Power Measurements on DOCSIS Downstream QAM Signals

The DOCSIS downstream QAM signal is a complex digital modulation method that has become increasingly common with the proliferation of the cable modems in to the cable TV market. This significantly increases the chances that ARRIS engineers and technicians will encounter the QAM signals in engineering development labs, on the manufacturing floor, at the cable headend and at the subscriber sites. They will have to accurately determine the actual power level of a DOCSIS downstream QAM signal. Unfortunately, traditional methods of measuring signal power rely on the measurement of the carrier power of the communications or broadcast signal in question. These methods will fail with QAM signals since the QAM signal suppresses the carrier and places all the signal power in the noise like information-bearing portion of the signal. The noise like characteristics of the QAM signal render spectrum analyzer power measurements subject to errors if the analyzer has not been set up properly or if the error are not correctly compensated for. This paper will describe how to set up a spectrum analyzer with channel power or noise marker capabilities will accurately measure the DOCSIS downstream signal power either alone or in the presence of other channel signals (including adjacent channels).

For truly accurate power measurements, a calibrated RMS RF power meter can't be beat. These devices can give absolute power accuracy to +/- 0.25 dB or better. But the RMS RF power meter has one major flaw, the meter has no selectivity, so it measures the total power of all the signals at it's input port. This will work fine when the signal to be measured is significantly larger than any other signal on the coax or is the only signal on the coax, e.g.: when measuring the CMTS output power at it's output port. The RMS RF power meter performs poorly when you are trying to determine DOCSIS downstream QAM channel power after it has been combined with the rest of the video and digital data signals to form the cable plant downstream signal.

Since the DOCSIS Downstream QAM signal is noise like in nature, the methods for measuring noise power with a spectrum analyzer (Channel Power and Noise Marker functions) are useful in measuring the total signal power of the QAM signal. For noise power measurements on a spectrum analyzer, measurement errors will occur unless care is taken in setting up the spectrum analyzer mode. This paper will not dwell on all the details except to say that the non-linear logarithmic processing of the signals in the spectrum analyzers can result in significant measurement errors for noise like signals. The interested readers can educate themselves by getting the Hewlett Packard (now Agilent) application note AN-1303, titled Spectrum Analyzer Measurement and Noise. This AP-note goes into considerable detail explaining the many ways that a Spectrum Analyzer or a Vector Analyzer can introduce errors into a noise power measurement. It also explains to the operator how to correct for the errors.

This paper will describe how to set up a spectrum analyzer to accurately measure the channel power of a DOCSIS Downstream QAM signal without having to remember the corrective fudge factors that AP-1303 describes. This paper uses the methods from the AP-note to describe the proper setup of a spectrum analyzer that will allow fast, accurate measurement of channel power to the accuracy of the analyzer (~ +/- 1.5 dB for most analyzers). Two methods are given one using the Noise Marker function and the other

using the Channel Power function. Most spectrum analyzers produced in the late 90's have one or both of these functions built in. Some will automatically set up the analyzer in the proper configuration while the channel power or noise marker functions are engaged (use them when you can). My experience is that it requires detailed reading of the users manuals and/or long conversations with the spectrum analyzer applications engineers to determine how accurate these automatic setups are. Usually it is far quicker to evaluate or calibrate the spectrum analyzer automatic channel power results with a calibrated RMS RF power meter.

In the event that the analyzer available for your use does not support either of these modes, the analyzers can be used to estimate the channel power by a variety of means. Most involving taking a measurement and adding fudge factors to it to get the proper channel power. These methods are subject to measurement errors, operator interpretation errors and fudge factor errors. For this reason, I do not recommend them for use when absolute accuracy counts. For example, one of the most popular methods is to set the resolution bandwidth to the analyzers largest bandwidth or to the largest bandwidth above the channel bandwidth. Then set spectrum analyzer center frequency to the center frequency of the channel and set the marker to the center frequency of the channel. The marker power is the signal power estimate. The engineer/technician must then adjust the power estimate based on the relative ratio of the resolution bandwidth to channel bandwidth. In some cases, the engineer/technician must further adjust the channel power based on the best guess at how much of the adjacent channel signal bled through the resolution bandwidth filter and corrupted the power reading. In a pinch, this method can work, but this estimation technique is subject to a wide range of errors (+/- 5db and more) and is NOT recommended for use when absolute accuracy is needed.

To properly set up the spectrum analyzer to measure the noise like signals (QAM), some information about the measured signal must be known and is used to determine the spectrum analyzer set up. Specifically the signal bandwidth or channel bandwidth and the symbol rate needs to be known. For DOCSIS downstream, the signal bandwidth is 6 MHz with a symbol rate of 5.056941 MHz for QAM 64 and 6 MHz with a symbol rate of 5.360537 MHz for QAM 256. EURO-DOCSIS has an 8 MHz channel bandwidth with a symbol rate of 6.952 MHz for both QAM 64 and QAM 256.

1) **Preset analyzer to force it to the default mode.** For most units, this is accomplished by powering up the unit. On most HP spectrum analyzers pushing the green button labeled "preset" will work.
2) **Set the detector mode to sample mode.** This ensures that the value calculated by the spectrum analyzer for channel power or noise power are not biased up by the peak detector. Most analyzers have a detector sample mode, a detector peak mode and a detector minimum mode. Detector peak mode is typically the default mode so it will require active steps to switch to detector sample mode. Failure to set to ample mode can result up to a 3 to 5 dB error in channel power.
3) **Set the resolution bandwidth to less than 1/40 of the symbol rate**. This will ensure that each frequency point measurement is the result of at least 35 to 40 symbols, thus ensuring a valid statistical sample. For all DOCSIC downstream signals use 100KHz.

DOCSIS downstream QAM 64 at 5.056941 MHz (5.056941MHz/40= 126.4KHz => use 100KHz RBW),
DOCSIS downstream QAM256 at 5.360537 MHz (5.360537MHz/40= 134.0KHz => use 100KHz RBW).
DOCSIS downstream QAM 64 at 6.952 MHz (6.952MHz/40= 173.8KHz => use 100KHz RBW),
DOCSIS downstream QAM256 at 6.952 MHz (6.952MHz/40= 173.8KHz => use 100KHz RBW).

4) **Set video bandwidth (VBW) to 10 times the resolution bandwidth (RBW)** VBW = RBW * 10. DOCSIS downstream 100 KHz * 10 = 1 MHz. This ensures that the video filters averaging effect causes no more than 0.1dB error.
5) **Set input attenuation to place input signal in the spectrum analyzers linear range** (see cautions 1 and 2 below).
6) **Set span to be 1.2 to 1.4 times the signal bandwidth and check that ~400 frequency steps are used across the span (401 is the HP default setting).** This ensures that an adequate number of samples across the signal bandwidth are used to calculate the channel power. For the 6 MHz DOCSIS bandwidth set span to 8 MHz (8MHz / 6MHz = 1.333), For the 8 MHz DOCSIS bandwidth set span to 10 MHz (10MHz / 8MHz = 1.250).
7) **Set spectrum analyzer center frequency to center frequency of signal or channel to be measured.**
8) **Set spectrum analyzer to display channel power over signal bandwidth.** Channel bandwidth for DOCSIS downstream = 6MHz US or 8 MHz EURO-DOCSIS. Read signal channel power off screen.

If the Spectrum analyzer does not have a channel power option, but has a noise marker function that gives noise power in dBm/Hz, the noise power function can be used to measure channel power.

1) **Preset analyzer to force it to the default mode.** For most units, this is accomplished by powering up the unit. On most HP spectrum analyzers pushing the only green button labeled "preset" will work.
2) **Set the detector mode to sample mode.** This ensures that the value calculated by the spectrum analyzer for channel power or noise power are not biased up by the peak detector. Most analyzers have a detector sample mode, a detector peak mode and a detector minimum mode. Detector peak mode is typically the default mode so it will require active steps to switch to detector sample mode. Failure to set to ample mode can result up to a 3 to 5 dB error in channel power.
3) **Set the resolution bandwidth to less than 1/40 of the symbol rate**. This will ensure that each frequency point measurement is the result of at least 35 to 40 symbols, thus ensuring a valid statistical sample. For all DOCSIC downstream signals use 100KHz.
DOCSIS downstream QAM 64 at 5.056941 MHz (5.056941MHz/40= 126.4KHz => use 100KHz RBW),
DOCSIS downstream QAM256 at 5.360537 MHz (5.360537MHz/40= 134.0KHz => use 100KHz RBW).
DOCSIS downstream QAM 64 at 6.952 MHz (6.952MHz/40= 173.8KHz => use

100KHz RBW),
DOCSIS downstream QAM256 at 6.952 MHz (6.952MHz/40= 173.8KHz => use 100KHz RBW).

4) **Set video bandwidth (VBW) to 10 times the resolution bandwidth (RBW)** VBW = RBW * 10. DOCSIS downstream 100 KHz * 10 = 1 MHz. This ensures that the video filters averaging effect causes no more than 0.1dB error.
5) **Set input attenuation to place input signal in the spectrum analyzers linear range** (see cautions 1 and 2 below).
6) **Set span to be 1.2 to 1.4 times the signal bandwidth and check that ~400 frequency steps are used across the span (401 is the HP default setting)**. This ensures that an adequate number of samples across the signal bandwidth are used to calculate the channel power. For the 6 MHz DOCSIS bandwidth set span to 8 MHz (8MHz / 6MHz = 1.333), For the 8 MHz DOCSIS bandwidth set span to 10 MHz (10MHz / 8MHz = 1.250)
7) **Set spectrum analyzer center frequency to center frequency of signal to be measured.**
8) **Turn on noise marker function and set noise marker to channel center frequency.**
9) **Read noise marker power in dBm/Hz. To get the channel power add the correction factor of 10*log (symbol rate in Hz) to the noise marker power.** (Symbol rate must be in Hz.) For the 6 MHz DOCSIS signals: the QAM64 correction factor is 67.0 dB, the QAM256 correction factor is 67.3 dB. For EURO-DOCSIS QAM 64 and QAM 256 the correction factor is 68.4 dB.

The above methods will allow accurate channel power measurement as long as the following four cautions are observed:

Caution 1: care must be taken when measuring noise like signals in the presence of wide band signals (e.g. the 50 MHz to 860 MHz combined cable plant downstream signal). If the linear power limit of the spectrum analyzer is exceeded, signal compression in the Spectrum Analyzer front end can produce inter-modulation products. These inter-modulation products can result in power measurement errors, especially when measuring low-level signals in the presence of high power signals. To determine if this is a problem: A) Take the power measurement. B) Then add a 3-dB attenuator at the spectrum analyzer input and the signal source and re-measure the power. C) If adding 3-db attenuation between the analyzer input and the measured signal results in more than 3-db signal power reduction then the spectrum analyzer front end is in compression and the measurement is in error.

Caution 2: If spectrum analyzer noise floor is within 15 dB of the QAM signal "Flattop", spectrum analyzer noise will cause the measured power to read too high by more than 0.1 dB. This error can be corrected for by measuring the channel power of the signal plus the spectrum analyzer noise and then measuring the channel power of the spectrum analyzer noise power alone. To measure spectrum analyzer noise power alone, terminate the spectrum analyzer input with a 50-ohm load (75 ohm for 75 ohm-input analyzers). Both power measurements must be converted to converted to Watts, the

signal power can be found by subtracting the noise channel power (in Watts) from the signal plus the spectrum analyzer noise power (in Watts). The closer the QAM "Flattop" is to the noise floor the more uncertain this signal power calculation becomes. This process will work reliably to within 6 dB above the noise floor. Note: reducing the resolution bandwidth (RBW) will NOT allow you to pull the QAM signal out of the noise floor (as with tones). The noise power and the QAM signal in the resolution bandwidth filters are reduced by same amount thus the ratio will remain the same.

Caution 3: DOCSIS signals are defined for 75 ohm impedance coax, most spectrum analyzers and RMS RF power meters are designed for 50 ohm impedance coax. Therefore, a 75 to 50 ohm min-loss pad or a 75 to 50 ohm impedance transformer should be used at the measuring device to prevent mismatch errors. In either case, the loss of the transformation device (5.7 dB for the min-loss pad) will reduce the power input to the spectrum analyzer or RMS RF power meter by the same loss. This loss needs to be added to the power reading to get the correct power level. (Ignore this is you are using a 75-ohm spectrum analyzer or RMS RF power meter).

Caution 4: This method of channel power measurement is NOT valid for DOCSIS Upstream signals due to the burst nature of the upstream signals. Using these methods for upstream power measurement will significantly under report the burst QAM signal power. The amount of the under report will vary depending on the amount of upstream traffic that occurs during the measurement.

In summary for DOCSIS downstream signals, the relevant parameters for accurate spectrum analyzer setup are:

QAM	Baud rate (Hz)	Channel Bandwidth	Min Resolution Bandwidth	Min Video Bandwidth	Detector Mode	Span	Noise Marker Correction Factor
64	5,056,941	6 MHz	100KHz	1MHz	sample	8MHz	67.0 dB
256	5,360,537	6 MHz	100KHz	1MHz	sample	8MHz	67.3 dB
64	6,952,000	8 MHz	100KHz	1MHz	sample	10MHz	68.4 dB
256	6,952,000	8 MHz	100KHz	1MHz	sample	10MHz	68.4 dB

Questions on this paper can be directed to:

==========

Jerry Archambault, BSEE, MSEE
RF Systems Architect
ARRIS, Inc.
6 Riverside Dr.
Andover, MA 01810-1140

jerry.archambault@arrisi.com
Phone: 978-946-4689
FAX: 978-946-4900
esn: 243-4689
Visit our web site at http://www.arrisi.com
also visit http://www.arrisi.com/products/cornerstone/data/cmts.html

==========