The Most Common Power Meter Mistake

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At least 50% of all power meter users make this mistake. It has happened to you. You measured an RF power level and later someone said, "…but I measured the power and got a different number." Who was right? Measuring RF power appears easy. Modern wattmeters and power meters are simple to use, and can provide digital measurement data to several decimal places in dBm or watts. But if they are so accurate, why is it so difficult to make good measurements? If you are making the most common mistake, correcting for it will dramatically improve your measurement accuracy.

For the most common power meter application, measuring the level of power in a signal, many users tend to forget that a power meter is *not* measuring what you want to know- the power level of the signal. Instead, it is measuring the total power over the entire bandwidth of the sensor, which for measurement purposes is practically infinite!

Power meters versus Wattmeters

Most people recognize that a calibrated power meter is a superior measurement instrument compared to a wattmeter. But what is the difference between a wattmeter and a power meter? Generally, a wattmeter is similar to a power meter in that they both measure broadband power, but unless you are correcting the power meter for frequency, you are using it as a wattmeter. The perceived plug-and-go measurement ability of power meters is one of the misconceptions that endear power meters to users. This paper describes how to account for frequency in your power meter measurements, making them as accurate as possible.

Correction factors, what are they?

Power meter sensors that do not employ electronic calibration come with a graph or tabular data showing the calibration factor and correction factors by frequency. Most users will take the reference calibration factor (CF) in percent and use it to cal the power meter at the cal reference frequency, for instance at 50 MHz. But what are all the other numbers for? They are correction factors, similar to the reference CF, and indicate the response of the sensor to power as measured at those frequencies across the entire measurement range of the sensor. The numbers are usually a percent of the full scale response, and can vary from 80% or so to 100%. Let's say your sensor reference CF is 100% (not uncommon) and the CF of the frequency at which your signal of interest occupies is 95%. If you, like many users, carefully perform a cal and then plug the sensor to the signal port and make your measurement, it is still in error by at least 5%, or about 0.2 dB. Since power sensors are available with correction factors as low as 90%, your measured power can be in error by as much as 10% without taking other known uncertainties into consideration. Assuming the power to be measured is within the sensor range, the signal-to-noise ratio is acceptable, and the VSWR of the measurement port is acceptable, then the most important correction you can make to improve the error is to account for the frequency of measurement.

First, remember that measurement accuracy at higher power levels makes a much bigger difference than those made at low power. At -20 dBm, a 0.2 dB error is only about 0.5 uW, but at +55 dBm the error is over 15 Watts!

Correcting for the test frequency

When you are using a power sensor with a correction table by frequency *you must enter the percent correction* as shown on the sensor for the frequency being measured. If you are using a power sensor with electronic calibration data you must still enter a frequency to allow the meter to make the correction. The main advantage of the electronic calibration sensors is you don't have to interpolate the correction percentage by frequency from the data table or graph. When you enter frequency, the meter will apply the correction, but *you must input frequency*. CF Uncertainty is still a factor when using power sensors, even when correction for frequency is applied. CF Uncertainty increases with frequency from about 1% to 3% depending on the frequency range, but failing to apply the correct CF to the measurement compounds the error.

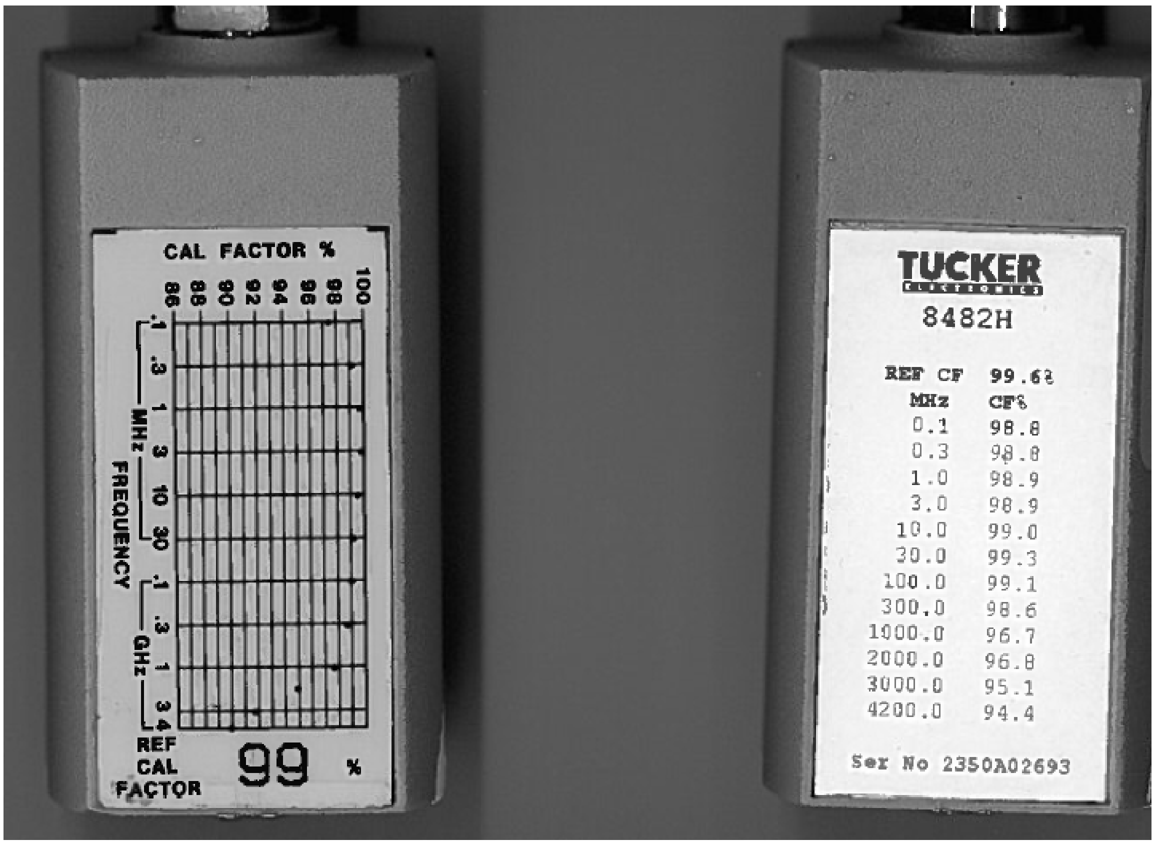

Fig.1 **Power sensors with Cal Factor (CF) data**.

CF as low as 90% is shown. For frequencies not enumerated, use straight-line interpolation of adjacent data. If your measurement frequency is *not* enumerated or between data provided, you are using the wrong sensor.

Measurement system slope and offsets

Applying corrections by frequency to power measurements goes beyond simply correcting the sensor. If the RF power level to be measured is not connected directly to the power meter head, whether the RF path is just an attenuator or an entire test bench setup, you must account for the "slope" of the RF path to correct your measurement. A common method uses a measurement "Offset" to add the attenuation of the path loss the power measurement displayed. Unfortunately, a single offset is frequently used, as the meter may only retain a single value. The Offset value *must be changed for each measurement frequency* that has a different loss. Some e-cal power meters allow you to input a table of offsets that will be interpolated by the meter. This is a great feature, but will occur only *when you input the measurement frequency*. High quality attenuators will come with calibration data, or measure the slope with a network analyzer for reference.

Bandwidth and Noise

Due to the high bandwidth of a power sensor, when using a power meter to measure power in a signal, the signal-to-noise ratio is important. Remember that Noise Power = KTB, and for a sensor BW of 26 GHz, B > 100 dB! Noise power can dominate the total power measured when signals fall as low -50 dBm or so. Adding a post-amplifier will not help the signal-to-noise, as the noise will be amplified as well as the signal. In this situation a filter is wanted, ideally a band-pass filter at the frequency of interest. Lacking a band-pass filter, a high- or low-pass filter (or both) can help. Check the ON/OFF power level of the system noise without the signal to see if the noise power is a factor in your measurement.

When making measurements of signals at higher power levels it is important to be aware of strong harmonics or other spurious signals that may contribute too much to the total power measured. Check the signal with a spectrum analyzer to make sure. In this case, again, filters need to be used to subtract that power before the sensor can see it.

At lower power levels a good spectrum analyzer (SA) may make a better measurement than a broadband power meter, as the SA will employ detection and filters that exclude the noise power.

VSWR can make a difference

Another practical power meter measurement correction that you can easily make is to assure yourself that the measurement uncertainty created by VSWR is minimized. When measuring with a sensor on an unknown port, you can make a quick check with a 6 dB pad to see if the measurement improves. Adding 6dB of loss increases the return loss by 12 dB, and will improve poor VSWR by a substantial amount, allowing a better measurement. The easiest way to do that is to use the power meter "Relative" measurement feature to "zero" the displayed power level, then add the pad and see if the level changes by 6 dB. As long as the signal level is still in the sensor range, if it changes more than the pad value the VSWR is adversely affecting the measurement, and you should use the pad. It might need more attenuation than 6 dB. In any case, *you must enter the percent correction* as shown on the attenuator for the frequency being measured or *you must input the measurement frequency*.

To reduce the measurement uncertainty of a relative measurement, try to keep the power applied to the sensor at the low end of the power range. The relative uncertainty can be as high as 6% at the high end, and as low as 1% at the low end.

Many factors contribute to making a successful power measurement- using the correct type of detector for your signal of interest, making allowances for gating and various forms of modulation, and more. But if you can avoid the biggest mistake and remember when you use a power meter that you are making a broadband measurement, not just measuring a discrete signal, you are on the way to getting better and more consistent results.