Semiconductor Microwave Devices

Most microwave devices are fabricated on a GaAs substrate because of its high mobility. A silicon substrate, on the other hand, has the advantages of low cost and high yield. The following table summarizes the various microwave solid-state devices and their applications.

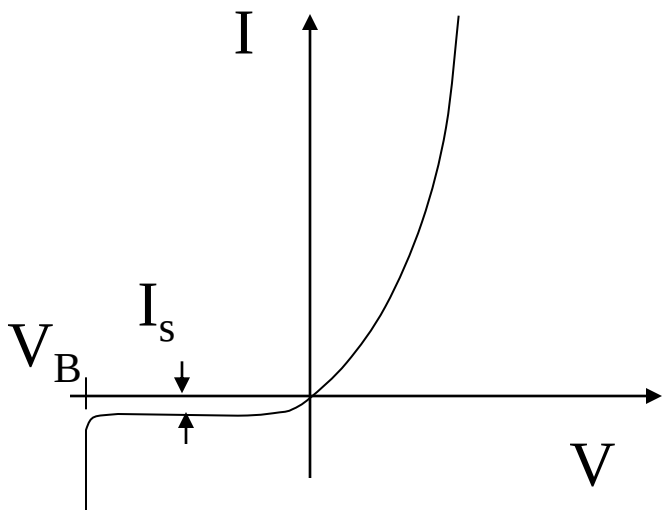
Device	Frequency Limitation	Substrate Material	Major Applications
IMPATT	< 300 GHz	Si, GaAs, InP	Transmitters Amplifiers
Gunn	< 140 GHz	GaAs, InP	Local oscillators, Amplifiers Transmitters
FET&HEMT	< 100 GHz	GaAs, InP	Amplifiers , Oscillators, Switches, Mixers, and Phase shifters
p-i-n	< 100 GHz	Si, GaAs	Switches, Limiters, Phase shifters, Modulators, and Attenuators
Varactor	< 300 GHz	GaAs	Multipliers, Tuning, Phase shifters, and Modulators

Microwave Diodes

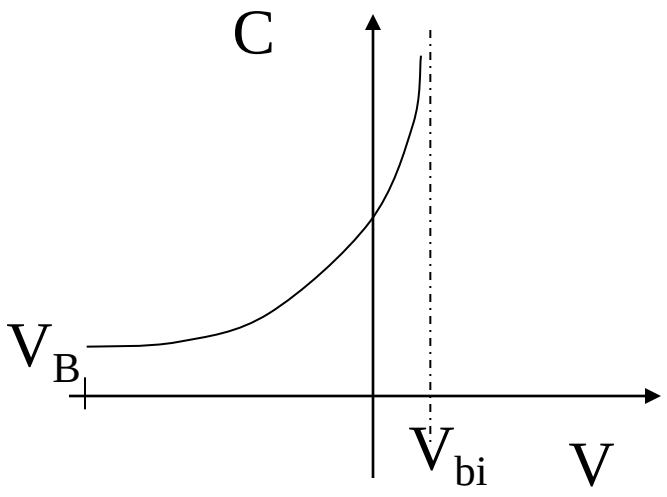
A microwave diode is much more than just a two-element device which has limited capabilities. It is a complex device which an integral part of many sophisticated microwave systems. Many devices have been developed using the non-linear *I-V* and *C-V* characteristics of the p-n or Schottky-barrier junction. Various applications are summarized below

Non-linear *I-V* Characteristics	Non-linear *C-V* Characteristics
Frequency mixing	Frequency multiplication
Harmonic generation	Voltage Controlled Oscillator
Switching	Voltage tuned filter
Modulation	Frequency conversion
Limiting	Harmonic generation
Detection	Parametric amplification

Non-Linear Characteristics of p-n and Schottky diodes



Non-linear I-V Characteristics of a diode



Non-linear I-V Characteristics of a diode

Varactor Devices and Circuits

Semiconductor p-n junction, or Schottky-barrier

n-type semiconductors with p-type diffusion

Important parameters:

- Q factor
- Cutoff frequency
- Breakdown voltage
- Sensitivity.

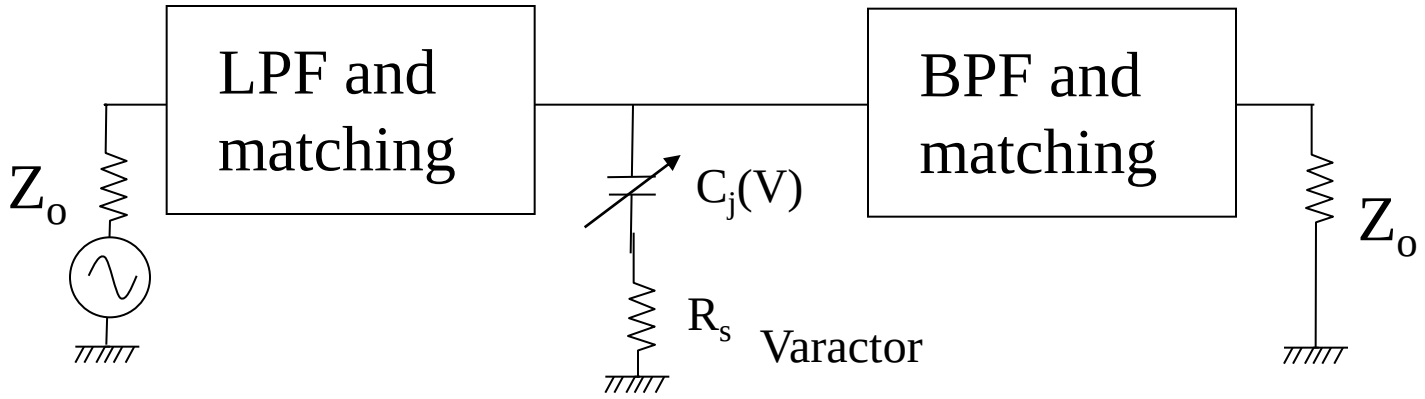
Applications:

(1) Voltage controlled Oscillator VCO:

- FM systems and frequency agile systems
- Instrumentation
- Electronic warfare (EW)
- Electronic counter measurement (ECM) systems.

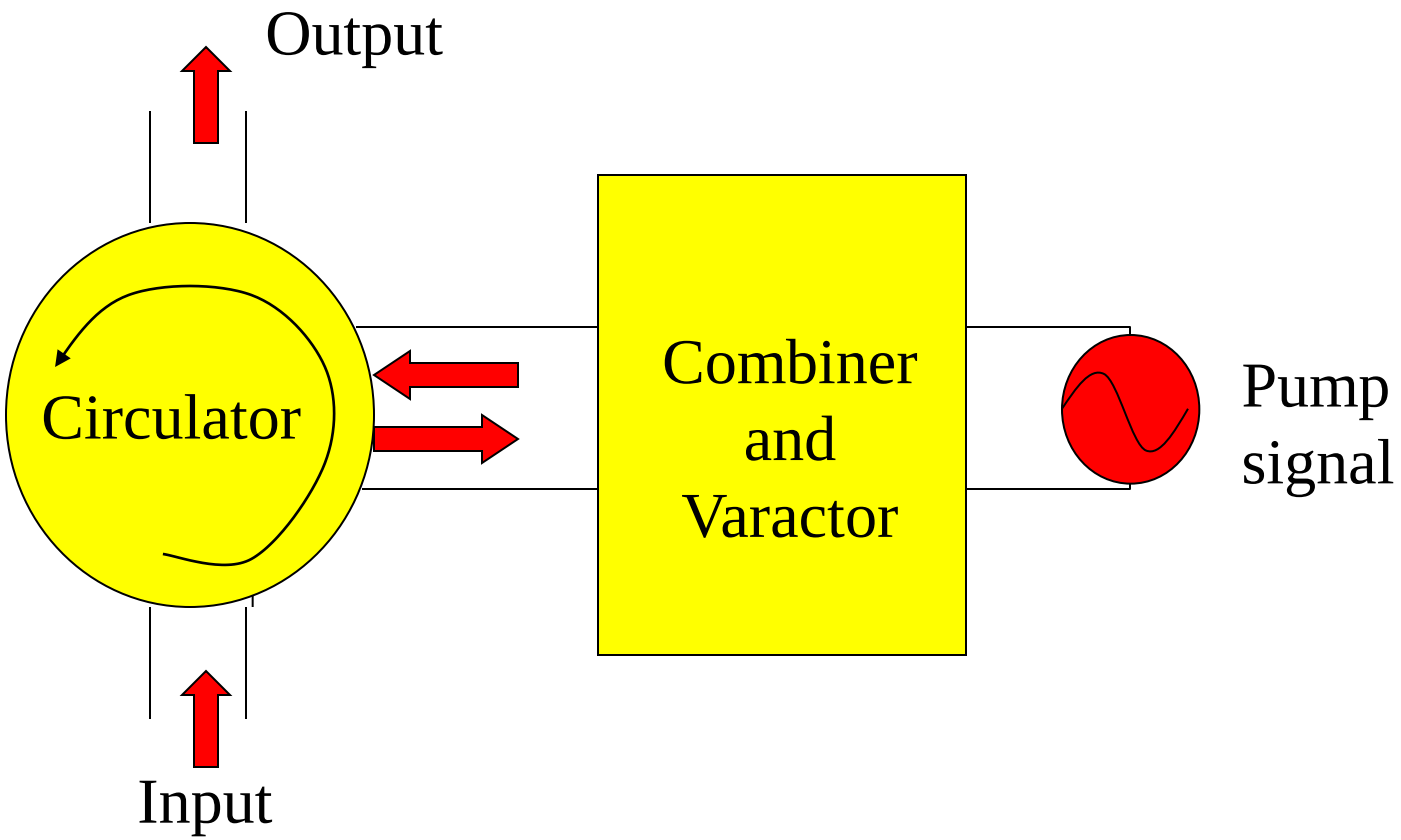
(2) Multiplier and harmonic generation

Feasible alternative for the generation of high frequency signal



(3) Parametric Amplifiers:

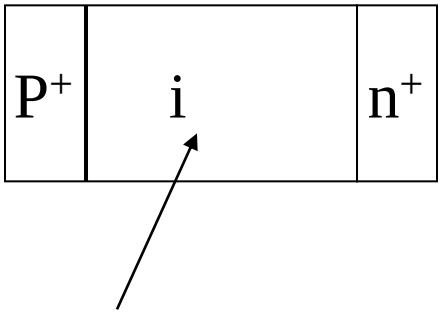
Provide very low noise amplification



p-i-n Diodes

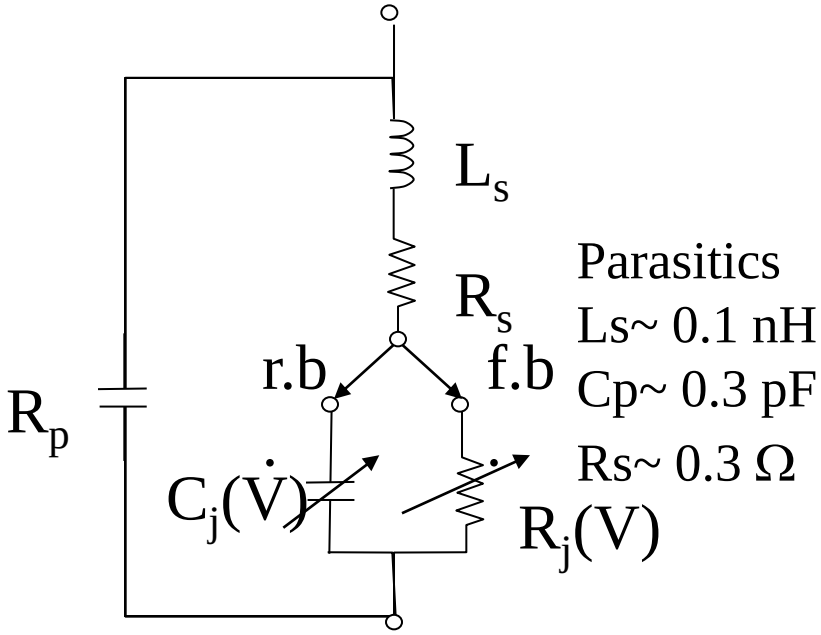
Similar to the pn diode with smaller junction capacitance

Very useful for a diode used a microwave switch



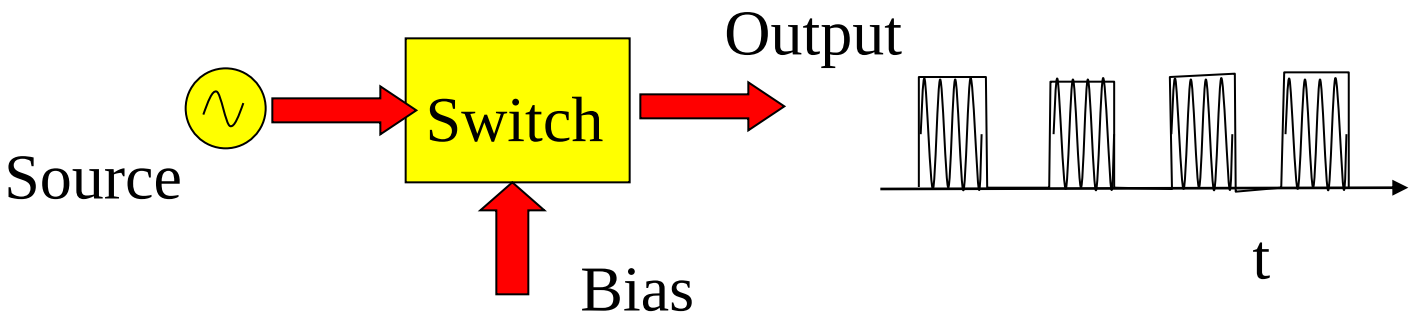
Weakly doped

P-i-n structure

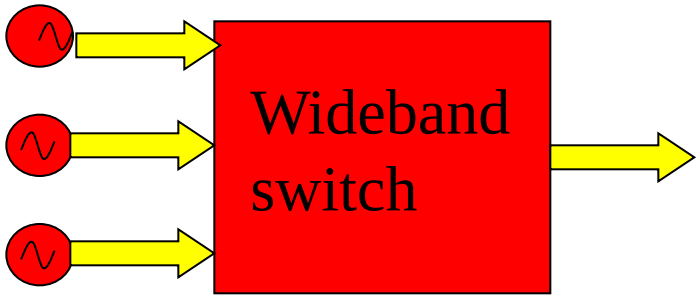


Equivalent circuit of p-i-n

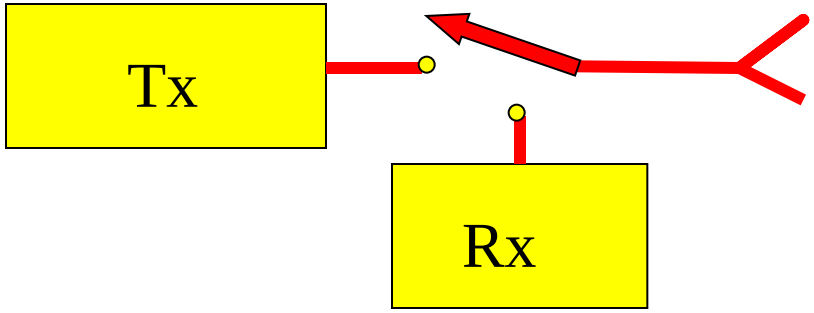
Switches Applications



(1) Modulators in communication systems



(2) Switch in wide band system



(3) To protect receiver from the transmitter (such as in radar system)

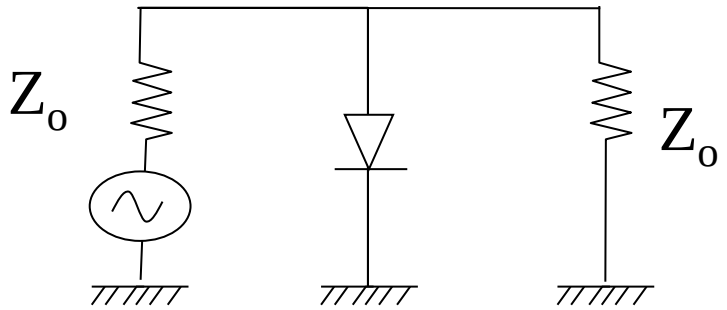
(4) Channel selection in wideband system

(5) Signal path control in measurement systems

As a switch the main important p-i-n diode parameters are Isolation and Insertion loss

p-i-n Diode Attenuator

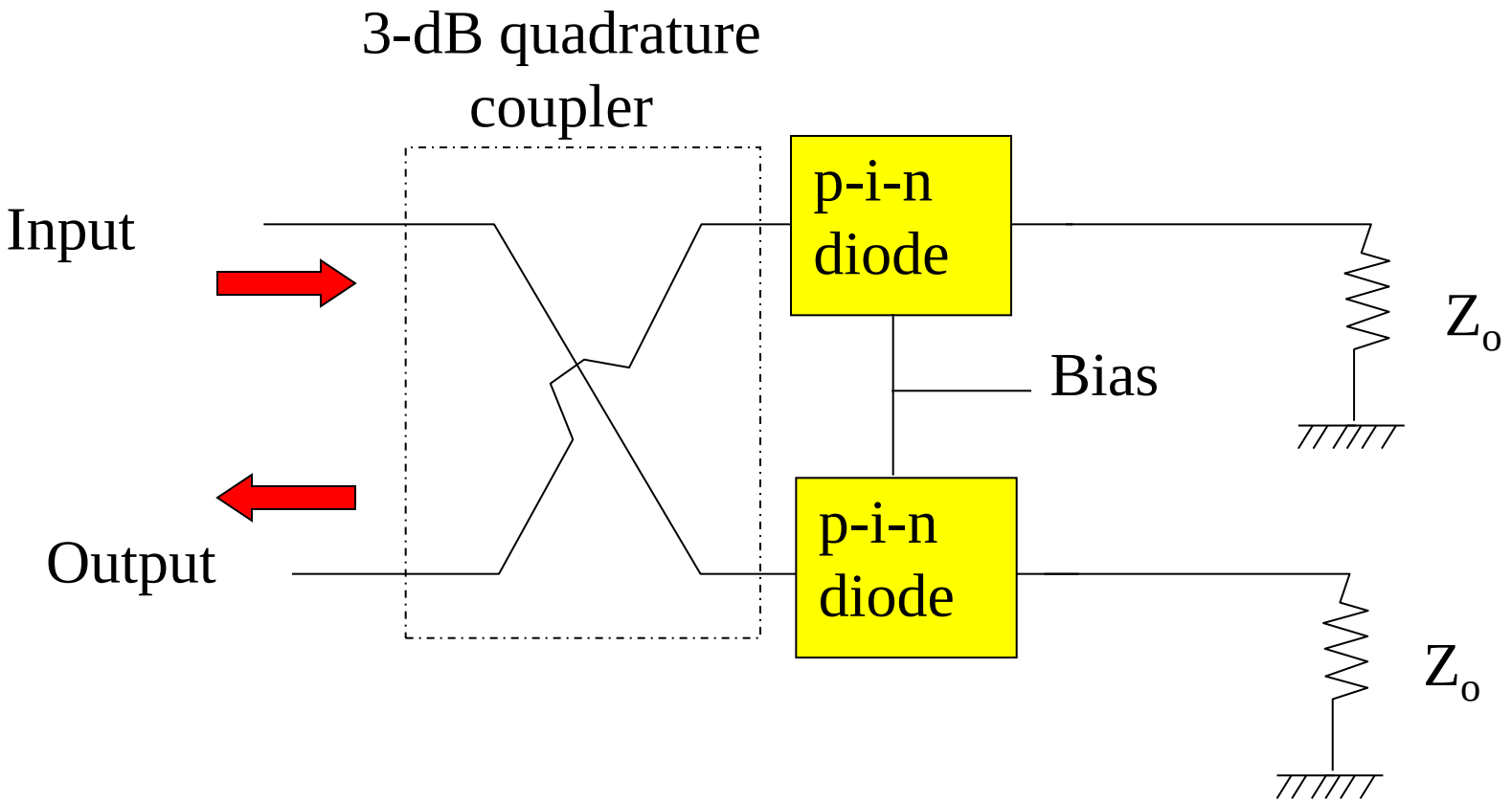
p-i-n diode attenuator circuits are used extensively in automatic gain control (AGC) and RF leveling applications as well as in electronically controlled attenuators and modulators



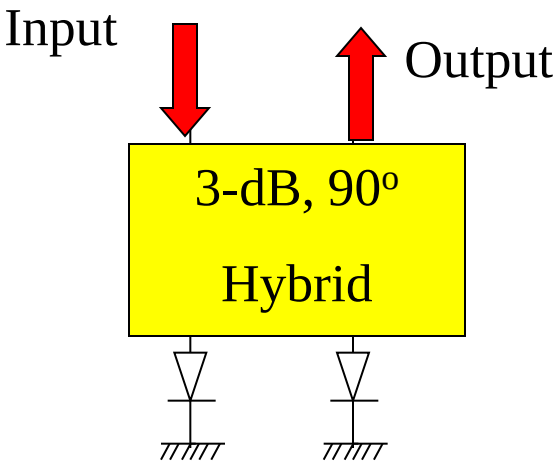
Reflective type

$$A = 20\log (1 + Z_o/2R_s)$$

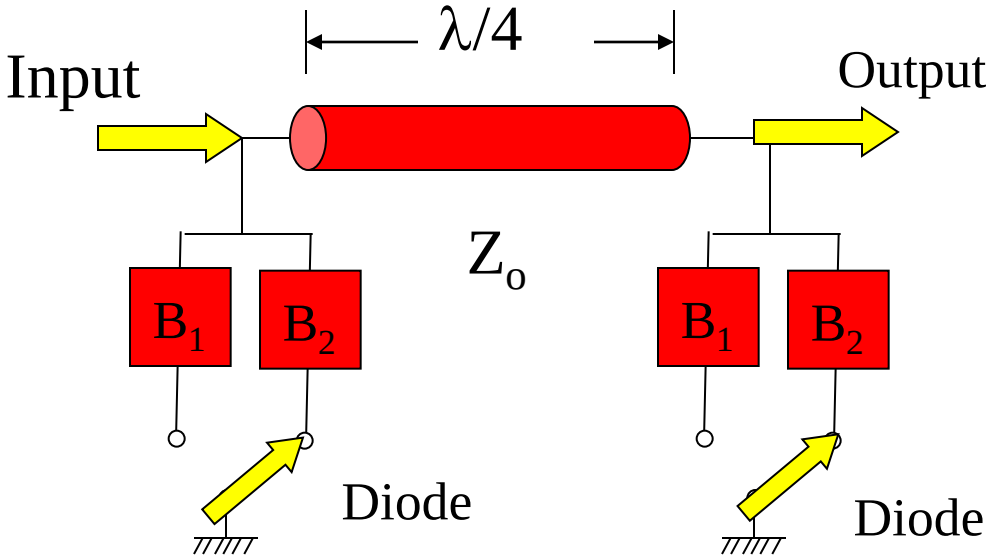
Matched attenuator



p-i-n Phase Shifters

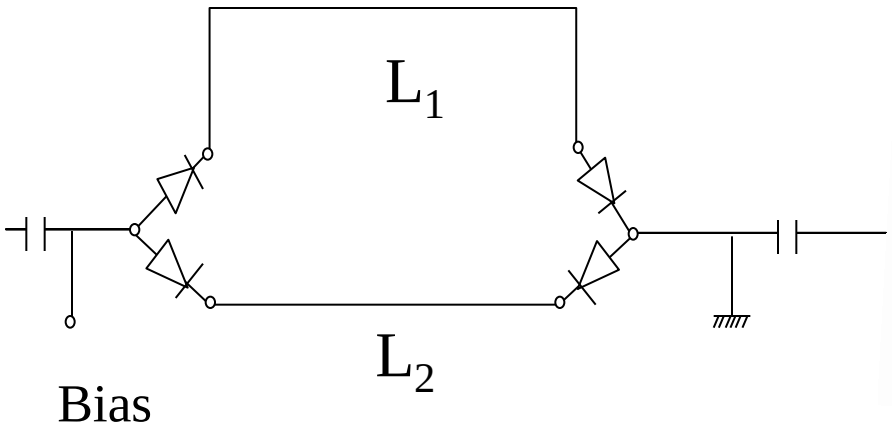


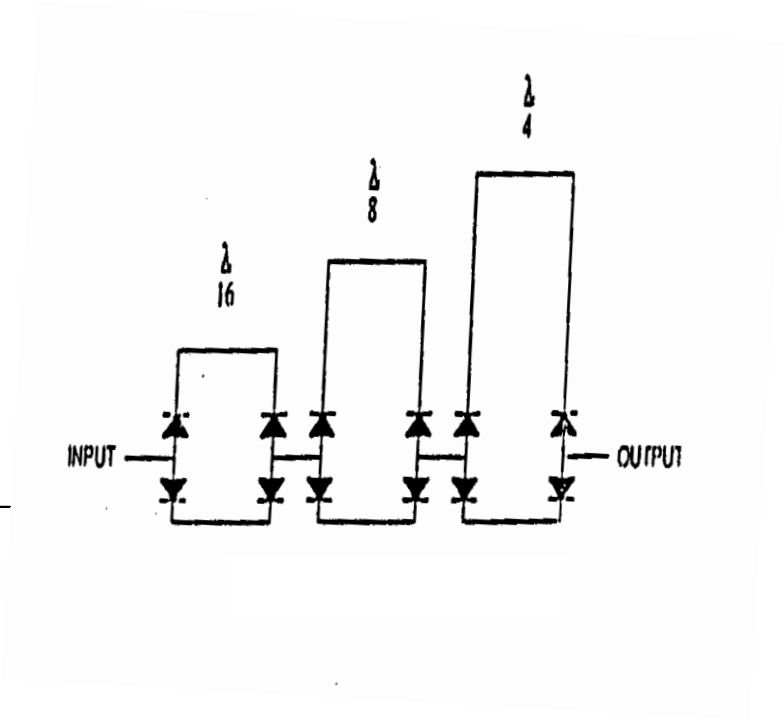
Hybrid coupler phase shifter. Uses the fewest diodes. Any phase shift increment can be obtained with proper design of the terminating circuit.



The loaded line phase shifter

Switched line phase shifter

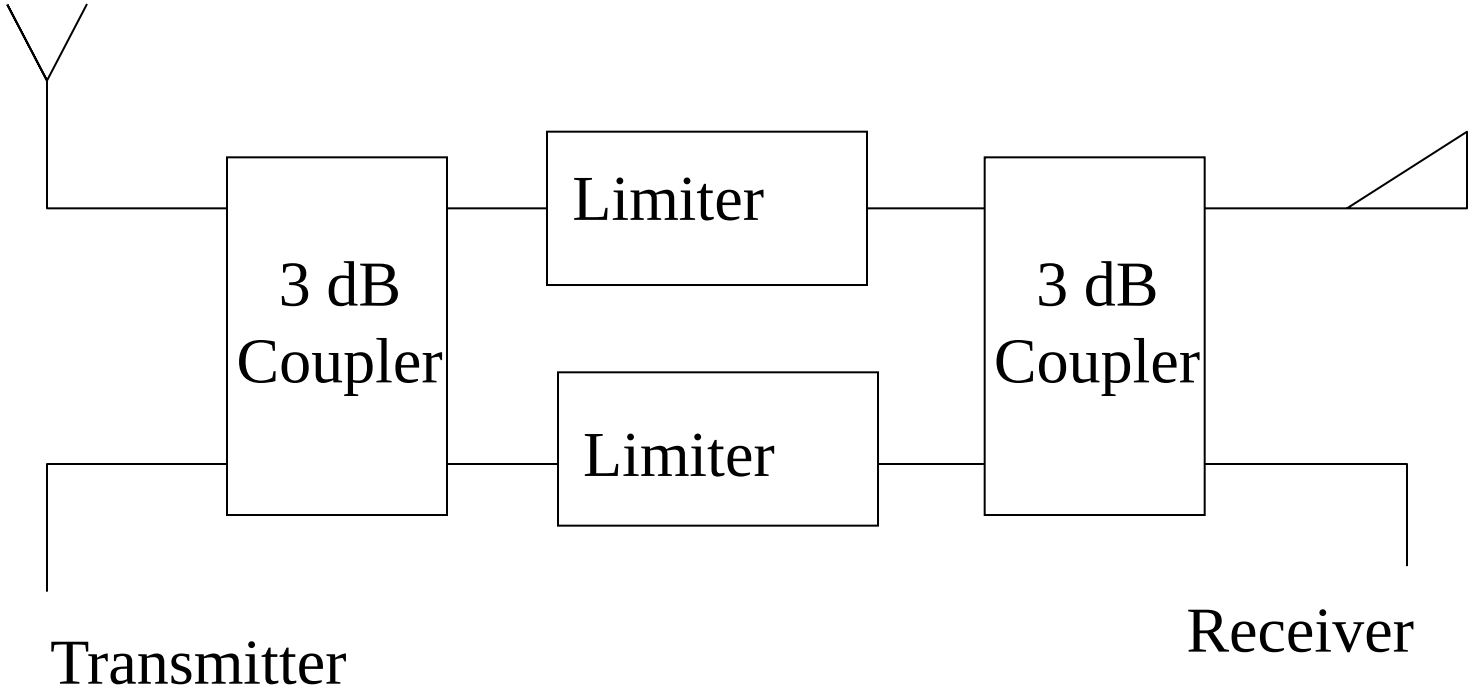


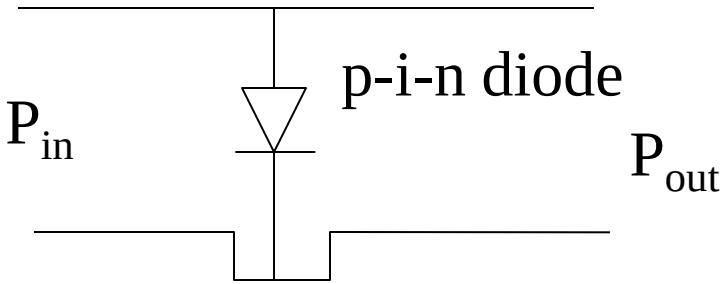


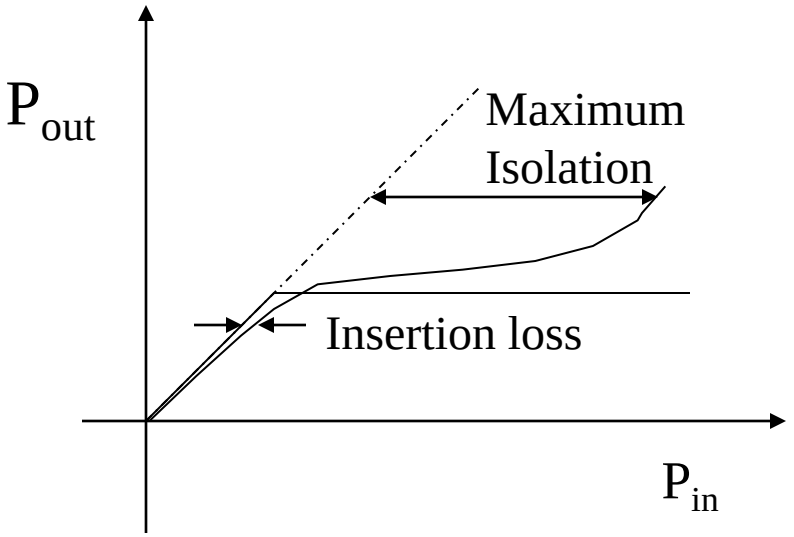
Switching action is used to obtain insertion phase by providing alternative transmission paths, the difference in electrical length being the desired phase shift

Limiter p-i-n Diodes

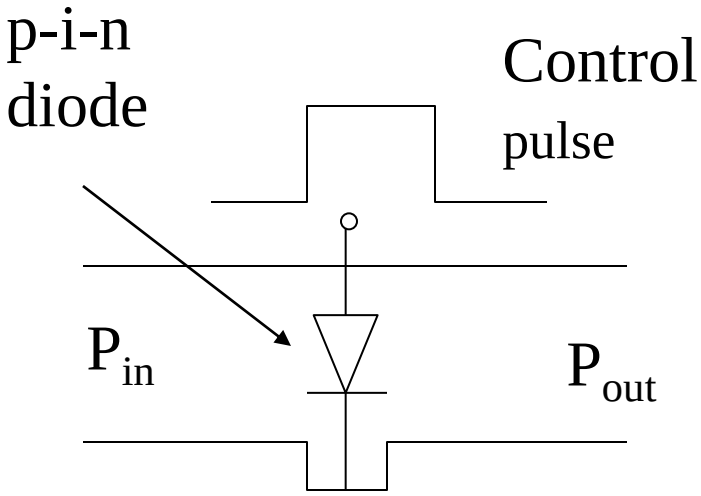
Used for protection applications



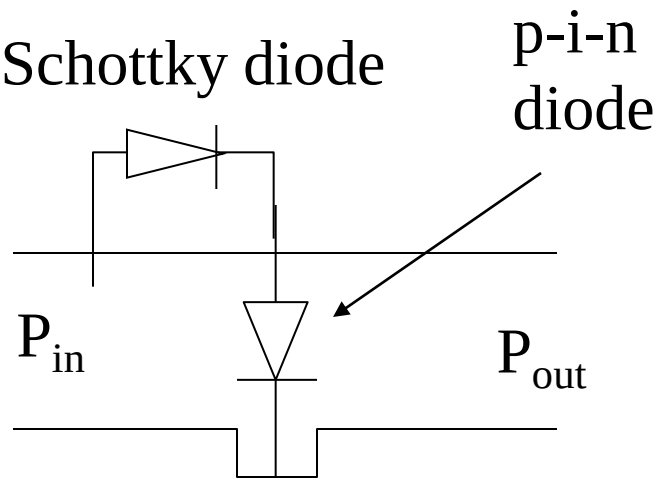




Passive Limitation. No exterior control is needed and the incident microwave power is responsible for switching from the high impedance state to low impedance state of the diode



Controlled limitations. This method gives lower losses, better isolation, but require a delicate control circuit. Any loose of control affect receiver protection



Controlled limitations. A small part of the incident signal is sampled and detected by Schottky diode whose the rectified current biases the diode in the forward state. The losses at low level are slightly higher, adjustments are very difficult