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TROUBLESHOOTING DIGITALLY MODULATED SIGNALS, PART 2

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Digitally modulated signals are a fact of life in the modern cable system, and keeping those signals healthy requires different equipment and knowledge than analog does. Here follows Part 2 of Ron Hranac's Expo workshop on troubleshooting digitally modulated signals.

Part 1 of this feature, which ran last month, covered the differences between analog and digital measuring techniques, quadrature amplitude modulation (QAM) analyzer operation and functions, performance guidelines, and the constellation. Part 2 picks up with linear distortions.

Linear distortions

The QAM analyzer's adaptive equalizer graph and in-channel frequency response and group delay displays are powerful tools for troubleshooting linear distortions. If the equipment supports displaying modulation error ratio (MER) and the constellation without adaptive equalization (or unequalized equivalent), use this capability to further quantify the severity of the impairment.

The screen shots on the left in Figure 1 show an unimpaired upstream 16-QAM signal with no micro-reflections of consequence, essentially flat in-channel frequency response, and negligible group delay (tens of nanoseconds). The unequalized MER is about 28 dB, a very good value. The constellation's symbol points are small and have no visible impairment.

Figure 1

The screen shots on the right show a severe micro-reflection in the equalizer graph. The micro-reflection caused 1.6 dB peak-to-valley amplitude ripple in the frequency response, as well as 270 ns peak-to-peak of group delay ripple (off scale!). The unequalized MER is about 21 dB, within a decibel or so of the unequalized MER failure threshold for 16-QAM, and the constellation points are fuzzy because of the low MER. A spectrum analyzer measurement showed better than 35 dB carrier-to-noise ratio (CNR), very little ingress, no impulse noise, no common path distortion (CPD), and no upstream laser clipping. Despite the apparently clean upstream—at least as seen on the spectrum analyzer—16-QAM would not work, but quadrature phase shift keying (QPSK) was fine.

Many QAM analyzers incorporate an adaptive equalizer graph, sometimes called "equalizer stress." The equalizer graph is ideal for troubleshooting micro-reflections. The vertical axis is in decibels, and the horizontal axis shows units of time (typically related to the QAM analyzer's adaptive equalizer tap spacing). The tallest vertical bar is the incident signal. If any of the other bars appear above the average "noise floor" to the right of the incident signal, the usual culprit is one or more micro-reflections. Determine the approximate offset in units of time between the incident signal's vertical bar and the reflection's vertical bar. Depending on the instrument, this may be done with moveable markers or by reading a horizontal scale.

(See Figure 2.) Some QAM analyzers are capable of calculating the distance automatically after entering the cable's velocity of propagation, as shown in Figure 3.

Figure 2

Figure 3

RF signals travel through 1 foot of coaxial cable in about 1 ns (1.17 ns per foot for 87 percent velocity of propagation coax). The time offset between the incident signal and echo in Figure 2 is approximately 2.5 s, which equals 2,500 ns. This is equivalent to about 2,500 feet. Divide by two to account for the reflection's round trip, and distance to the echo is about 1,250 feet. For improved accuracy, one can use 1.17 ns per foot to calculate the distance: (2,500/1.17)/2 = 1,068 feet.

An impedance mismatch that causes a severe micro-reflection also will cause amplitude ripple or standing waves to appear in the amplitude-vs.-frequency response. If the QAM analyzer supports in-channel frequency response measurements, the distance to a fault that is causing a micro-reflection can be calculated with the formula dft = 492 x (VP/FMHz), where dft is the distance in feet, VP is the cable's velocity of propagation expressed as a decimal (for example, 0.87 for 87 percent velocity of propagation), and FMHz is the frequency separation in MHz between adjacent ripple peaks. For the amplitude ripple in the center of Figure 2 (400 kHz spacing), the distance is 492 * (0.87/0.400) = 1,070 feet.

The 0.59 s micro-reflection under the QAM analyzer's marker (small arrow near the top center of the display) in Figure 3 corresponds to a distance of 590 feet assuming 1 ns per foot, which when divided by two yields an approximate distance of 295 feet. Using 1.17 ns per foot, the distance works out to (590/1.17)/2 = 252 feet, in agreement with the QAM analyzer's calculated value.

Operational RF levels

By definition, an analog TV channel's visual carrier level is the root mean square (RMS) amplitude of the instantaneous sync peaks, or peak envelope power. Digital channel power measurements use average power.

The DOCSIS Radio Frequency Interface Specification states that the cable modem termination system (CMTS) (or upconverter) output should be +50 dBmV to +61 dBmV. Good engineering practice suggests that something near the middle of this range is ideal—that is, +55 to +58 dBmV—leaving adequate headroom above the minimum and below the maximum to accommodate occasional signal level adjustments and also test equipment absolute accuracy and calibration. These values are suitable for digital video edge-QAM devices, too, unless otherwise stated by the manufacturer.

Many cable operators set the average power of 64-QAM digitally modulated signals 10 dB lower than what the amplitude of an analog TV channel's visual carrier would be on the same frequency. 256-QAM signals are often carried 5 dB to 6 dB below the level of what an analog TV channel would be on the same frequency. These ratios should be maintained everywhere in the network.

As mentioned previously, each digitally modulated signal's digital channel power should be in the -15 dBmV to +15 dBmV range at the cable modem (or set-top box) input, although many cable operators prefer to keep these values in the -10 dBmV to +5 dBmV or even -5 dBmV to +5 dBmV range.

Seeing under the haystack

The JDSU SDA-5000/Opt. 4 supports a unique feature that allows the user to see ingress or other interference under a 64- or 256-QAM digitally modulated signal without turning the carrier off. The instrument mathematically removes the haystack from the display, allowing the noise floor under the signal to be seen.

The spike in the center of the display in Figure 4 is not ingress or intermodulation distortion—it's the digitally modulated signal's suppressed carrier. Apparent ingress 1.75 MHz below center frequency would most likely be composite triple beat (CTB). Apparent ingress 1 MHz below center frequency—visible in this screen shot—would most likely be composite second order (CSO). In this example, the QAM analyzer's `B' marker (the vertical dashed line) has been placed on a -48.3 dBc beat 0.5 MHz above the digitally modulated signal's center frequency.

Figure 4

Upstream packet loss

Several QAM analyzers support upstream packet loss measurements—examples are shown in Figure 5. While conventional high-speed data can operate reasonably well with up to about 1 percent upstream packet loss, for reliable voice service the maximum upstream packet loss should not exceed about 0.1 percent to 0.5 percent.

Figure 5

Headend troubleshooting—integrated upconverter

When troubleshooting a problem that affects a large number of customers, start at the source: The CMTS or QAM modulator output. Figure 6 shows a CMTS with an integrated upconverter. Verify that the output level is within the specified or desired range: +50 to +61 dBmV in this example, although +55 to +58 dBmV is fairly typical. Check pre- and post-forward error correction (FEC) bit error rate (BER); there should be no bit errors here. MER should be as high as the QAM analyzer is capable of measuring, generally in the mid to high 30s. The constellation should show no signs of visible impairment and should have an overall square shape. In-channel frequency response should be essentially flat and group delay no worse than a few tens of nanoseconds.

Ensure that the digital channel power is sufficient so that the digitally modulated signal is 6 dB to 10 dB lower than what an analog TV channel's signal level would be on the same frequency. This may require an in-line attenuator between the CMTS or QAM modulator output and headend combiner input, depending on headend configuration.

Figure 6

Repeat all of these measurements at the headend combiner test point and downstream laser input to ensure that the signal is not being impaired by a problem between the CMTS or QAM modulator output and the combiner or laser.

Headend troubleshooting—external upconverter

As before, when troubleshooting a problem that affects a large number of customers, start at the source: The CMTS or QAM modulator output. Figure 7 shows a CMTS with an external upconverter. Verify that the CMTS or QAM modulator IF output level is within the specified or desired range: +42 dBmV, +/-2 dB in this example. Check pre- and post-FEC BER; there should be no bit errors here. MER should be as high as the QAM analyzer is capable of measuring, generally in the mid to high 30s. The constellation should show no signs of visible impairment and should have an overall square shape. In-channel frequency response should be essentially flat and group delay no worse than a few tens of nanoseconds. Repeat these measurements at the upconverter intermediate frequency (IF) input, and make certain that the upconverter is not being overdriven by too much signal. Most external upconverters require an IF input in the +25 to +35 dBmV range, so an in-line attenuator should be installed at or near the upconverter input.

Verify that the external upconverter's RF output level is within the specified or desired range: +50 to +61 dBmV in this example, although +55 to +58 dBmV is fairly typical. Repeat the previous measurements of pre- and post-FEC BER and MER, and look at the constellation for signs of impairment. The signal quality should be more or less the same as what was measured at the upconverter input.

Figure 7

Ensure that the upconverter's output digital channel power is sufficient so that it is 6 dB to 10 dB lower than what an analog TV channel's signal level would be on the same frequency. This may require an in-line attenuator between the upconverter RF output and headend combiner input, depending on headend configuration.

Repeat all of these measurements at the headend combiner test point and downstream laser input to ensure that the signal is not being impaired by a problem between the upconverter RF output and the combiner or laser.

Headend troubleshooting—combiner output and fiber link

At the points shown in Figure 8, measure downstream digitally modulated signal average power, pre- and post-FEC BER and MER. Evaluate the constellation for visible signs of impairment.

Figure 8

Bit errors at the downstream laser input but not at the CMTS or upconverter output (or QAM modulator output) may indicate sweep transmitter interference, interference from an adjacent channel, loose connections or combiner problems.

If a sweep transmitter is in use, temporarily turn it off. If the bit errors disappear, sweep transmitter interference is causing the degraded BER (probably only pre-FEC errors). It will be necessary to program suitable guard bands around the affected digital channel. Refer to the sweep transmitter instruction manual.

To troubleshoot suspected adjacent channel interference, temporarily turn off the adjacent channel(s). If the interference disappears, the problem is likely coming from one of the adjacent channels. This particular troubleshooting technique disrupts service on the adjacent channel(s), so make sure that other potential causes have been checked first.

Bit errors at the downstream node output but not at the downstream laser input are most likely caused by laser clipping. Laser clipping is almost always caused by excessive RF input levels. Go back to the headend and carefully measure the amplitude of every downstream signal and readjust as required. This should reduce or eliminate the clipping (and bit errors at the node); if not, it may be necessary to reduce the overall laser RF input. In most cases when this must be done, reducing all levels a decibel or so is all that is needed. Refer to the optoelectronics manufacturer's documentation for details about correct link setup at the laser and node.

Measuring average power over a wide bandwidth—say, 35 MHz (upstream) or 550 MHz (downstream)—is a useful way to set total input power to a laser transmitter. Sunrise Telecom's AT2500RQ spectrum/QAM analyzer supports variable bandwidth digital channel power measurements, as does the HP/Agilent 8591C spectrum analyzer.

Out in the field

Go to an affected subscriber's premises. Measure the digitally modulated signal's RF level, MER, pre- and post-FEC BER, and evaluate the constellation for impairments. Look at the equalizer graph for evidence of micro-reflections. Also check in-channel frequency response and group delay. If the QAM analyzer supports it, repeat these measurements in the upstream.

Be sure to measure upstream transmit level and packet loss.

If upstream transmit level is at or near the maximum (+58 dBmV for QPSK, +55 dBmV for 16-QAM), the most likely culprit is one or more drop problems. In typical installations, cable modem upstream transmit levels will be in the +30 to +45 dBmV range—give or take a bit—although there can be exceptions.

Upstream packet loss should not exceed about 1 percent for conventional high-speed data service and 0.1 percent to 0.5 percent for reliable voice service.

If downstream impairment(s) exist at the subscriber premises (let's call this test point `S') but not at the node (test point `N'), use the divide-and-conquer technique to locate the problem. First confirm whether the impairment exists at the tap port to rule out a subscriber drop problem. Assuming it's not a drop problem, go to a point halfway between the node and affected subscriber and repeat the tests. If impairments are found at the halfway point (test point `H'), that means the problem is somewhere between there and the node `N.' If there are no impairments, then the problem exists between the halfway point `H' and the customer premises `S.' After determining whether the problem is upstream or downstream of this location, go to a point halfway between `H' and either `N' or `S.' Continue dividing the signal path into smaller and smaller half sections until the problem is found.

The divide-and-conquer technique can be used to troubleshoot upstream problems, too.

Measurement and troubleshooting summary

A QAM analyzer is a very powerful tool for troubleshooting digitally modulated signals. Table 1 is a recap of several measurement and troubleshooting capabilities available in many of the instruments currently available to the cable industry.

Table 1

Learn to use the features available in your QAM analyzer! Many of these instruments perform a variety of pre-defined automated measurements, which can be thought of as somewhat analogous to using a modern digital single lens reflex (DSLR) camera in its fully automatic mode for "point-and-shoot" operation. Those same DSLRs include a variety of what can be called creative modes—shutter priority, aperture priority and even full manual operation—which give the photographer more control over the pictures being taken. Likewise, dig a little more deeply into the capabilities of QAM analysis and take advantage of sophisticated measurement functions for more in-depth troubleshooting of digitally modulated signals.

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