LOG PERIODIC FRACTAL KOCH ANTENNA FOR WIRELESS APPLICATIONS

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ABSTRACT

In wireless communication system, antenna is one of the important devices to allow two ways communications. At lower frequency bands, the antenna size is bigger compared to the higher frequency band. Various techniques have been used in reducing the antenna size such as fractal technique and higher dielectric constant while maintaining the performance of the antenna. In this work, the fractal Koch geometry has been used as a method to reduce the size of the developed antennas. This is based on the advantages that are inherent for fractal Koch geometry in reducing the size and maintaining the performances. The design of the antenna begins with the understanding of the basic antenna properties such as return loss, radiation pattern including the understanding of the Koch geometry. A number of designs has been developed such as zero, first, second (0^{th}, 1^{st}, 2^{nd}) and series iteration which are targeted for wideband and Ultra High Frequency (UHF). The simulation work is done using Computer Simulation Technology (CST 2008) software. About 27 % reduction of the antenna size has been achieved by using fractal Koch technique. The designs obtained from simulation are fabricated on FR4 board using wet etching technique. The results from simulation and measurement have been compared and analyzed. The antennas show good return loss lower than -10 dB at the desired frequency, directional radiation patterns with beamwidth of 110 degree, wide bandwidth up to 200 %, and gain between 5 dBi and 8 dBi.

ABSTRAK

Dalam sistem perhubungan wayarles, antena merupakan salah satu peranti yang penting dalam memastikan wujudnya perhubungan dua hala. Pada jalur frekuensi rendah, saiz antena adalah lebih besar berbanding pada jalur berfrekuensi tinggi. Pelbagai teknik telah digunakan untuk mengurangkan saiz antena antaranya menggunakan teknik fraktal dan pemalar dielektrik yang tinggi tanpa menjejaskan prestasi sediada. Dalam kerja ini, rekabentuk geometri fraktal Koch telah digunakan sebagai satu teknik untuk mengecilkan saiz antena yang dibangunkan. Ini adalah berdasarkan kelebihan yang terdapat pada rekebentuk geometri Koch yang mampu mengecilkan saiz disamping mengekalkan prestasi antena tersebut. Rekabentuk antena ini bermula dengan memahami ciri-ciri asas sesuatu antena seperti kehilangan balikan, corak sinaran dan sebagainya disamping memahami fraktal geometri itu sendiri. Beberapa rekabentuk telah dibangunkan seperti lelaran sifar, pertama, kedua dan sesiri untuk aplikasi jalur lebar dan jalur frekuensi ultra tinggi (UHF). Kerja-kerja simulasi dilakukan dengan menggunakan perisian Teknologi Simulasi Komputer (CST 2008). Dengan menggunakan teknik fraktal Koch**,** didapati bahawa saiz antena berkurang sebanyak 27 %. Rekabentuk yang diperoleh daripada simulasi telah difabrikasikan dengan papan FR-4 menggunakan teknik punaran basahan. Keputusan daripada kerja-kerja simulasi dan pengukuran dibandingkan dan dianalisis. Kesemua antena menunjukkan kehilangan kembali yang baik dibawah -10 dB pada frekuensi berkaitan, corak sinaran terarah dengan lebaralur 100 darjah, lebar jalur yang besar iaitu melebihi 200 % serta gandaan antara 5 dBi dan 8 dBi.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
	LIST OF SYMBOLS	xvii
1	**INTRODUCTION**	
	1.1 Introduction	1
	1.2 Project Background	1
	1.3 Problem Statement	2
	1.4 Objective	3
	1.5 Scope of the Study	3
	1.6 Project Contribution	4
	1.7 Organization of the Thesis	4
2	**LITERATURE REVIEW**	
	2.1 Introduction	6
	2.2 Fractal Antenna Technology	6
	2.2.1 Fractal Geometry	7
	2.2.2 Fractal Antenna Classification	8

	2.2.3	Advantages of Fractal Antenna	9
2.3	Antenna Properties		10
	2.3.1	Operating Frequency	10
	2.3.2	Radiation Pattern	11
	2.3.3	Bandwidth	12
	2.3.4	Gain	13
	2.3.5	Polarization	13
	2.3.6	Half Power Beam Width	14
2.4	Log Periodic Technique		14
	2.4.1	Fractal Koch Log Periodic Antenna Design	16
	2.4.2	Backfire Radiation	18
2.5	Previous Work		18
	2.5.1	Fractal Antenna Design for RFID Application	19
	2.5.2	Hilbert Curve Fractal Antenna: A Small Resonant Antenna for VHF / UHF Applications	20
	2.5.3	Analysis of the Patch Antenna based on the Minkowski fractal	21
	2.5.4	An Overview of Fractal Antenna Engineering Research	22
	2.5.5	Size Reduction and Bandwidth Enhancement of Snowflake Fractal Antenna	23
	2.5.6	Fractal Antenna A Novel Antenna Miniaturization Technique and applications	24
	2.5.7	Ultra-Wideband Planar Antenna for UHF Communications	25
	2.5.8	Analysis, Design and Simulation of Log Periodic Antenna for Mobile Communication Bands.	26
	2.5.9	Design of Fractal UWB Antenna	27
2.6	Chapter Summary		28

3	**METHODOLOGY**		
	3.1	Introduction	29
	3.2	Methodology	29
	3.3	The Design of 0th and 1st Iteration Fractal Koch Antenna for Broadband Applications	32
	3.4	The Design of 0th, 1st and Series Iteration Fractal Koch Antenna for UHF Band Applications	35
	3.5	The Design of 0th and 2nd Iteration Fractal Koch Antenna	38
	3.6	Port Creation	41
		3.6.1 SMA Port	43
		3.6.2 Port Modes	44
	3.7	Fabrication Process	45
	3.8	Measurements Setup	46
		3.8.1 Input Return Loss Measurement	46
		3.8.2 Radiation Pattern Measurement Setup	47
	3.9	Chapter Summary	50
4	**RESULTS AND DISCUSSION**		
	4.1	Introduction	51
	4.2	Broadband Fractal Koch Antennas	51
		4.2.1 Result of Input Return Loss for Broadband Antennas	52
		4.2.2 Analysis of Radiation Pattern for Broadband Fractal Koch Antennas	55
		4.2.3 Half Power Beam Width (HPBW)	61
		4.2.4 Analysis of Gain for Broadband Fractal Antennas	62
		4.2.5 Current Distribution Analysis	64
	4.3	Fractal Koch Antenna 0th , 1st and Series Iteration for UHF Band Applications	65
		4.3.1 Analysis of Return Loss for UHF Fractal Koch Antennas	66
		4.3.2 Analysis of Radiation Pattern for UHF Fractal Koch Antennas	71

4.3.3 Half Power Beamwidth (HPBW) 75
4.3.4 Analysis of Gain for Fractal Koch for UHF Band Application 75
4.3.5 Current Distributions of 0^{th}, 1^{st} and Series Iteration Antennas 77
4.4 Fractal Koch Antenna for 0^{th} and 2^{nd} Iteration 78
4.4.1 Analysis of Return Loss for Fractal Koch Antenna for DTV 79
4.4.2 Analysis of Radiation Pattern for Fractal Koch Antennas 83
4.4.3 Half Power Beamwidth (HPBW) 86
4.4.4 Analysis of Gain for Fractal Koch Antennas 86
4.4.5 Current Distribution Analysis of 2^{nd} Iteration 88
4.5 Summary 90

5 CONCLUSION AND FUTURE WORK
5.1 Conclusion 91
5.2 Key Contribution 92
5.3 Propose Future work 93

REFERENCES 94

Appendices A-I 99 – 146

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Summary of experimental result	21
3.1	Design Specification of the Broadband Antenna	32
3.2	Dimension of 0^{th} and 1^{st} iteration antenna for broadband applications	34
3.3	Comparison of size reduction of broadband fractal Koch antenna	34
3.4	Design Specification of the Broadband Antenna	35
3.5	Dimension of 0^{th} iteration antenna for UHF band applications	37
3.6	Comparison of size reduction of UHF fractal Koch antenna	38
3.7	Design Specification of the Fractal Koch Antenna	39
3.8	Dimension of Fractal Koch antenna	40
3.9	Comparison between 0^{th} and 2^{nd} iteration	41
4.1	Half Power Beam Width for Broadband Fractal Koch Antenna	62
4.2	Gain and efficiency of 0^{th} and 1^{st} iteration broadband antenna	62
4.3	Half Power Beamwidth for UHF Fractal Koch Antenna	75
4.4	Gain of 0^{th}, 1^{st} and series iteration antenna for UHF band applications	76
4.5	Half Power Beamwidth for Second Iteration Fractal Koch Antenna	86
4.6	Simulated gain for 0^{th} and 2^{nd} iteration antenna	87

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Example of Fractal Antennas, (a) Sierpinski Carpet, (b) Cantor Set, (c) Koch Curve, (d) Sierpinski Gasket, (e) 3D Sierpinski, (f) Fractal Tree	8
2.2	Fractal Antenna Classification	9
2.3	Type of iterations	10
2.4	Coordinate system for radiation pattern measurement	11
2.5	Configuration of Log Periodic Antenna	15
2.6	A half-wave dipole and the Koch Fractal dipole	19
2.7	Generation of Hilbert Curve antenna	20
2.8	Radiation pattern in two orthogonal planes	20
2.9	Fabricated Square and fractal patch antenna	21
2.10	Fabricated Array Square and fractal patch antenna	21
2.11	Return loss at different iteration factor	22
2.12	Koch curves and fractal trees used in miniaturized dipole antennas	22
2.13	Sierpinski Carpet and Sierpinski Gasket Antenna	22
2.14	Geometry of original Koch Snowflake for four iterations	23
2.15	Simulated return loss of Snowflake fractal antenna	23
2.16	Radiation pattern of new Snowflake at third iteration at 5.875 GHz	24
2.17	Mathematically generated plants, created using *Fractint*	24
2.18	The iterative generation procedure for Minkowski Island	25
2.19	Geometry of the ultra-wideband patch antenna	25
2.20	Simulated and measured return losses	26

2.21	Schematic diagram of LPDA	26
2.22	Output from simulation	27
2.23	Antenna prototype	27
2.24	Simulated and measured return loss	28
2.25	Measured radiation pattern	28
3.1	Flow Chart of Research Methodology	31
3.2	0^{th} Iteration Fractal Koch Broadband Antenna	33
3.3	1^{st} Iteration broadband fractal Koch antenna	33
3.4	0^{th} iteration Fractal Koch Antenna for UHF band applications	36
3.5	1^{st} iteration fractal Koch antenna for UHF band applications	36
3.6	Series Iteration fractal Koch antenna for UHF band applications	37
3.7	Layout of 0^{th} Iteration Fractal Koch Antenna	40
3.8	Layout of 2^{nd} Iteration Fractal Koch Antenna	40
3.9	Parameter of Coaxial Structure	42
3.10	Design flow for SMA port	43
3.11	Port Mode (E Field)	44
3.12	Port Mode (H Field)	44
3.13	Etching Process	45
3.14	Calibrated input return loss a) Before calibration, b) After calibration	47
3.15	Measurement Return Loss (S_{11}) process	47
3.16	Radiation pattern measurement setup in anechoic chamber	48
3.17	Measurement Radiation Pattern, a) Anechoic Chamber, b) Signal Genrator and Spectrum Analyzer	49
4.1	Broadband Fractal Koch Antenna a) 0^{th} Iteration b) 1^{st} Iteration	52
4.2	Comparison between simulated return loss for 0^{th} iteration and 1^{st} iteration fractal broadband antennas.	53

4.3	Comparison between measured return loss for 0th iteration and 1st iteration fractal broadband antennas	53
4.4	Comparison between simulated and measured returns loss broadband fractal Koch antenna a) 0th iteration, b) 1st iteration.	54
4.5	Simulated and measured radiation patterns for 0th iteration broadband fractal Koch antenna, a) E-Plane at 2GHz (b) H-Plane at 2 GHz, (c) E-Plane at 5 GHz, d) H-Plane at 5 GHz, (e) E-Plane at 7 GHz and(f) H-Plane at 7 GHz.	57
4.6	Simulated and measured radiation patterns for 1st iteration broadband fractal Koch antenna, a) E-Plane at 2 GHz, b) H-Plane at 2 GHz, c) E-Plane at 5 GHz, d) H-Plane at 5 GHz, e) E-Plane at 7GHz and f) H-Plane at 7 GHz.	59
4.7	Comparison radiation pattern for 0th and 1st iteration antennas, a) E-Plane at 2 GHz, b) H-Plane at 2 GHz, c) E-Plane at 5 GHz, d) H-Plane at 5 GHz, e) E-Plane at 7GHz and f) H-Plane at 7 GHz.	60
4.8	Gain comparison between Horn antenna and broadband antennas.	63
4.9	Current distribution of the 0th iteration broadband fractal Koch antenna a) At frequency 1 GHz, b) At frequency 3 GHz, c) At frequency 6 GHz.	64
4.10	Current distribution of the 1st iteration broadband fractal Koch antenna a) At frequency 1 GHz, b) At frequency 3 GHz, c) At frequency 6 GHz	64
4.11	Fractal Koch antenna for UHF application, a) 0th Iteration, b) 1st Iteration, c) Series Iteration	65
4.12	Comparison simulated return loss for 0th iteration, 1st iteration and Series iteration UHF Fractal Koch Antennas	67
4.13	Simulated return loss with different flare angle	67
4.14	Comparison measured return loss for 0th iteration, 1st iteration and series iteration UHF Fractal Koch Antennas.	68

4.15	Comparison simulated and measured return loss UHF Fractal Koch Antennas a) 0th iteration, b) 1st iteration, c) Series iteration	69
4.16	Simulated and measured radiation patterns for 0th iteration UHF fractal Koch antenna, a) E-Plane at 0.8 GHz, b) H-Plane at 0.8 GHz, c) E-Plane at 2 GHz, and d) H-Plane at 2 GHz.	71
4.17	Simulated and measured radiation patterns for 1st iteration UHF fractal Koch antenna, a) E-Plane at 0.8 GHz, b) H-Plane at 0.8 GHz, c) E-Plane at 2 GHz, and d) H-Plane at 2 GHz.	73
4.18	Simulated and measured radiation patterns for Series iteration UHF fractal Koch antenna, a) E-Plane at 0.8 GHz, b) H-Plane at 0.8 GHz, c) E-Plane at 2 GHz, and d) H-Plane at 2 GHz.	74
4.19	Gain comparison between Horn antenna and UHF antennas	76
4.20	Current Distribution of the 0th iteration antenna a) At frequency 0.5 GHz, b) At frequency 0.8 GHz, c) At frequency 2 GHz.	77
4.21	Current Distribution of 1st iteration antenna a) At frequency 0.5 GHz, b) At frequency 0.8 GHz, c) At frequency 2 GHz	77
4.22	Current Distribution of Series iteration antenna, a) At frequency 0.5 GHz, b) At frequency 0.8 GHz, c) At frequency 2 GHz.	78
4.23	Fractal Koch Antenna a) 0th Iteration b) 2nd Iteration	78
4.24	Simulated return loss for 0th iteration and 2nd iteration antenna	79
4.25	Simulated return loss by changing the degree of flare	80
4.26	Measured return loss for straight and second iteration antenna	81

4.27	Simulated and measured return loss Fractal Koch antenna for DTV application a) 0^{th} iteration, b) 2^{nd} iteration	82
4.28	Simulated and measured radiation patterns for 0^{th} iteration fractal Koch antenna, a) E-Plane at 0.7 GHz, b) H-Plane at 0.7 GHz, c) E-Plane at 0.8 GHz, and d) H-Plane at 0.8 GHz.	83
4.29	Simulated and measured radiation patterns for 2^{nd} iteration fractal Koch antenna, a) E-Plane at 0.7 GHz, b) H-Plane at 0.7 GHz, c) E-Plane at 0.8 GHz, and d) H-Plane at 0.8 GHz.	85
4.30	Gain comparison between Horn antenna and UHF antennas	87
4.31	2^{nd} Iteration antenna before and after the size reduction a) Before the cutting, b) After the cutting.	88
4.32	Current distribution of 2^{nd} Iteration antenna before and after the size reduction a) Before the cutting, b) After the cutting.	89
4.33	Return loss graph for trim and without trim edge	89

LIST OF SYMBOLS

dB	-	decibel
ε_r	-	Dielectric constant
h	-	Substrate height
$\boldsymbol{\tau}$	-	Scaling factor
λ_g	-	Guided wavelength
(r,θ,φ)	-	Spherical coordinate system
E	-	Electric
H	-	Magnetic
f_u	-	Upper cutoff frequency
f_l	-	Lower cutoff frequency
N	-	Number of elements
d	-	distance between elements
θ	-	phase
λ_0	-	wavelength in free space
l	-	transmission line length
Z_o	-	characteristic impedance
ε_{eff}	-	effective dielectric constant
c	-	velocity of light in free space
f_r	-	operating frequency
$tan\ \delta$	-	dissipation factor
$BW\%$	-	bandwidth in percentage

LIST OF APPENDIXES

APPENDIX	TITLE	PAGE
A	List of Publications	99
B	Log Periodic Koch Antenna Design	122
C	Method to Create Fractal Koch Antenna Using CST	125
D	Measured Radiation Patterns	128
E	3D Simulated Radiation Patterns	136
F	Specification of Horn Antenna	139
G	SMA Connector Specifications	140
H	FR 4 specification	141
I	Hittite Signal generator	143

CHAPTER 1

INTRODUCTION

1.1 Introduction

This thesis proposes the development of fractal Koch antenna design that can be implemented for wireless applications at Ultra High Frequency (UHF) band, Digital TV broadcasting (DTV), Digital Video Broadcasting (DVB) and Wireless Regional Area Network. In the first chapter, the background of the project is discussed while providing the problem statement, objective, scope of the study, project contributions and organization of the thesis.

1.2 Project Background

Antenna design has become one of the most active fields in the communication studies. In the early years when radio frequency was found, simple antenna design was used as a device to transmit electrical energy or radio wave through the air in all direction. This innovative way of communication to replace wired technology to wireless technology was first introduced by Galileo Marconi when he successfully initiated the first wireless telegraph transmission in 1895 [1]. The wireless technology has expanded rapidly not only for commercial but also for military purposes.

In modern telecommunication systems, the requirement for antennas with wider bandwidth and smaller dimensions than conventional are preferred. This has initiated research on antenna 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. A few researches have been made in designing the fractal properties for the antennas.

Several antenna configurations based on fractal geometries have been reported in recent years [2] – [5]. 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 antennas with reduced size have been obtained using Koch curve fractal geometry. Furthermore, design equations for these antennas are obtained in terms of its geometrical parameters such as fractal dimension. Antenna properties have also been linked to fractal dimension of the geometry. In order to lay the 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 [6].

1.3 Problem Statement

The demands for UHF communication systems have increased; low-profile systems have drawn and bring much interest to researchers. In making such low-profile communication systems, the size of the antenna is critical. Therefore, many techniques such as using higher dielectric substrate, multiple layers and by optimizing the shape of the antennas have been proposed and applied to the microstrip and planar antennas. The application of fractal geometry to conventional antenna structures optimizes the shape of the antennas in order to increase their electrical length, which thus reduces their overall size. Fractal shape antenna elements present various advantages; multiband frequency and reduced antenna size.

[7]. It's bring fractal shapes becomes more enticing among researchers due to their capabilities. In applications where spaces are constraints, alternative smaller designs need to be considered. The ability to reduces the antenna size without degrade the overall performances of the antenna bring much interest to the antenna research. Therefore, in this project, fractal Koch antenna for three different applications is introduced. The main task here is to reduce the size of the antennas by using fractal technique. The literature about the fractal types, history and some of the previous work is elaborated in chapter 2.

1.4 Objective

The main objectives of this project are as follows:

1) To design, fabricate and analyze the fractal Koch antennas that can be use for Ultra High Frequency (UHF) and broadband applications.
2) To reduce the size of the antenna by using fractal Koch technique for first, second and series iterations.
3) To compare between simulated and measured result and analyze the input return loss, radiation pattern, gain and current distribution of the antennas.

1.5 Scope of Study

The scope of this research begins with understanding the antenna properties and fractal antenna geometries. The literature and the advantages of fractal antenna have been studied.

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

The validation work has been carried out in term of return loss, radiation pattern and gain using appropriated equipment such as Network Analyzer, Spectrum Analyzer, Signal Generator and Anechoic Chamber.

Then, the result obtained from simulation and measurement is compared, analyzed and documented.

1.6 Project Contribution

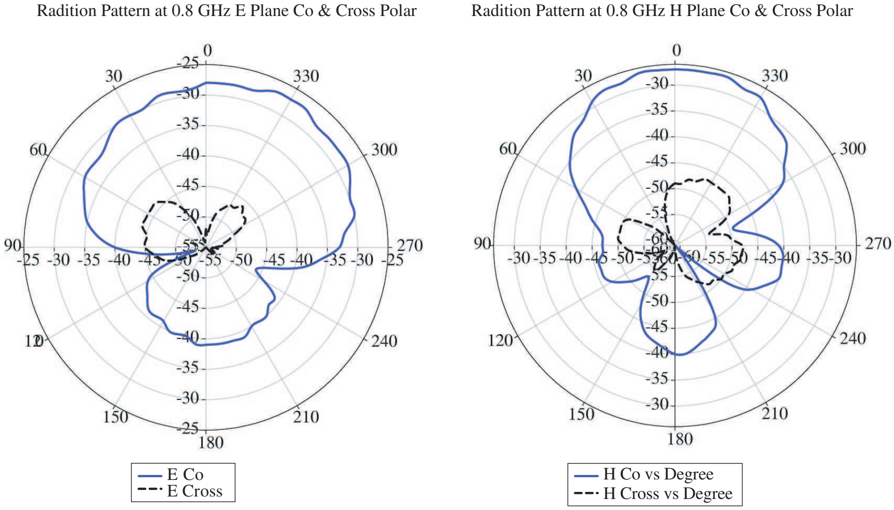
The applications of the fractal Koch antenna can be applied in many wireless applications. The technique to reduce the size of the antenna can be implemented by using fractal shape. In this work, fractal Koch geometry has been applied to the antennas design to reduce the size of the antennas. The 0^{th}, 1^{st}, 2^{nd} and Series iteration antennas have been design for broadband and UHF band applications. The performance of these antennas has been analyzed and observed.

1.7 Organization of the Thesis

The organization of the thesis is divided into five chapters. The first chapter consists of introductions which provide information regarding background of the project, problem statement, objectives, scope of studies, project contribution and organization of the thesis.

The second chapter is the literature review which provides information regarding fractal antenna technologies. Besides, a basic concept such as log periodic concept and some related previous works are shown in this chapter.

Project methodology, in which the method employed in this work, is explained in chapter 3. The design and development of 0^{th}, 1^{st}, Series and 2^{nd} iteration of fractal Koch antenna with different applications is discussed in this



(c) Series Iteration

Figure 13. Co and cross polar for E and H plane LPFKA at 0.8 GHz.

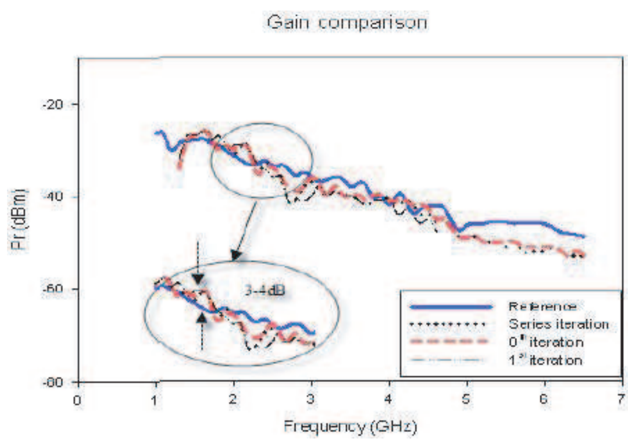


Figure 14. Gain comparison between horn antenna and LPFKA.

Figure 12. The simulated and measured radiation patterns for E-co and H-co correlate well. However, the existing of the back lobes for measured radiation pattern does not much affect the main beam of the antenna especially at 0.8 GHz for E-co polar and at 2 GHz for H-co polar. The measured radiation patterns show that the antennas are linearly polarized. The differences between co and cross polar determined the polarization of the antennas. In this case, co and

cross polar for both E and H planes are more than 3 dB as shown in Figure 13.

4.4. Analysis of Gain for Fractal Koch Antenna

The measured gain for UHF Fractal Koch antennas has been compared with the reference antenna. All three prototypes of this antenna exhibit a similar pattern compared to each other. As can be seen, the 0th, 1st and series iteration LPFKA give similar patterns. The antennas have been measured and compared in terms of power received by varying the frequency range and the value of power received in dBm. The antenna has a higher gain when it gives higher values at that particular frequency. However, it might have a lower gain when it is working outside its operating region.

5. CONCLUSION

The Log Periodic Fractal Koch antennas with three different structures such as the 0th, 1st and series iterations have been designed, simulated and fabricated. The simulated and measured results in terms of return loss, radiation pattern and gain have been compared and analyzed. The simulated current distribution of the antennas shows a good correlation between radiating elements and resonant frequencies. Moreover, the size of the antennas has been reduced up to 7% for the 1st iteration and up to 26% for series iteration antenna compared to the 0th iteration. The radiation patterns of all fabricated antennas are similar to the simulated ones. In addition, the gains of the antennas also are similar to that of the fabricated antennas. It shows that by applying the number of iterations to the antenna, the size of the antennas can be reduced. The performances of the antennas are maintained throughout the frequency range of the designed. The comparison between simulated and measured results has been shown and discussed in this paper, and it shows a good agreement for both results.

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