CABLE PLANT RF LEVEL VERIFICATION

INVENTOR:

THOMAS HOLTZMAN WILLIAMS

Correct Amplifier/Node RF Level Verification

CableLabs

Tom Williams Distinguished Technologist

t.williams@cablelabs.com

March 20, 2019/Sept. 11, 2020

Clear Thinking About Impairments

- Additive vs. multiplicative
  - Additive is there whether your test signal is there or not
  - Multiplicative is some nonlinear bad thing that happens to your desired signal, usually due to too-high level.
- Linear vs. Nonlinear distortions
  - Echoes, group delay are linear
  - If relative distortion gets worse at high composite RF levels, distortion is nonlinear
  - Nonlinear spreads to other freq. bands. Linear does not.
- We need two new numbers for upstream characterization:
  - When fully loaded how many dB to clipping?
  - Currently, what percentage of total upstream energy is ingress?

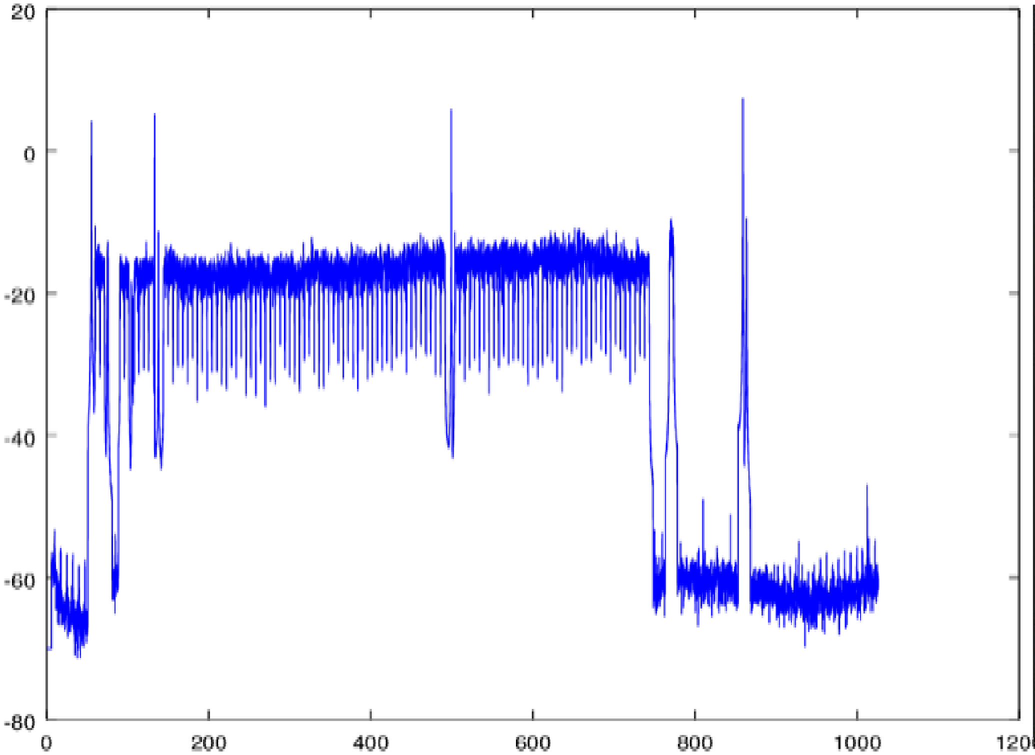
Background

- Optimal cable plant RF levels are a challenge
  - Spectrum analyzers, unlike oscilloscopes, don't show how loaded a plant is. And they filter out clipping impulses.
- Upstream
  - Composite signal level is time variable
  - In the upstream plant, signals are bursty. And additive noise is unpredictable, as a percentage of total power.
  - Upstream peak power levels are rarely hit.
- Downstream
  - Composite signal level is steady, with a Gaussian probability
  - Composite total power is usually low in additive noise (e.g. LTE ingress)
  - Signals are digital, so no pictures to view. (NTSC video was revealing.)
  - Random noise and distortion "look" the same => CCIN
  - We now have MER per subcarrier, but don't know what is the interference

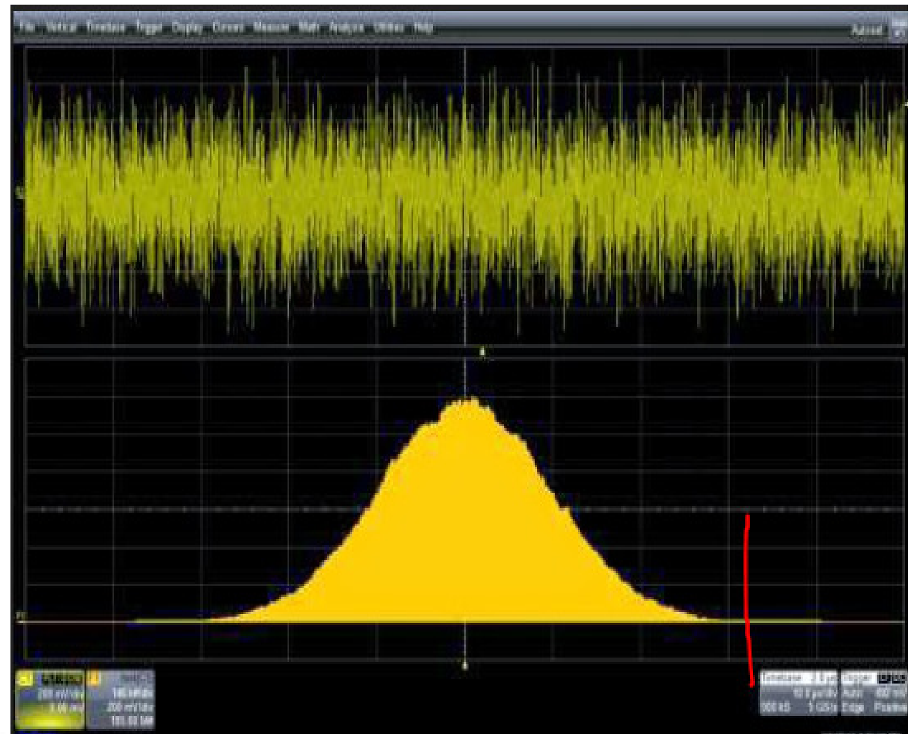
The RF Loading Problem

CableLabs

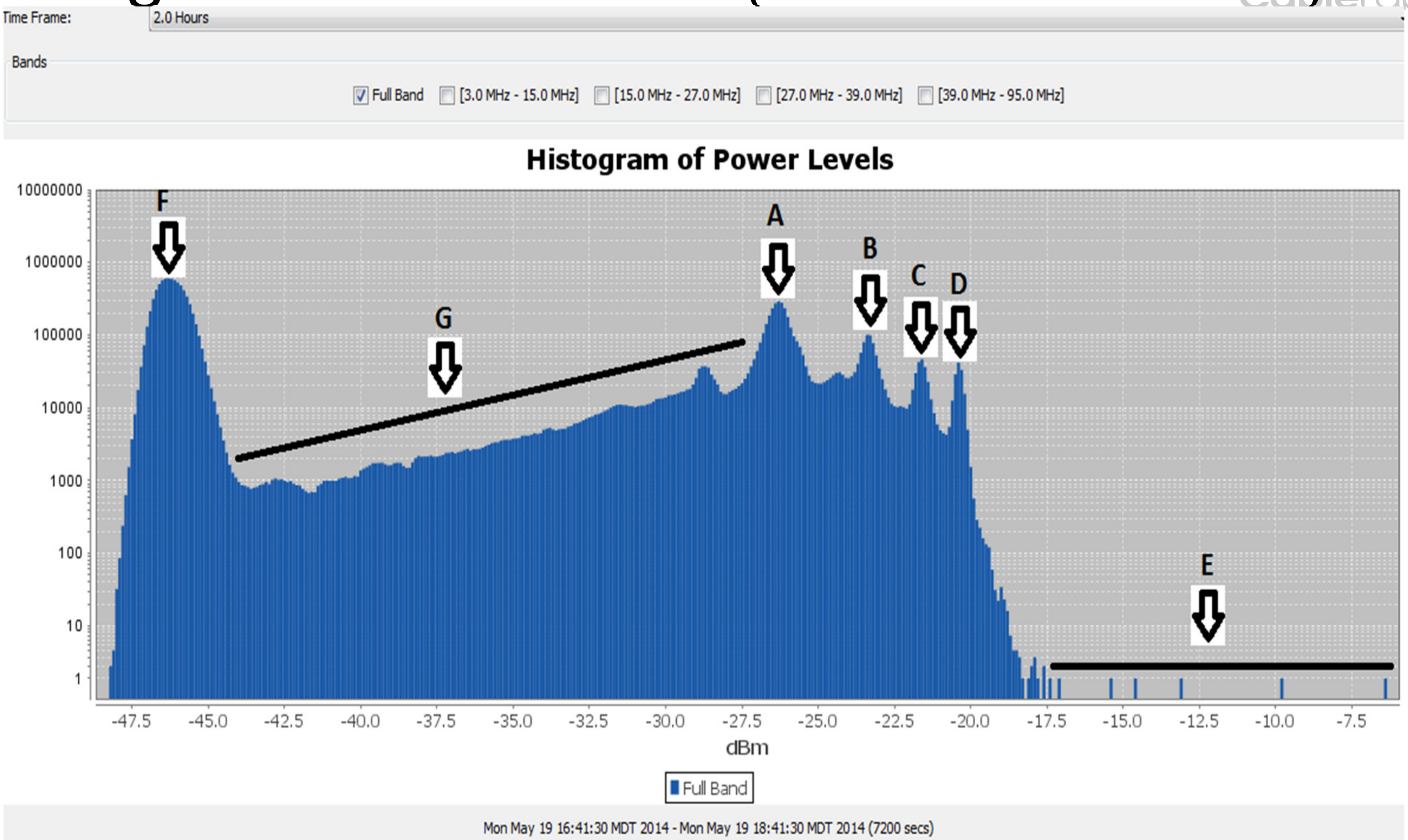
What We Have



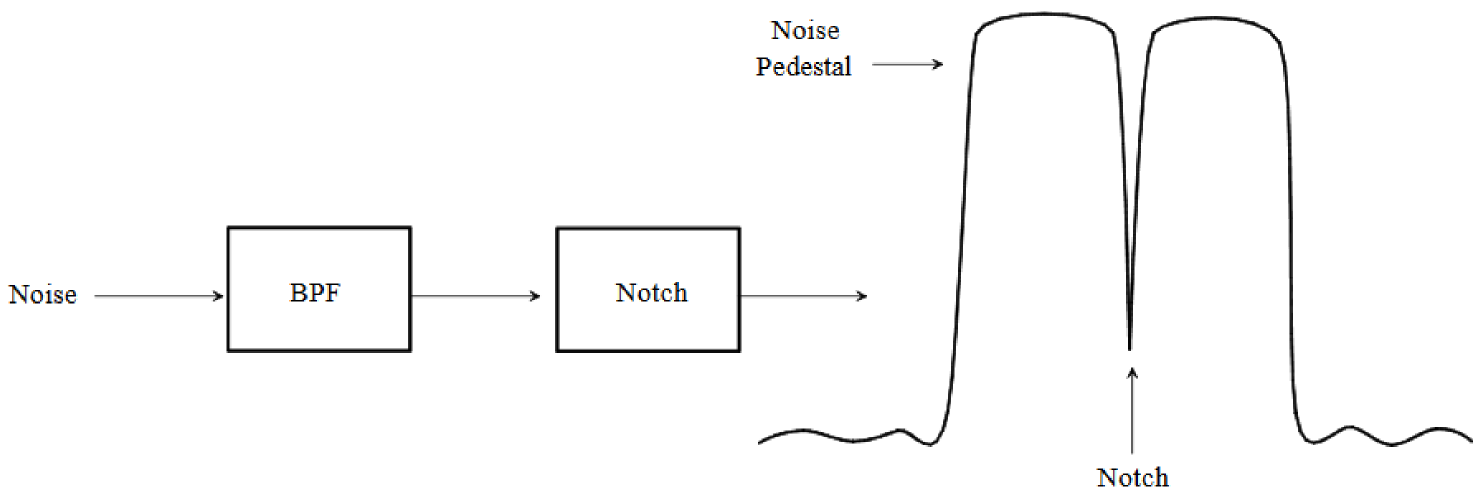
What We Need



Background: Joule Tool (where is Gauss?)



Background NPR – Noise Power Ratio Test

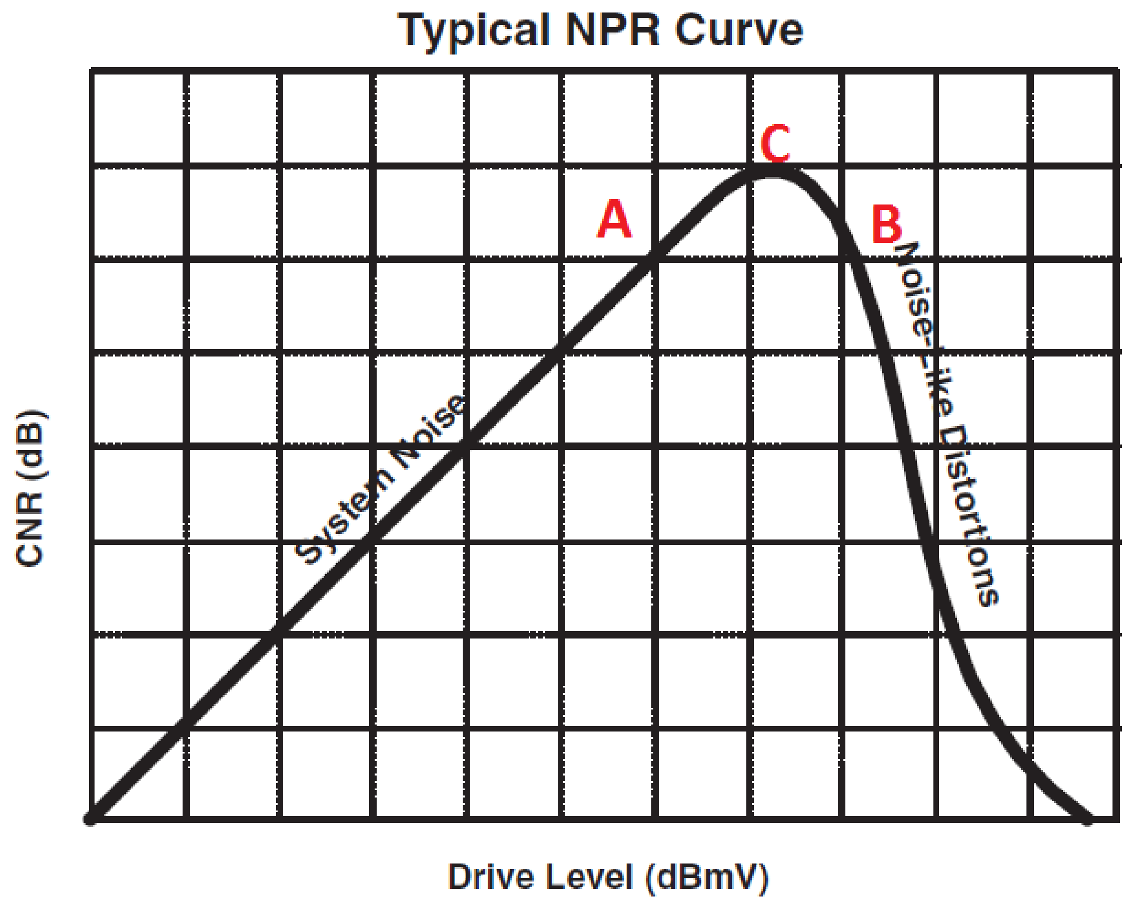


Background: Amplifier/Laser Level Verification

© Arris

- Point C is optimal (w/o noise)
- Point B is over-driven
  - Nonlinear distortion is dominan
- Point A is under-driven
  - Random noise is dominant

Need to back off to allow headroom for upstream ingress



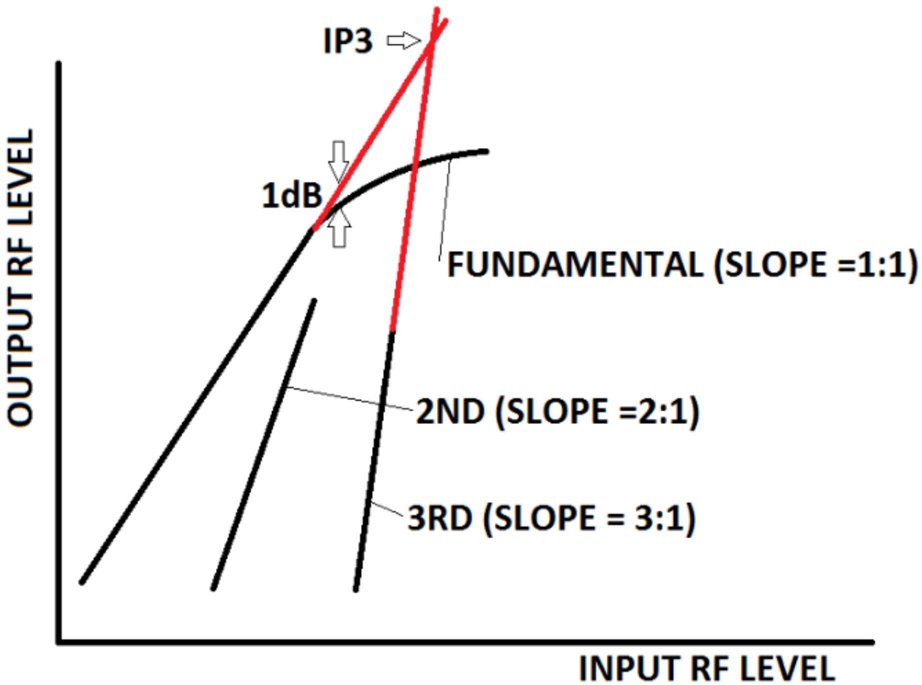
Idea 1 – User MER Per Subcarrier to Verify Correct Downstream Amplifier Level

- Problem: Random noise and Nonlinear Distortion look the same in digital systems.
  - HOW TO TELL THEM APART???
- While measuring MER on CMs connected to an amplifier, change amp's output level up and down
- First Method - Change AGC pilot signal relative to digital carrier
  - All amplifiers in cascade will set AGC to pilot level
  - Can be done from headend
- Second Method - Change gain of amplifier (knob adjustment at amp)
  - Next amplifier in cascade with AGC should undo level shift
- Can measure MER on Single Carriers (64 and 256 QAM)
- Can measure MER per subcarrier on Multi-Carriers (OFDM)
- This is a PNM audit tool. Noise and distortion should both increase gradually as you move from amp to amp

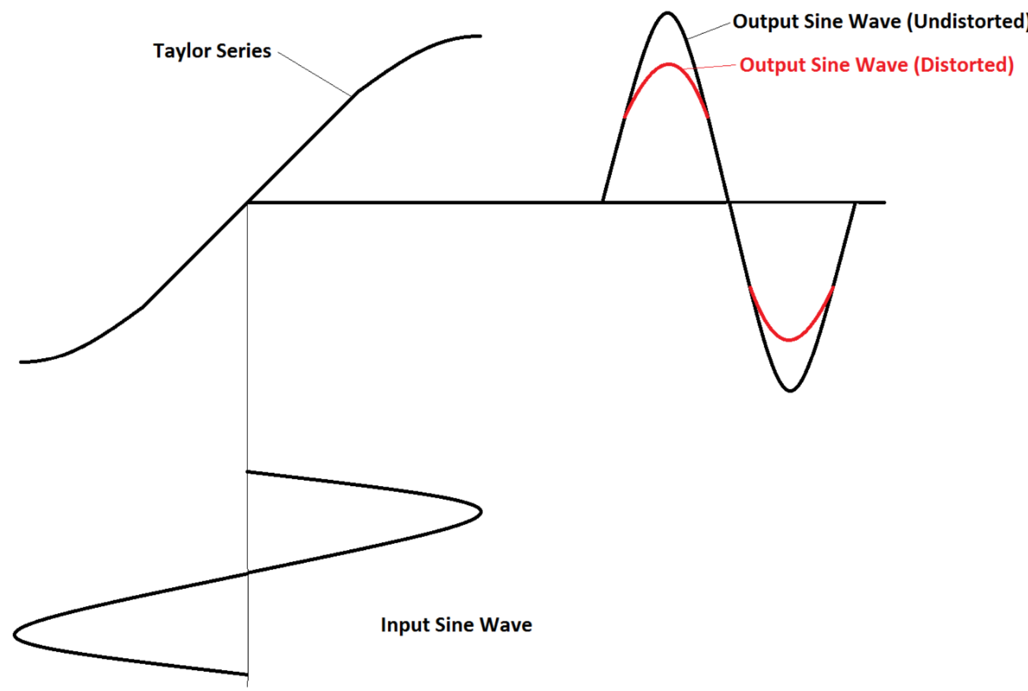
Nonlinear Distortions – How to Tell

CableLabs

Intercept Point (IP) Diagram



Taylor Series Explanation - 3rd order

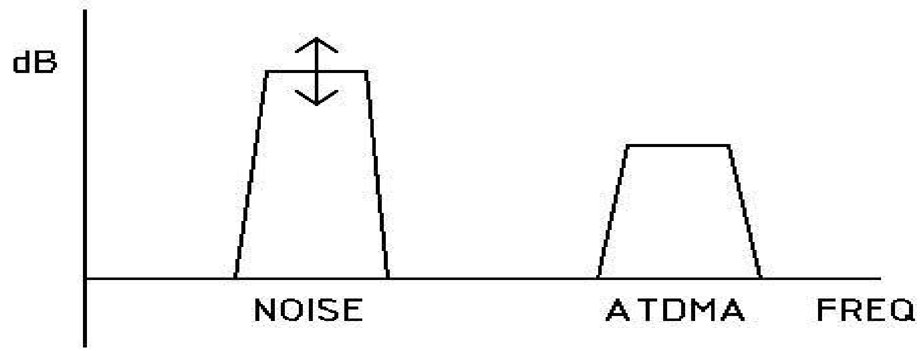


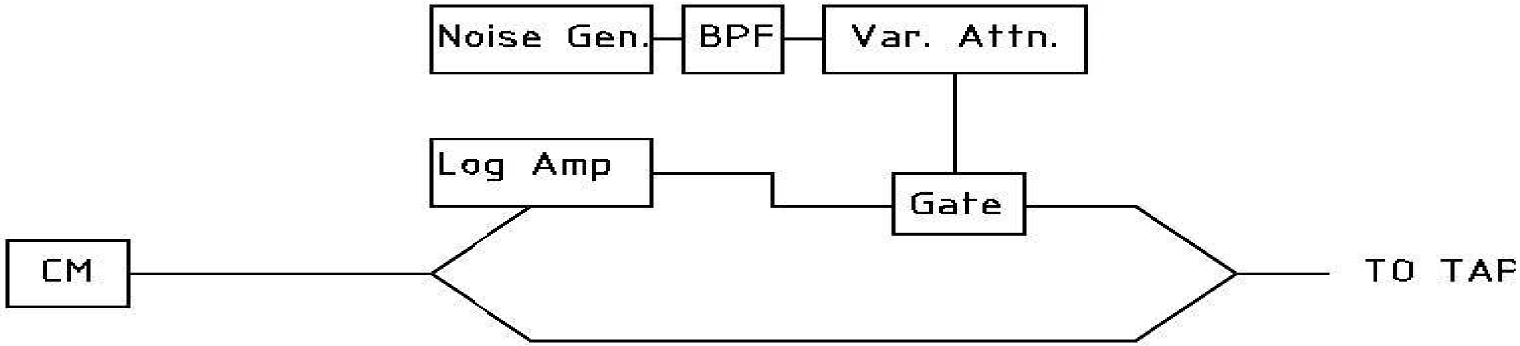
Upstream Verification

CableLabs®

- Need to have full upstream loading to test lasers, amps and A-Ds
- Ingress will use up dynamic range
- Clipping can occur in optic portion or coaxial portion
- Clipping can be one-sided (laser) or symmetrical (A-D)
- New: Triggered upstream spectral capture: MER per subcarrier can be married with triggered upstream spectrum capture. SID captures ID of bad house/CM

Idea #2 – Add Variable Noise to a CM burst





Quick Clip Test

- Build a box that a CM transmits through, and the box adds out-of-band RF loading noise (8-14.4MHz) while the CM is transmitting.
- Out of band loading is adjustable.
- CM transmits pings, and every ping gets more accompanying loading until nonlinear distortion makes the pings un-receivable.
- Alternate loading with other waveform, like PN sequence, OFDMA, chirp
- Alternate: have CM vendor make an orange test CM or build this functionality into the Hitron tech meter.
- Alternate: use triggered upstream spectrum analysis and analyze composite burst for distortion with DSP

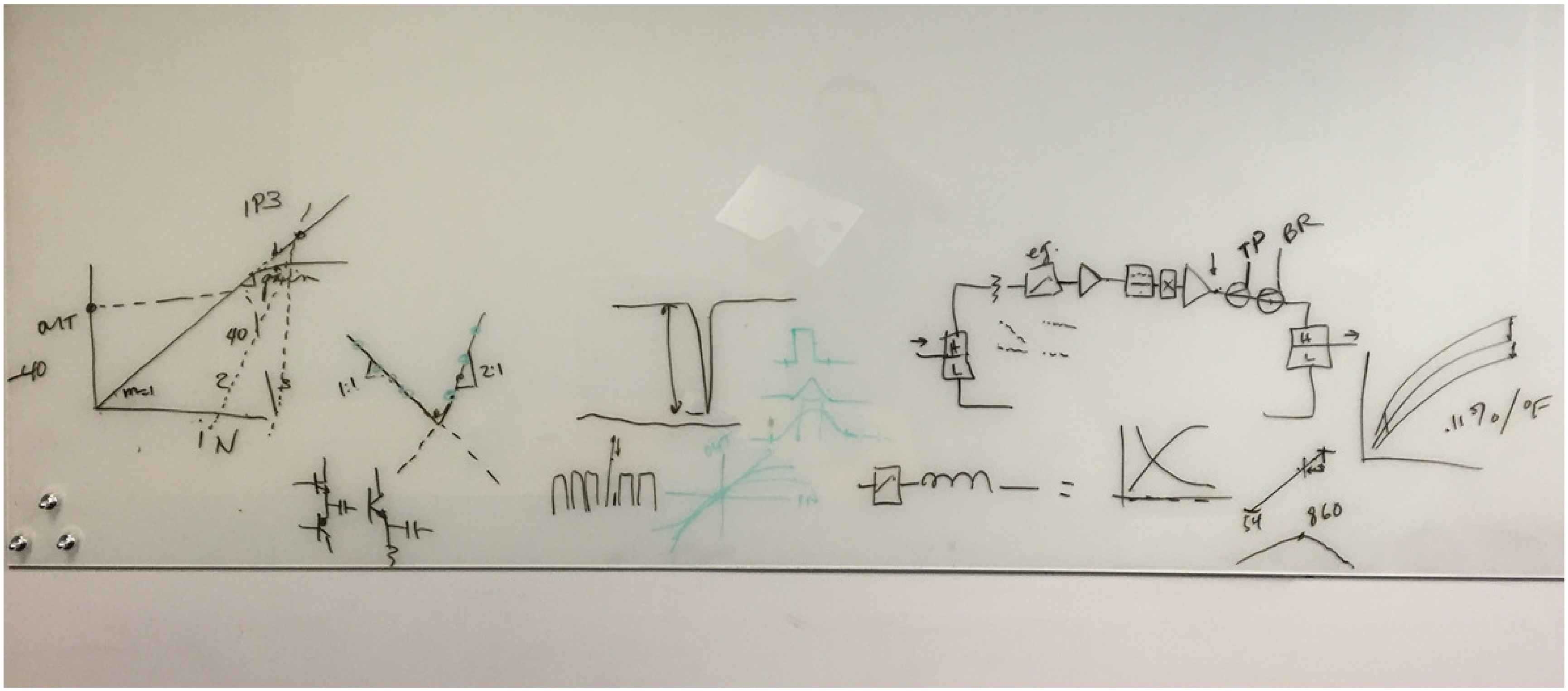
Summary of Ideas 1/2

- Idea 1: Adjust downstream pilot carriers up and down while observing MER per subcarriers on OFDM subcarriers.
- Idea 2: Have an upstream CM with a test mode where an CM's upstream transmission is accompanied with an adjustable amount of loading RF energy out-of-band. Energy can be a CW, ATDMA carrier, random noise, PN sequence. Missed ping means clipping. See slide 11 for block diagram.
- Idea 2A Same accompanying out of band energy, but composite burst captured with Triggered Upstream Spectrum Analysis and analyzed for distortion on out of band energy with DSP.

Summary of Ideas 2/2

- Idea 3: Mine the data in a CM's A-D converter for voltage samples and build a histogram for the composite downstream signal.
- Idea 4. A clip detector output pin in A-D converters, so clipped samples can be counted. This applies to CMTS receivers, upstream fiber node transmitters, and CM front ends.
- Idea 5. Make software in field meters to integrate RF downstream spectrum to give total power number. Compute ingress %.

Whiteboard Sketches



Other “Funny Business” to Discover

- Common Path Distortions (house or plant diodes)
- Broken Amplifier
  - Unbalanced Push-Pull
  - High nonlinear distortion
  - Lousy noise figure
- Defective components, maxed-out AGCs
- Overdriven house amplifiers
- Temperature change effects

Backup slide - Downstream

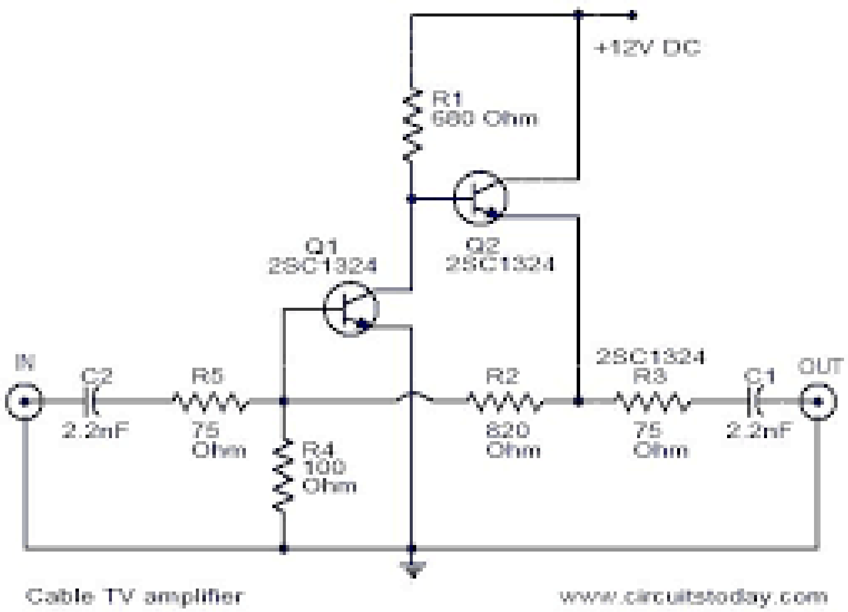
CableLabs

- CCIR –composite carrier to interference ratio
- Random noise and nonlinear distortion “look” the same in digital plant
- In analog days, Composite Triple Beat (CTB) was easy to see vs. random noise. (So were other impairments, like hum mod, CW interference etc.)
- Prior CL research in nonlinear distortion detection in vacant band
  - Used an expensive LeCroy digital O-Scope to analyze “noise” to determine if impairment was random noise or distortion.

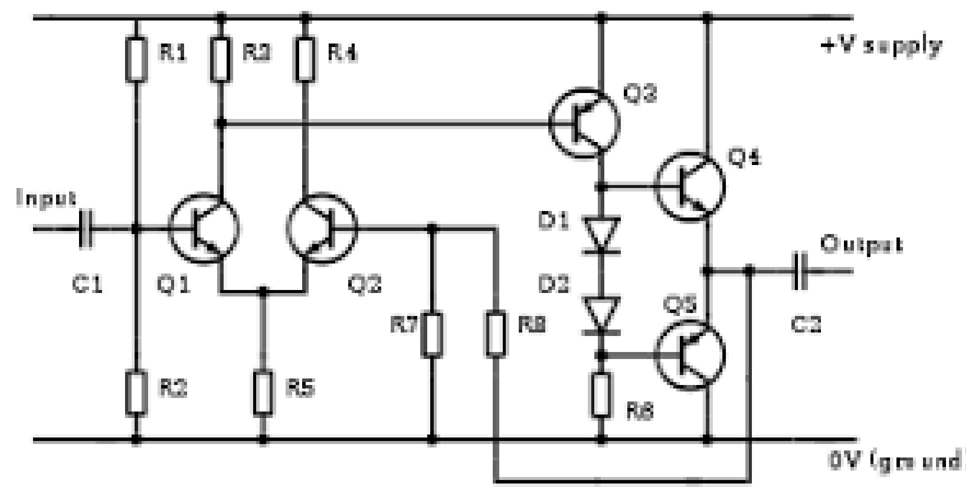
Single Ended vs. Push-Pull Amps

CableLabs®

Single Ended 2nd order dominant



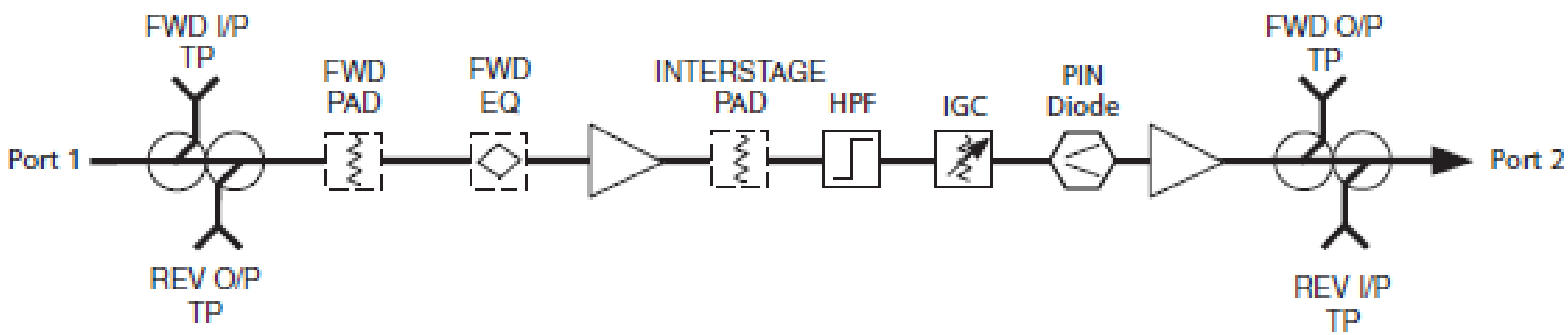
Push-Pull 3rd order dominant



Forward Amplifier Diagram

CableLabs
Copyright Arris

Simplified Forward Path Block Diagram



Return Amp Block Diagram

CableLabs

Simplified Return Path Block Diagram