menunjukkan bahawa teknik geometri Koch boleh digunakan untuk mengurangkan panjang elemen LPA, tetapi frekuensi yang lebih rendah cenderung untuk beralih ke frekuensi yang lebih tinggi apabila bilangan iterasi bertambah. Frekuensi yang teranjak telah dipulih dengan memperkenalkan slot di setiap elemen LPA. Dengan menggunakan teknik slot fraktal Koch pada leleran ke-2, didapati saiz antenna berkurang sebanyak 28.7 %. Kesemua antena telah diuji dan diukur dari segi pekali pantulan, corak radiasi dan gandaan. Keputusan simulasi dan pengukuran telah dibandingkan dan dianalisa. Kesemua antena menunjukkan keputusan yang baik dengan nilai pemalar pantulan S_{11}<-10 dB pada frekuensi jalur UHF televisyen digital, corak sinaran terarah dengan lebaralur 75°, lebar jalur yang besar iaitu melebihi 95% serta gandaan purata 6 dBi sepanjang julat frekuensi. Antena yang dicadangkan adalah sesuai digunakan untuk aplikasi ini.

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LIST OF ABBREVIATIONS

BW	-	Bandwidth
CPW	-	Co-Planar Waveguide
CST	-	Computer Simulation Technology
dB	-	Decibel
dBi	-	Decibel Isotropic
DCS	-	Digital Code Squelch
DTV	-	Digital Terrestrial Video
FR-4	-	Flame Retardant-4
FKLPA	-	Fractal Koch Log Periodic Antenna
GSM	-	Global System Mobile
LPA	-	Log Periodic Antenna
LPDA	-	Log Periodic Dipole Antenna
ISM	-	Industrial Sciences Medical
PCS	-	Personal Communications Service
RF	-	Radio Frequency
RFID	-	Radio Frequency Identification
SMA	-	Sub Miniature Version A
TV	-	Television
TVWS	-	Television White Spectrum
UHF	-	Ultra High Frequency
UWB	-	Ultra Wide Band
VSWR	-	Voltage Standing Wave Ratio
WiMAX	-	Worldwide Interoperability for Microwave Access
WLAN	-	Wireless Local Area Network

LIST OF SYMBOLS

λ	-	Wavelength
c	-	Speed of light
ε_r	-	permittivity
λ_0	-	Free Space wavelength
λ_c	-	wavelength at center frequency
λ_g	-	guided wavelength
f_c	-	Center frequency
f_H	-	High frequency
f_L	-	Low frequency
h	-	Height of substrate
L	-	Length of patch
W	-	Width of patch
L_{eff}	-	Effective length

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Antenna design has grown to be one of the most active fields in the wireless communication [22]. In the early years, whilst radio frequency became determined, simple antenna design was the main tool used to transmit electrical energy or radio wave via the air in all paths [23]. The wireless technology has improved swiftly not only simply for commercial use, but also for navigation [24], [25].

In modern-day telecommunication systems, the requirement for antennas with wider bandwidth [26] and smaller dimensions [27] than conventional ones are desired. This has initiated studies of the antenna in numerous directions, one among those via the usage of fractal shaped antenna elements. In current years [28], numerous fractal geometries [29] have been brought for antenna applications with varying degrees of achievement in enhancing antenna characteristics [30]. Some of these geometries were especially beneficial in decreasing the dimensions of the antenna [31], [32] whilst other designs intended to be incorporating multi-band [33], [34], [35] behaviors. Several researches were made in designing the fractal shape properties for the antennas.

The deployment of digital terrestrial broadcasting (DTV) has stretched all over the world and Malaysia has announced their involvement since 2005 [36]. The Malaysian conventional analog TV will be replaced with DTV by 2018 [36]. DTV standard allows contents provider to transmit programs in high definition video and six channel-surround audios. The bandwidth allocation of DTV is rather extensive and

imposes the need for a broadband [9] reception antenna. In order to support the DTV front end device, a compact yet broadband [37] reception antenna which covers from 460 MHz to 870 MHz [36] [38] will be designed for the DTV receiver.

Many studies have been carried on frequency independent antennas since the late 1950s and experiments with several geometries such as spiral, biconical and fractal have been developed. Log periodic dipole array (LPDA) was firstly introduced by DuHamel and Isbell in 1957 [39] as one of the frequency independent antenna. Printed log-periodic dipole antenna has been given a great deal of interest and is becoming an attractive candidate in this area due to its merits such as a light weight, low cost, and easy to integrate [40]. Directional antenna has an advantage of higher gain [41] than omni-directional antenna because it can radiate in a specific direction. Besides, log-periodic dipole array (LPDA) antennas are extensively used in different applications due to their broadband characteristics [42], high gain [43], and low cross-polarization ratio [44]. This type of antenna was recommended at the beginning of the 1960s. In [45], Carrel demonstrated on how to design an LPDA per specifications in terms of bandwidth and directivity [46], [47].

Several antenna configurations which are totally based on fractal geometries [48], [49] had been pronounced in recent years. These were low profile antennas with slight benefits [50] and can be made operative at many frequency bands [51] and as a result, they become multifunctional [52]. In this study, the antennas with a reduced size had been obtained by using Koch curve fractal geometry with a combination of slot curve [53]. Furthermore, design equations for the antennas are acquired in phrases of its geometrical parameters such as fractal size. Antenna properties have also been linked to the fractal dimension of the geometry. In an effort to lay the principles for the understanding of the behavior of such antennas, the nature of fractal geometries is explained first, before providing the reputation of literature on antennas using such geometries.

1.2 Problem Statement

As the demands for UHF communication system have increased, a low-profile system has been drawn and brought much interest to researchers. The size of the antenna is important for making it to be a low-profile communication system. Hence, numerous methods such as using dielectric substrate, multiple layers and by optimizing the shape of the antennas have been proposed and applied to the microstrip and planar antennas.

Most televisions, whether analog or digital, need antennas to receive signals. Generally, former antenna used for television broadcasting is bulky in size and is usually placed outdoor. Therefore, this research aims to design and develop a compact log periodic dipole antenna for UHF digital TV application. The proposed antenna design will be compact in size and can be incorporated with the digital box. A new approach inspired by the fractal geometry with slot will be employed in order to design the compact antenna. Furthermore, it will provide a stable radiation pattern and gain throughout the DTV band.

1.3 Objectives

The primary objectives of this project are as follows:

i. To design and develop a new technique of size reduction in a log periodic dipole antenna for UHF/DVB TV application.

ii. To reduce the size and improve the shifting frequency of the antenna using fractal Koch technique and slotted insertion for first, second and series iterations LPA.

iii. To compare and analyze the antenna performance between simulation and measurement results in terms of reflection coefficient, radiation pattern, gain and current distributions of the antenna.

1.4 Scope of Works

The scope of this research begins with the understanding the concept and characteristics of the log periodic dipole antenna (LPDA), fractal geometries and slot techniques. The literature and the advantages of fractal antenna and slot techniques have been studied.

Four different iteration have been designed which were on 0^{th} iteration, 1^{st} iteration, 2^{nd} iteration and series iteration fractal Koch log periodic antenna. Then follow by slotted 0^{th} iteration, slotted 1^{st} iteration, slotted 2^{nd} iteration and slotted series iteration which improves more on the bandwidth performance.

The simulation process has been carried out using Computer Simulation Technology (CST) software to analyse the performance of the antennas. After the optimal design is confirmed, the designed structures are fabricated on Flame Retardant 4 (FR4) board using wet etching technique.

The antenna performances were then investigated and compared in terms of reflection coefficient, gain and radiation pattern. Lastly, all data were compiled for thesis documentation.

1.5 Thesis Outline

This thesis is organized into six chapters whereas in each chapter will describe the several aspects and design of the work. The outline of the study in six chapters is organized as follows:

A brief introduction to the UHF antenna, the principle motivation, scope of research and objectives are presented in Chapter 1.

In chapter two, the background of the log periodic antenna, UHF fractal antenna and microstrip slot antenna are discussed. Previous works on UHF antenna design which include log periodic antenna, fractal Koch antenna and slot technique are reported and summarized.

As for chapter three, it discusses the methodology of the research. The flow of work is presented, where two main work stages are described. The first stage of work which is the design and simulation are explained in detail. For the second stage of work, the fabrication and measurement of the antennas are thoroughly discussed.

Chapter four provides detailed discussions of the basic log periodic fractal Koch antenna. It starts with an explanation of the design for 0^{th}, 1^{st}, 2^{nd} and series iteration. Analysis of the suitable flare angle on the radiating element for compactness is also discussed in this chapter as a contribution to the compact design using fractal Koch geometry. The critical part of this design is to know how the parameter of the antenna affects the bandwidth of the antenna. A detailed examination of the different iteration of fractal Koch that influences the performance has been studied.

Chapter five explains the bandwidth enhancement performance of the previous antenna design with the slotted design on each of the elements. Slotted ring at the element is implemented for compactness. The size of the radiating element becomes smaller compared to its fundamental lambda.

Chapter six concludes the overall research work and discusses some potential future work. It highlights the significance of this study in this field and how it can be developed further in the future.

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