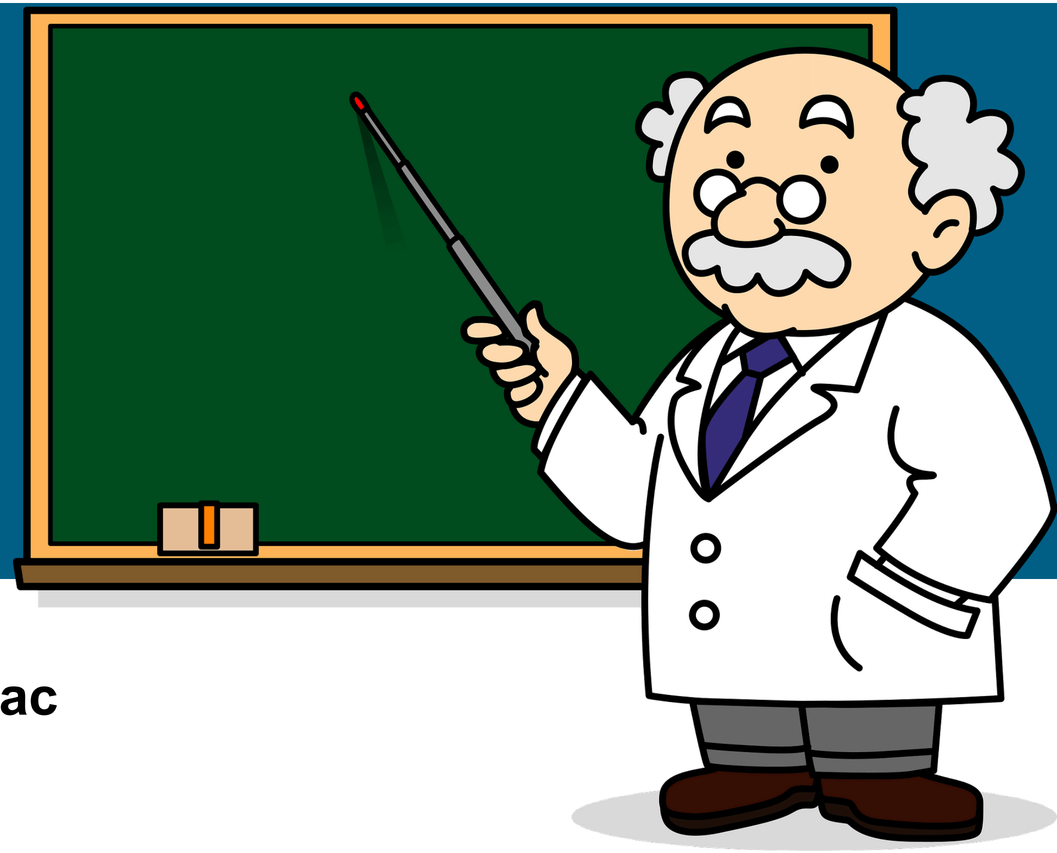
Did You Know?
(Part 2)



A Presentation by Ron Hranac

Distortions in an All-Digital Network

- **Did you know** that distortions such as composite triple beat (CTB) distortion, composite second order (CSO) distortion, and common path distortion (CPD) don't go away in an all-digital network?

  Rather than clusters of discrete beats that occur in a network carrying large numbers of analog TV channels, the digital distortions are noise-like!

  Those noise-like distortion products are variously known as composite intermodulation noise (CIN), composite intermodulation distortion (CID) or intermodulation noise (IMN) – which should *not* be confused with thermal noise.

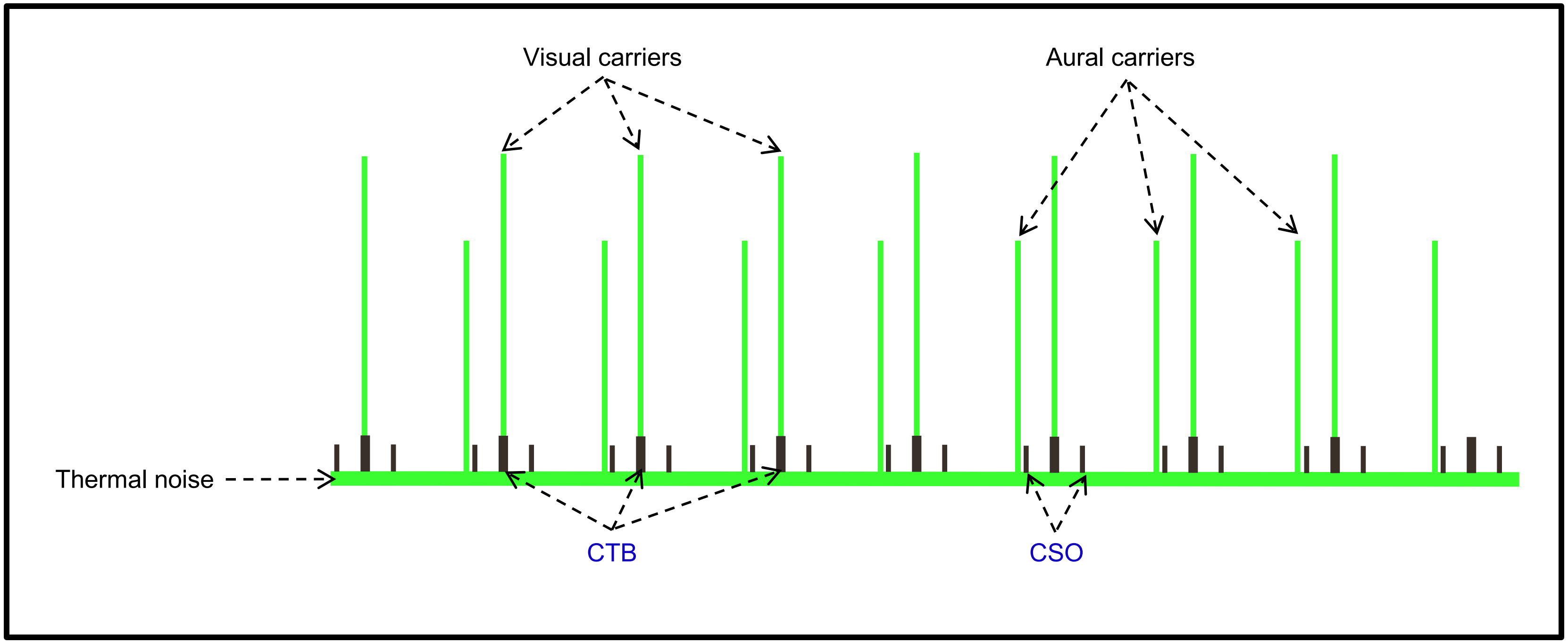
Distortions in an All-Digital Network

- Confusion does occur, though. We know that raising RF levels in the plant improves the carrier-to-noise ratio (CNR), where “N” is thermal noise. But in a system with a lot of digital signals, **did you know** raising levels improves CNR to a point, then the noise floor starts to *increase* and the CNR appears to get worse?

  That seems counterintuitive, but the now-elevated noise floor no longer is just thermal noise. It’s a combination of thermal noise and the previously mentioned noise-like distortions. When characterizing plant performance in the presence of CIN, the term “carrier-to-composite noise (CCN) ratio” commonly is used. Indeed, CCN is a much more appropriate measurement metric than is CNR under these circumstances, because there is no practical way to differentiate thermal noise from CIN (at least not without disrupting service).

- The following examples illustrate this

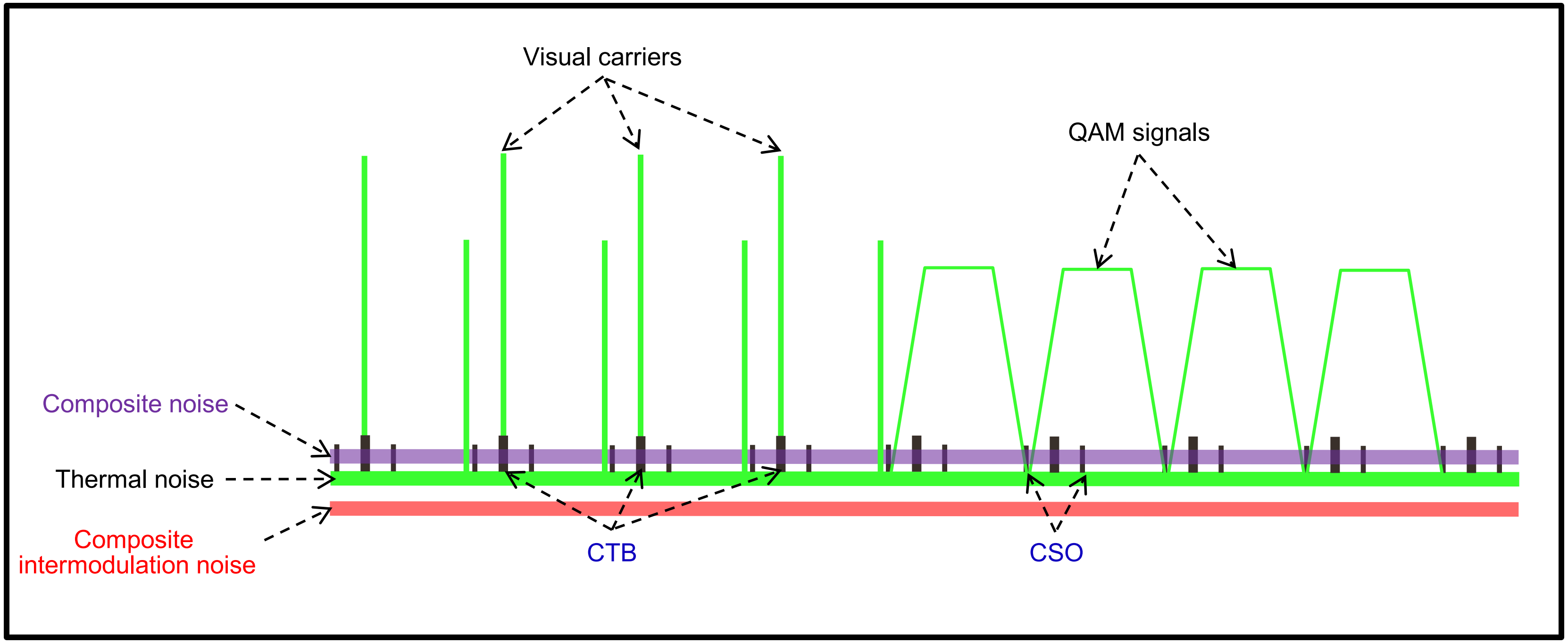
Distortions in an All-Analog Network



For each 1 dB increase in system carrier levels:

- **CTB** ratio degrades by 2 dB
- **CSO** ratio degrades by 1 dB
- **CNR** improves by 1 dB

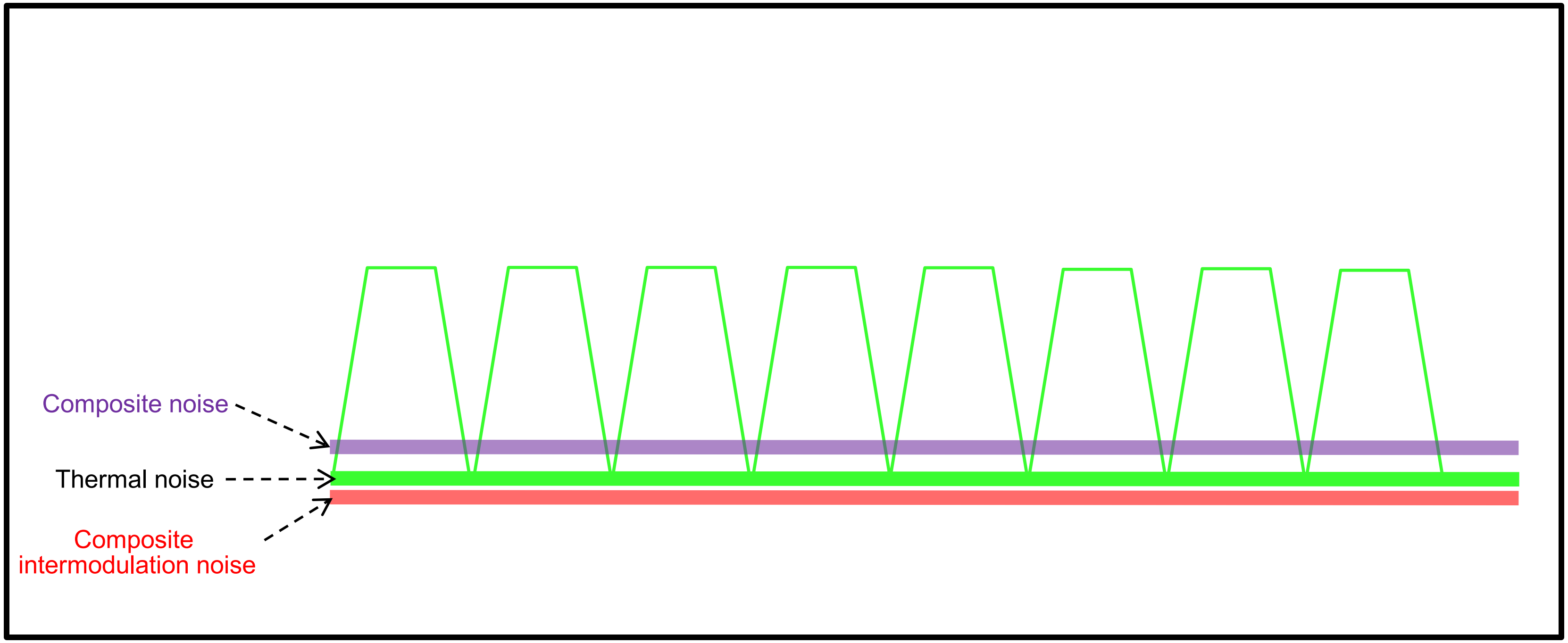
Distortions in an Analog + Digital Network



For each 1 dB increase in system carrier levels:

- CNR, CTB, & CSO ratios behave as before with all-analog operation
- **CIN** ratio degrades by 1 to 2 dB (mix of 2^{nd} & 3^{rd} order components)
- **CCN** ratio degradation depends on **CIN** and **CNR** values

Distortions in an All-Digital Network



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Decibel Millivolt

- **Did you know** dBmV expresses power in terms of voltage?

  The 0 dB reference for decibel millivolt, 0 dBmV, equals 13.33 nanowatts (nW) of power, defined as 1 millivolt (RMS) across an impedance of 75 ohms. That is, 1 mV in a 75 ohms impedance is 13.33 nanowatts (nW), which we call 0 dBmV.

  Other signal levels in dBmV are technically ratios of those levels' voltages to the 0 dBmV 1 mV "reference":

  $\text{dBmV} = 20\log_{10}(\text{level in mV}/1\text{ mV})$

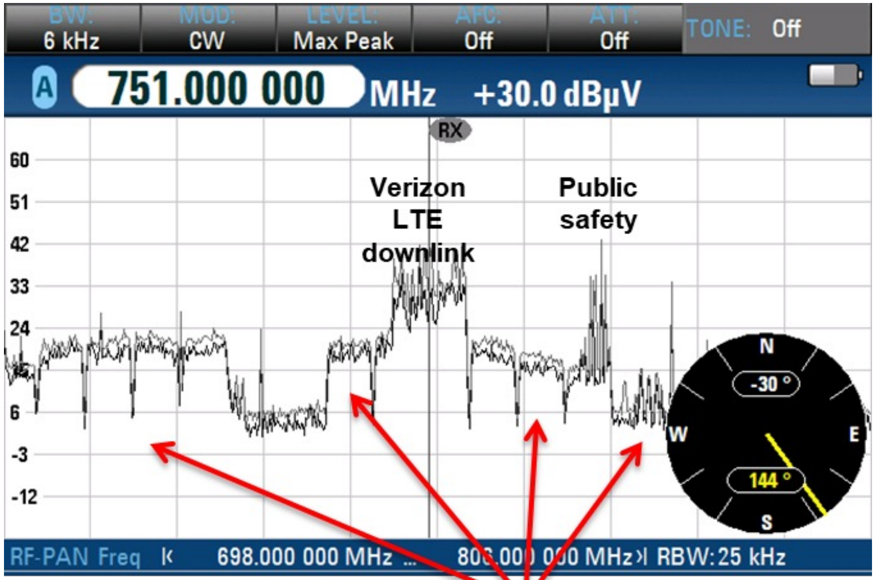
Graphic source: Sunrise Telecom (VeEX)

Signal Leakage in an All-Digital Network

- **Did you know** leaking digital signals can cause harmful interference to over-the-air services?

  Despite the fact that an SC-QAM signal's power is spread across most of the 6 MHz channel bandwidth, moderate to high field strength leaks involving those noise-like SC-QAM signals can indeed cause harmful interference!

Communications transceiver's S9+15 dB S-meter reading caused by 400 µV/m digital leak at 10 ft.



Signal Leakage in an All-Digital Network

- And **did you know** that older legacy leakage detectors can't be used to measure leaking digital signals?

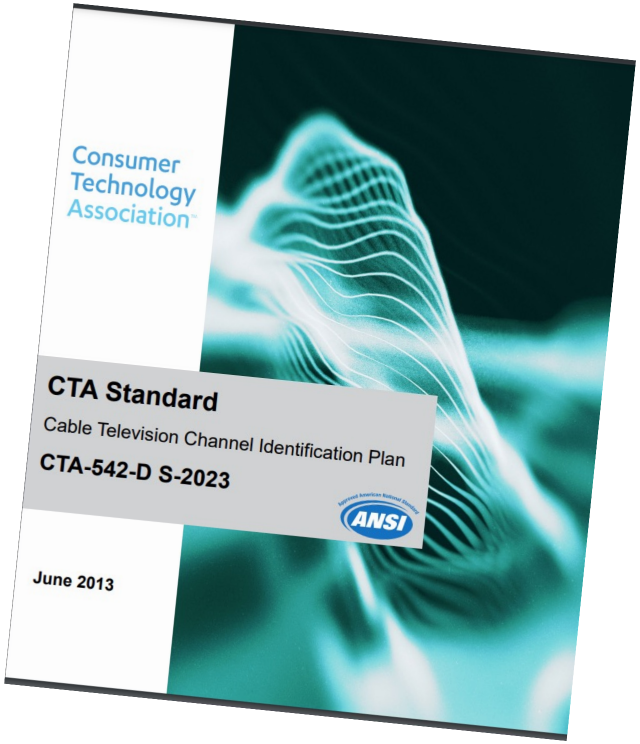
  Those older detectors are compatible only with a modulated analog TV signal's visual carrier or a CW carrier.

- The good news is that all leakage detector manufacturers now have digital-compatible, multi-band leakage detector technology available.

  Most of the new-generation leakage detectors monitor a low-level test signal that is injected in between adjacent SC-QAM signals.

6 MHz-Wide Channels in a Cable Network

- **Did you know** the 6 MHz-wide channel designation in cable networks is defined in the Consumer Technology Association Standard CTA-542-D S-2023 (“Cable Television Channel Identification Plan”)?
- In years past, the channel designations were variously known as IS-6, NCTA, NCTA/EIA, EIA, EIA/CEA, and CEA channels, but today are CTA channels.



UHF TV Ingress

- **Did you know** that when an over-the-air UHF TV channel – whether analog or digital – leaks into a cable network it can interfere with *two* cable channels?

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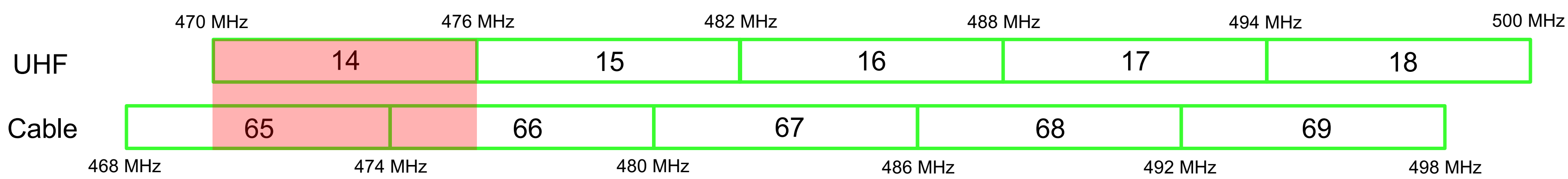
  There is a 2 MHz overlap (or offset) between North American over-the-air UHF channel slots and North American STD and IRC cable channel slots



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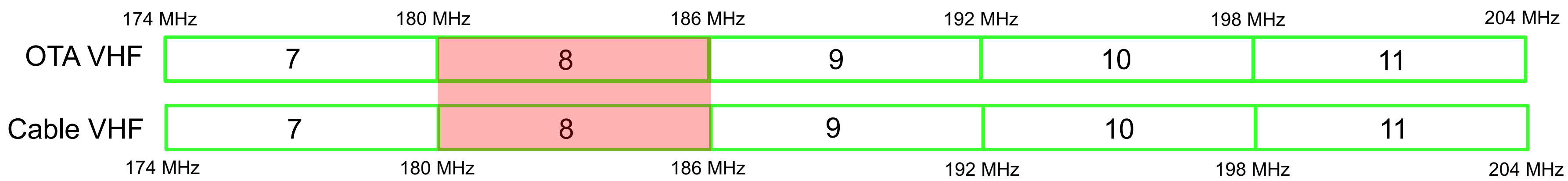
  Over-the-air and cable VHF channel slots use the same allocations (e.g, 174-180 MHz for Ch. 7, 180-186 MHz for Ch. 8, and so on)



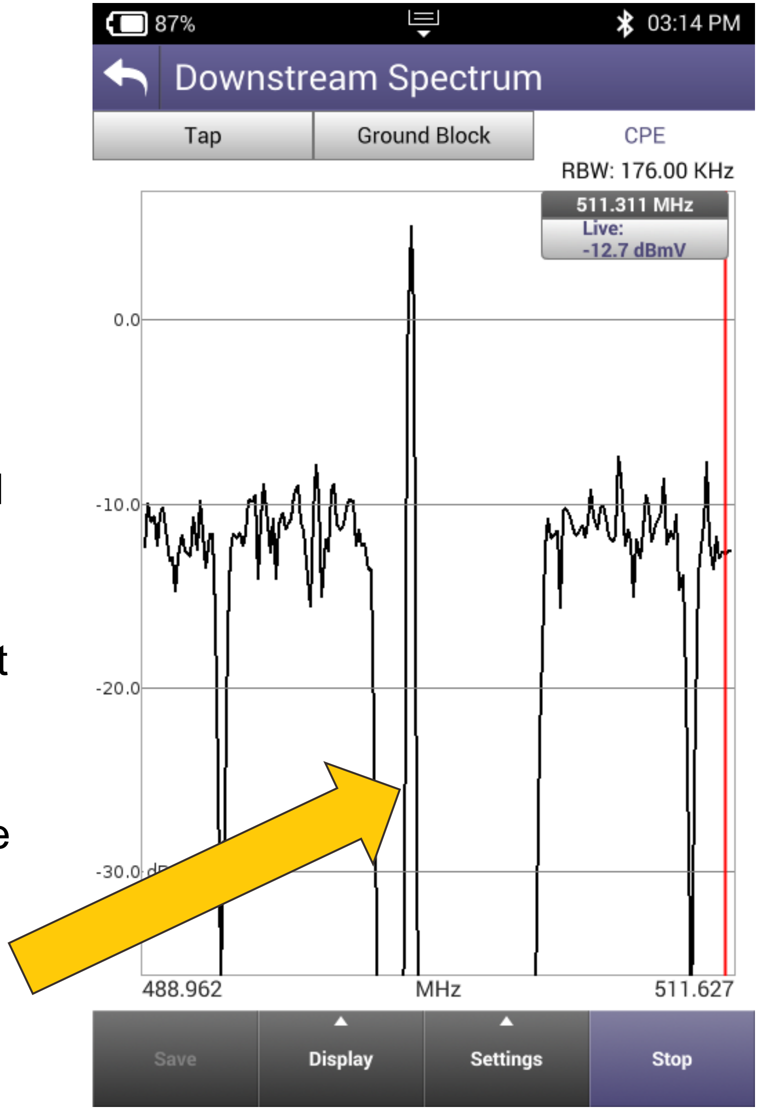
Digital Signals and Amplifier AGC

- **Did you know** most older amplifier automatic gain control (AGC) circuits don't play nicely with a digital signal on the AGC pilot frequency?

  Those AGC circuits originally were designed for analog TV channels or CW carriers, *not* for noise-like digital signals.

  Most amplifiers manufactured during the last several years have digital-compatible AGC, but many older amplifiers do not.

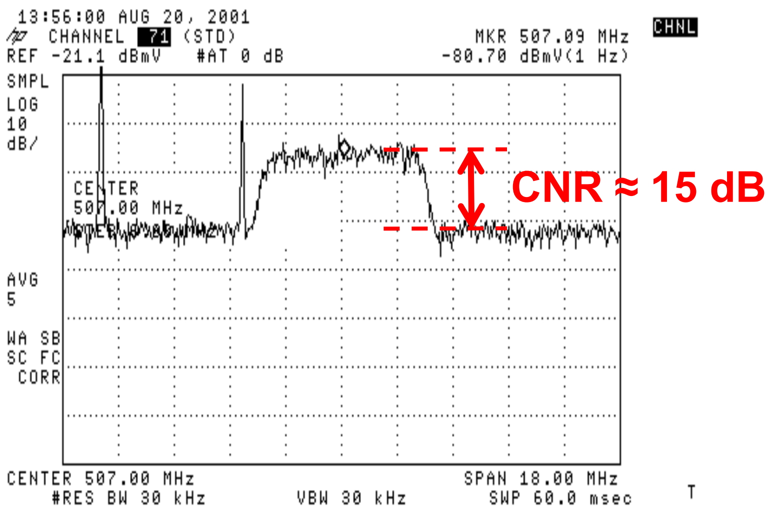
  In most instances, it will be necessary to use an analog TV channel or CW carrier on the AGC pilot frequency if you want those older amplifiers' AGC circuits to work properly.



SC-QAM Signal CNR

- **Did you know** when using a spectrum analyzer to measure the carrier-to-noise ratio of an SC-QAM signal, the CNR is simply the signal's height above the noise floor in dB?

  Make certain that the spectrum analyzer is displaying the cable system's noise floor, and not the test equipment's noise floor!

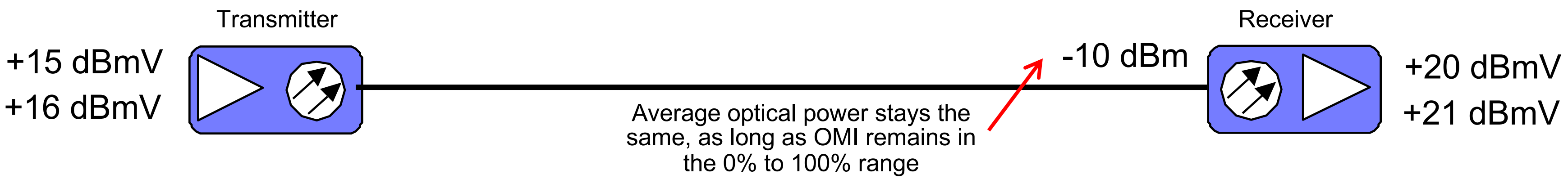


Graphic source: Agilent (Keysight)

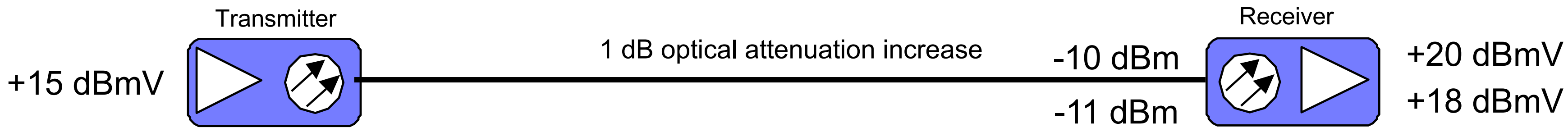
AM Optical Fiber Links

- **Did you know…**

  …assuming an optical fiber link is operating within its linear range, a 1 dB change in signal level at the RF input to the optical transmitter will result in a 1 dB change in signal level at the optical receiver's RF output?



  …and a 1 dB change in optical power at the input to the optical receiver will cause a 2 dB change in signal level at the optical receiver's RF output?



AM Optical Fiber Links

- **Did you know** the 1 dB optical power-versus-2 dB RF power relationship in AM fiber links is *not* because "optical decibels are twice as big as RF decibels"?

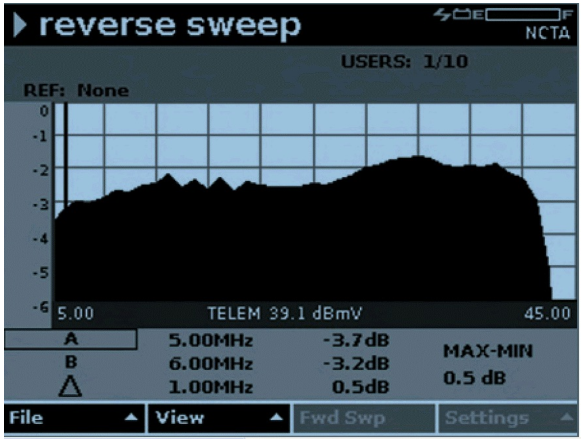
  From *Modern Cable Television Technology, 2nd Ed.**:

  In fact, optical transmitters and receivers are not linear devices but "square law" devices; that is, the instantaneous light output power of a transmitter is proportional to the input *current* and thus to the square root of the input signal power. At the other end of the circuit, the RF output power from the detector is proportional to the square of the optical power received, so the total link is nominally linear (predistortion is often used to overcome residual nonlinearities). As will be seen, however, the square law transfer function has an effect on noise and distortion addition. In particular, because of the square law detector transfer function, a change of 1 dB in optical loss will result in a 2-dB change in detected RF power, leading to the commonly stated, but incorrect, statement that "optical decibels are twice as big as RF decibels."

* By Ciciora, Walter; J. Farmer, D. Large, M. Adams; Morgan Kaufmann Publishers; ©2004

Frequency Response

- **Did you know** the broadband sweep gear we use to align and maintain our outside plants only shows half of the measured frequency response?

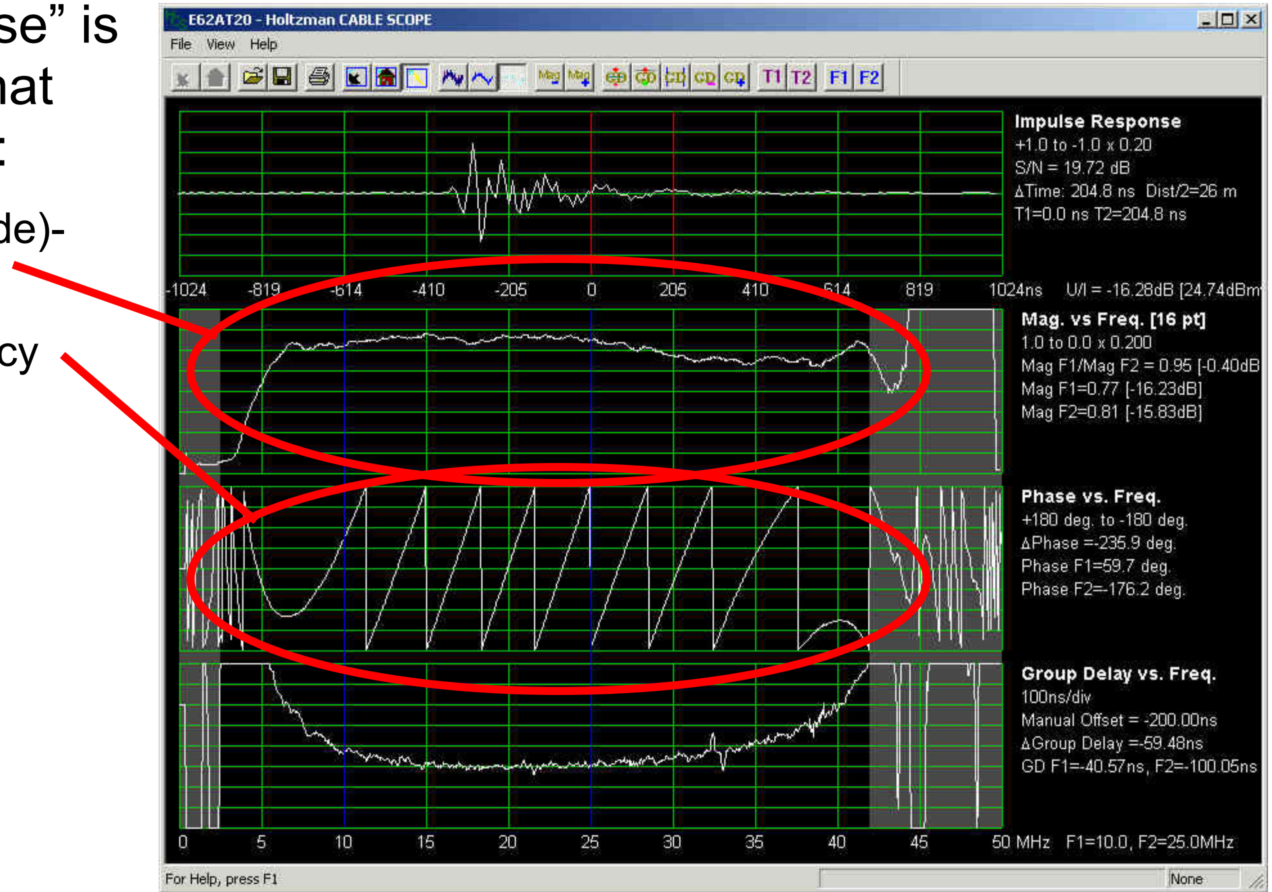


- Well, maybe “half” isn’t the right word here, but a sweep display only shows one *part* of the complete frequency response

Graphic source: JDSU (Viavi)

Frequency Response

- “Frequency response” is a complex quantity that has two components:
  - Magnitude (or amplitude)-versus-frequency
  - Phase-versus-frequency



Graphic source: Holtzman, Inc.

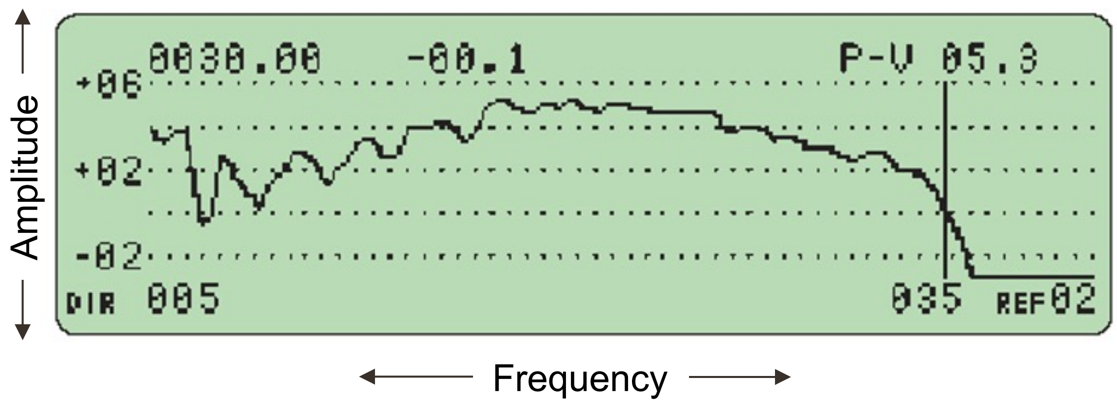
Frequency Response

- "Frequency response" is a complex quantity that has two components:

  Magnitude (or amplitude)-versus-frequency

  Phase-versus-frequency

- The display of a conventional broadband sweep receiver shows us amplitude-versus-frequency, but not phase-versus-frequency.

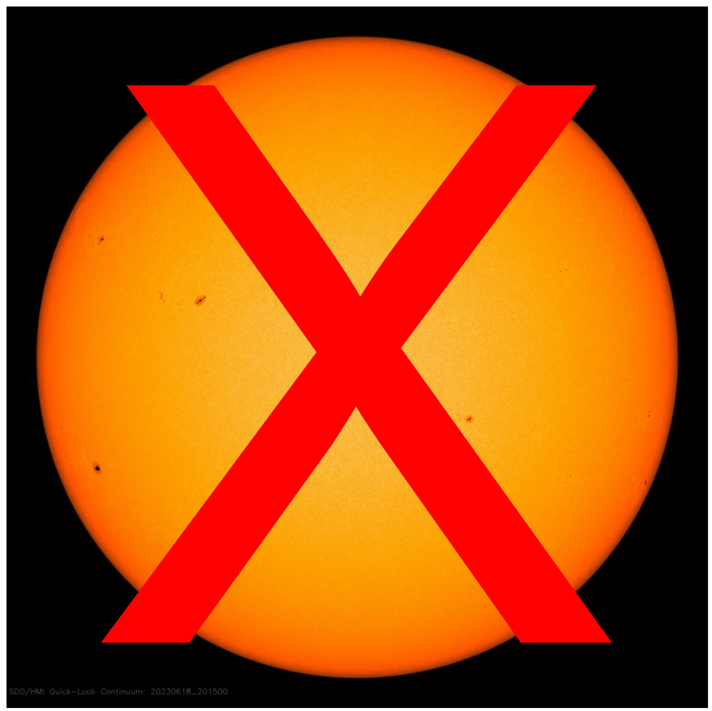


Frequency Response

- Ideally, amplitude-versus-frequency should be flat, and phase should change in proportion to frequency. When amplitude-versus-frequency is not flat, we see amplitude ripple (“standing waves”), amplitude tilt and/or other response impairments. When phase-versus-frequency is out of whack, we have group delay distortion.

Solar Transit Outages

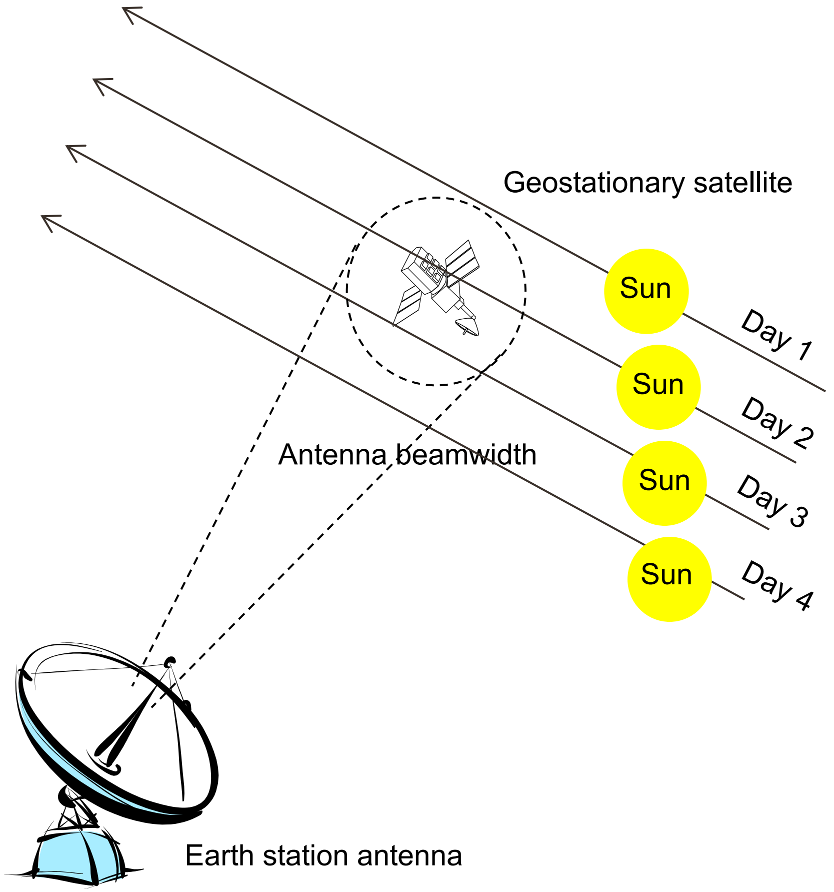
- **Did you know** that what are sometimes called “sunspot outages” have nothing to do with sunspots?



Graphic source: https://sdo.gsfc.nasa.gov/data/

Solar Transit Outages

- Those outages actually are solar transit outages – also called sun fade or sun outages – which are twice-yearly satellite reception outages that happen when the Sun lines up behind geostationary satellites. The Sun emits electromagnetic radiation across a wide range of frequencies, including those used by communications satellites.
- When the Sun is behind a satellite from the perspective of a given earth station antenna, the RF energy from the Sun is strong enough to exceed the desired signal(s) from that satellite (on sunny days the heat can get pretty intense at the antenna focal point if the dish is solid/shiny). Solar-transit outages occur for a few minutes on each of several days near the spring and autumn equinoxes.



Reliability vs. Availability

- **Did you know** that reliability and availability are not the same thing?

  Availability: The ratio of time that a service, device, or network is available for use to total time, usually expressed as percent of the total time.

  Reliability: Probability that a system or device will not fail during some specified period.

- In addition to percent, availability is sometimes stated as some number of nines, such as "four-nines availability."

  For example, four-nines availability – expressed as 99.99% – means that a service is available 8759.12 hours out of 8760 total hours in a year. Another way to look at it is the service will be *unavailable* about 53 minutes per year!

Total Power

- **Did you know** a quick way to estimate approximate total power is based on the rule-of-thumb that each time the number of channels doubles – assuming all channels have the same signal level – the total power increases 3 dB (3.01 dB)?

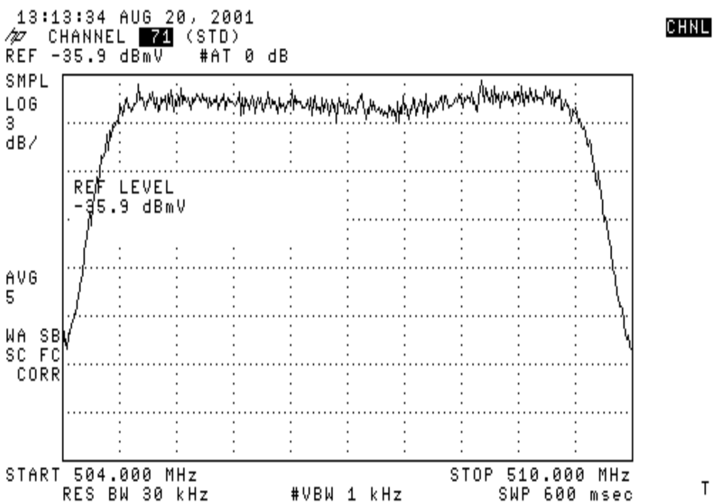
Number of Channels	Power per Channel	Total Power
1	0 dBmV	0 dBmV
2	0 dBmV	+3 dBmV
4	0 dBmV	+6 dBmV
8	0 dBmV	+9 dBmV
16	0 dBmV	+12 dBmV
32	0 dBmV	+15 dBmV
64	0 dBmV	+18 dBmV
128	0 dBmV	+21 dBmV

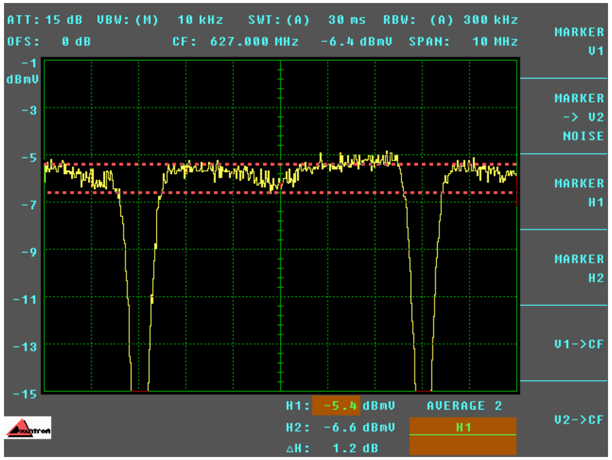
Of course, if you like math, you can use the formula

$$P_{total} = P_{per\ channel} + 10\log_{10}(N)$$

QAM Signal Amplitude Ripple

- **Did you know** a quick way to determine the approximate in-channel flatness of an SC-QAM signal is to use a properly adjusted spectrum analyzer to observe the top of the “haystack”?

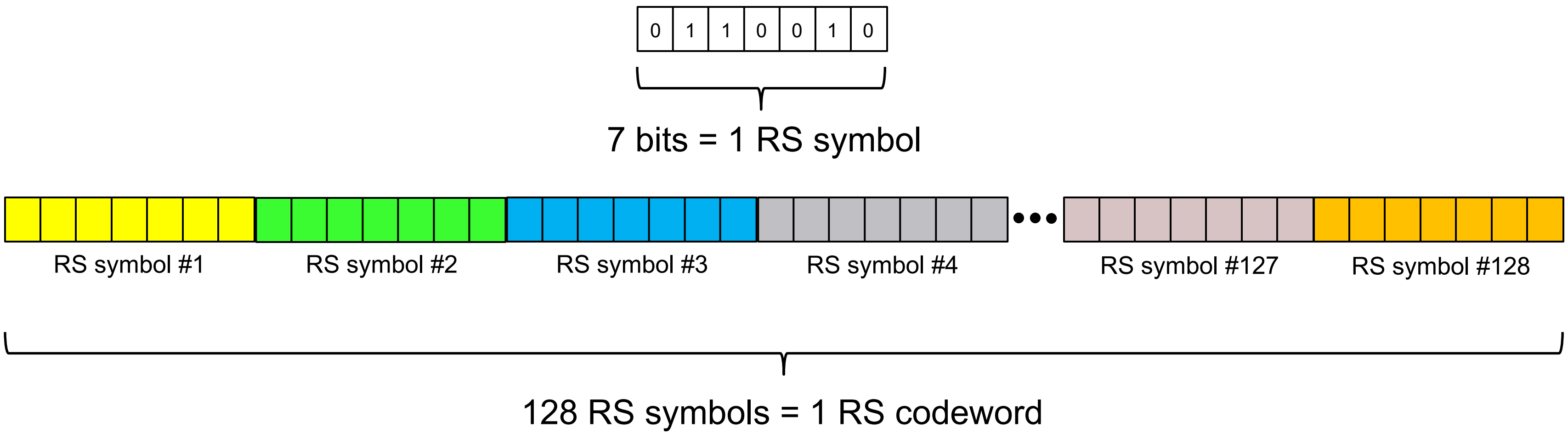




Graphics sources: Agilent (Keysight) and Sunrise Telecom (VeEX)

Codeword Errors

- **Did you know** that in DOCSIS downstream Reed Solomon (RS) forward error correction (FEC), 7 bits = 1 RS symbol, and 128 RS symbols = 1 RS codeword?



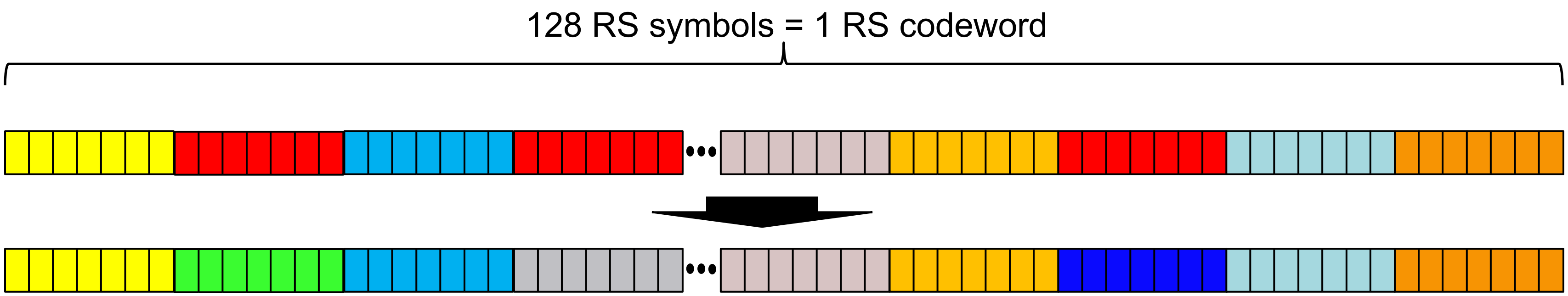
In each RS codeword: 122 RS symbols = data symbols, 6 RS symbols = parity symbols

Codeword Errors

- **Did you know** that *any* number of bit errors in a RS symbol means the entire symbol is errored?

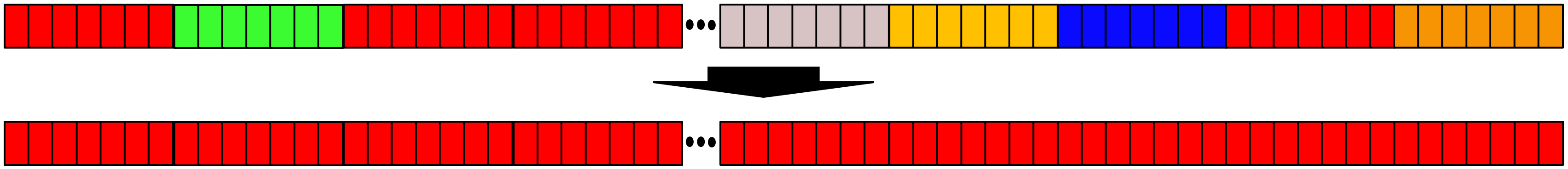
Codeword Errors

- **Did you know** that for a RS FEC configuration of “t = 3” the FEC decoder can fix up to any 3 errored symbols in a RS codeword?



This is a correctable codeword error

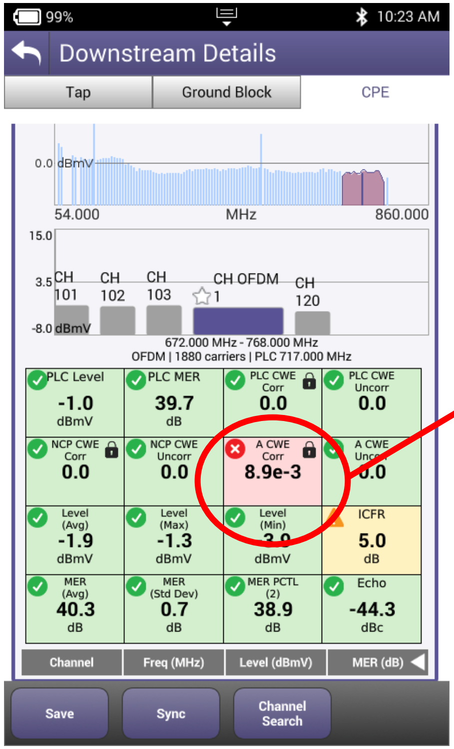
- **Did you know** that when there are *more* than 3 errored symbols in a codeword the entire codeword is errored?



This is an uncorrectable codeword error

DOCSIS 3.1 Codeword Errors

- **Did you know** that it's <u>normal</u> to see correctable codeword errors in a DOCSIS 3.1 OFDM signal?



Don't be surprised if you see **correctable codeword errors**. This is <u>normal</u> for the forward error correction used in DOCSIS 3.1, especially with higher modulation orders.

DOCSIS 3.1 Codeword Errors

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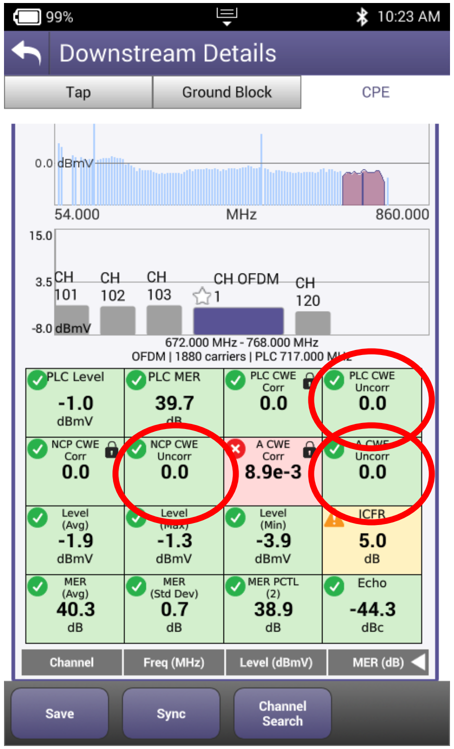
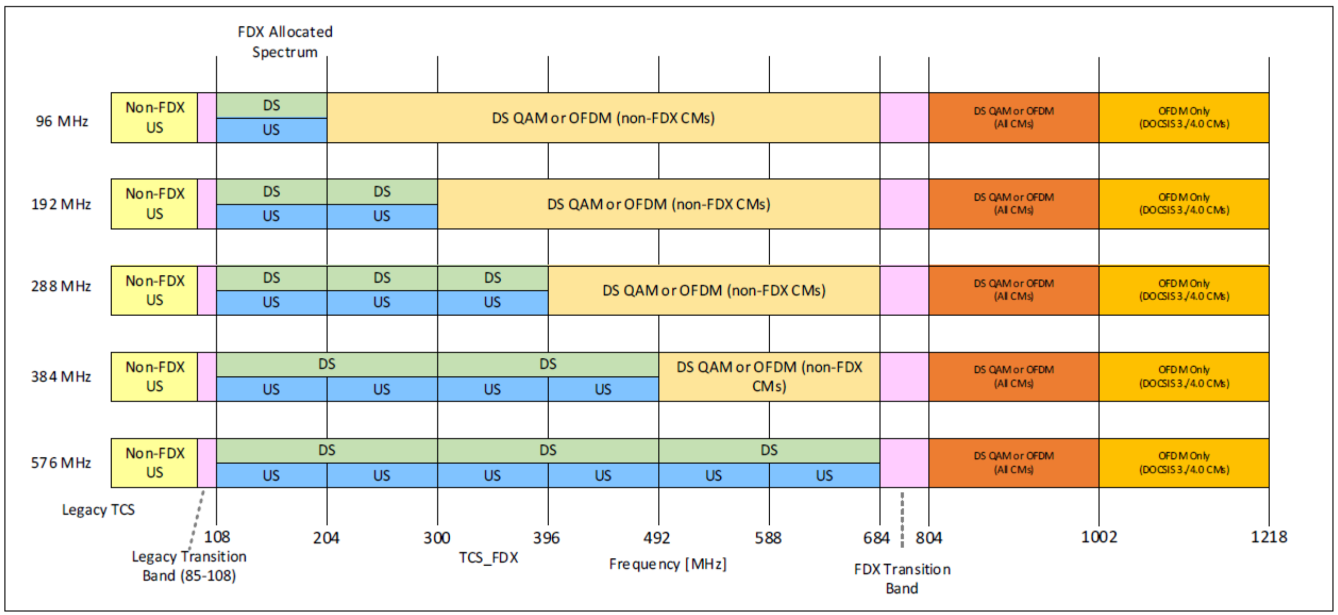


What's important is **uncorrectable codeword errors** (there shouldn't be any!).

FDX DOCSIS

- **Did you know** that full duplex (FDX) DOCSIS allows downstream and upstream signals to simultaneously occupy the same frequencies?



The “magic” of echo cancellation and other technologies allows the FDX downstream and upstream signals to occupy the same frequencies at the same time.

So many topics, so little time …

- If you missed Part 1 of **Did You Know?**, you can find a recording on YouTube at https://www.youtube.com/watch?v=OroTExhZeuY