UNIVERSITI TEKNIKAL MALAYSIA MELAKA

OPTIMIZATION OF MICROSTRIP YAGI-UDA ANTENNA FOR WIDEBAND APPLICATION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology Department of Electronic and Computer Engineering Technology (Hons)

by

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I hereby, declared this report entitled Optimization of Microstrip Yagi-Uda Antenna for Wideband Application is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Electronic Engineering Technology (Telecommunication) with Honours. The member of the supervisory is as follow:

…………………………………………

MADAM RAHAINI BT MOHD SAID

(Project Supervisor)

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MD ASHADI B. MD JOHARI

(Project Co-Supervisor)

ABSTRAK

Mikrostrip antena dianggap sebagai antara antena yang dipilih untuk dibangunkan kerana kesederhanaan dalam reka bentuk dan kos yang rendah. Walau bagaimanapun, antena mikrostrip yang dibina dengan reka bentuk Yagi-Uda tidak banyak dibangunkan terutamanya untuk aplikasi jalur lebar. Tambahan pula, sifat-sifat optimum untuk antena ini beroperasi tidak dikenal pasti dengan sepenuhnya. Oleh itu, kajian ini dijalankan bertujuan untuk mengkaji pengoptimuman mikrostrip Yagi-Uda antena untuk aplikasi jalur lebar. Dua antena mikrostrip Yagi-Uda dengan dimensi yang berbeza telah direka melalui perisian Advanced Design System (ADS). Kesan daripada sifat-sifat dimensi, sudut polarisasi, frekuensi dan jarak disiasat untuk mendapatkan kuasa keluaran yang terbaik sebagai respons. Bahagian analisis telah dijalankan untuk mengkaji kesan sifat-sifat dengan menggunakan kaedah 2^4 reka bentuk faktorial. Analisis melalui perisian Design Expert (DOE) mengenal pasti bahawa penyelesaian optimum untuk mikrostrip Yagi-Uda antena adalah 15 cm dimensi, 180° sudut polarisasi, 3000 MHz frekuensi dan 15 cm jarak. Tetapan optimum dipilih untuk mempengaruhi mikrostrip Yagi-Uda antena untuk beroperasi dengan kuasa keluaran yang terbaik.

ABSTRACT

Microstrip antenna is considered to be among the selected antenna to be developed due to its simplicity in design and low cost. Nevertheless, the microstrip antenna implemented with the Yagi-Uda design are not much developed especially for wideband application. Furthermore, the optimum properties for the antenna to operate are not being identified enough. Therefore, this research conducted aims to study the optimization of microstrip Yagi-Uda antenna for wideband application. Two microstrip Yagi-Uda antennas with different dimension were designed through Advanced Design System (ADS) software. The effect of properties which are dimension, polarization angle, frequency and distance was investigated to obtain the best output power as the response. The analysis part was conducted on studying the effect of the properties by using 2^4 factorial design method. The analysis through Design Expert (DOE) software identified that the optimal solution for the microstrip Yagi-Uda antenna are 15 cm dimension, 180˚ polarization angle, 3000 MHz frequency and 15 cm distance. These optimal settings are selected for affecting the microstrip Yagi-Uda antenna to operate with the best output power.

DEDICATION

To my beloved parents
Nor Jalani Bin Mahmud and Kamisah Binti Yusof

To my supervisor and co-supervisor
Mdm Rahaini Bt. Mohd Said and Mr. Md. Ashadi B. Md. Johari

ACKNOWLEDGEMENT

In the name of Allah, the most gracious, the most merciful,

I would like to express my sincere gratitude to my parents and colleagues for providing an endless support from the beginning of this research until it is completed. This research also owes its existence to the guidance, inspiration and support of my supervisor, Madam Rahaini Bt. Mohd Said and my co-supervisor, Mr. Md. Ashadi B. Md. Johari. Special thanks to all individuals who may have contributed towards the completion of this research.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ADS	-	Advanced Design System
ANOVA	-	Analysis of Variance
DOE	-	Design of Experiment
MHz	-	Mega Hertz
dB	-	Decibel
$^\circ$	-	Degree
η	-	Eta (Efficiency)
Γ	-	Gamma (Gain)
φ	-	Phi (Gain)
π	-	Pi
ρ	-	Rho
θ	-	Theta

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Antenna is a communication interface which is used for transmitting and receiving electromagnetic waves. There are numerous aspects such as radiation pattern, gain, operating frequencies and bandwidth corresponding to various applications that affecting the selectivity in developing an antenna. The demands for a low cost, high gain and simplicity in construction of antenna had intrigue towards the development of Yagi-Uda antenna that has been widely used today. The Yagi-Uda antenna is utilized to either receive or transmit electromagnetic radiation with more prominent directivity or gain since it is a directional antenna meaning it focuses a great deal on one direction. In this way, Yagi-Uda antenna has discovered critical common sense application, for example, applications in high frequencies (VHF and UHF) because of its simplicity and flexibility.

In addition, a rapid growth in technologies corresponding with various research activities being pursued had proposed for Yagi-Uda antenna being implemented in microstrip as firstly developed by John Huang in 1989 (J. Huang, 1989). His proposed antenna comprised of four patches that were electromagnetically coupled to each other in which resulting to have a good F/B ratio and 8 dBi maximum gain. He also proposed the same concept of microstrip antenna for mobile satellite vehicle application (Huang & Densmore, 1991). The antenna had a maximum gain of 14 dBi despite its use in certain applications was problematic. Therefore, this project aims to produce a microstrip Yagi-Uda antenna for wideband application.

Besides, this project is intended to analyze several properties thus, investigating the optimum performance for the microstrip Yagi-Uda antenna. Those properties will be analyzed by using the Design of Experiment (DOE) software as to obtain their finest combination in affecting the performance of the microstrip Yagi-Uda antenna.

1.2 PROBLEM STATEMENT

These days, there are various microstrip antenna produced. This type of antenna were researched and developed to suits with various kind of applications and frequency bands. However, there are not many microstrip antenna with Yagi-Uda type especially in wideband application were developed. Besides, the optimum properties are not much identified as those particular antennas were produced to have a specific properties only. Therefore, this project propose to develop a microstrip Yagi-Uda antenna specifically for wideband application. Additionally, the performance of this antenna will be optimized by using the statistical analysis approach as to ensure that the antenna would functions at its peak. As a result, a microstrip Yagi-Uda antenna that have reached its optimum level can be produced. On the other hand, this project also could contribute to be as one of the achievement towards the antenna technology development.

1.3 OBJECTIVES

This research paper concentrates predominantly towards these objectives that are:

i. To study and produce a microstrip Yagi-Uda antenna for wideband application by using Advance Design System (ADS) Software.
ii. To investigate the significant properties which affecting the performance of microstrip Yagi-Uda antenna for wideband application.
iii. To identify the most ideal properties for optimizing the performance for Yagi-Uda antenna.

1.4 SCOPES

The extent of this research will concentrate principally on the optimization of Yagi-Uda microstrip antenna properties for wideband applications. The antenna will be designed by utilizing the Advance Design System (ADS) software and will be printed on the negative strip board. There are four properties that are to be highlighted which are dimension, frequency, distance and angle of polarization. Each of those property will be varied to have two unique qualities as to observe for their effect. For instance, the distance property will be evaluated by two distinct values that implies either the distance is far or nearby. The analyzing process for the properties will be executed by utilizing the Design of Experiment (DOE) software. However, this research was limit by the designing procedure of the microstrip antenna. A comprehensive and specific stages for designing the microstrip antenna according to several criteria such as type of patch, type of software used and specific operating frequency are definitely required. It is also would be beneficial if the procedure comprises a clear explanation about some vital calculations. For instance, it is useful if there is a complete procedure for designing a dual-band microstrip dipole antenna by using CST Microwave Studio software. This would contribute positively for a better flow of designing procedure thus for obtaining a greater results.

CHAPTER 2

LITERATURE REVIEW

2.1 MICROSTRIP ANTENNA

The idea of microstrip antenna was initially proposed in 1953 by Deschamps, a quarter century before the practical antennas were introduced and turned out to be exceptionally prevalent in the 1970s (Bernhard, Mayes, Schaubert, & Mailloux, 2003). Microstrip antennas are extensively used in wireless communication system due to their advantages such as ease of integration with feed networks, low-cost fabrication and low-profile (Kumar, Thakur, & Sanghi, 2013). In its least complex structure, microstrip antenna is a dielectric substrate board sandwiched in the middle of two conductors as shown in Figure 2.1. The lower conductor is known as ground plane and the upper conductor is known as radiating patch. The patch can have any possible shape and can be made of conducting material such as gold or copper (Mutiara, 2011). Microstrip antenna is ordinarily utilized at frequencies from 1 to 100 GHz (Peixeiro, 2011).

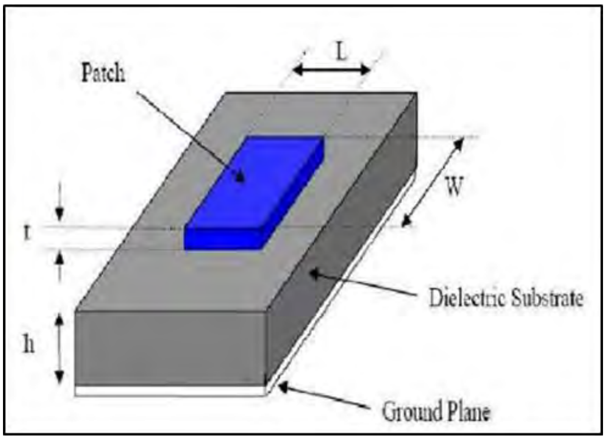


Figure 2.1 Structure of Microstrip Antenna.

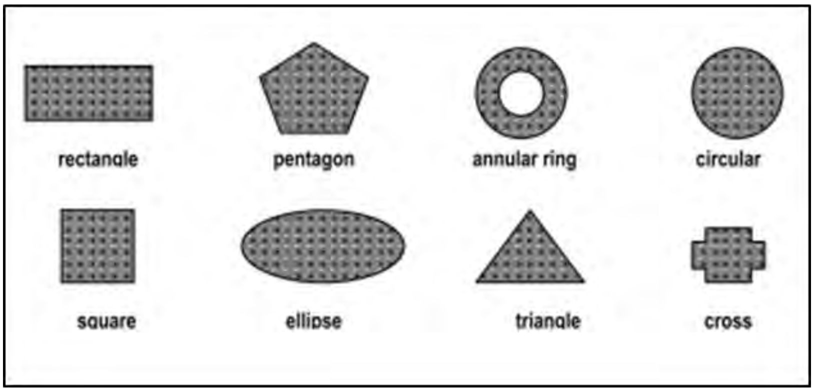


Figure 2.2 Several shapes of a microstrip antenna.

2.1.1 SUBSTRATE

As one of the part in the microstrip antenna configuration, it is vital to select for the appropriate dielectric substrate. Selection of dielectric material with suitable dielectric constant is essential as it provides a key role for the performance of antenna. It directly affects bandwidth, radiation loss, shift in operating frequency and gain (Hanumante, Bhattacharjee, Roy, Chakraborty, & Maity, 2014). Besides, the substrate's height also is important for controlling the bandwidth and surface waves (Yavalkar, Dahatonde, Rathod, & Deosrkar, 2013). A substrate with a low dielectric constant would provide for a better performance compared to the substrate with a high dielectric constant (Khan & Nema, 2012). The table below summarizes for the properties of several substrates that can be used.

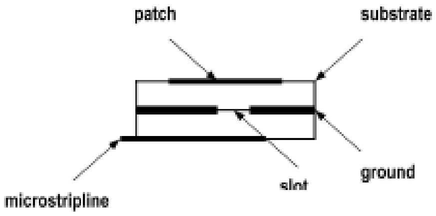
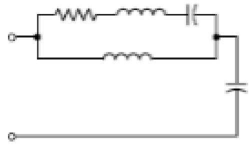
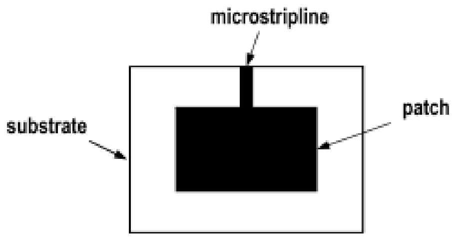
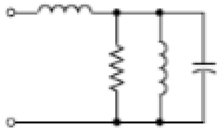
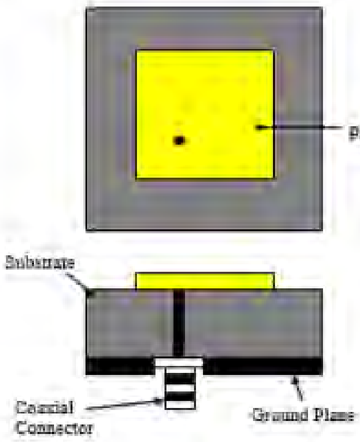
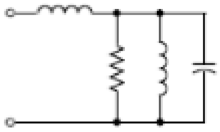
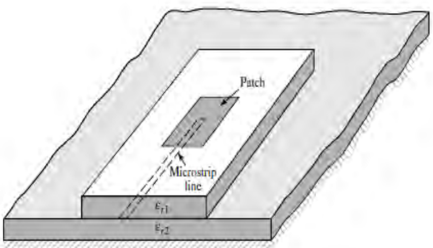
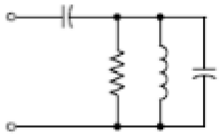
Table 2.1 Properties of different substrates.

Parameters	Bakelite	FR4 Gloss Epoxy	R04003	Taconic TLC	RT Duroid
Dielectric constant	4.78	4.36	3.4	3.2	2.2
Loss tangent	0.0345	0.0113	0.002	0.002	0.0004
Water absorption	0.5- 1.3%	0.25%	0.06%	<0.02%	0.02%
Tensile strength	60 MPa	<310 MPa	141 MPa	-	450 MPa
Volume resistivity	$3x10^{15}$ Mohm.cm	$8x10^{7}$ Mohm.cm	$1700x10^{7}$ Mohm.cm	$1x10^{7}$ Mohm.cm	$2x10^{7}$ Mohm.cm
Surface resistivity	$5x10^{10}$ Mohm.cm	$2x10^{5}$ Mohm.cm	$4.2x10^{9}$ Mohm.cm	$1x10^{7}$ Mohm.cm	$3x10^{7}$ Mohm.cm
Breakdown voltage	20-28 kV	55 kV	-	-	>60 kV
Peel strength	-	9 N/mm	1.05 N/mm	12 N/mm	5.5 N/mm
Density	1810 kg/m^3	1850 kg/m^3	1790 kg/m^3	-	2200 kg/m^3

2.1.2 FEED TECHNIQUE

There are four common methods for exciting a specific microstrip antenna which are the aperture coupling, coaxial probe and microstrip line. The table below shows for the structure of different feed techniques that are widely used.

Table 2.2 Types of feed techniques.

Type	Structure	Equivalent Circuits
Aperture coupling feed		
Microstrip line feed		
Coaxial feed		
Proximity coupled feed		

Firstly, the radiating patch and the feed line are on different sides of the ground plane in the aperture coupling method. This method is used for avoiding the spurious radiation escapes from the feed line thus corrupting the polarization of the antenna. As for allowing independent optimization of the radiating element and the feed mechanism, a slot is cut in the ground plane for coupling the microstrip feed line to the patch. Usually, the bottom substrate uses a high dielectric substrate while the top substrate utilize a substrate with low dielectric constant (Singh & Tripathi, 2011). Next, in microstrip line method, the feed is positioned at the edge as to provide the impedance control. The arrangement provides several advantages such as ease of fabrication as the feed can be on the same substrate and the level of the input impedance can be controlled easily. However, this technique suffers for spurious feed radiation and poor surface wave efficiency (Soh, Rahim, Asrokin, & Aziz, 2005).

The coaxial feed or also known as probe feed is a very common technique used and as shown in the table, the center conductor extends through the substrate and is soldered to the radiating patch. The outer conductor of the coaxial connector is connected to the ground plane. The benefits of this method is that the feed can be selectively placed at any locations inside the patch in order to match with its input impedance. It also has low spurious radiation and easy to fabricate. Despite on that, the drawbacks of this method is that it provides narrow bandwidth and difficult to build as a hole need to be drilled in the substrate (M.Arulaalan & L.Nithyanandan, 2014). Last but not least, the proximity coupled feed which also known as electromagnetic coupling scheme designed by having the feed line in between two substrates and the radiating patch is placed on top of the upper substrate. This method eliminates spurious feed radiation and gives high bandwidth as the thickness of the particular microstrip antenna increases. Two different dielectric substrates also can be used as to optimize the performance. However, it is hard to fabricate as the two dielectric substrates need a proper alignment (Bisht, Saini, Prakash, & Nautiyal, 2014). The table shown below summarizes for the comparison of different feeding techniques.

Table 2.3 Comparison of different feeding techniques.

Characteristics	Microstrip line feed	Coaxial feed	Aperture coupled feed	Proximity coupled feed
Spurious feed radiation	More	More	Less	Minimum
Reliability	Better	Poor due to soldering	Good	Good
Ease of fabrication	Easy	Soldering and drilling required	Alignment required	Alignment required
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth	2-5%	2-5%	21%	13%