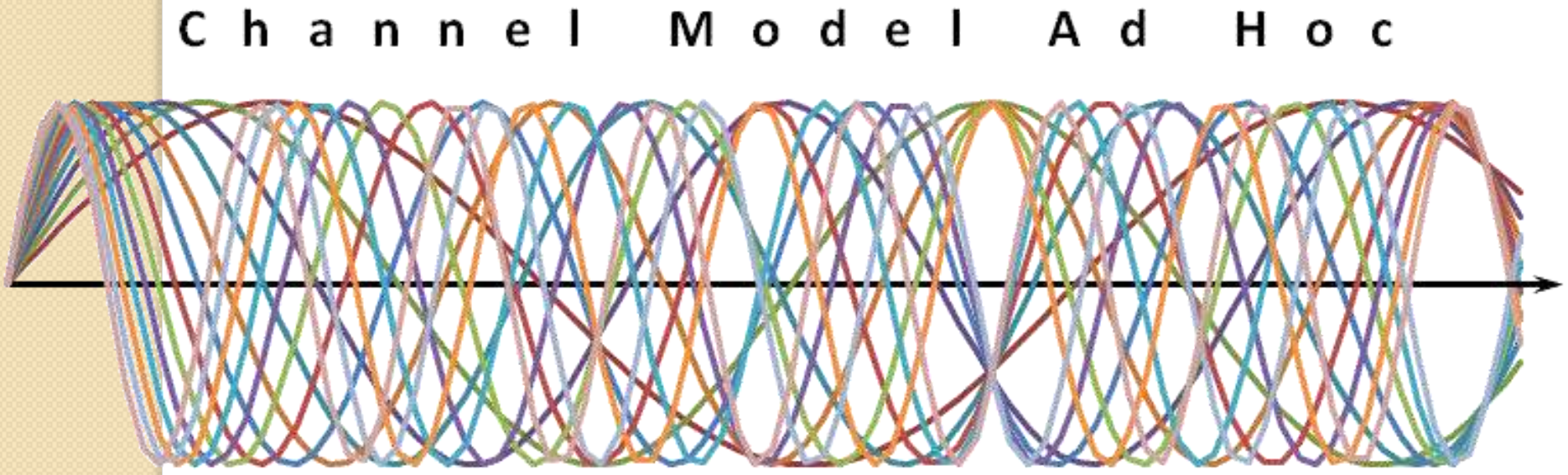
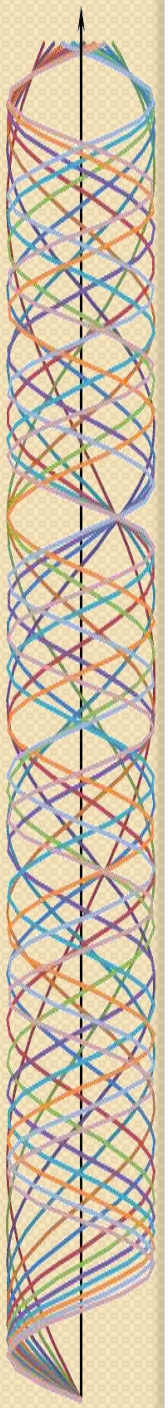
IEEE p802.3bn EPoC

Channel Model Ad Hoc committee

Baseline Channel Model recommendations

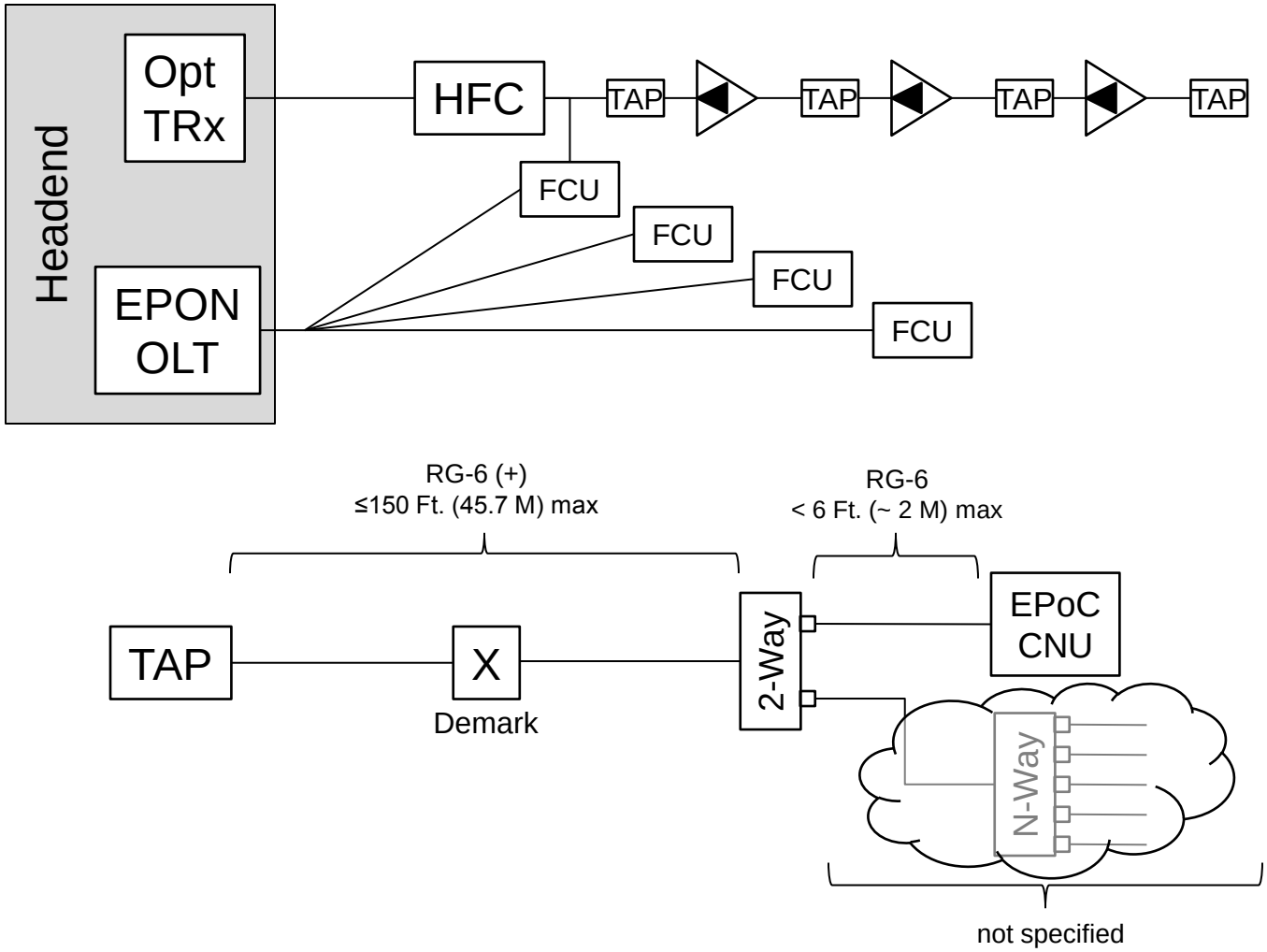


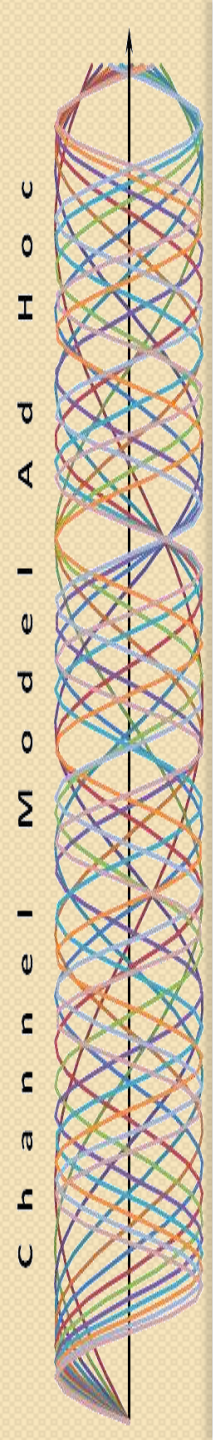


Agenda

- Topology illustrations
- Parameter Table

Baseline Topology

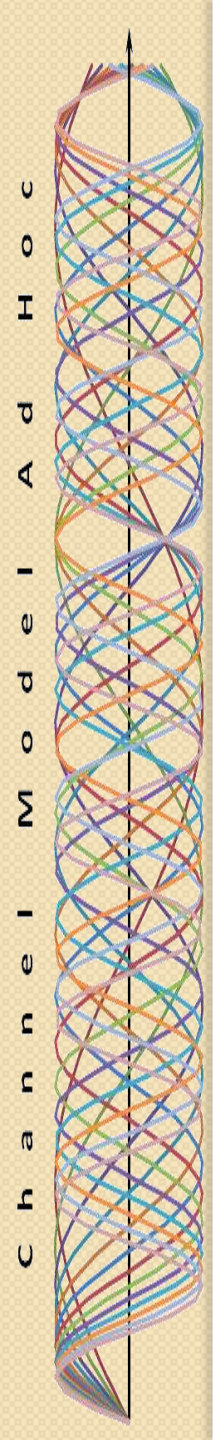




Baseline Parameter Table (1 of 5)

Downstream

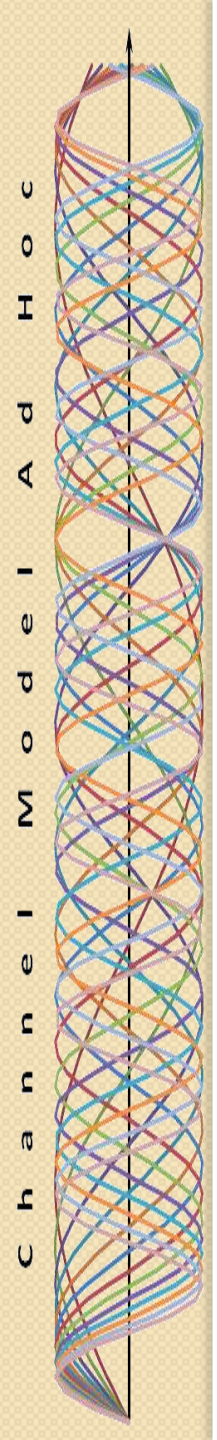
System Description	
HFC D/S Spectrum	1.0 GHz
Cascade Depth	N+3
Channel Loading	48 Analog (32 removed for EPoC) + 75 Digital + EPoC Band (digital PSD@-6 dBc)
Optical Architecture	Linear Optics 1310 nm (nominal link length) Legacy, EPoC RF Coupled after Node
Home Architecture	Up to max drop length & 2-way splitter



Baseline Parameter Table (2 of 5)

Downstream

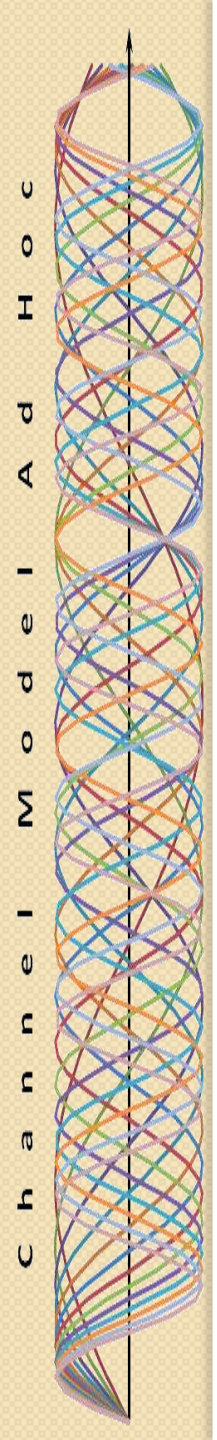
	#	Parameters	Baseline Channel Conditions	Notes/Dependency
Spectrum	1	**Frequency range**	54 MHz - 1 GHz	Note 1
	2	**OFDM Bandwidth**	192 MHz	
RF Level	3	**OFDM Power at CPE Input (dBmV)**		Notes 2-4
		6 MHz BW	-2	
		24 MHz BW	4	
		96 MHz BW	10	
		192 MHz BW	14	Note 5
SNR	4	**SCN Ratio (Signal to Composite Noise Ratio)**	44	Note 6
		Variation over 6 MHz BW (dB)	N/A	Reference Basis 6 MHz
		Variation over 24 MHz BW (dB)	1.5	
		Variation over 96 MHz BW (dB)	2.5	
		Variation over 192 MHz BW (dB)	3.0	



Baseline Parameter Table (3 of 5)

Downstream

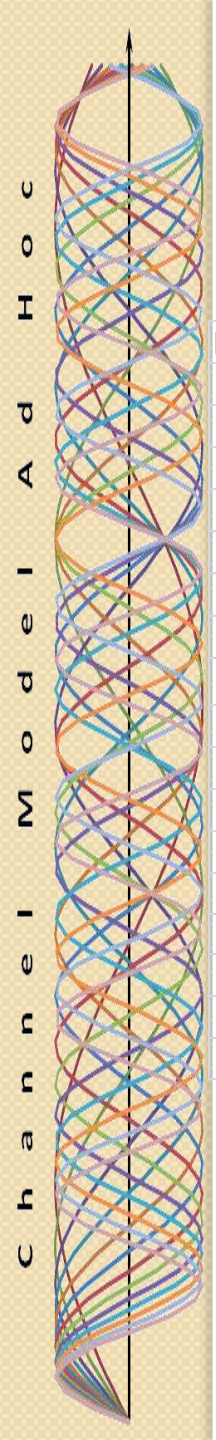
Interference				
Narrowband	5	**CTB Interference (20 kHz BW)**		Notes 7, 8
		# of interfered subcarriers @ 35-40 dBc	0%	
		40-45	1%	
		>45	0%	
	6	**CSO Interference (20 kHz BW)**		Note 9
		# of interfered subcarriers @ 35-40 dBc	0%	
		40-45	0%	
		45-50	2%	
		>50	0%	
	7	**Narrowband Interference (Other)**		
		Bandwidth (MHz)	N/A	
		Level, dBc (PSD)	N/A	
Wideband	8	**Burst Interference**		Note 10
		Bandwidth (MHz)	30	
		Level, dBc (PSD)	-20	
		Duration (usec)	16	
		Period (Hz)	Infrequent	
	9	**Impulse (white) Noise**		Note 11
		Level, dBc (PSD)	N/A	
		Duration (nsec)	N/A	
		Period (kHz)	N/A	



Baseline Parameter Table (4 of 5)

Downstream

Freq Response				
Amplitude	10	**Amplitude Slope**		Note 12
		dB/MHz	0.01	
	11	**Amplitude Variation**		SCTE Definition, Echo not included
		(dB pk-pk/6 MHz)	1	
		(dB pk-pk/24 MHz)	3	
		(dB pk-pk/192 MHz)	5	
		(dB pk-pk/Total DS BW)	9	
Phase	12	**Group Delay Variation, nsec**		
		Over 24 MHz		
		Mid Band	25	
		Band Edge (24 MHz)	145	
		Over 192 MHz		
		Mid Band	200	
		Band Edge (24 MHz)	320	
Echo	13	**Echo Profile, dBc**		Notes 13, 14
		.5 usec	-20	
		1 usec	-25	
		1.5 usec	-30	
		2 usec	-35	
		3 usec	-40	
		4.5 usec	-45	
		5 usec	-50	
Spurious Modulation	14	**AM/Carrier hum modulation %**	3%	

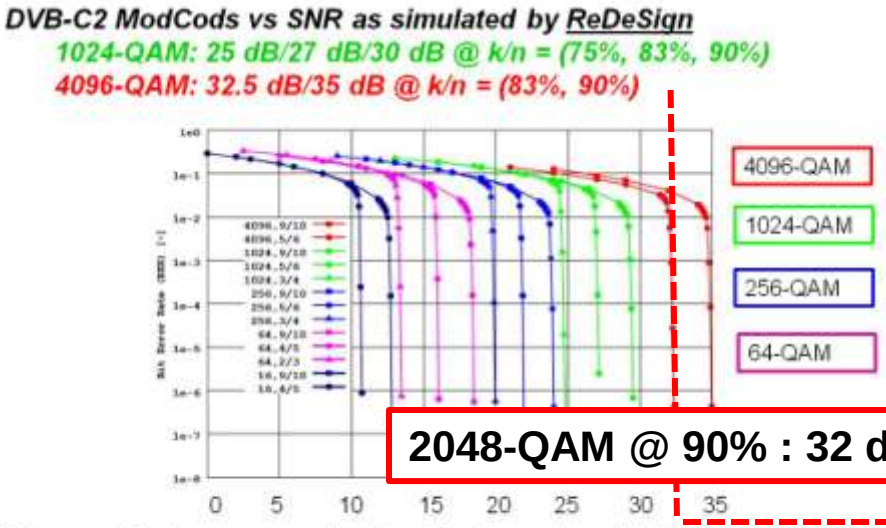


Baseline Parameter Table (5 of 5)

Downstream

Notes	
1	If not defined otherwise, assume typically behaving link but where the behavior is the worst (freq, location)
2	Frequency dependence of coax for broadband calculations: Loss B (dB) = Loss A (dB) x SQRT(B/A)
3	Reference virtual port level for 6 MHz signal at 1 GHz; 15 dBmV Tap port level, 100 ft drop, 2-way splitter
4	(Max Freq - OFDM BW) spectrum range used for drop loss
5	Small drop slope effect on calculation
6	SCN includes HFC geography impact (location in cascade depth)
7	50 kHz Subchannel Reference, Live Video, fully contained within subchannel
	Subcarriers with Interference (50 kHz subcarriers): Every 70 subcarriers, a cluster of three interfers: I_0, I_0 + 25 kHz, I_0 - 25 kHz
8	Typ = CTB/CSO Worst Case Freq; Good CTB/CSO in low-distortion band, Analog contiguous at low end of band
	NCTA measurement method (avg); Error rate simulation should account for PAR and peak durations
9	Worst spectrum regions for CTB and CSO are not the same
10	D/S Burst Characterization in process; BW based on percentage of errored carriers in 8-Channel wide DOCSIS CM
	Duration based on large scale CM sweep of UCER with known interleaver settings; Levels per ReDesign channel model
11	Laser Clipping PSD captured in SCN for out-of-band EPoC Signals
12	Typical tilt, first tap, not equalized, 50 ft drop assumed (Minimum drop impact)
13	Echo mask range for a Single Dominant echo - Does not imply an assumptions about multiple echoes.
14	Meas@700-800 MHz, representive of 99% of modems

Downstream SCN

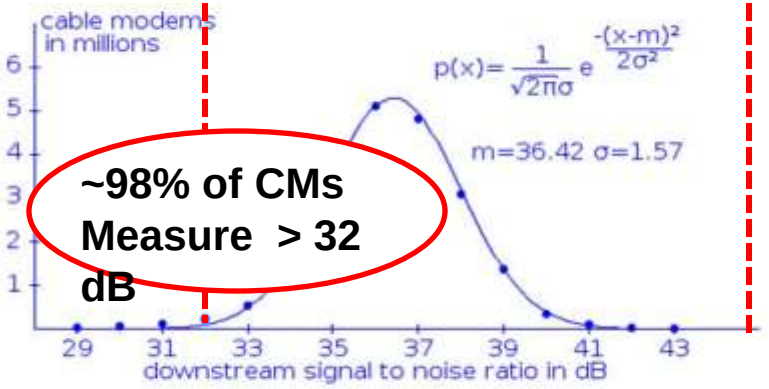


2048-QAM @ 90% : 32 dB

Reference: Performance evaluation of advanced modulation and coding , 30 November 2009, ReDeSign – 217014

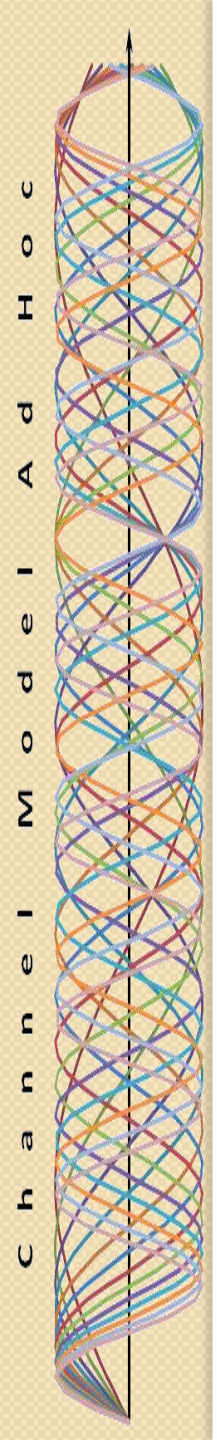
DVB-C2 may not be selected but its performance is representative of expected minimum performance

Recommended Nominal Baseline



- All modems, not MTAs (closer to a POE Gateway)
- Actual measurement is of MER, (worse than SNR) and includes CM NF and other implementation losses
- CMs designed for 256-QAM max

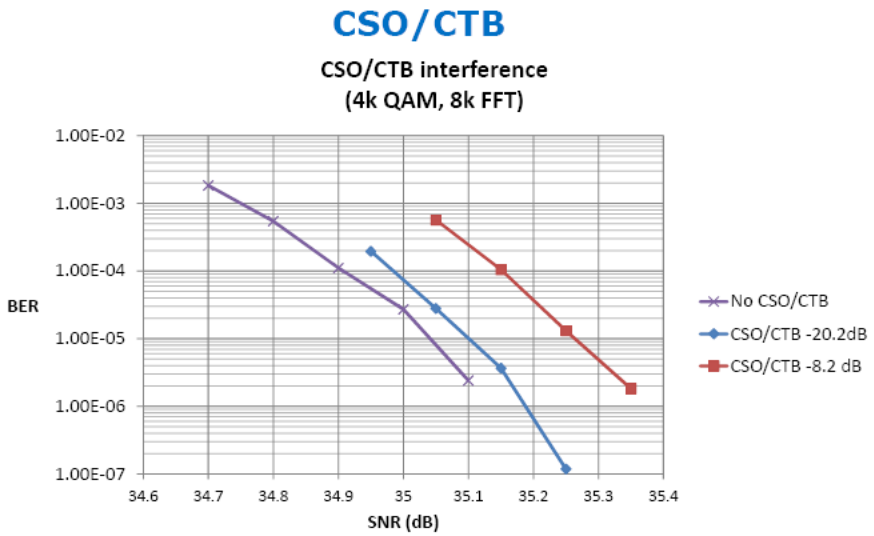
Reference: MSO CM SNR Measured Distribution



Capacity Objectives Worksheet

Spectrum (MHz) =	192					
OFDM OH D/S	7%					
OFDM OH U/S	10%					
HFC Channel SNR (dB) Nominal =	44	Downstream				
	45	Upstream				
	QAM Depth	**QAM (b/s/Hz)**	**FEC Efficiency**	**Spectral density (b/s/Hz)**	**% Gain vs Legacy**	**Total Mbps**
512 QAM OFDM LDPC MoCA 2.0 4k	512	9	84.80%	7.63	7.63	1318.81
SNR = 27 dB				**Upstream**	**5.36%**	
512 QAM OFDM LDPC (16200)	512	9	88.89%	8.00	8	1428.48
SNR = 27 dB				**Downstream**	**10.44%**	
SNR Margin = 17 dB / 18 dB						
1024 QAM OFDM LDPC MoCA 2.0 4k	1024	10	84.80%	8.48	8.48	1465.34
SNR = 30 dB				**Upstream**	**17.07%**	
1024 QAM OFDM LDPC (16200)	1024	10	88.89%	8.89	8.89	1587.20
SNR = 30 dB				**Downstream**	**22.71%**	
SNR Margin = 14 dB / 15 dB						
2048 QAM OFDM LDPC MoCA 2.0 4k	2048	11	84.80%	9.33	9.33	1611.88
SNR = 33 dB				**Upstream**	**28.77%**	
2048 QAM OFDM LDPC (16200)	2048	11	88.89%	9.78	9.78	1745.92
SNR = 33 dB				**Downstream**	**34.98%**	
SNR Margin = 11 dB / 12 dB						
4096 QAM OFDM LDPC MoCA 2.0 4k	4096	12	84.80%	10.18	10.18	1758.41
SNR = 36 dB				**Upstream**	**40.48%**	
4096 QAM OFDM LDPC (16200)	4096	12	88.89%	10.67	10.67	1904.64
SNR = 36 dB				**Downstream**	**47.25%**	
SNR Margin = 8 dB / 9 dB						

Non-AWGN Considerations



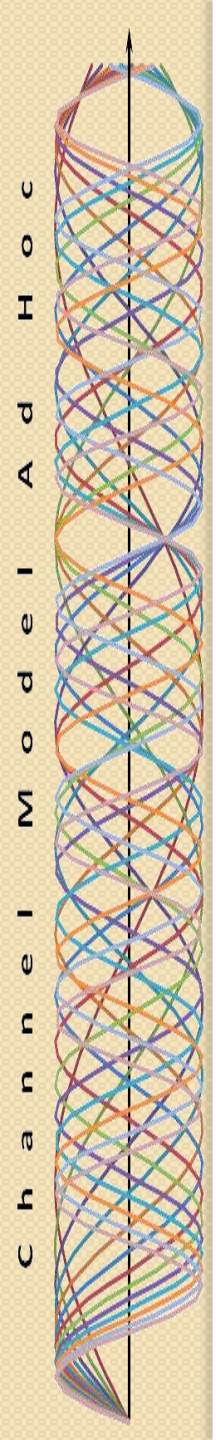
** Intel Simulations*

Less than 0.3 dB SNR Loss for 4096-QAM for CSO/CTB interference characteristics more than 10 dB worse than baseline characteristics (includes peaking effects of distortion beat piles)

No 4096-QAM Loss due to described Burst Noise characteristics with acceptable interleaver depths (multiple FEC schemes compared @1e-8 BER)

Minimum Interleave depth N 4K OFDM (20µs)	
On one OFDM symbol	On two consecutive OFDM symbols
11 [0.33ms]	14 [0.40ms]
(19) [0.51ms]	**20 [0.53ms]**
(10) [0.31ms]	16 [0.44ms]

** Broadcom Simulations*

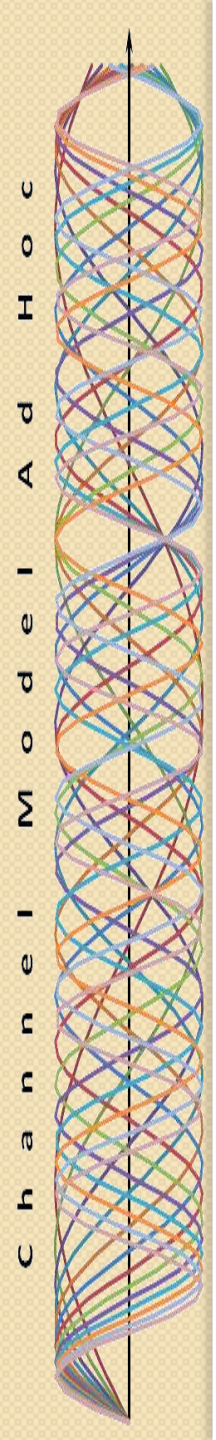


Baseline Parameter Table (1 of 5)

Upstream

System Description		
HFC U/S Spectrum	300 MHz	
Node Architecture	N+3	
Channel Loading	Remote Tx/Rx	
HE Architecture	N/A - EPON Return	
Premise Architecture	Two Way Combining	

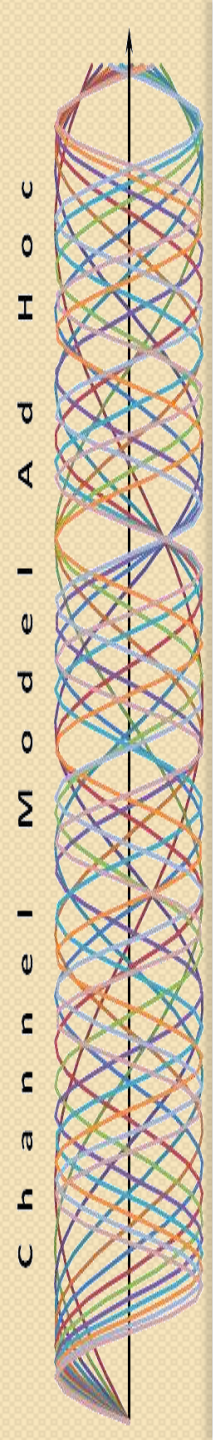
Note: "System Description" is extended to 300 MHz in order to evaluate Gbps capacity objectives against 192 MHz of upstream BW. The downstream baseline description used a legacy forward path spectrum (legacy and a return of 85 MHz have nearly identical performance downstream) allowing for D/S evaluation of the more conservative case of a heavier optical and RF load of legacy channels to set impairment levels. The two are not simultaneously compatible – the downstream parameters can only improve as legacy load diminishes such as with 300 MHz of upstream. Alternatively the bandwidth efficiency of the upstream could be evaluated in 85 MHz of return and compared to the objectives in terms of bps/Hz. Using the "linear scaling" clause of the objective.



Baseline Parameter Table (2 of 5)

Upstream

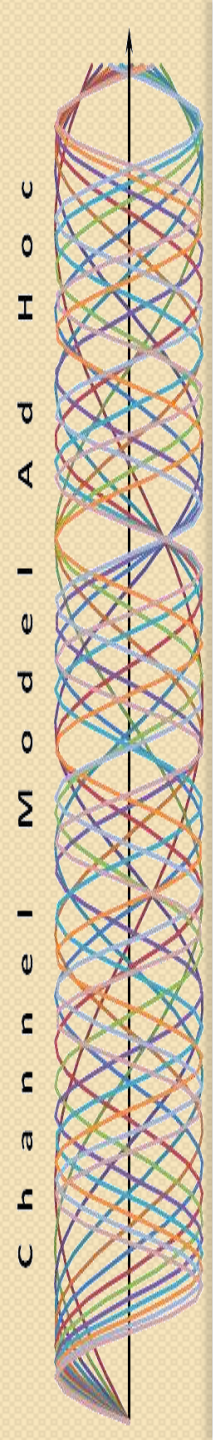
	#	Parameters	Baseline Channel Conditions	Notes/Dependencies
Spectrum	1	**OFDM Bandwidth**	192 MHz	
	2	**Frequency range**	100-292 MHz	
Path Loss	3	**Path Loss (dB)**	44	Max loss to first active
		Variation Freq, 24 MHz BW	1	Note 1
		Variation Freq, 96 MHz BW	2.5	
		Variation Freq, 192 MHz BW	5	
Added Noise	4	**Input Noise PSD**	- 115 dBmV/Hz	Contibutions of amplifiers



Baseline Parameter Table (3 of 5)

Upstream

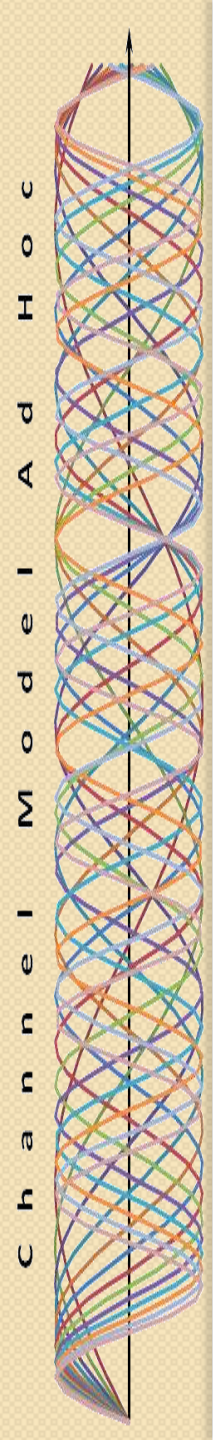
Interference	5	**FM Band Interference**		
Narrowband		Bandwidth	8	Spectrum Overlap
		Level, dBc (PSD)	-40	Note 2
	6	**Common Path Distortion**		
		dBc	N/A	
		% effected subcarriers	N/A	
	7	**Other Bands**	TBD	New Upstream spectrum
		dBc	-50	Note 3
		% effected subcarriers	1	50 kHz subcarriers
Wideband	8	**Burst Interference**		Note 4
		Bandwidth (MHz)	TBD	Non-white characteristics (Note 5)
		Level, dBc (PSD)	0	
		Duration (usec)	1	
		Period (Hz)	1000	



Baseline Parameter Table (4 of 5)

Upstream

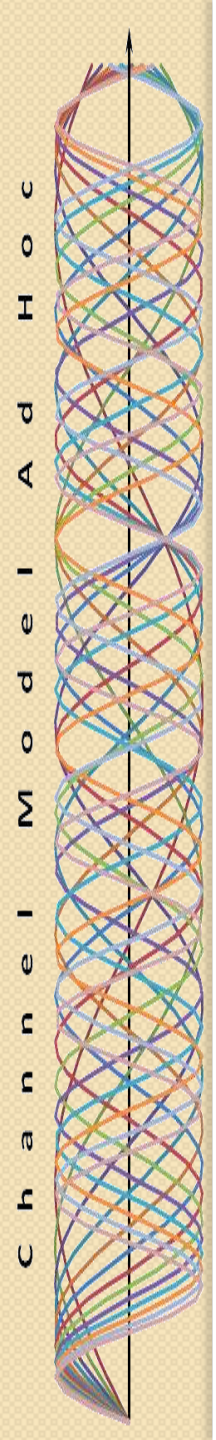
Freq Response				
	9	**Amplitude Slope**	N/A	Captured in Path Loss
Amplitude	10	**Amplitude Variation**		included
		(dB pk-pk/24 MHz)	1.5	
		(dB pk-pk/96 MHz)	2.5	
		(dB pk-pk/192 MHz)	3	
Phase	11	**Group Delay Variation**		
		Over 24 MHz		
		Mid Band	25	
		Band Edge (24 MHz)	280	
		Over 48 MHz		
		Mid Band	50	
		Band Edge (24 MHz)	305	
		Over 192 MHz	575	
Echo	12	**Echo Profile, dBc**		Note 5-6
		.5 usec	-16	
		1 usec	-22	
		1.5 usec	-29	
		2 usec	-35	
		3 usec	-42	
		4.5 usec	-51	
		5 usec		
	13	**AM/Carrier hum**	5%	



Baseline Parameter Table (5 of 5)

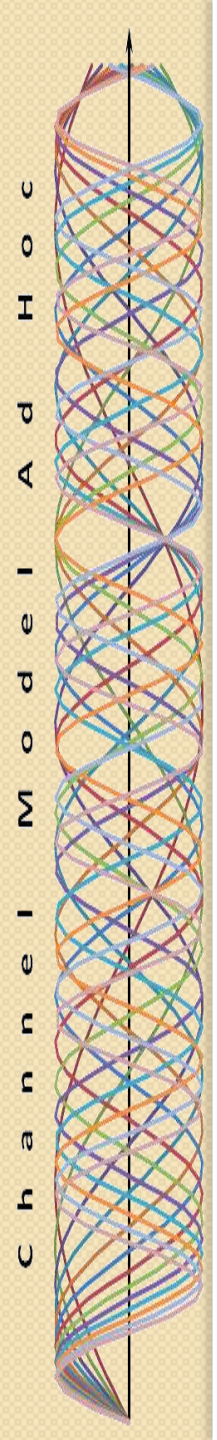
Upstream

Notes	
1	Path Loss adopted for consistency although return path, although RF actives include upstream gain
2	Measured samples in MSO location of high field strength environment
3	Projected (for 50 kHz) from acceptable D/S interference level for analog video band (now upstream band); single dominant interferer and ingress point
4	U/S burst characterization in process; Ref CableLabs 1997 Report "Characterization of Upstream Transient Impairments on Cable Television
5	No linear optical return - no U/S Laser Clipping (white) impairment
6	Measured Upstream CM (97% criteria) extrapolated to band (30 MHz measured to 100 MHz)
7	Echo mask range for a Single Dominant echo - does not imply an assumptions about multiple echoes



Path Loss to SCN Value

- Baseline Path Loss 44 dB (@300 MHz)
- ***No Linear Optical Link Degradation !***
- CPE Tx Power Assumption: 60 dBmV
- Assume Tx from end of cascade (actual worst path loss is first Tap under baseline N+3 assumptions used)
  - Amplifier noise PSD adds in either case
- Signal: Rx Input Level ≥ 16 dBmV
  - Sufficient signal power to drive cascade
  - Sufficient signal power for high Rx SNR
- Noise: Assume Rx NF = 10 + “Baseline Input Noise PSD”
  - SNR = 16 – [(-115 dBmV/Hz) + 3 + 10Log(192) + 60]
  - **SNR ≥ 45 dB**



Capacity Objectives Worksheet

Spectrum (MHz) =	192					
OFDM OH D/S	7%					
OFDM OH U/S	10%					
HFC Channel SNR (dB) Nominal =	44	Downstream				
	45	Upstream				
	QAM Depth	**QAM (b/s/Hz)**	**FEC Efficiency**	**Spectral density (b/s/Hz)**	**% Gain vs Legacy**	**Total Mbps**
512 QAM OFDM LDPC MoCA 2.0 4k	512	9	84.80%	7.63	7.63	1318.81
SNR = 27 dB				**Upstream**	**5.36%**	
512 QAM OFDM LDPC (16200)	512	9	88.89%	8.00	8	1428.48
SNR = 27 dB				**Downstream**	**10.44%**	
SNR Margin = 17 dB / 18 dB						
1024 QAM OFDM LDPC MoCA 2.0 4k	1024	10	84.80%	8.48	8.48	1465.34
SNR = 30 dB				**Upstream**	**17.07%**	
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SNR = 30 dB				**Downstream**	**22.71%**	
SNR Margin = 14 dB / 15 dB						
2048 QAM OFDM LDPC MoCA 2.0 4k	2048	11	84.80%	9.33	9.33	1611.88
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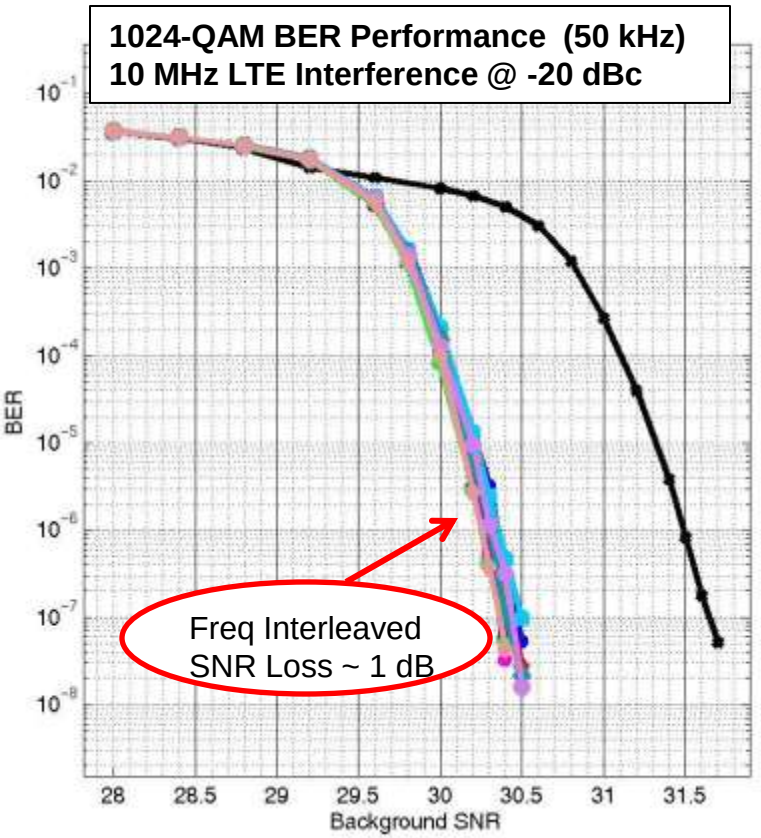
2048 QAM OFDM LDPC (16200)	2048	11	88.89%	9.78	9.78	1745.92
SNR = 33 dB				**Downstream**	**34.98%**	
SNR Margin = 11 dB / 12 dB						
4096 QAM OFDM LDPC MoCA 2.0 4k	4096	12	84.80%	10.18	10.18	1758.41
SNR = 36 dB				**Upstream**	**40.48%**	
4096 QAM OFDM LDPC (16200)	4096	12	88.89%	10.67	10.67	1904.64
SNR = 36 dB				**Downstream**	**47.25%**	
SNR Margin = 8 dB / 9 dB						

Non-AWGN Considerations

Narrowband Interference



* ***Broadcom Simulations***

20 dB worse C/I than baseline

2 MHz more C/I BW than baseline

C/I contribution of "Other Bands" baseline is 17 dB lower (negligible)

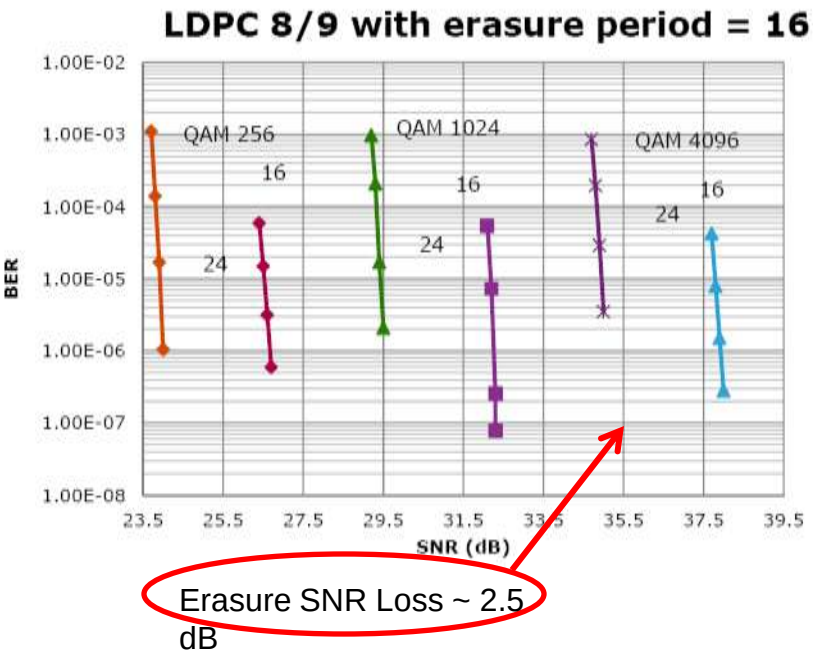
2048-QAM loss vs AWGN may be slightly higher than 1024-QAM (not simulated)

⇒ 1 dB Loss vs AWGN significantly overstates SNR loss compared to baseline conditions

⇒ Still, 1 dB of loss is easily absorbed by available SNR margin shown

Non-AWGN Considerations

Wideband Interference



* ***Intel Simulations***

20% shorter erasure period

Weaker code against burst than anticipated upstream codes and rates (by approx 1 dB)

4096-QAM loss vs AWGN slightly worse than 1024-QAM or 2048-QAM

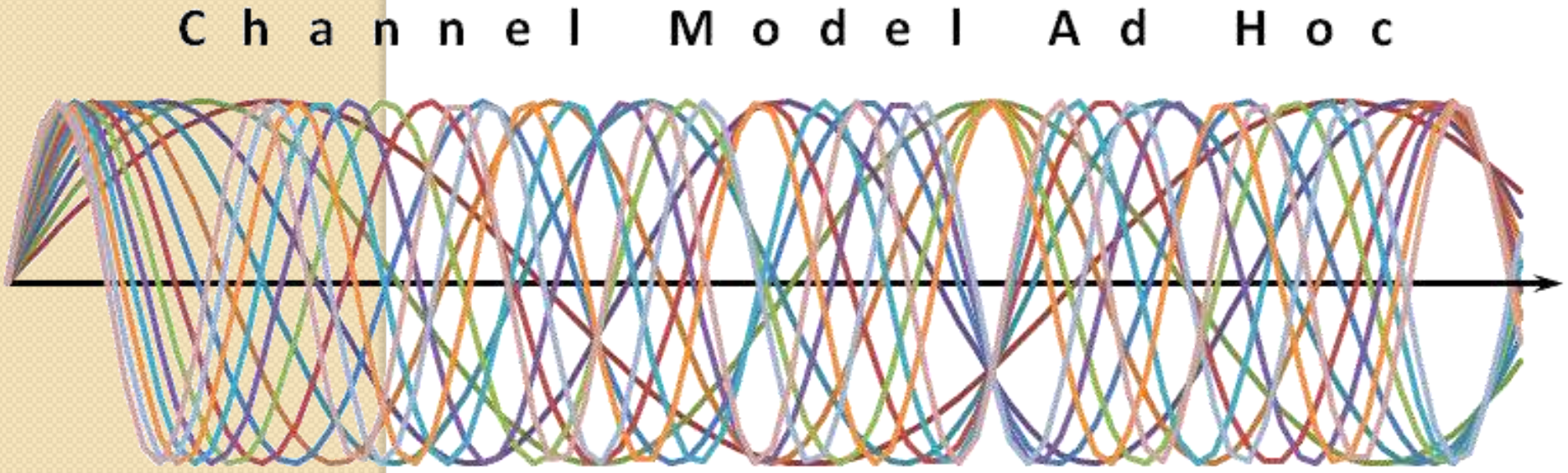
⇒ 2.5 dB Loss vs AWGN overstates SNR loss compared to baseline conditions

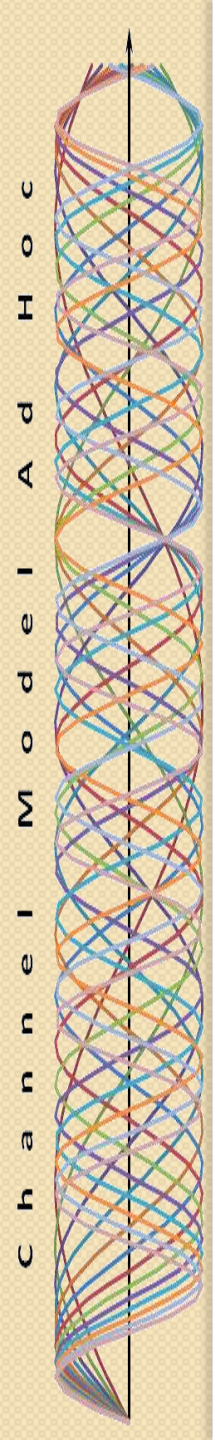
⇒ Still, 2.5 dB of loss is easily absorbed by available SNR margin shown

In addition, under simultaneous burst and interference conditions resulting in 3.5 dB loss to SNR, margin is sufficient.

SNR penalty may result in fidelity constraints and decreased allowable implementation losses

THANK YOU



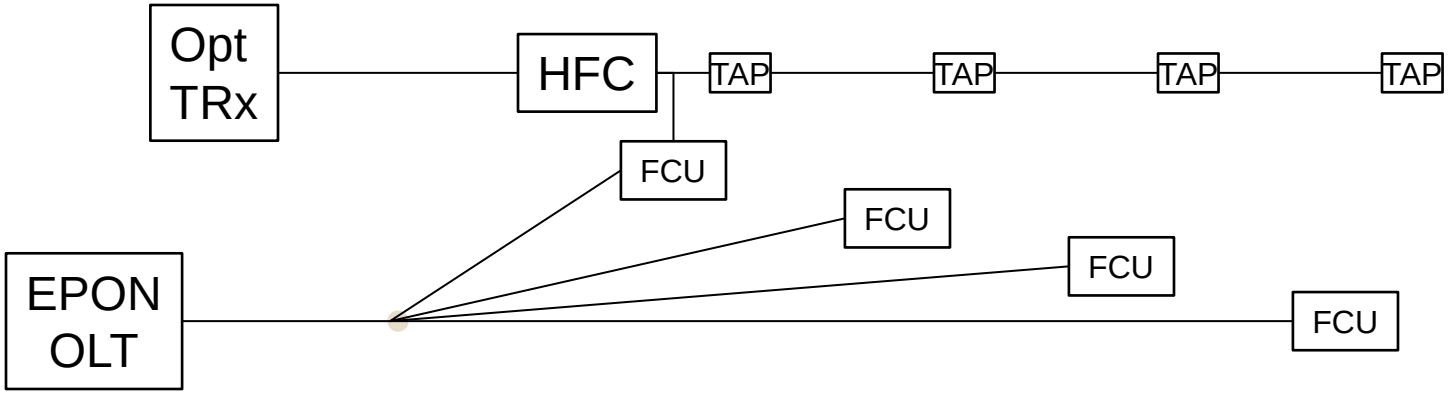


Straw Poll

- Straw Poll text.

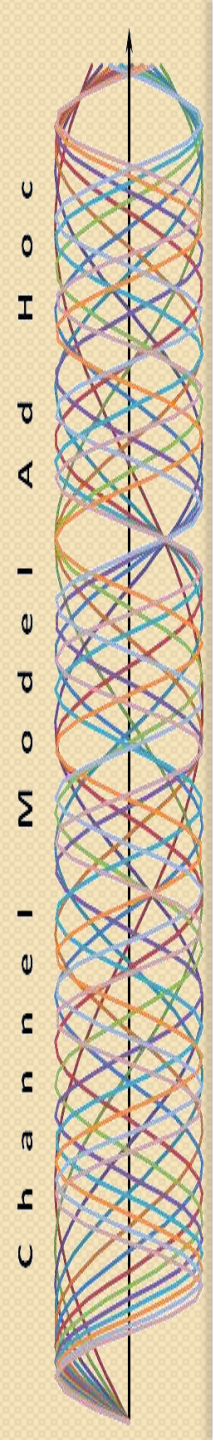
- Yes _____
- No _____
- Other _____

Node +0 (All Passive)



- Details needed:
  - Diplexer connecting EPoC to COAX

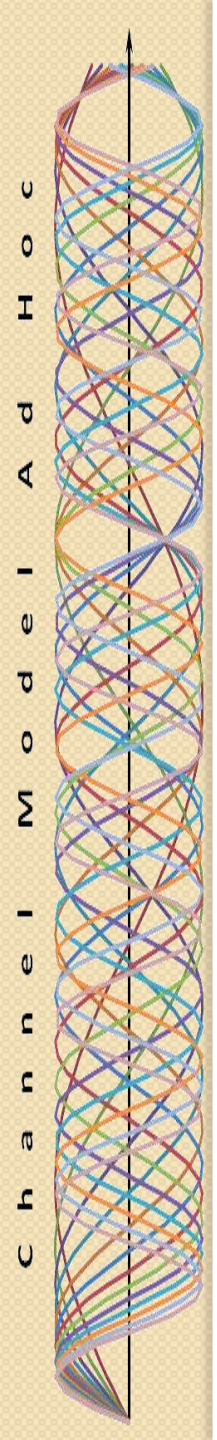
- Topology parameters needed:
1. Optical reach of HFC networks
2. Optical reach of EPON networks
3. Channel loading of HFC networks (can all digital be assumed?)
4. Amplifier spacing; typical and max.
   ex: typical ≤ 800 ft. maximum ≤ 1500 ft.
5. Feeder cable types
6. Drop Cable types & reach



Parameter List

- Progress report
  - Clarify highest RF Spectrum needed (1.2 or 1.7 GHz) with RF Spectrum ad Hoc

Topology	US	DS	March Madness[1]	Presentation
Node +6	PHX 1301	PHX 1301	Yes	2
Node +3 (Baseline)	2/21 Call	2/21 Call	Yes	2
Node +0 <1GHz	2/15 Call	2/15 Call	Yes	2
Node +0 >1GHz			TBD	
Node +0 MDU			TBD	
Node +3 Analog			Yes	2
others				
Baseline Channel	Derive from N+3		Yes	1
Notes 1) Motion to accept in March meeting.				

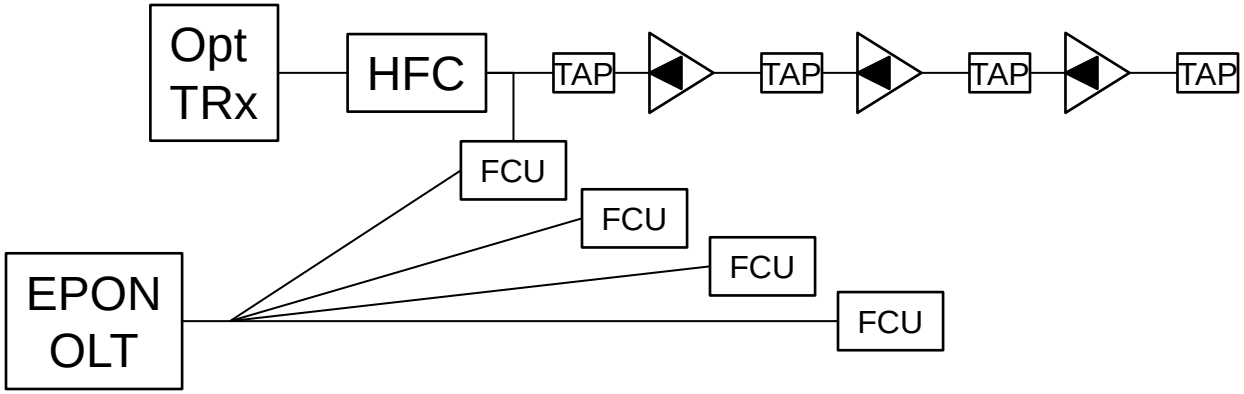


Topologies

- Illustrations

Topology	March Madness	Presentation
Node +6 (digital EPON distribution)	Yes	2
Node +3 (digital EPON distribution)	Yes	2
Node +0 (Last Amp < 1GHz)	Yes	2
Node +0 (Last Amp < 1.8GHz)	TBD	
Node +0 (All Passive/MDU)	TBD	
Node +3 (analog EPoC distribution)	Yes	
EPoC Only (no HFC)		
Baseline Channel (Node +3 digital)	Yes	1

Baseline Channel Topology



- Node +3 (digital EPON distribution)

- Topology parameters needed:
1. Optical reach of HFC networks
2. Optical reach of EPON networks per 802.3
3. All digital channel loading assumed
4. Amplifier spacing; typcal and max. ex: typical ≤ 800 ft. maximum ≤ 1500 ft.
5. Feeder cable types; ??
6. Drop Cable types & reach
   - RG 6, ≤ 150 ft. (45.7 M)

Drop / Subscriber Premise

Typical