BANDWIDTH ENHANCEMENT OF SPIRAL ANTENNA WITH DEFECTED GROUND STRUCTURE

MOHAMED OSMAN MOHAMED

A project submitted in
fulfillment of the requirement for the award of the
Degree of Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

JANUARY 2018

This thesis is dedicated to my parents.

For their endless love, support, encouragement and prayers.

ACKNOWLEDGEMENT

First and foremost, I would like to thank Allah Almighty for giving me the strength, knowledge, ability and opportunity to undertake this project and to persevere and complete it satisfactorily. Without his blessings, this achievement would not have been possible.

Secondly, I would like to take opportunity to thank my supervisor Dr Noorsaliza Binti Abdullah for her support and encouragement during this project. At many stages in the course of this research project, I benefited from her advice, particularly so when exploring new ideas. Her positive outlook and confidence in my project inspired me and gave me confidence. Her careful editing contributed enormously to the production of this thesis.

Last but not least, I am extremely grateful to my mother, Fadumo Omar Samatar and my wife, Salma Ali Adan for their love, prayers, caring and sacrifices for educating and preparing me for my future. And I express my thanks to my sisters, brothers, aunts,uncles', relatives and friends for their endless support and valuable prayers in completing this project.

ABSTRACT

In wireless communications systems, harmonics and unwanted frequency other than designed one becomes a dominant factor in limiting quality and capacity of transmitted or received signal. Rectangular spiral antenna (RSA) is designed in order to obtain the required parameter responses at 2.45 GHz for Wifi application. The proposed antenna is excited through the coaxial feed line which is connected from the ground of the antenna. RSA of length 16cm and width 20cm is designed on the substrate dielectric material FR-4 having dielectric constant $\varepsilon_r = 4.3$ and thickness 1.6 mm. Conventional rectangular spiral antenna without DGS has very low bandwidth. This antenna has 64.8MHz which is very low and the fractional percentage is 2.63%. The defect ground structure (DGS) has gained much attention over the last few years for its ability to enhance the bandwidth and gain. After applied DGS the bandwidth enhanced to 245MHz which is very high compared to the conventional antenna. The antenna without DGS has multiple frequencies which are 1.3734, 2.0886 and 2.6538 other than the desired frequency.The DGS also effectively suppress harmonics frequencies of the spiral antenna, shows a better result compared to the conventional antenna. It effectively suppressing spurious frequency and reduces the amplitude of the unwanted multiple bands since the antenna radiates only one resonating frequency.

ABSTRAK

Dalam sistem komunikasi tanpa wayar, harmonik dan frekuensi yang tidak dikehendaki selain daripada itu yang dicipta menjadi punca kepada kualiti yang terhad dan kapasiti dalam isyarat penghantar dan yang diterima. Rectangular Spiral Antenna(RSA) dicipta untuk mendapat parameter yang dikehendaki iaitu 2.45 GHz untuk Wifi aplikasi. Antena yang digunakan ini menggunakan saluran suapan sepaksi yang disambungkan dari bawah bahagian antena. RSA menpunyai panjang 16cm dan lebar 20cm diperbuat daripada bahan dielektrik FR-4 yang telah di dielektrik dan tidak berubah yang mempunyai ketebalan 1.6 mm. RSA konvensional tanpa DGS mempunyai jalur lebar yang sangat rendah. Antena ini mempunyai 64.8MHz yang sangat rendah dan peratusan pecahan ialah 2.63%. Kecacatan pada struktur di bumi (DGS) telah mendapat banyak perhatian sejak beberapa tahun kebelakangan ini dengan keupayaannya untuk meningkatkan jalur lebar dan keuntungan. Selepas DGS digunakan jalur lebar ditingkatkan kepada 245MHz yang sangat tinggi berbanding dengan antena konvensional. Antena tanpa DGS mempunyai frekuensi yang banyak iaitu 1.3734, 2.0886 dan 2.6538, selain daripada frekuensi yang dikehendaki. DGS juga berkesan menyekat frekuensi harmonik daripada antenna lingkaran telah menunjukkan hasil yang lebih baik berbanding dengan antena konvensional.Ia berkesan menyekat frekuensi palsu dan mengurangkan amplitud daripada banyak pelbagai jalur kerana antena memancarkan hanya satu frekuensi resonasikan.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

ε_r	-	Permittivity of the substrate
ε_{reff}	-	Effective permittivity of the substrate
BW	-	Bandwidth
CST MWS	-	Computer Simulation Technology Microwave studio
FB	-	Fractional bandwidth
FR-4	-	Flame Retardant 4
GHz	-	Giga Hertz
%BW	-	percentage of bandwidth
PCB	-	Printed circuit boards
RF	-	Radio-wave
DGS	-	Defective ground structure
UHF	-	Ultra high frequency
UWB	-	Ultra-wideband
WB	-	Wideband
WLAN	-	Wireless local area network
RSA	-	Rectangular spiral antenna

CHAPTER I

INTRODUCTION

1.1 Introduction

Wireless technology provides less expansive equipment's and flexible way for communication purpose. Antenna has its own importance in communication systems; it provides radiation of electromagnetic energy uniformly in all directions. Antenna is a transducer, which converts one form of energy in to another. Here it is designed to transmit or receive electromagnetic waves from one source to destination.[1-3].

Wi-Fi networks use radio technologies. A person with a Wi-Fi enabled device such as a PC, cell phone or PDA can access to the internet when in proximity of an access point. The region covered by one or several access points is called a hotspot. Hotspot can range from a single room to many square miles of overlapping hotspots. The rectangular spiral antenna with defected ground was chosen for this work due to the circular polarization characteristic and the frequency independent characteristics for Wi-Fi applications. Furthermore, this type of antenna can be used to enhance bandwidth and gain[4].

Rectangular spiral microstrip antenna can be fed by using coaxial probe or microstrip line edge feed. In this project, the method of feeding is coaxial feed where the antenna fabricated and printed hole at the back. The Spiral antenna usually has spurious frequency and to overcome this Defected Ground Structure (DGS) on the ground plane of the transmission is made. The DGS at the ground of the transmission line acts like a low pass filter which will determine the frequency that can be passed through the transmission line.

Recently, both defected ground structure (DGS) and electromagnetic band gap (EBG) have received much attention because of their use in radar, satellite, microwave areas and mobile communication systems. Such systems often require circuits to be as small as possible. The DGS components are the dominant technology which can provide size reduction and has the capability of harmonics and spurious suppression[5].

The DGS is realized by etching a certain pattern in the backside metallic plane which perturbs the current distribution in the ground, and hence increases the effective inductance and capacitance of the microstrip line. Therefore, a DGS cell is equivalent to an LC circuit[6]. DGS is realized by etching off a simple shape in the ground plane, depending on the shape and dimensions of the defected the shielded current distribution in the ground plane is disturbed, resulting a controlled excitation and propagation of the electromagnetic waves through the substrate layer, the shape of the defect may be changed from the simple shape to the complicated shape for the better performance.

The DGS is easy to be an equivalent L-C resonator circuit. DGS can be in different size like rectangular, triangular, and circular dumb shell [7]. The rectangular dimension of the DGS represents the inductor and the narrow lattice is the capacitor. The value of the inductor and the capacitor will affect the cut off frequency of the filter that is produce by the DGS.

1.2 Problem Statement

The regular spiral antenna usually has spurious frequency which can make the signal at the operating frequency corrupt, spurious becomes a dominant factor in limiting quality and capacity. In order to suppress the spurious frequency and enhance bandwidth and gain, it can be achieved by adding either low pass or band pass filter that can be used to reject the spurious frequency. By using this method, it can increase the cost of the antenna.The Spiral antenna of the Defected Ground Structure (DGS) has gained much attention over the last few years for its ability of effectively suppressing spurious frequency and increasing the bandwidth.

To overcome that problem, it is proposed to use DGS which is being used spiral with coaxial feed from the ground, because it is easy to design and fabricate.The simulation of the antenna done in CST software.

1.3 Objectives of Study

1. To design rectangular spiral antenna with DGS at 2.45 GHz with bandwidth and gain enhancement.
2. To fabricate and test the antenna.
3. To compare and analyse the result between simulation and measurement.

1.4 Scopes of Study

The scope of this project are:

I. To design and fabricate rectangular spiral antenna with DGS and the designed antenna must suppress any spurious frequencies other than the designed frequency.
II. The antenna is designed to enhance the bandwidth and gain and to explore and simulate the basic parameters of rectangular spiral antenna using CST microwave Studio software.
III. To compare the simulation and measurement result of the designed antenna.

1.5 Theses outlines

This thesis is organized into five chapters. The first Chapter 1, it will cover on introduction on the whole thesis. It also includes the objectives, problem statements, scope of works and main introduction of the project.

Chapter 2 explains on the literature review of the project. The literature review begins with the introduction, followed by antenna parameters. Introduction is an explanation on the overview of the literature. As for the antenna topic, it is about the general description of an antenna. It is also cover on the basic principal of the antenna. This project is more focusing on rectangular spiral antenna. It is important to recognize the parameter of the antenna before designing the antenna itself.

Chapter 3 describes project methodology where it is focusing on the method that used to complete the project accordingly. The methodology will be presented in the flowchart which clearly explained about how this project is planned and organized in completing the project.Chapter 4 presents the result for the system designed and discussion of overall result. The conclusion and recommendation of this project will be discussed in chapter 5.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This chapter elaborates spiral antenna as frequency independent antennas, some of the previous works related to spiral antenna, backing techniques of spiral antenna, feeding technique of spiral antenna and Frequency selective surface structures. Literature review is significant part for understanding the specification characteristics to model rectangular spiral antenna with DGS. Literature review is one of the processes of developing rectangular spiral antenna with DGS which operates at the resonant frequency 2.45 GHZ, for this project. The literature review explains on the antenna and the basic antenna operation, basic antenna parameter, the feeding technique.

One of the important components in Wi-Fi application is an antenna. The characteristics needed for a Wi-Fi antenna is an omni-directional antenna with circular polarization [8]. Spiral antennas were introduced in 1950s by Edwin Turner [9] who demonstrated experimentally that an Archimedean spiral resulted in constant input impedance and circular polarization over a wide range of frequencies [10].

The early work on spiral antennas was published in the late 1950's and early 1960's. The planar equiangular spiral antenna and the unidirectional equiangular spiral or conical log spiral antenna were presented by Dyson (1959a, 1959b). Bandwidths of greater than 20:1 were observed with nearly constant impedance and pattern performance [11].

The early work on spiral antennas was based on experiment and the band theory. The band theory essentially means that the spiral operates in the region where the circumference of the spiral is equal to a wavelength. In the early 1960's more rigorous mathematical explanations were pursued.

Curtis (1960) derived the radiation patterns for an Archimedean spiral by approximating the spiral as a series of semicircles. Wheeler (1961) looked at the radiation from various regions of an equiangular spiral using a similar technique to Curtis, but without the semicircle approximation.

Spiral antennas are typically backed by a lossy cavity. The lossy cavity improves the low frequency impedance behaviour and axial ratio of the spiral by reducing reflections from the end of the each arm of the spiral. The lossy cavity also absorbs the back radiation from the spiral providing for a larger pattern bandwidth by reducing the reflection from the ground plane that causes pattern nulls [12].

2.2 Bandwidth Enhancement Techniques of Spiral with DGS

There is a major limitation of narrow bandwidth in Spiral antennas. There are some methods to enhance the bandwidth of an antenna like using slot loaded patch, Slot loaded on ground, modifying the feed, shorting pin and multilayer resonator.

2.2.1 Slot Loaded Patch

For improve the bandwidth of a spiral antenna, cut a slot in the patch of half wavelength long at desired resonant frequency .There are many different shapes of slot like E, H, U, etc. Using slot is the easy way to achieve the moderate bandwidth by proper dimensions of slot.

There is no analytical method is develop so far to compute the exact dimensions for slot dimensions but it is good agreement to compare the length of slots equal to half wavelength long at desired resonance[13].

2.2.2 Defective Grounding Technique (DGT)

DGS is an etched periodic or non-periodic cascaded configuration defect in ground of a planar transmission line which disturbs the shield current distribution in the ground plane cause of the defect in the ground. This disturbance will change characteristics of a transmission line such as line capacitance and inductance. In a word, any defect etched in the ground plane of the microstrip can give rise to increasing effective capacitance and inductance. The different types of defect ground structures are shown in figure 2.1 below.

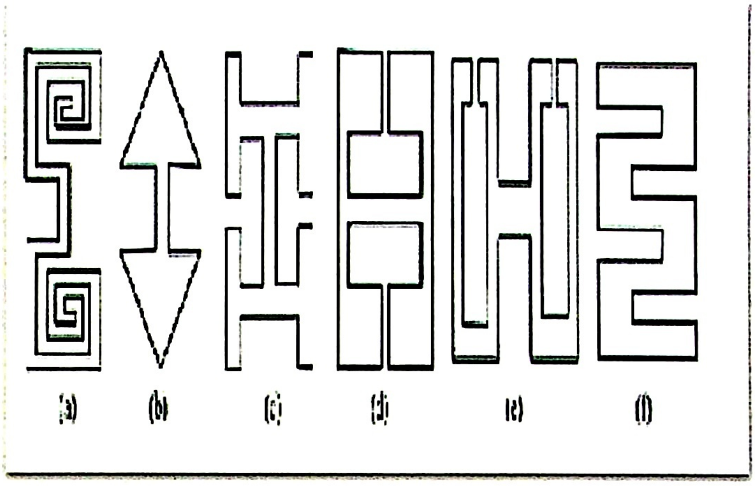

Figure 2.1: Various DGSs: (a) spiral head (b) arrow head slot (c) "H" shape slots (d) a square open-loop with a slot in middle section (e) open loop dumbbell & (f) IDC DGS.

2.3 Spiral Antenna as a Frequency Independent Antenna

In 1954, although discouraged by many experts, E. M. Turner wound a long-wire dipole into a spiral form and connected its terminals to a two-wire feed line [14].At that time, the largest antenna bandwidths were on the order of one octave, but the results obtained with the first spiral experiment were so encouraging that an immediate research effort was launched. Octave bandwidth implies that the higher frequency (f_H) of operation is double the lower frequency (f_L), for example, an antenna that works from 2GHz to 4GHz has one octave bandwidth [14].

At the present time, wideband frequency independent antennas are irreplaceable components of many communication platforms, various electronic warfare, military communication, satellite communication, direction-finding systems and atmosphere, ground and space exploration stations. In this work, the term wideband indicates on the frequency bandwidth (*Bf*) either in ratio ($Bf=f_H/f_L$) or fractional bandwidth (*Bf in percentage is* $Bf= (f_H-f_L)/f_C$) and $f_C=f_H+f_L/2$).

Frequency independent (FI) antenna is a type of antenna in which its pattern, bandwidth, gain and other characteristics vary insignificantly with frequency. Spiral antenna is good example for FI antennas and its bandwidth can reach up to 40:1 for both the input impedance and the radiation pattern [15].

Spiral antennas are classified into several types; square spiral, star spiral, Archimedean spiral and equiangular spiral. The square spiral antenna has the same advantages as circular Archimedean spiral antenna at the lower frequencies. A star spiral provides as much size reduction as the square spiral and it allows tighter array packing that the square spiral does not allow. However, one of the major disadvantages of the star spiral antenna is its dispersive behavior. Equiangular spiral antennas have similar characteristics of the Archimedean spiral antenna but their design is more complex compared to circular Archimedean spiral antennas. Therefore, in this project, rectangular spiral antenna is chosen due to its wide bandwidth, frequency independent characteristics and simple design compared to the other types of spiral antennas [16]. Figure 2.2 illustrates examples of the wideband frequency independent spiral antennas.

Figure 2.2: Examples of two arm Spiral Antenna: (a) Archimedean Spiral, (b) Equiangular Spiral and (c) Square Spiral [16].

REFERENCES

[1] Constantine A. Balanis- Antenna Theory Analysis and Design, Second Edition, John Wiley & Sons,2001.
[2] David Sinchez-Hemindez and Ian D. Robertson, "Analysis and Design of a Dual-Band Circularly Polarized Microstrip Patch Antenna" IEEE Transactions on Antennas and Propagation, issue 43, No2, February, 1995.
[3] Yogesh Kumar Gupta1, R. L. Yadava2, R. K. Yadav3, "Performance Analysis of 2.3 GHz Microstrip Square Antenna Using ADS, International Journal of Research in Management, Science & Technology, Vol. 1; No. 2, December 2013.
[4] M.F.Abdul Khalid, M.A. Haron, A. Baharuddin and A.A Sulaiman, "Design of a spiral antenna for Wi-Fi application," IEEE Inter. RF and Micowave Conf. Proc., K.Lumpur, pp. 428-432, Dis 2-4, 2008.
[5] Insik, C. and L. Bomson, "Design of defected ground structures for harmonic control of active microstrip antenna," IEEE Antennas Propag. Soc. Int. Symp., Vol. 2, 852–855, 2002.
[6] L. H. Weng, Y. C. Guo, X. W. Shi, and X. Q. Chen "An overview on Defect Ground Structure" in PIER VOl.7,173-189,2008.
[7] T.-W. Yoo and K. Chang, "Theoretical and experimental development of 10 and 35 GHz rectennas," IEEE Trans. Microwave Theory Tech., vol. 40, pp. 1259-1266, June 1992.
[8] Mohammed N. Afsar, Yong Wang and Rudolf Cheung, "Analysis and Measurement of a Broadband Spiral Antenna'' IEEE Antenna and Prop. Magazine, 1, pp. 59-64, Feb. 2004.
[9] E. M. Turner, "Spiral Slot Antenna'', US Patent 2863145, Oct. 1955.
[10] Rod Waterhouse, Printed Antennas for Wireless Commnunications, John Wiley & son, Inc., 2007.
[11] J.D. Dyson, "The Equiangular Spiral Antenna," IRE Transactions on Antennas and Propagation, 1959:181–187.

[12] Y. Amin*, Q. Chen, L. R. Zheng, and H. Tenhunen, —Design and fabrication of wideband archimedean spiral antenna based ultra-low cost —green modules for rfid sensing and wireless applicationsl. Progress In Electromagnetics Research, Vol. 130, 241–256, 2012.
[13] J. Y. Sze, et al "slotted rectangular microstrip antenna for bandwidth enhancement" IEEE Trans porpag.48, 2002, pp.1149.

[14] M. A. Ferendeci And B. Liu.; "Broadband slotted spiral antennas with thin dielectric substrates", Radio and Wireless Conference, RAWCON. IEEE, 2002, page(s): 59-62.
[15] B. R. Cheo and V. H. Rumsey, "A Solution to the Frequency Independent Antenna Problem" IRE Trans. Antennas Propagat., vol. 9, pp. 527-534, 1967.
[16] U. Saynak and A. Kustepeli, "A Novel Square Spiral Antennas for Broadband Applications," Frequenz, vol. 63, no, 1-2, P. 14, 2009.
[17] IEEE Standard Test Procedures for Antennas, IEEE Standard 149TM, 1979, Reaffirmed December 10, 2008.
[18] K. K. Mei, "On the Integral Equations of Thin Wire Antennas," IRE Trans. Antennas Propagat., vol. 13, pp. 374–378, 1965.
[19] N. Padros et al., "Comparative study of high-performance GPS receiving antenna designs," IEEE Trans. Antennas Propagat., vol. 45, pp. 698–706, 1997.
[20] H. A. Wheeler, "The radian sphere around a small antenna," Proceedings of the I.R.E., vol. 35, p. 1325-1331, August 1959.
[21] R. H. Duhamel and J. P. Scherer Frequency Independent Antennas in Antenna Engineering Handbook, 3rd ed. R. C. Johnson, 1993.
[22] Ahn, D.; Park, J.-S.; Kim, C.-S.; Kim, J.; Qian, Y.; Itoh, T., "A design of the low pass filter using the novel microstrip defected ground structure," Microwave Theory and Techniques, IEEE Transactions on , Vol.49, no.1, pp.86-93, Jan 2001.
[23] C. S. Kim, J. S. Park, D. Ahn, and J. B. Lim, "A novel 1-D periodic defected ground structure for planar circuits," IEEE Microw. Wireless Compon. Lett., Vol. 10, no. 4, pp.131–133, Apr. 2000.
[24] Ashwini K. Arya, M. V. Kartikeyan, A .Patnaik, "Defected Ground Structure in the perspective of Microstrip antenna," Frequency, Vol.64, Issue5-6, pp.79-84,Oct 2010.
[25] 26. Sung, Y. J., C. A. Ahn, and Y. S. Kim, "Size reduction and harmonic suppression of rat-race hybrid coupler using defected ground structure," IEEE Microwave and Wireless Components Letter, Vol. 14, No. 1, 7–9 Jun. 2004.
[26] J. S. Lim, H. S. Kim, J. S. Park, D. Ahn, and S. Nam, "A power amplifier with efficiency improved using defected ground structure," IEEE Microwave Wireless Compon. Lett., Vol. 11, pp. 170–172, Apr. 2001.
[27] H.Takhedmit, B.Merabet, A 2.45-GHz Low Cost and Efficient Rectenna.
[28] N. H. Abdul Hadi, K. Ismail, S. Sulaiman and M. A. Haron, " Design of a Rectangular Spiral Antenna for Wi-Fi Applicatio" IEEE, SHAH ALAM MALAYSIA, Feb. 13~16, 2011 ICACT2011.
[29] H. K. Gupta and P. K. Singhal "Patch Antennas Designs with Defect Ground Structure in Efficient Rectenna Design for Wireless Power Transmission" IJECCT 2012, Vol. 2 (4).
[30] A. K. Arya, A. Patnaik, and M. V. Kartikeyan, "Microstrip patch antenna with skew-F shaped DGS for dual band operation" Progress In Electromagnetics Research M, Vol. 19, 147-160, 2011.
[31] Sumit Kumar Manjhi, Mayank Mehra, Gaurav Dwivedi Dr. D. K. Raghuvanshi, "A Review on Microstrip Antenna to Enhance the Bandwidth" IJECEAR Vol. 2, ISSUE 2, Feb. 2014.
[32] Sanghamitra Dasgupta, Bhaskar Gupta and Hiranmoy Saha, "Development of Circular Microstrip Patch Antenna Array for Rectenna Application" IEEE INDICON 2010, Kolkata, INDIA December 17-19, 2010.