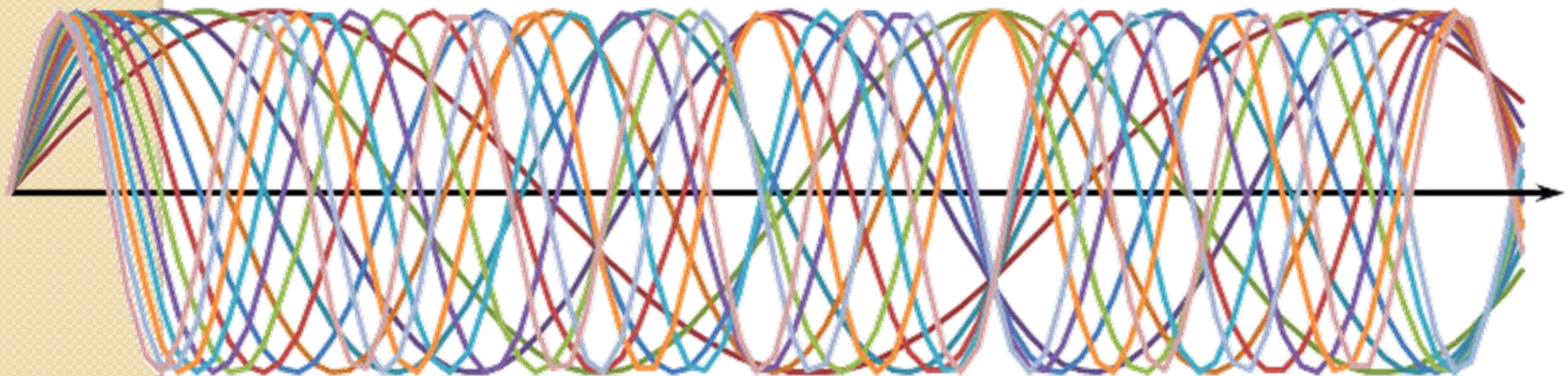


Channel Model Downstream Description and Update

802.3bn Face to Face, Jan 2013

Rob Howald, Duane Remein, Hal Roberts, Saif Rahman

C h a n n e l M o d e l A d H o c





Topics

Downstream Table (HFC Architecture Case)

Question and TBD Items

EPoC Architectures to Evaluate
Downstream
Upstream

Upstream Table (Parameters only)

Appendix – Original Presentation Table

Page 1 of 5 of D/S Table



EPoC Scenario	B		
HFC D/S Spectrum	1.0 GHz		
Cascade Depth	N+4		
Channel Loading	48 A+75 D+EPoC Band (same as digital PSD@-6 dBc)		
Optical Architecture	Linear Optics (Legacy), EPoC RF Coupled @ Node		
Home Architecture	Up to max drop length & 2-way splitter		



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	Parameters	Typical ¹	Limit	Good	Notes/Dependency
Spectrum	Frequency range	54 MHz - 1 GHz			
	OFDM Bandwidth	192 MHz			
RF Level	OFDM Power at CPE Input (dBmV)	15 dBmV, 100 ft, 2-way	10 dBmV, 150 ft, 2-way	20 dBmV, 50 ft, direct	Notes 2, 3
	6 MHz BW	-2	-10	10	Note 4
	24 MHz BW	4	-4	16	
	96 MHz BW	10	2	22	
	192 MHz BW	17	9	28	Note 5
SNR	SCN Ratio (Signal to Composite)	44	41	46	Note 6
	Variation over 6 MHz BW (dB)	N/A	N/A	N/A	Reference Basis is 6 MHz
	Variation over 24 MHz BW (dB)	1.5	Ops Field Alignment	0.5	
	Variation over 96 MHz BW (dB)	2.5	Q1	1.0	
	Variation over 192 MHz BW (dB)	3.0	(Q1 Ans: N/A)	1.0	(Meas - CL Anonymization)



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Channel Model Add Hoc

Narrowband	5	CTB Interference (20 kHz BW)				Note 7
		# of interfered subcarriers @ 30-35 dBc	0%	0%	0%	Note 8
		35-40	0%	1%	0%	+ X CL - #analog - #amps
		40-45	1%	0%	0%	
		>45	0%	0%	1%	(Meas - CL Anonymization)
	6	CSO Interference (20 kHz BW)				Note 9
	# of interfered subcarriers @ 30-35 dBc	0%	0%	0%		
	35-40	0%	2%	0%	+ X CL - #analog - #amps	
	40-45	0%	0%	0%		
	45-50	2%	0%	0%		
	>50	0%	0%	2%	(Meas - CL Anonymization)	
	7	LTE Interference				
D/S		Bandwidth (MHz)	10	40	None	
		Level, dBc (PSD)	-30	-30	N/A	
U/S		Bandwidth (MHz)	10	10	None	
		Level, dBc (PSD)	-40	-20	N/A	
	8	Additive Interference (other)				Additional bands & levels
		Bandwidth (MHz)		Q2		(e.g. Land Mobile 808-901)
		Level, dBc (PSD)				
Wideband	10	Burst Noise	Q3	CL Meas Initiative	None	Typ: Public Safety Burst Profile
		Bandwidth (MHz)	1			
		Level, dBc (PSD)	-20	0		
		Duration (usec)		25		
		Period (Hz)	(Occasional)	10		
			Normal D/S Laser Clipping		Clipping + Other (CL Initiative)	Normal D/S Laser
		Level				
		Duration (nsec)	0.5		0.5	
		Period (kHz)	100		100	Avg - Poisson Pulse Train

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Freq Response						
Amplitude	12	Amplitude Slope	Typ Tilt, 1st Tap, not Equalized	Greater of Max tilt or 10 dB Rule	Drop Only (Equalized)	
			dB/MHz	0.01	0.02	0.004
				0.01	0.02	0.004
	13	Amplitude Variation	Ops Field Alignment	Q4	Meas - Cascade P-V	Note 11
			(dB pk-pk/6 MHz)	(Ans: Cascade P-V Rule)	6	1.0
			(dB pk-pk/24 MHz)			1.5
		(dB pk-pk/192 MHz)	5	Meas by MSO	2.0	
		(dB pk-pk/Total DS BW)	5		4.0	
Phase	14	Group Delay Variation, nsec		Spec Cascade		Fewer actives
		Over 24 MHz				
		Mid Band	35	70		Active specs + Cascade
		Band Edge (24 MHz)	200	250		
		Over 192 MHz				(TBD Model BRCM)
		Mid Band	280	560		
Echo	15	Echo Profile, dBc	99%	SCTE-40	Majority (≥ 50%)	Echo Mask - Does not imply a particular number of echoes
		.5 usec	-20	-10	-30	Note 12
		1 usec	-25	-15	-35	
		1.5 usec	-30	-20	-35	Q5
		2 usec	-35		-40	(Ans: Need to include RL vs Freq for other bands)
		3 usec	-40		-45	
		4.5 usec	-45	-30	-50	
		5 usec	-50		-55	
Spurious Modulation	16	AM/Carrier hum modulation (dBc)	-30	-26	-40	

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Notes

- | | |
|----|--|
| 1 | Typically behaving link but where the behavior is the worst (freq, location) |
| 2 | Frequency dependence of coax for broadband calculations: $\text{Loss B (dB)} = \text{Loss A (dB)} \times \text{SQRT}(B/A)$ |
| 3 | Reference virtual port level for 6 MHz signal at 1 GHz |
| 4 | (Max Freq - OFDM BW) spectrum range used for drop loss |
| 5 | Small drop slope effect on calculation |
| 6 | SCN include HFC geography impact (location in cascade depth) |
| 6 | 7 50 kHz Subchannel Reference, Live Video, Fully contained within subchannel
Subcarriers with Interference (6 MHz grid OFDM cf): 1 (CSO), 26 (CTB), 51 (CSO) ; Move 70 tones, repeat, etc |
| 7 | 8 Typ = CTB/CSO Worst Case Freq; Good CTB/CSO in low-distortion band, Analog contiguous at low end of band |
| 8 | 9 Worst spectrum regions for CTB and CSO are not the same |
| 9 | 10 Reference Technical Papers: Mazo, Shi, Pan & Green |
| 10 | 11 50 ft drop assumed (Minimum drop impact) |
| 14 | 12 Meas@700-800 MHz. Freq Dep (one-way loss) increase, fmin: 7 dB for .5-1.0 usec Tap-amp, 9 dB for > 1 usec amp |
| 12 | 13 DRFI D/S Mask + J.83B Compliant RF Tuner |

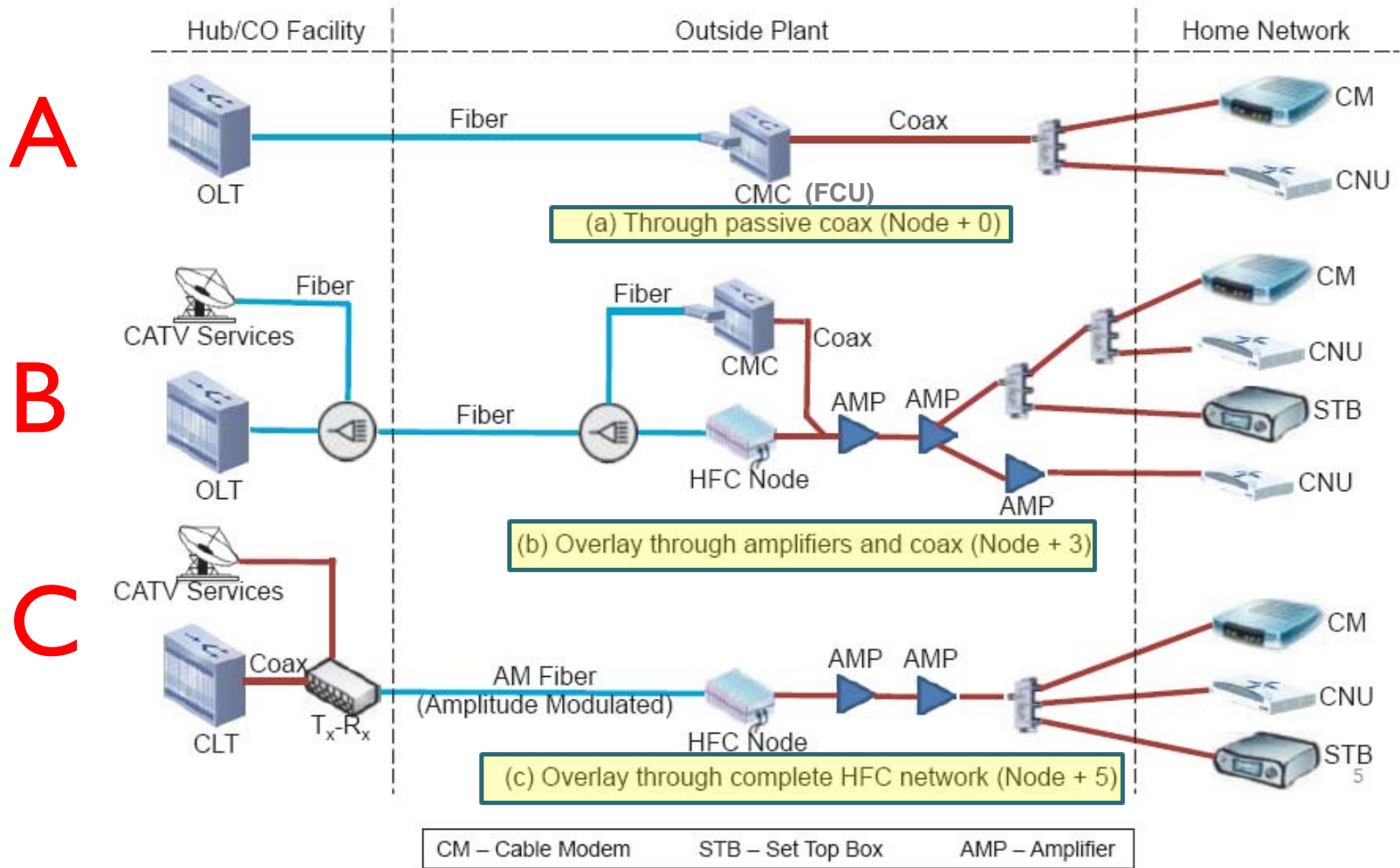
Q1 through Q5 on D/S Table

- 1) Are there MSO Field Operation guidelines that can be shared for setup and alignment of plant levels and CNR variation across a coaxial segment?
- 2) What other additive narrowband interference sources and relative levels have been noted and recorded (e.g. land mobile)?
- 3) What to assume for “Typical” Burst noise characteristics - WIP
- 4) Recent plant wideband frequency responses on the reflector indicate some pretty extreme scenarios. How should these be captured? What should be considered as representing a “typical” or “limit” case, and what should be discounted as “in need of repair?”
- 5) Are there any other freq bands where delay spread has been captured? What cable type typically is run around headend between optical receivers and CMTS?



EPoC Architectures to Evaluate

EPoC Architecture Options



Reference: Bhaumik, Partha et al, "EPON Protocol over Coax (EPoC): System Overview and Design Issues," (TBD), (currently under editorial review IEEE Communications Magazine)

Channel Model Add Hoc



DS Priority Architectures – A & B

Optics

EPoN Link – 20 km (no RF performance contribution)

Cascade Depths

N+0 (A)

N+3 (B)

Drop Architecture

150 ft RG6

2-Way Splitter

15 dBmV Tap Port Level (Ref 6 MHz carrier)

Coaxial Spectrum

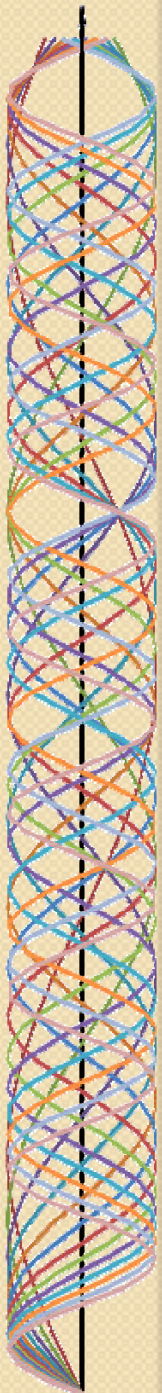
54 MHz – 1 GHz, 14 dB Uptilt (B)

1.2 GHz – 1.7 GHz, same dB/MHz Uptilt (A)

RF Loading

0 Analog, OFDM @ Current Digital Levels (PSD) (B)

Consider some Tx Level & Path Loss assumptions



US Priority Architectures – A & B

Optics

EPON optical link (No RF contribution)

RF Cascades

N+3, Node with 4x RF Combining, # Amps = 12 (B)

N+0, Node with no RF Combining (A)

Spectrum Allocations

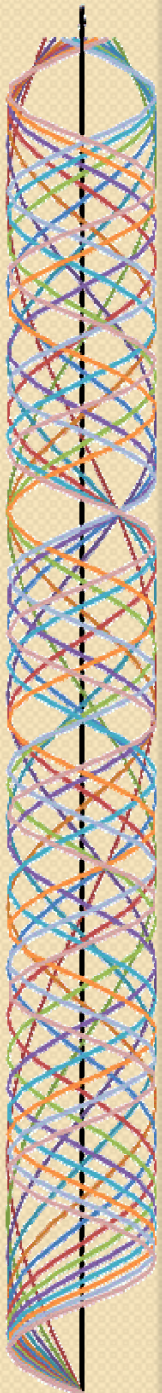
5 MHz – 85 MHz

5 MHz – 200 MHz

1.2 GHz – 1.7 GHz (N+0 Only), upgraded Taps (A)

900 MHz – 1.1 GHz, excess Tap BW only (A maybe B)

65 dBmV Available CPE Linear Tx Power



Upstream Scenario Description

Scenario	1	
HFC D/S Spectrum	85 MHz	
Node Architecture	30 Amplifiers	
Channel Loading	Linear DFB Optics 1310 nm, 20 km	
HE Architecture	No HE Combining	
Premise Architecture	Two Way Combining	





Upstream Table (Parameters Only)

Upstream Parameters

1	OFDM Bandwidth
2	Frequency range
3	OFDM Power at CMTS Input
	6.4 MHz BW
	24 MHz BW
	80 MHz BW
	192 MHz BW
4	SCN Ratio (Signal to Composite Noise Ratio)
	Variation Freq, 6.4 MHz BW
	Variation Freq, 24 MHz BW
	Variation Freq, 80 MHz BW
	Variation Freq, 192 MHz BW

5	FM Band Interference
	Bandwidth
	Level, dBc (PSD)
6	Other Known Bands
7	Common Path Distortion
8	Additive Spurious interference (other)
	dBc Range
	Percentage of effected subcarriers
9	Burst noise (spectrum, duration, duty, dBc)
10	Impulse noise (white, duration, duty, dBc)

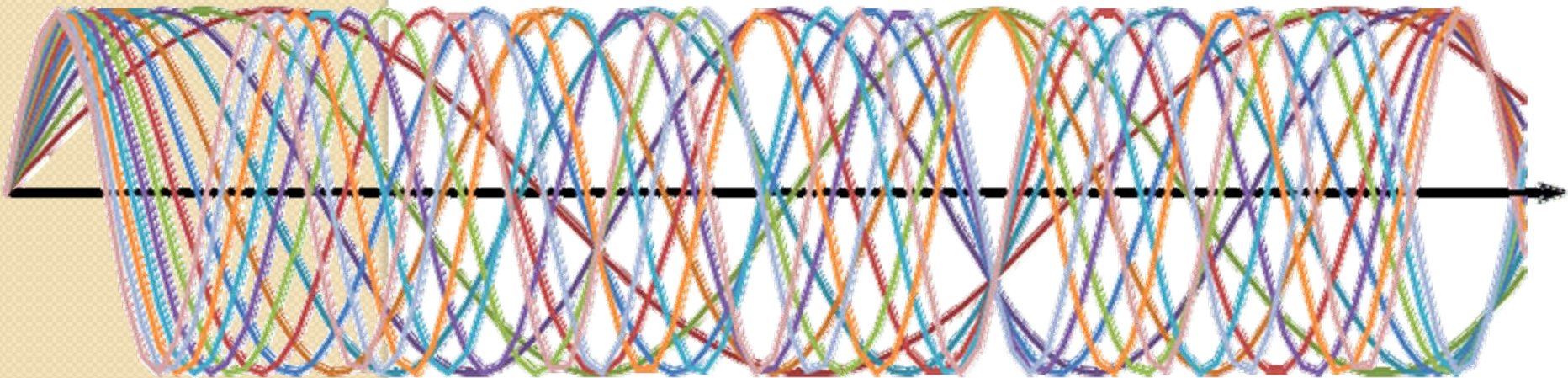


Upstream Parameters

11	Amplitude Slope
12	Amplitude Variation
	(dB pk-pk/6.4 MHz)
	(dB pk-pk/24 MHz)
	(dB pk-pk/192 MHz)
	(dB pk-pk/Total US BW)
13	Group Delay Variation
	(ns/MHz over 24 MHz)
	Mid Band
	Upper Band Edge
	(ns/MHz over 192 MHz)
	Mid Band
	Upper Band Edge
14	Delay Spread Profile, dBc
	.5 usec
	1 usec
	1.5 usec
	2 usec
	3 usec
	4.5 usec
	5 usec
15	AM/Carrier hum modulation

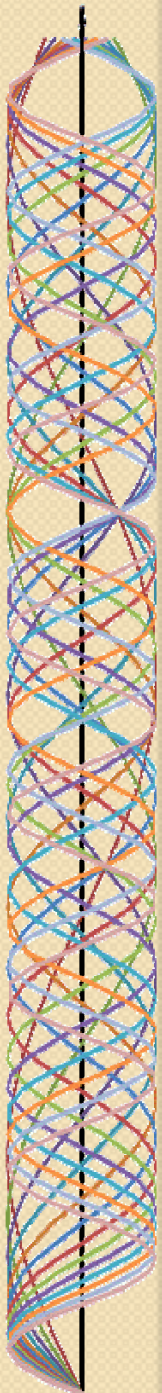
APPENDIX – D/S TABLE FROM ORIGINAL PRESENTATION

C h a n n e l M o d e l A d H o c



Page 1 of 5 of D/S Table

Scenario	A
HFC D/S Spectrum	1.0 GHz
Cascade Depth	N+6 (EOL)
Channel Loading	79 Analog + 53 Digital
Optical Architecture	Linear Optics 1310 nm, nominal link leng
Home Architecture	Up to max drop length & 4-way splitter



Page 2 of 5

	#	Parameters	Typical ¹	Limit	Good	Notes/Dependency
Spectrum	1	Frequency range	54 MHz - 1 GHz			
	2	OFDM Bandwidth	192 MHz			
RF Level	3	OFDM Power at CPE Input (dBmV)	15 dBmV, 100 ft, 2-way	10 dBmV, 150 ft, 4-way	20 dBmV, 50 ft, direct	Notes 2, 3
		6 MHz BW	-2	-14	10	Note 4
		24 MHz BW	4	-8	16	
		96 MHz BW	10	-2	22	
		192 MHz BW	17	5	28	Note 5
SNR	4	SCN Ratio (Signal to Composite)	43	40	46	
		Variation over 6 MHz BW (dB)	N/A	N/A	N/A	Reference Basis is 6 MHz
		Variation over 24 MHz BW (dB)	1.5	Ops Field Alignment Criteria	0.5	
		Variation over 96 MHz BW (dB)	2.0	Q1	1.0	
		Variation over 192 MHz BW (dB)	2.0		1.5	(TBD CL Data Anonymization)

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Narrowband	5	CTB Interference (20 kHz BW)				Note 6
		# of interfered subcarriers @ 30-35 dBc	0%	1%	0%	Note 7
		35-40	1%	0%	0%	
		40-45	0%	0%	0.5%	
		>45	0%	0%	0.5%	(TBD CL Data Anonymization)
	6	CSO Interference (20 kHz BW)				Note 8
		# of interfered subcarriers @ 30-35 dBc	0%	2%	0%	
		35-40	0%	0%	0%	
		40-45	2%	0%	0%	
		45-50	0%	0%	1%	
		>50	0%	0%	1%	(TBD CL Data Anonymization)
	7	LTE Interference				
		Bandwidth (MHz)	10	40	None	
		Level, dBc (PSD)	-3	-20	N/A	
	8	Additive Interference (other)				Additional bands & levels
		Range of dBc		Q2		(e.g. Land Mobile 808-901 MHz)
		Percentage of effected subcarriers				
Wideband	10	Burst noise (spectrum, duration, duty, dBc)	Q3	25 usec, 10 Hz, 0 dBc	None	
	11	Impulse (white) noise (duration, duty, dBc)	<.5 nsec, avg 12 usec, 10x AWGN pk	Same	Same	Laser Clipping only type Poisson Impulse train w duration & amplitude PDFs (Note 9)

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Freq Response							
Amplitude	12	Amplitude Slope	Typ Tilt, 1st Tap, not Eq	Max Uptilt or 10 dB Rule	Only (Eq)		
			dB/MHz	0.01	0.02	0.004	Note 10
Amplitude	13	Amplitude Variation	Ops Field Alignment Criteria	Q4	Typ Cascade Rules	SCTE Definition, Echo not included	
			(dB pk-pk/6 MHz)	6	1.0		
			(dB pk-pk/24 MHz)		1.5		
			(dB pk-pk/192 MHz)		2.0		
			(dB pk-pk/Total DS BW)		4.0		
Phase	14	Group Delay Variation, nsec	Spec Cascade				
			Over 24 MHz				
			Mid Band	40	80		
			Band Edge (24 MHz)	240	300		
			Over 192 MHz				
			Mid Band	320	640		
Echo	15	Delay Spread Profile, dBc	99%	SCTE-40	Majority	Echo Mask - Does not imply a particular number of echoes	
			.5 usec	-20	-10	-30	Note 11
			1 usec	-25	-15	-35	
			1.5 usec	-30	-20	-35	Q5
			2 usec	-35		-40	
			3 usec	-40		-45	
			4.5 usec	-45	-30	-50	
			5 usec	-50		-55	
Spurious Modulation	16	AM/Carrier hum modulation (dBc)	-30	-26	-40		

Channel Model Add Hoc

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Notes

- 1 Typically behaving link but where the normal behavior is the worst (freq, location)
- 2 Frequency dependence of coax for broadband calculations: $\text{Loss B (dB)} = \text{Loss A (dB)} \times \text{SQRT}(B/A)$
- 3 Reference virtual port level for 6 MHz signal at 1 GHz
- 4 (Max Freq - OFDM BW) spectrum range used for drop loss
- 5 Small drop slope effect on calculation
- 6 50 kHz Subchannel Reference, Live Video, Fully contained within subchannel
- 7 Typ = CTB/CSO Worst Case Freq; Good CTB/CSO where distortion is low
- 8 Worst spectrum regions for CTB and CSO are not the same
- 9 Reference Technical Papers: Mazo, Shi, Pan & Green
- 10 50 ft drop assumed (Minimum drop impact)
- 11 Meas@700-800 MHz. Freq Dep (one-way loss) increase, fmin: 7 dB for .5-1.0 usec, 9 dB for > 1 usec
- 12 DRFI D/S Mask + J.83B Compliant RF Tuner

THANK YOU

C h a n n e l M o d e l A d H o c

