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A NOVEL APPROACH TO TROUBLESHOOTING LINEAR DISTORTIONS

By RON HRANAC

Linear distortions—micro-reflections, amplitude ripple/tilt and group delay—wreak havoc upon the digital signals carried on our cable networks, causing inter-symbol interference, degraded modulation error ratio (MER) and, if severe enough, packet loss. These nasty gremlins generally require specialized test equipment to troubleshoot.

What if you could identify and locate the sources of linear distortions in the field using your existing cable-modem termination system (CMTS) and cable modems? Given the large number of DOCSIS devices deployed by cable operators, why not take advantage of them for outside plant troubleshooting?

During SCTE's 2008 Cable-Tec Expo, CableLabs' Alberto Campos, Eduardo Cardona and Lakshmi Raman presented a paper titled "Pre-equalization Based Pro-Active Network Maintenance Methodology." The authors proposed using cable modem upstream transmitter adaptive pre-equalizer coefficients to identify and locate the sources of linear distortions. The basic idea involves deriving complex frequency-response signatures from those coefficients, looking for signatures indicative of the presence of linear distortions, and overlaying modem location information from the cable company's customer database on a system topology display of some sort—for instance, digitized outside plant maps. Not only would this approach give an indication of the severity of linear distortions, one could determine their approximate locations.

"Can one really use modem pre-equalization coefficients to troubleshoot linear distortions? Yes, indeed!" About 18 months ago, CableLabs formed a proactive network maintenance (PNM) working group to implement the ideas presented in the Expo '08 paper. I've enjoyed being a member of the working group along with some of the top engineers in the industry. The output of our effort was a best-practices document published by CableLabs earlier this year. That document is available at http://cablelabs.com/specifications/CM-GL-PNMP-V01-100415.pdf. The working group also published a reference implementation and demo package, which can be downloaded at http://www.cablelabs.com/cablemodem/ri/.

A Cable-Tec Expo technical workshop paper, best practices document, reference implementation and demo package are all fine, but can one really use modem pre-equalization coefficients to troubleshoot linear distortions? Yes, indeed!

Larry Wolcott, Distinguished Engineer, and Phil Chang, Principal Engineer, both with Comcast and members of the CableLabs working group, teamed with some of their colleagues to create an internal tool called "Scout Flux" that is based on PNM best-practices guidelines (sample screen shots from Scout Flux are included in the previously mentioned CableLabs document). Scout Flux has helped Comcast technical personnel sort out plant and drop problems. Examples include locating corroded connectors, using "north/south" methods to isolate plant with impedance mismatches, identification of common in-home wiring problems, locating water flooded taps, identification of the presence of such additive impairments as ingress and impulse noise, location of radial cracks in hardline cable, root-cause analysis of conditions that create correctable and uncorrectable forward error correction (FEC) errors and even distance calculations. The latter typically are most accurate from the amplifier if the frequency response ripples are smaller/tighter;

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otherwise, are most accurate from inside the home if there is a single, large ripple in the coefficient-derived response signature.

Scout Flux has been useful for "troubleshooting repeat and chronic trouble calls," he adds. "Oftentimes, the equalizers do a great job at hiding the underlying causes of customer troubles. I believe this accounts for a surprising amount of 'no trouble found.'"

Consider that if a plant or drop problem were right on the ragged edge of the performance cliff, the pre-equalizer could mask it when things aren't quite over the edge. That would be the "things-are-working-fine-right-now" scenario. But when performance just tipped over the edge and upstream pre-equalization could no longer compensate, the subscriber would see a problem. Naturally, it would go away when the tech showed up.

Comcast's Scott Johnston, CommTech 5 in the company's Oregon market, agrees: "This is one of the most common uses for Flux in my system. We use it to verify repairs and customer performance. It gets used often on repeat trouble calls, and most of the I/R team has been trained on the use of Flux. In my opinion, this is just like BER performance. If you're using error correction, then there's a problem. Same with Flux...if adaptive equalization is in use, there's a problem. To me, it doesn't matter if it gets corrected by FEC or with adaptive equalizers; there's still an underlying reason those correction techniques are in use in the first place."

Todd Szuter, senior staff engineer for Comcast's Greater Boston region, adds, "We have had much success locating bad hard-line splices and underground cable damage. In many instances, we would not have seen the problems until they began to affect the customer experience. Distance calculations and the observation 'hey that bush is right in line with our cable run' have put us right on top of underground problems without having to de-splice and TDR the cable."

He continues, "The overwhelming cause of degraded nodes is additive ingress. In these scenarios, we target the customers exhibiting the worst pre-equalized reflections and in-channel frequency response (ICFR) first, then work down the list from there, adding to the list customers showing an ICFR >1 dB at the CMTS and modems that are transmitting at their maximum. Usually, we can decrease the error rate significantly within the first six to 10 targeted customers.

"When troubleshooting hard-line plant problems, the north/south method used in conjunction with distance calculations derived from micro-reflections has put us right on top of the problem better than 90 percent of the time. Blown terminators are easy to locate with the reflection calculations being very close to the distance between the active and end-of-line. Distance calculations have also proved to be close enough when locating other impedance problems — such as water or squirrel damage and poor craftsmanship — using an active as the first reflection point. Radial cracks, having some of the worst ICFR, and multiple reflections have required us to hit a few more poles before they are found. An experienced technician who is familiar with the system can usually deduce where the problem is.

"A number of scenarios convinced me actives are good (or bad, depending on how you look at it) reflection points. In one example from the early days of experimentation with Scout Flux, I had dozens of customers showing a reflection indicating a mismatch at 585 feet. The common point was a distribution amplifier. We looked on either side of the amp and found no damage at that distance and beyond. After scratching my head, I noticed that a feeder line off the amplifier was 528 feet to a single end-of-line tap. The two customers off the tap were not data/voice subscribers. I sent the technician there, and he found the drops to be chewed and the tap full of water. After replacing the water-damaged tap, the reflection was no longer present."

According to Wolcott, system personnel are recognizing certain pre-equalizer response signatures that, for instance, indicate such specific drop problems as loose "F" connectors and backwards splitters!

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Other cable operators are looking at implementing the PNM guidelines. It's clear the original proposal to use cable modem pre-equalizer coefficients to troubleshoot linear distortions was right on the money. Modem pre-equalization has to be enabled, of course, and DOCSIS 2.0-and-later modems are best because of their 24-tap pre-equalizers.

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