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DENVER, CO
OCTOBER 17-20





DOCSIS 3.1 Downstream Early Lessons Learned

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- 192 MHz max spectrum even though actual is 204.8 MHz
 - May notice time offsets 20X because 10.24 vs 204.8 MHz clocking
- Modulations of 16-QAM – 4096-QAM
- Five data profiles & 5 mixed modulation per profile
- Automatic profile selection and exclusion bands
- Cross-bonding with SC-QAM with OFDM preference
 - Primary can be SC-QAM or OFDM
- CMs support 32 SC-QAM + 2 OFDM blocks
 - Up to 4K QAM support even though 8K & 16K QAM are options in the spec
 - CM spectrum 1 GHz, 1.218, 1.794 GHz?
 - CM US diplex?

Max Carrier/OFDM to Base Channel Power

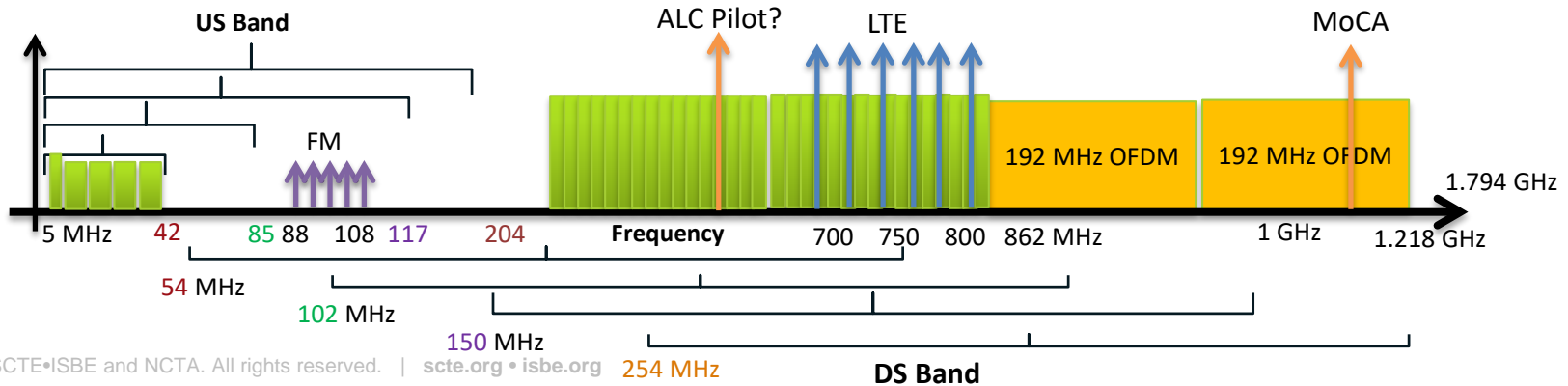
Supported Ranges in dBmV

Note: Working on tilt functionality

Max Carrier	No OFDM	24 MHz OFDM	48 MHz OFDM	96 MHz OFDM	192 MHz OFDM	384 MHz OFDM
8	41 – 50	39 – 48	37 – 46	35 – 44	32 – 41	29 – 38
16	37 – 46	36 – 45	35 – 44	34 – 43	31 – 40	29 – 38
24	35 – 44	34 – 43	34 – 43	32 – 41	31 – 40	28 – 37
32	34 – 43	33 – 42	32 – 41	31 – 40	30 – 39	28 – 37
48	31 – 40	31 – 40	31 – 40	30 – 39	29 – 38	27 – 36
64	30 - 39	30 – 39	29 – 38	29 – 38	28 – 37	26 – 35
96	28 – 37	28 – 37	27 – 36	27 – 36	26 – 35	25 – 34
128	26 – 35	26 – 35	26 – 35	26 – 35	25 – 34	24 – 33
158	25 – 34	25 – 34	25 – 34	25 – 34	24 – 33	- Not Possible -

Note: Base Channel Power Range maximum value is 1 dB above DOCSIS DRFI specification

- DS out to 1.218 GHz for actives/passives with higher options (1.794 GHz)
- D3.1, 192 MHz block(s) starts at 111 MHz optional & **261 MHz mandatory**
 - D3.1 CM's filter may negate any D3.0 operation < 261 MHz
- Potential ingress sources
- US decision affects low-end of DS
- What about DS ALC pilot?



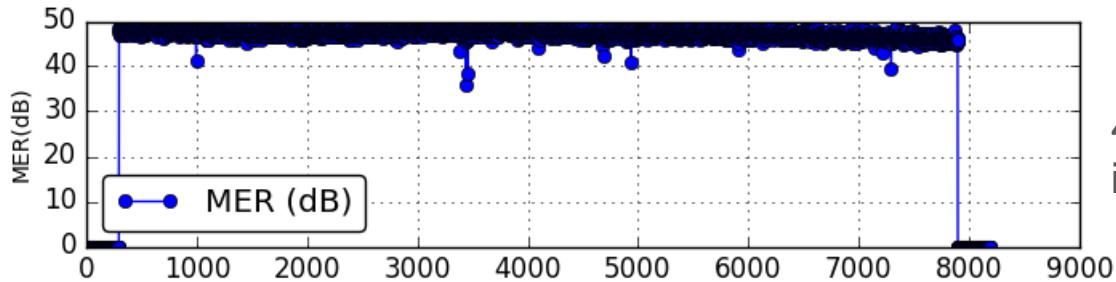
- Define OFDM ch with 192 MHz width using 25 kHz subcarrier spacing
- Wideband ch has 1 SC-QAM plus OFDM (both primary)
- Run speed test through CMs ~ 1.4 Gbps
- Force test CM to use 4096 QAM profile (3)
- Add interfering signal - 2 SC-QAM from another DS port & combine with working port
- Add variable padding to interfering signal
 - Start padding at 30 dB and reduce incrementally
- Observe speed test to make sure no packets lost
- Other testing also involved 8 SC-QAM for interference



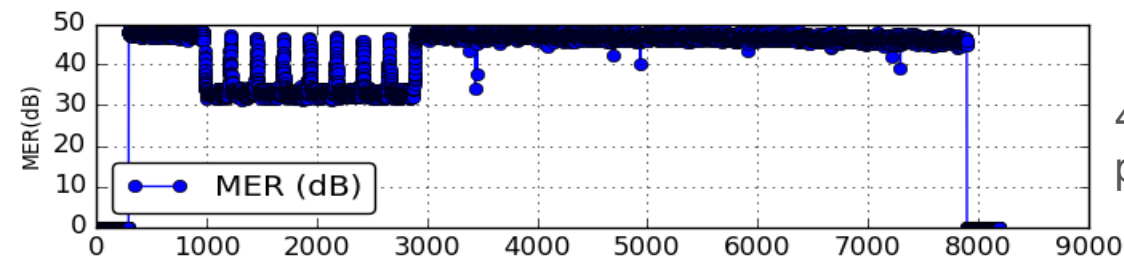
DOCSIS 3.1 PHY Spec – Table 7-41

RxMER (in ¼ dB)	RxMER (in dB)	QAM	Bit Loading
60	15	16	4
84	21	64	6
96	24	128	7
108	27	256	8
122	30.5	512	9
136	34	1024	10
148	37	2048	11
164	41	4096	12
184	46	8192	13
208	51	16384	14

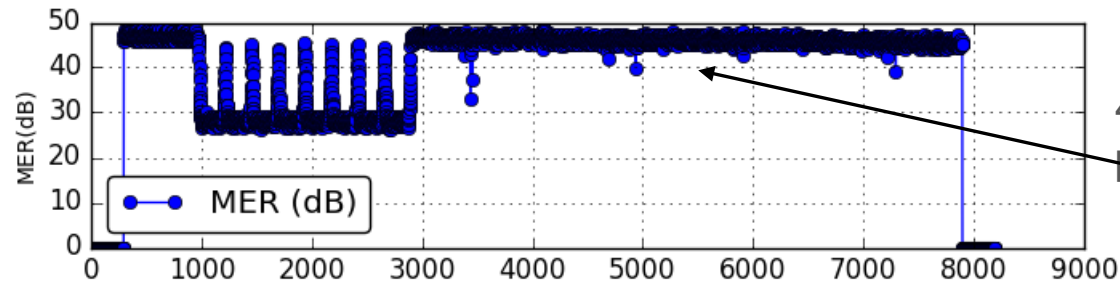
Test CM with 8 SC-QAM Interference



47.40 dB avg RxMER w/ No interference



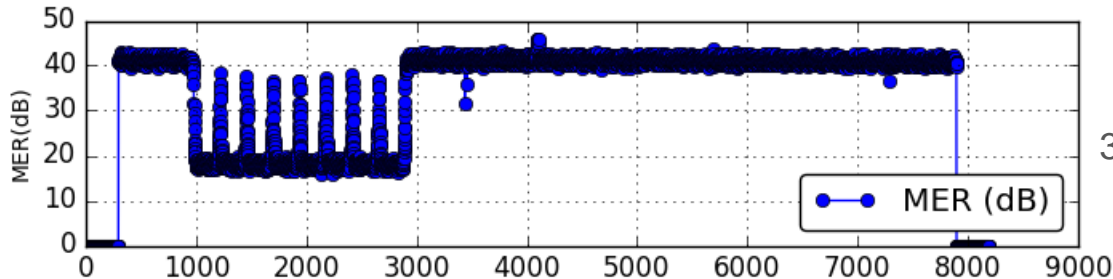
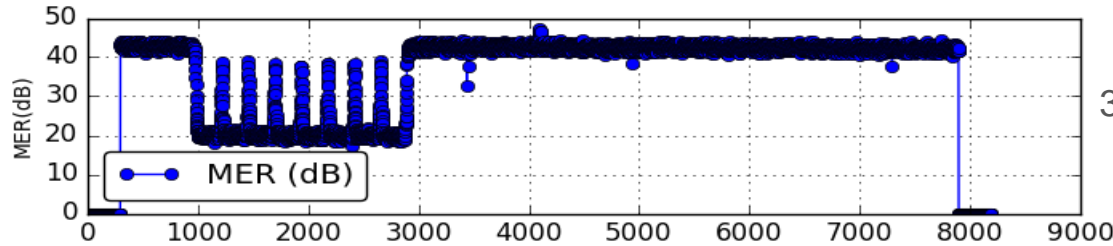
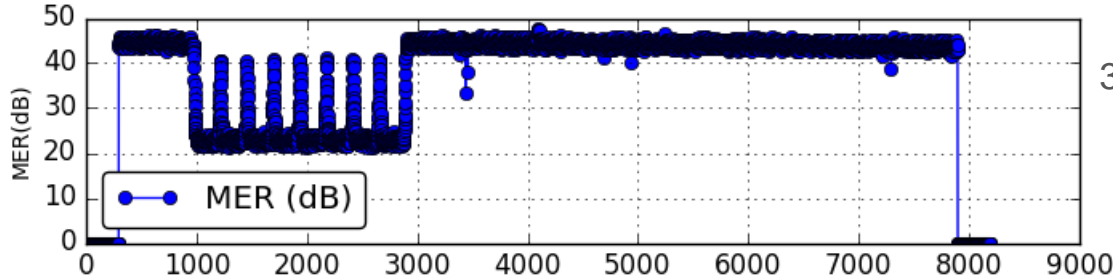
43.65 dB avg RxMER w/ 25 dB padding



41.88 dB avg RxMER w/ 20 dB padding

Very slight RxMER decrease for all subcarri

Test CM with 8 SC-QAM Interference (cont)



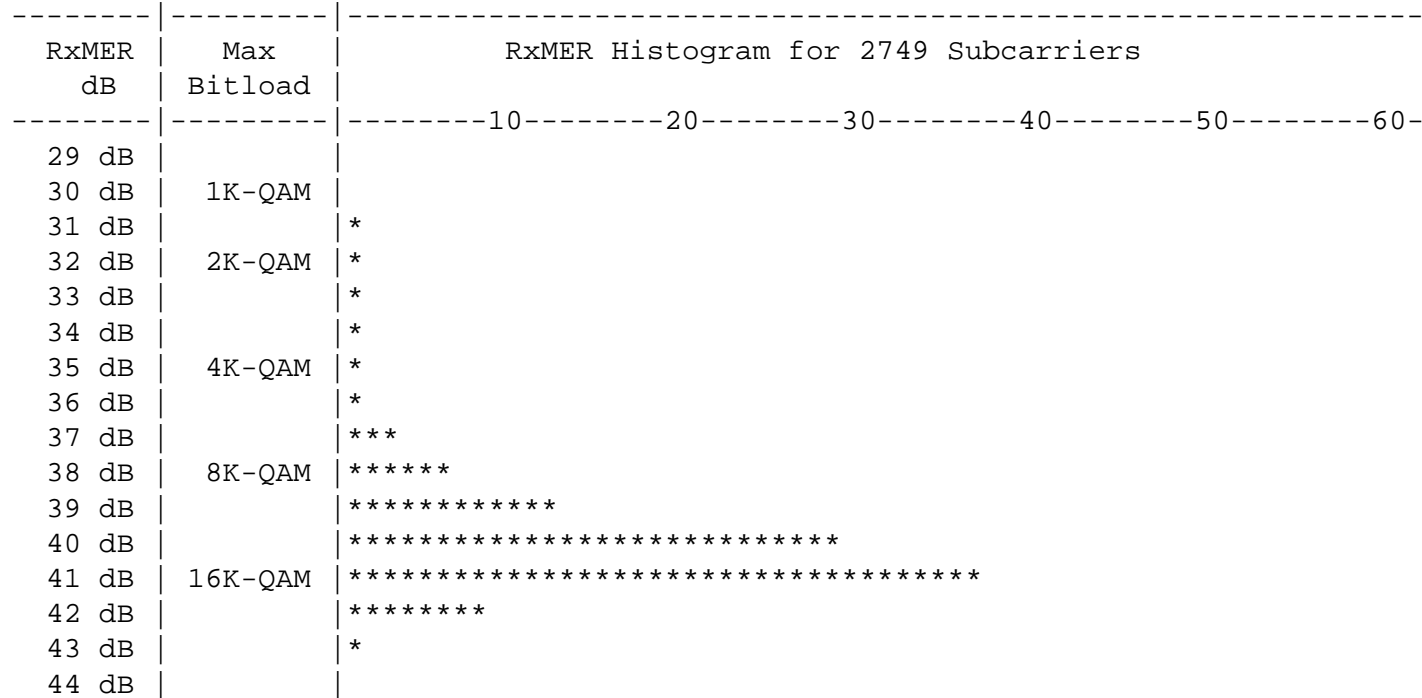
© 2017 Note that ALL RxMER values drop after RxMER in 48 MHz interference dips below 25 dB

- Steady-state interference did not affect throughput as anticipated even at very low MER readings
 - Possibly added affect of LDPC, time/freq interleaving and FFT functionality
- Overall subcarrier MERs dropped when impaired subcarrier MER < ~25 dB
 - Actual impaired spectrum may be a deciding factor
 - Not an issue when exclusion bands used
 - Possibly an added affect of FFT functionality and/or overdrive
- Some CMs appear to incorrectly report MER ~ 6 dB higher than other CMs and may be based on pilot readings
- Mixed-mod profiles probably not necessary for ingress, but roll-off maybe

- Suggested deviation from defaults
 - `cBR8(config)#cable downstream ofdm-prof-mgmt exempt-sc-pct` **10**
 - ✓ 2% default
 - `cBR8(config)#cable downstream ofdm-prof-mgmt mer-margin-qdb` **12**
 - ✓ $12/4 = 3$ dB correction factor with 0 default
- CMTS transmits to CM on control profile (profile 0) until RxMER information received from CM to determine optimal configured profile
- CMTS periodically polls CM to gather RxMER and recommend best profile
- Catch-all of cm-status message of unfit profile
- Can statically map CM to particular data profile
 - `cBR8(config)#cable down ofdm-flow-to-profile profile-data <1-5> mac-addr <>`
- CMs can lock to 4 profiles + control in NVRAM
 - Will need DBC to support 5th & could cause dropped packets

Bit Loading Information from D3.1 CM

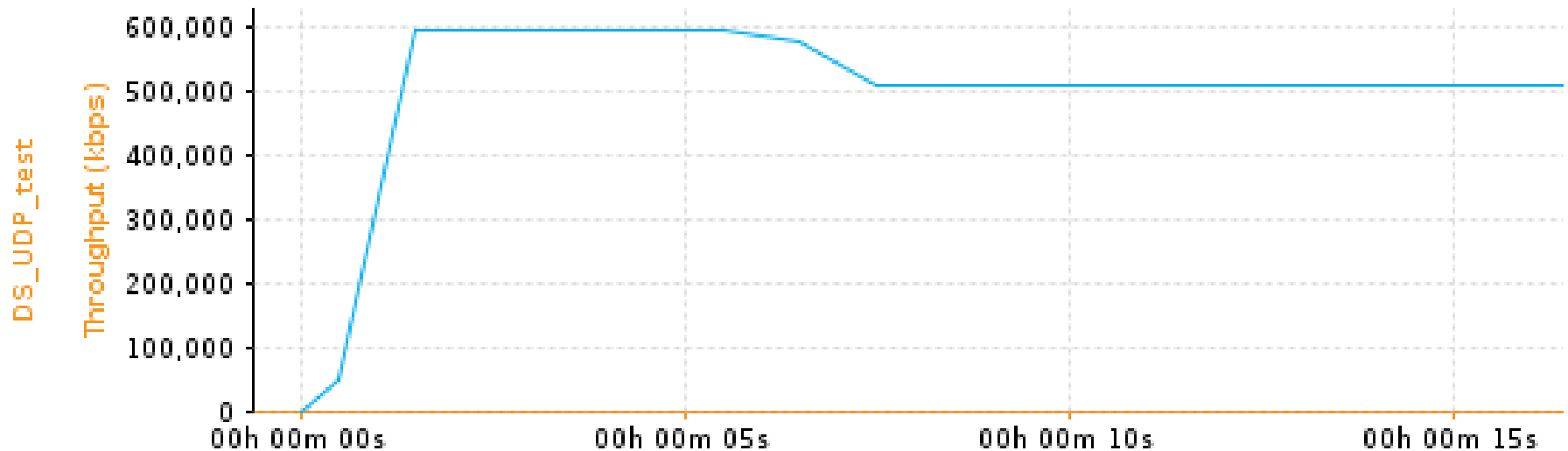
CM> /cm_hal/ofdm_analyzer 32 0



- Shows % of subcarriers that would be able to run given modulation
- CM> /cm_hal/ofdm_mer 32 10 (collects RxMER directly from CM)

- PLC is 16-QAM and very resilient
 - Still best practice to find “clean” spectrum
- Cross-bonding may be in best interest
- When D3.1 CM reports non-primary RF ch impairment for SC-QAM or OFDM
 - CM marked p-online
 - If RF ch impairment < configured DS resiliency thresholds, D3.1 CM’s service flows moved to resiliency bonding group or Narrowband interface
 - If RF ch impairment > configured DS resiliency thresholds, impaired RF ch temporarily deactivated from all BGs

- Can exploit Powerboost™ and peak-rate TLV to satisfy speed test without over-provisioning the typical 10%
- CM file with 510 Mbps max rate, 600 Mbps peak rate, and 70 MB DS max burst
 - Approximately 6 sec Powerboost achieved



OFDM Settings to Maximize Speeds

- `cyclic-prefix 192`
 - Make value as low as HFC plant will support - 192 is lowest and 1024 is default
- `pilot-scaling 48`
 - Keep at lowest setting – default is 48
- `roll-off 128`
 - Make as large as possible but must be less than cyclic prefix value
- `subcarrier-spacing 25KHZ`
 - Less overhead for 25 kHz but most testing to date done with 50 kHz
- `profile-control modulation-default 256-QAM`
 - Configure 4K, 2K, & 1K-QAM data profiles
- `profile-ncp modulation-default 64-QAM`
 - Make NCP as high as plant will support

OFDM DS Speed Estimates (25 kHz)

Channels	Spectrum	DOCSIS 3.0	DOCSIS 3.1 (25 kHz subcarrier)		
		256 QAM	1024 QAM	2048 QAM	4096 QAM
4 channel	24 MHz	151 Mbps	172 Mbps*	189 Mbps*	206 Mbps*
8 channel	48 MHz	302 Mbps	373 Mbps*	410 Mbps*	448 Mbps*
16 channel	96 MHz	603 Mbps	776 Mbps*	853 Mbps*	931 Mbps*
24 channel	144 MHz	905 Mbps	1178 Mbps*	1296 Mbps*	1414 Mbps*
32 channel	192 MHz	1206 Mbps	1584 Mbps**	1742 Mbps**	1910 Mbps**
	2x192 MHz		3168 Mbps**	3484 Mbps**	3802 Mbps**

* **25 kHz subcarriers**, running same modulation, 1.175 MHz guard bands, roll-off 192, cyclic prefix 256, 2 x NCP (64-QAM)

** **25 kHz subcarriers**, running same modulation, 1.725 MHz guard bands, roll-off 128, cyclic prefix 192, 2 x NCP (64-QAM)

- Can utilize CM FBC for DS “sweep” and ingress testing and verification
 - Can activate CMTS RF without incurring licensing
- 100% corr FEC is expected
- PNM functionality
- No special cm file needed for D3.1 but CM must be in MTC mode (US bonding)
- Performance & features supported can vary dramatically with firmware on CM
- Fiber deep architectures and Remote-PHY will allow much higher speeds
- Utilize CMTS features for robustness & “self-healing”
 - Load balance (2.0 & 3.0), US and DS resiliency, dynamic modulation, ...
- Future SDN of OFDM profile management may not be as critical as first thought

- US max Tx level is 65 dBmV
 - Translates to 53 dBmV for same bandwidth as 4, 6.4 MHz ATDMA chs which is 51 dBmV/ch
- US Tx level reports based on 1.6 MHz bandwidth
 - 6 dB correction factor compared to 6.4 ATDMA ch
- At least 1 SC-QAM with OFDMA
 - T4 multiplier of 2
 - Resiliency (SM on both)
 - Max Tx doesn't change much
 - May be simpler for voip and other scheduled flows
- Only 2 IUCs may negate usage of lower spectrum with lower modulation

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THANK YOU!

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