A NEW DISCUSSION REGARDING DROP RELATED IMPAIRMENTS - PIM

arcom DIGITAL

A DISCUSSION OF DROP RELATED NETWORK IMPAIRMENTS AND NEW TECHNIQUES FOR IDENTIFICATION AND TROUBLESHOOTING

OVERVIEW

This paper explores the signal levels associated with Common Path Distortion (CPD) at various points within the cable television network, and demonstrates that traditional CPD cannot be the source of network affecting impairments within the drop. A different type of impairment, referred to as Passive Inter-modulation (PIM), can be both network and subscriber affecting. Finally, we describe new test equipment tools and techniques that can be used to identify and isolate PIM sources.

arcom
DIGITAL

ASSESSING THE POTENTIAL OF INTERMODULATION DISTORTION PRODUCTS IN THE TRUNK AND DROP

Common Path Distortion (CPD) is a widely understood and expected impairment within HFC networks. Fig. 1 shows an example of noise generated in the 5–42 MHz upstream spectrum at a non–linear junction (CPD source) from a number of analog and QAM signals in the downstream spectrum. The screen presentation is from the Xcor Hunter return path monitoring platform. The top half of the screen displays the output of the correlation function, showing the time distance to the CPD source. The bottom half of the screen shows the return frequency spectrum. The CPD source manifests as an increased noise floor which deteriorates the carrier–to–noise ratio (CNR) of the return channels.
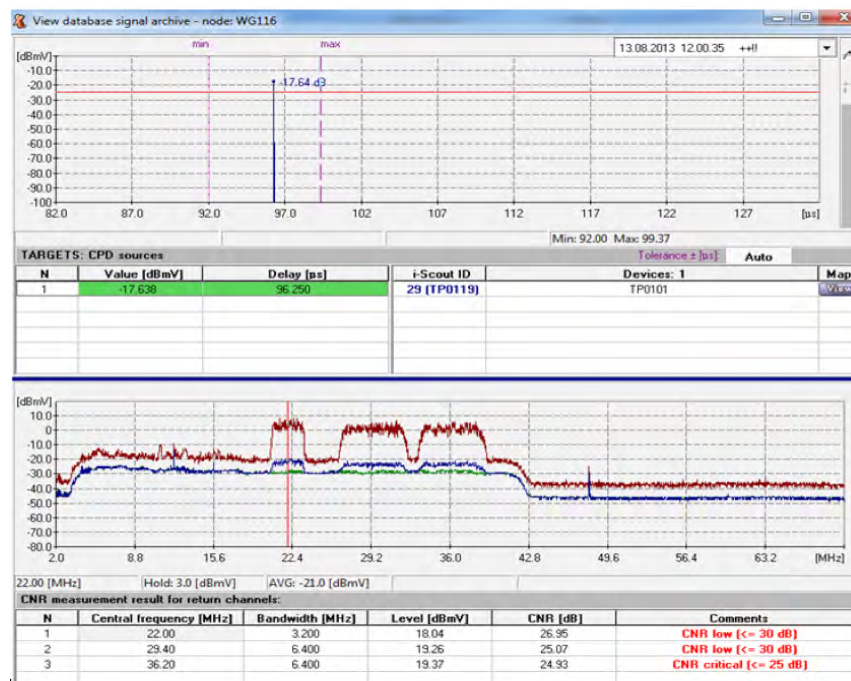

Figure 1:

CPD noise

The CPD noise within the upstream spectrum is a combination of second, third and higher order inter–modulation (IM) products from downstream signals. But the most significant contribution to CPD noise level comes from the second order IM (f1 – f2). The level of IM products is reduced dramatically with reduced levels of downstream signal and with increasing order of IM. For example, if downstream level is lowered by 3 dB, then the level of second order IM is reduced by 6 dB and level of third order is reduced by 9 dB. This is why the most probable location of network affecting CPD sources are in the trunk line portion of the network, where downstream signal level is at a maximum. The most severe location for a CPD source from a return path impact perspective is at the output of an amplifier because the level of upstream signal is at a minimum (+15 dBmV typical), but the level of the downstream signal is at a maximum (+45 dBmV typical).

Fig. 1 presents a CPD instance detected at the headend. While we do not know the location of the impairment's generation or the exact corresponding signal level; we can see that the CPD noise level can be interpreted as –25 dBc relative to the QAM signal level. So, if this CPD source was at the output of amp (the worst case for impacting upstream), then the estimated level of CPD relative to downstream level may be defined as the upstream signal level minus the CPD noise level (relative to the return) minus the downstream signal level, or (15 dBmV – 25 dBc – 45 dBmV) = – 55 dBc.

arcom
digital

Alternatively, if this CPD source was located at a terminator (a historically common and well documented CPD source location) or at a last tap, where downstream level is approximately + 27 dBmV and upstream level is approximately + 22 dBmV, then the corresponding estimated level of CPD relative to downstream will be : (22dBmV – 25dBc – 27 dBmV) = – 30 dBc. To summarize, the expected level of IM products generated relative to the downstream level may vary from as high as – 30 dBc for signal level +27 dBmV to –55dBc for signal level +45 dBmV. It should be noted that the CPD noise represented above is generated from a fully loaded network with a large number of downstream channels.

The discussion and reasoning above is provided to better under-stand what level of CPD can be expected at the drop network between the tap and cable modem (CM) or television. The level of downstream signal at the drop is typically between +10 to 0 dBmV, while upstream signal level from the CM is typically between + 40 to +55 dBmV. Based on the above calculation and model for CPD occurring within the lowest signal level location in the hardline (–30dBc@+27 dBmV), we can expand and investigate the scenario where CPD occurs in the drop, in this example with best case typical downstream signal level of +10 dBmV.

arcom
DIGITAL

Table 1:

	Drop	Ref. Last Tap
Signal Level, dBmV	10	27
CPD Level, dBc	-47	-30
Nominal CPD level, dBmV	-37	-3

As illustrated in table 1, the CPD level at the drop will be reduced by 17dB in dBc from the level at the tap scenario. The nominal CPD level will be reduced by a minimum of 34 dB to –37 dBmV. This is more than 80 dB less than the upstream signal level at the drop. As such, it makes little sense to even discuss "classical" CPD in drop line, as it is impossible for this level of CPD from the forward signals to cause any impairment to return traffic.

The described signal levels and CPD relationships for the hardline and drop scenarios are illustrated in Fig. 2.
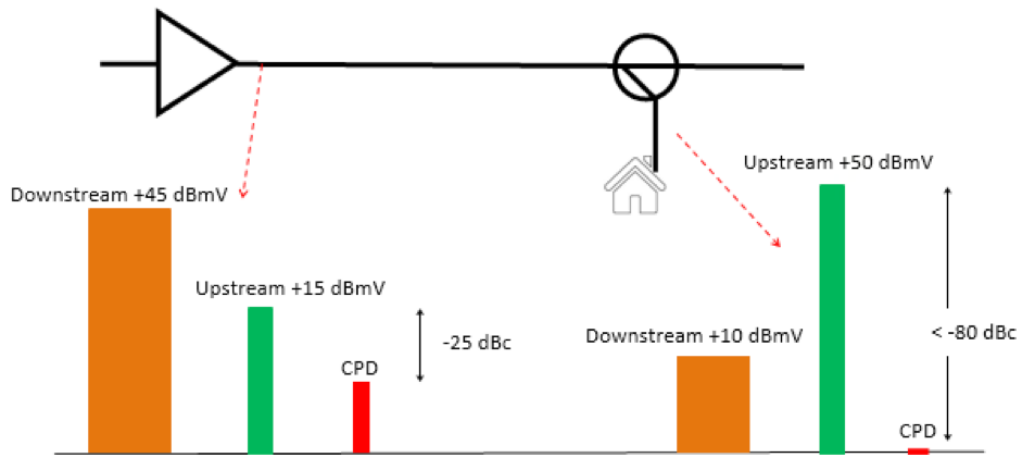

Downstream +45 dBmV

Upstream +15 dBmV

-25 dBc

CPD

Upstream +50 dBmV

Downstream +10 dBmV

< -80 dBc

CPD

Figure 2:

CPD level comparison at trunk and drop

ANALYSIS OF IM PRODUCTS GENERATED FROM CM SIGNALS

Now let us investigate what happens when the upstream CM signal is applied to the same CPD source at some location within the drop (ground block, splitter or tap connector). Unlike the model discussed in the previous section, only a few QAM channels are presented from the cable modem. As such, the signal level in the presented model needs to be scaled down accordingly.[1]

It is well known that increasing the number of QAM channel by two times increases the level of second order IM by approximately 3 dB. So, the coefficient of re–calculation of CPD level to level of second order IM of various numbers of QAM channels may be approximately defined by formula:

K (dB) = 3 x (log2(N)),

Where N is number of QAM channels generating CPD.

---

1 As reference, investigation and testing for IM products from non-linear elements is a widely used practice in the wireless industry. The standard test procedure utilizes a two tone model and test procedure (for example, IEC standard 62037-2).

arcom
digital

In cases where CPD is produced by 132 QAM channels (860 MHz all digital HFC such as was the environment in Fig. 1) the coefficient of re-calculation of CPD will be approximately K = 22 dB – this needs to be subtracted from the model to properly scale for the two return channel scenario in the drop.

Table 2:

	Drop	Possible CM output levels		
Signal Level, dBmV	27	40	45	50
CPD Level, dBc	-30	-17	-12	-7
Nominal CPD level, dBmV (Signal level - CPD level)	-3	23	33	43
2nd order IM nominal level for two QAMs, dBmV (Nominal CPD level subtracting K)	-25	1	11	21
2nd order IM relative level for two QAMs, dBc	-52	-39	-34	-29

Table 2 illustrates how second order IM levels are re-calculated for a two QAM model in the scenario of CDP source –30 dBc @ +27 dBmV, and is scaled up to include typical CM output levels.

arcom
digital

In Fig. 3 and Fig. 4, IM products are shown from a DOCSIS 3.0 CM with four bonded QAM channels. There are two types of non-linear products generated in this case. The first group is second, third and higher order IM products located around the QAM channels in the upstream (Fig. 3). The level of these IM products for two QAM channels may be up to –29 dBc (see table 2 for two signal model) relative to upstream QAMs in the case of maximum CM output level. Obviously these IM products will impact CNR and BER at the CMTS for this particular CM, and this degradation of BER will not be related to any typically encountered impairment in the return path such as ingress, micro-reflection, CPD (trunk line) or impulse noise. So, troubleshooting this specific distortion will present a sort of puzzle for the technician.
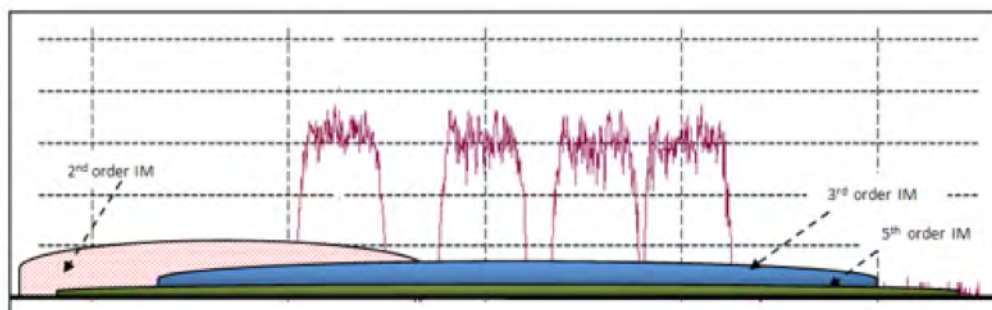

Figure 3:

IM products from PIM at upstream

arcom
digital

The next group of IM products (Fig. 4) are second, third and higher order harmonics from upstream QAMs which fall at higher frequencies within the downstream spectrum.
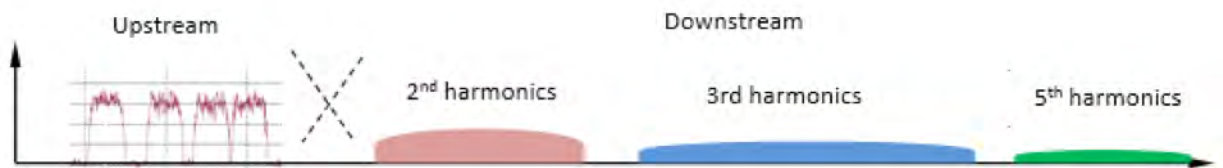

Figure 4:

IM products at downstream

The level of harmonics will decrease with increasing frequency, but they may be large enough relative to the low level downstream signal at the drop to be disruptive. For example, using the same CPD trunk model discussed above and presented in table 2, the level of second harmonic for the minimum level of CM + 40 dBmV will be +1 dBmV, while the maximum downstream level is +10 dBmV. Obviously this high level of harmonics may impact other QAM downstream channels within that home (pixilation, frozen pictures at TV sets, etc.).

Since the impairment scenario described above is different from the "classical" CPD found in HFC networks, in which the common path is the downstream signal, we will refer to this impairment as PIM (passive intermodulation), consistent with the name that the wireless industry uses to describe the inter–modulation distortion that occurs in passive components.

arcom
digital

It should be also be noted that with migration to mid split HFC, the impact from PIM harmonics generated by CM signals will increase, because more upstream QAM and OFDM channels will generate PIM harmonics.

To summarize, "classical" CPD impairment is not a real problem in the drop and it makes little sense to expend resources on trouble-shooting CPD in this part of the network. However, PIM within the drop may cause distortions in both the upstream and downstream due to large CM signal levels. Usually the PIM source will be associated with another issue such as intermittent contact simulating a randomly jumping CM signal level, micro-reflections, ingress, etc. where the existence of some impairment or anomaly may be identified using existing proactive network maintenance tools. Conversely, it will be possible to do additional analysis and look at cases of poor SNR correlated with the lack of micro-reflections, ingress, and forward CPD to conclude that PIM exists in a drop. Regardless, there is a necessity for tools capable of detection and location of PIM at the drop.

The PIM troubleshooting process can change greatly depending on whether or not home service can be temporarily disconnected from the network. Because of this, the method for PIM testing is split into two cases.

arcom
digital

PIM TROUBLESHOOTING WITHIN THE DROP

In situations where the service technician can temporarily disconnect the drop line from the tap, the optimal solution is to use an active Xcor radar with chirp probing signals inserted at the tap. The main advantage of the active radar is that the bandwidth of the probe chirp signal may be increased to hundreds of MHz for optimal time resolution and accuracy of location within the short drop line. This method is illustrated in Fig. 5. The active Xcor radar is implemented in the next generation variants of the Arcom Digital Quiver, models S and XT. The expected accuracy of PIM location is approximately six inches due to a 100 MHz probe signal placed at the lower portion of downstream spectrum from 150 to 250 MHz.
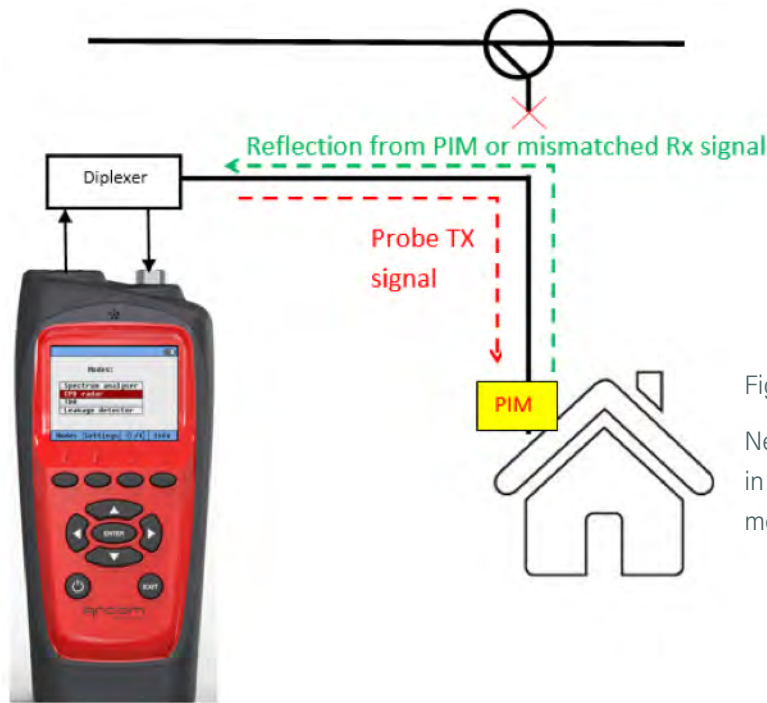
Figure 5:

Next Generation Quiver S in Active Xcor radar and mode

In this scenario the Quiver in active radar mode should configured with the maximum selected signal level as shown in Fig. 6.
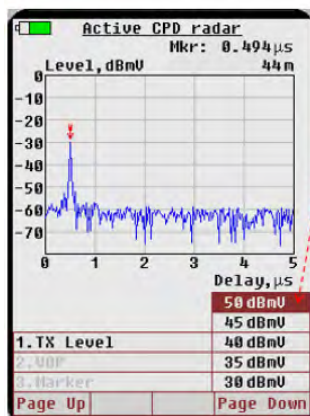

Figure 6:

When disconnection of service is not possible, a variant of the above described active radar is utilized. In such cases, Quiver is connected to a coax cable port, at the location temporarily replacing the CM connection as shown in Fig.7.
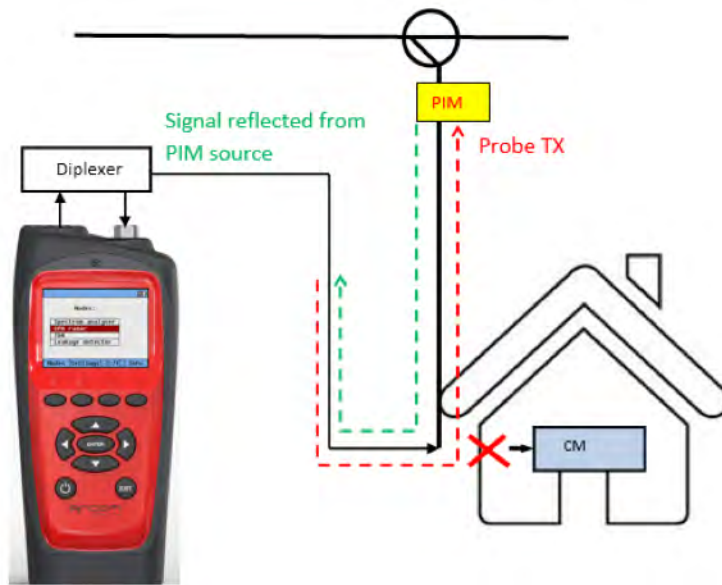
Figure 7:

Next Generation Quiver in Active radar mode, connected at CM location

The Quiver transmit level should be set to the minimum level as shown in Fig. 8. The pulse transmitted between 150–250MHz will have a duration of <1 second, so if there is any interruption to the forward signal of any nearby customer, it will not be noticeable. In no case will it affect any return transmission and it will be invisible to the CMTS.
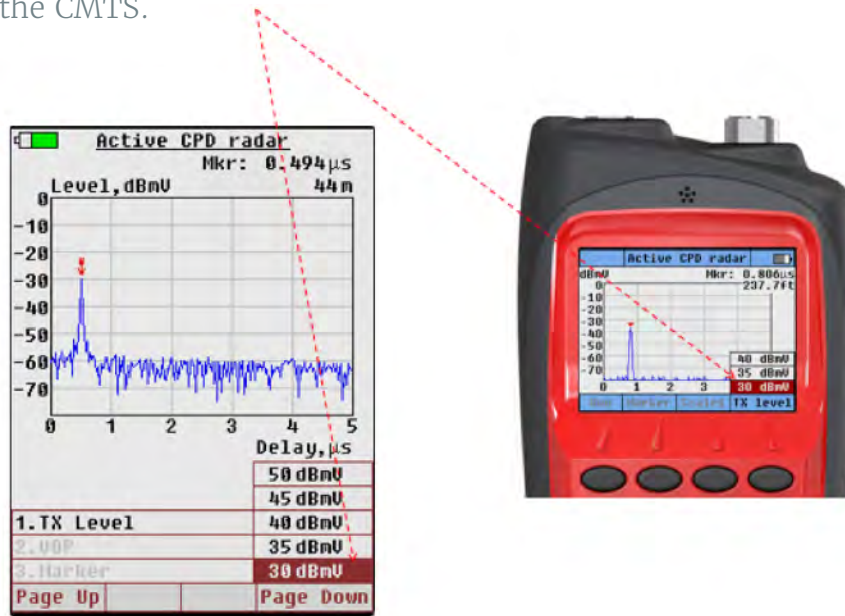

Figure 8

An additional feature introduced in the next generation Quiver is that it has patent pending Network Traffic Compatible (NTC) Time Domain Reflectometer (TDR). The NTC TDR employs a very low level spread spectrum probing signal within the upstream bandwidth inserted in the forward. The level of the probing signal is 35 dB (or lower) less than the QAM signal level from the CM and the probing signal is generated in less than a second to test drop the line for mismatches. For example, at the scenario shown in Fig. 7 the level of NTC TDR probe signal can be selected as 5 dBmV which is 35 dB less then minimal level of CM signal +40 dBmV. This low level and short operation time guarantees prevention of any interference with the CMTS. From the other side, the sensitivity of NTC TDR is approximately −60 dBmV due to a spread spectrum signal and large processing gain that allows confident detection of any impedance mismatch along the drop line to tap.

If you refer back to Fig. 7, the technician has the opportunity to quickly switch from Xcor (PIM) radar mode to NSI TDR mode to test the drop line from the CM to tap for micro−reflections. This test will not interrupt the CMTS or any other CMs at home or MDUs and it will be extremely accurate because the probing signal will originate from the point of CM connection.

/ CONCLUSIONS

- Traditional CPD generated from forward signals will not cause noticeable impairments in the drop portion of the network.

- PIM sources at the drop network may impact both upstream and downstream service of a particular customer due to generation of IM from high level CM signal.

- Troubleshooting PIM at drop networks is important because PIM may be associated with other impairments such as micro-reflections and ingress. This makes testing the drop network for PIM beneficial for home certification.

- The next generation Quiver is first device in the industry capable of detecting and locating PIM within the drop network. This device also has a non-service interrupting TDR mode for location of micro-reflections at the drop and hard line network, a leakage detector mode working at full downstream spectrum with analog, pilot and OFDM signals and return/ forward FFT spectrum analyzer modes.

.01 PIM generated within the drop is an impairment requiring attention.

.02 Classical CPD within the drop cannot be network affecting due to inherent signal levels.

.03 PIM within the drop may impact both upstream and downstream traffic for that subscriber.

.04 New tools are now available to help better identify these impairments and to troubleshoot the home network.

arcom
digital

WWW.ARCOMDIGITAL.COM

FOR MORE INFORMATION CALL / 800.448.1655

OUTSIDE THE U.S. DIAL / +1.315.422.1230

CLEARLY BETTER.

arcom digital

/ APPENDIX

Results of Physical PIM Simulation in Lab

1. The 2nd and 3rd order IM generated by one upstream QAM channel

3rd order IM

2nd order IM

2. The 2nd and 3rd order IM generated by three upstream QAM channels

3rd order IM

2nd order IM

3. Harmonics generated by upstream QAM channels

3rd order harmonics

2nd order harmonics

arcom digital