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DIGITAL TROUBLESHOOTING, PART 1

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Digitally modulated signals are used to transport high-speed data, video and voice on cable networks. These signals are subject to a variety of impairments that can seriously impact the quality and reliability of the services being provided. More often than not, simply measuring signal level or looking at the display on a conventional spectrum analyzer isn't enough to fully troubleshoot problems or characterize the health of a digitally modulated signal.

For instance, how often does a set-top box or maybe the subscriber drop get replaced to "fix" blocking or tiling in the picture after a signal level measurement seems to indicate all is well? What about slow data throughput with a cable modem? Or voice quality problems with a voice over Internet protocol (VoIP) installation? Fortunately, several test equipment manufacturers have provided the cable industry with a relatively low cost tool to evaluate digitally modulated signals: the QAM (quadrature amplitude modulation) analyzer. QAM analyzers support a suite of sophisticated measurements, but many of the functions available in this category of test equipment often go unused or are not well-understood.

This two-part article (part 2 will be next month) includes an overview of the features available in many QAM analyzers and, more importantly, how to use those features to trouble shoot problems with digitally modulated signals. This understanding is critical to achieving and maintaining the reliability necessary for new services being deployed on today's cable networks.

An all-too-common scenario

Assume that a customer calls to complain about tiling in the picture of one of the digital video channels. A service tech goes to the customer's home and using a signal level meter (SLM) finds that the downstream digital channel power on the QAM channel in question is +6.3 dBmV. This is an acceptable value. The tech happens to have a spectrum analyzer available and looks at the digitally modulated signal. See Figures 1 and 2. The "haystack" appears to be normal, so the tech swaps the customer's set-top box for a new one. Problem solved!

FIGURE 1: Acceptable Digital Channel Power

FIGURE 2: Haystack Appears Normal
Or is it?

What's missing?

It is impossible to fully evaluate a digitally modulated signal merely by measuring its average power or looking at it on a spectrum analyzer. It's necessary to "look inside" the signal to see what's going on. This is where the QAM analyzer plays an important role.

In addition to measuring analog TV channel signal level and digitally modulated signal average power (digital channel power), most QAM analyzers support several functions that can be used to characterize the health and performance of downstream and upstream digitally modulated signals: Constellation display, pre- and post- forward error correction (FEC) bit error rate (BER), and modulation error ratio (MER) are the most common ones.

Some of the lesser known capabilities of QAM analyzers include the ability to characterize linear distortions: amplitude ripple (poor in-channel frequency response), micro-reflections, and on instruments that support it, group delay. Most QAM analyzers can be used to troubleshoot transient impairments such as sweep transmitter interference and laser clipping. Tracking down some types of in-channel ingress is even possible with most QAM analyzers. A QAM analyzer's constellation display is one of the most powerful troubleshooting tools available in this type of test equipment, yet is often not used to the extent that it should be.

How a QAM analyzer works

The typical QAM analyzer design is similar to what is shown in the block diagram in Figure 3. The user interface is the instrument's keypad and display and possibly an Ethernet or other external connection to, say, a personal computer (PC). The tuner is, as its name implies, used to select the digitally modulated signal of interest. The QAM demodulator functions include carrier frequency acquisition, carrier phase tracking, symbol rate tracking, and adaptive equalizer and J.83 channel decoding. By probing into these elements of the QAM demodulator, one can retrieve information on MER, pre- and post-FEC BER, and channel response. This is part of physical layer testing.

FIGURE 3: DOCSIS MAC Layer

In the example shown in Figure 3, DOCSIS media access control (MAC) layer analysis is used with the upstream transmitter to retrieve specific parts of the data content for tracking cable modem registration and connection-keeping. This is the logical bidirectional connection layer up to the cable modem termination system (CMTS). By monitoring MAC messages, failed steps in the process can be detected and monitored.

SLM functionality is for the measurement of analog TV channel signal level and digitally modulated signal average power. In the block diagram, the SLM is shown connected to the input side of the diplex filter, allowing measurement of signals below 50 MHz.

A QAM analyzer is one of the most valuable tools for troubleshooting digitally modulated signals. As mentioned previously, most QAM analyzers support analog signal level and digital channel power measurement, downstream constellation display, pre- and post-FEC BER and MER. Some also can perform upstream measurements, such as transmit level, packet loss and throughput testing.

Basic QAM analyzer functions

The QAM analyzer screen shots in Figures 4 and 5 show examples of downstream 64-QAM and 256-QAM digitally modulated signals.

FIGURE 4: 64-QAM Constellation

FIGURE 5: 256-QAM Constellation

The 64-QAM signal's digital channel power is -3 dBmV, an acceptable value. The constellation has tight symbol points, an overall square shape, and shows no signs of visible impairments such as phase noise or coherent interference. MER is well above the recommended 27 dB minimum for 64-QAM. But pre- and post-FEC BER are much higher than they should be, with values of 3.00E-05 (3 x 10 -5) and 2.00E-05 (2 x 10 -5) respectively. Figure 4 illustrates the importance of evaluating multiple parameters on a QAM analyzer. In this case, the digital channel power, MER and constellation are fine, but the BER indicates a problem—perhaps sweep transmitter interference, downstream laser clipping, an upconverter problem in the headend or a loose connection.

The 256-QAM signal's constellation has tight symbol points, an overall square shape, and no signs of visible impairment. MER is in the mid 30s, well above the recommended 31 dB minimum value for 256-QAM. There are no pre- or post-FEC bit errors. This is a problem-free signal.

Performance guidlines

Here are performance guidelines for other parameters that can be measured with a QAM analyzer:

Digital channel power for each digitally modulated signal at the input to a DOCSIS cable modem should be in the -15 to +15 dBmV range, although many operators have found that -10 to +5 dBmV is a good sweet spot. These values are suitable for digital set-top boxes, too.
The minimum recommended MER for 64-QAM is 27 dB, and for 256-QAM the minimum recommended MER is 31 dB. These values include 3 to 4 dB headroom for reliability. MER in the headend and node downstream output should be as high as the QAM analyzer is capable of measuring (typically mid-30s or greater) and in the low to mid-30s at the customer premises.
There should be no pre- or post-FEC bit errors in the headend or at the node's downstream output. Ideally, there should be no bit errors at the customer premises, either, although the DOCSIS Radio Frequency Interface Specification states that post-FEC BER at the cable modem input should be 1.0E-08 (1 x 10 -8) or less at specified signal levels and carrier-to-noise ratios (CNR).
Recommended worst-case upstream packet loss for high-speed data is 1 percent, and the worst-case upstream packet loss for voice should not exceed about 0.1 percent to 0.5 percent.

The constellation

Learn to interpret the constellation display. The constellation should have an overall square shape, the symbol points small and well-defined, and there should be no signs of visible impairment. Figure 6 illustrates examples of several types of impairments as they appear on a constellation display.

FIGURE 6A: Impairments Shown in the Constellation Display (Graphics courtesy of JDSU/Acterna, Sunrise Telecom and Trilithic.)

FIGURE 6B: Impairments Shown in the Constellation Display (Graphics courtesy of JDSU/Acterna, Sunrise Telecom and Trilithic.)
This two-part article was adapted from a paper slated for Cable-Tec Expo, courtesy of the SCTE. Watch for the second half next month.

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