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UPSTREAM CNR

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I'd venture a guess that many readers would agree that upstream plant issues can best be summed up as job security. Return path operation in two-way cable networks certainly has its share of challenges, among them maintaining decent carrier-to-noise ratio (CNR). The DOCSIS assumed upstream CNR at the cable modem termination system (CMTS) input is 25 dB minimum, regardless of modulation type. In practice, we really want to be higher than the DOCSIS assumed minimum, and modern HFC architectures can help us achieve that goal. Indeed, out of hundreds of upstreams I've looked at over the past several years, few were lower than about 30 dB CNR.

Before I get too far along in this discussion, it might be useful to define the noise in CNR. Here I'm assuming noise is thermal noise, also called additive white Gaussian noise (AWGN). In that sense, then, noise does not include discrete ingress, impulse or burst noise, composite intermodulation noise, and nasties such as common path distortion (CPD). The vast majority of upstream thermal noise comes from two sources: the outside plant's return amplifiers and the upstream fiber links. That means the CNR "seen" by the CMTS is largely a function of HFC network design and operation and how we combine upstreams back in the headend or hub. For an in-depth and three-cups-of-strong-coffee look at CNR, may I suggest "Carrier-to-Noise Ratio in Cable Networks," available on-line here. In case you were wondering, this tome is my handiwork, with input from some of my esteemed colleagues. But I digress.

Examples

I'd like to work through a few examples to illustrate upstream CNR that one is likely to run across in the real world. The starting assumption is a two-way HFC network, with the node's service area comprising about eight miles of plant designed with five actives per mile. That works out to 40 amplifiers total, plus the node. Given an average housing density of 85 homes passed per mile of plant, the node service area's house count is around 680.

We'll further assume that all of the return amplifiers are identical with 10 dB noise figure (NF) and input levels designed for +18 dBmV—unity gain at work here. That gives us a standalone CNR for each amplifier of 59.16 – 10 dB NF + 18 dBmV input = 67.16 dB. The combined CNR at the upstream input to the node is 67.16 dB – 10log(40) = 51.14 dB. So far, so good.

What about the fiber link? Standalone upstream fiber link CNR can vary from the low 30s to as high as mid 40s, depending on technology, age, how it's set up, and so on. Let's assume 37 dB standalone CNR for our hypothetical upstream fiber link.

To find out what the CNR is at the output of the headend optical receiver, we can use power addition to combine the fiber link's standalone 37 dB CNR with the coax plant's 51.14 dB CNR. The formula to combine different CNRs is:

Plugging 37 dB and 51.14 dB into the formula gives us a combined CNR of 36.84 dB.

Misalignment

What would happen if all 40 amplifiers in the node's service area were inadvertently misaligned 6 dB low?

The standalone CNR of each amplifier would be 59.16 – 10 dB NF + 12 dBmV input = 61.16 dB, and the combined CNR of all 40 amps 61.16 – 10log(40) = 45.14 dB.

Assuming the fiber link is properly set up and still providing a standalone CNR of 37 dB, using power addition to combine the coax plant's 45.14 dB CNR with the fiber link's CNR gives us 36.38 dB. Interesting! The combined CNR at the output of the optical receiver didn't really change much.

Let's look at this from the perspective of the fiber link being misaligned, causing its standalone CNR to drop from 37 dB to, say, 31 dB.

If the outside plant is properly aligned and the CNR at the input to the node is the original 51.14 dB, the combined CNR drops to 30.96 dB. Yikes! Taking the analysis one step further, assume now that all 40 amplifiers are set up 6 dB low for a combined CNR of 45.14 dB, and the fiber link also is misaligned such that its standalone CNR is 6 dB low. Combining 45.14 dB CNR with 31 dB CNR gives us 30.84 dB.

As you can see, the fiber link is a significant contributor to upstream CNR! If the link is misaligned, upstream CNR is going to get hammered.

At the CMTS

What CNR is the CMTS going to see? Well, that depends in part on how many nodes are being combined and connected to each CMTS upstream port. Let's assume that the coax plant and fiber links are all perfectly aligned, and the combined CNR at the output of each headend optical receiver is 36 dB.

Obviously, if headend return path combining is set up for one node per CMTS upstream port (1:1), the CNR at each CMTS input will be 36 dB. If two nodes are feeding each CMTS upstream port, the CNR will be 3.01 dB worse, or 32.99 dB. 3:1 combining gives us 31.23 dB, 4:1 is 29.98 dB, 8:1 is 26.97 dB, 10:1 is 26 dB, and 12:1 is 25.21 dB.

So, then, what happened to that original 36 dB CNR per upstream? Each time we doubled the number of nodes combined at the CMTS upstream port, the CNR got worse by 3 dB (actually 3.01 dB).

Now imagine all of the fiber links being out of whack by 6 dB and going through this same combining exercise. Not good.

Just for grins, let's look at a 4:1 node combining scenario, in which the upstream CNRs at the outputs of the four optical receivers are something like 35 dB, 32 dB, 26 dB, and 29 dB.

The combined CNR is 23.26 dB, which will make for iffy return path performance when you toss in all the other usual return path gremlins. We can play around with headend combining to make things a little better.

For instance, moving to 2:1 combining and putting the 35 dB CNR upstream with the 26 dB CNR upstream gives us 25.49 dB CNR; the 32 dB CNR upstream combined with the 29 dB CNR upstream is good for 27.24 dB. This gets us a little better than the DOCSIS assumed minimum at each CMTS upstream port, but in my opinion the numbers should be higher.

A better option is to fix whatever is causing the two lower CNRs—26 dB and 29 dB in this example—to be what they are.

One more thing: What happens to the CMTS's reported "upstream SNR" (actually modulation error ratio or MER) during all of this? Plant misalignment or combining upstreams will degrade the MER!

Bottom line? I think you know the answer.

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