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VeEX

The Verification Experts

Are You Ready for DOCSIS 3.1

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Today's Speaker

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- 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

DOCSIS 3.0 Today

DOCSIS 3.0
Where are we today?

8x4 Bonding	300MB
16x4 Bonding	600MB
24x4 Bonding	**900MB****
32x8 Bonding	**1GB****

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

DOCSIS 3.1 Introduction

What is DOCSIS 3.1?

- **Goals**
  - Achieve 10+ Gbps in the DS
  - Achive 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

Capacity

		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 *With Amp Upgrade*	500 to 1794 MHz *With Tap Upgrade*
	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

DOCSIS 3.1 Basics

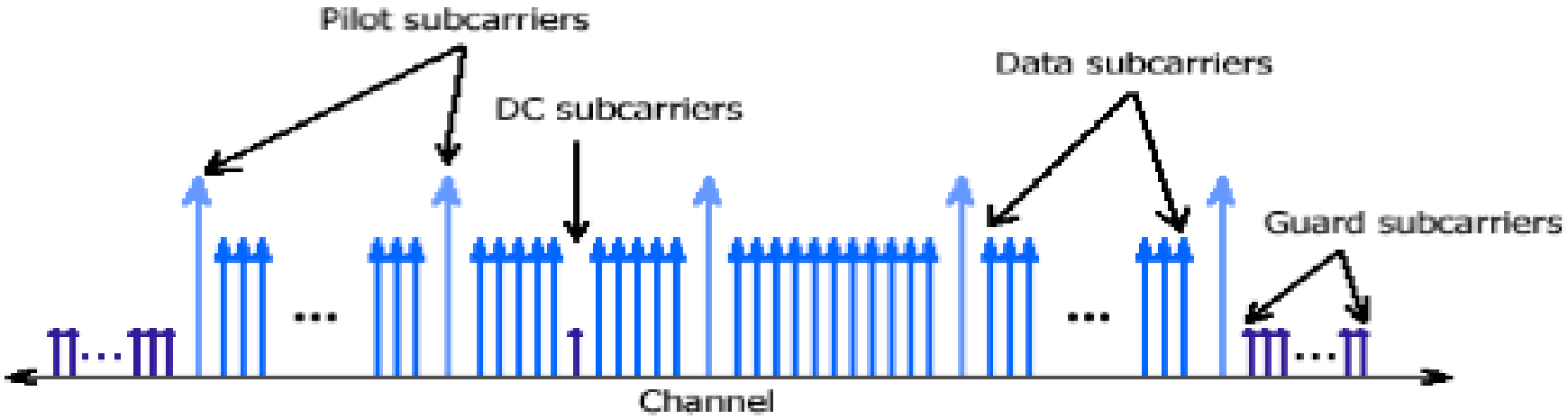
Example of Spectrum Options

- 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

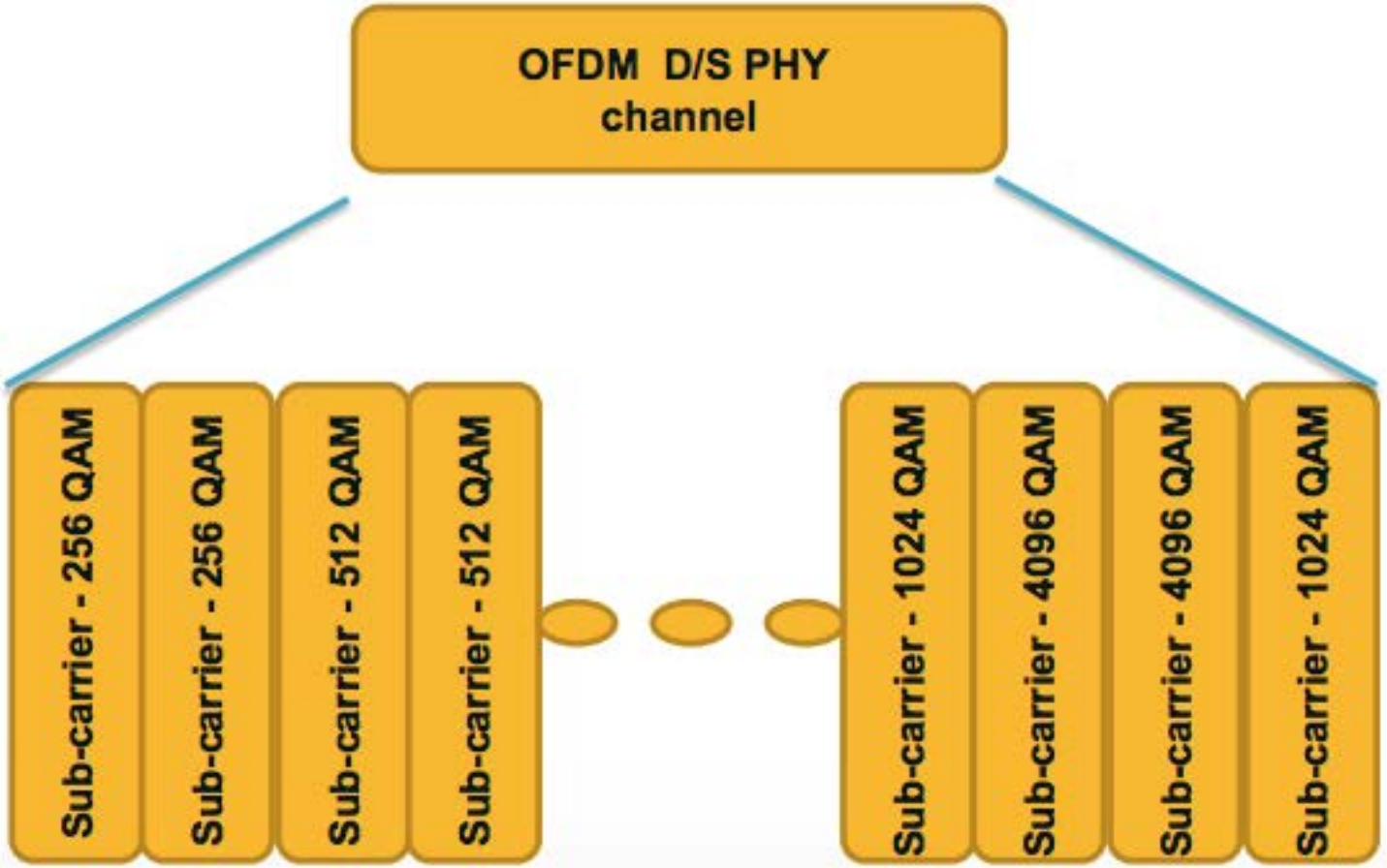
- 1. Use the current sub-split 42/65 MHz (> 200 Mbps)
- 2. mid-split 85 MHz (> 400 Mbps)
- 3. high-split 230 MHz (> 1Gbps)

OFDM



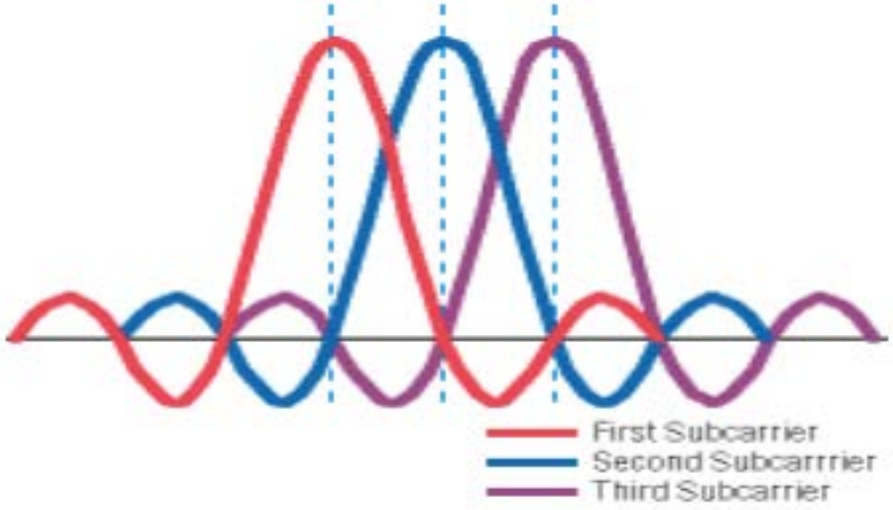
- **Orthogonal Frequency Division Multiplexing** = large collection of very narrow QAM sub-carriers
- Sub-carriers are grouped into OFDM blocks which are processed by FFT

No wasted Capacity

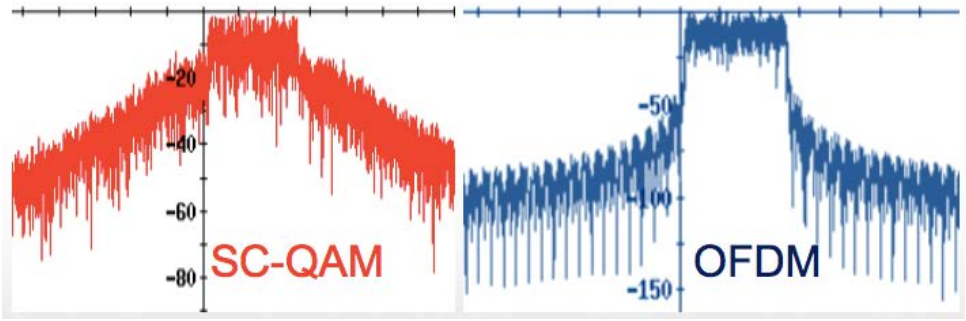


OFDM Concept

- OFDM sub-carriers can be packed tightly without interfering with each other

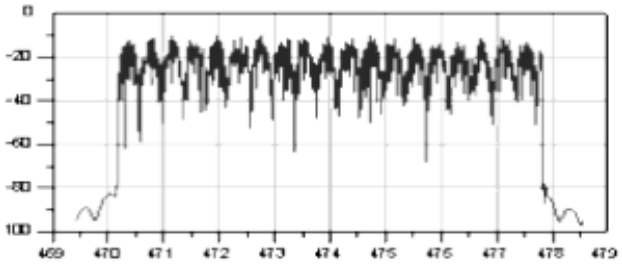


- OFDM sub-carriers fall off faster at the band edges

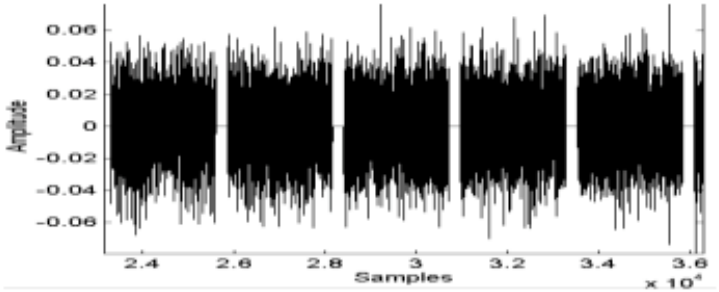


OFDM Secret Weapon

- Narrow Sub-carriers means long symbols

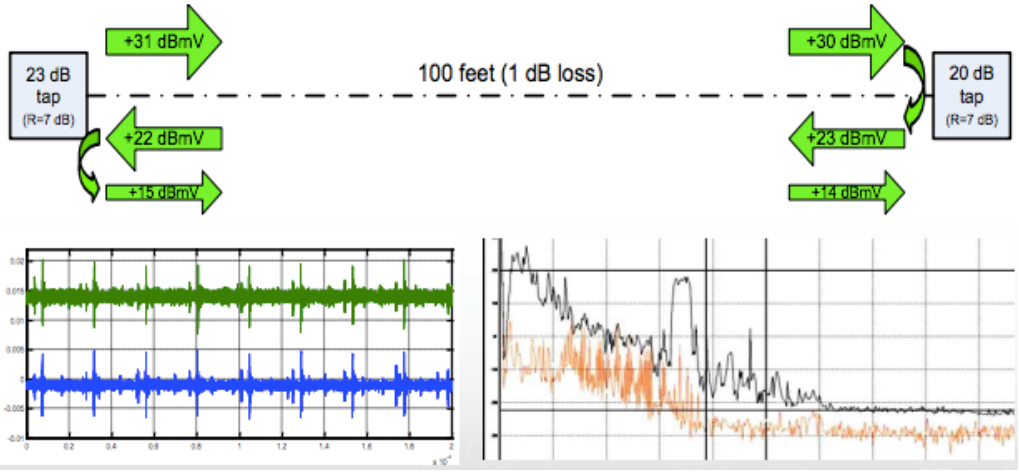


frequency



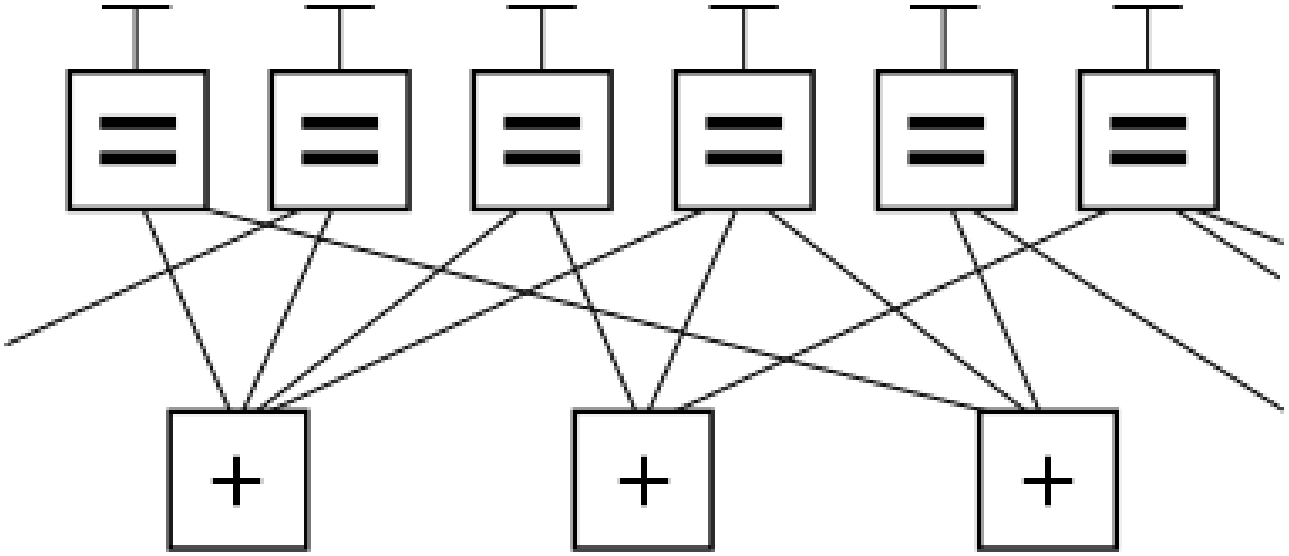
time

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



LDPC FEC

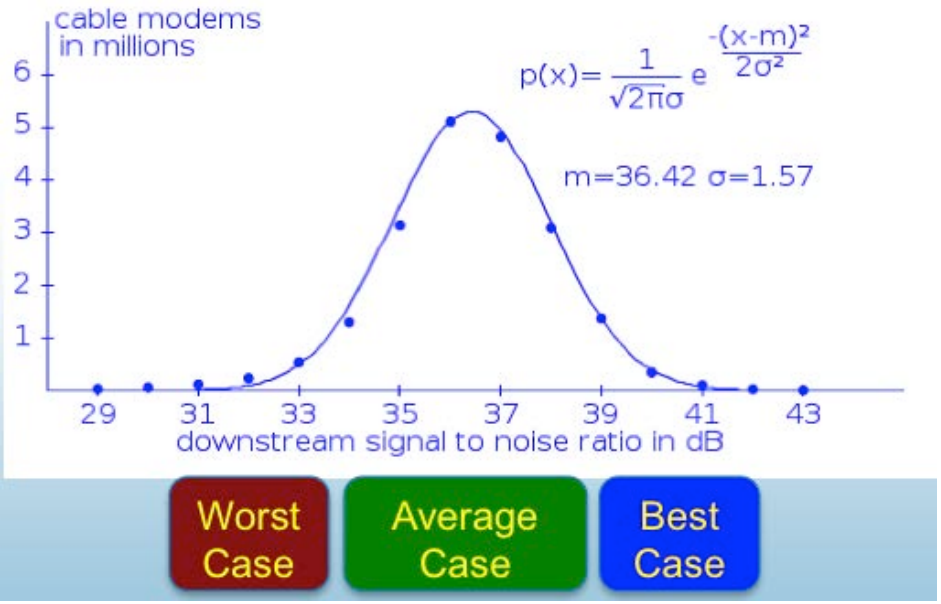
- FEC = Forward Error Correction
- LDPC = Low Density Parity Check
  - Invented by Robert Gallager in 1962
  - Could not be implemented in HW until recently
  - Much more robust than Reed-Solomon



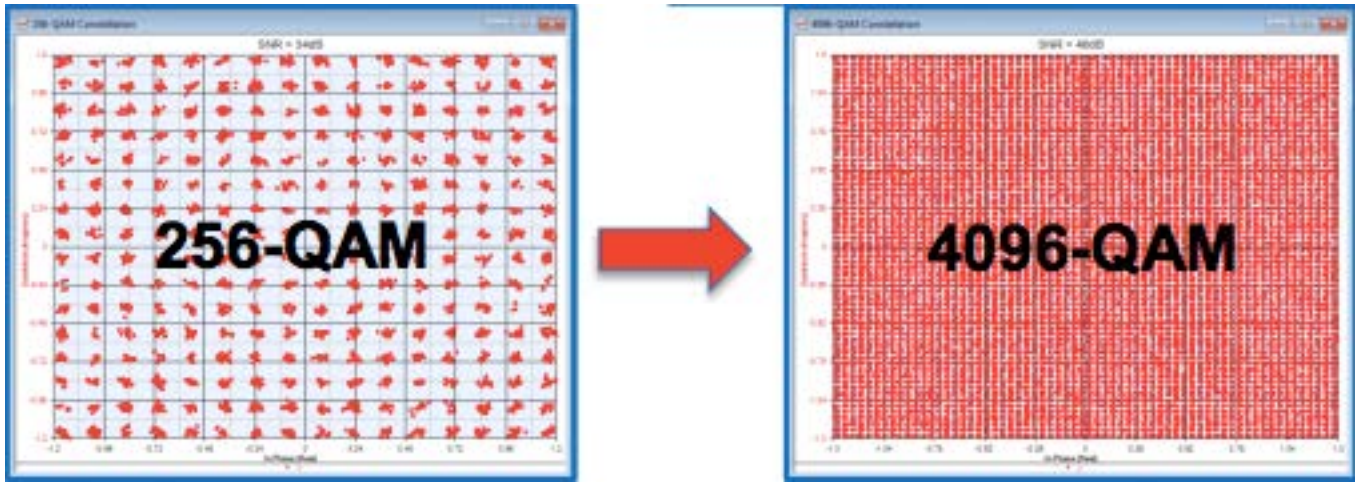
LDCP Forward Error Correction
Basics

- **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?

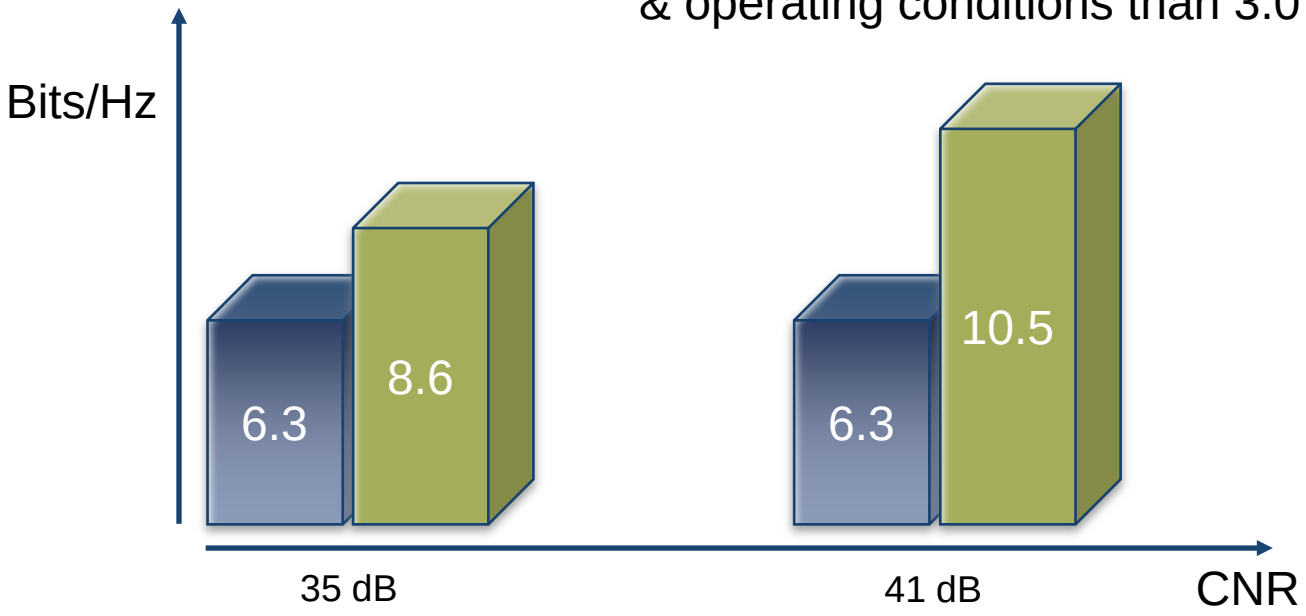


- HFC Plant has at least 8 dB variation in CNR across plant
- Multiple profiles allow operators to leverage SNR variation to improve system capacity
- Example with 4 profiles
  - A. Worst (mostly QAM256)
  - B. Average (mostly QAM1024)
  - C. Better (mostly QAM2048)
  - D. Best (mostly QAM4096)



OFDM - More for less

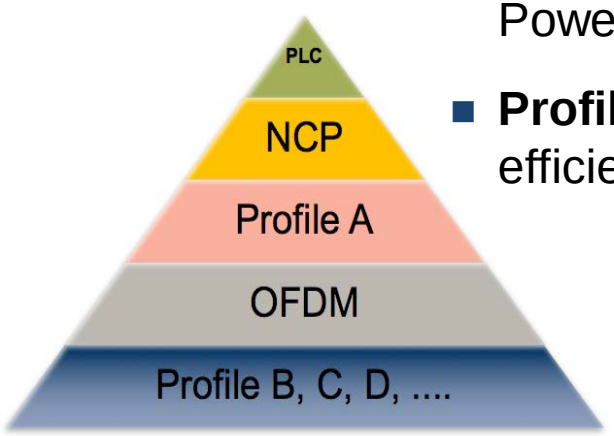
- OFDM/3.1 gives more Bits/Hz at the same CNR & operating conditions than 3.0



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 Measurements

- **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

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.

Test 3: Profile A

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

Test 4: OFDM Overall

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 02 %	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 @ 2nd 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

Test 5: Profiles B,C

Profile B, C, D, ...

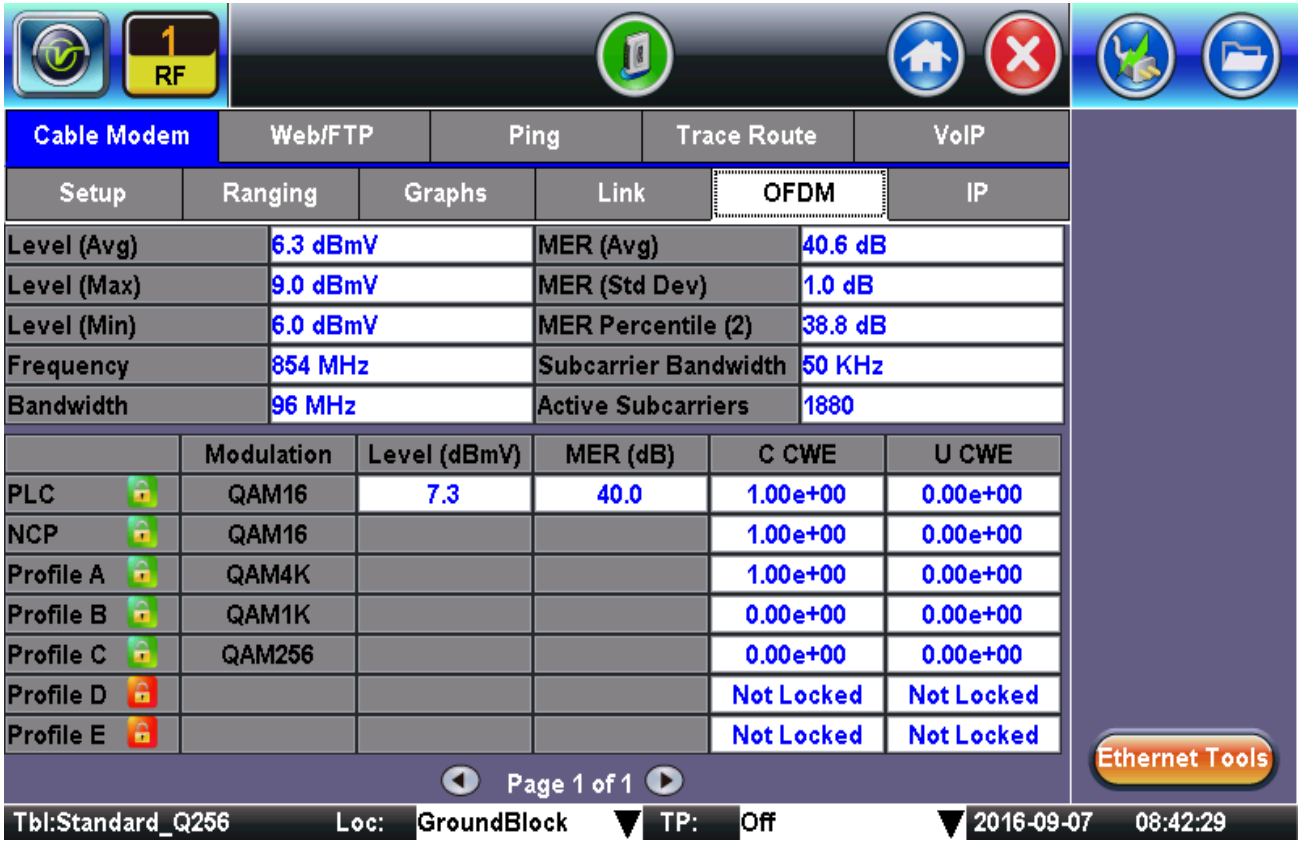
	Modulation	Level (dBmV)	MER (dB)	C CWE	U CWE
PLC	QAM16	11.7	44.0	1.00e+00	0.00e+00
NCP	QAM16			1.00e+00	0.00e+00
Profile A	QAM256			0.00e+00	0.00e+00
Profile B	QAM1K			0.00e+00	0.00e+00
Profile C	QAM4K			0.00e+00	0.00e+00
Profile D				Not Locked	Not Locked
Profile E				Not Locked	Not Locked

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

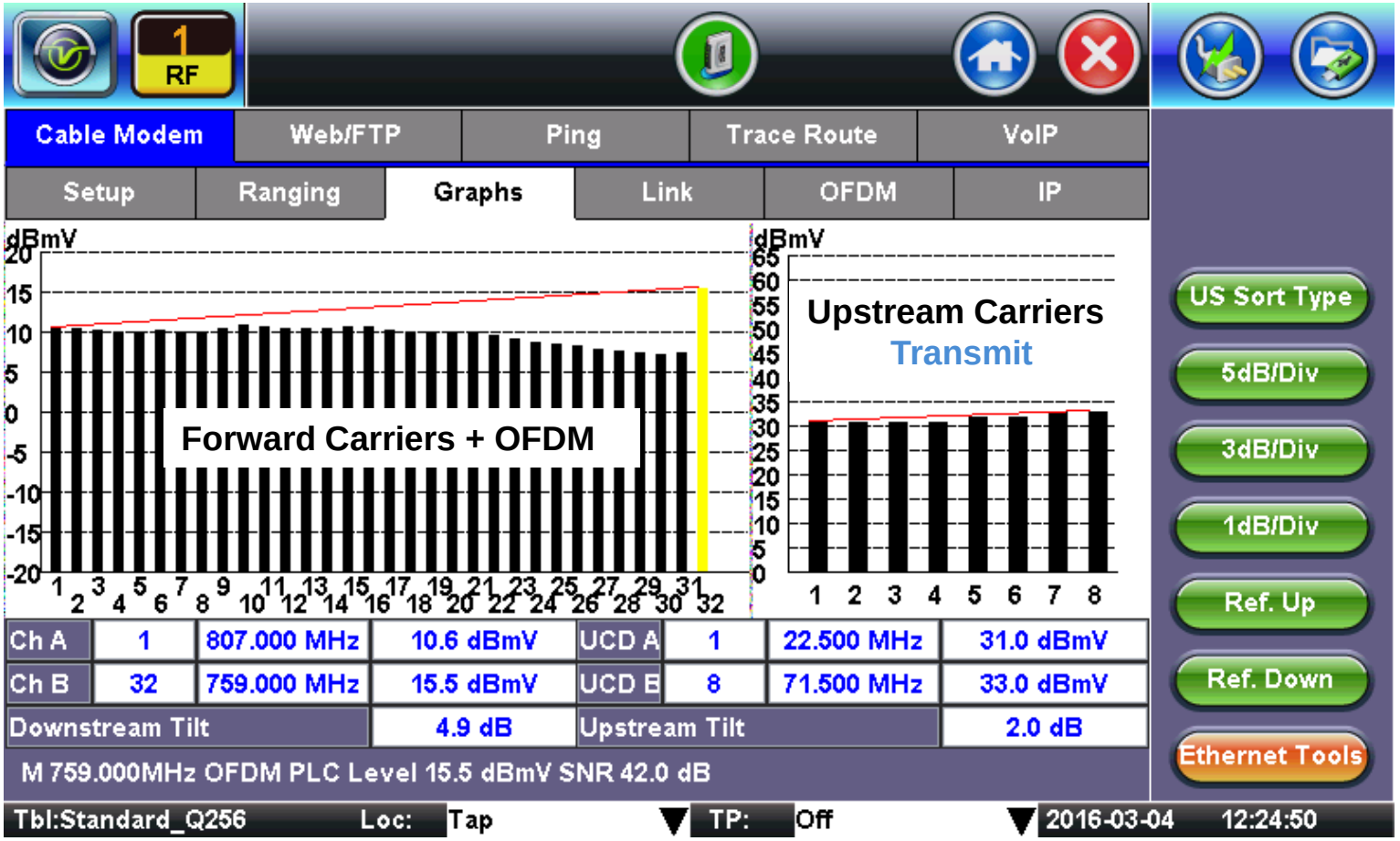
Modulation	Min SNR
QAM4096	41 dB
QAM2048	37 dB
QAM1024	34 dB
QAM256	27 dB
QAM16	15 dB

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



Service Level Testing
Balance of Carriers

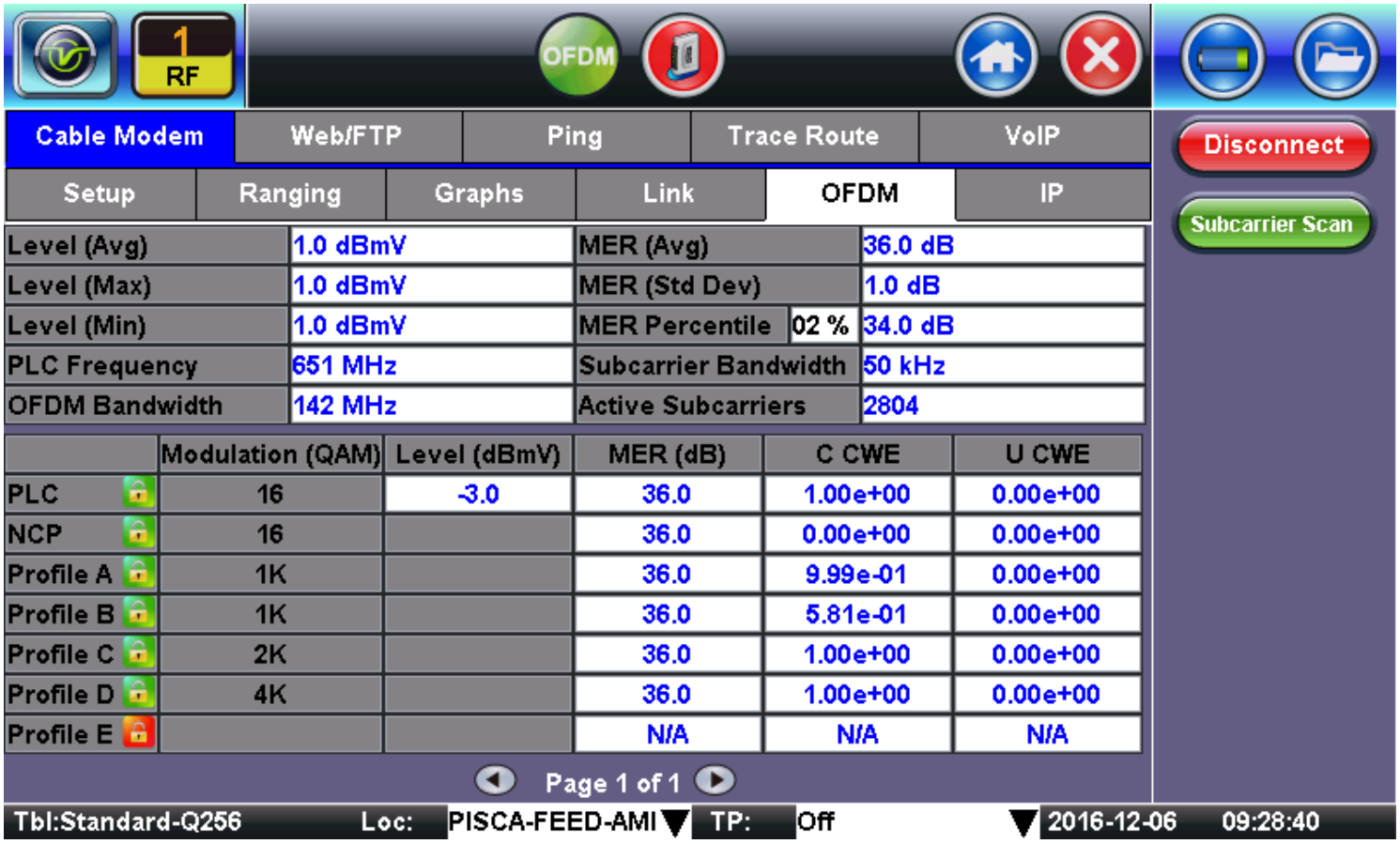


- Verify Forward & Transmit Balance
- “Tilt” for DOCSIS Carriers

Service Level Testing

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

Service Level Testing



- 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

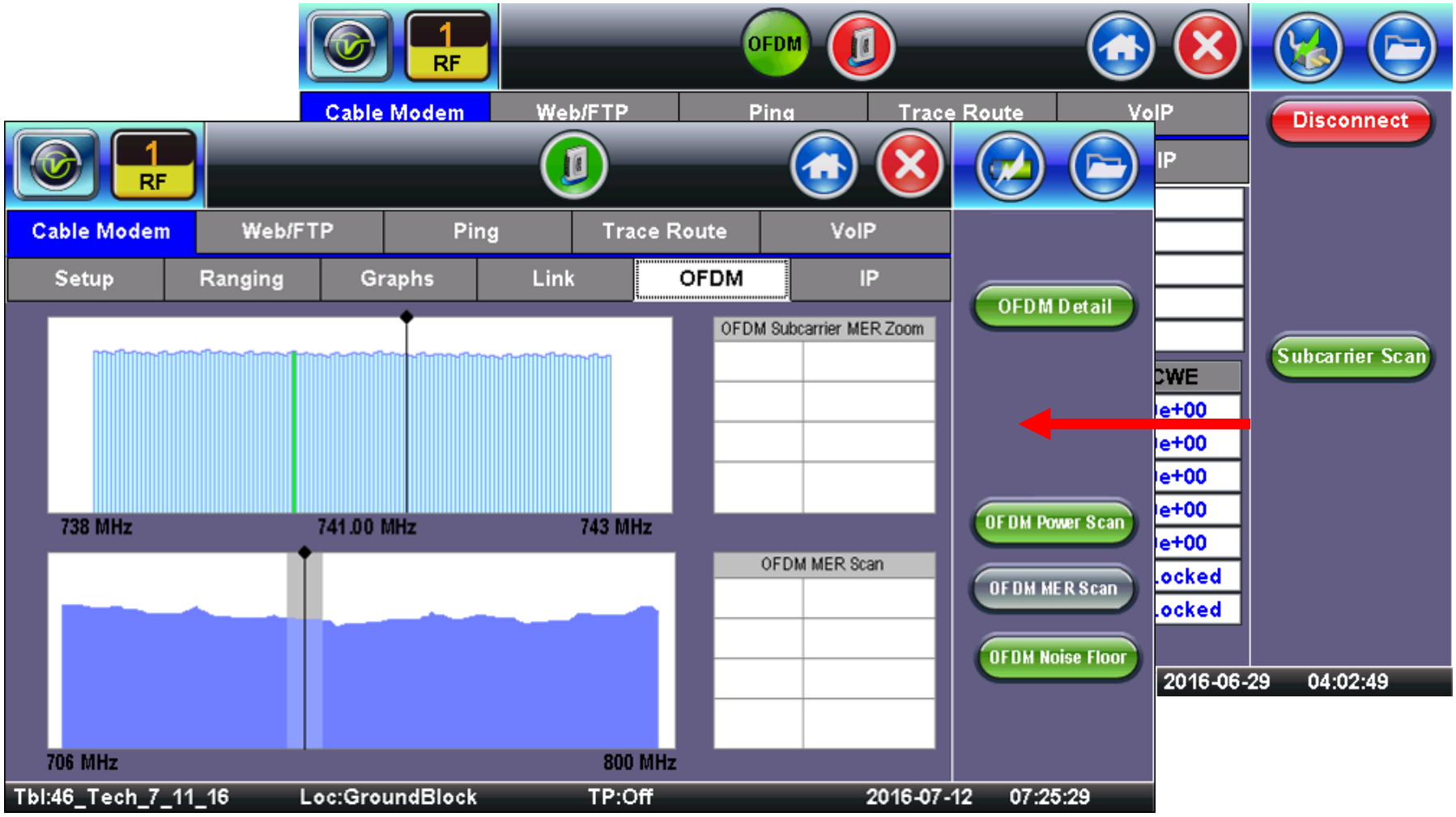
Setup	Ranging	Graphs	Link	OFDM	IP

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

Trouble?

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

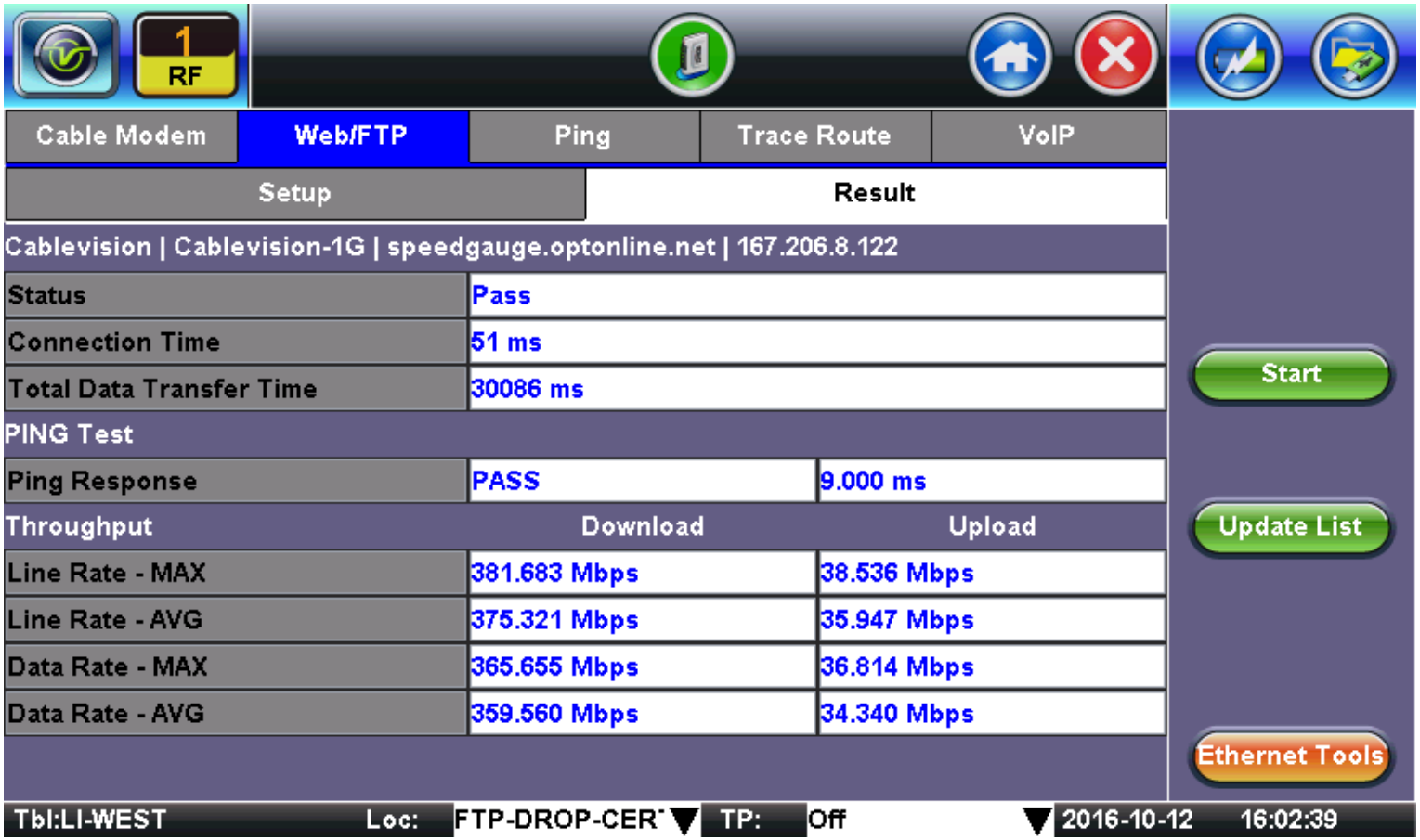
OFDM Sub-carrier Scan
OFDM Noise Floor

Noise may be present driving down MER/Modulation

IP Functions
PING

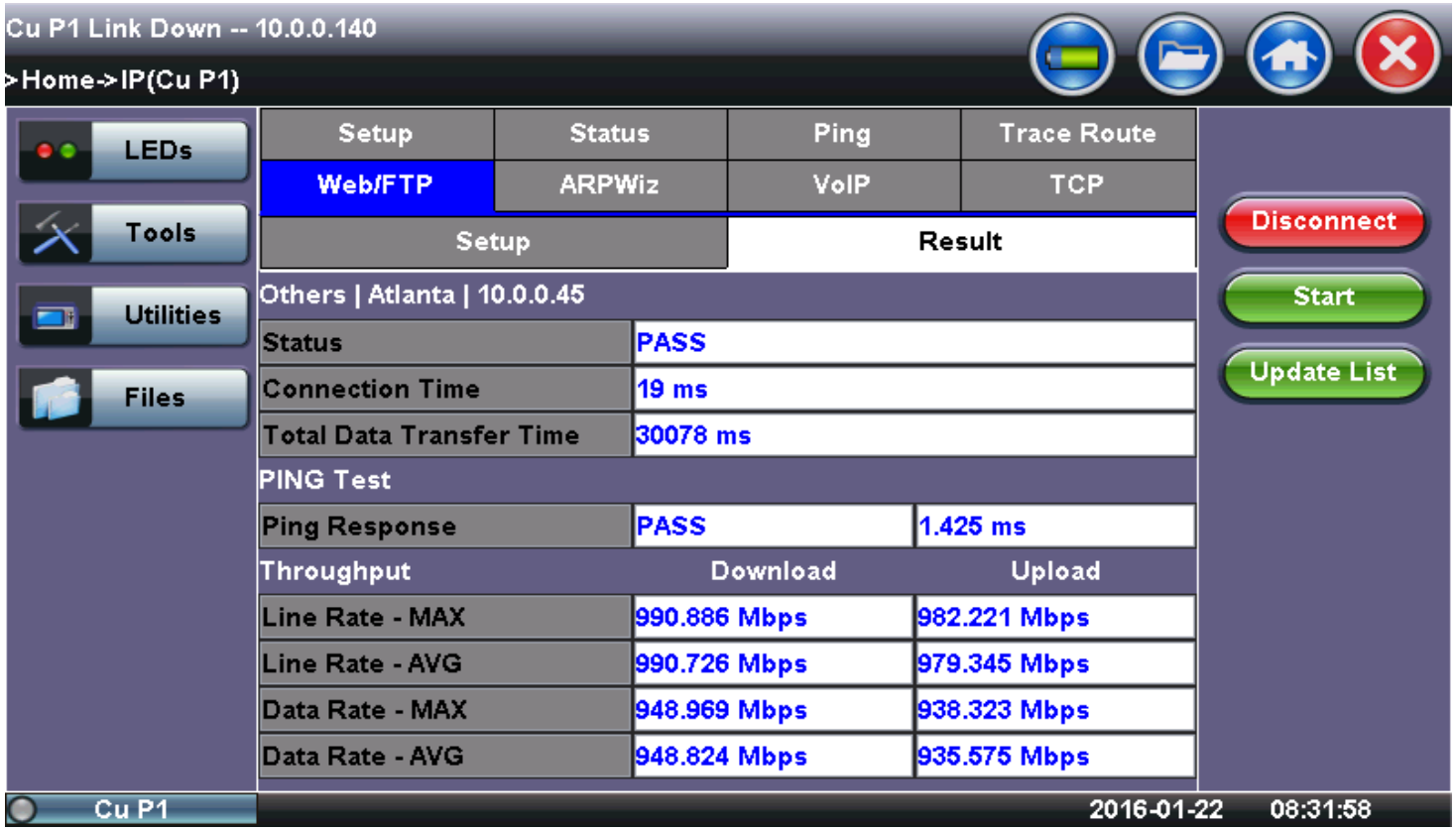
- PING for connectivity/Latency to CMTS, Internal IP or Public IP

IP Functions
VeTEST



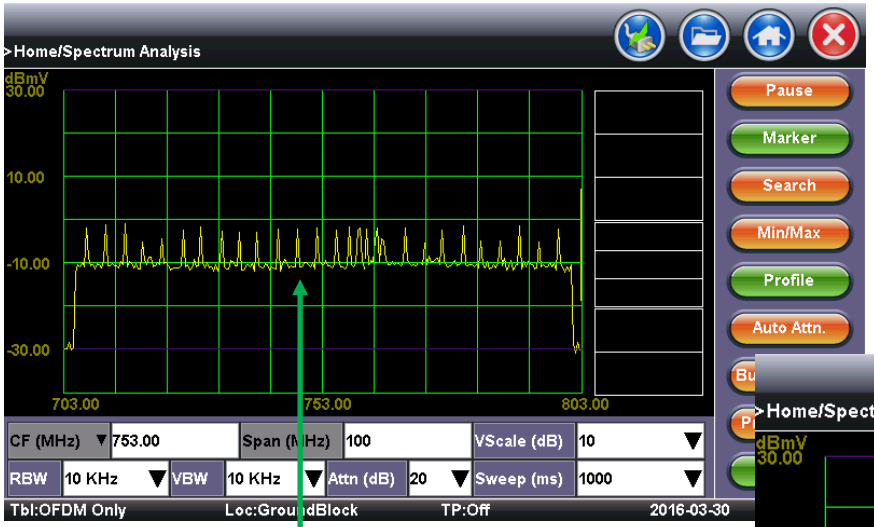
- Throughput testing on RF
- On or Off Net

IP Functions
VeTEST



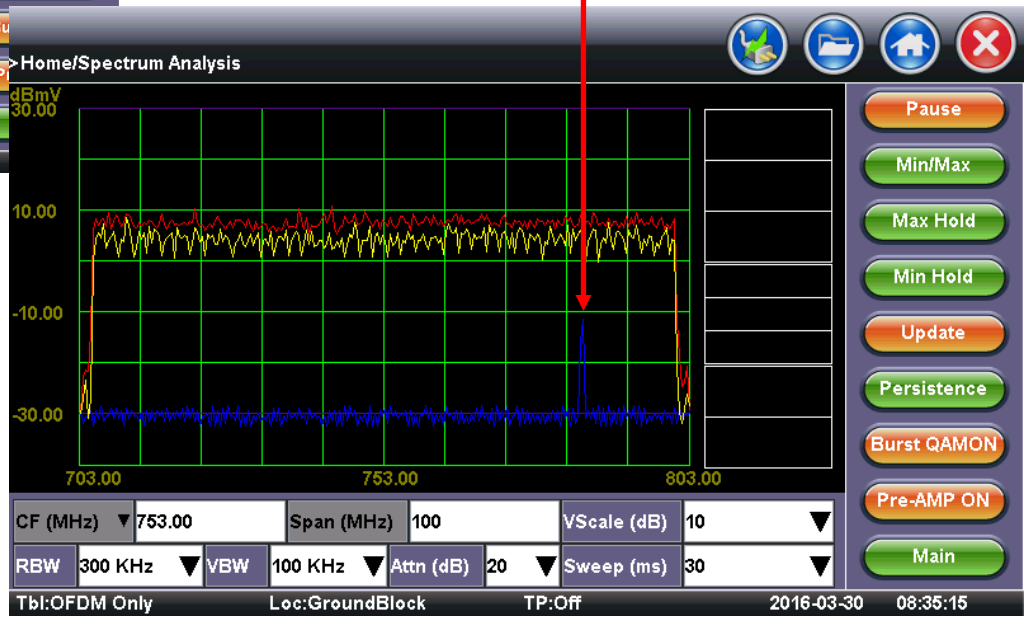
- Throughput testing both on Ethernet Port
- On or Off Net

Using Spectrum to find Noise under OFDM



OFDM 96 MHz
Running clean

Noise Detected @ NCP
Could cause modems to switch to 3.0



Questions???

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