TECHNICAL COLUMNS

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WHY USE TERMINATORS?

By RON HRANAC

Transmission line theory tells us that when the impedances of a signal source, transmission medium—usually assumed to be lossless for analysis purposes—and load or termination are equal, all of the power in an incident wave transmitted by the source is absorbed by the load.

When the impedance of, say, the load and transmission medium aren't the same, some or all of the power in the incident wave is reflected back toward the source. The magnitude of the reflection depends upon the severity of the impedance mismatch.

The worst-case impedance mismatch occurs when a transmission line element is an open circuit, a short circuit or pure reactance. Any of these conditions results in 100 percent of the power in the incident wave being reflected back toward the source. (To understand the "why?" behind reflections from an open or short circuit, see my December 2005 column, "Impedance Mismatches and Reflections" [www.cable360.net/ct/operations/testing/15296.html].)

Impedance mismatches exist everywhere in our cable networks. Every connector, amplifier, splitter, directional coupler, power inserter, tap and even the coaxial cable itself represents an impedance mismatch of some sort (there is a reason why we say the nominal impedance of our networks is 75 ohms). The question is: How severe are those impedance mismatches?

One way to characterize their severity is return loss (R), which is the ratio in decibels of incident power PI to reflected power PR, described mathematically as R = 10log10(PI/PR). From this, when all of the incident power is absorbed by the load, R = infinity (∞). When all of the incident power is reflected by an open, short or pure reactance, R = 0 dB.

OK, impedance mismatches cause reflections. But do reflections cause problems?

The short answer is "it depends."

A reflected wave interacts with the incident wave to produce standing waves. A good example is the amplitude ripple that might show up on a sweep display when a feeder end-of-line terminator is damaged or missing. Whether or not a given reflection is problematic is a function of the amplitude of the reflected wave relative to the incident wave—the previously discussed return loss—and the reflection's time delay.

In analog TV, a reflection may manifest itself as visible ghosting in the picture. The ghost image may or may not be objectionable, depending on how far it's offset from the main image (time delay) and its amplitude (how visible it is relative to the main image).

A very close-in or short-time-delay reflection may not be visible at all as typical ghosting, instead just smearing or softening the edges of the picture. Some TVs incorporate ghost-canceling capability to reduce or eliminate visible ghosts, using a ghost-canceling reference (GCR) signal transmitted in the video's vertical blanking interval.

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In the world of digital transmission, reflections cause inter-symbol interference, which in turn degrades modulation error ratio (MER). Adaptive equalization is used to compensate for the effects of channel-response impairments caused by reflections, more specifically micro-reflections. The latter are simply reflections with short time delays, from less than a symbol period to perhaps several symbol periods. If reflections are severe enough, though, adaptive equalization may not be able to help.

How can reflections be eliminated? From a practical standpoint, there is no way to get rid of all of them. Remember, every device in our RF networks represents an impedance mismatch of some sort. We can make an effort to minimize the nasty but controllable impedance mismatch-related reflections. The place to start? Open circuits, which cause 100 percent of the incident wave to be reflected back toward the source. Good engineering practice suggests that all ends-of-line, unused amplifier and node outputs, and unused tap spigots, splitter and directional coupler ports be terminated properly with a 75-ohm impedance-resistive load. Widely used locking terminators without built-in resistors do not terminate tap spigots, and so-called self-terminating taps (4 dB 2-port, 8 dB 4-port, and 11 dB 8-port) don’t terminate the ends-of-line unless all of the F spigots are themselves properly terminated!

The argument against using locking terminators with resistors goes back to the 1980s, when the then-available versions had little or no provisions for weatherproofing; some couldn’t even be tightened adequately on the mating interface. Corrosion eventually built up on the threads, pretty much doing away with the ground return path between the terminator and the tap. The locking terminator bodies became inefficient little antennas, contributing to low-level background signal leakage.

So we as an industry asked the manufacturers to make ’em without resistors, which we’ve been using since. A few years ago, some of the major connector companies introduced significantly improved designs that took care of the problems of the past, so there no longer is any reason to not use locking terminators with resistors.

Do all unused or open tap spigots really have to be terminated? Reflections from open spigots will have an amplitude whose difference relative to the incident signal is equal to approximately twice the tap loss. One could reasonably argue that low-value taps will benefit the most from terminating unused spigots. For instance, a 4 dB tap’s open spigot reflection will be about -8 dBc at the input port—that is, the return loss at the unused spigot is close to 0 dB because of the open circuit while the return loss “seen” at the tap’s input port is about 8 dB (I say “about” and “close to” in part because of variations in tap insertion loss-versus-frequency and the fact that an unused spigot isn’t a perfect open circuit at all frequencies).

In contrast, the reflection from an open spigot on a 26 dB tap will be about -52 dBc at the input port. The latter is unlikely to be an issue, but reflections from open spigots on low-value taps very well could be, especially in what is called a “multiple transit micro-reflection scenario.”

The trouble with selectively terminating unused tap spigots is ensuring consistency. Imagine a tech in the field pondering the following: “Which tap values get terminators and which ones don’t? Is it 14 dB and lower? Or was that supposed to be 14 dB and higher?” That kind of confusion likely will result in none of them getting terminated. That leads me back to my earlier comment that good engineering practice suggests terminating all of them.

Here’s what I think we should be doing: Ensure that all unused 5/8-24 ports in nodes, amplifiers, and line splitters and directional couplers, and all ends-of-line taps with actual “thru” ports have KS-type port terminators installed; use the correct drop passives for the number of active outlets—that is, don’t install a four-way splitter when a three-way is all that’s needed. Where unused drop passive ports can’t be avoided, install terminators and, to the extent possible, terminate all unused tap spigots.

I’m not suggesting you go out right now and install proper terminators everywhere. I understand the reality of the cost and effort to undertake something like that. But why not make installing terminators (and getting rid of non-resistor locking terminators) part of everyone's daily job duties going forward? Over time, the task will get done.

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