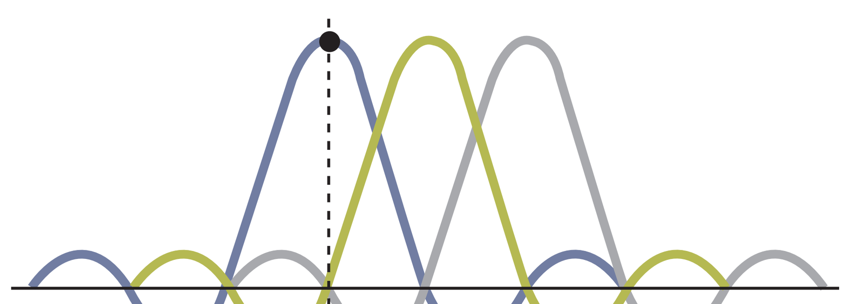
DOCSIS 4.0

VeEX
The Verification Experts

OFDM Basics

Orthogonal Frequency Division Multiplexing

- OFDM is a transmission technique that consists of multiplexing multiple individual subcarriers
- For DOCSIS 3.1/4.0, these subcarriers are QAM modulated
- Orthogonality enables subcarriers to be closely spaced together, without interfering with each other

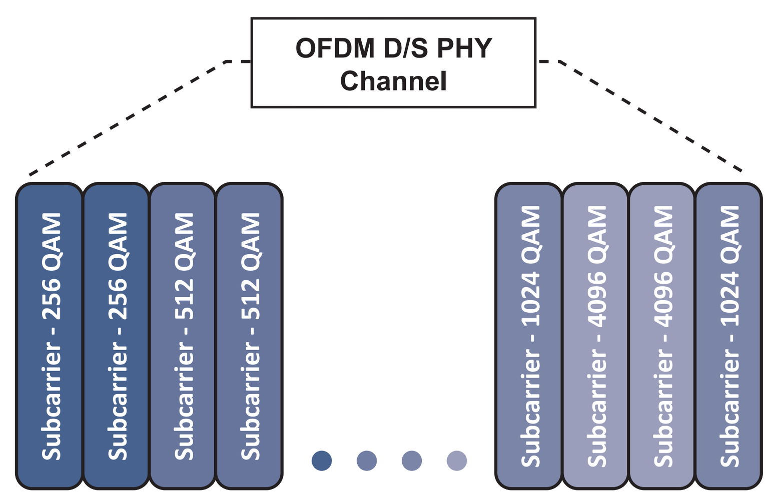


OFDMA Upstream

- Orthogonal Frequency Division Multiple Access
- DOCSIS 3.1/4.0 replaces TDMA with OFDMA subcarriers
- More robust with time and frequency interleaving and LDPC coding

OFDM Subcarriers

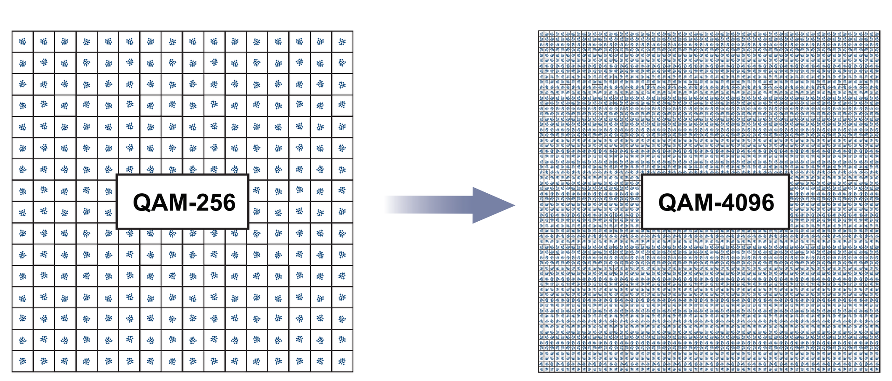
- Subcarriers have precise frequency with either 25 kHz or 50 kHz spacing
- Thousands of OFDM subcarriers are packed close together and each individual subcarrier can use different QAM modulation depending on line quality
- Up to 7600 (25 kHz) or 3800 (50 kHz) subcarriers comprise a 190 MHz wide OFDM data channel with 1 MHz guard bands on each end



Higher Order QAM

Higher Order QAM Modulation with Dynamic Adaptation

- D3.1 / D4.0 supports multiple modulation profiles: base modulation and higher modulation profiles
- Different profiles can be used depending on customer line quality
- Higher quality lines can utilize higher modulation profiles
- Dynamic adaptation to line conditions. When an impairment appears, the affected OFDM subcarrier can downshift to a lower order modulation to help ensure robust, error free transmission

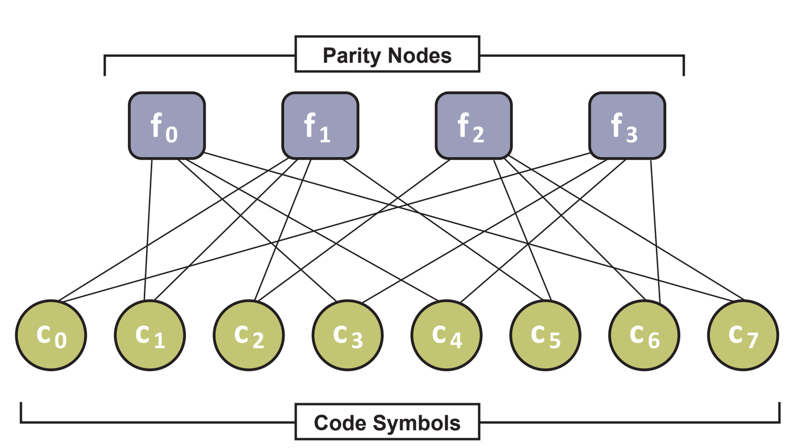


Modulation Capability			
Modulation	SNR Min	SNR Max	bps/Hz
QAM-256	26	29	8
QAM-512	29	32	9
QAM-1024	32	35	10
QAM-2048	35	38	11
QAM-4096	38	41	12

General Facts

Low Density Parity Check (LDPC)

- D3.1 / D4.0 uses this advanced forward error correction (FEC) technology which provides performance close to the Shannon Theoretical Limit
- Uses frequency and time interleaving for robustness against interferers and bursts
- Greater spectral efficiency
- LDPC FEC can yield a nearly 2 bit gain from Reed Solomon FEC



Low Latency

- DOCSIS 4.0 specifies support for Low Latency Services with a target of a 99 percentile round trip time of 1 millisecond for packets traversing the DOCSIS network
- Use of next-generation TCP protocols and non-TCP applications which do not cause buffering delay
- Adds support for a proactive scheduler to mitigate media access delay
- Enhances the performance of latency sensitive services like multiplayer gaming

Bit Node vs. Parity Node Graph

Bit Node = Code Symbol

Parity Node = Parity Equation

A line is drawn between Nodes only if the bit is involved in the parity equation

$$\begin{bmatrix} 0 & 1 & 0 & 1 & 1 & 0 & 0 & 1 \\ 1 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \end{bmatrix}$$

Parity Check Matrix has low 1s in comparison to 0s

Extended Spectrum (ESD)

Getting Even More Out of the HFC Network

- Expands Downstream spectrum from 1218 MHz used in DOCSIS 3.1 to 1794 MHz (future expansion to 3 GHz is being considered)
- Expands Upstream spectrum to 684 MHz

The following may need to be upgraded to support DOCSIS 4.0:

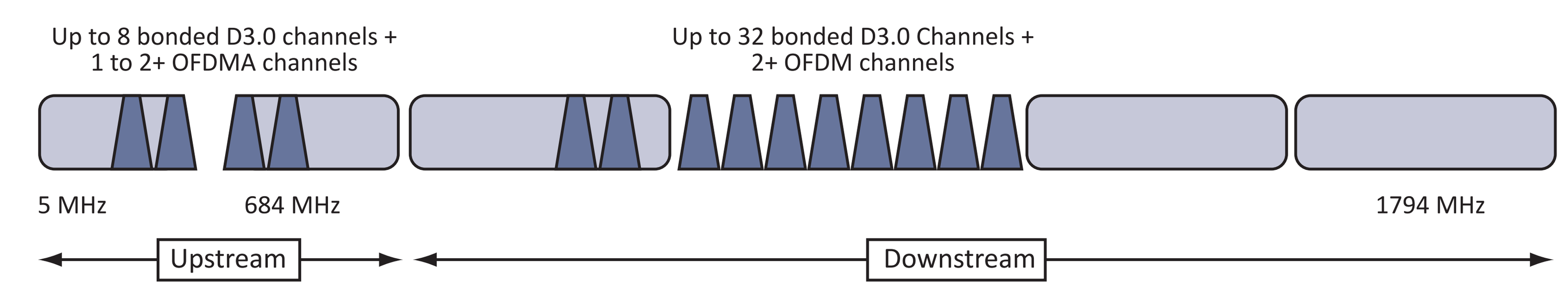
- Changing Amplifiers versus going to a Node+0 architecture
- Tap Faceplates to accommodate high-output RF levels from next generation Nodes/Amps
- Tap Housings to accommodate 1.8 GHz taps and future 3 GHz taps

DOCSIS Spectrum and Data Throughput Evolution				
		DOCSIS 3.0	DOCSIS 3.1	DOCSIS 4.0
Downstream	Max Spectrum	1002 MHz	1218 MHz	1794 MHz
	Throughput	1 Gbps	5 Gbps	10 Gbps
Upstream	Max Spectrum	85 MHz	204 MHz	684 MHz
	Throughput	200 Mbps	1 to 2 Gbps	6 Gbps

OFDM Channel Capacity

Sample Channel Bandwidth		
Channel Width	Spectral Efficiency	Channel Capacity
192 MHz	8.1996	1.5 Gbps
96 MHz	8.1996	787 Mbps
48 MHz	8.1996	394 Mbps
24 MHz	8.1996	197 Mbps
Channel Capacity = Spectral Efficiency x Channel Bandwidth		

HFC Network Expansion



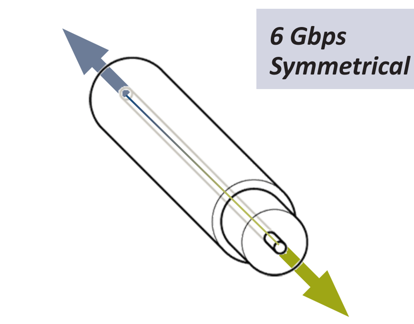
RF Channel Transmission Characteristics

	Parameter	Value	
DOWNSTREAM	Frequency range	Cable system normal downstream operating range from 108 MHz to 1218 MHz. Extended operating ranges includes upper downstream edge of 1794 MHz.	
	RF channel spacing (design bandwidth)	24 to 192 MHz	
	One way transit delay from headend to most distant customer	≤ 0.400 ms (typically much less)	
	Signal-to-Composite Noise Ratio	≥ 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-Cross modulation ratio	Not less than 41 dB	
	Carrier-to-any other discrete interference (ingress)	Not less than 41 dB	
	Maximum amplitude variation across the 6 MHz channel (digital channels)	≤ 1.74 dB pk-pk / 6 MHz	
	Group Delay Variation*	≤ 113 ns over 24 MHz	
	Micro-reflections bound for dominant single echo	-20 dBc for echos ≤ 0.5 µs -25 dBc for echos ≤ 1.0 µs -30 dBc for echos ≤ 1.5 µs -35 dBc for echos > 2.0 µs	-40 dBc for echos > 3.0 µs -45 dBc for echos > 4.5 µs -50 dBc for echos > 5.0 µs
	Carrier hum modulation	Not greater than -30 dBc (3%)	
	Maximum analog video carrier level at the CM input	17 dBmV	
	Maximum number of analog carriers	121	
	**Cascaded group delay could possibly exceed the ≤113 ns value within approximately 30 MHz above the downstream spectrum's lower band edge, depending on cascade depth, diplex filter design, and actual band split.*		
UPSTREAM	Frequency range	Cable standard upstream frequency range is from a lower band-edge of 5 MHz to upper band-edge 85 MHz.	
	One way transit delay from most distant customer to headend	≤ 0.400 ms (typically much less)	
	Carrier-to-interference plus ingress ratio	Not less than 25 dB	
	Carrier hum modulation	Not greater than -26 dBc (5.0%)	
	Maximum amplitude variation across the 6 MHz channel (digital channels)	≤ 2.78 dB pk-pk / 6 MHz	
	Group Delay Variation**	≤ 163 ns over 24 MHz	
	Micro-reflections bound for dominant single echo	-16 dBc for echos ≤ 0.5 µs -22 dBc for echos ≤ 1.0 µs -29 dBc for echos ≤ 1.5 µs	-35 dBc for echos > 2.0 µs -42 dBc for echos > 3.0 µs -51 dBc for echos > 4.5 µs
	Seasonal and diurnal reverse gain (loss) variation	Not greater than 14 dB min to max	
	***Cascaded group delay could possibly exceed the ≤163 ns value within approximately 10 MHz of the upstream spectrum's lower and upper band edges, depending on cascade depth, diplex filter design, and actual band split.*		

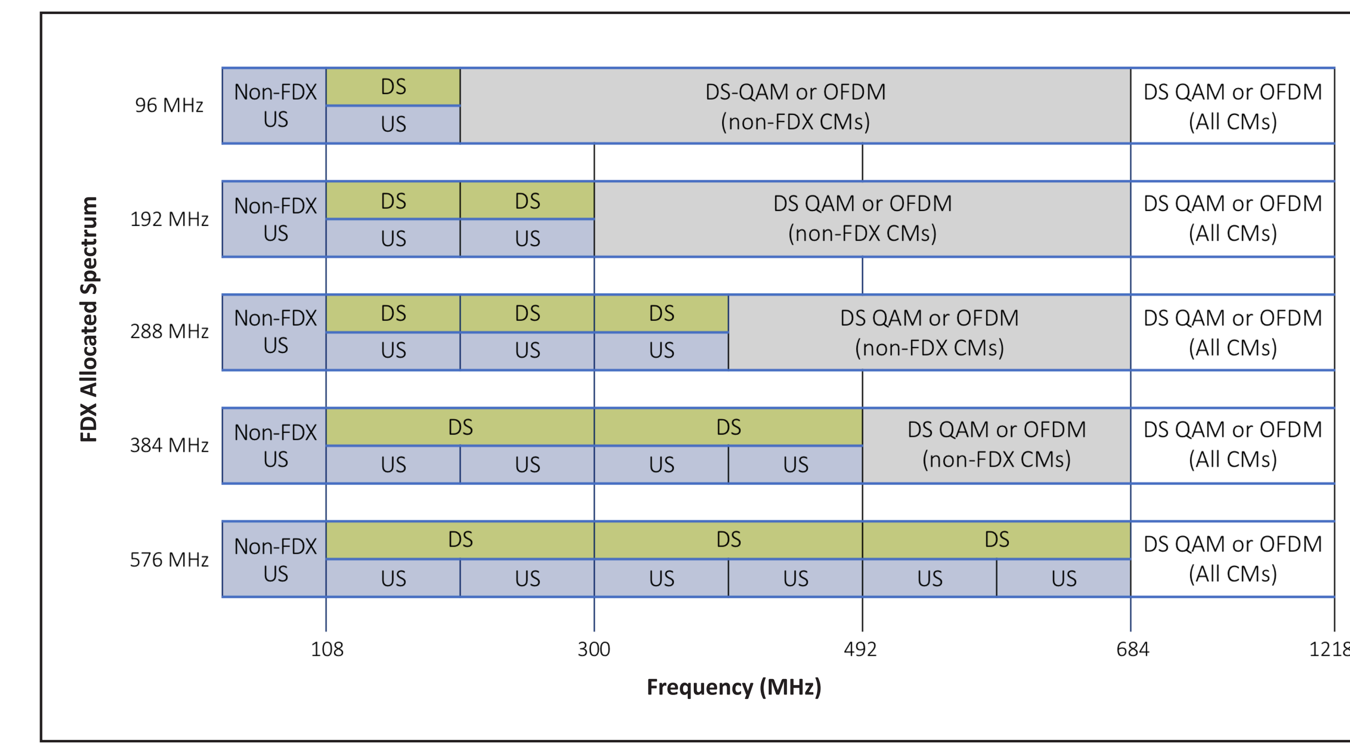
Full Duplex (FDX)

Enabling Higher Symmetrical Services

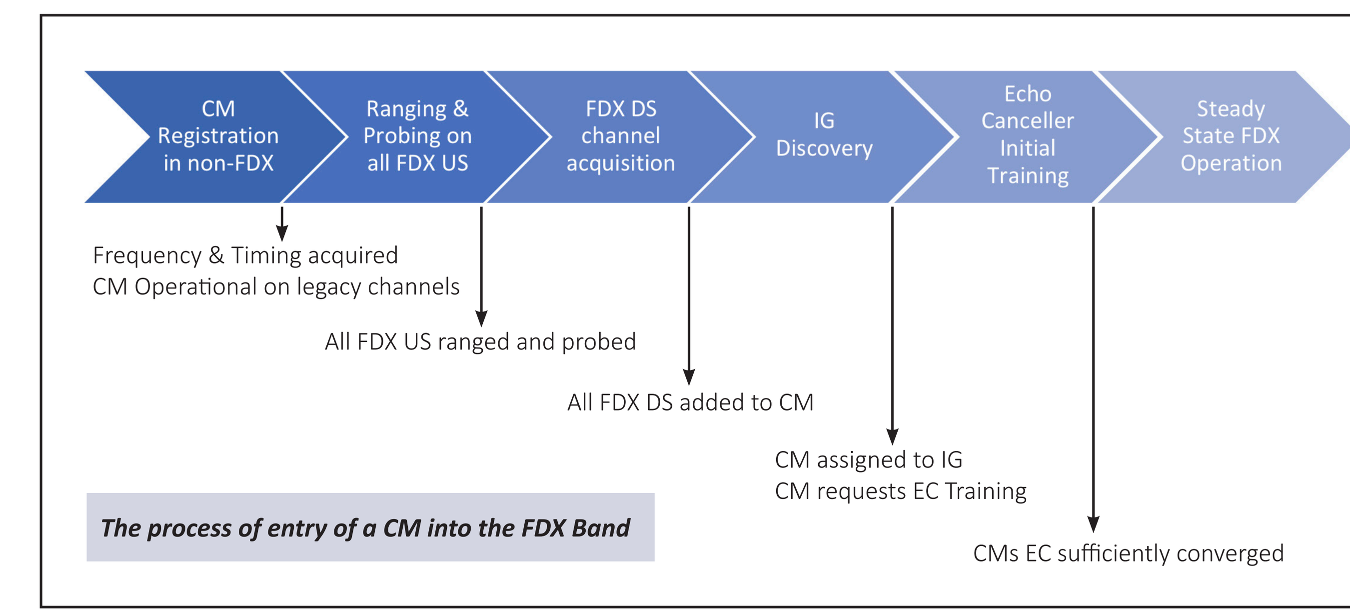
- Full Duplex DOCSIS (FDX) allows for concurrent use of the same block of spectrum for upstream and downstream traffic in the 108 MHz to 684 MHz spectrum
- Features Self-interference cancellation and Intelligent scheduling
- Enables expansion of Upstream traffic to 6 Gbps
- Multi-gigabit symmetric services, ideal for Business Services
- Requires Node+0 architecture



Configurable FDX Allocated Spectrum Bandwidths



CM FDX Entry Sequence



VeEX® Test Solutions

AT2500-3G Headend Analyzer

- Features a best-in-class 3 GHz Spectrum Analyzer
- OFDM Analyzer with powerful Subcarrier Scan (patent pending)
- VeCheck Fast Full Band Scan
- Optional DOCSIS Test Module

CX380C Field Maintenance Tool

- Features a fast 1.8 GHz Spectrum Analyzer
- Supports Sweep: 1.8 GHz Downstream and 204 MHz Upstream
- DOCSIS Modem Emulation
- Works in conjunction with the **CaLan 3010H+** Sweep System
- OFDM Analyzer with powerful Subcarrier Scan (patent pending)

CaLan 3010H+ Sweep System

- 1U 19" Headend Unit for Sweep
- 1.8 GHz Transmitter and 204 MHz Receiver
- Works in conjunction with the **CX380C** and **CX380s-D3.1** field test sets
- Fully integrated with the VeSion™ Cloud-based One System Platform

For more information, visit **www.veexinc.com**

DOCSIS Test Solutions

CaTV Test Solutions