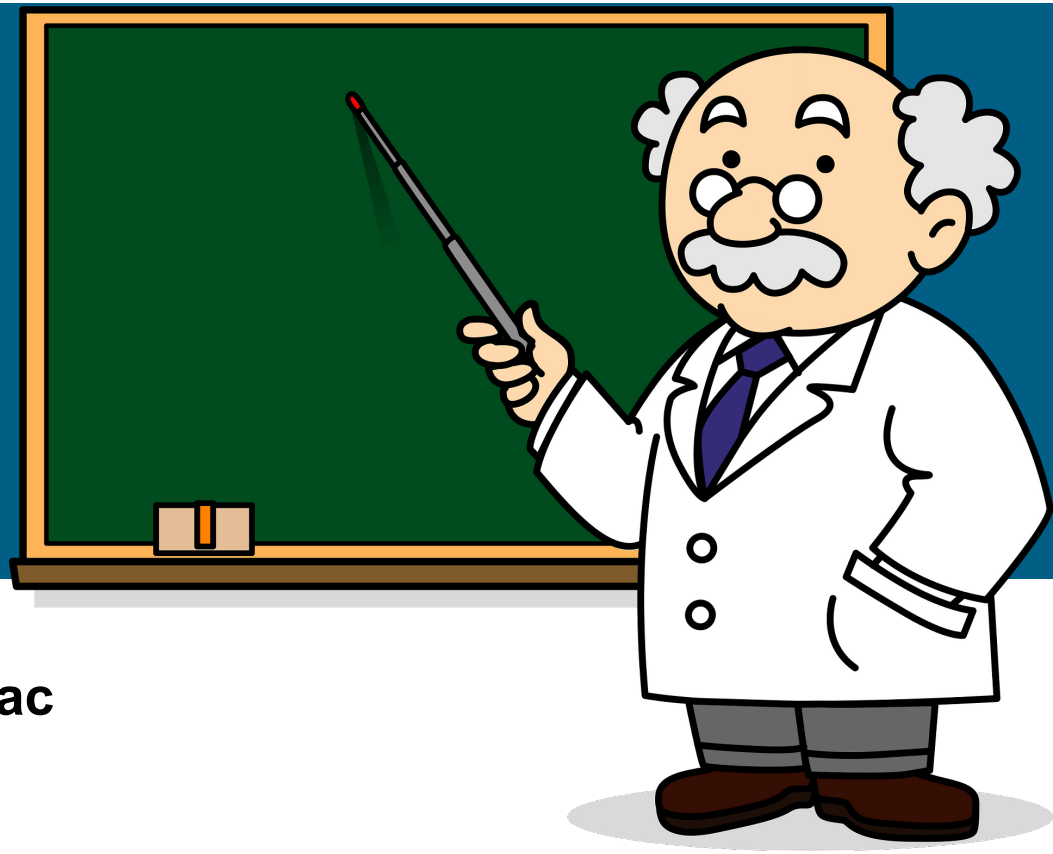
Did You Know?
(Part 1)



A Presentation by Ron Hranac

Terminology

- **Did you know** MSO is an abbreviation for *multiple system operator*?

  "MSO" is a corporate entity such as Charter or Comcast that owns and/or operates more than one cable system. It's not a generic abbreviation in the same sense that, say, LEC (local exchange carrier) is.

  A local cable system is not an MSO – although it might be owned by one – it's just a cable system

All MSOs are cable operators, but not all cable operators are MSOs

COX

Charter COMMUNICATIONS

COMCAST

Cable One®

Terminology

- **Did you know** headend is one word?

  It's not "head end" or "head-end"

Terminology

- **Did you know** modem is derived from a combination of the first part of the words modulator and demodulator?

  A cable modem is an electronic interface between a cable network and personal computer or other device, converting RF signals on the cable network into baseband digital data and vice versa.

Graphic source: Cisco

Terminology

- **Did you know** BER is an abbreviation for *bit error ratio*?

  BER is the ratio of errored bits to the total number of bits transmitted, received, or processed over a defined amount of time.

- Mathematically, two formulas are commonly used to calculate BER:

$$BER = \frac{(number\ of\ errored\ bits)}{(total\ number\ of\ bits)}$$

$$BER = \frac{(error\ count\ in\ measurement\ period)}{(bit\ rate\ x\ measurement\ period)}$$

BER example

- Let's say that 1,000,000 bits are transmitted, and 3 bits out of the 1,000,000 bits received are errored because of some kind interference between the transmitter and receiver
- BER in this example is calculated by dividing the number of errored bits received by the total number of bits transmitted:

  BER = 3/1,000,000 = 0.000003

- Most BER measurements are expressed in scientific notation format, so 0.000003 = 3×10^{-6}
- 3×10^{-6} also can be written as 3 x 10^-6 or 3.0E-06

Terminology

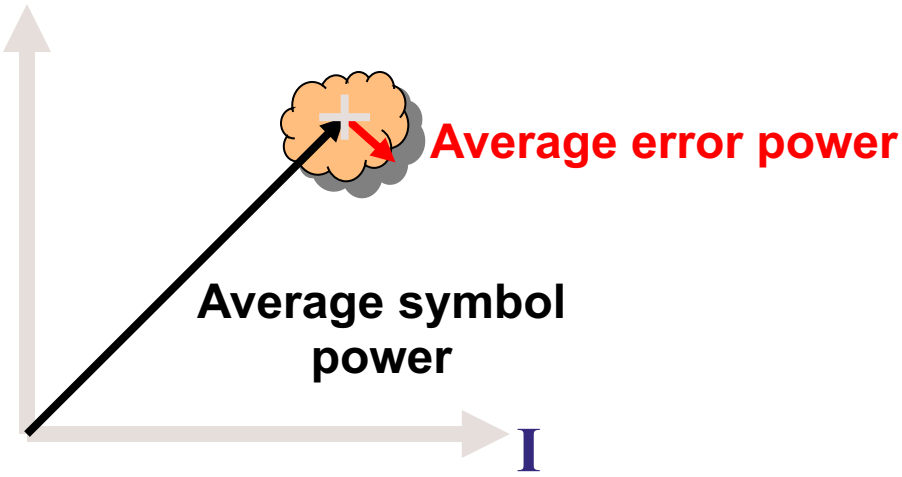
$$MER = 10\log_{10}\left[\frac{\sum_{j=1}^{N}\left(I_j^2 + Q_j^2\right)}{\sum_{j=1}^{N}\left(\delta I_j^2 + \delta Q_j^2\right)}\right]$$

- **Did you know** MER is an abbreviation for *error ratio*?

  It's not modulation error *rate*

  MER is the ratio of average signal constellation power to average constellation error power – that is, digital complex baseband signal-to-noise ratio (SNR). Indeed, MER is often called SNR.

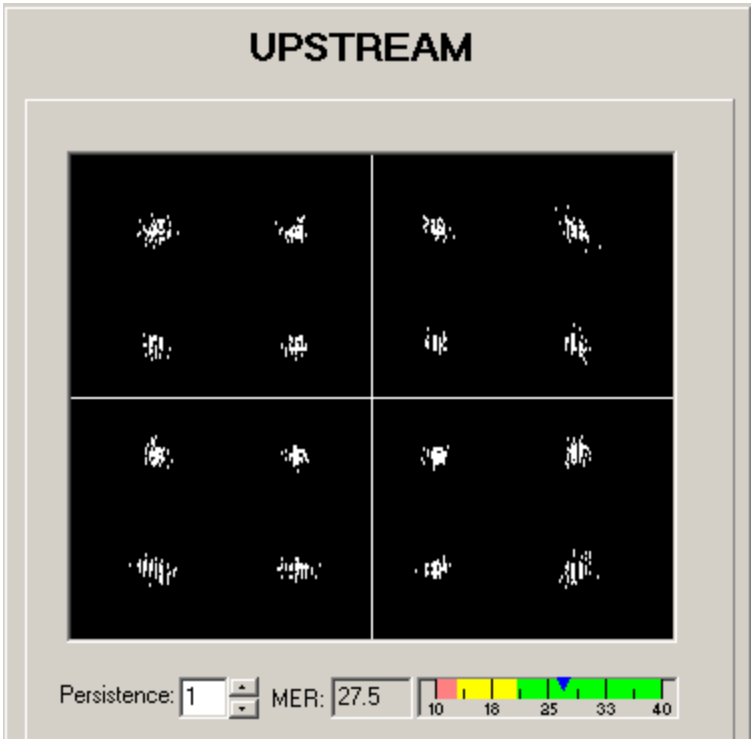
  MER = $10\log_{10}$(average symbol power/average error power)

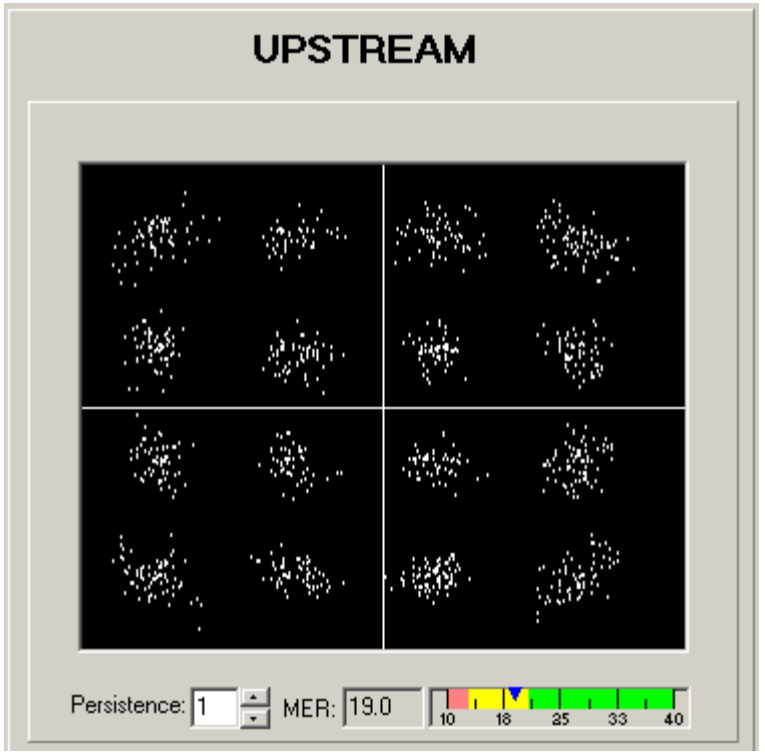


In effect, MER is a measure of how "fuzzy" or spread out the symbol points in a constellation are.

Terminology

Examples of good and not-so-good MER (in these examples, more accurately *receive modulation error ratio*, or RxMER)





Graphics source: Filtronic Sigtek, Inc.

CMTS “Upstream SNR”

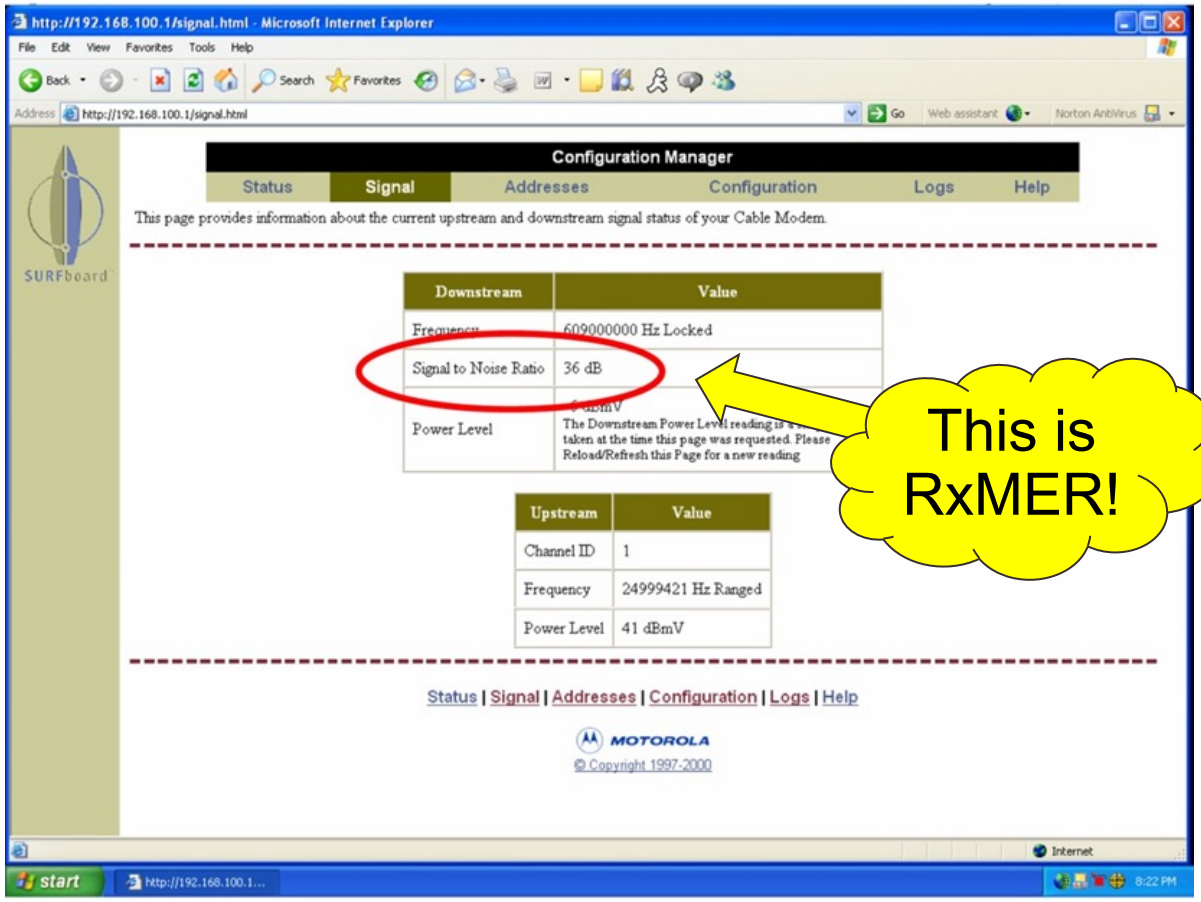
- **Did you know** that a CMTS’s reported upstream SNR actually is MER, or more specifically, RxMER?

  Factors that can affect the reported RxMER value include transmitter phase noise, receiver phase noise, CNR, linear distortions (micro-reflections, amplitude ripple/tilt, group delay), nonlinear distortions (common path distortion, etc.), in-channel ingress, laser clipping, improper modulation profiles, upstream data collisions…

Cable3/0 Upstream 0 is up
Frequency 25.392 MHz, Channel Width 3.200 MHz, QPSK Symbol Rate 2.560 Msps
Spectrum Group is overridden
BroadCom SNR_estimate for good packets - 26.8480 dB
Nominal Input Power Level 0 dBmV, Tx Timing Offset 2035

Cable modem and STB “SNR”

- **Did you know** that a cable modem’s and set-top’s reported downstream SNR also is RxMER?



Terminology

- **Did you know** CLI is an abbreviation for *cumulative leakage index*?

  CLI is NOT the same thing as signal leakage! CLI is a mathematical snapshot of a cable system's overall signal leakage performance at a given point in time.

  One cannot detect, test, or measure CLI

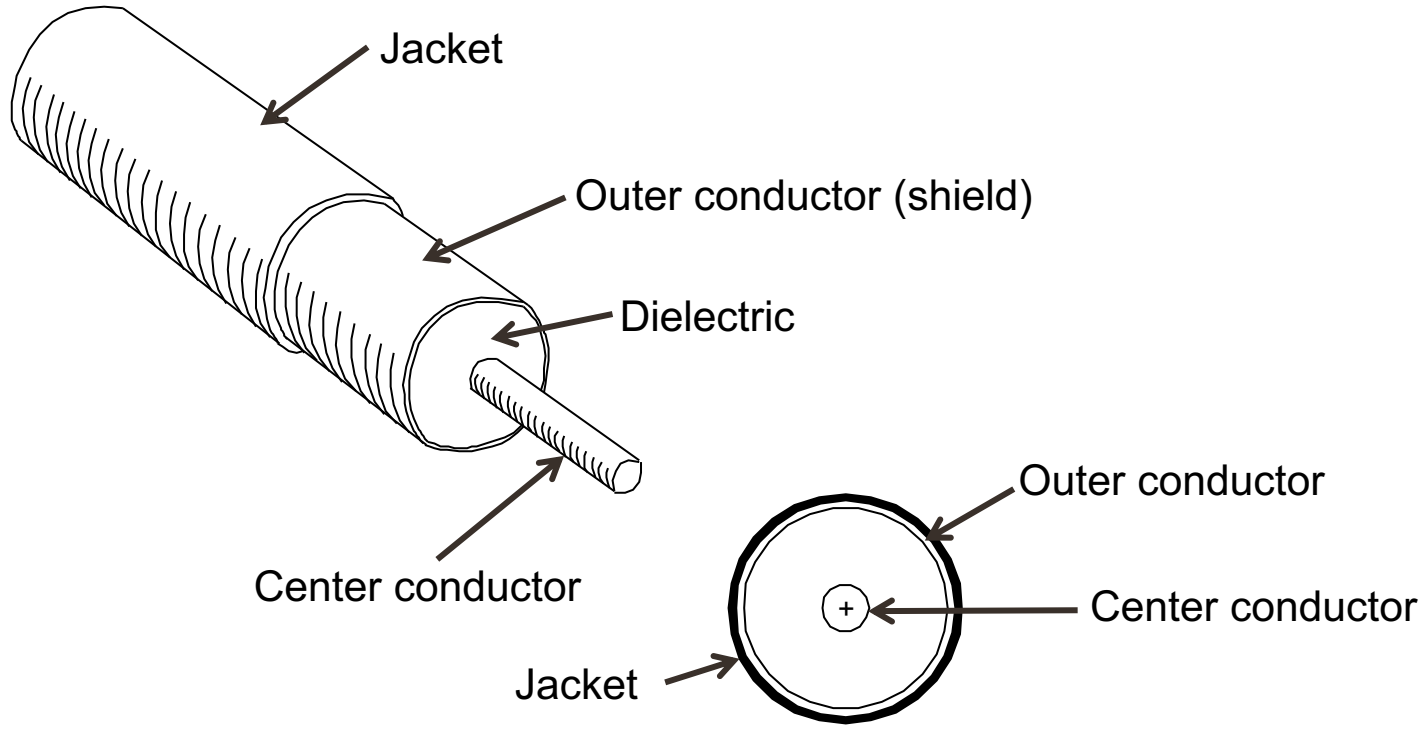
  One must measure signal leakage in order to *calculate* CLI

$$I_{\infty} = \frac{1}{\emptyset} \sum_{i=1}^{n} E_i^2,$$

Photo source: JDSU (Viavi)

Terminology

- **Did you know** the “coax” in coaxial cable refers to the fact that the center and outer conductors – as viewed from the end of the cable – share a *common axis*?

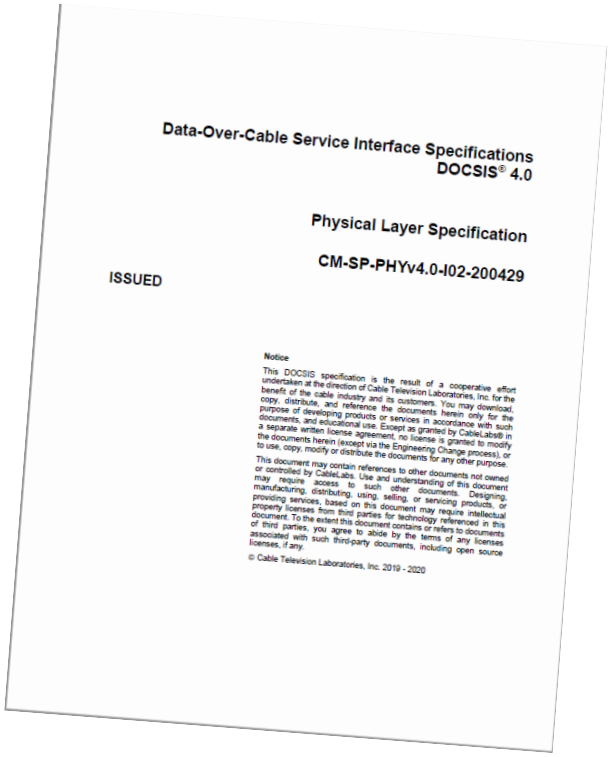


Terminology

- **Did you know** that DOCSIS® is an abbreviation for Data-Over-Cable Service Interface Specifications?

  Among other things, DOCSIS defines interoperability between cable modem termination systems (CMTSs) or converged cable access platforms (CCAPs) and cable modems.

  The latest version is DOCSIS 4.0, and is available for download from CableLabs' web site (www.cablelabs.com).


Data-Over-Cable Service Interface Specifications
DOCSIS® 4.0

Physical Layer Specification

CM-SP-PHYv4.0-I02-200429

ISSUED

Notice

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Terminology

Department of Redundancy Department

- **Did you know** the following are redundant?

  "Cable MSO" (if the entity is an MSO, it's a cable operator)

  "AM modulation" (*amplitude modulation* modulation)

  "FM modulation" (*frequency modulation* modulation)

  "QAM modulation" (*quadrature amplitude modulation* modulation?)

  "RF frequency" (*radio frequency* frequency?)

  "NIC card" (*network interface card* card?)

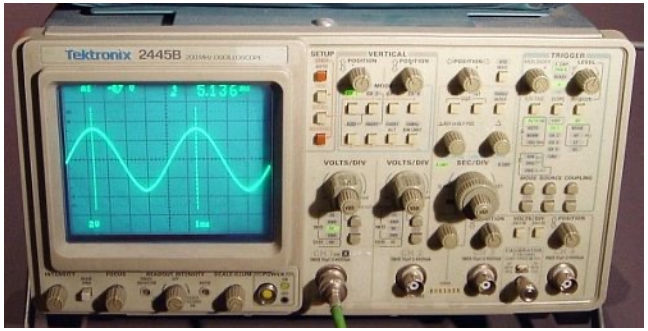
  "PIC card" (*physical interface card* card?)

  "PIN number" (*personal identification number* number?)

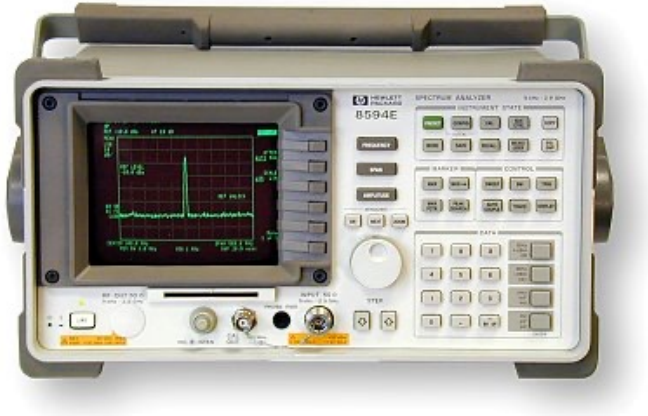
  "PON network" (*passive optical network* network?)

Time and frequency domains

- **Did you know** a sinusoidal signal can be observed on an oscilloscope, which displays that signal in the time domain – amplitude in the vertical axis versus time in the horizontal axis (left image, below)? A spectrum analyzer displays the sinusoidal signal in the frequency domain – amplitude in the vertical axis versus frequency in the horizontal axis (right image, below).



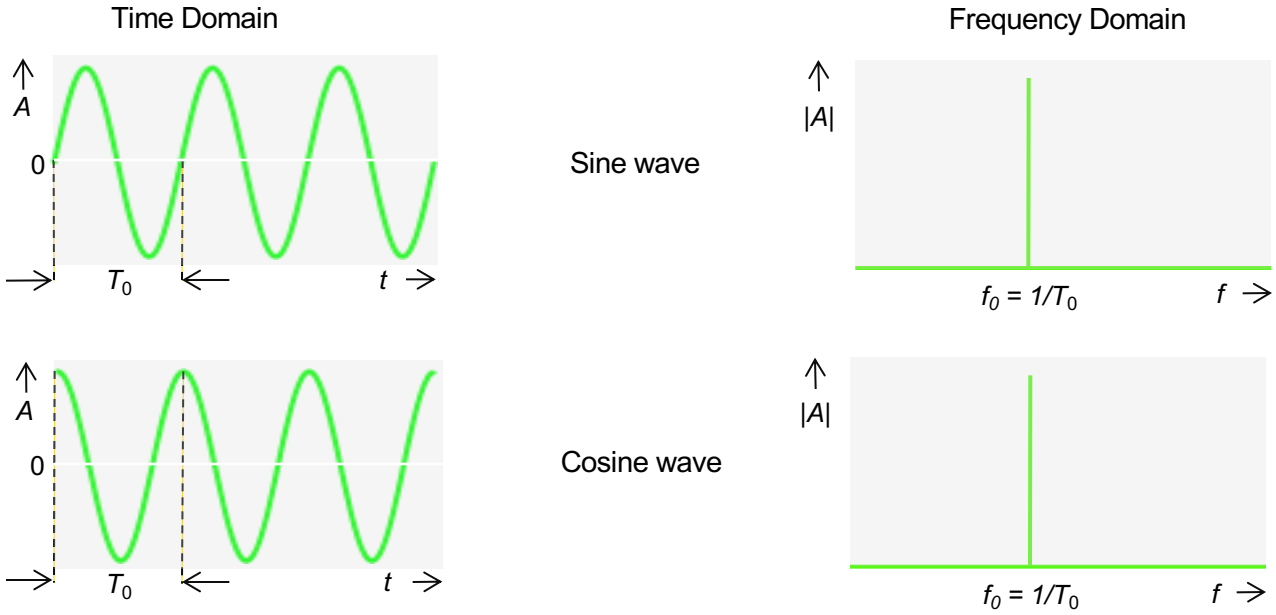
Time domain display of sinusoidal signal



Frequency domain display of sinusoidal signal

What about a cosine wave?

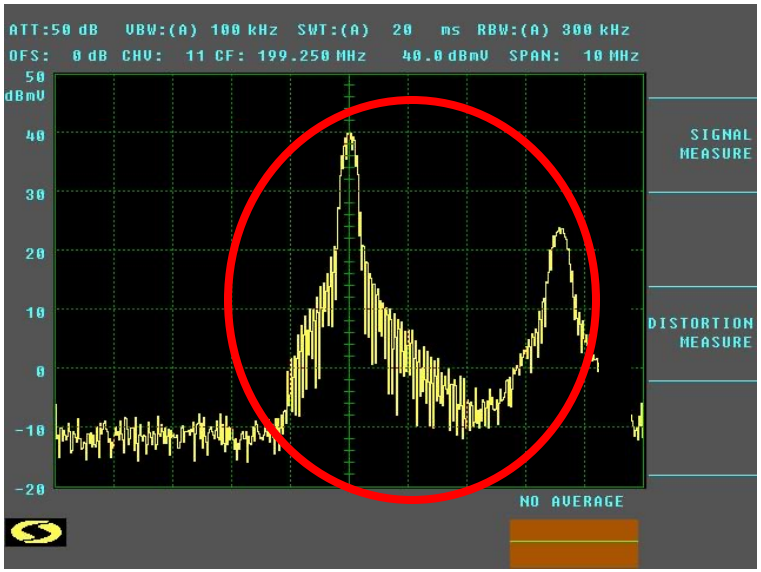
- **Did you know** a sine wave and cosine wave of the same frequency and amplitude will appear identical in the frequency domain? The only difference is their relative phases. This difference can be seen in the time domain but not in the frequency domain.



Graphics adapted from example in: *Fundamentals of Spectrum Analysis* (Rohde & Schwarz)

Time and frequency domains

Modulated analog NTSC visual carrier



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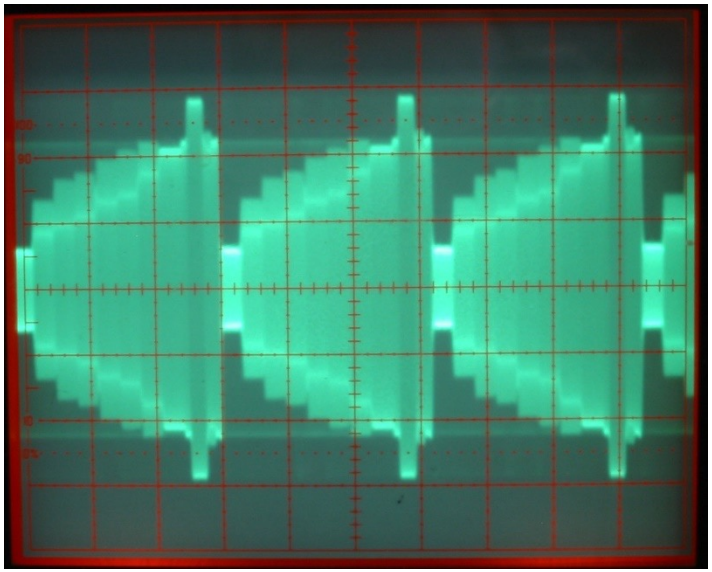
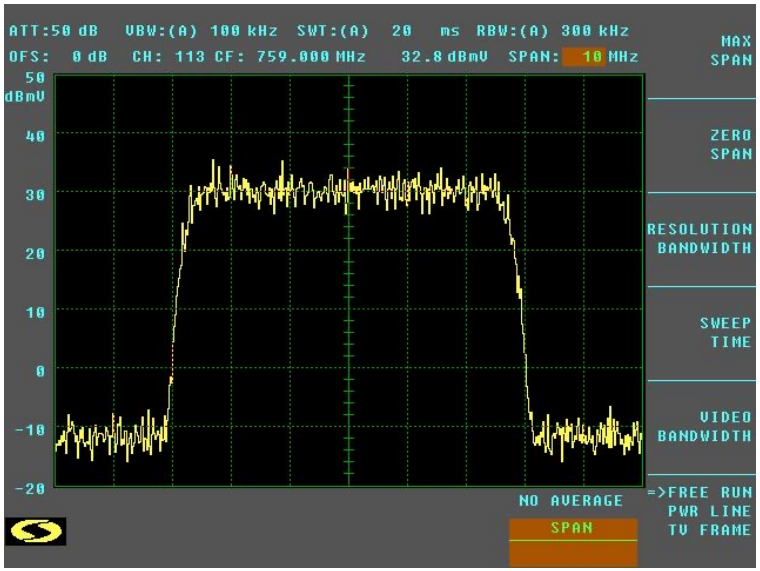


Frequency domain:
Amplitude versus frequency

Time domain:
Amplitude versus time

Time and frequency domains

64-QAM digitally modulated signal



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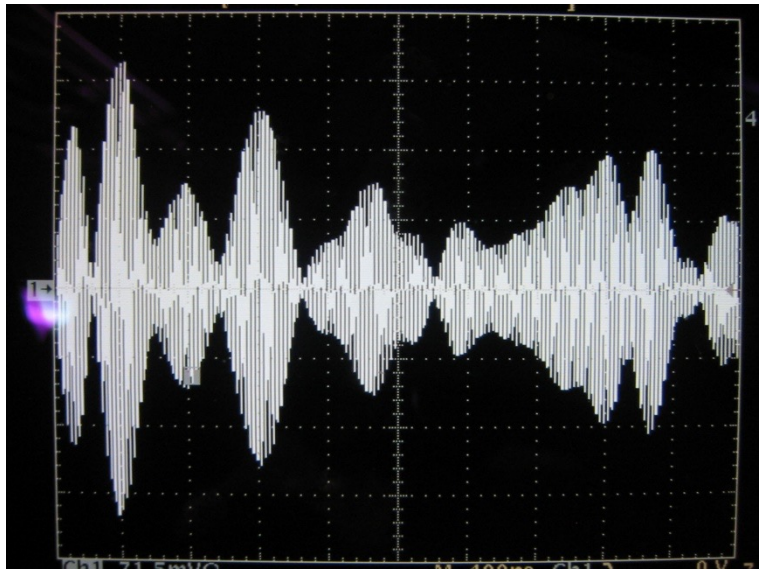


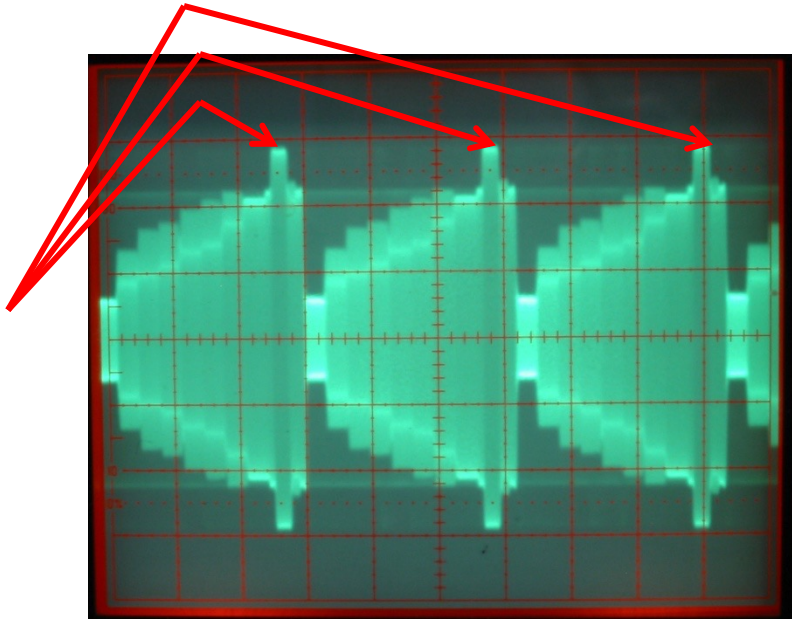
Frequency domain:
Amplitude versus frequency

Time domain:
Amplitude versus time

Analog TV channel signal levels

- **Did you know** that when we measure the RF level of analog TV channel visual carriers, we don't measure peak power? We measure peak envelope power (PEP), which is the average power of one cycle during the modulation crest. A visual carrier's modulation crest occurs during sync pulses.

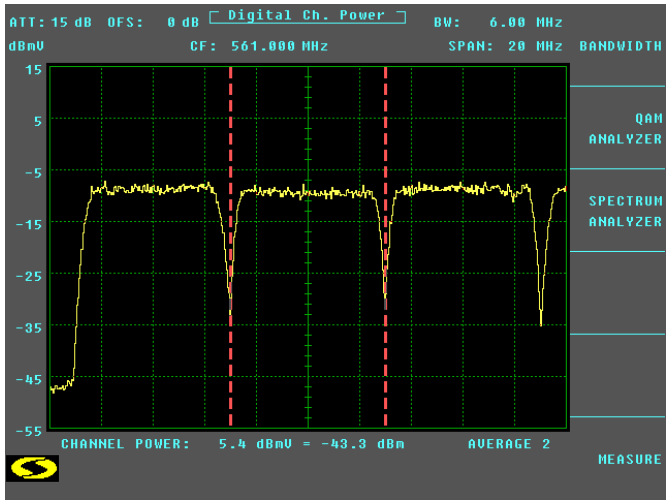
When video modulation is present, the visual carrier's amplitude is the power during the sync peaks.

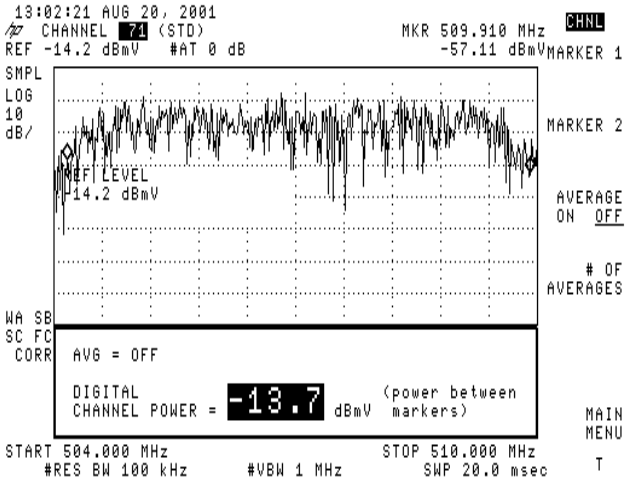


Modulated analog visual carrier in the time domain

Digital signal levels

- **Did you know** that when we measure the RF level of digital signals carried on cable networks, we measure the entire signal's average power, also known as *digital channel power* or *digital signal power*?





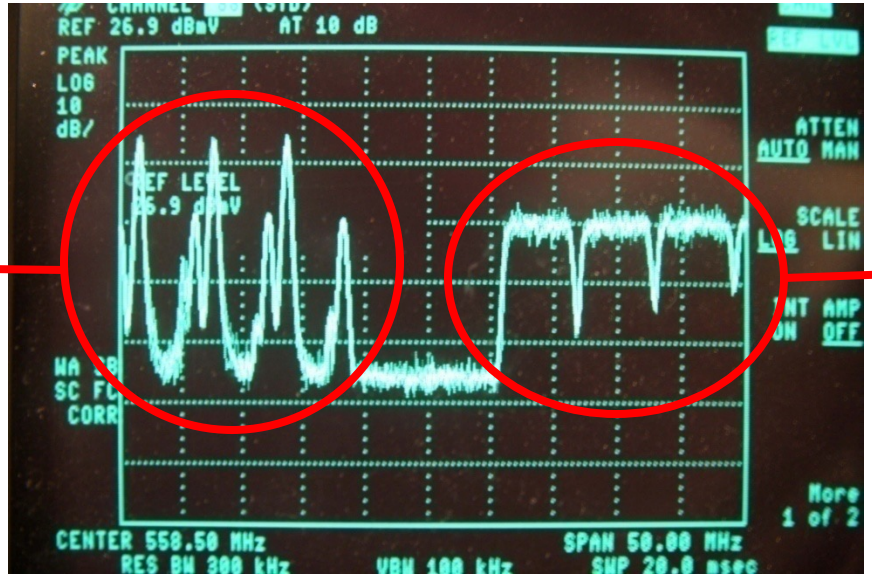
Graphics source: Sunrise Telecom (VeEX) and Agilent (Keysight)

Digital or analog?

- **Did you know** the “digital” signals we carry in our HFC networks aren’t really “digital,” they’re analog?

  Our networks can’t carry baseband digital data – for the purists, a length of coaxial cable can, but that digital data won’t make it past the first active – so we have to convert the digital data we want to transmit to and from subscribers into analog RF signals.

These are analog…



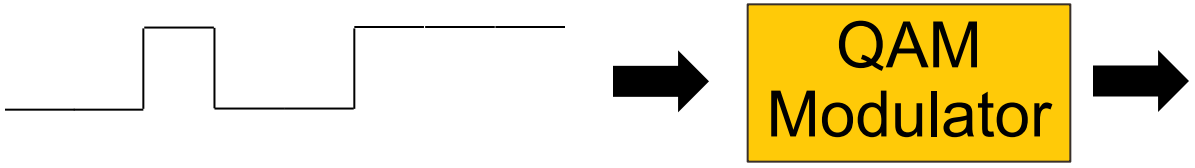
…and so are these!

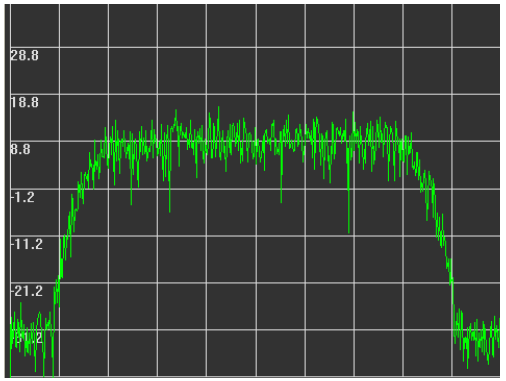
What's a QAM?

- **Did you know** digital data is converted into an analog RF signal using quadrature amplitude modulation (QAM), which results in a double-sideband, suppressed-carrier analog RF signal?

  The digital information to be transmitted is represented by variations in the RF signal's phase and amplitude. There are no zeros and ones per se in the RF "digital" signals carried in our HFC networks.

  The resulting RF signal is called a single carrier quadrature amplitude modulation (SC-QAM) signal.





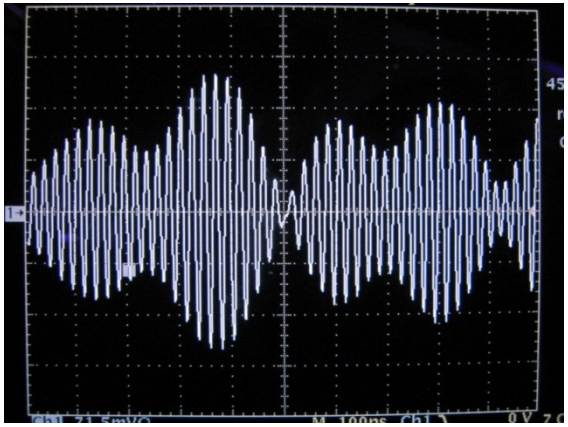
SC-QAM signal in the frequency domain

QAM signal graphic source: Trilithic (Viavi)

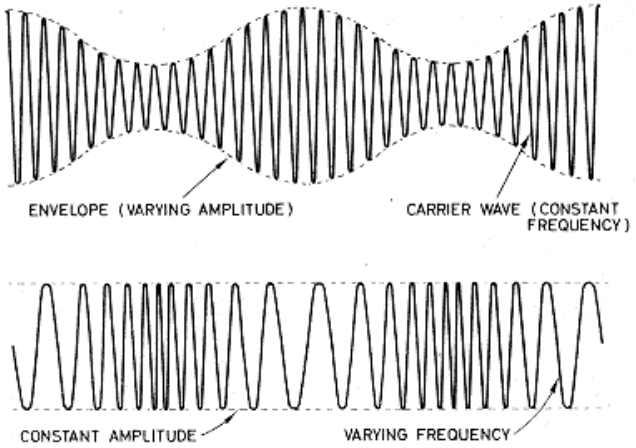
What's a QAM?

- **Did you know** QAM is a type of modulation, like amplitude modulation (AM) or frequency modulation (FM)?

  Technically it's incorrect to call an *SC-QAM signal* or a *QAM modulator* a "QAM." Doing so is no different than calling an FM signal or an FM broadcast transmitter a "FM." Let's see, would we pronounce that "foom"?



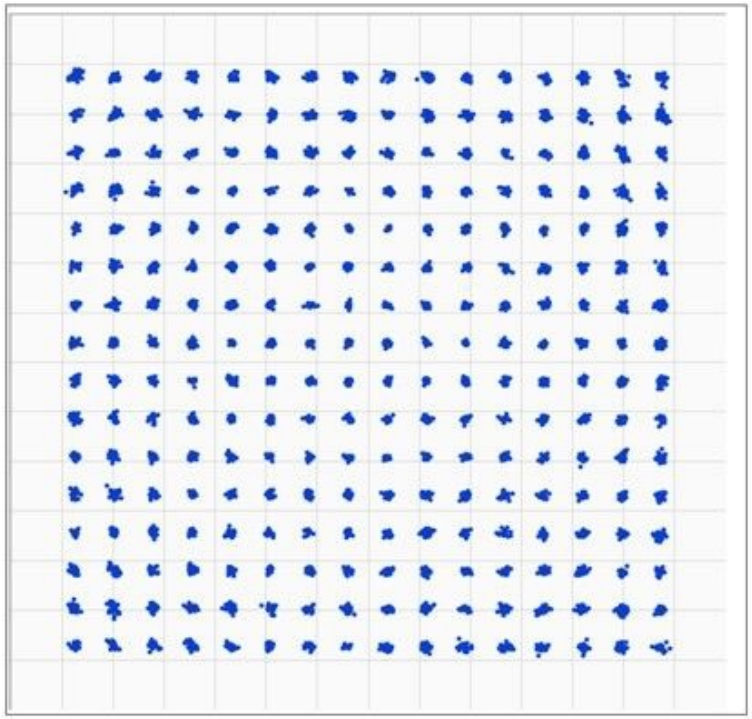
SC-QAM signal in the time domain



AM signal (top) and FM signal (bottom) in the time domain

What's a constellation?

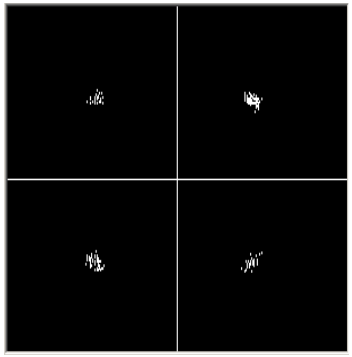
- **Did you know** in what is commonly called M-ary encoding (where "M-ary" is derived from "binary"), M refers to the number of *conditions* such as amplitudes, phases, frequencies, etc.? For example, a 256-QAM digital signal has 256 combinations of amplitudes and phases that represent 256 different symbols, and can be described as a 256-point signal constellation. Each of a 256-QAM signal's symbols is a unique group of 1s and 0s. In the case of 256-QAM, each symbol comprises eight bits.

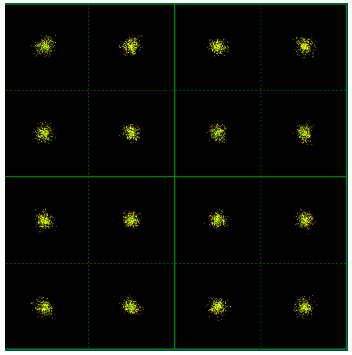


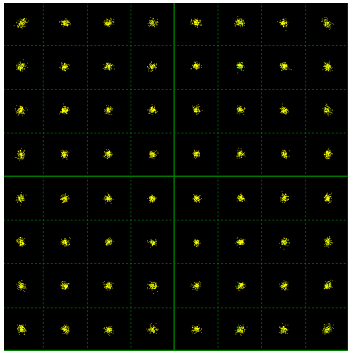
256-QAM constellation

What's a constellation?

- 4-QAM has 4 points in the constellation (more commonly known as quadrature phase shift keying, or QPSK)
- 16-QAM has 16 points in the constellation
- 64-QAM has 64 points in the constellation, and so on







Graphic sources: Filtronic Sigtek and Sunrise Telecom (VeEX)

So many topics, so little time …

- Join us again next time for Part 2 of **Did You Know?**