Proactive Network Maintenance (PNM) Paves the Way for More Upstream Bandwidth

A Technical Paper prepared for SCTE by

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Table of Contents

List of Figures

List of Tables

1. Introduction

Cable operators are moving towards wider upstream spectrum for improved speed and bandwidth. Activating new upstream spectrum can come with a number of unforeseen challenges. Fortunately, over a dozen years of Proactive Network Maintenance (PNM) experience can provide an excellent foundation for detecting, characterizing and repairing many of the common obstacles. The result is faster, smoother orthogonal frequency division multiple access (OFDMA) deployments and finding and fixing network problems before our customers are impacted.

In this paper, the authors, Hayakawa, O'Dell, Schauer and Wolcott present the latest results of mid-split and OFDMA from the field. They review a number of unforeseen issues including technical and operational solutions. From frequency response issues caused by long-forgotten network equipment and filters to partial-bonding caused by in-home amplifiers, there are plenty of opportunities to get ahead of. This paper provides valuable insight for cable operators embarking on mid-split and high-split transformations in conjunction with OFDMA technology.

2. Evolution of Pre-Equalization Analysis and Proactive Network Management

CableLabs has evolved three generations of DOCSIS PNM. Starting in DOCSIS 1.1, evolving through DOCSIS 2.0, and reaching wide deployment with the advent of DOCSIS 3.0, cable operators have a rich body of data to identify and correct impairments in the RF plant. While there are numerous data sets available in the DOCSIS and PNM requirements, the pre-equalization coefficients are among the most useful to isolate subtle degradations in RF plant performance.

Processing equalization data involves manipulating complex coefficients in the frequency and time domains utilizing Fourier transformations and related mathematics. The scope of these mathematics is outside of this presentation. They may be summarized as the dynamic manipulation of RF energy across frequency bands to compensate for non-ideal coaxial cable plant parameters.

Collection of pre-equalization data also depends on the cable modem SNMP Set and TFTP file return mechanism described in the DOCSIS 3.0 PNM specification. This process is outside the scope of this presentation as well; operators are encouraged to develop their infrastructure to support these new data sets.

In 1999, the first-generation pre-equalization work in DOCSIS 1.1 codified publishing complex equalization coefficients and dynamic RF management to the cable plant. It also experienced growing pains. The original eight coefficients, the accuracy of the measurements, and the implementation of the specification required significant revision as it moved from the laboratory to full production.

The second-generation pre-equalization work implemented in DOCSIS 2.0 improved the pre-equalization modeling. The number of coefficients expanded from 8 to the now familiar 24 as well as improvements to the algorithms.

Pre-equalization analyses advanced to a current best practice with the third generation of PNM in DOCSIS 3.0. CableLabs released a formal PNM specification and built richer data sets into the base DOCSIS MIBs as well.

With DOCSIS 3.1 OFDMA, CableLabs brings the fourth generation of PNM to cable plants. Changing from classic 6.4 MHz wide Single Carrier QAM channels to OFDMA channels that are up to 96 MHz wide with thousands of 25 or 50 kHz subcarriers brings new capabilities and analytical needs.

The DOCSIS 3.0 PNM capabilities have been covered in depth in previous SCTE papers. They are summarized and compared to the capabilities that DOCSIS 3.1 add to the analyses. These reflect major changes that operators need to embrace and will be detailed later in this paper.

Table 1 – PNM Features compared

US Measurement	DOCSIS 3.0 SC-QAM	DOCSIS 3.1 OFDMA
Channel Ranging Status	Exposed for each SC-QAM US channel on the CM and vital for detecting partial bonding.	Exposed for each OFDMA channel on the CM and include stronger indications of partial service.
Speed test	Coarse reductions in expected speed due to US channel impairments. Losing one out of four bonded US channels will result in up to a 25% reduction in measured US speed.	Subtle reductions in expected speeds due to OFDMA US channel impairments. Partial service capabilities, improved error correction, and larger bandwidth will ameliorate but not eliminate reduction in US speed
Spectrum analysis at CMTS	Collected from CMTS spectrum analysis table with limits on narrow or wide channels	New and expanded CMTS spectrum analysis table. New US triggered spectrum capture PNM file available for all US types
Rx power, MER, FEC at CMTS	Collected from CMTS and analyzed along D1.1, D2.0, and D3.0 evolutionary path.	New channel status table entry with expanded power, MER, and OFDMA performance data. New profile status entry reflecting total, correctable, and uncorrectable codewords per US OFDMA profile. New PNM US OFDMA Rx Power and Rx MER files reflecting OFDMA specific
Spectrum analysis at CM	Available for DS spectrum with limited support for US capture and extended upstream bands.	Expanded to include mid-split and high-split frequencies.
Tx power at CM	Long established 53dBmV (with some extensions)	Higher overall due to OFDMA: must be capable of transmitting a total average output power of 65dBmV
Upstream pre-EQ coefficients at CM	Collected from CM and analyzed along D1.1, D2.0, and D3.0 evolutionary path.	New PNM file. Revised analyses describe in the next sections.

2.1. Differences Between SC-QAM and OFDMA Pre-EQ

There are important changes in Data Over Cable Service Interface Specification (DOCSIS) 3.1 and OFDMA that provide improved troubleshooting capabilities over the DOCSIS 3.0 predecessor, single channel quadrature amplitude modulation (SC-QAM). The first is the larger DOCSIS 3.1 OFDMA channel width of up to 96 MHz, contrasted to the fixed SC-QAM channel widths of either 3.2 MHz or 6.4 MHz. With the wider channels, there is greater time resolution, which provides more precise distance calculations than narrower channels that also contain guard bands and roll off. The time resolution is calculated as the reciprocal of the total equalizer bandwidth.

For example, if an OFDMA channel is configured to operate with 50-kHz subcarrier spacing. In the frequency domain, each equalizer coefficient represents 50 kHz. For SC-QAM using 24-tap equalization coefficients of 6.4 MHz-width, each coefficient represents 233.33 kHz. This is over 4.6 times improvement in the frequency resolution of the equalized channel bandwidth. However, the resolution improvement is even greater when considering the additional inefficiencies inherent with SC-QAM channel shaping and adaptive pre-equalization. First, if the SC-QAM channels have spacing or guard bands, which the unoccupied spectrum will not be subject to the equalizer bandwidth used for troubleshooting. Also, because DOCSIS uses a root raised cosine shaping filter, the SC-QAM channels have a roll off factor of 0.2, leaving only 0.8 of the channel used for the symbol bandwidth. In the case of 6.4 MHz wide channels, only 5.12 Msym/s are visible to the equalizer. Likewise with the 3.2 MHz wide channels, the channel alpha is 2.56 Msym/s.

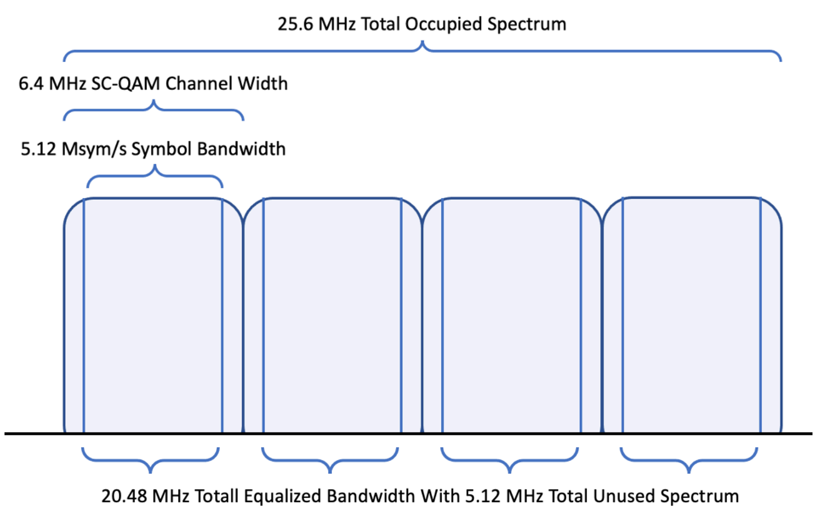

Figure 1 – Example of SC-QAM equalized spectrum

Figure 1 shows example comparison of 4 SC-QAM channels configured at 6.4 MHz channel bandwidth. While these channels occupy 25.6 MHz of spectrum, only 20.48 MHz of spectrum is available for troubleshooting. Also note that 5.12 MHz of that spectrum is spread across 5 spans of non-contiguous frequency spectrum, creating gaps that cannot be used reliably for troubleshooting.

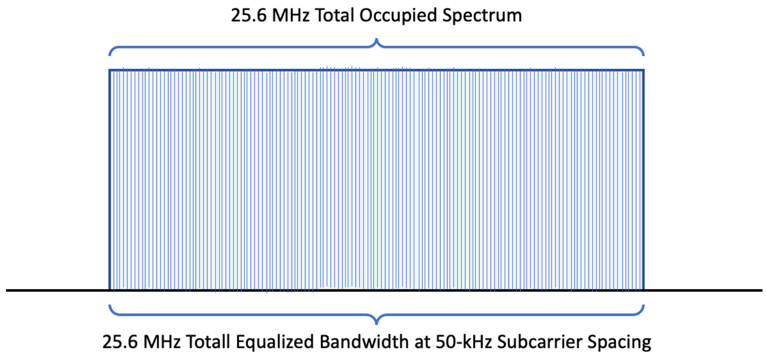

Figure 2 – Example of OFDMA equalized spectrum

In comparison, Figure 2 shows an equivalent OFDMA channel configured at the same frequency spectrum of 25.6 MHz wide at 50-kHz subcarrier spacing. The entire 25.6 MHz of spectrum is equalized at 50 kHz frequency resolution, providing a total of 512 contiguous sample points, compared to nearly 88 sample points in the previous example (Figure 1).

3. Coefficient Reporting

3.1. Raw Coefficients

When a DOCSIS 3.1 modem has an operational OFDMA channel and its pre-equalizer is enabled, the modem can report the pre-equalizer coefficients. It will upload the coefficients on a specified trivial file transfer protocol (TFTP) server upon a request via simple network management protocol (SNMP) when the coefficients are available. The request typically takes several seconds involving a few SNMP commands and polling, sometimes ending up with a timeout and a failure.

The pre-equalizer covers all the subcarriers between the lowest and highest active subcarriers. Each coefficient is a complex number for a subcarrier and specifies an amplitude and phase adjustment to the subcarrier's transmission. The complex number is encoded with a pair of 16-bit fixed point numbers for the real and imaginary parts. Presenting the coefficients' magnitude values in the log scale gives the familiar amplitude of frequency response. Taking the differentials of coefficients' phase values gives the group delay.

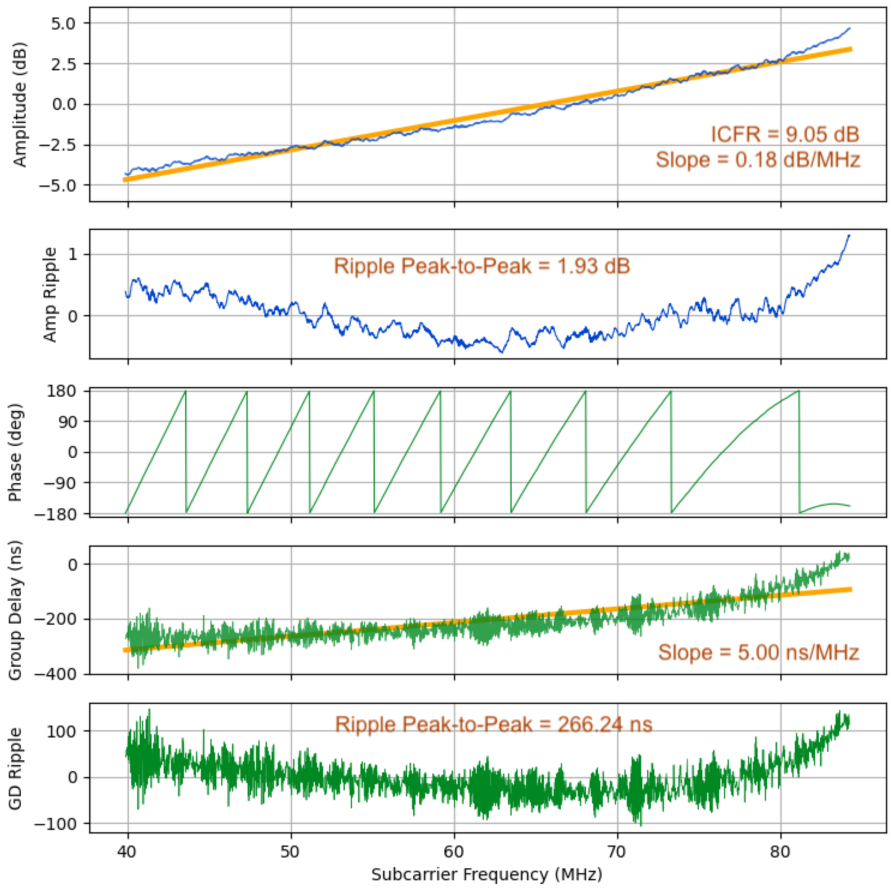

Figure 3 – Example of OFDMA pre-equalizer coefficients and metrics

3.2. Pre-equalizer Metrics

The raw pre-equalizer coefficients are thousands of complex numbers. In order to assess the plant health, we need simpler metrics (Figure 3). The most straightforward is the in-channel frequency response (ICFR) which is the difference between the maximum and minimum of the subcarriers' amplitudes in dB.

Meanwhile, the modem performs the linear fit on the amplitude curve and publishes the following metrics on the SNMP table **docsPnmCmUsPreEqTable**. They are cheaper to retrieve than the coefficients as it takes only a few SNMP queries. The modem does the same calculation on the group delay, too.

- Linear fit
  - Mean (docsPnmCmUsPreEqAmpMean)
  - Slope (docsPnmCmUsPreEqAmpSlope)
- Nonlinear component (ripple)
  - Peak-to-peak (docsPnmCmUsPreEqAmpRipplePkToPk)
  - RMS (docsPnmCmUsPreEqAmpRippleRms)

The modem will have a low in-channel frequency response (ICFR) as well as low amplitude slope and ripple metrics when it is on a clean leg of the hybrid fiber-coaxial (HFC) node. We looked at thousands of modems on a 44.4 MHz-wide channel among a few hundred nodes and observed the following relationship between the ICFR and the linear fit metrics.

Table 2 – ICFR and coefficient metrics

ICFR Range (dB)	Modem Count		Average Slope (dB/MHz)	Average Ripple Pk-to-pk (dB)	Average Ripple RMS (dB)
0..2	342	7.7%	0.015	1.148	0.204
2..3	1027	23.1%	0.037	1.278	0.235
3..5	1672	37.6%	0.072	1.505	0.289
5..7	798	17.9%	0.111	1.752	0.345
7..10	337	7.6%	0.159	2.353	0.498
10..15	216	4.9%	0.238	3.400	0.703
15..20	24	0.5%	0.204	9.876	2.084
20 or more	33	0.7%	0.158	21.812	3.082

3.3. Coefficient Overflows and Underflows

Each of real and imaginary coefficient parts can take a value between -4 and 4 with a 1/8192 increment. The practical maximum magnitude of a coefficient is 4 in linear (+12 dB) because the magnitudes over 4 will be clipped when the phase is at or near a multiple of 90 degrees.

The magnitude shouldn't go very low either because the coefficient will lose the resolution. In an extreme case where the magnitude is the minimum (1/8192), the phase resolution is 90 degrees. The amplitude resolution is 0.004 dB at the 1/4 magnitude (-12 dB) whereas it is 0.03 dB at the 1/32 magnitude (-30 dB). In most cases the amplitude stays above -15 dB. In very extreme cases we have seen some coefficients collapsed down to zero (0+0j).

Coefficient amplitudes above +12 dB or below -15 dB including the 0+0j value are a good indication of anomaly.

3.4. Monitoring a Large Group of Nodes and Modems

Retrieving the raw coefficients is slow and could fail after all. When monitoring thousands and millions of modems, it is economical to ask for the raw coefficients only when the modem can report them and its HFC condition looks interesting. There are several steps to consider before asking for the coefficients. The step 1-3 can be done by querying just the cable modem termination system (CMTS).

1. Does the HFC node have an OFDMA channel?
2. Is the modem online?
3. Has the modem succeeded in ranging the OFDMA channel?
4. Is the modem's preequalizer enabled?
5. Does the modem have the coefficient metrics at docsPnmCmUsPreEqTable?
6. Are the coefficient metrics interesting or bad enough? Such as the amplitude ripple peak-to-peak is greater than 5 dB or the RMS is greater than 3 dB.

When a modem with bad coefficient metrics is found, it makes sense to retrieve the raw coefficients from it as well as the modems nearby or of the entire node altogether to see whether the modem's impairment is isolated or prevalent and to narrow down the possible location of impairment cause. If some modems exhibit a similar impairment and they are in the same neighborhood on the HFC topology, it is likely that a single cause is affecting those modems. Overlaying the modems' pre-equalizer amplitude curves gives a good insight.

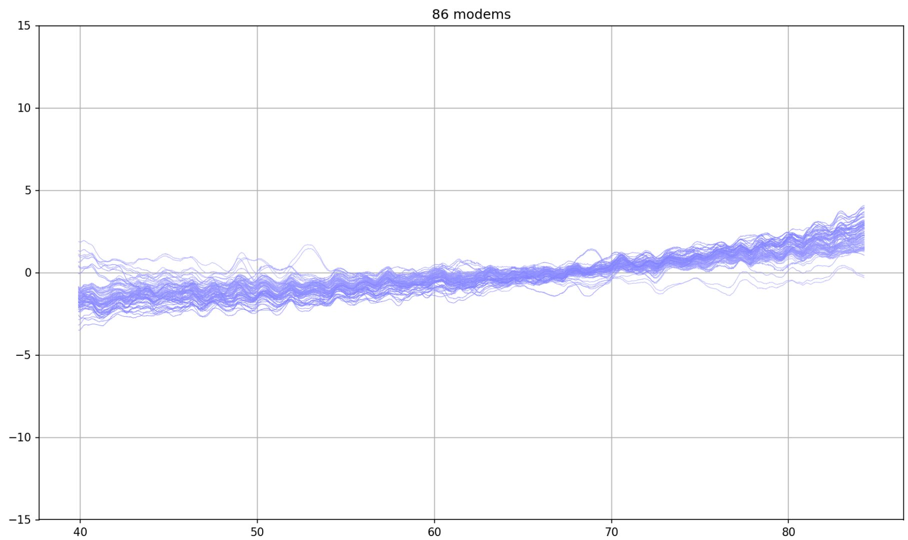

Figure 4 – Multiple modems' pre-equalizer amplitudes on a node

Figure 4 is an example of overlay plot for a node. The modems on this node and most of the others had relatively low ICFRs. Some of them had many modems sharing the same minor microreflections whose cause would be near the CMTS or remote PHY device (RPD).

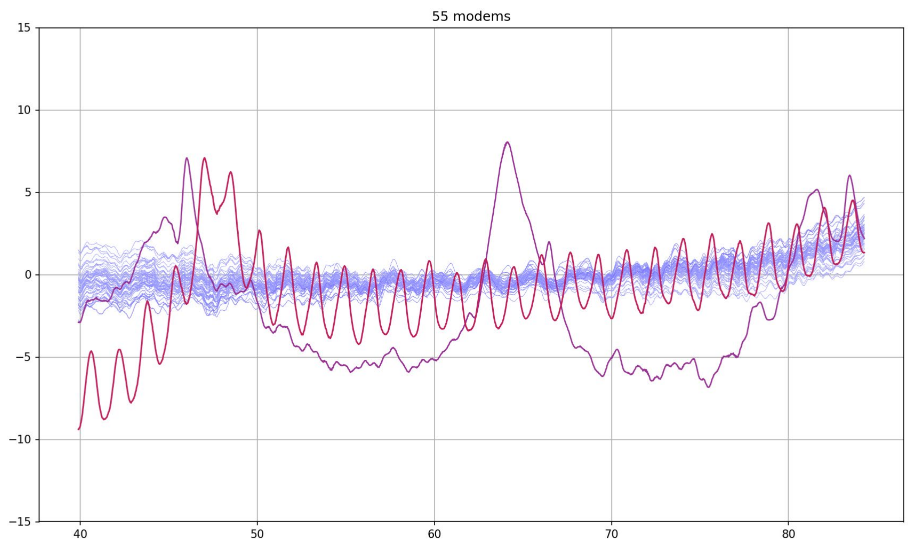

Figure 5 – Two modems under impairment with different signatures

On this node, two modems saw a high ICFR with very different curve signatures (Figure 5). The causes of impairment for the two were certainly different and likely between the tap and house. Indeed, they were on very different legs of the node. Several more nodes had multiple modems with isolated impairments.

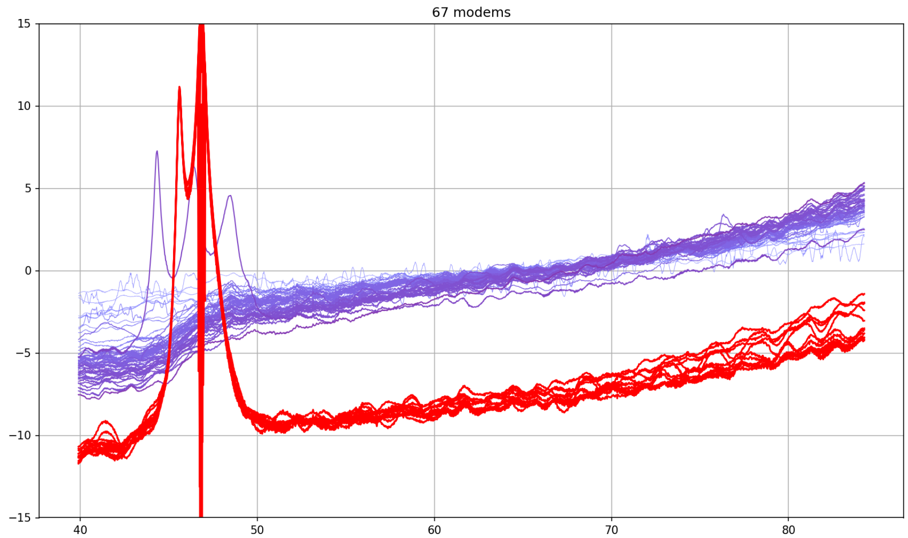

Figure 6 – Multiple modems under heavy impairment with the same signature (red)

The more interesting situation, where multiple modems reported very similar frequency responses, was found in several other nodes. On one of such nodes, twelve out of 67 OFDMA-enabled modems showed a very similar pair of amplitude spikes whereas others didn't (Figure 6). The spike and dip at 48 MHz were anomalies by themselves as they exceeded the +12 dB ceiling and the -15 dB floor. The twelve were so similar that they were likely to be nearby each other under the same impairment. It turned out that they were all on the same branch of the node and the branch had no unimpaired modem, seen when mapped in Figure 7.

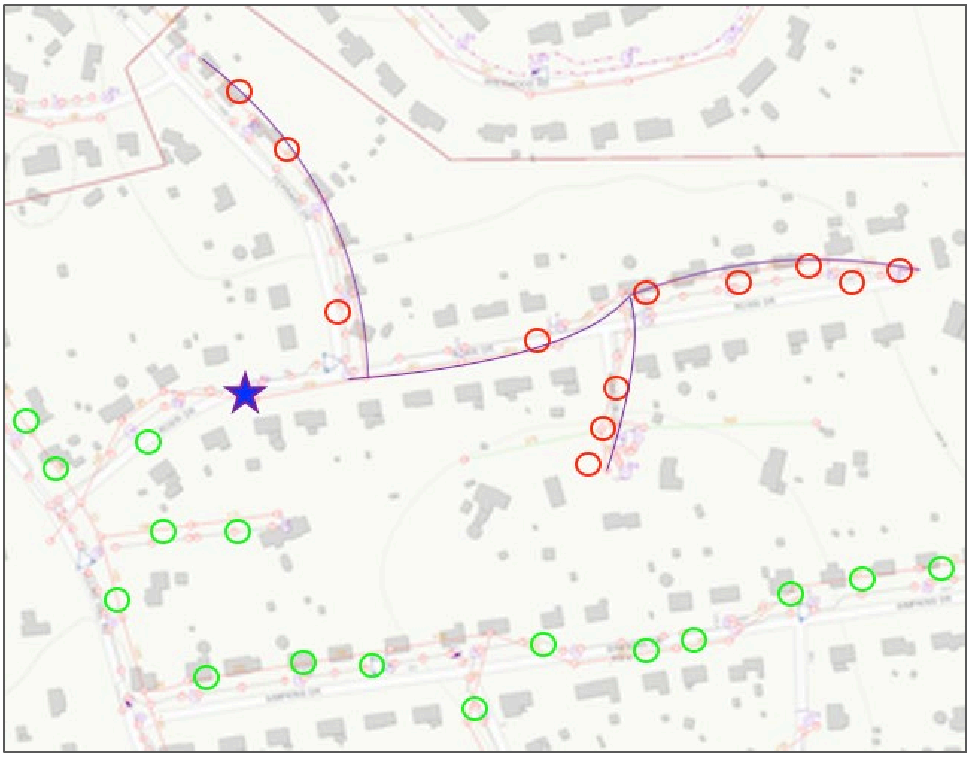

Figure 7 – Impaired modems mapped on the same network branch

It was an easy guess that the impairment came from where the bad branch began. It allowed the field technician to spot an old line equalizer easily. Once the equalizer was removed, the spikes went away in Figure 8.

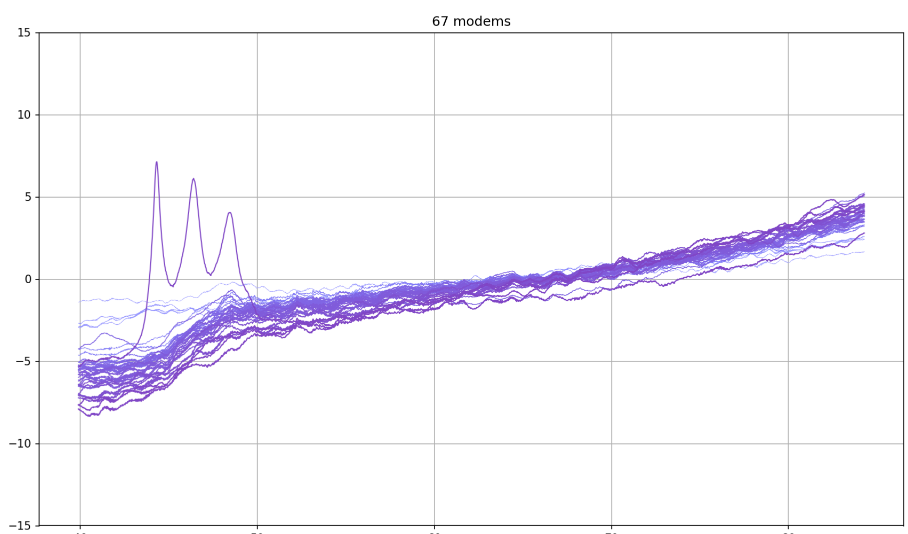

Figure 8 – Same 12 modems' frequency reponse after repair

4. Learnings From the Field

4.1. Legacy plant

Every bandwidth expansion in the Hybrid Fiber Coaxial network has been met with unforeseen obstacles, both in the downstream and upstream. The flexibility of coaxial cable itself has allowed operators to upgrade electronics and optics and leverage the same coaxial cables successfully for many years. As the designed have evolved, so have the active and passive components deployed in the network.

When we consider the "return" portion of the spectrum, today understood to be 5 MHz – 42 MHz, even this has undergone several iterations. From 30 MHz as the upper band edge, to 40 MHz and ultimately 42 MHz, each of those seemingly minor changes have introduced complexity to the activation and reliable operation of the newly activated portion. Line passives, and return equalizers are a couple of the common passive components that can be disruptive to a bandwidth expansion, or network upgrade.

Line passives like equalizers, and conditioned taps have allowed designers and engineers to build networks that deliver very consistent levels to a large number of subscribers within the service area. Using passive plug-in components (Figure 9) like cable equalizers, cable simulators, return attenuators, or even high pass filters in the taps themselves, it is possible to condition the output signals at every tap port in the network to be within a small target window. They can also allow for the expansion of the feeder or distribution systems to a greater service area, resulting in fewer nodes or amplifiers, and reducing upgrade and operating costs.

However, some of these components do have frequency specific diplexers that would need to be replaced when expanding the bandwidth, and particularly in the upstream portion of the spectrum.

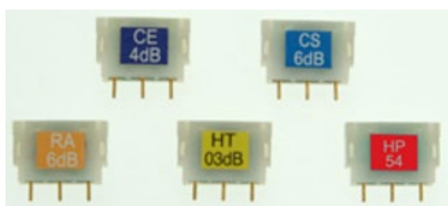

Figure 9 – Example of passive plug-in components

Some line equalizers, in addition to adding equalization to the forward bandpass to account for normal cable losses over long coaxial cable spans, can have a diplexed return path portion to introduce attenuation to the upstream path. These line equalizers would prohibit any expanded bandwidth above the diplex frequency from being enabled at the customer premises southbound of the passive device, examples in Figure 10 and Table 3.

Table 3 – Line equalizer properties showing 5 MHz to 42 MHz operation

Parameter	Frequency (MHz)	Equalization Mode	
		Typical	Maximum
Bandwidth Split (MHz)	---	42/51	
Cable Equalization (dB)	5-42 51-750	0 8	

Figure 10 – Conditioned line equalizer

In many cases a walk out is done prior to a system upgrade. This is useful in identifying the location of the previously installed amplifier locations, any traffic or access issues, or verification of passive devices that may need replaced. However, on occasion amplifiers are placed and the locations of these active devices are not updated on the system maps, or design documents. Instances such as: disaster recovery, temporary or special events, or temporary amplifier placements due to coaxial cable deterioration. While these are intended to be temporary, they can be overlooked and left in the system unnoticed. In these instances, they can cause unexplained failures in the recently expanded portions of the spectrum and may require a full physical walk-out of the network to locate.

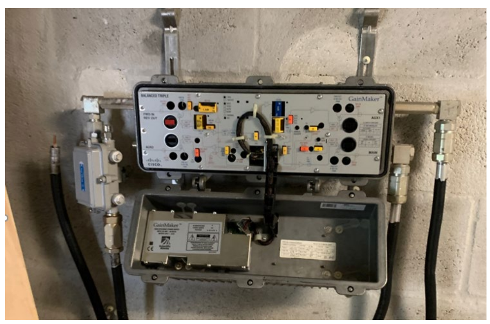

Figure 11 – Sub-split amplifier installed in a mid-split system

In addition to “old” amplifiers, another potential obstacle to the activation of expanded spectrum is “old” passive plug-in components, example in Figure 9. Several amplifier platforms have remained largely unchanged through several generations, and the form factors for the passive plug-ins in the amplifiers themselves have also remained unchanged. Forward and Return equalizers in particular are a concern. Often, then new nodes and amplifiers are placed, the new portions of spectrum are not immediately activated with signals. The legacy channel line-ups are often retained for a period of time after splicing is complete. In these instances, it is difficult to immediately identify if a legacy plug-in component has been installed in an amplifier using PNM tools. Legacy verification practices such as the use of a signal generator and a spectrum analyzer would be required to ensure that the expanded bandwidth was usable, and there were no legacy components improperly installed in either an active or passive device.

Figure 12 – Sub-split return equalizers installed in mid-split amplifiers

As with the figure above we recognize that it can be difficult to identify the bandpass frequency of the return equalizers, unless you have a key to the letter code which denotes the upper band edge. In the example of Figure 12, the "S" on the return equalizer denotes an upper band edge of 40 MHz. The form factor however is the same as the mid-split return equalizer and can easily be installed in error. If the construction or maintenance teams use legacy sub-split channels for amplifier alignment or device recovery verification, then all indications will be that the system is operating normally and without error.

However, when the additional spectrum is activated, these devices can cause excessive tilt, due to the loss cause by the sub-split passive component, seen in Figure 13.

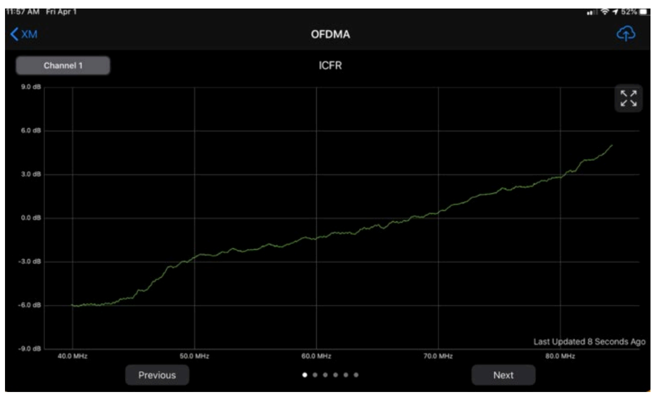

Figure 13 – Frequency response of OFDMA channel through a sub-split equalizer

4.2. Partial bonding

When the expanded portion of spectrum, like OFDMA is activated, the long loop automatic level control (ALC) function of DOCSIS devices located in the customer premises will attempt to use that portion of spectrum (if capable) and attempt to adjust the transmit power of the device at that frequency to accommodate the CMTS range request. This can result in a significant difference in transmit levels at the device when compared to the traditional sub-split upstream channels. If the transmit delta or tilt are severe enough to violate the dynamic range window of the device, the device will ultimately be forced into a partially bonded state.

There can also be legacy devices left in the network or drop system that can result in failure to activate the expanded portion of the spectrum. In-home amplifiers are commonly used to increase the amplitude of signals in the home. There have been many different generations of in-home amplifiers deployed, and many, if not most of them, were designed and built for CATV systems that operated sub-split return paths. These sub-split diplexed devices can result in a failure to activate any additional bandwidth above 40 or 42 MHz. Other considerations for the subscriber drop system, are legacy filters and traps. These devices have been used for many years to manage service and channel access, or for frequency specific bandwidth management like, high pass or low pass filters to manage ingress in the premise. The location and placement of these filters may result in some DOCSIS devices to be unable to acquire a clear and unobstructed path back to the node. These instances would result in capable devices being considered as being in a partially bonded state.

4.3. Performance limitations – how to detect?

Depending on the phase of construction, and the business unit involved, there can be different methods to detect obstacles to the activation of "new" spectrum. As discussed in the Section 4.1, there are plenty of legacy devices that can remain in the trunk and distribution system that can affect the signal flow through the expanded spectrum areas. We have also identified several potential obstacles in the premise wiring system. While these effectively result in the same thing, there may be different methodologies to identifying where the obstacle exists.

During the construction phase of the upgrade, once the node, and all the amplifiers have been spliced in and activated, there are several legacy practices that can still be used for spectrum testing and validation. For many years, active sweep transmitters installed in the headend allowed technicians to prove connectivity, frequency response and level validation of a newly constructed network. The introduction of technologies like Remote-PHY and Remote MAC-PHY have rendered this practice obsolete, as the signal generation point is at the node, and no longer in the headend or hub. There are still however, hand-held signal generators and receivers that can successfully be used to insert a carrier at an insertion point, like a terminating tap, and receivers that can detect that inserted signal at an endpoint, like the optical node return input test point. This method is still perfectly valid; however, it requires a lot of time and mobility to validate all the potential end points in a node. Some test equipment can generate QAM signals in the return band to be received on a spectrum analyzer and be evaluated for both amplitude and quality.

The use of intelligence tools is a more efficient way to validate the upstream signal path, however it is also not without challenges. At the earliest stages of the construction and activation process, the downstream and upstream channel plans may not be fully evolved to activate capable devices in the premises. Further, the intelligence tools themselves may not yet be capable of collecting the additional telemetries available from the CMTS or v-CMTS and localizing them to a point in the network which could be causing the failure. It is incumbent on the operators to engage the tooling teams early in the engineering process of an upgrade to begin to develop the application programming interfaces (APIs) and endpoints between systems to be able to integrate newly activated spectrum telemetry into existing tool suites. The use of field strength meters with embedded D3.1 modems can be useful spectrum validation tools as well.

4.4. Customer performance aspects – speed tests

After all the construction, activation and validation steps have been completed, and the capable devices have been configured with the appropriate firmware to successfully use the newly activated spectrum, it is finally time to see the fruits of all that labor. Just how fast can we go? There are many different methods to evaluating throughput, or speed, and different locations in the network where it can be measured.

Wireless device tests, hardwired computer tests, and field test equipment used by the technical staff can all garner slightly different results. Which one is right? The answer may be that all of them are. As with many aspects of the telecommunications network, the answer may be a nuanced one. Speed tests are a snapshot in time, of the performance of the path between the requesting device and a speed test server located somewhere on the network. There are many factors that affect the results of a speed test, such as: the type of device being used to initiate the test, the methodology it uses to connect to the network (i.e. wired or wireless), the location of the speed test server, relative to the initiating device, the volume of traffic on the network, and whether the test is customer initiated, or a background test executed by the provider.

There have been many studies and publications created on the different types, and the benefits of the various methodologies, but the focus of this paper is not to evaluate speed test methodologies, rather to provide some experiential suggestions on how best to use PNM tools and practices to successfully activate and validate mid or high split networks. To that end, here are a couple of simple suggestions. The first and possibly most gratifying way is to use a capable field strength meter at a point in the network to validate the use of all the available spectrum. The ability to use a field meter with a DOCSIS 3.1 embedded modem and configured to hit a speed test server can quickly confirm that the upstream path is capable of transporting signals in the expanded portion of the spectrum.

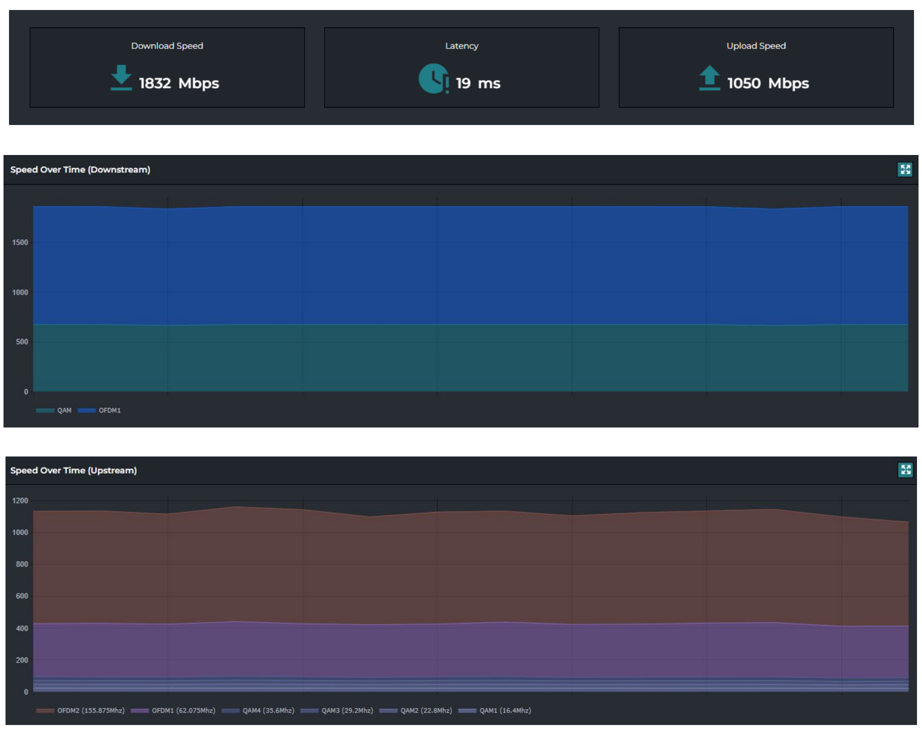

Figure 14 – Field meter speed test results in high-split system

This simple test validates a few things. First that the modem in our test equipment was successfully able to connect and transmit data through the expanded spectrum, and that we were able to achieve a reasonably high data rate through the network. Understanding that this is only one test from a specific point in the network, and a point in time, we can replicate this at various terminations in the network to validate that there aren't any significant obstacles between the point of the test, and the node location. Devices like the one used for the speed test illustrated in Figure 14 can also provide additional data regarding the quality of the network as it pertains to any impairments that may exist upstream from the test point.

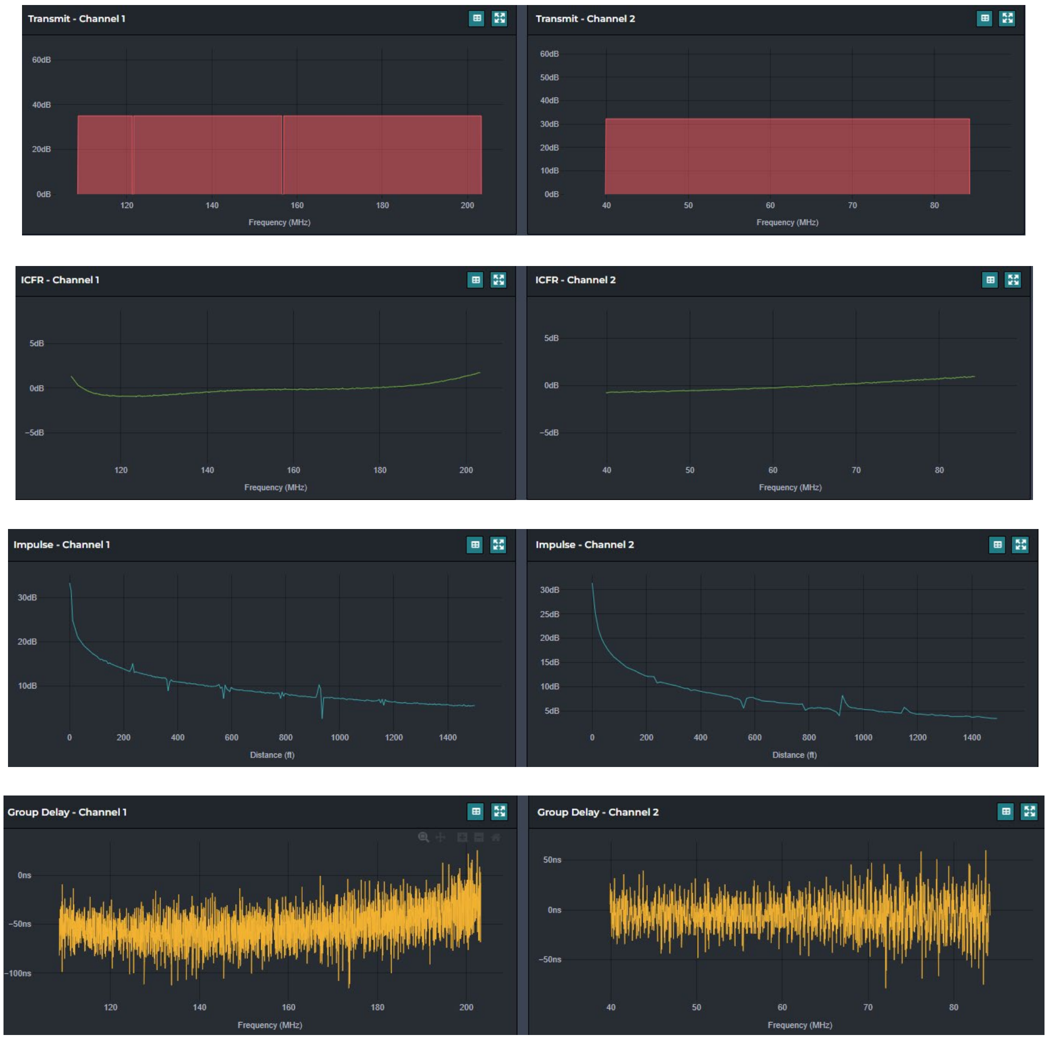

Figure 15 – Upstream signal analysis of expanded upstream using a field meter

Having data points like these are analogous to PNM tool results once the spectrum is activated, and devices are enabled to begin using this spectrum. They can be reliably used to indicate impairments in the transmission medium (coaxial cables), or of passive or active devices that may still be present in the network and have gone unidentified.

There is obvious value in using field test equipment for validation of speeds, and the additional performance data that it can provide. It is, however, time consuming and labor intensive. The other alternative is to do bulk "background" speed testing once devices are activated and online. There are pros and cons to this method also, however. On the plus side, the volume of devices located in different parts of the network can be very useful in localizing potential plant impairments that influence speed. This is also useful in validating those devices are successfully using the expanded spectrums based on their speed results. While they may not be extremely precise on the actual network speed the way that a subscriber-initiated test could be, they are at least directional with respect to the functional operation of the outside plant portion of the network. The bulk speed tests may not fully stress the network in the way that a subscriber-initiated test does either or transmit as much data to calculate a more precise throughput or speed result, but it can be a good indicator of relative health and functionality of the network. Another potential downside to the bulk testing, is that it doesn't provide any meaningful intelligence on the quality of the coaxial plant or any potential impairments, provided that the subscriber modems are still able to transmit data through the expanded spectrum at some level.

4.5. Implications of PMA

Profile Management Applications (PMA) aren't uniquely associated to the introduction of OFDM or OFDMA signals in expanded spectrums. CMTS's and cable modems have been able to be configured for some level of adaptability to changing plant conditions for many years. These applications are extremely useful in managing data packet loss in the presence of impairments in the network. As the reliability and quality of the customer experience on broadband networks is becoming increasingly valued, their deployments are becoming more commonplace. These applications can adjust the modulation profiles of A-TDMA transmissions as well as ODFMA transmissions. While this is important to the experience of the customers in the degraded service area, it can add complexity to the operational priorities. Prior to the enablement of PMA, an impairment in the network that resulted in measurable packet loss would be identified using packet counters, or other intelligence tools, and would trigger a prioritized repair ticket for a system technician in a relatively short period of time. With the advent of these dynamic management applications, there are some operational considerations that need to be understood. For instance: 1) The poller timing of a monitoring tool(s). 2) The frequency of the PMA analysis and profile change recommendation. 3) Ticket creation and dispatch timing for a packet loss event.

These timing components need to be understood and synchronized to prevent scenarios where a technician is dispatched to an event before the profile management application has had an opportunity to mitigate the impairment. It is understood that the impairment still exists and may need to be identified and mitigated by a network technician, however, the synchronization of the event, mitigation and ticket creation will allow the business to properly prioritize the workforce to address the most impactful events first. The cable plant is a dynamic and ever-changing organism. Many events caused by transient noise in the upstream path, are moderate in severity and can be easily managed by the profile management application without ever sending a technician to affect a repair. There could be instances where the profile management application will intentionally not be engaged to downgrade profiles. Instances where the upstream interface has high utilization, or the profiles downgrade options have already been exhausted, are occasions where it is recommended to dispatch a repair technician to the node as a high priority repair.

5. Conclusion

As cable operators begin to use wider upstream spectrum on OFDMA channels and improve speed and bandwidth, spectrum activation can have challenges. In this first OFDMA PNM attempt, we revisited and applied some of our lessons learned with PNM and SC-QAM adaptive pre-equalization and were able to quickly find several nodes with multiple modems severely impaired and to locate some of the impairment causes. As we deploy mid-split and high-split to more nodes and customers, we will explore more PNM techniques, measurements, and channel configurations, such as wider channels, excluded subcarriers, cataloging ICFR signatures and impairment causes, and analysis along other measurements (Tx power, Rx MER, etc.), to serve us well for troubleshooting and repairing this new service.

Abbreviations

ALC	automatic level control
APIs	application programming interfaces
CM	cable modem
CMTS	cable modem termination system
dB	decibel
DOCSIS	Data Over Cable Service Interface Specification
DS	downstream
HFC	hybrid fiber-coaxial
ICFR	In-channel frequency response
kHz	kilohertz
MHz	megahertz
Msym/s	megasymbols per second
OFDMA	orthogonal frequency division multiple access
PNM	proactive network maintenance
SC-QAM	single channel quadrature amplitude modulation
RF	radio frequency
RPD	remote PHY device
RMS	root mean square
SNMP	simple network management protocol
TFTP	trivial file transfer protocol
US	upstream

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