Application Note

JD730 Series Power Sensors

Measurement Overview

This document describes the basic functions and important features of VIAVI Solutions® Power Sensors JD730 Series.

Background

The output power level of a component or system is one of the most important factors in the overall performance of almost any RF equipment.

In a system, each component in signal processing must receive the proper power level from the previous component and forward the proper power level on to the succeeding component. If the output power level is too low, the signal can be at noise level. Alternatively, if the power level is too high, the performance will not be linear resulting in distortion and even might cause system damage.

The signal's power is therefore critical to performance at every level, from the most fundamental devices to the overall system.

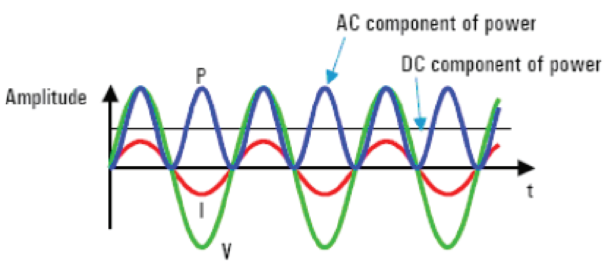
The Power Meter function measures the transmission power of the system. This function can be performed either with spectrum analysis or with external power sensors. Two kinds of external power sensors are available, Directional (Through line) and Terminating, its application depends on the methodology of power measurement.

Power vs. Frequency

At DC and low frequencies, voltage and current measurements are simple and straightforward. If a power measurement is needed, power is easily calculated using the following formula:

$$P = IV = \frac{V^2}{R} = I^2R$$

However, as the frequency approaches 1 GHz, voltage and current measurements become difficult and impractical, therefore in most applications it is required to make direct power measurements. A key reason for this approach is due to the variability of voltage and current along a transmission line, since standing waves are produced by the interaction of incident and reflected waves. However, power maintains a constant value along the transmission line.



Units & Definitions

Power is defined as the amount of energy transferred per time, and the basic unit is the watt (W). In electrical terms, 1 W is dissipated when a 1 A current flows across a potential 1 V difference.

$$1W = 1A \times 1V$$

Note that the decibel (dB) is 10 times the logarithmic ratio of two power levels, P1 and P2. Therefore, it is a relative metric. We can use a decibel to express absolute power by assigning an absolute or reference level to P1. At microwave frequencies, we usually assign 1 mW to P1, and describe absolute power in terms of dBm, or dB relative to 1 mW.

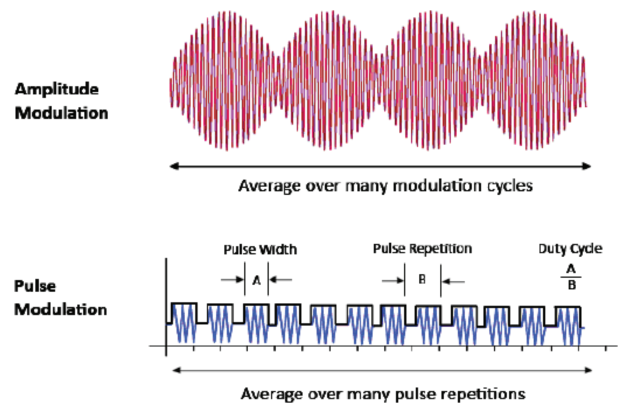
$$\text{Relative Power in decibel (dB)} = 10 \log \left(\frac{P_2}{P_1}\right)$$

$$\text{Absolute Power in decibel (dBm)} = 10 \log \left(\frac{P}{1mW}\right)$$

Power Measurements

Average Power

Since the instantaneous power of a modulated signal varies with time, it is difficult to measure. Instead, an average power is most commonly measured. To measure average power accurately, the time constant of the sensing device must be sufficiently long with respect to the lowest frequency component in the signal being measured. The power of a modulated amplitude signal must be the averaged over several cycles. Similarly, the power of the pulsed signal must be averaged over many pulse repetitions to obtain an accurate measurement. Test equipment for average power measurements is economical, easy to use, and most importantly accurate.



Pulse Power

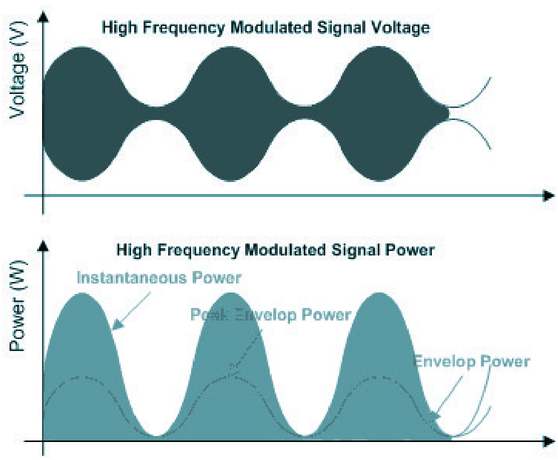
For a pulsed RF signal, such as a radar signal, the ratio of the pulsed width to the pulsed repetition interval is called duty cycle. Traditionally, the power of a pulsed RF signal is determined by measuring the average power of the pulse and then dividing the result by the pulse duty cycle.

$$\text{Pulse Power} = \frac{\text{Average Power}}{\text{Duty Cycle}}$$

The measurement result is a mathematical representation of the pulse power, rather than an actual measurement, and assumes a constant peak power. The pulse power averages out any distortion in the pulse, such as overshoot or ringing. For this reason, it is called pulse power, and not peak power, or peak pulse power.

Accurate pulse power measurements require that the modulated signal be a rectangular pulse with a constant duty cycle as shown above. Other pulse shapes, such as triangular, Gaussian, or with a nonconstant duty cycle will cause erroneous results. And pulse power measurement is not applicable for digital modulated systems where the duty cycle is not constant and the pulse amplitude and shape is variable.

Envelop and Peak Envelop Power



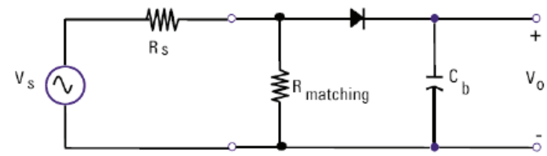
The upper graph of the above diagram shows the voltage envelope of a high frequency modulated signal. The lower graph shows the instantaneous power envelope of this signal, and the envelope power.

The envelope power is measured by averaging the power over a large time period compared to the period of the highest modulated frequency, but short compared to the period of the carrier. This allows the proper analysis of the modulation and transient conditions, without examining the details of the RF carrier.

The peak of the envelope is measured as peak power by a peak power meter and is a measure of the maximum signal power.

Power Sensor

The power sensor consists on different elements including a diode detector that rectifies the incoming signal, a matching resistor, approximately 50 ohms, which is the termination for the RF signal, and the RF signal voltage, VS, is converted to a DC voltage, V0 at the diode, while the bypass capacitor, Cb, is a low pass filter that removes any RF signal getting through the diode.

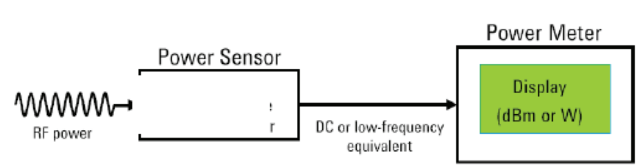


Power Measurement using Power Sensor & Power Meter

Although a variety of instruments measure RF power, the most accurate is the combination of power meter with a power sensor.

One of the main differences between these instruments is frequency selectivity. A spectrum analyzer measures in a particular resolution bandwidth whereas the power meter is not frequency selective, since it measures the average power over the full frequency range of the sensor and will include the power of the carrier as well as any harmonics or spurs.

The lack of frequency selectivity is the main reason that power sensors can only measure down to about –30 dBm and spectrum analyzers can measure signals much lower when a narrow resolution bandwidth is used. The convenience of lower cost and accuracy of the power meter and power sensor makes it the most popular method for measuring power in RF applications.



This above diagram shows the basic methodology of measuring high frequency power using the combination of power meter and power sensor. The power sensor converts high frequency power to a DC or low frequency signal that the power measure can measure and relate to an RF power level. The meter displays the direct signal as a power value in decibels or watts.

Conclusions

Power is one of the most fundamental characteristics of RF systems and components, and the measurement methodologies varies from the use of spectrum analyzers to a combination of power sensors and power meters, which offer a more accurate measurement.

VIAVI offers solutions for both methodologies with its base station and RF analyzers which can utilize its spectrum analysis functionality to perform power measurements without external power sensors. And the Power Sensor series for high precision measurements, which can interface with other VIAVI instrument's power meters, as well as a stand-alone solution driven by a PC.

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