PIN Diodes

Abstract

Ok so I need to write a report on PIN diodes for my nonlinear microwave devices class

I have a bunch of point form notes ready but I need your help to convert them into sentences

The notes aren't all in order so you will need to make sure everything flows logically

In order to make sure what you give me sounds human and how I write, I'm going to give you a few samples of past reports that I've done

Here is the first sample:

PIN Diode Basics

Overview

The PIN diode is a type of diode similar to the regular PN junction diode, but with an intrinsic region (no doping or light doping) inserted in the middle of it (which effectively becomes the junction/ depletion region).

Talk about:

What it is (PN with I in the middle), useful for RF and high frequency circuits (MHz and above usually), Impedance is controlled by the DC bias current

Can allow for controllable resistance at RF/ microwave frequencies. Is (DC) current controlled

Can be used as a switch, variable attenuator, phase shifter, modulator, limiter, and detector. Can control large RF power signals with small DC bias currents

Can be made from many different materials depending on the use case and frequency range of interest

Main difference is that the I region in the middle acts like a “bucket of charge” which allows the diode to pass current in the reverse direction for a short amount of time. Technical term is that the PIN diode has a much slower reverse recovery time which allows a sufficiently high frequency to pass through. But this is dependant on the bias current. The lower the frequency, the higher the bias current

Reverse recovery time is 100s of ns vs ns or ps for a fast switching diode. For a signal to pass through, it just needs to not deplete the stored charge in the junction of the PIN diode (ie the intrinsic region)

Important parameters:

R_S series resistance under forward bias (strong (linear) function of bias current)

C_T total capacitance at zero or reverse bias (strong function of reverse bias voltage)

R_D parallel resistance at zero or reverse bias

V_R maximum allowable DC reverse bias voltage τ carrier lifetime

During forward bias, holes and electrons do not immediately recombined which increases the carrier lifetime and gives a larger stored charge. Which then lowers the effective resistance of the diode

During reverse bias, diode acts like a capacitor as there are no stored charges in the I region

Thicker I region allows for higher RF breakdown voltage and better linearity/ distortion properties

Thinner I region has a faster switching time

Generally the lower the breakdown voltage, the lower the signal power it can take, the lower the cost

Common misconception: carrier lifetime is the only parameter which determines the cut off frequency and distortion. Reality: yes carrier lifetime matters but so does the thickness of the I region

Typically PIN diodes have wider I region which allows it to take larger RF voltages than varactors or Schottky diodes -> makes PIN diodes great for high power RF switches

Low frequency PIN diodes are available, but typically PIN diodes are used above a MHz

Large Signal Modeling/ IV

Valid for frequencies below the transit time frequency

PIN behaves like a regular PN junction diode (same IV curves)

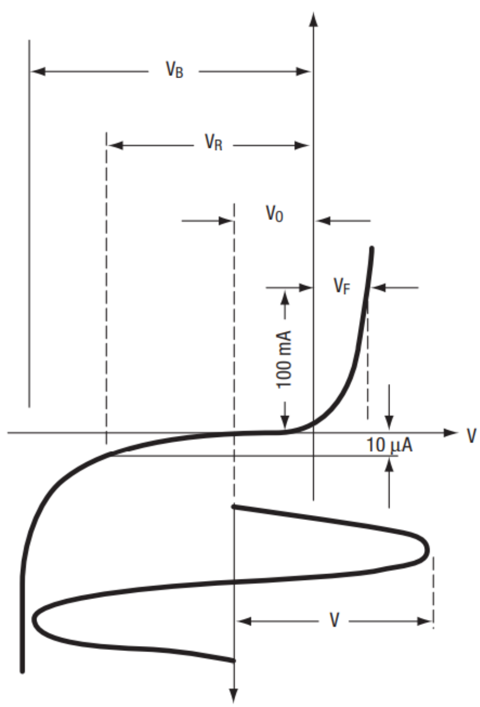


Figure 1: from skyworks app note

RF Model

Want $Q \gg \frac{I_{RF}}{2\pi f}$ for RF current to pass

Forward Bias

Q = I_F × τ (in coulombs)

W = I region width

I_F = forward bias current

τ = carrier lifetime

μ_n = electron mobility

μ_p = hole mobility

I_fwd = forward bias current

$$R_s = \frac{W^2}{(\mu_n + \mu_p)Q} = \frac{W^2}{(\mu_n + \mu_p)\tau I_{fwd}}, for\ f > \frac{1300}{W^2}\ (f\ in\ MHz, W\ in\ \mu m)$$

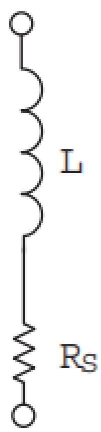


Figure 2: from skyworks

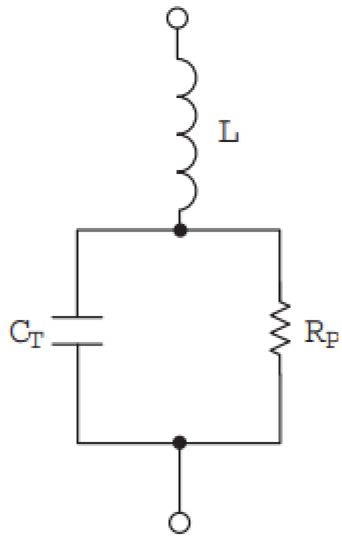


Figure 3: taken from skyworks

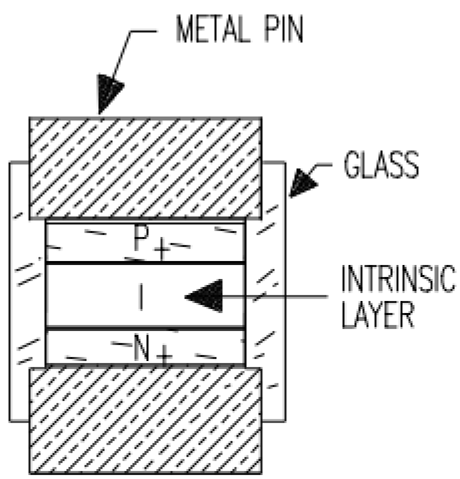


Figure 4: taken from diode handbook

L is from the parasitics of packaging (less than 1 nH)

Equation above is valid for frequencies higher than the I region transit time $f > \frac{1300}{W^2}$ (assuming RF current doesn't effect Q)

Reverse Bias (or No Bias)

ε = dielectric constant of material (usually Si)

A = area of diode junction

$$C_T = \frac{\epsilon A}{W}, for\ f > \frac{1}{2\pi\rho\epsilon}$$

ρ is the resistivity of the I region

At lower frequencies, PIN can act like a varactor (capacitance will change with reverse bias voltage), most RF applications, R_P is insignificant

Max negative voltage swing shouldn't exceed V_B

Switching Speed Model

When switching is important (full on to full off), use this

2 different switching speeds

T_FR is time from forward bias to reverse bias, dependant on carrier lifetime

T_RF is time from reverse bias to forward bias, I_F is the forward bias current, I_R is the initial reverse current

$$T_{FR} = \tau \ln\left(1 + \frac{!_F}{I_R}\right)$$

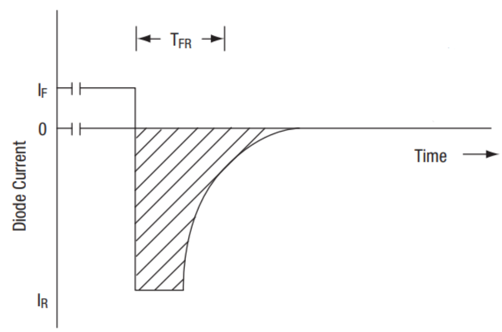


Figure 5: from skyworks

WHY YOU SHOULD USE A PIN DIODE

1. Rugged, High Reliability

2. High Voltage Capability > 2000 Volts

3. High Current Capability > 25 Amperes continuous

4. High surge Current Capability > 500 Amperes (1 pulse 8.3 ms ,½ sine)

5. Low Distortion < -60dBc @ 455 KHz

6. High Power Gain > 10,000 : 1

7. Fast Switching speed < 100 ns

8. Small Physical Size

9. Various Thermal Packaging Available

10. RF Relay Replacement - mechanical, mercury, etc

(Above from diodes handbook)

PIN Diode Switches

Overview

Talk about:

PIN Diodes can conduct in the reverse too! But only when there is an excess of charge in the intrinsic region. There are 2 conditions for that to be the case, there must be enough bias current, and the rf signal swings need to be fast enough to not deplete the stored charge in the "bucket" of the PIN diode

Frequencies that will work are dependant on the material that the diode is made out of. For Si PIN diodes, lower frequency is about a MHz and upper frequencies are in the GHz region (2 GHz to at least 40 GHz depending on the construction – from macom diode datasheet)

Hard to achieve more than 40 dB of isolation when using a single PIN diode (due to radiation, inadequate shielding and coupling). To overcome this, use compound switches and tuned switches

Main idea with using them as switch is when the diode is forward biased it will act as a low impedance path. When it is reverse biased it will act as a high impedance path. Clever circuit topologies can be used to exploit this

Isolation of a switch depends on the capacitance of the reverse biased junction

Insertion loss depends on the series impedance

Generally for a PIN diode switch to be able to switch large amounts of power, it needs to be configured to reflect power when the switch is open (from diode handbook)

Isolation

How effective the switch is at not passing RF power through the switch when it is supposed to be open

$$Isolation\ (dB) = P_{out,closed}\ (dB) - P_{out,open}\ (dB)$$

Insertion Loss

How much power is dissipated in the switch when it is closed

Bad for communication systems as it causes the systems noise figure to increase by the switches insertion loss

$$IL\ (dB) = P_{out,closed}\ (dB) - P_{in,closed}\ (dB)$$

Single Pole Single Throw

Series Implementation

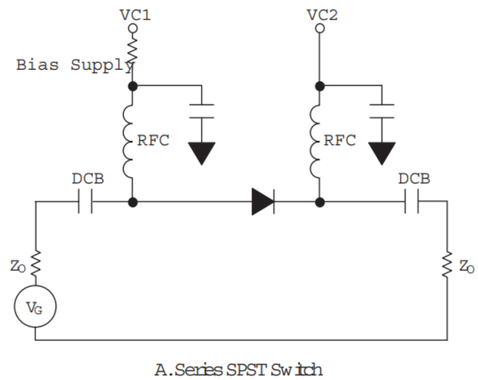


Figure 6 taken from skyworks

When Vc1 > Vc2, diode is conducting, the switch is closed

When Vc1 < Vc2, diode is reverse biased, switch is open

When bias current increased (Vc1 is getting bigger with respect to Vc2), R_S gets smaller, which lowers the insertion loss

When reverse biased, switch appears open with some reverse bias capacitance. IL becomes high and RF signal is reflected back -> this is a reflective switch

Bias circuitry is usually a bias tee and some form of creating a bias current (simple resistors, current mirrors). Negative voltage isn't needed, 0V bias can work

Used when min insertion loss is needed over signal bandwidth, Easier to realize on single sided PCB design (no vias needed)

$$IL = 20\log\left(1 + \frac{R_s}{2Z_0}\right)$$

$$Isolation = 10log\left[1 + \frac{1}{(4\pi f C Z_0)^2}\right]$$

$$P_D = \frac{4R_sZ_0}{(2Z_0 + R_s)^2} P_{AVS}, P_{AVS} = \frac{V_{gen}^2}{4Z_0}$$

$$P_D = \frac{R_s}{Z_0} P_{AVS}\, for\; Z_0 \gg R_s$$

Above (equations for P_D) are only for perfect matches. If not perfect matches, multiply by $(\frac{2VSWR}{VSWR+1})^2$

$$I_{peak} = \sqrt{\frac{2P_{AVS}}{Z_0}} \left(\frac{2VSWR}{VSWR + 1}\right)$$

$$V_{peak,RF} = \sqrt{8Z_0P_{AVG}}$$

Shunt Implementation

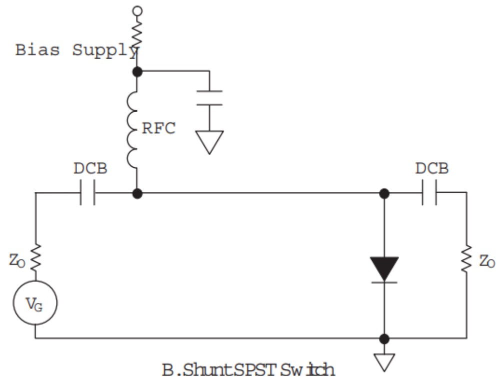


Figure 7 got from skyworks

Provides higher isolation over wider bandwidth. Can handle more power since its easier to sink into the diode

$$IL = 10\log\left[1 + \frac{1}{(\pi f C_T Z_0)^2}\right]$$

$$Isolation = 20\log\left(1 + \frac{Z_0}{2R_s}\right)$$

Add 6 dB for the isolation of a multi throw switch

$$P_D = \frac{4R_sZ_0}{(Z_0 + 2R_s)^2}P_{AVS}$$

$$P_D = \frac{4R_s}{Z_0}P_{AVS}\,for\,Z_0 \gg R_s$$

$$I_{peak} = \sqrt{\frac{8P_{AVS}}{Z_0}}$$

$$V_{peak,RF} = \sqrt{2Z_0P_{AVS}}\left(\frac{2VSWR}{VSWR + 1}\right)$$

Multi Throw

Used more often, usually difficult to realize using only shunt diodes

Can be made from taking SPST switches and combining them (1 diode per branch). If both branches are symmetric, they can be analysed as their SPST equivalent, but isolation goes up by 6 dB. Happens because other branch is able to accept the RF power which causes the RF voltage across the OFF diode to be 50% less than the equivalent SPST case (from diode handbook)

Performance can be improved by using compound switches (both series and shunt elements)

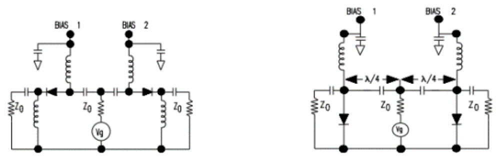


Figure 8: got from handbook

IL is slightly higher than single throw due to mismatches caused by capacitances of open diodes. Isolation can become more of a problem as the circuit grows due to coupling

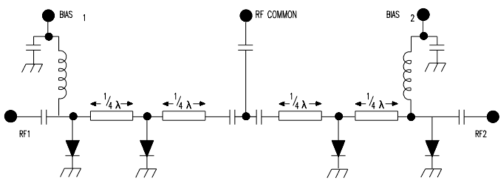


Figure 9 from handbook

Tuned Switches

Narrowband applications (usually the case for RF switches)

Quarter wave transformer rotates a normalized impedance around the smith chart. On open circuit becomes a short at the other end and vice versa

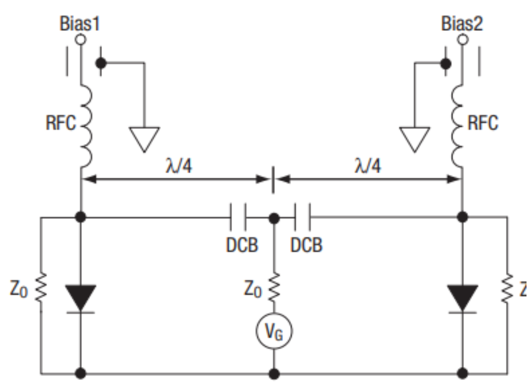
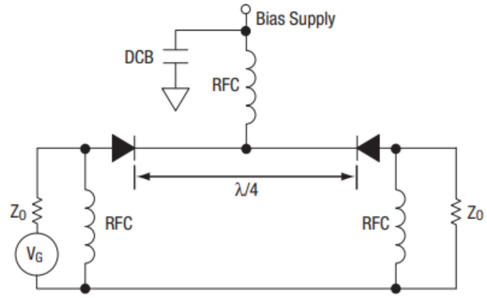
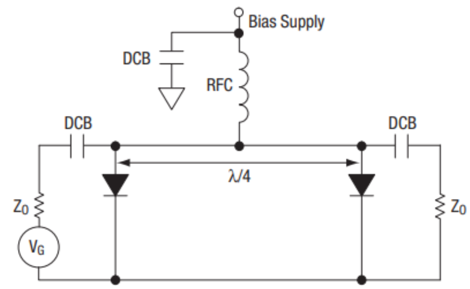


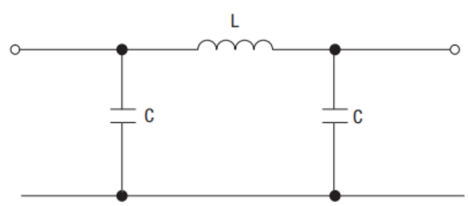
Figure 10: from skyworks



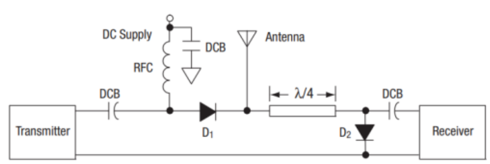
A. Tuned Series Switch



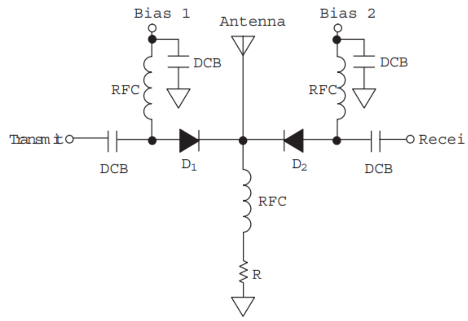
B. Tuned Shunt Switch



$L = \frac{Z_0}{2\pi f_0}$ (Henries) $C = \frac{1}{2\pi f_0 Z_0}$ (Farads)



A. Antenna Switch Using λ/4 Line Length



Compound switches

Used to further improve the isolation -> can look at this as a cascade of switches when considering the isolation

Different from multi throw in that combinations of series and shunt diodes are used to improve performance

Can use ELL/ Series Shunt or TEE configurations

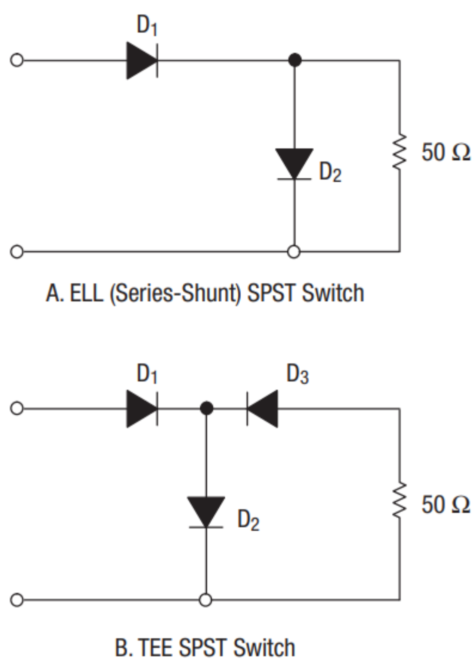


Figure 11: from skyworks

Series Shunt Compound Switches

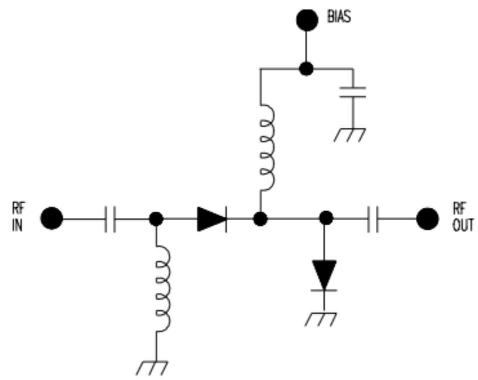


Figure 12 from handbook

TEE Compound Switches

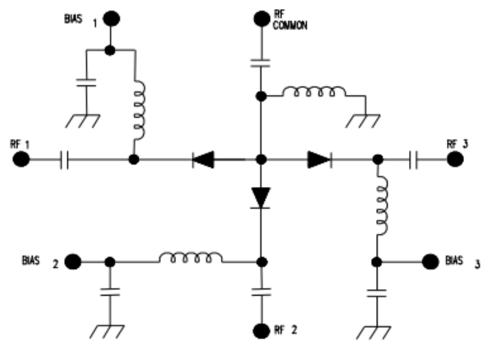


Figure 13 from handbook

Offers improved isolation from the cascade idea, but the insertion loss is degraded. VSWR is also degraded do to potential mismatches. Bias circuit is also more complex

Summary Table

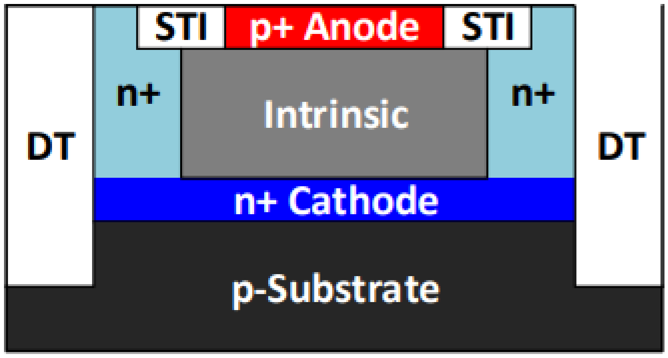
TYPE	ISOLATION (dB)*	INSERTION LOSS (dB)
SERIES	$10\log\left[1+\frac{1}{(4\pi fC_T Z_0)^2}\right]$	$20\log\left(1+\frac{R_S}{2Z_0}\right)$
SHUNT	$20\log\left(1+\frac{Z_0}{2R_S}\right)$	$10\log\left[1+(\pi fC_T Z_0)^2\right]$
SERIES-SHUNT	$10\log\left[\left(1+\frac{Z_0}{2R_S}\right)^2 + \frac{1}{4\pi fC_T Z_0}\left(1+\frac{Z_0}{R_S}\right)^2\right]$	$10\log\left[\left(1+\frac{R_S}{2Z_0}\right) + (\pi fC_T)^2 (Z_0+R_S)^2\right]$
TEE	$10\log\left[1+\left(\frac{1}{2\pi fC_T Z_0}\right)^2\right] + 10\log\left[\left(1+\frac{Z_0}{2R_S}\right)^2 + \left(\frac{1}{4\pi fC_T R_S}\right)^2\right]$	$20\log\left(1+\frac{R_S}{2Z_0}\right) + 10\log\left[1+(\pi fC_T)^2 (Z_0+R_S)^2\right]$

* For SPNT Switch, Add 6 dB

Figure 14 from handbook

Practical Example

This paper presents a W-band SPDT switch implemented using PIN diodes in a new 90 nm SiGe BiCMOS technology. The SPDT switch achieves a minimum insertion loss of 1.4 dB and an isolation of 22 dB at 95 GHz, with less than 2 dB insertion loss from 77-134 GHz, and greater than 20 dB isolation from 79-129 GHz. The input and output return losses are greater than 10 dB from 73-133 GHz. By reverse biasing the off-state PIN diodes, the P1dB is larger than +24 dBm.



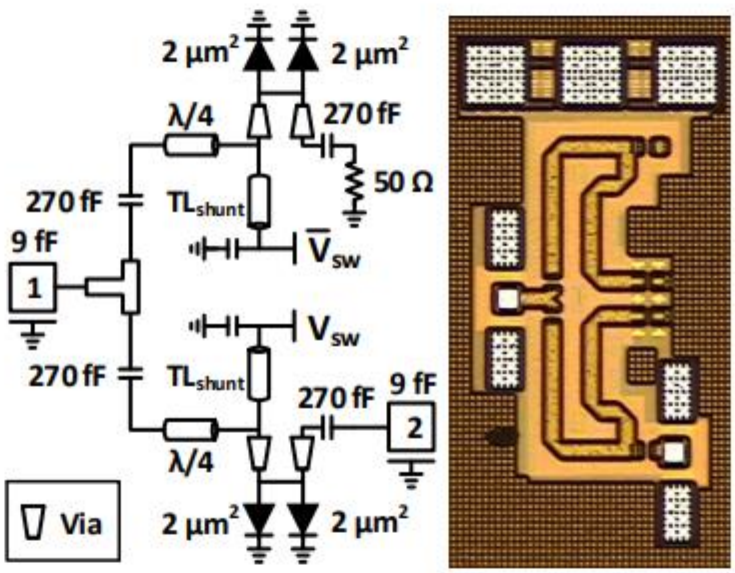


Fig. 3. Schematic and chip micrograph of the SPDT switch.

TABLE I
COMPARISON OF STATE-OF-THE-ART
W-BAND SPDT SWITCHES

Reference	[5]	[6]	[7]	[8]	**This Work**
Technology	GaAs	130nm SiGe	130nm SiGe	90nm SiGe	**90nm SiGe**
Device	PIN	nMOS	PIN	HBT	**PIN**
Topology	λ/4 shunt	λ/4 shunt	Series-shunt	λ/4 shunt	**λ/4 shunt**
Freq. (GHz)	75-110	85-105	50-78	77-110	**73-133**
Insertion Loss (dB)	1.1-1.6	2.3-3.0	2.0-2.7	1.4-2.0	**1.4-2.0***
Isolation (dB)	21-22	20-21	25-35	17.5-19	**19-22**
P_{1dB} (dBm)	-	-	-	+19	**> +24****
Area (mm^2)	0.94	0.05	0.11	0.14	**0.14**

* Aluminum pads have not been de-embedded.
** Limited by available source power.

Variable Attenuators

Overview

An attenuator is a network which is meant to introduce a known amount of loss in the signal path.

PIN diodes can also be used as a current controlled attenuator

$$R_s = \frac{some\ constant}{I_{forward}}$$

The series resistance is what is used to do the attenuation (in combination with another shunt impedance to form a voltage divider)

R_S can be from 10 kohms to 1 ohm depending on the bias current (R_S defines the dynamic range or the attenuator)

PIN diode attenuator can be used in automatic gain control/ leveling control loop to provide a prescribed output power regardless of what the input power it (with in reason)

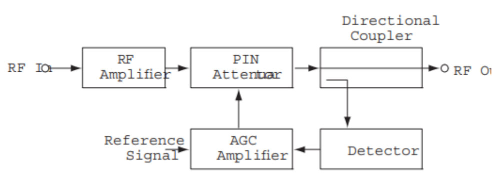


Figure 15 skyworks

Attenuators tend to be more distortion sensitive than switches (usually when bias current results in lower amount of stored charge)

Thin I region operates at lower forward bias current than thicker one (great for DC power saving), but thicker one generates less distortion (higher 3rd order intermod and compression point)

Used extensively in ALC loops and leveling circuits. Using PIN diodes in these circuits provides less power dissipation, lower signal distortion (happens when thicker I regions are used). Can achieve wide DR of attenuation for frequencies below 1 MHz to well over a GHz (from skyworks)

Reflective Attenuators

Identical to reflective PIN diode switches, but bias current is controlled in a more continuous fashion instead of just 2 different bias currents/ voltages for on and off

Attenuation for series connected attenuator: $A = 20\log\left(1 + \frac{R_S}{2Z_0}\right)$

Attenuation for shunt connected attenuator

This assumes reactive part of PIN Z is insignificant. R_S needs to be swapped with Z_S if that isn't the case

These attenuate by producing a mismatch

Matched Attenuators

Have (nearly) constant impedance across the whole attenuation range. Use wither multiple PIN diodes with different biasing conditions or BW limited circuits using resonant/ tuned elements

Can also be made by putting a reflective attenuator in series with a circulator

More common approach would be to use 90 degree hybrid

Loss is entirely due to transmission loss and not reflections/ mismatch. Ports can be swapped since the overall resistive network is direction independent

Quadrature Hybrid Attenuators

Attenuation for quadrature hybrid shunt connected attenuator: $A = 20\log\left(1 + \frac{2R_S}{Z_0}\right)$

Attenuation for quadrature hybrid series connected attenuator: $A = 20\log\,(1 + \frac{2Z_0}{R_S})$

Better than topology using circulators since it is lower cost, also capable of handling twice the input power (since the 90 degree hybrid divides the power by 2). Load resistor must be capable of dissipating half of the max input power at the full attenuation

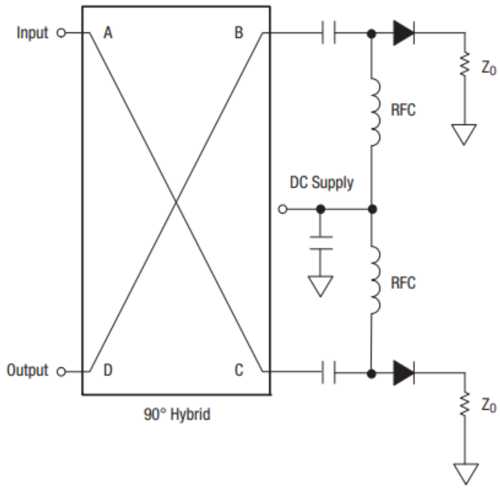


Figure 16 skyworks

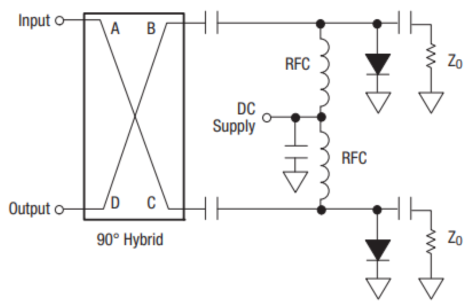


Figure 17 skyworks

Both series and shunt give good DR, but series is recommended used at high attenuation (more than 6 dB) while shunt is good for low attenuation

Matching is a result of how the 90 degree hybrid works. Power from port A goes to port B and C with 90 degree phase shift (D is isolated). Then the power is reflected back to port A and D from port B and C. Power reflected to port A cancels (from port B and C from the phase shifting). Which gives the circuit a matched input port

It is possible to get rid of the load resistors by the diodes. This lets there be more bias current which allows for more stored charge in the diode which gives less distortion

But the purpose of the resistor is to make the circuit less sensitive to device variation and mismatch. Plus having those resistors doubles the power handling capability

Quarter Wave Attenuators

Quarter wave transformers can also be used to implement a matched attenuator

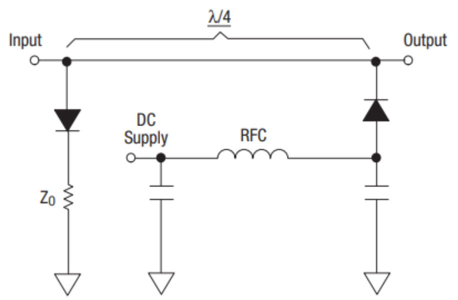


Figure 23. Quarter-Wave Matched Attenuator (Series-Connected Diodes)

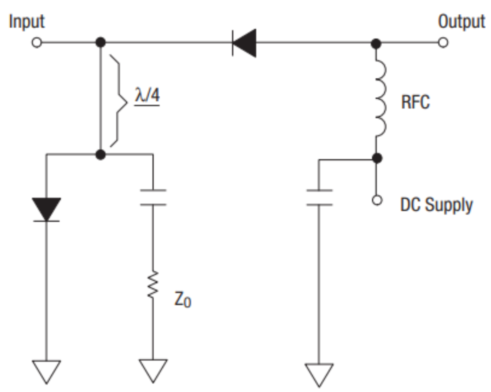


Figure 24. Quarter-Wave Matched Attenuator (Shunt-Connected Diodes)

Figure 18 both from skyworks

Attenuation for quadrature hybrid series connected attenuator: $A = 20\log\,(1 + \frac{Z_0}{R_s})$

Attenuation for quadrature hybrid shunt connected attenuator: $A = 20\log\left(1 + \frac{R_s}{Z_0}\right)$

Matched condition happens when both diodes have the same resistance

Series is better for high attenuation, shunt for low attenuation

Possible reason is less distortion in those cases (uses more bias current though)

Pi and Bridged Tee Attenuators

When matched attenuators are needed for broadband applications, pi or bridged tee circuits are used

Bridged Tee: $A = 20\log\left(1 + \frac{Z_0}{R_{s1}}\right), When\ Z_0 = \sqrt{R_{s1}R_{s2}}\ the\ attenuator\ is\ matched$

Pi: $A = 20\log\left(\frac{R_{s1}+Z_0}{R_{s1}-Z_0}\right), When\ R_{s3} = \frac{2R_{s1}Z_0^2}{R_{s1}^2-Z_0^2}\ and\ R_{s1} = R_{s2}\ the\ attenuator\ is\ matched$

All this means is the bias currents through the diodes need to be adjusted to maintain matching conditions for various attenuation levels (diodes are biased at different points, and these bias points must track each other)

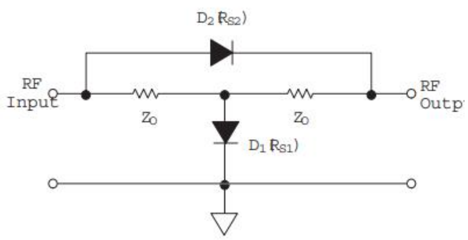


Figure 26. Bridged TEE Attenuator

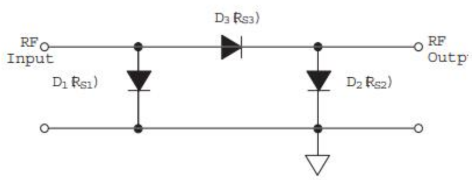


Figure 19 skyworks

Only the unbalanced networks are shown. For a balanced network, just reflect the circuit about a plane of symmetry and divide all the component values by 2

Modulators

Used in high power modulator circuits

PIN diode switches and attenuators can be used in modulators -> AM modulation (bias current is the information and the RF signal is the LO, basically acts as a mixer)

Square wave/ pulse modulation can use the switches (ASK modulation, QPSK)

Linear modulation can use the attenuator

Design of high power and low distortion modulation follows same guidelines and equations as for switches and attenuators

PIN diodes used should have thick I regions

Series or back to back configs reduce distortions

Trade off in using PIN diodes as modulators is a lower max modulation frequency and higher modulation current

Quadrature hybrid is recommended building block for modulator (from skyworks) Inherent isolation mins undesired AM PM conversion

R_S can only vary slowly due to the high carrier lifetime/ reverse recovery time, which limits the modulation bandwidth

Microwave Power Modulators

PIN diodes are the preferred element for microwave power modulators (from handbook)

Switching speed needs to be fast enough for the modulation rate (don’t have carrier lifetime too high) without introducing nonlinearities into the modulation. Carrier lifetime needs to be long enough to supress the intermodulation distortion enough

For linear modulators, the 90 degree hybrid attenuator will work given the hybrid has the bandwidth needed

Just feed the modulation to the bias port

Demodulators

A 90 degree hybrid attenuator can also be used to demodulate signals (LO and RF into the 90 degree hybrid, IF comes out the bias port). However this isn’t a good approach.

Better approach would be to use a carrier sync/ PLL to do the demodulation

Practical Example

25 to 65 GHz broadband low LO driving wide modulation bandwidth monolithic BPSK modulator from PIN diodes made. Made from GaAs

LO power of -15 dBm

EVM of 1.8% @ 30 GHz

Modulation BW > 500 MHz

Good eye opening up to 500 Mbps

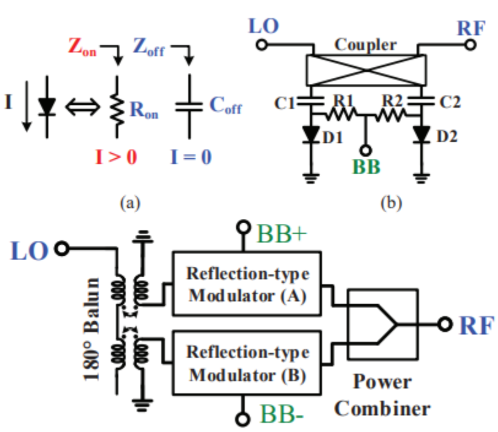


TABLE I.
PERFORMANCE SUMMARY OF THE PREVIOUSLY REPORTED STATE-OF-THE-ART BPSK MODULATORS AND THIS WORK

Reference	MMIC Process	Frequency (GHz)	LO Driving Power (dBm)	Modulation BW (MHz)	Phase Im. (°)	Amplitude Im. (dB)	EVM @ symbol rate 1 MS/s (%)	Chip Size (mm^2)
[5]	1-μm HBT	50 - 110	-8	3	5	2.5	<6	1×1
[6]	0.13-μm CMOS	25 - 55	12	15			4	0.64×0.67
[7]	2-μm GaAs	30 - 50	0	3000			<11	1×1
[8]	0.13-μm CMOS	15 - 75	4	>1000	3	0.5	3	0.5×0.35
[9]	0.5-μm GaAs HEMT	30 - 130	-10	>1000	5	0.8	<5	0.8×0.7
[10]	0.1-μm InP HEMT	115 - 135		10000	5	0.2	5	1×2
This work	**GaAs PIN Diode**	**25 - 65**	**-15**	**>500**	**<6**	**<0.9**	**<4**	**0.7×0.8**

Phase Shifters

Essentially take a PIN diode switch and add in some reactive elements that is switched in and out

Can be used in phased array (electronically scannable array) to control phase of each antenna element

Simple Phase Shirt Examples (Non PIN Diodes)

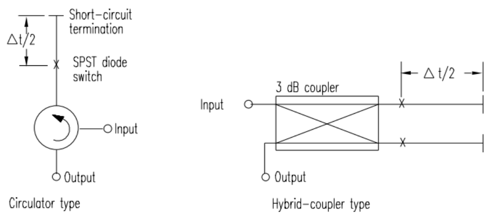


Figure 20 from handbook

Basically, signal is incident on a splitting device (hybrid or circulator), it then passes through a non terminated transmission line. The signal then reflects and is routed to the output through the splitting device. The phase shift happens do to the time delay associated with the non terminated transmission line

However, this approach is narrowband

General Idea

To create a phase shift, a reactive element needs to be switched into the signal path

Every phase shifter has a maximum amount of phase shift it can provide

Instead, phase shifter are organized into “cells” where each cell provides some phase shift and the cells are cascaded one after the other. Each one of these cells can function as a “bit” -> it can be turned on and off providing discrete steps of phase shift

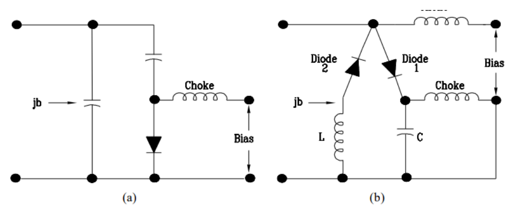


Figure 5.6 Two Possible Loading Elements of the 3 dB Hybrid-coupler in Figure 5.5.

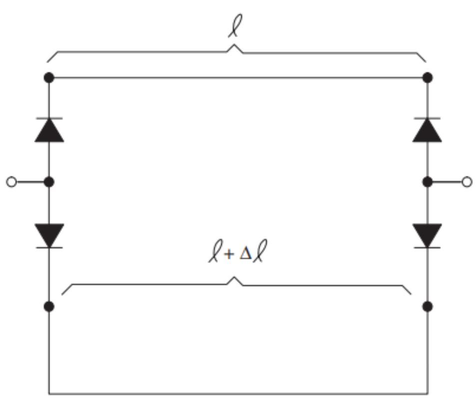
Figure 21 from handbook

Diodes can be used in forward or reverse bias depending on the configuration and circuit requirements

Switched Line

Principle is have two separate (of just more than one) branches that can be switched in and out. The electrical length of each branch is different (delay line is added into branch). When the signal adds at the output port, there is a different delay on each signal and this gives a phase shift

$$\Delta\theta = \frac{2\pi\Delta l}{\lambda}$$



Bias circuit is not shown (should be bias tees at top and bottom TLs)

Phase shift happens when signals add at the output. The length of the TL is different in each branch and that gives an overall phase shift

Series diodes are used

Loaded Line

Different from switched line

Shunt diodes are used

Works by switching in reactive elements in shunt

Can handle higher power since not all of RF signal needs to go through the diodes

$$\tan\left(\frac{\theta}{2}\right) = \frac{B_n}{1 - \frac{B_n^2}{8}}, where\ B_n is\ the\ suseptance\ that\ is\ switched\ in$$

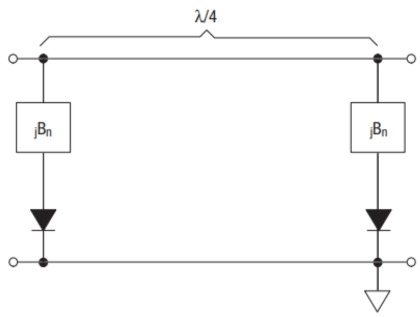


Figure 22 skyworks

$$\tan\left(\frac{\theta_{max}}{2}\right) = \frac{V_B I_{fwd}}{4P_{RF}}$$

Practical limits on the amount of phase shift is 45 degrees

Reflective

Can handle the highest RF power and have the largest incremental phase shifts with the fewest number of diodes (with circuit based around 90 degree hybrid)

$$\sin\left(\frac{\theta_{max}}{2}\right) = \frac{V_B I_{fwd}}{8P_{RF}}$$

Can handle twice the peak power as the other 2 configs (for the same diodes)

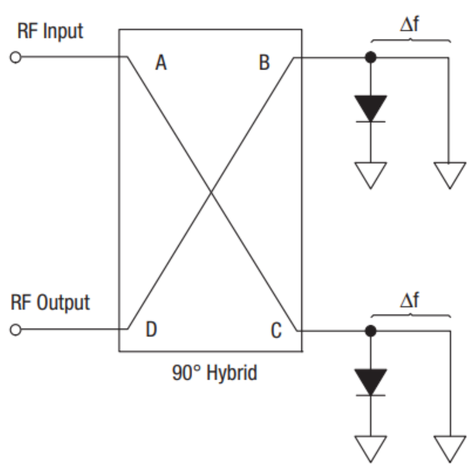


Figure 23 from skyworks

Practical Example (from paper)

Used MACOM's MA4FCP200 PIN diode to make 4 bit phase shifter based on hybrid coupler design

Preformed better than those it compared to

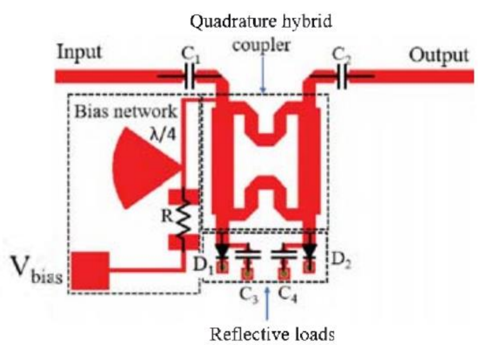
Fabricated on Taconic TLX8 (PCB material)

Gave significantly lower IL than comparisons

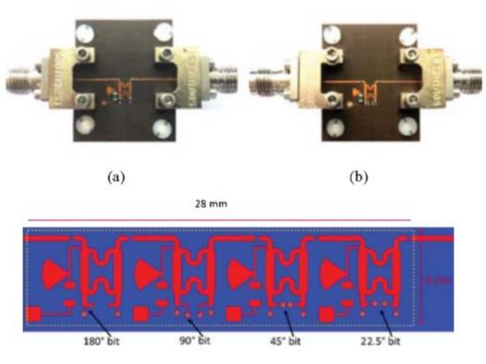
TABLE I. PERFORMANCE COMPARISON OF PHASE SHIFTERS

Ref.	[8]	[9]	[10]	**This work***
Technology	CMOS	GaAs	CMOS	**PIN diode PCB**
Freq. (GHz)	26 - 30	33 -35	29 - 37	**18.7**
Bits	5	4	4	**4**
RL (dB)	NA	>12	>11	**>15**
IL (dB)	<16.5	<14.2	<12.8	**4.7**
RMS phase error (°)	<3.3	<5	<8.8	**1@18.7 GHz**

* Simulated results



C. Circuit fabrication



Detectors

Can also be used as (photo detectors)

Photo Detectors

Alpha Radiation Detection

(PIN) photodiodes have been widely studied in recent times for detecting and measuring different types of ionizing radiations owing to their superior characteristics when compared to conventional gas-filled or scintillator based detectors. PIN diodes are also explored for detecting neutrons with a suitable converter layer (10B or 6LiF). PIN diode energy resolution is influenced by various experimental conditions and is not completely understood. In the present work, role of diode leakage current, applied reverse bias, alpha sourcedetector distance, diode size and gamma radiation on the PIN diode performance in terms of energy resolution (FWHM) when exposed to alpha radiation (239Pu, 241Am,244Cm) is studied.

Xray Detection

References

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