MULTIPLE PHASE SHIFTER DESIGN BY USING PIN DIODE FOR MIMO APPLICATION

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"I hereby declare that this report is the result of my own except for quotes as cited in the references."

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Date : 7th MAY 2009

DEDICATION

Special dedication belongs to my beloved parents, Yaacob Mariman and Norraini Lamin. My special thanks to my kind hearted supervisor Mohamad Zoinol Abidin Abd Aziz, all lecturers in faculty of electronics and computer engineering and also to all my dearest friends.

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Thank you very much.

ABSTRACT

This project presents a Multiple Phase Shifter Design by using PIN Diode for MIMO Application. Multiple Phase Shifter design is a method, where to differentiate multiple signal and the interferences. Besides, it is also to increase the performance channel and to improve the data rate. The multiple phase shifter circuit is designed with consist multiple input multiple output. PIN diode is used as a switch. The Multiple Phase Shifter 4x4 is designed to produce various output signals with different phase at 2.4GHz frequency. The designed methods are used to complete the project included calculation and simulation. Calculation method is done to obtain the width, *W* and the length, *L* of phase shift for each phase angles. Simulation method is done to design the phase shifter circuit by using Microwave Office 2006 software. The simulation design constructed based on desired phase shift, which are begin with simulation for single input single output, single input multiple output and multiple input multiple output. These design focused on certain different phase; 0°, 45°, -45°, 90°, -90°, 135°, 180°/-180° and 360°. The magnitude for return loss for each port in input port around -20dB and the isolation for every port is more than -3dB. The beam rosette pattern is changing based on the phase different in output. The analysis that had been done is the more length, *L* of the phase shift caused the different phase greater than or smaller than. The size of the layout of phase shift was 20.08mm in length and 2.82mm in width.

ABSTRAK

Projek ini adalah sebuah penganjak fasa berbagai yang menggunakan diod PIN untuk aplikasi MIMO. Perisian gelombang mikro (AWR) digunakan untuk merekabentuk litar yang mempunyai berbagai masukan dan keluaran dengan penggunaan diod PIN sebagai suis. Binaan litar ini adalah untuk mendapatkan hasil keluaran berbagai fasa yang berbeza pada frekuensi 2.4GHz. Kaedah yang digunakan untuk merekabentuk dengan melakukan pengiraan dan simulasi. Kaedah pengiraan digunakan untuk mendapatkan nilai ketebalan dan panjang jalur penghantaran setiap sudut. Kaedah simulasi dilakukan untuk merekabentuk litar menggunakan perisian *Microwave Office 2006.* Simulasi ini melalui tiga peringkat iaitu rekaan dengan satu masukan satu keluaran, satu masukan banyak keluaran dan banyak masukan banyak keluaran. Rekabentuk litar ini fokus pada beberapa beza fasa; 0°, 45°, -45°, 90°, -90°, 135°, 180°/-180° dan 360°. Kehilangan pergi balik bagi setiap masukan adalah sekitar -20dB, manakala sisihan adalah lebih daripada -3dB. Bentuk sinaran roset berubah mengikut beza fasa pada keluaran. Analisa yang di buat adalah kepanjangan anjak fasa akan menyebabkan beza fasa semakin berubah menjadi semakin bertambah atau semakin berkurang. Saiz rekaan adalah dengan panjang sebanyak 20.08mm dan lebar sebanyak 2.82mm.

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MIMO	Multiple Input Multiple Output
PIN	*p-Type* and *n-Type* Semiconductor Region with Intrinsic Region
RF	Radio Frequency
UHF	Ultra High Frequency
KU	Kurtz-under
dc	Direct Current
W	Width
L	Length
Ø	Phase
S_{21}	Forward Transmission Coefficient of 50Watt Terminated Output
S-parameter	Scattering Parameter
°	Degree
dB	Decibel
ABCD matrix	Ray Transfer Matrix Analysis
l_1	First Transmission Line Length
l_2	Second Transmission Line Length
$\Delta_{\emptyset}$	Phase Different between Two Bias States
λ_g	Waveguide
π	pi
μA	micro-Ampere
p-n	*p-Type* and *n-Type*
p	Hole
n	Electron
WLAN	Wireless Local Area Network
LAN	Local Area Network
Wi-max	Worldwide Interoperability for Microwave Access
CDMA	Code Division Multiple Access
DSL	Digital Subscriber Lines

3G	Third Generation of Telecommunication
SISO	Single Input and Single Output
SIMO	Single Input and Multiple Output
MISO	Multiple Input and Single Output
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
3GPP	3rd Generation Partnership Project
3GPP2	3rd Generation Partnership Project 2
d	Thickness
ε_r	Relative Permittivity
TEM	Transverse Electromagnetic
Z_o	Characteristic Impedance
v_p	Free Space Phase Velocity
L	Inductance
C	Capacitance
c	Speed of Light
η_o	Free Space Impedance
Ω	Ohm
ε_r	Dielectric Constant
ε_e	Effective Dielectric Constant
μ_e	Non-Magnetic Material
α_d	Attenuation Due to Dielectric Loss
α_c	Attenuation Due to Conductor
R_s	Surface Resistivity
δ	Tangent Loss
BFN	Beamforming Network
GL	Grating Lobes
λ	Wavelength
d	Distance
θo	Beam Angle
AF	Array Factor
β	Phase Difference
FR4	Flame Retardant 4
mm	millimeter
GHz	Gigahertz

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CHAPTER I

INTRODUCTION

1.1 Project Background

Multiple Input and Multiple Output (MIMO) has attracted attention in wireless communication with the significant increase in data through put and link range without additional bandwidth. This MIMO pioneer described ways to send data from multiple users on the same frequency or time channel using multiple antennas at the transmitter and receiver.

The multiple phase shifter have been design to produce the multiple output signal in different phase for multiple antenna users. Phase shifter is a device in which the transmission line of phase shift can be shifted. The function of the phase shifter is to control the phase characteristics in the processing of a microwave signal.

PIN diode is used as a switch. PIN diode are most widely used as switching elements to control microwave and RF power from UHF through KU bands in a variety of switch configurations. The resistance value of PIN diode is determined only by the forward biased *dc* current. The simulation is performed by using Microwave Office software.

1.2 Objective of Project

The objective of this project is to design and simulate the 4x4 Multiple Phase Shifter Design by using PIN diode for MIMO Application at frequency 2.4GHz to know the return loss, isolation, different phase angle and the beam rosette pattern.

1.3 Problem Statement

In many fields of electronics, it is often necessary to change the phase of signal to differentiate multiple signals to improve data rate and increase the channel performance. Using PIN diode as a switch, the multiple phase shifter is produce output signals in different phase to get more phase angle at certain frequency. This signal is send data from multiple users on the same frequency or time channel using multiple antennas at the transmitter and receiver. When send data in the same time and same frequency, the signal will lead the interference. It is also to increase the network capacity and channel performance. Therefore, this is the challenges to the RF designers in getting output signals in different phase.

1.4 Scope of Project

Design a Multiple Phase Shifter 4x4 at the frequency of 2.4 GHz by calculating the width, *W* and length, *L* and phase, *ø*. The circuit design using Microwave Office software to simulate the phase shift and analyze the phase different between each output, return loss, isolation and beamwidth rosette pattern.

CHAPTER II

BACKGROUND STUDY

2.1 Phase Shifter

A phase shifter is an instrument that produces an adjustable change in phase angle of the wave transmitted through it. Ideally, it should perfectly match to the input and output lines and should produce attenuation.

A microwave phase shifter is a two-port device that capable on producing a true delay of a microwave signal flowing. Phase shifter function as to control the phase characteristics and to change the transmission phase angle of S_{21} in the processing of a microwave signal. This phase shifter will shift a desired signal to a desired phase location via a digital or analog command and accomplished in a passive device. This device is provides low insertion loss, which is the attenuation of the microwave signal and equal amplitude network in all phase states [1].

The attenuation of the phase shifter can be calculated from S-parameter and expressed in decibels as [2]:

$$(\text{Insertion loss})_1 = 20 \log \; |S_{21}| \quad (2.1)$$

$$(\text{Insertion loss})_2 = 20 \log \; |S_{12}| \quad (2.2)$$

Phase shifter can be analog or digital. Analog phase shifters provide a continuously variable phase. Most of the phase shifters are in digital variety because there are more immune to noise. Digital phase shifters provide a discrete set of phase states that controlled by two state phase bit [1].

Phase shifter has several most common methods. There are the hybrid coupler phase shifter circuit, the direct transmission loaded line phase shifter circuit, the switched line phase shifter circuit and rotary phase shifter for analog phase shifter [1].

2.1.1 Hybrid Coupler Phase Shifter

The hybrid coupler phase shifter uses the fewest diodes (two per bit). The proper design of the terminating circuit can be obtained by any phase shift increment. This hybrid coupler provides a 3dB power split for two output arms with a 90° phase difference. This coupler can be a branch line hybrid coupler, a backward wave or a proximity coupler hybrid [3].

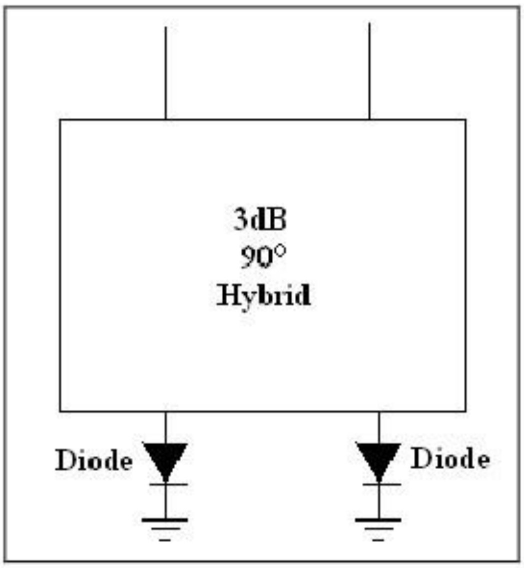

Figure 2.1 Hybrid Coupler Phase Shifter

2.1.2 Direct Transmission Loaded Line Phase Shifter

The direct transmission loaded line phase shifter is a method, which more attractive for high frequency applications. The phase shifter design is based on two factors. First factor is any symmetric pair of quarter-wavelength spaced shunt susceptance will have mutually cancelling reflections if their normalized susceptances are small compared with unity. The second factor is shunt capacitance elements electrically lengthen a transmission, whereas inductive elements shorten it. This loaded line can be analyzed using the *ABCD* matrices [3]

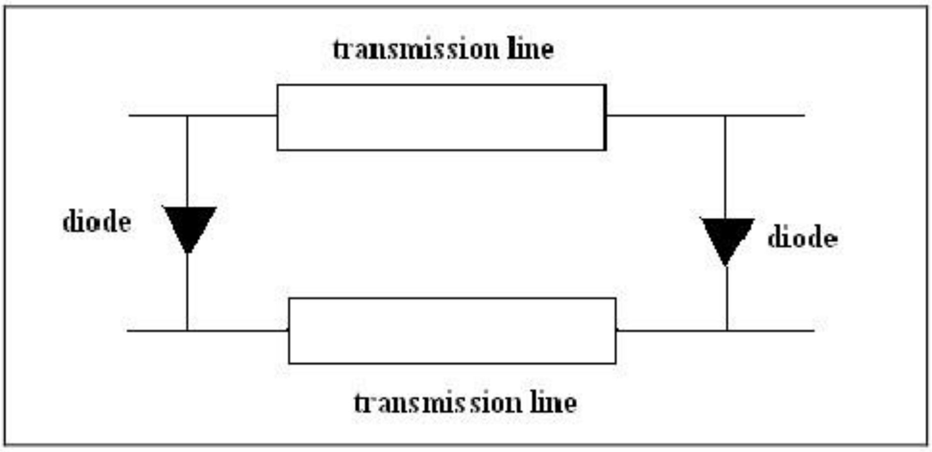

Figure 2.2 Loaded Line Phase Shifter

2.1.3 Switched Line Phase Shifter

This switched action to obtain insertion phase by providing alternative transmission paths, which is the difference in electrical lengths being the desired phase shift. This approach offers the opportunity for true time delay rather than steady-state phase control. Although, this switched has disadvantage that the four diodes are needed per bit [3].

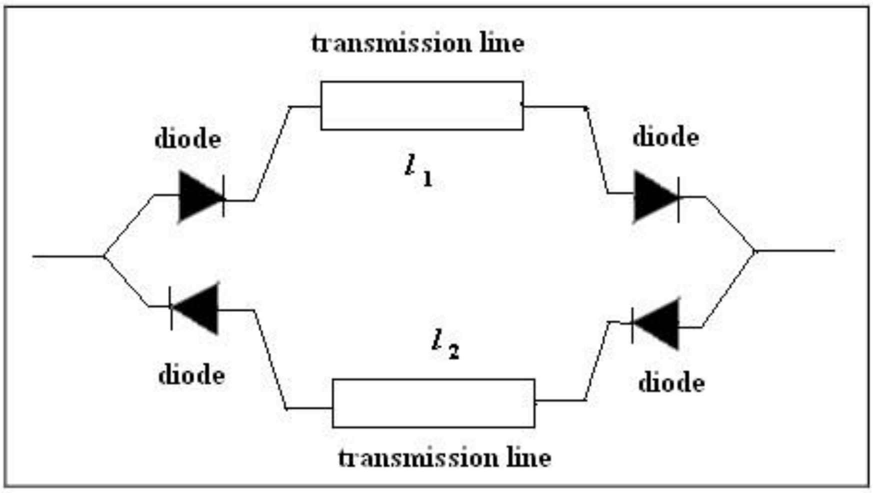

Figure 2.3 Switched Line Phase Shifter

As shown in figure, the signal flows through the lower line length of l_1 if the bias is positive. If the bias is negative, the signal flows through the lower line with a path length of l_2. The phase difference between the two bias states is [1]:

$$\Delta_{\phi} = \frac{2\pi}{\lambda_g}(l_1 - l_2) \tag{2.3}$$

2.1.4 Rotary Phase Shifter

The rotary phase shifter is a precision instrument that is widely use microwave measurements. The quarter-wave plates are oriented at an angle of 45° relative to the broad wall of the rectangular guide in the rotary phase shifter [1].

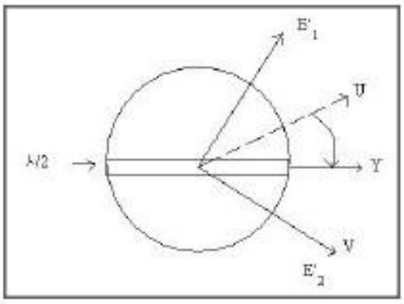

Figure 2.4 Rotary Phase Shifter

One major application of phase shifters is in phased-array antennas. Each antenna element in phase-array antenna is connected to a phase shifter. By varying the phase of each element, the array radiation beam can steer to the desired direction electronically [1].

2.2 Diode

Diodes allow electricity to flow in only one direction. The arrow of the circuit symbol shows the direction in which the current can flow. Diodes are the electrical version of a valve and early diodes were actually called valves [3].

A little energy pushing its way through the diode is use up by electricity. There is a small voltage across a conducting diode called forward voltage drop and it is about 0.7V for all normal diodes which are made from silicon. The forward voltage drop of a diode is almost constant whatever the current passing through the diode so they have a very steep characteristic.

A perfect diode does not conduct when a reverse voltage is applied but all real diodes leak a very tiny current of a few μA or less. This tiny current can be ignored in most circuits because it will be very much smaller than the current flowing in the forward direction. However, all diodes have a maximum reverse voltage. If maximum reverse voltage is exceeded, the diode will fail and pass a large current in the reverse direction and this is called breakdown [4].

2.2.1 PIN Diode

A PIN diode is a semiconductor device that operates as a variable resistor at RF and microwave frequencies. The resistance value of the PIN diode is determined only by the forward biased *dc* current. An important additional feature of the PIN diode is its ability to control large RF signals while using much smaller levels of *dc* excitation [2].

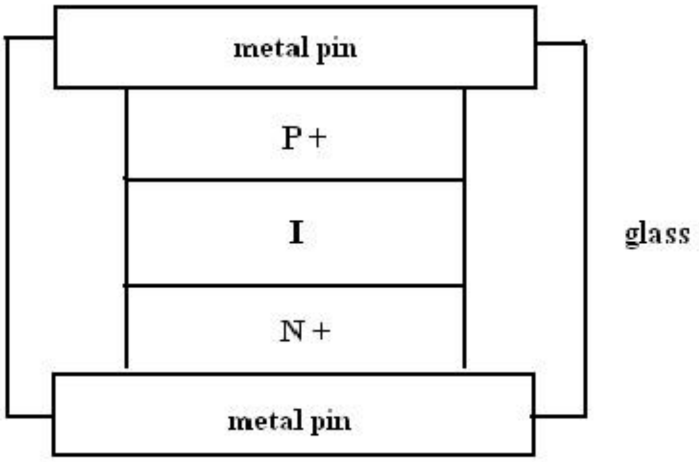

Figure 2.5 Cross Section of PIN Diode

A PIN diode obeys the standard diode equation for low frequency signals. The diode looks like an almost perfect resistor at higher frequencies, while at low frequencies, the charge can be removed and the diode turns *off.* The diode never turns off because there is not enough time to remove the charge in high frequency. Besides, the PIN diode has a poor reverse recovery time.

The depletion region for PIN diode exists almost completely within the intrinsic region. This depletion region is much larger than in a PN diode and increases the area where electron-hole pairs can be generated. The wide intrinsic region also means the diode will have a low capacitance when reverse biased.

PIN diode is similar to the *p-n* diode but with a smaller junction capacitance. The structure of PIN diode consists of a heavily doped *p-region* and a heavily doped *n-region* separated by a layer of high resistivity material that is nearly intrinsic as shown in Appendix A.

The device functions in forward bias or reverse biased modes. When forward biased, injects a charge into the resistivity layer. The amount of voltage that is given decides the amount of charge and its conductivity. This forward direction will act as a variable resistor. The resistance of the PIN diode decreases and eventually becomes