BEAMFORMING NETWORK DESIGN BY USING BUTLER MATRIX

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"I declare that the work submitted in this thesis entitled **Beamforming Network Design By Using Butler Matrix** is my own, except for works that I have been clearly cited in the references".

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Special to my parents, supervisor, lecturer and friends.

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ABSTRACT

Nowadays, communication systems are moving towards higher data rate transmission. MIMO is one of the techniques which is new and widely explore by the researchers. MIMO concept can achieve by implement Beamforming Network into the system. This project will design the beamforming network by using Butler Matrix concept. This paper presents the design, simulation and fabricate of a four-port Butler matrix to feed an any antenna for Wireless Local Area Network (WLAN) at 2.4 GHz. The design process begins with calculation of design specification such transmission line, width and length. The Butler matrix consists of the main components, which is the hybrid coupler, crossover and phase shifters. Then, the design circuit will be simulate using Microwave Office Software 2004. The design will be fabricated by using an etching technique and will be implemented on FR4 board. Results from simulation and fabrication is then being compared in term of return loss (S_{ii}), transmission coefficient (S_{ji}), isolation (S_{ij}) and the phase difference between each port.

ABSTRAK

Pada ketika ini, sistem komunikasi sedang memacu ke hadapan dengan penghantaran maklumat yang mempunyai data yang lebih besar. MIMO merupakan salah satu teknik yang baru dan masih kajian yang meluas bagi pengkaji dalam bidang ini. Konsep MIMO juga mengguna pakai teknik 'Beamforming Network' dalam sesuatu sistem. Projek ini direkabentuk dengan menggunakan Butler Matrix direkabentuk dengan membuat simulasi dan fabrikasi 4 x 4 Butler Matrix untuk menyesuaikan mana-mana jenis antena pada keadaan 2.4 GHz (WLAN). Rekabentuknnya mestilah dalam bentuk kompak supaya ia mudah digunakn dalam apa jua bentuk keadaan. Kemudian, rekabentuk litar ini akan dilakar dengan menggunakan Microwave Office Software 2004. Setelah itu, ia dilakar di atas papan FR4 dengan menggunakn teknik punaran (etching). Setiap keputusan dari simulasi dan fabrikasi perlulah merujuk kepada 'kehilangan balikan' (S_{ii}), 'jalur pengantaran' (S_{ji}), 'pemencilan' (S_{ij}) and 'perbezaan fasa' pada setiap sumber supaya ia boleh dibandingkan dengan setiap keputusan yang dihasilkan.

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LIST OF ABREVIATION

a	-	Side length
a_{eff}	-	Efficiency Value of Side Length
AS	-	Angular Spread
BW	-	Bandwidth
BFN	-	Beamforming Network
BM	-	Butler Matrix
d	-	Substrate Thickness
dB	-	Decibel
Degs / °	-	Degree
DG	-	Diversity Gain
ESA	-	European Space Agency
Freq	-	Frequency
FR4	-	Flame Retardant 4
GHz	-	Giga Hertz
IEEE	-	Institute of electrical and Electronic Engineering
ISM	-	Industrial, Scientific and Medical
km	-	Kilometer
Log	-	Logarithm
LOS	-	Line of Sight
Mag	-	Magnitude
MEA	-	Multi Element Antenna
MHz	-	Mega Hertz
MIMO	-	Multiple Input Multiple Output
mm	-	Millimeter
MPA	-	Multiport Power Amplifier
MWO	-	Microwave Office 2004

P	-	Power
PCB	-	Printed Circuit Board
RF	-	Radio Frequency
RL	-	Return Loss
Rx	-	Receiver
SD	-	Selection Diversity
SNR	-	Signal to Noise Ratio
T	-	Conductor Thickness
Tan δ	-	Tangent Loss
Tx	-	Transmitter
V	-	Voltage
W	-	Width
WLAN	-	Wireless Local Area Network
Z	-	Impedance
Z_o	-	Characteristic Impedance
θ	-	Phase
ε_r	-	Effective Dielectric
ε_{eff}	-	Effective Permittivity
ℓ	-	Length
π	-	Phi
λ	-	Wavelength
λg	-	Waveguide
3-D	-	3 Dimension

CHAPTER I

INTRODUCTION

1.1 Introduction

As demand for wireless communications continues to grow, wireless operators face increasing network capacity challenges. Smart antenna technology currently provides a viable solution to capacity-strained networks and lends itself to the migration to high speed networks [1,2].The primary advantages of using smart antennas in wireless networks are to increase the number of voice calls and the amount of data throughput, to avoid interference and to ease network management. A basic understanding of smart antenna technology provides an explanation of the application of smart antennas in wireless communications.

The basic principle behind smart antennas is to control or reduce interference Typically, this is accomplished through the use of narrow beams at the base site for both on the forward and reverse links. A smart antenna system combines multiple antenna elements with signal processing capability to optimise its radiation pattern and reception pattern in response to the signal environment.

The transmit and receive patterns are automatically updated as the subscriber moves through the cell or as signal conditions change. Currently, switched diversity omni directional antennas are the standard for use in a wireless access point (WAP) in WLAN. However this method has its drawbacks. Among them are low channel capacity, low signal to interference ratio and the small area coverage 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. Beamforming networks were originated in the late 1950s by Jesse Butler [6].

The term beamforming relates to the function performed by a device or apparatus in which energy is radiated by an aperture antenna is focused along a specific direction in space. The 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 $2n$ where n is an integer). [5]

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 o 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.[6]

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. [3]

1.2 Problem Statements

In applications where size, weight, cost, performance, ease of installation, and aerodynamic profile are constrains, low profile antennas like microstrip antennas are required. Because microstrip inherently has narrow bandwidths (BW) and in general, are half-wavelength structures operating at the fundamental resonant mode researchers have made efforts to overcome the problem of narrow bandwidth. [1]

Traditionally, a wideband antenna in the low frequency wireless bands can only be achieved with heavily loaded wire antenna, which usually means different antennas are needed for different frequency bands. And this will increased the cost to developing the antenna. [2] The high expense of implementing the multiple RF chains motivates the recent popularity of antenna selection schemes. [9]

1.3 Project Objective

These project objectives are to design, simulate and fabricate a 4 x 4 Butler Matrix by using Beamforming network. The designs require transmission line such as width and length, isolation and return loss in a specified at 2.4 GHz. Finally, the design Beamforming network should work properly in the Wireless Local Area Network (WLAN) environment.

1.4 Scope of Works

This project consists of a eight phases. For the first phase, study the concept of beamforming network and butler matrix technique. In order to understand all the basic theory and concept of the related topic of this project, some research were made in Beamforming network using design 4 x 4 Butler Matrix technique and exploring the function of Microwave Office 2004. All the material that related to the beamforming, MIMO, butler matrix and other related this project in books, journals and articles have been collected.

The design parameters such as transmission line such as width and length will be calculated. Then, the 4 X 4 Beamforming network circuit will be simulate by using Microwave Office 2004. The transmission coefficient, isolation and phase difference for each port have been simulated. Then, the designs have been fabricated by using an etching technique. The prototypes have been measured and the results have been compared with the simulation result.

1.5 Thesis Structure

Thus thesis is divided into five chapters covers the research works that have been through for Beamforming Network design by using 4 x 4 Butler Matrix. Chapter II reports the literature review of the basic concepts in Beamforming Network design using by 4 x 4 Butler Matrix circuit design. Chapters III describe the design, simulation and calculation process.

The Microwave Office 2004 (MWO) software was used to deliver the design and simulation process. The simulation and analysis result are reported in chapter IV. Chapter V concludes the research work and gives for future development of the research project.

1.6 Chapter Summary

This chapter is an introducing for objective and scope of work of the project. The introduction and importance of the project also be explained. Besides, the thesis structure is highlighted. The research work performed will be reported in the following chapter.

CHAPTER II

LITERATURE REVIEW

2.1 Smart Antenna Technology

In mobile communication systems, capacity and performance are usually limited by two major impairments. They are multipath and co-channel interference [5]. Multipath is a condition which arises when a transmitted signal undergoes reflection from various obstacles in the propagation environment. This gives rise to multiple signals arriving from different directions. Since the multipath signals follow different paths, they have different phases when they are arrive at the receiver.

The result is degradation in signal quality when they are combined at the receiver due to the phase mismatch. Co-channel interference is the interference between two signals that operate at the same frequency. In cellular communication the interference is usually caused by a signal from a different cell occupying the same frequency band. Smart antenna is one of the most promising technologies that will enable a higher capacity in wireless networks by effectively reducing multipath and co-channel interference [6]. This is achieved by focusing the radiation only in the desired direction and adjusting itself to changing traffic conditions or signal environments.