COMPACT BUTLER MATRIX DESIGN

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To my loving parents and family members, supervisor, lectures
and my dearly friends…….

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ABSTRACT

With the growing technology of wireless local area network (*WLAN*), the demand for wireless communication to increase its capacity increases as well. As the number of users increase, the co-channel interference fading also increases. This reduces the transmission quality in wireless systems and limits their performances. The technology of smart antennas seems to be able to reject interference signals and increase desired signal level, which will enhanced capacity. The beamforming network is a network that controls the phases and amplitudes of the excitation current for smart antennas. A signal processor will control which port of the beamforming network is used to feed or receive signals while the beamforming network will feed the signal to an array of antennas. The purpose of this project is to design a compact 4 x 4 beamforming network based on Butler matrix concept. Two designs for the Butler matrix were developed. The first design is a large layout which is 263.73 cm^2 while for the second design it is more compact where the size was reduces for 53.59 % from the first design. In order to produce the reduction size of the design, the length of transmission line has been optimized and meander line techniques have been used. The Microwave Office 2006 software was used to simulate both designs. Both designs were export to CorelDRAW12 software before printed and then fabricated on the *FR4 PCB*. End of the project, it is found that Design 2 display better characteristics in both simulation and fabrication compared to Design 1. It also has the added advantage of being compact in size.

ABSTRAK

Dengan perkembangan teknologi jaringan setempat tanpa wayar (*WLAN*), permintaan terhadap komunikasi tanpa wayar untuk peningkatan kemampuannya meningkat dengan baik. Apabila bilangan pengguna meningkat, gangguan pemudaran saluran turut sama meningkat. Ini akan mengurangkan kualiti pemancaran dalam sistem tanpa wayar dan seterusnya menghadkan kebolehan sistem. Penggunaan antena bijak boleh menolak isyarat gangguan dan meningkatkan tahap isyarat yang dikehendaki dan seterusnya akan meningkatkan kemampuan sistem. Jaringan pembentukan alur adalah jaringan yang mengawal fasa dan amplitud arus pengujaan untuk antena bijak. Satu isyarat pemprosesan akan mengawal pangkalan yang akan digunakan oleh jaringan untuk menghantar atau menerima isyarat manakala jaringan pembentuk alur akan menyuap isyarat kepada satu rangkaian antena. Tujuan projek ini adalah untuk merekacipta jaringan pembentuk alur yang padat berdasarkan konsep matriks 4 x 4. Dua rekabentuk untuk matrik Butler telah direalisasikan. Rekabentuk pertama adalah rekabentuk yang besar di mana saiznya adalah 263.73 cm^2 manakala untuk rekabentuk yang kedua adalah lebih padat di mana saiznya berkurang sebanyak 53.59 % daripada saiz rekabentuk yang pertama. Bagi menghasilkan pengurangan saiz rekabentuk, panjang garisan pemancar hendaklah di kurangkan dan teknik lengkokkan telah digunakan. Perisian Microwave Office 2006 dan susun atur dipindahkan pada Perisian CorelDRAW12 sebelum dicetak dan seterusnya rekabentuk ini kemudian difabrikasikan di atas *PCB FR4*. Penghujung projek, ia menunjukkan Rekabentuk 2 menunjukkan ciri-ciri yang lebih baik dalam simulasi dan fabrikasi berbanding Rekabentuk 1. Ia juga mempunyai kelebihan dari segi saiznya yang lebih padat.

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LIST OF ABBREVIATIONS

BFN	-	Beamforming Network
BER	-	Bit Error Rate
d	-	Substrate Thickness
FR4	-	Flame Retardant 4
GHz	-	Giga Hertz
IEEE	-	Institute of electrical and Electronic Engineering
MIMO	-	Multiple Input Multiple Output
mm	-	Millimeter
MWO	-	Microwave Office 2006
h	-	Conductor Thickness
Tan *d*	-	Tangent Loss
β	-	Average output phase
W	-	Width
LAN	-	Local Area Network
WLAN	-	Wireless Local Area Network
Z	-	Impedance
Zo	-	Characteristic Impedance
ε_r	-	Relative Permitivity
ε_{eff}	-	Effective Permitivity
ℓ	-	Length
π	-	Phi
λ	-	Wavelength
λg	-	Waveguide

cm	-	centimeter
PCB	-	Printed Circuit Board
RF	-	Radio Frequency
RSSI	-	Received Signal Strength Indicator
SNR	-	Signal to Noise Ratio
SNIR	-	Signal to Noise and Interference Ratio
UV	-	Ultra Violet

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CHAPTER I

INTRODUCTION

1.1 Project Background

As demand for wireless communications continues to grow, wireless operators face increasing network capacity challenges. As the number of users increase, the channel interference fading also increases. This may reduces the transmission quality in wireless systems and limits their performance. Several studies have proposed that by using smart antenna to reject interference and will enhanced capacity.

In many antenna array applications, the need for multiple beams has arisen. Different multi-beam antenna prototypes are implemented for the applications in base stations [1],[2] to improve the quality of transmission and enhance the cellular capacity, range, and coverage [3] because the antenna array is capable of pointing to desired targets automatically in real time. Moreover, the multipath fading interferences phenomenon in communications systems can be solved using switched beam antenna array for rejecting interference signals and increasing desired signal level [1]. Compared with adaptive antenna arrays, switched beam systems have advantages in implementation because of its simplicity in the design [1].

A smart antenna system for *WLAN* applications based on switched beam system, it can produce narrow multi-beams in different directions instead of omni-directional patterns. However this method has its drawbacks. Among them are low channel capacity, low signal to interference ratio and the small area by the antenna. Switched beam architectures are being proposed as a means to either increase coverage area or decrease the necessary input power for effective communication through wireless channel. The beam scanning can be obtained by different feedings with the phase increment provided by Butler Matrix.

Beamforming networks were originated in the late 1950s by Jesse Butler. The term beamforming relates to the function performed by a device in which energy is radiated by an aperture antenna is focused along a specified direction in space. This objective is either to preferentially receive a signal from that direction or to preferentially transmit a signal in that direction. The Butler matrix was first discussed by Butler in 1960. The conventional Butler Matrix is a multiple beamed antenna system. It consists of a linear antenna array and many output ports. Usually, the number of output ports equals the number of input antennas, which is often a binary number (or 2^n where n is an integer) [4].

The system can be explained through a matrix expression, hence the name.
The Butler Matrix provides the Beamforming Network with the ability to increase the signal to noise ratio (*SNR*). An array of hybrid junctions and fixed-phase shifters are used to achieve the desired results. It exhibits both good and bad features of this *BFN*, it is a simple network using components easily implemented in stripline or microstrip, but conductor crossovers are required [4]. The advantages of Butler Matrix are their simplicity and easy fabrication characteristics. Butler matrix is used widely in antenna feed applications in beamforming networks, multiport power amplifiers, adaptive smart antenna systems for direction finding purposes and in satellite communication applications [1].

1.2 Objective

The objective of this project are to design, simulate and fabricate a compact beamforming network by using 4 x 4 Butler Matrix base on microstrip technology operating at frequency 2.4 GHz.

1.3 Scopes of Project

Scope of this project is to study the theory of beamforming network and Butler Matrix technique. In order to understand all the basic theories and concepts of the related topic of this project, some literature review had been made in beamforming network using 4 x 4 Butler Matrix techniques and exploring the function of Microwave Office 2006. The materials that related to the beamforming, Butler Matrix and others such as in books, journals and articles have been collected. The design parameters for transmission line such as width and length had been calculated. Then, the 4 x 4 beamforming network circuits have been simulated by using Microwave Office 2006. The transmission coefficient, isolation and phase difference for each port have been simulated. Then, the designs have been fabricated by using chemical etching technique. The measurement has been measured by using Network Analyzer. The circuits have been measured and the results are compared with the simulation result.

1.4 Problem Statement

Butler Matrix is one of the main components used in designing the beam forming network. However the sizes of beam forming network for many ports are quit large. Compact Butler Matrix will implement the meander line technique in order to reduce the overall sizes of beam forming network [2].