GRAPHENE – BASED VIVALDI ANTENNA USING CST SOFTWARE

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For God, my beloved mother, father, brothers, sisters and friends

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ABSTRACT

In this thesis, the performance of Vivaldi antenna are studied based on the two different materials that build up the antenna that is graphene and copper. Performance of the Vivaldi antenna is investigated by parametric study to get the optimized design based on the return loss response. The results of performance of Vivaldi antenna are only cover the simulation and the simulations are using CST Studio Suite software. Two Vivaldi antennas are design for the operating frequency range from 8 to 12 GHz frequency band with return loss better than 10 dB. These two antennas are design based on parametric study result. Both antennas are used microstrip to slotline transition feeding. This antenna is constructed using FR4 substrate which has dielectric constant ϵ_r 4.30 and graphene and copper material which is has 0.508mm and 0.035mm thickness. The parameter of antenna such as gain, directivity, efficiency and return loss are discussed.

ABSTRAK

Dalam thesis ini, prestasi Vivaldi antenna dikaji berdasarkan dua bahan berbeza yang diguna untuk membuat antenna iaitu graphene dan tembaga. Prestasi Vivaldi antenna dikaji dengan mengunakan teknik kajian parametrik untuk mendapatkan reka bentuk antenna yang optimum berdasarkan tindak balas kembali kehilangan. Keputusan prestasi Vivaldi antenna ini hanya merangkumi bahagian simulasi dan simulasi menggunakan perisin CST Studio Suite. Dua Vivaldi antenna direka untuk julat frekuensi opersi dari 8 hingga 12 GHz dengan kembali kehilangan lebih baik daripada 10dB. Dua antenna ini direka berdasarkan keputusan dari kajian parametrik. Kedua-dua antenna menggunakan jenis peralihan microstrip ke slotline. Antenna ini dibina daripada papan cetak FR4 substart yang mempunyai pemalar dielektrik $\in_r$ 4.30 dan bahan graphene dan tembaga yang mempunyai ketebalan 0.508mm dan 0.035mm. Parameter antenna seperti keuntungan, kearahan, kecekapan dan kembali kehilangan telah dibincangkan.

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CHAPTER 1

PROJECT INTRODUCTION

1.1 Introduction

Vivaldi antenna is simple planar that are very broadband. The basic shape of Vivaldi antenna can be seen in Figure 1.1 and Figure 1.2 The antenna feed connecting two symmetric of a planar metallic antenna. Sometimes Vivaldi antenna referred to as the Vivaldi notch antenna, and also known as the tapered slot antenna (TSA), is easy to fabricate on a circuit board, and can provide ultra-wide bandwidth.

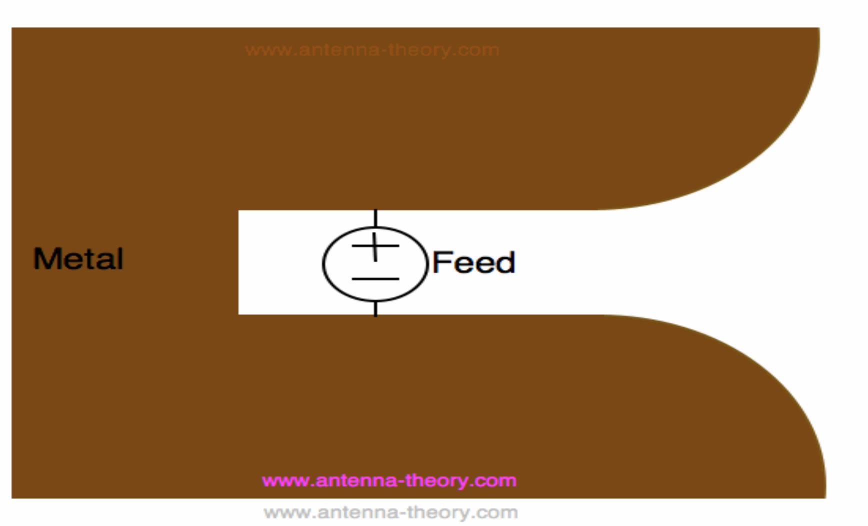

Figure 1.1 Basic shape of Vivaldi antenna

1.1.1. Vivaldi Antenna Design

There are three fundamental types of Vivaldi antenna:

a) Tapered slot Vivaldi antenna

Tapered slot Vivaldi antenna is the original design introduced by Gibson in 1979[8]. It's basically a flared slotline, fabricated on a single metallization layer and supported by a substrate dielectric. The taper profile is exponentially curved, creating smooth transition from the slot line to the open space. This structure introduces two limits for the operational band- width of the antenna, following the rule for slotline radiation [6].

b) Antipodal Vivaldi Antenna

Antipodal Vivaldi antenna was investigated by W. Nester in 1985 and E. Gazit in 1988 [7] as a solution of the feeding problems associated with Gibson's original design. In the antipodal configuration, antenna is created on a dielectric substrate with two-sided metallization. Main disadvantage of the antipodal configuration is cross-polarization, observed especially for higher frequencies. This is caused by the skew of the slot fields. The skew is changing along the length of the taper, being highest in the closed end of the antenna, where high frequencies are being radiated; while at the open end is usually negligible, depending on the substrate thickness [6].

c) Balanced Antipodal Vivaldi Antenna

One of the latest improvements of the original design was presented by Langley, Hall and Newham in 1996[9]. This design evolves from the antipodal version. The cross-polarization is reduced by adding another layer of metallization, creating a balanced stripline structure. Positive aspect of this design is the fact that the feeding line is created by a triplate stripline. This is reducing the radiation of the antenna feed, which could occur in case of open feed lines of the antipodal and tapered slot Vivaldi. This solution suppresses perturbances of the radiation pattern caused by the open feed lines. There are also some disadvantages of the balanced design. Naturally, the construction of such antenna is more complicated due to the triplate structure, preventing it from fabrication in some lab environments [6].

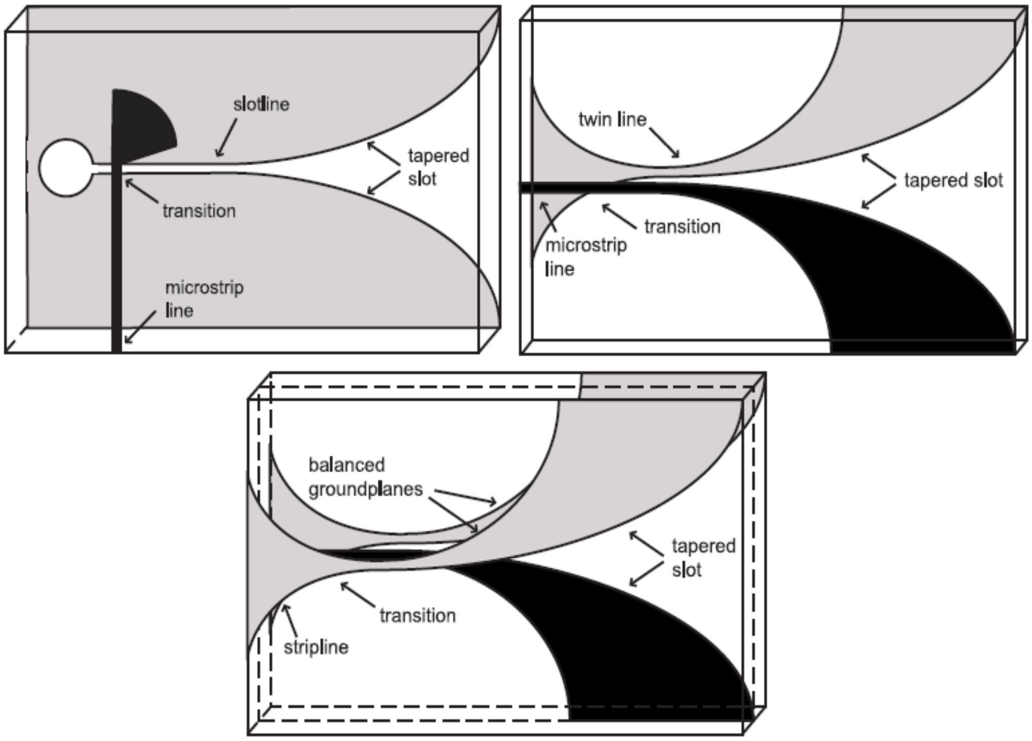

Figure 1.2: Tapered slot Vivaldi antenna, Antipodal Vivaldi Antenna, Balanced Antipodal Vivaldi Antenna

Vivaldi antenna is a type of a travelling-wave antenna of the “surface-type”. The waves travel down the curved path of the flare along the antenna. In the region where the separation between the conductors is small when compared to the free-space wavelength, the waves are tightly bound and as the separation increases, the bond becomes progressively weaker and the waves get radiated away from the antenna. This happens when the edge separation becomes greater than half-Radiation from high-dielectric substrates is very low and hence for antenna applications significantly low dielectric constant materials are chosen [13].

At different frequencies, different parts of the antenna radiate, while the radiating part is constant in wavelength. Thus the antenna theoretically has an infinite bandwidth of operation and can thus be termed frequency independent. As the wavelength varies, radiation occurs from a different section which is scaled in size in proportion to the wavelength and has the same relative shape. This translates into an antenna with very large bandwidth [13].

Vivaldi antennas provide medium gain depending on the length of the taper and the shape of the curvature. The gain also changes with frequency, with values ranging typically from 4 dBi to 8 dBi. Because of the exponential shape of the tapered radiating structure, antenna maintains approximately constant beamwidth over the range of operating frequencies.From the time-domain point of view, the principle of radiation through the tapered slot is lacking any resonant parts, which results in very low distortion of radiated pulses.This aspect, together with large bandwidth of the antenna, makes Vivaldi very good UWB radiator in cases when directional antenna is desired [6].

1.1.2. Transmission Line

A transmission line is a device designed to guide electrical energy from one point to another. Transmission line is use to transfer the energy output of the transmitter to the antenna with the least possible power lost [10]. Usually antenna is located far away from the transmitter so the transmission is used to connect the transmitter and antenna. The transmission line must be perfectly matched to achieving a good transmission. Mismatch will occur when a transmission line is not properly terminated at the receiver end and some of energy wills reflect back into transmission line from load. The amount of incident energy that is reflected is represent by the reflection coefficient, r. The magnitude of reflection coefficient can vary from 0 to 1[10].

Antenna consists of a feed line, which is usually microstrip or stripline, transition from the feedline to the slotline or balanced stripline and the radiating structure. Radiating structure is usually exponentially tapered, however, examples of parabolic, hyperbolic or elliptical curves [6]. The continuous scaling and gradual curvature of the radiating structure ensures theoretically unlimited bandwidth, which is, in practice, constrained by the taper dimensions, the slot line width and the transition from the feed line. The limitation introduced by transition was later partially overcome in the antipodal design investigated.

1.1.3. Parameters of Antenna

a) Radiation Pattern

An antenna radiation pattern or antenna pattern is defined as a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. There can be field patterns (magnitude of the electric or magnetic field) or power patterns (square of the magnitude of the electric or magnetic field).Often normalized with respect to their maximum value. The power pattern is usually plotted on a logarithmic scale or more commonly in decibels (dB) [17].

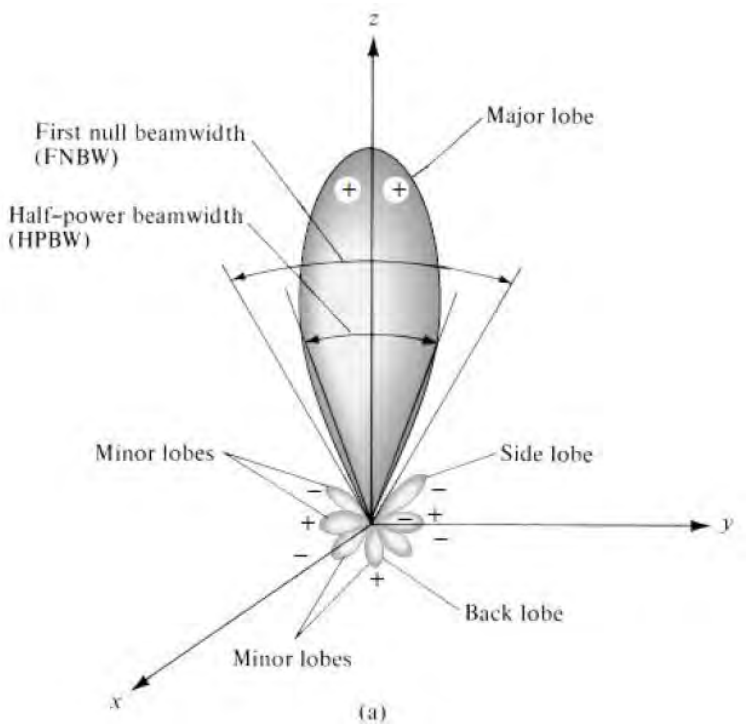

Figure 1.3: Radiation pattern lobes [17].

A radiation lobe is a portion of the radiation pattern bounded by regions of relatively weak radiation intensity.

• Main lobe

• Minor lobes

• Side lobes

• Back lobes

b) Beamwidth

The beamwidth of an antenna is a very important figure of merit and often is used as a trade-off between it and the side lobe level; that is, as the beamwidth decreases, the side lobe increases and vice versa. The beamwidth of the antenna is also used to describe the resolution capabilities of the antenna to distinguish between two adjacent radiating sources or radar targets [17].

c) VSWR and Return loss

The parameter VSWR is a measure that numerically describes how well the antenna is impedance matched to the radio or transmission line it is connected to. VSWR (Voltage Standing Wave Ratio) is function of the reflection coefficient, r, which describes the reflected from the antenna. VSWR is the ratio of the maximum to minimum values of the standing wave pattern that is created when signal is reflected on a transmission line. VSWR is a voltage standing wave ratio [17]. The voltage standing wave ratio is a measure of how well a load is impedance-matched to a source. It is always express as a ratio with 1 in the denominator (2:1, 3:1, etc). The lowest value of VSWR is 1 and it means when VSWR equal to 1, all the power is transfer from source to load. If the VSWR for antenna is below than 2, it show the performance of antenna is satisfactory in term of VSWR

$$VSWR = \frac{1+|r|}{1-|r|} \qquad (1.1)$$

Reflection coefficient is also known as S11 or return loss. VSWR is always a real number and positive numbers for antenna. The smaller VSWR value, the better the antenna is matched to the transmission line and the more power is delivered to the antenna. The minimum VSWR is 1.0 where no power is reflected from the antenna, which is ideal.

d) Directivity

Directivity is defined as ratio of radiation intensity, in a given direction, to the radiation intensity that would be obtained if the power accepted by the antenna where radiating isotropic ally [19]. Directivity is a fundamental antenna parameter. It is measure of how directional an antenna's radiation pattern. The directivity of antenna can be calculate using Poynting Vector, P, that show the average real power per unit area radiated by an antenna in free space. The directivity equation is given below [20]:

$$D = \frac{P_a}{P_o} \quad (1.2)$$

$$D|_{dB} = 10log_{1o}\frac{P_a}{P_o} \quad (1.3)$$

$$P_o = \frac{P_a}{4\pi r^2} \quad (1.4)$$

P_a is total power radiated by antenna and r is distance between the two antennas. The antenna gain takes into account loss so the gain of an antenna will always be less than the directivity.

e) Gain

Antenna gain is the term for antenna that shows the amount of power that transmitted in the direction of peak radiation to that of an isotropic source. Antenna gain commonly quoted in real antenna's specification sheet because it takes into account the actual lossess that occurs. If the gain of antenna is 3db, it is means the power received far from antenna will be 3dB higher than what would be received from lossless isotropic antenna. Antenna gain is related to directivity by equation below:

$$G = \varepsilon_r D \quad (1.5)$$

Theoretically, gain of antenna always greater than 0dB and can be high as 40-50dB for the very large antenna like dish antenna [17]. If the input power appeared as radiated power, directivity is equal to gain [18].

f) Radiation efficiency

Radiation efficiency is the ration of total power radiate by an antenna to the net power accepted by the antenna from the connected transmitter [19]. The equation of efficiency of antenna is given below:

$$E = \frac{P_{radiated}}{P_a} = \frac{R_r I^2}{(R_r + R_L) I^2} = \frac{R_r}{(R_r + R_L)} = \frac{1}{1 + R_L/R_r} \quad (1.6)$$

R_L is loss resistance which corresponds to the loss of antenna and R_r is the radiation resistance. For good antenna efficiency, radiation resistance must be big and loss resistance to be as small as possible.

1.1.4 Graphene

Graphene is the name given to a flat monolayer of carbon atoms tightly packed into a two dimensional (2D) honeycomb lattice, and is a basic building block for graphitic materials of all other dimensionalities. Graphene is a sheet of carbon just one atom thick, in a honeycomb structure, and it has many desirable electronic properties. Electrons move through graphene with virtually no resistance—50 to 500 times faster than they do in silicon [21].

Theoretically, graphene (or "2D graphite") has been studied for sixty years, and is widely used for describing properties of various carbon-based materials. Forty years later, it was realized that graphene also provides an excellent condensed-matter analogue of (2+1)-dimensional quantum electrodynamics, which propelled graphene into a thriving 5 theoretical toy model. On the other hand, although known as an integral part of 3D materials, graphene was presumed not to exist in the free state, being described as an "academic" material and was believed to be unstable with respect to the formation of curved structures such as soot, fullerenes and nanotubes. Suddenly, the vintage model turned into reality, when free-standing graphene was unexpectedly found three years ago and especially when the follow-up experiments confirmed that its charge carriers were indeed mass-less Dirac fermions. So, the graphene "gold rush" has begun [14].

1.2 Objectives

For this project, there are three main objectives that were listed:

- To analyze the optimized design Vivaldi antenna with different material (graphene and copper).
- To simulate the Vivaldi antenna using CST Studio Suite software
- To analyze performance of antenna on return loss, gain, efficiency and directivity

1.3 Problem Statement

Antenna is devices that use to transmit or receive radio or television signal. The type of Vivaldi antenna has been applied widely in satellite communications, remote sensing, and radio telescope. However, the capabilities of Vivaldi antenna that built up of copper are lagging in transmit and receive the signal and need an improvement concomitant with the advance of technology. Graphene is the substance that has ability to replace the copper because it has characteristic of conductivity that is better than copper in scope of antenna. Based on graphene characteristics, it is able to transfer data either uploading or downloading up to terahertz (THz) [21].

1.4 Scope

The scope of this project is to design a graphene Vivaldi antenna with the operating range frequency from 8 to 12GHz. The projects only focus and study on the Tapered slot Vivaldi antenna (TSA) type. The parameter of antenna such as return loss, gain, efficiency and directivity were evaluated and analyze. Before that, parametric study is made to get the optimize design of Vivaldi antenna. This project only covered on the simulation process by using the CST Studio Suite software.

CHAPTER 2

LITERATURE REVIEW

2.1 Graphene

The use of graphene in built of antenna could bring significant benefit such as extreme miniaturization, monolithic integration with graphene RF nanoelectronics, efficient dynamic tuning and even transparency and mechanical flexibility [1]. This project were about to study the Vivaldi antenna and improve the directivity or gain of this antenna. Graphene has a big potential replaced the copper in scope of antenna. Table below shows the comparison between copper and graphene.

	Copper	**Graphene**
Conductivity (S/m)	5.96 X 107 [19]	10^8
Melting Point (K)	1356	3800
Density (g/cm3)	19.30	2.1-2.2
Thermal conductivity (W/m-K)	401	5000 [20]
Young's Modulus(GPa)	110-128	1000

Table 2.1: Comparison between copper and graphene

The use of graphene for antenna could potentially lead to very interesting features such as miniaturization, integration with graphene RF active electronics [15], dynamic tuning and even optical transparency and mechanical flexibility.