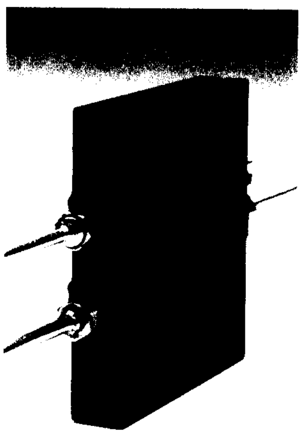
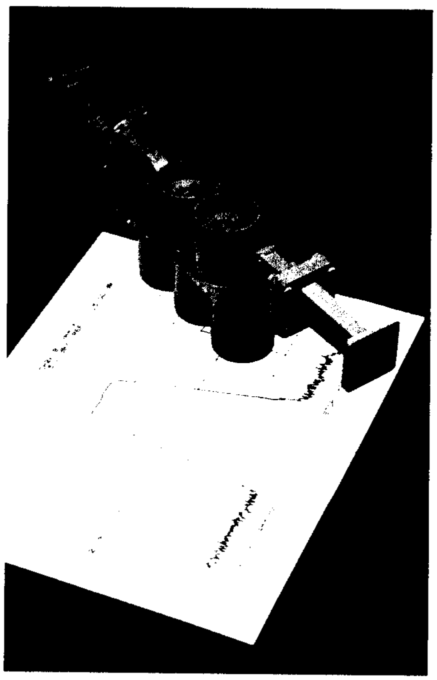
Product Note 8757-1

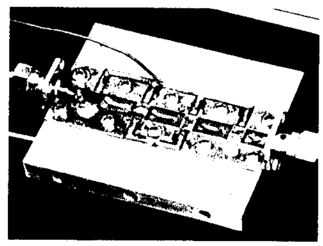
HEWLETT PACKARD

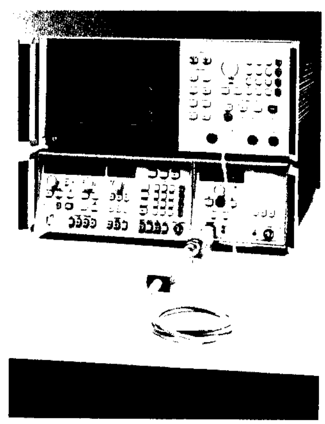
Microwave Component Measurements

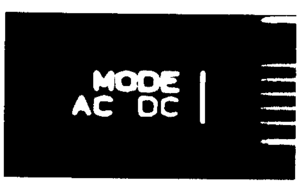
Using AC detection with the HP 8757A and 8756A scalar network analyzers to make more accurate measurements











The increasing need for higher performance microwave components has put additional demands on the test equipment used to characterize their frequency response. Scalar network analyzers are often used to characterize microwave components in volume production, and hence must be easy to use, and as accurate as possible. While the features of the many scalar analyzers currently available are similar, their measurement performance can vary significantly. The scheme used by Hewlett-Packard scalar network analyzers to detect RF signals, known as AC detection, provides unique benefits such as minimizing the effect of unwanted signals, broadband RF noise, RFI, and thermal drift. As a result, measurement accuracy is improved. Measurements of signals at low levels are also faster when AC detection is used.

There are two methods used to detect microwave signals for display and measurement with scalar network analyzers. One method uses a modulated RF signal (AC detection), and the other uses unmodulated RF (DC detection). Currently, only Hewlett-Packard scalar analyzers can offer both detection schemes.

AC detection improves the ability of the scalar network analyzer to measure filters and isolators because of its low noise floor, which results in 5 dB more dynamic range or sensitivity over DC detection. Mixer measurements are more accurate when made using AC detection because LO feedthrough does not affect conversion efficiency measurements.

Measurements of cables and antennas (during fault testing for example) are improved as well, because of AC detection's resistance to RFI. The accuracy of measurements made during temperature testing is improved because AC detection rejects voltage offsets caused by the detector's diode as it responds to thermal change.

Since the benefits and applications of DC detection are fairly well understood, this note will primarily addresss the benefits and applications of AC detection. This note will illustrate the benefits of using AC detection with the HP 8757A and 8756A to make scalar network measurements on microwave components. The HP 8757A offers AC/DC detection capability. The HP 8756A offers AC detection only.

System operation using AC detection

The setup used for measuring the reflection and transmission characteristics of the device under test (DUT) is shown in Figure 1. The sweep oscillator generates a swept RF signal which is applied to the device under test. The directional bridge and detector detect the signals reflected and transmitted by the DUT, converting these signals into a voltage which is then fed to the scalar network analyzer for processing prior to display and measurement.

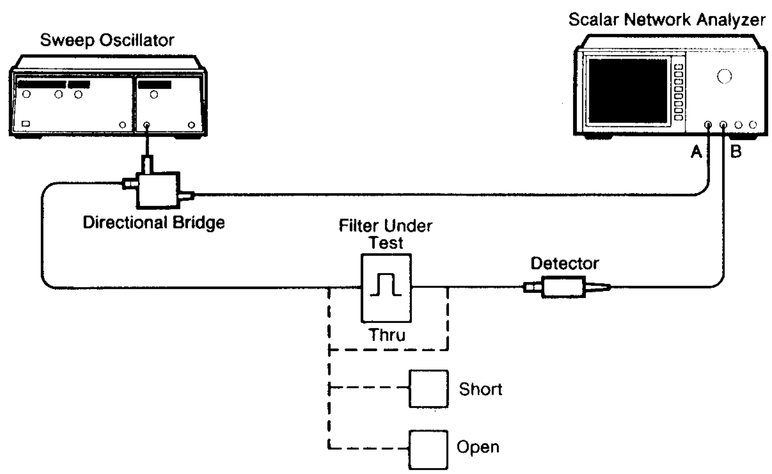


Figure 1. Setup for measuring the frequency response of a microwave component using the HP 8757A scalar network analyzer. The device's return loss and insertion loss can be measured simultaneously with this configuration.

With AC detection, the stimulus signal generated by the sweep oscillator is amplitude-modulated by a 27.778 kHz square wave. This modulated RF signal is applied to the DUT, and the resulting reflected and transmitted signals are detected by broadband diode detectors. (Figure 2). The output of the detectors is a 27.778 kHz square wave whose amplitude corresponds to the magnitude of the RF signal incident on the diode. This square wave is then fed to the AC log amplifiers within the scalar analyzer, where it is processed for display on the analyzer's screen. With DC detection, the stimulus signal is not modulated.

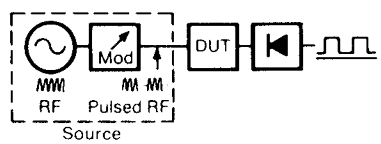


Figure 2. Block diagram showing system operation in AC detection mode. The diode detects the modulated signal, and the modulation envelope is passed to the input of the scalar network analyzer.

Benefits of AC detection

There are four main benefits of using AC detection in scalar network measurements. High-level broadband noise is rejected, undesired RF signals are not detected, thermal effects are minimized, and fast sweep times are possible even at low power levels.

Rejection of high-level broadband noise

Since the receiver (the log amplifiers in the scalar network analyzer) effectively operates like a tuned AC voltmeter operating at 27.778 kHz, signals which are not modulated are not measured. In many applications, such as measurements of high-gain limiting amplifiers, noise will be present when the desired stimulus signal

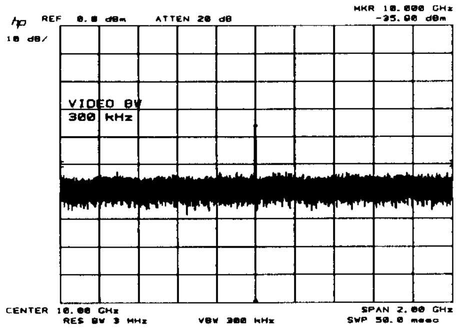


Figure 3. (a) Spectrum showing a microwave signal in the presence of high-level noise.

is being measured. This noise can be substantially higher than the noise floor of the detectors (Figure 3a), and as a result, the effective dynamic range of the measurement system can be limited if a conventional detection technique is used. However, with AC detection, the RF signal is modulated with the desired square wave, and the measurement system is sensitive only to signals which have this modulation. Because the noise is random in nature, and not modulated, only the desired signal is measured, giving a true representation of the performance of the device under test (Figure 3b).

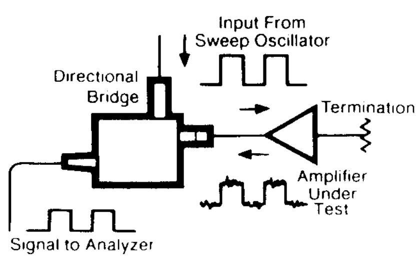


Figure 3. (b) AC detection rejects broadband noise present at the detector input.

Non-modulated RF signals are not detected

Similarly, the scalar network analyzer's response to non-modulated RF signals is minimized when AC detection is used. In DC detection systems, the analyzer will detect any RF signal within the bandwidth of the diode detector, which is typically from 10 MHz to 18 or 26.5 GHz. With AC detection, the detector also responds to any and all signals present at its input, but the analyzer responds only to the square wave portion of the detector's output. The amplitude of the desired, modulated signal is measured accurately, and the effects of other non-modulated signals are minimized.

Table 1 shows measured power levels of a desired RF signal and how it deviates from its actual value (measured with a power meter) in the presence of a second signal at the same frequency, using both AC and DC detection. Note that superior results are obtained with AC detection, because the effect of the undesired (and unmodulated) signal is minimal. With DC detection, both the desired and undesired signals are detected, and hence the measured power level is inaccurate.

Thermal effects are mimimized

With AC detection, the effect of temperature on diode operation (and hence signal detection) is minimized because only the modulated RF signal is measured, and any DC voltage offset of the diode's output voltage induced by temperature changes is ignored, much like the DC voltage offset caused by the presence of non-modulated signals. Detector sensitivity to changes in temperature are a paramount concern when measurements of device performance as a function of temperature are being made, especially at low power levels (less than −40 dBm).

Detector sensitivity to thermal change can be checked using a heat gun to heat up the detector. Set the analyzer to measure the noise floor, point the gun at the detector's input connector, and monitor the trace to see if the trace shifts in amplitude as the connector is warmed.

Faster allowable sweep rates at low power levels

AC detection allows faster measurement speeds because the operation of the receiver is not limited by the settling time of the log amplifiers at low power levels. (Very simply put, it is a lot faster to measure small voltage differentials which is the case with AC detection, than to measure a constant voltage/current at low levels). With the HP 8757A, this improvement in speed is obtained regardless of whether AC or DC detection is used, because AC signal processing is always used in the log amplifiers.

Power level of AC modulated signal: 0 dBm

dBc*	AC Mode	DC Mode	Power Meter
0	−1.65	4.09	2.84
−10	0.31	0.89	0.40
−20	0.24	0.32	0.15
−30	0.25	0.19	0.03

Power level of AC modulated signal: −10 dBm

dBc*	AC Mode	DC Mode	Power Meter
+10	−13.17	0.70	−0.19
0	−10.41	−6.33	−7.15
−10	−9.83	−9.30	−9.59
−20	−9.83	−9.86	−10.00
−30	−9.81	−9.89	−10.02

Power level of AC modulated signal: −30 dBm

dBc*	AC Mode	DC Mode	Power Meter
+30	−33.40	0.30	0.06
+20	−31.00	−9.71	−9.89
+10	−30.43	−19.52	−19.57
0	−30.43	−27.09	−26.94
−10	−30.42	−30.12	—
−20	−30.37	−30.5	—
−30	−30.38	−30.56	—

Power level of AC modulated signal: −20 dBm

dBc*	AC Mode	DC Mode	Power Meter
+20	−22.90	0.09	0.13
+10	−20.47	−9.46	−9.46
0	−20.00	−16.95	−16.99
−10	−20.02	−19.67	−19.66
−20	−20.02	−20.07	−20.00
−30	−19.98	−20.07	−20.05

* Amplitude of the unmodulated, undesired signal relative to the desired AC modulated signal.

Table 1. Measured power levels of a 27.778 kHz square-wave modulated signal at 10 GHz in the presence of a non-modulated signal at the same frequency with varying amplitude, using AC and DC detection. These values are empirical, indicative of the typical performance obtainable using AC detection.

Measurement applications

How do these benefits provide better measurements and accuracy? Let's look at several common devices and how AC detection produces superior results.

Amplifier measurements

AC detection is especially useful when measuring the gain of limiting amplifiers. The broadband noise level is high enough in such measurements that DC detection will respond to both the noise and the actual output signal from the amp, which is undesirable. AC detection rejects the broadband noise, and measures only the actual signal. Figure 4 shows measurements of amplifier output power made using AC and DC detection. When DC detection is used, the broadband noise is detected along with the desired output signal, and the indicated power is higher than it should be.

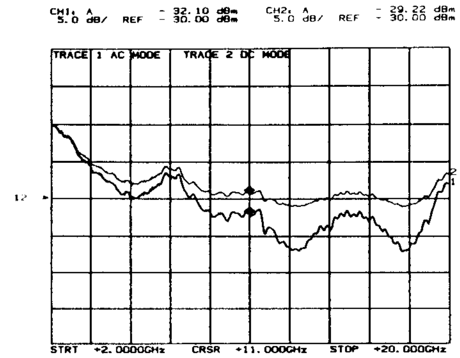


Figure 4. Measurement of an amplifier's absolute power output with broadband noise present at the detector input made using AC and DC detection modes (traces 1 and 2, respectively).

AC detection also allows about 5 dB more dynamic range than DC detection because the noise floor in AC detection is 5 dB lower (−55 dBm in AC mode versus −50 dBm in DC mode for the HP 85025A/B detectors). This additional dynamic range is required when making measurements of amplifier input return loss or when calibrating for gain measurements of amplifiers with low input power levels and very high gain.

High insertion loss measurements (switches, isolators, and filters)

During filter tuning, high dynamic range and sweep speed is required. AC detection is best for such measurements because of its better dynamic range and faster response time at low power levels without reduced bandwidth, allowing faster sweep rates (Figure 5). Since AC detection is also not affected by high-level noise, an amplifier can be inserted between the device's output and the detector to increase the dynamic range up to 90 dB or more.

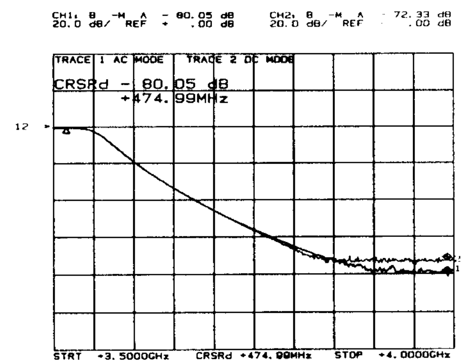


Figure 5. Plot of a lowpass filter's insertion loss made using AC and DC detection modes (traces 1 and 2, respectively). Note the increased dynamic range when AC detection is used.

Mixer measurements

When measuring mixer conversion loss, the presence of the LO feedthrough signal at the IF port of the mixer under test will impact the accuracy and dynamic range of the scalar analyzer if DC detection is used, because the detector responds to the LO feedthrough as well as the IF. However, if AC detection is used with non-modulated LO signals, and a modulated RF signal, the detector will respond to the modulated IF and the effect of the LO feedthrough is minimized (Figure 6).

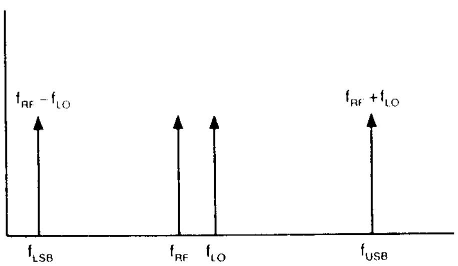


Figure 6. (a) Spectrum showing the signals present at the mixer's IF port.

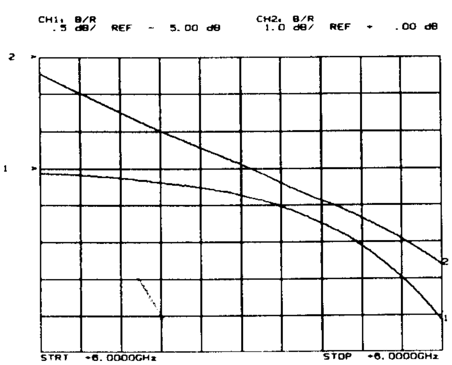


Figure 6. (b) Plot of a measurement of mixer conversion compression using AC and DC detection. Trace 1, obtained using AC detection, shows the correct conversion compression characteristic. Trace 2, obtained using DC detection, shows the effect of the LO feedthrough signal.

Antenna measurements

Periodic maintenance of microwave communications systems requires that the reflection performance of the transmit/receive antennas be measured. To perform this test, the system is taken "off-line" and a stimulus signal applied to the antenna feed, and the reflected signal is sampled with a directional coupler or bridge. However, the antenna is still receptive to any signals arriving from the outside environment that are within its bandwidth, and these signals will be present at the detector during the reflection measurement. If AC detection is used, the effects of these interfering signals are minimized, whereas with conventional detection approaches, these signals can have a large effect on the apparent return loss of the antenna (Figure 7).

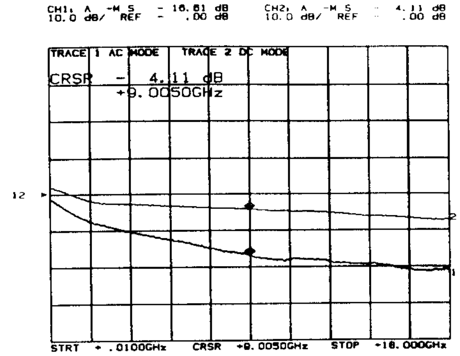


Figure 7. Measurement of antenna return loss made using AC and DC detection in the presence of a non-modulated signal at 10 GHz with the same amplitude as the actual stimulus signal.

The same problem occurs when fault location measurements are performed on coaxial or waveguide transmission lines that are terminated with an antenna. The scalar analyzer and computer (Figure 8) require a ripple pattern which is purely a function of

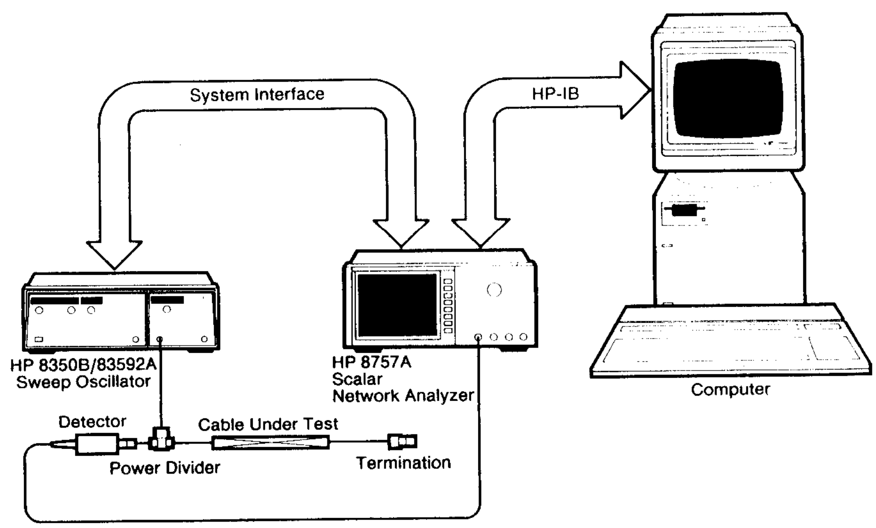


Figure 8. Setup for measurement of fault return loss as a function of distance using a scalar network analyzer and computer.

one and only one signal's reflections to calculate an accurate Fourier transform indicative of the distance to the mismatch which caused the reflection(s). The presence of other signals in the transmission line being tested can have an effect on the final measurement results if a DC detection system is used (Figure 9).

Another case where AC detection is advantageous is when the detectors are far removed from the scalar analyzer, as when measuring transmission through a waveguide run up a microwave tower. Any RFI-induced voltages on the cables leading from the detector to the analyzer are ignored by the analyzer because they are not modulated by the required 27.778 kHz signal.

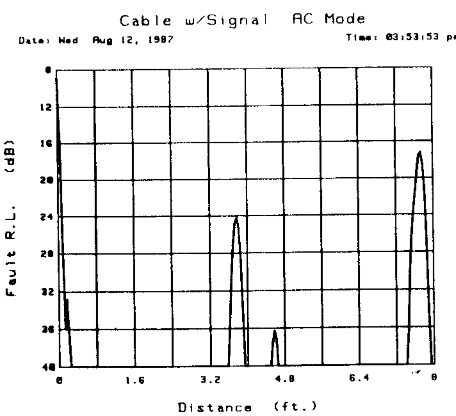


Figure 9. (a) Fault location measurement of a known fault at 3.8 feet in a RG-141 cable made using AC detection in the presence of a non-modulated signal at 10 GHz, with the same amplitude as the actual stimulus signal.

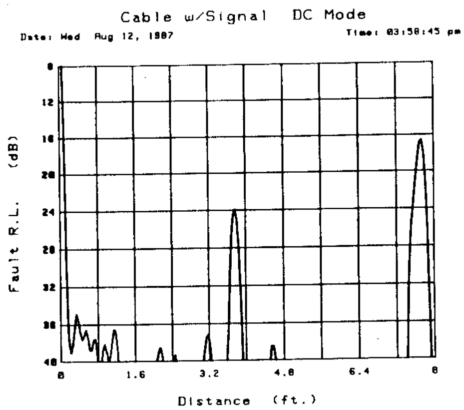


Figure 9. (b) Same measurement made using DC detection.

Where DC detection is best used

The HP 8757A can use DC detection (non-modulated RF) in applications where the DUT might be sensitive to modulation. Devices which may be affected are: amps with automatic gain control circuits built-in, devices with gain at audio frequencies, and very narrow bandwidth (<1 MHz) devices. In these cases, the HP 8757A can be used in DC mode. This is accomplished by simply pressing a softkey under the SYSTEM menu on the analyzer.

If a RF source is used in the test setup which cannot be modulated as required for AC detection, DC detection can be used.

With all broadband passive devices, and most amplifiers, AC modulation has no adverse effect on the DUT's performance and offers significant advantages as described above.

List of References

HP Application Note 183, *"High Frequency Swept Measurements,"* HP literature number 5952-9200.

HP Application Note 327-1, *"Extended Dynamic Range of Scalar Transmission Measurements Using the HP 8757A, HP 8756A and HP 8755C Scalar Network Analyzers,"* HP literature number 5953-8882.

HP Application Note 345-1, *"Amplifier measurements using the scalar network analyzer,"* HP literature number 5954-1599.

HP Application Note 345-2, *"Mixer measurements using the scalar network analyzer,"* HP literature number 5954-8369.

Scalar Seminar Handbook, HP literature number 5954-1586.

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