Distorted 3GHz

High frequency does not guarantee high performance. Time domain parameters could be slowing you down.

BY STEVE LAMPEN, SUDHEENDRA PRASAD AND DALE REED

You've just hooked up new SMPTE 292-rated cable assemblies between your HDTV cameras and control surface. You fire everything up and experience tiling, slow motion and skipped frames — anything but a high-definition image. But the cables and connectors exceeded the spec. They were supposed to be capable of beyond 3GHz. So, what happened?

Evaluating the transmission components based only on suppliers' claims of high-frequency performance omits several critical signal characterization factors. These factors, in combination with frequency, will determine whether or not an HD transmission system delivers on-spec performance.

The data rate race

The wireline and connector business has, until recently, fueled a frequency race. The more-is-better philosophy is that designing cable and connectors to transmit at frequencies that provide headroom well in excess of the digital data rate will ensure HDTV signal quality.

When the transition to digital began, there was a good reason to emphasize frequency. The scrambled NRZI encoding scheme implemented for SD digital video (and carried over to HD) uses voltage transitions (1Hz = 1 bit) to represent the zeroes and ones. As data rates increased, so did the fundamental frequency; the 1.485Gb/s data rate for uncompressed HD thus requires a fundamental frequency of 750MHz. But it's more difficult to pass digital signals than analog ones, so testing signal transmissions to the third harmonic of the fundamental frequency (2.25GHz) became commonplace as a way to ensure output quality.

SMPTE realized it had a problem with harmonics. The 750MHz specification does not deal with how large a pipe needs to be to carry the signal. When testing an HD signal at the 750MHz fundamental frequency, what comes out of the scope looks like a sine wave — not the square wave that represents a true on/off pulsed digital signal. Why does this occur? What else should broadcast engineers be looking and testing for?

What goes out must not come back

After frequency, the next characteristic that needs to be tested is insertion loss — the total amount by which power received is less than power transmitted after a device has been inserted. Insertion loss applies to the entire connector/cable system and manifests as a decrease in amplitude. Measured in dB, the sources of insertion loss include the connector/cable's conductor, the dielectric material, signal reflection within the connector/cable and radiation external to the connector/cable.

The next characteristic that must be evaluated is return loss, for which the primary culprit is impedance mismatch. Unlike analog transmission, the margin of error in digital transmission is a razor-thin 1dB. The good news is that it's easier to recover a missed zero or one than to recover a waveform. The bad news is that if you go outside that range, you've fallen off the digital cliff.

Inside that 1dB margin is where the digital artifacts, such as tiling, pixelating and arrested/retarded motion, arise. That's why it's absolutely critical for HD transmission that cable assemblies deliver a return loss performance of –20dB or better. (Note: SMPTE recommends the return loss for cables to be better than -15dB from 5MHz to 1.5GHz, with the upper frequency limit raised to at least 3GHz for HD.)

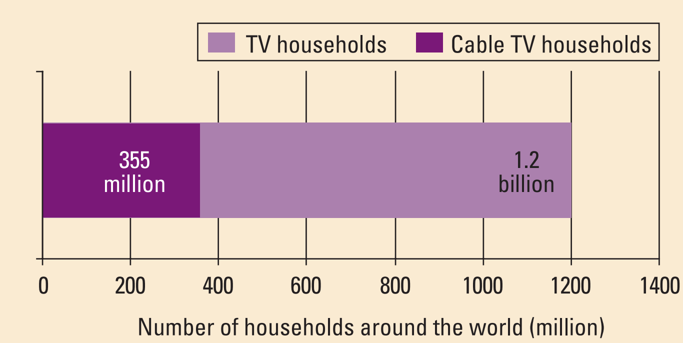
The problem is return loss creates standing waves within the wireline. The voltage standing wave ratio (VSWR) indicates the presence of

FRAME GRAB

A look at the consumer side of DTV

Worldwide cable TV households

Out of 1.2 billion TV households, 355 million subscribe to cable



Source: In-Stat *www.in-stat.com*

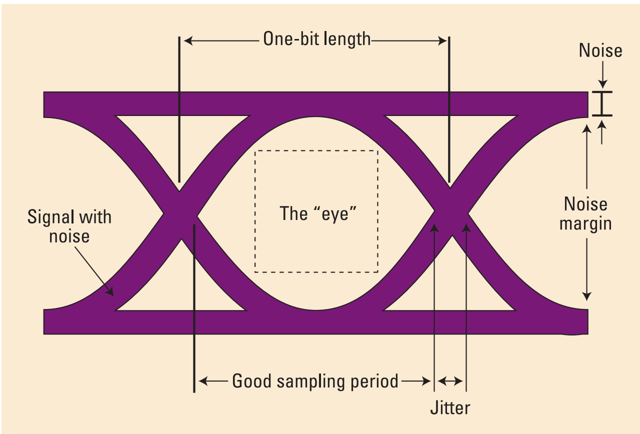


Figure 1. Eye test components

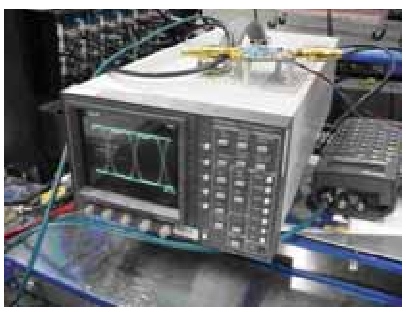


Figure 2. Ideal eye pattern test

standing waves. VSWR is a unitless ratio relating reflected voltage to incident voltage. VSWR is most pronounced at impedance mismatches. In a worse case scenario, the reflected wave is equal to the incident wave and 180 degrees out of phase, resulting in a perfect standing wave in which no signal passes through.

Manufacturing cable that is true 75Ω impedance across the full run length is difficult, which limits how much consistency can be engineered in. In practice, though, how that cable is deployed and handled has a lot more to do with the actual return loss than what's designed in. The performance of a perfectly good cable can be severely denigrated if it's installed incorrectly, stepped on, run over or overbent. Many users introduce distortion into the wireline simply by tightening wire ties with a gun around cable bundles or raceways at precisely spaced intervals, which introduces predictable harmonic distortion.

There are two easy ways to avoid this problem. First, use Velcro ties instead of plastic, being careful not to distort the cable jacketing. And, second, randomly space the wireline ties to eliminate the possibility of induced harmonic reflections.

A clear eye for a clear image

Cable manufacturers' specifications are generally missing the distance over which the cables will meet the SMPTE 292 spec. Similarly, understanding the active electronics' responsibility in delivering clean signal to spec vs. the connector/cable system frequently isn't dealt with thoroughly. Of greatest concern, though, is that there are parameters usually left out altogether that, within the frequency requirements of SMPTE 292, will indicate whether or not an HD transmission will deliver. Time domain factors include rise/fall time, amplitude, jitter, DC offset, overshoot and noise. Of these time domain parameters, rise/fall time and jitter are the most critical to digital transmission, in addition to where significant variation in performance within and between systems can occur.

Using an eye chart test is the best way to measure how clean a digital signal is when it passes through a component or an integrated system. As shown in Figure 1, the eye chart gives a visual depiction of one-bit length, and the eye pattern is created by the overlapping waveforms in opposite polarity. The width of the displayed waveform indicates the level of noise in the signal. And the width of the intersection points of the waveforms represent the amount of jitter present in the signal. The distance between the bottom and top of the eye represents the noise margin; the greater the distance, the lower the noise level.

The eye pattern displayed on the test equipment in Figure 2 represents an ideal eye — clean waveforms with little if any distortion, wide noise margin or narrow jitter overlaps. Figure 3 illustrates an unacceptable eye test. Noise and waveform distortion cause the system to be incapable of telling the zeroes from the ones. Figure 4 shows a better eye pattern, but there is still too much noise and jitter to deliver consistent broadcast-quality HD video. This is the state in which excessive digital artifacts, such as tiling and motion stops, would occur. Figure 5 shows an acceptable — but not ideal — eye pattern. There is enough

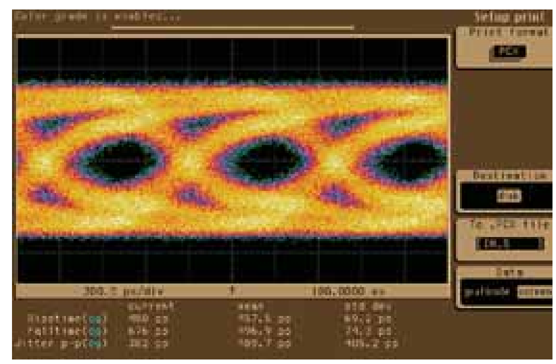


Figure 3. An example of a poor eye test

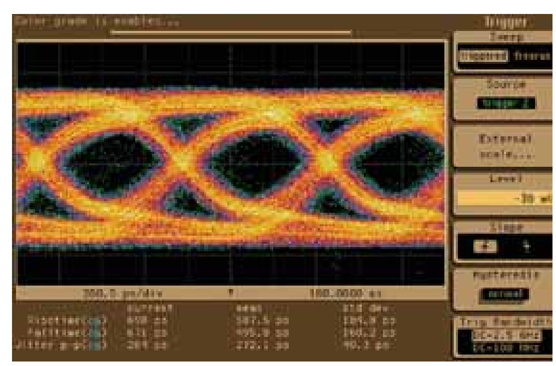


Figure 4. This eye test is better than Figure 3, but it still contains too much noise and jitter.

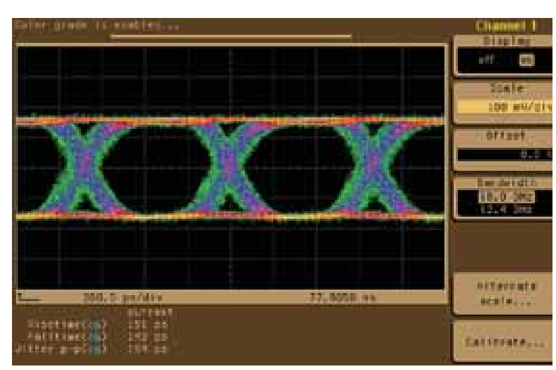


Figure 5. While not ideal, this eye test is acceptable for broadcast-quality video.

separation between the waveform overlaps to indicate that the system is able to clearly distinguish the zeroes and ones, but the visual indication is that the jitter (the overlap areas) is perilously close to the point at which the HD image would be of unacceptable quality.

It's a question of balance

Emphasizing frequency capacity as the primary HD engineering criterion without considering the time domain parameters increases the chance of over-engineering or under-engineering. This can make the difference between consistent, clear signal transmission and endless workarounds.

When considering alternative components and sources for your HD network, ask the supplier for information on time domain performance as well as frequency domain. Be discriminating, and ask for specific data that backs up manufacturers' claims. In particular, ask for eye diagrams, rise/fall times and noise levels. Understand the conditions under which manufacturers' testing is done. Do side-by-side testing of components and systems to eliminate variations — controlling for test methods as well as test conditions.

This doesn't mean components and equipment rated above 1.5GHz have no value. Digital signals are harder to pass than pure RF, which is probably why the third harmonic rule came into practice. Cables rated at 2GHz with –20dB return loss are in common use, and better cables can deliver up to 3GHz with –22dB/–23dB return loss. Some high-frequency connectors will deliver 3GHz at –30dB return loss, which is better than most video cables. Cable assemblies and active electronics that have headroom to accommodate potential changes in standards is a comfort factor that engineers appreciate.

Don't just look at frequency. Rise/fall time, jitter and noise are critical performance factors unique to digital signal transmission. This is especially true for HD transmission because it's done in real time, unlike packet-data IP transmission over Ethernet. If you lose packets because of errors, you are guaranteed to get them back, but in HD, if you lose data, it's gone.

The good news is that it is possible to know what your current components and active electronics deliver in the time domain today — and what you will need to acquire in the future to get the results you need. In HD transmission, the path to consistent, crystal clear picture quality is a clear eye. BE

Steve Lampen is multimedia technology manager for Belden, Sudheendra Prasad is engineering manager for 360 Systems and Dale Reed is senior vice president of marketing and sales for Stratos International.