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By **Ron Hranac**, former *Senior Technology Editor,* **Access Intelligence** and *Communications Technology* **Magazine**

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WHAT IS A MICRO-REFLECTION?

By RON HRANAC

The study of transmission lines often begins with the assumption that a signal source, a lossless transmission line, and load have equal impedances. Under that scenario, all of an incident wave's power transmitted from the source is absorbed by the load.

In the real world, the impedances of the source, transmission line, and load are seldom, if ever, exactly the same. Furthermore, transmission lines are not lossless, and will attenuate the signals passing through them. Consider a situation in which a transmission line and load do not have equal impedances.

When this happens we say that an impedance mismatch exists, and some or all of the incident wave will be reflected by the impedance mismatch back toward the source. In a cable network, the nominal impedance is 75 ohms. The key word here is "nominal" — every connector, splice, passive, active, and even the cable itself represents an impedance mismatch of some sort.

"A micro-reflection falls into a class of impairments known as linear distortions."

One common way to characterize the severity of an impedance mismatch is return loss, which is the difference in decibels (dB) between the amplitude of the incident and reflected signals, described mathematically as $R = 10\log(PI/PR)$, where R is return loss in dB, PI is incident power and PR is reflected power, both in watts. If all of the incident power is absorbed by the load, the return loss is infinite and there is no impedance mismatch. If the load is an open or short circuit, the return loss is 0 dB. Typical return loss values for the components used in coaxial cable networks vary from a few dB to 30 dB or more.

If you're interested in the mechanics behind the creation of a reflection at an impedance mismatch — specifically an open or short circuit — take a look at my December 2005 column, "Impedance Mismatches and Reflections," available on-line at www.cable360.net/ct/operations/testing/15296.html.

Definitions, examples

Okay, so an impedance mismatch causes a reflection, or echo. Where the heck does the term micro-reflection come from and what does it have to do with reflections caused by impedance mismatches?

The simple answer is that reflections and micro-reflections are the same thing. The terminology difference is largely related to the reflection's time delay relative to the incident signal. When discussing data transmission over cable networks, we are especially interested in reflections that have very short time delays, on the order of less than a symbol period to perhaps several symbol periods — in other words, close-in or "micro" reflections.

Why are micro-reflections important? Simple: A micro-reflection falls into a class of impairments known as linear distortions, and can cause amplitude ripple (standing waves), group delay ripple, inter-symbol interference, and degraded modulation error ratio (MER).

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What, then, is meant by a reflection's time delay? Let's first look at an example involving ghosting in the picture of an analog TV channel. A trailing edge ghost, which appears on the right side of the main image, is generally caused by a reflection somewhere in the signal path between the transmitter or modulator and TV set. The ghost is the same image as the main image, but it has been delayed slightly time-wise relative to the main image.

Let's say we're looking at a 19-inch diagonal display TV set, which, with a 4:3 aspect ratio has a screen height of 11.4 inches and a screen width of 15.2 inches. Assume a trailing edge ghost is offset to the right of the main image by about three-quarters of an inch, or 5 percent of the TV screen's width.

We can guesstimate the ghost's time delay using that information. In an NTSC picture, each horizontal line takes 63.5556 microseconds (µs) to scan across the TV screen. The horizontal blanking portion of the line is 10.9 µs, leaving 52.66 µs for the active video portion of the line. Assuming the TV set's display shows all of the active portion of each line, 5 percent of 52.66 µs is 2.63 µs. That is, the ghost is delayed slightly relative to the main image; in this example the ghost's time delay is 2.63 µs.

This basic concept of reflections applies to both analog TV channels and digitally modulated signals.

Let's look at another example, this one with two water-damaged taps separated by 100 feet of coax. Assume that the span of coax has 1 dB of loss, and the water damage has caused both taps' return loss to degrade from an out-of-the box 15 to 18 dB to 7 dB. For the sake of discussion, the first tap is a 23 dB 4-port, and the second tap is a 20 dB 4-port. Further assume that an incident signal whose amplitude is +31 dBmV leaves the output connector of the 23 dB tap.

"Reflection time delays on the order of less than a symbol period to several symbol aperiods are of interest."

When that incident signal reaches the 20 dB tap's input connector, its amplitude will be +31 dBmV – 1 dB cable loss = +30 dBmV. Most of the incident signal will continue downstream beyond the 20 dB tap, but some of that signal will be reflected by the 7 dB return loss impedance mismatch of the water-damaged 20 dB tap. The amplitude of the reflection will be +30 dBmV – 7 dB return loss = +23 dBmV. That first reflection will travel back towards the 23 dB tap, where its amplitude will be +23 dBmV – 1 dB = +22 dBmV. Here most of the reflection will continue upstream beyond the 23 dB tap, but the 7 dB return loss of the also-water-damaged 23 dB tap will result in the first reflection being re-reflected at an amplitude of +22 dBmV – 7 dB return loss = +15 dBmV. This second reflection will travel toward the 20 dB tap, reaching it at +14 dBmV. And so on.

What will we see at the input connector of the 20 dB tap?

The signals of primary concern are the +30 dBmV incident signal and the +14 dBmV reflection. The amplitude difference between the two is +30 dBmV – +14 dBmV = 16 dB. We can also say that the reflection is – 16 dBc relative to the incident signal. The – 16 dBc reflection will have a time delay relative to the incident signal, defined by the roundtrip propagation time between the 23 dB and 20 dB taps. The cable span between the two taps is the previously mentioned 100 feet. Since it takes RF signals 1.17 nanosecond (ns) to travel through 1 foot of coax that has 87 percent velocity of propagation, the reflection's roundtrip time is (100 feet + 100 feet) x 1.17 ns = 234 ns. This tells us that the – 16 dBc reflection's time delay relative to the +30 dBmV incident signal at the input to the 20 dB tap is 234 ns.

For what it's worth, a – 16 dBc 234 ns reflection is sufficient to be a problem for 256-QAM (quadrature amplitude modulation) operation.

So how does the term micro-reflection fit in all of this? Earlier I said that reflection time delays on the order of less than a symbol period to several symbol periods are of interest with digitally modulated signals. A downstream DOCSIS 256-QAM signal has a symbol rate of 5.360537 megasymbols per second (Msym/sec), so the period of each symbol is 1/5,360,537 = 0.000000186548 second or about 187 ns.

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In this case, reflections with a time delay of somewhat less than 187 ns to a few microseconds can be described as micro-reflections.

Ron Hranac is technical leader, HFC Network Architectures, for Cisco Systems, and former senior technology editor for *Communications Technology*. Reach him at rhranac@aol.com.