DESIGN 5G WIDEBAND FRACTAL ANTENNA

JUMSIYE BINTI SALLEH

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by

JUMSIYE BINTI SALLEH

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LIST OF SYMBOLS

BW_p	Percentage of Bandwidth
c	Free space velocity of light (3 x 10^8 m/s)
D	Maximum antenna dimension
F_i	Length of inset-fed line
f_h	Higher cut-off frequency
f_l	Lower cut-off frequency
f_o	Operation frequency
g	Air gap at the slot
G_{AUT}	Gain of Antenna under Test (AUT)
G_s	Gain of known gain standard antenna
h	Height of the substrate
L	Actual length of the patch
Lf	Length of microstrip line
Lg	Length of the ground patch
P_{AUT}	Received power of Antenna under Test (AUT)

P_s	Received power of known gain standard antenna
R_1	Distances for Near-field region
R_2	Distances for Far-field region
t	Height of copper
W	Width of patch
Wf	Width of microstrip line
Wg	Width of the ground patch
Zo	Characteristic impedances
ε_{reff}	Effective dielectric constant
ε_r	Dielectric constant of the substrate
ΔL	Extension of the length
λ	Wavelength
Ω	Ohm

LIST OF ABBREVIATIONS

.DXF	.Drawing Exchanged Format
3D	3 Dimension
5G	Fifth generation
ADS	Advanced Design System
AUT	Antenna under Test
CST	Computer Simulation Technology
dB	Decibel
dBm	Decibel-Mill watts
FR4	Fire Retardant
HFSS	High Frequency Structure Simulator
Hz	Hertz
LineCalc	Line Calculate
LTE	Long Term Evolution
MoM	Method of Moments
PCB	Printed Circuit Board

RF	Radio Frequency
RL	Return Loss
SMA	Subminiature Version A
UV	Ultra-violet
UWB	Ultra-bandwidth
VNA	Vector Network Analyzer
VSWR	Voltage Standing Wave Ratio

ABSTRAK

Micsrostrip patch antena adalah salah satu antena reka bentuk yang dapat pengecilan antena yang mempunyai lebih efisien yang antena konvensional pada masa kini. Ini kerana kesan evolusi sistem komunikasi tanpa wayar moden yang merupakan generasi kelima, rangkaian 5G yang memerlukan antena kecil dan padat. Microstrip geometri fraktal adalah reka bentuk yang digunakan untuk mendapatkan respon luas-band yang diperlukan untuk melaksanakan lebar liputan untuk banyak aplikasi dengan kelajuan tinggi rangkaian 5G. Dalam projek ini, antena adalah reka bentuk dan simulasi dengan menggunakan CST Microwave Studio. Objektifnya adalah untuk mereka bentuk antena fraktal untuk peranti komunikasi mudah alih pada masa kini, untuk melaksanakan satu kajian parametrik pada parameter dalam reka bentuk luas-band antena fraktal, untuk memalsukan reka bentuk luas-band antena fraktal untuk komunikasi tanpa wayar moden dan untuk menganalisis reka bentuk luas-band antena fraktal yang sesuai untuk 5G sistem komunikasi pada masa kini. Lelaran antena fraktal dan pengubahsuaian reka bentuk akan meningkatkan jalur lebar. Selain itu, antena telah dipalsukan pada FR-4 substrat dan kemudian diuji. Keputusan pengukuran bagi cadangan tunggal antena Design II menyediakan persembahan yang lebih baik yang beroperasi pada 9.57 GHz (rapat kepada 10 GHz) dengan lebar jalur yang lebih luas adalah 7.03GHz (8.18 -15.21 GHz), VSWR adalah 1.19 yang boleh disepadukan ke dalam banyak peranti mudah ali`h untuk sistem 5G.

ABSTRACT

Microstrip patch antenna is one of the designed antenna that able to miniaturization the antenna which has more efficient that conventional antenna nowadays. This is because the impact of evolution modern wireless communication system that is fifth generation, 5G network that needed the small and compact antenna. Microstrip Fractal geometry is the design that used to obtain a wide-band response that required to perform the wide-coverage for many application with high speed of the 5G network. In this project, the antenna was designed and simulated by using CST Microwave Studio. The objective is to design a fractal antenna for portable communication device nowadays, to perform a parametric study on of parameter in design the wideband fractal antenna, to fabricate a wideband fractal antenna for modern wireless communication and to analyze a wideband fractal antenna that suitable for 5G system communication nowadays. The iteration of the fractal antenna and the modification of design will improve the bandwidth. Moreover, the antenna was fabricated on FR-4 substrate and then tested. The measurement results for proposed of single Design II antenna provides better performances which operate at 9.57 GHz (closely to 10 GHz) with wider bandwidth is 7.03GHz (8.18-15.21 GHz), VSWR is 1.19 which can be integrated into many portable devices for the 5G system.

CHAPTER 1

INTRODUCTION

1.1 Project Background

In the demand for technology grows nowadays by evolution from fourth-generation, 4G to fifth-generation, the 5G system gives impact in modern communication. Therefore, the effect of the evolution clearly can see when the speed of the data rate 5G network (up to 1Gbps) faster than the 4G network (up to 20Mbps). Moreover, the 5G system allows the higher coverage area with higher radio frequency in a mission to accelerate a development of Internet of Things (IoT) [1-2]. Besides that, this evolution leads to the design of advanced antenna which smaller, compact, easy to fabricate and required to have a multiband and wideband range which gives a good signal performances for the user. Consequently, the problem above can be overcome when used the theory of the microstrip patch antenna.

Microstrip patch antenna has their own advantage which is low profile, lightweight, reduction in size and inexpensive of manufacturing cost. This antenna can represent in shape of rectangular, square, triangular, and circular etc. Hence, the varied design of shapes and mode of the antenna can give a flexible value of resonant frequency, polarization, signal pattern and impedances [3]. The advantages of the microstrip patch antenna are more efficient than the conventional antenna but the disadvantage of this antenna is suffered on narrow bandwidth and low gain. However, the microstrip fractal geometry able to solve the sensitive narrow bandwidth [4&5]. Therefore, the microstrip fractal geometry has been proposed in this research and it also able to miniaturization antenna design that can be used in modern communication.

Fractal derive from Latin words Fractuss means “broken” that coined by Benoit B. Mandelbrot [6]. Fractal antenna actually geometry shaped that have self-similar properties with their iteration process of design that leads to increase the length and increase the perimeter of the antenna which means more available space for receive or transmit information. The various fractal antenna number of a shape such as Sierpinski’s carpet, Sierpinski’s gasket, Koch, Giusepe Peano, and Minkowski etc. Moreover, this antenna more powerful and compact because it alters the traditional relationship of bandwidth, gain, and size. Next, the fractal antenna also which more familiar to miniature the antenna and multiband. In the other hands, it also attractive to perform a wide operation bandwidth [6-11].

1.2 Problem Statement

The rapid growth of modern communication system affects the data traffic system of high capacity for the user. Therefore, it requires developing the next generation of a wireless system which is the 5G network that supports a massive system capacity. Unfortunately, this system used high spectrum frequency than the radio frequency that has been used nowadays. In fact, this new system also demands of the small size of devices which is corresponding to miniaturization of antenna designs also in this new technology. Furthermore, the requirement performances for this antenna designs, on the higher data rate transfer which related to having a wider bandwidth. Therefore, this project determining whether the fractal antenna suitable to be the best miniaturization and shaped for wide-band of higher network signal system. Moreover, the antenna also needs to be in good performances of gain, therefore, the array design need to be performed.

1.3 Objective of Project

The specific objective of this project are as follow:

i. To design a fractal antenna for portable communication device nowadays.
ii. To perform a parametric study on of parameter in design the wideband fractal antenna.
iii. To fabricate a wideband fractal antenna for modern wireless communication.
iv. To analyze a wideband fractal antenna that is suitable for 5G system communication nowadays.

1.4 Scope of Project

The main scope to achieve the objective of this project divide into two main part, which is software and hardware. Software more focuses on the design a fractal antenna by using the (Computer Simulation Technology) CST Microwave Studio 2013 based on a characteristic of the fractal antenna. Basically, the simulation result should design the antenna works where the return loss is below -10dB, the gain Voltage Standing Wave Ratio (VSWR) is less than 2 which make the antenna works efficiently. Moreover, the bandwidth needs to be focus equal or more than 50MHz. Next, hardware part it comes on Printed Circuit Board (PCB) the fabrication process of the fractal antenna. Then, it is test and analyses by using the Network Analyzer, Spectrum Analyzer, and Signal Generator for proving the result from the simulation process.

1.5 Report Outline

Overall, this thesis project organized into five chapter that describes the full from introduction until the conclusion. The first chapter of this thesis is an introduction that explained the background, problem statement, objectives and project scope of this project.

Chapter 2 focus on the literature review of other works done by the present research that related to this project and it more about the concept in the designed a fractal antenna and the implementation design for wide operating bandwidth.

Next, Chapter 3 is about the methodology of this project in software design part and the hardware implementation. Firstly, it discusses the software design. The process of the designing a fractal antenna by using CST Microwave Studio 2013 in range frequency of the 5G system. Then, it follows the design of basic efficient antenna, characteristic and requirement in fractal antenna design. Secondly, is explained the method of hardware implementation to measure the parametric study.

Moreover, Chapter 4 present of result and discussion for this project. In this part, shows the outcome to prove the result is functionally and perform same as simulation or not.

Lastly, Chapter 5 will show the conclusion of this project which summarizes the aims and restatement the overall results. Then, it also presents of the limitation and the future works.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

From the previous chapter, shows that the design of the fractal antenna was the important role that in achieving the wide operation bandwidth in this project. Therefore, the previous research on the design of fractal antenna and the implementation in the design of the wideband antenna was presented in this chapter. Then, the concept and theorem or the procedure in design the fractal antenna were well described.

2.2 Determination of 5G Operating Frequency

The 5G wireless system was the evolution of the new system in modern wireless communication which generally describes as a communication system for anyone and anything. Basically, the 5G wireless was the combination evolution of Long Term Evolution (LTE) for existing spectrum and new radio access technology on the new spectrum of radio frequency. The target of new spectrum frequency for 5G wireless in millimeter wave [12-14]. These some of the electronic company that already tested the potential of 5G technologies was Alcatel-Lucent (3-6 GHz), Fujitsu (3-6 GHz), Ericsson (15 GHz), Samsung (28 GHz) and Nokia (70 GHz) [13]. Next, the most frequency of the previous researcher to design the 5G antenna is 28GHz [15-20]. Unfortunately, in this project use 10GHz as operating frequency because of the limitation of using tools frequency.

2.3 Antenna Properties

The performances of the antenna were determined by using several parameters that were interrelated to be specific for complete the description of the antenna performances [3].

2.3.1 Radiation Pattern

Radiation pattern actually describes the power radiated through the antenna and also represented a graphical of the antenna radiation properties as a function of position in spherical coordinates. There were contents of two common type of antenna patterns which was power pattern and field pattern. The power pattern happens when the power that radiated and in spherical coordinate position while field pattern happens when the magnetic field or electrical field with spherical coordinate position also [3].

Reactive field and radiation field where both are antenna field type. Moreover, by referring Figure 2.1 shows the antenna field region consists of three main regions that were reactive near field region, near-field *(Fresnel*) region and far-field (*Fraunhofer*) region. The reactive near field region was the region immediately surrounding the antenna where the reactive field was dominant. Then, near-field *(Fresnel*) region was the region between the far-field and reactive near-field where the radiation field was dominant. Lastly, far-field (*Fraunhofer*) region is the region farthest away from antenna where the field distribution is essentially independent of the distances from antenna [3-4].

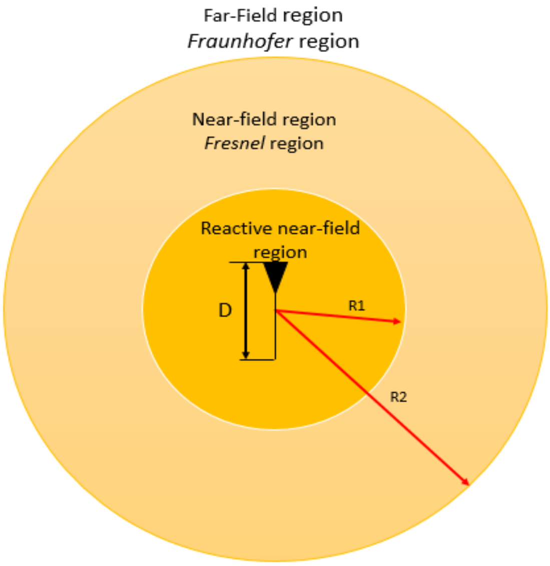

Figure 2.1: Antenna Field Region [3] [4].

Where

D = maximum antenna dimension (m)

$$R_1 = 0.62\sqrt{\frac{D^3}{\lambda}} \tag{2.1}$$

$$R_2 = \frac{2D^2}{\lambda} \tag{2.2}$$

By referring Equation 2.1 above, R1 is to define the value of reactive near-field region while Equation 2.2, R2 is to determine the value of far-field region for the antenna.

2.3.2 Bandwidth

The bandwidth is determined when the frequency ranges meet the certain specification of performances criteria. This means the return loss, RL for the antenna performances must meet less than -10dB. Equation 2.3 leads to determine the percentage of the bandwidth ratio.

$$Percentage\ of\ Bandwidth\, ratio,\ BW_p = \frac{f_h - f_l}{f_o} \times 100\% \quad (2.3)$$

Where

f_h = Higher cut-off frequency

f_l = Lower cut-off frequency

f_o = Operating Frequency

2.3.3 Directivity

Directivity was the ratio of radiation intensity in a given directional from the antenna to the radiation intensity averaged over all directions. The simple words the directivity was to measure the ability of the antenna to focus the energy in one direction [29].

$$D(\emptyset,\theta) = \frac{Radiation\ intensity\ of\ antenna\ in\ direction\ (\emptyset,\theta)}{Means\ radiation\ inetnsity\ in\ all\ directions} \quad (2.4)$$

$$= \frac{Radiation\ intensity\ of\ antenna\ in\ dierction\ (\emptyset,\theta)}{Radiation\ intensity\ of\ isotropic\ antenna\ radiating\ the\ same\ total\ power}$$

The equation 2.4 is the common expression directivity based on used isotropic antenna in the unity of decibel, dB while in to convert the unit of the directivity to dBi was used expression below:

$$D\ (dBi) = 10 \log D \quad (2.5)$$

2.3.4 Gain

The gain of the antenna was closely related to the directivity whereas it takes from the efficiency of the antenna as well the directional capabilities. If the antenna 100% efficiency, means both the gain and directivity are equals. Gain was defined by [29]

$$G = D \times e \tag{2.6}$$

Where

D = directivity as power ratio

e = antenna efficiency

2.4 Previous Design of Fractal Antenna

The variety of fractal geometry shape are Sierpinski Carpet, Koch, Minkowski and Giusepe Peano were used in previous works. The performances of antenna that will be described well are the return loss, bandwidth, gain, and VSWR in this section before further designs are being chosen in this project.

According to Sika Shrestha, Seong Ro Lee and Dong-You Choi [9], the proposed design of rectangular patch with the simple fractal structure of second-order Sierpinski carpet, inset notch, and perturbation added at corner. This antenna performs of dual band frequency antenna for radio frequency, RF energy Harvesting with 2.45 GHz and 5.8 GHz ISM bands for RFID and other wireless application. The antenna was simulated using a finite-element-method based Ansoft High-Frequency Structure Simulator (HFSS) software. Then, the antenna was fabricated using FR4 substrate. The simulation and the measurement result are presented for the return loss and bandwidth at S_{11} versus frequency graph, gain, VSWR, radiation pattern, Smith Chart and extra of impedances versus frequency only for simulation. The simulated return loss at 2.45 GHz and 5.8 GHz are 35.52dB and 39.6dB respectively, but the measured of return loss which operates at 2.45 GHz and 5.76 GHz are 21.2dB and 18.22dB respectively. Moreover, the simulated bandwidth percentages at 2.45 GHz and 5.8 GHz are 2.44% and 3.44% respectively, while the measure of bandwidth percentages which operate at 2.45 GHz and 5.76 GHz are 2.04% and 2.08%.

By referring work in E. C. Lee et al. [10], the flexible Minkowski Fractal antenna was design for Very High Frequency, VHF application. The basic square patch antenna has been used as starting of design then proceed with the design of Minkowski Fractal until 3rd iteration and using an L-shaped folded ground plane which operates at 136 MHz. The designed antenna was simulated using CST Microwave Studio and two material are used in for this antenna design that is copper tape and the Shield Super fabric. The return loss of simulated and measured results are shown in four resonant frequency of an antenna produced at less than S_{11}= -10dB and at least S_{11} = -6dB respectively.

In previous work [11], Dipika. S. Sagne, Rahul. S. Batra and P. L. Zade have constructed a modified geometry Sierpinski Carpet fractal antenna up to 3rd iteration for wireless. The aims of the design to increase the gain that operates at 2.45 GHz. The designed antenna was simulated using High-Frequency Structure Simulator (HFSS) software on FR4 substrate. The 1/3 dimension of the patch was the factor in design the 1st iteration of Sierpinski carpet microstrip antenna. The result of simulated and measured are presented for the single design of antenna and the arrays form of the antenna because want to increase the gain value. It was shown that the gain increase further when the number of elements in array higher which obtained between 2 or 4 elements, then for 4 elements had the higher gain 6.85dB than 2 elements.

In a more recent study, Wen-Ling Chen, Guang-Ming Wang and Chen-Xin Zheng [21] propose the small-size antenna in the design of combination Koch and Sierpinski Fractal shapes. Both shaped use until the 3rd order of iteration by using factor formula in the design of Koch and Sierpinski carpet that are 1/4 factor and 1/3 factor respectively. The measurement result was shown from the 1st iteration until 3rd iteration such as the resonant frequency, f_r , percentage bandwidth and size reduction. The increasing of the iteration will make the increasing of percentage bandwidth that are at 1st iteration was 0.49% and at 3rd iteration was 0.68%. Moreover, the size of reduction also increase when the iteration increase that are at 1st iteration was 66.2% and at 3rd iteration was 77.1%. While the resonant frequency, f_r decrease when the iteration increase that are at 1st iteration was 0.8912 GHz and at 3rd iteration was 0.733 GHz. The aims in design this antenna was successfully because the small-size patches was produced.

According to Munish Kumar [22], the proposed design of the 1st iteration of Minkowski fractal antenna was analyzed by using the microstrip feed. This design operates in 2.455 GHz band by using RT/Duroid 5880 substrate and simulated on IE3D simulation software. The changes of variable value of the length in the design of 1st iteration Minkowski fractal antenna showed the variety result of the return loss and bandwidth, gain, directivity, VSWR, radiation efficiency and antenna efficiency by simulation process only. The final result of this antenna for the best value of length in design Minkowski showed from 0th iteration to 1st iteration such as the return loss gets reduces from -10.9726dB to -24.9774dB respectively. Moreover, the bandwidth also improved from 0th iteration to 1st iteration the value are from 11.45 MHz to 18.9MHz respectively. Therefore, this design of Minkowski fractal antenna works well in performances for the Bluetooth application.

In conclusion, Table 2.1 shows summarize the uses of fractal geometry shape in the previous works. Therefore, from all journal stated that the Sierpinski carpet is familiar in the design of the fractal antenna. By referring [21], the combination of the certain fractal antenna also can perform well in design to miniaturization the antenna. Initially, the design mostly starts from microstrip patch antenna that needs to calculate the length and width of the patch. In design, it important to measure the performances of antenna mostly using the result of the return loss and bandwidth, gain, VSWR and the radiation pattern. Basically, the efficient antenna works on the return loss that less than -10dB and the VSWR less than 2 or approaching 1. The modification of the design can give a change the performances value of antenna, therefore, it also can change the application of antenna. Besides that, the application has been compared in Table 2.1. Therefore, all this element was important in design the model of Fractal Antenna in this project.

Table 2.1: The Comparison between various configuration designs of Fractal Design in the previous works.

References	[9]	[10]	[11]	[21]	[23]
Frequency	1 to 7 GHz	100 to 240 MHz	1 to 14 GHz	0.7 to 1.6 GHz	2 to 7 GHz
Fractal geometry Theory.	Rectangular patch with 2nd iteration of Sierpinski carpet.	Square patch with 3rd iteration of Minkowski	Square patch with 1st until 3rd iteration of Modified Sierpinski Carpet.	Square patch with a combination of 1st iteration of Sierpinski Carpet and 1st until 3rd iteration of Koch curve.	Square patch with 1st iteration of Minkowski
Type of substrate.	Fire Retardant (FR4)	i) Conductive copper tape ii) ShieldIt conductive textile.	Fire Retardant (FR4)	Substrate with permittivity $€_r = 2.65$	RT/Duroid 5880 substrate
Design in term of feeding method.	Inset-fed	L-shaped folded ground plane	Modified location of microstrip feed line	Microstrip feed line	Microstrip feed line

Table 2.1: The Comparison between various configuration designs of Fractal Design in the previous works (Cont.)

References	[9]	[10]	[11]	[21]	[23]
Tool for Simulation	High-Frequency Structure Simulator (HFSS)	Computer Simulator Technology (CST) Microwave Studio	High Frequency Structure Simulator (HFSS)	-	IE3D simulation
Return Loss	S11 operate in less than -10dB				
Application	Dual-band patch antenna for RF Energy Harvesting	Very High Frequency (VHF)	Wireless Communication	Integrated low-profile wireless communication	Bluetooth application

2.5 Design Technique of Fractal Antenna Procedure

The Fractal antenna design procedure must start with the design of the microstrip patch antenna design than proceed with the shaped of Fractal antenna that needs to be used. In this project, the Sierpinski carpet was proposed to be designed.

2.5.1 Design of Microstrip Patch Antenna

According [3&11] the design of the microstrip antenna in calculating the width and the length of the patch. In Figure 2.2 show the illustration of the microstrip patch antenna. Firstly, use Equation 2.1 in determine the width, W of the patch.

$$W = \frac{c}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \tag{2.7}$$

Where

f_r = The resonant frequency or operating (Hz)

ε_r = The dielectric constant of the substrate

c = Free space velocity of light (3×10^8 m/s)

Next, the value of length need to determine first the effective dielectric constant, ε_{reff} using Equation 2.2, the extension of the length, ΔL using Equation 2.3, and then use the Equation 2.4 to determine the actual length of the patch, L.

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\frac{1}{\sqrt{1+12\frac{h}{W}}}\right] \tag{2.8}$$

Where

h = Height of the substrate

$$\Delta L = 0.412h \left[\frac{(\varepsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)}\right] \qquad (2.9)$$

$$L = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} - 2\Delta L \qquad (2.10)$$

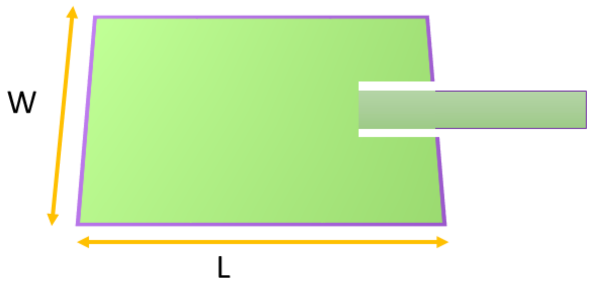

Figure 2.2: Microstrip Patch antenna [3]

2.5.2 Design of Feed Microstrip Antenna

The feeding method consists of the very type that popular to be used which are microstrip line, coaxial probe, aperture coupling and proximity coupling. The easy to fabricate was the microstrip line feed which more simple to match with the controlling the insert position but in design, it has the radiation bandwidth limit typically 2-5%. Next, the feeding of the coaxial probe where the position of outer conductor are connected to the ground of the patch and the inner conductor connected to radiation patch. This feeding method was easy to fabricate and match, but it possible has a narrow bandwidth and more difficult to model. The aperture coupling is the most difficult to fabricated and it also has a narrow bandwidth like coaxial probe feed. [3] [23]. In this project, the microstrip line was chosen feeding method because it easier to fabricate and simple.

Moreover, the microstrip inset-fed line can be calculated by using this expression formula:

$$Fi = 10^4 \,(0.001669 \times {\varepsilon_r}^7 + 0.13761 \times {\varepsilon_r}^6 - 6.1782 \times {\varepsilon_r}^5 + 93.187 \times {\varepsilon_r}^4 - 682.69 \times {\varepsilon_r}^3 + 2561.9 \times {\varepsilon_r}^2 - 4043 \times \varepsilon_r + 6697) \times \frac{L}{2} \tag{2.11}$$

Where

ε_r = Dielectric constant

L = Length of the patch

In the implement to increase the gain performances, the feed network was the very important part that involved of the overall antenna which connected it individually into a network by using transmission line. This same technique in design the single antenna become an array. The feed network consists of series and parallel feed. Figure 2.3 shows the parallel feed network which used to simple power spilled.

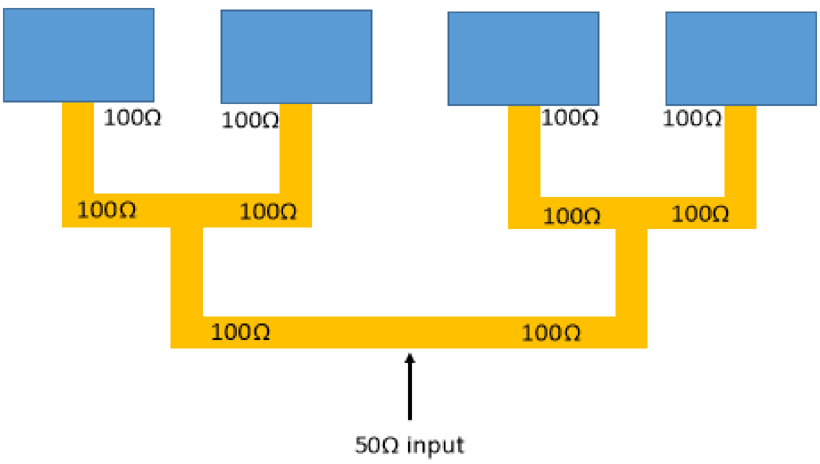

Figure 2.3: Parallel Feed Network [3] [29]

2.5.3 Design of Fractal Antenna - Sierpinski carpet

The Sierpinski carpet was chosen in design the fractal antenna and the iteration of the geometry was easy to understand and design. The simple formula in design the slot in the patch that using of 1/3 factor of the length patch. The illustration of iteration for Sierpinski carpet was shown below in Figure 2.4 [11].

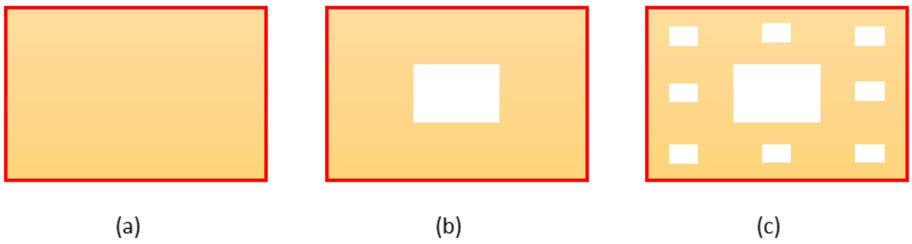

Figure 2.4: (a) 0^{th} iteration of Sierpinski carpet, (b) 1^{st} iteration of Sierpinski carpet, (c) 2^{nd} iteration of Sierpinski carpet [11]

2.6 Previous Research of Wideband Antenna

The design of the fractal antenna mostly operates for the multiband antenna as a state in section 2.4. Hence, there got some technique to make the antenna operate as a wideband antenna in this section will be discussed in detail by referring the previous work of vary researcher.

M. Al-Husseini et al. [24] proposed the Design I of by basic geometry, rectangular shaped with the ground of the design is partial and comprises a rectangular section and semi-circular one. Next, Design II is modified Design I by cut round at all corners and the 2^{nd} iteration of Sierpinski carpet was used. Then, the design of feed line connects with the matching of trapezoidal shapes. The simulation process by using the Ansoft HFSS, which based on the finite element method and MoM-based on the ADS Momentum. From

HFSS, the return loss of both designs are less than -10dB at a frequency of Design I was 3.84GHz to 10.34GHz then for Design II was 3.75 GHz to13.6GHz. From ADS Momentum-computed, the return loss of both designs was less than -10dB at a frequency of Design I was 3.22GHz to 12.2GHz then for Design II was 3.15 GHz to 14 GHz. The result shows that both design antenna has improvement of bandwidth from Design I to Design II for each of simulation software. But there were differences if compare both software by design due to the fact of Momentum that assume an infinite substrate while HFSS simulate the finite size of the substrate.

According Mohammad Ojaroudi and Ozlem Aydin Civi [25], proposed the design to improve the impedances of bandwidth by constructed the square patch with a microstrip feed line deflected by inverted the U-shaped on one side. Then, the ground of the patch consists of the rectangular defected ground by an inverted U-shaped protruded strip. By cutting the dimension of inverted U-shaped must be a suitable value it able to enhanced impedance bandwidth. The antenna design was simulated by using Ansoft HFSS. The result shown of fabricated antenna shows that the return loss at a frequency of 3.2G Hz to 10.5 GHz is less that -10dB. This means that design antenna function as a wideband antenna.

In a more recent study, Homayoon Oraizi and Shahram Hedayati [26] used to combine two type of fractal that are for type I uses first the Minkowski and then Koch fractal. While Type II is the reverse order process of Type II. Both designs applied the coaxial feed for the feeding method of design. Besides that, in design to decreases the effective dielectric, enhanced the bandwidth and reduce of reduction quality factor, they place the air gap between the substrate and the ground plane. The cutting of the rectangular slit at the center of an edge was design to achieve the circular polarization with the maximum bandwidth. The square slots are cut around the feed point on a patch to have the maximum frequency band. The Ansoft HFSS software was used in simulation design in their project. The result of the simulation and measurement are shown the designed antenna operate between 2 GHz to 3 GHz. To summarize that this design has improved the performances of the antenna.

In addition, Homayoon Oraizi and Shahram Hedayati [27] has developed the combination of 1st iteration of Giusepe Peano and 2nd iteration of Sierpinski Carpet fractals for monopole antenna in the application of the ultra-bandwidth, UBW frequency. Giusepe Peano applied to every edge of the square patch while Sierpinski Carpet applied by cutting the patch area until 2nd iteration. Hence, the design of the feed is applied the tapered for impedances matching. Moreover, the ground plane was designed by applying the combination of the rectangular and the semi-elliptical shape which the semi-elliptical had matched with the tapered feed. The antenna design simulates by using Ansoft HFSS. The result of simulation and measurement was shown the antenna operate from 1 GHz to 15 GHz with return loss less than -10dB. From the result, the design of the antenna that has been developing operate in omnidirectional radiation pattern, a good gain which between 3dB to 5dB, the VSWR less than 2 and high efficiency. Besides that, the comparison of the return loss between the each of common fractal geometry which is Koch, Minkowski, T-type and Giusepe Peano also shown for various application system of UWB.

By referring to work Yoges Kumar Choukiker and Santanu Kumar Behera [28], the Modified of Sierpinski Square Fractal, MSSF with band notch covering UWB application has been present in their project. The proposed design of MSSF have the cover in the range 3.1 GHz to 10.6 GHz and the band-notch characteristic at 5.5 GHz cover between

5GHz to 6 GHz range of frequency. While the ground plane was designed in partially rectangular shaped with matching to the feed of antenna. The result of the simulation shown the return loss in every stage in the design of the MSSF geometry. This antenna operates in the target range of frequency with a stable of the radiation pattern. To conclude that the design was used for the UWB application.

As to conclude that, Table 2.2 shows summarize in method to enhance the impedances of the bandwidth need strategies in modified the design of the antenna. Moreover, the design of the feeding method also can influence the changes of bandwidth antenna. Besides that, the advantage has been compared in Table 2.2. Therefore, all this element was important in design the model of Wideband Fractal Antenna in this project.

Table 2.2: Parameter Comparison between various configuration designs of Wideband Design.

References	[24]	[25]	[26]	[27]	[28]
Frequency	3.15 to 14GHz	3.2 to 10.5GHz	2 to 3 GHz	1 to 15 GHz	3.1 to 10.6 GHz
Fractal Geometry	Rectangular patch with 2nd iteration of Sierpinski carpet	square patch only without fractal geometry.	Square patch with combination Minkowski and Koch fractal.	Square patch with c combination of 1st iteration of Giusepe Peano and 2nd iteration of Sierpinski Carpet	Square patch with Sierpinski Fractal
Improvement of Design in term of ground plane	Partial and comprises a rectangular section and semi-circular one.	Rectangular defected ground by an inverted U-shaped protruded strip	Place the air gap between the substrate and the ground plane	Combination of the rectangular and the semi-elliptical shape	Partially rectangular shaped
Improvement of Design in term of patch	Cut round at all corners	-	• Square slots is cut around the feed point • cutting of the rectangular slit at the center of an edge	-	Modified of Sierpinski Square Fractal

Table 2.2: Parameter Comparison between various configuration designs of Wideband Design (Cont.)

References	[24]	[25]	[26]	[27]	[28]
Improvement of Design in term of feeding method.	Trapezoidal shapes	Feed line defected by inverted the U-shaped	Coxial feed	Tapered / Trapezoidal shape	Feed line with band notch
Return Loss	S11 operate in less than -10dB				
Advantages	• low-cost • small size • better return loss • simple design	• simple structure • introduce of inverted U-shaped to improve more than 100% of bandwidth • good omnidirectional radiation	• Small size • Can improve antenna characteristic	• small size • can use for various application • simple design	• inexpensive • small size • low profile antenna • notch band is new band rejection present