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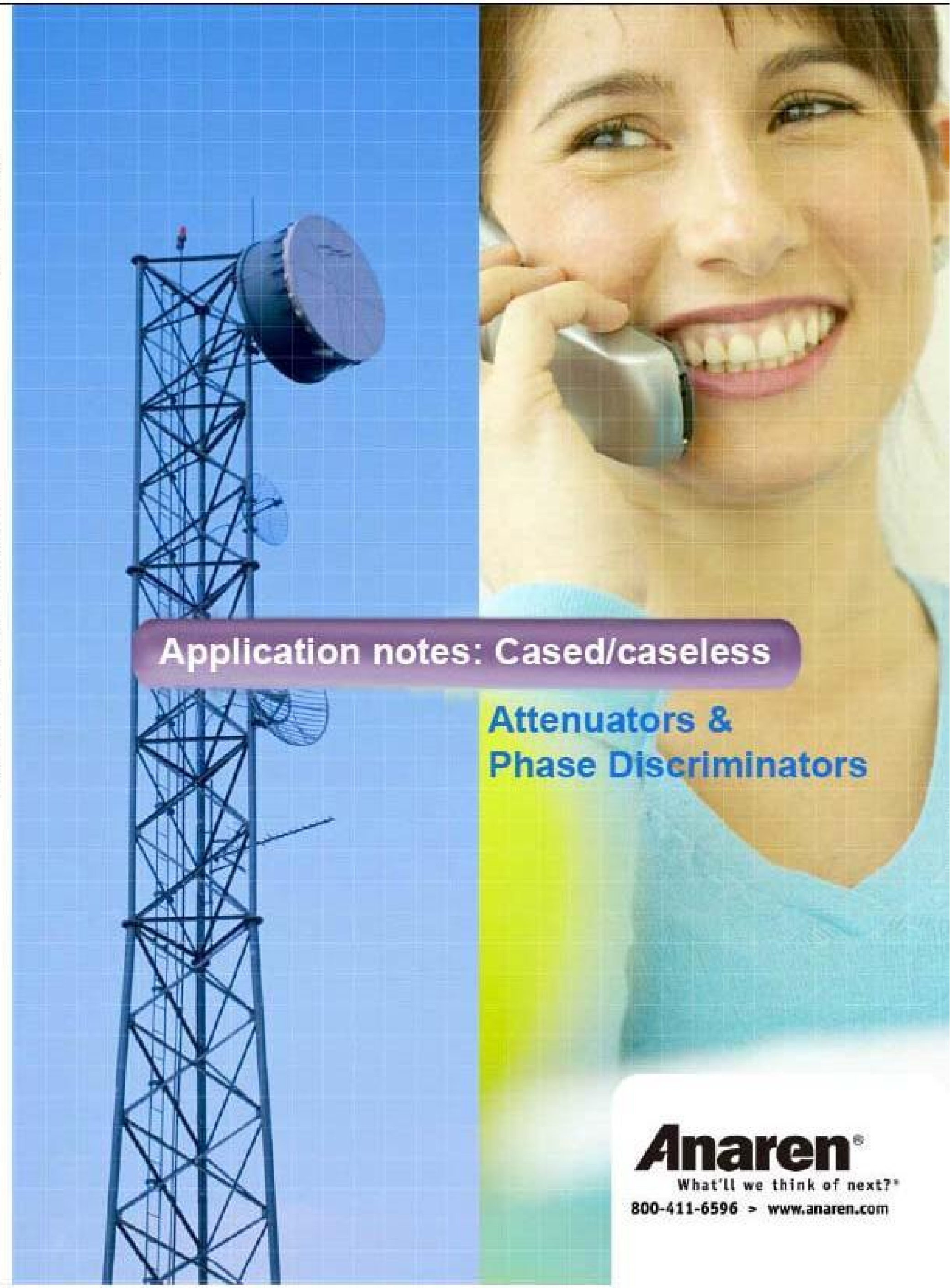
Cased/Caseless Components



Application notes: Cased/caseless

Attenuators & Phase Discriminators

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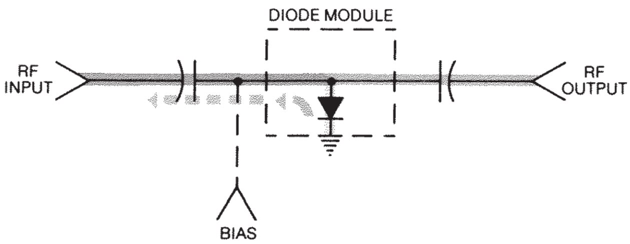
There are two basic types of PIN control devices, reflective and non-reflective. As the name implies, reflective attenuators reflect some portion of the input power back to the driving source; the amount reflected being a function of the attenuation level. Non-reflective (absorptive) attenuators absorb this reflected power in some manner so that it never appears at the input or output ports. Since any reflected power is a measure of VSWR, the absorptive attenuator offers better VSWR characteristics than the reflective device.

Reflective Attenuator

Fig. 1 is a simplified block diagram of a reflective attenuator.

Figure 1 - Reflective Attenuator



When the PIN diodes are zero-biased, or reverse-biased, they appear as open circuits which permit most of the RF input power to travel to the RF output port. Whenever, the diodes draw bias current, their RF resistance decreases and they absorb some of the RF input, but simultaneously reflect some back to the input port. The remainder of the RF input passes on to the output port. At maximum bias current, when the diodes have very low RF resistance, most of the RF input will be reflected back to the input port resulting in a high input VSWR.

Absorptive Attenuators

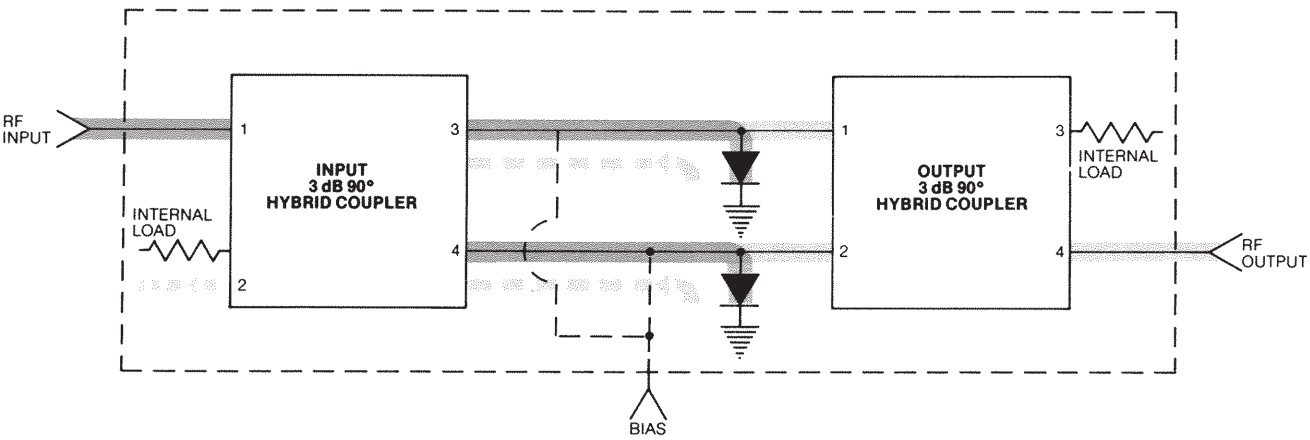
Fig. 2 is a simplified block diagram of a non-reflective (absorptive) attenuator. The VSWR of an absorptive unit remains good at any attenuation (bias) state because of the properties of the input and output hybrid couplers.

The input 3 dB 90° hybrid coupler divides the RF input at port 1 equally to ports 3 and 4. When the PIN diodes are zero-biased, or reverse-biased, they basically appear as open circuits which permits nearly all the RF input to travel to ports 1 and 2 of the output 3 dB 90° hybrid coupler. The output coupler combines these inputs to port 4, the RF output port.

Whenever the diodes draw bias current, their RF resistance decreases and they absorb a portion of the RF input while simultaneously reflecting some of the RF input back to ports 3 and 4 of the input coupler.

The remainder of the RF input is combined in the output coupler to the RF output port. That portion of the RF input, reflected by the diodes to the input coupler, is combined to port 2, which is terminated internally with a 50 ohm load. Thus, none of the reflected RF input appears at the RF input port even at maximum bias when the diodes have very low RF resistance.

Figure 2 - Simplified Block Diagram of 60360 Series Non-Reflective PIN Diode Attenuator



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Power Handling

At a certain value of diode impedance, the diodes will be absorbing some maximum amount of power. This point occurs at approximately the 6 to 10 dB attenuation state of the attenuator and limits the maximum power handling of the attenuator. At lower attenuation (bias) settings the diodes pass most of the microwave energy along the transmission line to the output hybrid; at higher attenuation (bias) settings most of the energy is reflected back to the hybrid internal load and is dissipated there.

Maximum RF power ratings (burnout levels) are 2 watts CW at 25° C, linearly derated above 25° C to 1 watt at +95° C. Pulse power ratings (1 microsecond wide, 0.001 duty cycle) are 50 watts peak at 25° C, linearly derated above 25° C to 25 watts at +95° C. These "burnout" ratings are very conservative and are based on worst case analysis for heat sinking, attenuation level and rate of temperature rise (thermal shock).

There are other effects limiting power handling for the absorptive attenuators and attenuator/drivers. Before the maximum PIN diode burnout rating is exceeded, diode self rectification effects (frequency and power sensitive) can limit the power handling because of harmonic generation and accompanying distortion products.

Insertion Loss

With Anaren attenuators and attenuator/drivers, insertion loss is primarily a function of RF dispersive losses in the 90° input and output hybrids and PIN diode modules, and increases with increasing RF frequency.

Attenuator Flatness

Attenuator flatness is a function of input and output match, hybrid performance, and diode-module tracking. The input and output match is tightly controlled due to attenuator design, excellent hybrid performance and because the modules are Anaren designed and built. The combination these factors assures the exceptionally high degree of uniformity required for the attenuator specifications and applications.

Attenuation flatness is specified as ±2 dB maximum for attenuation settings up to 45 dB for L thru X band units. The typical data curves of attenuation versus frequency on pages 66-67 show, for lower attenuation values and/or narrower bandwidths, flatness is dramatically improved. A 20% BW at any attenuation setting will provide a typical flatness of ±0.25 dB. As the attenuation curves also show, the octave-band specifications are generally valid 10% out-of-band and the X band specifications are typical for 20% out-of-band performance.

Vector Modulator

Aside from the conventional applications of PIN attenuators such as modulators, switches, and levelers, the PIN attenuator can be connected in complex networks to provide a variety of functions. One such application is a Vector Modulator (Figure 5) which utilizes PIN attenuators, in-phase power dividers, 90° and 180° couplers. With the correct control signals, all value of phase and an amplitude (over 55 dB dynamic range) can be generated. In this application the control signals shown in Figure 5 control the vectors as illustrated in Figure 6. The control signals are analog and vary between 0 and +10V, +10 volts being the "absence of" the vector signal. For example, a vector of unity amplitude and relative phase of –90° would require +10 Volts on A-2, B-1 and A-1 and 0 volts on B-2.

Insertion loss through the vector modulator is approximately 12dB. Since the network utilizes PIN diodes it can be operated at relatively high input levels with low intermodulation levels. The Vector Modulators can be operated at a level of 100 mw (+20 dBm) input for harmonics 50 dB down.

Figure 5 - Vector Modulator

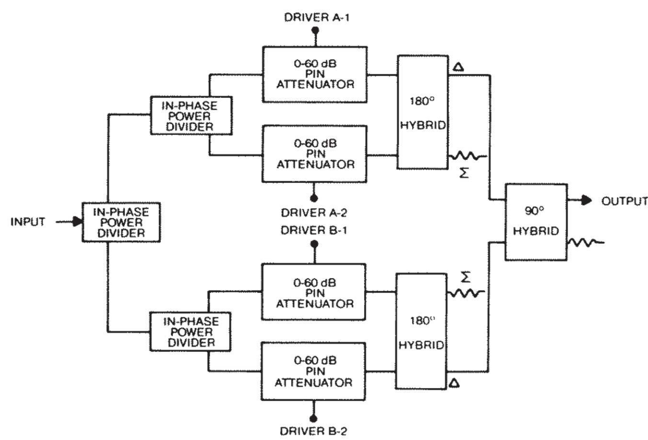
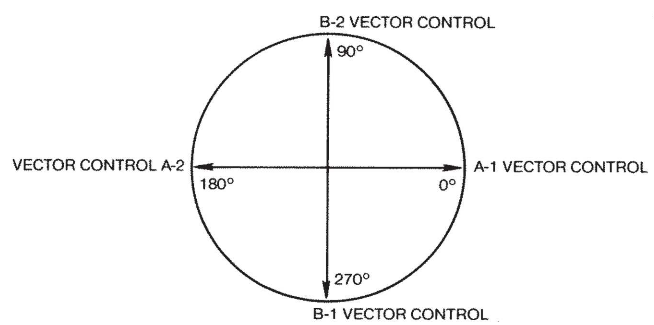


Figure 6 - Vector Modulation Control Diagram

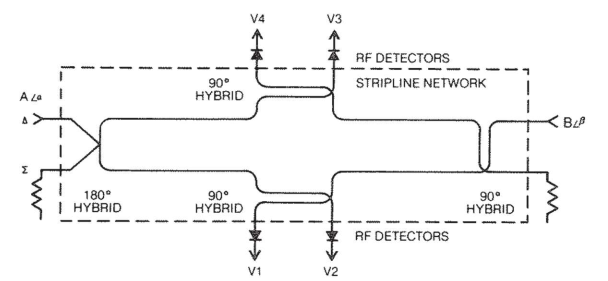


The Phase Discriminator (correlator) and Frequency Discriminator are similar devices. Both use a common principle; a unique phase difference between two RF signals is determined. The phase angle is measured (by interferometry) and, instantaneously, the required phase, frequency or amplitude signature of the RF signal is obtained.

Phase Discriminators

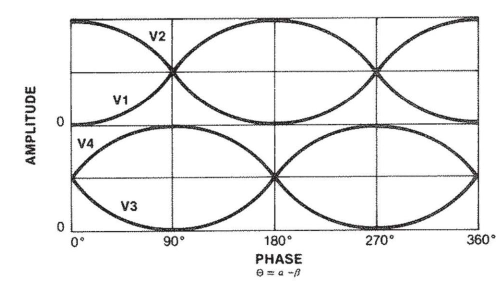
Consider first the phase discriminator (correlator) network shown in Figure 1.

Figure 1 - Phase Discriminator (Correlator) Network



The passive RF portion of this device is a two-channel processing network. Two RF input signals ($A \angle \alpha$ and $B \angle \beta$) are divided to the four output ports. The resultant outputs are square-law detected and have the amplitude and phase relationships shown in Figure 2.

Figure 2 - Instantaneous Video Amplitude Versus Phase

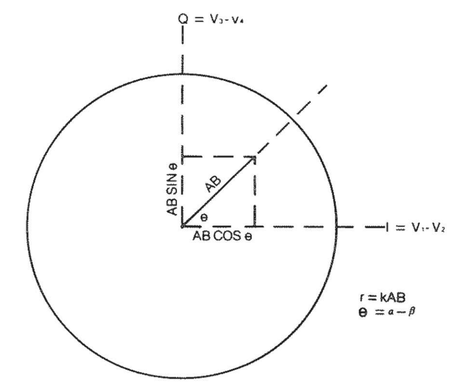


These video voltages are a function of the relative phase between inputs A and B ($\theta = \alpha - \beta$) and are proportional to:

$$V_1 = (A^2 + B^2) + 2AB\cos\theta$$
$$V_2 = (A^2 + B^2) - 2AB\cos\theta$$
$$V_3 = (A^2 + B^2) + 2AB\sin\theta$$
$$V_4 = (A^2 + B^2) - 2AB\sin\theta$$

Connecting V1 and V2 to the +X and –X deflection plates of an oscilloscope, and connecting V3 and V4 to the +Y and –Y deflection plates, respectively, will produce a circular (polar) display. The radius of the display will be proportional to AB and the angular displacement proportional to θ, as indicated in Figure 3.

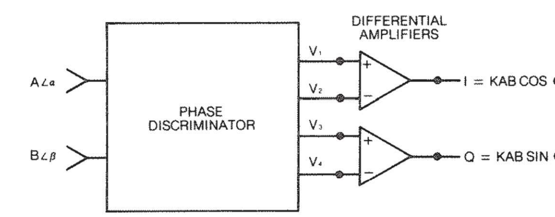
Figure 3 - Polar Discriminator Display



Alternatively, outputs V1 thru V4 can be combined in differential amplifiers as shown in Figure 4. These two resulting bipolar voltages are also the X-Y coordinates of a polar display and are of the form:

$$I = kAB\cos\theta$$
$$Q = kAB\sin\theta$$

Figure 4 - Simplified Block Diagram Phase Discriminator/Video Amps.



These two video outputs are, in fact, the in-phase (I) and quadrature (Q) components of the correlation of the two RF signals over a time period corresponding to the video bandwidth (30 nanoseconds for 15 MHz video bandwidth). To increase the correlation time, simply reduce the video bandwidth.

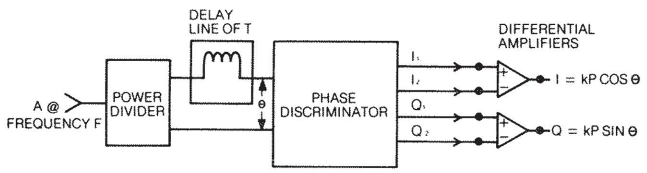
When I and Q are applied to the oscilloscope the beam is deflected from the center of the display. The vector radius is again proportional to AB (signal power) and the angle at which it occurs is θ (the relative phase angle between A and B). CW signals would produce a dot at the vector tip (in a completely dc coupled network). Pulsed signals will produce a strobe along the vector radius.

The phase discriminator (correlator) can serve as a common signal processing network for systems designed to monitor bearing, polarization and frequency of AM or FM radiated signals.

Frequency Discriminators

A frequency discriminator uses a phase discriminator and adds a power divider/delay line at the RF input as shown in Figure 5. The unknown RF signal A is divided to a reference and delay path. The differential delay (T) creates a phase difference (θ) between the two signals which is linear function of frequency (f) and is given by $\theta = 2\pi$ ft.

Figure 5 – Frequency Discriminator



The two signals are applied to the phase discriminator which provides four detected video voltages proportional to:

$$V_1 \equiv I_1 = \frac{kP}{2}(1 + \cos\theta) \quad V_3 \equiv Q_1 = \frac{kP}{2}(1 + \sin\theta)$$

$$V_2 \equiv I_2 = \frac{kP}{2}(1 - \cos\theta) \quad V_4 \equiv Q_2 = \frac{kP}{2}(1 - \sin\theta)$$

Where: P is the RF signal power level
k is a constant related primarily to delay line insertion loss

These output voltages are used in the same manner as described in the previous section on phase discriminators. All four outputs can be applied directly to an oscilloscope or they can be differenced in a pair of differential video amplifiers to produce bipolar voltages:

$$C = I_1 - I_2 = kP\cos\theta$$
$$S = Q_1 - Q_2 = kP\sin\theta$$

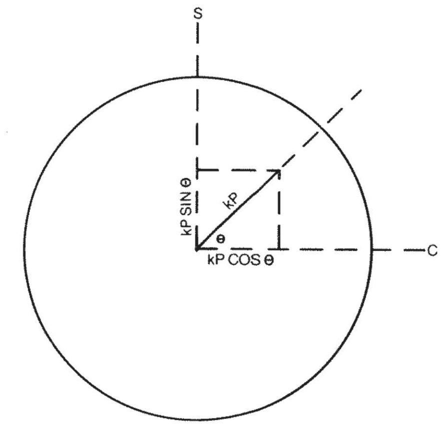
Either method would result in a display as shown in Figure 6. Again, the deflection radius (kP) is proportional to the power of the RF signal. For the frequency discriminator, however, the angle (θ) is now linearly proportional to the *frequency* of the RF Signal. This proportionality constant depends on the differential delay required and determines the length of the delay line.

The frequency discriminator display is obviously ambiguous if required to operate over more than 360°. The delay time is therefore selected so that varying the frequency from start (F min) to stop (F max) yields approximately 275°–330° rotation on the oscilloscope display. The unambiguous bandwidth for a discriminator with a differential delay, T, is given by:

$$\Delta f = \frac{1}{T}$$

For example, an S-band discriminator designed to work from 2 to 4 GHz typically would require a differential delay of about 0.39 nanoseconds. This would provide an unambiguous bandwidth of 2.56 GHz, with the phase angle θ varying from 281 degrees at 2 GHz to 562 degrees at 4 GHz.

Figure 6 – Polar Display of Discriminator Video Outputs



The phase/frequency relationship is theoretically linear. However, owing to construction tolerances, a practical discriminator exhibits a phase linearity error. Depending on the operating band, at any given frequency, the actual phase angle produced may be in error by as much as plus or minus 12 degrees. For any given discriminator, this is a reproducible error. That is, the same angle will always be produced for the same frequency. The actual phase/frequency function is thus:

$$\theta = 2\pi fT \pm \epsilon$$

where ϵ is the phase linearity error.

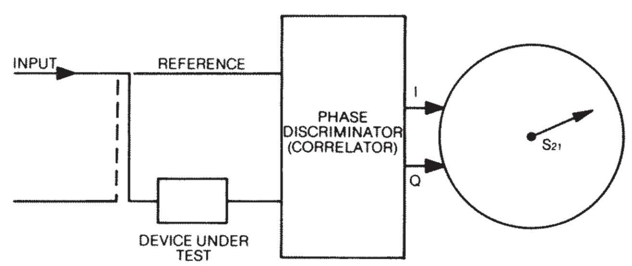
Application Information

Test & Measurement Networks:

Measurement of Transfer Characteristics

The transfer characteristics of a device can be rapidly and accurately determined over wide bandwidths with a correlator connected as shown in Fig. 7.

Figure 7 – Connection Of Correlator For Determination Of Transfer Characteristics



The reference signal is adjusted to equal 1 $\angle^0$ on the CRT display. The polar display is then proportional to the transfer characteristics of the device under test.

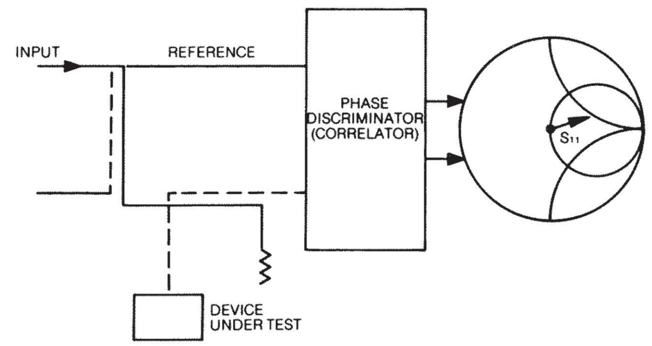
This testing technique is particularly useful for measuring the transfer characteristics of phase-shifters and microwave transistors.

The vector display can be continuously monitored as successful states of the phase-shifter are switched into the circuit; microwave transistors can readily be tested for both gain and insertion phase over wide bandwidths.

Smith Chart Plotter

A correlator connected as shown in Fig. 8 will provide a fast, accurate Smith Chart display of the input impedance of a device under test.

Figure 8 – Connection Of Correlator For Display Of Input Impedance.



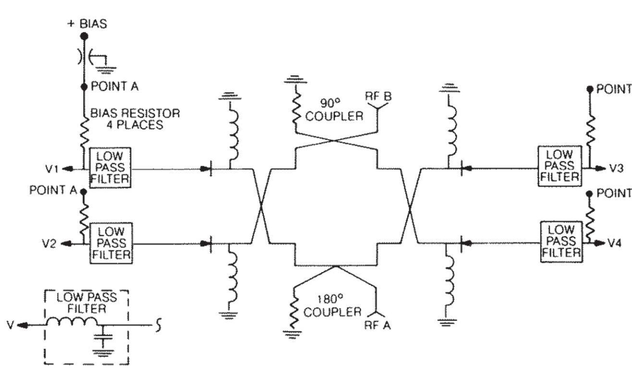
As indicated, an additional coupler is required to obtain a signal proportional the reflection component. With a Smith Chart plot on the face of the CRT the input impedance of the device being tested can be read directly.

If a leveled sweep source is used, the octave bandwidth of the correlator makes it possible to quickly match devices over wide bandwidths.

Video Interface Considerations

Anaren phase discriminators Series 20750, which do not include video amplifiers, use Schottky Barrier diodes as detectors. Because of the voltage potential necessary, to bring the Schottky Barrier detectors into conduction an external bias voltage (+5V) is used to forward bias the detectors. This bias level is set for optimum tangential sensitivity and linearity and is established by four fixed resistors inside the discriminators. (Figure 9)

Figure 9 – Phase Discriminator Series 20750



Due to the voltage drop across the detectors caused by the external bias, there is a dc offset voltage present on the video output terminals. This offset voltage value is a function of the diode VF characteristics and may be between 200 mV and 450 mV DC.

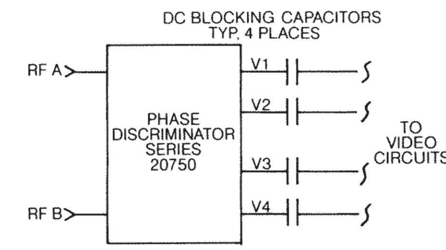
Certain precautions must be taken when connecting the video outputs of the 20750 series discriminators to external circuits:

1. The connecting circuit must be of sufficient high dc resistance (greater than 500K ohms) so that it does not shunt all or part of the detector bias current. If the connecting circuits dc resistance is not high enough the discriminator will not perform to specification. However, this will not affect the reliability of the discriminator. The discriminator will function correctly when reconnected to a high dc resistance video circuit.

There are various methods that can be used to interface the discriminators video outputs. Two are listed below:

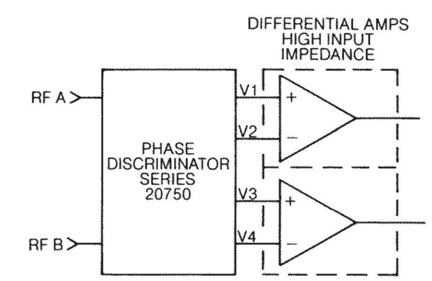
(a) Install series blocking capacitors in the video circuits. This will affect the low frequency response of the video signal but will prevent bias shunting to the video load. (Figure 10) The Anaren discriminator series 2A0750 uses this method. They have integrated ac coupled video amplifiers which interface with the video detectors.

Figure 10 - Installation of Series Blocking Capacitors



(b) Connecting the detector outputs to a differential amplifier having a high input impedance (greater than 500K ohms) The detector offset voltage appears as a common mode voltage to the differential amplifiers and the zero signal output should be near zero. Slight offsets due to circuit imbalances can be trimmed out. (Figure 11)

Figure 11 - Connecting Outputs to High Input Impedance



2. Precautions should be taken to prevent static discharge damage to the discriminators. The RF detector diodes used in the Anaren discriminators are protected against applications of reverse bias voltages but are static sensitive. These detectors may be permanently damaged by careless handling. Antistatic handling procedures must be used.