white paper

Measuring Cable TELEVISION Network Downstream Signal Amplitudes

Summary

Many of today's signal level meters, spectrum analyzers, and quadrature amplitude modulation (QAM) analyzers support the measurement of both analog TV channels and 64- and 256-QAM digitally modulated carriers. TV channel signal level or amplitude generally refers to the channel's visual carrier amplitude, which is defined as the root mean square (rms) value of the instantaneous synchronizing peak. Digitally modulated carrier amplitude is a measure of the signal's average power.

Note: Analog TV channel visual carrier amplitude and digitally modulated carrier average power are commonly measured in decibel millivolt (dBmV), a unit of power expressed in terms of voltage. Mathematically, dBmV = 20log (signal amplitude in millivolts/1 millivolt).

When configuring, maintaining, or troubleshooting a DOCSIS® cable modem termination system (CMTS), one important task is to make certain that the 64- or 256-QAM digitally modulated carrier's average power is correct. This applies to CMTSs that use external upconverters, as well as those with integrated upconverters.

This document summarizes the step-by-step procedures pertaining to the measurement of analog TV channel and downstream digitally modulated carrier amplitudes using Agilent's (formerly Hewlett-Packard's) 8591C spectrum analyzer. Many other makes and models of test equipment support similar measurements. Consult the respective manufacturer's technical documentation for details.

Caution: Take appropriate precautions for ESD protection when performing the measurements described in this document. As well, connect the spectrum analyzer to the same AC circuit as the equipment that is being measured.

CMTS Configuration

Before measuring CMTS downstream digitally modulated carrier amplitude, ensure that the CMTS's configuration is correct. Cisco® CMTSs that use external upconverters—for instance, the Cisco uBR7246VXR Universal Broadband Router with MC16C line cards—provide a 44 MHz center frequency downstream intermediate frequency (IF) output. Euro-DOCSIS® line cards provide a 36.125 MHz center frequency downstream IF output.

The Cisco IOS® Software command to turn on the downstream IF output is:

```
cable downstream IF-output
```

This command is enabled by default. Cisco Systems® line cards that require external upconverters are labeled with the nominal downstream IF output power. The downstream IF output amplitude is not adjustable.

Note: Refer to the upconverter manufacturer's technical documentation for information about external upconverter setup and configuration.

The Cisco uBR7100 Series Universal Broadband Router, Cisco 5x20U and 5x20S Broadband Processing Engines for the Cisco uBR10012 Universal Broadband Router, and Cisco uBR7200 Series MC28U and MC16U Broadband Processing Engines for the Cisco uBR7246VXR product feature integrated upconverters. Downstream radio frequency (RF) output frequency and amplitude are user adjustable. You may configure the integrated upconverter with the following Cisco IOS Software commands, where `down-freq-hz` is the digitally modulated carrier's center frequency in hertz, and `power-level` is the digitally modulated carrier's average power in dBmV:

```
cable downstream frequency down-freq-hz

no cable downstream rf-shutdown

cable downstream rf-power power-level
```

When using high-availability configurations, the downstream RF output power will be synchronized from the working interface to the protect interface in Cisco IOS Software Release BC2 code and greater. It may be preferable to not synchronize the level over, and preconfigure the protect interface for a set output level. It also may be preferable to set a delta on the protect interface as compared to the working interface.

A command configured on the protect interface exists to achieve this:

```
cable downstream rf-power {power-level | hccp-delta diff-pwr | hccp-override override-pwr}|

where power-level equals the desired RF output power level in dBmV. The valid range is +45 to
+63 dBmV.
```

Note: The official range for acceptable power levels in the DOCSIS standard is +50 to +61 dBmV. Cisco cable interfaces exceed DOCSIS, but power levels beyond the DOCSIS-specified values should be used only in lab and test environments.

`hccp-delta diff-pwr` (applicable to protect interfaces only):

When using N+1 hot standby connection-to-connection protocol (HCCP) redundancy, the protect interface adds the `diff-pwr` value to the current working interface's power value when a switchover occurs. This allows the router to accommodate relative differences between the RF power levels in the working and protect interfaces. The valid range for `diff-pwr` is -12 to +12 dB.

`hccp-override override-pwr` (applicable to PROTECT interfaces only):

When using N+1 HCCP redundancy, the protect interface uses the `override-pwr` value instead of the working interface's current RF power value when a switchover occurs. This allows the router to accommodate absolute differences between the RF power levels in the working and protect interfaces. The valid range for `override-pwr` is +45 to +63 dBmV.

Configuration Example

To configure an integrated upconverter to operate on cable channel 62 (453 MHz center frequency) and +56 dBmV output power for slot 8, subslot 0, downstream port 0, use the following commands:

```
conf t

int c8/0/0

ubr(config-if)#cable downstream frequency 453000000

ubr(config-if)#no cable downstream rf-shutdown

ubr(config-if)#cable downstream rf-power 56
```

Confirm with the command:

```
show controllers cable {slot/port | slot/subslot/port} [downstream|upstream [port]]
```

Note: Leaving downstream or upstream out of the command will provide details that include the integrated upconverter's downstream frequency and power level. For example, the command show controllers cable 8/0/0 displays interface controllers information for slot 8, subslot 0, downstream port 0:

```
ubr10k#sh contr c8/0/0

Interface Cable8/0/0

Hardware is MC520S

JIB version 15


Cable 8/0/0 JIB hardware status:

  JIB Downstream port   Enabled


  JIB Upstream   port 0 Enabled

  JIB Upstream   port 1 Enabled

  JIB Upstream   port 2 Enabled

  JIB Upstream   port 3 Enabled

  JIB Upstream   port 4 Enabled
```

```
…

…

  Upconverter:  Wavecom

 Cable8/0/0 Upconverter is Enabled Output is Enabled

  Model: 74-2094-05 Serial Number: 0WAV0626005U CLEI Code: FFFFFFFFFF

  HW Rev:    PC2D0108 SW Rev: 010, NVRAM Rev: 006 ECI number FFFFFF

  Downstream Frequency 453.0000 MHz

  RF Power 56.0 dBmv

…

  Cable8/0/0 Downstream is up

  Frequency 453.0000 MHz, Channel Width 6 MHz, 64-QAM, Symbol Rate 5.056941 Msps

  FEC ITU-T J.83 Annex B, R/S Interleave I=32, J=4

Downstream channel ID: 0
```

For more information about cable-specific Cisco IOS Software commands, refer to the *Cisco Broadband Cable Command Reference Guide*, available online at: http://www.cisco.com/univercd/cc/td/doc/product/cable/bbccmref/index.htm

Analog TV channel amplitude measurement

The DOCSIS *Radio Frequency Interface Specification* recommends that the average power of a downstream digitally modulated carrier be set 6 dB to 10 dB below what the amplitude of an analog TV channel on the same frequency would be. Before measuring or setting the amplitude of a digitally modulated carrier, first measure the amplitude of the cable network's analog TV channels.

Note: Refer to the headend equipment manufacturer's technical documentation for information about modulator and processor RF amplitude adjustment.

Plug the 8591C into a convenient AC power source—preferably one that is on the same electrical circuit or phase as the equipment being measured—and press the <LINE> button to turn on the instrument. Let the spectrum analyzer warm up for 15 to 30 minutes, then perform a full amplitude and frequency calibration (refer to the 8591C's instruction manual). Be sure to store the new calibration settings.

After warm-up and calibration, connect the analyzer to the RF source being measured. The 8591C is capable of automated carrier amplitude measurements, which will reduce the likelihood of user error. The following provides an example of how to measure the amplitude of an analog TV channel.

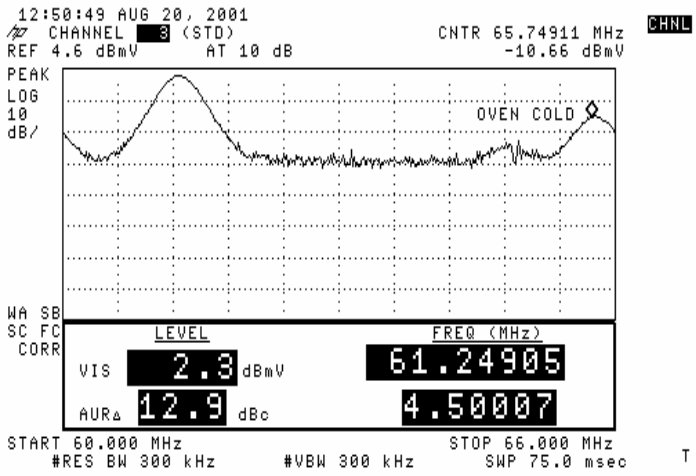
Note: The procedure described here assumes the 8591C's internal cable TV channel plan has been set to North American standard (STD) channelization.

To measure cable channel 3, press the following keys in the order shown:

<MODE> <CABLE TV ANALYZER> <CHANNEL MEAS> <CHANNEL SELECT> <3> <ENTER> <CARRIER LVL & FREQ>

The analyzer will perform the amplitude measurement automatically (see Figure 1), and indicate the visual carrier amplitude and visual-to-aural carrier amplitude delta. If the frequency measurement function has been activated, the analyzer also will display carrier frequencies. To conclude the carrier measurement, press <MAIN MENU>.

Figure 1. Analog TV Channel Measurement



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To measure a second analog TV channel, for example channel 78, press the following keys in the order shown below:

<CHANNEL SELECT> <7> <8> <ENTER> <CARRIER LVL & FREQ>

When the level measurement is complete, press <MAIN MENU>.

Where to Measure CMTS Downstream Power

Figure 2 shows where signals should be measured when using an external upconverter. It is highly recommended that all three points be measured to ensure proper CMTS downstream: IF output amplitude, upconverter IF input amplitude, and upconverter RF output amplitude. Check the upconverter manufacturer's specifications for recommended IF input amplitude. Typical values are +25 to +35 dBmV, which means that in most cases an in-line attenuator between the CMTS downstream IF output and external upconverter IF input will be necessary. The upconverter's RF output should be in the +50 to +61 dBmV range specified by DOCSIS, with +55 to +58 dBmV being fairly typical. Keep in mind that the specified absolute amplitude

accuracy of most test equipment is generally around ±2 dB. Measurement results within 2 to 3 dB of the expected value are acceptable.

Measure downstream output power from CMTSs and line cards with integrated upconverters directly at the downstream output (Figure 3).

Caution: To avoid the possibility of damaging the MCX connectors used on the Cisco 5x20U or 5x20S Broadband Processing Engines, do not attempt to connect an F connector-equipped test lead directly to the line card connector. Instead, connect the spectrum analyzer to the end of a downstream cable that is already connected to the line card, to a convenient test point, or the output of the external RF switch (if used). Be sure to account for attenuation between the line card's output connector and spectrum analyzer input. If a direct connection to the line card's MCX connector is found to be necessary, use an appropriate MCX-to-F adapter (part number MCXF/FF), available from White Sands Engineering: http://www.whitesandsengineering.com

Figure 2. Downstream Measurement Test Points (External Upconverter)

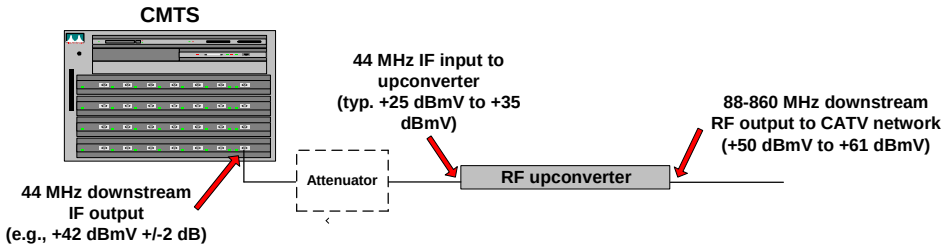
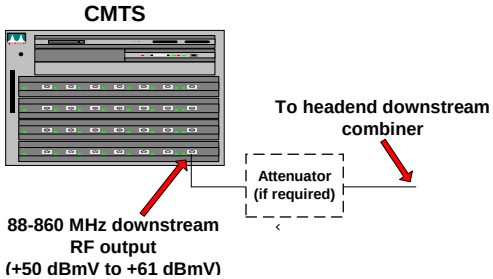


Figure 3. Downstream Measurement Test Point (Integrated Upconverter)



Downstream digitally modulated carrier amplitude

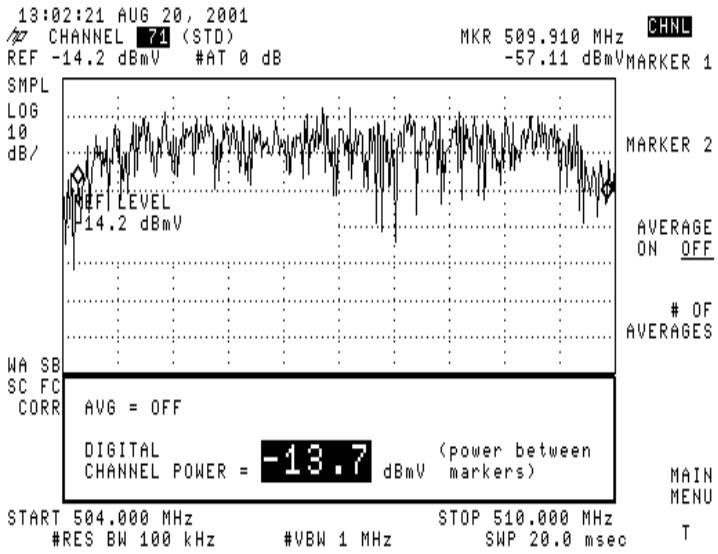
The following steps will provide an accurate measurement of a 64- or 256-QAM digitally modulated carrier's average power, using the 8591C's digital channel power measurement function. This can be done immediately following analog TV channel level measurements.

Note: The procedure described here assumes that the 8591C's internal cable TV channel plan has been set to North American standard (STD) channelization.

For instance, to measure the amplitude of a digitally modulated carrier on channel 71 (507 MHz center frequency), press the following keys in the order shown. See Figure 4. These steps assume the 8591C is still in "cable TV analyzer" mode.

<CHANNEL SELECT> <7> <1> <ENTER> <MAIN 1 OF 3> <MAIN 2 OF 3> <DIGITAL CH POWER> <AVERAGE ON OFF>

Figure 4. Annex B Digital Channel Power Measurement



Turning on the digital channel power average function will allow the analyzer to perform 10 measurements and average the results. When the 10 measurements are complete, record the result, then press <MAIN MENU> to conclude the measurement.

Note: Digital channel power average function is not the same thing as the spectrum analyzer's video average function. Make sure that video average is not turned on during these measurements; otherwise the displayed digital channel power will be as much as 2.5 dB below its actual value.

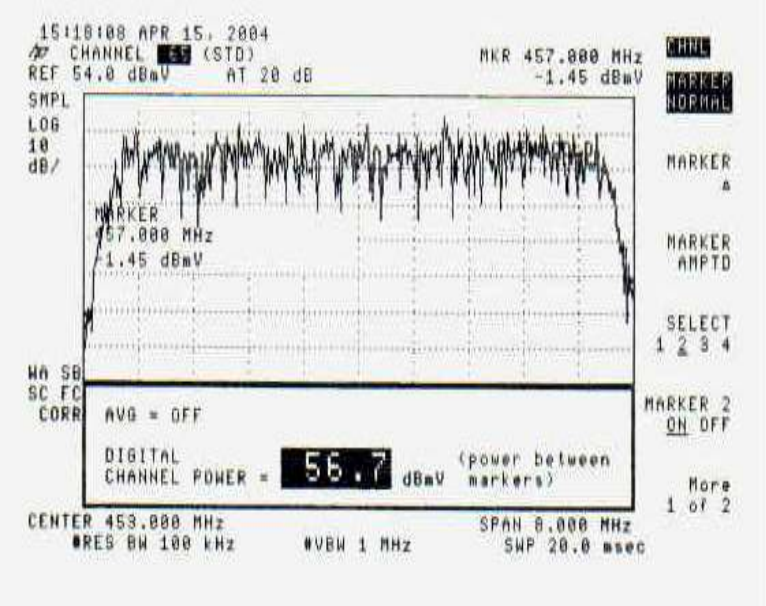
Measuring Annex A digitally modulated carriers

When the 8591C's cable channel plan is set to North American STD, the following steps may be used to measure 8 MHz bandwidth Annex A digitally modulated carrier average power.

For instance, to measure the amplitude of a 453 MHz center frequency Euro-DOCSIS digitally modulated carrier, press the following keys in the order shown. These steps assume the 8591C is still in "cable TV analyzer" mode. See Figure 5.

<CHANNEL SELECT> <6> <5> <ENTER> <MAIN 1 OF 3> <MAIN 2 OF 3> <DIGITAL CH POWER> <AVERAGE ON OFF> <FREQUENCY> <CENTER FREQ> <4> <5> <3> <MHZ> <SPAN> <SPAN> <8> <MHZ> <AMPLITUDE> <⇑> or <⇓> <MKR> <SELECT 1> <4> <4> <9> <MHZ> <SELECT 2> <4> <5> <7> <MHZ>

Figure 5. Annex A Digital Channel Power Measurement



Conclusion

When followed, these procedures help ensure an accurate measurement of analog TV channel and downstream digitally modulated carrier amplitudes using Agilent Technologies' 8591C spectrum analyzer. This helps ensure the 64- or 256-QAM digitally modulated carrier's average power is correct. General procedures here apply to other makes and models of test equipment. For specific step-by-step procedures, however, please consult the respective manufacturer's technical documentation.

References

Cisco uBR Series Hardware Installation Guide, Chapter 4 - Connecting the Cisco uBR7200 Series Router to the Cable Headend
http://www.cisco.com/en/US/products/hw/cable/ps2217/products_installation_guide_book09186a0080227a82.html

"Obtain Power Measurements of a DOCSIS Downstream Signal Using a Spectrum Analyzer" (Cisco Document ID: 47064)
http://www.cisco.com/en/US/tech/tk86/tk319/technologies_tech_note09186a00801f9789.shtml

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