Module 3

DOCSIS 3.0 Concepts

Agenda

- DOCSIS 3.0 Overview
- DOCSIS 3.0 terminology
- DOCSIS modem registration
- Advanced Troubleshooting

Drivers for D3.0 – Other than Verizon & AT&T!

DOCSIS 3.0 Overview

- DOCSIS 3.0 Specification(s)
  - DOCSIS 3.0 Interface Specifications (Released December 2006)
  - Equipment readily available
- Downstream data rates of 160 Mbps or higher
  - Channel Bonding
  - 4 or more channels
- Upstream data rates of 120 Mbps or higher
  - Channel Bonding
  - 4 or more channels
- Internet Protocol version 6 (IPv6)
  - *Current System (IPv4) is limited to 4.3B numbers*
  - IPv6 greatly expands the number of IP addresses
    - Expands IP address size from 32 bits to 128 bits
    - IPv6 supports 3.4×10^{38} addresses;
    - Colon-Hexadecimal Format
- 100% backward compatible with DOCSIS 1.0/1.1/2.0

256QAM => ~40Mbps

8 x 256QAM => ~304 Mbps

64QAM => ~30Mbps

4 x 64QAM => ~108 Mbps

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

DOCSIS Comparison

DOCSIS Version	Max Downstream Throughput (net)	Max Upstream Throughput (net)
1.x	42.88 (38) Mbit/s	10.24 (9) Mbit/s
2.0	42.88 (38) Mbit/s	30.72 (27) Mbit/s
3.0	n x 42.88 (38) Mbit/s 8 x 38 = 304 Mbit/s	n x 30.72 (27) Mbit/s 4 x 27 = 108 Mbit/sec

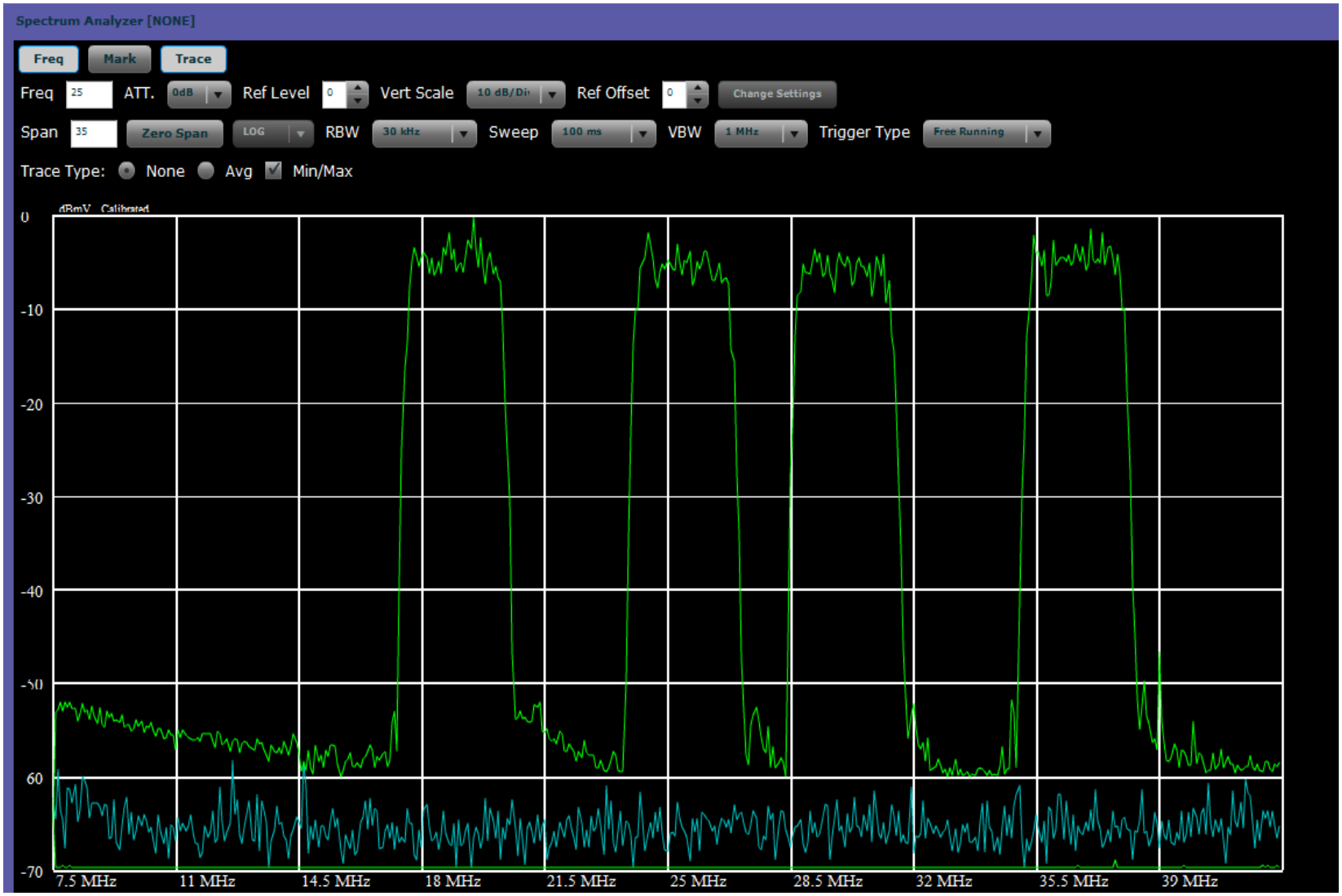
DOCSIS® 3.0 Assumed Downstream RF Channel Transmission Characteristics

Parameter	Value
Frequency range	108 to 1002 MHz edge to edge
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
Carrier-to- CTB, CSO, X-MOD, Ingress	Not less than 41 dB
Amplitude ripple	3 dB within the design bandwidth
Group delay ripple in the spectrum occupied by the CMTS	75 ns within the design bandwidth
Micro-reflections bound for dominant echo	-10 dBc@ <= 0.5 µsec -20 dBc@ <= 1.5 µsec -30 dBc@ > 1.5 µsec
Maximum analog video carrier level at the CM input	17 dBmV

DOCSIS® 3.0 Assumed Upstream RF Channel Transmission Characteristics

Parameter	Value
Frequency range	5 to 85 MHz edge to edge
Carrier-to-interference plus ingress 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
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

The Bonded Upstream



Power Variance – 6dB Bonded vs. Unbonded

DOCSIS 3.0 Cable Modem 1 Channel Transmit Power Levels

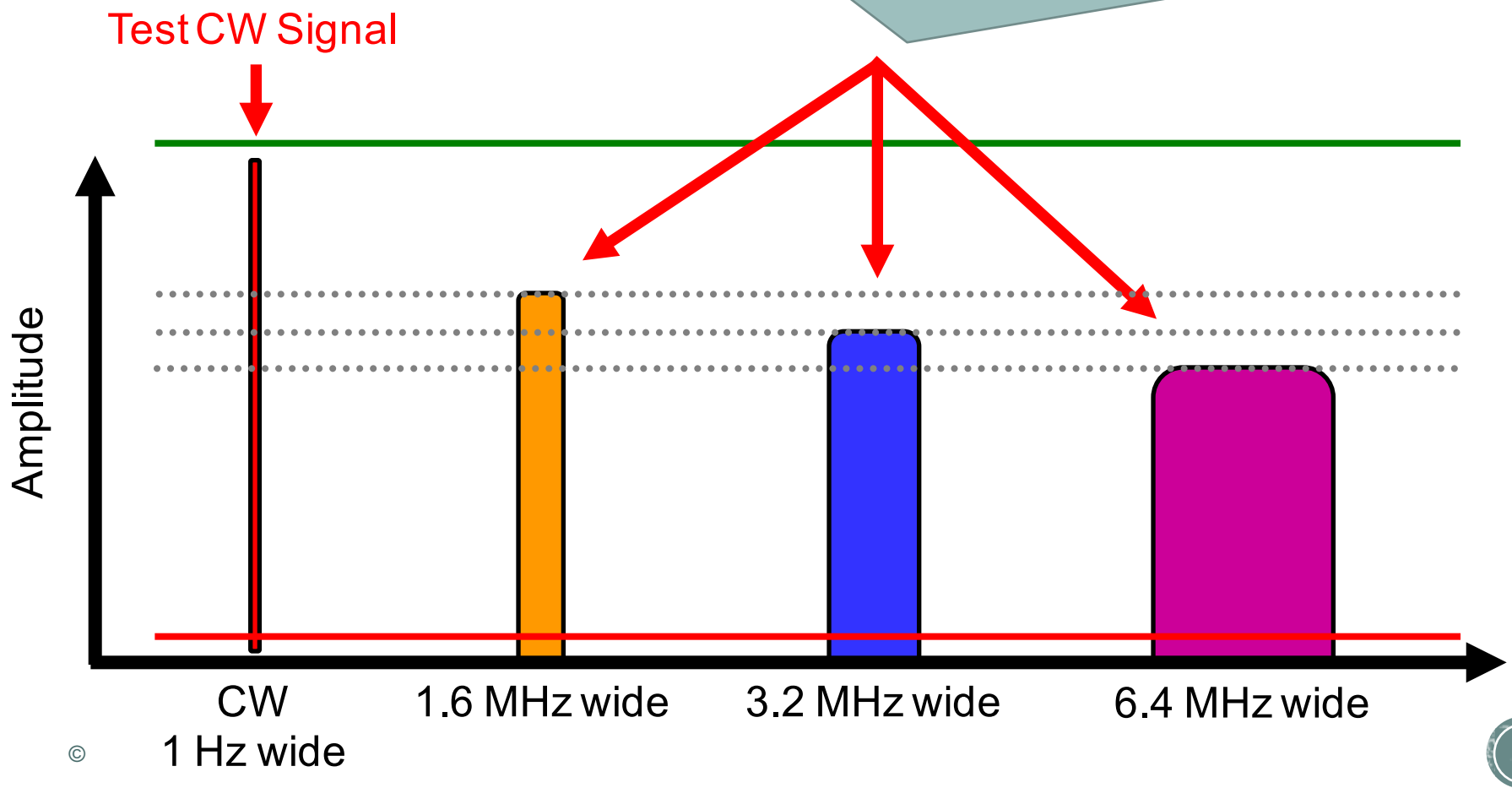
Constellation	Constellation Gain G_{const} Relative to 64 QAM (dB)	P_{min} (dBmV) L	M	H	P_{max} (dBmV) TDMA	P_{max} (dBmV) S-CDMA	$P_{min} - G_{const}$ (dBmV)	$P_{max} - G_{const}$ (dBmV) TDMA	$P_{max} - G_{const}$ (dBmV) S-CDMA
QPSK	-1.18	17	20	23	61	56	18.18	62.18	57.18
8 QAM	-0.21	17	20	23	58	56	17.21	58.21	56.21
16 QAM	-0.21	17	20	23	58	56	17.21	58.21	56.21
32 QAM	0.00	17	20	23	57	56	17.00	57.00	56.00
64 QAM	0.00	17	20	23	57	56	17.00	57.00	56.00
128 QAM	0.05	17	20	23	N/A	56	16.95	N/A	55.95
(P_{min} is a function of Modulation Rate, with L = 1280 kHz, M = 2560 kHz, and H = 5120 kHz.)									

DOCSIS 3.0 Cable Modem 4 Channel Transmit Power Levels

Constellation	Constellation Gain G_{const} Relative to 64 QAM (dB)	P_{min} (dBmV) L	M	H	P_{max} (dBmV) TDMA	P_{max} (dBmV) S-CDMA	$P_{min} - G_{const}$ (dBmV)	$P_{max} - G_{const}$ (dBmV) TDMA	$P_{max} - G_{const}$ (dBmV) S-CDMA
QPSK	-1.18	17	20	23	55	53	18.18	56.18	54.18
8 QAM	-0.21	17	20	23	52	53	17.21	52.21	53.21
16 QAM	-0.21	17	20	23	52	53	17.21	52.21	53.21
32 QAM	0.00	17	20	23	51	53	17.00	51.00	53.00
64 QAM	0.00	17	20	23	51	53	17.00	51.00	53.00
128 QAM	0.05	17	20	23	N/A	53	16.95	N/A	52.95
(P_{min} is a function of Modulation Rate, with L = 1280 kHz, M = 2560 kHz, and H = 5120 kHz.)									

Measuring Upstream Carrier Amplitudes

These carriers will NOT have the same peak amplitude level when measured on a typical spectrum analyzer when they are each hitting the CMTS at "0 dBmV power per channel".



Real Life Scenario

Cable8/1/3-upstream0	WLN15 - 0 - 0 - 0/25.0 Mhz	WL_WLN15 25.000 MHz	1882.10 (99.99%)	0.12 (0.01%)	0.00 (0.00%)	155.39	116	35.9
Cable8/1/3-upstream1	WLN15 - 0 - 0 - 0/28.2 Mhz	WL_WLN15 28.200 MHz	1685.95 (99.43%)	8.24 (0.49%)	1.35 (0.08%)	167.93	149	36.1
Cable8/1/3-upstream2	WLN15 - 0 - 0 - 0/31.4 Mhz	WL_WLN15 31.400 MHz	678.82 (99.75%)	1.29 (0.19%)	0.40 (0.06%)	158.36	93	36.1
Cable8/1/3-upstream3	WLN15 - 0 - 0 - 0/34.6 Mhz	WL_WLN15 37.000 MHz	93.76 (73.66%)	30.93 (24.30%)	2.59 (2.04%)	126.85	77	30.6

- Upstream at 37 MHz – 64-QAM, 6.4 MHz BW
  - Twice as wide and 3 dB lower than other carriers
- 24.3% FEC errors, 30.6 dB MER
- 25 MHz, 28.2 MHz, 31.4 MHz @ 64-QAM, 3.2 MHz okay
- Why? What is the problem, what is the recommended solution without going into the field?

- ***cable upstream 3 equalization-coefficient***

Terminology & Registration

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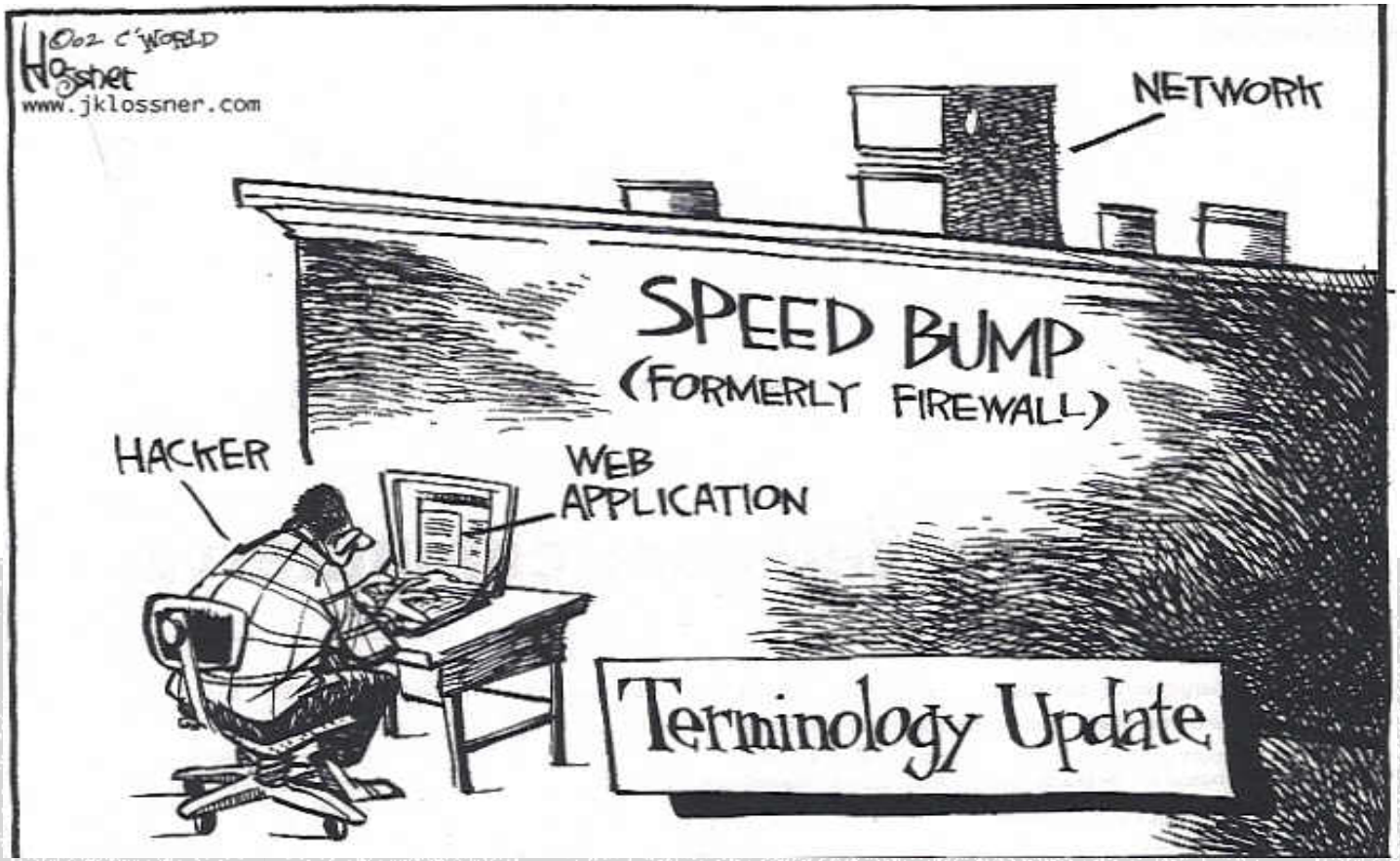


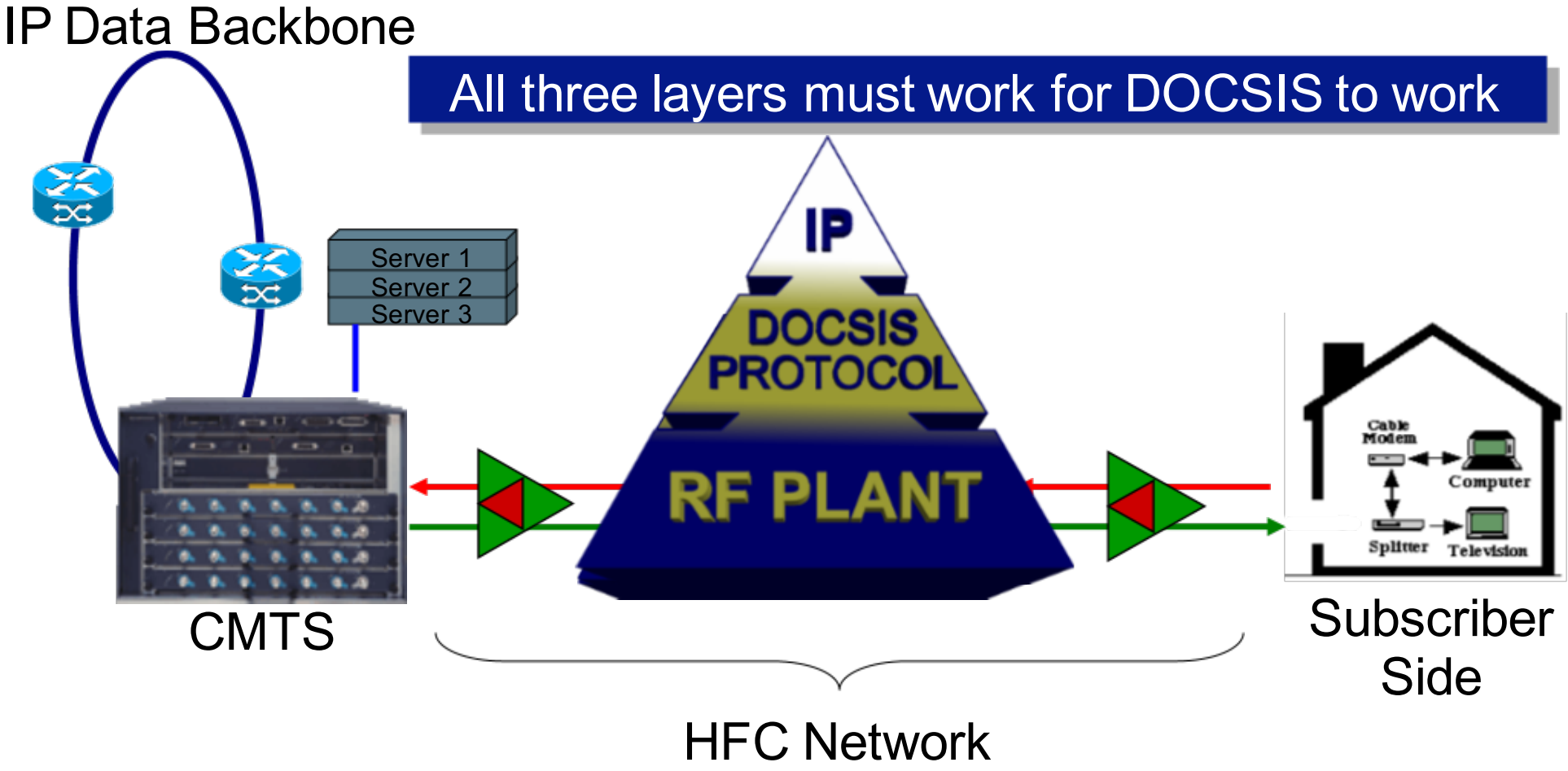
Downstream Terminology

- Primary Downstream Channel(s)
  - Master clock, UCD, MAPs, etc.
  - CMs Registration + PDU
- Non-Primary Capable Channel(s)
  - PDU only
  - D3.0 modems
- Downstream Service Group (DSG)
  - DS bonded CHs available to CM
- Upstream Channel Descriptor – UCD
  - MAC message to CMs describing US CH

Upstream Terminology

- Upstream Channel
  - Physical Upstream Channel (DOCSIS RF), or
  - Logical Upstream Channel (share same RF ch)
- Upstream Bonding Group (UBG)
  - Set of US bonded channels for CM

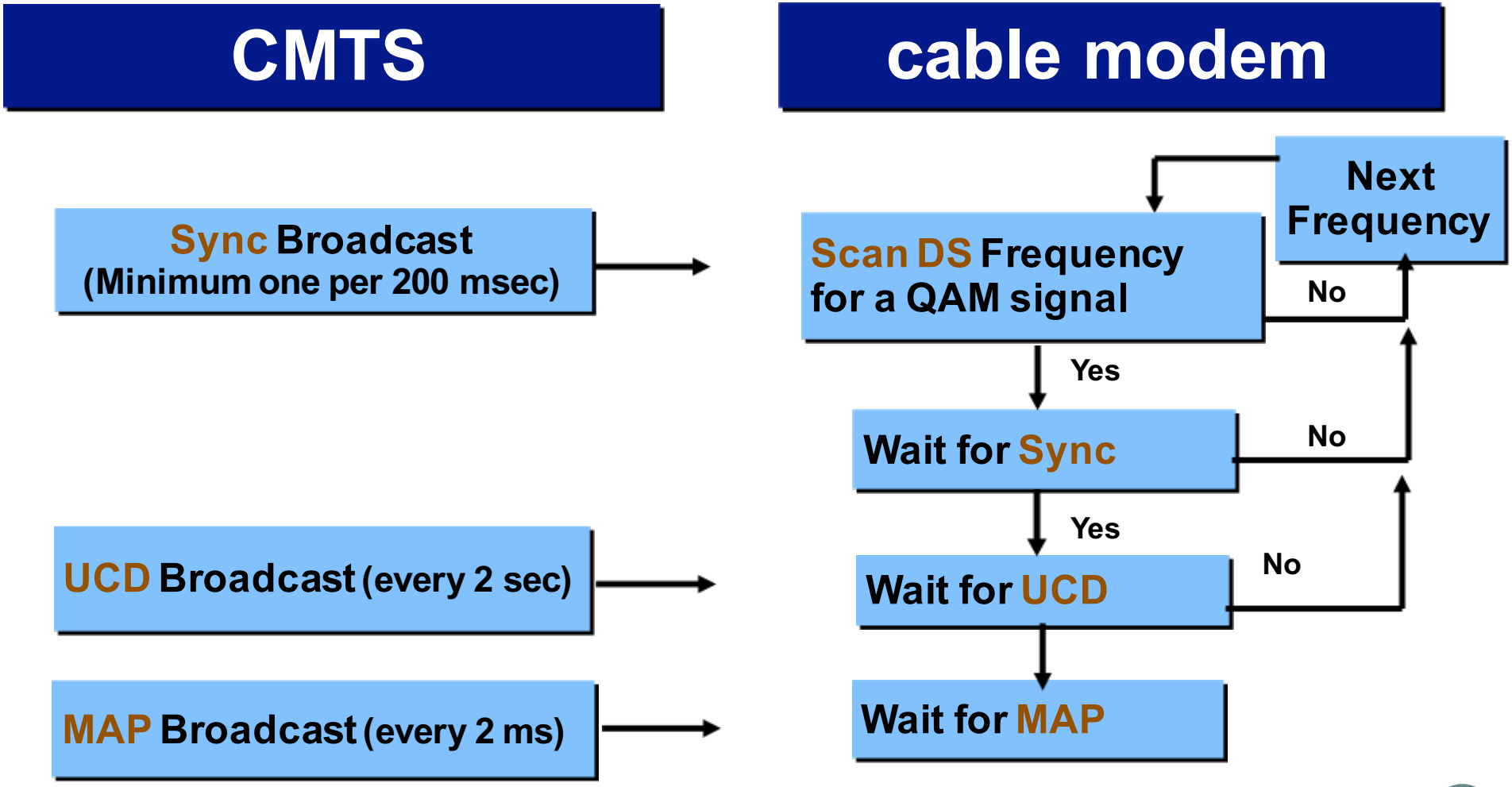
DOCSIS Communications Model



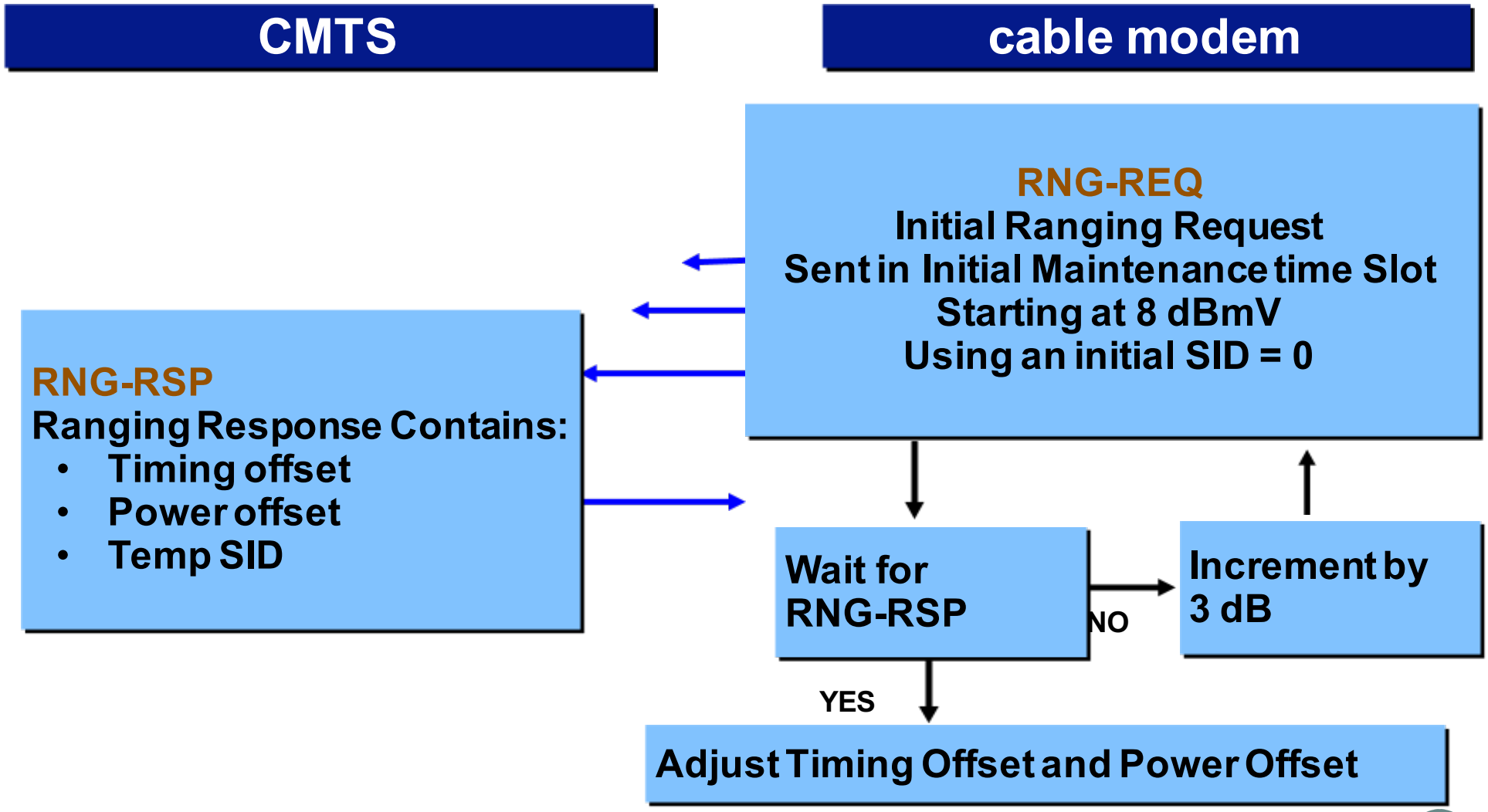
Cable Modem Registration – DOCSIS 1.x/2.0

- CM registration requires the physical layer for signal transport
- DOCSIS and IP protocol layers are necessary to communicate the proper messages for modems to come online
- The next slides illustrate the interaction of these layers

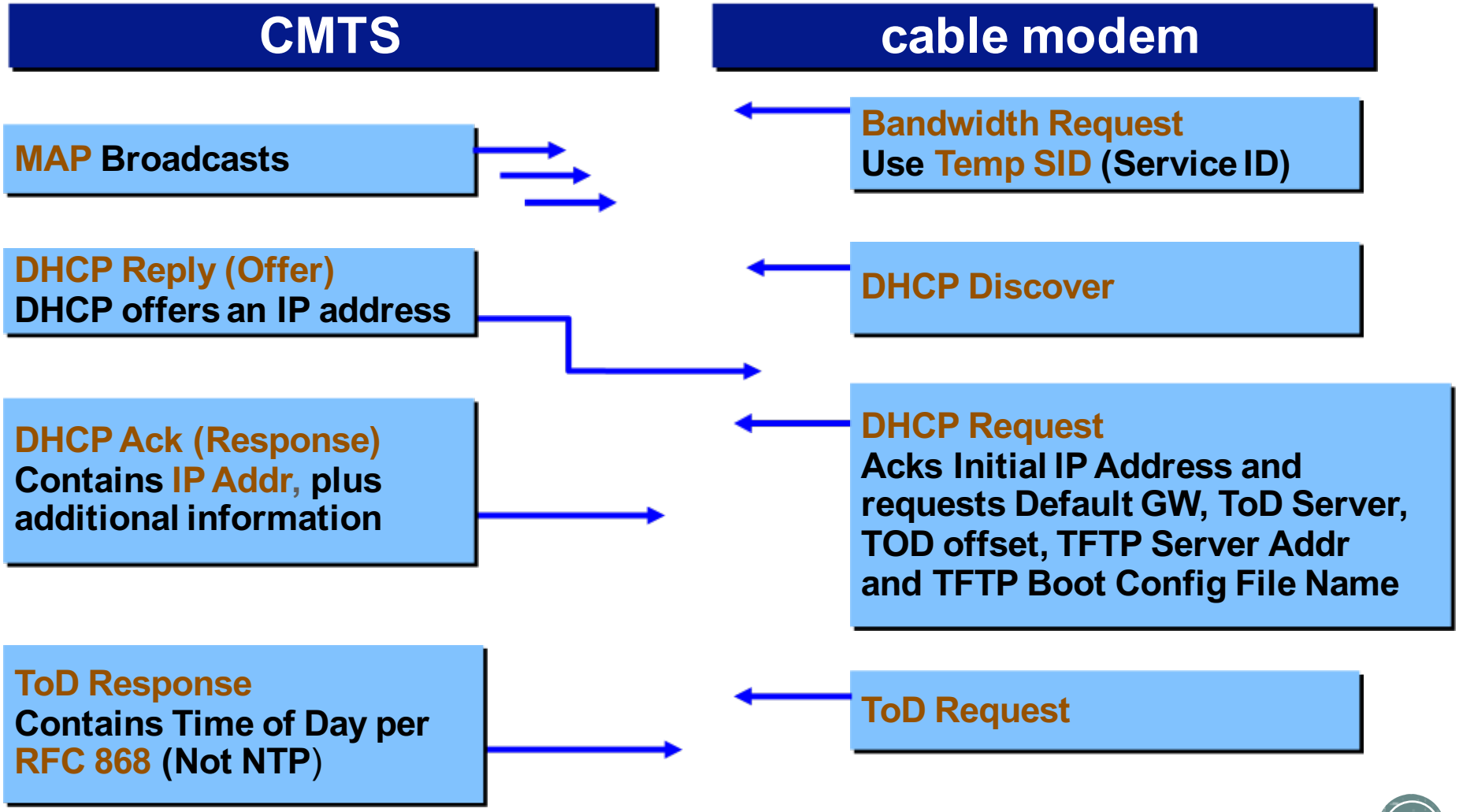
DS Freq. Acquisition



CM Ranging



DHCP Overview



TFTP & Registration

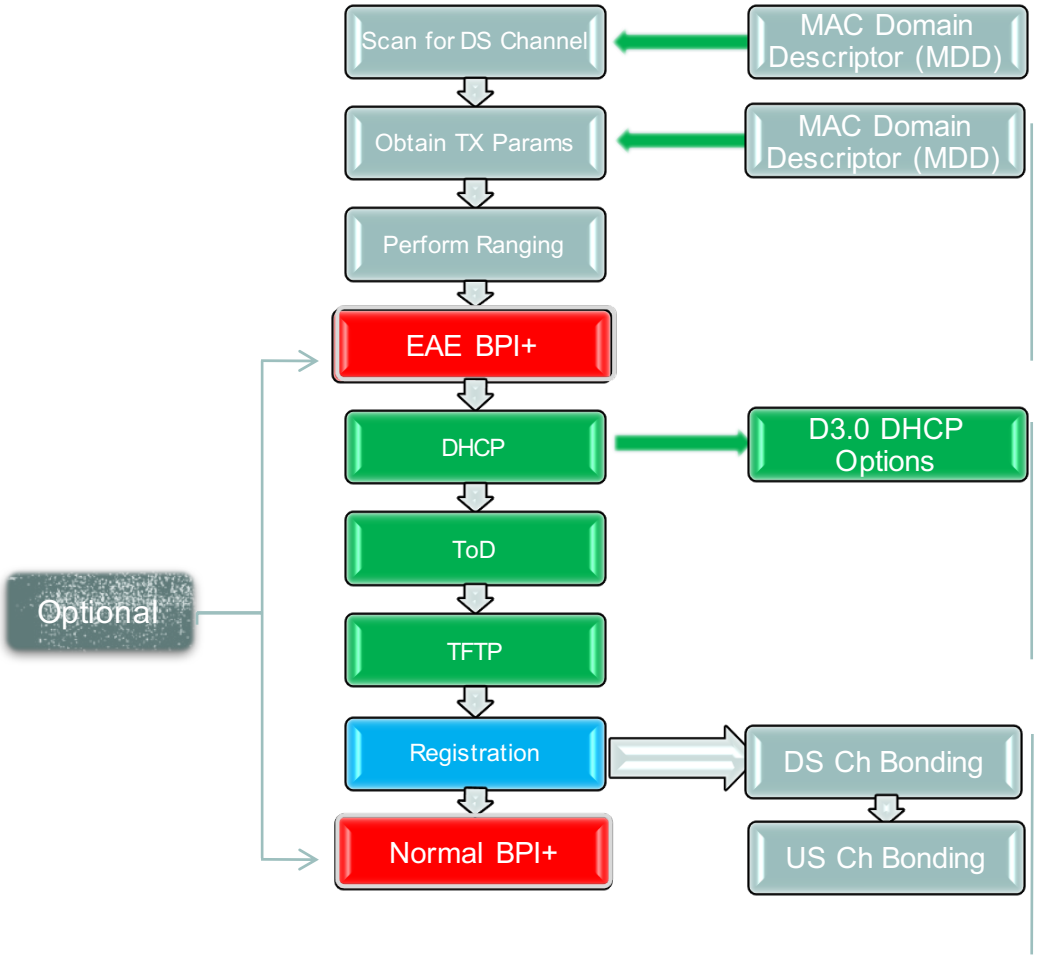
CMTS	cable modem
TFTP Boot File Transfer DOCSIS config file which contains Classifiers for QoS and schedule, Baseline Privacy (BPI), etc.	← **TFTP Boot Request** For 'Boot File name'
→	**Validate file MD5 Checksum** **Implement Config**
←	**Registration Request** **Send QoS Parameters**
Registration Response Contains Assigned SID Modem registered →	
←	**Registration Acknowledge** **Send QoS Parameters**

CM Registration Summary

- Downstream channel search
- Ranging
- DHCP
- ToD
- TFTP
- Registration
- Optional BPI Encryption

- Ranging occurs at least every 30 seconds when online
  - T3 timeout part of this and typically indicate upstream problems
  - T4 timeout typically indicate downstream problems

D3.0 Modem Registration



Provides Primary Ch ID on Secondary Chs

- MD-DS-SG
- MD-US-SG
- Ch Parameters: Freq, Modulation, etc.
- Security: EAE
- DHCP IPv4/IPv6 or suppressed and in config
- If no MDD → DOCSIS 2.0 mode!

- IPv4 Only (DHCPv4)
- IPv6 Only (DHCPv6)
- Alternate Provisioning Mode (APM)
  - DHCPv6 then DHCPv4
- Dual-stack Provisioning Mode (DPM)
  - DHCPv6 and DHCPv4

- RCC for downstream channels
- TCC to add upstream channels

Advanced Troubleshooting

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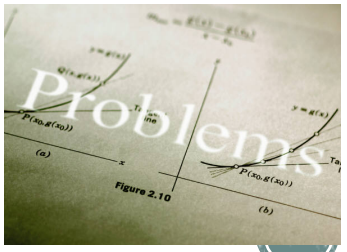
Advanced Field Troubleshooting

- Why is DOCSIS 3 Troubleshooting Different?
  - Multiple Bonded Channels
    - Downstream
      - Not that different.
      - The channels are constant carrier
      - Multiple downstream channels have been around forever
    - Upstream
      - Still most vulnerable portion of plant
      - The modem is no longer limited to a single upstream transmit path
      - In some ways this is actually easier with DOCSIS 3.0

You Likely Know Your Problems

- Downstream – Typically not so bad
  - CTB, CSO, CNR under digital channels
  - Levels not correct into home (high, low, tilt)
  - Suck-outs, especially if you have contractors doing disconnects
  - Cheap modulators & upconverters never save you money
  - DOCSIS 3.0 headaches - Channel bonding, isolation, legacy
- Upstream – Your Achilles heal
  - Easy: AWGN noise, impulse noise, coherent noise, CPD, Laser clipping
  - Hard: Group delay, frequency response, micro-reflections
  - Insane: DOCSIS 3.0 – multiple upstreams – power levels
- Theft of Service

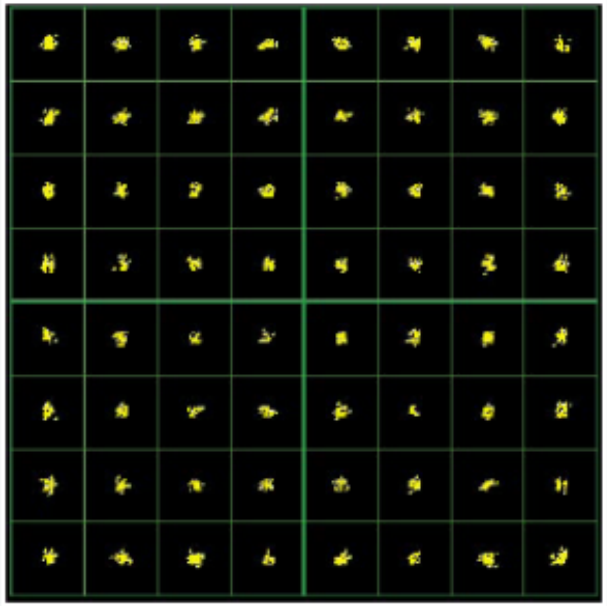


Likely Upstream Problems

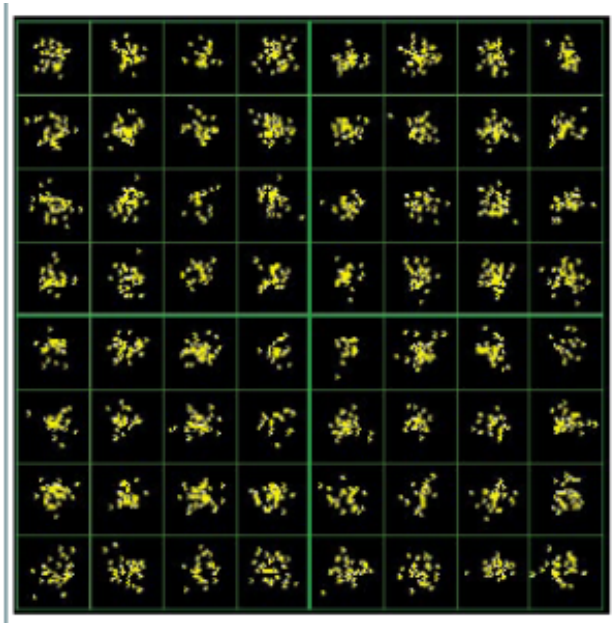
- Four times the US bandwidth (four bonded channels) creates a new dynamic for troubleshooting and monitoring:
- 6.4 MHz * 4 = 25.6 MHz (without guard bands)
- Increased likelihood for laser clipping
- Increased probability for problems with ingress, group delay, micro-reflections, and other linear distortions
- Inability to avoid problem frequencies such as Citizens' Band, Ham, Shortwave, and hop between CPD 6MHz spacing
- Where are you going to put your sweep points?

Test Equipment .....has Advanced!

Downstream Impairments



Good MER

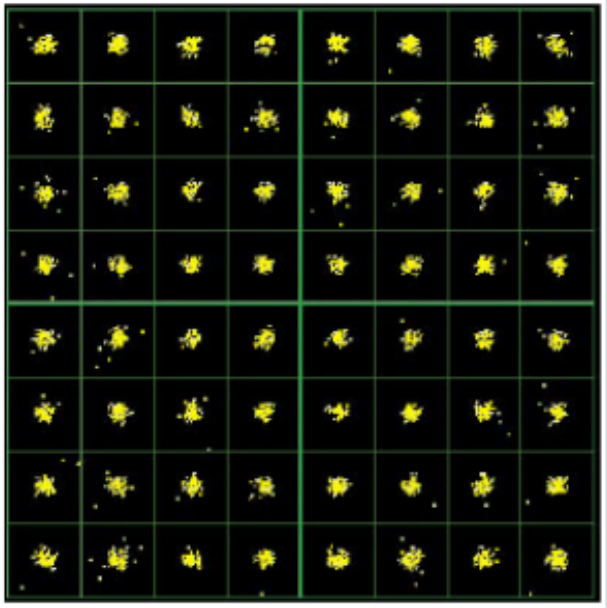


Noise

Gaussian noise impairments. Clusters poorly defined and spread out.

Possible Causes:

Low RF levels, low inputs to RF amplifiers



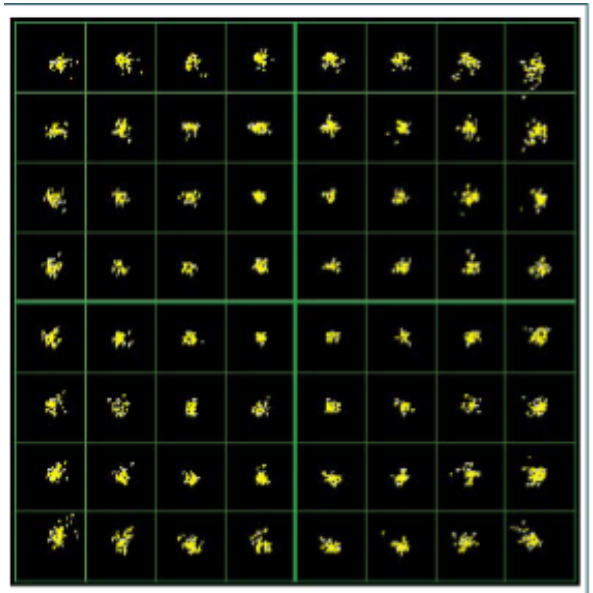
Intermittent Interference

On/Off interference below the desired QAM signal. Isolated dots appear away from the main cluster.

Possible Causes:

Laser clipping, intermittent ingress (2-way radios & paging systems)

Downstream Impairments

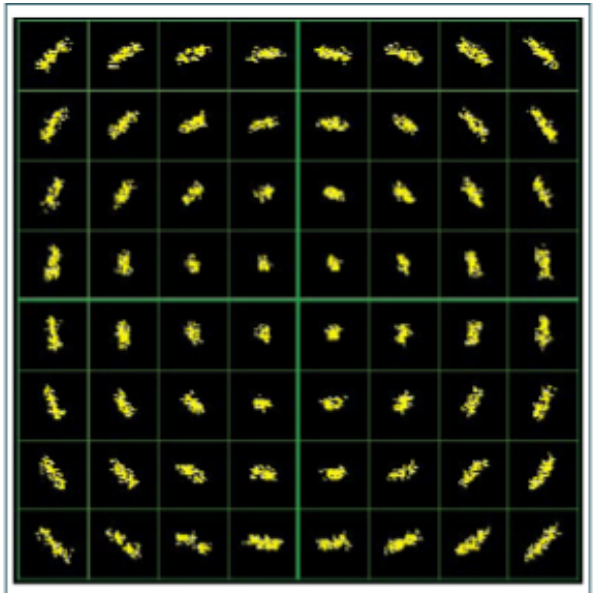


Compression

Non-linear distortion. Clusters are "pulled in" at the corners.

Possible Causes:

Overdriven or bad RF/IF amps, IF/RF filters, up/down converters, IF equalizers, bad clock recovery circuits

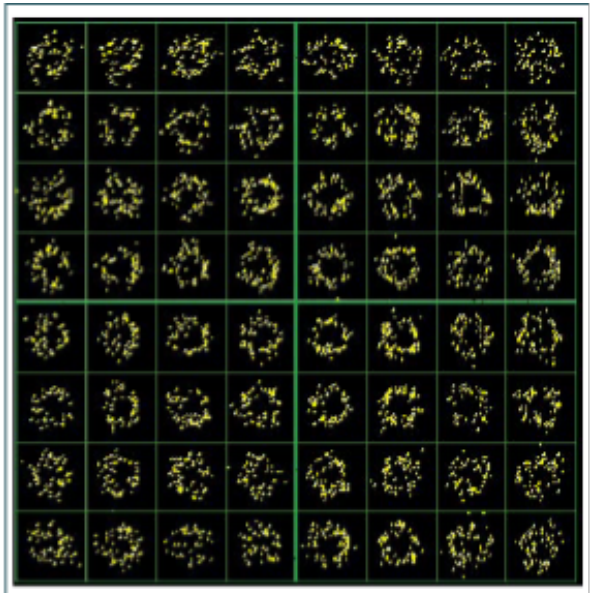


Phase Noise

Phase shift of I & Q data. The clusters appear to rotate around the center of the constellation.

Possible Causes:

Headend IF amplifiers and Up/Down converters



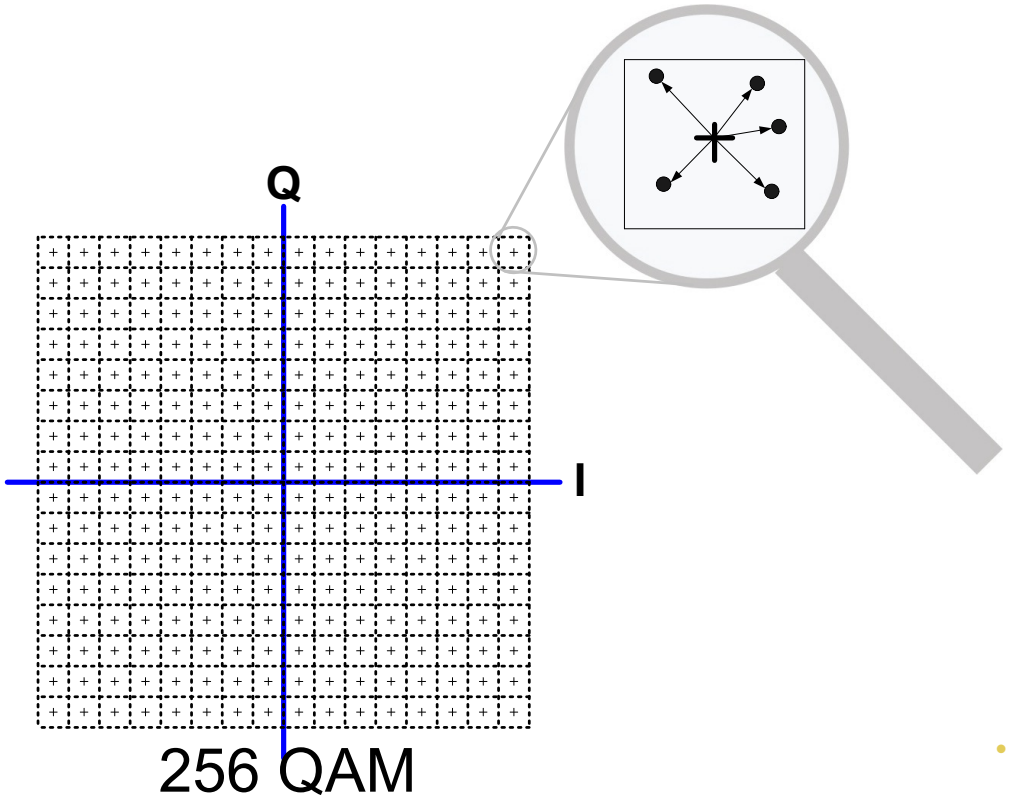
Coherent Disturbance

Interference from a signal under the desired QAM signal. Clusters appear doughnut shaped.

Possible Causes:

Ingress, CW Interference

Modulation Error Ratio (MER)



- The quality of a QAM signal can be defined by the dispersion of the constellation's points considering the target value
- The error or dispersion power is calculated by the value mean square of the error vectors (real value VS target value)

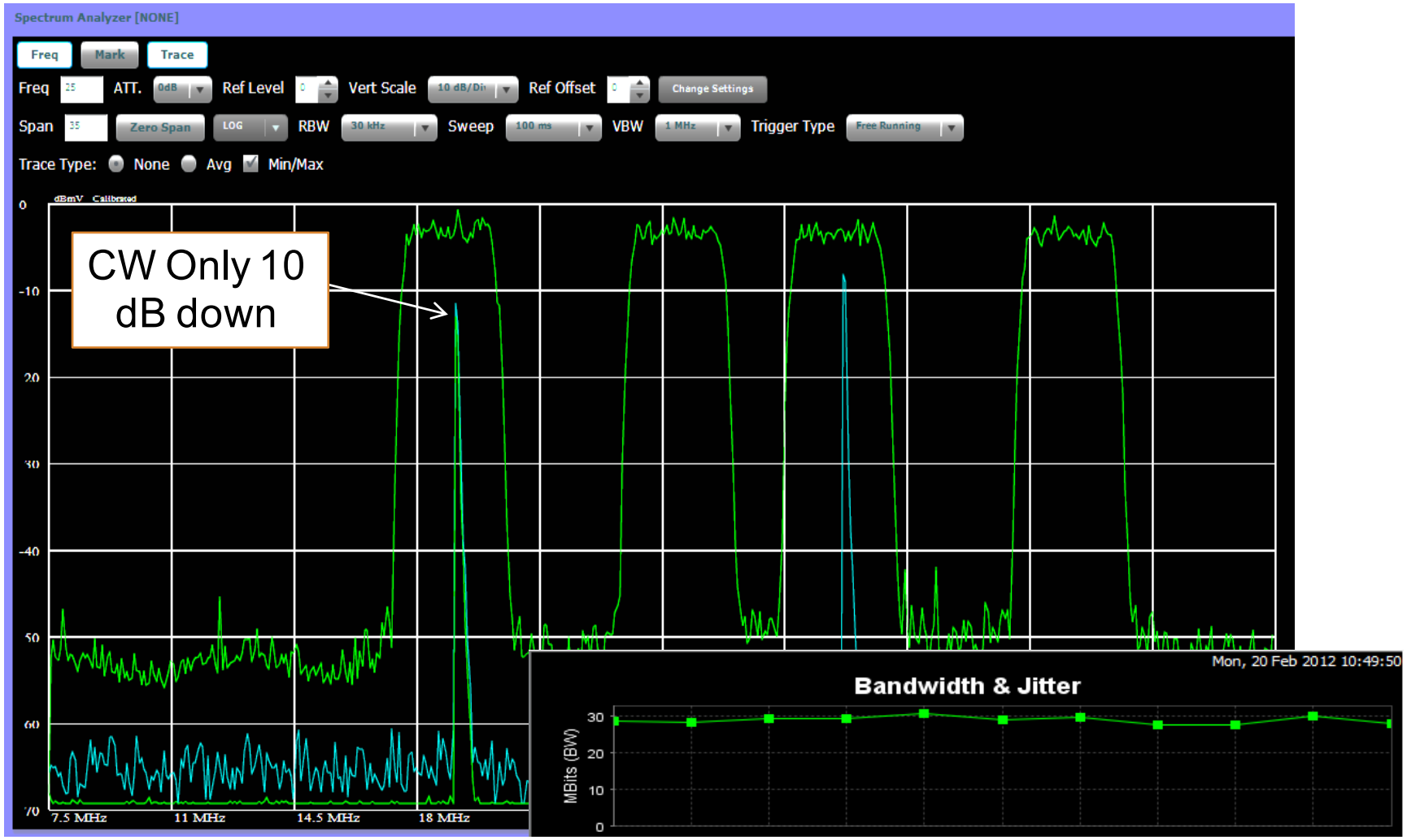
- MER is the ratio in dB between the average power of the signal and the power of the error vectors

$$MER_{symb}(dB) = 10 \bullet \log_{10}\left\{\frac{E_{av}}{\frac{1}{N}\sum_{j=1}^{N}\left|e_j\right|^2}\right\}$$

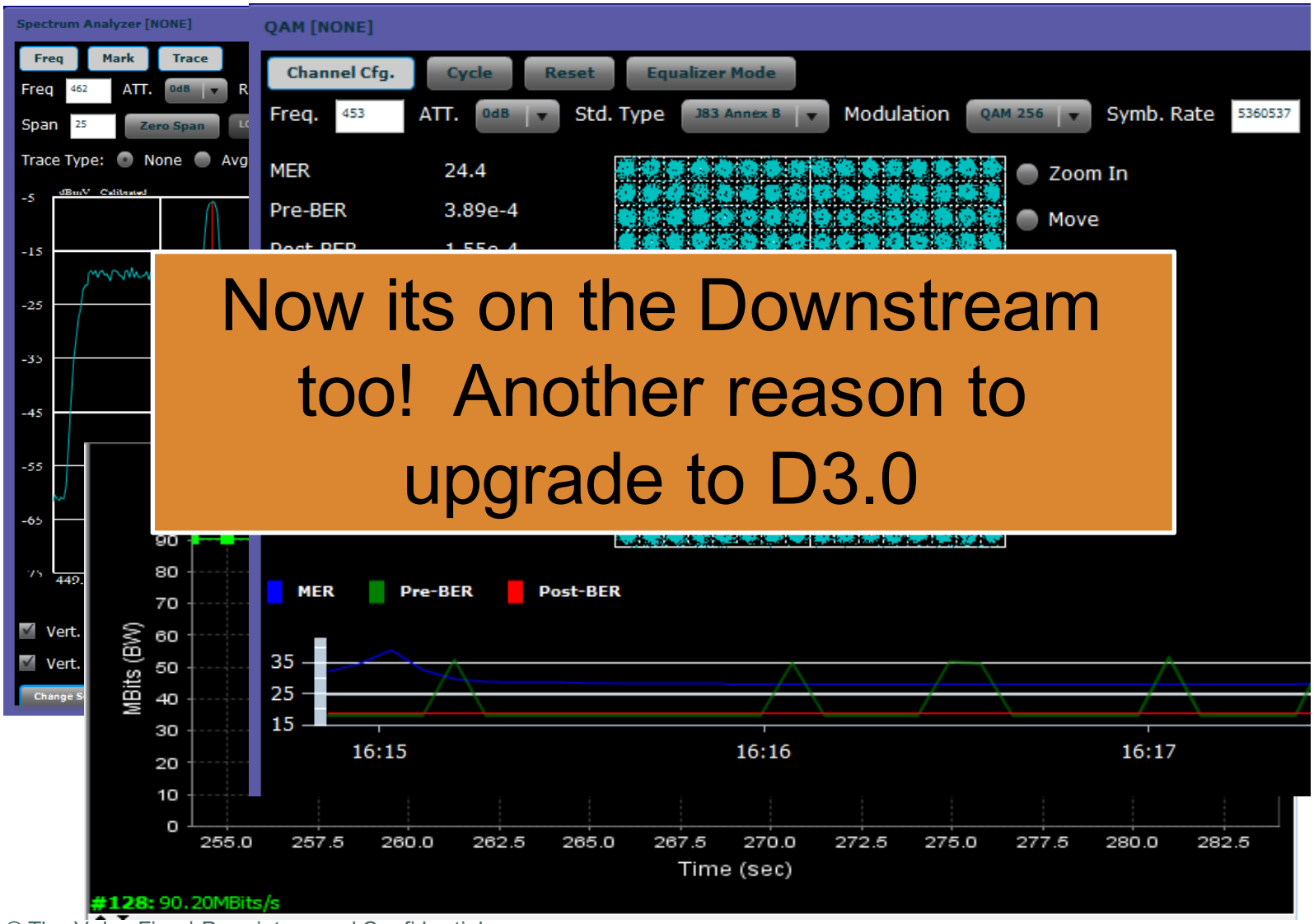
MER

BER	64-QAM MER	256-QAM MER	Quality
10^{-10}	>35	>35	Excellent
10^{-8}	27-34	31-34	Good
10^{-6}	23-26	28-30	Marginal
10^{-5}	<23	<28	Fail

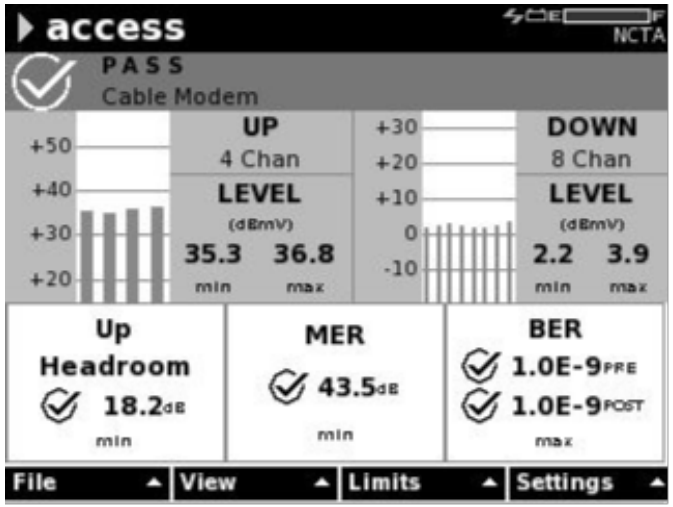
Upstream Ingress Cancellation – On default

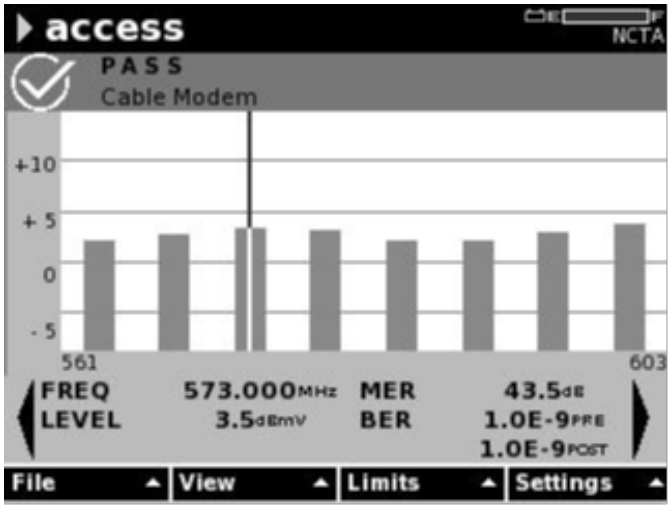


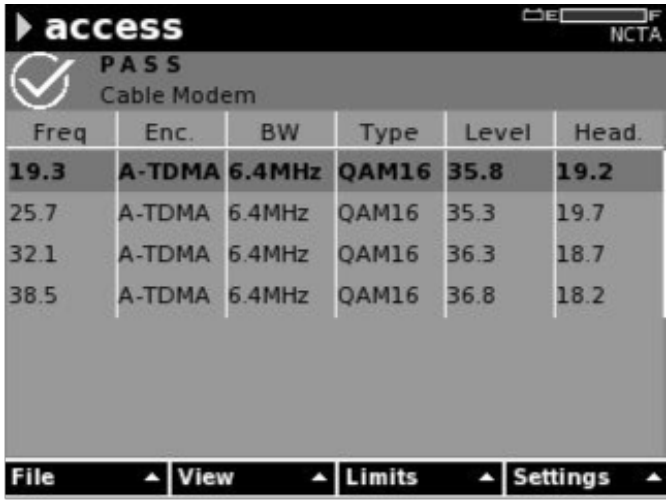
Something New – DOCSIS 3.0 Modems

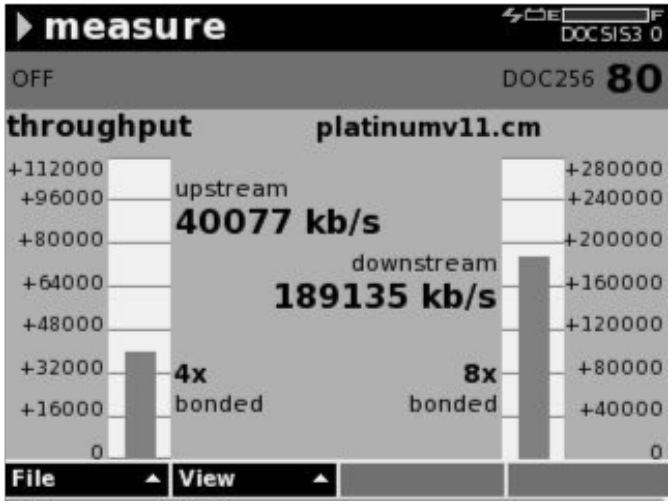


Testing DOCSIS 3.0 Meter – JDSU / Viavi DSAM



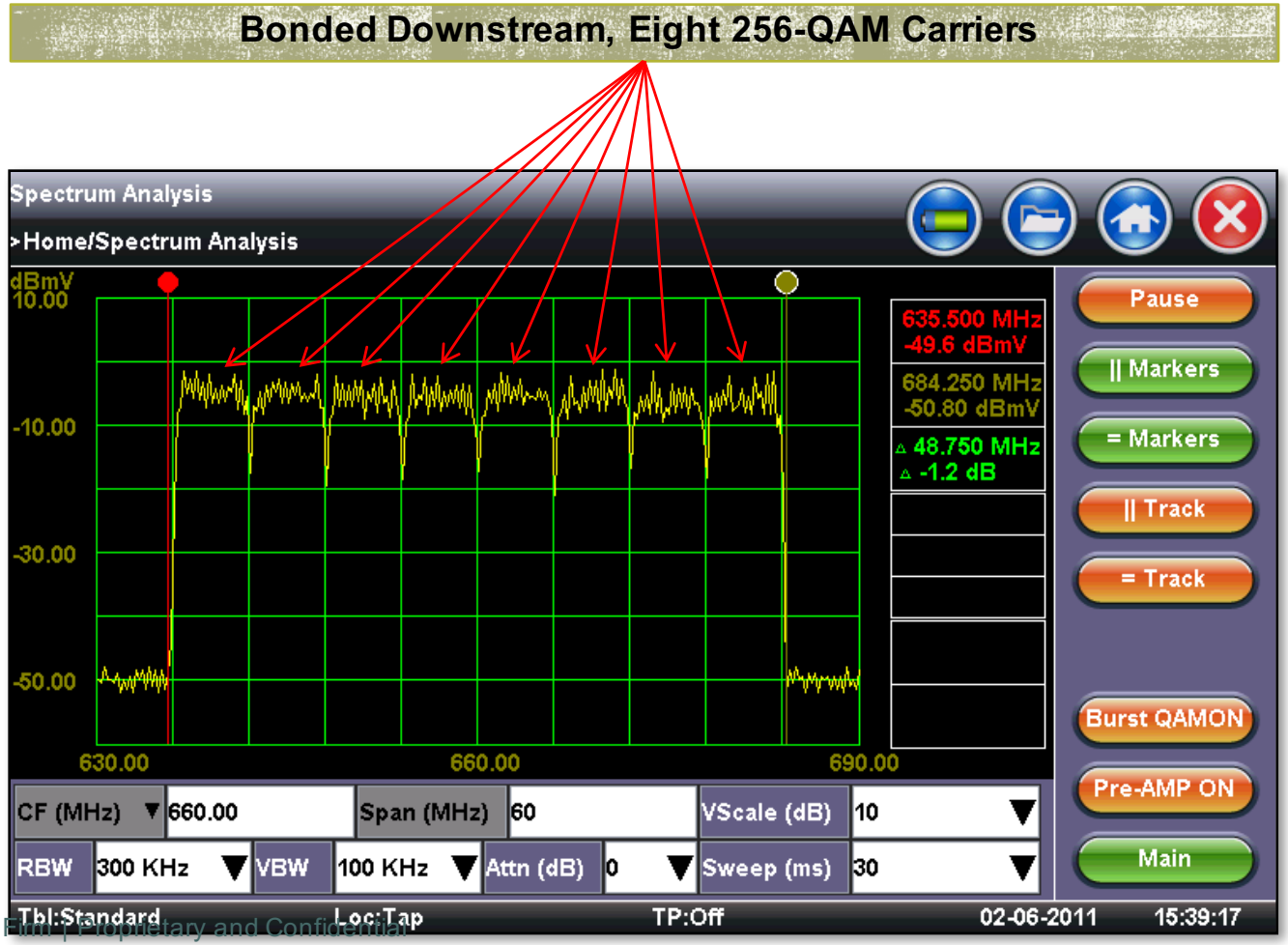






DOCSIS 3.0 Channel Bonding

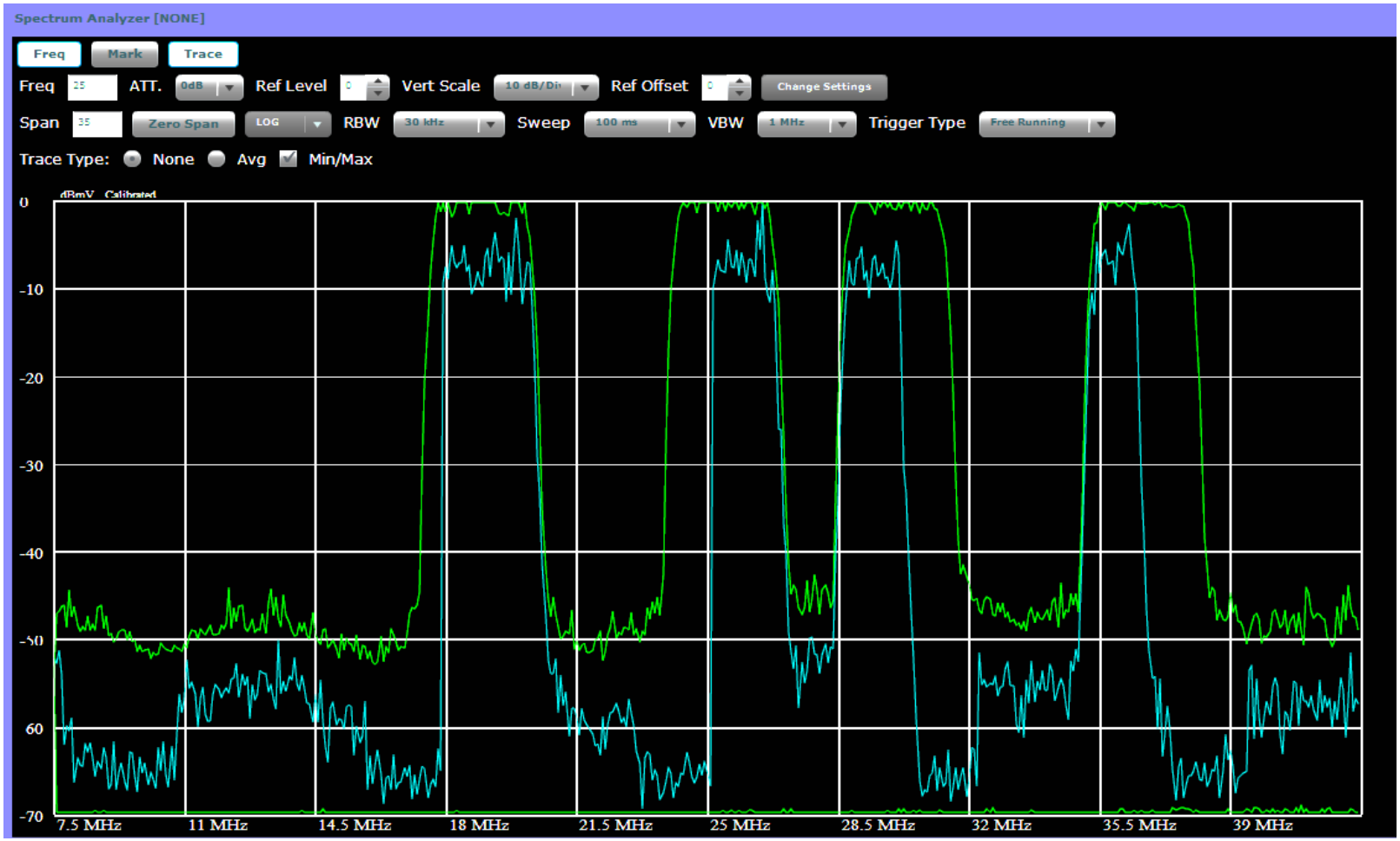
- Eight channel downstream



VeEX CX380 CM Screen Shot

- D3 8x4 Channel Bonding: Details

A Clean Upstream: Or Is It for 64-QAM?



Impact to Adaptive EQ from Impulse Noise

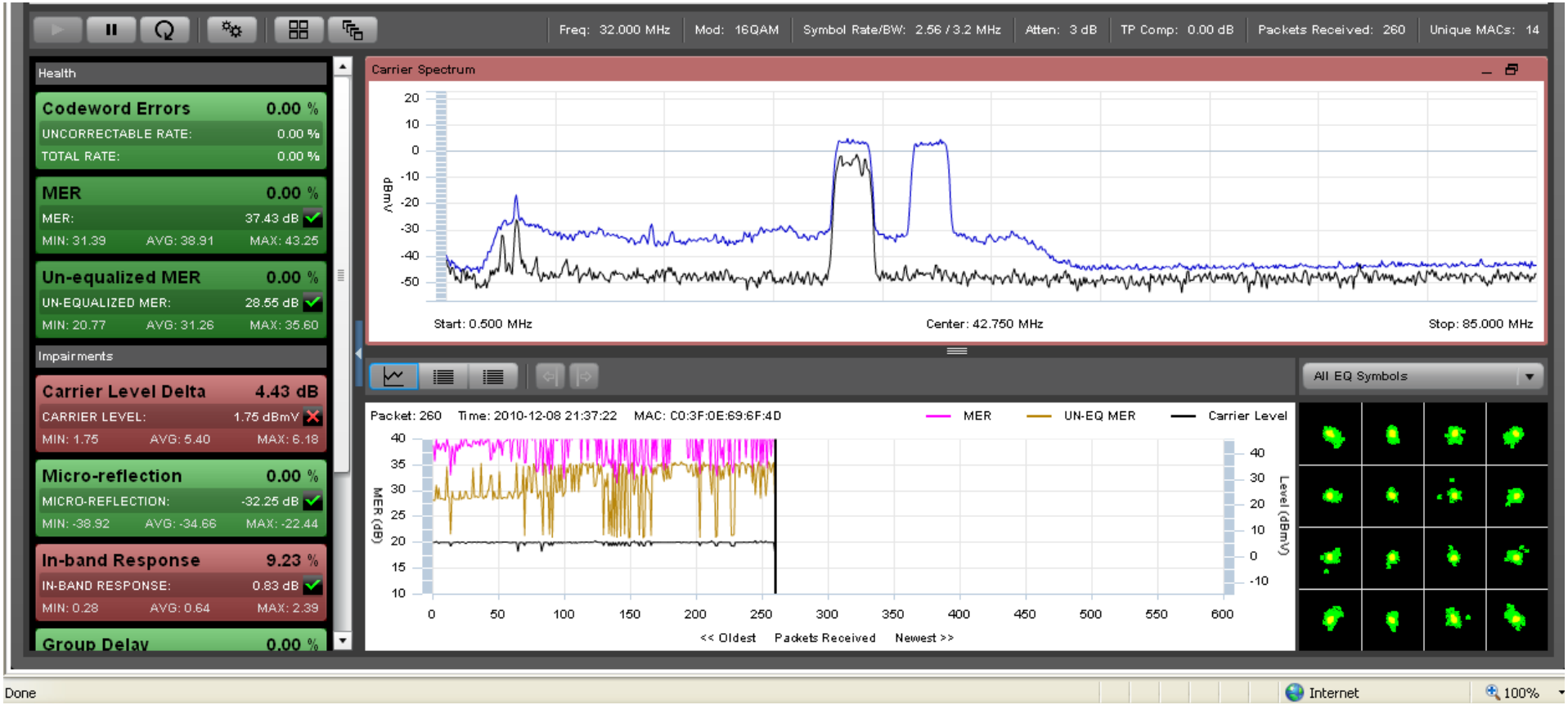
```
CiscoUBR#scm phy
MAC Address    I/F          Sid   USPwr   USMER  Timing  DSPwr   DSMER   Mode    DOCSIS
                                   (dBmV)  (SNR)  Offset  (dBmV)  (SNR)           Prov
                                           (dB)                    (dB)
a47a.a4b7.c60e C1/0/U0      1     45.75   36.12  2398    0.00    -----   atdma*  1.1
a47a.a4b7.c60e C1/0/U1      1     45.75   36.12  2333    0.00    -----   atdma*  1.1
a47a.a4b7.c60e C1/0/U2      1     45.75   36.12  2399    0.00    -----   atdma*  1.1
a47a.a4b7.c60e C1/0/U3      1     45.75   36.12  2399    0.00    -----   atdma*  1.1
0023.74f6.7ad9 C1/0/U0      2     45.25   36.12  2400    0.00    -----   atdma*  1.1
0023.74f6.7ad9 C1/0/U1      2     45.25   36.12  2400    0.00    -----   atdma*  1.1
0023.74f6.7ad9 C1/0/U2      2     45.25   36.12  2397    0.00    -----   atdma*  1.1
0023.74f6.7ad9 C1/0/U3      2     45.25   36.12  2400    0.00    -----   atdma*  1.1
0026.2482.9dc4 C1/0/U0      3     44.25   36.12  3958    0.00    -----   atdma*  1.1
0026.2482.9dc4 C1/0/U1      3     44.75   36.12  3958    0.00    -----   atdma*  1.1
0026.2482.9dc4 C1/0/U2      3     44.75   36.12  2121    0.00    -----   atdma*  1.1
0026.2482.9dc4 C1/0/U3      3     44.25   36.12  3958    0.00    -----   atdma*  1.1

CiscoUBR#scm phy
MAC Address    I/F          Sid   USPwr   USMER  Timing  DSPwr   DSMER   Mode    DOCSIS
                                   (dBmV)  (SNR)  Offset  (dBmV)  (SNR)           Prov
                                           (dB)                    (dB)
a47a.a4b7.c60e C1/0/U0      1     45.75   18.92  2398    0.00    -----   atdma*  1.1
a47a.a4b7.c60e C1/0/U1      1     45.75   36.12  2333    0.00    -----   atdma*  1.1
a47a.a4b7.c60e C1/0/U2      1     45.75   36.12  2399    0.00    -----   atdma*  1.1
a47a.a4b7.c60e C1/0/U3      1     45.75   36.12  2399    0.00    -----   atdma*  1.1
0023.74f6.7ad9 C1/0/U0      2     45.25   36.12  2400    0.00    -----   atdma*  1.1
0023.74f6.7ad9 C1/0/U1      2     45.25   36.12  2400    0.00    -----   atdma*  1.1
0023.74f6.7ad9 C1/0/U2      2     45.25   36.12  2397    0.00    -----   atdma*  1.1
0023.74f6.7ad9 C1/0/U3      2     45.25   36.12  2400    0.00    -----   atdma*  1.1
0026.2482.9dc4 C1/0/U0      3     44.25   36.12  3958    0.00    -----   atdma*  1.1
0026.2482.9dc4 C1/0/U1      3     44.75   36.12  3958    0.00    -----   atdma*  1.1
0026.2482.9dc4 C1/0/U2      3     44.75   36.12  2121    0.00    -----   atdma*  1.1
0026.2482.9dc4 C1/0/U3      3     44.25   36.12  3958    0.00    -----   atdma*  1.1
```

Ways to Mitigate Impact of Impulse Noise

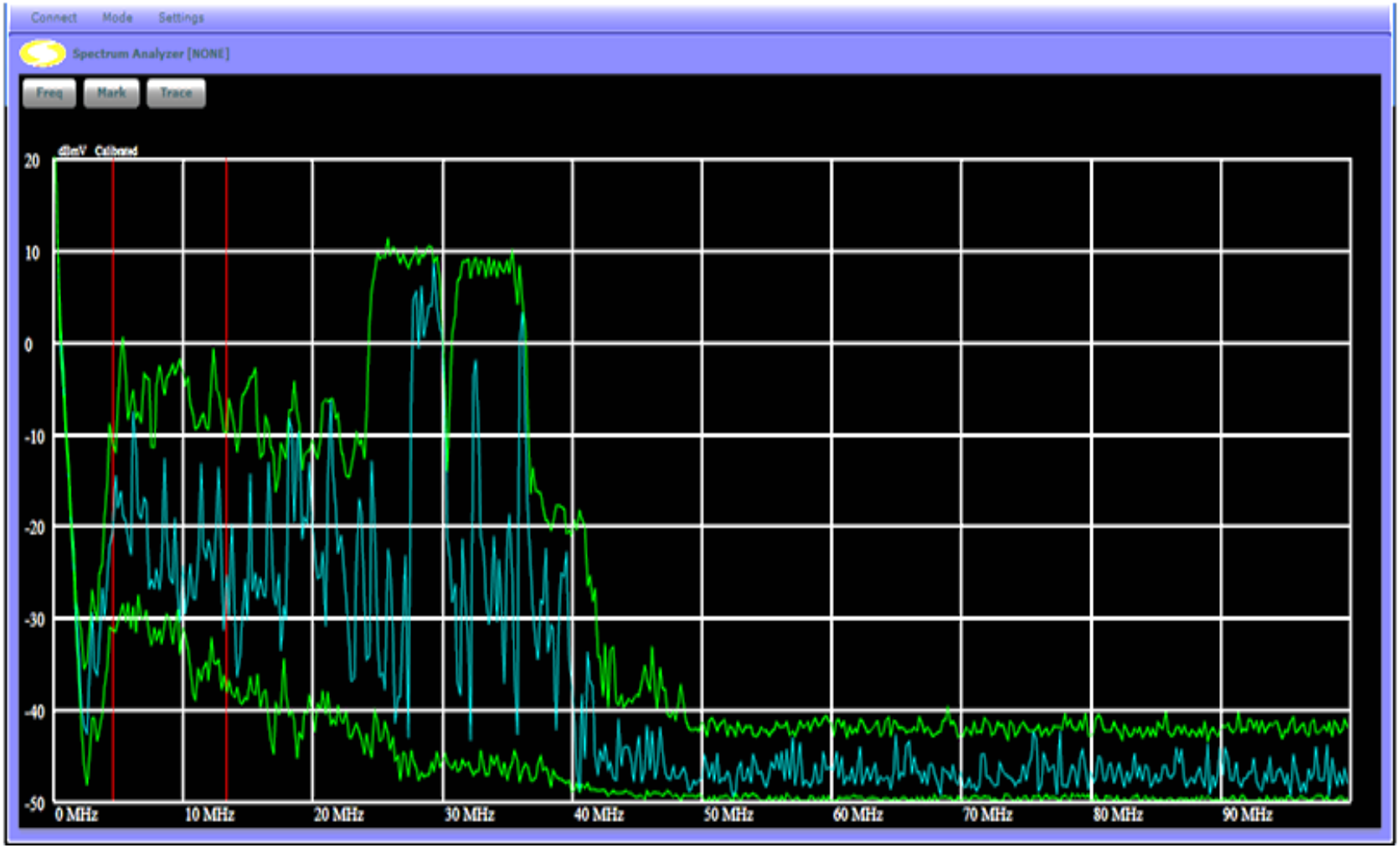
- Clean up plant
- Improve robustness of modulation profile from:
  - cable modulation-profile 224 initial 5 34 0 48 16qam scrambler 152 no-diff 64 fixed qpsk1 1 2048
  - cable modulation-profile 224 station 5 34 0 48 16qam scrambler 152 no-diff 64 fixed qpsk1 1 2048
- To:
  - cable modulation-profile 224 initial 5 34 0 48 16qam scrambler 152 no-diff **384** fixed qpsk1 **0** 2048
  - cable modulation-profile 224 station 5 34 0 48 16qam scrambler 152 no-diff **384** fixed qpsk1 **0** 2048
- Changing 64 to 384 increases the preamble length, thus enhancing the training sequence on capturing the packet and lessening the effects of impulse noise
- Changing the 1 to a 0 enables dynamic interleaving mode, increasing the effectiveness of Forward Error Correction (FEC) as impulse noise increases in the system

Monitoring Transient Events?

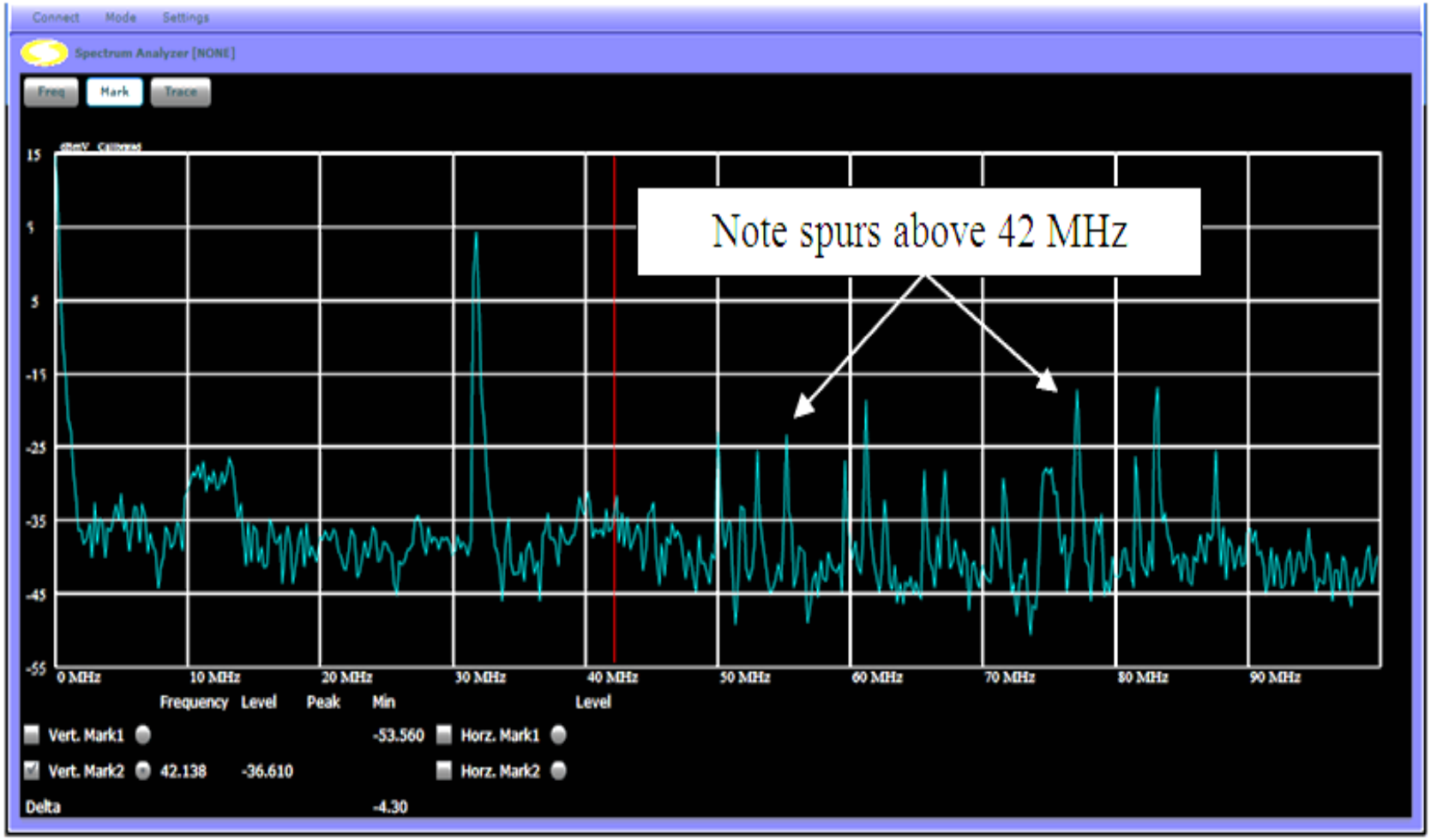
- Laser Clipping or Impulse Noise for example…
  - Plan on laser clipping being a popular word



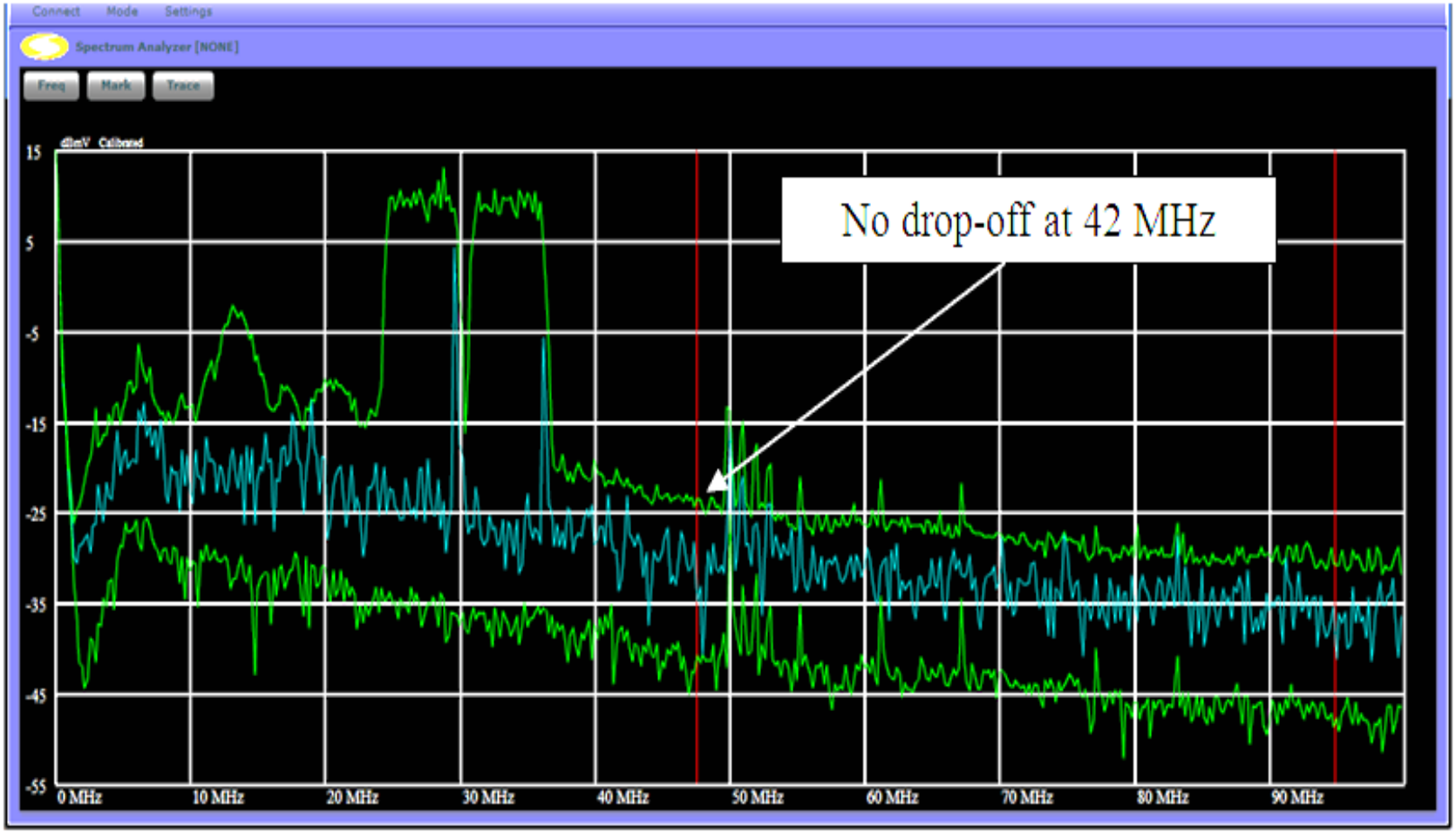
Two 64-QAM Bonded Channels



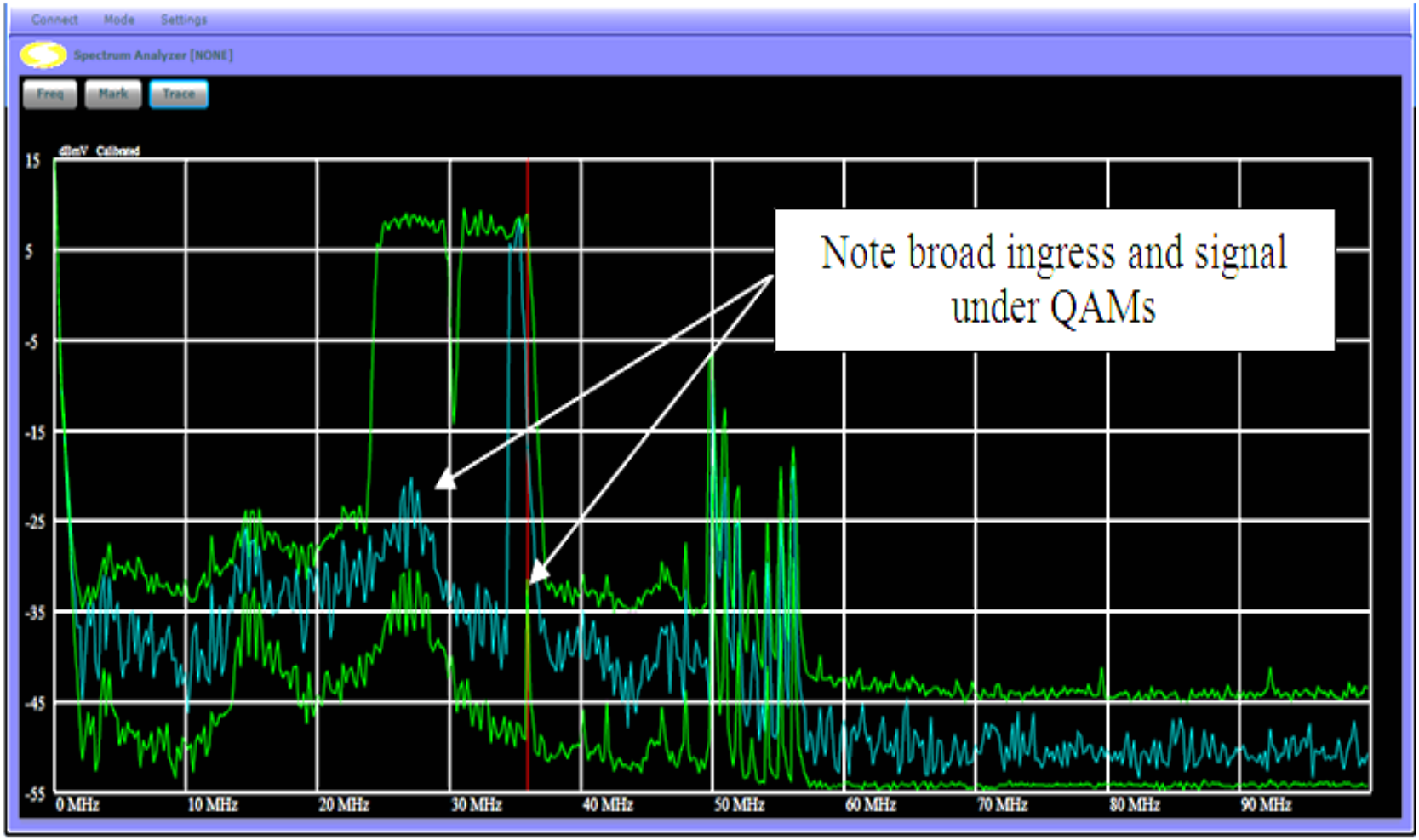
Laser Clipping – FP Laser



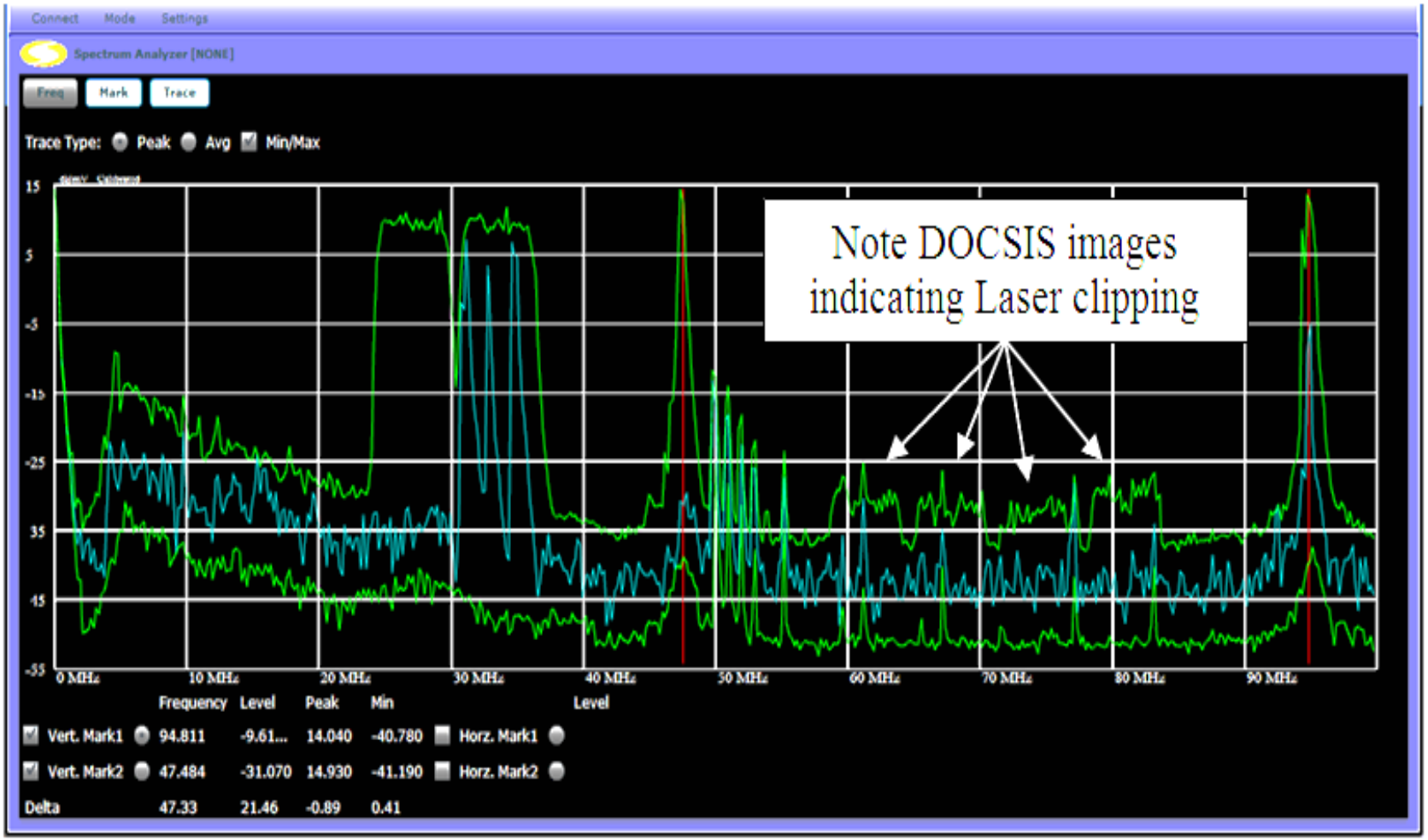
Laser Clipping – Hard to See



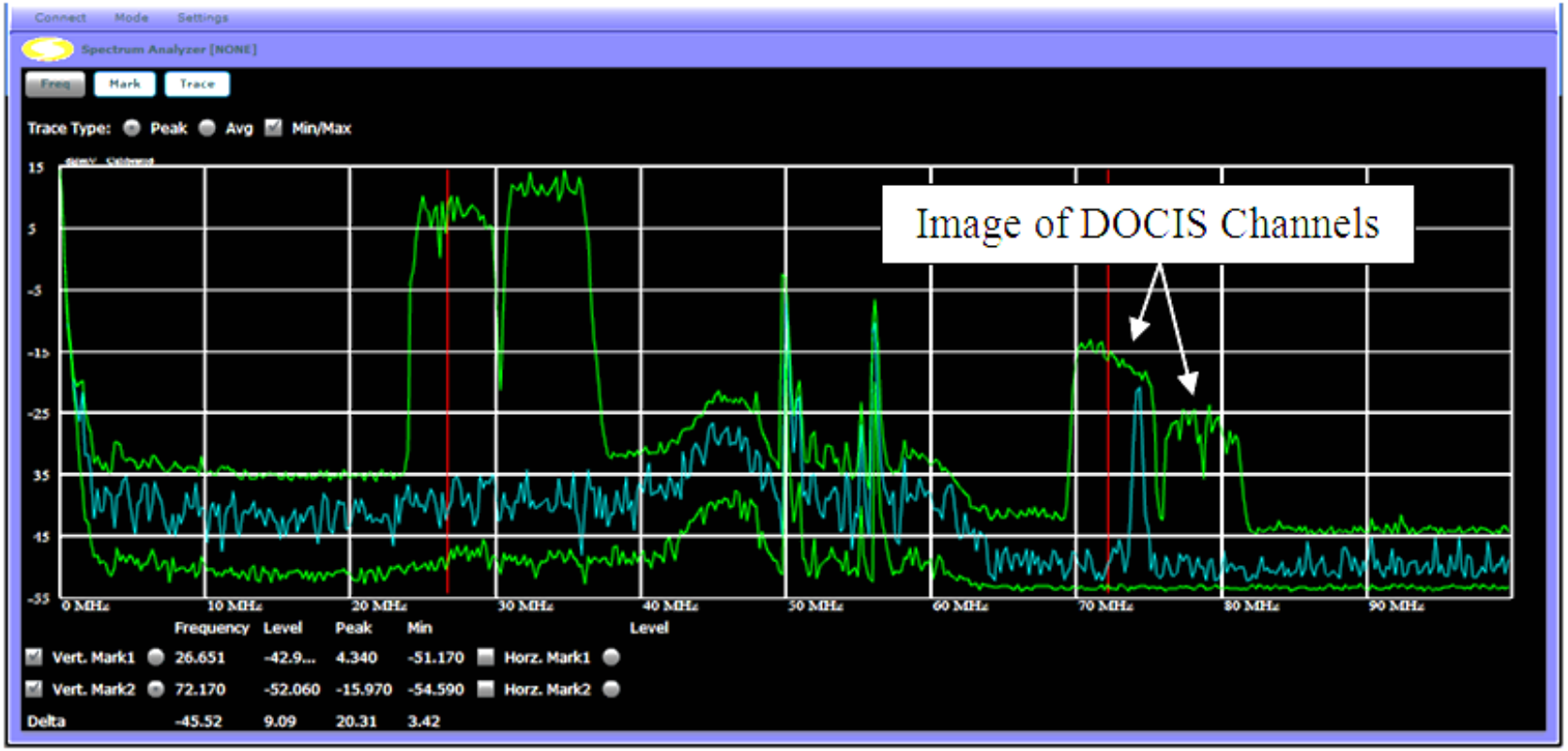
Ingress Under QAM



Laser Heterodyning

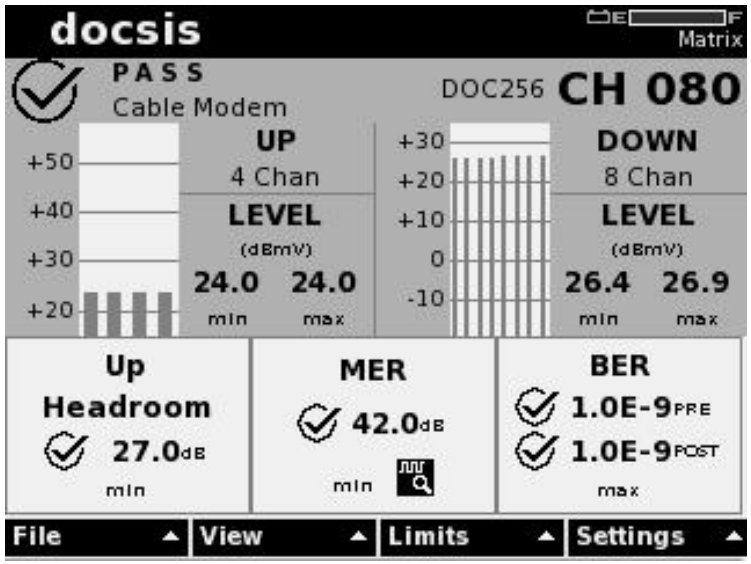


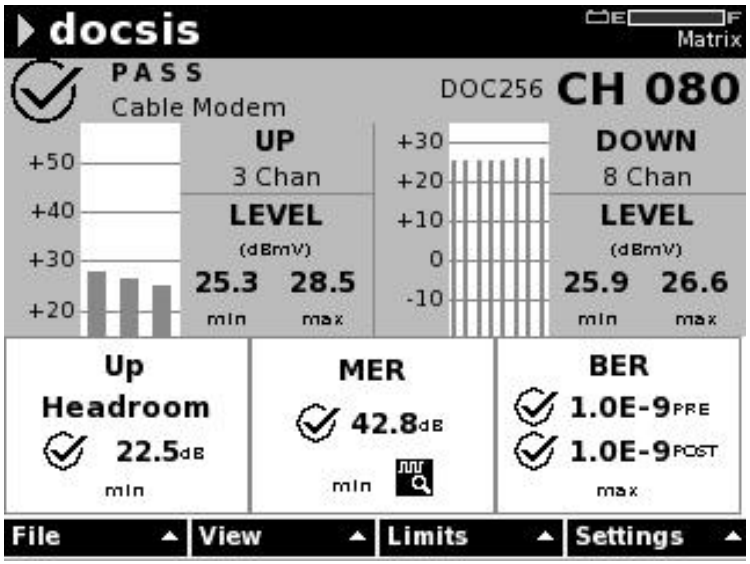
Digital Return – RF above 42 MHz



Partial Service Troubleshooting

- Partial Service exhibits itself as missing channels
- Does not exhibit as Packetloss or Throughput issue

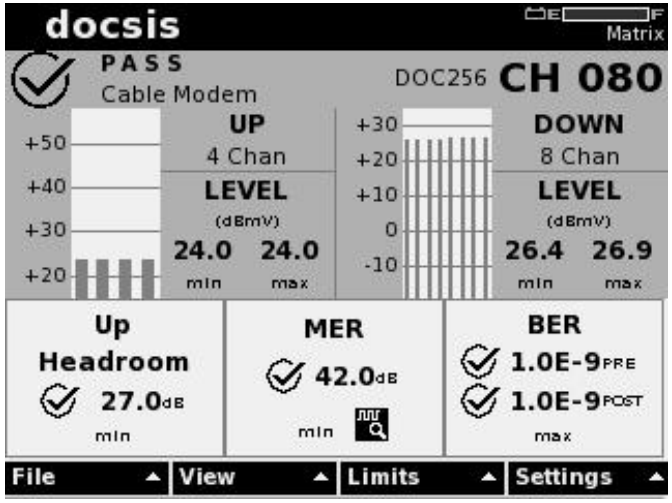




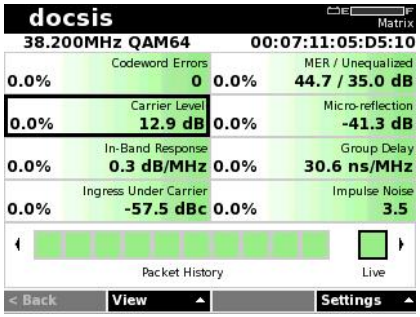

```
CiscoUBR#scm
                                                                        D
MAC Address    IP Address     I/F          MAC            Prim RxPwr   Timing Num I
                                           State          Sid  (dBmv)  Offset CPE P
0023.74f6.7ad9 10.10.10.4     C1/0/UB      w-online       1    0.00    2331   1   N
a47a.a4b7.c60e 10.10.10.3     C1/0/UB      w-online       2    0.50    2332   0   N
0026.2482.9dc4 10.10.10.2     C1/0/U0      online         3    -0.50   2117   1   N
```

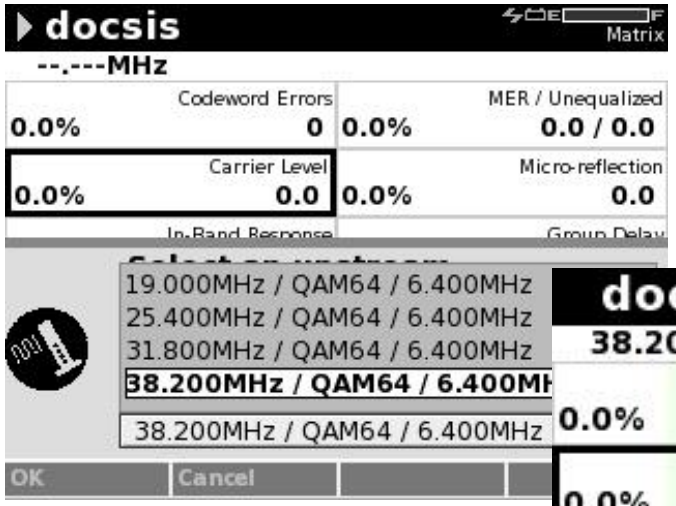
Impaired Service Troubleshooting

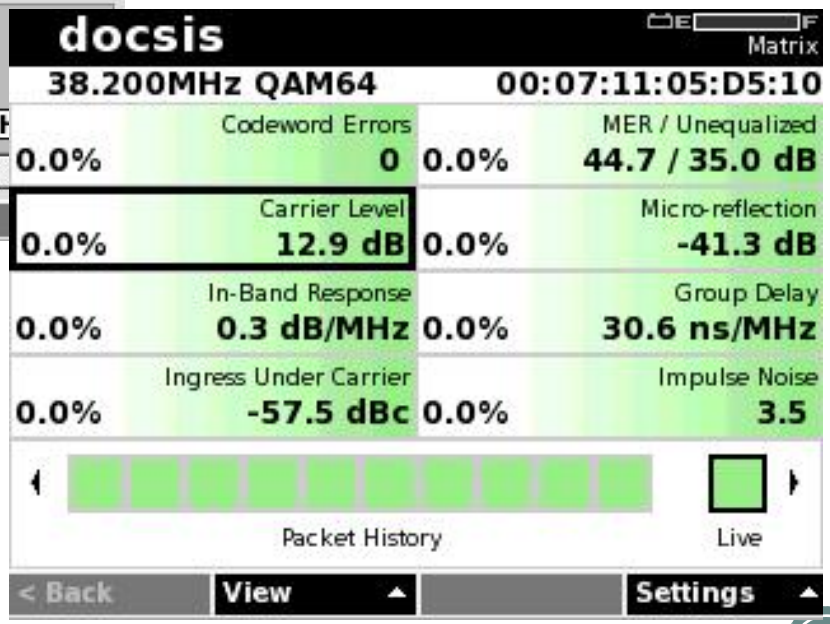
- An impaired service may or may not exhibit codeword errors and packetloss
- When troubleshooting impaired service, it is critical to view the performance of the individual upstream channels.



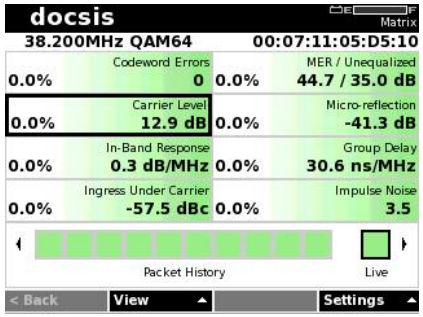
Impaired Service Troubleshooting

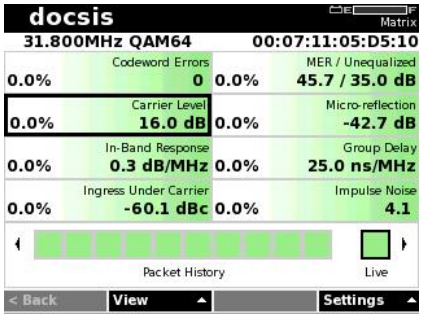


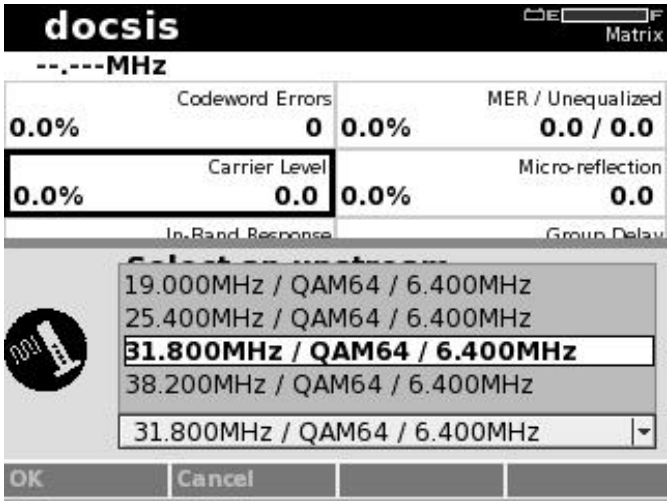


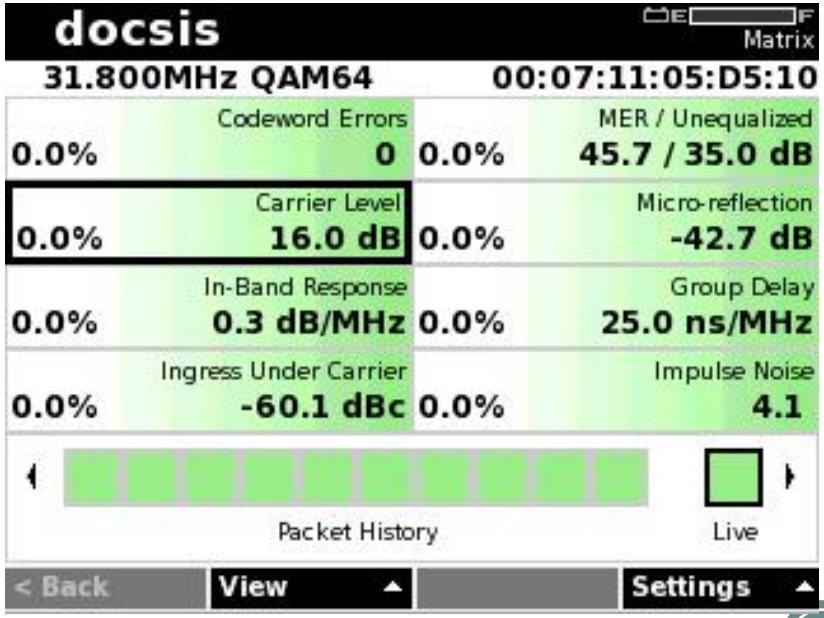


Impaired Service Troubleshooting

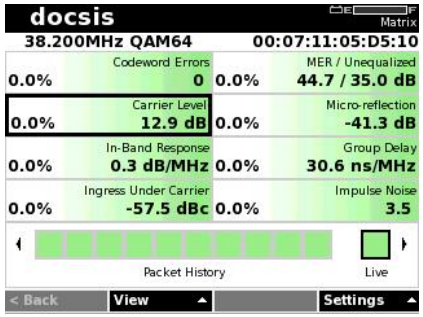


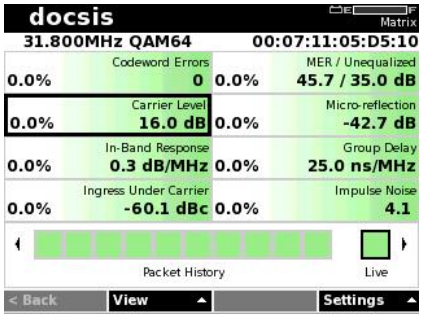


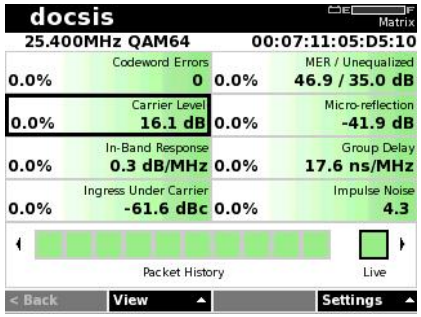


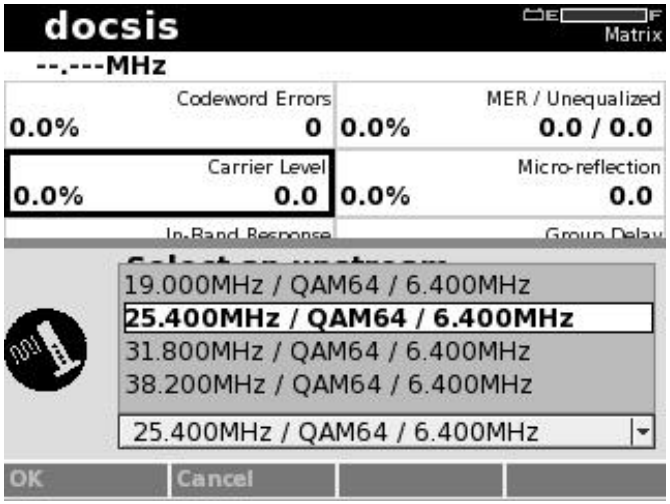


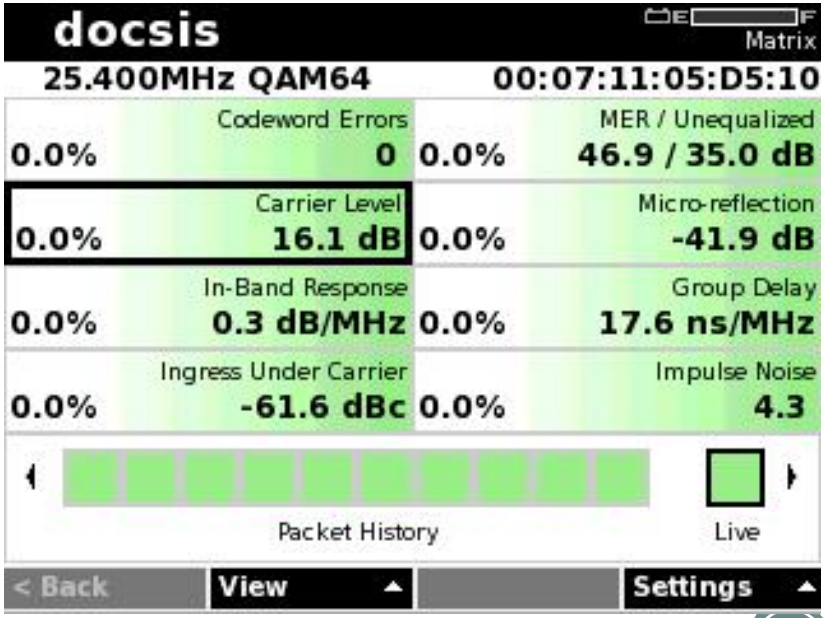
Impaired Service Troubleshooting



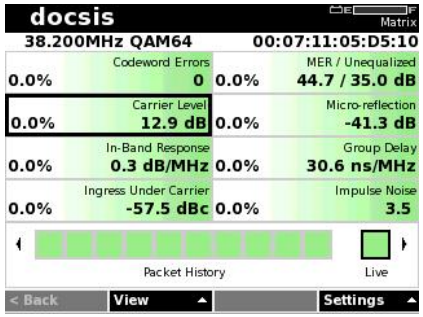


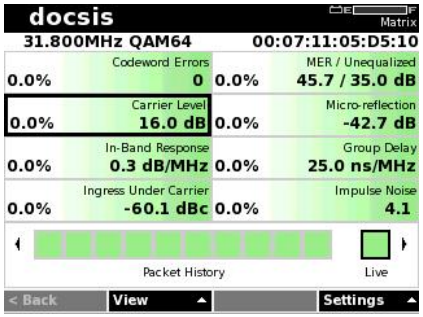


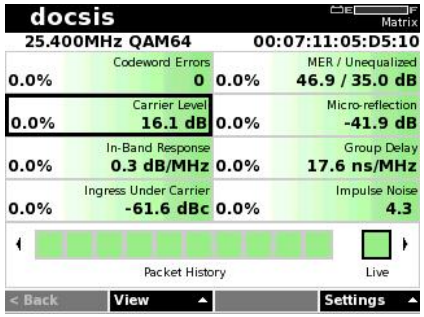


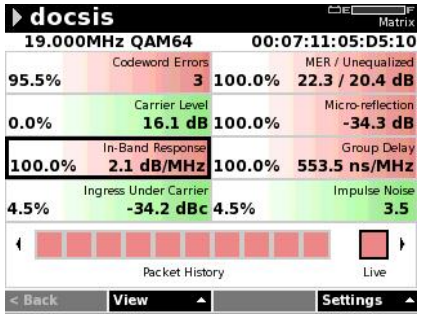


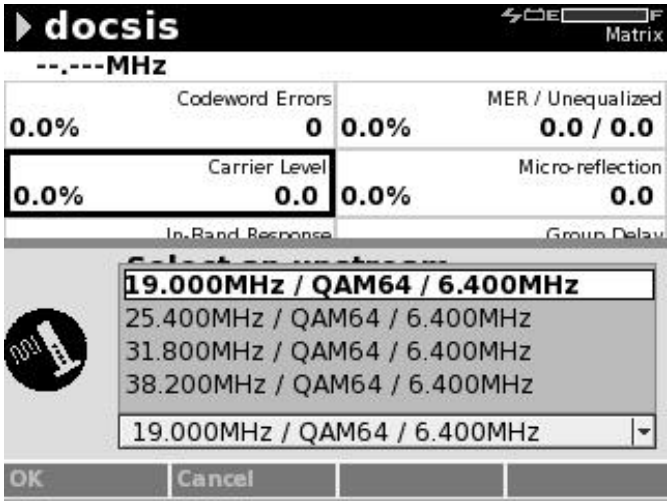
Impaired Service Troubleshooting

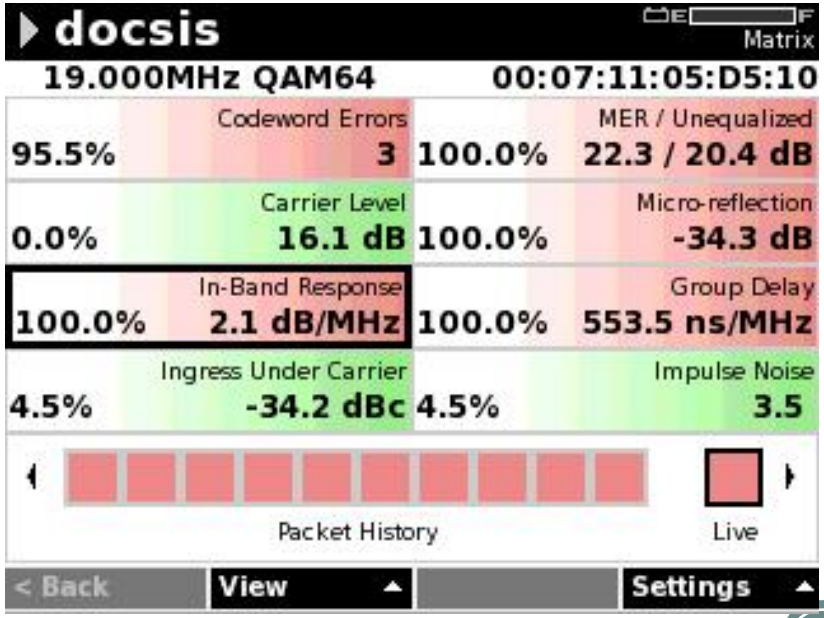




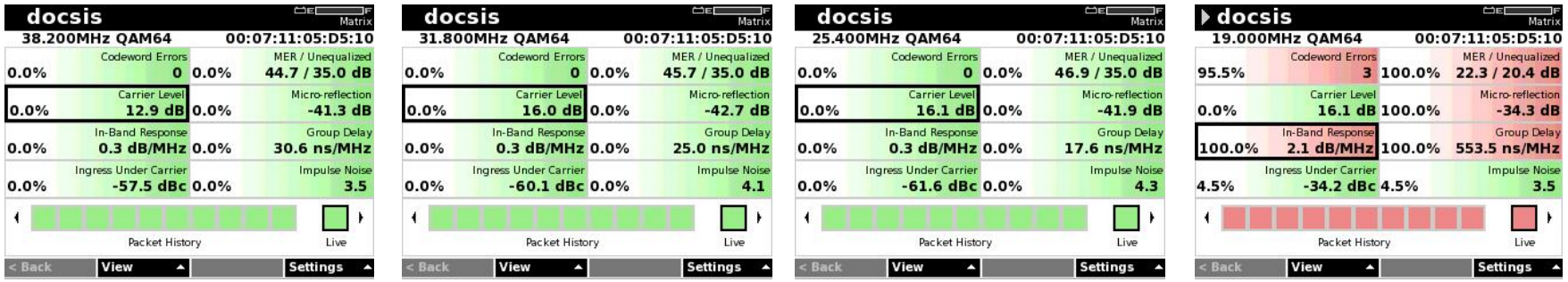








Impaired Service Troubleshooting



- Obviously there is an issue with the channel at 19 MHz

- Utilize this method to traverse the network and find the impairment causing this issue

Summary

- CMTS and SNMP data provide good troubleshooting
  - But not all of it
- DOCSIS 3.0
  - Significantly more throughput
  - Supports legacy D2.0 modems
  - D3.0 modems load balance in the upstream w/o loss of service
- Advanced test equipment is an investment that
  - Saves you time and money
  - Gets your subscribers back online and keeps them there
  - Makes you a predictable and reliable service provider
  - Seamlessly integrates headend & field – 2 places / 1 person

End Module 3 Questions?