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Network Operations Subcommittee

SCTE OPERATIONAL PRACTICE

SCTE 258 2020

DOCSIS 3.1 Downstream OFDM Power Definition, Calculation, and Measurement Techniques

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1. Introduction

1.1. Executive Summary

Cable operators are familiar with characterizing and measuring downstream per-channel RF power, or signal level, for 6 MHz- and 8 MHz-wide analog TV signals and single carrier quadrature amplitude modulation (SC-QAM) signals. Analog TV channel signal level in most cases refers to the visual carrier's peak envelope power (PEP).[1] An SC-QAM channel's signal level is its average power, also known as digital channel power or digital signal power.[2]

DOCSIS 3.1 uses orthogonal frequency division multiplexing (OFDM) in the downstream. The nature of OFDM is such that transmission is not limited to legacy 6 MHz and 8 MHz channel bandwidths. Indeed, DOCSIS 3.1 supports downstream OFDM signals with a minimum modulated spectrum of 22 MHz to a maximum encompassed spectrum of 190 MHz, which occupy at least 24 MHz and 192 MHz respectively, including a portion of the OFDM band-edge spectral skirts (taper regions).

Since the introduction of DOCSIS 3.1, there have been many questions about how to quantify downstream OFDM channel power. The DOCSIS 3.1 Physical Layer Specification [1] ("DOCSIS 3.1 PHY spec") includes details about CMTS downstream transmit signal fidelity and power. This Operational Practice explains the channel power-related parameters included in the specification, how OFDM power is measured, and includes examples to illustrate how to calculate these parameters. The reader is urged to review Sections 7.5.9 and 7.5.10 of the DOCSIS 3.1 PHY spec for more information.

1.2. Scope

The DOCSIS 3.1 PHY spec's description of downstream OFDM transmit power calculation can be confusing for some. The material in this Operational Practice is divided into two major parts. The first part discusses the measurement of OFDM power, and the second part explains how OFDM signal power is calculated for the purpose of establishing downstream signal fidelity requirements.

1.3. Intended Audience

The intended audience of this Operational Practice is cable industry technical personnel who are involved with deployment, operation, and maintenance of DOCSIS 3.1 technology.

1.4. Areas for Further Investigation or to be Added in Future Versions

A future version of this Operational Practice – or a new Operational Practice – could include an overview of DOCSIS 3.1 orthogonal frequency division multiple access (OFDMA) upstream transmit power.

2. Normative References

The following documents contain provisions, which, through reference in this text, constitute provisions of this document. At the time of Subcommittee approval, the editions indicated were valid. All documents are subject to revision; and while parties to any agreement based on this document are encouraged to

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[1] Peak envelope power is the average power of one cycle during the modulation crest. The modulation crest of an analog TV signal's modulated visual carrier occurs during synchronizing pulses.
[2] Digital channel power or digital signal power is the average power of the entire SC-QAM signal, across its occupied bandwidth (i.e., 6 MHz or 8 MHz).

investigate the possibility of applying the most recent editions of the following documents, they are reminded that newer editions of those documents might not be compatible with the referenced version.

2.1. SCTE References

- No normative references are applicable.

2.2. Standards from Other Organizations

- No normative references are applicable.

2.3. Published Materials

- No normative references are applicable.

3. Informative References

The following documents might provide valuable information to the reader but are not required when complying with this document.

3.1. SCTE References

- No informative references are applicable.

3.2. Standards from Other Organizations

- [1] Data-Over-Cable Service Interface Specifications DOCSIS® 3.1 Physical Layer Specification (CM-SP-PHYv3.1-I16-190121)
- [2] Data-Over-Cable Service Interface Specifications Downstream RF Interface Specification (CM-SP-DRFI-I14-131120)

3.3. Published Materials

- Hranac, R., “The Power of QAM,” *Communications Technology*, October 2006
- Hranac, R., “Total Power,” *Communications Technology*, October 2008
- Hranac, R., “Total Power, Part 2,” *Communications Technology*, November 2008
- Hranac, R., “dBmV: Voltage or Power? (Part 1),” *Communications Technology*, July/August 2011
- Hranac, R. “dBmV: Voltage or Power? (Part 2),” *Communications Technology*, September/October 2011

4. Compliance Notation

shall	This word or the adjective "***required***" means that the item is an absolute requirement of this document.
shall not	This phrase means that the item is an absolute prohibition of this document.
forbidden	This word means the value specified shall never be used.
should	This word or the adjective "*recommended*" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighted before choosing a different course.
should not	This phrase means that there may exist valid reasons in particular circumstances when the listed behavior is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behavior described with this label.
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deprecated	Use is permissible for legacy purposes only. Deprecated features may be removed from future versions of this document. Implementations should avoid use of deprecated features.

5. Abbreviations and Definitions

5.1. Abbreviations

CCAP	converged cable access platform
ceil	ceiling function
CMTS	cable modem termination system
CTA	Consumer Technology Association (formerly Consumer Electronics Association)
dB	decibel
dBmV	decibel millivolt
DOCSIS	Data-Over-Cable Service Interface Specifications
DRFI	[DOCSIS] Downstream RF Interface [Specification]
e.g.	for example (*exempli gratia*)
FFT	fast Fourier transform
HFC	hybrid fiber/coax

Hz	hertz
i.e.	that is (*id est*)
kHz	kilohertz
ln	natural logarithm
log	logarithm
MHz	megahertz
NTSC	National Television System Committee
OFDM	orthogonal frequency division multiplexing
OFDMA	orthogonal frequency division multiple access
PEP	peak envelope power
PHY	physical layer
QAM	quadrature amplitude modulation
RF	radio frequency
SC-QAM	single carrier quadrature amplitude modulation
TV	television

5.2. Definitions

ceiling (ceil)	A mathematical function that returns the lowest-valued integer that is greater than or equal to a given value.
CTA channel	A 6 MHz portion of the RF spectrum based upon CTA-542-D R-2018 Cable Television Channel Identification Plan (formerly CEA 542-D).
decibel millivolt (dBmV)	Unit of RF power expressed in terms of voltage, defined as decibels relative to 1 millivolt, where 1 millivolt equals 13.33 nanowatts in a 75 ohm impedance. Mathematically, dBmV = 20log(value in mV/1 mV).
encompassed spectrum	See Section 10.
minimum	The smallest value in a set.
modulated spectrum	See Section 10.
N	The number of legacy DOCSIS channels per RF port that a CMTS or other signal source is capable of generating.
N_{eq}	The number of *equivalent* legacy DOCSIS channels per RF port a CMTS or other signal source is capable of generating, defined by the formula $N_{eq} = N + 32 * N_{OFDM}$

N_{eq}'	The number of *active* equivalent legacy DOCSIS channels a CMTS or other signal source generates per RF port.
N_{OFDM}	The number of downstream OFDM channels per RF port a CMTS or other signal source is capable of generating.
N*	The *adjusted* number of active channels combined per RF port. See Section 7 and the Appendix.
occupied bandwidth	See Section 10.
OFDM power	The average RF power of an OFDM signal, which is usually characterized in two ways: (1) OFDM power per CTA channel – that is, the average power per 6 MHz (which may not be uniform across the OFDM signal because of exclusion bands and other factors). Also called OFDM channel power. (2) OFDM total power: The average power over the entire occupied bandwidth of the OFDM signal, defined mathematically as Total power = Power per CTA channel + $10\log_{10}$(Number of CTA channels occupied by the OFDM signal).
peak envelope power (PEP)	The average power (watts) during one cycle of the RF signal at the crest of the modulation envelope.
power	The rate at which work is done, or energy per unit of time, expressed in watts. 1 watt of power is equal to 1 volt causing a current of 1 ampere. Mathematically, $P_{AVG} = I_{RMS}*E_{RMS}*\cos\theta$, where P_{AVG} is average power, I_{RMS} is root mean square current, E_{RMS} is root mean square voltage, and $\cos\theta$ is the cosine of the phase angle difference in degrees between the current and voltage.
power per CTA channel	The average power in a 6 MHz bandwidth, expressed in dBmV.
total power	The combined power of all signals and/or signal components in a defined bandwidth.

6. Part 1: OFDM RF Power Measurement

6.1. Cable Network Signal Levels

Cable operators for decades have measured the signal level of analog TV channels in terms of the PEP of the visual carrier. Figures 1 and 2 show examples of per-channel NTSC visual and aural carrier level measurements using commonly available test equipment.

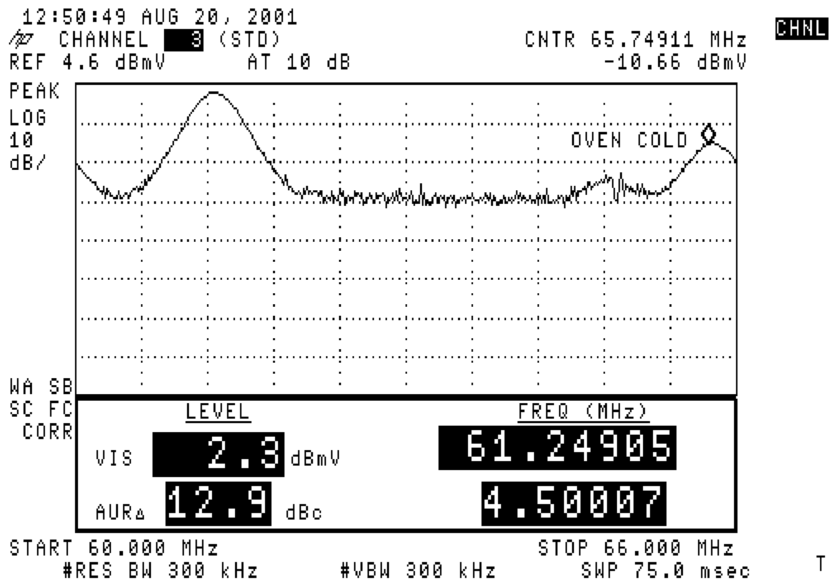

Figure 1. Spectrum analyzer measurement of analog TV channel signal levels. Courtesy of Hewlett Packard/Agilent (now Keysight).

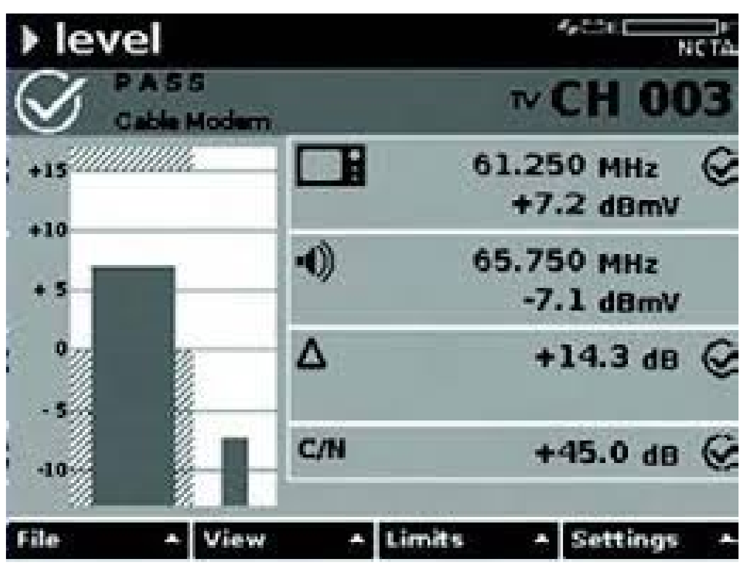

Figure 2. Signal level measurement of analog TV channel signal levels. Courtesy of JDSU (now Viavi Solutions, Inc.).

When cable operators started carrying digital signals on their networks, quantifying the signal level of those digital signals was at first difficult. Field instruments available at the time were not designed to measure an SC-QAM signal's average power. Some operators tried to use a spectrum analyzer to visually compare the height of the QAM "haystack" to the height of an adjacent analog TV channel's visual carrier, but this often resulted in incorrect levels (a spectrum analyzer's displayed SC-QAM signal "haystack" height varies with different instrument resolution bandwidth settings). Over time, cable TV test equipment manufacturers incorporated digital channel power measurement capability into their products, which typically involves an automatic measurement of several small "slices" across the SC-QAM signal's bandwidth and integrating the results to provide the equivalent of what a thermocouple power meter would measure. Examples are shown in Figures 3 and 4.

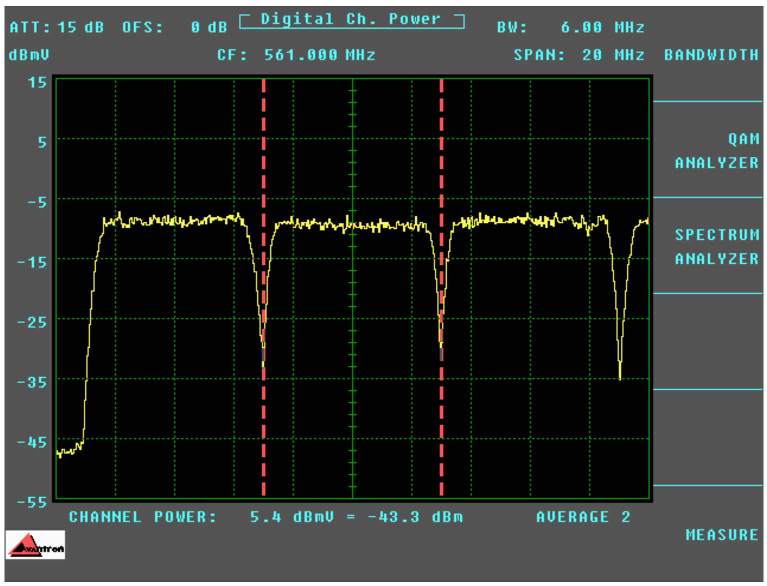

Figure 3. Digital channel power measurement (between the two vertical markers) of a 6 MHz-wide SC-QAM signal. Courtesy of Sunrise Telecom (now VeEx).

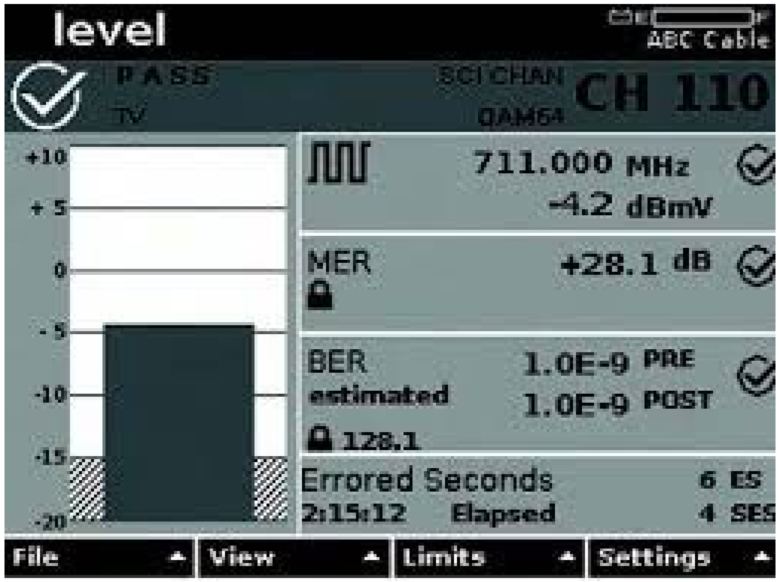

Figure 4. Digital channel power measurement using a cable TV signal level meter. Courtesy of JDSU (now Viavi Solutions, Inc.).

6.2. Enter DOCSIS 3.1

What happens when the power being measured is that of a DOCSIS 3.1 OFDM signal? If the OFDM signal occupies 192 MHz, how does one characterize the signal's average power? Per-subcarrier? The full 192 MHz? Or some other parameter?

The RF power of an OFDM signal is usually characterized in two ways: power per CTA channel – that is, the OFDM signal's RF power per 6 MHz – and the OFDM signal's total power. When measuring an OFDM signal's power per 6 MHz or total power, care should be taken during the measurement to ensure accurate results, especially with respect to test equipment configuration.[3]

6.2.1. Power per 6 MHz

Expressing OFDM power as the RF power per CTA channel provides signal level information comparable to SC-QAM digital channel power.

Figure 5 illustrates OFDM power (commonly called OFDM channel power) as measured by a third-party field meter. The OFDM signal being measured is 96 MHz wide. Each short blue horizontal line represents power per 6 MHz. Note that in addition to the graphical representation of OFDM channel power, the instrument also reports the average power, and the maximum and minimum power – all power per 6 MHz values.

[3] Some instruments support user-selectable detectors, and other instruments select the detector type automatically without the need for user intervention. Incorrect detector type could impact the accuracy of the measurement results. Refer to the test equipment manufacturer's instructions for recommendations on detector selection (if applicable) for measuring the average power of the OFDM signal.

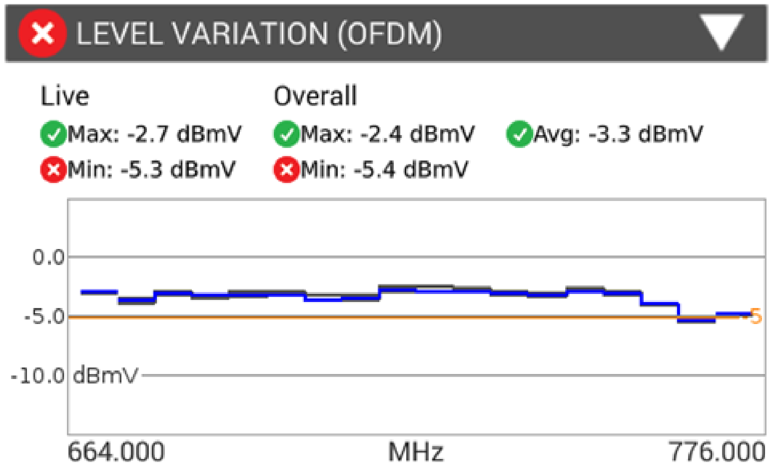

Figure 5. Example of OFDM channel power (power per 6 MHz) reported by a field meter for a 96 MHz-wide OFDM signal.

When configuring an OFDM signal source's RF output power, in most cases the OFDM channel power should be set to achieve the same power spectral density (PSD) as SC-QAM signals (that is, the same average power per 6 MHz). In other words, the heights of the OFDM and SC-QAM "haystacks" as seen on a spectrum analyzer should be the same. See Figure 6. Note: The "spikes" sticking up above the top of the OFDM signal in Figure 6 are the signal's continuous pilots, which are boosted by 6 dB relative to the power of the data subcarriers. The pilots are visible in this example because of the test equipment's resolution bandwidth and video bandwidth settings. The tops of those pilots should not be used when matching the OFDM signal's PSD with that of the SC-QAM signals.

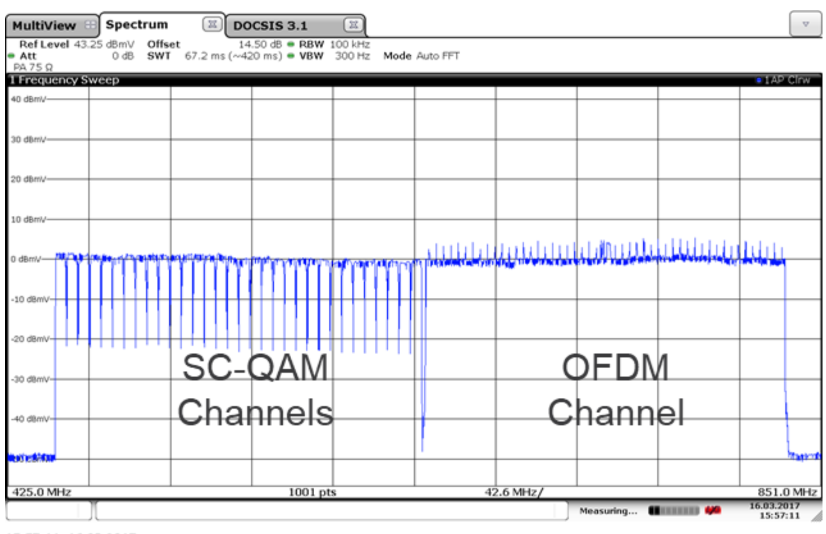

Figure 6. Spectrum analyzer display showing SC-QAM signals and an OFDM signal with the same PSD.

6.2.2. Total Power

A DOCSIS 3.1 OFDM signal's total power is measured as the average power over virtually the entire spectrum of the OFDM signal. This is the same as is done when measuring the digital channel power of a legacy DOCSIS SC-QAM signal, except legacy SC-QAM signals have an occupied bandwidth of 6 MHz or 8 MHz. For DOCSIS 3.1 OFDM signals, while the bandwidth is not time-varying, it can take on any of a range of values. As with legacy SC-QAM channels, a DOCSIS 3.1 OFDM signal's spectrum rolls off rapidly at the lower and upper band edges, where there is still signal power in the skirts of the modulated subcarriers which are at the edges of the modulated spectrum.

A DOCSIS 3.1 OFDM channel includes at least 1 MHz of spectrum without modulated subcarriers – also known as the "taper region"[4] – located at each band edge. The OFDM channel then consists of all the CTA channels which contain any portion of the band edge spectral taper regions, and all the CTA channels in between; the sum of the bandwidth of all these CTA channels (which is a multiple of 6 MHz) is the occupied bandwidth of the OFDM channel. All of this occupied bandwidth, a multiple of 6 MHz, should be included in the total power measurement. The total power of the OFDM signal is its average power, although some negligible skirt power beyond the occupied bandwidth exists and is overlooked. Still, this is virtually all the spectrum of the OFDM signal and virtually the total power of the OFDM signal. Figure 5 shows a total power measurement of a downstream OFDM signal, in which the total power between the two vertical markers is 59.68 dBmV. In this example the OFDM channel bandwidth is 96 MHz, which includes a taper region at each band edge of the OFDM signal.

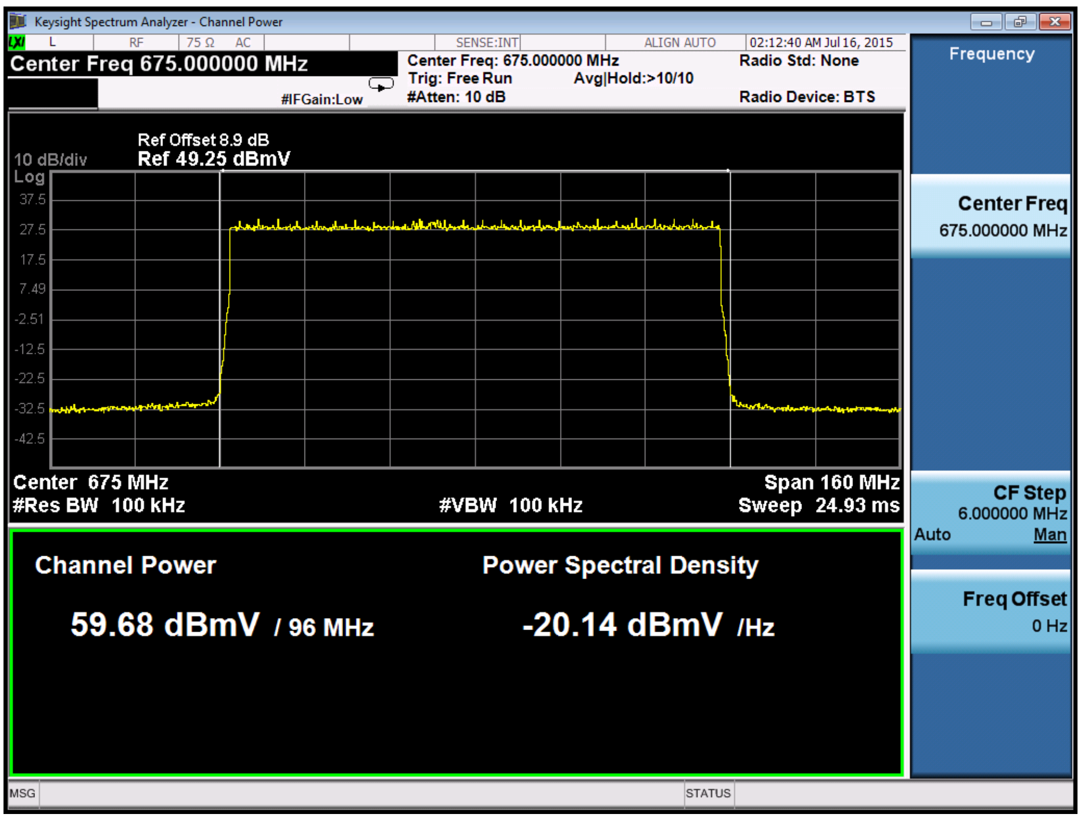

Figure 7. Total power measurement for a 96 MHz-wide OFDM signal. In this example the total power is 59.68 dBmV.

The total power of a DOCSIS 3.1 OFDM signal also can be calculated; see Section 7.2 for examples.

[4] The *minimum* bandwidth of the spectral taper region at the lower and upper band edge of a DOCSIS 3.1 downstream OFDM channel is 1 MHz, but can be a larger value, as given in Appendix V of the DOCSIS 3.1 PHY spec.

7. Part 2: Understanding CMTS OFDM Power Configuration

The addition of OFDM signals to the cable network signal lineup will normally require the CMTS output power level configuration be consistent with existing headend combining networks. Many operators have elected to migrate their headend systems to converged cable access platform (CCAP) equipment which generates a full line-up of SC-QAM and OFDM signals for digital video, DOCSIS 3.0 and DOCSIS 3.1 services. The CCAP's RF output levels may need to accommodate analog optical transport systems to serve hybrid fiber/coax (HFC) nodes in the field. The CCAP output levels may be flat or tilted as required to satisfy the HFC design rules established by each operator.

Independent of this deployment practice, the DOCSIS 3.1 specification authors needed to describe how the CMTS output fidelity should be defined. They documented their agreement about this in Section ***7.5.9.1 CMTS Output Electrical Requirements*** in the DOCSIS 3.1 Physical Layer Specification. This section of the DOCSIS 3.1 Specification is not intended to define how the CMTS should be configured for any network deployment.[5] It assumes that the power for each legacy SC-QAM channel in the lineup is set to the same value. Any OFDM signal generated by the CMTS is treated as the equivalent of a sum of SC-QAM channels which would occupy the total spectrum of the OFDM signal. Section 7.5.9.1 says that the total power (the average power) of an OFDM signal is the sum of the power of all these virtual legacy digital channels which were "generated" in place of the OFDM signal.

Here's the relevant wording from the spec: "CMTS power is configured by power per CEA channel and number of occupied CEA channels for each OFDM channel." The spec goes on to say "For each OFDM channel, the total power is Power per CEA channel + $10\log_{10}$(Number of occupied CEA channels) for that OFDM channel."[6]

The aforementioned text seems straightforward enough, but there is potential confusion surrounding how CMTS output power is defined in the spec's ***Table 42 - CMTS Output Power***. As mentioned previously, an OFDM signal's total power is measured (or calculated) over its occupied bandwidth, while Table 42 describes the required power capabilities for the modulator in terms of the power per 6 MHz. Further confusing things is a description in ***Table 44 - CMTS OFDM Channel Characteristic*** that describes certain characteristics of an OFDM channel (emphasis on "channel").

When discussing an OFDM signal, it is important to be clear what is meant by the following: an OFDM channel (sometimes called OFDM block), an OFDM signal (often intended to be the same thing as an OFDM channel), the OFDM signal's total power, and its per 6 MHz power (aka OFDM channel power).

A suggestion for the logical progression for configuring the downstream lineup power is outlined in the following paragraph, and then detailed examples are provided.

The first step is to plan the downstream spectrum that is to be modulated, accounting for all the CTA channel slots which are occupied by OFDM signals and legacy SC-QAM signals. Count the number of occupied CTA channels in this lineup, and denote this number of CTA channels for the entire downstream lineup as $N_{occupied}$. Use the DOCSIS 3.1 PHY spec's Table 42 to determine the range of admissible values of modulated power per 6 MHz using $N_{occupied}$ (in place of N_{eq}') and the modulator

[5] Calculation of per-channel power of DOCSIS SC-QAM signals is described in the DOCSIS Downstream RF Interface Specification [2].

[6] The CEA-542-D standard was renamed CTA-542-D when the Consumer Electronics Association changed its name to the Consumer Technology Association. The latest version of the standard is "CTA-542-D R-2018 Cable Television Channel Identification Plan," so the correct designation for 6 MHz channels on cable networks is "CTA channels" rather than "CEA channels" (or the older "EIA channels").

capability N_{eq}, and select a value from within this range (if the modulator has more capability than the ranges in Table 42, the operator may select such value for which the modulator is capable and is desired). The next step is to determine the OFDM channel power for any OFDM signal, based on the occupied bandwidth of the OFDM signal.

The next step for the modulator is to determine the power settings for each subcarrier, given the OFDM channel power, but this is beyond the scope of this document.

[Also adding potential confusion, the spec intentionally uses a different reference in the spurious emissions requirements for signal power, referenced as "0 dBc" in 6 MHz, than is used to set up the total power for the OFDM channel. The spurious emissions requirements are referenced to the "0 dBc" signal power, which derives from a) the amount of modulated spectrum, and b) the highest power 6 MHz within the OFDM signal (the 6 MHz containing the PHY link channel (PLC) also contains no inactive subcarriers, and more boosted subcarriers than the remaining 6 MHz spans of spectrum in the OFDM signal). On the other hand, the OFDM channel power is based on the occupied bandwidth. The amount of modulated spectrum and the occupied bandwidth are different values. (This document does not delve into why the different definitions are applied in the spec, but the definitions were reasoned.)]

An excerpt from Table 42 is included here for reference:

Table 1. Excerpt from DOCSIS 3.1 PHY specification.

$$\text{for } N^* \equiv \begin{cases} \mathit{minimum}[4N_{eq}', \text{ceiling}\left[\frac{N_{eq}}{4}\right]], & N_{eq}' < N_{eq}/4 \\ N_{eq}', & N_{eq}' \geq N_{eq}/4 \end{cases}, \text{ Adjusted Number of Active Channels Combined per RF Port}$$

Parameter	Value
Required power per channel for N_{eq}' channels combined onto a single RF port:	Required power in dBmV per channel 60 – ceil [3.6*$\log_2(N^*)$] dBmV
Range of commanded transmit power per channel	≥ 8 dB below required power level specified below maintaining full fidelity over the 8 dB range
Range of commanded power per channel; adjusted on a per channel basis	CMTS MUST: 0 dBc to -2 dBc relative to the highest commanded transmit power per channel, within an 8 dB absolute window below the highest commanded power. CMTS MAY: *required power* (in table below) to *required power - 8 dB*, independently on each channel.

The terms N*, N_{eq}, N_{eq}', "ceil," "ceiling," and "minimum" in the table may benefit from clarification. The first usage of some of the terms can be found in the DOCSIS 3.1 PHY spec's section **7.5.9 Fidelity Requirements**: "CMTSs capable of generating *N*-channels of legacy DOCSIS plus N_{OFDM}-channels of OFDM per RF port, for purposes of the DRFI output electrical requirements, the device is said to be capable of generating N_{eq}-channels per RF port, where $N_{eq} = N + 32*N_{OFDM}$ "equivalent legacy DOCSIS channels.""

Let's look at the terms "ceil" and "minimum" first.

- ceil – An abbreviation for ceiling, which, according to the DOCSIS 3.1 PHY spec's glossary is "A mathematical function that returns the lowest-valued integer that is greater than or equal to a given value." For example, solve the following equation:

  ceil(13/3) = ?

By itself, (13/3) = 4.33, but when the ceiling function is applied, 4.33 is "rounded up" to the nearest integer. So, ceil(13/3) = 5. If the value to which the ceiling function is applied is an integer – for instance, ceil(12) – the returned value is ceil(12) = 12.

- minimum – The smallest value in a set. Consider the set of numbers [10, 2, 15, 8]. In this case, minimum[10, 2, 15, 8] = 2. If the set contains formulas, the minimum is the smallest valued answer or solution to the formulas.

The following is an overview of the various "N" terms (refer to the Appendix for more information).

- N – The number of legacy DOCSIS channels per RF port that a CMTS is *capable* of generating (According to **6.4.2 Downstream Electrical Input to the CM** "A CMTS MUST support at least 32 active downstream channels").
- N_{OFDM} – The number of downstream OFDM channels per RF port the CMTS is *capable* of generating. (According to **7.2.2 Downstream CMTS Spectrum** "The CMTS MUST support a minimum of two independently configurable OFDM channels each occupying a spectrum of up to 192 MHz in the downstream.")
- N_{eq} – The number of *equivalent* legacy DOCSIS channels per RF port the CMTS is capable of generating, defined by the formula

  $N_{eq} = N + 32 * N_{OFDM}$

  For example, assume the CMTS is capable of 32 SC-QAM channels and two 192 MHz-wide OFDM channels per RF port. In this example, N = 32 and $N_{OFDM} = 2$. Solving for N_{eq}, we get

  $N_{eq} = 32 + 32 * 2$
  $N_{eq} = 32 + 64$
  $N_{eq} = 96$

  In other words, the CMTS is capable of generating the *equivalent* of 96 legacy DOCSIS SC-QAM channels per RF port.
- N_{eq}' – The number of *active* equivalent legacy DOCSIS channels per RF port. According to the DOCSIS 3.1 PHY spec, the number of equivalent active legacy DOCSIS channels in the OFDM channel N_{eq}' is the ceiling function applied to the modulated spectrum[7] divided by 6 MHz.

  Here's an example of calculating N_{eq}'. Assume that the CMTS is configured to generate just one 96 MHz-wide OFDM channel per port. For a 96 MHz-wide downstream OFDM channel with no exclusion bands and with the minimum 1 MHz-wide taper region on each end of the channel, the modulated spectrum is 94 MHz, so N_{eq}' = ceil[94 MHz/6 MHz] = 16 active equivalent legacy SC-QAM DOCSIS channels.
- N* – The *adjusted* number of active channels combined per RF port. The DOCSIS 3.1 PHY spec says "For an N_{eq}-channel per RF port device, the applicable maximum power per channel and spurious emissions requirements are defined using a value of N^* = minimum($4N_{eq}'$, ceiling[N_{eq}/4]) for $N_{eq}' < N_{eq}/4$, and $N^* = N_{eq}'$ otherwise."

  That is, if $N_{eq}' < N_{eq}/4$, then N* = minimum[$4N_{eq}'$, ceil(N_{eq}/4)]. Or, if $N_{eq}' \geq N_{eq}/4$, then N* = N_{eq}'.

[7] See Section 10 for more information about *modulated spectrum*, *encompassed spectrum*, and *occupied bandwidth*.

The importance of N* is that in Table 42 of the DOCSIS 3.1 PHY spec, the required power per channel for N_{eq}’ channels combined onto a single RF port is stated as “Required power in dBmV per channel 60 – ceil[3.6*$\log_2$(N*)] dBmV.” Note that the ceiling function is used in this equation. Also note that the logarithm function is base-2, not the more common base-10.[8]

7.1. Power Calculation Examples

The following examples illustrate how to calculate a DOCSIS 3.1 CMTS’s downstream OFDM transmit power.[9] For the examples, assume the CMTS is capable of generating 32 legacy SC-QAM channels (N = 32) and two 192 MHz-wide OFDM channels (N_{OFDM} = 2) per RF port. For this hypothetical CMTS, then, N_{eq} = 96. Further assume that the intended full downstream lineup will have $N_{occupied}$ as given in the following examples. Note that $N_{occupied}$ is the number of CTA channels occupied by the entire downstream lineup, but if there is only one channel in the downstream lineup, then that channel alone determines $N_{occupied}$.

7.1.1. Example 1.

In order to calculate the power per channel (that is, power per 6 MHz), it’s necessary to first determine the value of N*. To do that, we need the values for N_{eq} and N_{eq}’, to use Table 42, but where the latter is N_{eq}’ = $N_{occupied}$ for the first step in determining output power.

Assume the CMTS is configured for a single 192 MHz-wide OFDM channel per RF port, with the OFDM channel’s modulated spectrum equal to 190 MHz and a taper region of 1 MHz on each side, and centered within the CTA channel boundaries so that $N_{occupied}$ = 32. From the previously stated assumptions for these examples, we know that N_{eq} = 96.

N_{eq}’ = $N_{occupied}$
N_{eq}’ = 32 active equivalent legacy SC-QAM DOCSIS channels

Next, solve for N_{eq}/4, which in this example is 96/4 = 24. Here, N_{eq}’ > N_{eq}/4 (that is, 32 > 24), so N* = N_{eq}’, or N* = 32. Now we can calculate the per-channel power:

60 – ceil[3.6*$\log_2$(N*)]
60 – ceil[3.6*$\log_2$(32)]
60 – ceil[3.6*5]
60 – ceil[18]
60 – 18 = 42

The per-channel power in this example is 42 dBmV.[10]

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[8] See Section 8 for information on how to calculate base-2 logarithms.
[9] See [2] for information on characterization and calculation of downstream DOCSIS SC-QAM per-channel power.
[10] Note: If the 192 MHz of OFDM channel bandwidth were used instead for legacy SC-QAM channels, and no other legacy digital channels were transmitted, then (192 MHz)/(6 MHz per channel) = 32 SC-QAM channels would be modulated and the same per-channel power of 42 dBmV would result for each of those legacy SC-QAM channels.

7.1.2. Example 2.

Assume the CMTS is configured for a single 24 MHz-wide OFDM channel per RF port, with the OFDM channel's modulated spectrum equal to 22 MHz, and taper region of 1 MHz on each side, and centered within the CTA channel boundaries so that $N_{occupied} = 4$. Now solve for N_{eq}' using the formula

$N_{eq}' = N_{occupied}$
$N_{eq}' = 4$ active equivalent legacy SC-QAM DOCSIS channels

Next, solve for $N_{eq}/4$, which is 96/4 = 24. In this example, $N_{eq}' < N_{eq}/4$ (that is, 4 < 24), so it's necessary to use the equation $N^* = \text{minimum}[4N_{eq}', \text{ceil}(N_{eq}/4)]$ to calculate N*.

$N^* = \text{minimum}[4N_{eq}', \text{ceil}(N_{eq}/4)]$
$N^* = \text{minimum}[16, 24]$
$N^* = 16$

Now calculate the per-channel power:

$60 – \text{ceil}[3.6*\log_2(N^*)]$
$60 – \text{ceil}[3.6*\log_2(16)]$
$60 – \text{ceil}[3.6*4]$
$60 – \text{ceil}[14.4]$
$60 – 15 = 45$

The per-channel power in this example is 45 dBmV.

7.1.3. Example 3.

Assume the CMTS is configured for two independent 192 MHz-wide OFDM channels per RF port, with each OFDM channel's modulated spectrum equal to 190 MHz, and a taper region of 1 MHz on each side of each OFDM channel, and each centered within the CTA channel boundaries so that $N_{occupied} = 64$.

<u>Two 192 MHz-wide OFDM channels:</u>

$N_{eq}' = N_{occupied}$
$N_{eq}' = 64$ active equivalent legacy SC-QAM DOCSIS channels

The total N_{eq}' for the two OFDM channels is the sum of the individual N_{eq}' values, or 32 + 32 = 64.

Next, we solve for $N_{eq}/4$, which is 96/4 = 24. In this example, $N_{eq}' > N_{eq}/4$ (that is, 64 > 24), so $N^* = N_{eq}'$, or N* = 64.

Now calculate the per-channel power:

$60 – \text{ceil}[3.6*\log_2(N^*)]$
$60 – \text{ceil}[3.6*\log_2(64)]$
$60 – \text{ceil}[3.6*6]$
$60 – \text{ceil}[21.6]$
$60 – 22 = 38$

The per-channel power in this example is 38 dBmV.

7.2. Total Power

What is the total power for each of the three previous examples? We know the per-channel power for each example (remember, DOCSIS 3.1 downstream transmit power for the CMTS is configured by *power per CTA channel or power per 6 MHz*). Recall that the DOCSIS 3.1 spec says "For each OFDM channel, the total power is Power per CEA channel + $10\log_{10}$(Number of occupied CEA channels) for that OFDM channel."

Knowing that, let's calculate the total power for each of the three examples.

7.2.1. *Example 1.*

The per-channel power was calculated to be 42 dBmV. The occupied bandwidth of the single 192 MHz-wide OFDM channel is 32 CTA channels, so the total power is

$P_{total} = 42 + 10\log_{10}(32)$
$P_{total} = 42 + 10 * \log_{10}(32)$
$P_{total} = 42 + 10 * 1.51$
$P_{total} = 42 + 15.05$
$P_{total} = 57.05$ dBmV

7.2.2. *Example 2.*

The per-channel power was calculated to be 45 dBmV. The occupied bandwidth of the single 24 MHz-wide OFDM channel is four CTA channels, so the total power is

$P_{total} = 45 + 10\log_{10}(4)$
$P_{total} = 45 + 10 * \log_{10}(4)$
$P_{total} = 45 + 10 * 0.60$
$P_{total} = 45 + 6.02$
$P_{total} = 51.02$ dBmV

7.2.3. *Example 3.*

The per-channel power was calculated to be 38 dBmV. The occupied bandwidth of the two 192 MHz-wide OFDM channels is 64 CTA channels, so the total power is

$P_{total} = 38 + 10\log_{10}(64)$
$P_{total} = 38 + 10 * \log_{10}(64)$
$P_{total} = 38 + 10 * 1.81$
$P_{total} = 38 + 18.06$
$P_{total} = 56.06$ dBmV

8. How to Calculate Base-2 Logarithms

The equation in Table 7-37 of the DOCSIS 3.1 PHY spec that is used to calculate required power in dBmV per channel is $60 – \text{ceil}[3.6*\log_2(N^*)]$. Note that the logarithm function in the equation is base-2 ($\log_2$), not the more common base-10 ($\log_{10}$).

Scientific calculators have a base-10 logarithm function. Some scientific calculators also have a natural logarithm (ln) – also called base-*e* or $\log_e$ – function. How can one calculate the base-2 logarithm of a given quantity? The following examples illustrate two ways to do so using base-10 and natural logarithm functions.[11]

8.1. Base-10 Logarithm Method

To find the base-2 logarithm of a quantity x, use the formula

$\log_2(x) = \log_{10}(x)/\log_{10}(2)$

For example, calculate the base-2 logarithm of the number 24.

$\log_2(24) = \log_{10}(24)/\log_{10}(2)$
$\log_2(24) = 1.380211/0.301030$
$\log_2(24) = 4.584963$

8.2. Natural Logarithm Method

To find the base-2 logarithm of a quantity x, use the formula

$\log_2(x) = \ln(x)/\ln(2)$

For example, calculate the base-2 logarithm of the number 24.

$\log_2(24) = \ln(24)/\ln(2)$
$\log_2(24) = 3.178054/0.693147$
$\log_2(24) = 4.584963$

[11] Microsoft Excel supports calculation of base-2 logarithms, using the formula LOG(**number**, [base]). For example, to calculate the base-2 logarithm of the value in a spreadsheet's cell number B6, the formula for that cell would be =LOG(B6, 2).

9. Per-Channel Power Calculation Table

To help simplify some of the math in this Operational Practice, the following table summarizes data used to calculate downstream transmit power for values of N* from 1 to 185, the latter equivalent to 1110 MHz of spectrum (108 MHz to 1218 MHz).

Table 2. Per-channel power calculation.

N*	$\log_2(N^*)$	$[3.6*\log_2(N^*)]$	$ceil[3.6*\log_2(N^*)]$	$60 - ceil[3.6*\log_2(N^*)]$ *dBmV*
1	0	0	0	60
2	1	3.6	4	56
3	1.5849625	5.705865003	6	54
4	2	7.2	8	52
5	2.32192809	8.358941142	9	51
6	2.5849625	9.305865003	10	50
7	2.80735492	10.10647772	11	49
8	3	10.8	11	49
9	3.169925	11.41173001	12	48
10	3.32192809	11.95894114	12	48
11	3.45943162	12.45395383	13	47
12	3.5849625	12.905865	13	47
13	3.70043972	13.32158299	14	46
14	3.80735492	13.70647772	14	46
15	3.9068906	14.06480614	15	45
16	4	14.4	15	45
17	4.08746284	14.71486623	15	45
18	4.169925	15.01173001	16	44
19	4.24792751	15.29253905	16	44
20	4.32192809	15.55894114	16	44
21	4.39231742	15.81234272	16	44
22	4.45943162	16.05395383	17	43
23	4.52356196	16.28482304	17	43
24	4.5849625	16.505865	17	43
25	4.64385619	16.71788228	17	43
26	4.70043972	16.92158299	17	43
27	4.7548875	17.11759501	18	42
28	4.80735492	17.30647772	18	42
29	4.857981	17.48873158	18	42
30	4.9068906	17.66480614	18	42
31	4.95419631	17.83510672	18	42
32	5	18	18	42

33	5.04439412	18.15981883	19	41
34	5.08746284	18.31486623	19	41
35	5.12928302	18.46541886	19	41
36	5.169925	18.61173001	19	41
37	5.20945337	18.75403212	19	41
38	5.24792751	18.89253905	19	41
39	5.28540222	19.02744799	20	40
40	5.32192809	19.15894114	20	40
41	5.357552	19.28718722	20	40
42	5.39231742	19.41234272	20	40
43	5.42626475	19.53455312	20	40
44	5.45943162	19.65395383	20	40
45	5.4918531	19.77067115	20	40
46	5.52356196	19.88482304	20	40
47	5.55458885	19.99651987	20	40
48	5.5849625	20.105865	21	39
49	5.61470984	20.21295544	21	39
50	5.64385619	20.31788228	21	39
51	5.67242534	20.42073123	21	39
52	5.70043972	20.52158299	21	39
53	5.72792045	20.62051364	21	39
54	5.7548875	20.71759501	21	39
55	5.78135971	20.81289497	21	39
56	5.80735492	20.90647772	21	39
57	5.83289001	20.99840405	21	39
58	5.857981	21.08873158	22	38
59	5.88264305	21.17751498	22	38
60	5.9068906	21.26480614	22	38
61	5.93073734	21.35065442	22	38
62	5.95419631	21.43510672	22	38
63	5.97727992	21.51820772	22	38
64	6	21.6	22	38
65	6.02236781	21.68052413	22	38
66	6.04439412	21.75981883	22	38
67	6.06608919	21.83792109	22	38
68	6.08746284	21.91486623	22	38
69	6.10852446	21.99068804	22	38
70	6.12928302	22.06541886	23	37
71	6.14974712	22.13908963	23	37
72	6.169925	22.21173001	23	37
73	6.18982456	22.28336841	23	37

74	6.20945337	22.35403212	23	37
75	6.22881869	22.42374729	23	37
76	6.24792751	22.49253905	23	37
77	6.26678654	22.56043155	23	37
78	6.28540222	22.62744799	23	37
79	6.30378075	22.69361069	23	37
80	6.32192809	22.75894114	23	37
81	6.33985	22.82346001	23	37
82	6.357552	22.88718722	23	37
83	6.37503943	22.95014195	23	37
84	6.39231742	23.01234272	24	36
85	6.40939094	23.07380737	24	36
86	6.42626475	23.13455312	24	36
87	6.4429435	23.19459659	24	36
88	6.45943162	23.25395383	24	36
89	6.47573343	23.31264035	24	36
90	6.4918531	23.37067115	24	36
91	6.50779464	23.4280607	24	36
92	6.52356196	23.48482304	24	36
93	6.53915881	23.54097172	24	36
94	6.55458885	23.59651987	24	36
95	6.56985561	23.65148019	24	36
96	6.5849625	23.705865	24	36
97	6.59991284	23.75968623	24	36
98	6.61470984	23.81295544	24	36
99	6.62935662	23.86568383	24	36
100	6.64385619	23.91788228	24	36
101	6.65821148	23.96956134	24	36
102	6.67242534	24.02073123	25	35
103	6.68650053	24.0714019	25	35
104	6.70043972	24.12158299	25	35
105	6.71424552	24.17128386	25	35
106	6.72792045	24.22051364	25	35
107	6.74146699	24.26928115	25	35
108	6.7548875	24.31759501	25	35
109	6.76818432	24.36546357	25	35
110	6.78135971	24.41289497	25	35
111	6.79441587	24.45989712	25	35
112	6.80735492	24.50647772	25	35
113	6.82017896	24.55264426	25	35
114	6.83289001	24.59840405	25	35

115	6.84549005	24.64376418	25	35
116	6.857981	24.68873158	25	35
117	6.87036472	24.73331299	25	35
118	6.88264305	24.77751498	25	35
119	6.89481776	24.82134395	25	35
120	6.9068906	24.86480614	25	35
121	6.91886324	24.90790765	25	35
122	6.93073734	24.95065442	25	35
123	6.94251451	24.99305222	25	35
124	6.95419631	25.03510672	26	34
125	6.96578428	25.07682342	26	34
126	6.97727992	25.11820772	26	34
127	6.98868469	25.15926487	26	34
128	7	25.2	26	34
129	7.01122726	25.24041812	26	34
130	7.02236781	25.28052413	26	34
131	7.033423	25.32032281	26	34
132	7.04439412	25.35981883	26	34
133	7.05528244	25.39901677	26	34
134	7.06608919	25.43792109	26	34
135	7.0768156	25.47653615	26	34
136	7.08746284	25.51486623	26	34
137	7.09803208	25.5529155	26	34
138	7.10852446	25.59068804	26	34
139	7.11894107	25.62818786	26	34
140	7.12928302	25.66541886	26	34
141	7.13955135	25.70238487	26	34
142	7.14974712	25.73908963	26	34
143	7.15987134	25.77553681	26	34
144	7.169925	25.81173001	26	34
145	7.17990909	25.84767272	26	34
146	7.18982456	25.88336841	26	34
147	7.19967234	25.91882044	26	34
148	7.20945337	25.95403212	26	34
149	7.21916852	25.98900667	26	34
150	7.22881869	26.02374729	27	33
151	7.23840474	26.05825706	27	33
152	7.24792751	26.09253905	27	33
153	7.25738784	26.12659623	27	33
154	7.26678654	26.16043155	27	33
155	7.27612441	26.19404786	27	33

156	7.28540222	26.22744799	27	33
157	7.29462075	26.2606347	27	33
158	7.30378075	26.29361069	27	33
159	7.31288296	26.32637864	27	33
160	7.32192809	26.35894114	27	33
161	7.33091688	26.39130076	27	33
162	7.33985	26.42346001	27	33
163	7.34872815	26.45542136	27	33
164	7.357552	26.48718722	27	33
165	7.36632221	26.51875997	27	33
166	7.37503943	26.55014195	27	33
167	7.38370429	26.58133545	27	33
168	7.39231742	26.61234272	27	33
169	7.40087944	26.64316597	27	33
170	7.40939094	26.67380737	27	33
171	7.41785251	26.70426905	27	33
172	7.42626475	26.73455312	27	33
173	7.43462823	26.76466162	27	33
174	7.4429435	26.79459659	27	33
175	7.45121111	26.82436	27	33
176	7.45943162	26.85395383	27	33
177	7.46760555	26.88337998	27	33
178	7.47573343	26.91264035	27	33
179	7.48381578	26.9417368	27	33
180	7.4918531	26.97067115	27	33
181	7.49984589	26.99944519	27	33
182	7.50779464	27.0280607	28	32
183	7.51569984	27.05651942	28	32
184	7.52356196	27.08482304	28	32
185	7.53138146	27.11297326	28	32

10. DOCSIS 3.1 Spectrum and Bandwidth

Encompassed spectrum, *modulated spectrum*, and *occupied bandwidth* are three terms used to describe characteristics of downstream OFDM and upstream OFDMA channels. Understanding the terms' meanings is important when characterizing downstream transmit power. Here are the definitions of the three terms, from the DOCSIS 3.1 PHY spec's glossary. Following the definitions are graphic examples that help to illustrate their meaning.

10.1. Encompassed Spectrum

1) For an OFDM or OFDMA channel, the range of frequencies from the center frequency of the channel's lowest active subcarrier minus half the subcarrier spacing, to the center frequency of the channel's highest active subcarrier plus half the subcarrier spacing.
2) For an SC-QAM channel, the encompassed spectrum is the signal bandwidth (i.e., 6 MHz or 8 MHz in the downstream; 1.6 MHz, 3.2 MHz, and 6.4 MHz in the upstream).
3) For the RF output of a downstream or upstream port including multiple OFDM, OFDMA, and/or SC-QAM channels, the range of frequencies from the lowest frequency of the encompassed spectrum of the lowest frequency channel to the highest frequency of the encompassed spectrum of the highest frequency channel.

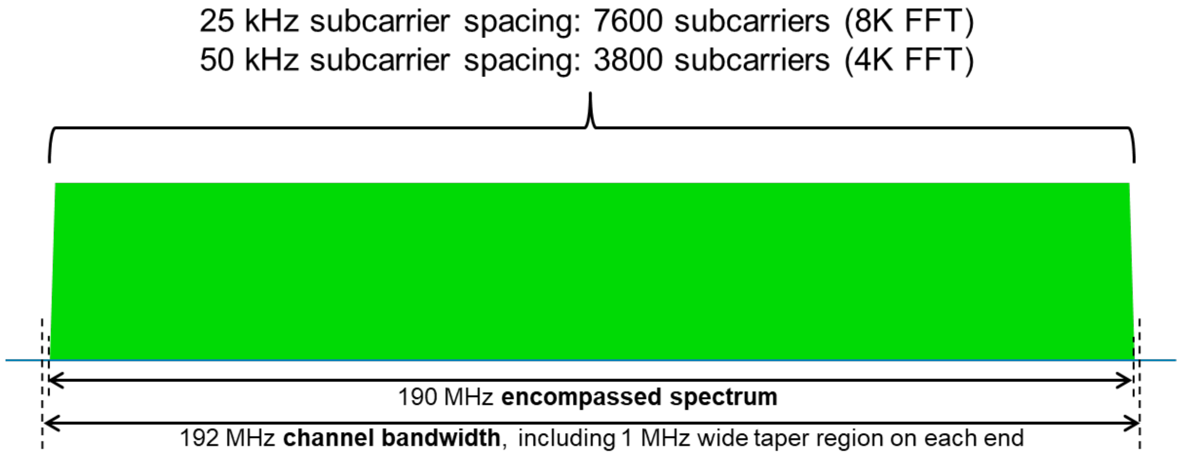
10.2. Modulated Spectrum

1) Downstream modulated spectrum - Encompassed spectrum minus the excluded subcarriers within the encompassed spectrum, where excluded subcarriers include all the individually excluded subcarriers and all the subcarriers comprising excluded sub-bands. This also is the spectrum comprising all active subcarriers. Note: For this definition, the width of an active or excluded subcarrier is equal to the subcarrier spacing.
2) Upstream modulated spectrum - The spectrum comprising all non-zero-valued subcarriers of a cable modem's OFDMA transmission, resulting from the exercised transmit opportunities. Note: For this definition, the width of a transmitted subcarrier is equal to the subcarrier spacing.

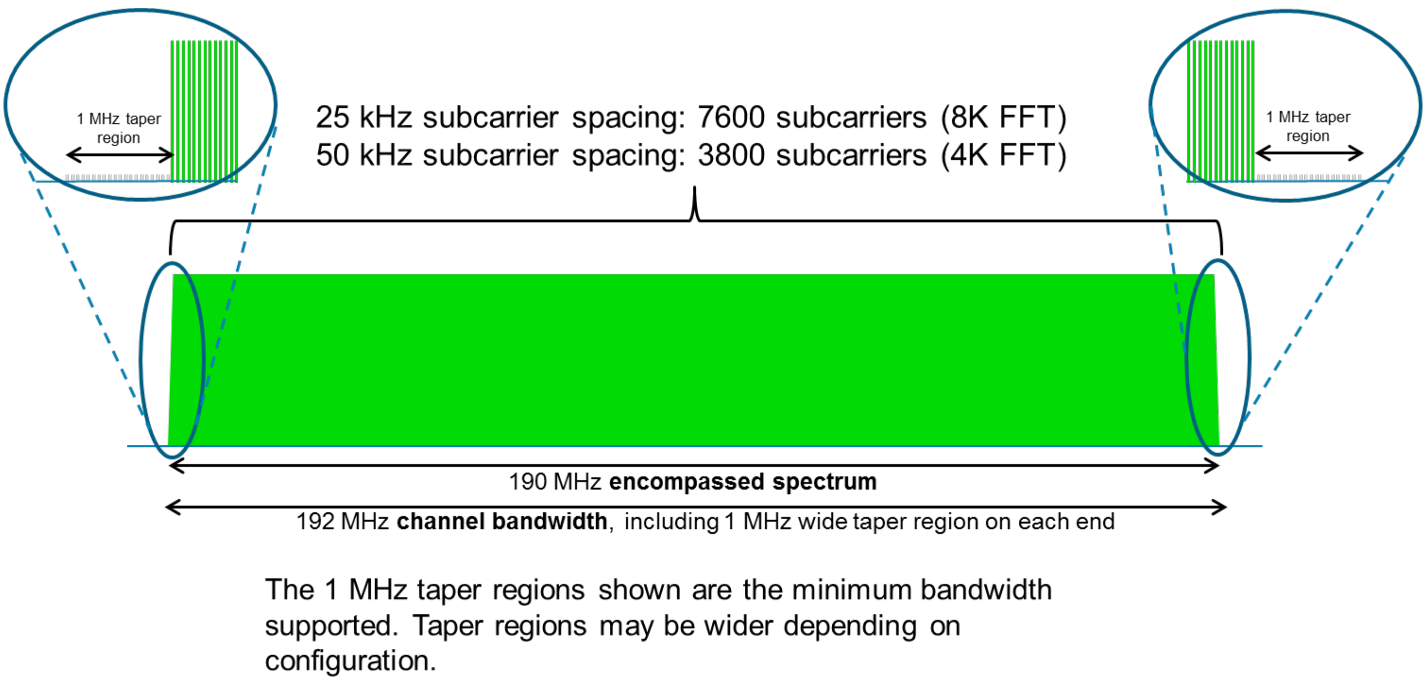
10.3. Occupied Bandwidth

1) Downstream - The sum of the bandwidth in all standard channel frequency allocations (e.g., 6 MHz spaced CTA channels) that are occupied by the OFDM channel. The CTA channels which are occupied by the OFDM signal are those which contain any of the Modulated Spectrum and/or taper region shaped by the OFDM channels' transmit windowing, where the values for the taper regions are defined in Appendix V as a function of the Roll-Off Period. It is possible, but not problematic, for a CTA channel to be "occupied" by two OFDM channels.
2) Upstream - a) For a single OFDMA channel, the sum of the bandwidth in all the subcarriers of that OFDMA channel which are not excluded. The upstream occupied bandwidth is calculated as the number of subcarriers which are not excluded, multiplied by the subcarrier spacing. b) For the transmit channel set, the sum of the occupied bandwidth of all OFDMA channels plus the bandwidth of the legacy channels (counted as 1.25 times the modulation rate for each legacy channel) in a cable modem's transmit channel set. The combined bandwidth of all the minislots in the channel is normally smaller than the upstream occupied bandwidth due to the existence of unused subcarriers. The bandwidth occupied by an OFDMA probe with a skip value of zero is equal to the upstream occupied bandwidth.

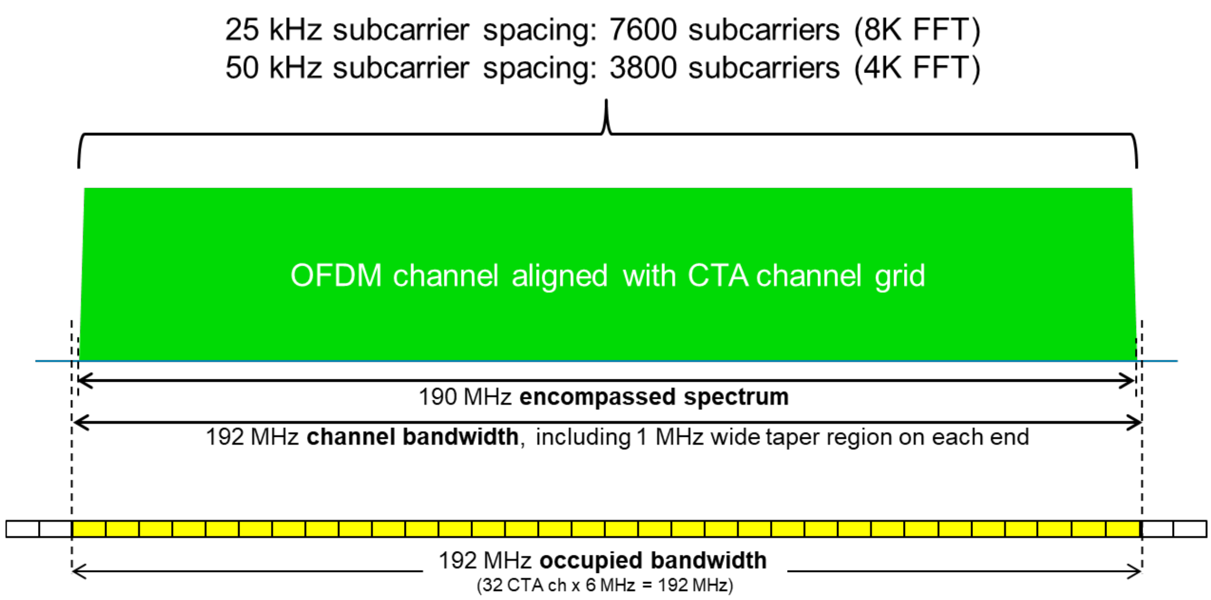
10.4. Downstream encompassed spectrum example (1 MHz taper regions):



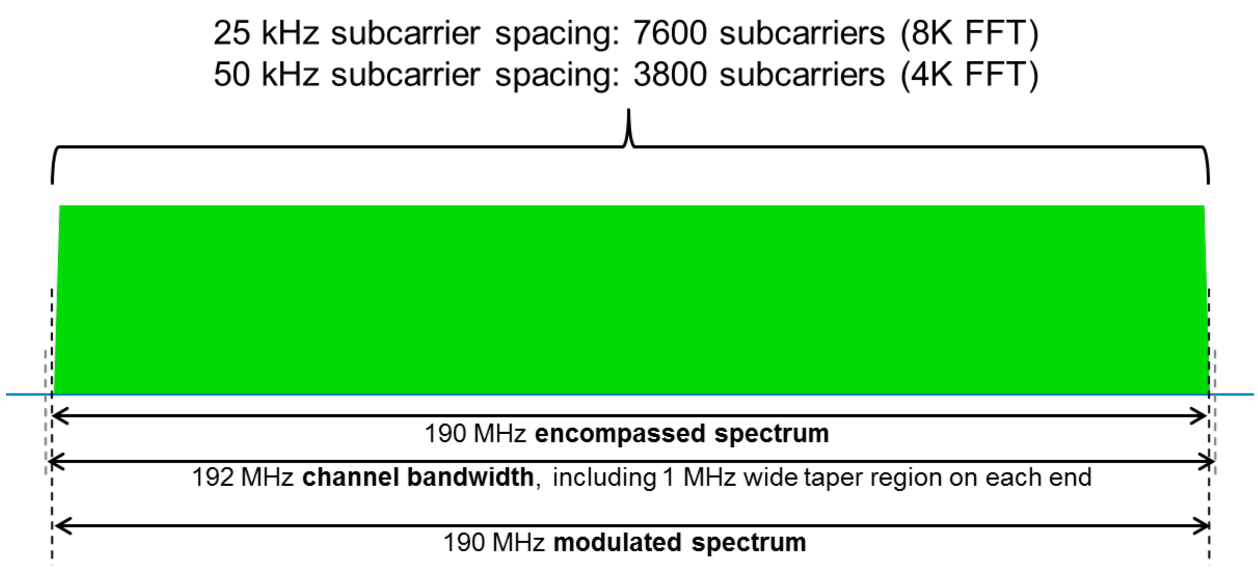
10.5. A closer look at taper regions:



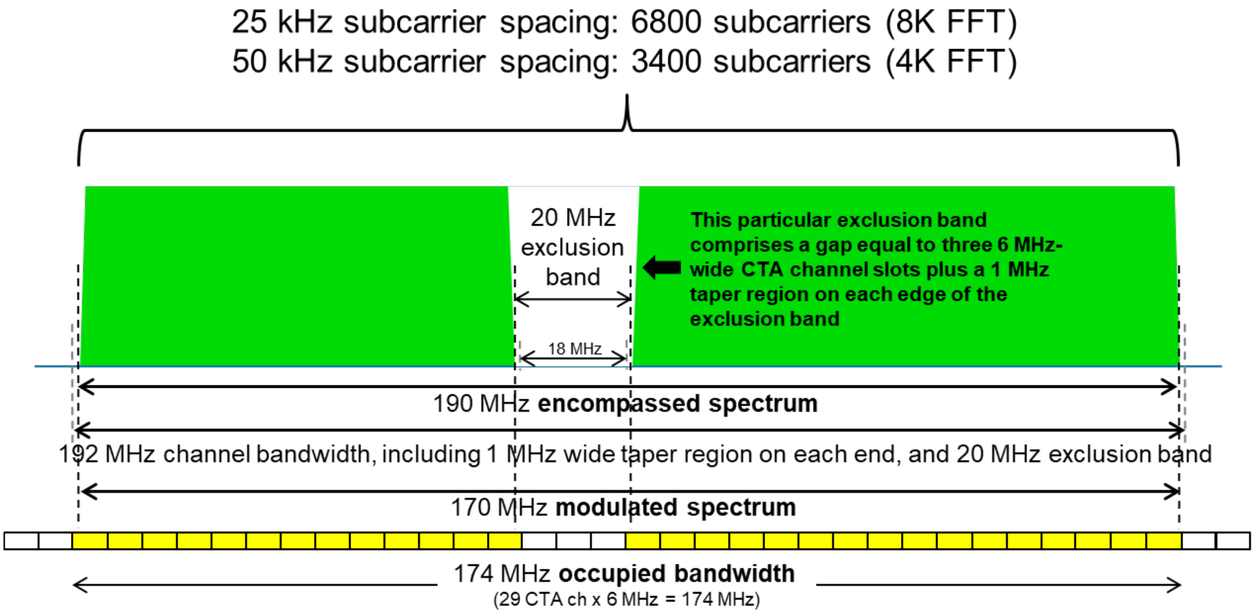
10.6. Downstream occupied bandwidth example:



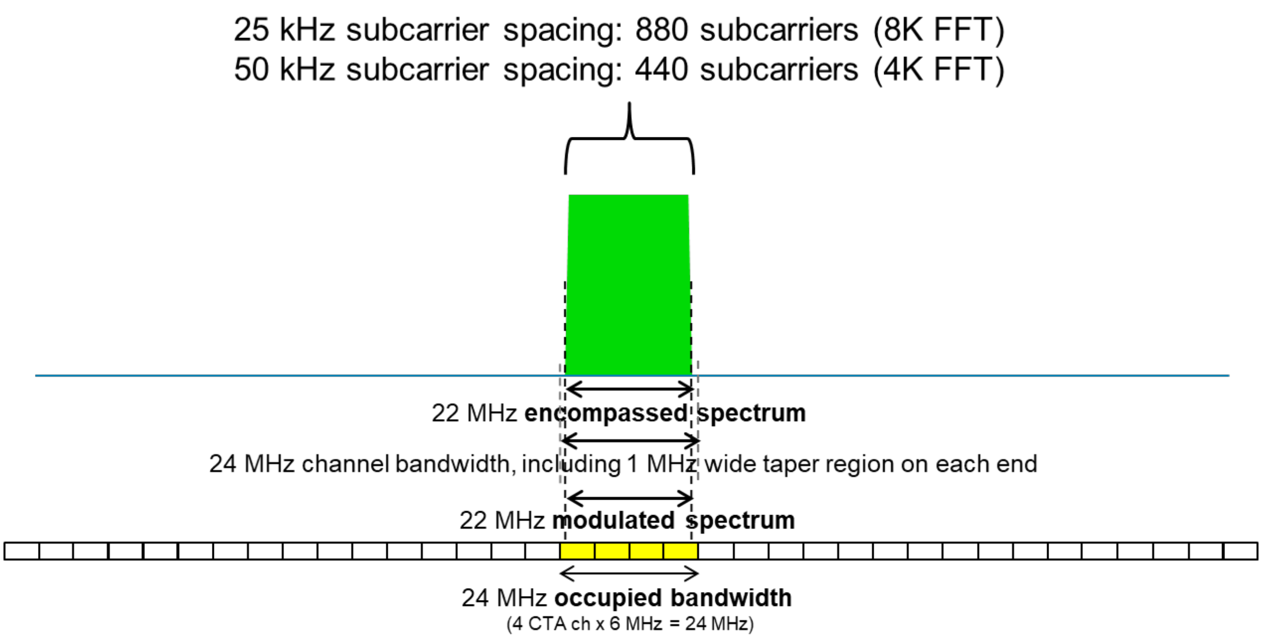
10.7. Downstream modulated spectrum example (1):



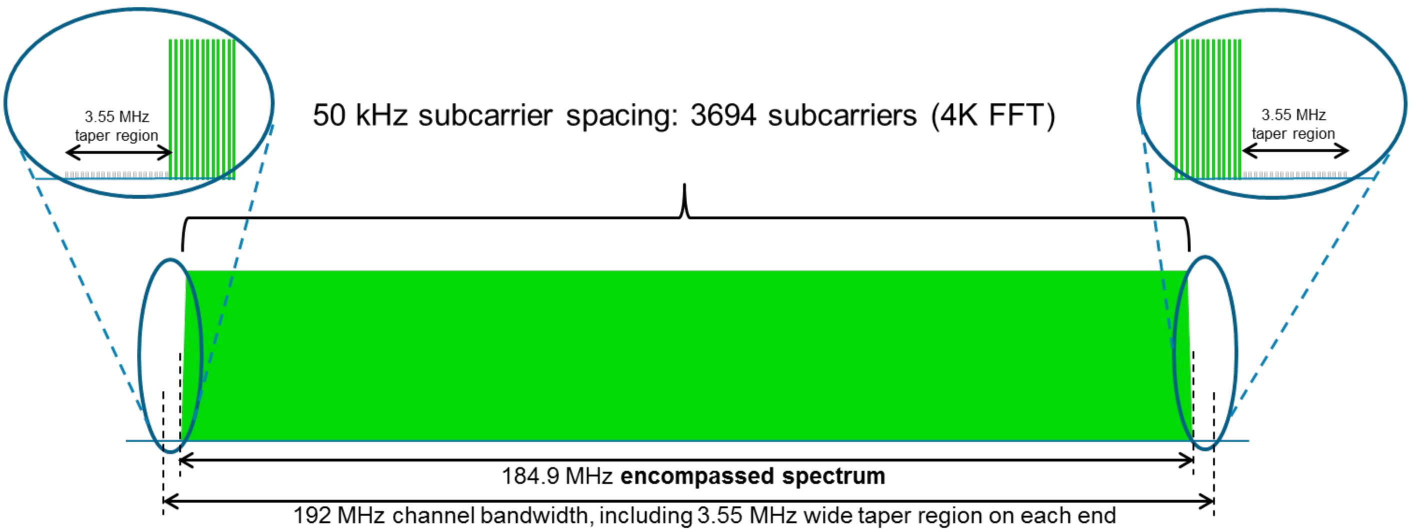
10.8. Downstream modulated spectrum example (2):



10.9. 24 MHz bandwidth channel example:



10.10. Configuration example from DOCSIS 3.1 PHY spec Appendix:



FFT	Roll-Off Period Samples (N_{rp})	Taper Region (MHz)
4K	64	3.550

11. Summary

This Operational Practice discusses DOCSIS downstream OFDM transmit power calculation, based upon information and formulas in the DOCSIS 3.1 Physical Layer Specification. Several step-by-step examples of per-channel power and total power are included to help clarify what can otherwise be complicated calculations. The reader is reminded that per-channel power calculations for legacy SC-QAM channels are described in the DOCSIS DRFI spec [2].

12. Appendix: A Closer Look at "N" Terms

Section 7 of this document includes an excerpt from Table 7 of the DOCSIS 3.1 Physical Layer Specification. Within that table are mathematical formulas that include a variety of "N" terms: N*, N_{eq}, and N_{eq}'. The definitions of those and other "N" terms can be found in Section 7 (see page 17). But where do those terms come from, and what is their significance?

The terms' history goes back to the CableLabs document *Data-Over-Cable Service Interface Specifications Downstream RF Interface Specification*, commonly referred to as DRFI – in this case, version I01 of that spec (CM-SP-DRFI-I01-050805). The first version of DRFI was issued in 2005 and included RF specifications for DOCSIS SC-QAM signal sources such as edge-QAM and CMTS modulators. In particular, the spec's Table 6–4 "DRFI Device Output Power" included the following parameters (left column) and values (right column) summarizing the required power per channel, where the uppercase letter N described the number of combined channels per device port. In those days, the ability for a signal source to simultaneously generate multiple DOCSIS SC-QAM channels per port was quite a technical achievement.

Required power per channel for *N* channels combined onto a single RF port. '*N*' = number of combined channels:	Required power in dBmV per channel
$N = 1$	60 dBmV
$N = 2$	56 dBmV
$N = 3$	54 dBmV
$N = 4$	52 dBmV
$N > 4$	60 – ceil [3.6*log2(*N*)] dBmV

Table 6.5 in version I01 of DRFI included specifications for CMTS and edge-QAM modulators' out-of-band noise and spurious emissions. The parameters in Table 6.5 were closely tied to N. According to Section 6.3.5.1.3 of DRFI, "One of the goals of the DRFI specification is to provide the minimum intended analog channel CNR protection of 60 dB for systems deploying up to 119 DRFI compliant QAM channels."

Later versions of DRFI added the term N' (pronounced "en prime"), which referred to the number of operational SC-QAM channels per port, in contrast to N, the maximum number of SC-QAM channels per port that could be generated. For example, if a given CMTS were capable of generating a maximum of 32 channels per port, then N=32. If that same CMTS were configured to generate 16 channels on that port, then N'=16.

DRFI version I10 divided CMTS and edge-QAM modulator capability into three categories, from the perspective of N. The first category was those devices that could generate only one SC-QAM channel per port (N=1); the second category was those devices that could simultaneously generate more than one (N>1) but no more than eight (N≤8) SC-QAM channels per port; and the third category was those devices that could generate more than eight (N≥9) SC-QAM channels per port.

Why differentiate among devices with the capability to generate different numbers of SC-QAM channels per port? The reason is largely related to out-of-band noise and spurious emissions. Indeed, DRFI I10 included separate out-of-band noise and spurious emissions requirements for devices supporting N≤8, devices supporting N≥9 and N'≥N/4, and devices supporting N≥9 and N'<N/4. For the latter, there was

another term added to the mix: N’’ (pronounced “en double prime”), where N’’ ≡ Effective Number of Active Channels for Spurious Emissions Requirements= minimum[4N’, ceil(N/4)].

DRFI I10 included a relaxation of the out-of-band noise and spurious emissions for certain scenarios. The technical reasons for the relaxation of the fidelity and output power requirements for N’ < N/4 (and similarly for N_{eq}’ < N_{eq}/4 with the advent of OFDM, see below) in the downstream cable modulator requirements, is related to difficulty meeting nonlinearity fidelity in a modulator with a high bandwidth capability, when used with a much smaller modulated bandwidth. In other words, when the downstream transmitted modulated bandwidth is reduced (smaller N’), the total power goes up, which adds more stress to the intermodulation products produced – that is, it tends to increase the distortion power created. As well, the allocation of spurious emissions – the raw power in a given measurement bandwidth such as 6 MHz – for *that* transmitter port goes *down* because there is an assumption that *other* transmitters are contributing their own additional noise to that same band, in the system application.

The aforementioned simply means that a) the total power is higher with smaller N’, and b) the allowed power in a given spurious emissions measurement bandwidth (compared to the power in a 6 MHz channel) is reduced proportionally with N’ reduction, too, to keep the system budget for the number of transmitted channels (119) constant.

Although the total power and the instantaneous power of the modulator are primary drivers of fidelity requirements, concentrating the power in too small a bandwidth was seen (known) as problematic by vendors, and cable operators agreed to some relaxations in the DRFI specification when a modulator would be set to operate at less than 25% of its maximum modulated spectrum – hence the “N/4” seen in the spec.

When DOCSIS 3.1 introduced OFDM, new N terms were added: N_{OFDM}, N_{eq}, N_{eq}’, and N*, where N_{OFDM} is the number of OFDM channels per device RF port the CMTS is capable of generating; N_{eq} is the number of equivalent legacy DOCSIS SC-QAM channels per RF port the CMTS is capable of generating (for example, an OFDM channel, including taper region, spanning 192 MHz spectrally aligned with SC-QAM channelization, corresponds to 32 equivalent legacy DOCSIS SC-QAM channels); N_{eq}’ is the number of active equivalent legacy DOCSIS channels per port; and N* is the adjusted number of active channels combined per RF port.

Recall, N’’ is the Effective Number of Active Channels for Spurious Emissions Requirements= minimum[4N’, ceil(N/4)], for SC-QAM downstream modulators (per DRFI), where “effective” means “effective in terms of the spurious emissions requirements.” For downstream modulators capable of generating OFDM, and perhaps additionally SC-QAM, N* is directly analogous to N’’ described in DRFI. N* ≡ Adjusted Number of Active Channels for Spurious Emissions Requirements= minimum[4 N_{eq}’, ceil(N_{eq}/4)]. In DOCSIS 3.1, the term “adjusted” was adopted in the definition for N* instead of the term “effective” which had been used in DRFI for N’’. The term “adjusted” is probably more appropriate, but the DRFI definition was not refined; it is, after all, a purely editorial matter, and subjective at that. Nonetheless, the difference of that one word in the definitions for N’’ and N*, “effective” versus “adjusted,” may lead to some confusion, which is unfortunate. The two terms are completely analogous and the same technical reasons apply to both: the downstream cable spurious emissions requirements for downstream modulators which are only engaging a small portion of their downstream modulation capability are challenging (as described above), and N’’ (for SC-QAM) and N* (for OFDM and SC-QAM) provide spec relaxation for signal power and spurious emissions for modulators using less than 25% of their modulated spectrum capability.