

SPECIAL REPORT:

WHAT IS SIGNAL LEVEL?

Part 2

By Ron Hranac



An Industry Expert Digs In

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SPECIAL REPORT: WHAT IS SIGNAL LEVEL?

In the previous installment, we established a foundation for digging a little deeper into the concept of signal level. As was stated at the end of Part 1, most RF carrier power measurements are expressed in average power. Does that rule apply to signal level measurements in cable networks? Read on to find out.

Imagine a sine wave viewed in the time domain – that is, amplitude versus time, as might be seen on an oscilloscope. See Figure 4.

The AC waveform's amplitude or level can be characterized in a variety of ways. For instance, we can measure the sine wave's peak-to-peak, peak, RMS or average values of current and voltage, as illustrated in Figure 5.

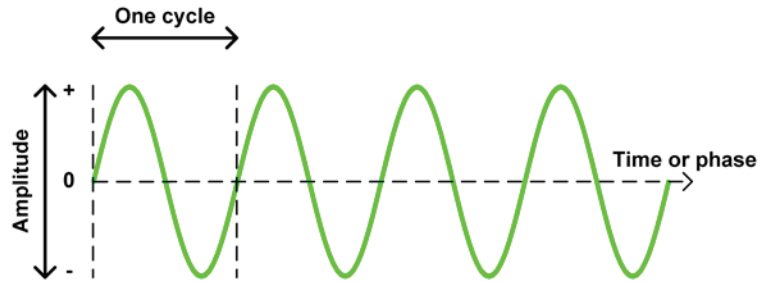


Figure 4. Time domain display of a sine wave.

The voltage or current of an AC waveform is usually expressed as an RMS value. For instance, the electricity from a North American household electrical outlet is a low frequency (60 Hz) sine wave whose RMS voltage is about 117 VAC. See Figure 6.

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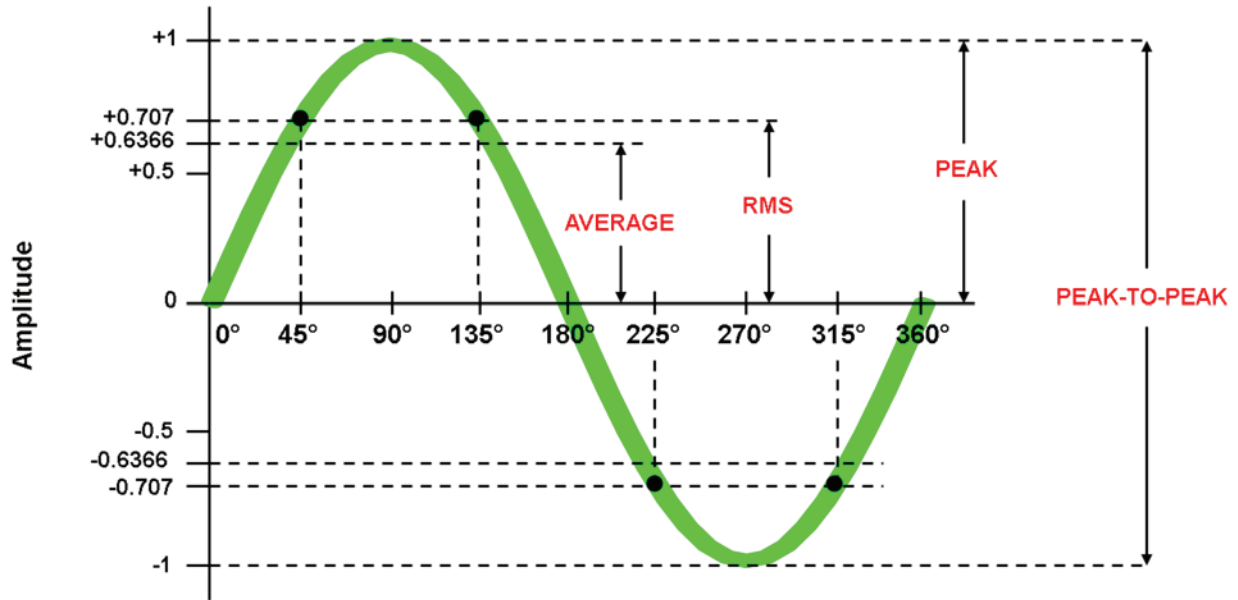


Figure 5. Relationships between RMS, average, peak, and peak-to-peak values of AC current and voltage (example courtesy of ARRL).

An unmodulated sinusoidal RF signal is a high frequency (typically several kilohertz, megahertz, or more) AC waveform. The amplitude of an RF signal also can be expressed in a variety of ways: voltage (volts), current (amperes) or power (watts).

Let's look at some example RF signal voltages at various locations in a cable network. As you might suspect, per-channel signal voltages in a 75-ohm impedance cable network can vary over a considerable range of values:

- Line extender output: 100 mV RMS
- Tap spigot output: 7.08 mV RMS
- TV set input: 1 mV RMS
- Line extender input: 10 mV RMS

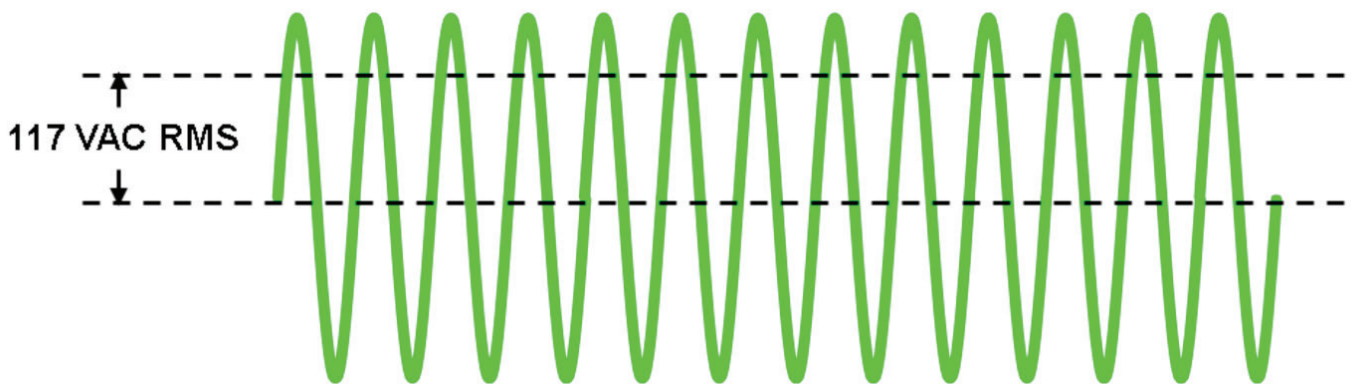


Figure 6. North American household electrical waveform.

The decibel and dBmV

A convenient way to deal with this wide variety of signal levels is to use the decibel (dB). A signal level in millivolts may be expressed in decibels as a ratio of that signal level to a reference of 1 mV across 75 ohms, or 13.33 nanowatts. This relationship forms the basis for the decibel-millivolt (dBmV), which is technically a unit of power expressed in terms of voltage. Mathematically, $\text{dBmV} = 20\log_{10}(\text{millivolts}/1 \text{ mV})$.

For example, 10 mV RMS is +20 dBmV:

$$\text{dBmV} = 20\log(10 \text{ mV}/1 \text{ mV})$$

$$\text{dBmV} = 20 * \log(10)$$

$$\text{dBmV} = 20 * 1$$

$$\text{dBmV} = 20$$

After converting to dBmV, the previous signal level examples become:

Line extender output: 100 mV RMS = +40 dBmV

Tap spigot output: 7.08 mV RMS = +17 dBmV

TV set input: 1 mV RMS = 0 dBmV

Line extender input: 10 mV RMS = +20 dBmV

Adding modulation to the mix

What happens when the RF carrier is, say, amplitude modulated? Where in the varying amplitude signal shown in Figure 7 do we measure the signal level?

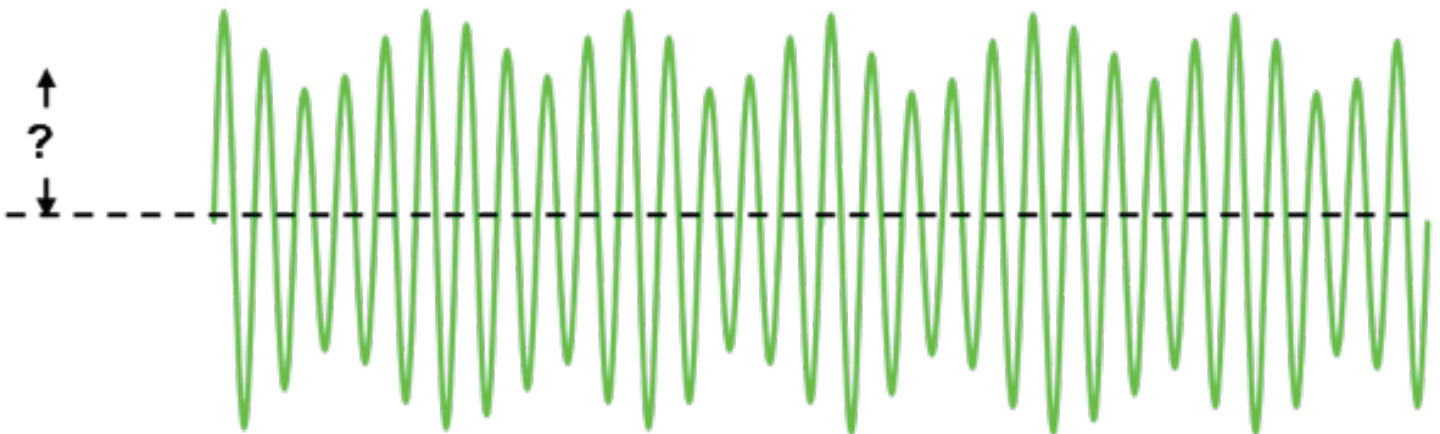


Figure 7. Varying amplitude sine wave.

One approach is to measure peak envelope power (PEP), where PEP is the average power (watts) during one cycle at the crest of the modulation envelope.

Start with peak envelope voltage (PEV) – for this example let’s assume the PEV is 14.14 mV, as shown in Figure 8.

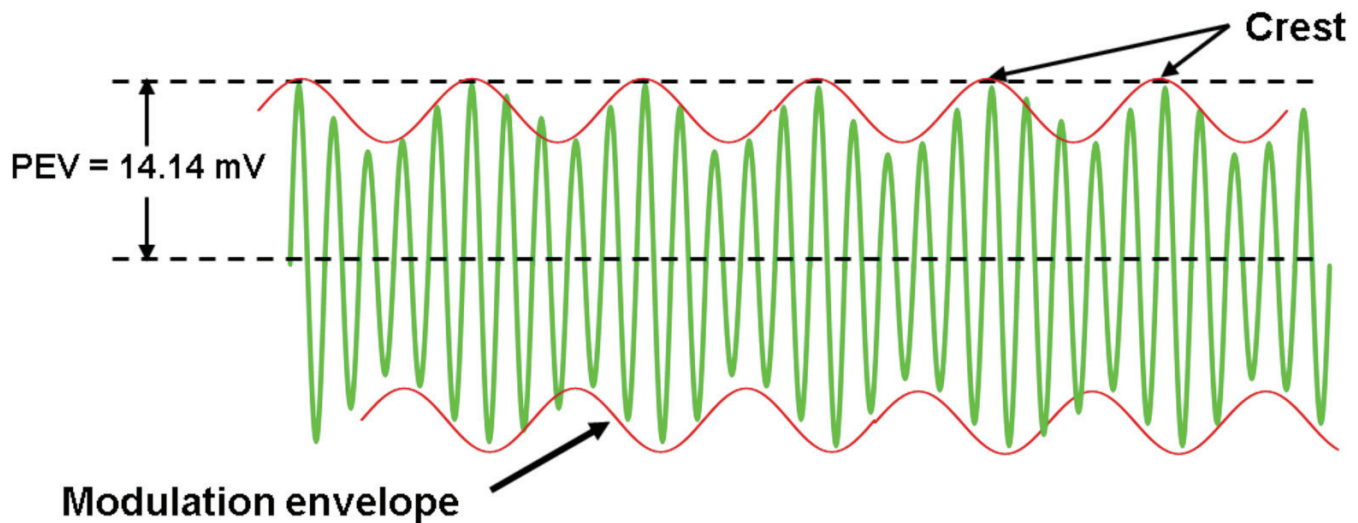


Figure 8. Modulation envelope and peak envelope voltage.

$$PEP = (PEV \times 0.707)^2/R$$

$$PEP = (0.01414 \text{ volt} \times 0.707)^2/75 \text{ ohms}$$

$$PEP = (0.01)^2/75$$

$$PEP = 0.0001/75$$

$$PEP = 1.33 \times 10^{-6} \text{ watt, (0.00000133 watt, or } 1.33 \mu\text{W), during each cycle at the crest of the modulation envelope.}$$

It would be quite cumbersome to express cable network signal levels in PEP – as in “the line extender’s per-channel input signal level is 0.00000133 watt PEP.” As previously mentioned, PEP is the average power of one cycle during the crest of the modulation envelope, which, in the case of an analog National Television System Committee (NTSC) TV signal’s visual carrier occurs during the sync pulses.

The sync pulses represent the carrier’s maximum power; the sync pulses have a constant amplitude even as picture content varies.

Assuming a 75-ohm impedance, 0.00000133 watt is 10 mV RMS, or +20 dBmV.

Here, +20 dBmV is the RMS value of the instantaneous sync peaks – a unit of power (0.00000133 watt PEP) expressed in terms of voltage (10 mV RMS).

The unmodulated analog TV signal’s visual carrier amplitude in the left screen shot in Figure 9 is 100 mV RMS, or +40 dBmV. When video modulation is applied, the carrier’s amplitude is measured just during the sync peaks (arrows in right screen shot). Here, too, the level is 100 mV RMS, or +40 dBmV.

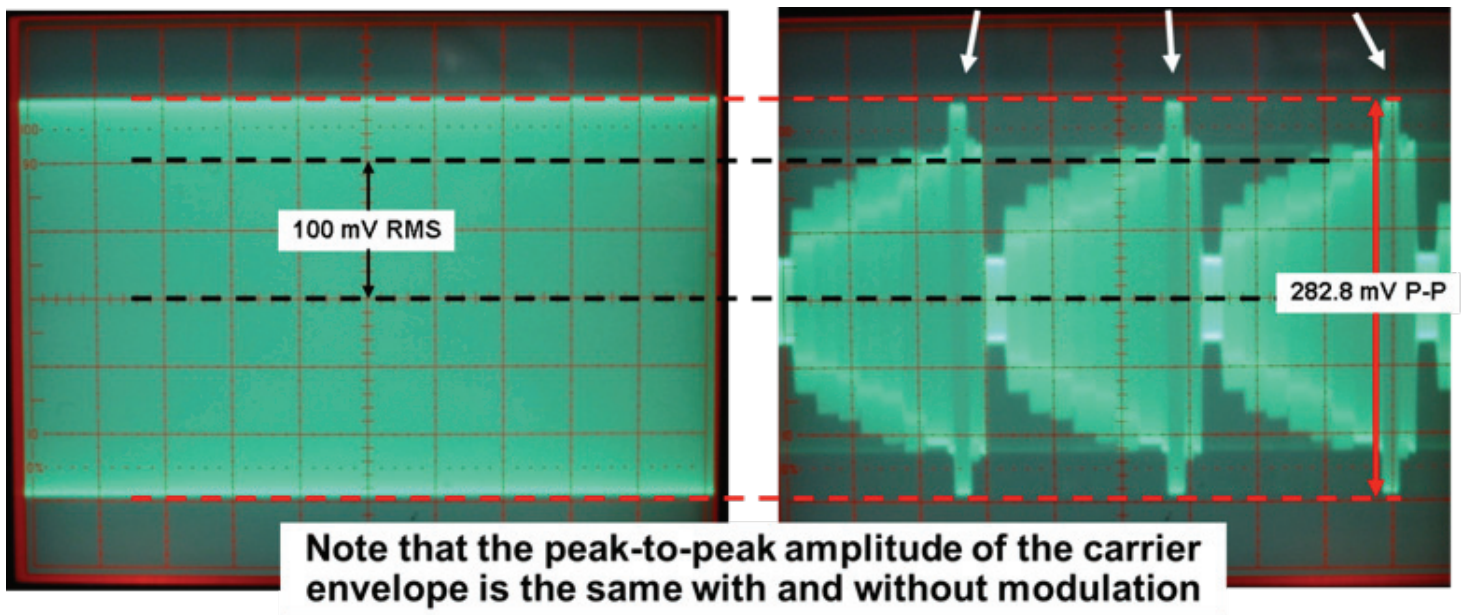
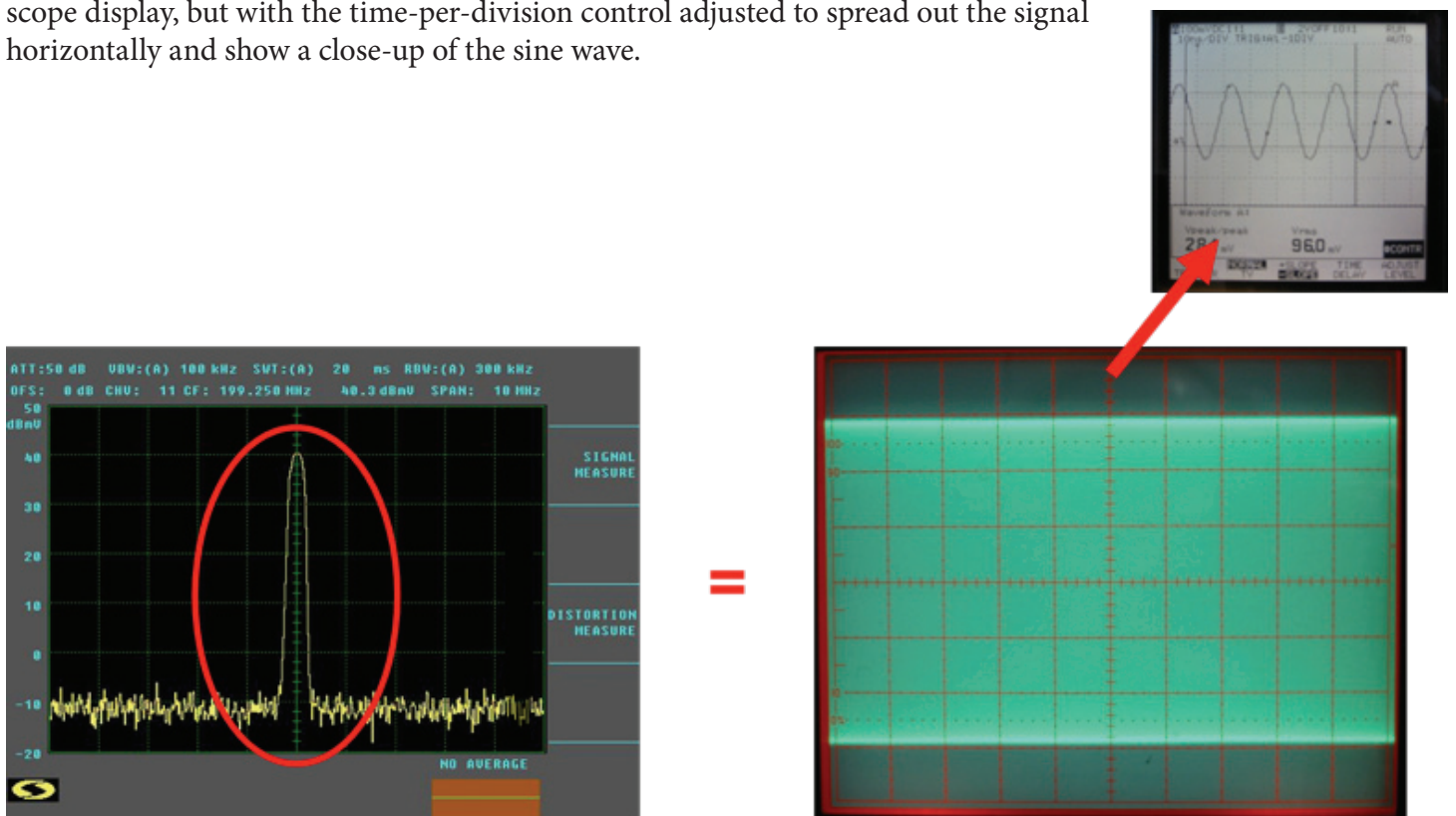


Figure 9. Unmodulated and modulated analog TV signal's visual carrier in the time domain.

The previous example is a measurement in the time domain; the screen shots were taken from an oscilloscope display. The screen shots in Figure 10 show a frequency domain representation of an unmodulated carrier as seen on a spectrum analyzer (left image), and the same signal as seen in the time domain on an oscilloscope (right image). The smaller inset screen shot in the upper right also is from an oscilloscope display, but with the time-per-division control adjusted to spread out the signal horizontally and show a close-up of the sine wave.



**Frequency domain:
 Amplitude versus frequency**

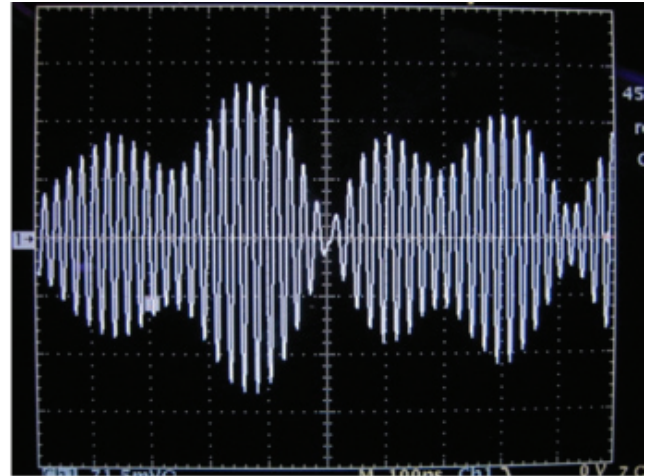
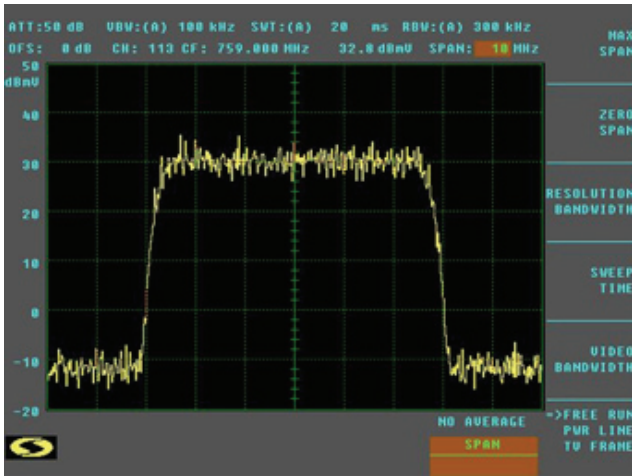
**Time domain:
 Amplitude versus time**

Figure 10. Unmodulated RF carrier in the frequency and time domains.

What about QAM signals?

As just discussed, the level of an analog TV signal is the PEP of its visual carrier.

When measuring the level of a quadrature amplitude modulation (QAM) signal, we measure that signal's average power (not its PEP), also called digital channel power or digital signal power.



**Frequency domain:
Amplitude versus frequency**

**Time domain:
Amplitude versus time**

Figure 11. 64-QAM signal in the frequency and time domains.

Most digital-capable signal level meters (SLMs), QAM analyzers, and similar test equipment measure the level at several points across a QAM signal's occupied bandwidth – say, 6 MHz – then integrate the results to provide the average power of the entire “haystack.” Results are typically comparable to what a thermocouple power meter would measure.

The screen shot on the left in Figure 11 shows a frequency domain representation of a 64-QAM signal as seen on a spectrum analyzer, and the right screen shot is the same signal as seen in the time domain on an oscilloscope.

Wrapping up the basics

When we measure the level of an analog TV signal's visual carrier, we are measuring its peak envelope power. When we measure the level of a QAM signal, we are measuring the entire haystack's average power. The measurement results can certainly be expressed in watts or even volts, but those values tend to be pretty cumbersome. Use of the decibel in the form of dBmV provides a handy way of stating signal level relative to a specified reference, where 0 dBmV equals 1 mV or 13.33 nW across 75 ohms.

Is measuring signal level enough?

The answer definitely falls into the “it depends” category. Sometimes we just need to know the signal level, perhaps to ensure that an amplifier is adjusted correctly. But signal level alone doesn't tell the whole story.

A classic example is the service technician who visits a subscriber's home to troubleshoot an intermittent tiling problem in some of the digital video pictures. The first thing checked usually is the signal level. Let's assume the

input levels to the set-top box are OK. “Ah, must be the set-top,” says the tech. So he swaps out the box. Maybe that will fix the problem, maybe not. The signal level doesn’t tell what the *quality* of the signal is.

A little more detective work with a QAM analyzer might show bit errors and low modulation error ratio (MER) on a couple adjacent downstream QAM signals, perhaps indicating in-channel ingress from an over-the-air UHF TV station. Instead of a faulty set-top, the culprit in this example might be a loose connector at the ground block outside, allowing the over-the-air interference to get into the drop. Signal levels are fine, but signal quality is not.

Clearly, there is risk in relying upon just signal level. Yes, it’s an important metric, but sometimes one must dig a little deeper to sort out a problem.

“What is signal level? It’s the power of a signal, stated in dBmV, which is technically a unit of power expressed in terms of voltage.”

Calibration

When a signal level meter reads +10 dBmV, is the signal level really +10 dBmV? This is another “it depends.” The good news is that most modern test equipment capable of measuring signal level – when properly calibrated and used in accordance with the manufacturer’s instructions – has pretty decent accuracy, perhaps in the range of ± 1.5 dB or so. But in the real world, instruments bounce around in the back of service vehicles, are exposed to the elements, occasionally get dropped, and may be used for months or years without being checked for accuracy. Yes, some instruments have a built-in calibration feature, but what if the internal calibrator is out of spec?

All test equipment requires occasional factory-level calibration. Check with the manufacturer for recommended calibration service intervals, and cycle the test equipment as required through the calibration process at the factory or an authorized service center.

Troubleshooting tips

A book could be written about specific troubleshooting tips using a signal level meter and similar instruments, so the following is provided as general guidance.

- √ Become familiar with the instrument’s setup and operation – read the manual.
- √ As discussed previously, ensure that the equipment meets factory calibration requirements.
- √ When using a given piece of test equipment for troubleshooting, follow the manufacturer’s instructions for warm-up (if applicable) and field calibration. Ensure that the battery is fully charged.
- √ The test lead should be made from suitable quality cable such as tri-shield or quad-shield coax.
- √ Keep the test lead as short as possible to minimize unnecessary signal attenuation. If the lead is much more than about 3 or 4 feet in length, it may be necessary to account for coax attenuation at higher frequencies. For example, 10 feet of 6-series drop cable has about 0.64 dB of loss at 1 GHz, and 25 feet of the same cable has about 1.6 dB of loss at 1 GHz.
- √ Avoid the use of push-on fittings on test leads. As convenient as push-on fittings are, intermittent connections

may result. The fittings themselves, depending on design, may allow ingress interference from over-the-air signals, too.

- √ Depending on the specific problem, it may be necessary to measure signal levels on anywhere from one to multiple channels. When looking at problems that may affect a wider frequency range, measure levels on several channels that are representative of the entire operating spectrum.
- √ One problem that may be overlooked is total downstream RF power exceeding the capability of a set-top, modem, other CPE, or even the test equipment itself. Checking RF input levels at just the higher frequencies may provide insufficient information. Significant reverse tilt can cause levels at low frequencies to be too high, possibly overdriving the affected device despite more or less correct levels at higher frequencies.
- √ If signal level is OK but problems persist, it might be necessary to do a little digging into the quality of the signal or signals in question with more sophisticated test equipment.
- √ Use the tried-and-true divide-and-conquer technique for troubleshooting. Identify a location where the problem exists and one where it doesn't exist, then go to the half-way point between those two locations. If the problem is present at the half-way point, it is occurring somewhere between the half-way test point and the point where the problem does not exist. Conversely, if there is no problem at the half-way point, the problem is occurring somewhere between that half-way point and the point where the problem does exist. Keep dividing the plant, drop, etc., into smaller half-segments until the source of the problem has been found.

What is signal level? It's the power of a signal, stated in dBmV, which is technically a unit of power expressed in terms of voltage. Measuring signal level in a cable network is relatively straightforward, and modern test equipment simplifies the task of accurate measurement of both analog TV signals and QAM signals. Understanding the limitations of signal level measurement is important, though: Sometimes signal level might be fine, but signal quality might not.

Part One of this Special Report is available [here](#).



Ron Hranac is the Technical Leader for Cisco Systems.

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