Docsis 3

The HFC Pipe to the Home is Huge!

DOCSIS® 3.0

The BAD news is that ingress from one home can potentially kill upstream services for hundreds of your subscribers!!!

Maximum and (Maximum Usable)DownStream Speeds

	Downstream	
Version	**DOCSIS**	**EuroDOCSIS**
1.x	42.88 (38) Mbit/s	55.62 (50) Mbit/s
2.0	42.88 (38) Mbit/s	55.62 (50) Mbit/s
3.0 ---------- 4 channel	171.52 (+152) Mbit/s	+222.48 (+200) Mbit/s
3.0 ---------- 8 channel	+343.04 (+304) Mbit/s	+444.96 (+400) Mbit/s

DOCSIS® 3.0 Overview

- New Specifications
  - DOCSIS 3.0 Interface Specifications (released December 2006)
  - CPE equipment in development stages(Bronze, Silver, Full)
- Downstream data rates of **160 Mbps** or higher
  - Channel Bonding
  - 4 or more channels

1 x 256QAM => "up to" ~40Mbps
4 x 256QAM => "up to" ~160 Mbps

- Upstream data rates of **120 Mbps** or higher
  - Channel Bonding
  - 4 or more channels

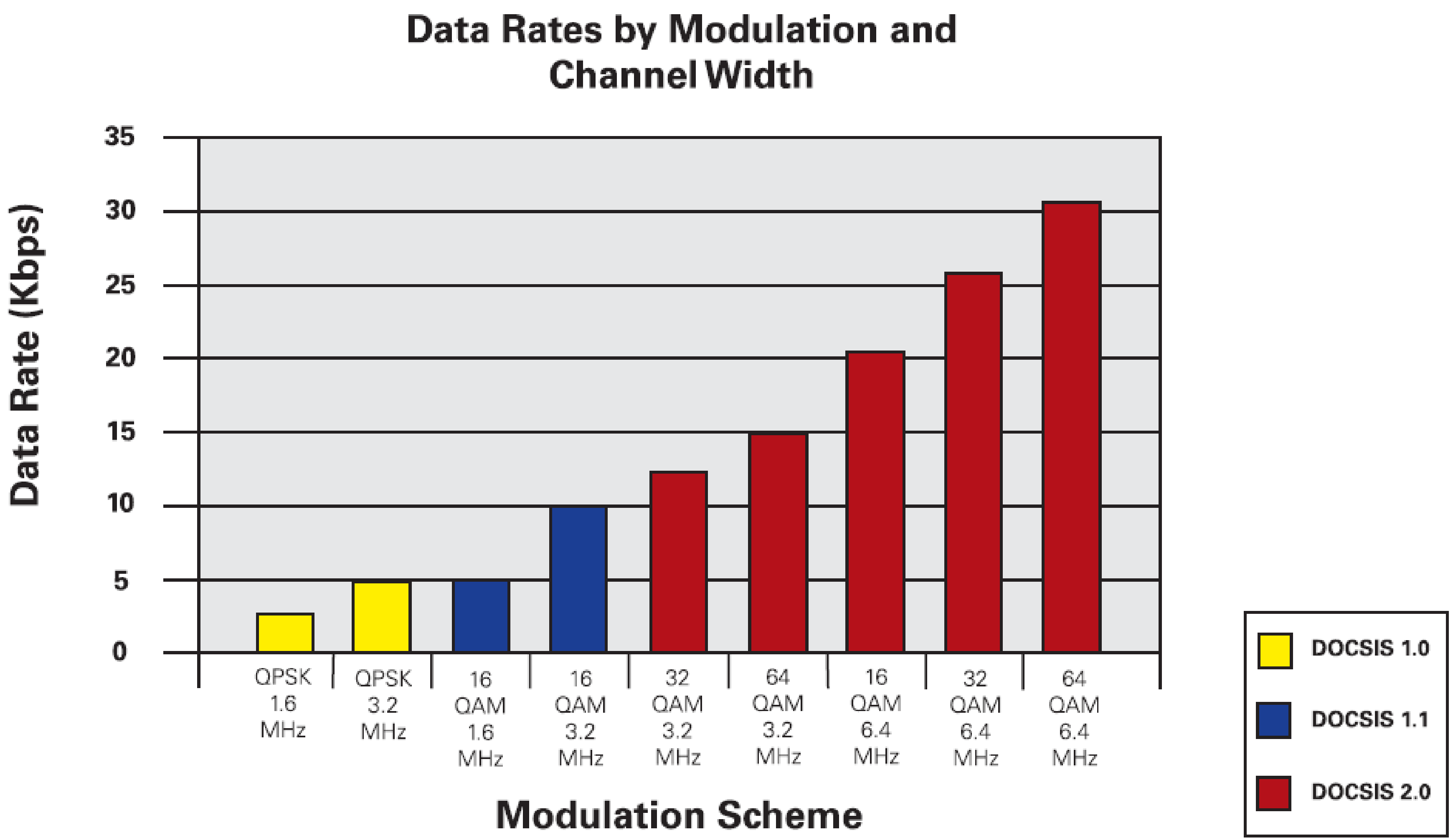
1 x 64QAM => "up to" ~30Mbps
4 x 64QAM => "up to" ~120 Mbps

- Internet Protocol version 6 (IPv6)
  - IPv6 greatly expands the number of IP addresses
    - Expands IP address space from 32 bits to 128 bits
    - IPv6 supports 3.4×10^{38} addresses;
    - Colon-Hexadecimal Format

4923:2A1C:0DB8:04F3:AEB5:96F0:E08C:FFEC

- **100% backward compatible with DOCSIS 1.0/1.1/2.0**

Un-Bonded Upstream Data rates

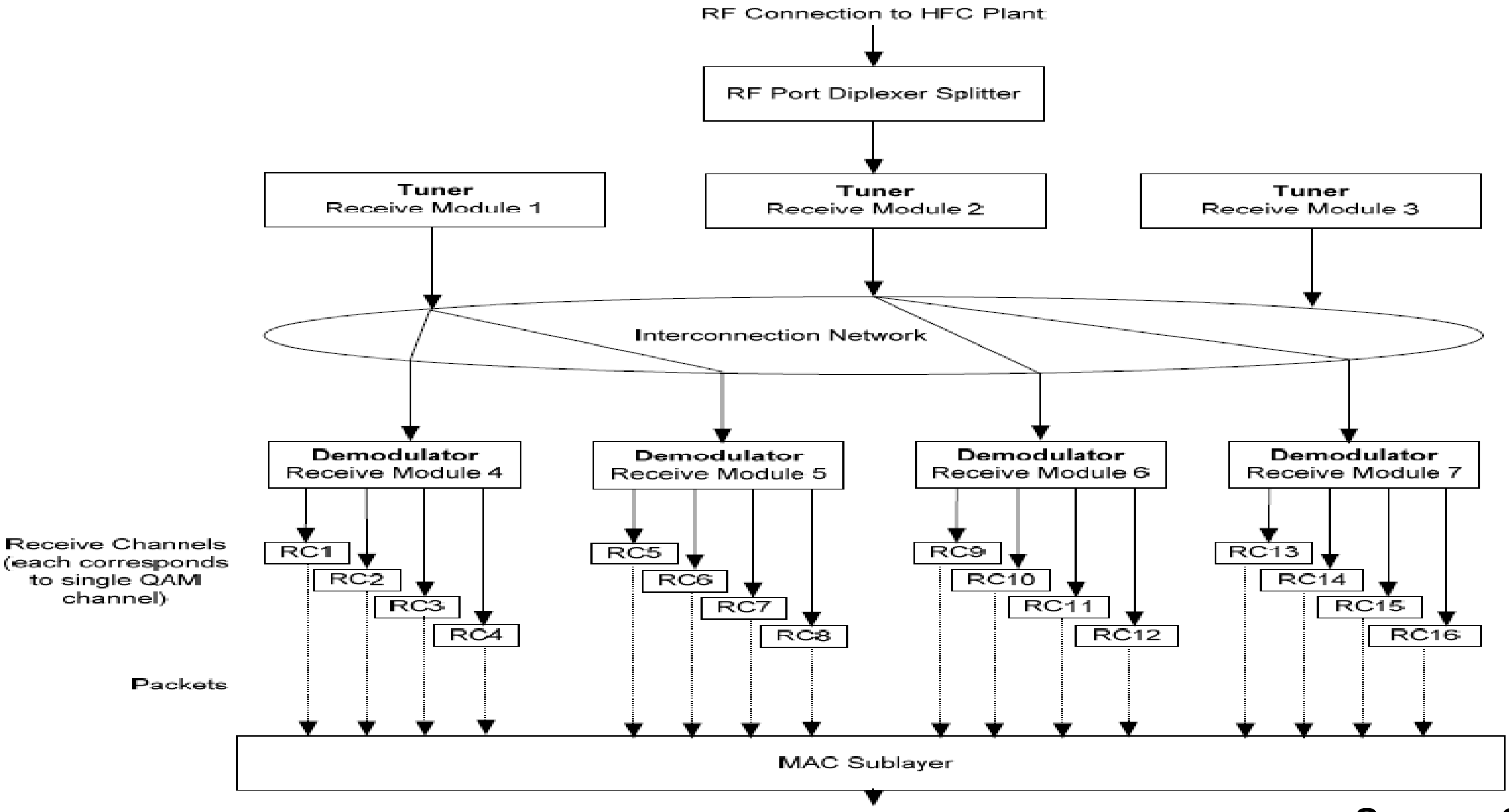


- *Courtesy Motorola*

Security

- DOCSIS 1.0 had BPI (Baseline Privacy Interface)
  - Did not hardware authenticate Cable Modems
- DOCSIS 1.1 and 2.0 have BPI+
  - Digital Certificate based security
  - No more spoofing MAC addresses
- DOCSIS 3.0 adds more enhancements – and the specification is now named “Security”, or BPI/SEC
- BPI/SEC encrypts data flows between the CPE and the CMTS
  - BPI/BPI+ use 56 bit encryption – SEC uses 128 bit encryption

SCTE Downstream Modem Configuration



Source: SCTE

SCTE Docsis 3.0 Downstream RF Spec

Table 5-1 - Assumed Downstream RF Channel Transmission Characteristics

Parameter	Value
Frequency range	Cable system normal downstream operating range is from 50 MHz to 1002 MHz. However, the values in this table apply only at frequencies ≥ 108 MHz (including Pre-3.0 DOCSIS modes).
RF channel spacing (design bandwidth)	6 MHz
Transit delay from head-end to most distant customer	≤ 0.800 ms (typically much less)
Carrier-to-noise ratio in a 6 MHz band	Not less than 35 dB[1,2]
Carrier-to-Composite triple beat distortion ratio	Not less than 41 dB[1,2]
Carrier-to-Composite second order distortion ratio	Not less than 41 dB[1,2]
Carrier-to-Cross-modulation ratio	Not less than 41 dB[1,2]
Carrier-to-any other discrete interference (ingress)	Not less than 41 dB[1,2]
Amplitude ripple	3 dB within the design bandwidth[1]
Group delay ripple in the spectrum occupied by the CMTS	75 ns within the design bandwidth[1]
Micro-reflections bound for dominant echo	-10 dBc @ ≤ 0.5 µs -15 dBc @ ≤ 1.0 µs -20 dBc @ ≤ 1.5 µs -30 dBc @ > 1.5 µs[1]
Carrier hum modulation	Not greater than -26 dBc (5%)[1]
Burst noise	Not longer than 25 µs at a 10 Hz average rate[1]

Parameter	Value
Maximum analog video carrier level at the CM input	17 dBmV
Maximum number of analog carriers	121

1. Measurement methods defined in [NCTA] or [CableLabs1].
2. Measured relative to a QAM signal that is equal to the nominal video level in the plant.

Source: SCTE

SCTE Docsis 3.0 Upstream RF Spec

Table 5-2 - Assumed Upstream RF Channel Transmission Characteristics

Parameter	Value
Frequency range	5 to 42 MHz edge to edge or 5 to 85 MHz edge to edge
Transit delay from head-end to most distant customer	≤ 0.800 ms (typically much less)
Carrier-to-interference plus ingress (the sum of noise, distortion, common-path distortion and cross modulation and the sum of discrete and broadband ingress signals, impulse noise excluded) ratio	Not less than 25 dB[1]
Carrier hum modulation	Not greater than -23 dBc (7.0%)
Burst noise	Not longer than 10 µs at a 1 KHz average rate for most cases[2,3]
Amplitude ripple across upstream operating frequency range	0.5 dB/MHz
Group delay ripple across upstream operating frequency range	200 ns/MHz
Micro-reflections – single echo	-10 dBc @ ≤ 0.5 µs -20 dBc @ ≤ 1.0 µs -30 dBc @ > 1.0 µs
Seasonal and diurnal reverse gain (loss) variation	Not greater than 14 dB min to max

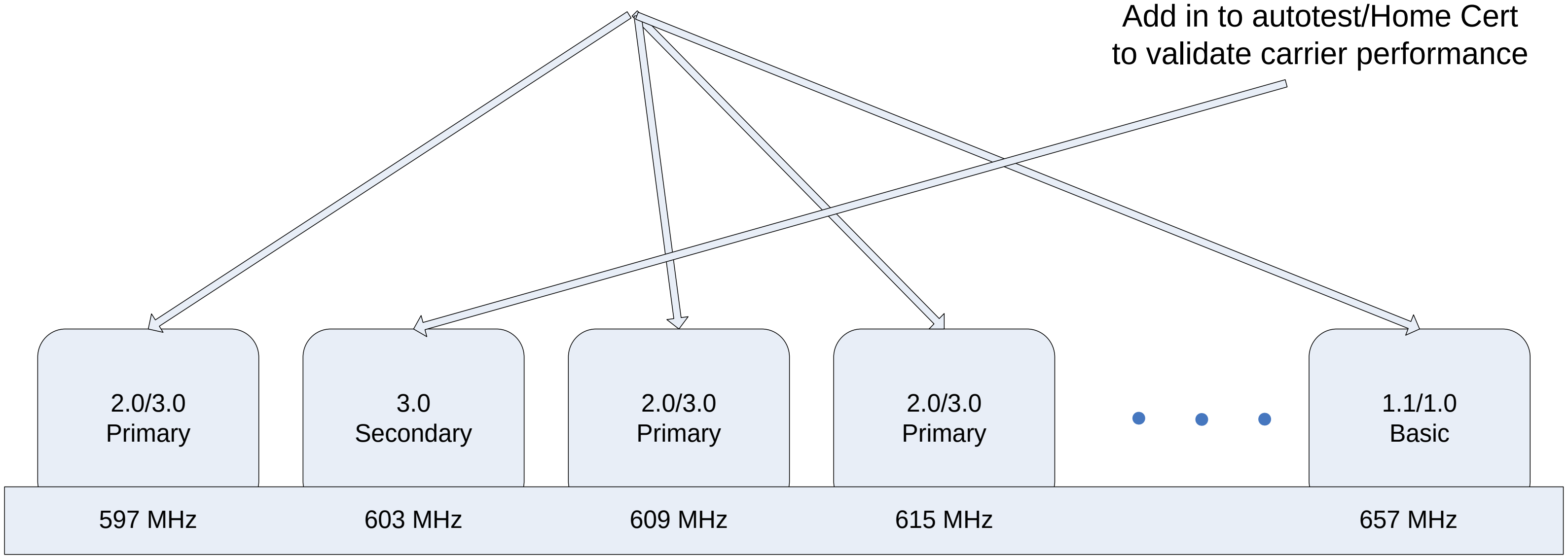
1. Ingress avoidance or tolerance techniques may be used to ensure operation in the presence of time-varying discrete ingress signals that could be as high as 10 dBc. The ratios are guaranteed only within the digital carrier channels.
2. Amplitude and frequency characteristics sufficiently strong to partially or wholly mask the data carrier.
3. Impulse noise levels more prevalent at lower frequencies (<15 MHz).

Source: SCTE

DOCSIS 3.0 Downstreams

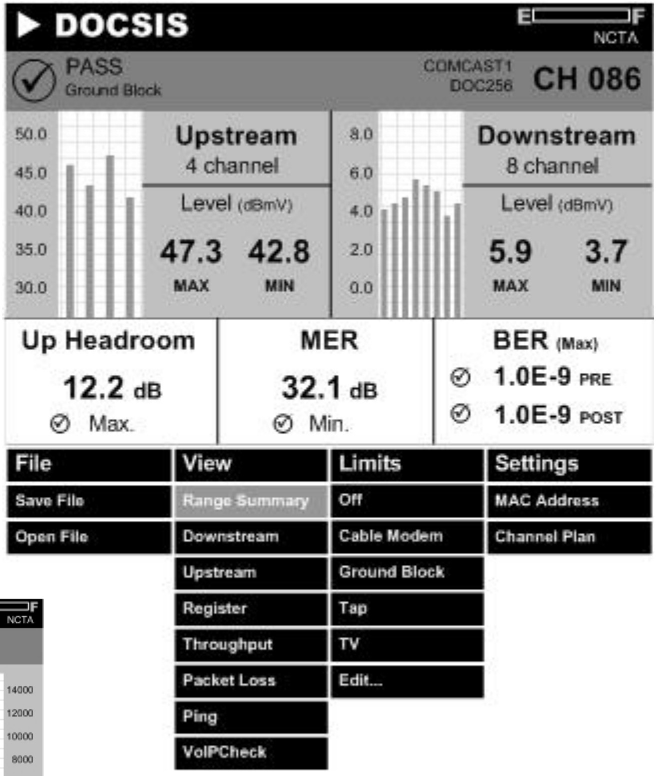
Add to Channel plan as DOCSIS carriers
Add in to autotest/Home Cert to validate DOCSIS performance

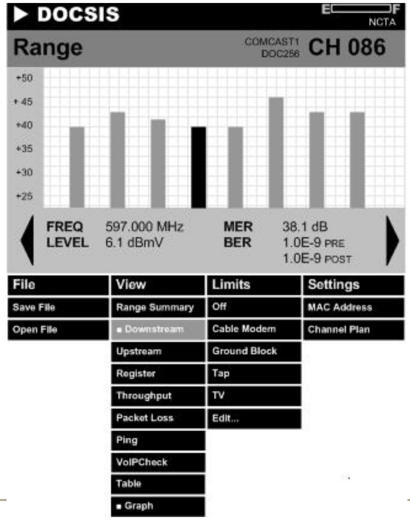
Add to Channel Plan as Video Carrier
secondary carriers do not contain channel descriptors or ranging information
Add in to autotest/Home Cert to validate carrier performance

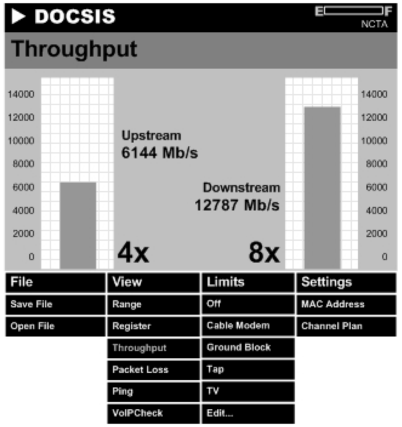


DSAM 3.0 Bonded Carrier testing – coming soon

- Keeping it simple for the technicians
- Validate overall performance
- Identifying individual US/DS channel issues







BER Example

- A 256QAM channel transmits at a symbol rate of 5M symbols per second
- Bit rate = 8 bits per symbol X 5M symbol per second =40M bits per second
- Error Incident = Bit rate X BER = Errors Per Second

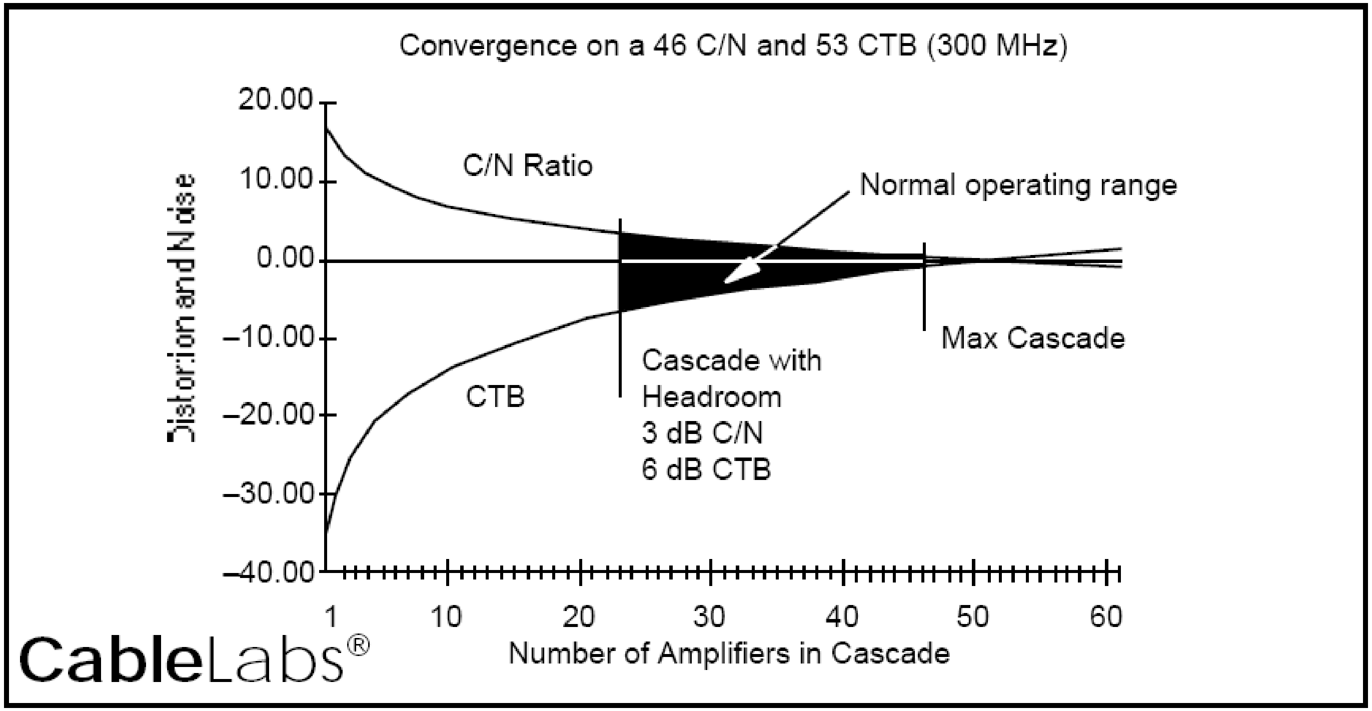
BER	**Error Frequency**	**Error Incident**
10^{-12}	1 in 1 Trillion bits	25000 secs between errs (6.94 hrs)
10^{-11}	1 in 100 Billion bits	2500 secs between errs (41.67 mins)
10^{-10}	1 in 10 Billion bits	250 secs between errs (4.167 mins)
10^{-9}	1 in 1 Billion bits	25 seconds between errors
10^{-8}	1 in 100 Million bits	2.5 seconds between errors
10^{-7}	1 in 10 Million bits	4 errors per second
10^{-6}	1 in 1 Million bits	40 errors per second
10^{-5}	1 in 100 Thousand bits	400 errors per second
10^{-4}	1 in 10 Thousand Bits	4000 errors per second
10^{-3}	1 in 1 Thousand bits	40000 errors per second

Sweep and Maintenance

Major Operational Challenges

- **Plant Certification and Maintenance:**
  - Elevate plant performance to ensure reliable service
  - HFC: Sweep & advanced return path certification
  - Metro Optical: Fiber and transport analysis
- **Monitor Performance:**
  - Continuously monitor the health of your upstream and downstream carriers
  - Proactively identify developing problems before customers do
  - Monitor both physical HFC & VoIP service call quality
  - Utilize advanced performance trending and analysis to prioritize
- **Get Installations Right the First Time**
  - Improve installation practices to prevent service callbacks & churn
  - Verify physical, DOCSIS® and PacketCable™ performance
  - Drive consistency across all technicians
- **Troubleshoot Fast:**
  - When issues occur, find and fix fast
  - Isolate and segment from NOC, dispatch right tech at right time
  - Field test tools that can find problems and verify fix

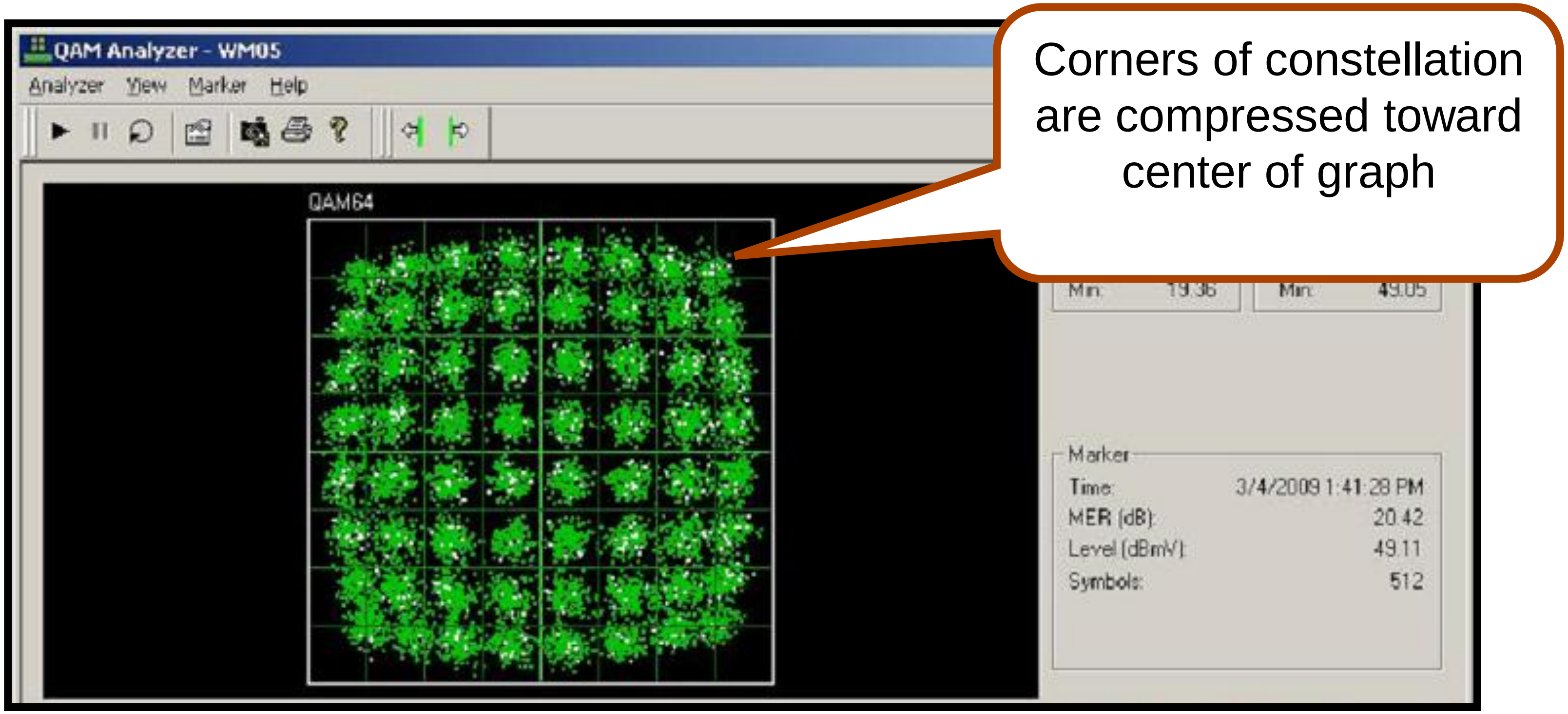
WHY SWEEP?



DISTORTIONS IN A CASCADE

- CATV amplifiers have a trade-off between noise and distortion performance
- Tightly controlling frequency response provides the best compromise between noise and distortion.

Compression



Amplifier Compression

Amplifier compression often manifests as rounding of the corners of the constellation.
Laser clipping often manifests as increased spread in the corners of the constellation.
Both are caused by overdriving an amplifier or laser usually due to ingress or misalignment. (unity gain)
May become more prevalent as more DOCSIS® upstream carriers are added.

Incorrect Levels

- Low Video Levels
- Produces noise in the picture

- High Video Levels

Produces distortion in the picture

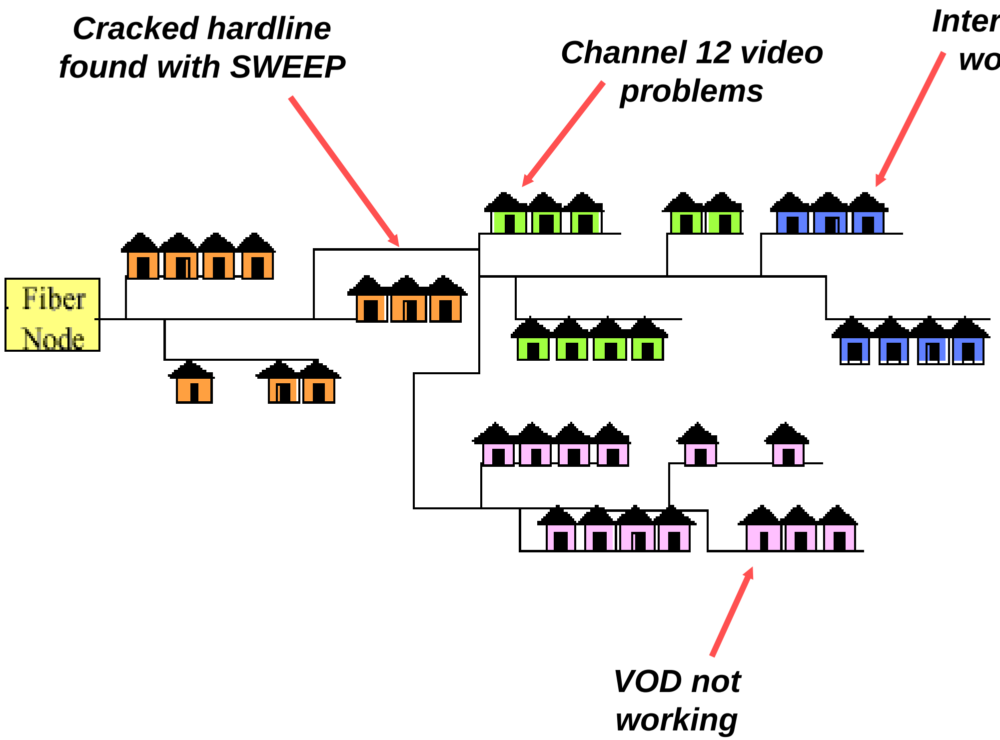
Low Digital levels

- **Causes Digital signal to Degrade.**

- **This causes Tiling and Loss of high Speed internet access.**

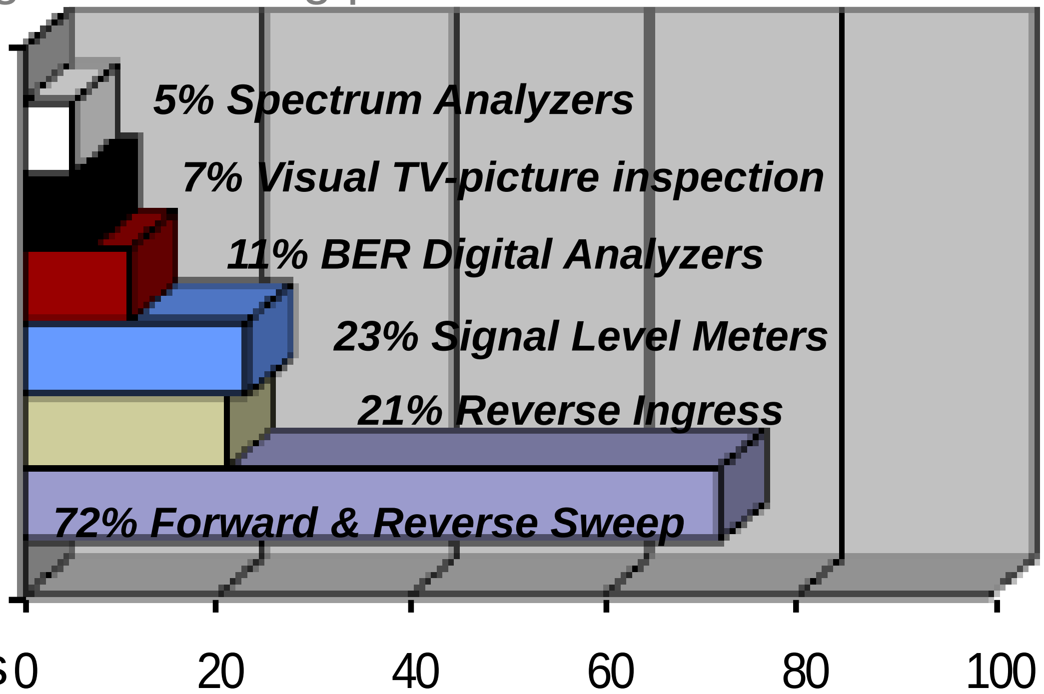
WHY SWEEP?

- Less manpower needed
- Sweeping can reduce the number of service calls



What Faults Cause CATV Signal Failure?

- 80-90% of the time, the same faults…
- Success rate of finding and fixing the following problems:
  - Signal Levels
  - TILT
  - Gain / Loss
  - Suck-outs
  - C/N & HUM
  - CTB/CSO
  - CPD
  - BER / MER
  - Reflections / Standing waves



Sweep Verifies Construction Quality

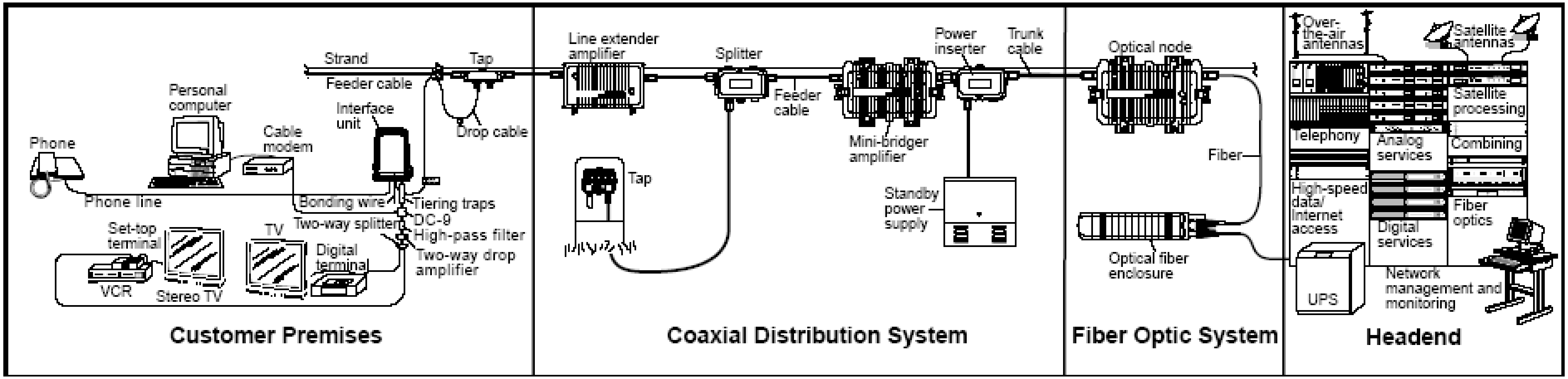
Sweep can find craftsmanship or component problems that aren't revealed with other tests

- Damaged cable
- Poor connectorization
- Amplifier RF response throughout its frequency range
  - Gain
  - Slope
- Loose face plates, seizure screws, module hardware…….

All of these issues could lead to major ingress and micro-reflection problems!

HFC Networks

- Combines fiber optics with coaxial distribution network
- Return path is more sensitive than the forward path
- Most of the ingress comes from home wiring on low value taps
- Wide variety of aging hardware with many connectors



Today's "HFC" networks must be optimized for both forward and reverse performance

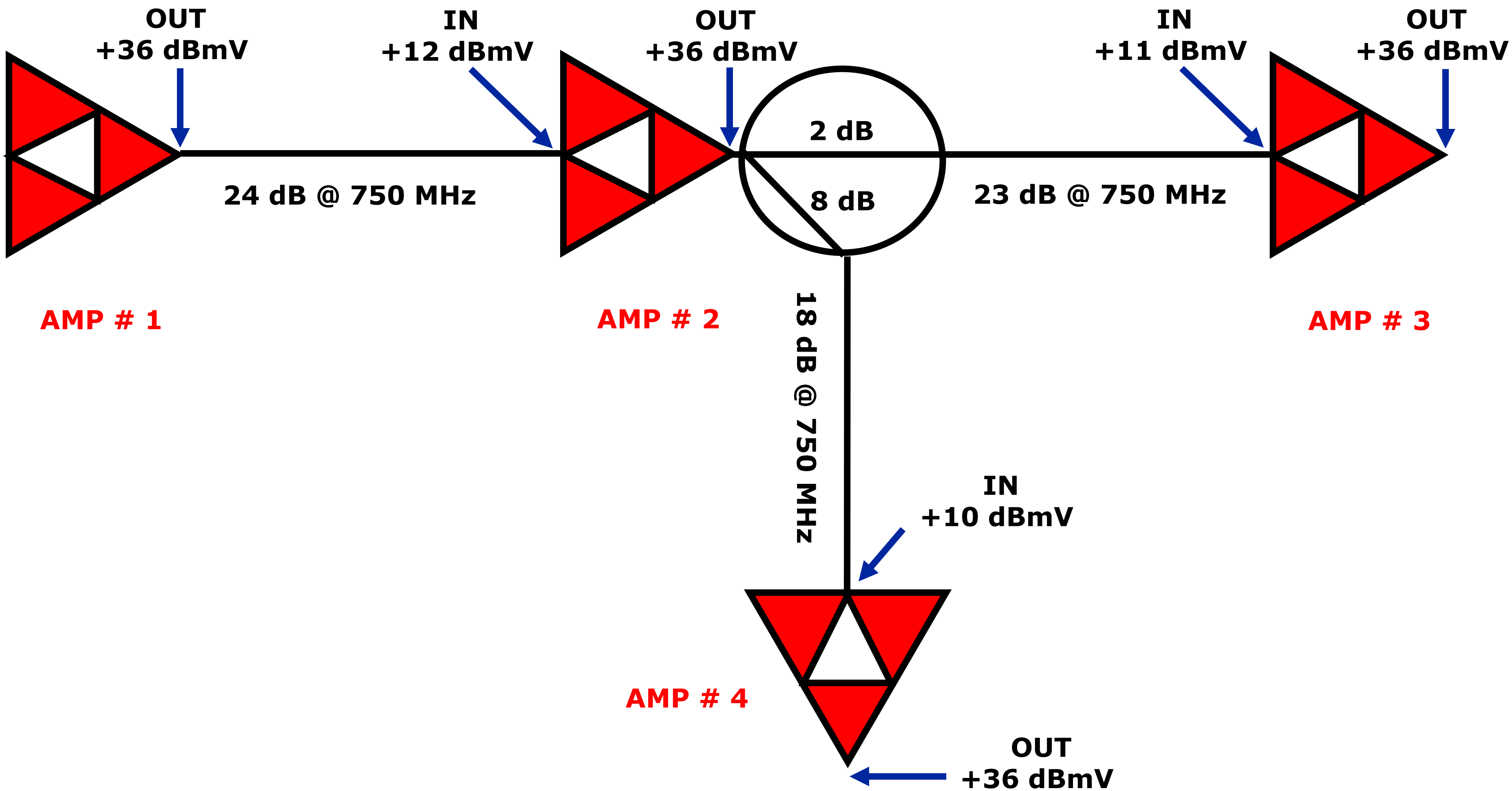
Impairments

Frequency response— Frequency response problems are due to improper network alignment, un-terminated lines, or damaged components. When reverse frequency response and equipment alignment have been done incorrectly or not at all, the result can be excessive thermal noise, distortions, and group delay errors.

Forward System

- Diverging System
- Constant Outputs with Variable Inputs
- Fixed Signals
  - video / audio / digital carriers
- System Noise
  - is the sum of cascaded amplifiers
- Balance or Align (Sweep)
  - compensate for losses before the amp

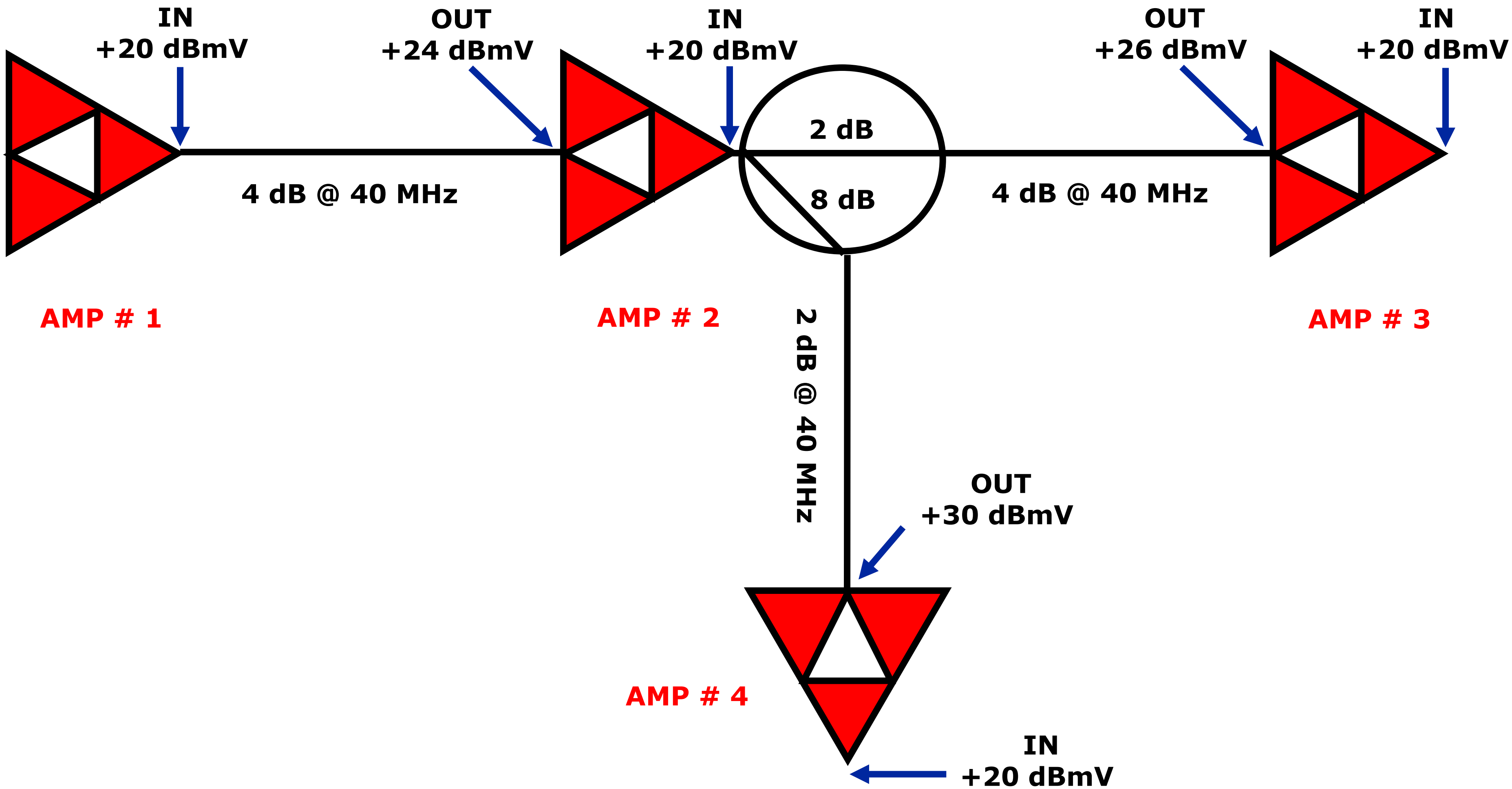
Forward Path Unity Gain



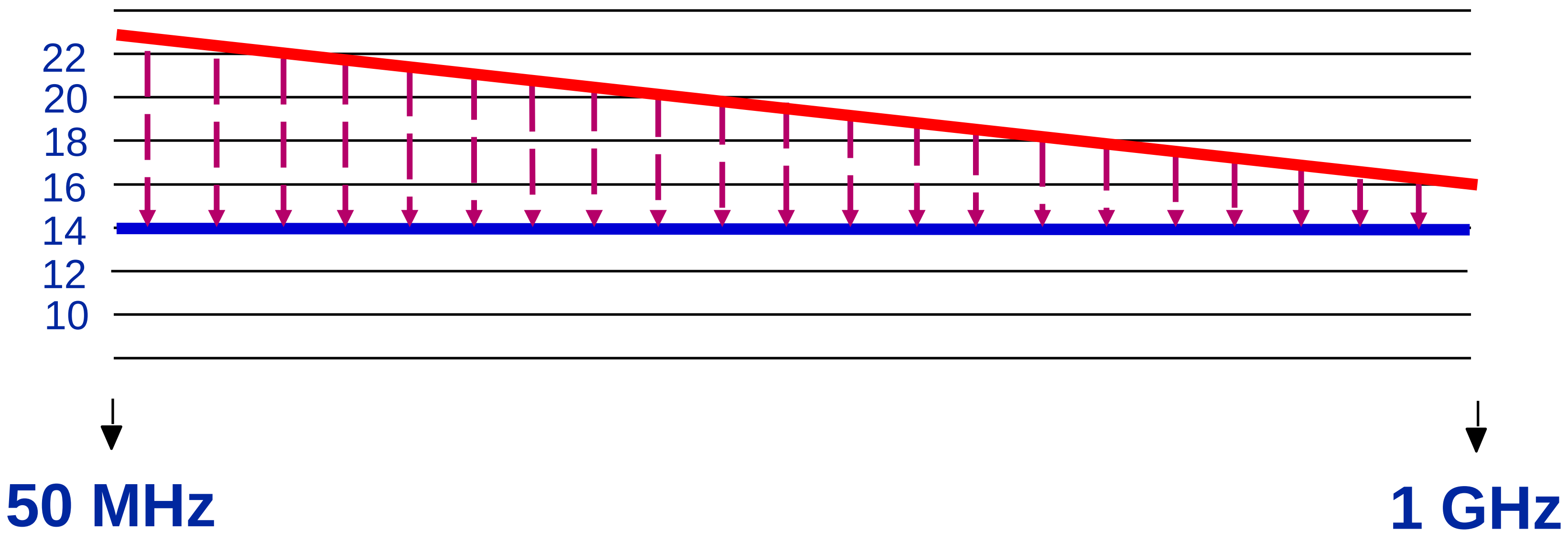
Reverse System

- Converging System
- Constant Inputs with Variable Outputs
- No Fixed Signals
  - impulse digital carriers
- System Noise
  - is the sum of all active components
- Balance or Align (Sweep)
  - compensate for losses after the amp

Return Path Unity Gain



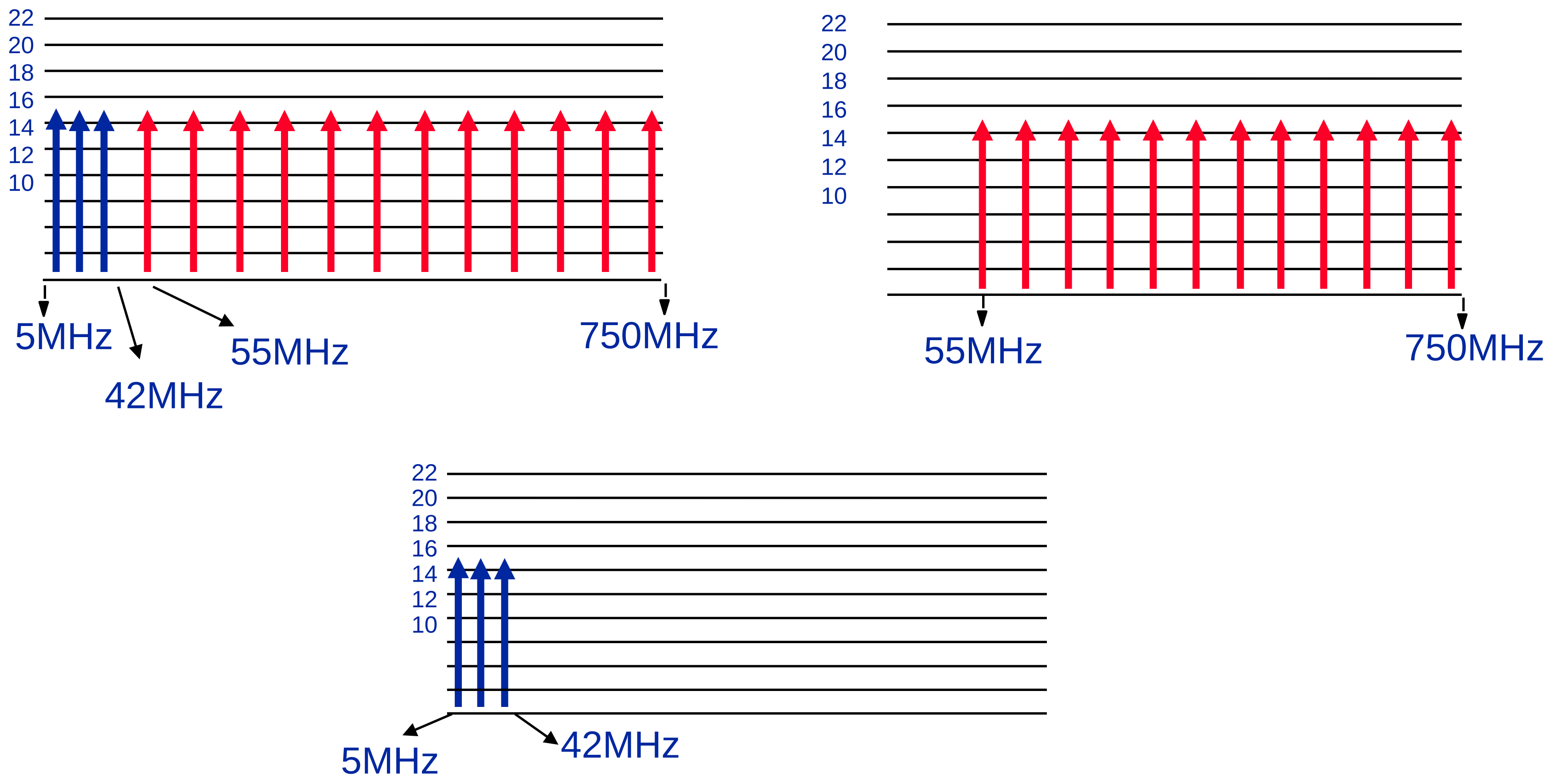
Equalizers



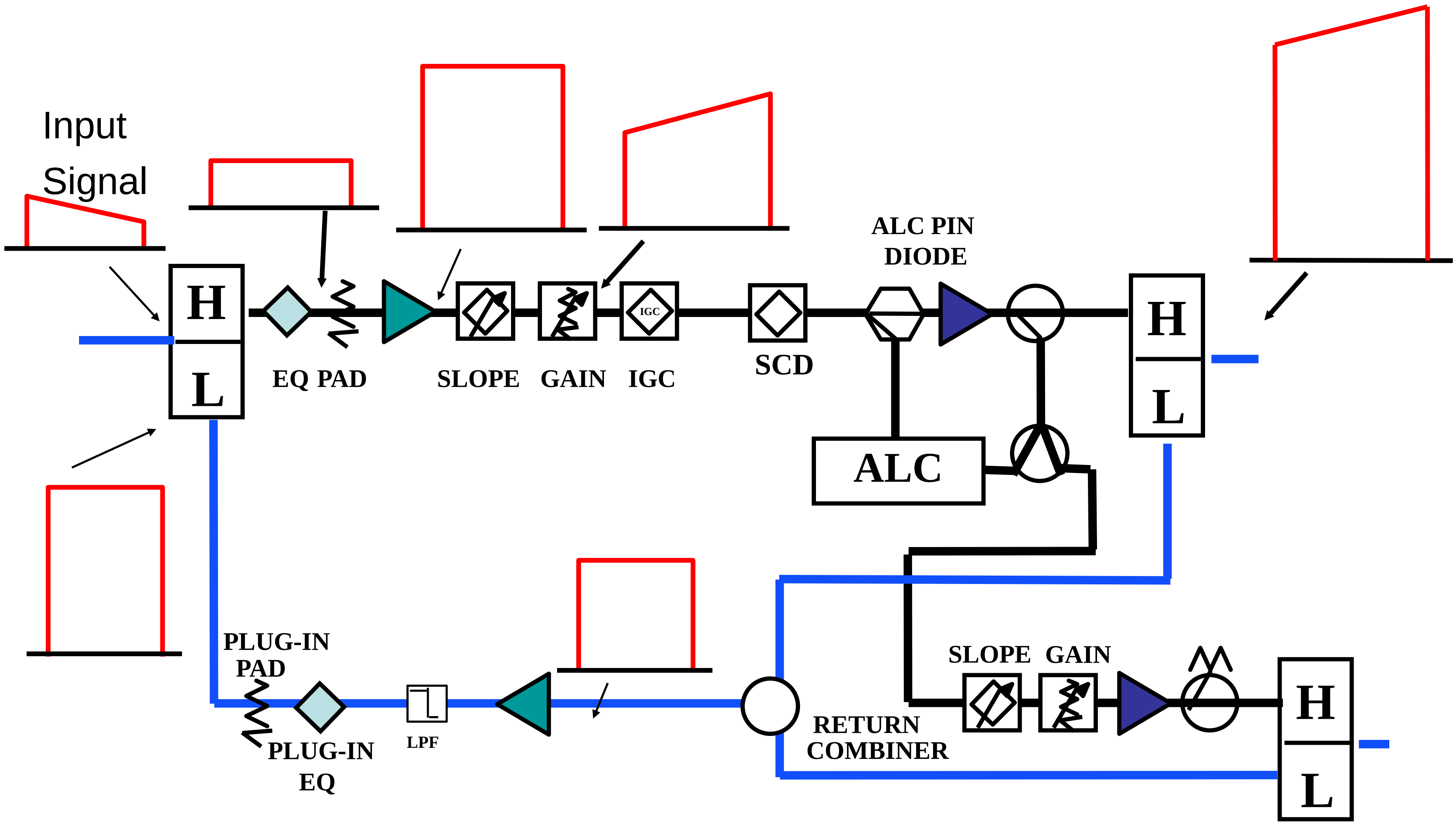
- Equalizers attenuate the low frequencies more than the highs, to compensate for cable loss

Diplex Filter

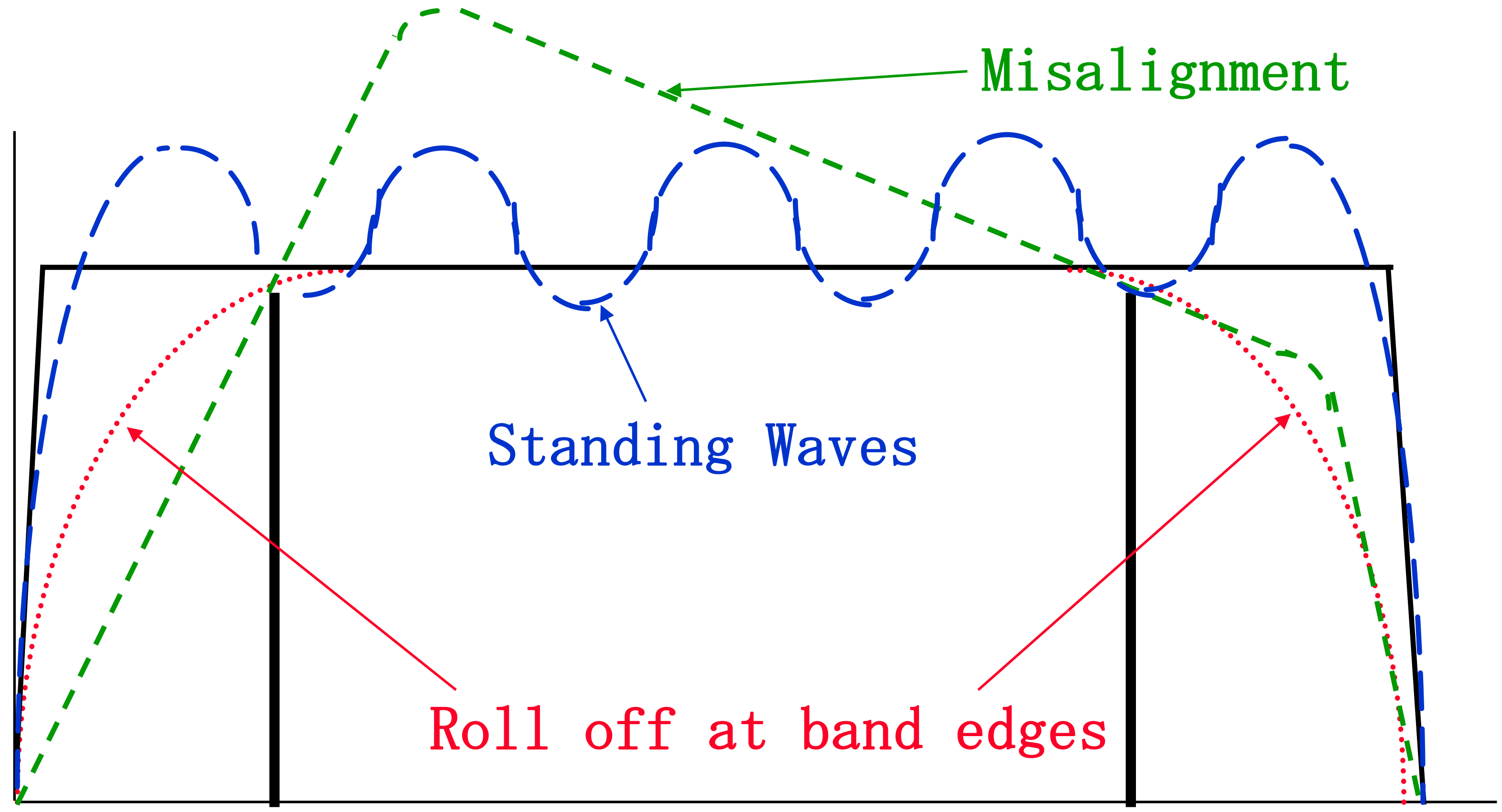
- A Diplex Filter separates signals by frequency



Functional Block Diagram

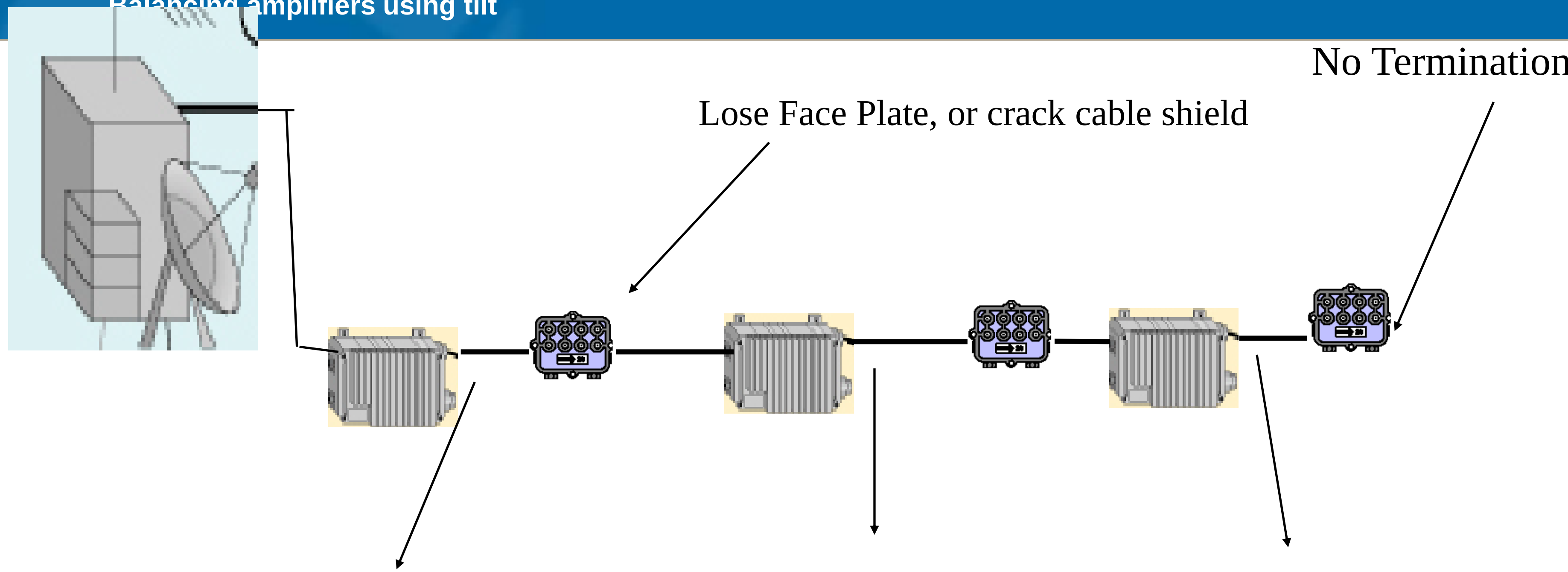


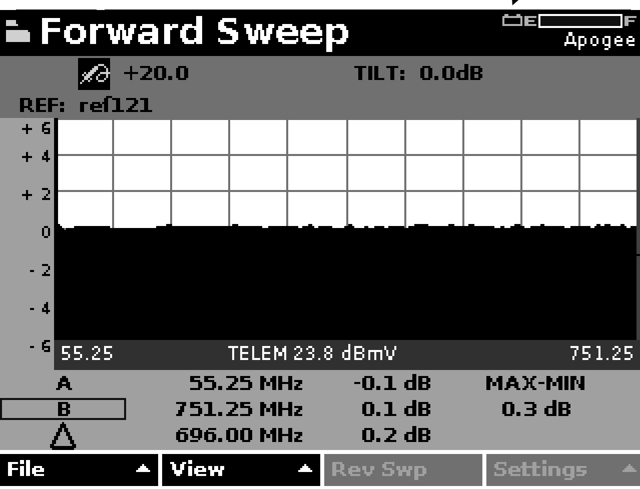
A Sweep Finds Problems That Signal Level Measurements Miss



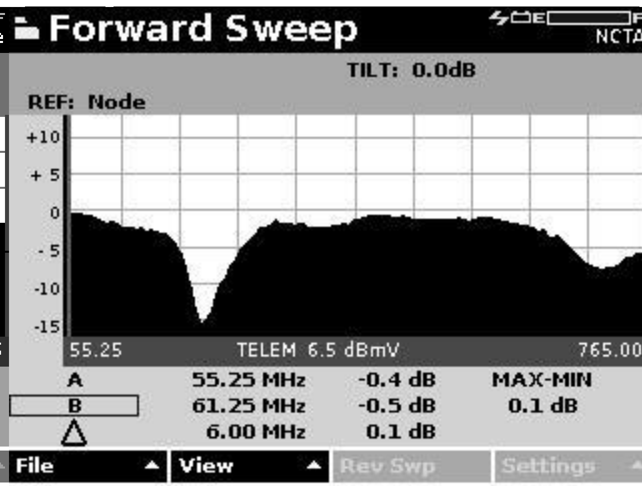
Balancing Amplifiers

Balancing amplifiers using tilt

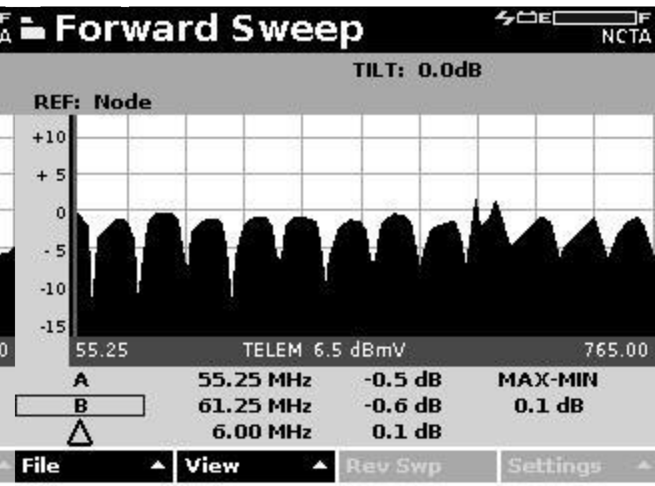




Node Reference Signal



Sweep response with a Resonant Frequency Absorption



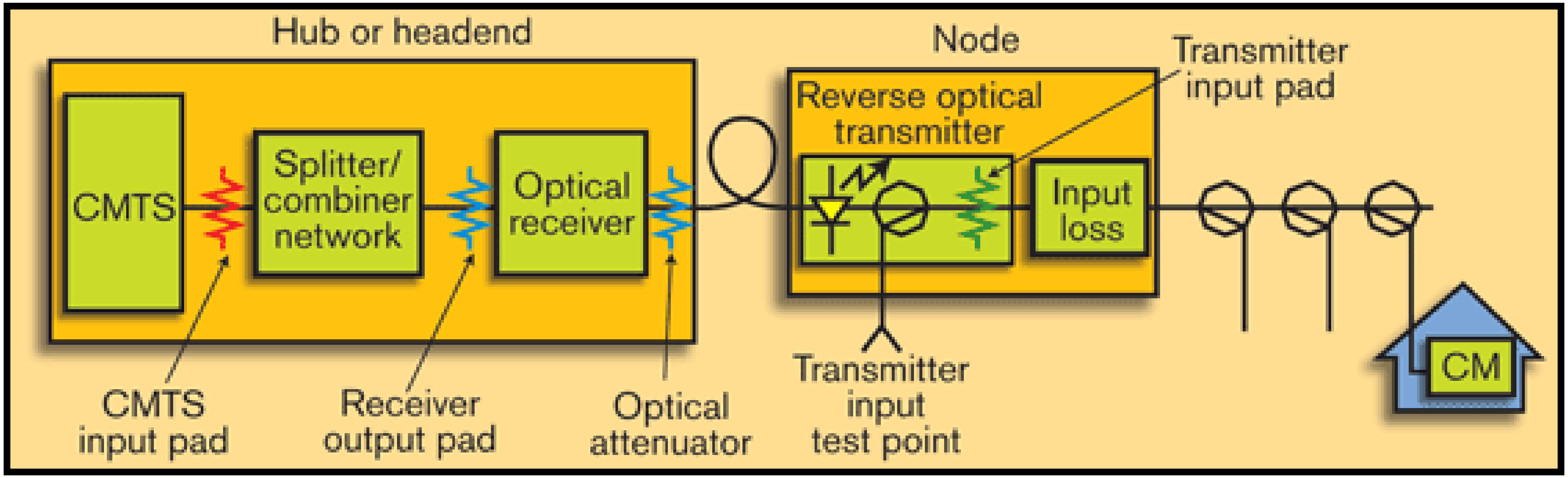
Sweep response with standing waves

Setting the Transmitter "Window"

- RF input levels into a return laser determine the CNR of the return path.
  - Higher input – better CNR
  - Lower input – worse CNR
- Too much level and the laser 'clips'.
- Too little level and the noise performance is inadequate
- Must find a balance, or, "set the window" the return laser must operate in
  - Not only with one carrier but all the energy that in in the return path.
  - The return laser does not see only one or two carriers it 'sees' the all of the energy (carriers) that in on the return path that is sent to it.

*Source - Cisco Systems, Inc.

Simplified DOCSIS® Upstream Block Diagram



Contact the manufacturer of your lasers, optical receivers and CMTS and ask them for their recommended RF and Optical input/output levels and setup procedures.

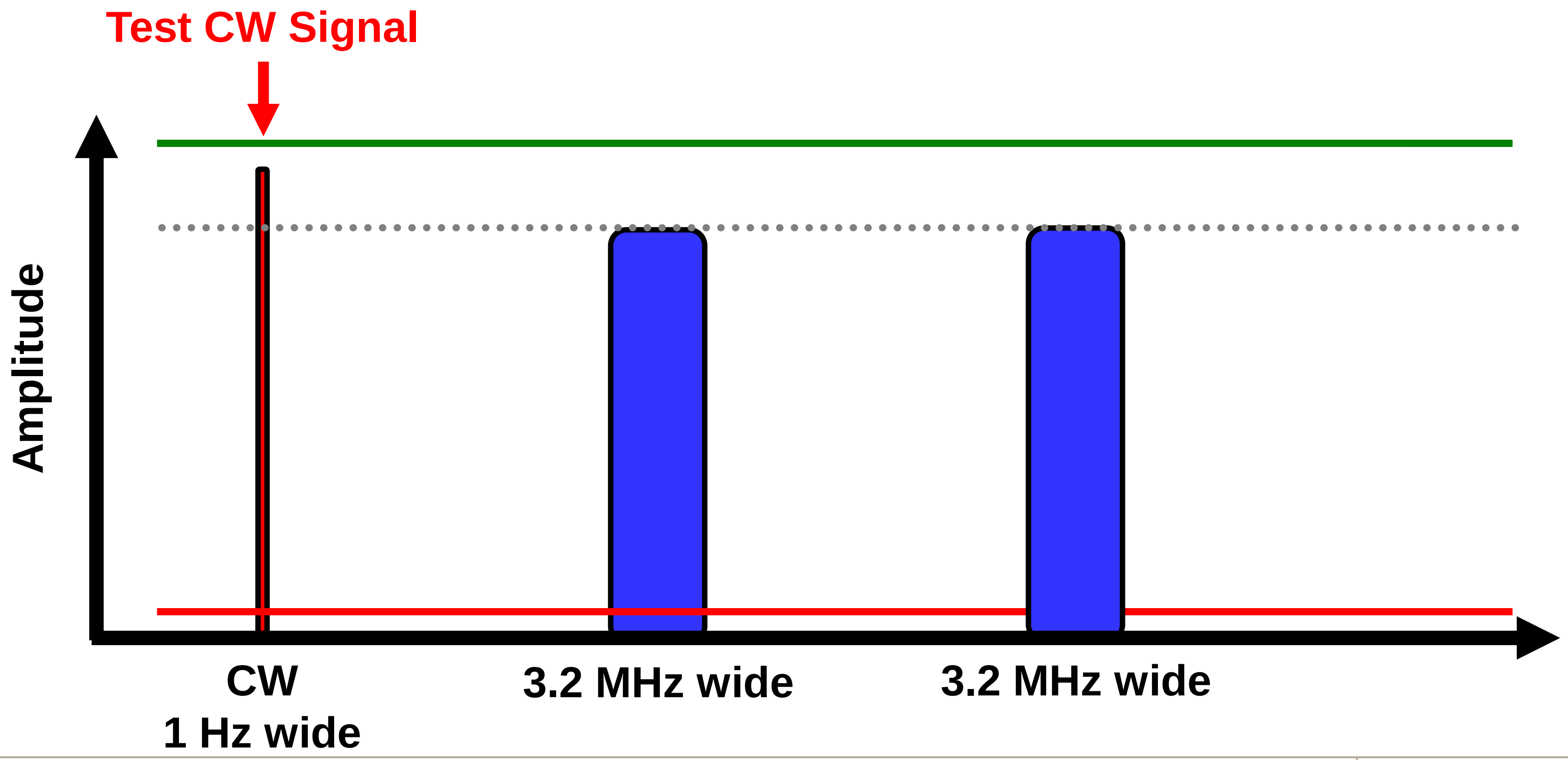
Sweeping the Return Path

Example chart showing injection levels at each test point

Return Sweep Cheat Sheet - Sweeping to the Input of a Return Amp				
	Various Types of Test Points			
	Node Return Test Point Compensation (TPC)	Trunk Amp Test Point Compensation (TPC)	Bridger Amp Test Point Compensation (TPC)	Line Extender Amp Test Point Compensation (TPC)
Desired Input Level into Return Amp or Return Laser	17 dBmV	17 dBmV	17 dBmV	17 dBmV
Internal Coupling Loss	5 dB	1 dB	14 dB	5 dB
Test Point Loss	30 dB	20 dB	20 dB	20 dB
Total Loss Between Sweep meter and return amp input	35 dB	21 dB	34 dB	25 dB
Sweep Telemetry and Sweep Pulse insertion level	52 dBmV	38 dBmV	51 dBmV	42 dBmV

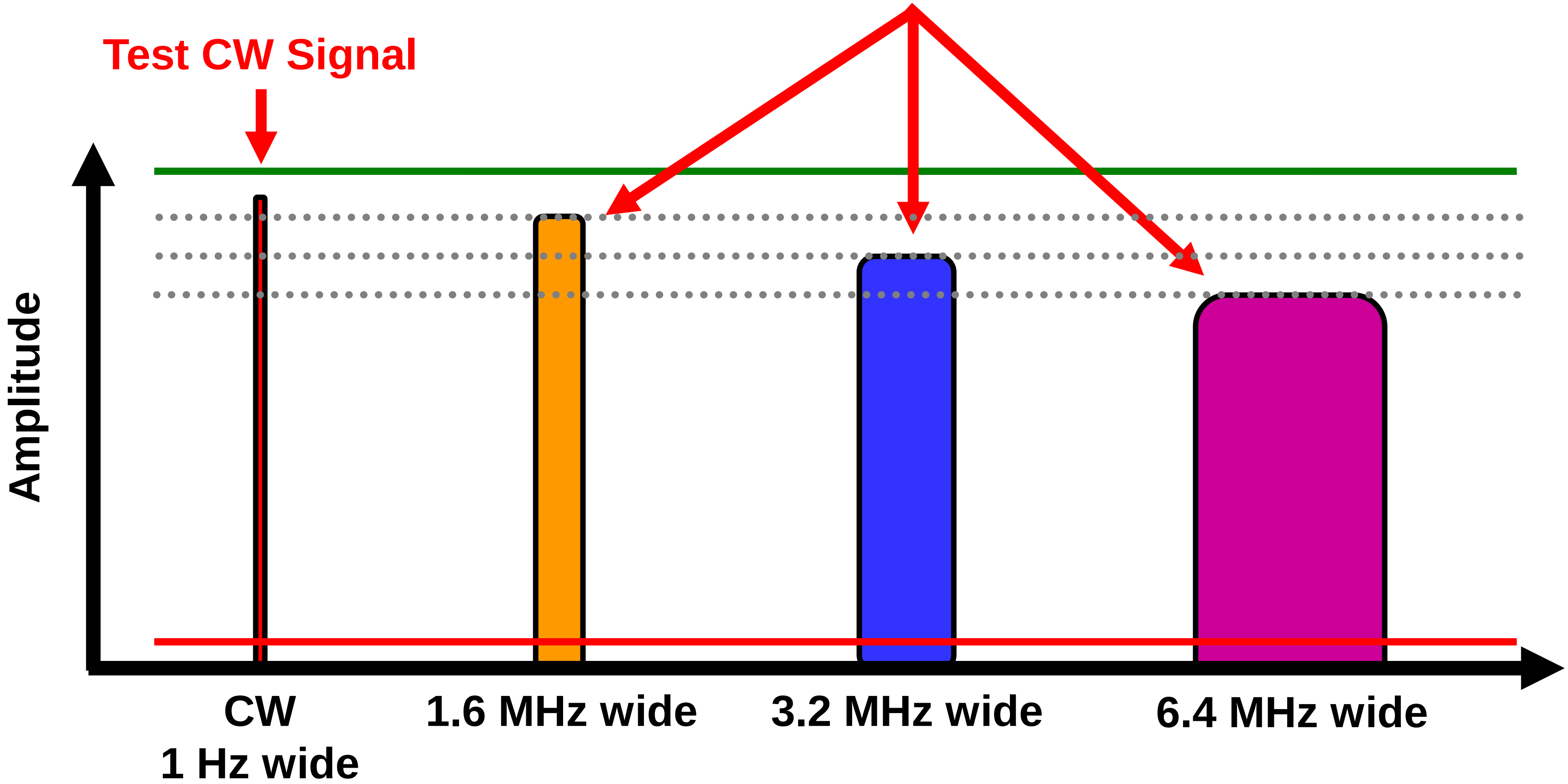
Measuring Upstream Carrier Amplitudes

These two DOCSIS® carriers will have the same peak amplitude when hitting the input port of a CMTS at 0 dBmV "constant power per carrier" and then measured with a typical spectrum analyzer.

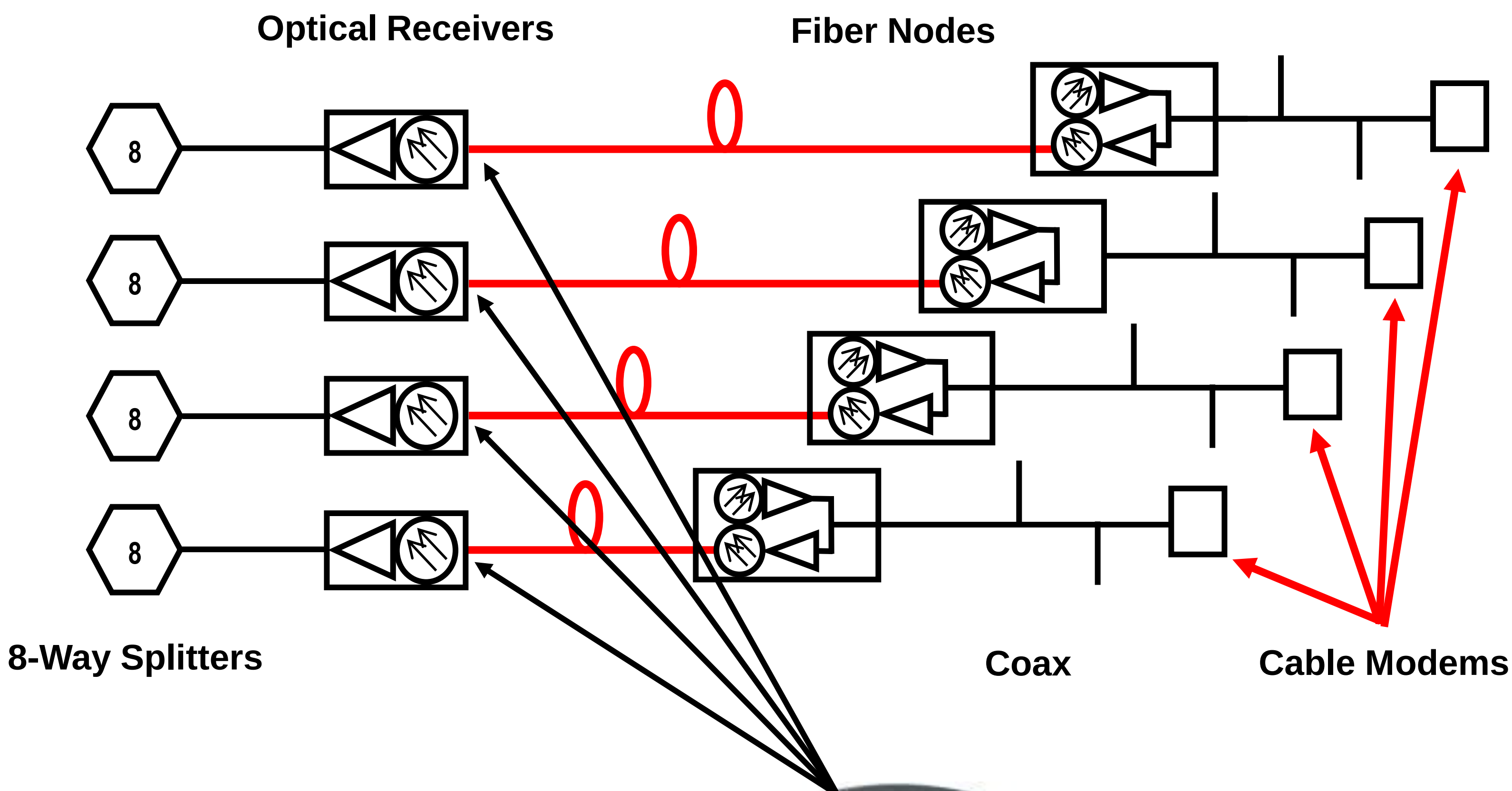


Measuring Upstream Carrier Amplitudes

These three DOCSIS® carriers will NOT have the same peak amplitude when hitting the input port of a CMTS at 0 dBmV "constant power per carrier" and then measured with a typical spectrum analyzer or signal level meter.



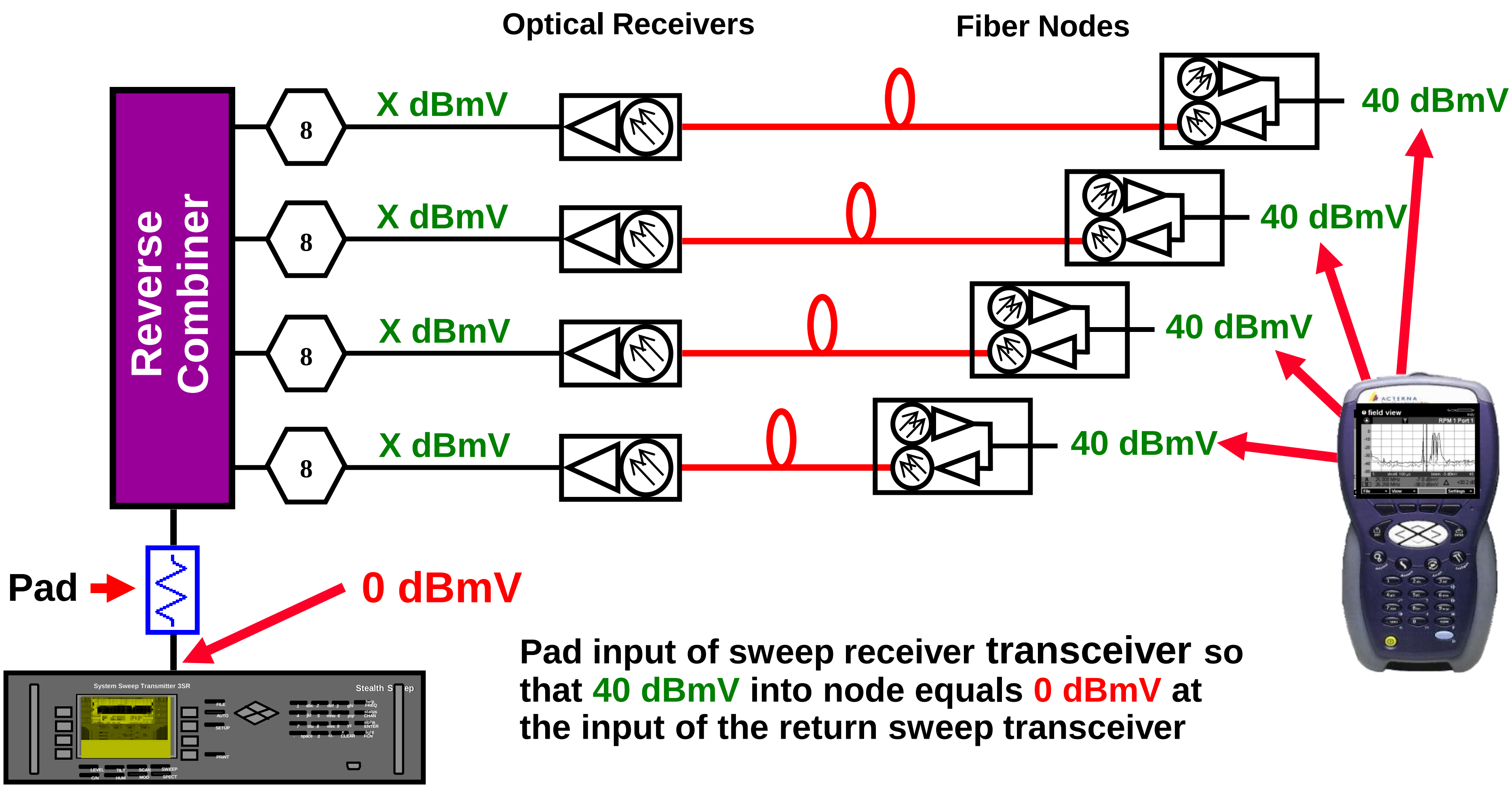
Optimize the Optical Links in Your HFC Networks!



Verify that all optical links have the correct light level at the input of each optical receiver!

Verify that all fiber and RF connections are secure and properly seated!

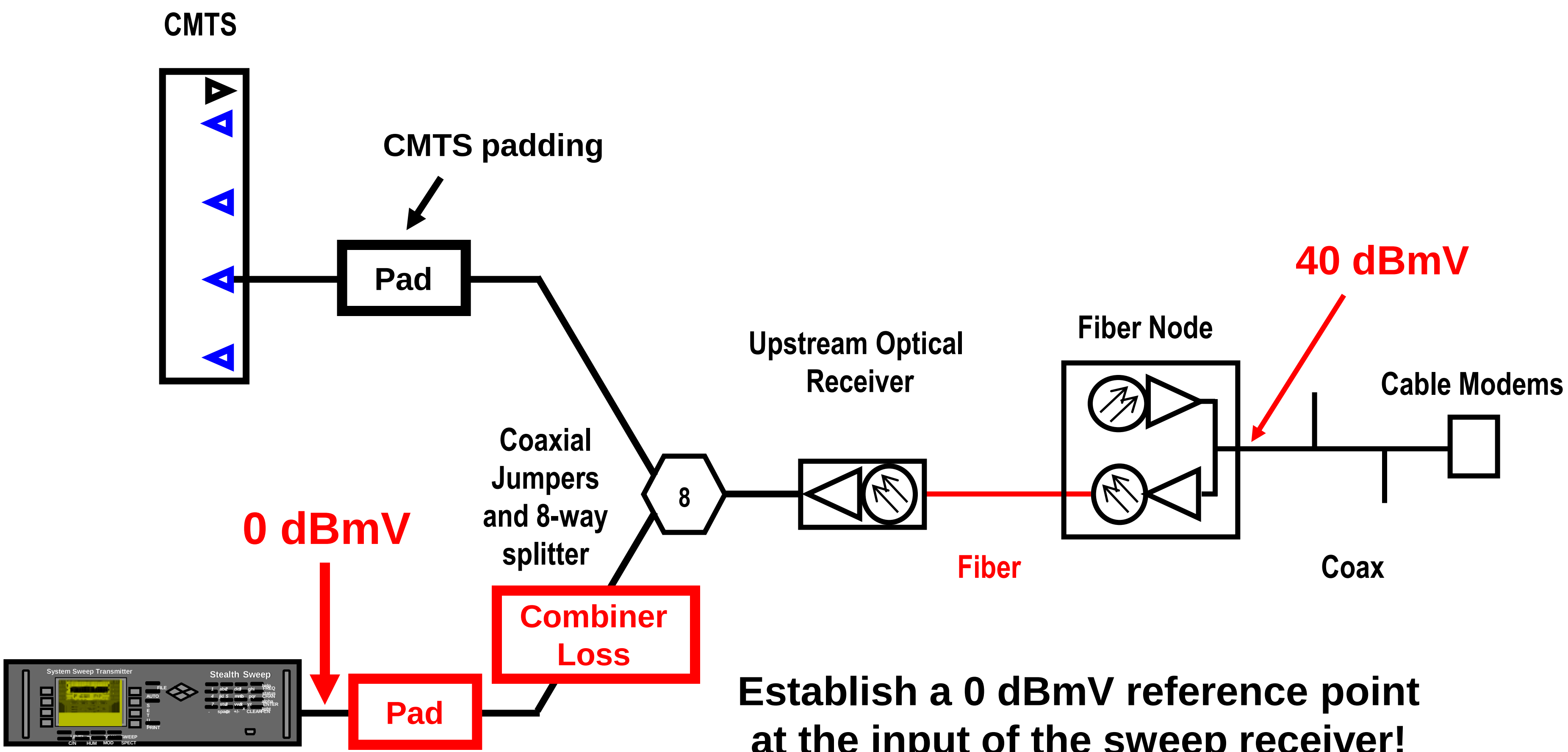
Optimize the RF Input to Return Sweep Transceiver



Pad input of sweep receiver **transceiver** so that 40 dBmV into node equals 0 dBmV at the input of the return sweep transceiver

There are typically between 16 and 32 nodes combined together for return path sweeping

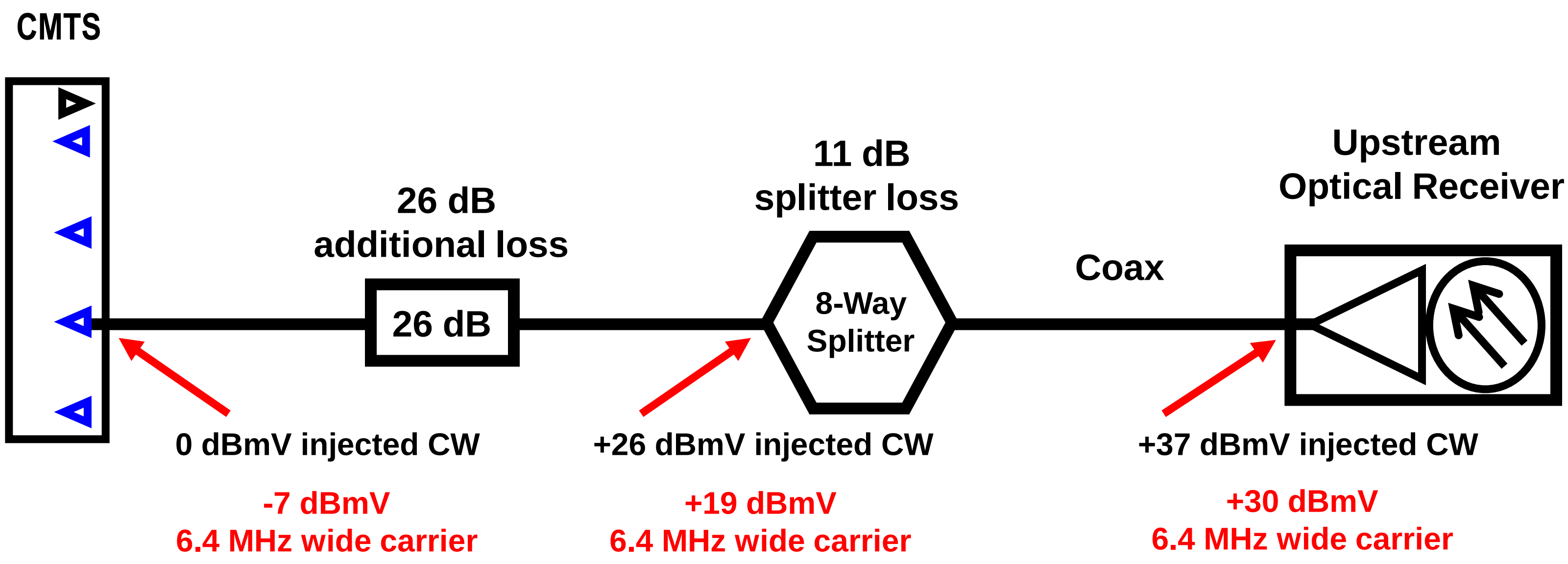
Typical Sweep Interface with DOCSIS® Network



Establish a 0 dBmV reference point at the input of the sweep receiver!

External attenuation should be added after combining multiple nodes to achieve 0 dBmV level at sweep receiver input port

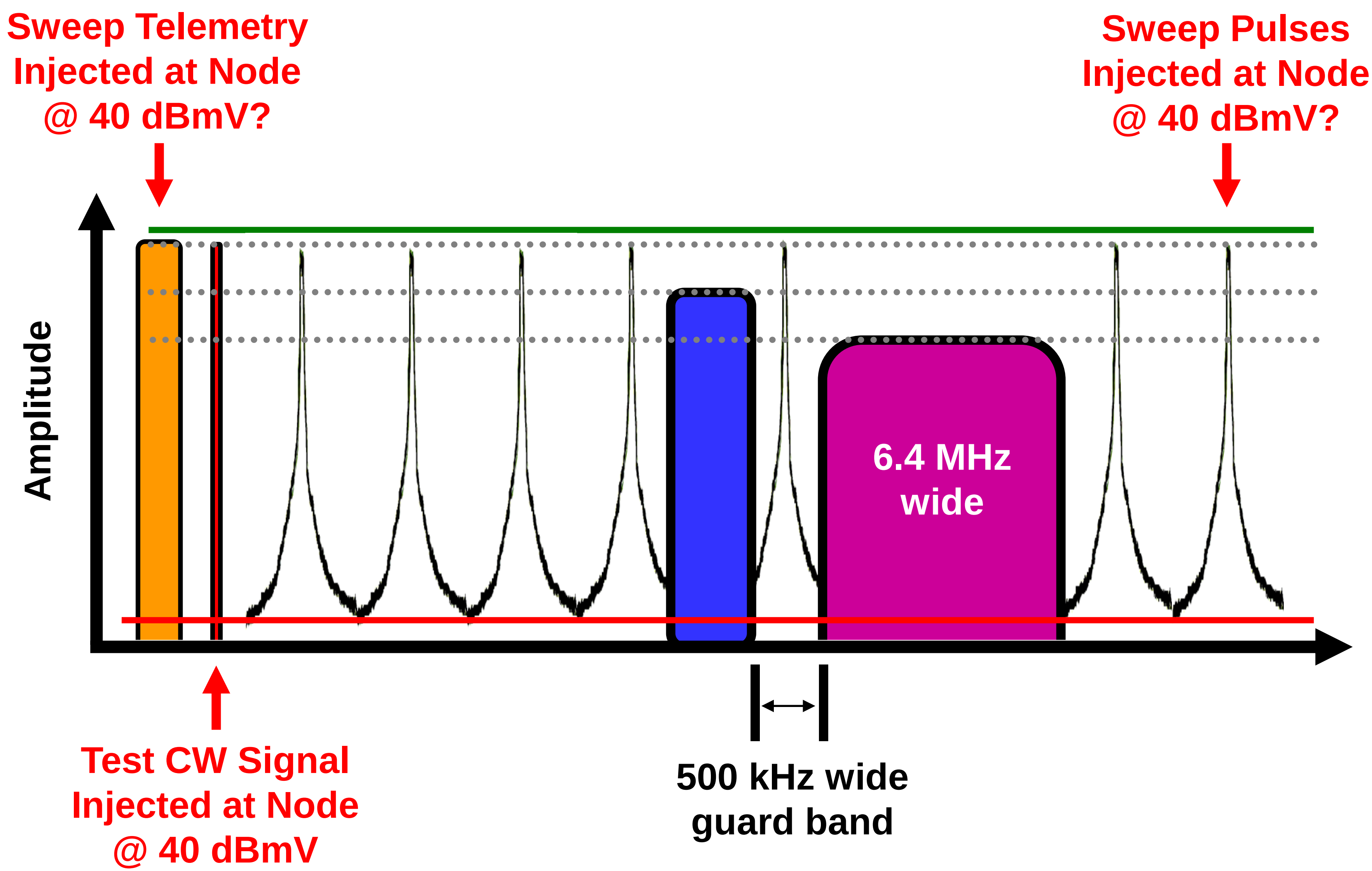
Optimize Dynamic Input Range of the CMTS



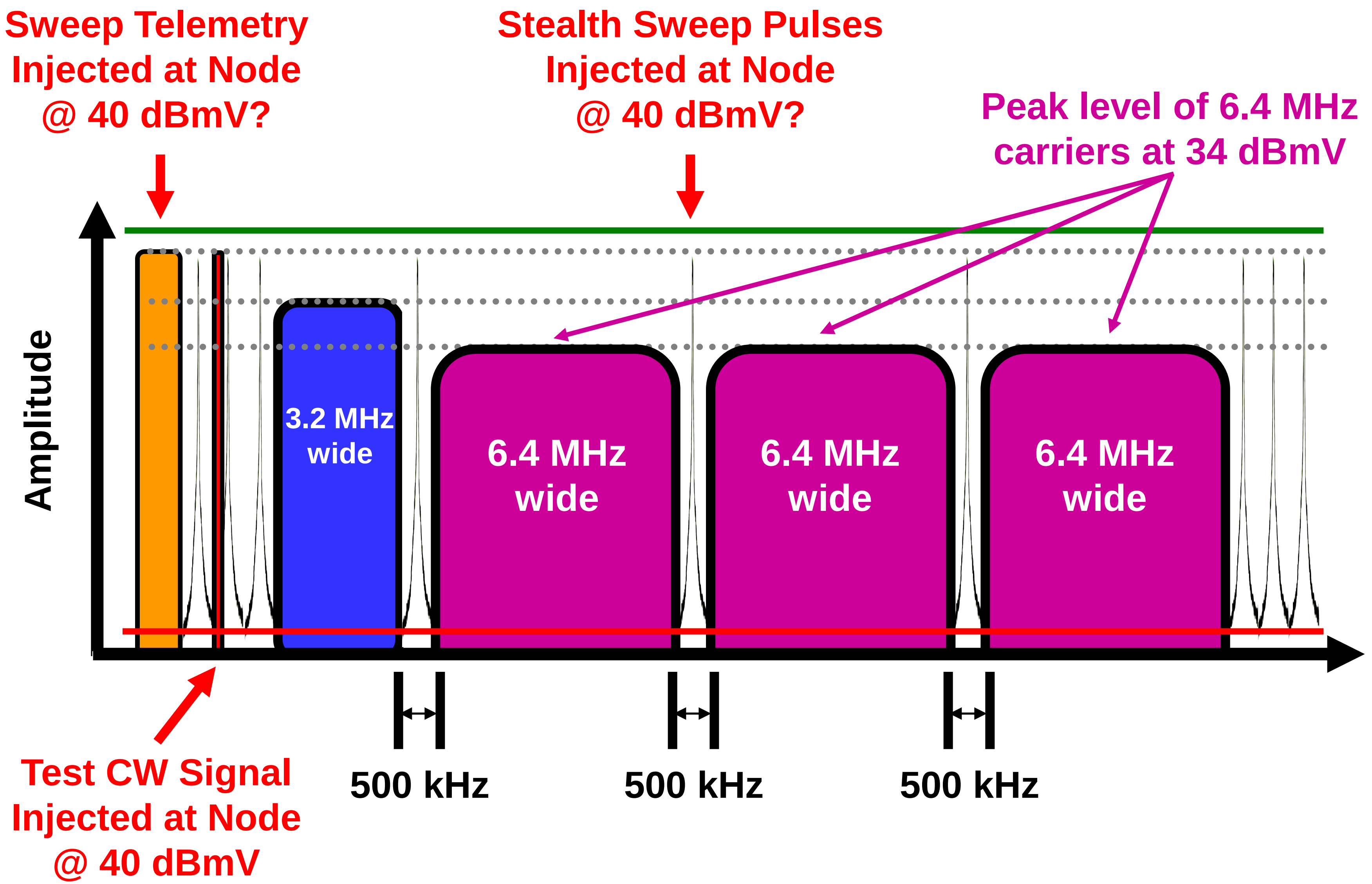
Example: Some systems will add 26 dB of external padding between the splitter and CMTS to attenuate the injected CW signal down to a **peak level** of 0 dBmV at the input port of the CMTS. The CMTS is typically configured to instruct the 6.4 MHz modem carriers to hit the input port of the CMTS at 0 dBmV "**constant power per carrier**".

JDSU

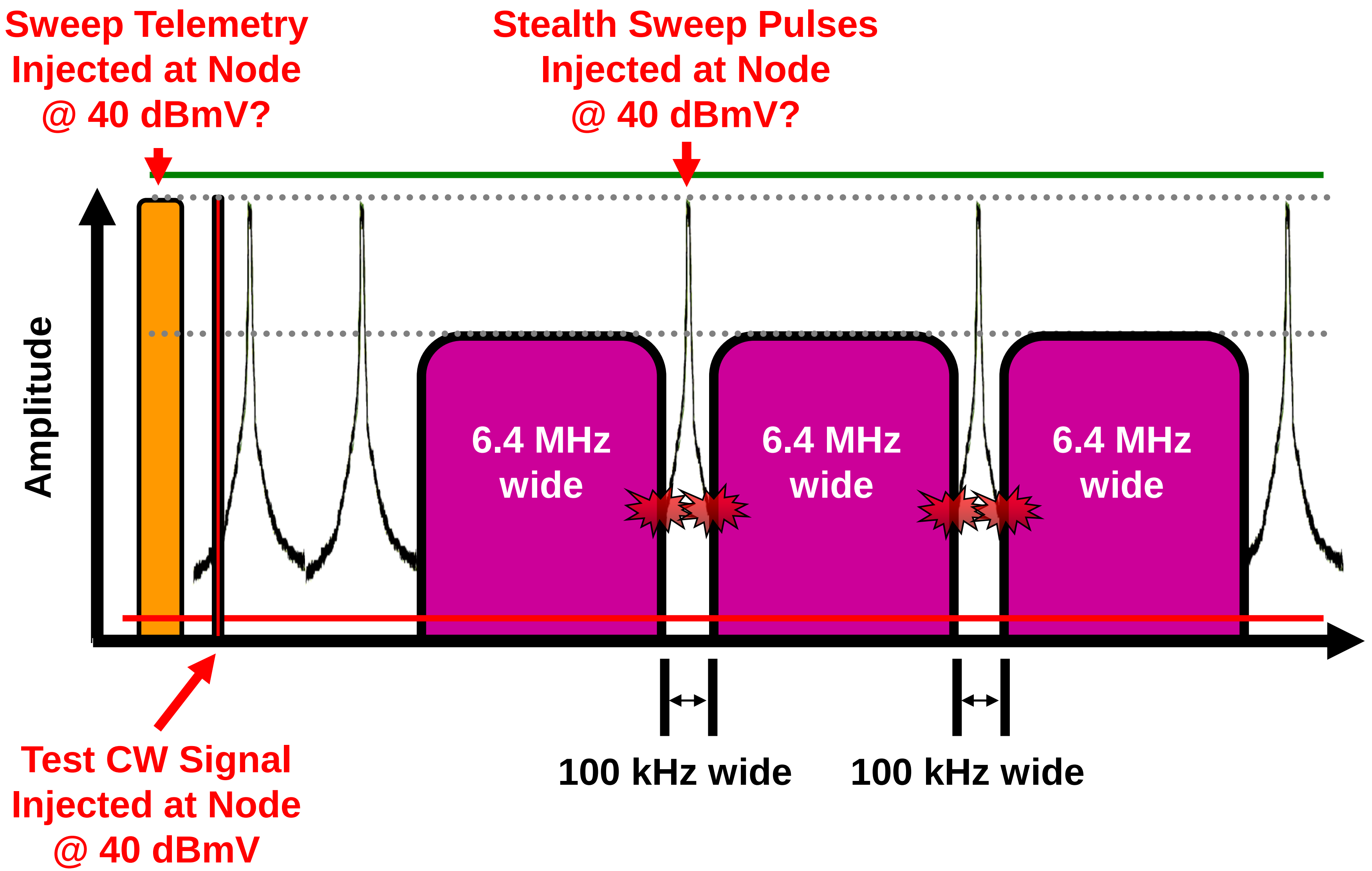
Stealth Sweep Pulses Compared to Carriers



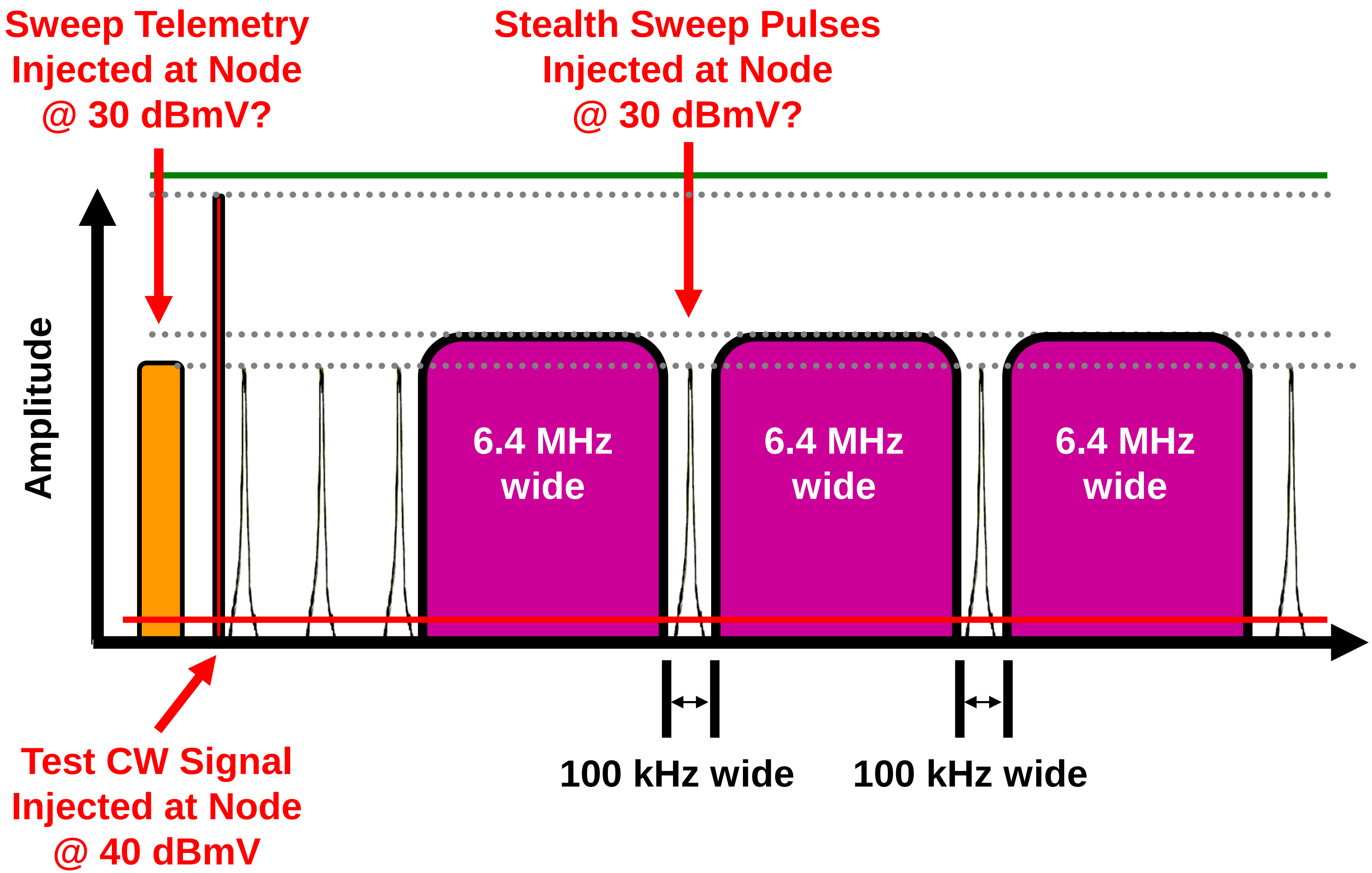
Stealth Sweep Pulses Compared to Carriers



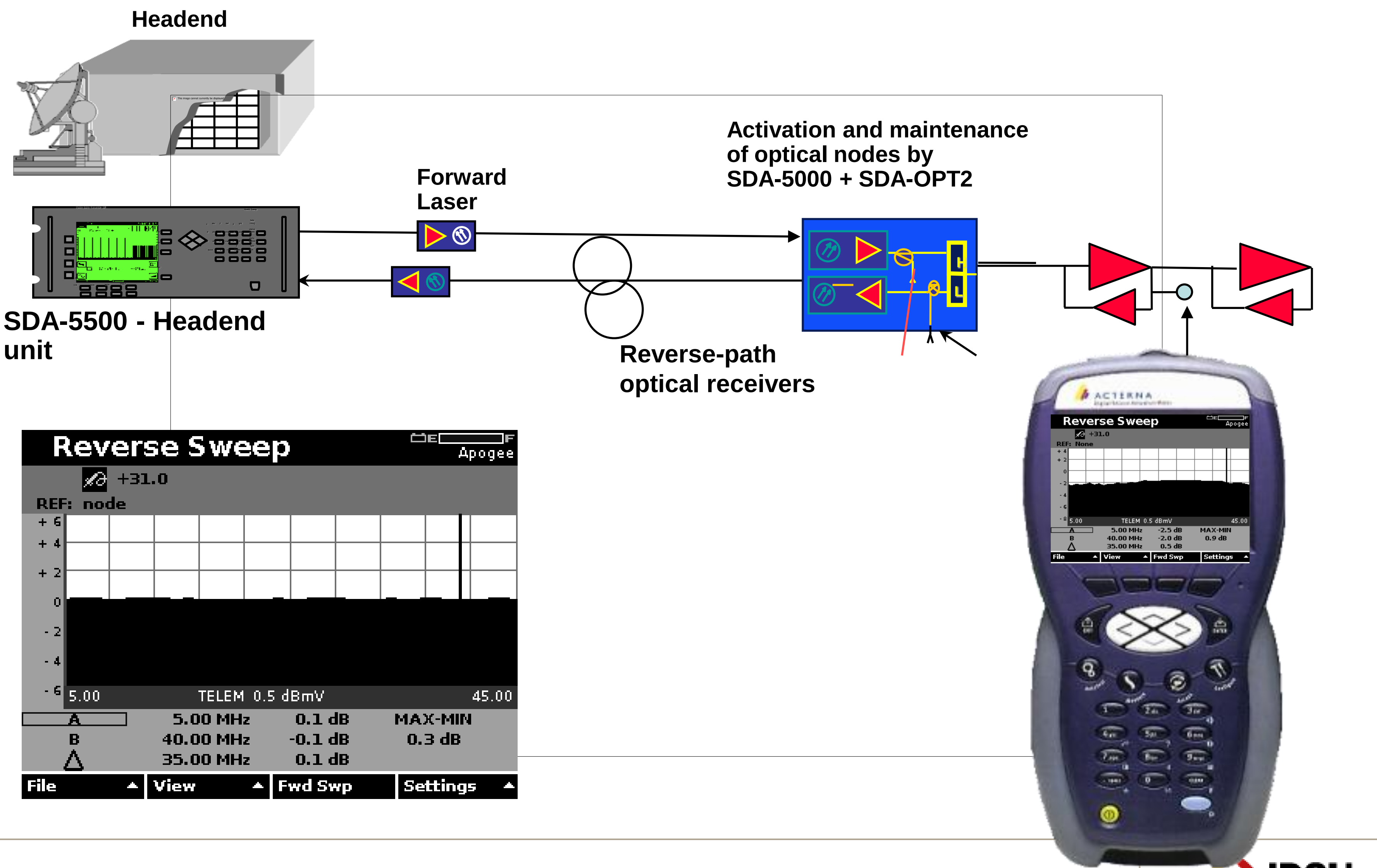
Stealth Sweep Pulses Compared to Carriers



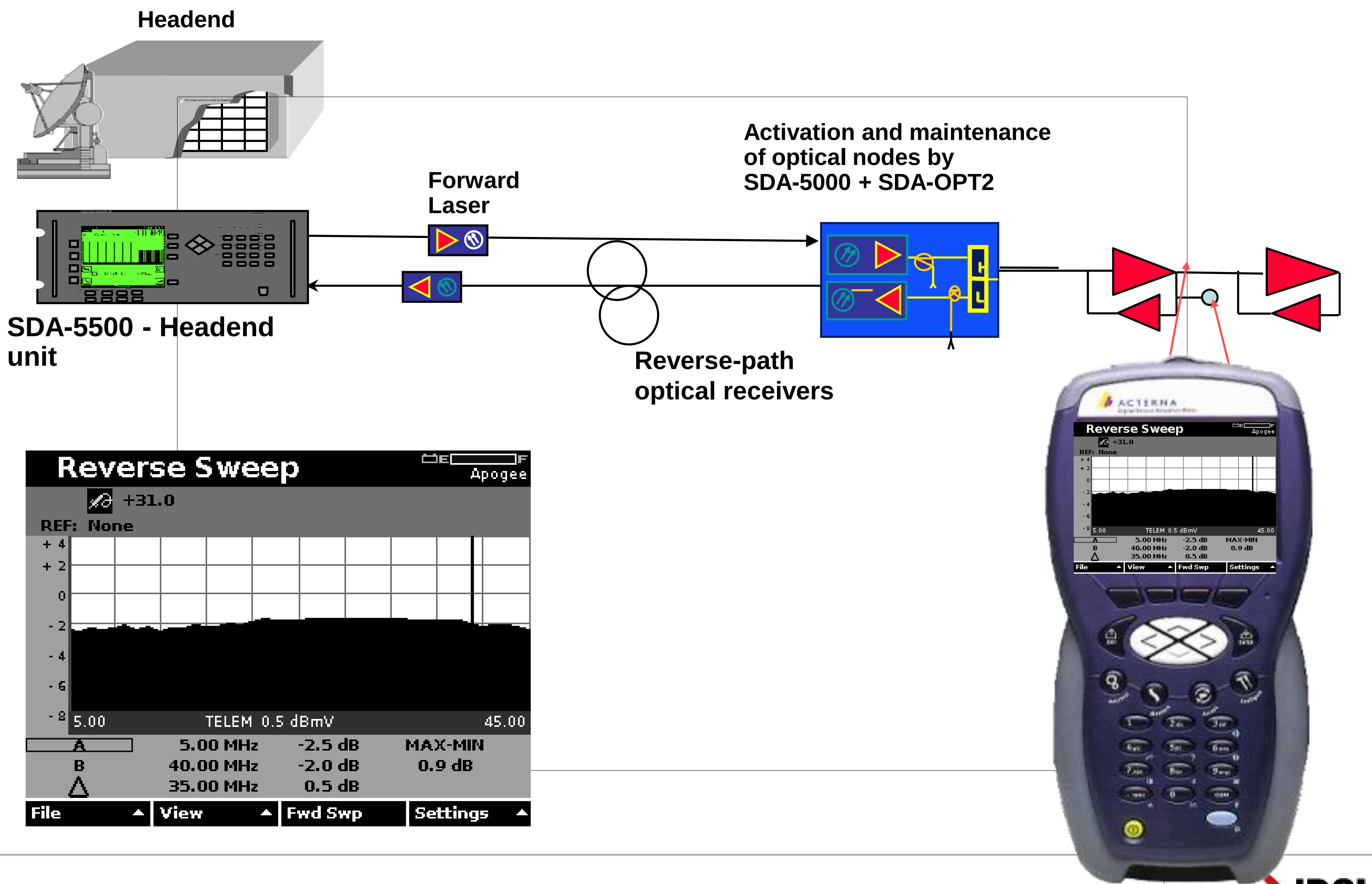
Stealth Sweep Pulses Compared to Carrier



Sweeping the Node

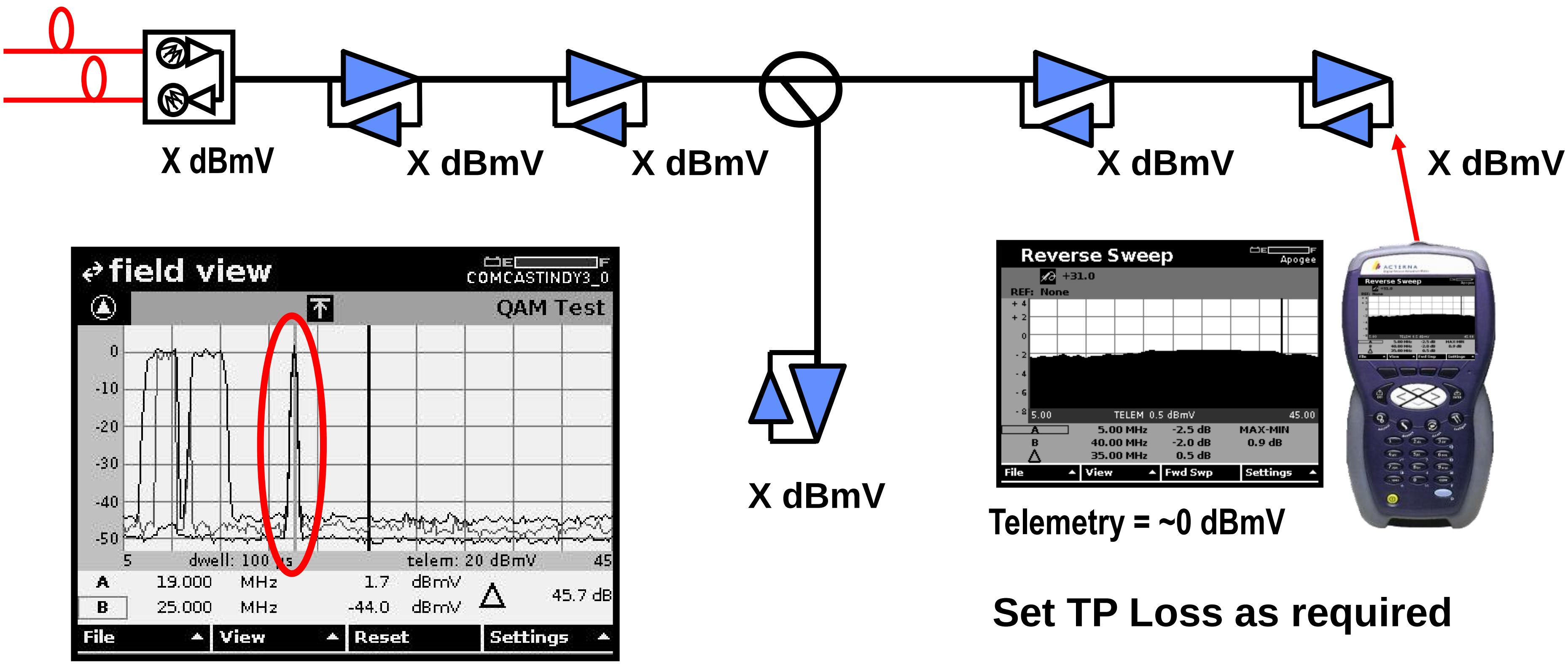


Sweeping the Reverse Path



Optimize the HFC Pipe for Unity Gain

Maintain unity gain with constant inputs

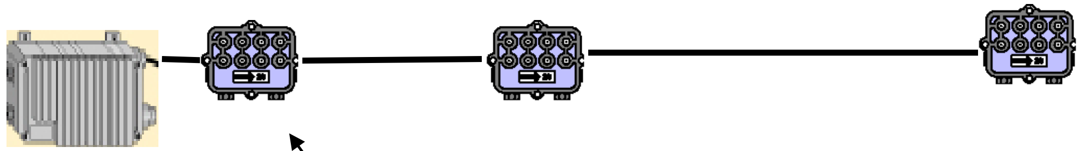


Use the DSAM Field View Option
to inject a CW test signal into various
test points and view remote spectrum

Set TP Loss as required

Sweep and Balancing Amplifiers

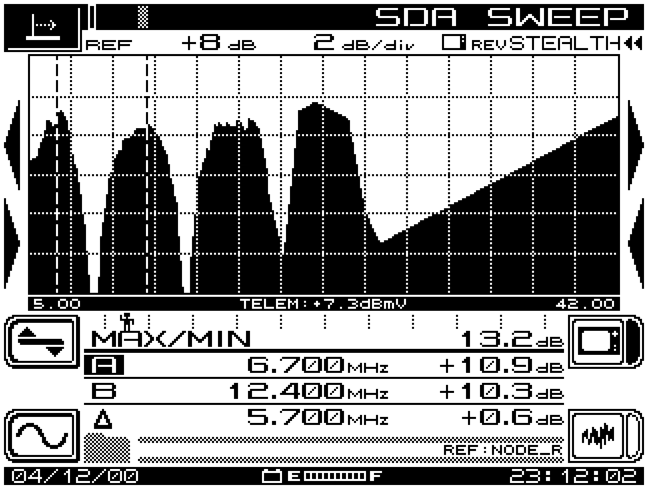
1 ft 160 ft 310 ft



Sweeping the Seizer screw with a 6dB pad

Where is the problem?

$$\frac{492 \times VOP}{FRE} = Distance$$

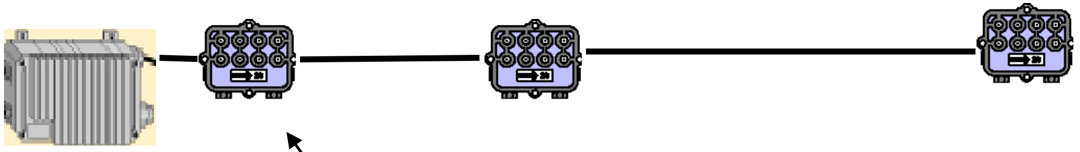


Result

$$\frac{492 \times 0.82}{5.7} = \frac{403}{5.7} = 70.7 \text{ feet}$$

Troubleshooting with Sweep

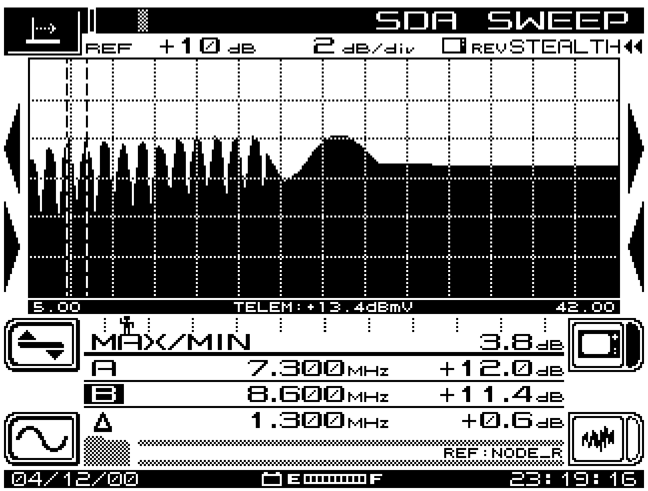
1 ft 160 ft 310 ft



Sweeping the
Seizer screw
with a 6dB pad

Where is the problem?

$$\frac{492 \times VOP}{FRE} = Distance$$

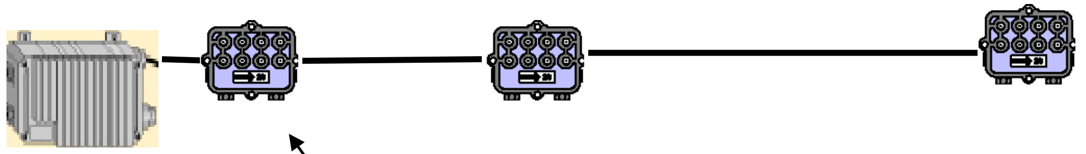


Result

$$\frac{492 \times 0.82}{1.3} = \frac{403}{1.3} = 310 \text{ feet}$$

Troubleshooting with Sweep

1 ft 160 ft 310 ft

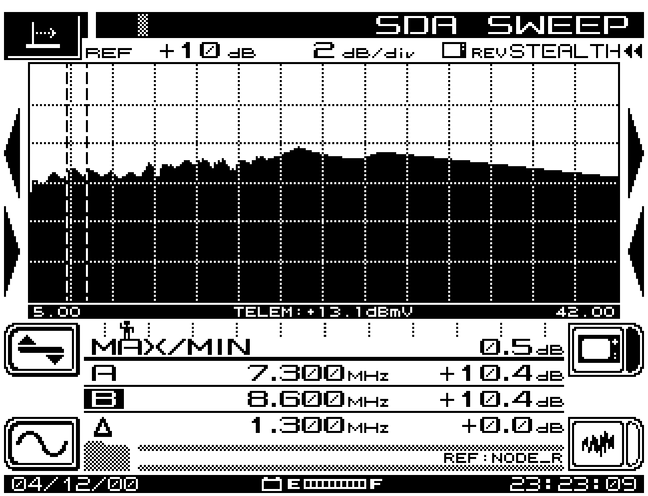


Terminate Tap

Sweeping the Seizer screw with a 6dB pad

Where is the problem?

$$\frac{492 \times VOP}{FRE} = Distance$$

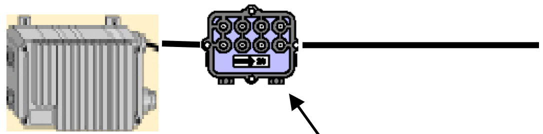


Result

$$\frac{492 \times 0.82}{1.3} = \frac{403}{1.3} = 310 \text{ feet}$$

Sweepless Sweep for distance

1 ft 100 ft



No termination

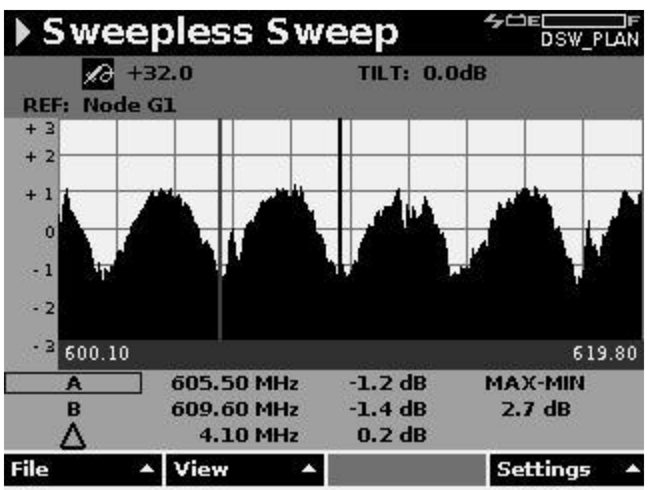
Sweeping the Seizer screw

600 MHz to 620 MHZ

100 KHz Resolution

Where is the problem?

$$\frac{492 \times VOP}{FRE} = \text{Distance}$$

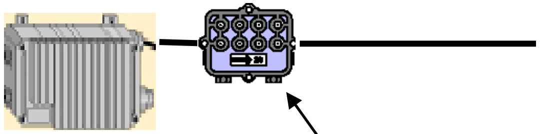


Result

$$\frac{492 \times 0.82}{4.1} = \frac{403}{4.1} = 96 \text{ feet}$$

Sweepless Sweep for distance

1 ft   100 ft



Sweeping the Seizer screw

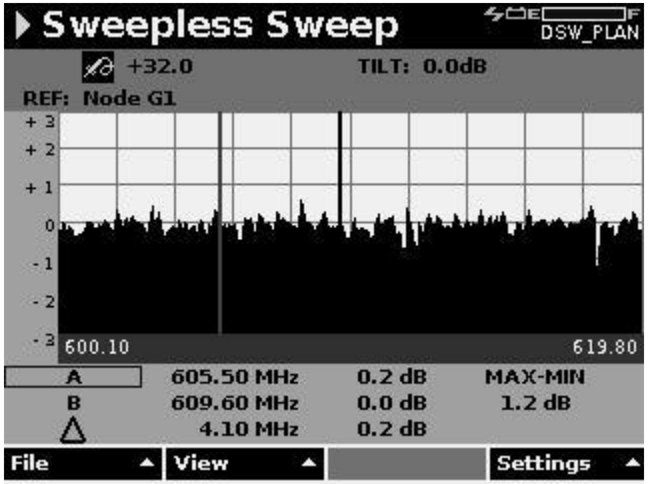
With termination

600 MHz to 620 MHZ

Where is the problem?

100 KHz Resolution

No Problem



Result

JDSU