THE E AND H ANTENNA DESIGN FOR BROADBAND APPLICATION

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Dedicated to my lovely father and mother.

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ABSTRACT

The major weakness of a conventional microstrip patch antenna is its narrow bandwidth. A *E* and *H* antenna is designed based on the structure of *E* and *H* itself to have a wider bandwidth to overcome this problem. The broadband characteristic is obtained by proper selecting the *E* and *H* structure. Two parallel slots and two series slots are incorporated into the patch antenna. The parallel slots reduce the size of the antenna, while the series slots reduce the return loss of the antenna. The *H* antenna is designed based on stepped impedance resonator while *E* antenna is based on transmission line model. Then, by intersecting both antennas, the E and H antenna is obtained. The *E* and *H* antenna has a compact dimension of $42.36 \times 23.77 mm^2$. The simulation of the antenna is carried out to obtain the return loss, bandwidth, gain, directivity and radiation pattern. Next, the antenna is fabricated on FR4 board. The *E* and *H* antenna offers a low profile, broadband and a compact antenna element. Measurement results also showed satisfactory performance of the antenna with an achievable bandwidth of 65.6%. The directivity of this antenna is 3.538dBi with achievable gain of -25.9dB which is an inefficient value of gain for an antenna.

ABSTRAK

Kelemahan utama antena konvensional mikrostrip tompok merupakan lebar jalurnya yang sangat kecil. Antena *E* dan *H* telah direka berdasarkan struktur huruf E dan H itu sendiri untuk mempunyai lebar jalur yang lebih besar untuk mengatasi masalah ini. Struktur *E* dan *H* yang sesuai perlu dipilih untuk memperoleh ciri-ciri jalur lebar. Dua alur selari dan dua alur sesiri digabungkan ke dalam satu mikrotrip tompok antena. Alur selari dapat mengecilkan saiz antena, manakala alur sesiri pula dapat mengurangkan kehilangan kembali sesuatu antena. Antenna *H* direka berdasarkan alat resonans langkah galangan manakala antenna *E* pula berdasarkan model talian transmisi. Selepas itu, dengan menyilangkan kedua-dua bentuk itu, antenna *E* dan *H* diperoleh. Antenna berbentuk *E* dan *H* mempunyai dimensi sebanyak $42.36 \times 23.77mm^2$. Simulasi untuk antenna ini adalah bagi mendapatkan kehilangan balikan, lebar jalur, gandaan, keterarahan dan juga corak radiasi. Selepas itu, antenna difabrikasikan menggunakan papan FR4. Antena ini menyumbangkan ciri-ciri sebuah antena dengan lebar jalur beserta saiz yang lebih kompak dan ringan. Keputusan pengukuran adalah memuaskan dengan pencapaian lebar jalur sebanyak 65.6%. Keterarahan antena ini ialah sebanyak 3.538dBi manakala gandaan bagi antenna ini ialah sebanyak -25.9dB di mana nilai gandaan yang negatif merupakan satu nilai gandaan yang tidak efisien bagi sesebuah antenna.

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ΔL	-	Length extension
θ	-	Resonator length
$\mathcal{E}_{\text{eff}}$	-	Effective dielectric constant
$\mathcal{E}_{\text{r}}$	-	Dielectric constant
BMPAA	-	Broadband Microstrip Patch Antenna Array
BW	-	Bandwidth
CST	-	Computer Simulation Technology
D_o	-	Maximum directivity
dB	-	Decibel
f_r	-	Resonant frequency
FR4	-	Flame Retardant 4
h	-	Height of dielectric substrate
HPBW	-	Half power beam-width
IEEE	-	Institute of Electrical and Electronics Engineers
IMT	-	International Mobile Telecommunication
K	-	Impedance ratio
L	-	Length
LIEH	-	L-Probe fed Inverted Hybrid E-H
L_s	-	Slot length
PCB	-	Printed Circuit Board
P_{rad}	-	Total radiated power

P_s	-	Slot position
SWR	-	Standing Wave Ratio
U_{max}	-	Maximum radiation intensity
UV	-	Ultra-violet
W	-	Width
W_s	-	Slot width

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CHAPTER 1

INTRODUCTION

1.1 Introduction

A conventional microstrip patch antenna has been very popular due its numerous advantages such as low profile, light weight, and compatible with microwave integrated circuit but the major weakness is its narrow bandwidth [1-6]. The bandwidth of the conventional microstrip patch antenna is only about 11.2 MHz [7]. The *E* and *H* antenna is designed based on the character *E* and *H* itself. The purpose of this project is to design an antenna for broadband application that can operate with a wider bandwidth compared to conventional microstrip patch antenna. The broadband resonant can be obtained by proper selecting the structure of *E* and *H*. An end-loaded slot antenna can be used to reduce the length of a slot antenna without changing its resonant frequency.

A novel *H*-shaped patch antenna is proved to have a smaller size, less number of modes, absence of harmonic resonance, and the provision of pure reactive impedances at its harmonic resonance, and the provision of pure reactive impedances at its harmonics that can result in increased transmitter efficiency [8].

In the other hand, a wide-band *E*-shaped patch antenna is introduced. Two parallel slots are incorporated into the patch of a microstrip antenna to expand it bandwidth. When two parallel slots are incorporated into the antenna patch, the bandwidth increases above 30% from the conventional microstrip patch antenna [9].

A novel wideband L-Probe fed inverted hybrid *E-H* shaped microstrip patch antenna (LIEH) covering the International Mobile Communications – 2000 (IMT-2000) band is designed that adopts contemporary techniques such as L-probe feeding, inverted patch structure with air-filled dielectric and slotted patch. The results is an antenna with an achievable bandwidth of 17.20% at 14 dB return loss (SWR=1.5) [10].

1.2 Objectives

The objectives of this project are to design an *E* and *H* shaped antenna that can operate at broadband frequencies. The suitable width and length of the desired antenna will be determine by proper selecting the *E* and *H* structure that will satisfy the broadband resonant. The return loss of the antenna is expected to be less than -10 dB and the bandwidth of the antenna is wider than the bandwidth of the conventional microstrip patch antenna.

1.3 Problem Statement

A conventional microstrip patch antenna is known to have many advantages but the major weakness is its narrow bandwidth. A bandwidth is the difference between the highest frequency and the lowest frequency. An antenna that has a wider bandwidth is suitable for broadband application. In addition, the antenna with smaller size is an advantage [8].

1.4 Scope

The scope of this project is to design an *E* and *H* antenna with suitable width, *W* and length, *L* for broadband application. The simulation of return loss and bandwidth of the antenna is carried out using Computer Simulation Technology (CST) Microwave Studio. The optimization of *H* antenna involved its impedance ratio and resonator length. However, the optimization of *E* antenna involved its slot position and slot length. Next, after it satisfy the require condition, the antenna is fabricated on FR4 board using chemical etching technique. The antenna's performance is measured such as its bandwidth, gain, directivity, return loss, radiation pattern and etc.

1.5 Methodology

Figure 1 shows the design flow diagram for *E* and *H* antenna design. Firstly, to obtain enough information about this project, a literature review is carried out from journals and books. After that, the design process started with calculation for antenna parameters for example the width and length, by referring to the method that has been reviewed. Then, the simulation of return loss, bandwidth, radiation pattern and etc is carried out. The design process of the antenna will be started all over again if the simulation did not satisfy the requirements of the desired antenna which is called an optimization of antenna parameters. The fabrication of the antenna is carried out after the desired antenna has been obtained. After the fabrication, the antenna's return loss, bandwidth and radiation pattern is measured.

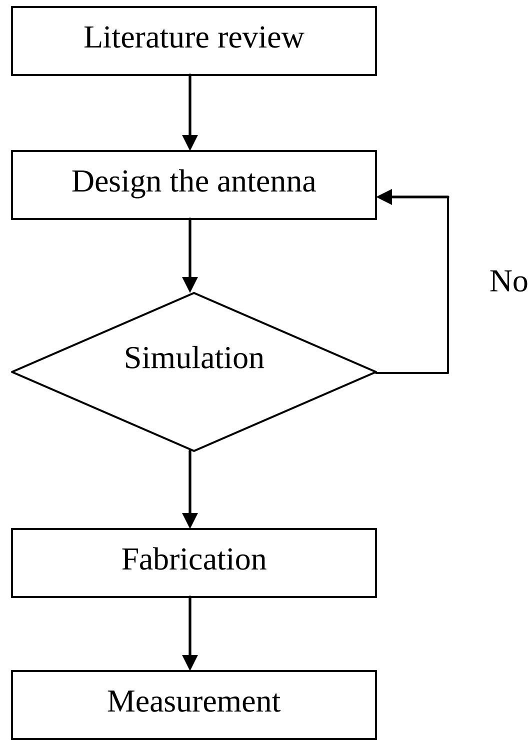

Figure 1.1 Design flow diagram for *E* and *H* antenna

CHAPTER 2

LITERATURE REVIEW

An antenna or commonly known as an aerial is defined as “a means for radiating or receiving radio waves”, from the *IEEE Standard Definitions of Terms for Antennas.* In other words, an antenna is taken as the transitional structure between free space and a guiding device. There is various types of antenna for example, wire antennas, aperture antennas, microstrip antennas, array antennas, reflector antennas and lens antennas [11].

The antenna is basically a transducer which converts electromagnetic energy in a cable into an electromagnetic radiated power in free space. Various characteristics of an antenna determine how efficient the conversion is performed. The antenna is expected to have as much energy as possible carried on as radiation and it should not be capable of consuming energy itself. It is important that the antenna concentrates its radiated energy as efficiently as possible in the required way. If so, either a wide coverage range or a reduced transmitting power can be achieved, until the range is exactly suit the one required [11].

2.1 Fundamental Parameters of Antennas

The fundamental parameters of the antenna are necessary to describe the performance of the antennas. The radiation pattern of an antenna is a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. It can be determined in the far-field region and is represented as a function of the directional coordinates. The radiation properties include power flux intensity, radiation intensity, field strength, directivity phase or polarization.

In the other hand, the directivity of an antenna is defined as "the ratio of the radiation intensity in a given direction from the antenna to the radiation intensity averaged over all directions. The average radiation intensity is equal to the total power radiated by the antenna divided by 4π. If the direction is not specified, the direction of maximum radiation intensity is implied". The directivity can be written as in equation (2.1) below

$$D_{\max} = D_o = \frac{4\pi U_{\max}}{P_{rad}} \quad (2.1)$$

where D_o is the maximum directivity, U_{max} represents the maximum radiation intensity measured in Watt per unit solid angle, and P_{rad} is the total radiated power measured in Watt (W) [11].

Another useful parameter that is used to describe an antenna performance is gain. The gain of an antenna is defined as

$$G = \eta . D \quad (2.2)$$

where η indicates the efficiency of the antennas where η is always less than the directivity. For most antenna types, the own loss is so low that G = D can be considered.

The bandwidth of an antenna is defined as "the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard". For broadband antennas, the bandwidth is usually expressed as the ratio of the upper-to-lower frequencies of acceptable operation. Because the