Society of Cable Telecommunications Engineers

Maintaining an All Digital Plant

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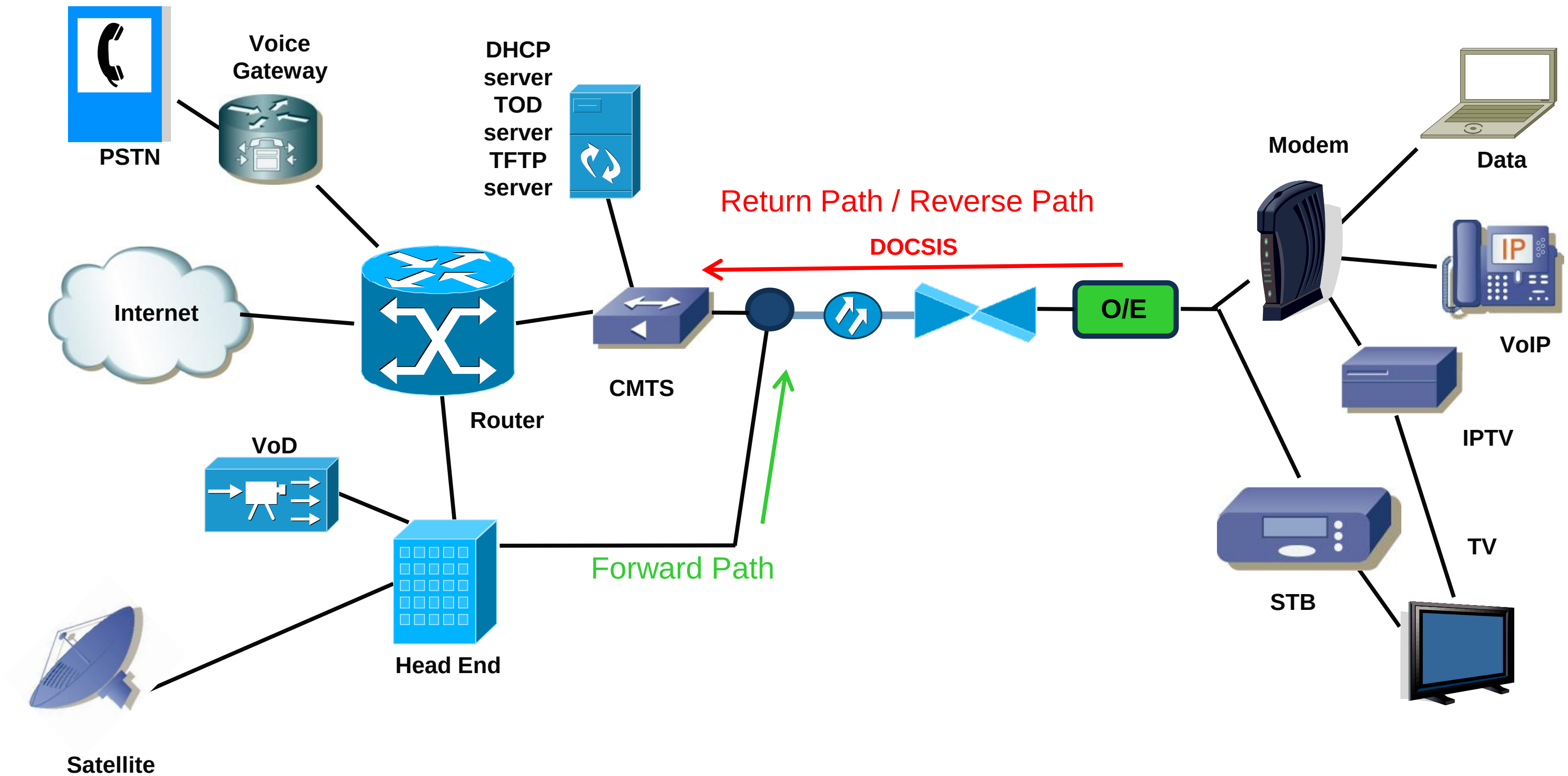
SCTE Iowa Heartland Chapter

Technical Session Overview

- Physical Layer (PHY) metrics used by operators to measure digital health
- QAM performance metrics that are used to asses the forward and return paths
- Network layer metrics used to measure digital health at the service level
- Possible Physical and Network layer causes
- DOCSIS 3.0 Existing technology
- DOCSIS 3.1 Introduction

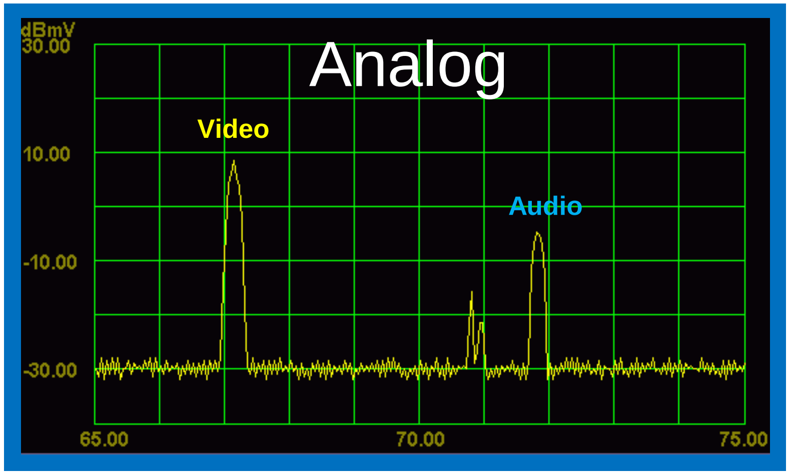
CATV HFC Network



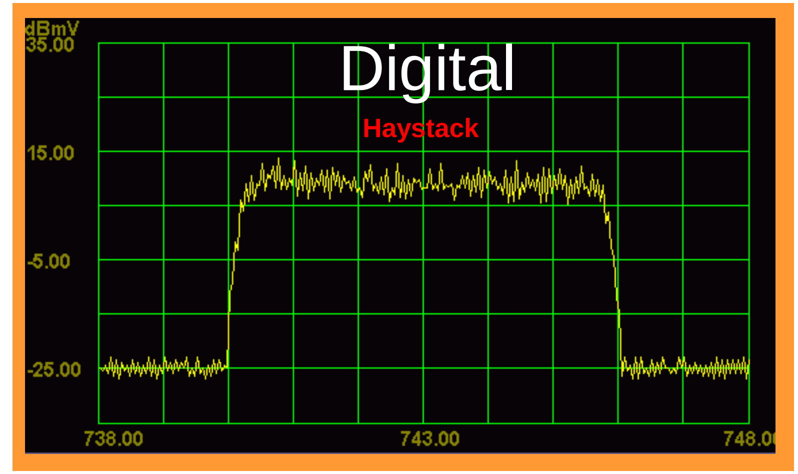
HDTV, HSD, SDV, VoIP, Broadband revenue generating services are made possible **by Digital Cable Services.**

VeEX
The Verification Experts

Analog vs. Digital



- Video and two audio channels are modulated to three separated frequencies within a 6MHz bandwidth.
- They are transmitted at different levels. Normally, a video channel is about 10dB higher than the audio channels.
- Signals are in analog nature, therefore, will tolerate more sustained noise however the picture will degrade.



- Video and audio signals are digitized to digital 0 and 1, QPSK or QAM-16/64/256 modulated, then transmit in a 6MHz band.
- Digital symbols (bits) are embedded in the Haystack.
- High digital bit rates can be transmitted in a 6MHz band for up to 40Mbps suitable for internet, VoIP, or HDTV services.
- Noise can affect the digital bit streams.
- Uses FEC (forward error correction) to correct errors caused by noise.

Digital Signal Modulation

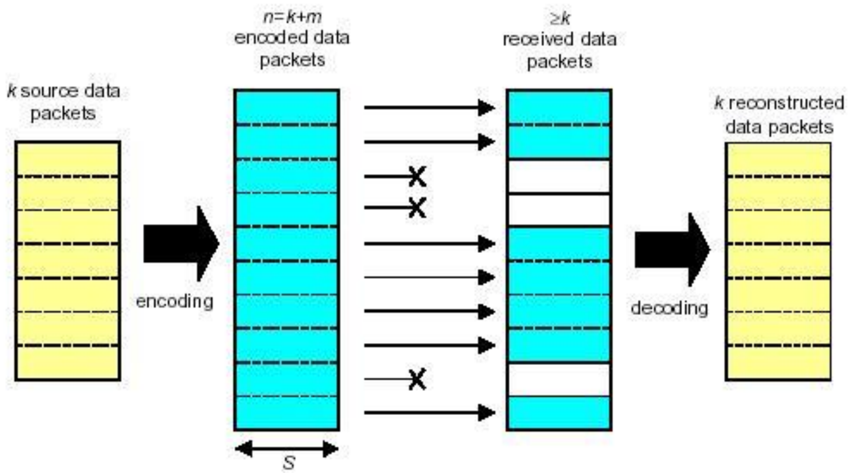
- Modulation algorithms:
  QPSK - Quadrature Phase Shift Keying
  QAM - Quadrature Amplitude Modulation

- QPSK has been used for many years and is the same as QAM-4.

- QAM modulates both phase and amplitude with more levels to achieve higher bit rate than QPSK, for example; QAM-16, -64, -128,-256, and -1024

Forward Error Correction (FEC)

- Adds additional information (data) to the original data stream
- The additional information is generated by using Reed Solomon encoder calculated from the original data stream before transmitting
- By using the same Reed Solomon decoder at the receiving end, bit errors can be detected as are called Pre-FEC errors
- By going through the error correction algorithm, some Pre-FEC errors can be corrected. When Pre-FEC errors become significant and some errors can be not corrected, they are called Post-FEC errors
- Post-FEC errors cause the poor TV quality or Internet data retransmission. (Slow Speeds!)

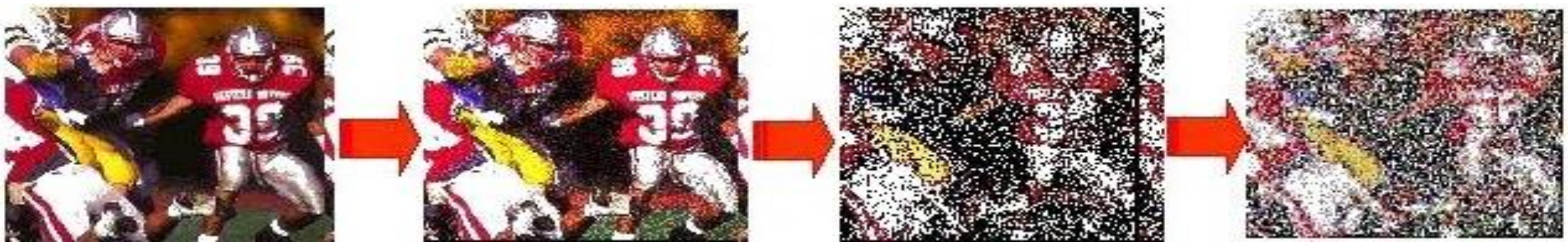


The Cliff Effect – Analog vs. Digital

- Most visible on digital transmission (Digital Cable TV, Satellite TV, over-the-air terrestrial TV)
- Image perfect until saturation
  - Sudden degradation in quality
  - Pixelization, frozen frames

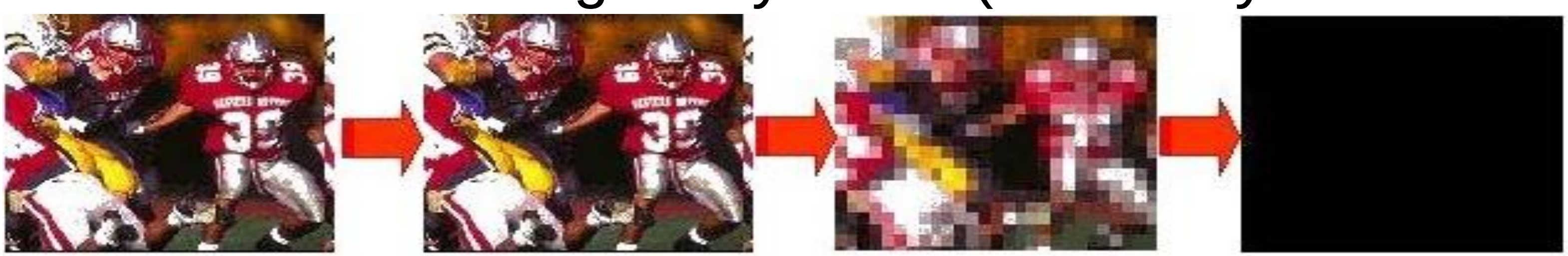
Digital TV vs. Analog TV

Effect of noise on Analog Systems (Gradually Poorer C/N)



45dB C/N 35dB C/N 25dB C/N 20dB C/N

Effect of noise on Digital Systems (Gradually Poorer MER)



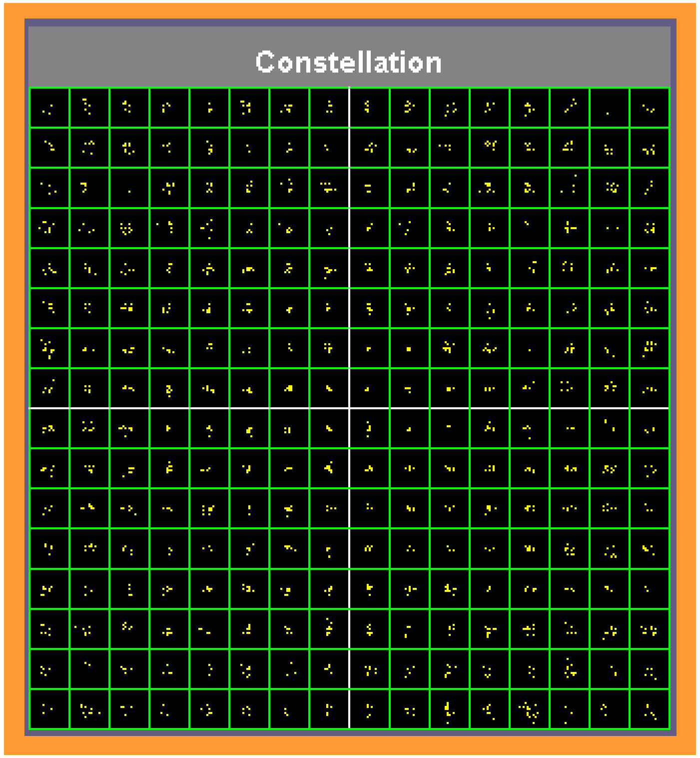
35dB MER 32dB MER 30dB MER 28dB MER

Noise has very little effect on Digital systems until the system fails completely. (Digital Channel with a QAM256)

QAM – Constellation Diagram

Quadrant 4

Quadrant 1



Quadrant 3

Quadrant 2

Each box in the constellation diagram contains one symbol

QAM64: 6 bits per symbol, 64 boxes

QAM256: 8 bits per symbol, 256 boxes

QAM 64 or QAM 256 are commonly used

	Modulation type	Std. Symbol Rate (MHz)	Max data rate (Mbps)
Annex A (8MHz)	QAM64	6.952	41.4
Annex A (8MHz)	QAM256	6.952	55.2 (440 max 8 Ch bonding)
Annex B (6MHz)	QAM64	5.057	38
Annex B (6MHz)	QAM256	5.361	43 (320M @ 8 Ch bonding) (800M @ 20 ch bonding)

DOCSIS (Data-Over-Cable Service Interface Specifications) Reverse Path / Upstream Data Rate

DOCSIS	Bandwidth (MHz)	Modulation type	Max data rate (Mbps)
1.0	3.2	QPSK	5.12
1.1	3.2	QPSK QAM-16	5.12 10.24
2.0	6.4	**QAM-16** (QAM-64)	10.24 30.72
3.0	6.4	**QAM-16** (QAM-64)	10.24 120 (4 channel bonding)
3.1		**OFDM**	10+Gbps DS 1+ Gbps US

Standard symbol rate (bandwidth): 1.28 (1.6), 2.56 (3.2), 5.12 (6.4) MHz

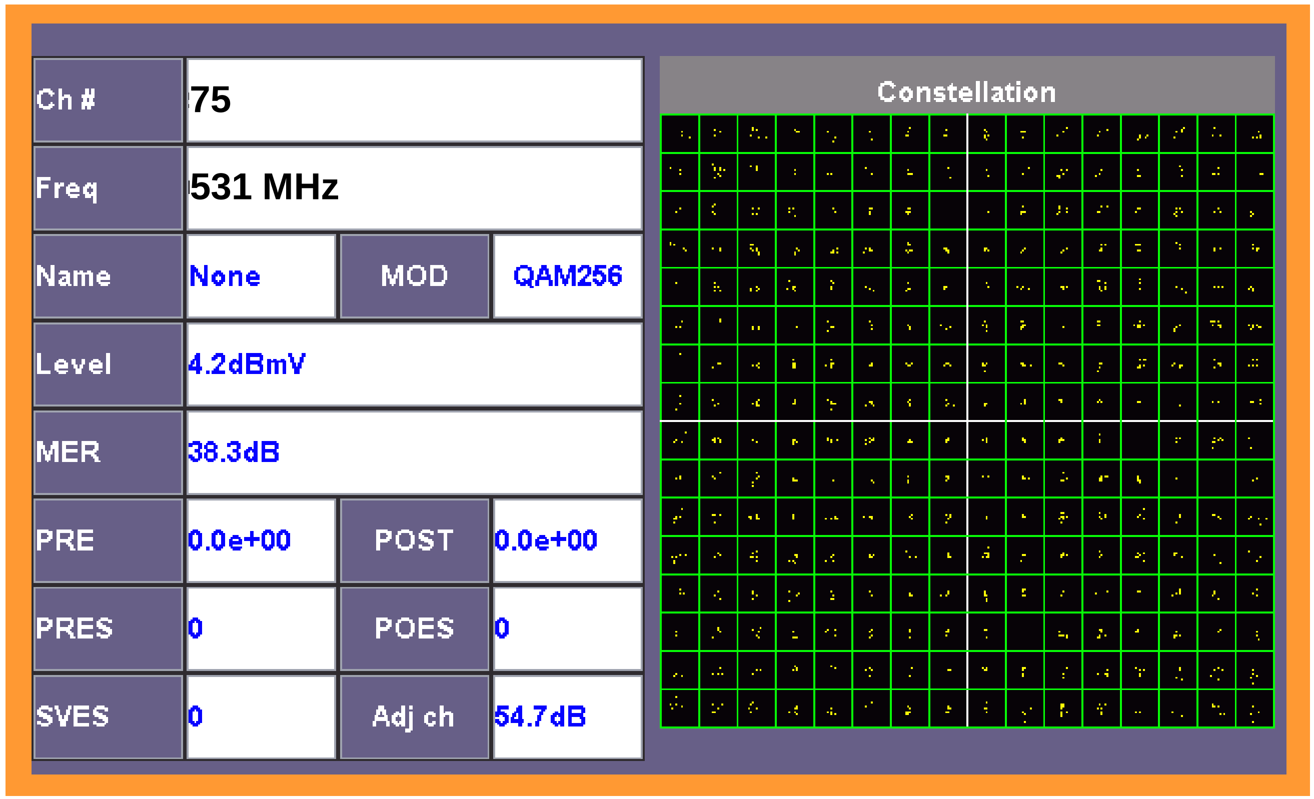
Measuring Analog Channels

Channel	4	67.25MHz	
Name	None	NTSC	
Video	9.5dBmV		
Audio 1	-4.9dBmV		
V/A1	14.3dB		
Audio 2	N/A		
V/A2	N/A		
ADJ Ch.	57.4dB		
C/N	>45dB	HUM	0.0%

CSO/CTB		
	dBc	MHz
CSO-1	-59.6	68.50
CSO-2	-59.6	68.00
CTB	-59.6	67.25
CSO-3	-59.6	66.50
CSO-4	-59.6	66.00

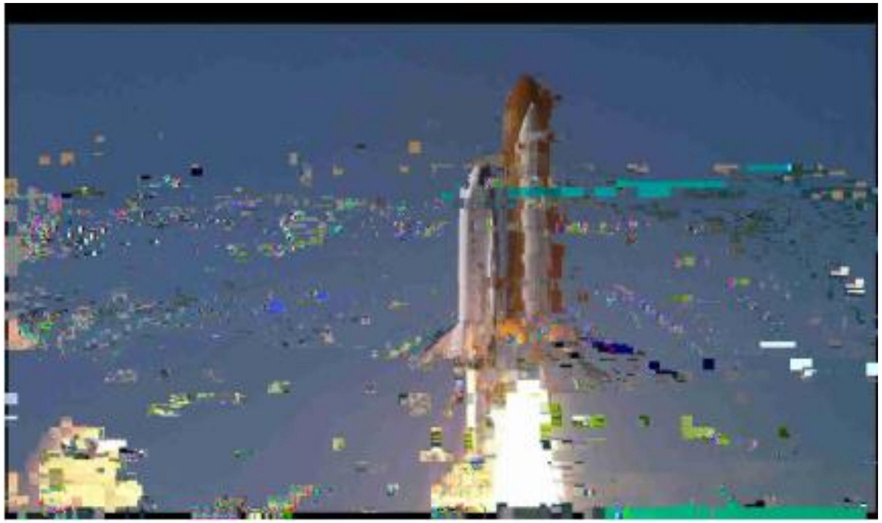
1. Video and audio signal levels
2. Carrier to Noise
3. Adjacent channel and HUM
4. More advanced meter measures CSOs and CTB

Measuring Digital Channels

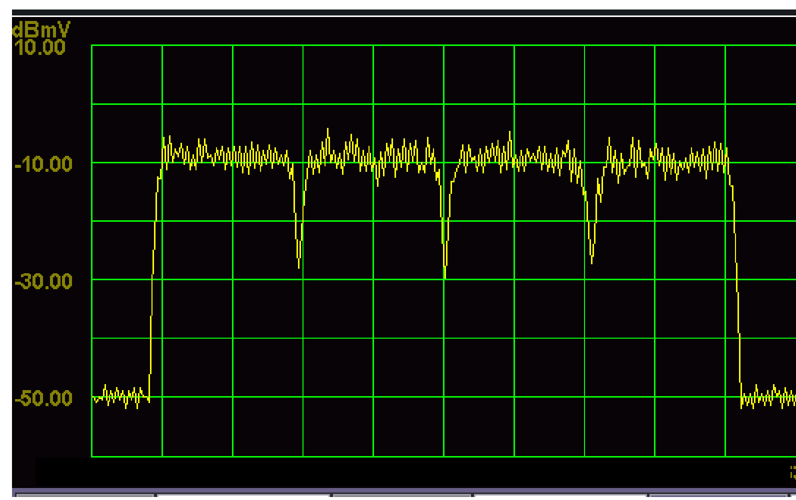


1. Signal Level, MER
2. Checks for Pre and Post FEC errors = 0

Tiling, what is the problem ?



Ch #	75		
Freq	531 MHz		
Name	None	MOD	QAM256
Level	4.6dBmV		
MER	38.6dB		

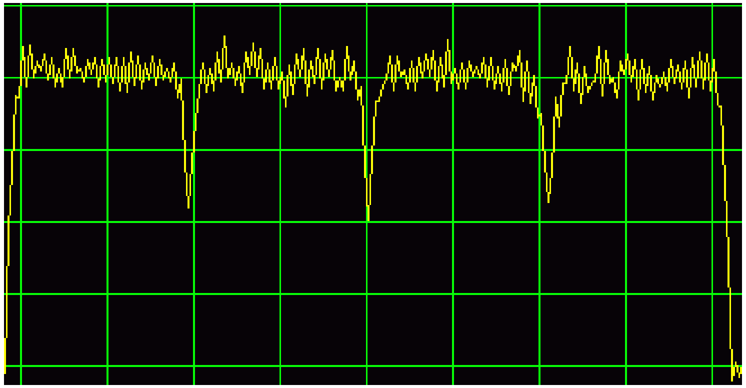


What does our signal level meter and spectrum analyzer tell us about the digitally modulated signal on Channel 75 (531 MHz)?

- ✓ Its average power level is +4.6 dBmV
- ✓ The “haystack” looks OK
- ☞ Hmmm, must be the STB!

What's missing ?

- While a signal level meter and conventional spectrum analyzer are valuable tools, they don't tell the whole story about the health of downstream and upstream digitally modulated signals.
- How, then, can one "look inside" the haystack to see what's going on?



QAM Analyzers support a suite of sophisticated measurements:

- Analog channel signal level
- Digital channel average power
- Constellation display
- Modulation error ratio (MER)
- Pre- and post-FEC bit error rate
- Adaptive equalizer graph

Some instruments support other measurements such as ;
- in-channel frequency response, group delay
- ingress or interference under the carrier
- Phase jitter
- Max amplitude change
- HUM
- EVM

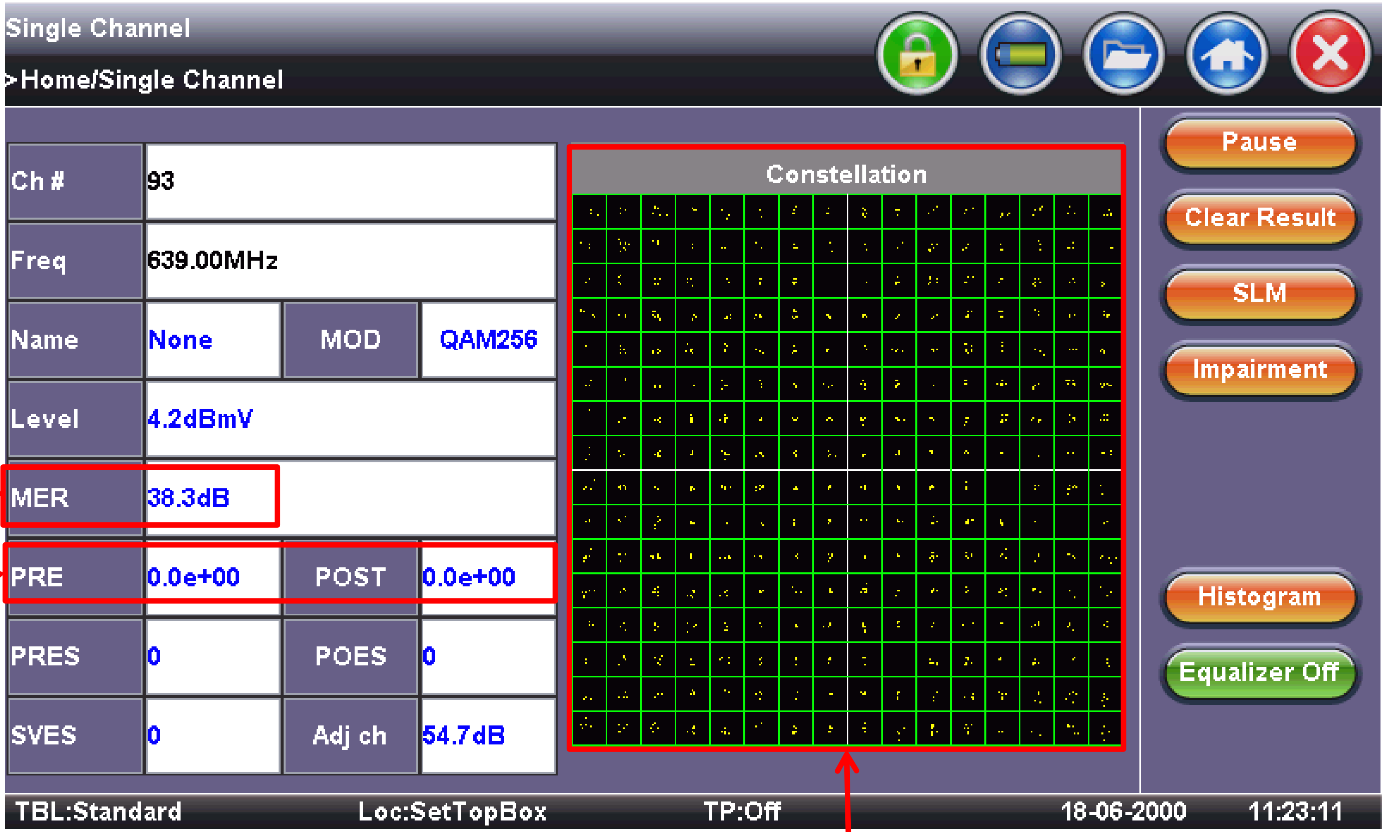
Some instruments with DOCSIS cable modem can measure the upstream channels of their;
- upstream transmit level
- IP Ping, Trace Route
- Web browser, Throughput
- VoIP, IPTV

More advanced instruments support additional measurements such as;
- Symbol rate error
- Frequency error
- Un-equalized MER
- Echo margin
- Noise margin
- Equalizer stress
- ASI MPEG
- MPEG analysis

Downstream Performance: QAM Analyzer

MER
64-QAM: 27 dB min
256-QAM: 31 dB min

Pre- and post-FEC BER



Constellation

Downstream Performance: Pre/Post-FEC BER

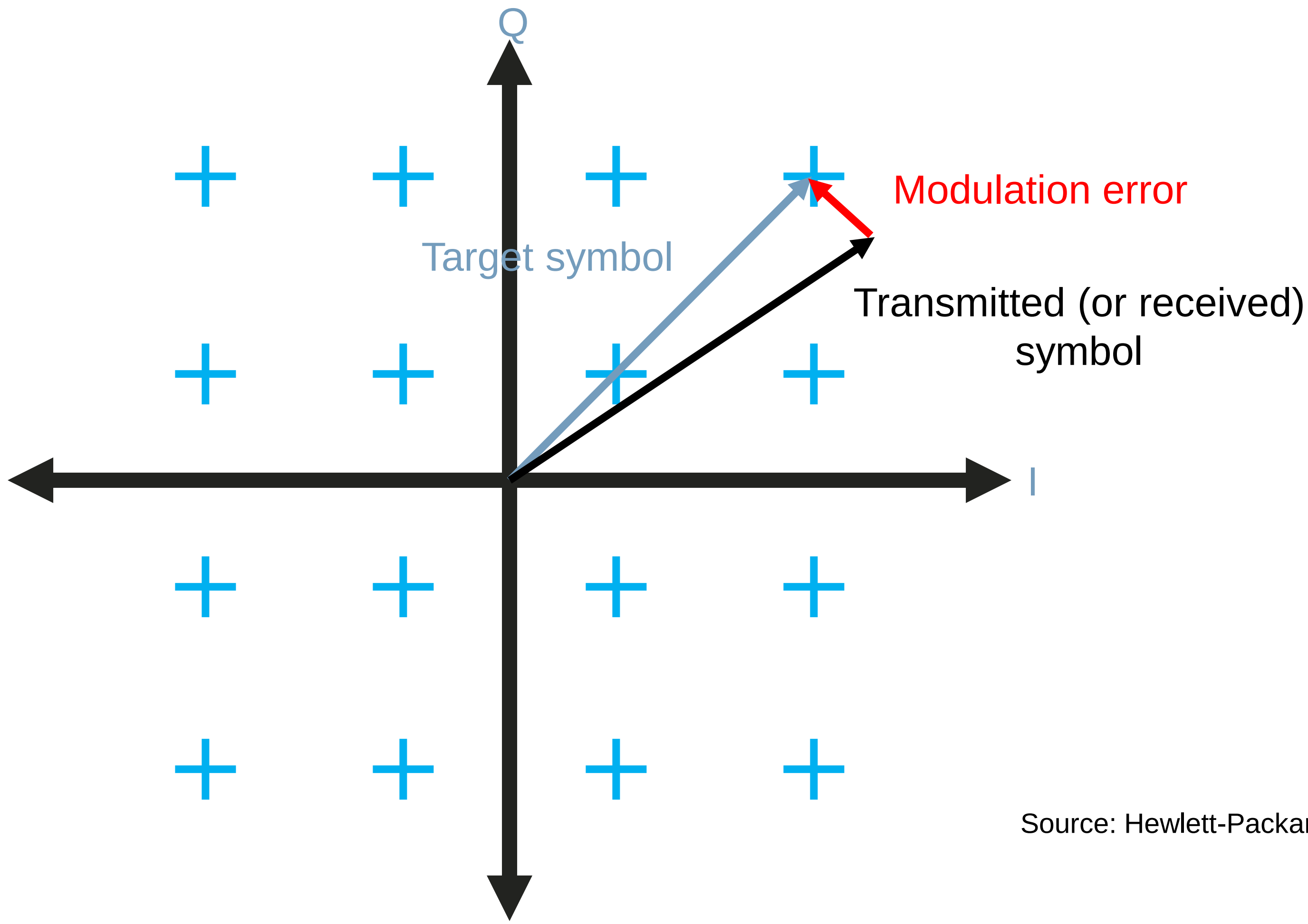
Ch #	93		
Freq	639.00MHz		
Name	None	MOD	QAM256
Level	4.6dBmV		
MER	37.9dB		
PRE	4.0e-05	POST	1.9e-05
PRES	3	POES	3
SVES	0	Adj ch	54.9dB

PRE	4.0e-05	POST	1.9e-05

In this example, digital channel power, MER and the constellation are fine, but pre- and post-FEC BER indicate a problem—perhaps sweep transmitter interference, downstream laser clipping, an upconverter problem in the headend, or a loose connection at the customer premise.

Modulation Quality: Modulation Error Ratio

Modulation error = Transmitted symbol – Target symbol

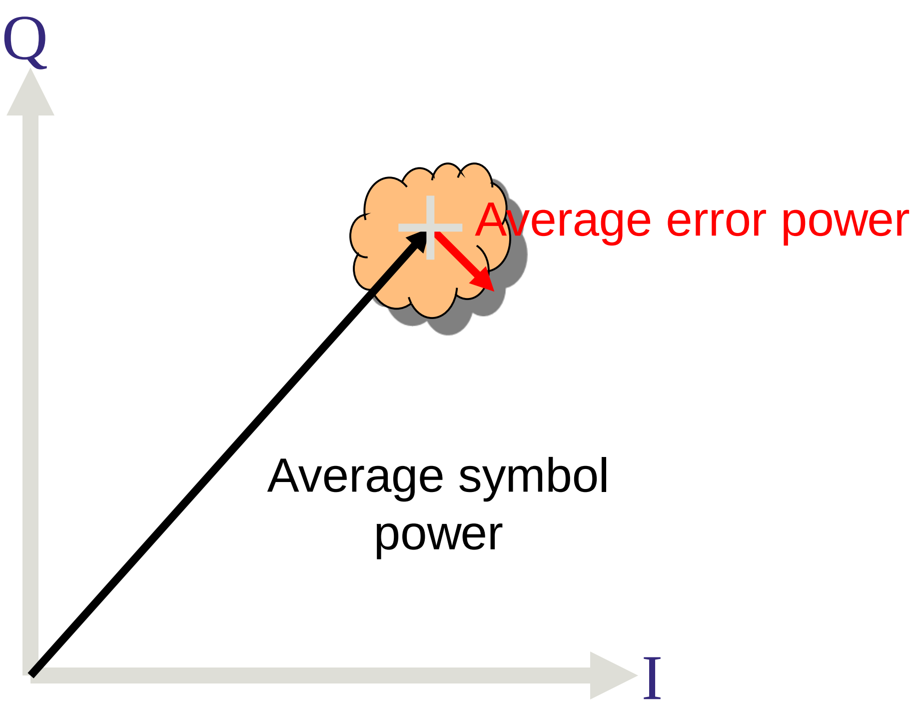


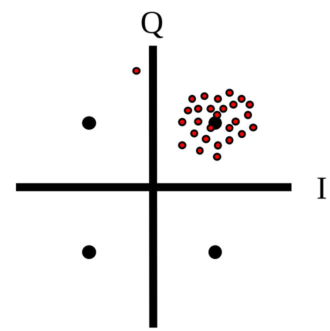
Source: Hewlett-Packard

Modulation Error Ratio

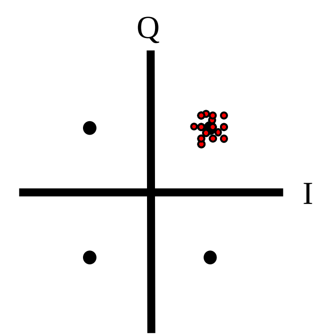
$$MER = 10\log_{10}\left[\frac{\sum_{j=1}^{N}\left(I_j^2 + Q_j^2\right)}{\sum_{j=1}^{N}\left(\delta I_j^2 + \delta Q_j^2\right)}\right]$$

MER = 10log(average symbol power/average error power)





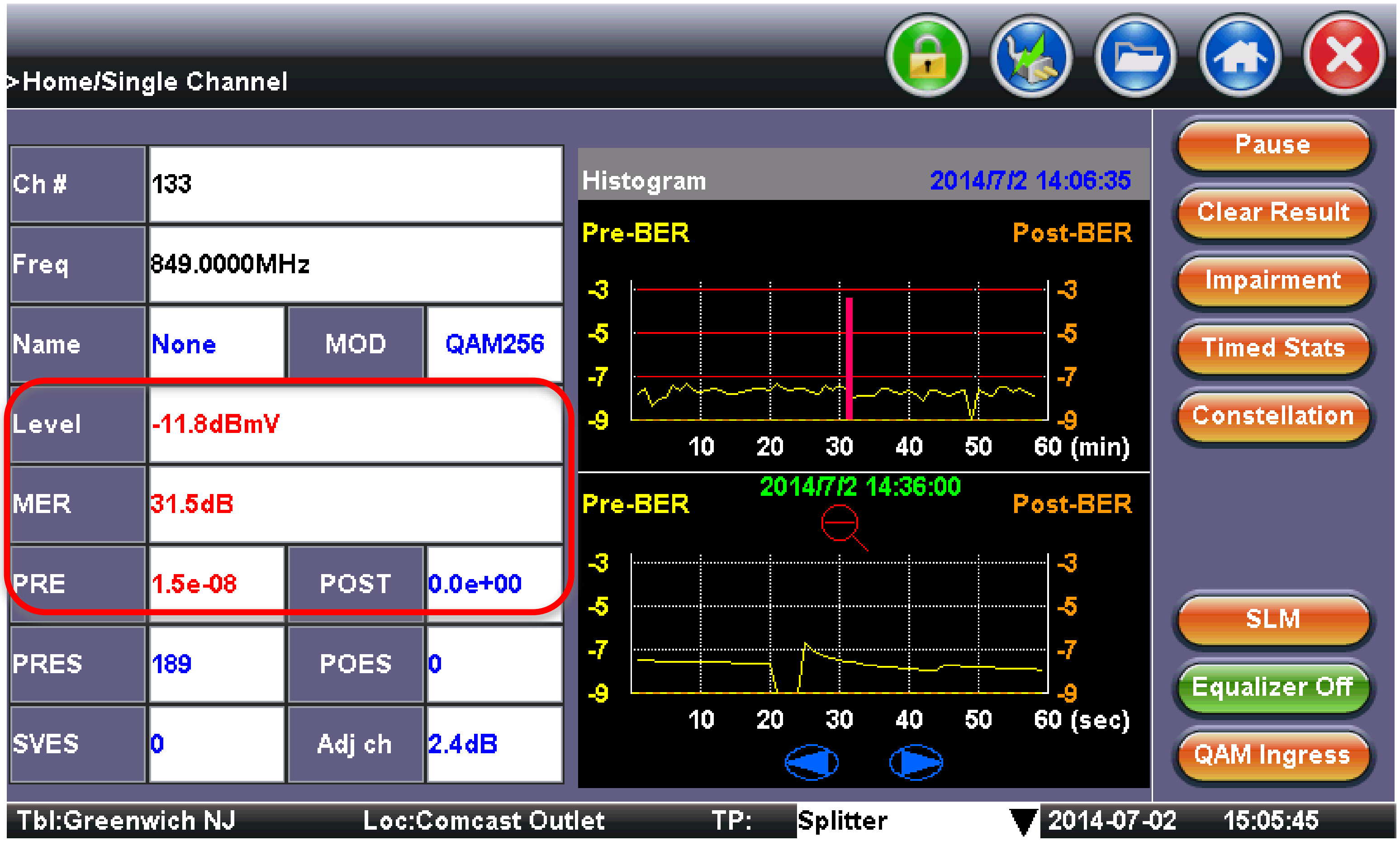
A large “cloud” of symbol points means low MER—this is not good!



A small “cloud” of symbol points means high MER—this is good!

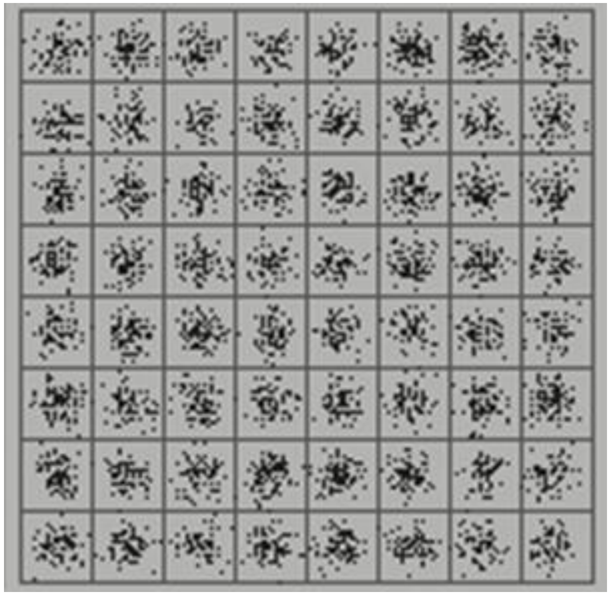
Source: Hewlett-Packard

Intermittent Troubles

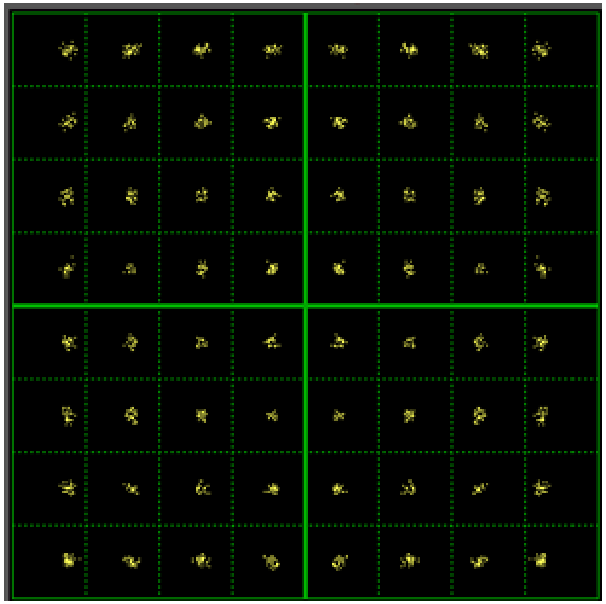


Constellation Display

Poor CNR or low MER

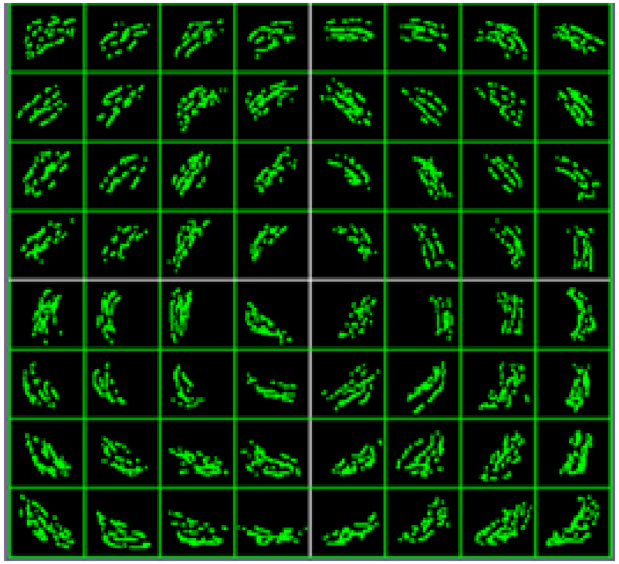


I-Q imbalance

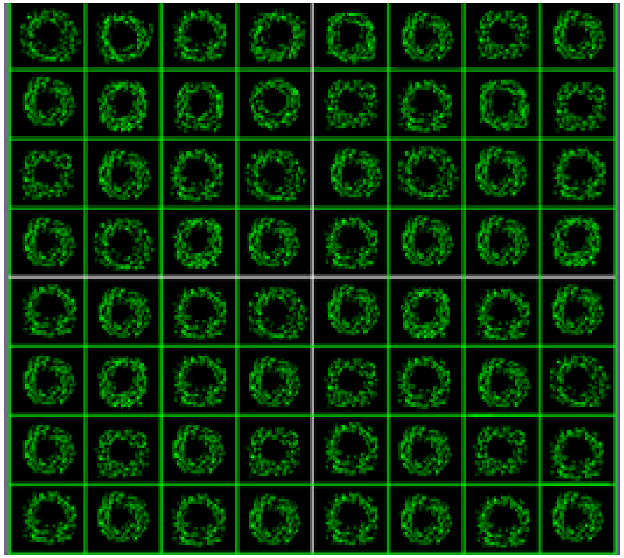


Constellation Display

Phase Jitter/Noise

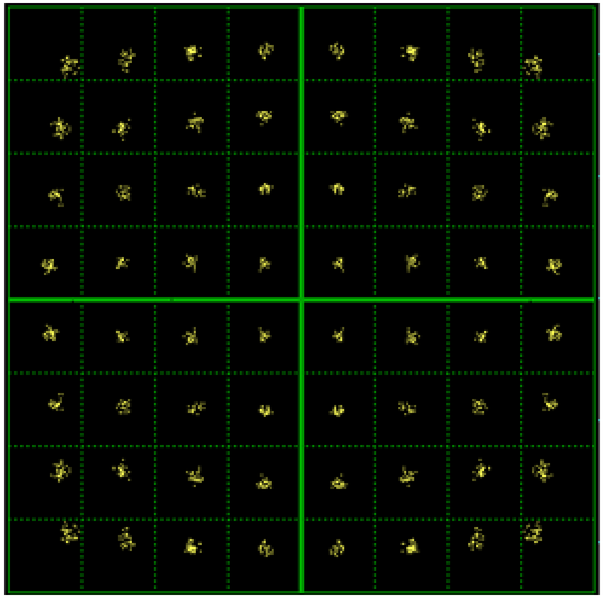


Coherent Interference

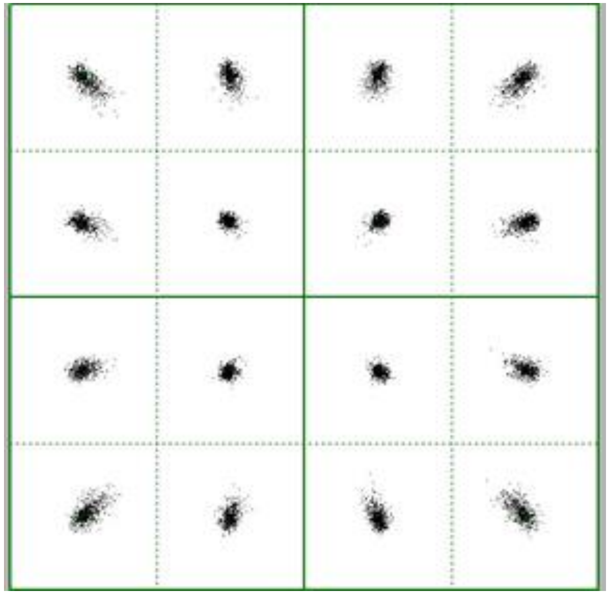


Constellation Display

Gain compression

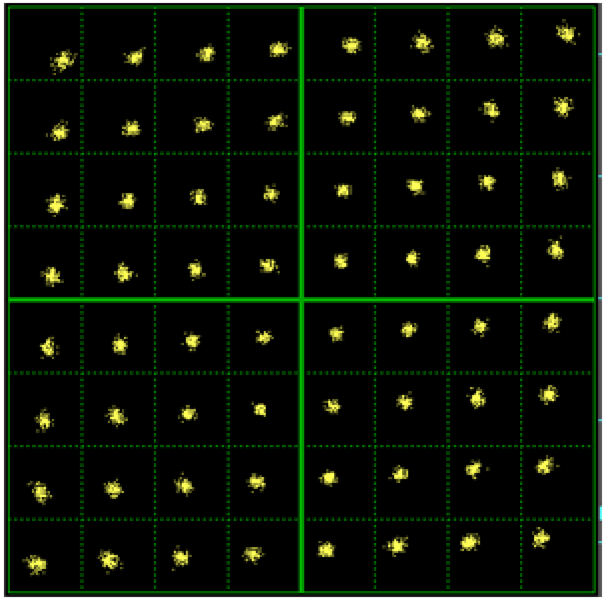


Gain compression
Upstream Laser Clipping

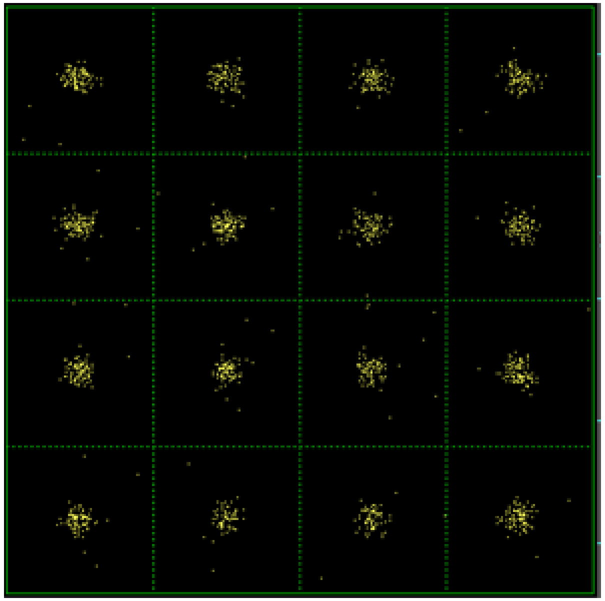


Constellation Display

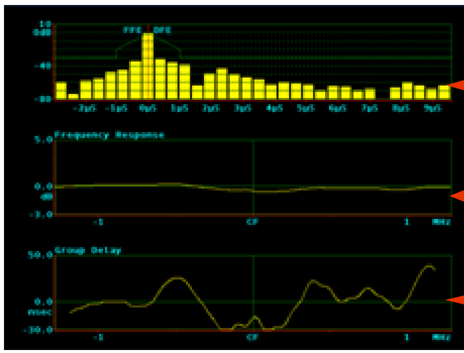
Quadrature distortion

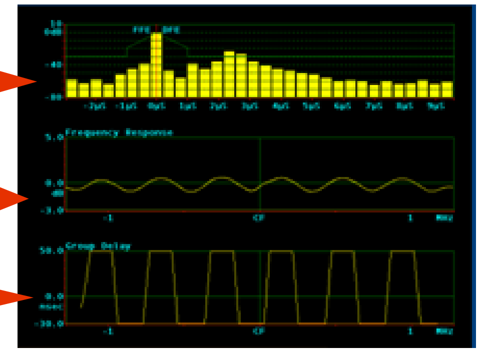


Zoom function



Linear distortions

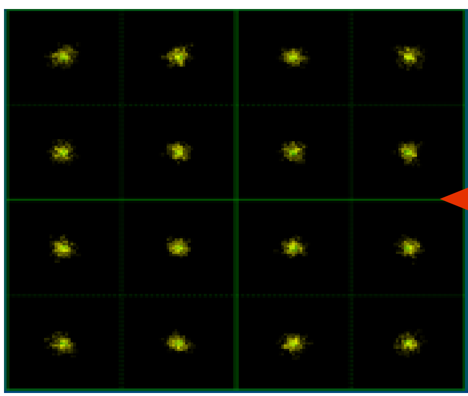


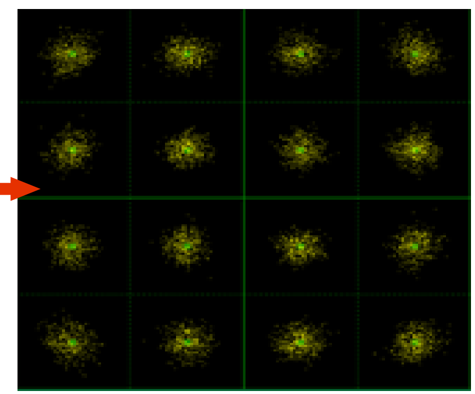


Equalizer graph

In-channel
frequency response

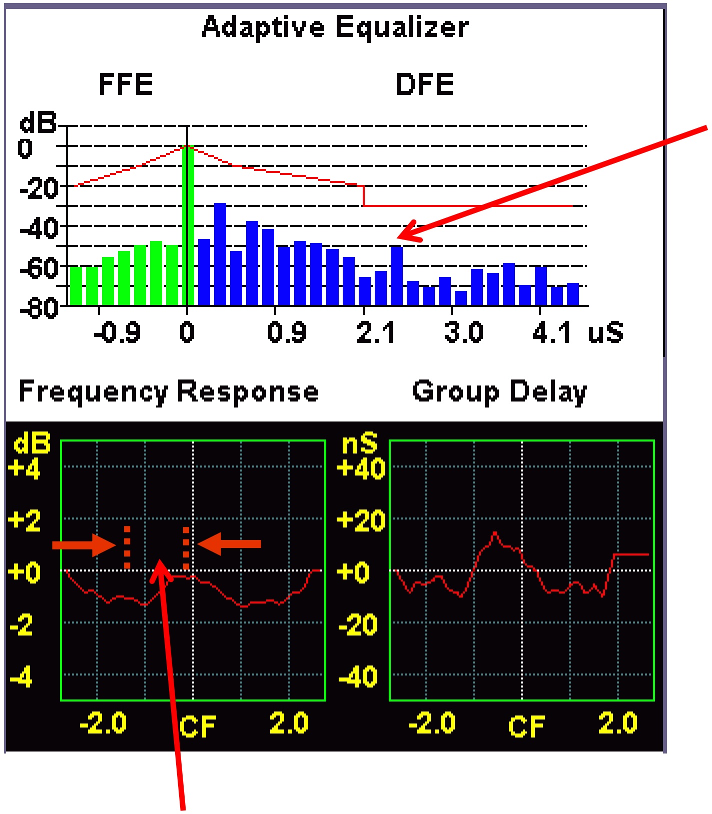
In-channel
group delay





Un-equalized-equivalent
constellation and MER

Linear distortions



Micro-reflection at about 2.5 µs (2500 ns):
Assume ~1 ns per ft., 2500/2 = 1250 ft
(actual is 1.17 ns per ft: (2500/1.17)/2 = 1068 ft)

Frequency response ripple ~400 kHz p-p:
Distance to fault = 492 x (.87/.400) = 1070 ft.

Linear Distortions: In-depth understandings

ECHO MARGIN

The Coefficients of the Equalizer will also reveal the presence of an Echo, (a.k.a. micro-reflections). The Equalizer will cancel such an echo, and in doing so, the equalizer coefficient which corresponds to the delay of the echo will be much higher than the surrounding ones, “it sticks out of the grass”. The relative amplitude of this coefficient is an indication of the seriousness of the echo, and its position gives the delay of the echo, hence its roundtrip distance.

The Echo Margin is the smallest difference between any coefficients and a template defined by Cablelabs, as a safety margin before getting too close to the “cliff effect”. It is normal to notice relatively high coefficients close to the Reference as this corresponds to the filters in the modulator / demodulator pair and to the shape of QAM signal.

Linear Distortions: In-depth understandings

EQUALIZER STRESS

- The Equalizer Stress is derived from the Equalizer coefficients and indicate how much the Equalizer has to work to cancel the Linear distortions, it is a global indicator of Linear distortions. **The higher the figure, the less stress**.

NOISE MARGIN

- We all know that the lower the MER, the larger the probabilities of errors in transmission (Pre-FEC and then Post-FEC); the MER degrades until errors are so numerous that adequate signal recovery is no more possible (cliff effect). As Noise is a major contributor to the MER, we define Noise Margin as the amount of noise that can be added to a signal (in other words, how much we can degrade MER) before get dangerously close to the cliff effect. Noise is chosen because on the one hand it is always present, and on the other hand it is mathematically tractable. Other impairments, such as an Interferer, are not easily factored into error probabilities.

Linear Distortions: In-depth understandings

EQUALIZED MER vs. UN-EQUALIZED MER

The MER (Modulation Error Ratio) is the ratio of the QAM signal to Non-Linear distortions of the incoming QAM signal. The MER should have included the Linear distortions to indicate the health of the signal; but the QAM demodulator cannot operate properly without the Equalizer and the Equalizer uses the MER as a tool to adaptively cancel the Linear distortions. Consequently it is convenient to distinguish the MER (non-linear distortions only) from an Un-equalized MER (non-linear and linear distortions), the Un-equalized MER is calculated from the MER and Equalizer Stress.

The Un-equalized MER is always worst than the MER. A small difference between the two indicates little Linear distortions, a large difference shows that there are strong Linear distortions. Even if the Linear distortions are cancelled by the Equalizer, we have to keep in mind that the Equalization is a dynamic process as it tracks Linear distortions by trial and error even after converging. The larger the Linear distortions the larger the tracking transients are, hence more probability of transmission error (pre-FEC or Post-FEC BER).

Linear Distortions: In-depth understandings

PHASE JITTER

Phase Jitter is caused by instability of the carrier of the QAM signal at the demodulator. This instability could be found at the QAM modulator and up-converter or in the QAM receiver (Local Oscillators used in frequency conversions). The phase jitter introduces a rotation of the constellation, where the symbols clusters elongate and get closer to the symbol's boundary. Eventually some symbols will cross the boundary and cause an error in transmission. The QAM demodulator has a Phase lock loop to track phase variations of the carrier; it tracks easily long term drift as well as some short terms variations (up to 10 or 30 kHz) but it cannot track very fast variations above its loop response. So in a QAM demodulator, the wideband jitter is more damageable than short term jitter.

Linear Distortions: Recommendations

TABLE 1 DOCSIS SPECIFICATIONS, DOWNSTREAM

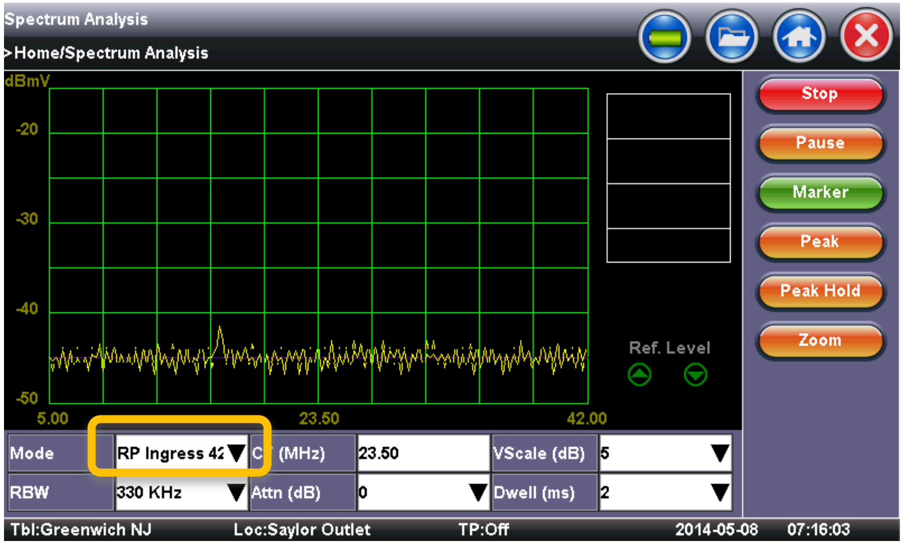
Assumed Downstream RF Channel Characteristics DOCSIS Radio Frequency Interface Specifications	
Parameter	**Value**
Carrier-to-noise ratio in a 6 MHz band	Not less than 35 dB
Carrier-to-composite triple beat distortion ratio	Not less than 41 dB
Carrier-to-composite second order distortion ratio	Not less than 41 dB
Carrier-to-any other discrete interference	Not less than 41 dB
Amplitude ripple	3 dB within the design bandwidth
Group delay ripple in the spectrum occupied	75 ns within the design bandwidth
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
Carrier hum modulation	Not greater than -26 dB (5%)

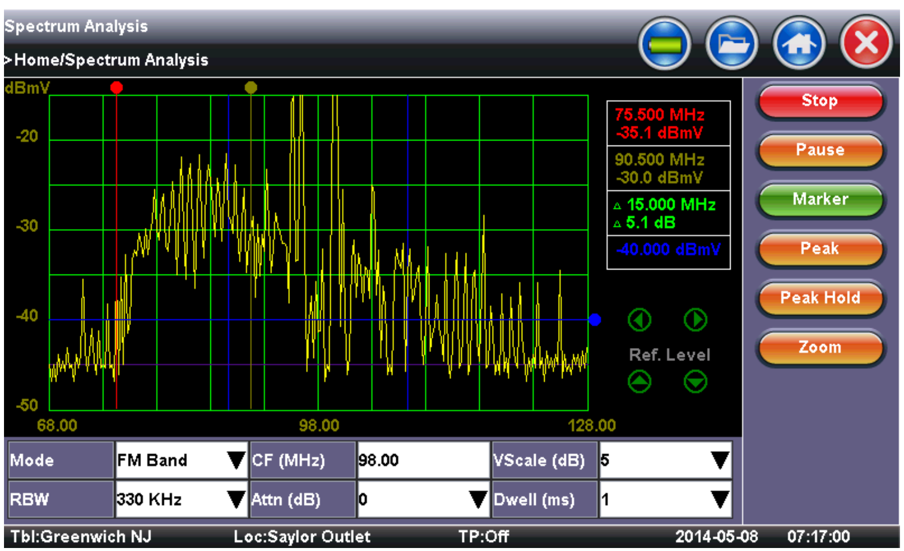
TABLE 2 DOCSIS SPECIFICATIONS, UPSTREAM

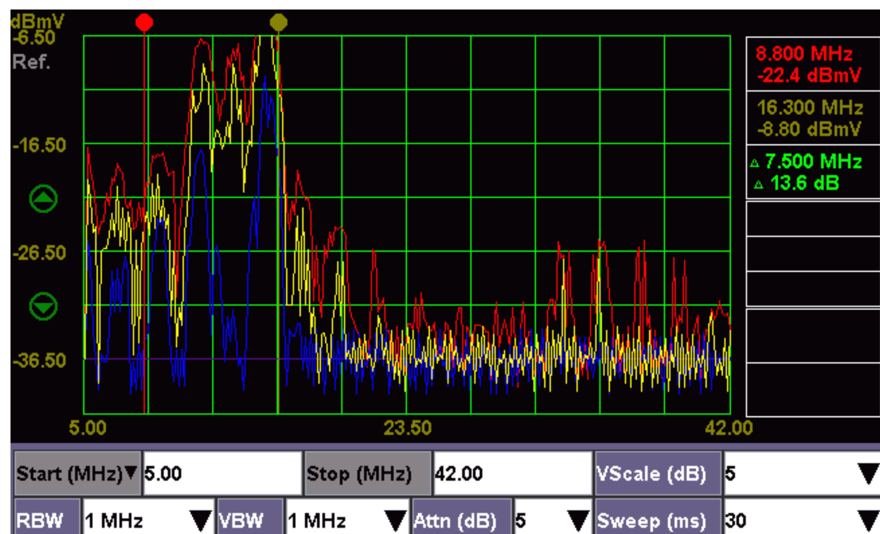
Assumed Upstream RF Channel Characteristics DOCSIS Radio Frequency Interface Specifications	
Parameter	**Value**
Carrier-to-interference plus ingress ratio	Not less than 25 dB
Amplitude ripple	0.5 dB / MHz
Group Delay ripple	200 ns / MHz
Micro-reflections bound for dominant echo	-10 dBc @ <= 0.5 µs -20 dBc @ <= 1.0 µs -30 dBc @ > 1 .5 µs

Other Factors Harm QAM…

Ingress!!







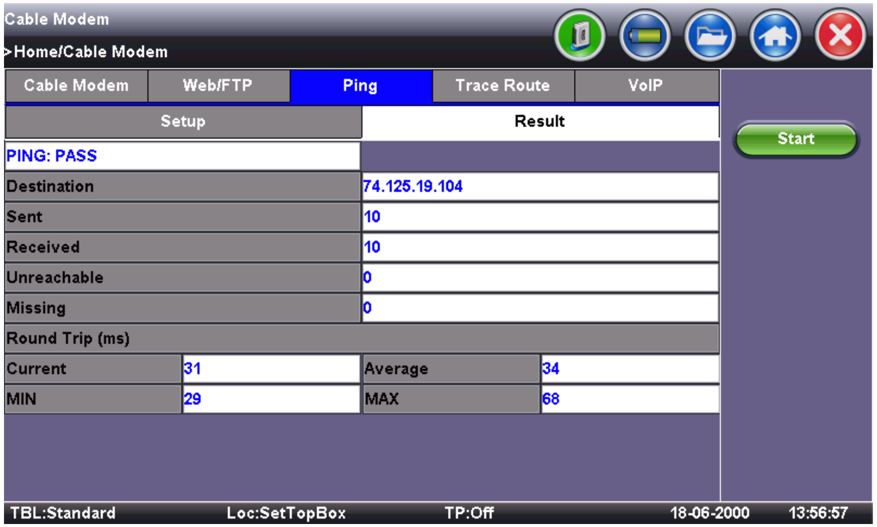
Measurement and Troubleshooting Summary

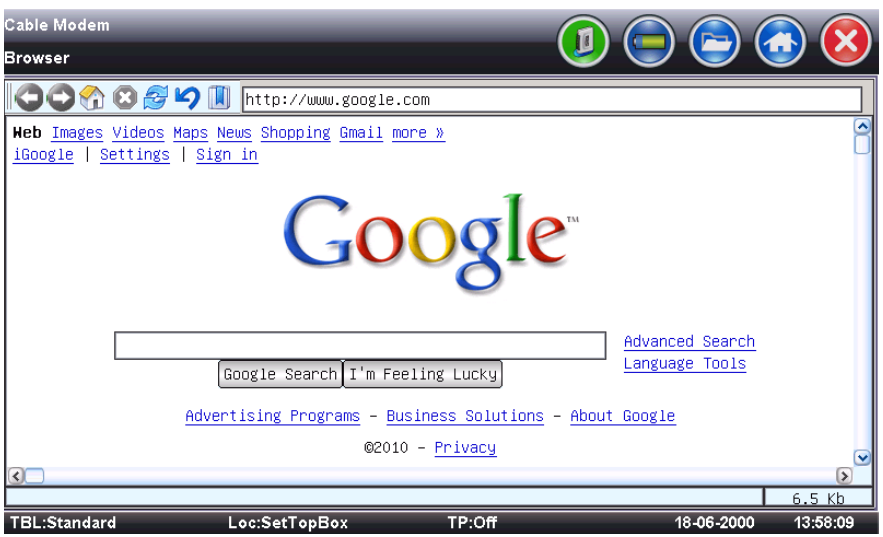
- Constellation display
  - Low MER or CNR
  - Phase noise
  - I-Q imbalance
  - Coherent interference (ingress, beats)
  - Gain compression
  - Laser clipping
  - Sweep transmitter interference
- Pre- and post-FEC BER
  - Sweep transmitter interference
  - Laser clipping
  - Loose connections
  - Low MER or CNR
- Equalizer graph
  - Micro-reflections

- Linear distortions
  - Adaptive equalizer graph
  - In-channel frequency response
  - In-channel group delay
  - Constellation display (unequalized)
  - MER (unequalized)
- Transient impairments
  - Pre- and post-FEC BER
  - Constellation display zoom function
  - Upstream packet loss
- Signal level problems
  - Analog TV channel signal level
  - Digital channel power
  - Upstream transmit level
  - Constellation display

Up/Downstream Performance – Cable Modem

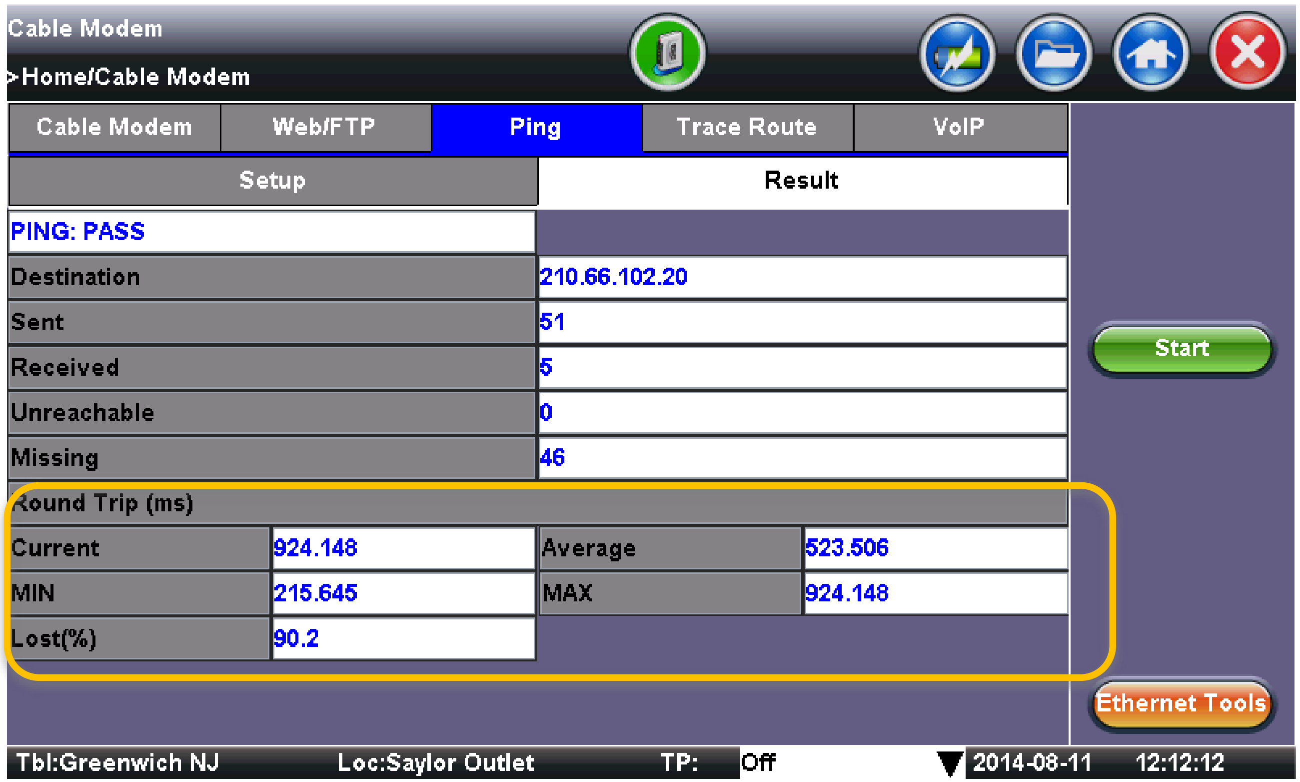
What Digital Impairments do to Data





- Proper IP connection and throughput should be verified at the cable modem service location.
- Web Browsing
- Ping
- Speed Tests

Obvious Packet Loss Issue

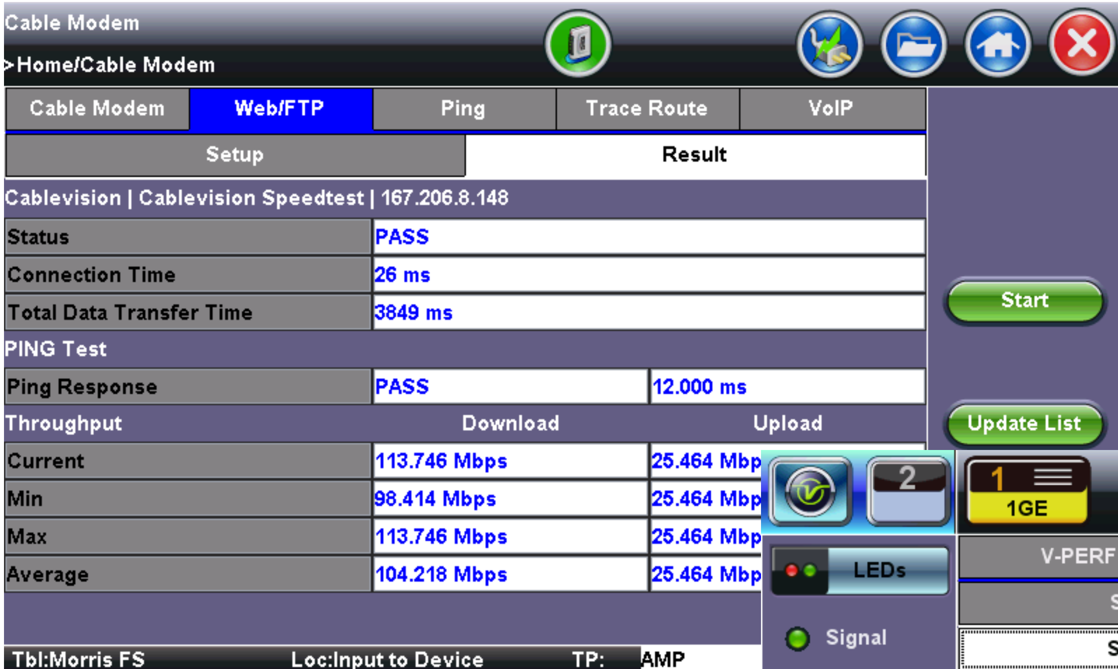


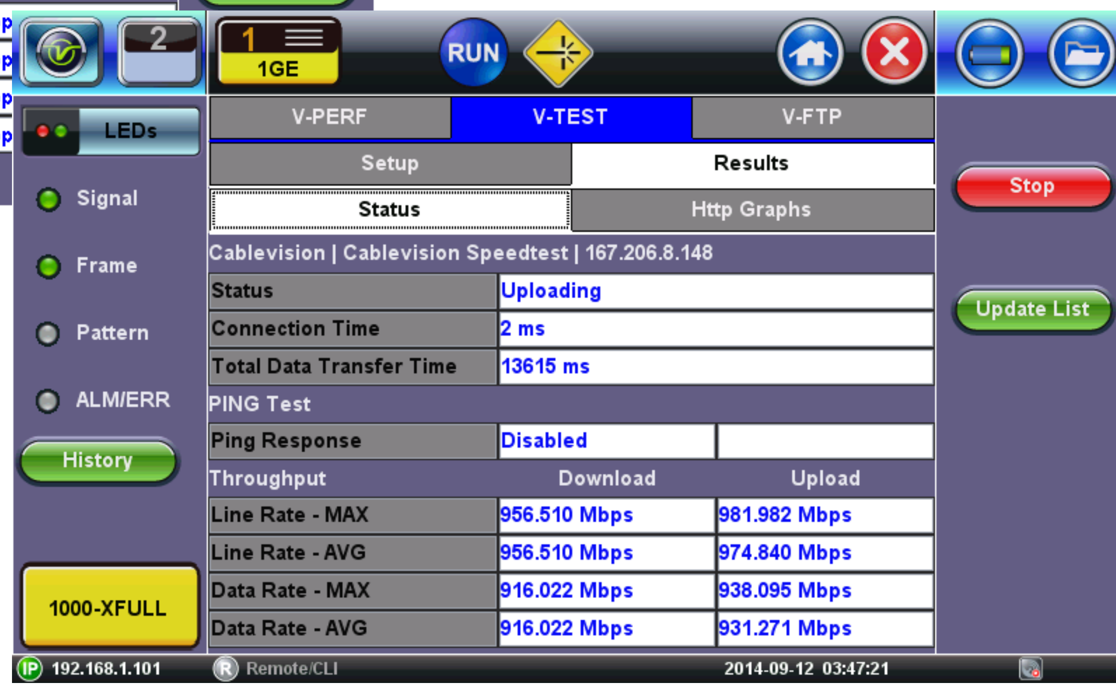
- Many Lost Packets
- Out of Control Delay

Modem Bonding Group Performance

Speed Testing

Verify Down/Upload Performance

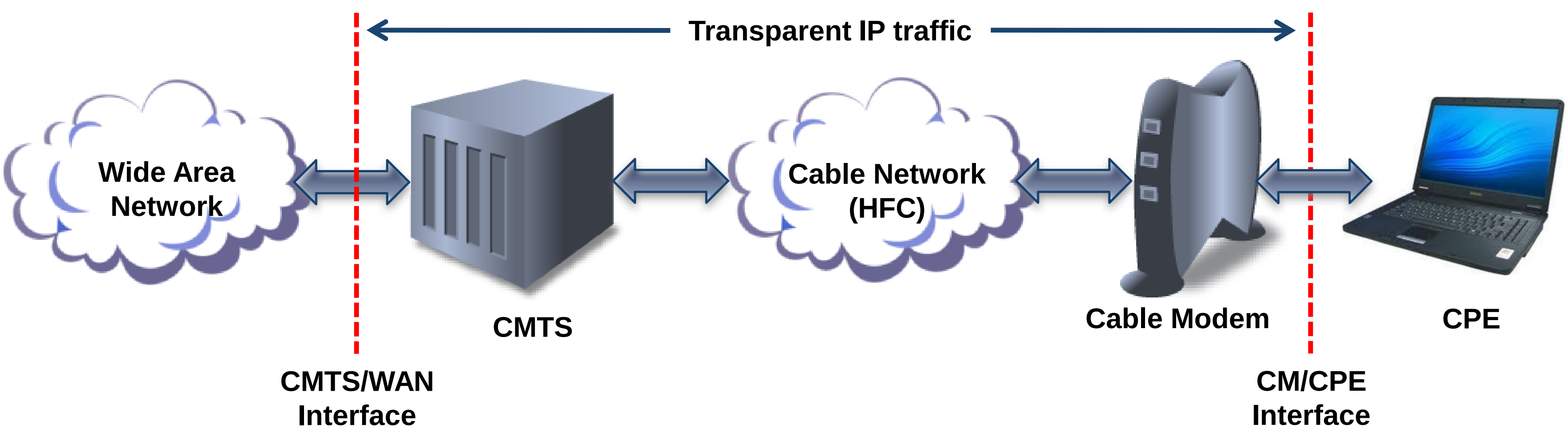




Cable Modem or Ethernet Interface

DOCSIS 3.0 existing technology

- DOCSIS system
  - Enables transparent bi-directional of Internet Protocol (IP) traffic, between the cable system headend and customer location
- DOCSIS specification
  - Defines PHY & MAC layer protocols for communication & Ethernet frame transport between CMTS & CM
- DOCSIS network comprises:
  - Cable Modem Termination System (CMTS) located at the headend
  - Cable Network - an all-coaxial or hybrid-fiber/coax (HFC) cable network
  - Cable Modem (CM) located at the Customer Premise



DOCSIS 1.0 (1999)

- 1st products certified (CableLabs started project in 1996)
- Open standard for high-speed data over cable
- Modest security, Best-effort service

DOCSIS 1.1 (2000)

- Quality-of-Service (QoS) service flows
- Baseline Privacy Interface (BPI+) Certificates
- Improved privacy & encryption process

DOCSIS 2.0 (2002)

- Improved throughput & robustness on Upstream
- 64/128 QAM modulation & higher symbol rates with FEC
- Programmable interleaving to upstream channels

DOCSIS 3.0 (2006)

- Channel bonding (4U/4D) for increased capacity
- IPv6 support
- Improved security (AES)

DOCSIS 3.0

Business Drivers

- Support high bandwidth services of 50 to 100Mbps
- Migrate existing customers to higher tier services
- Better and more robust data encryption
- Provide more IP address space using IPv6
- Limit and reduce node splits
- Reduce overall cost of CMTS ports
  - Independent scalability of upstream & downstream

DOCSIS 3.0

Higher Bandwidth Applications

Web 2.0

Digital Photos

Home Networks

Gaming

Data & VoIP

MP3 WMV

VOD DVR/PVR

DVD Blu-ray

You Tube

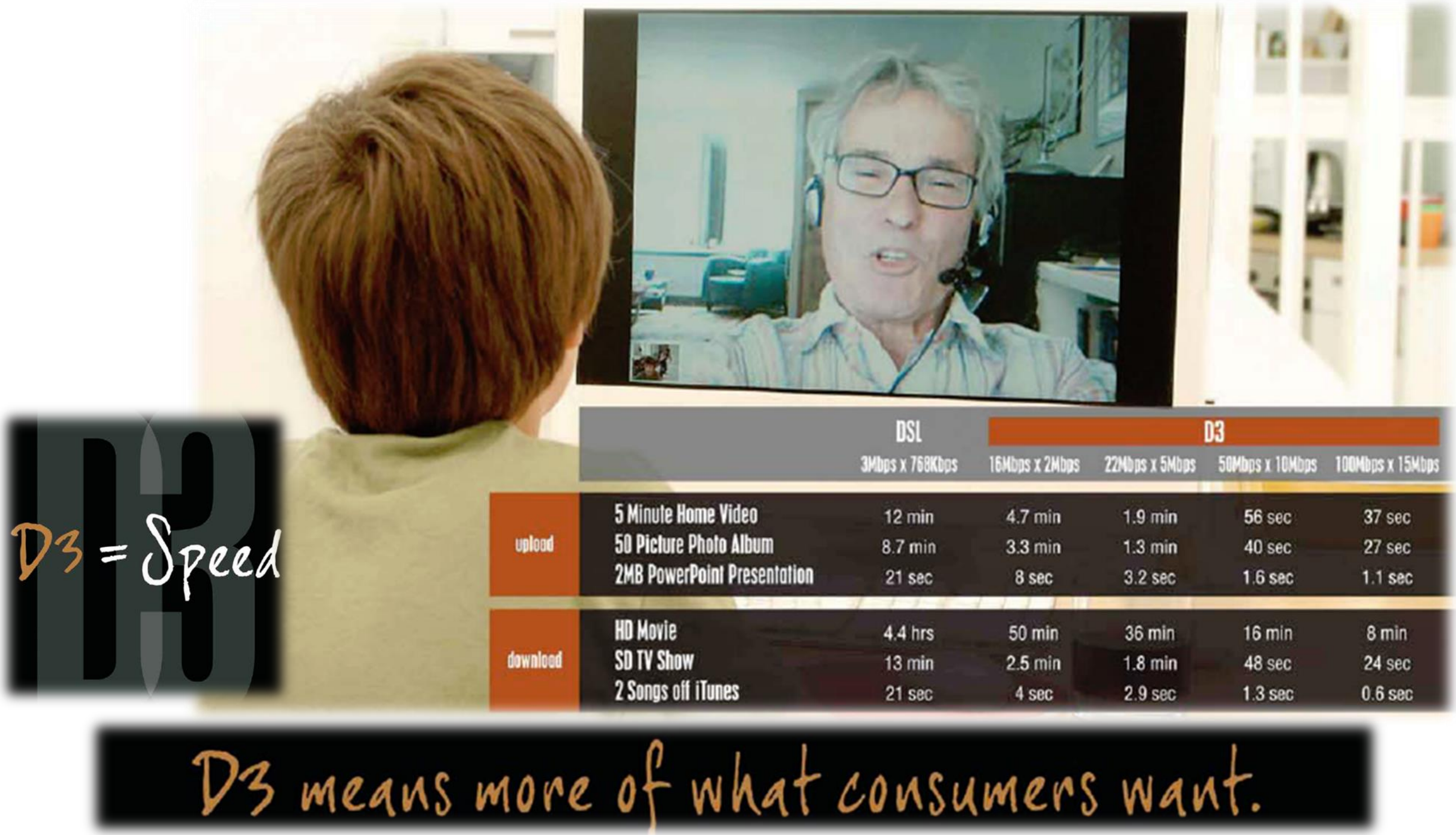
SDTV HDTV

iPod Walkman

Mobile Video

DOCSIS 3.0

Consumers greed for speed



		DSL	D3			
		3Mbps x 768Kbps	16Mbps x 2Mbps	22Mbps x 5Mbps	50Mbps x 10Mbps	100Mbps x 15Mbps
upload	5 Minute Home Video	12 min	4.7 min	1.9 min	56 sec	37 sec
	50 Picture Photo Album	8.7 min	3.3 min	1.3 min	40 sec	27 sec
	2MB PowerPoint Presentation	21 sec	8 sec	3.2 sec	1.6 sec	1.1 sec
download	HD Movie	4.4 hrs	50 min	36 min	16 min	8 min
	SD TV Show	13 min	2.5 min	1.8 min	48 sec	24 sec
	2 Songs off iTunes	21 sec	4 sec	2.9 sec	1.3 sec	0.6 sec

DOCSIS 3.0

Services driving Channel Bonding

- High bandwidth residential data and content
  - Video and photo uploads
  - Proliferation of social networking sites and applications
- IP “Video over DOCSIS” (VDOC)
  - High definition Video to multiple devices
  - PCs, hybrid STBs, portable devices
  - High bandwidth Internet streaming
- High Bandwidth Video conferencing
  - Cisco TelePresence
- Commercial service
  - High bandwidth symmetrical data services
  - Bonded E1/T1 circuit emulation
  - High bandwidth Ethernet / L2VPN services

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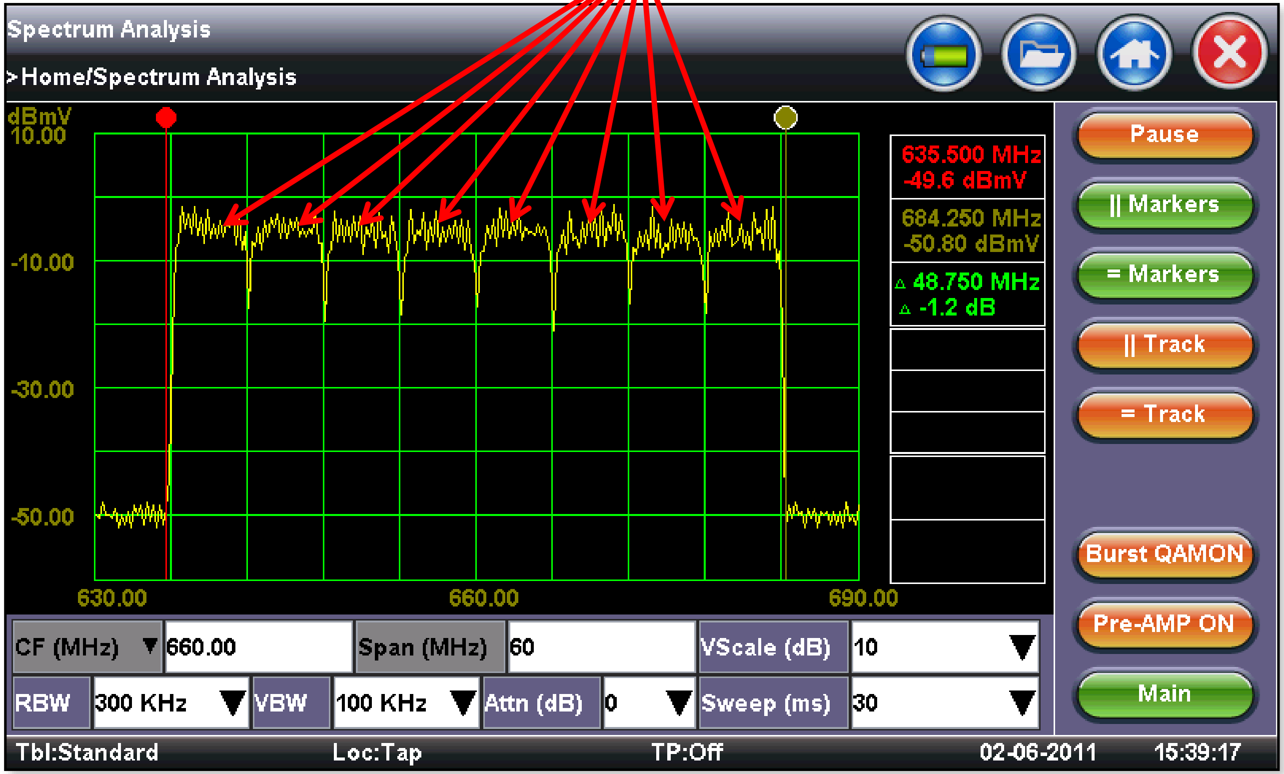
DOCSIS 3.0

Major Feature Overview

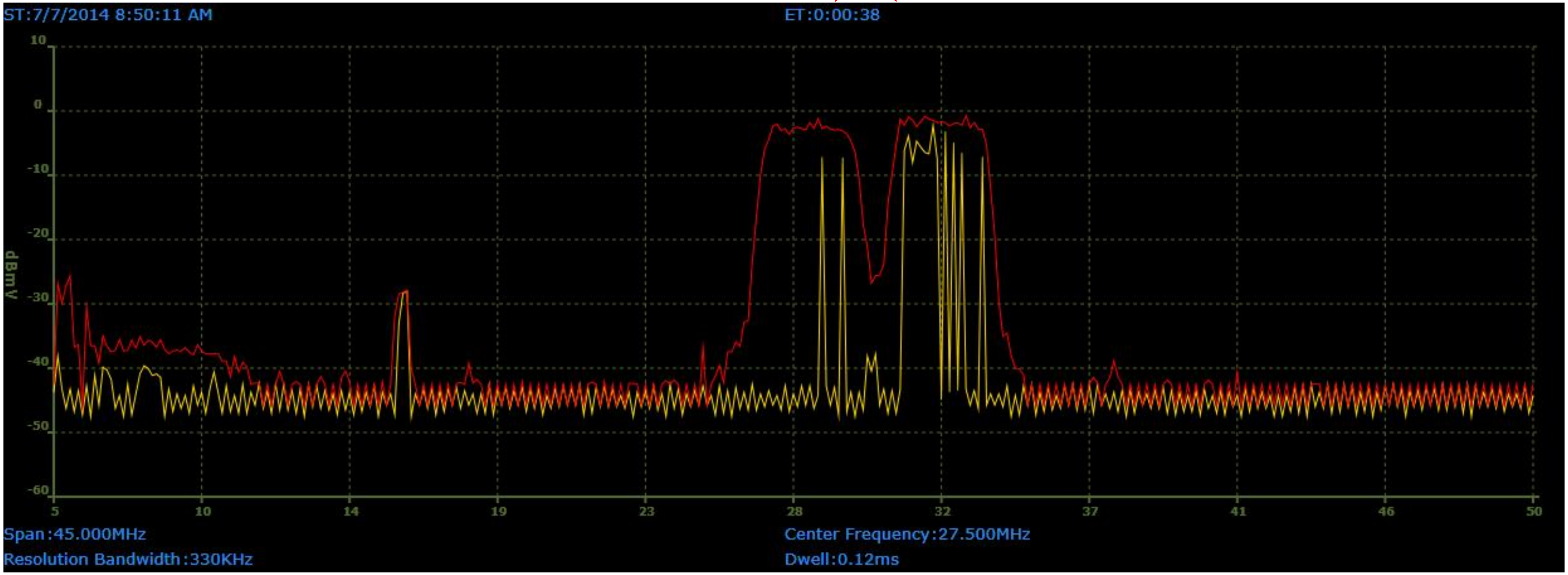
Increased DS bandwidth	• Bonded Downstream Channels • 56Mbps (RAW) each, 448Mbps Total
Increased US bandwidth	• Bonded Upstream Channels • 27Mbps (RAW) each, 122Mbps Total
IPv6	• IPV6 allows for 3.4×10^{38} IP addresses • IP addresses are lengthened from 32 bits to 128 bits
Backwards compatibility	• Existing DOCSIS 1.0, 1.1 and 2.0 systems • Scalable deployment with easy subscriber migration
IP Multicast	• IPTV-type applications • Efficient “switched-video-like” bandwidth usage
Commercial	• E1 & T1 circuit emulation
Network Security	• Early Authentication and Encryption (EAE) and AES 128bit encryption which is more robust and secure

- Channel bonding basically means data is transmitted to/from Cable Modems using multiple individual RF channels instead of a single channel

Using DOCSIS 3.0, data is transmitted to cable modems using multiple channels



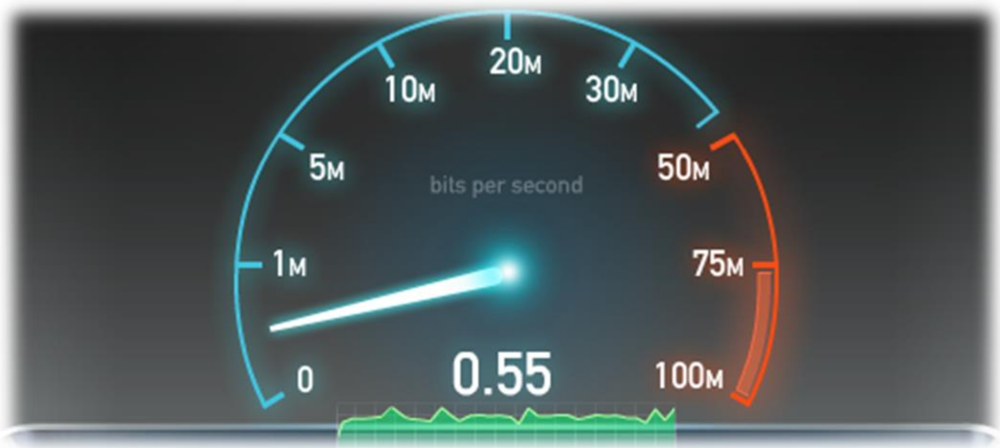
Using DOCSIS 3.0, upstream data is transmitted using multiple channels



DOCSIS 3.0

Throughput Compared

DOCSIS Version	Date Rates – Annex B	
	Downstream	Upstream
1.1	~ 42.88 (38) Mbps	10.29 (9) Mbps
2.0	~ 42.88 (38) Mbps	30.72 (27) Mbps
3.0 (4 Channels)	~ 171.52 (150+) Mbps	122.88 (108+) Mbps
3.0 (8 Channels)	~ 343.04 (300+) Mbps	122.88 (108+) Mbps



DOCSIS 3.0

Quick Summary

- DOCSIS 3.0 review
  - Physically the same as DOCSIS 2.0 signals
  - Consists of multiple QAM signals bonded logically together
  - Bonded channels can be contiguous or non-contiguous:
    - Contiguous - consists of frequency consecutive signals
    - Non-contiguous – interspersed with other carriers
  - MPEG-2 transport for downstream signals
  - QAM transport for upstream signals
  - IPv4 or IPv6 support
  - Enhanced security using EAE, etc.

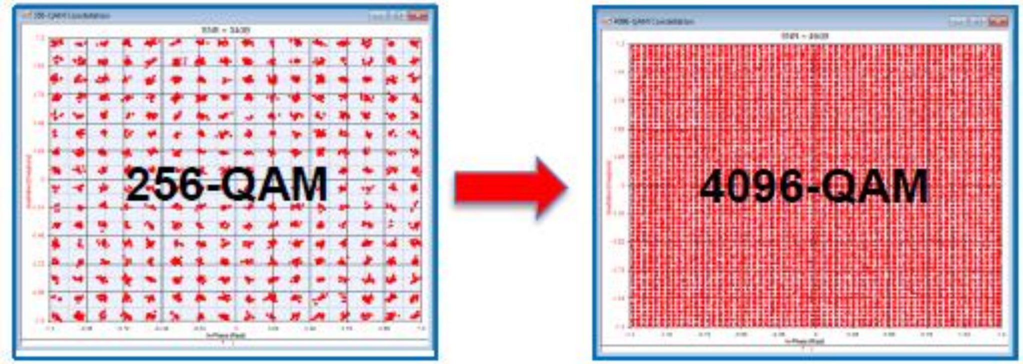
DOCSIS 3.1 Introduction

Why DOCSIS 3.1?

- Traffic growth is driven by demand and competition
- The DOCSIS 3.1 spec will greatly increase the bandwidth performance of the HFC plant using OFDM PHY & LDPC FEC
- 10+ Gbps Downstream & 1+ Gbps Upstream will permit DOCSIS to satisfy subscriber BW needs well in to the future
- DOCSIS scales very well.
  - Efficient spectrum utilization
  - Node splits
  - Adding BW (DS & US)
    - Mid-split/High-Split architecture
    - DOCSIS Enhancements (higher modulations, new PHY/FEC, etc.)

More Capacity needed?

- Higher orders of modulation (HOM)



- Elimination/ Reduction of RF guard band

- Greater capacity achieved primarily through LDPC (HOM in clean channel) and OFDM (elimination of guard bands and HOM in impaired channels)
- Close to 2X improvements over DOCSIS 3.0

DOCSIS 3.1 Delivers More Throughput

- DOCSIS 3.1 delivers more throughput in existing spectrum
  - Capitalizes on the new LDPC FEC & OFDM PHY technologies
  - Permits higher modulation orders (QAM 1024, 4096 & etc.)
  - Eliminates 6MHz & 8MHz channelization (N.A & Europe can unify)
  - Upstream operation up to at least 200MHz
  - Downstream operation to at least 1.2GHz
  - Will use bit-loading to adjust to the HFC plant

Multi Phase Network Migration Path

- Existing Phase - Use the available spectrum efficiently
- Phase 1 - Node segmentations and splits
- Phase 2 - Expand systems with CCAP systems densities
- Phase 3 - Add more capacity with DOCSIS 3.1 features
  - CATEGORY 1: Use DOCSIS 3.1 with existing spectrum
    - Higher order modulations
    - New FEC (LDPC)
    - New PHY (OFDM)
  - CATEGORY 2: Expand the US spectrum using High split as goal architecture
    - Mid-Split (85MHz) as and intermediate step
    - High-split (204MHz or more)
  - Category 3: Expand the DS spectrum beyond 1 GHz (ex: 1.2GHz or 1.8GHz)

Network Migration in DOCSIS 3.1

- Option #1 DS OFDM first, keeping the US spectrum unchanged
  - Create a single DS OFDM channel (48, 96, 192… MHz wide)
    - Reclaim spectrum or enable beyond 860 MHz
  - Move heavy & power users to the DS OFDM channel
    - Accommodates high throughputs needed by heavy users and peak rates needed by power users
    - Requires less SC-QAM channels… Spectrum could be reclaimed
    - Offers better service to the rest of customers
  - Keep the US spectrum as-is and run in D3.0 mode (if no significant demand is present)
  - Increase the number of DS and/or US DOCSIS 3.1 channels as needed… Move more customers to DOCSIS 3.1

Network Migration in DOCSIS 3.1

- Option #2 (DS OFDM, and growing US Spectrum)
  - Create a single DS OFDM channel (48, 96, 192… MHz wide)
    - Reclaim spectrum or enable beyond 860 MHz
  - Move heavy & power users to the DS OFDM channel
    - Accommodates high throughputs needed by heavy users and peak rates needed by power users
    - Requires less SC-QAM channels… Spectrum could be reclaimed
    - Offers better service to the rest of customers
  - Grow the US spectrum (204MHz?)
    - Keep SC-QAM D3.0 channels in the middle of the US spectrum (ex: 20-60MHz)
    - Use the bottom and top portions of US spectrum for OFDM (ex: 5/10-20 & 60-160/204MHz
    - Requires less SC-QAM channels… Spectrum can be reclaimed
  - Increase the number of DS and/or US DOCSIS 3.1 channels as needed. Move more customers to DOCSIS 3.1

Network Migration in DOCSIS 3.1

- Options 1 & 2 can offer
  - Gradual phasing for DOCSIS 3.1
  - Fast throughputs for heavy users
  - Better service to other users
  - Seamless co-existence between legacy and new equipment

Network Migration in DOCSIS 3.1

- Option #3 (Seed the market with DOCSIS 3.1 modems operating in DOCSIS 3.0 mode
  - Once a percentage of D3.1 exceeds some predefined threshold, assign DS (and US?) spectrum for D3.1 operation
  - Move D3.1 CMs to the new spectrum and operate in D3.1 mode
  - Gradually move customers to D3.1 and grow D3.1 spectrum as needed
  - US spectrum can be left as is or get expanded to 5-204MHz depending on traffic demand
  - This approach does not require turning on D3.1 spectrum immediately

Summary

- All Digital means, the old fashion way of testing = blind
- New set of testing parameters = new visibility and possible prediction
- DOCSIS 3.0 adds channel bonding for an increased capacity over previous versions
  - Improved security
  - IPV6 Support
- DOCSIS 3.1 will greatly increase the capacity in the existing spectrum using OFDM and LDPC FEC
  - Higher Orders of Modulation (HOM) is possible
  - Scales very well

VeEX
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Questions???

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