GRAPHENE-BASED NANO PATCH ANTENNA FOR MICROWAVE RADIATION USING CST SOTWARE

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ii

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iii

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iv

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For my beloved father, Hamdan bin Ghazali and my mother, Nor 'Aisah bt Dusir,

For my family and friends who always supports me.

Alhamdulillah, Thank you

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ABSTRACT

Antenna, which also called an aerial, is a critical component in wireless communication system that used electromagnetic radiation with an antenna at both transmitting and receiving end. It is a device that is made to efficiently emit and receive radiated electromagnetic waves and ease all the electromagnetic waves that it receive in to free space wave. In this report, the graphene-based Nano patch antenna at microwave frequency have been introduced and presented simulation results for the antenna. Simulation have been done by using CST Software. Besides the fact that graphene material is a moderate conductor at microwave frequency, the graphene can still exhibit sharp resonances frequency at 12 GHz. The simulation clearly demonstrated that the graphene as patch material of Nano antenna gives lowest value of return loss which is -68.55 dB compared with using copper as patch material with -24.79 dB of return loss. A prototype of graphene-based Nano patch antenna were designed on a silicon dielectric substrate with relative dielectric constants of 12.9. An analysis of graphene Nano antennas with rectangular, diamond and elliptical geometries also been presented. The comparison between return loss, gain, radiation efficiency and directivity between those three geometries were tabulated and discussed. The obtained results can be useful to design efficient Nano antenna for microwave wireless communication.

ABSTRAK

Antenna adalah konduktor yang boleh menghantar dan menerima isyarat seperti gelombang mikro, radio atau isyarat satelit. Dalam penghantar isyarat, sebuah pemancar radion membekalkan frekuensi radio arus elektrik berayun ke terminal antenna, dan antenna memancarkan tenaga daripada arus sebagai gelombang elektromagnetik (gelombang radio). Dalam projek ini, tampalan antenna bersaiz nano berasaskan 'graphene' berfungsi pada frekuensi gelombang mikro telah diperkenalkan dan hasil simulasi untuk antenna ini telah dipersembahkan. Simulasi telah dilakukan menggunakan perisian CST. Selain daripada fakta yang mengatakan bahawa 'graphene' adalah pengalir arus elektrik yang sederhana pada frekuensi gelombang mikro, 'graphene' masih mampu mempamerkan frekuensi salunan yang tepat pada 12 GHz. Hasil simulasi secara terangan telah menunjukkan bahawa 'graphene' sebagai bahan tampalan menghasilkan kehilangan pembalikan yang paling rendah, iaitu sebanyak -68.55 dB berbanding dengan menggunakan bahan tembaga yang mempunyai nilai kehilangan pembalikan sebanyak -24.79 dB. Sebuah contoh sulung tampalan antenna bersaiz nano berasaskan 'graphene' telah direka bentuk di atas lapisan dua pengalir yang diasingkan oleh satu dielektrik silicon dengan nilai dua pengalir yang diasingkan oleh satu dielektrik yang tetap iaitu 12.9. Sebuah analisa mengenai antenna bersaiz nano menggunakan bahan 'graphene' dalam bentuk segi empat tepat, bentuk berlian dan bentuk bujur juga telah dipersembahkan. Perbandingan tentang kehilangan pembalikan, gandaan, kecekapan radiasi dan pusat arah di antara ketiga-tiga bentuk telah direkodkan, dijadualkan dan dibincangkan. Hasil yang diperolehi boleh digunakan untuk mereka bentuk antenna bersaiz nano yang berkesan untuk alat komunikasi tanpa wayar.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Antenna and antenna systems are the eyes and ears of wireless communication systems, which experienced an unprecedented rapid expansion. The wireless systems, no matter how simple or complex, cannot operate efficiently unless they utilize transmitting and receiving elements or antennas to efficiently radiate and receive the waves that carry the information. The future of the communication systems is even more challenging, and their efficacy will depend on what engineers and scientist can invent and contribute. In fact, some of the future services and performances of wireless communication may be dependent on and limited antenna design which will require our imagination and vision to push the outer limits of the laws of physics.

1.1 Overview

1.1.1 Coplanar Patch Antenna

For last few decades, planar antenna have been a field of interest for many researchers. With the revolution in electronic circuit miniaturization and large

scale integration in the earlier 70's, demand for compact antenna with small size, which can be integrated with MMIC designs increased. Since planar antennas are substrate based antennas and their properties like ease in fabrication, and easy integration with MMIC and PCB designs, increased popularity of planar antenna and influenced large number of research in this field. Planar patch antenna have advantages like low profile, lightweight and ease fabrication. Microstrip patch antenna is the most popular of all the other type of planar antennas. It consists of grounded substrate with conducting patch above the substrate. But they have certain disadvantages too like low gain, narrow bandwidth and low efficiency [2].

Coplanar patch antenna is new and better alternative of microstrip patch antenna. A coplanar patch antenna has ground and patch on the same side of the substrate with a gap width. Since the effective dielectric constant for a coplanar antenna design is lower than microstrip antenna design, the surface wave excitation is reduced to a large extent and due to the reason coplanar antenna have high radiation efficiency and wider bandwidth. Also, coplanar patch antennas easy to fabricate, have low radiation loss, less dispersion, uniplanar configuration and easy MEMS based reconfigurable antennas can be designed without using via holes as used in case of microstrip design.

Coplanar patch antenna have been increasingly studied this recent years. The coplanar waveguide, compared to microstrip line, has more advantages such as low radiation loss, less dispersion, uniplanar configuration and easy mounting of shunt lumped elements or active devices without hole as for the microstrip line [17].

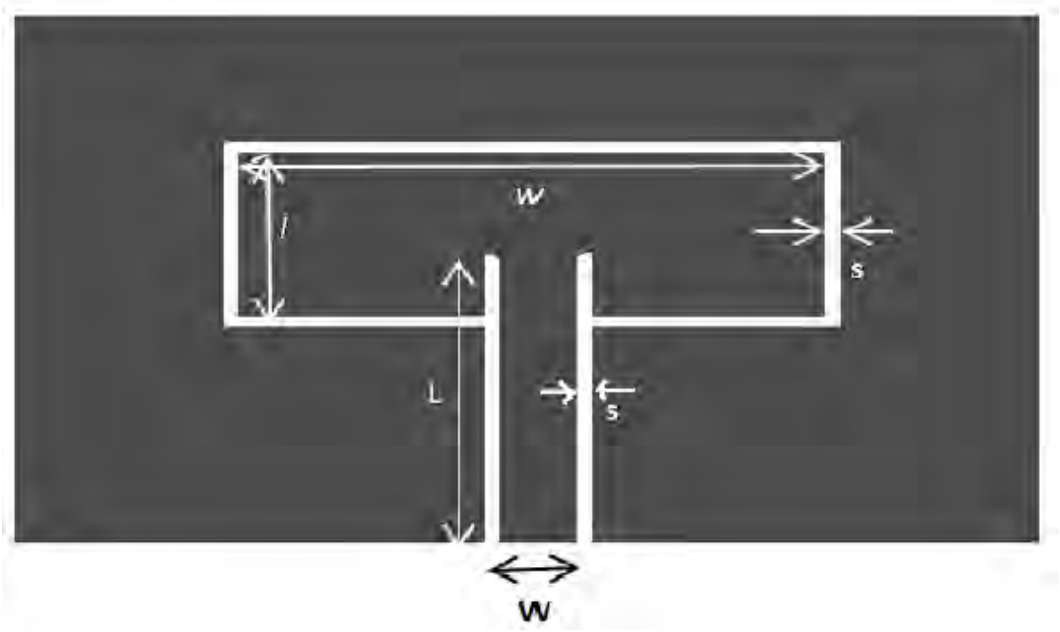

Figure 1.1: Schematic Diagram of Inset Fed Coplanar Patch Antenna

1.1.2 Antenna Characteristics

An antenna is a critical device in wireless communication system that provide a means of radiating and receiving waves. It will ease all the electromagnetic waves that it receive in to free space wave. There are numerous important antenna characteristics that should be measured when choosing an antenna for your application as follows [3]:

i. Radiation Patterns
ii. Power Gain
iii. Directivity
iv. Polarization
v. Return Loss

1.1.3 Graphene

Graphene is a flat monolayer of carbon atom tightly packed into 2D honeycomb lattice. The layer of graphene stacked on top of each other form graphite. Graphene had been isolated in 2004 by two Russian-born researcher at University of Manchester, Andre Grim and Kostya Novoselov [8]. Graphene is ultralight, strongest material, superb conductor and thinnest material in the world.

Graphene's special properties are as follows [14]:

1. Conductivity: Electrons are the particles that make up electricity. So when graphene permits electrons to move rapidly, it is allowing electricity to move speedily. It is known to move 200 times faster than silicon because they travel with such slight interruption. It is also an excellent heat conductor. Graphene conductive impartial of temperature and works naturally at room temperature.
2. Strong: It would take an elephant with tremendous balance to break through a sheet of graphene. It is very robust due to its unbroken pattern and the durable bonds between the carbon atoms. Even when patches of graphene are stitched together, it remains the toughest material out there.
3. Flexible: These tough bonds between graphene's carbon atoms are also very flexible. They can be distorted, pulled and curved to a certain extent without breaking, which means graphene is stretchable and bendable.
4. Transparent: Graphene absorbs 2.3 percent of the visible light that hits it, which means you can see across the graphene without having deal with any glare.
5. Thin: Thinnest material on earth – 1 million times thinner than a human hair

1.1.4 Type of Metallic Patch Etched on Antenna

Table 1.1: Type of Metallic Patch Etched on Antenna and its Properties [14]

	Copper	SWCNT	MWCNT	Graphene
Conductivity(s/m)	5.96 x 10^7[5]	10^2[6,7]	10^5[7,8]	10^8[9,10]
Melting point (K)	1356		3800 (graphite)	
Tensile strength (GPa)	0.22	22.2+2.2	11-63	
Thermal conductivity (x 10^{-3}W/m-K)	0.385	1.75-5.8	3	3-5
Temp. Coeff. Of resistance (x 10^{-3}/K)	4	<1.1	-1.37	-1.47
Mean Free path @ room temperature	40	10^3	2.5 x 10^4	10^3
Maximum Current Density (A/cm^2)	10^7	10^9	10^9	10^8

1.2 Problem Statement

Microstrip patch antennas are growing in popularity for usage in wireless applications due to their low-profile structure. They are low fabrication charge, hence can be manufactured in huge quantities, and simply integrated with microwave integrated circuits (MICs). However, microstrip patch antenna has some disadvantages such as narrow bandwidth, low efficiency, and low gain. Nowadays, due to the growing of usage of technologies in life, the demand for the high speed usage of wireless application. Graphene is one of material that can be used to improve the usage of antenna in high speed. Unfortunately, the application

of graphene in passive guide devices and antennas from microwave to THz have been far less exploited.

1.3 Aim and Objectives

The aim of the thesis is to design graphene-based nano-pach antenna operating at microwave frequency (8-16GHz), identify the effect of changing the shape of graphene patch towards the antenna efficiency and to analyze the potential interest and limitation of using graphene in microwave frequency for antenna application.

1.4 Scope

A design of a coplanar graphene-based nano-patch antenna will be done in the CST software. The material in the patch is simulated only by using graphene. The antenna will not be fabricated since the graphene is very expensive and due to the lack of technology to handle graphene. The frequency range use to simulate the design is around 8 GHz to 16 GHz. The parameter will be varying such as the value of length of graphene (L), width of graphene (W), thickness of graphene (Tg) and shape of graphene patch. Then, the antenna's performances are compares in terms of gain, return loss and radiation efficiency.

1.5 Organization of the Thesis

An introduction to coplanar patch antenna is given in the Chapter II. Apart from the advantages and disadvantages of coplanar patch antenna, the various models of analysis are listed. The properties of graphene also introduced in this chapter.

Chapter III deals with antenna parameters and the choice of substrate. The theory of radiation, various parameters and design aspects are discussed. All possible substrates for the design of coplanar patch antenna with their dielectrics constants and permittivity are given.

Chapter IV consists of all the results obtained from different varieties of parameters of graphene-based nano-patch antenna. The results obtained are stated clearly and also being discussed.

Chapter V is the last chapter. In this chapter, the conclusion is made based on the results obtained. Other than that, some recommendation also stated for future works.

CHAPTER II

LITERATURE REVIEW

A patch antenna (also called as a rectangular microstrip antenna) is a type of radio antenna with a low profile, which can be attached on a flat surface. It consist of metallic patch etched on a dielectric substrate which has a grounded metallic plane at the opposite side. Differed from patch antenna, coplanar patch antenna consist of metallic patch and grounded plane etched on the same side. Coplanar patch antenna are simple to fabricate and easy to transform and customize.

2.1 Coplanar Patch Antenna

The antennas fed by coplanar waveguide (CPW) have been increasingly studied in recent years. Many different configurations, including slot antennas loop slot antennas and slot coupled microstrip patch antennas have been proposed and investigated.

The coplanar patch antenna has advantages, compared with the microstrip antenna, such as easier to connect with active devices, providing a unidirectional radiation pattern, and so on [25]. Introducing the concept of coplanar patch also makes easy to employ the various techniques developed for microstrip patch antennas in the development of many kinds of new coplanar patch antennas.

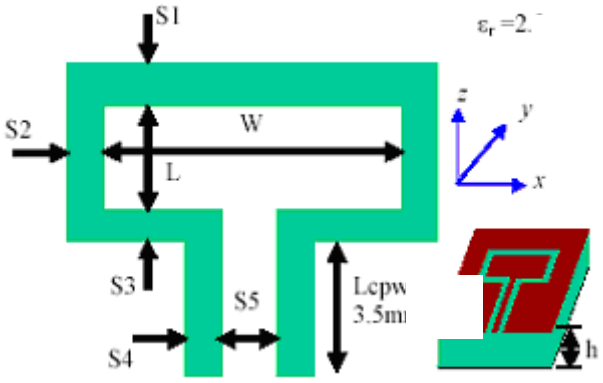

Figure 2.1: A Coplanar Patch Antenna Geometry and Parameter

In its fundamental form, a coplanar patch antenna consist of radiating patch and ground plane on the same side which has a dielectric substrate on the other side as shown in Figure 2.1. The patch is generally built of conducting material such as copper or gold and can take any possible shape. The radiating patch, the feed line and the ground are usually etched on the dielectric substrate [2].