SCTE ISBE CABLE-TEC EXPO '16

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DEVICE TESTING AND EVALUATION OF PNM TEST OPERATIONS VIA SIGNAL ANALYSIS

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#CableTecExpo

Essential Knowledge for Cable Professionals™

Introduction

DOCSIS 3.1 offers greater spectral efficiency, robustness, and multiple modulation profiles to get us closer to Shannon Limit

- How to optimize capacity?
  - Old way: use expensive test equipment, labor intensive field measurements
  - New way: use 3.1 PNM features + open source software to automate it at scale
- In this presentation, we'll address the following:
  - Is a DOCSIS 3.1 CM with enhanced PNM functionality indeed a viable alternative to lab-quality test equipment
  - How can cable operators use new PNM in DOCSIS 3.1 CMs' to optimize capacity and how close can we get to the Shannon Limit
    - Individually, as well as collectively, reliably and predictively

Method

- Great insight into network health can be provided simply by using the DOCSIS 3.1 PNM feature Downstream Receive Modulation Error Ratio Per Subcarrier (RxMER) to determine OFDM signal fidelity at the CM tuner frontend

- The analysis toolset used is an in-house developed application called OpenPNM. It is currently being used for our DOCSIS 3.1 trials in the evaluation of OFDM signal fidelity via RxMER and FEC Summary
  - Also provides OFDM modulation profiles and leverages variable bit loading

Validating the Sensitivity of the CM RxMER via Signal Analysis

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This test is to compare the CM's ability to measure the MER accurately at the receiver front end versus a lab quality signal analyzer. The signal analyzer was configured to perform spectrum, vector, and DOCSIS OFDM analysis.

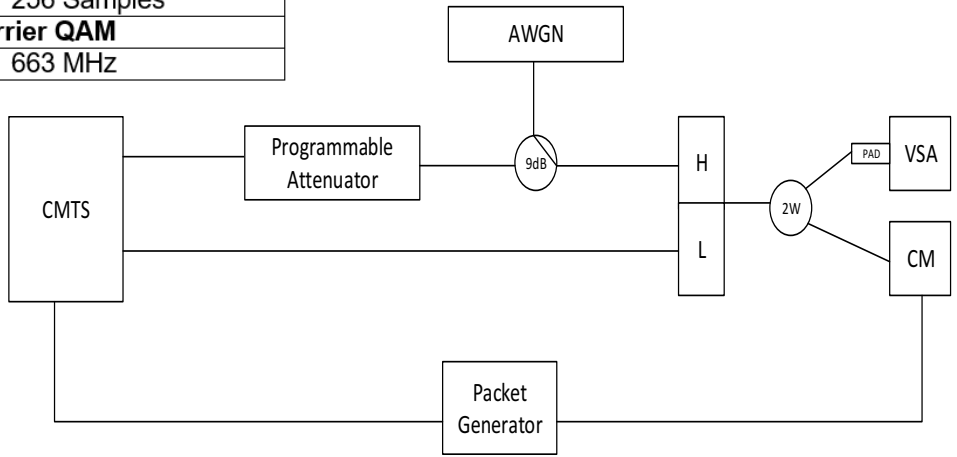
If PNM-based metrics are to be used moving forward for critical plant repairs and improvements, this evaluation is essential to determine the performance and assessment of the OFDM signal fidelity from the perspective of the CM.

Validating the Sensitivity of the CM RxMER via Signal Analysis

CMTS OFDM Configuration			
OFDM 96MHz (BW) (Tests 1 – 6)		**OFDM 96MHz (BW) (Tests 7 – 11)**	
Start Frequency*	786 MHz	**Start Frequency**	786 MHz
Stop Frequency*	882 MHz	**Stop Frequency**	882 MHz
PLC**	832 MHz	**PLC**	832 MHz
Profile A	4096QAM	**Profile A**	1024QAM
Cyclic Prefix	1024 Samples	**Cyclic Prefix**	1024 Samples
Roll-Off	256 Samples	**Roll-Off**	256 Samples
Single Carrier QAM		**Single Carrier QAM**	
Center Frequency	663 MHz	**Center Frequency**	663 MHz

Table 5 - CMTS OFDM Test Configuration based

System Setup



Validating the Sensitivity of the CM RxMER via Signal Analysis

Test results were within 0.3 dB of lab vector analyzer!

TEST	PROFILE-A	VSA MER (dB)	PNM RxMER (dB)	SNR (dB)	THRUPUT (Mbps)	LDPC CODE ITERATION
1	4KQAM	46.0	43.2	46	773	1
2	4KQAM	38.0	37.9	38	773	2
3	4KQAM	37.1	37.2	37	773	12
4*	4KQAM	36.7	36.4	36	773	15
5**	4KQAM	36.4	35.6	35	340	20
6	4KQAM	36.18	-	34	-	ALL ERRORS
7	1KQAM	35.0	34.2	35	651	-
8	1KQAM	33.2	33.2	34	651	-
9	1KQAM	32.4	31.3	33	651	-
10*	1KQAM	30.71	30.3	30	651	-
11	1KQAM	-	-	29	-	ALL ERRORS

Table 6 - Sensitivity of the CM RxMER via Signal Analysis Summary Results

PROFILE-A*	MINIMUM MER	VSA	(MM-V) DELTA	PNM	(MM-P) DELTA
4KQAM	36.1 dB	36.7 dB	.6 dB	36.4 dB	.3 dB
1KQAM	30.1 dB	30.7 dB	.6 dB	30.3 dB	.4 dB

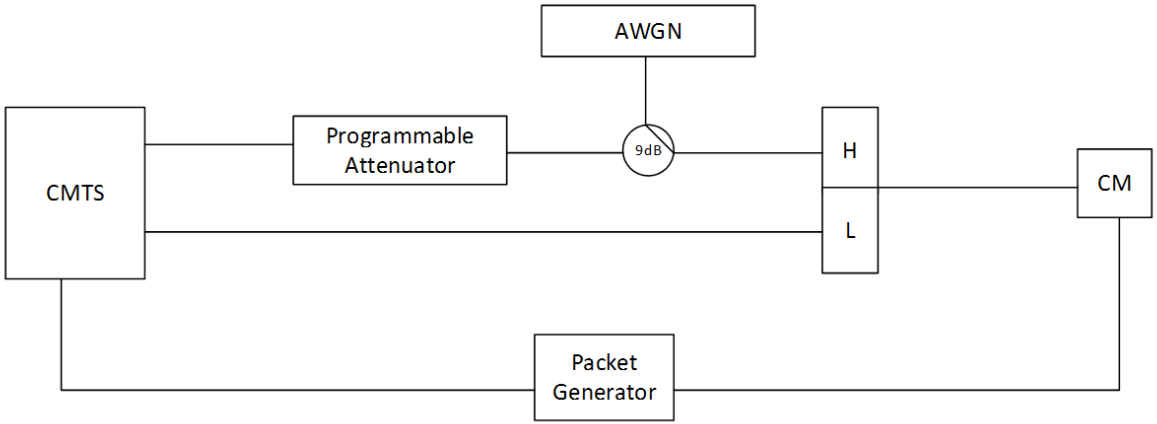
Table 7 - Sensitivity of the CM RxMER via Signal Analysis Results

OFDM Modulation Profile Transition

- **Verify demotion of OFDM profiles in AWGN**
- **3 profiles used (not all D3.1 features supported yet)**

CMTS OFDM Configuration	
OFDM 96MHz (BW)	
Start Frequency	786 MHz
Stop Frequency	882 MHz
PLC	832 MHz
Profile A	256-QAM
Profile B	1024-QAM
Profile C	4096-QAM
Cyclic Prefix	1024 Samples
Roll-Off	256 Samples
24 x Single Carrier QAM	
Center Frequency	597 - 735 MHz

Configuration



Setup

OFDM Modulation Profile Transition

- **Test proved CM/CMTS capability to demote CM to lower profile**
- **Validates the sensitivity of the CM RxMER KPI in 3.1**

TEST	PROFILE QAM**	PNM RxMER (dB)	AWGN (dB)	THRUPUT (Mbps)
1	4068	40.7	-	910
2	1024	37.36	37.0	910
3	1024	35.44	34.0	910
4	1024	31.50	31.0	910
5	1024	32.4	30.0	910
6	1024	31.54	29.0	910
7	1024	30.66	28.0	910
8	256	29.78	27.0	910
9*	256	24.99	22.0	492
10	256	24.39	21.5	492
11	256	24.28	21.3	492
12	256	24.12	21.1	492
13	256	-	-	-

Table 8 - OFDM Modulation Profile Transition 4096-QAM – 256-QAM Test Results

TEST	PROFILE QAM	PNM RxMER (dB)	AWGN (dB)	THRUPUT (Mbps)
1	4068	40.24	40	910
2	4068	39.13	38	910
3	4068	38.40	37	910
4	4068	37.72	36	910
5*	1024	36.88	35	910

Table 9 - OFDM Modulation Profile Transition 4096-QAM Re-Test

RxMER Analysis

- MER as proxy for SNR is now standardized across vendors
- OpenPNM application plots MER magnitude vs. subcarrier freq.
  - MER varies from Rx level variation, ingress strength variation among subcarriers, or both
  - In displaying the RxMER, user can observe any ingress or network impairments
  - The following figures are from a Comcast DOCSIS 3.1 field trial
  - CMs with a standard deviation greater than one with a skewness value less than -1 were searched to detect sharp ingress

RxMER Analysis

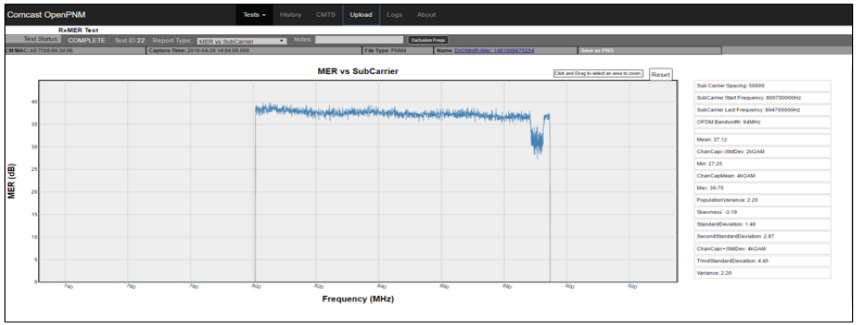


Figure 8 - RxMER Response - Signal Ingress

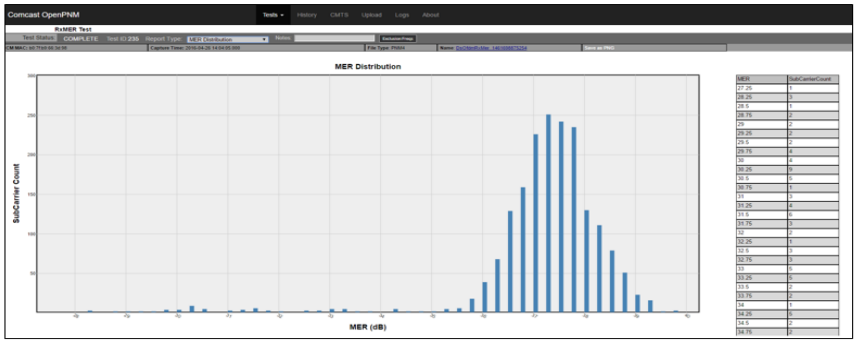


Figure 9 - MER Distribution indicating Skewness - Skewness < -1 or -3.19

Comcast's corporate offices, rather than in the field, which shows the power of the centralized monitoring provided by PNM technology.

It is unknown how the signal ingress was introduced, but one can see the side statistics by using the standard deviation and skewness as key performance indicators (KPI). Using automation, CMs can be quickly screened for a potential problem.

RxMER Analysis

- These are captured from a DOCSIS 3.1 field trial and indicate a type of oscillation in MER
- Both are showing a skewness of > -1, and a severity of MER response swing of a standard deviation of greater than 1 dB

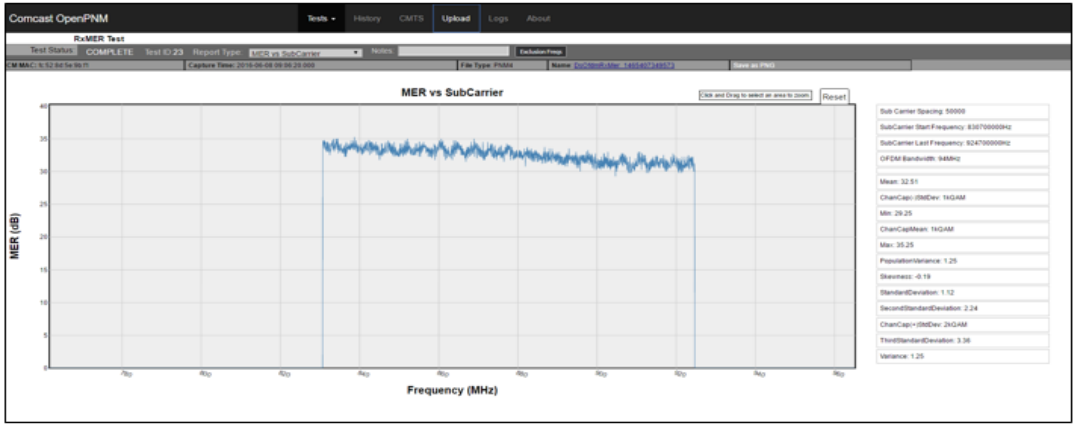


Figure 11 - RxMER Response – Oscillation

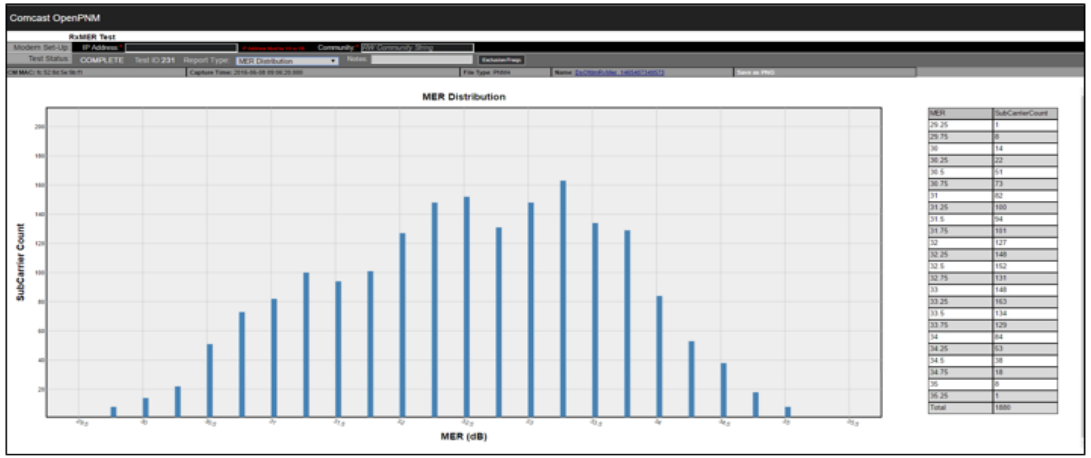


Figure 12 - MER Subcarrier Distribution - Oscillation – Skewness < -1 or -0.19

RxMER Analysis

- Figure 11 and Figure 13 are captured from a DOCSIS 3.1 field trial and indicate a type of oscillation.
- Both are showing a skewness of > -1, and a severity of MER response swing of a standard deviation of greater than 1 dB.

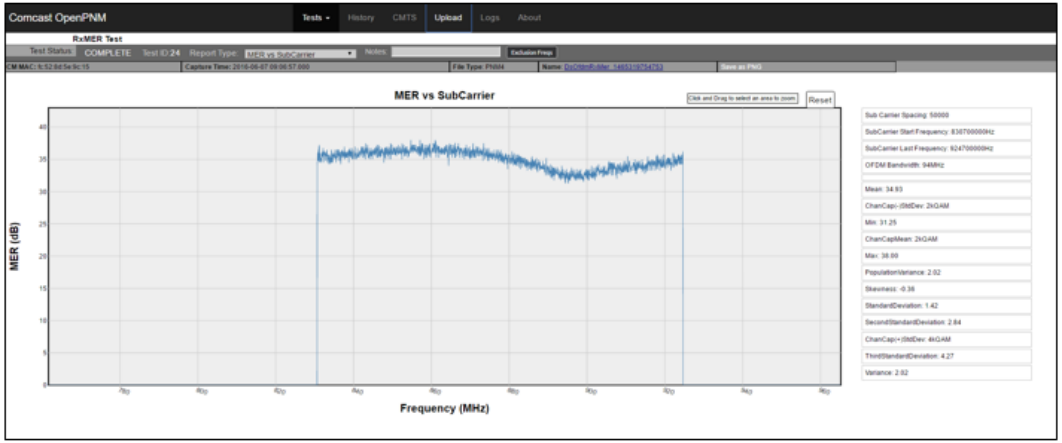


Figure 13 - RxMER Response – HUM Like

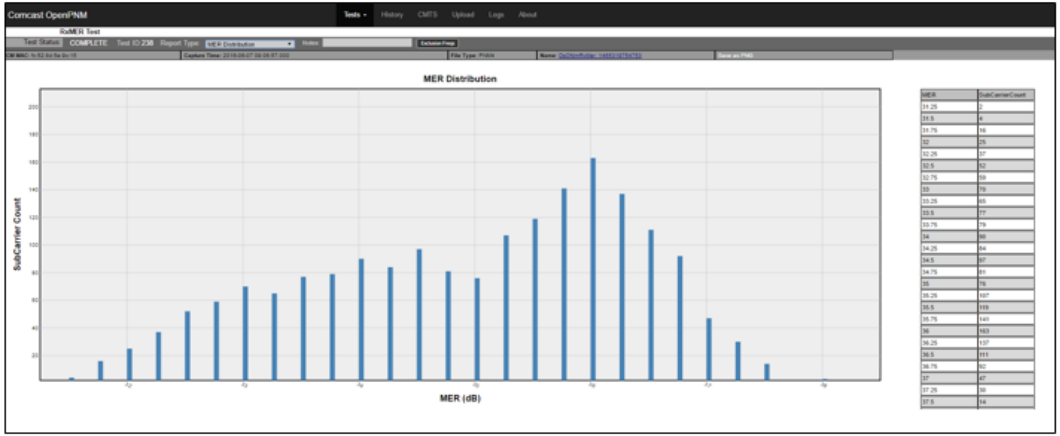


Figure 14 - MER Distribution - HUM Like - Skewness > -1 or -0.36

RxMER Analysis

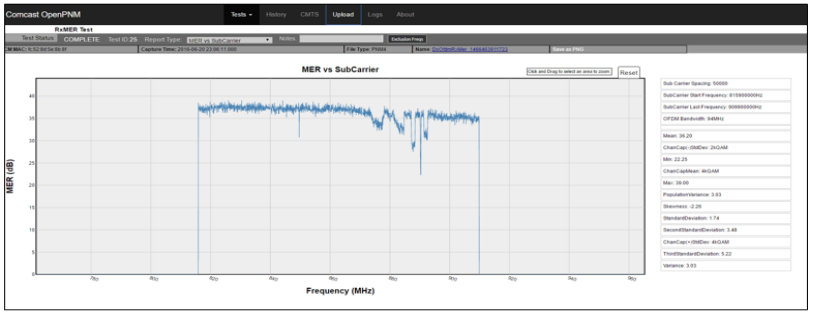


Figure 15 - Multiple Signal Ingress

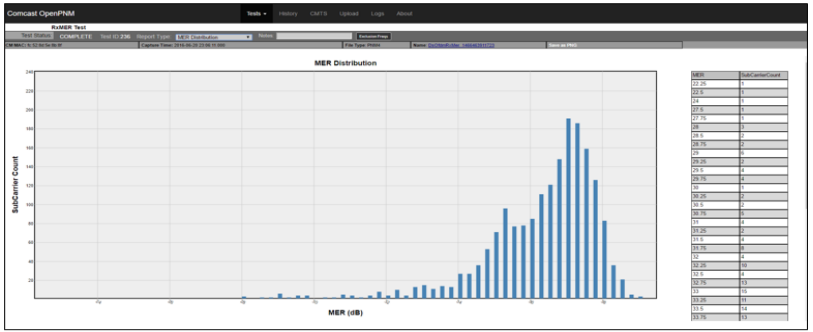


Figure 16 - MER Distribution – Skewness < -1 or -2.26

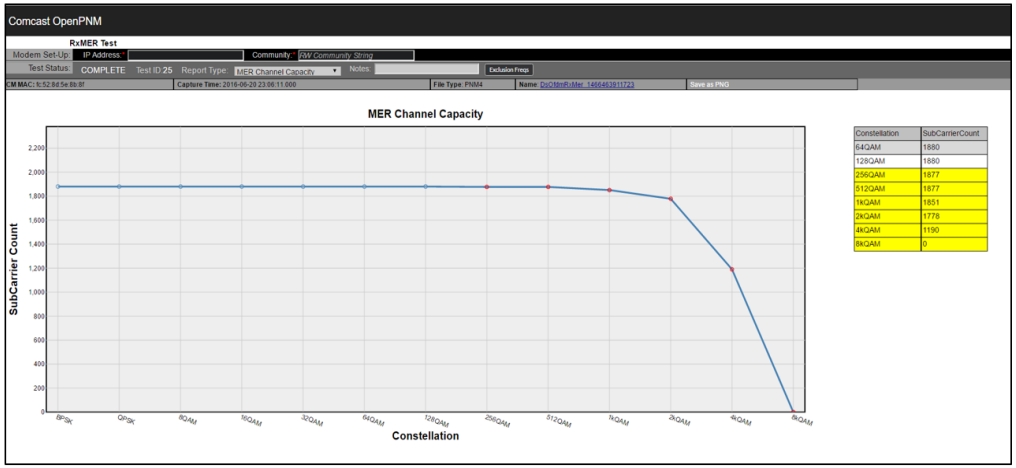


Figure 17 - MER per subcarrier Channel Capacity

Skewness < -1 or 2.26

RxMER Analysis

MER Per Subcarrier Channel Capacity

The previous slides shows the per-subcarrier channel capacity performance from an MER point-of-view. Each subcarrier is evaluated against the required minimum MER for bit-per-symbol (b/sym) or equivalent the order of modulation, M-QAM.

Although the MER response shows multiple signals ingress that are causing a reduction of MER for a subset of subcarriers, as is seen in Channel Capacity Chart displays, the impact is limited to a reduction from 4K-QAM to 2K-QAM, which means 12 b/sym to 11 b/sym. This gives a throughput reduction of about 8.5% if the CM is demoted to a lesser modulation profile.

Conclusion

The two hypotheses of this paper were shown to be correct:

- A DOCSIS 3.1 CM with enhanced PNM functionality is indeed a viable alternative to lab-quality test equipment

- Cable operators can indeed use DOCSIS 3.1 CMs to determine how close the HFC can get to the upper bound of the Shannon Limit both individually as well as collectively

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