CHAPTER - 4

PIN DIODE RF MODULATORS

NOTES

PIN DIODE MODULATORS

INTRODUCTION

In Chapter 1, it was said that a Microwave PIN diode is a semiconductor device that operates as a variable resistor, whose value is defined by the d-c bias state or by a low frequency (compared to the RF Carrier Wave) variable bias.

In Chapter 2, the PIN Diode was described as a Switching Element, whose control current is switched ON & OFF to control the RF signal.

In Chapter 3, the PIN Diode was described as an Attenuating Element, whose control current was varied continuously (but perhaps also in discrete steps) to produce various levels of attenuation to the RF signal.

The main difference between the two applications is the manner in which the bias conditions are defined for the PIN diode circuit. In both applications, only one signal (or one band of signals) was present in the PIN circuit.

In Chapter 4, the PIN diode is described as a Modulator Element. Modulator applications are much more complex to analyze in that two discrete signal frequencies are present in the PIN diode simultaneously. These consist of the RF Carrier Wave (usually a single frequency in the RF or Microwave Bands) and a much slower varying, lower frequency signal (a sub-band of the d-c to 10 MHz range). The lower frequency signal current represents a relatively slowly varying "bias current" that modulates the I-region impedance that the PIN diode exhibits to the RF Carrier Wave current, causing the amplitude of the RF Carrier Wave to change.

A detailed analysis of a specific modulator design depends on the relative maximum amplitudes of the two signals, the location of the two signals in the frequency spectrum, and the waveform of the low frequency modulating signal [1]. The two modulator designs, described in this chapter, are the Continuous Amplitude Modulation and Pulsed Amplitude Modulation. They are readily implemented with PIN diodes. These modulator networks are assumed to be broadband with no restrictions on the impedance termination at various sideband frequencies. The reader is referred to the general literature for other design constraints.

The RF & Microwave modulation techniques to be discussed in Chapter 4 are distinct from the Digital Modulation Techniques that prepare the information signal for transmission through the RF Channel [2].

MODULATION - BASIC CONCEPTS

Modulation [1 , 3] is a process whereby certain characteristics of an RF Carrier Wave are varied or modified in accordance with a message or information signal which may be Analog or Digital in format. Modulation is also called Up-Conversion since the information signal is "up-converted" from the Signal Band (usually some segment of the d-c to 10 MHz band, depending on the waveform of the Signal)) to the RF Carrier Wave Band (usually in the RF or Microwave Bands) for efficient transmission through the RF Channel. Ordinarily, there is at least a 5 : 1 separation in frequency between the Signal Band and the RF Carrier Wave Band for ease in designing the RF Filters needed to provide isolation between the circuit components operating in a multi-band network.

RF & MICROWAVE AMPLITUDE MODULATION

If the RF Carrier Wave is Continuously Amplitude Modulated by an Analog Signal Source, the Modulated RF Wave is always present in the modulated output. This PIN Diode Modulator Circuit is actually a PIN Diode Attenuator circuit in which the PIN diode is “forward biased” by the signal wave while the RF Carrier Wave is also present in the PIN diode. The forward biased Resistance of the PIN diode is (relatively) slowly and continuously varied by the information signal waveform producing a Continuous Amplitude-Modulated RF wave, as shown in Figure 4.1. Note that the RF carrier frequency retains its sinusoidal wave-form while the amplitude envelope varies at the modulation frequency. The RF carrier wave has peak amplitude “A”, while the modulation wave has peak amplitude “B”. The modulation index “K” is given by: $K = B / A$, and is a measure of the depth of modulation. If K = 1, the RF Carrier Wave is said to be 100 % modulated.

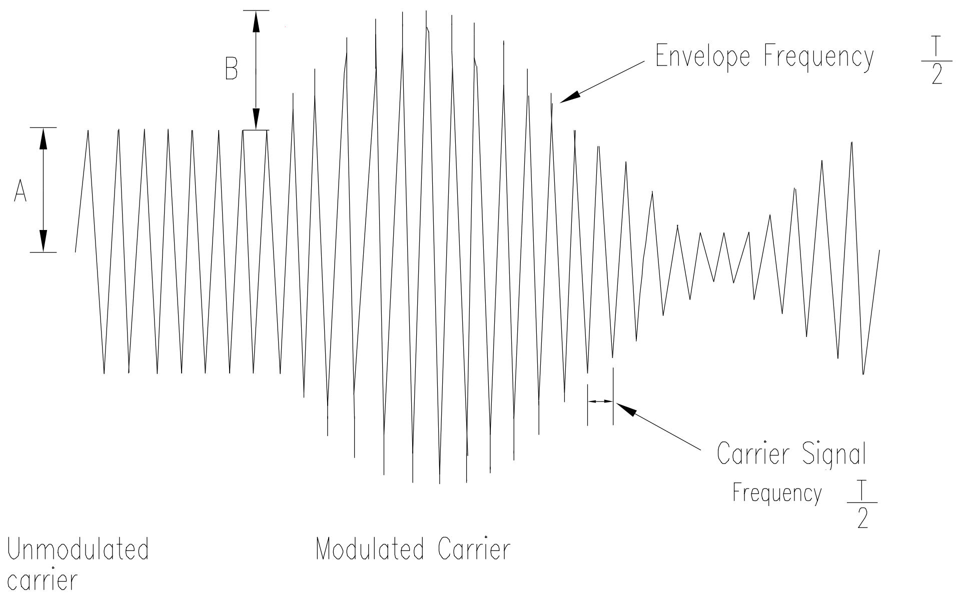

Figure 4.1 Continuous Amplitude - Modulated Wave

The frequency spectrum of the Continuous Amplitude Modulated wave is shown in Figure 4.2, which shows three distinct frequencies: the RF Carrier (F_C), its lower sideband ($F_C - F_S$), and its upper sideband ($F_C = F_S$). The sidebands are separated from the carrier frequency by the magnitude of the frequency of the modulation signal (Fs). Figure 4.2 is the frequency domain representation of the waveform in Figure 4.1 because only the amplitude of each sinusoidal wave and its appropriate location in the frequency spectrum are shown. Both sidebands exist because the modulation network is broadband and they are therefore terminated in the Characteristic Impedance Zo = 50 Ohms.

Balanced Amplitude-Modulation can be used to suppress the Carrier Wave. This can be achieved by using two hybrids, one at each of the Carrier Frequency and the Modulation Signal Frequency, and two PIN diodes, in a balanced network [4]. One of the sidebands can then be filtered to obtain a Single Sideband Output Waveform (SSB-AM), which greatly increases transmitter efficiency.

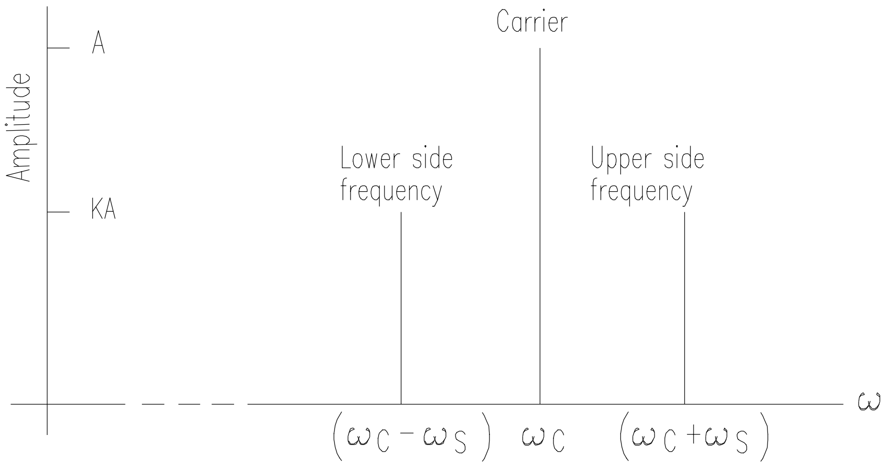

Figure 4.2 Frequency Spectrum of the Continuous Amplitude-Modulated Wave

MICROWAVE POWER MODULATORS

PIN diodes are the preferred active elements for Microwave Power Modulators. The switching speed must be fast enough for the PIN diode to respond to the modulating signal, without introducing non-linear modulation effects. The PIN diode's minority carrier lifetime should be long enough to provide a low level of RF Intermodulation Distortion.

PIN diode Modulator applications use circuit configurations that are similar to PIN diode attenuator circuits. Since the modulation signal is fed into the d-c bias port, the bias circuitry must be sufficiently broadband that the modulation signal is not distorted. Isolation between the modulation insertion port and the RF Carrier input port should be at least 50 to 60 dB. The RF circuitry should be sufficiently broadband to terminate the RF carrier and both sidebands in 50 Ohms.

For pulsed and continuous (linear analog) modulators, the quadrature hybrid circuit shown in Figure 4.3 satisfies the bandwidth and Isolation requirements. Such quadrature hybrids are available from about 10 MHz to 4 GHz in compact form.

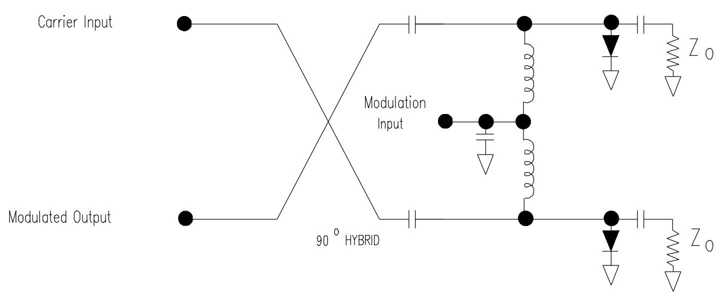

Figure 4.3 Quadrature Hybrid Matched Modulator

Dynamic Ranges of up to 80 dB are achievable in certain Continuous AM designs since the PIN Diode's lifetime characteristic improves the modulation linearity over the AM signal amplitude range. The unique characteristic of large signal PIN Diode Continuous AM modulators is that the PIN Diode device parameters can be adjusted so that modulation efficiency and linearity are optimized.

If the RF Carrier Wave is pulse modulated, no RF signal output is present between pulses. This PIN Diode Pulse Modulator is a PIN Diode Switch circuit that is rapidly biased ON (the low Insertion Loss state) and OFF (the high Isolation State) according to the alternating polarities of the pulsed information signal. In the pulse modulation mode, the RF Carrier Wave is not transmitted during the OFF state. Usually, the output signal of the Pulse Information Source is sufficiently weak that it must be amplified by a modulation driver (Amplifier) circuit so that the PIN Diode can be driven ON and OFF without distortion of the pulsed RF output waveform.

DEMODULATION

Demodulation is described here to complete the view of the Modulator as an integral part of the RF Channel [2]. Baseband Signal Processing prepares the Modulation Signal for Up-Conversion to the RF Channel's Carrier Band. Ultimately, the Modulated RF Carrier is received and Demodulated for additional Baseband Signal Processing. The success with which the original Modulation Waveform is retrieved by this process depends on the linearity (both amplitude & phase) of the modulation process and on the free space characteristics of the RF Channel.

Demodulation or Detection is the inverse process of Modulation. At the Receiver, the Amplitude Modulated Waveform is inputted to the Demodulator and the Modulation Signal is Down-Converted to baseband (d-c to 10 MHz). Ideally, the Demodulated Wave should be a faithful replica of the original Modulation Wave that inputted the Transmitter's Modulation Circuit. A re-labeled version of Figure 4.3 is shown below to indicate that basically, a Demodulator circuit is a Modulator circuit with the inputs and output reversed (Figure 4.4).

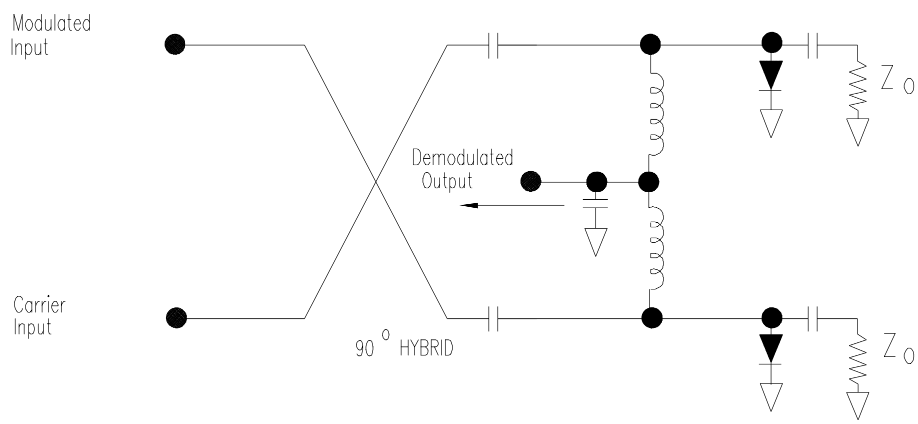

Figure 4.4 Quadrature Hybrid Marched Demodulator

APPLICATION	**RECOMMENDED PIN DIODE TYPES**
High Power >1 W	UM2100, UM4000, UM4300, UM9552
AGC	UM4000, UM6000, UM7000
Low Frequency	UM2100, UM4000, UM4300, UM9552
Ultra Low Frequency	UM2100, UM9552