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Network Operations Subcommittee

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**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

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

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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 (<i>exempli gratia</i>)
FFT	fast Fourier transform
HFC	hybrid fiber/coax

Hz	hertz
i.e.	that is (<i>id est</i>)
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, $\text{dBmV} = 20\log(\text{value in mV}/1 \text{ mV})$.
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 <i>equivalent</i> legacy DOCSIS channels per RF port a CMTS or other signal source is capable of generating, defined by the formula $N_{\text{eq}} = N + 32 * N_{\text{OFDM}}$

N_{eq}	The number of <i>active</i> 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 <i>adjusted</i> 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 + $10\log_{10}(\text{Number of CTA channels occupied by the OFDM signal})$.
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, $P_{AVG} = I_{RMS} \cdot E_{RMS} \cdot \cos\theta$, 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.

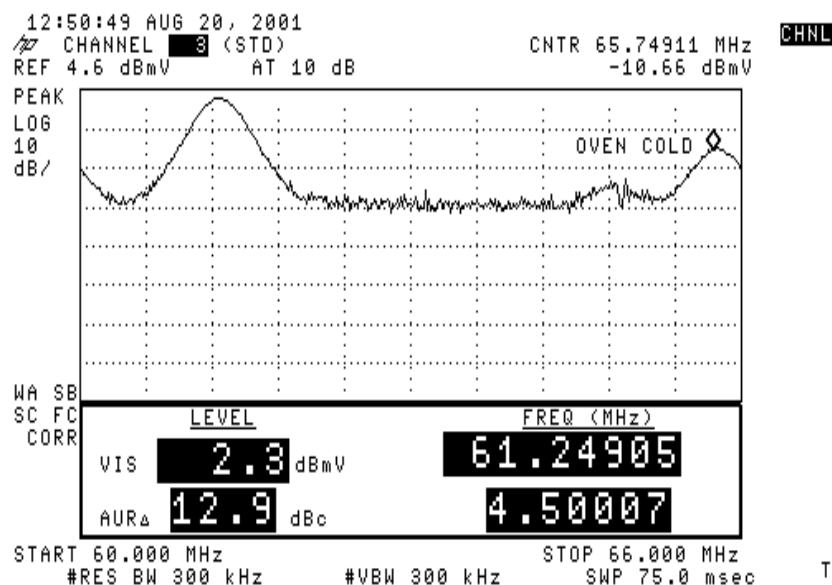


Figure 1. Spectrum analyzer measurement of analog TV channel signal levels. Courtesy of Hewlett Packard/Agilent (now Keysight).

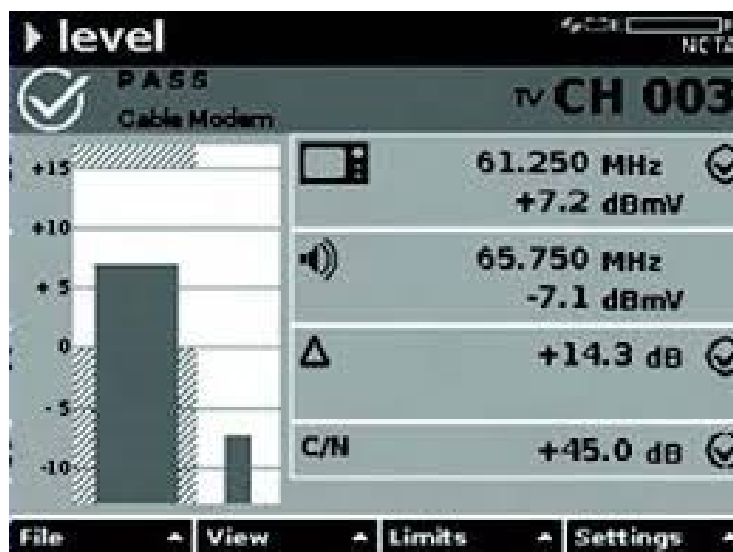


Figure 2. Signal level measurement of analog TV channel signal levels. Courtesy of JDSU (now Viavi Solutions, Inc.).