Upstream RF Troubleshooting

Ron Hranac

Technical Leader, Broadband Network Engineering

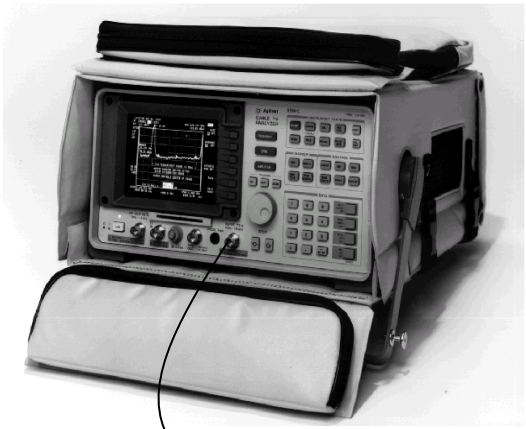
CMTS Configuration

- **Check this first—incorrect CMTS configuration is a common problem!**

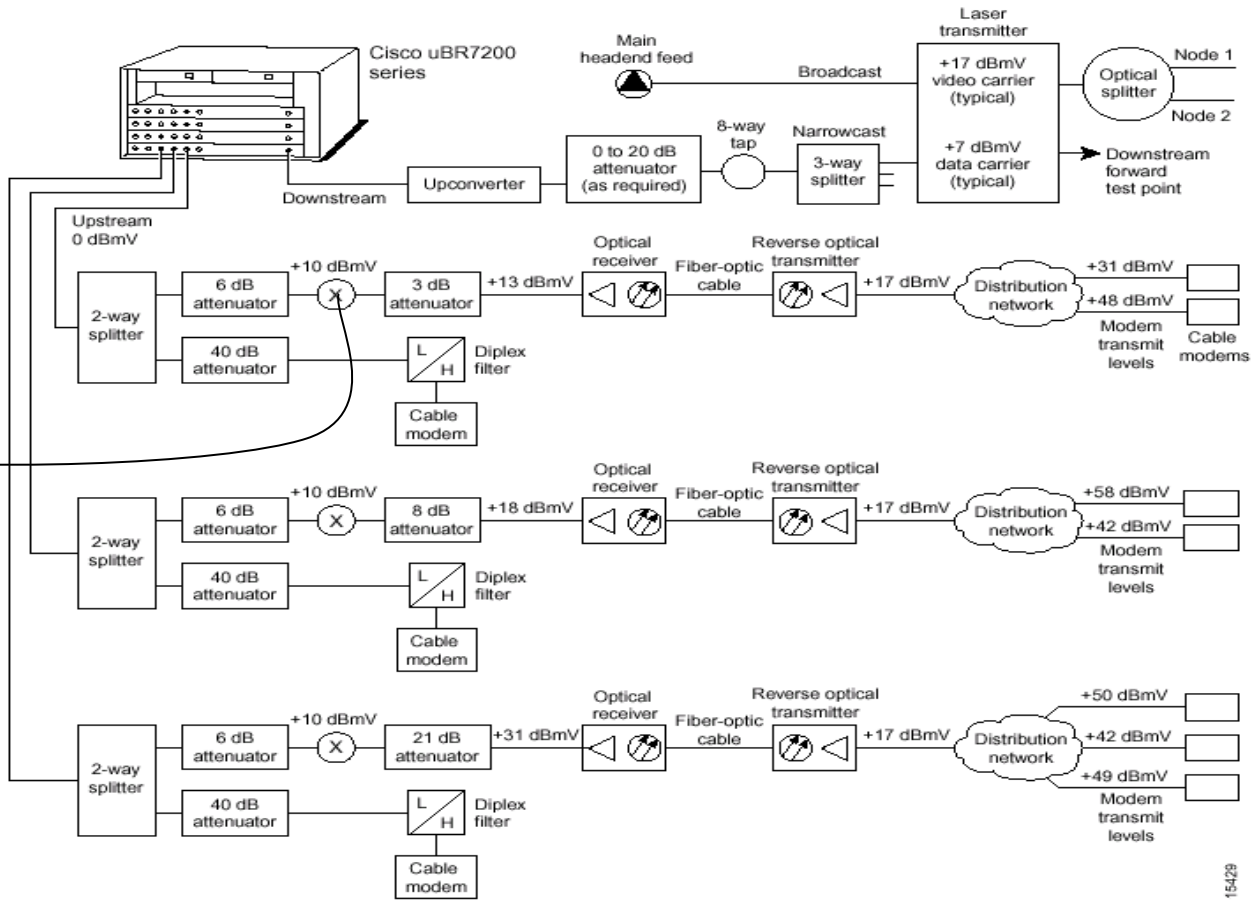
Upstream Challenges

- **Most CATV systems use a sub-split band plan**
  - **50-860 MHz downstream, 5-42 MHz upstream**
- **Problems with sub-split in two-way networks:**
  - **Upstream noise funneling**
  - **Prevalence of manmade noise in upstream frequency spectrum**
  - **Lack of upstream reference signals**
  - **Difficult to locate problems**

Check the Upstream at the CMTS



Connect a spectrum analyzer to the upstream test points

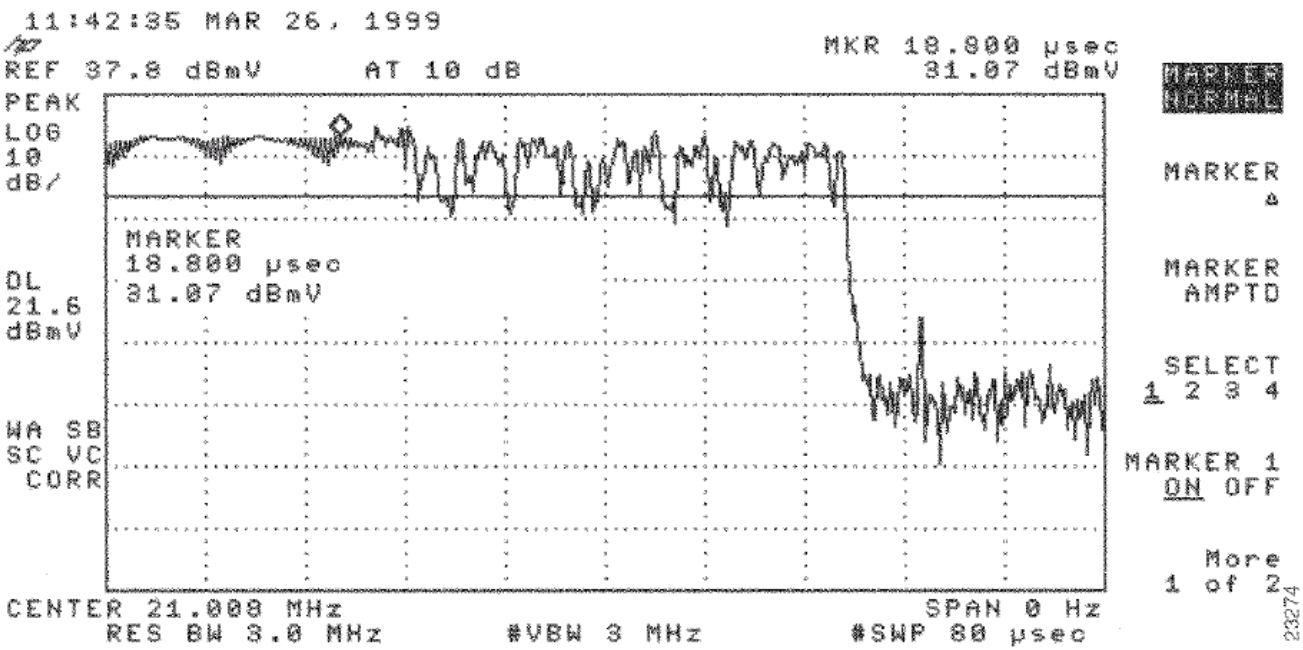


Upstream Integrity

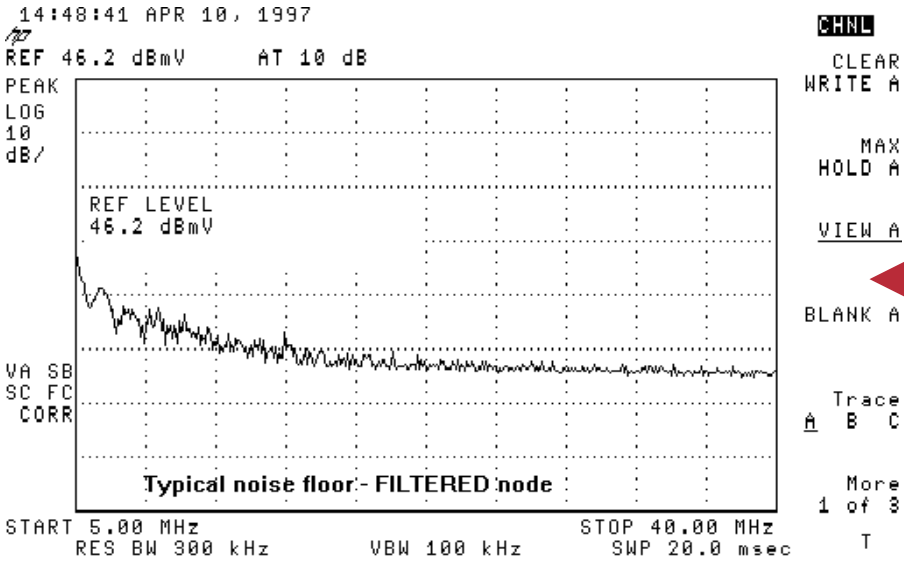
- **Verify that the upstream digitally modulated carrier amplitude at the input to the CMTS upstream port is within spec**
  - **A typical value is 0 dBmV, but this may vary depending on the CMTS manufacturer's specs and CMTS configuration**
- **Check the upstream carrier-to-noise, carrier-to-ingress, and carrier-to-interference ratios**
  - **DOCSIS specifies a *minimum* of 25 dB for all three parameters**

Digitally Modulated Carrier Amplitude

- **Because of the bursty nature of upstream digitally modulated carriers, it's difficult to measure average power level**
- **The zero-span method is the easiest way to obtain an accurate amplitude measurement**

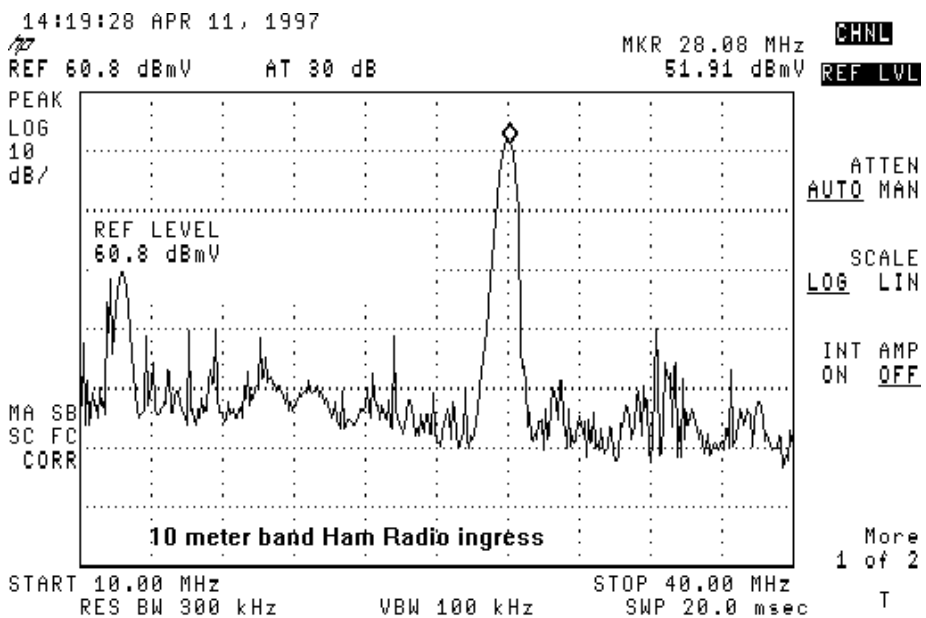


Upstream Spectrum



Does the upstream look like this?

…or like this?



Upstream RF Impairments

Stationary Impairments

- Thermal noise
- Intermodulation distortion
- Frequency response
- Transit delay
- Group delay

Upstream RF Impairments

Transient Impairments

- RF ingress
- Impulse noise
- Signal clipping

Upstream RF Impairments

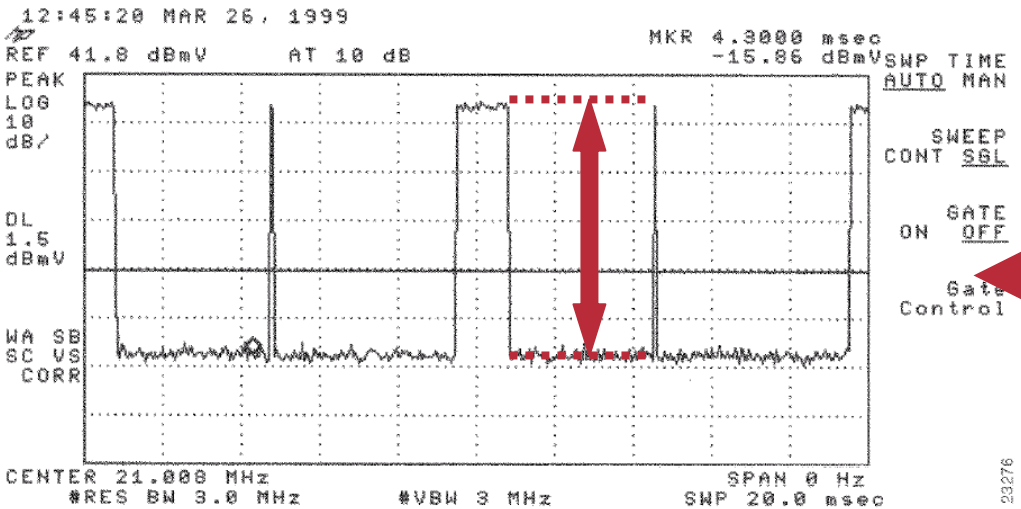
Multiplicative Impairments

- Transient hum modulation
- Intermittent connections

Thermal Noise

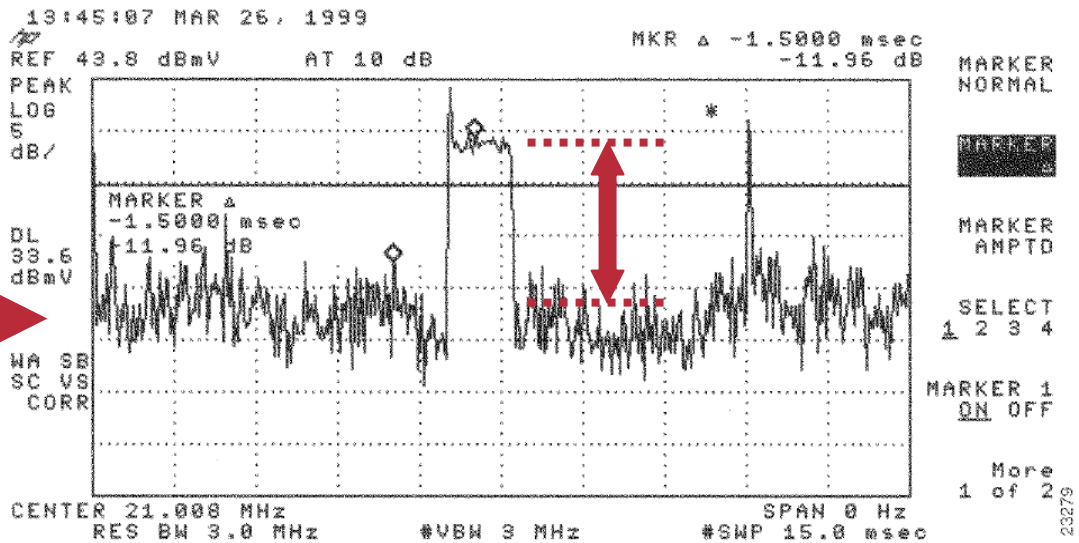
- **Characteristic of all active components:**
  - **Optoelectronics**
  - **Upstream amplifiers**
  - **In-home devices**
- **Improper network alignment or defective equipment can cause high levels of thermal noise—as can improper upstream combining—which will degrade carrier-to-noise ratio**

Thermal Noise



Good carrier-to-noise ratio (~50 dB)

Poor carrier-to-noise ratio (~12 to 15 dB)



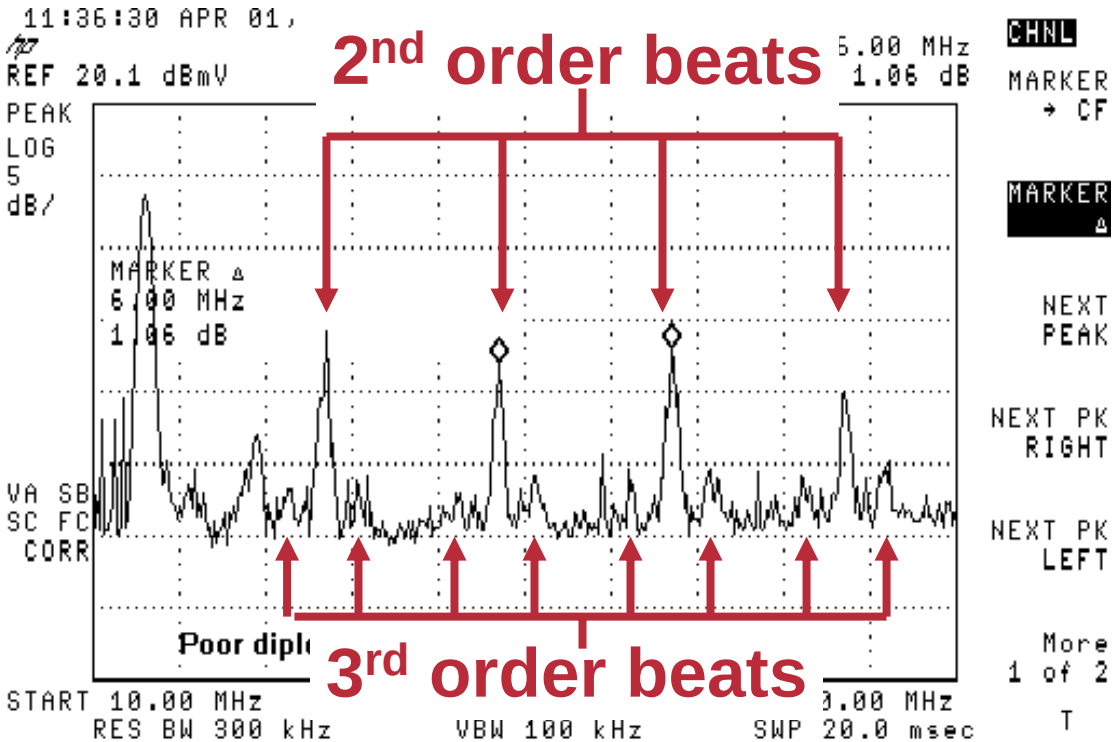
Intermodulation Distortion

- **Second and third order distortions most prevalent**
- **Active devices**
- **Passive components: common path distortion, passive device intermodulation**

Intermodulation Distortion

- **An example of *common path distortion***

  Note large 2nd order beats spaced every 6 MHz, and smaller 3rd order beats +/-1.25 MHz from 2nd order beats

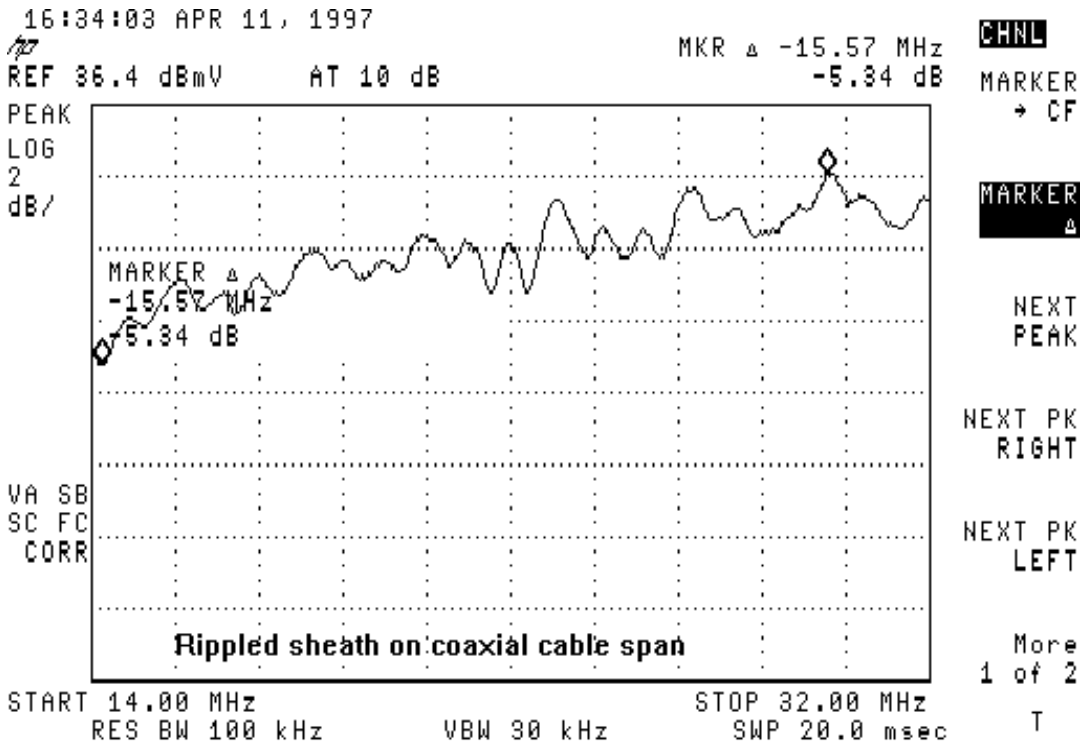


Frequency Response

- **Amplifier alignment**
  - **Input and output levels**
  - **Proper pads and equalizers**
- **Sweep versus multiple carriers**
- **Alignment-related problems**
  - **Frequency response problems can cause group delay errors**
  - **Misalignment can cause increase in noise and distortions**

Frequency Response

- **Defective coaxial cable caused frequency response problem**

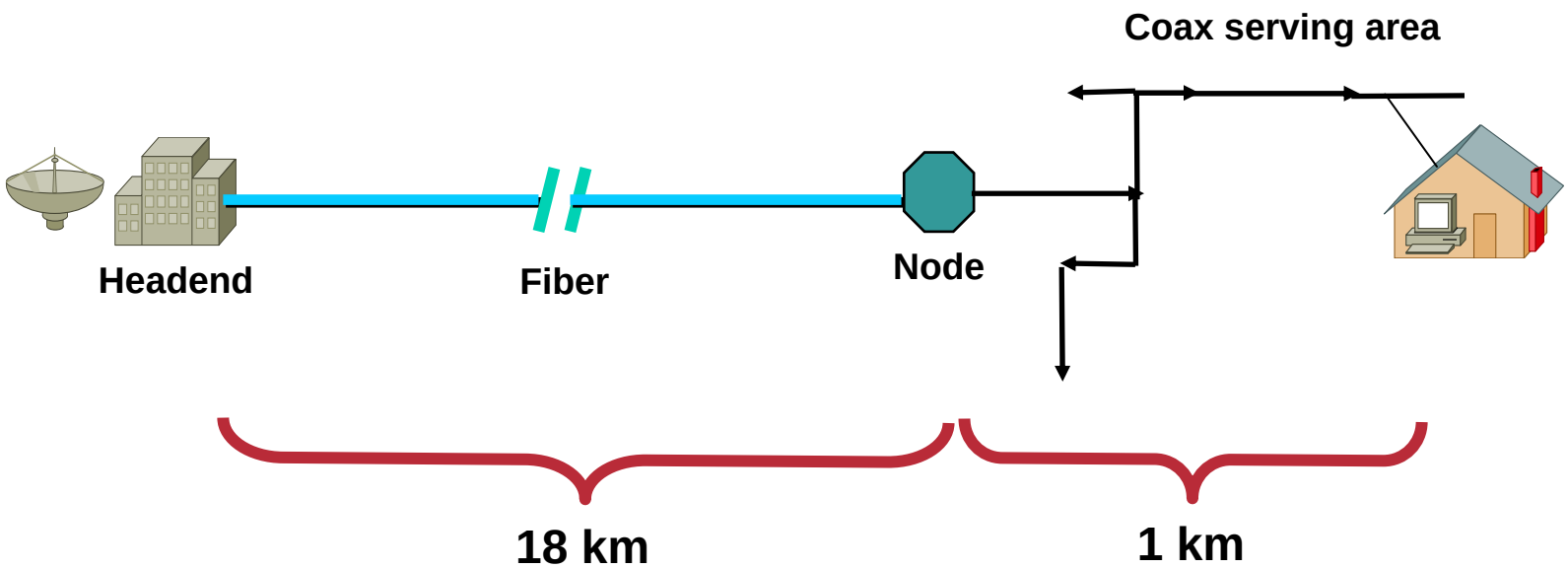


Transit Delay

- **Electromagnetic signals travel at the speed of light**
  - **In free space the speed of light is 299,792,458 meters/second**
  - **In CATV coaxial cable, it's about 87% of the free space value**
  - **In optical fiber, it's about 67% of the free space value**
  - **RF and optical signals take a finite amount of time to travel through a CATV network**

Transit Delay (cont'd)

- **Signals traveling one way—say, from the subscriber to the headend—through 1 km of coax and 18 km of fiber: about 95 microseconds (µsec) transit delay**
- **The DOCSIS transit delay specification is <0.800 millisecond (msec) one way**



Group Delay

- **From the *IEEE Standard Dictionary of Electrical and Electronics Terms*:**

  Group delay is “the derivative of radian phase with respect to radian frequency. It is equal to the phase delay for an ideal non-dispersive delay device, but may differ greatly in actual devices where there is a ripple in the phase versus frequency characteristic.”

Group Delay (cont'd)

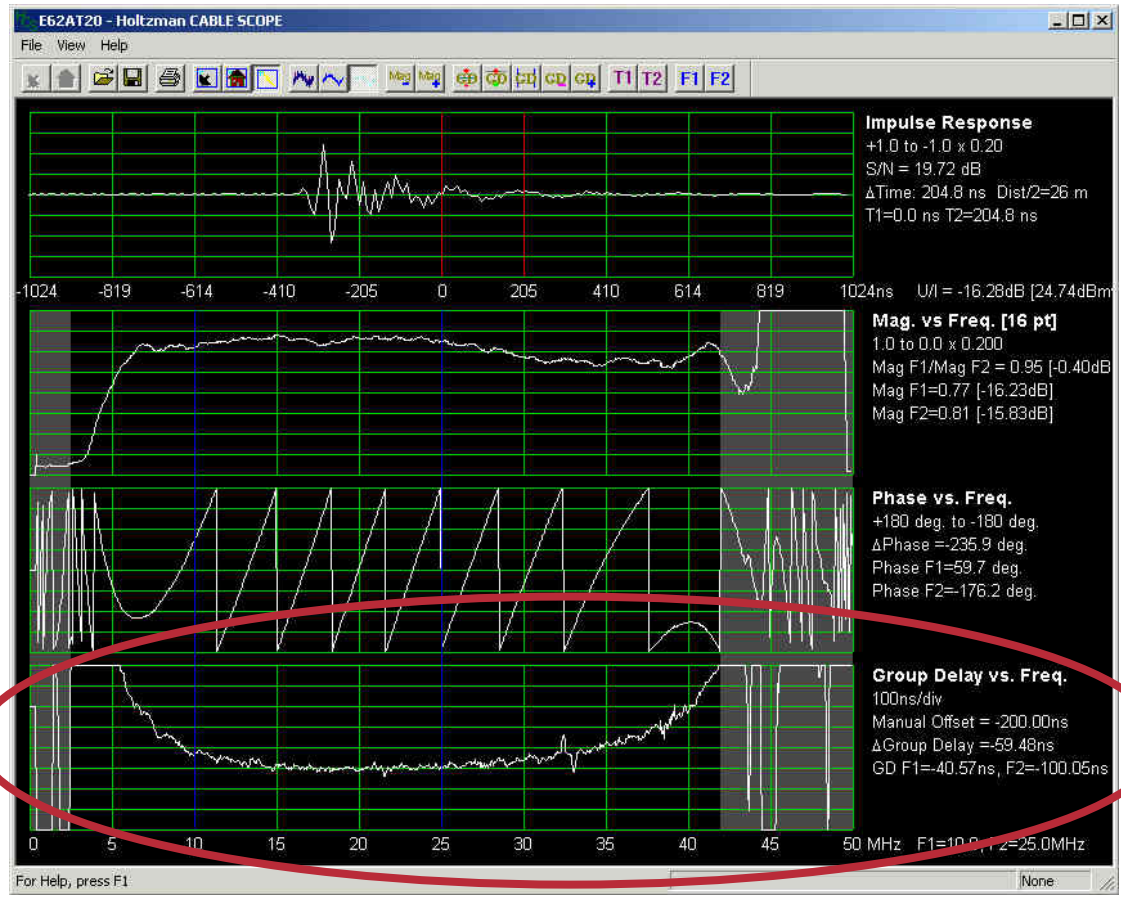
- **Group delay is defined in units of time, typically nanoseconds (ns)**
- **In a system, network or component with no group delay, all frequencies are transmitted through the system, network or component with equal time delay.**
- **Frequency response problems in a CATV network will cause group delay problems.**

Group Delay (cont'd)

- **If a cable network's group delay exceeds a certain amount, data transmission and bit error rate may be affected.**
- **As long as group delay remains below a defined threshold—DOCSIS specifies 200 nanoseconds/MHz in the upstream—group delay-related BER shouldn't be a problem.**

Group Delay (cont'd)

- **Upstream group delay measurements require specialized equipment**
- **When obvious problems have been ruled out, check group delay**

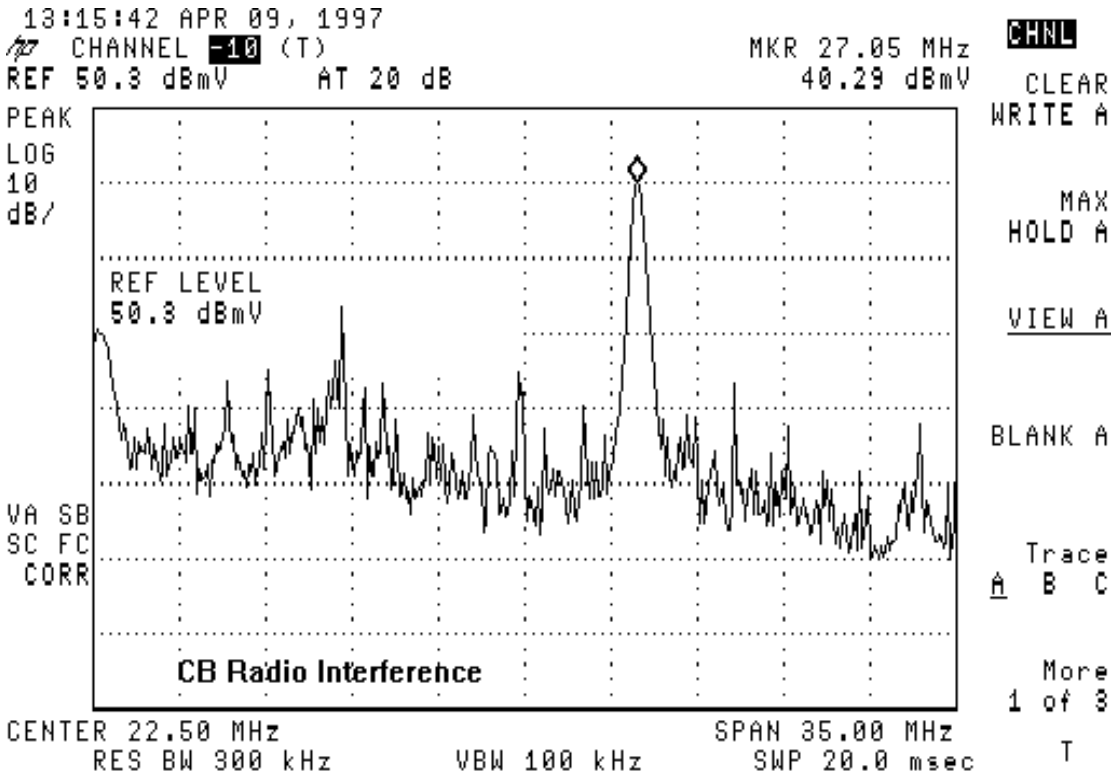


RF Ingress

- **Upstream spectrum is shared with over-the-air users**
  - **Shortwave broadcasts**
  - **Citizens band (“CB”) radio**
  - **Amateur (“ham”) radio**
  - **Government communications**
- **RF signals can enter network through cable shielding defect**

RF Ingress

- **CB radio operator had installed his own cable outlets**

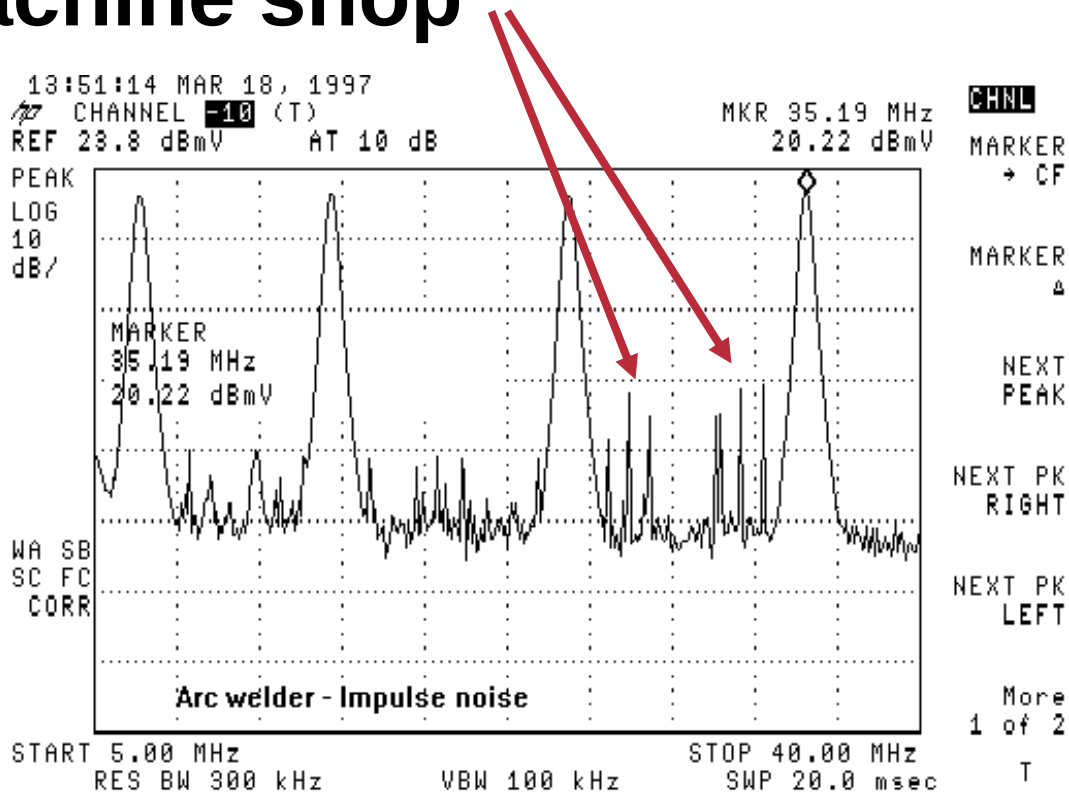


Impulse Noise

- **Most upstream data transmission errors caused by bursts of impulse noise**
- **Fast risetime, short duration (<100 microseconds)**
- **Most less than 10 microseconds duration**
- **Significant energy content over most of upstream spectrum**
- **Common sources: vehicle ignitions, neon signs, lightning, power line switching transients, electric motors, electronic switches, household appliances**

Impulse Noise

- **Impulse noise from arc welder in machine shop**



Signal Clipping

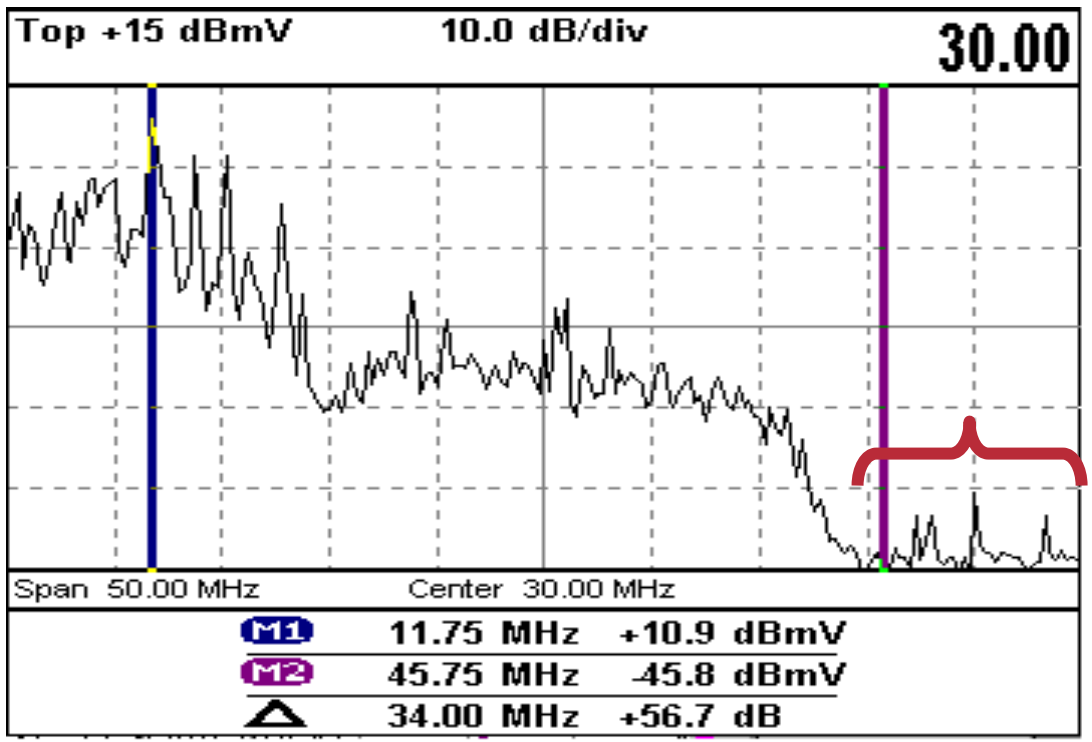
- **RF ingress and impulse noise may cause signal clipping**
- **Excessive signals from in-home devices such as pay-per-view converters also may cause signal clipping**
- **Clipping (compression) occurs in upstream amplifiers and fiber optics equipment**
  - **Upstream lasers most susceptible**

Signal Clipping (cont'd)

- **Most energy that causes compression is in 5 MHz to 15 MHz range**
- **Signals at all other frequencies are affected by cross-compression**
  - **Cross-compression affects *all* upstream frequencies**
  - **Can reduce data throughput**

Signal Clipping (cont'd)

Noise above ~40 MHz (~65 MHz in a Euro-DOCSIS network) is most likely caused by laser clipping

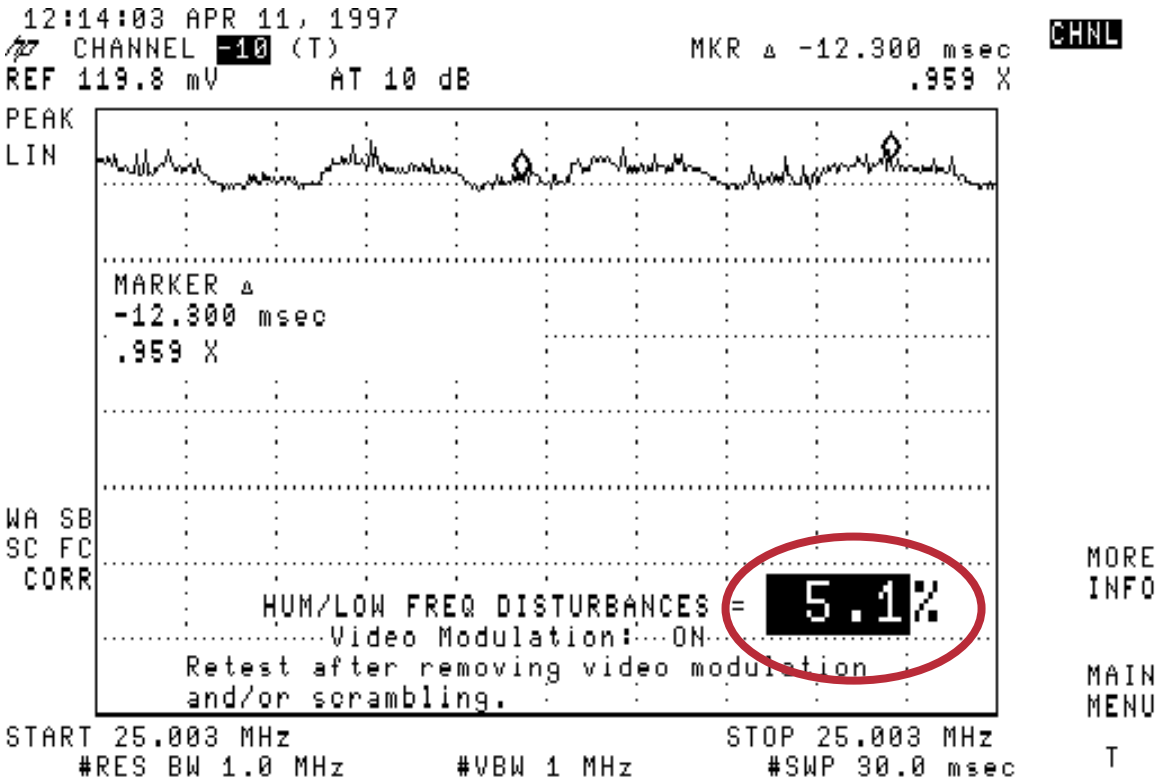


Transient Hum Modulation

- **Ferrite components in network and drop passive devices**
  - **High current causes ferrite material to saturate**
- **Switching power supply noise and harmonics**

Transient Hum Modulation

- **Hum modulation problem caused by defective connector on customer's VCR**



Intermittent Connections

- **Self-induced**

  Network maintenance: changing pads & equalizers, amplifier modules

- **Craft-related**

  Loose or damaged connectors

  Poor quality installation

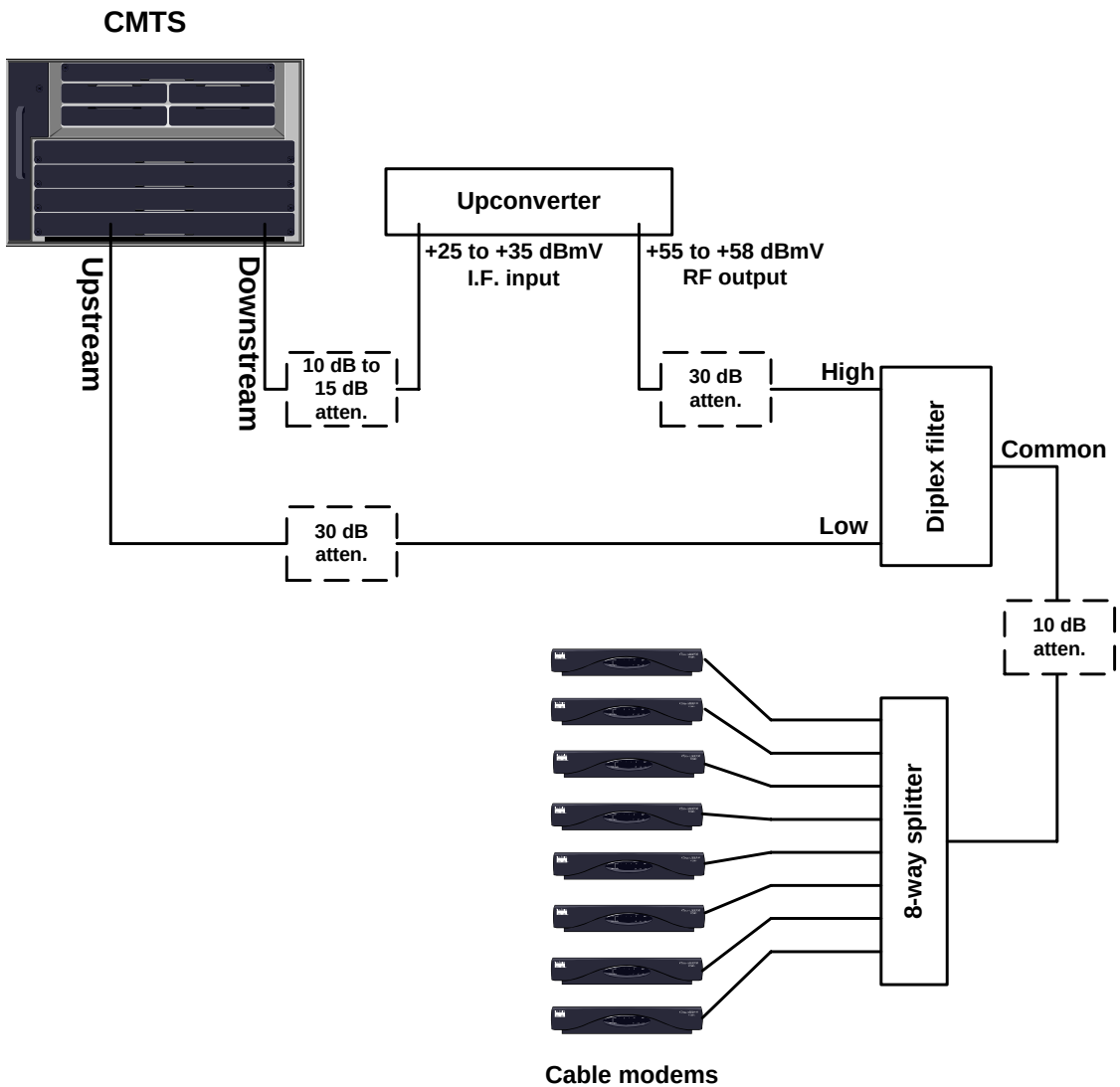
Sweep Transmitter Operation

- Many cable operators use broadband sweep equipment for network maintenance.
- Sweep transmitter interference to upstream digitally modulated carriers is a common problem. When it happens, degraded BER performance occurs.
- To avoid sweep interference problems, make sure the reverse sweep transmitter has appropriate guard bands programmed around each upstream digitally modulated carrier.

Still Having Problems?

- **If everything appears to check out OK in the headend but cable modem operational problems still exist in the field, it may be a cable network problem**
- **This can be verified by connecting the CMTS to a six-foot plant**

Six-Foot Plant

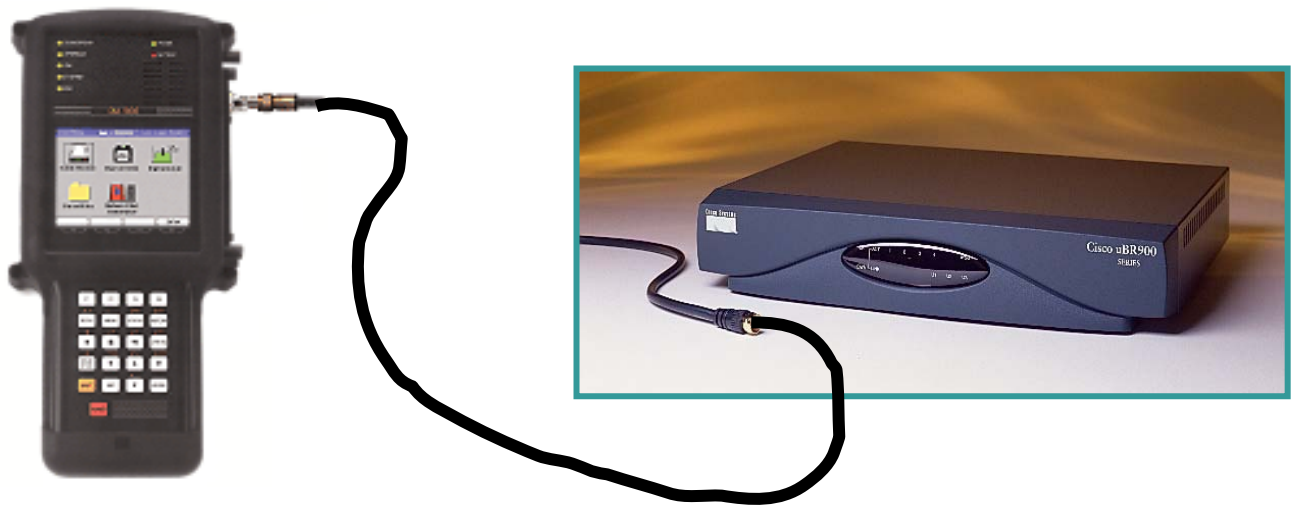


Still Having Problems?

- **If CMTS configuration is correct and headend problems have been ruled out, it's time to move to the outside plant.**

Out in the Field…

- **Use appropriate test equipment to characterize the return path between the subscriber premises and CMTS.**

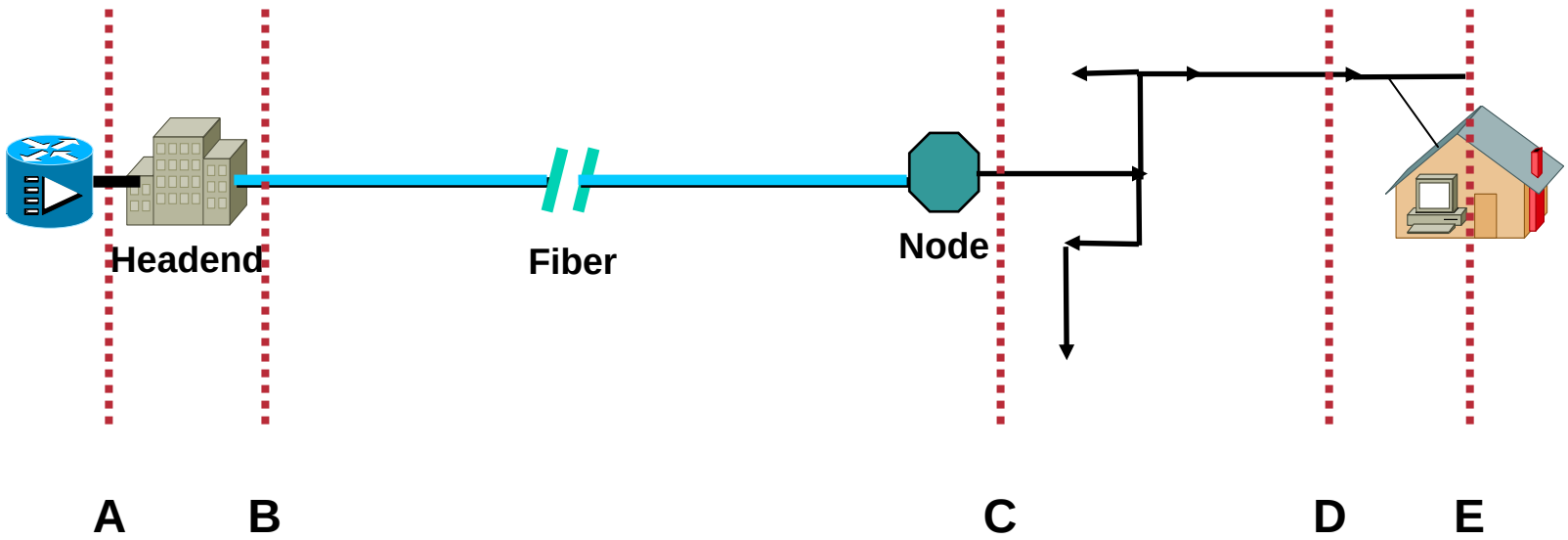


Out in the Field…

- **Verify that the amplitude of the upstream digitally modulated carrier at the cable modem output is in the +8 dBmV to +58 dBmV range for QPSK, and +8 dBmV to +55 dBmV for 16-QAM.**
- **Correct levels at the first upstream active?**

Out in the Field…

- **Use the “divide and conquer” method to locate problems in the network**



A Few Potential Problems

- **Improper RF levels**
- **Poor “carrier-to-junk” ratio (the DOCSIS minimum spec is 25 dB for both QPSK and 16-QAM)**
- **Headend upstream combining/splitting**
  - **Too many nodes or homes passed per CMTS upstream port**
- **Upstream fiber links not correctly aligned**
- **Forward and reverse amplifiers not correctly aligned**

A Few Potential Problems

- **Ingress, impulse noise, spurious interference, distortions, laser clipping**
- **Loose or intermittent connections**
- **Hum modulation (the DOCSIS maximum spec is 7%, or –23 dBc)**
- **Microreflections (analogous to multipath or ghosting in analog TV pictures)**

DOCSIS 1.0 Upstream RF Channel Transmission Characteristics

Parameter	Value
Frequency range	5 to 42 MHz edge to edge
Transit delay from the most distant CM to the nearest CM or CMTS	<=0.800 msec (typically much less)
Carrier-to-noise ratio	Not less than 25 dB
Carrier-to-ingress power (the sum of discrete and broadband ingress signals) ratio	Not less than 25 dB (Note 2)
Carrier-to-interference (the sum of noise, distortion, common-path distortion, and cross-modulation) ratio	Not less than 25 dB
Carrier hum modulation	Not greater than –23 dBc (7%)
Burst noise	Not longer than 10 µsec at a 1 kHz average rate for most cases (Notes 3, 4, and 5)
Amplitude ripple	5-42 MHz: 0.5 dB/MHz
Group delay ripple	5-42 MHz: 200 ns/MHz
Micro-reflections -- single echo	-10 dBc@ <= 0.5 µsec -20 dBc@ <= 1.0 µsec -30 dBc@ > 1.0 µsec
Seasonal and diurnal signal level variation	Not greater than 8 dB min to max

DOCSIS 1.0 Electrical Output From the Cable Modem

Parameter	Value
Frequency	5 to 42 MHz edge to edge
Level range (one channel)	+8 to +55 dBmV (16QAM) +8 to +58 dBmV (QPSK)
Modulation type	QPSK and 16QAM
Symbol rate (nominal)	160, 320, 640, 1,280 and 2,560 ksym/sec
Bandwidth	200, 400, 800, 1,600 and 3,200 kHz
Output impedance	75 ohms
Output return loss	>6 dB (5-42 MHz)
Connector	F connector per [IPS-SP-406] (common with the input)

DOCSIS 1.1 Upstream RF Channel Transmission Characteristics

Parameter	Value
Frequency range	5 to 42 MHz edge to edge
Transit delay from the most distant CM to the nearest CM or CMTS	<=0.800 msec (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
Carrier hum modulation	Not greater than –23 dBc (7%)
Burst noise	Not longer than 10 µsec at a 1 kHz average rate for most cases (Notes 3, 4, and 5)
Amplitude ripple 5-42 MHz:	0.5 dB/MHz
Group delay ripple 5-42 MHz:	200 ns/MHz
Micro-reflections -- single echo	-10 dBc@ <= 0.5 µsec -20 dBc@ <= 1.0 µsec -30 dBc@ > 1.0 µsec
Seasonal and diurnal reverse gain (loss) variation	Not greater than 14 dB min to max

DOCSIS 1.1 Electrical Output From the Cable Modem

Parameter	Value
Frequency	5 to 42 MHz edge to edge
Level range (one channel)	+8 to +55 dBmV (16QAM) +8 to +58 dBmV (QPSK)
Modulation type	QPSK and 16QAM
Symbol rate (nominal)	160, 320, 640, 1,280 qne 2,560 ksym/sec
Bandwidth	200, 400, 800, 1,600 and 3,200 kHz
Output impedance	75 ohms
Output return loss	>6 dB (5-42 MHz)
Connector	F connector per [ISO-169-24] (common with the input)