

بسم الله الرحمن الرحيم

**Sudan University of Science and Technology  
College of Graduate Studies**

# **The PIN Diode As a Microwave Control Element**

**A thesis Submitted in Partial Fulfillment for the  
requirements of the degree of M.Sc  
In  
(Electrical Engineering (Power**

**:Prepared By  
Waleed Tajeldin Hassan**

**Supervised by: Amir Ahmed Dawood**

**November. 2006**

## **Dedication**

**To my parents  
To my brothers & sisters  
To my colleagues**

## **ACKNOWLEDGEMENT**

I would like to express my deep thanks to all who helped me to achieve this project especially to my supervisor

Amir Ahmed Dawood

for the effort, patience and precious experience which had greatly supported and led to the success of this work.

## **ABSTRACT**

Switching and phase shifting are done, in the past with mechanical . or electromechanical devices

With the advent of ferrite and PN junction semiconductor devices these operations can be carried out at speeds of at least two or three orders .of magnitude faster than with electromechanical devices

In the case of ferrites , the control operations are carried out by changing the magnitude & direction of an externally applied magnetic field .to the ferrite

In the case of PN junction semiconductor devices , the control is achieved by varying the bias current or bias voltage across the solid state .devices

Of the several PN junction devices available , the PIN silicon diode is the most widely used for two state (digital) microwave control . operation

The applications of junction diodes to microwave switching and . phase shifter are numerous and varied

One example is the switching of the power of RF source to several .antennas or performing duplexing in a radar system

Another application of PIN diode and perhaps the most important application is the possibility of electronically steering phase array antennas .using PIN diode phase shifters

في الماضي الفتح والغلق وإزاحة الطور في الأجهزة كانت  
تقوم به أجهزة ميكانيكية أو كهربائية وميكانيكية.  
مع عهد أجهزة الخام الحديدي (Ferrite) وأشباه الموصلات أصبحت  
هذه العمليات تجري بسرعات أضعاف سرعة الأجهزة الكهروميكانيكية.  
في حالة أجهزة خام الحديد (Ferrite) التحكم في هذه العمليات يجري  
بتغيير مقدار واتجاه مجال مغناطيسي خارجي يسلط على الخامة الحديدية.  
في حالة أجهزة أشباه الموصلات يتم التحكم بتغيير تيار الانحياز أو  
جهد الانحياز. استخدامات ثنائيات الوصل في الفتح والغلق وإزاحة الطور في  
حيز الميكرويف متعددة ومتنوعة مثال لذلك توزيع القدرة الراديوية لعدة  
هوائيات وكذا عملية توزيع القدرة بين المرسل والمستقبل في الهوائي في  
نظم الرادار.  
استخدام آخر وربما من أهم الاستخدامات لثنائي PIN هو إمكانية  
قيادة وتوجيه مصفوفات الهوائي الطوريه باستخدام المزاوحات الطورية  
المستخدمة لثنائي PIN.

## Contents

Abstract	I
----------	---

ملخص	II
Content	III
List of symbols	V
List of figure	VI
<b>Chapter One: INTRODUCTION</b>	
REVIEW 1-1	1
PIN diode 1-2	2
Construction 1-2-1	2
Diode resistant 1-2-2	3
Operation 1-2-3	6
<b>Chapter Two : PIN Diode As Switch</b>	
INTRODUCTION 2-1	8
The PIN diode as a switching performance 2-2	8
Equivalent circuit 2-2-1	8
Insertion loss 2-2-2	9
Isolation 2-2-3	11
Power Handling Capabilities 2-2-4	11
Switching Speed 2-2-5	14
PIN diode Switching Configuration 2-3	14
Single-throw Switches 2-3-1	15
Multi-throw Switches 2-3-2	17
Multi-Diode Construction 2-3-3	20
Limitations 2-3-4	22
<b>Chapter Three :The PIN diode performance in micro strip circuits</b>	
Introduction	23 3-1
The Micro strip 3-2	23
Parameters of The Microstrip Transmission line 3-2-1	24
Microstrip losses 3-2-2	30
Construction And Circuit Techniques of Microstrip Switches 3-3	30
Construction 3-3-1	30
Chip bonding methods 3-3-2	31
Bias circuits 3-3-3	32
<b>Chapter Four: The PIN diode as digital phase shifter</b>	
Introduction	34 4-1
Definition of a phase shifter 4-2	34

phase shifter circuits 4-3	35
Insertion losses 4-4	41
<b>Chapter Five: The PIN diode performance in micro strip circuits</b>	
Phased arrays 5-1	44
The choice of PIN diode phase shifters 5-2	49
<b>Chapter Six :Conclusion and Recommendations</b>	
6-1Conclusions	50
<b>Recommendations 6-2</b>	51
REFERENCES	52

## List of Symbols



P	positive region
N	negative region
I	intrinsic region
$C_j$	junction capacitance
C	case capacitance
$L_c$	inductance
$C_T$	total capacitance
$R_D$	diode resistance
G	junction conduction
R	series resistance
$I_F$	forward bias current
$I_R$	reverse bias current
$t_d$	delay time
$t_t$	transition time
$t_{RR}$	reverse recovery time
w	conductor width
t	conductor thickness
h	dielectric thickness
$\epsilon_r$	dielectric constant
$\epsilon_{eff}$	effective dielectric constant

## List of Figure

Figure (1-1) Electrical Equivalent Circuit of a PIN diode	4
Figure (1-2a) PIN diode forward mode	5

Figure (1-2b) PIN diode reverse bias mode	5
Figure (1-3) PIN diode in high frequency switching	7
Figure (2-1) The Equivalent circuit of The PIN diode In Both Bias Conditions	9
Figure (2-2) Series switching with the diode forward biased	10
Figure (2-3) Variation of insertion loss with bias current for series diode	10
Figure (2-4) Shunt switch with the diode reverse biased	12
Figure (2-5) Variation of insertion loss with frequency for DC1028 diode in 50 $\Omega$	12
Figure (2-6) Series switch with the diode reverse biased	12
Figure (2-7) Variation of isolation with frequency	13
Figure (2-8) Shunt switch with the diode forward biased	13
Figure (2-9) Variation of isolation with bias current for shunt diode in 50 $\Omega$	14
Figure (2-10) Reverse recovery time	15
Figure (2-11) shunt mounted configuration	16
Figure (2-12) Series mounted configuration	17
Figure (2-13) single pole double throw switch	18
Figure (2-14) Simplified operational equivalent circuit for SPDT switch	19
Figure (2-15) Simplified multi throw switches	21
Figure (2-16) Attenuation Vs spacing for two shunt diodes mounted on a 50 ohm line	22
Figure (3-1) The microstrip	24
Figure (3.2)a $Z_0$ against the dimension of microstrip	29
Figure (3.2)b The dimension of microstrip against $Z_0$	29
Figure (3-3) Basic microstrip construction of a multi throw switch	31
Figure (3-4) Bias network	33
Figure (4-1) Definition of transmission phase and loss	35
Figure (4-2) Schematic for switched delay line phase shifter	36
Figure (4-3) Four bit switched line phase shifter	36
Figure (4-4) periodically loaded phase shifter	37
Figure (4-5) The reflection phase shifter	38
Figure (4-6) Methods of achieving hybrid coupler properties	39
Figure (4-7) Hybrid coupled phase shifter	40
Figure (4-8)a performance of Switched path circuit	42
Figure (4-8)b Switched path circuit	43
Figure (5-1) Phase arrayed antenna steering with phase shifter	45
Figure (5-2) Antenna scanning by beam swinging by phase change	47
Figure (5-3) Back to back rotating arrays	48

