MICROSTRIP SIERPINSKI CARPET ANTENNA DESIGN

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A thesis submitted in fulfillment
of the requirement for the award of the
Degree of Master of Engineering
(Electrical-Electronics & Telecommunications)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

MARCH, 2005

To my beloved parents:

Thank you for giving me the chance to be what I can be.

ACKNOWLEDGEMENTS

I wish to express my thankfulness to my supervisor Dr Mohamad Kamal A Rahim for his invaluable guidance, patience and support through the completion of this project. I also would like to thanks En Mohammad Zoinol Abidin Abd Aziz for his help on experimental testing.

Finally, I would like to thank everyone that has been involved in this project directly or indirectly for their help and contribution.

ABSTRACT

Low cost of fabrication and low profile features of microstrip antennas, attract many researchers to investigate the performance of this antenna in various ways. Fractal antenna is a new member in the family of antennas. They have peculiar properties that make them suitable for applications where wideband and multiband are important parameters of the overall performance. Fractal technology allowed us to design miniature antennas and integrate multiple telecommunication services such as cellular (GSM 900 and GSM 1800), wirelessLAN, GPS and hiperLAN2 into a single device. Microstrip sierpinski carpet antenna and sierpinski carpet monopole antenna are designed in this project. The main objective of this project is to design a multiband antenna. The design involved simulations, fabrications and measurements. Mathcad 2001 is used to obtain the size of the basic square patch antenna and simulation was done using Micropatch v.2 and Microwave Office. The fabrication and testing was done at Wireless Communication Centre (WCC). Wideband and multiband operation was observed in sierpinski carpet monopole antenna.

ABSTRAK

Ciri-ciri antena microjalur yang berprofil rendah dan kos fabrikasi yang murah telah membuka laluan kepada para penyelidik untuk mengkaji prestasi antena ini dalam pelbagai cara. Antena pecahan ini masih dikategorikan baru dalam antenna. Antena pecahan ini mempunyai ciri-ciri khusus yang membolehkan ia digunakan dalam aplikasi yang mana jalur lebar dan jalur banyak merupakan parameter yang penting bagi menentukan prestasi keseluruhan. Teknologi pecahan ini membenarkan kita merekabentuk antena yang bersaiz kecil dan memuatkan pelbagai servis telekomunikasi seperti GSM (GSM 900 dan GSM 1800), wirelessLAN, GPS dan hiperLAN2 didalam satu peranti sahaja. Antena tampal pecahan mikrojalur dan antena hamparan tegak direka dalam projek ini. Objektif utama projek ini adalah untuk merekabentuk antena yang mempunyai banyak jalur frekuensi. Proses yang terlibat dalam merekabentuk antena ini ialah simulasi, fabrikasi dan pengukuran. Program Mathcad 2001 digunakan bagi mendapatkan saiz antena segiempat tampal dan simulasi dilakukan menggunakan Micropatch v.2 dan Microwave Office. Fabrikasi dan pengukuran dilakukan di makmal Pusat Perhubungan Tanpa Wayar (WCC). Antena hamparan tegak dapat beroperasi dalam jalur lebar dan banyak frekuensi.

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LIST OF SYMBOLS

BW	Bandwidth
f	Frequency
L	Length of the Microstrip Patch Antenna
W	Width of the Microstrip Patch Antenna
h	Substrate thickness
$\tan \delta$	Loss tangent of dielectric material
V	voltage
G	Gain
ε_r	Relative Permittivity
ε_{eff}	Effective Relative Permittivity
ΔL	Fringe factor
c	Velocity of electromagnetic waves in free space
VSWR	Voltage standing Wave Ratio
CW	Clock wise
CCW	Counter clock wise

CHAPTER I

INTRODUCTION

1.1 Project Background

Modern telecommunication systems require antennas with wider bandwidths and smaller dimensions than conventionally possible. This has initiated antenna research in various directions, one of which is by using fractal shaped antenna elements. In recent years several fractal geometries have been introduced for antenna applications with varying degrees of success in improving antenna characteristics. Some of these geometries have been particularly useful in reducing the size of the antenna, while other designs aim at incorporating multi-band characteristics. Yet no significant progress has been made in corroborating fractal properties of these geometries with characteristics of antennas.

Several antenna configurations based on fractal geometries have been reported in recent years. These are low profile antennas with moderate gain and can be made operative at multiple frequency bands and hence are multi-functional. In this work the multi-band (multifunctional) aspect of antenna designs are explored further with special emphasis on identifying fractal properties that impact antenna multi-band characteristics. To lay foundations for the understanding of the behavior of such antennas, the nature of fractal geometries is explained first, before presenting the status of literature on antennas using such geometries.

Fractal geometry allows us to design a miniature antenna and integrate multiple telecommunication services into single device. One of the most relevant trends for wireless devices is miniaturization. Miniaturization become important for the next generation of antennas for wireless applications which have to integrate multiple services such as cellular (GSM 900 and GSM 1800), wireless LAN 2.4 GHz, GPS 1.575 GHz, radio and hiperLAN2 5.25GHz into one device such as handsets, laptops and PDAs. In this situation, we need the smallest antenna to make use of the available wireless service and for coverage of the different frequency bands is made possible with multiple-band antenna design.

1.2 Objective

Objective of this project is to design and fabricate a multi band antenna using sierpinski carpet fractal antenna and microstrip fractal antenna. Parameters that influence antenna's performance in term of matching and bandwidth are studied to achieve this objective. Design and fabrication processes are based on simulation using Microwave Office.

1.3 Scope of Work

Scope of this project:-

i. Design and fabricate a sierpinski carpet fractal antenna and a microstrip fractal antenna.
ii. Investigate the performance of the sierpinski carpet fractal antenna and microstrip fractal antenna.

1.4 Dissertation Overview

In this dissertation, several topics are covered and they are organized into six chapters. This first chapter, the introduction to the project, gives an explanation of the objective, scope of work and project background.

Chapter II begin with the description of antenna characteristics. This is followed by discussion of relevant theory and literature review on the designed antenna structures. Matching techniques and method of analysis are also presented.

Chapter III presents the antenna design procedure and the fabrication of the designed antennas. This chapter discusses the design of basic microstrip square patch antenna and microstrip fractal patch antenna.

Chapter IV presents brief description of software used in designing and simulating the antenna structures. Some examples of the simulation results are included.

Chapter V presents some results and analysis that obtained from simulation and measurement.

Chapter VI presents the conclusions for this thesis. Some ideas for future works of this project are suggested.

CHAPTER II

ANTENNA THEORY

2.1 Introduction to the antenna

Antenna is the device for radiating or receiving electromagnetic wave in free space. The antenna is the interface between transmission line and free space. Antenna passive is the reciprocal devices. It can be used for transmitting or receiving signal. Antenna active is not the reciprocal devices.

Passive antenna has various shape and geometries such as wire antennas, aperture antennas and printed antennas. Dipole antennas, loop antennas and helix antennas are classified as wire antennas while horn antennas and slot antennas are classified as aperture antennas. For printed antennas, there have patch antennas and printed slot antennas. Patch antennas is being discuss further in this chapter.

2.2 Antenna Properties

To describe the performance of an antenna, definitions of various properties are necessary. Some of the basic properties of antennas are discussed below.

2.2.1 Impedance

The input impedance of the antenna must identically match the characteristic impedance of the transmission line in order to achieve maximum energy transfer between a transmission line and an antenna. If the input impedance of the antenna does not match with the characteristic impedance of the transmission line, a reflected wave will be generated at the antenna terminal and travel back towards the energy source. This reflection of energy results in a reduction in the overall system efficiency. This loss in efficiency will occur if the antenna is used to transmit or receive energy.

2.2.2 Voltage Standing Wave Ratio (VSWR)

VSWR is the ratio between the maximum voltage and the minimum voltage along the transmission line. The equation of VSWR is given by:

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{2.1}$$

Where $\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$ (2.2)

Where Γ = reflection coefficient

Z_L = load impedance

Z_0 = characteristic impedance

The VSWR indicate that how closely or efficiently an antenna's terminal input impedance is matched to the characteristic impedance of the transmission line. The large number of VSWR, the greater the mismatch between the antenna and the transmission line.

In many systems, the antenna is required to operate with a VSWR better than 1.5:1 with a 50 Ω impedance. Therefore an antenna VSWR should be closely to the 50Ω of the antenna impedance. The system are perfectly match if the VSWR equals to 1:1 where there is no power reflected and all the energy are absorbed at their input terminal.

2.2.3 Bandwidth

Bandwidth refers to the range of frequency that the antenna will radiate effectively where the antenna meets a certain set of specification performance criteria. An antenna that operates over a wide frequency range and still maintain satisfactory performance must have compensating circuits switched into the system to maintain impedance matching. The relationship between VSWR and the bandwidth are shown in figure 2.1.

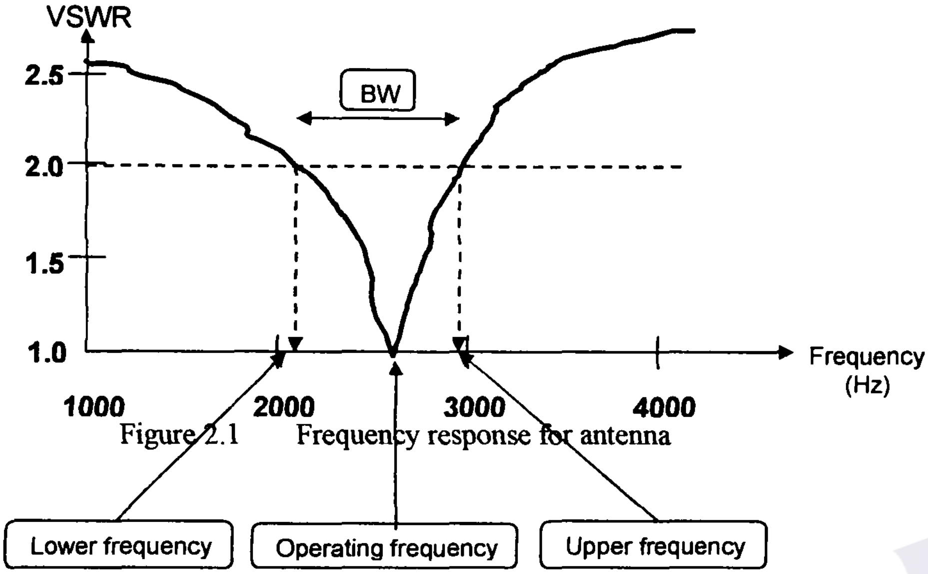

Figure 2.1 Frequency response for antenna

To determine the bandwidth on the input return loss graph, the difference in frequency is taken at the points where the curve cut the -10dB level. The difference then divided by the resonant frequency to give the percentage bandwidth. In a similar manner, the VSWR bandwidth is taken to be the range of frequency that correspond to a VSWR of less then 2. These can be expressed by:

$$-10dB\%BW = \frac{f_{hi} - f_{lo}}{f_r} x100\% \qquad (2.3)$$

$$VSWR\%BW = \frac{f_{hi} - f_{lo}}{f_r} x100\% \qquad (2.4)$$

Where f_{hi} = upper frequency

f_{lo} = lower frequency

f_r = operating frequency

2.2.4 Radiation pattern and Half power beamwidth (HPBW)

An antenna's radiation pattern is the characteristics that most affect system coverage and performance. The radiation pattern of antenna simply describes how an antenna focuses or directs the energy it radiates or receives. All antennas do not radiate more total energy than is delivered to their input connector. Antenna radiation pattern are typically presented in the form of a polar plot for a 360° angular pattern in one of two sweep planes and it is presented on a relative power dB scale as shown in Figure 2.2.

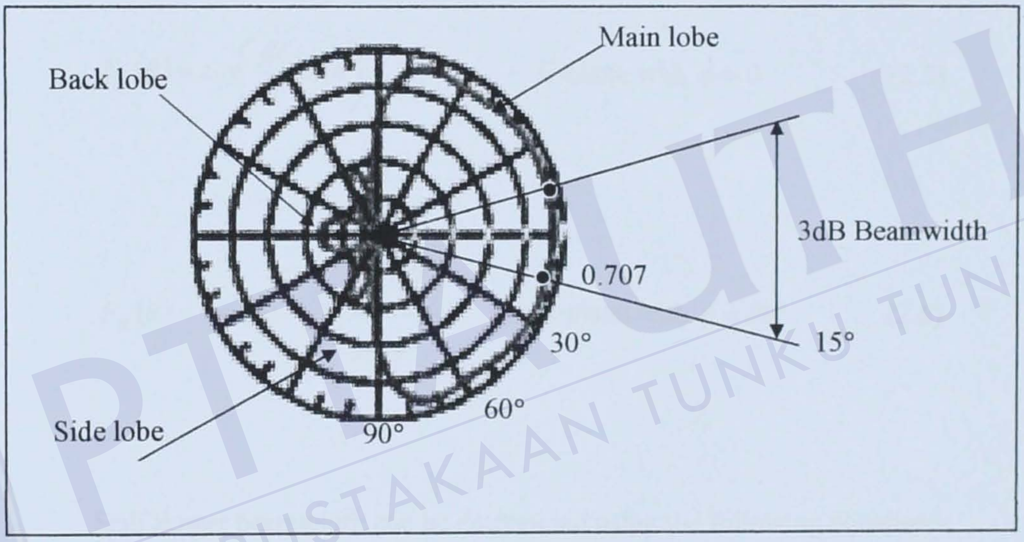

Figure 2.2 Radiation pattern and 3dB Beamwidth

From Figure 2.2, the field strength drops to 0.707 (measure in μ(V/m)) of the maximum voltage at the center of the lobe. These points are known as the half power points.

The other radiation pattern properties of significance are the antenna's side lobes, back lobes and front to back ratio (f/b). In practice, it is impossible to eliminate antenna side lobes and back lobes completely. Antenna side and back lobes affect antenna and system performance in several ways. First, energy delivered to or received by side and back lobes is from a direction other than the intended region of coverage and is therefore wasted. At a transmitter, energy delivered to side and back lobes maybe directed towards other receive systems causing interference. Then at a receiver, energy from other transmit sites may be receive through the side and back lobes causing interference within the system.

The radiation pattern can be expressed in a mathematical equation:

$$F_E(\theta) = cos\left(\frac{\beta\ell}{2} sin\,\theta\right) \qquad \text{E-plane with } \phi = 0 \qquad (2.5)$$

$$F_H(\theta) = cos(\theta)\frac{sin\left(\frac{\chi\ell}{2} sin\,\theta\right)}{\frac{\beta\ell}{2} sin\,\theta} \qquad \text{H-plane with } \phi = 90° \qquad (2.6)$$

Half Power beamwidth can be determined using the following equation:

$$\theta_E = 2\,cos^{-1}\left[\frac{7.03}{2k_0^2L^2 + k_0^2h^2}\right]^{\frac{1}{2}} \qquad (2.7)$$

$$\theta_H = 2\,cos^{-1}\left[\frac{1}{2\left(1 + \frac{k_0L}{2}\right)}\right]^{\frac{1}{2}} \qquad (2.8)$$

2.2.5 Gain

In the definition of the antenna gain level, an isotropic antenna is typically used as a reference standard. An isotropic antenna is a theoretical antenna radiating energy equally in all direction of space. This antenna has a directivity of 0 dB since energy is distributed equally in all direction. The gain of an antenna must equal to its directivity if the antenna 100% efficient. The gain of an antenna is therefore equal to the directivity less any losses in the antenna. Gain which referred to an isotropic radiator is expressed as "dBi". Gain referred to a half wavelength dipole, which has an isotropic gain of 2.16 dBi.

$$\text{Directivity, } D = \frac{4\pi U}{P_{rad}} \tag{2.9}$$

Where U = radiation intensity

P_{rad} = total radiated power

$$\text{Efficiency, } \eta = \frac{R_{radiated}}{R_{radiated} + R_{dielectric}} \tag{2.10}$$

Where $R_{radiated}$ = radiation resistance

$R_{dielectric}$ = dielectric resistance

$$\text{Gain, } G = \eta D \tag{2.11}$$

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