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# Are You Ready for DOCSIS 3.1

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- 6 Years Telecom/MSO Sales
- 4 Years Telecom/MSO/ISP/WSP/NEM Field Engineering





# Technical Session Overview

- ✓ DOCSIS 3.0 Review
- ✓ DOCSIS 3.1 Introduction
- ✓ DOCSIS 3.1 Basics
- ✓ Using the Tools
- ✓ Digging In



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## DOCSIS 3.0 Today



■ 8x4 Bonding	300MB
■ 16x4 Bonding	600MB
■ <b>24x4 Bonding</b>	<b>900MB**</b>
■ <b>32x8 Bonding</b>	<b>1GB**</b>

All fine but **customer** and **competitors**  
pushing for more!



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## DOCSIS 3.1 Introduction



## ■ Goals

- Achieve 10+ Gbps in the DS
- Achieve 1+ Gbps in the US
- Backward compatibility with D3.0/D2.0/D1.1
- Better Spectral Efficiency

## ■ Technology (New Acronyms)

- OFDM, OFDMA, LDPC (Low Density Parity Check)
  - New DS and US Spectrum
  - Re-use of the D3.0 MAC Concepts
- D3.1 offers Throughput and Services equivalent to FTTH but much more cost-effectively



		Current	Stage 1 (1G)	Stage 2 (1.3G)	Stage 3 (1.8G)
Downstream	Spectrum	54 to 1002 MHz	108 to 1002 MHz	258 to 1274 MHz <i>With Amp Upgrade</i>	500 to 1794 MHz <i>With Tap Upgrade</i>
	Modulation	QAM-256	QAM-256	QAM-1024 and higher	QAM-1024 and higher
	Channels	8	24/32	158	200
	Throughput	300 Mbps	1 Gbps	7 Gbps	10+ Gbps
Upstream	Spectrum	5 to 42 / 65 MHz	5 to 85 MHz	5 to 204 MHz	5 to 400 MHz
	Modulation	QAM-64	QAM-64	QAM-256 and higher	QAM-1024 and higher
	Channels	4	12	32	60
	Throughput	100 Mbps	650 Mbps	1.5 Gbps	2+ Gbps



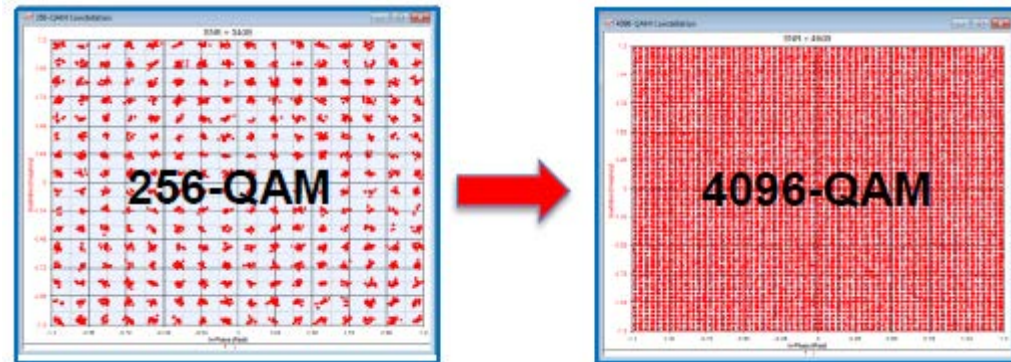
# Why DOCSIS 3.1?

- Traffic growth is driven by demand and competition (FiOS, U-Verse, G.Fast, other FTTH)
- 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 (Is it all hype)?
- Additional Business Services (EoD, EPL)
- 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

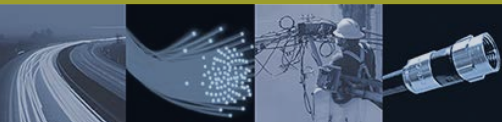
# DOCSIS 3.1 Delivers More Throughput

- DOCSIS 3.1 delivers more throughput in existing spectrum
  - 750MHz, 860MHz and higher plant
  - 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





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## DOCSIS 3.1 Basics



# Example of Spectrum Options

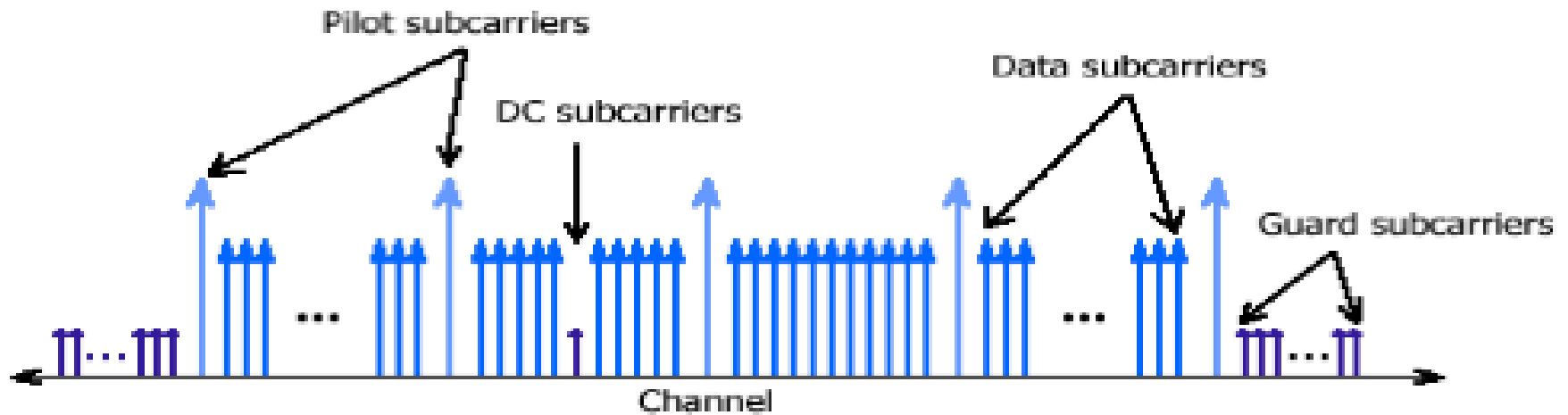
## ■ Downstream Spectrum Options

- 1. Initially use 750/862/1002 MHz Plants (> 6 Gbps)
- 2. Next up to 1.2 GHz with amp upgrade (> 7Gbps +)
- 3. Long-term to 1.7 GHz with tap upgrade (> 10Gbps +)

## Upstream Spectrum Options

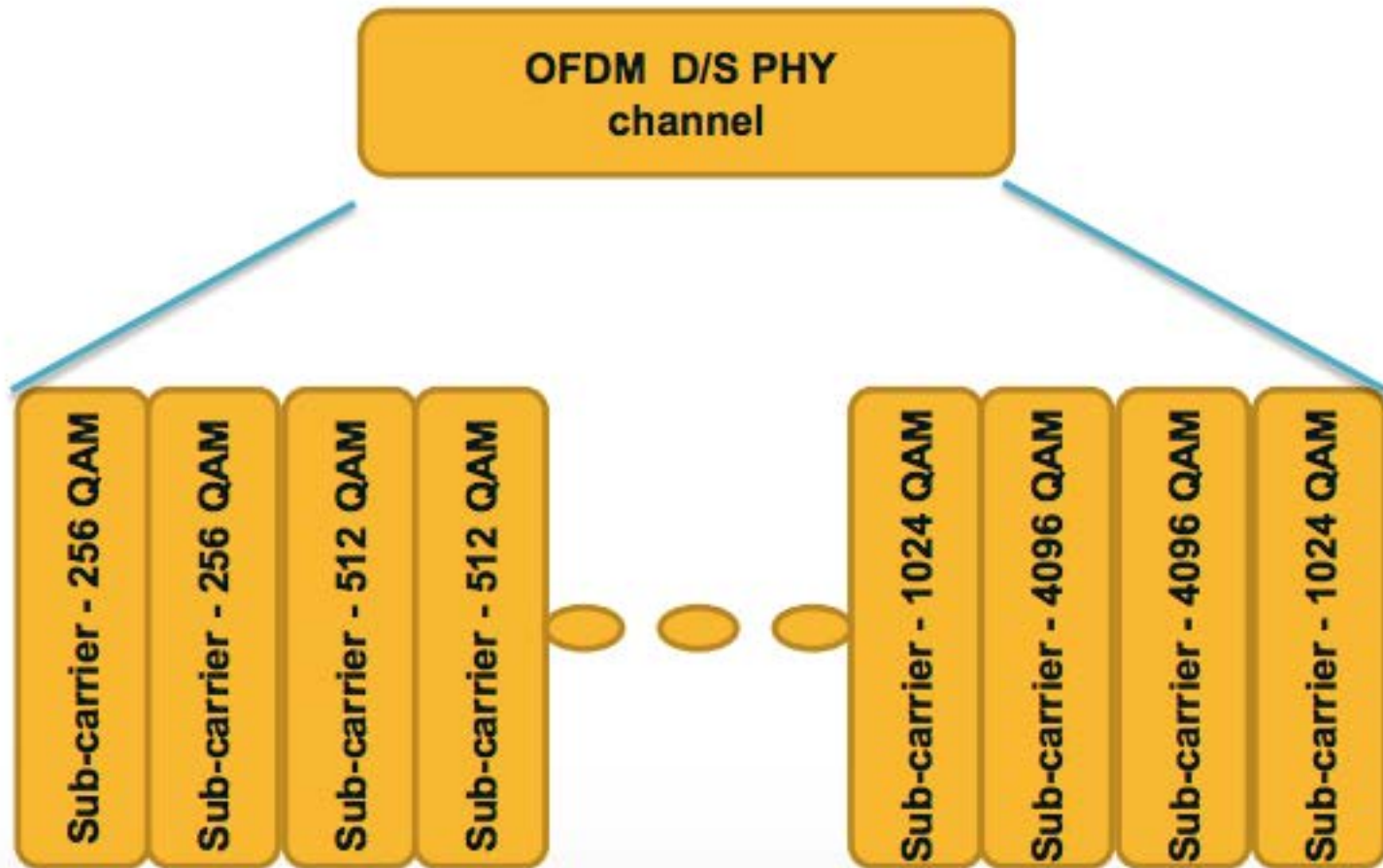
- 1. Use the current sub-split 42/65 MHz (> 200 Mbps)
- 2. mid-split 85 MHz (> 400 Mbps)
- 3. high-split 230 MHz (> 1Gbps)





- **Orthogonal Frequency Division Multiplexing** = large collection of very narrow QAM sub-carriers
- Sub-carriers are grouped into OFDM blocks which are processed by FFT

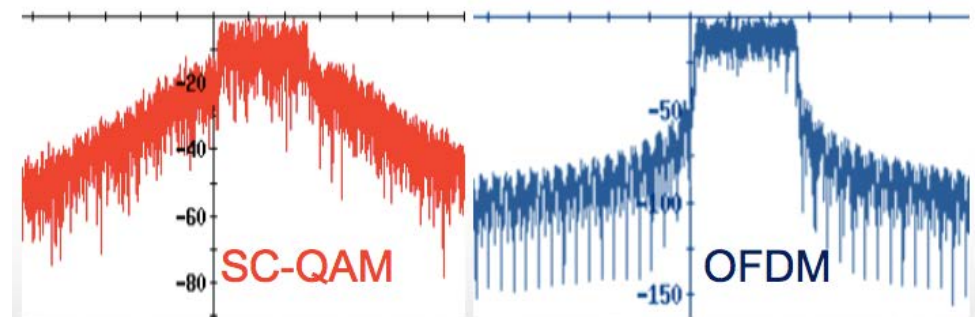
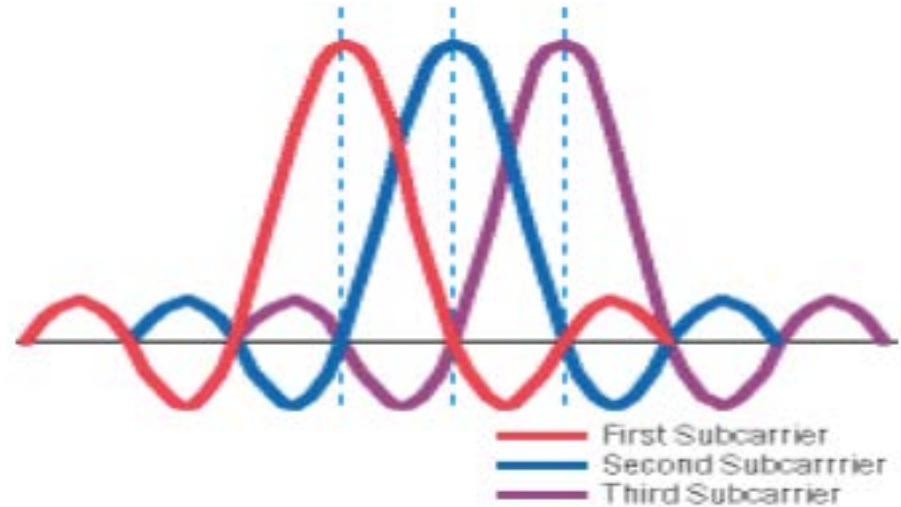
# No wasted Capacity





# OFDM Concept

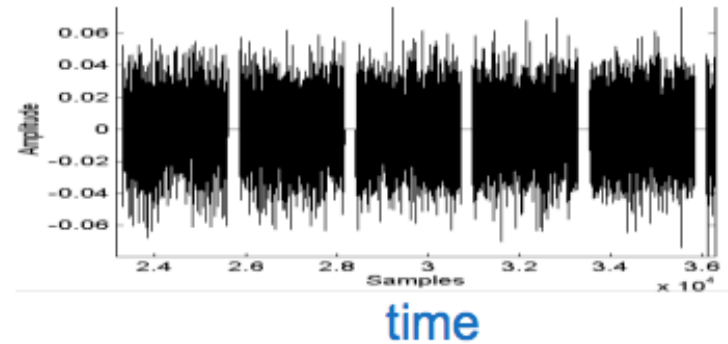
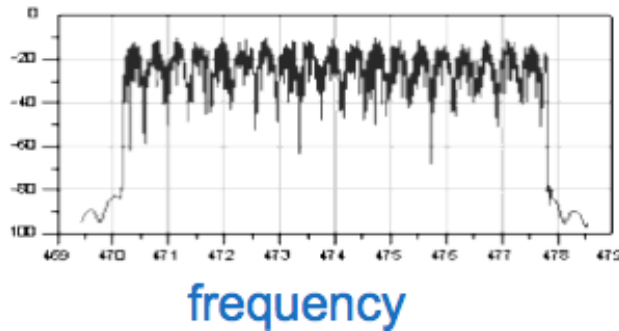
- OFDM sub-carriers can be packed tightly without interfering with each other
- OFDM sub-carriers fall off faster at the band edges



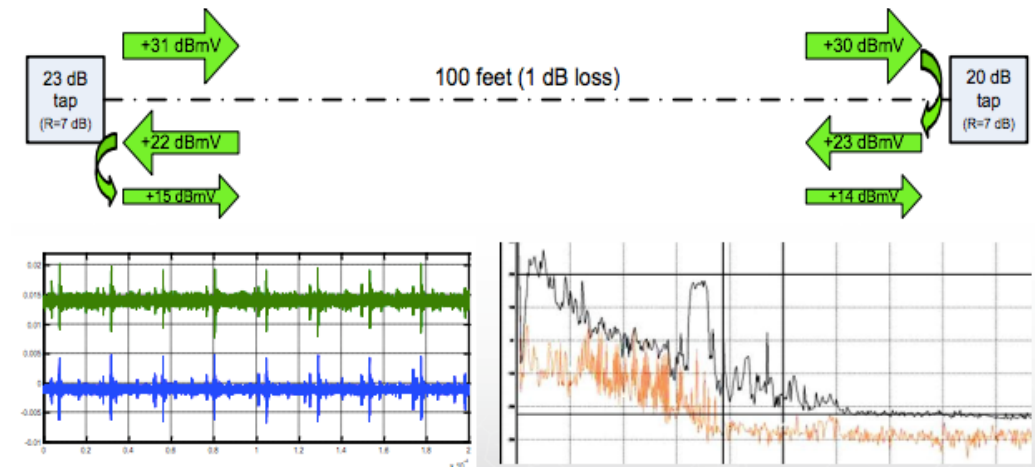


# OFDM Secret Weapon

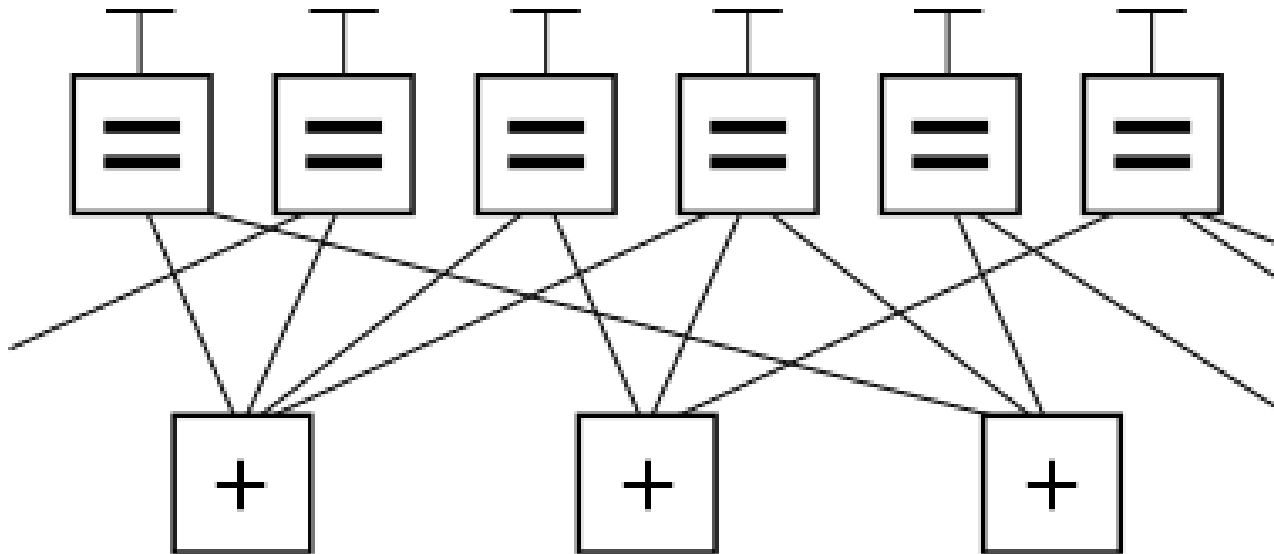
- Narrow Sub-carriers means long symbols



- Benefits are easy mitigation of
  - Micro-reflections
  - Ingress, Impulse and Burst Noise



- FEC = Forward Error Correction
- LDPC = Low Density Parity Check
  - Invented by Robert Gallager in 1962
  - Could not be implemented in HW until recently
  - Much more robust than Reed-Solomon

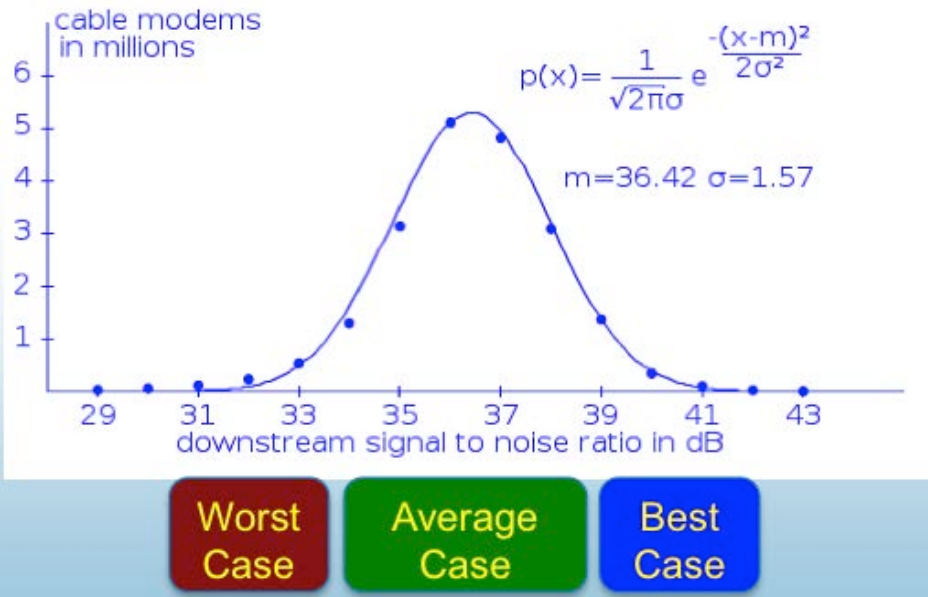


# LDCP Forward Error Correction

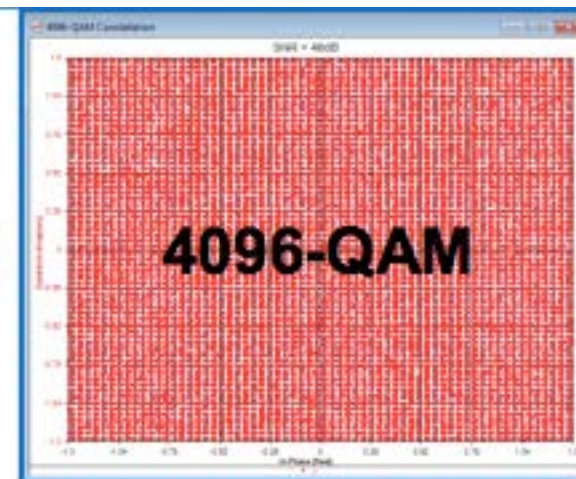
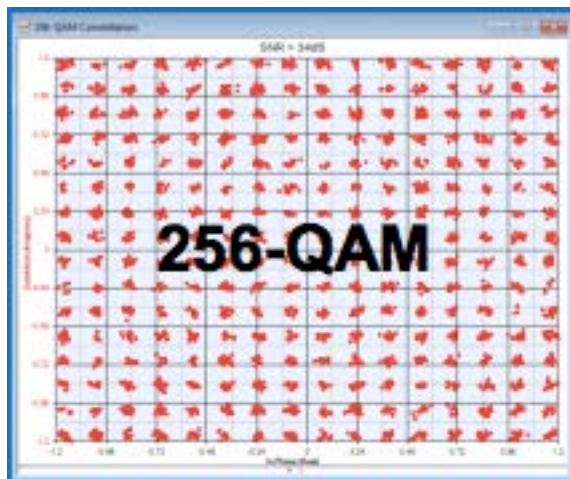
## Basics

- **L**ow **D**ensity **P**arity **C**heck
- Advanced Forward Error Correction technology which provides performance that is close to channel capacity (Shannon Theoretical Limit).
- Frequency and time interleaving are used to provide robustness against narrowband interferers and burst events.
- Far superior error correction capabilities.
  - Greater spectral efficiency
  - Nearly a 2 Bit Gain from Reed Solomon FEC
  - Current DOCSIS 3.0 networks that support QAM-256 can support QAM-1024 with DOCSIS 3.1
- Proven and Robust. LDCP is already used in major transmission technologies including Wireless LAN (802.11n), LTE, DVB-C2, and DVB-S2 (Digital Video Broadcasting – Satellite)

# Downstream Profiles QAM4K Anyone?

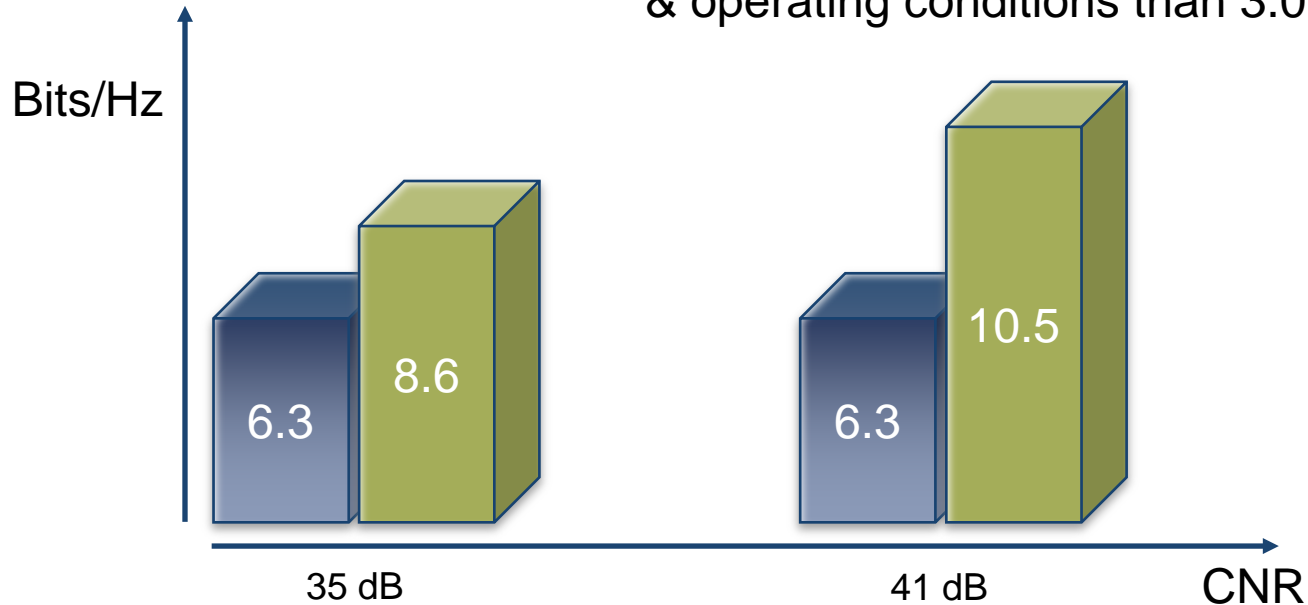


- HFC Plant has at least 8 dB variation in CNR across plant
- Multiple profiles allow operators to leverage SNR variation to improve system capacity
- Example with 4 profiles
  - A. Worst (mostly QAM256)
  - B. Average (mostly QAM1024)
  - C. Better (mostly QAM2048)
  - D. Best (mostly QAM4096)



# OFDM - More for less

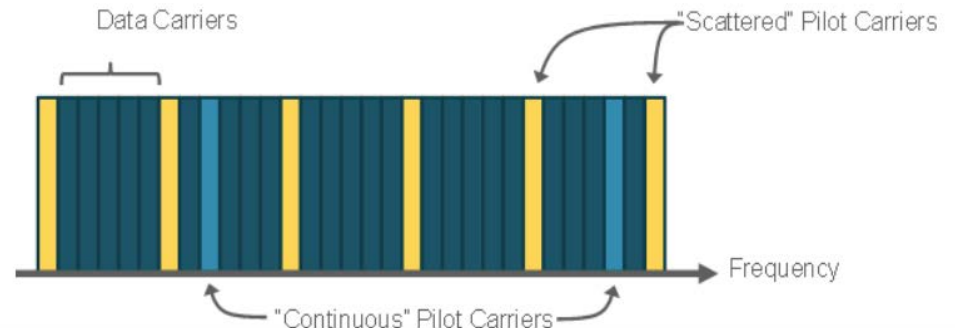
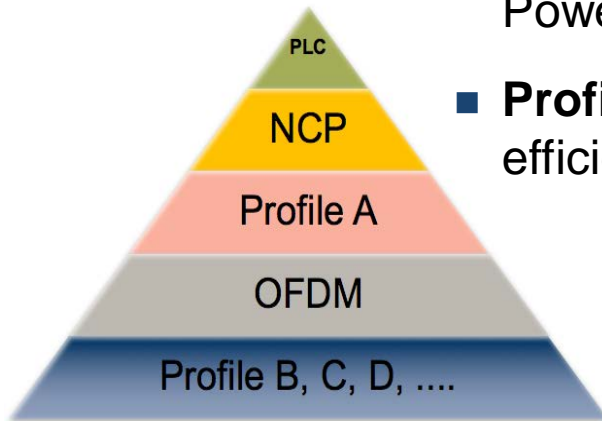
- OFDM/3.1 gives more Bits/Hz at the same CNR & operating conditions than 3.0



35%	Efficiency gain 3.1 vs. 3.0
6.3	Max Bits/Hz on 3.0
10.5	Max Bits/Hz on 3.1 w/ QAM 4096
8.5	Typical Bits/Hz on 3.1 w/mixed QAM (256~4096)

# Building Blocks in Details

- **PLC:** (Physical Link Channel) all necessary information to decode and use the OFDM Signal – your passport
- **NCP:** (Next Codeword Pointer) provides the modems with which Code Words (CW) are present and on each profile which CW to use
- **Profile A:** used for Boot Profile - **No profile A no 3.1**. All 3.1 modems will use Profile A
- **OFDM:** Information about the overall OFDM channel Avg Power, MER, and Noise
- **Profiles B, C and D:** Provide higher modulations for greater efficiency



## ■ OFDM Overall

- Level, MER, ICFR, Echo

## ■ PLC (Physical Link Channel)

- Level, MER, CWE and UCWE

## ■ NCP (Next Codeword Pointer)

- Level, MER, CWE, and UCWE

## ■ Profiles A, B, C, D

- MER, CWE, and UCWE

Cable Modem		Web/FTP	Ping	Trace Route	VoIP
Setup	Ranging	Graphs	Link	OFDM	IP
Level (Avg)	11.1 dBmV	MER (Avg)	44.7 dB		
Level (Max)	13.0 dBmV	MER (Std Dev)	1.4 dB		
Level (Min)	11.0 dBmV	MER Percentile 02 %	41.5 dB		
Frequency	759 MHz	Subcarrier Bandwidth	50 kHz		
Bandwidth	96 MHz	Active Subcarriers	1880		
	Modulation	Level (dBmV)	MER (dB)	C CWE	U CWE
PLC	QAM16	11.7	44.0	1.00e+00	0.00e+00
NCP	QAM16			1.00e+00	0.00e+00
Profile A	QAM256			0.00e+00	0.00e+00
Profile B	QAM1K			0.00e+00	0.00e+00
Profile C	QAM4K			0.00e+00	0.00e+00
Profile D				Not Locked	Not Locked
Profile E				Not Locked	Not Locked

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Tbl:Standard Loc: Tap TP: Off 2016-08-04 07:28:49

# Test 1: PLC (Phy Link Channel)





		Modulation	Level (dBmV)	MER (dB)	C CWE	U CWE
PLC		QAM16	11.7	44.0	1.00e+00	0.00e+00

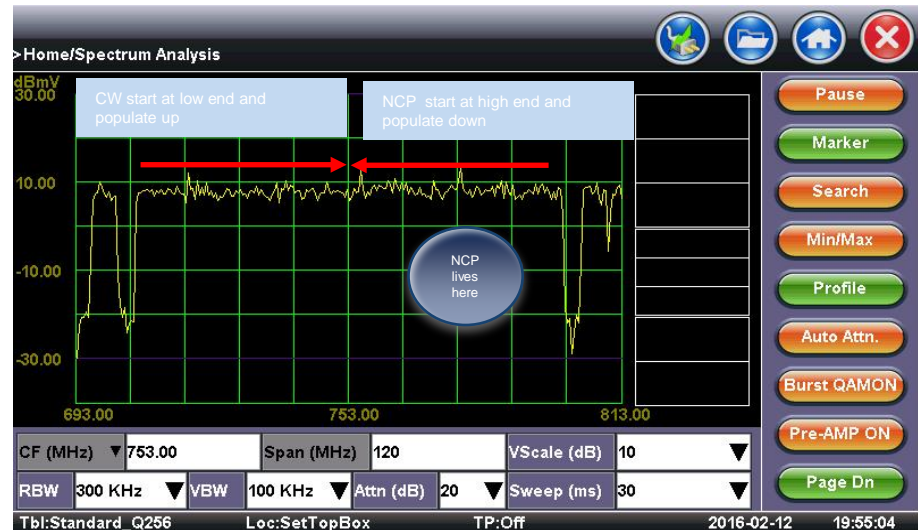
- **PLC needs to be locked**
- U CWE (Uncorrectable CWE): 0
- SNR > 44 dB (QAM16 OFDM)
- Level > 19 dBmV
- C CWE (Correctable CWE): Should be 0 but as long as they are corrected, it is okay (We currently display 100% corrected) << This is a known issue with the Broadcom chipset.



# Test 2: NCP (Next Codeword Pointer)




## NCP

		Modulation	Level (dBmV)	MER (dB)	C CWE	U CWE
PLC		QAM16	11.7	44.0	1.00e+00	0.00e+00
NCP		QAM16			1.00e+00	0.00e+00



- NCP needs to be locked
- U CWE (Uncorrectable CWE): 0
- C CWE (Correctable CWE): Should be 0 but as long as they are corrected, it is okay (We currently display 100% corrected) << This is a known issue with the Broadcom chipset.

## Profile A

	Modulation	Level (dBmV)	MER (dB)	C CWE	U CWE
PLC 	QAM16	11.7	44.0	1.00e+00	0.00e+00
NCP 	QAM16			1.00e+00	0.00e+00
Profile A 	QAM256			0.00e+00	0.00e+00

- **Profile A needs to be locked**
- U CWE (Uncorrectable CWE): 0
- C CWE (Correctable CWE): Should be 0 but as long as they are corrected, it is okay
- **IMPORTANT:** If Profile A has not achieved locked or gets UCWE, modems will roll back to 3.0 > Look for Profile A performances if modem only locks in DOCSIS 3.0 mode



## OFDM








Setup	Ranging	Graphs	Link	OFDM	IP
Level (Avg)	11.1 dBmV		MER (Avg)	44.7 dB	
Level (Max)	13.0 dBmV		MER (Std Dev)	1.4 dB	
Level (Min)	11.0 dBmV		MER Percentile <u>02</u> %	41.5 dB	
Frequency	759 MHz		Subcarrier Bandwidth	50 kHz	
Bandwidth	96 MHz		Active Subcarriers	1880	

- Desirable Average Level 11.1 dBmV
- Frequency – 759 MHz
- Good MER Average > 44.7
- MER Standard Deviation 1.4 dB
- MER @ 2<sup>nd</sup> Percentile > 40 dB
- Bandwidth – 96 MHz
- Active Subcarriers - 1880

Modulation	Min MER
QAM4096	41 dB
QAM2048	37 dB
QAM1024	34 dB
QAM256	27 dB
QAM16	15 dB

## Profile B, C, D,

....

	Modulation	Level (dBmV)	MER (dB)	C CWE	U CWE
PLC 	QAM16	11.7	44.0	1.00e+00	0.00e+00
NCP 	QAM16			1.00e+00	0.00e+00
Profile A 	QAM256			0.00e+00	0.00e+00
Profile B 	QAM1K			0.00e+00	0.00e+00
Profile C 	QAM4K			0.00e+00	0.00e+00
Profile D 				Not Locked	Not Locked
Profile E 				Not Locked	Not Locked

- Profile needs to be locked
- U CWE (Uncorrectable CWE) and CWE (Correctable CWE): varies
- SNR see table per profile

Modulation	Min SNR
QAM4096	41 dB
QAM2048	37 dB
QAM1024	34 dB
QAM256	27 dB
QAM16	15 dB

# Service Level Testing

## Connection Summaries

- Lock onto primary
- Verify Bonding of SC QAM and OFDM on the Forward
- Verify Bonding on the Return
- Verify Average Power

Setup	Ranging	Graphs	Link	OFDM	IP
Level (Avg)	6.3 dBmV		MER (Avg)	40.6 dB	
Level (Max)	9.0 dBmV		MER (Std Dev)	1.0 dB	
Level (Min)	6.0 dBmV		MER Percentile (2)	38.8 dB	
Frequency	854 MHz		Subcarrier Bandwidth	50 KHz	
Bandwidth	96 MHz		Active Subcarriers	1880	

	Modulation	Level (dBmV)	MER (dB)	C CWE	U CWE
PLC	QAM16	7.3	40.0	1.00e+00	0.00e+00
NCP	QAM16			1.00e+00	0.00e+00
Profile A	QAM4K			1.00e+00	0.00e+00
Profile B	QAM1K			0.00e+00	0.00e+00
Profile C	QAM256			0.00e+00	0.00e+00
Profile D				Not Locked	Not Locked
Profile E				Not Locked	Not Locked

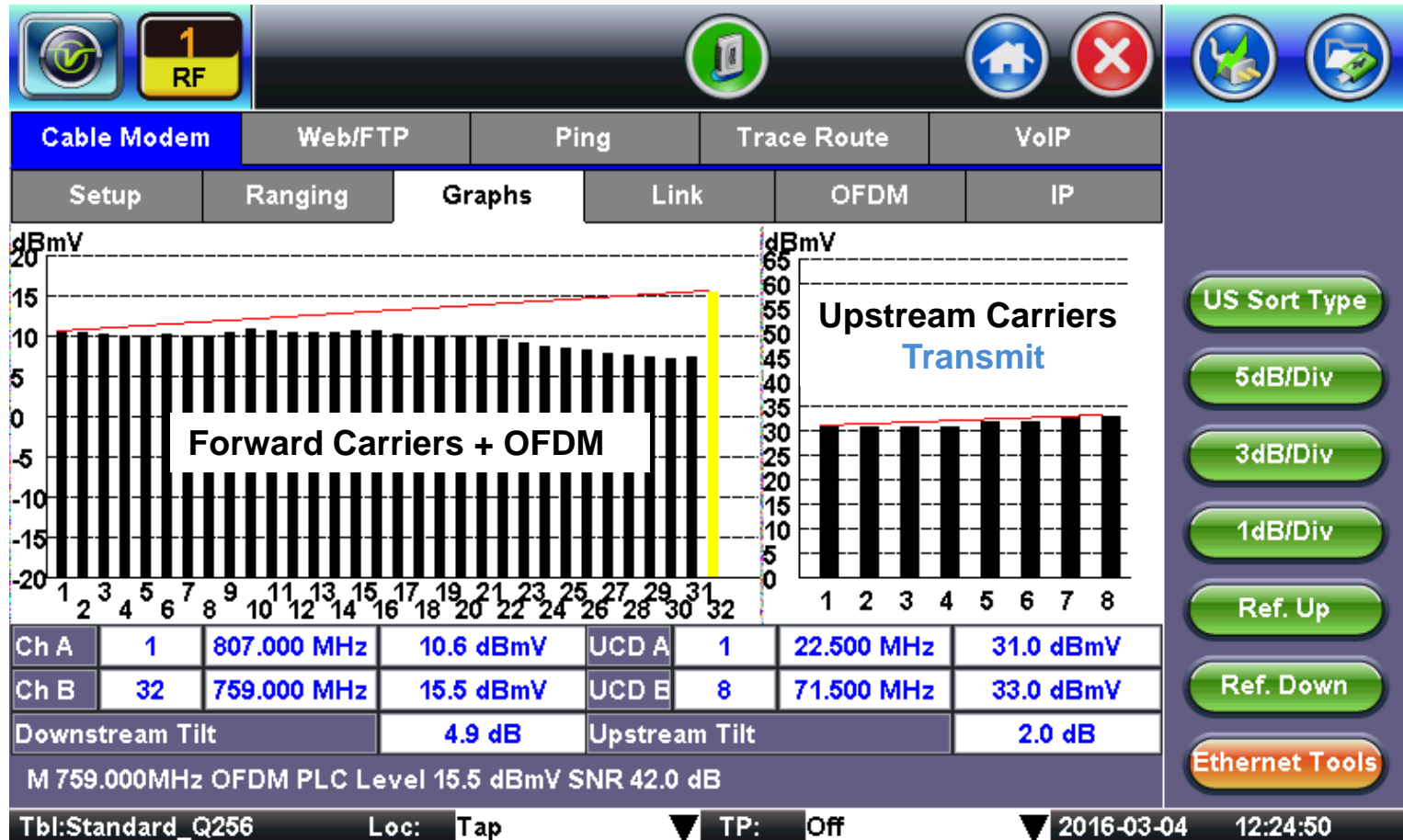
Page 1 of 1

Tbl:Standard\_Q256 Loc: GroundBlock TP: Off 2016-09-07 08:42:29

Ethernet Tools

# Service Level Testing

## Balance of Carriers



- Verify Forward & Transmit Balance
- “Tilt” for DOCSIS Carriers



# Service Level Testing

Setup	Ranging		Graphs		Link	OFDM		IP
Channel #	1	2	3	4	5	6	7	8
DS (MHz)	909.00	915.00	921.00	927.00	933.00	939.00	945.00	951.00
MSymbol/Sec	5.361	5.361	5.361	5.361	5.361	5.361	5.361	5.361
Modulation	QAM256	QAM256	QAM256	QAM256	QAM256	QAM256	QAM256	QAM256
Level(dBmV)	12.1	12.0	11.7	11.4	11.6	11.3	11.1	11.1
MER (dB)	46.1	45.8	45.3	45.2	45.4	45.2	45.2	45.2
Pre BER	0.0e+00	0.0e+00	0.0e+00	0.0e+00	0.0e+00	0.0e+00	0.0e+00	0.0e+00
Pre SEC	0	0	0	0	0	0	0	0
Post BER	0.0e+00	0.0e+00	0.0e+00	0.0e+00	0.0e+00	0.0e+00	0.0e+00	0.0e+00
Post SEC	0	0	0	0	0	0	0	0

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Tbl:Standard Loc: Tap TP: Off 2016-09-24 08:22:12

Ethernet Tools

- Check bonded SC QAM's for any errors and verify MER is good across all carriers



# Service Level Testing

The screenshot displays the VeEX software interface for OFDM verification. The top navigation bar includes icons for a home screen, a red 'X' for disconnect, and a folder icon. Below this, a menu bar offers options: Cable Modem, Web/FTP, Ping, Trace Route, VoIP, Setup, Ranging, Graphs, Link, OFDM, and IP. The main display area is divided into two sections. The upper section shows summary statistics for the OFDM test, and the lower section is a table of modulation profiles.

Level (Avg)	1.0 dBmV	MER (Avg)	36.0 dB
Level (Max)	1.0 dBmV	MER (Std Dev)	1.0 dB
Level (Min)	1.0 dBmV	MER Percentile 02 %	34.0 dB
PLC Frequency	651 MHz	Subcarrier Bandwidth	50 kHz
OFDM Bandwidth	142 MHz	Active Subcarriers	2804

	Modulation (QAM)	Level (dBmV)	MER (dB)	C CWE	U CWE
PLC	16	-3.0	36.0	1.00e+00	0.00e+00
NCP	16		36.0	0.00e+00	0.00e+00
Profile A	1K		36.0	9.99e-01	0.00e+00
Profile B	1K		36.0	5.81e-01	0.00e+00
Profile C	2K		36.0	1.00e+00	0.00e+00
Profile D	4K		36.0	1.00e+00	0.00e+00
Profile E			N/A	N/A	N/A

Page 1 of 1

Tbl:Standard-Q256 Loc: PISCA-FEED-AMI TP: Off 2016-12-06 09:28:40


## ■ Perform OFDM verification





## Summary

Review the OFDM Basic configuration and measurements






**PLC** (Physical Link Channel) – Level, Lock & U CWE

	Modulation	Level (dBmV)	MER (dB)	C CWE	U CWE
PLC 	QAM16	11.7	44.0	1.00e+00	0.00e+00

**NCP** (Next Codeword Pointer) – Lock, U CWE

	Modulation	Level (dBmV)	MER (dB)	C CWE	U CWE
PLC 	QAM16	11.7	44.0	1.00e+00	0.00e+00
NCP 	QAM16			1.00e+00	0.00e+00

**Profile A** – Lock, U CWE

	Modulation	Level (dBmV)	MER (dB)	C CWE	U CWE
PLC 	QAM16	11.7	44.0	1.00e+00	0.00e+00
NCP 	QAM16			1.00e+00	0.00e+00
Profile A 	QAM256			0.00e+00	0.00e+00
Profile B 	QAM1K			0.00e+00	0.00e+00
Profile C 	QAM4K			0.00e+00	0.00e+00



## Summary

Review the OFDM Basic configuration and measurements

OFDM overall parameters

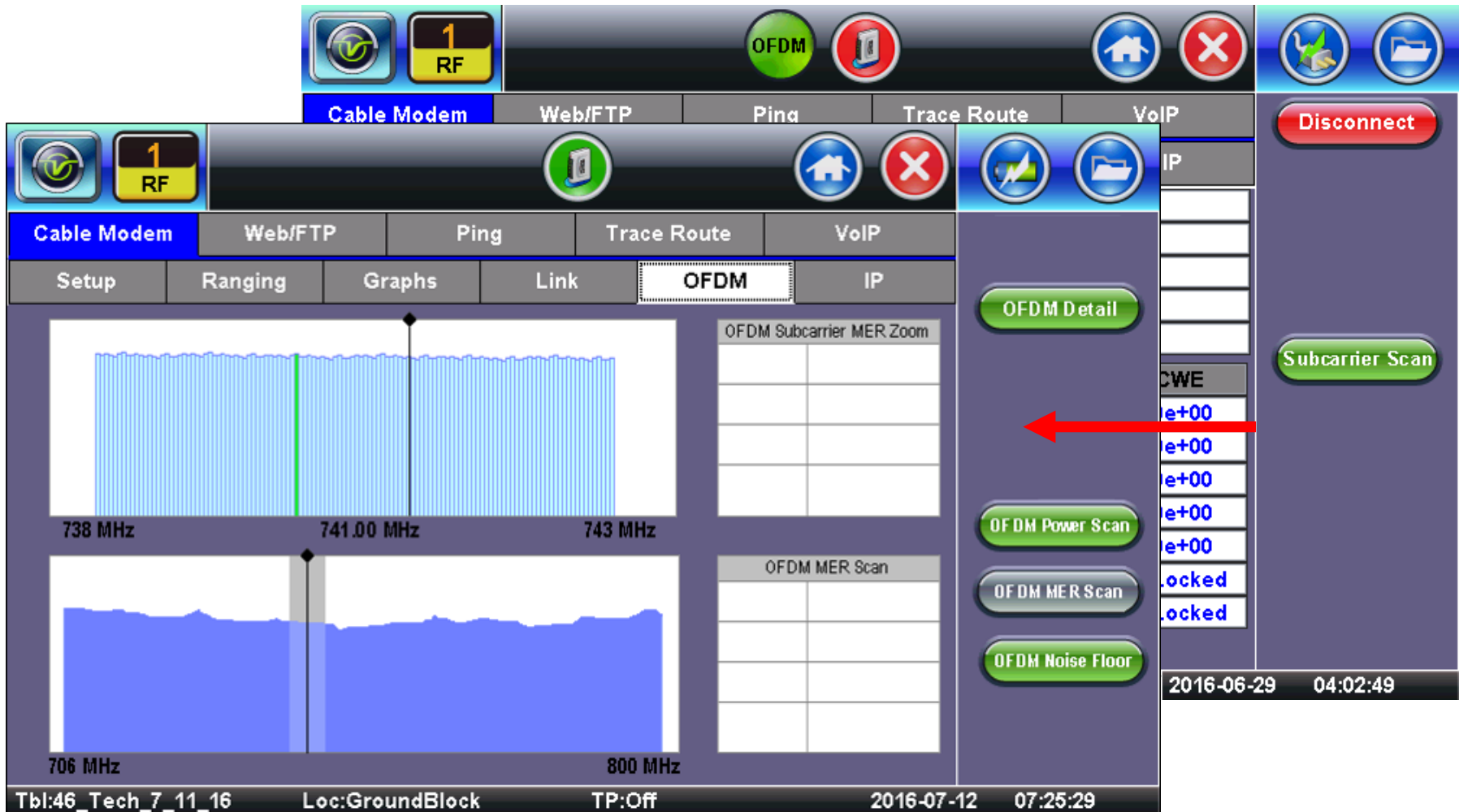
- Average 6MHz Power Level
- Average MER
- MER Standard Deviation
- MER 2 Percentile

Setup	Ranging	Graphs	Link	OFDM	IP
Level (Avg)	11.1 dBmV		MER (Avg)	44.7 dB	
Level (Max)	13.0 dBmV		MER (Std Dev)	1.4 dB	
Level (Min)	11.0 dBmV		MER Percentile 02 %	41.5 dB	
Frequency	759 MHz		Subcarrier Bandwidth	50 kHz	
Bandwidth	96 MHz		Active Subcarriers	1880	



What Happens if  
your 3.1 service is  
not performing?

# OFDM Sub-carrier Scan MER Scan



See where MER may be low and move on to noise/ingress

# OFDM Sub-carrier Scan

## OFDM 6 MHz Power



Verify Power Level on subcarriers in 6MHz increments



# OFDM Sub-carrier Scan

## OFDM Noise Floor





The screenshot shows the VeEX Ping utility interface. At the top, there are icons for various functions: a green checkmark, a yellow '1 RF' button, a green folder icon, a blue home icon, a red 'X' icon, and two blue circular icons with green and red arrows. Below these is a tabbed menu with 'Cable Modem', 'Web/FTP', 'Ping' (selected), 'Trace Route', and 'VoIP'. The main area is divided into 'Setup' and 'Result' sections. The 'Setup' section shows 'PING: In Progress...' and the 'Result' section shows the following data:

Setup		Result	
Destination		167.206.14.199	
Sent		101	
Received		101	
Unreachable		0	
Missing		0	
Round Trip (ms)			
Current	14.766	Average	15.239
MIN	13.775	MAX	18.699

On the right side of the interface, there is a red 'Stop' button and an 'Ethernet Tools' button at the bottom. The status bar at the very bottom shows 'Tbl:Standard\_Q256', 'Loc: GroundBlock', 'TP: Off', and the date/time '2016-06-20 15:00:46'.

- PING for connectivity/Latency to CMTS, Internal IP or Public IP



The screenshot shows the VeTEST application interface. At the top, there's a toolbar with icons for a router, a yellow '1 RF' button, a server icon, a home icon, a close icon, and two network-related icons. Below the toolbar is a tabbed interface with 'Cable Modem', 'Web/FTP' (selected), 'Ping', 'Trace Route', and 'VoIP'. The 'Web/FTP' tab is active, showing a 'Setup' section with the test target 'Cablevision | Cablevision-1G | speedgauge.optonline.net | 167.206.8.122'. Below this is a 'Result' section with a table of test results. The 'Status' is 'Pass'. The 'Connection Time' is '51 ms'. The 'Total Data Transfer Time' is '30086 ms'. The 'PING Test' section shows a 'Ping Response' of 'PASS' with a '9.000 ms' response time. The 'Throughput' section shows a table with 'Download' and 'Upload' rates for 'Line Rate' and 'Data Rate' (MAX and AVG). On the right side of the interface, there are three green buttons: 'Start', 'Update List', and 'Ethernet Tools'. At the bottom, there's a status bar showing 'Tbl:LI-WEST', 'Loc: FTP-DROP-CER', 'TP: Off', and the date/time '2016-10-12 16:02:39'.

Setup	Result
Cablevision   Cablevision-1G   speedgauge.optonline.net   167.206.8.122	
Status	Pass
Connection Time	51 ms
Total Data Transfer Time	30086 ms
PING Test	
Ping Response	PASS 9.000 ms
Throughput	Download Upload
Line Rate - MAX	381.683 Mbps 38.536 Mbps
Line Rate - AVG	375.321 Mbps 35.947 Mbps
Data Rate - MAX	365.655 Mbps 36.814 Mbps
Data Rate - AVG	359.560 Mbps 34.340 Mbps

- Throughput testing on RF
- On or Off Net





Cu P1 Link Down -- 10.0.0.140

> Home->IP(Cu P1)

LEDs Tools Utilities Files

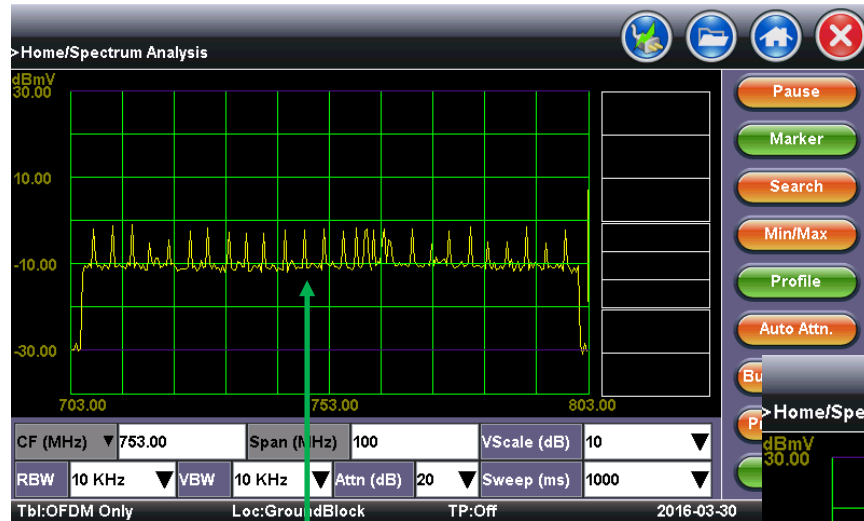
Setup	Status	Ping	Trace Route		
Web/FTP	ARPWiz	VoIP	TCP		
Setup		Result			
Others   Atlanta   10.0.0.45					
Status	PASS				
Connection Time	19 ms				
Total Data Transfer Time	30078 ms				
PING Test					
Ping Response	PASS	1.425 ms			
Throughput		Download	Upload		
Line Rate - MAX	990.886 Mbps	982.221 Mbps			
Line Rate - AVG	990.726 Mbps	979.345 Mbps			
Data Rate - MAX	948.969 Mbps	938.323 Mbps			
Data Rate - AVG	948.824 Mbps	935.575 Mbps			

Disconnect Start Update List

Cu P1 2016-01-22 08:31:58

- Throughput testing both on Ethernet Port
- On or Off Net

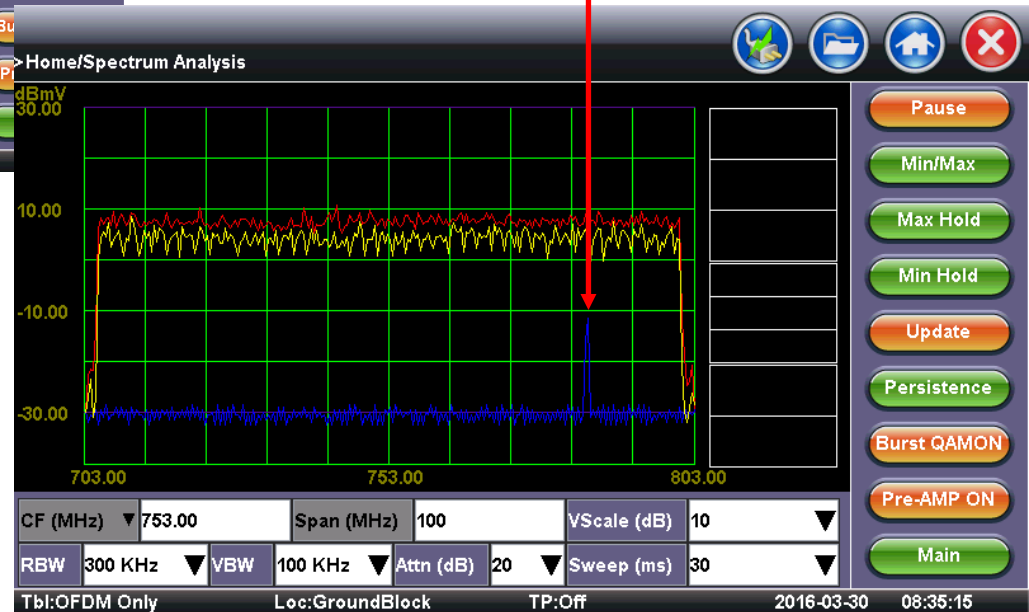
# Using Spectrum to find Noise under OFDM



OFDM 96 MHz  
Running clean

Noise Detected @ NCP  
 Could cause modems to switch to 3.0

A red arrow points from this text to the spectrum plot in the bottom right.





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# Questions???

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