DESIGN OF FRACTAL MINKOWSKI DIVERSITY ANTENNA FOR LTE AND WIFI APPLICATION

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ABSTRACT

The 4th Generation (4G) in which world has recently entered and many of the bigger operators and vendors have started deploying 4G networks in different countries. 4G includes higher releases of following two standards: Wireless Interoperability Microwave Access (WiMAX) and Long Term Evolution (LTE). In this project, the Minkowski fractal Array Diversity antenna is introduced.

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. The purpose of this project is to design microstrip patch antenna and execute the first iteration Minkowski fractal Array Diversity antenna in order to achieve an antenna with multi-band frequency of 1.8 GHz and 2.4 GHz for LTE system and WIFI. Design process involves a mathematical analysis, simulation and fabrication process. Fractal antenna properties were observed from the measurement of return loss, standing wave ratio (SWR), bandwidth and radiation pattern.

ABSTRAK

Dunia telah memasuki ena Generasi ke-4 (4G) dan banyak pengendali yang lebih besar dan vendor telah mula menggunakan rangkaian 4G di negara-negara lain. 4G termasuk siaran yang lebih tinggi daripada yang berikut dua piawaian: Wireless Interoperability Akses Gelombang Mikro (WiMAX) dan Evolusi Jangka Panjang (LTE). Dalam kertas projeh, Minkowski Array fraktal Kepelbagaian antena diperkenalkan.

Geometri fraktal membolehkan kita untuk mereka bentuk antenna yang kecil dan mengintegrasikan pelbagai perkhidmatan telekomunikasi merakabentuh dalam peranti tunggal. Salah satu trend yang paling relevan untuk peranti wayarles adalah pengecilan, saiz Tujuan projek ini adalah untuk mereka merakabentuh bentuk antenna tampal dan melaksanakan lelaran pertama Minkowski Array fraktal Kepelbagaian antena untuk mencapai antena dengan dua frekuensi 1.8 GHz dan 2.4 GHz untuk sistem LTE dan WIFI. Proses reka rekebentuh ini bentuk melibatkan analisis, simulasi, fabrikasi dan proses matematik. Ciri-ciri antena fraktal diperhatikan dari pengukuran rugi balasan, berdiri nisbah gelombang (SWR), jalur lebar dan conah radiasi.

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LIST OF ABBREVIATIONS

λ	Free space wavelength
f	Operating frequency
c	Speed of light
ε_r	Dielectric constant
D	Directivity
G	Gain
E	Efficiency
W	Width
L	Length
h	Substrate thickness
ΔL	Extended length due to fringing field effect
L_{eff}	Effective length
PCB	Printed circuit board
SWR	Standing wave ratio
VSWR	Voltage standing wave ratio
RL	Return loss
RCHP	Right hand circular polarization
LHCP	Left hand circular polarization
HPBW	Half power beamwidth
dB	Decibel
Z_{in}	Input impedance
Z_o	Characteristic impedance
S_{11}	Return loss or Reflection Coefficient (dB)
Γ	Reflection coefficient
R_{in}	Antenna resistance
X_{in}	Antenna reactance

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CHAPTER I

INTRODUCTION

1.1 Background

The 4th Generation (4G) in which world has recently entered and many of the bigger operators and vendors have started deploying 4G networks in different countries. 4G includes higher releases of following two standards: Wireless Interoperability Microwave Access (WiMAX) and Long Term Evolution (LTE). In this project, we shall study the technologies used to implement wireless interface of LTE. LTE uses Orthogonal Frequency Division Multiplexing (OFDM) as downlink access scheme and Single Carrier Frequency Division Multiple Access (SC-FDMA) as uplink access scheme. To improve diversity it uses multi antenna techniques called Multiple Input Multiple Output (MIMO) antenna systems on both sides of communications, introducing the concepts of Smart Antennas. Smart antenna can be helpful to achieve the requirements of WLAN, handover process and LTE 4G applications.

LTE is a new high-performance air interface standard for cellular mobile communication systems. It is one step toward the 4th generation (4G) of radio technologies designed to increase the capacity and speed of mobile telephone networks. LTE provides ultra-broadband speeds for mega multimedia applications by using a high performance antenna [1]. Substantially improving end-user throughputs, sector capacity and reduce user plane latency to deliver a significantly improved user experience. Mobile communication technologies develop at different frequencies range from 400 MHz to 4 GHz with bandwidth up to 20 MHz [1]. LTE technology facilities multiple antennas performance both transmit and receive operation to support high data rate application.

LTE service [2] can provide a better mobile communication quality than the existing GSM and UMTS services, mobile devices are desired to be able to cover the existing service bands and LTE bands at the same time. Some diversity antenna has been demonstrated for mobile terminals to cover the wireless frequency bands LTE/PCS1900/WLAN/GPS with high isolation between ports [3-5].

The use of multi-element antenna arrays has proven to be an effective means of turning multipath propagation to an advantage in wireless communication systems, by exploiting the diverse propagation characteristics of multipath components to increase the robustness of communication through diversity techniques, or the capacity of wireless links through spatial multiplexing of multiple symbol-streams. MIMO communication channel created when there are antenna arrays at both the transmitter and receiver through the use of sophisticated signal processing techniques, MIMO communication can offer a high link of capacity, enhance resistance to interference and link robustness or reduction in fading.

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. The miniaturization technique is one of the most relevant trends for wireless and telecommunication services as it becomes next generation of antennas for these applications which needed in multiple services. The design of this project will focus minkowski island fractal diversity antenna with multi-band frequency of 1.8 GHz and 2.4 GHz for LTE system and WIFI.

1.2 Problem Statement

LTE system for communication of high-speed data has been widely researched, which creates high demand for wideband unidirectional antennas to accommodate several wireless communication systems including the LTE system with excellent electrical characteristics such as wide impedance bandwidth, a symmetric radiation pattern, and stable gain over the operating band for signal quality, cost effectiveness, space utilization, and environmental friendliness. In the last few years, the dramatic development of telecommunication technology brought the need for devices that entail their parts to be ever smaller and lighter and also capable of operating optimally at many different frequencies simultaneously.

In many cases the use of fractal antennas can simplify circuit design ,reduce construction costs and improve reliability, furthermore they are self-loading, no antenna parts such as coils and capacitors are needed to make them resonant. Arranging the elements in a fractal pattern to reduce the number of elements in the array and obtain wideband array for multiband performance, consequently fractal shape antenna are becoming a useful way to design advanced antennas such as multiband antennas with approximately the same input characteristics for different frequency bands [6-7] ,and also as small size antennas. Other fractals have also been explored to obtain small size and multiband antennas such as Hilbert curve fractal, the minkowski island fractal [7], and the Koch fractal. This study presents the use of two different application LTE system and WIFI which will both satisfied the requirement of their application by using this type of design antenna of minkowski island fractal and simulation, which will give dual-band antenna, by using CST microwave studio.

1.3 Objective of the Project

The objective of this project is

I. To design of minkowski fractal diversity antenna for LTE system and WIFI
II. To fabricate the minkowski fractal diversity antenna and test the performance of the antenna experimentally

1.4 Scope of the Project

The scope of the project will consist of two main parts simulation and fabrication. The proposed antenna will focus on the following areas:-

I. Design and model a dual-band antenna with resonant frequency of 1.8 GHz and 2.4 GHz using CST software.
II. Investigate antenna parameters such as S-parameters S_{11}, gain, radiation pattern, and cross correlation.
III. Analyze the effect of mutual coupling on minkowski island fractal diversity antenna.
IV. Network Analyzer will be used to measure VSWR and S_{11}. Anechoic chamber will be measure the radiation pattern.

1.5 Thesis Outline

Chapter I discusses about the introduction, problem statement, objectives and scope of the project.

Chapter2 briefs literature studies of the micstrip antenna in order to get its basic fundamental the main aspects of the micstrip antenna such as its structure configuration radiation mechanism polarization feeding technique method analysis, Minkowski fractal diversity antenna, multiband antenna are covered, previous research related with the project also presented in this chapter

Chapter3 describes the design procedure of the single band micstrip patch antenna and dual band Minkowski fractal array antenna using coaxial feeding technique the designing and simulation using CST Microwave Studio is done and presented the fabrication procedure of the antenna various instrument used for antenna fabrication also is presented in this chapter.

Chapter4 analysis the results of the proposed antenna such as return loss (dB), radiation pattern, and gain and radiation efficiency. Also the comparison of the simulated and measured results is presented in this chapter.

Chapter 5gives the conclusion to this thesis and the future work continued antenna design by using a different structure configuration the use different dielectric substrate material as well as a combination of different substation structure.

1.6 Thesis Contributions

1. Modified the fractal Minkwoski fractal diversity array antenna in order to work the antenna for its applications
2. Calculate the spatial cross-correlation (SCC) so that the antenna can be perform as a diversity antenna

CHAPTER II

LITERATURE REVIEW

2.0 Antenna Overview

An antenna is a device that transmits and/or receives electromagnetic waves. Electromagnetic waves are often referred to as radio waves. Most antennas are resonant devices, which operate efficiently over a relatively narrow frequency band. An antenna must be tuned to the same frequency band that the radio system to which it is connected operates in, otherwise reception and/or transmission will be impaired [8].

2.1 Microstrip Antenna

In its simplest configuration, microstrip antenna consists of radiating patch on one side of a dielectric substrate which has a ground plane on the other side. The patch conductors, normally is copper or gold. The radiating patch and feeding lines is usually photo etched at the dielectric substrate. [9]

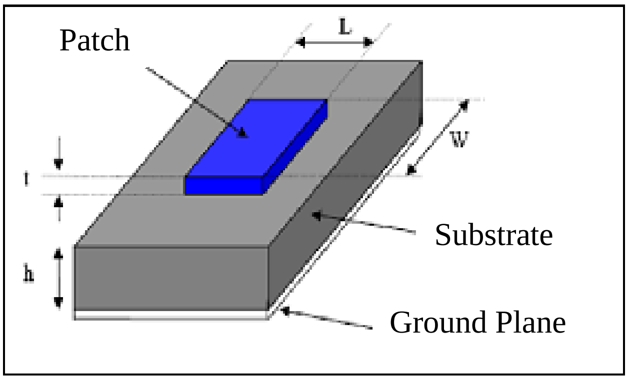

Figure 2.1 Microstrip Patch Antenna Structure

Based on the Figure 2.3, it shows the common microstrip patch antenna structure. L is the length of the patch, W is the width of the patch, h is the height of the patch and t is the patch thickness.

To achieve great antenna performance, thick dielectric substrate having low dielectric constant is needed. This will provide higher efficiency, larger bandwidth and greater radiation. But, in order to achieve this, larger antenna size will be needed. So, in order to produce a compact design, higher dielectric constant which are less efficient and will contribute to narrower bandwidth will be used. [9]

Microstrip antenna has several advantages compared to conventional microwave antenna. These types of antennas are light weight, low volume and thin profile configurations, which can be made conformal. The cost of fabrication is also low. So, it can be manufactured in large quantities. For the polarization types, it can support both linear and circular polarization depending on the radiation pattern. Microstrip patch antennas also are capable of dual and even triple frequency operations. [9].

On the other hand, microstrip patch antennas also have some disadvantages. These types of antenna have narrow bandwidth, low efficiency and also have low gain. [10]

2.1.1 Feeding Methods

Microstrip patch antennas can be fed by a variety of methods. These methods can be classified into two categories- contacting and non-contacting. In the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a microstrip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch. The four most popular feed techniques used are the microstrip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

The Coaxial feed or probe feed is one of the most common techniques used for feeding microstrip patch antennas. As seen from Figure 2.4, the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

The main advantage of this type of feeding scheme is that the feed can be placed at any desired position inside the patch in order to obtain impedance matching. This feed method is easy to fabricate and has low spurious radiation effects. However, its major disadvantage is that it provides narrow bandwidth and is difficult to model since a hole has to be drilled into the substrate. Also, for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems.

By using a thick dielectric substrate to improve the bandwidth, the microstrip line feed and the coaxial feed suffer from numerous disadvantages such as spurious feed radiation and matching problem. The non-contacting feed techniques which have been discussed below, solve these problems.

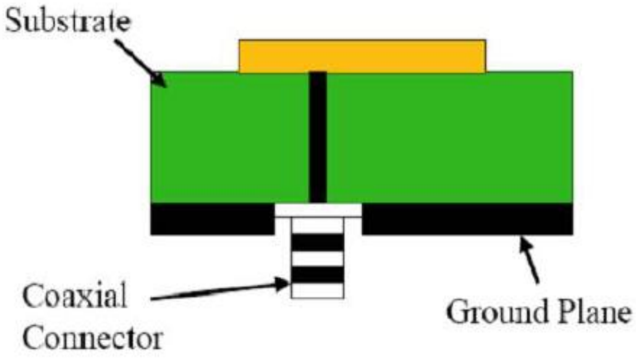

Figure 2.2: Coaxial probe feeding of microstrip antenna

2.2 Antenna Properties

There are a wide variety of antenna types and geometries but all antennas can be described with a set of parameters and terms as discussed below. These parameters provide information about the properties and characteristics of an antenna.

2.2.1 Directivity

It can be defined as the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged of all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π. If the direction is not specified, the direction of maximum radiation intensity is implied. [8]

If the direction is not specified, the direction of maximum radiation intensity can be expressed as

$$D_{max} = D_O = \frac{U_{max}}{Uo} = \frac{4\pi U_{max}}{P_{rad}} \tag{2.1}$$

Reference antennas usually are isotropic radiator where the radiated energy is the same in all direction and have directivity of 1 .It can be defined as

$$D = \frac{F_{\max}}{F_o} \tag{2.2}$$

The power gain G or simply the gain of an antenna is the ratio of its radiation intensity to that of an isotropic antenna radiating the same total power as accepted by the real antenna. It is the product of efficiency and directivity and accounts for the fact that loss reduces the power density radiated in a given direction [27].

2.2.2 Radiation pattern

An antenna radiation pattern or antenna pattern is defined as a mathematical function or graphical or graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far field and its represent as a function of the directional coordinates. Radiation properties include power flux density, radiation intensity, field strength, directivity, phase or polarization.

Often the field and power pattern are normalized with respect to their maximum value, yielding normalized field and power patterns. Also, the power pattern is usually desirable because a logarithmic scale can accentuate in more details those parts of the pattern that have very low values. For antenna, the

a) Field pattern (in linear scale) typically represents a plot of the magnetic of the electric or magnetic field as a function of the angular space.
b) Power pattern (in linear scale) typically represents a plot of the square of the magnitude of the electric of magnetic field as a function of the angular space.
c) Power pattern (in dB) represents the magnitude of the electric or magnetic field, in decibels, as a function of the angular.

It is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. The radiation property of most concern is the two or three-dimensional spatial distribution of radiated energy as the function of the observer's position along a path of surface of constant radius. [8]

2.2.2.1 Principal Patterns

For a linearly polarized antenna, the performance is usually described in terms of its principal E- and H-plane patterns. The E-plane is defined as the plane containing the electric-field vector and the direction of maximum radiation.

The H-plane is defined as the plane containing the magnetic-field vector and the direction of maximum radiation. [8]

2.2.2.2 Radiation pattern lobes

A radiation lobe is a portion of the radiation pattern bounded by regions of relatively weak radiation intensity. A major lobe also called as the main beam is defined as the radiation lobe containing the direction of maximum radiation. A minor lobe is any lobe except a major lobe. A side lobe is a radiation lobe in any direction other than the intended lobe. Usually a side lobe is adjacent to the main lobe and occupies the hemisphere in the direction of the main beam. A back lobe is a radiation lobe which the axis makes an angle of approximately 180 degrees with respect to the beam of an antenna. [8]

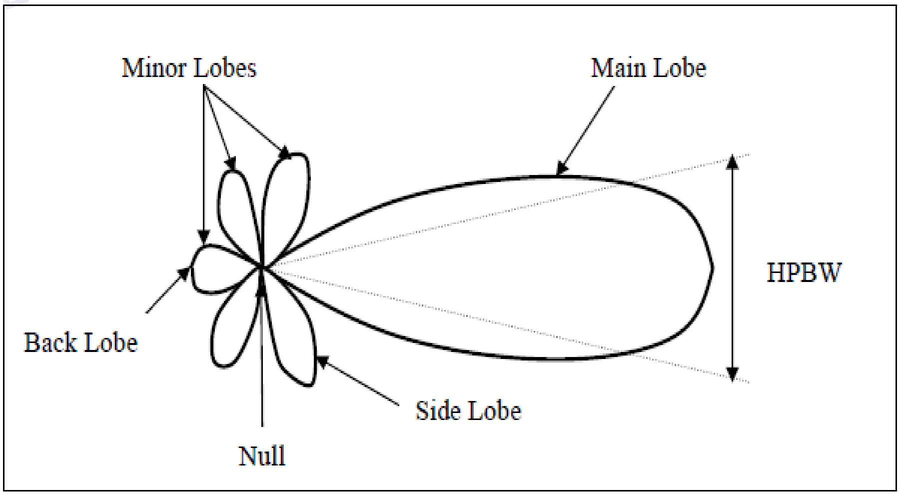

Figure 2.3: Radiation pattern of a generic directional antenna

2.2.3 Full and Half-power beamwidth

Associated with pattern of the antenna is parameter designated as beamwidth. The beamwidth of a pattern is defined as the angular separation between two identical points on opposite side of the pattern maximum. In an antenna pattern, there are a number of beamwidths. One of the most widely used beamwidths is the half power beamwidth (HPBW), which is defined by IEEE, as:” in a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation is one-half value of the beam”. Another important beamwidth is the angular separation between the first nulls of the pattern, and it is referred to as the first-null beamwidth (FNBW). Both the HPBW and FNBW are demonstrated.

It can be defined as in a plane containing the direction of the maximum of a beam, the angle between the two directions in which the radiation intensity is one-half of the maximum value of the beam. It is used to describe the 3dB beam width. As the beam width decreases, the side lobe increases and vice versa. [8] Antenna gain is inversely proportional to the beam width; the higher the gain, the narrower the antenna beam width. [8]

2.2.4 Gain

The gain, directive gain or power gain of an antenna is defined as the ratio of the intensity (power per unit surface) radiated by the antenna. The gain of an antenna is a passive phenomenon; power is not added by the antenna, but simply redistributed to provide more radiated power in a certain direction than would be transmitted by an isotropic antenna.

If an antenna has a greater than one gain in some directions, it must have a less than one gain in other directions as energy is conserved by the antenna. The gain that can be achieved by antenna is therefore trade-off between the ranges of the directions that must be covered by an antenna.

Antenna gain is the ratio of maximum radiation intensity at the peak of main beam to the radiation intensity in the same direction which would be produced by an isotropic radiator having the same input power. Isotropic antenna is considered to have a gain of unity.

Gain is closely related to directivity but it is a measure that takes into account the efficiency of the antenna and also the directional capabilities. Absolute gain of an antenna in a given direction is defined as the ratio of the intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna were radiated isotropically. The radiation intensity corresponding to the isotropically radiated power is equal to the power accepted by the antenna divided by 4π. [27]

It also can be expressed as

$$\text{Gain} = 4\pi \frac{\text{radiation intensity}}{\text{total input (accepted) power}} = 4\pi \frac{U(\theta,\phi)}{P_{in}} \qquad (2.3)$$

For a lossless isotropic source,

$$G = \frac{4\pi U(\theta,\phi)}{Pin(\text{lossless isotropic source})} \text{(dimensionless)} \qquad (2.4)$$

2.2.5 Input impedance

For efficient transfer of energy, the impedance of the radio, the antenna, and the transmission line connecting the radio to the antenna must be the same. Radios typically are designed for 50 ohms impedance and the coaxial cables (transmission lines) used with them also have a 50 ohm impedance. Efficient antenna configurations often have impedance other than 50 ohms, some sort of impedance matching circuit is then required to transform the antenna impedance to 50 ohms.

It is defined as the impedance presented by an antenna at its terminals or ratio of the voltage to current at a pair of terminals or the ratio of the appropriate components of the electric to magnetic fields at a point. The input impedance can be determined by the maximum power transfer between transmission line and the antenna. When the input impedance, antenna and transmission line are matched, maximum power transfer will be achieved. Reflected wave will be generated at the antenna terminal and travel back towards the energy source if it is not matched. It will cause reduction on overall system efficiency. [8]

The input impedance can be described as:

$$Z_1 = Zo\left|\frac{1+S_{11}}{1-S_{11}}\right| \tag{2.5}$$

Where

Z_1 = input impedance

Z_0 = characteristic impedance

S_{11}= return loss

2.2.6 Bandwidth

The term bandwidth is defines as the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard. For narrowband antenna, the bandwidth is expressed as a percentage of the frequency difference over the center frequency of bandwidth. The characteristics such as input impedance, gain and polarization of antenna do not necessarily affect the frequency.

So, there is no unique characterization of the bandwidth. There are distinctions made between pattern and input impedance variations. Pattern bandwidth and impedance bandwidth are used to emphasize this distinction. Gain, side lobe level, beamwidth, polarization and beam direction are associated with pattern bandwidth while input impedance and radiation efficiency are associated with impedance bandwidth. [8]

Narrowband by percentage can be expressed by

$$\text{BW} = \frac{\text{Higher cut-off frequency} - \text{Lower cut-off frequency}}{\text{operating frequency}} \text{ x } 100\% \qquad (2.6)$$

2.2.7 Reflection coefficient

Determining the value of the input reflection coefficient of the antenna is necessary to determine the location of the resonant bands. The input reflection coefficient, Γin, is obtained from expression below [8]:

$$\Gamma\text{in} = \frac{Z_{in} - Z_o}{Z_{in} + Z_o} \qquad (2.7)$$

Where

Z_{in} =input impedance of the antenna

Z_o=characteristic impedance used in the transmission line, as a reference.

The absolute value of the reflection coefficient can be also expressed as the ratio of the reflected power from the antenna input, Pin and the power delivered to the antenna, Pin as in expression below. [8]

$$|\Gamma in| = \frac{P_{\text{ref}}}{P_{\text{in}}} \qquad (2.8)$$

2.2.8 Polarization

Polarization of an antenna in a given direction is defined as the polarization of the wave transmitted (radiated) by the antenna. The polarization of a wave can be defined in terms of a wave radiated or received by an antenna in a given direction. The polarization of a wave radiated by an antenna in a specified direction at a point in the far field is defined as the polarization of the plane wave whose electric field strength is the same as that of the wave and whose direction of propagation is in the radial direction from the antenna.

Polarization can be classified as linear, circular and elliptical. The field is said to be linearly polarized if the vector that describes the electric field at a point in space as a function of time is always directed along a line. If the electric field traces is an ellipse, the field is elliptically polarized. For circular polarization, a time-harmonic wave is circularly polarized at a given point in space if the electric field or magnetic field vector at that point traces a circle as a function of time.

Polarization characteristics of an antenna can be represented by its polarization pattern which is defined as the spatial distribution of the polarizations of a field vector excited by an antenna taken over its radiation sphere.

2.2.9 Voltage Standing Wave Ratio (VSWR) and Return Loss

When a load is mismatched to a transmission line, not all power from the generator will be delivered to the load. The loss is called return loss and expressed as:

$$\text{RL} = -20 \log|\Gamma| \text{ dB} \tag{2.9}$$

A matched load, where the reflection coefficient, $\Gamma=0$, has return loss of ∞ dB, whereas a total reflection of all power, where $\Gamma=1$, has a return loss of 0 dB. In a mismatched line, the presence of reflected wave leads to standing wave, where the magnitude of the voltage oscillates along the line.

As the value of reflection coefficient increases, the ratio of the minimum and maximum voltage values (V_{max} and V_{min}) also increases. So, the Voltage Standing Wave Ratio (VSWR) measures the ratio of these voltages on a transmission line. It can be expressed as:

$$\text{SWR} = \frac{V_{\max}}{V_{\min}} = \frac{1+|\Gamma|}{1-|\Gamma|} = \frac{1+S_{11}}{1-S_{11}} \tag{2.10}$$

For an antenna to be reasonably functional, a minimum SWR $1.5 \leq$ is required.

2.2.10 The Near Field and The Far Field

In the near field region, the polar radiation pattern depends on distance from the antenna and there is reactive power flow in and out of region. One can imagine that the energy, instead of propagation uniformly and steadily away from the antenna, has an oscillatory longitudinal component.

In the far field, the polar radiation pattern is completely independent of distance from the radiating source. Far field is the region away from an antenna where the radiated wave essentially takes the form of a plane wave. Radiation patterns are generally assumed to be in far field of antenna. The transition from near to far field happens at the Rayleigh distance, which sometimes called the far field distance. An estimate for this distance may be made from this formula;

$$R_2 = \frac{2D^2}{\lambda} \tag{2.11}$$

Where,

R_2 = distance from the antenna surface

D = largest dimension of the antenna

λ = operating wavelength

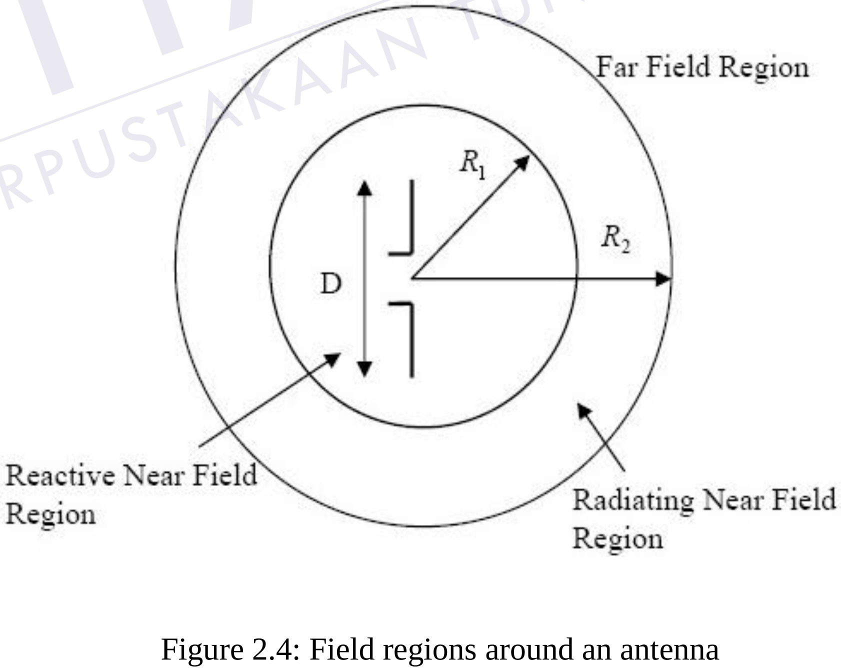

Figure 2.4: Field regions around an antenna

2.3 Transmission Line Model

This model represents the microstrip antenna by two slots of width W and height h, separated by a transmission line of length L. The microstrip is essentially a non-homogeneous line of two dielectrics, typically the substrate and air.

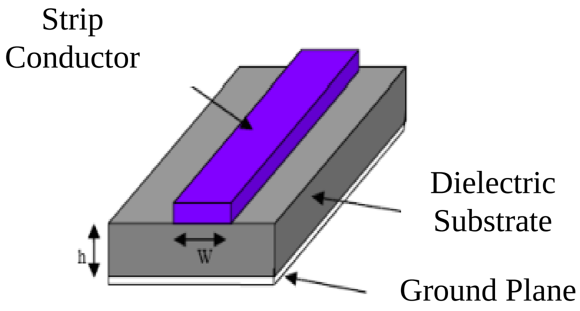

Figure 2.5(a) Microstrip Line

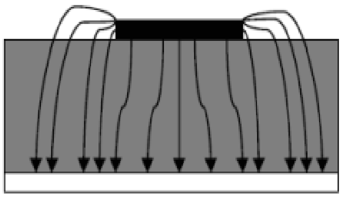

Figure 2.5(b) Electric Field Lines

Hence, as seen from Figure 2.5(b), most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse-electric-magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ε_{reff} is slightly less than εr because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in air.

The expression for $\varepsilon reff$ is given by 2.12

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left(1 + 12\frac{h}{w}\right)^{\frac{1}{2}} \qquad (2.12)$$

Where ε_{reff} = Effective dielectric constant

ε_r = Dielectric constant of substrate

h = Height of dielectric substrate

W = Width of patch

In the Figure 2.6(a) shown below, the microstrip patch antenna is represented by two slots, separated by a transmission line of length *L* and open circuited at both the ends. Along the width of the patch, the voltage is a maximum and the current is a minimum due to open ends. The fields at the edges can be resolved into normal and tangential components with respect to the ground plane.

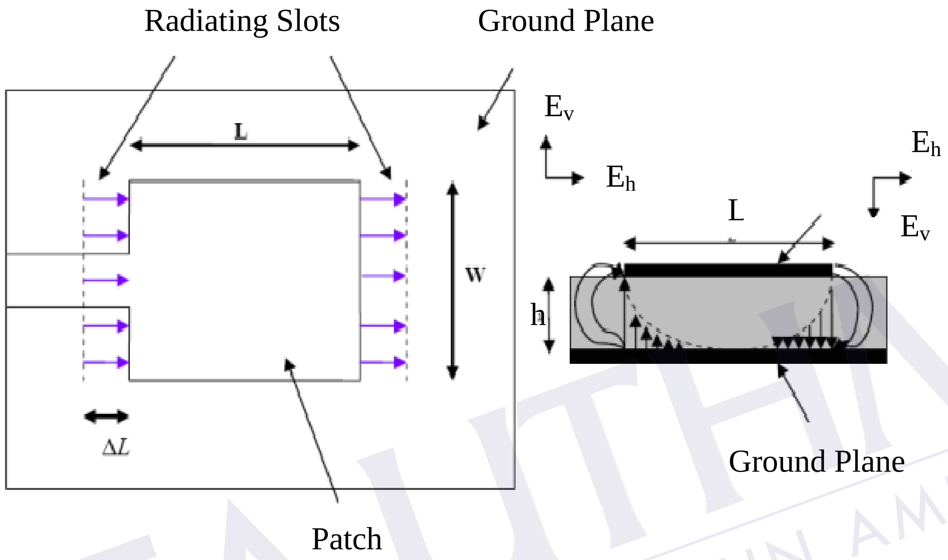

Figure 2.6(a) Top View of Antenna

Figure 2.6(b) Side View of Antenna

It is seen from Figure 2.6(b) that the normal components of the electric field at the two edges along the width are in opposite directions and thus out of phase since the patch is $\lambda/2$ long and hence they cancel each other in the broadside direction. The edges along the width can be represented as two radiating slots, which are $\lambda/2$ apart and excited in phase and radiating in the half space above the ground plane. The fringing fields along the width can be modelled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance ΔL, which is given as:

For a given resonance frequency for, the effective length is given by [10]:

$$L_{eff} = \frac{c}{2 f_o \sqrt{\varepsilon_{reff}}} \tag{2.13}$$

The fringing fields along the width can be modeled as radiating slots and electrically the patch of the microstrip antenna looks greater than its physical dimensions. The dimensions of the patch along its length have now been extended on each end by a distance, ΔL.

The ΔL can be expressed as [28]:

$$\Delta L = 0.412h \left(\frac{(\varepsilon_{reff} + 0.3)}{(\varepsilon_{reff} - 0.258)} \left[\frac{\frac{W}{h} + 0.264}{\frac{W}{h} + 0.8} \right] \right) \tag{2.14}$$

The effective length of the patch L_{eff} now becomes:

$$L_{eff} = L + 2\,\Delta L$$

Where

ΔL = Length due to fringing effects
L = Length of patch
L_{eff} = Effective length of the patch
h = Height of dielectric substrate
W = Width of patch
ε_{reff} = Effective dielectric constant

For efficient radiation the width, W is given by [28]:

$$W = \frac{c}{2 f_o \sqrt{\frac{\varepsilon_r + 1}{2}}} \tag{2.15}$$

2.4 Diversity Antenna

With the rapid increase in the number of wireless services, more and more wireless communication system may require diversity at the transmitter in addition to diversity at the receiver to combat the severe effect of fading. Diversity reception is a widely used technique in radio communication to reduce signal fading due to complex propagation environment. Fading is caused by multipath propagation of the radio signal in complex environment. Although polarization diversity is a very important form of antenna diversity, polarization properties of the antenna elements are not taking into account in the following theory, instead the emphasis of the analysis is on phase diversity characteristics of diversity antenna.

Multipath fading occurs in land mobile communication, therefore, the performance was degraded. To overcome this problem a special reception technique is used, namely the multiple receiver combining techniques which is known as diversity.

The concept of antenna diversity, a technique that can be used to recover radio communication in environments of difficult reception, it can greatly improve performance under multipath fading condition. OFDM technology is being used in many wireless local area networks (WLAN). Next generation wireless network such As Wimax.

OFDM is known to be very resistant to multipath fading compared to signal carrier system and efficiently utilizes the scarce frequency spectrum multi-path diversity is using time diversity in multi-path environments getting the information from repetitive signals traveling different paths.

Diversity techniques are used to mitigate the effects of the multipath phenomenon. There are several mechanisms to achieve diversity branches such as space diversity or spatial diversity, frequency diversity, angle diversity, polarization diversity, and pattern diversity. The most common and simple mechanism for achieving diversity branches is space diversity. By using two antennas with a distance between them, the phase delay makes multipath signals arriving at the antenna differ in fading. The minimum spacing between the antennas at a mobile terminal is required for sufficient low correlation between fading signals.

Diversity reception is a widely used technique in radio communication to reduce signal fading due to complex propagation environment. Fading is caused by multipath propagation of the radio signal in complex environment. Although polarization diversity is a very important form of antenna diversity, polarization properties of the antenna elements are not taking into account in the following theory, instead the emphasis of the analysis is on phase diversity characteristics of diversity antenna.

First encounter with diversity occurred in experiments with spaced receiving antennas at high frequencies. It was discovered that multi-path fading variations of signal received at one antenna have a tendency of being independent of fading variation at the other antenna, assuming a sufficient spacing between the two antennas. This observation lead to an experiment where a switch was used to derive the output signal from the stronger of two antennas at the observed time and resulted in a reduction of the depth of the fading effects compared to signals from either antenna alone.

2.5 Fractal Antenna

2.5.1 Introduction

Fractal antenna is an antenna that uses a self-similar design to maximize the length, or increase the perimeter (on inside section or the outer structure), of malenal that can receive or transmit electromagnetic single within a given total surface area. For this reason fractal antenna are very compact, are multi-bands or wideband, and have useful application in cellular telephone and microwave communication.

Fractal antenna response differs markedly from traditional antenna design, in that it is capable of operating optimally at many different frequencies simultaneously. Normally standard antenna have to be cut for the frequency for which they are to be used and thus the standard antennas only optimally work at that frequency. This makes the fractal antenna an excellent design for wideband application.

Fractals already are being used for compact, multi-frequency antennas in cellular phones and military communication hardware. Fractal antennas are now used in cellular phone antenna fitting inside the body of the phone, and the multi-frequency aspect of the antenna will allow GPS to be incorporation in the phone other application include compact, multi-frequency wireless LAN and maritime antennas.

Apply fractal to antenna element allows for smaller, resonant antennas which are multiband broadband and many be optimized for gain. The do not use additional loading components and are simple and cost-effective to fabricate. They can be mounted to constraining from factors such as the casing of hand held transceivers. Fractal antennas prove worthwhile, high performance, resonant antennas for much particular application.

There has been an ever-growing demand, in both the military as well as the commercial sectors, for antenna designs that possess the following highly desirable attributes which are compact size, low profile, conformal and multi-hand or broadband. [14]

There are a variety of approaches that have been developed over the years, which can be utilized to achieve one or more of these design objectives. For instance, an excellent overview of various useful techniques for designing compact (i.e., miniature) antennas may be found in [15] and [16]. Moreover, a number of approaches for designing multi-band (primarily, dual-band) antennas have been summarized in [17]. Recently, the possibility of developing antenna designs that exploit in some way the properties of fractals to achieve these goals, at least in part, has attracted a lot of attention. The term fractal, which means broken or irregular fragments, was originally coined by Mandelbrot [18] to describe a family of complex shapes that possess an inherent self-similarity or self-affinity in their geometrical structure. The original inspiration for the development of fractal geometry came largely from an in-depth study of the patterns of nature. For instance fractals have been successfully used to model such complex natural objects as galaxies cloud boundaries, mountain ranges, coastlines, snowflakes, trees, leaves, ferns, and much more. Since the pioneering work of Mandelbrot and others, a wide variety of applications for fractals continue to be found in many branches of science and engineering. One such area is fractal electrodynamics [19-25], in which fractal geometry is combined with electromagnetic theory for the purpose of investigating a new class of radiation, propagation, and scattering problems. One of the most promising areas of fractal electrodynamics research is in its application to antenna theory and design, traditional approaches to the analysis and design of antenna systems have their foundation in Euclidean geometry.

There has been a considerable amount of recent interest, however, to the possibility of developing new types of antennas that employ fractal rather than Euclidean geometric concepts in their design. We refer to this new and rapidly growing field of research as fractal antenna engineering. Because fractal geometry is an extension of classical geometry, its recent introduction provides engineers with the unprecedented opportunity to explore a virtually limitless number of previously unavailable configurations for possible use in the development of new and innovative antenna designs.

2.5.2 Geometries for Fractal Antenna Element Engineering

Fractal geometries are generated in an iterative fashion leading to self-similar structure. This iterative generating technique can best be conveyed pictorially. The best example is minkowski fractal the stating geometry of the fractal called the intricate, is a Euclidean square. Each of the four straight segments of the starting structure is replaced with the generator. This iterative generating procedure continues for an infinite number of times. The final result is a curve an infinitely intricate underlying structure that is not differentiable at any point.

This segment will provide a short-term overview of some of the more mutual fractal geometries that have been found to be useful in developing new and innovative designs for antennas. The first fractal that will have to consider is the popular Sierpinski gasket [26]. The first few stages in the construction of the Sierpinski gasket are shown in Figure 2.7. Another popular fractal is known as the Koch snowflake [26]. This fractal also starts out as a solid equilateral triangle in the plane, as illustrated in of Figure 2.8. Number of structures based on purely deterministic or random fractal trees has also proven to be extremely useful in developing new design methodologies for antennas and frequency selective surfaces. An example of a deterministic ternary (three branches) fractal tree is shown in Figure

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