Adventures in Return Loss

Introduction

This paper addresses path design for HD-SDI signals at 1.5 Gb/s and 3.0 Gb/s.[1]

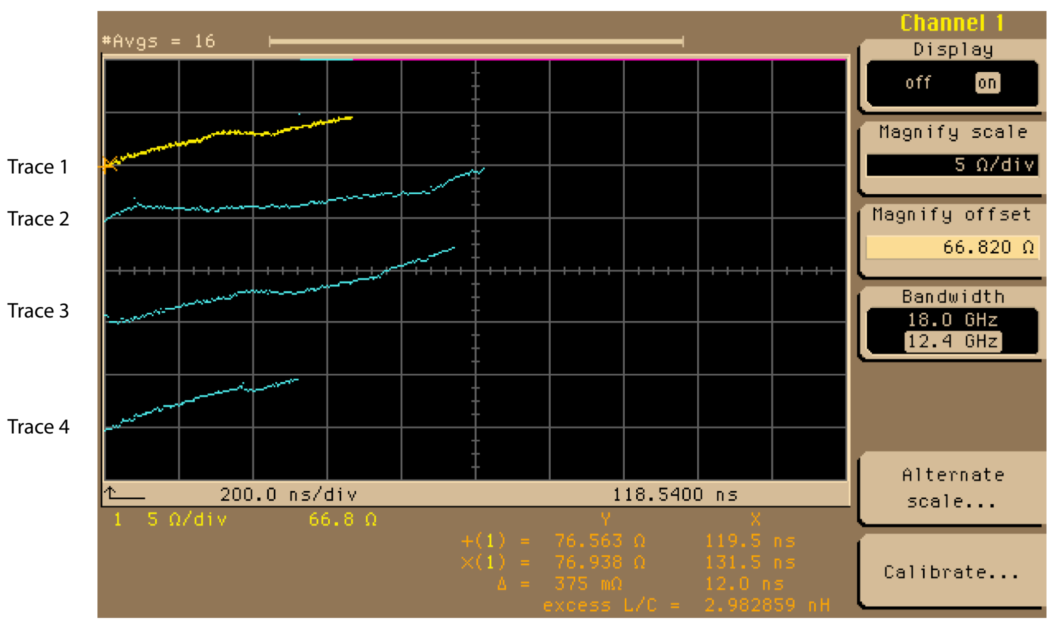
High-speed data transport for HD-SDI signals at 1.5 Gb/s is now common and, with SMPTE 424 in place, equipment manufacturers can start to provide products supporting 1080p50 and 1080p60 with serial interconnection at 3 Gb/s. A number of challenges were met, and overcome, in 1998 when the industry jumped from 270 Mb/s to 1.5 Gb/s. Patch bays, connectors, cables, and other connectivity devices used to wire a facility all required substantial upgrades and attention to detail to insure proper operation and data signal integrity at these new, higher rates.

Now, the SMPTE 424 standard raises the bar again. At 3 Gb/s, the quarter wave length of the fundamental just under 2 inches, and the quarter wave length of the third harmonic is just under 0.7 inches. With such short wavelengths, it is important to consider the loss budget of each item in the signal path very carefully.

The following discussion shows one method of analyzing coax, connectors, and patch bays to validate or predict the performance of a signal path. Various combinations of Belden 1505, 1694, and 7731 coax as well a various BNC connectors and 2 patch bays are modeled.

Coaxial Cable

The following are time domain reflectometry (TDR) measurements of various combinations of 75 Ω coaxial cable, coupled with high quality, 75 Ω BNC barrels. The traces show the rise in impedance, or loss, associated with distance, as the signal travels down the conductor.



1. This paper is actually an update to a paper originally published (by NVISION) in 1999. Comments have been added that show how technology has improved over time

The first trace is for 300 feet of 1694. Trace 2 is two 60-foot stubs of 1505 at either end of a 330-foot length of 7731. Trace 3 is one 30-foot stub of 1505, 300 feet of 1694, and 80 feet of 1505, and the last trace represents two 60-foot stubs of 1505 at either end of 120 feet of 1505.

Using the slope of the line as a figure of merit, the relative performance of the three cable types is calculated and shown along with similar data provided by Belden.

Cable Type	Measured	Calculated	Max Length, Recommended	Max Length, Belden Spec.	dB/100 ft at 750 MHz
1694	1, normalized	1, normalized	300	335 (400 today)	5.0
1505	0.768 of 1964	0.782 of 1964	230	272 (310 today)	6.5
7731	3.23 of 1964	1.48 of 1964	969**	494 (550 today)	3.7

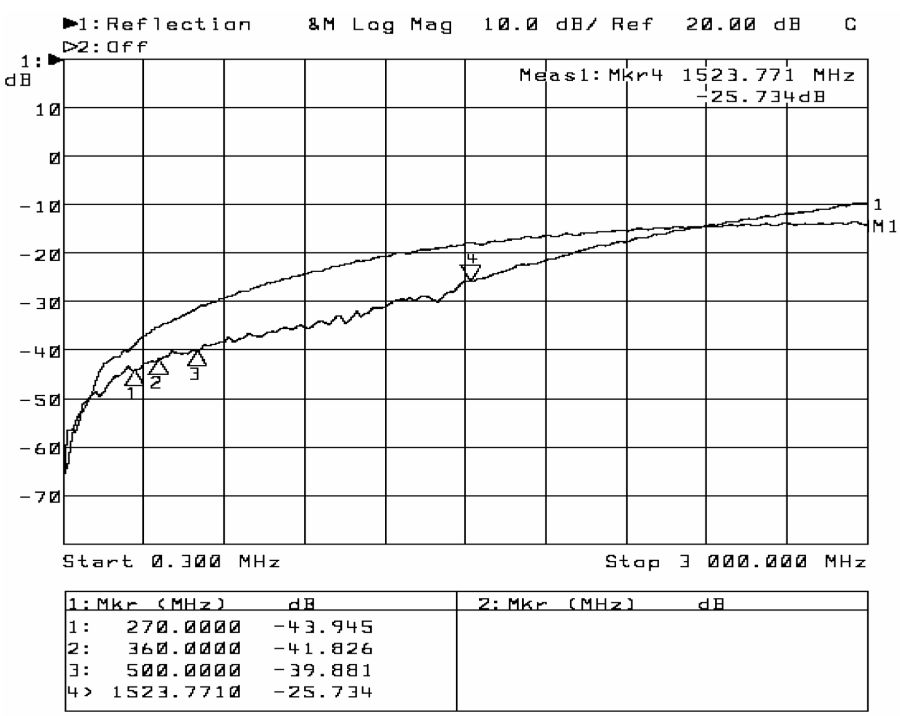
**It should be noted that some research is required to determine why there is such a large discrepancy between measured and calculated 7731 performance.

The performance ratios can be used to scale any cable scenario to match a 1694 equivalent. In 1998, 300 feet of 1694 was a safe figure in practice. Today, that metric has increased by 2, to 600 feet, or about 200 meters. Clearly, input receiver sensitivity has improved so that more loss can be accommodated than originally specified in the CCIR 601 standard used for the Belden calculations.

ICON and Patch

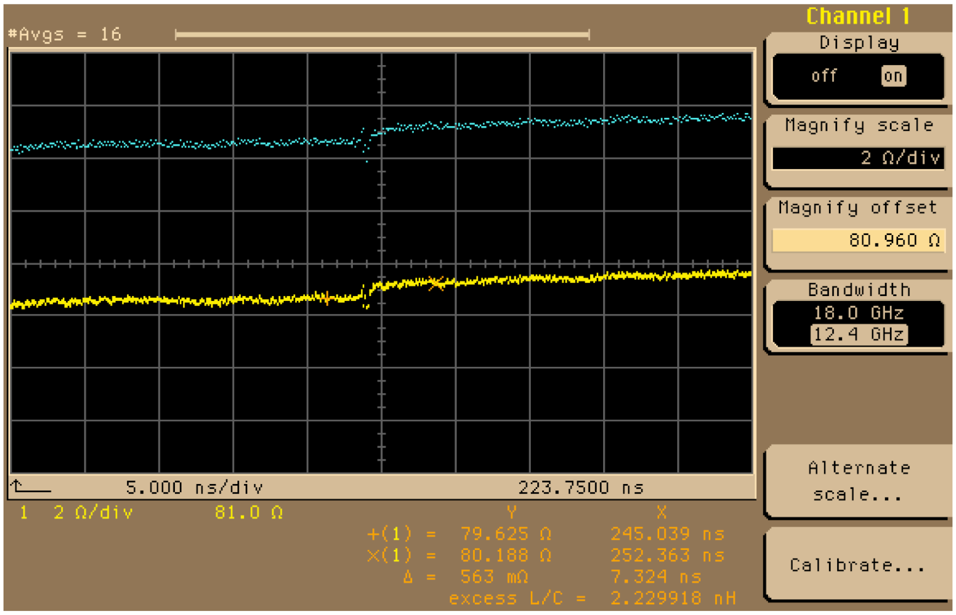
The next devices for consideration are patch bays and ICON. ICON, also know as a bulkhead connector panel, could be just a BNC barrel in the simplest case. The plots that follow show return loss of various patch jackfields, cables, and BNC components.

The following graph is ICON (BNC Barrel) return loss:



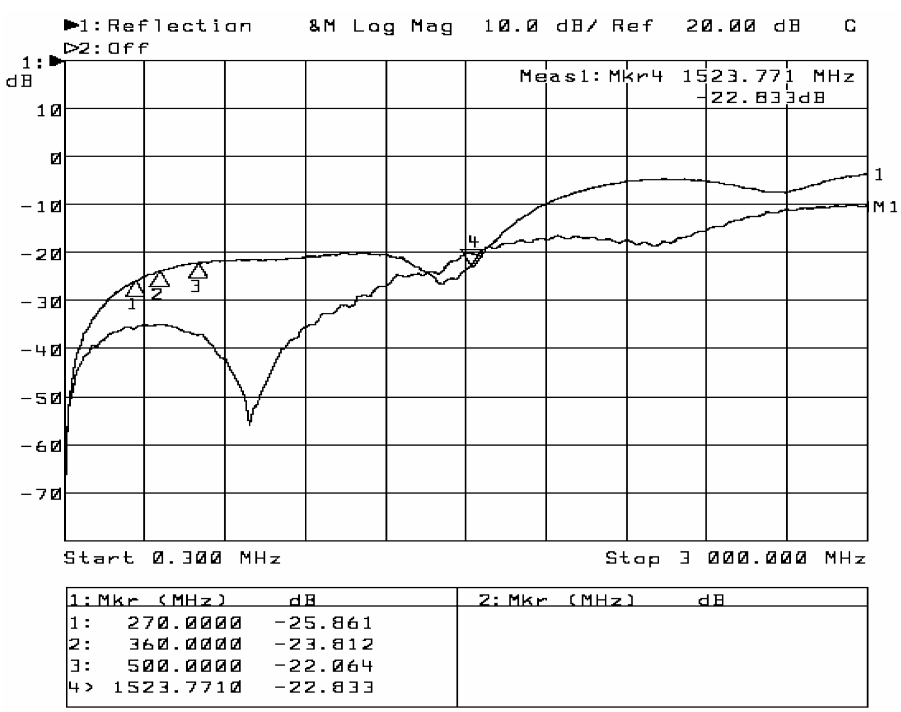
Note that even in 1999, both barrels shown meet the SMPTE return loss requirement for both SMPTE 292 and SMPTE 294. Although verification is required, there is a strong likelihood that high-quality ICON and bulkhead installations designed for HD-SDI at 1.5 Gb/s and installed in the last 5–8 years, will be in compliance with SMPTE 424 standards.

Then next plot shows ICON TDR performance. The ICON is isolated by two short lengths of low-loss coaxial cable. The discontinuity in the signal is caused by the change in connector impedance:



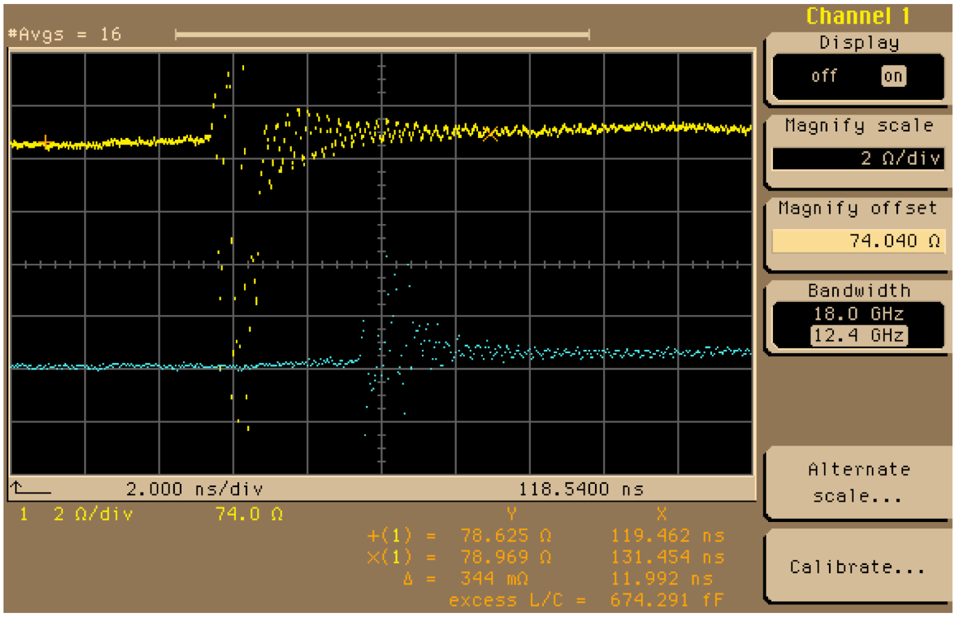
The amplitude of the discontinuity is a little over 1Ω, which should not present any problem. There is also some high frequency ringing, but again, with an amplitude of only 2Ω, there should be little impact on signal integrity.

The next plot shows return loss for the Normal patch:



Both are well within SMPTE spec for 1.5 Gb/s data but only one meets the SMPTE 424 standard (at or below –10 dB) in the 1.5–3.0 GHz frequency band.

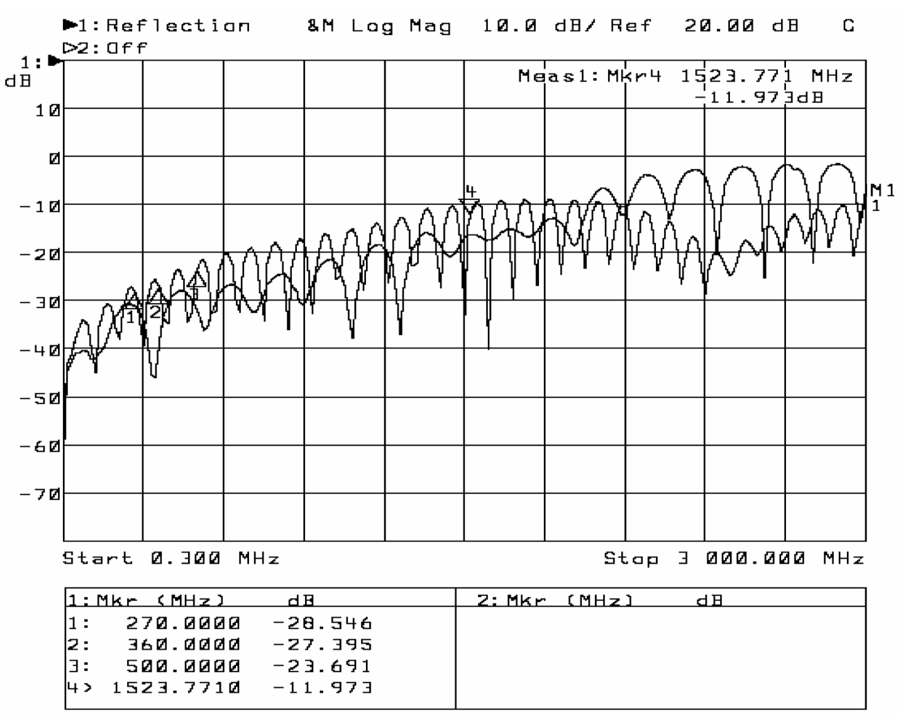
The next plot shows TDR performance:

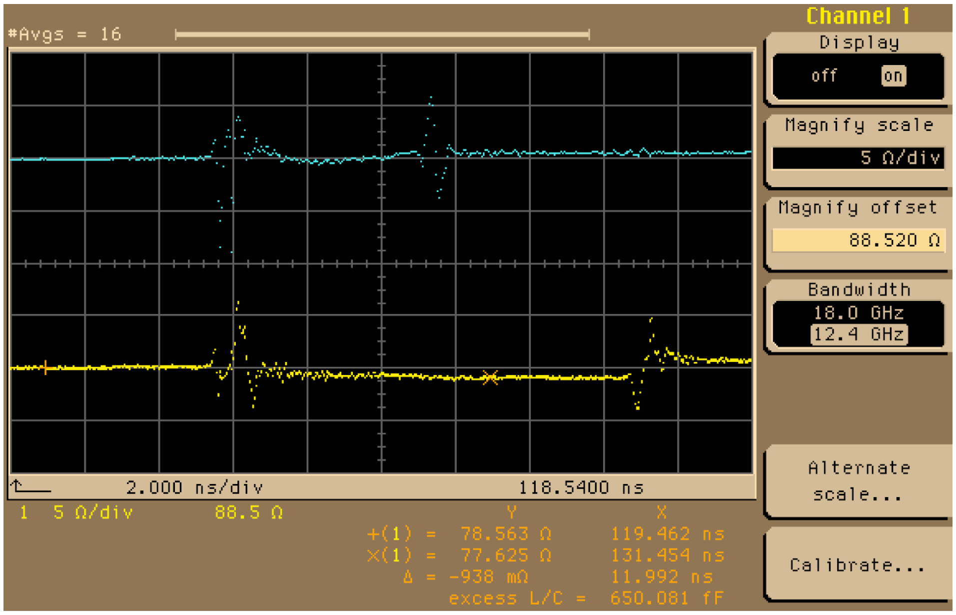


Notice that one unit has a much greater tendency towards ringing. The amplitude of the discontinuity is almost twice as large and the duration of the multi-beat or ringing is also almost twice as long.

Compliance with SMPTE 424 and loss ringing are key reasons to choose one patch bay over another.

The next two plots are of patch-through return loss and TDR. Note that for the TDR, the distance between discontinuities is related to the length of the patch cord.





Note that neither of these units meet the SMPTE 292 return loss specification. Today, these types of products have improved their design substantially for higher bit rates. However, both of these units were tested for bit error rate, and no problems were found, but the source was a laboratory-quality reference generator. Care should be take to ensure that no errors are introduced with equipment found in a typical application.

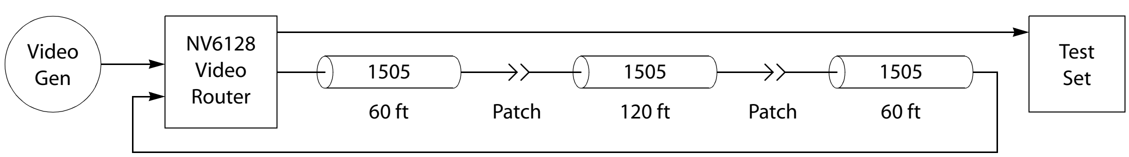
Because the Normal mode of operation is normal (pun intended) then perhaps the choice is clear. But it is preferable to find a unit that performs better. This is particularly true for 3 Gb/s operation.

System Performance

Some system performance measurements based on some actual “as built” models were taken. Four different transmission paths were configured and tested. They were various combinations of the previously mentioned cable and the cleaner ICON and Patch units. The cable paths were configured and connected between an output and input of the NV6128 SWB router. The cable under test was then fed with an HD-SDI check field from a Leader HD-SDI video generator. The output was taken from a different router output and fed to a Synthesis Research HDVA 292 for analysis.

Configuration 1

This is the test setup:

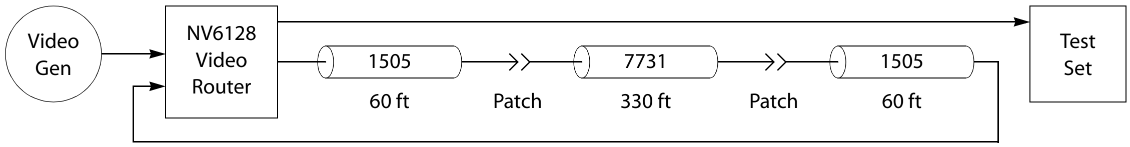


With Patch in *normal* position, 4 minutes of testing showed 0 bit errors.
With Patch in *through* position, 4 minutes of testing showed 0 bit errors.

Using the table at the beginning of this paper, excluding the patch point, 240 feet of 1505 is equivalent to 312.5 feet of 1694. Therefore, this should be right on the edge. But performance is solid. Performance would be better, and more loss budget would be available, if the 120 feet of 1505 were changed to 1694.

Configuration 2

This is the test setup:

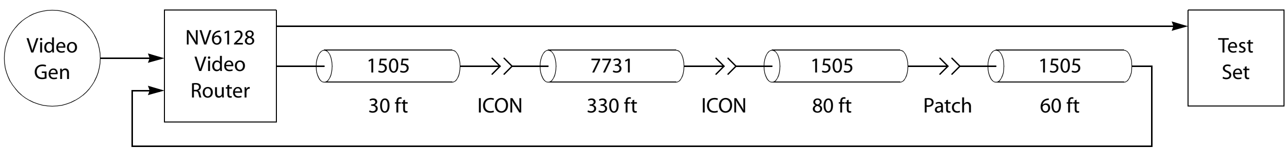


With Patch in *normal* position, 4 minutes of testing showed 0 bit errors.
With Patch in *through* position, 4 minutes of testing showed 0 bit errors.

Using the table at the beginning of this paper, excluding the patch point, the 1694 equivalent distance for this run is either 258 feet measured, or 379 feet calculated. Because it works so well, it would seem the 'measure' figure of merit for 7731 is more accurate. A more conservative approach would be to use 1694 for the 60-foot stubs, and assume 2:1 advantage for the 7731. This would give a normalized length of 285 feet, indicating that the run will be reliable, but close to the maximum length.

Configuration 3 "The Terminator" (Pun Intended)

This is the test setup:



With Patch in *normal* position, 4 minutes of testing showed 0 bit errors.
With Patch in *through* position, 4 minutes of testing showed 2 bit errors.

▲ It is equally likely that the bit error would have occurred in either Patch mode. Much longer time intervals would be required to determine whether the Patch contributed to the cliff or not.

Again, using Belden data, the 1694 equivalent length of this path is 443 feet. Using measured data, the path is 323 feet and should be near the edge of the loss budget, which the measured data indicates is true. For best results, this patch should have all 1505 stubs replaced with 1694. Using measured data, the effective length will then be 272 feet. Using conservative data, the effective length will be 335 feet. However, the path will probably perform without error in either of these last two scenarios, and in fact, did, when reconfigured as described.

One Last Comment

The source and destination of these cable test lengths were Miranda's SWB (Super Wide Band) drivers and receivers. Additional loss budget should be allocated for equipment not providing an equivalent level of performance. These data were taken in 1999. Today, the chip sets have enabled performance to nearly double, the cable lengths can be multiplied by two for 1.5 Gb/s, or used as is for 3 Gb/s.

Disclaimer: these results are typical. The intent of this application note is strictly to describe a methodology, not to guarantee results. This analysis should be performed using contemporary cable, connectors, patch bays, and active electronics based upon model topologies that might be built.