DOCSIS 3.1
Signal Generation and Analysis
June 25, 2014

Jeff Murphy
RF/uW Application Engineer
Atlanta, GA
When Separated, Agilent’s EM Business will be named

Unlocking Measurement Insights for 75 Years
Our Key Purpose Has Not Changed
We believe in “Firsts”

• It’s in our DNA.

• Bill Hewlett and Dave Packard shaped our purpose of believing in firsts 75 years ago.

• It launched Silicon Valley.

• We are committed to bring you a new generation of firsts – unlocking insights for you so you can bring a new generation of technologies into the world.
DOCSIS 3.1
Signal Generation and Analysis
June 25, 2014

Jeff Murphy
RF/uW Application Engineer
Atlanta, GA
Agenda

• Introduction to DOCSIS 3.1 OFDM
• Hardware Solution Overview
• Analyzing DOCSIS 3.1 signals
• Generating DOCSIS 3.1 signals
• System Level DOCSIS 3.1 testing
• Q&A
• Summary
What is DOCSIS 3.1?

DOCSIS 3.1 is the latest generation CATV Cable Television standard to allow higher capacity, higher speeds, and lower latency than previous CATV standards.

- Downstream Capacity of up to 8 Gbps
- Upstream Capacity of up to 400 Mbps – 1 Gbps
## DOCSIS Standards

http://www.cablelabs.com/specs

<table>
<thead>
<tr>
<th>DOCSIS</th>
<th>ITU-T</th>
<th>Time</th>
<th>Downstream(DS)</th>
<th>Upstream(US)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOCSIS 1.0</td>
<td>J.112 (Annex B, 1998)</td>
<td>March 1997</td>
<td>64 / 256 QAM</td>
<td>QPSK / 16 QAM</td>
</tr>
<tr>
<td>DOCSIS 1.1</td>
<td>J.112 (Annex B, 2001)</td>
<td>April 1999</td>
<td>64 / 256 QAM</td>
<td>QPSK / 16 QAM</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Single-carrier QAM</td>
<td>Single-carrier QAM</td>
</tr>
<tr>
<td>DOCSIS 3.1</td>
<td></td>
<td>Oct. 2013</td>
<td>Multi-carrier OFDM 16 to 4096 QAM (excluding 32QAM)</td>
<td>Multi-carrier OFDMA BPSK to 4096 QAM</td>
</tr>
</tbody>
</table>

http://www.cablelabs.com/specs
What is OFDM?
Orthogonal Frequency Division Multiplexing

OFDM is a modulation format that achieves:

- **high data throughput** by transmitting on hundreds or thousands of carriers simultaneously.
- **high spectral efficiency** by spacing the carriers very closely.
- **high data integrity** by transmitting at a relatively slow symbol rate.
- **high interference robustness** by allowing deactivating specific subcarriers
OFDM Compared to Single Carrier Modulation

**Single Carrier Modulation**
- 1 carrier
- Up to 1024 QAM

**Bandwidth = Symbol Rate * (1+a)**

**OFDM - Many carriers**
- Up to 4096 QAM / Carrier

**Bandwidth = #carriers x spacing**

Subcarrier Index up to 8192 (0-8191)

(Frequency)

128 Symbols/Frame (time)
## DOCSIS 3.1 – Downstream OFDM Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>4K mode</th>
<th>8K mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream master clock frequency</td>
<td>10.24 MHz</td>
<td></td>
</tr>
<tr>
<td>Downstream Sampling Rate (fs)</td>
<td>204.8 MHz</td>
<td></td>
</tr>
<tr>
<td>Downstream Elementary Period (Tsd)</td>
<td>1/(204.8 MHz)</td>
<td></td>
</tr>
<tr>
<td>Channel bandwidths</td>
<td>24 MHz … 192 MHz</td>
<td></td>
</tr>
<tr>
<td>IDFT size</td>
<td>4096</td>
<td>8192</td>
</tr>
<tr>
<td>Subcarrier spacing</td>
<td>50 kHz</td>
<td>25 kHz</td>
</tr>
<tr>
<td>FFT duration (Useful symbol duration) (Tu)</td>
<td>20 μs</td>
<td>40 μs</td>
</tr>
<tr>
<td>Maximum number of active subcarriers in signal (192 MHz channel)</td>
<td>3800</td>
<td>7600</td>
</tr>
<tr>
<td>Values refer to 190 MHz of used subcarriers.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum spacing between first and last active subcarrier</td>
<td>190 MHz</td>
<td></td>
</tr>
<tr>
<td>Cyclic Prefix</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.9375 μs</td>
<td>(192 * Tsd)</td>
<td></td>
</tr>
<tr>
<td>1.25 μs</td>
<td>(256 * Tsd)</td>
<td></td>
</tr>
<tr>
<td>2.5 μs</td>
<td>(512 * Tsd)</td>
<td></td>
</tr>
<tr>
<td>3.75 μs</td>
<td>(768 * Tsd)</td>
<td></td>
</tr>
<tr>
<td>5 μs</td>
<td>(1024 * Tsd)</td>
<td></td>
</tr>
<tr>
<td>Windowing</td>
<td>Tukey raised cosine window,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>embedded into cyclic prefix</td>
<td></td>
</tr>
<tr>
<td>0 μs</td>
<td>(0 * Tsd)</td>
<td></td>
</tr>
<tr>
<td>0.3125 μs</td>
<td>(64 * Tsd)</td>
<td></td>
</tr>
<tr>
<td>0.625 μs</td>
<td>(128 * Tsd)</td>
<td></td>
</tr>
<tr>
<td>0.9375 μs</td>
<td>(192 * Tsd)</td>
<td></td>
</tr>
<tr>
<td>1.25 μs</td>
<td>(256 * Tsd)</td>
<td></td>
</tr>
</tbody>
</table>

### Downstream Range Freq (MHz)

<table>
<thead>
<tr>
<th></th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical</td>
<td>54</td>
<td>1002</td>
</tr>
<tr>
<td>Extended</td>
<td>108 &amp; 258</td>
<td>1218 &amp; 1794</td>
</tr>
</tbody>
</table>

Channel Bandwidth: 24 – 192 MHz

[http://www.cablelabs.com/specs](http://www.cablelabs.com/specs)
# DOCSIS 3.1 – Upstream OFDMA Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2k Mode</th>
<th>4k Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampling Rate ($f_{sam}$)</td>
<td>102.4 MHz</td>
<td>1/102.4 MHz</td>
</tr>
<tr>
<td>Elementary Period Rate ($T_{sam}$)</td>
<td>10 MHz, ..., 96 MHz</td>
<td>6.4 MHz, ..., 96 MHz</td>
</tr>
<tr>
<td>Channel Bandwidths</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IDFT size (depending on channel bandwidth)</td>
<td>2048</td>
<td>4096</td>
</tr>
<tr>
<td>Subcarrier spacing</td>
<td>50 kHz</td>
<td>25 kHz</td>
</tr>
<tr>
<td>FFT duration (useful symbol duration) ($T_{us}$)</td>
<td>20 μs</td>
<td>40 μs</td>
</tr>
<tr>
<td>Maximum number of active subcarriers in signal (96 MHz channel)</td>
<td>1900</td>
<td>3800</td>
</tr>
</tbody>
</table>

Values refer to 95 MHz of active subcarriers

<table>
<thead>
<tr>
<th>Parameter</th>
<th>2k Mode</th>
<th>4k Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream Cyclic Prefix</td>
<td>0.9375 μs ($96 * T_{us}$)</td>
<td>1.25 μs ($128 * T_{us}$)</td>
</tr>
<tr>
<td></td>
<td>1.5625 μs ($160 * T_{us}$)</td>
<td>2.1875 μs ($224 * T_{us}$)</td>
</tr>
<tr>
<td></td>
<td>2.5 μs ($256 * T_{us}$)</td>
<td>2.8125 μs ($288 * T_{us}$)</td>
</tr>
<tr>
<td></td>
<td>3.125 μs ($320 * T_{us}$)</td>
<td>3.75 μs ($384 * T_{us}$)</td>
</tr>
<tr>
<td></td>
<td>5.0 μs ($512 * T_{us}$)</td>
<td>6.25 μs ($640 * T_{us}$)</td>
</tr>
</tbody>
</table>

### Upstream Range Freq (MHz)

<table>
<thead>
<tr>
<th></th>
<th>Lower</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical</td>
<td>5</td>
<td>42 &amp; 65</td>
</tr>
<tr>
<td>Extended</td>
<td>85, 117, 204</td>
<td></td>
</tr>
</tbody>
</table>

### Channel Bandwidth: 6.4 – 96 MHz

[http://www.cablelabs.com/specs](http://www.cablelabs.com/specs)
DOCSIS 3.1 Upstream OFDMA

DOCSIS 3.1 Upstream – OFDMA
(Orthogonal Frequency Division Multiple Access)

User 1 + User 2 + User 3 = Typical OFDMA
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• Q&A
• Summary
DOCSIS 3.1 Signal Analysis
Test Platform Hardware

High Performance Upstream

N5172B EXG / N5182B MXG
Vector Signal Generator

Up to 120 MHz BW (EXG)
Up to 160 MHz BW (MXG)

DUT

N9030A PXA
Up to 160 MHz BW

Highest Performance Upstream and Downstream

M8190A
AXI Arbitrary Waveform Generator

Up to 5 GHz BW

DUT

U5303A PCIe Digitizer
Up to 625 MHz BW

Agilent Technologies
June 25, 2014
DOCSIS 3.1 Signal Analysis
Test Platform Hardware

Typical Upstream / Downstream Configuration

DUT

M8190A
AXI Arbitrary
Waveform Generator

Up to
5 GHz BW

U5303A
PCIe Digitizer

Up to
625 MHz BW

M8190A
14-bit 8 GSa/s and 12-bit 12 GSa/s mode

2 GSa memory for long playtime

5 GHz analog bandwidth

Digital Upconversion

U5303A
1.6 GS/s or 3.2 GS/s with interleaving

DC to 1.4 / 1.6 GHz

12 bits
DOCSIS 3.1 System Overview

Signal Generation Software

M8190A Arbitrary Waveform Generator

Off the shelf components

89601B Vector Signal Analyzer

Digitizer U5303A / M9703A

N9030A PXA for Spectrum Measurements

Uncoded

Coded OR Uncoded
Typical High Performance DOCSIS 3.1 Setup
Agenda

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DOCSIS 3.1 Measurement Challenge:

Modulation Error Ratio (MER): The ratio of average signal constellation power to average constellation error power – that is, digital complex baseband signal-to-noise ratio – expressed in decibels (1)

- For measurements below 600 MHz
  \[ \geq 50 \text{ dB} \] Average over the complete OFDM channel.

- For measurements from 600 MHz to 1002 MHz
  \[ \geq 47 \text{ dB} \] Average over the complete OFDM channel.

- For measurements 1002 MHz to 1218 MHz
  \[ \geq 45 \text{ dB} \] Average over the complete OFDM channel.

(1) [http://www.cablelabs.com/specs/specification-search/?cat=docsis&scat=docsis-3-1](http://www.cablelabs.com/specs/specification-search/?cat=docsis&scat=docsis-3-1)
U5303A PCIe High-Speed Digitizer
with On-Board Processing

Product Description
• Revolutionary and fast **dual-channel 12-bit PCIe digitizer with programmable on-board processing**, particularly suited for OEM applications
• Includes a **Xilinx Virtex-6 FPGA** allowing implementation of custom real-time processing algorithms using the available **U5340A FPGA Development Kit**

Features
• 1 channel with 12-bit resolution **up to 3.2 GS/s sampling rate** with interleaving enabled
• 2 channels up to 1.6 GS/s simultaneous sampling rate per channel
• **DC up to 1.4 / 1.6 GHz frequency range**
• 50 Ω input, 1 V or 2 V full scale range (FSR)
• Up to 4 GB DDR3 on-board memory
• ± 200 fs channel-to-channel skew stability
• 15 ps trigger time interpolator (TTI)
• 225 fs sampling jitter
• On-board data processing using a **Xilinx Virtex-6 FPGA**
• Support for loading custom real-time processing
• **PCI Express 2.0 eight lanes (x8)**
• IVI-C and IVI-COM drivers for Windows
DOCSIS 3.1 Signal Analysis

**U5303A:**
- SR2: 1.6 GS/s
- INT: Interleave to 3.2 GS/s
- F10: DC to 1.4 GHz input range

**89601B VSA**

**PCIe Rack mount Expansion chassis**

**OR**

**Desktop PC:**

One Analysis Channel: DC – 1.4 GHz, 3.2 GS/s
or
Two Analysis Channels: 1.6 GS/s
The Key to DOCSIS 3.1 Measurements
89601B Vector Signal Analyzer

89601B VSA – v 18.0

Featuring:
• Enhanced Custom OFDM Demodulation Personality

• DOCSIS 3.1 Downstream Demodulation Setup Wizard
Modulation Error Ratio vs Error Vector Magnitude

\[ MER = \frac{RMS \text{ Average Signal Constellation Power}}{RMS \text{ Average Signal Constellation Error Power}} \]

\[ QAM \ EVM\% = \frac{RMS \text{ Average Signal Constellation Error Vector}}{\text{Magnitude of Constellation Maximum}} \]

\[ % \ EVM = \sqrt{\frac{1}{N} \sum_{n=0}^{N-1} (I_{err}[n]^2 + Q_{err}[n]^2)} \times 100\% \]

where:
- \( n \) = symbol index
- \( N \) = number of symbols
- \( I_{err} = I \text{ Ref} - I \text{ Meas} \)
- \( Q_{err} = Q \text{ Ref} - Q \text{ Meas} \)

Custom OFDM \( EVM(dB) = \frac{RMS \text{ Average Signal Constellation Error Power}}{RMS \text{ Average Signal Constellation Power}} \)

When “EVM Normalized by Reference” checkbox is selected in 89601B
For Custom OFDM, EVM Normalized by Reference can be selected, then EVM value in dB would be same as MER (MER = -EVM).
89601B Vector Signal Analyzer
DOCSIS 3.1 Downstream 4KQAM Demodulation – M8190A/U5303A – 200 MHz
89601B Vector Signal Analyzer
DOCSIS 3.1 Downstream 4KQAM Demodulation – M8190A/U5303A – 200 MHz
## E: Ch1 OFDM Error Summary

<table>
<thead>
<tr>
<th></th>
<th>Ch1</th>
<th>Ch2</th>
<th>Ch3</th>
<th>Ch4</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>EVM/MER</td>
<td>-53.899</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>-53.899 dB</td>
</tr>
<tr>
<td>EVMPeak</td>
<td>-41.975</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>-41.975 dB</td>
</tr>
<tr>
<td>PilotEVM</td>
<td>-62.542</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>-62.542 dB</td>
</tr>
<tr>
<td>DataEVM</td>
<td>-53.568</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>-53.568 dB</td>
</tr>
<tr>
<td>PmblEVM</td>
<td>-54.008</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>-54.008 dB</td>
</tr>
<tr>
<td>FreqErr</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>18.317 MHz</td>
</tr>
<tr>
<td>SymClkErr</td>
<td>0.00005</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>0.00005 ppm</td>
</tr>
<tr>
<td>CPE</td>
<td>0.02437</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>0.02437 %</td>
</tr>
<tr>
<td>SyncCorr</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>100 %</td>
</tr>
<tr>
<td>IQOffset</td>
<td>-36.158</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>-36.158 dB</td>
</tr>
<tr>
<td>IQQuadErr</td>
<td>-0.0015</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>-0.0015 deg</td>
</tr>
<tr>
<td>IQGainLmb</td>
<td>0.00136</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>0.00136 dB</td>
</tr>
<tr>
<td>IQTimeSkew</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
<td>***</td>
</tr>
</tbody>
</table>
89601B Vector Signal Analyzer
DOCSIS 3.1 Downstream 4KQAM Demodulation – M8190A/U5303A – 600 MHz
89601B Vector Signal Analyzer
DOCSIS 3.1 Downstream 4KQAM Demodulation – M8190A→U5303A at 1GHz
Analyzing Customer Generated DOCSIS 3.1 Signals

Demodulator needs to know:

- basic time, frequency and FFT parameters.
- which subcarriers are pilots?
- which subcarriers are preambles?
- what are the expected I-Q values for each preamble and pilot subcarrier?
- what is the expected modulation format for each data subcarrier?

Options to Configure 89601B for DOCSIS 3.1 Demodulation

89601B Setup Wizard
M9099T Waveform Creator
SystemVue
Modify User Accessible Text Files
**DOCSIS 3.1 Configuration Wizard**

<table>
<thead>
<tr>
<th>FFT Mode</th>
<th>Guard Interval</th>
<th>Data Modulation</th>
<th>Windowing</th>
</tr>
</thead>
<tbody>
<tr>
<td>4096</td>
<td>1/16, 1/8, 1/4, 3/64, 3/16</td>
<td>16QAM, 64QAM, 256QAM, 1024QAM, 4096QAM</td>
<td>0, 1/128, 1/64, 3/128, 1/32</td>
</tr>
<tr>
<td>8192</td>
<td>1/32, 1/16, 1/8, 3/128, 3/32</td>
<td>16QAM, 64QAM, 256QAM, 1024QAM, 4096QAM</td>
<td>0, 1/128, 1/64, 3/128, 1/32</td>
</tr>
</tbody>
</table>

Type in a number (odd not even) of subcarriers. Channel bandwidth allows for some band-gap between channels. (See details in next slide.)

**Channel Bandwidth (MHz)**

<table>
<thead>
<tr>
<th>FFT Mode</th>
<th>Channel Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>FFT 4096</td>
<td>22.5 MHz, 47.5 MHz, 95 MHz, 190 MHz</td>
</tr>
<tr>
<td>FFT 8192</td>
<td>451 MHz, 951 MHz, 1901 MHz, 3801 MHz</td>
</tr>
</tbody>
</table>

- 22.5 MHz
- 47.5 MHz
- 95 MHz
- 190 MHz
- 451 MHz
- 951 MHz
- 1901 MHz
- 3801 MHz
- 901 MHz
- 1901 MHz
- 3601 MHz
- 7601 MHz
# DOCSIS 3.1 Configuration Wizard

<table>
<thead>
<tr>
<th>FFT Mode</th>
<th>Guard Interval</th>
<th>Data Modulation</th>
<th>Window Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>4096</td>
<td>1/16, 1/8, 1/4, 3/64, 3/16</td>
<td>16QAM, 64QAM, 256QAM, 1024QAM, 4096QAM</td>
<td>0, 1/128</td>
</tr>
<tr>
<td>8192</td>
<td>1/32, 1/16, 1/8, 3/128, 3/32</td>
<td>64QAM, 256QAM, 1024QAM</td>
<td>1/64, 3/128, 1/32</td>
</tr>
</tbody>
</table>

Window size is typically not more than \(\frac{1}{2}\) of the size of the guard interval.

PLC Center Position is typically in the center of the band; 4096 FFT gives 2048 default, 8192 FFT gives 4096 default. If you select a different number, please make sure that PLC is within the bandwidth of the active subcarriers.
DOCSIS 3.1 Configuration Wizard
Example with successful setup file generation

You may get a pop-up viewer to show how your configured signal may look like in vertical (symbol, time domain) and horizontal (subcarrier, frequency domain) layout.

Color:
- WHITE (continuous pilots. PLC pilots and scattered pilots)
- BLUE (data subcarriers)
- CYAN (PLC preamble)
- RED (PLC data)
- BROWN (Exclusion subcarriers)
89601B Vector Signal Analyzer

DOCSIS 3.1 Upstream Demodulation Setup Wizard

For users who need to demodulate a Cable Modem Upstream Signal using Agilent 89601B VSA Software

*If you are interested in upstream DOCSIS 3.1 signal analysis with 89601B VSA software, please contact your local Agilent Sales Representative for DOCSIS 3.1 Upstream wizard beta request.
Upstream Signal Created and Measured with M8190A Arb and U5303A Digitizer
Example of Impairments that can be measured using 89601B

1. Amplitude & Phase Drift
2. Timing Errors
3. Spurious Interference
4. Clipping
5. I-Q Errors
Timing Error Between Source and Receiver
Timing Error After Clock Adjustment

Symbol rate set to 204.7997225 MHz instead of default 204.8 MHz
Phase Noise In Source
Phase Noise In Source Optimized
Interfering Pulsed QPSK Signal

INTERFERING PULSED QPSK SIGNAL 5 MSym/Sec - 200 µS PW 500 µS PRI, -50 dBm
Looking Closer At Frequency Of Interferer
Looking Closer At Timing Of Interferer
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M8190A – Main Features

- **Breakthrough performance**
- Up to 90 dBc SFDR for reliable and repeatable measurements
- 14 bit 8 Gsa/s or 12 bit 12 Gsa/s
- Variable sample rate from 125 Msa/s to 8/12 Gsa/s
- 2 GSa memory for long play time
- 5 GHz analog bandwidth
- For today’s and tomorrow’s apps
- Operation with leading software platforms
DOCSIS 3.1 Signal Generation Options

Signal Creation Options:

- **M9099T Waveform Creator** 2.0 offers ability to create “statistically correct” DOCSIS 3.1 waveforms

- **SystemVue** is software platform to develop “fully coded” Upstream / Downstream DOCSIS 3.1 compliant signals

- **User Defined Waveforms** using various programming languages

- **Waveforms provided via Agilent Consulting**

M8190A – Arbitrary Waveform Generator

- Deep Memory for Long Playback
- Widest BW for Network Characterization

Customer Receiver
M9099T Waveform Creator 2.0 - Downstream

DOCSIS 3.1 Segment 1

Basic Settings
- DOCSIS Type: Downstream

Downstream Settings
- FFT Mode: 4096
- Cyclic Prefix: 1.25 μs (256 * Tsd)
- Active Subcarriers: 3800
- Data Modulation: 4096-QAM
- Windowing: 0.625 μs (128 * Tsd)
- PLC Start Index: 2048

Continuous Pilots
Pilots that occur at the same frequency location in every OFDM symbol, and which are used for frequency and phase synchronization.
M9099T Waveform Creator 2.0 - Upstream

**Basic Settings**
- **DOCSIS Type**: Upstream
- **FFT Mode**: 4096
- **Cyclic Prefix**: 0.9375 µs (96 * Tsu)
- **Active Subcarriers**: 3800
- **Data Modulation**: 4096-QAM
- **Windowing**: 0.3125 µs (32 * Tsu)
- **K (Symbols/frame)**: 12
- **Pilot Pattern**: 8
- **Minislot Start**: 0
- **Minislot Stop**: 236

**Minislot Start**
Start position for a group of dedicated subcarriers, all with the same modulation order, for upstream transmission by a given cable modem.

**Waveform Layout**
- **Zoom**, **Scale To Fit**, **View Tracks**

**Output Device Window**
- **File (csv, binary or matlab)**
- **Waveform Preview**
- **Spectrum**

**Spectrum**
- **X**: 80 MHz
- **Y**: 125.198 dBm
- **Log Mag**:
- **dBm**:
- **Center**: 7.4506 nHz
- **Span**: 160 MHz
DOCSIS 3.1 Support in M9099T
Waveform Creator 2.0

M8190A Hardware Support

89601B VSA Setup File Generation
“Design to Test” with Agilent SystemVue
Accelerating Layer 1 Comms Design

- Connect Design to Test for rapid validation
- Rapid prototyping with integrated measurement
- Quickly capture “system level” design concepts
- Model implementation level impairments

Design  Validate  Test
Mixed Spectrum Combining And Resampling

Use *SignalCombiner* for mixed spectrum environments study (SC-QAM and OFDM)

The *SignalCombiner* model combines multiple input signals with different sample rates, different characterization (carrier) frequencies, and different bandwidths into a single signal at the specified characterization frequency and sample rate.
SystemVue Output DOCSIS 3.1 Downstream Combined with 88 DOCSIS 3.0 QAM Carriers
Agenda

• Introduction to DOCSIS 3.1 OFDM
• Hardware Solution Overview
• Analyzing DOCSIS 3.1 signals
• Generating DOCSIS 3.1 signals
• System Level DOCSIS 3.1 testing
• Q&A
• Summary
DOCSIS 3.1 Coded BER Measurement Setup

**SYSTEMVUE**

**DOCSIS 3.1 Coded Source**
- Automatic waveform creation & download
- Digital Modem Source for Linear Modulation
- DSSS System
- Payload_ModType=16-QAM
- Preamble_ModType=BPSK

**DOCSIS 3.1 Coded Receiver**
- Reference Receiver
- TrackingAlgorithm=LMS
- FreqSync_Mode=CIR Corr
- FrameSync_Algorithm=DiffCorr
- {DigMod_ReceiverL_FastDFE}
- Decision Feedback Equalizer
- Fast Computation Algorithm
- CIR --&gt; DFE coefficients

**Reference Receiver**
- (DigModReceiverL_FastDFE)
- FrameSync_Algorithm=DIR Corr
- FreqSync_Mod=OIF Corr
- TrackingAlgorithm=UMS

**BER/FER Measurement**
- BPSK, QPSK, ..., up to 4096-QAM
- 8-PSK, 16-PSK, 16-APSK, 32-APSK
- 16-Star QAM, 32-Star-QAM, and Custom APSK

**Reference Receiver**
- BPSK, QPSK, ..., up to 4096-QAM
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**Automatic waveform creation & download**

**M8190A 12 GSa/S Arbitrary Waveform Generator**

**DUT**

**M9703A / U5303A Digitizer**
- Now with low density parity check LDPC decoding

**BER/FER Measurement**
- DOCSIS 3.1 Coded Source
- Reference Receiver
Downstream BER Analysis With Agilent U5303A Digitizer and 89601B VSA Software

V1 (VSA_89600B_Source@Data Flow Models)
- VSATitle=Simulation output
- OutputType=Timed (Envelope/Real Baseband)
- VSATrace=B
- TStep=2.441e-9s [1/SamplingRate]

DOCSIS_Receiver
- FCarrier=500MHz [FCarrier]
- OversamplingRatio=2 [OversamplingRatio]
- FFT_Mode=4k Mode [FFT_Mode]
- CyclicPrefix=5 us (1024*Tsd)
- RollOffPeriod= 0 us (0*Tsd)
- ExclusionEdgeBand=31 [ExclusionEdgeBand]
- Is_ExclusionBands=NO [Is_ExclusionBands]
- PLC_StartSubcarrier=2000
- ContinuousPilots_M=60
- Payload_ModType=4096-QAM [Payload_ModType]
- NCP_Number=3 [NCP_Number]
- NCP_ModType=64-QAM [NCP_ModType]
- OFDMSync_Mode=Corr
- FreqSync_Mode=Corr
- TimeIntv_M=16
- CodewordType=non-Shortened
- DemapperType=ML
- SNRType=CSI

TEST

REF

Payload bits

1 1 0 1 0

B4 (PRBS@Data Flow Models)

D13 (InitDelay@Data Flow Models)
- N=4.924e+6 [BitsPerFrame]
- InitialDelay=0
DOCSIS 3.1 DS Coded Simulated BER Curves

Eb/No is the energy per bit to noise power spectral density...
Signal to noise ratio per bit
Detecting Amplifier Clipping using N9030A with Real Time Spectrum Analysis Frequency Mask Trigger

Detect spectral regrowth caused by amplifier clipping. Use the RTSA Frequency Mask Trigger (FMT) to trigger a 89601B recording. This allows post processing of clipping event.
DOCSIS / OFDM References

Custom OFDM Signal Generation Using SystemVue

Essentials of OFDM and MIMO Recorded Webcast
http://www.home.agilent.com/agilent/eventDetail.jspx?ckey=2167589&nid=-34958.0.00

Understanding OFDM Signal Generation and Analysis Recorded Webcast
http://www.home.agilent.com/agilent/eventDetail.jspx?ckey=2012246&nid=-34845.0.00

SystemVue Custom OFDM demonstration
http://www.youtube.com/watch?v=lFtCuKKi8Jw

SystemVue for OFDM
http://www.agilent.com/find/eesof-systemvue-ofdm

For more information about Agilent VSA
http://www.agilent.com/find/89601B
DOCSIS / OFDM References

M9099T Waveform Creator Application Software Data Sheet (DOCSIS 3.1 Coming in version 2.0)

Systems For OFDM Based Digital Signal Assessments For CATV Networks (2014)

Quickly Validate Designs for DOCSIS 3.1 Compliance – Application Brief

DOCSIS 3.1 Specification – Version I03 released 6/10/14
http://www.cablelabs.com/specs/specification-search/?cat=docsis&scat=docsis-3-1
DOCSIS / OFDM References

U5303A High Speed 2 Channel Digitizer
http://www.agilent.com/find/u5303A

M8190A Arbitrary Waveform Generator
http://www.agilent.com/find/m8190a

M9703A High Speed 8 Channel Digitizer
http://www.agilent.com/find/m9703a
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Summary

• Multiple hardware platforms optimized for your specific upstream / downstream measurement needs

• Advanced DOCSIS 3.1 OFDM/A Analysis using 89601B Vector Signal Analysis to find hidden spectral and timing errors

• M9099T Waveform Creator 2.0 to quickly create uncoded DOCSIS 3.1 Waveforms

• SystemVue for multi-carrier/format generation and analysis of both uncoded/coded DOCSIS 3.1 signals. Now with DOCSIS 3.1 BER analysis with low density parity check (LDPC) decoding.
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Thank You!