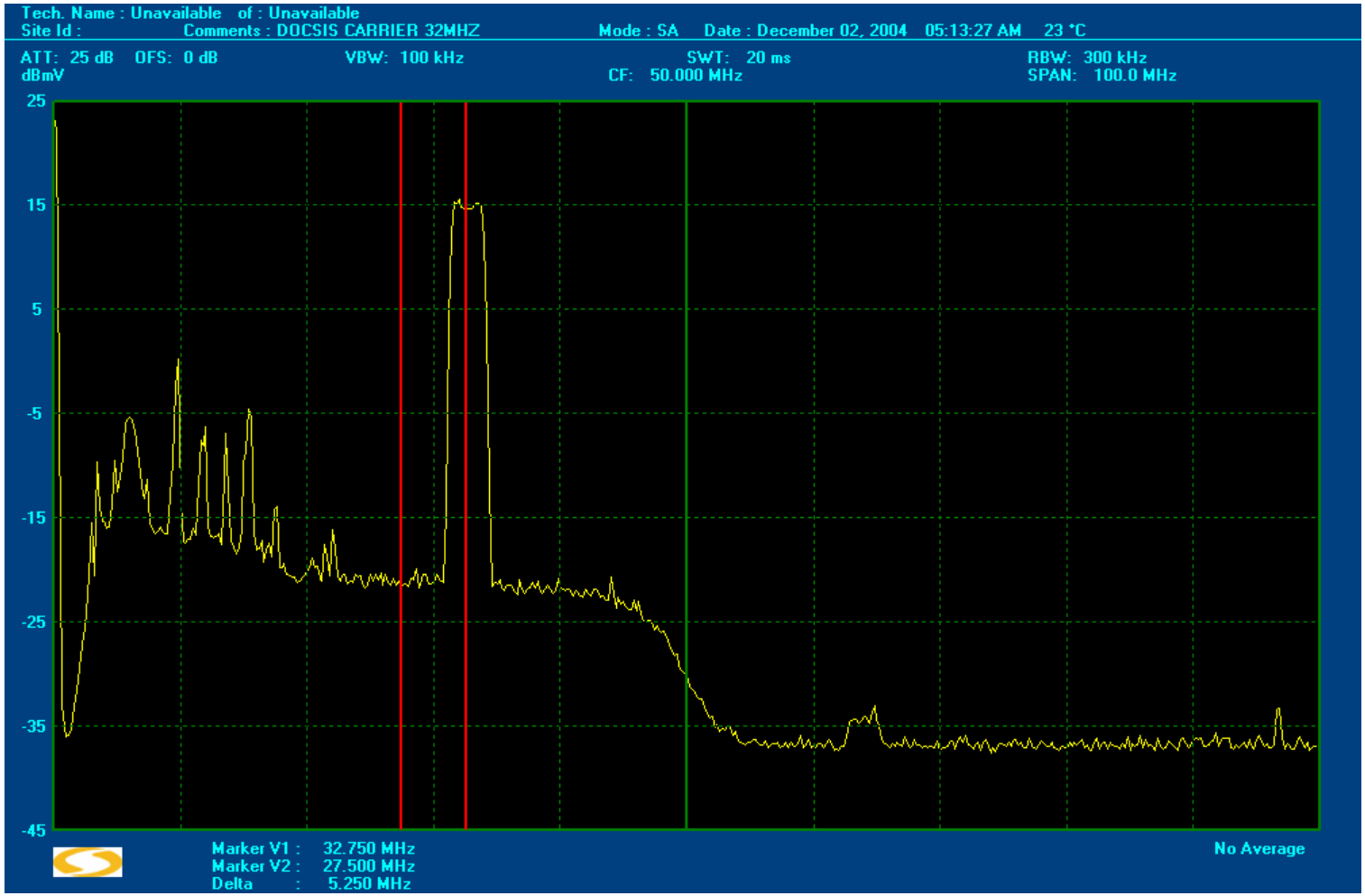
Understanding and Troubleshooting Linear Distortions: Micro-reflections, Amplitude Ripple/Tilt and Group Delay

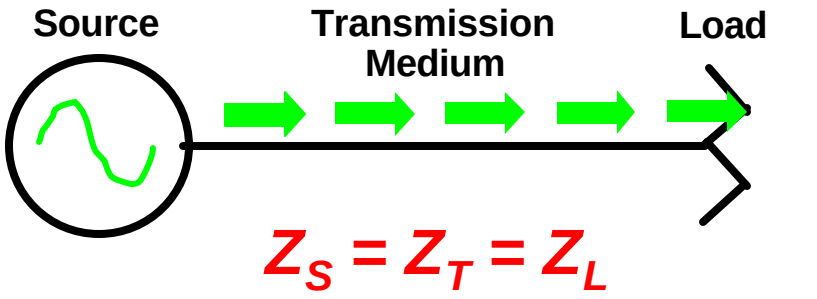
RON HRANAC

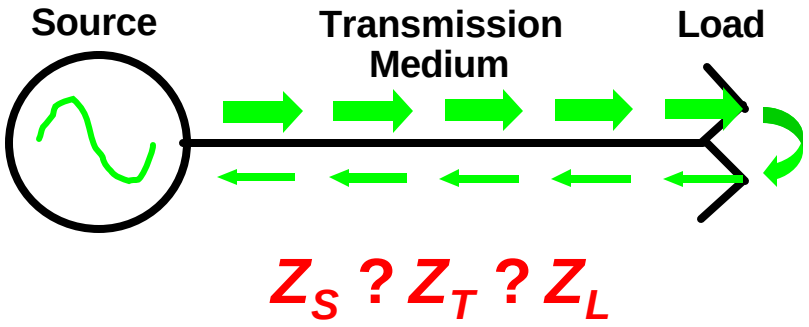
A Clean Upstream: Or Is It?

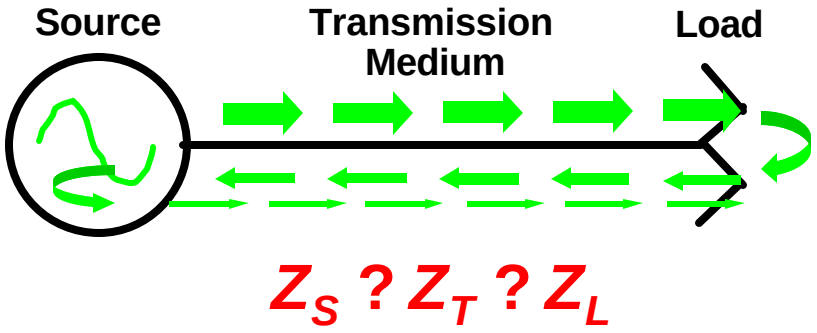


Graphic courtesy of Sunrise Telecom

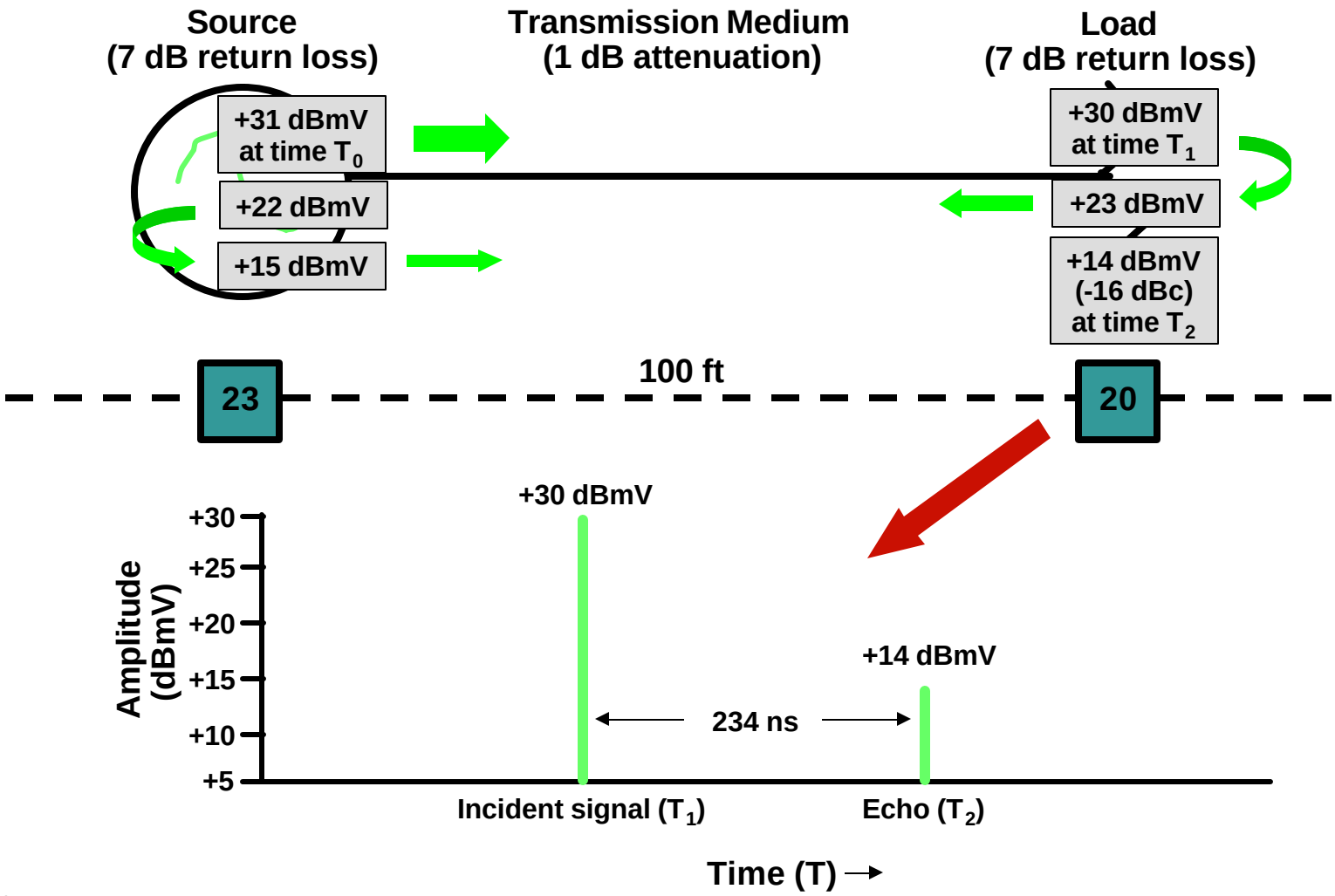
Transmission Line Theory 101



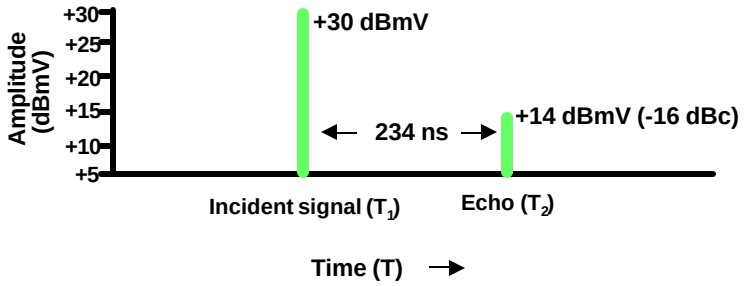


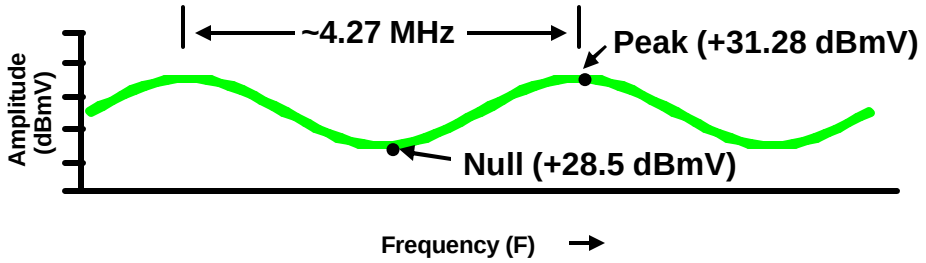


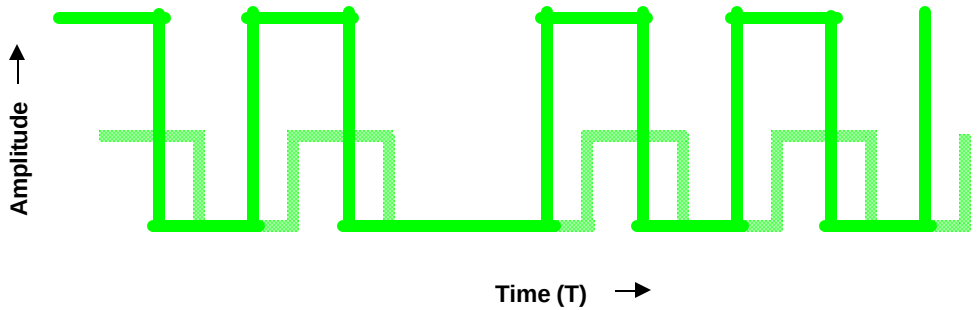
Impedance Mismatches



Micro-reflections—The Big Picture







Echo calculation courtesy of Holtzman, Inc.

Micro-reflections

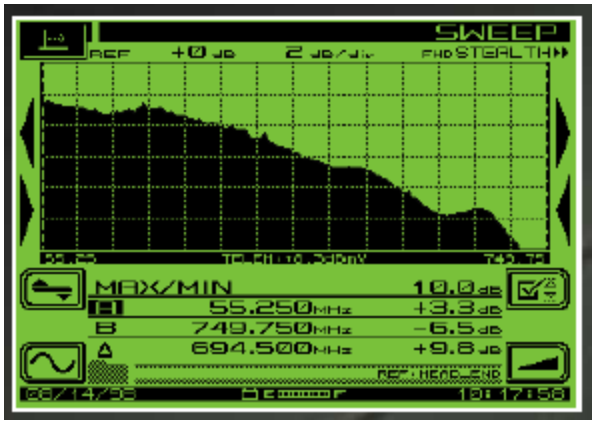
Causes:

- Damaged or missing end-of-line terminators
- Damaged or missing chassis terminators on directional coupler, splitter, or multiple-output amplifier unused ports
- Loose center conductor seizure screws
- Unused tap ports not terminated; this is especially critical on low value taps, but *all* unused tap ports should be terminated with 75-ohm terminations (locking terminators *without* resistors or stingers do not terminate the tap port)
- Poor isolation in splitters, taps and directional couplers
- Unused customer premises splitter and directional coupler ports not terminated
- Use of so-called self-terminating taps at feeder ends-of-line; these are the equivalent of splitters, and do not terminate the feeder cable unless *all* tap ports are terminated
- Kinked or damaged cable (includes cracked cable, which causes a reflection *and* ingress)
- Defective or damaged actives or passives (water-damaged, water-filled, cold solder joint, corrosion, loose circuit board screws, etc.)
- Cable-ready TVs and VCRs connected directly to the drop (return loss on most cable-ready devices is poor)
- Some traps and filters have been found to have poor return loss in the upstream, especially those used for data-only service

Amplitude Ripple/Tilt

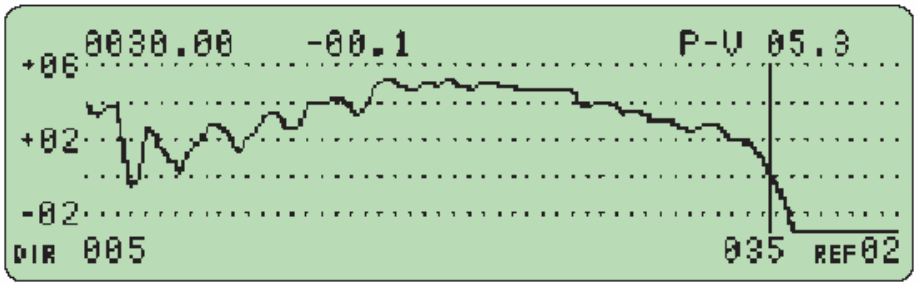
- **Amplitude ripple and tilt are known in cable industry vernacular as *frequency response*, and can refer to in-channel frequency response or the frequency response across a specified RF bandwidth such as 5-42 MHz**
- **The causes include gremlins such as improper network alignment and impedance mismatches (micro-reflections!)**

Amplitude tilt



Combination of amplitude ripple and tilt

Amplitude tilt, slight amount of ripple

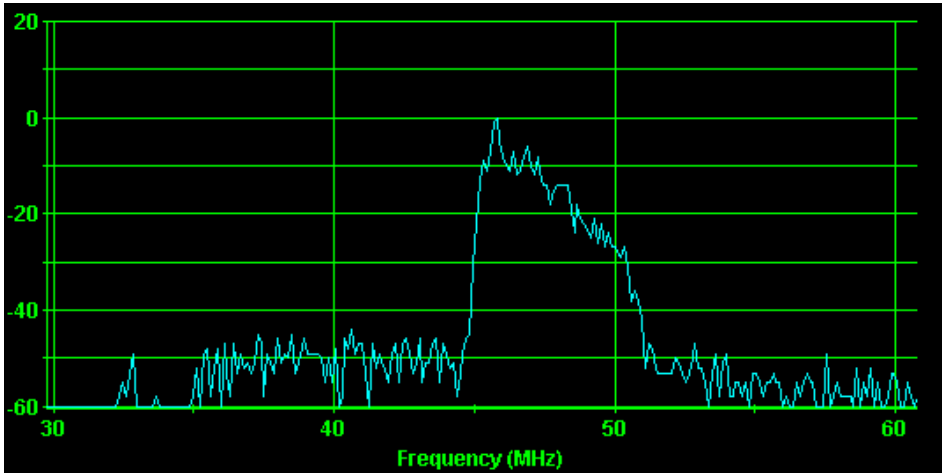


Graphics courtesy of Acterna and Sunrise Telecom

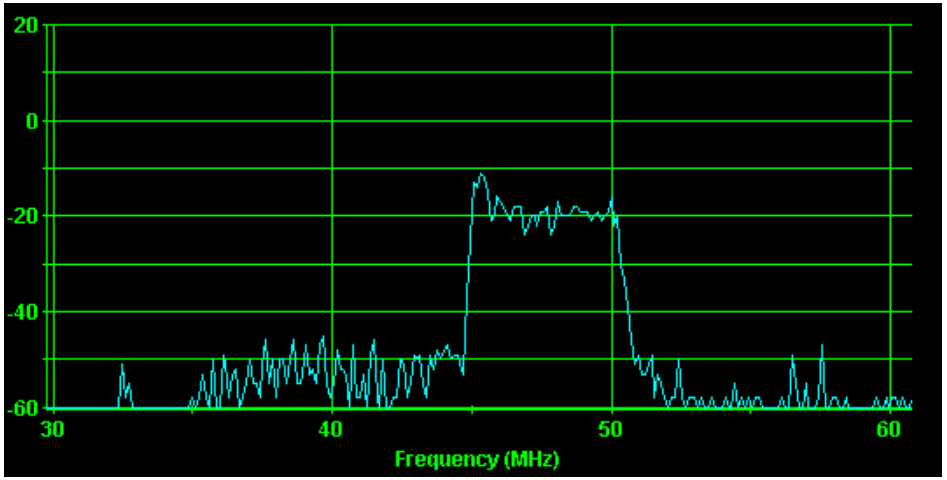
Amplitude Ripple/Tilt

Adaptive equalization

- This 6.4 MHz bandwidth A-TDMA digitally modulated signal exhibits severe in-channel amplitude tilt at the CMTS upstream input

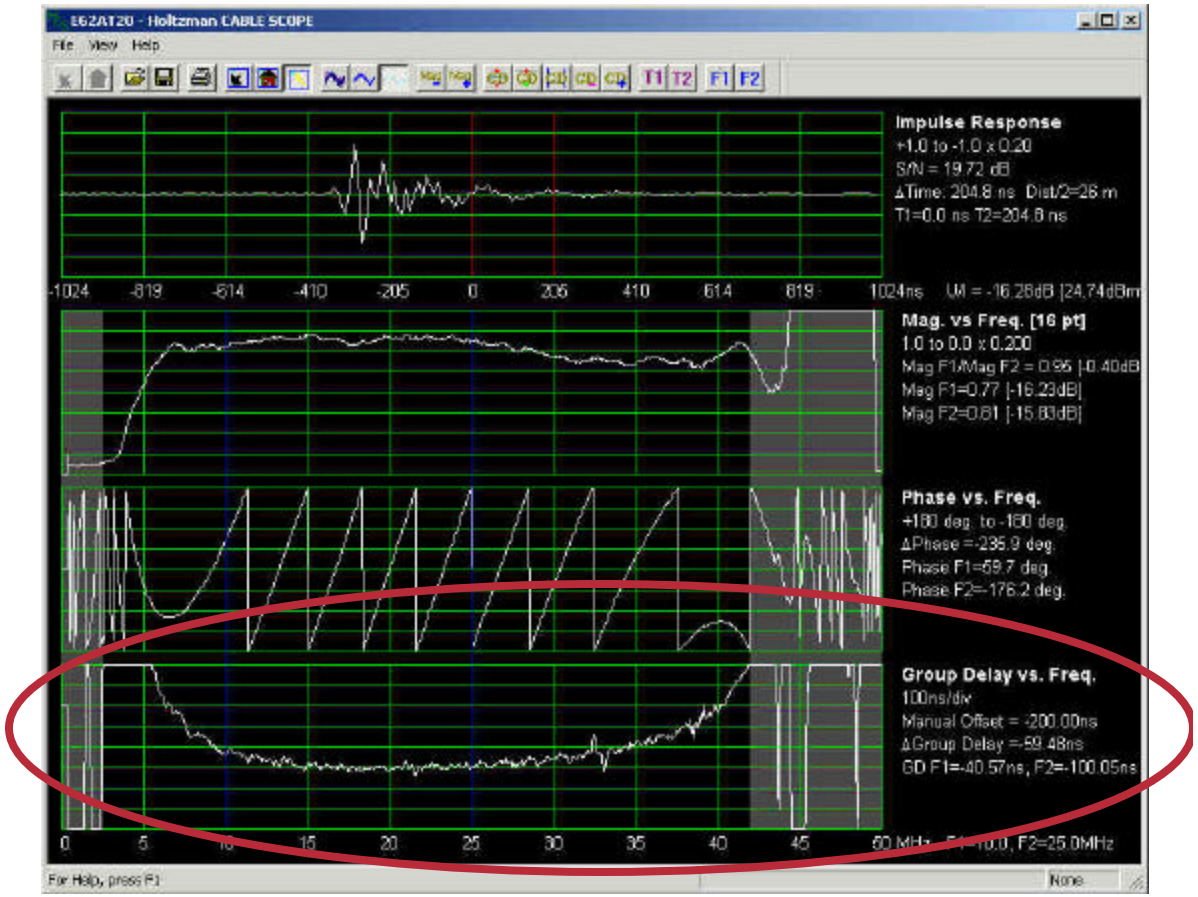


- Adaptive equalization (pre-equalization) in the cable modem is able to compensate for nearly all of the amplitude tilt



Group Delay

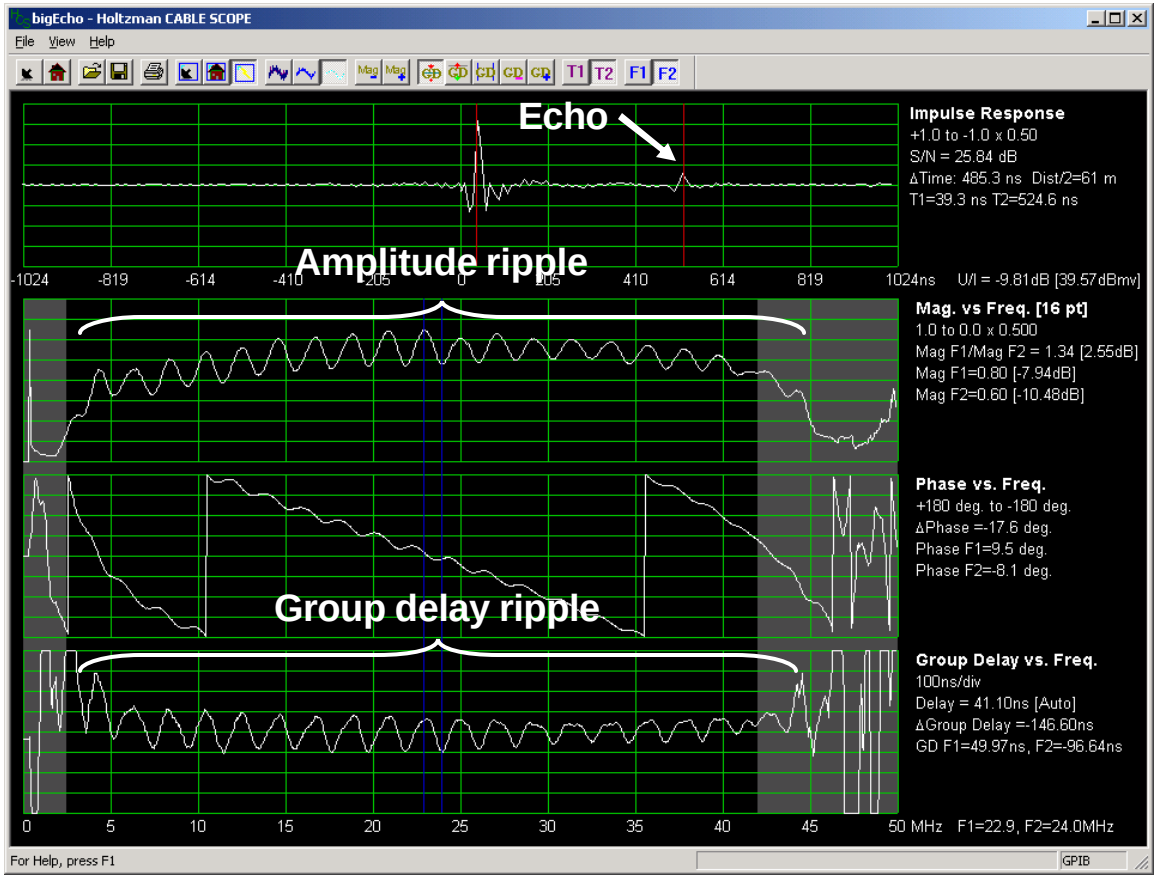
- Group delay is said to exist when signals at some frequencies take longer to travel through a circuit, amplifier or network than signals at other frequencies
- Group delay, like other linear impairments, causes inter-symbol interference, which degrades MER



Graphic courtesy of Holtzman, Inc.

Linear Distortions in the Real World

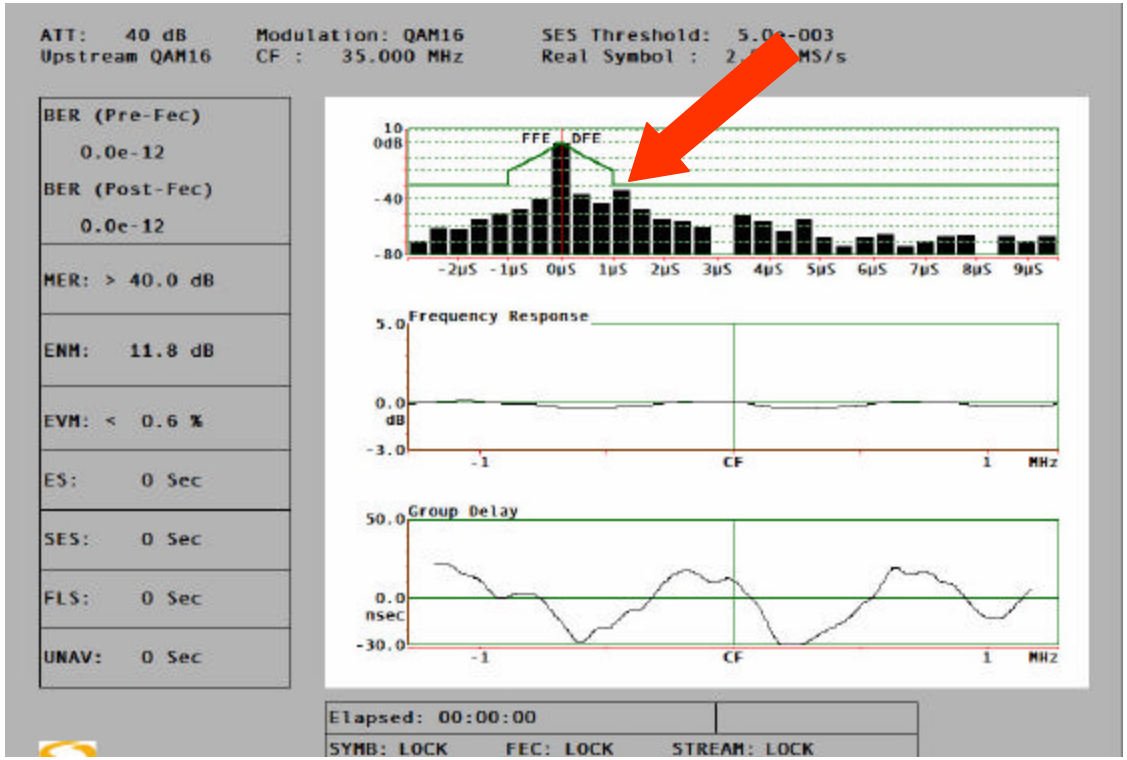
- In this example, an echo at ~485 ns causes visible amplitude ripple across the 5-42 MHz spectrum
- Group delay ripple also is present



Graphic courtesy of Holtzman, Inc.

Linear Distortions in the Real World

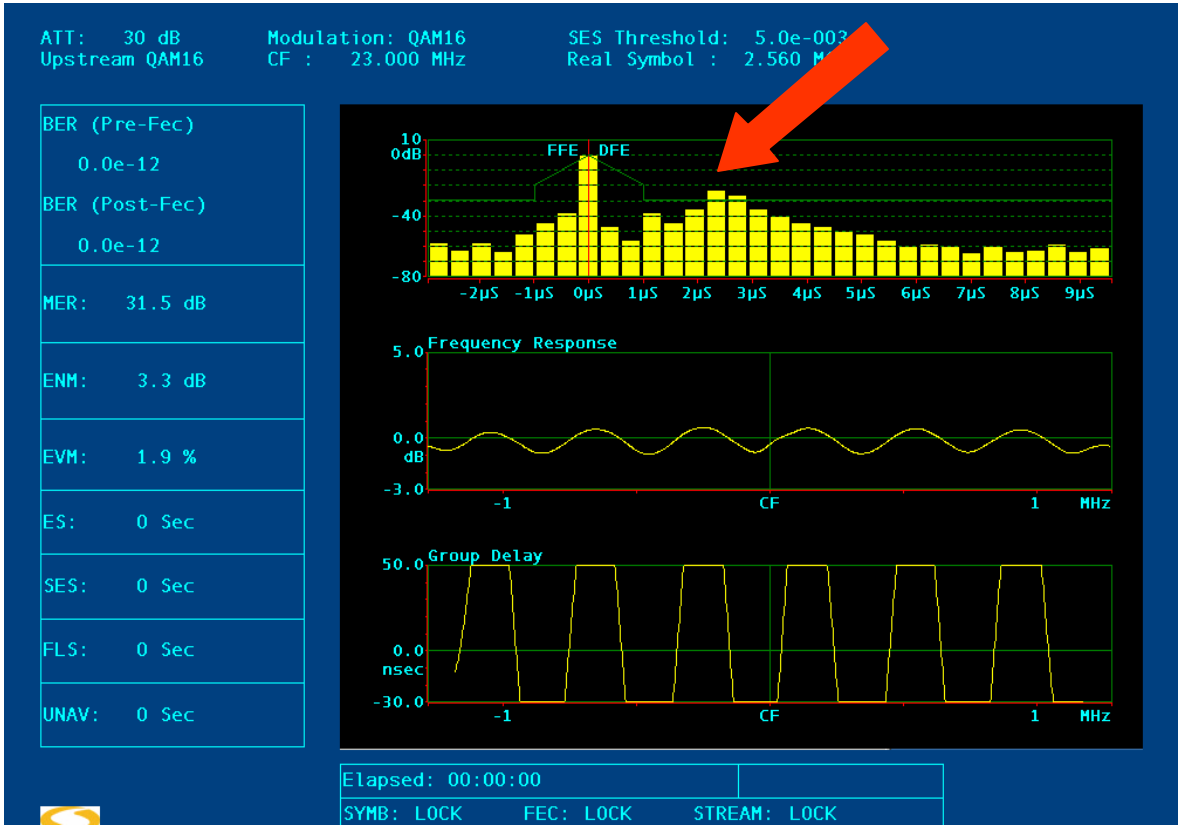
- **Here's another example: An approx. -33 dBc echo at just over 1 µs**
- **This echo meets the DOCSIS® upstream - *30 dBc at >1.0 µsec* parameter**
- **Here, too, the echo is sufficient to cause some amplitude and group delay ripple**



Graphic courtesy of Sunrise Telecom

A Clean Upstream: Or Is It?

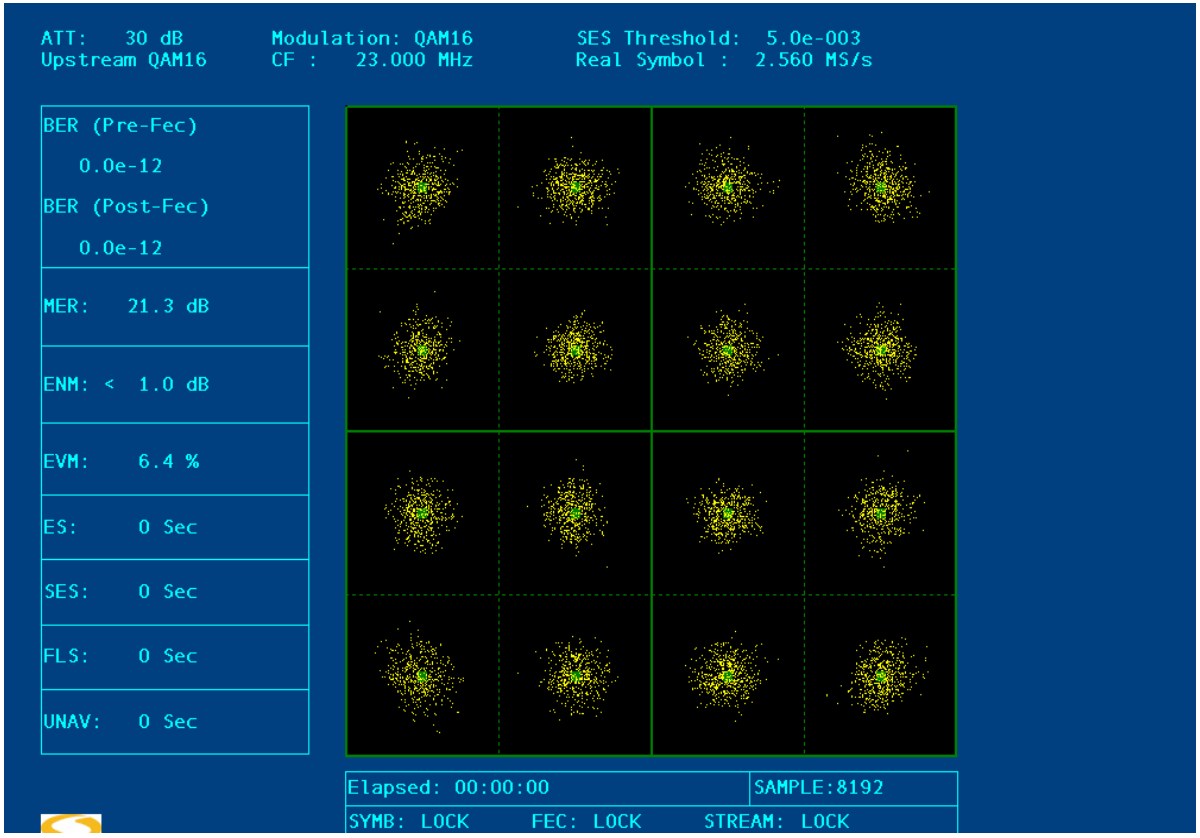
- **Remember the upstream slide at the beginning of this presentation?**
- **Here's why 16-QAM wouldn't work**



Graphic courtesy of Sunrise Telecom

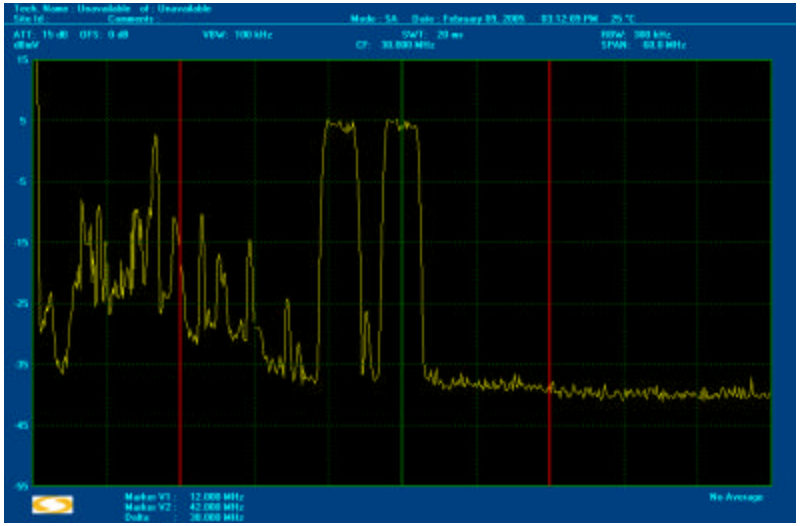
A Clean Upstream: Or Is It?

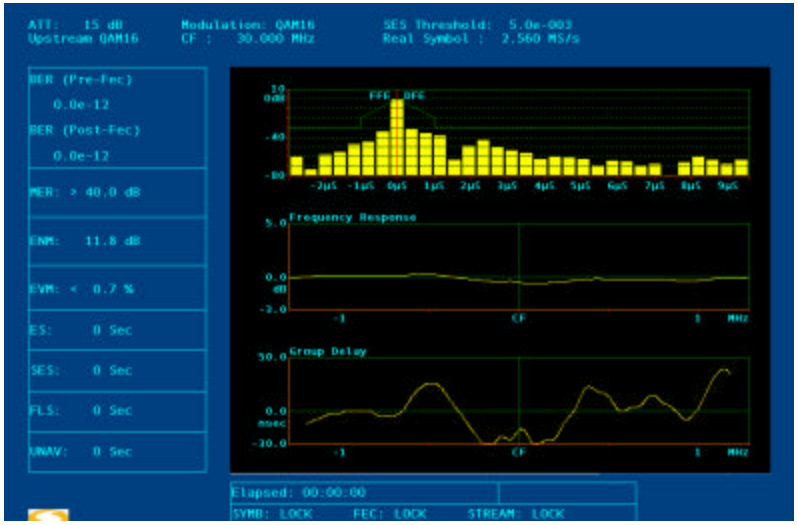
- **This upstream constellation shows a not-so-good 16-QAM signal**
- **Unequalized MER is 21.3 dB, close to the failure threshold for 16-QAM**



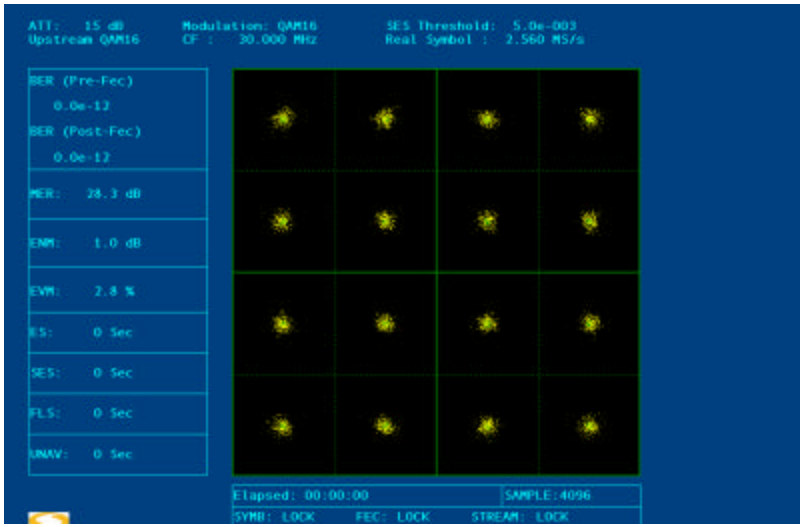
Graphic courtesy of Sunrise Telecom

A Clean Upstream





From a linear distortion perspective, this is what a relatively unimpaired upstream looks like



Graphics courtesy of Sunrise Telecom

Wrapping Up

- **Linear distortions are real problems in cable networks, and can seriously affect downstream and upstream data transmission**
- **Among the tools available to troubleshoot linear distortions are**
  - **Forward and reverse sweep, set to the maximum supported resolution**
  - **Adaptive equalization (DOCSIS 1.1 and 2.0 modems)**
  - **CMTS tools such as per-modem SNR (MER), FEC error information**
  - **Avoid upstream frequencies above about 35 MHz to minimize diplex filter-related group delay**
  - **Use of specialized test equipment to characterize and troubleshoot micro-reflections, amplitude and group delay ripple**
- **An understanding of linear distortions is critical to achieving the reliability necessary for new services being deployed on today's cable networks**