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DOWNSTREAM POWER MEASUREMENTS

By RON HRANAC

Ever wonder why we set the average power of a downstream digitally modulated signal several dB lower than what an analog TV channel would be on the same frequency? I like to ask this question at Society of Cable Telecommunications Engineers technical seminars, and the answers from attendees are varied. One of the more common replies is "the digital signal has more power." I invariably end up drawing an analog TV channel and a digital "haystack" on the board or flip chart, noting that each is, say, 0 dBmV. "Which has the greater power?" I query. "The digital channel," someone says.

I continue, "0 dBmV is 13.33 nanowatts (nW), so if each signal is 13.33 nW, the power in the two signals must be equal, right?"

Um, yes and no.

It's a bit of a trick question.

Peak vs. average power

When we speak of the signal level of an analog TV channel, the reference is almost always to a measurement of the visual carrier level. Specifically, the visual carrier level is defined as the root mean square (RMS) amplitude of the instantaneous sync peak. For all intents and purposes, that's the peak power.

But when we measure the amplitude of a digitally modulated signal, we measure its average power. Hmmm, that suggests there probably is a peak power component in there somewhere, and indeed there is.

Looking at a constellation diagram of a quadrature phase shift keying (QPSK) or quadrature amplitude modulation (QAM) digitally modulated signal, it's apparent that the outer corner symbol points represent peak symbol power. (It actually represents voltage, but power can be derived from that.) Chapter 4 of Modern Cable Television Technology, 2nd Edition, lists the peak symbol power-to-average symbol power ratio of several common digitally modulated signals.

QPSK: 0 dB
16-QAM: 2.55 dB
64-QAM: 3.68 dB
256-QAM: 4.28 dB

There is another piece to the peak power of a digitally modulated signal that must be considered when determining the total peak-to-average power ratio. It's called trajectory overshoot. A digitally modulated signal cannot change from one symbol state to another instantaneously. To do so requires an outrageous amount of bandwidth. The data transmitter's filtering defines the amount of trajectory overshoot during the transition from one symbol state to another. Trajectory overshoot affects the overall peak-to-average power. Francis Edgington of HEYS Professional Services (you may remember Francis from his days at Hewlett-Packard and Agilent Technologies-he's regarded as the father of the 8591C spectrum analyzer) has measured peak-to-average power ratio for several digitally modulated signal types and found the following typical values. These include trajectory overshoot.

QPSK: 3.5~4.5 dB
16-QAM: 5.8~6.8 dB
64-QAM: 6.3~7.3 dB
256-QAM: 6.5~7.5 dB

From this you can see that setting a 64-QAM signal, say, 6 dB lower than analog TV channel signal levels will result in the peak power of both being about the same, give or take a bit. Why does this matter?

Laser clipping

One very important reason to correctly set the amplitude of digitally modulated signals is to avoid laser clipping. Most of us tend to think of laser clipping as an upstream problem, caused by ingress or impulse noise. But downstream lasers can clip, too, and do so far more often than most of us realize.

A quick and dirty method to see whether a downstream laser is clipping is to use a QAM analyzer to check pre- and post-forward error correction (FEC) bit error rate (BER) on one or more digitally modulated signals at the downstream laser input test point and the node output test point. If the QAM analyzer shows no bit errors at the laser input but you see errors at the node-most likely pre-FEC errors-the laser probably is clipping.

The fix is to go back to the headend or hub and carefully measure and adjust, as required, the levels of all downstream signals with recently calibrated test equipment. It's especially important to correctly set the amplitude of your downstream digitally modulated signals relative to analog TV channel levels. Measuring analog TV channel levels is straightforward. The best way to measure digital signals is to use the digital channel power function available in most modern spectrum analyzers, signal level meters (SLMs) and QAM analyzers.

For more information on this topic, see "Downstream Power Measurements: Watts Up Doc?" in the September 2000 issue of Communications Technology (available here). Another useful document is the white paper "Measuring Cable Television Network Downstream Signal Amplitudes" available here.

I shudder when I hear that some folks set a 64- or 256-QAM digitally modulated signal's amplitude relative to TV channel levels using a spectrum analyzer in, say, 100 kHz resolution bandwidth and doing a simple marker delta between an adjacent visual carrier and the digital haystack. If this technique is used to set the apparent amplitude of the haystack 10 dB lower than the adjacent visual carrier, the result is not quite what's expected. The digital signal's average power won't be 10 dB down in this example (even though it might look like it on the analyzer's screen), but will be something on the order of 3 or 4 dB higher than the TV channel's visual carrier. Yikes!

The fix? Correctly measure the digital signal's average power, and set the average power 6 dB to 10 dB lower than the analog TV channel levels. Many operators set 64-QAM signals 10 dB down and 256-QAM signals 5 or 6 dB down. Granted, the 256-QAM signal has a somewhat higher overall peak-to-average power ratio than 64-QAM, but it also needs a higher carrier-to-noise ratio (C/N) to get the same BER as a 64-QAM signal.

Turn it down

Even after headend levels are set correctly, you may still see some evidence of downstream laser clipping. If so, it's likely the laser RF input levels are running a tad too close to the clipping threshold. Turning all RF levels down a dB or so will probably take care of it. Yes, that will drop the fiber link's C/N a dB, but the end-of-line C/N change will be somewhat less because of good ol' power addition of headend, fiber link and coax plant standalone C/N.

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