White Paper | BNC - HD1080p

Optimum Performance of Neutrik rearTWIST 75 Ω BNC-Connectors in HD 1080p applications

NEUTRIK

Content


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1 Scope

Based on the increasing demands of high resolution video formats, and high data rates coming along with it, more and more interest is focused on transmission lines (connectors, cables) and their response to high frequency signals. Broadcasters are facing the challenge of making their studios, OB vans etc. future-proof with regards to HD1080p and thus would like to ensure that their equipment will provide reliable performance.
Return Loss and Jitter are identified to be the key characteristics in judging compliance with high resolution standards.

We, Neutrik AG, as one of the leading manufacturers of BNC connectors, decided to accomodate the evolution of HD formats and to test our products with regards to the enhanced requirements. Theory on Return Loss and Timing Jitter and corresponding measurement results are the basis of this paper.

THEORY

2 HD Video Formats

At present the two common formats for HD video in the professional broadcast and production world are 720p/30 (a progressive format with 720 active lines progressively scanned at a rate of 30 frames/sec) and 1080i/60 (an interlaced format with 1080 active lines alternately scanned at a rate of 60 fields/sec). Both formats are usually distributed over a high-definition serial digital interface (HD-SDI) at a data rate of 1,5 Gbit/sec.
The next step in the search for the ultimate picture resolution is 1080p/60 which requires 3 Gbit/sec and thus twice the distribution data rate of 720p/30 & 1080i/60. Following the earlier established formats, 1080p/60* is distributed over HD-SDI.

* Please note that when this paper mentions 1080p/60, the 50-frame alternative 1080p/50, preferred in Europe, is also included.

2.1 SDI (Serial Digital Interface) - The Ideal Transport Interface

SD and HD SDI have become the ubiquitous interface standards within the professional broadcast industry, and the success of the SDI is broadly justified due to a number of specific characteristics:

- Ability to transport uncompressed signals
- Low latency
- Cost-effective implementation
- Robustness and reliability
- Seamless interoperability
- Reuse of existing infrastructure

Especially the opportunity to reuse the existing infrastructure has been one of the critical success factors for SDI and is characterized by the ability of the interface to evolve over time, while retaining the use of the existing cable installation, patch panels, and BNC connectors.
The so far latest step of evolution for the serial digital interface was the introduction of the 1080p/60 video image.

2.2 1080p - Why a Higher Capacity Interface Is Required

Among the obvious reason of higher resolution and hence the opportunity to display video material more realistic, 1080p provides an additional major advantage:

1080i and 720p, the two original HD formats are not ideally compatible. If deciding to go for one format, it is quite possible that a customer will request the material in the other format. Actually, the conversion between 1080i and 720p, or vice versa, is problematic, and may cause pixelization and other undesirable artifacts.
By shooting in 1080p/60 respectively 1080p/50, the higher frame rate HD image of 1080p/60 can be easily converted into either 1080i or 720p with no artifacts.

Thus, 1080p/60 provides the ability to offer a product in 1080i or 720p formats with no loss of image quality, and also introducing an extended life of material, as it will still be available when the 1080p distribution format emerges.

The drive to higher data rates and thus clock frequencies (SMPTE standard[1] specify that the clock frequency will equal the signal bit rate**) has focused increasing interest on Return Loss and Timing Jitter.

** The unit interval of a 270 Mb/sec SD-SDI signal equals one period of a 270 MHz clock or 3.7 ns. The unit interval of a 1.485 Gb/sec HD-SDI signal equals 673 ps or one period of a 1.485 GHz clock. Hence, the unit of a 2.97 Gb/sec high frame rate HD-SDI signal equals 336.7 ps or one period of a 2.97 GHz clock.

3 Return Loss

3.1 What Is Return Loss?

Return loss is signal attenuation caused by impedance variations in the structure of a cable or associated connectors. These variations cause the signal to reflect (return) back to the source. At lower frequencies, return loss is a minor effect; at frequencies above 50 MHz, it can have a significant effect. At frequencies used for high-definition video, 3000 MHz and higher, it is a major, even critical factor.

3.2 About Return Loss

With the introduction of HD signals coming along with higher data rates and thus increased clock

frequencies the impedance of BNC connectors became more important than ever.
Every deviate impedance has a negative influence on the "return loss" / "VSWR" (Voltage Standing Wave Ratio) which are important measurements for reflected signals in a transmission line.
Especially on high frequencies - as they occur when transmitting high frame rate HD signals (typical transmission @ 4.5 GHz) - an impedance mismatch results in a lot of return loss.

3.3 How To Measure Return Loss

Return loss is measured by the help of a Network Analyzer. The analyzer is set to nominal cable impedance (e.g. 75 Ω) and the tested cable is terminated with a 75 Ω load. A signal is introduced to the cable and the reflected signal is measured.

4 Timing Jitter

4.1 What Is Jitter?

This simple and intuitive definition is provided by the SONET specification[2]:
"Jitter is defined as the short-term variations of a digital signal's significant instants from their ideal positions in time."

Ideally, the time interval between transitions in an SDI signal should equal an integer multiple of the unit interval. In real systems, however, the transitions in an SDI signal can vary from their ideal locations in time. This variation is called time interval error (TIE), commonly referred to as jitter. This timing variation can be induced by a variety of frequency, amplitude, and phase-related effects.

4.2 Wander, Timing Jitter

The jitter spectrum in an actual SDI signal generally contains a range of spectral components. The recovered clock will generally track spectral components below the clock recovery bandwidth, but will not track spectral components above this bandwidth.
Hence, the impact of jitter on decoding depends on both the jitter's amplitude and its frequency components. This has led to a frequency-based classification of jitter.

Conventionally, the term "jitter" refers to short-term time interval error, i.e. spectral components above some low frequency threshold. For SDI signals, the SMPTE standards set this threshold at 10 Hz and refer to spectral components above this frequency as timing jitter.
The term wander refers to long-term time interval error. For SDI signals, components in the jitter spectrum below 10 Hz are classified as wander.

4.3 About Timing Jitter

Timing jitter has always degraded electrical systems, but the drive to higher data rates and lower logic swings has focused increasing interest and concern on it.

Impedance discontinuities through connectors and transmission lines as well as attenuation, cross talk, and noise coupling contribute to jitter. In all of the above cases, the jitter effect is due to some form of signal distortion and cannot be completely eliminated. Thus, the jitter introduced from these effects can be considered systematic and cumulative (arithmetically additive).

4.4 How To Measure Timing Jitter

Various methods to measure and estimate peak-peak jitter are common in industry.
We decided to use the eye diagram, which is a general tool for jitter measurement, since it gives insight into the amplitude behavior of the waveform as well as the timing behavior.

4.4.1 The Eye Diagram[4]

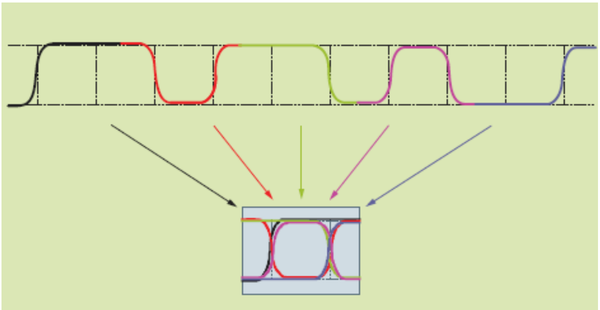


Figure 1

An eye diagram is created when many short segments of a waveform are superimposed such that the nominal edge locations and voltage levels are aligned, as suggested in stylized Figure 1 (Colours have been used to show how the individual waveform segments are composed into an eye diagram).
The waveform segments may be adjacent ones, as shown in the figure, or may be taken from more widely spaced samples of the signal.

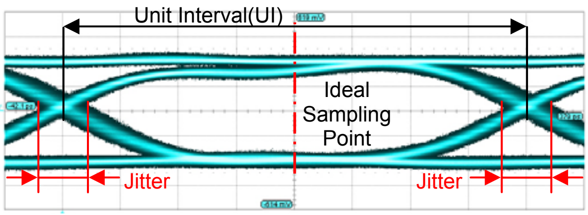


Figure 2

Colored eye diagrams are used to indicate the density of waveform samples at any given point of the display. Figure 2 shows such a color density display for a waveform that exhibits several types of noise.
As the jitter on a signal increases, the eye becomes less open, either horizontally, vertically or both. The eye is said to be closed when no open area remains in the center of the diagram.

MEASUREMENTS

5 Return Loss

5.1 Measurement Setup

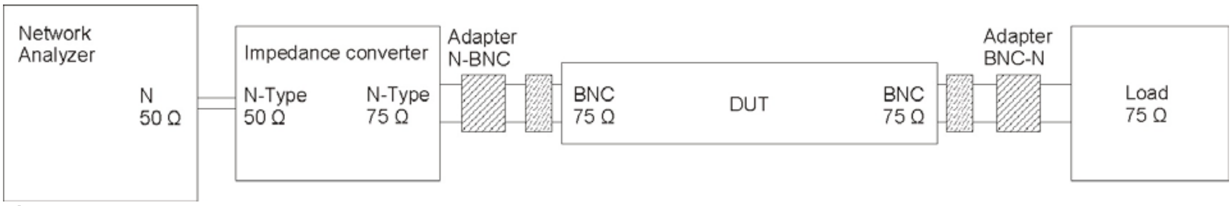
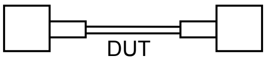


Figure 3

5.2 Measurement Conditions

Return loss measurement has been carried out with Neutrik NBNC75BTU11 75 Ω BNC connectors. To compare the results of the Neutrik connectors, we have chosen the BNC connectors of a European manufacturer (Standard series & HD optimized series), whose products are widely spread in broadcast applications across Europe, as reference.
All tested cable assemblies have been terminated with 20 m of the well-known Belden 1694A 75 Ω coax cable.

a) Single cable (length 20m) with both ends terminated for connector evaluation



SMPTE 424M[3] specifies a return loss of better than 10 dB between 1.485 GHz and 3 GHz and better than 15 dB from 5 MHz to 1.485 GHz (values below SMPTE limits are indicated red in Figure 4).
All test specimens were sweep tested up to 4.5 GHz.

5.3 Measurement Results

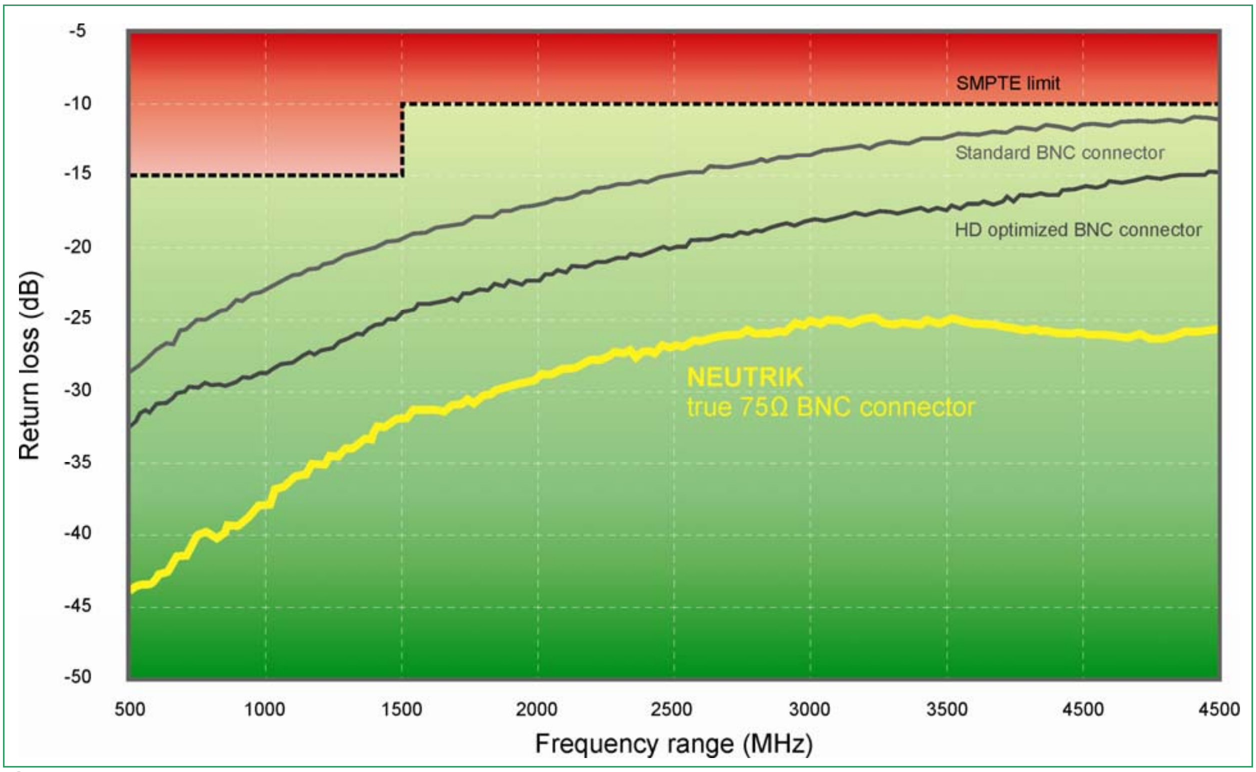


Figure 4

5.4 Conclusion

The cable assembly with the Neutrik rearTWIST® 75 Ω BNC Connectors offer at least 15 dB return loss budget with respect to SMPTE 424M requirements. This is a minimum of 7 dB more return loss budget compared to European manufactured products.

To achieve this outstanding result every Neutrik BNC connector has been adapted to the measurements of a small group of cables, this guarantees the best possible performance and a minimized return loss.
Neutrik BNC connectors feature a true 75 Ω design that meet the stringent requirements of high frame rate HDTV and sustain consistent impedance at high frequencies up to 4.5 GHz.
The higher the frequencies the more pronounced is the "skin effect“, which means that the energy moves to the outside of the conductor. Therefore, the plating of outer and centre contacts is more important than for audio connectors with low frequencies - both contacts of Neutrik BNC connectors are gold plated.

6 Timing Jitter

6.1 Measurement Setup

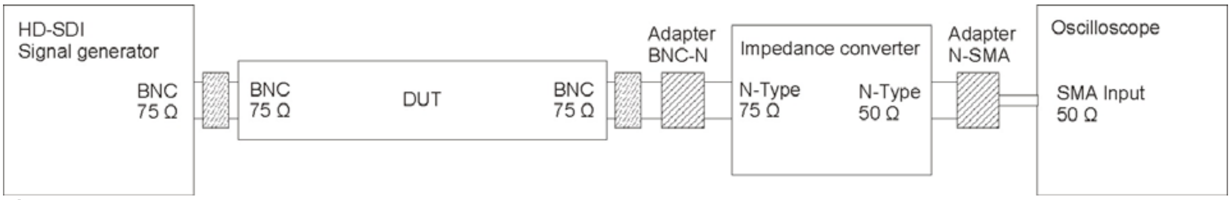
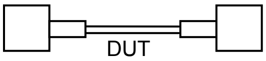


Figure 5

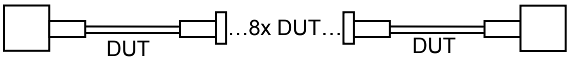
6.2 Measurement Conditions

For jitter measurements we nominated the Neutrik NBNC75BTU11 75 Ω BNC connector. To judge the results of the Neutrik connectors, we have chosen the BNC connectors of a European manufacturer (Standard series & HD optimized series), whose products are widely spread in broadcast applications across Europe, as reference.
All tested cable assemblies have been terminated with 1m of the well-known Belden 1694A 75 Ω coax cable.

a) Single cable (length 1m) with both ends terminated for connector evaluation



b) 10 pcs of cables (length 1m each) connected in series via adapters to exhibit the influence of several connections as they typically occur on broadcast applications when patching signal leads



SMPTE publishes standards, recommended practices (RP), and engineering guidelines (EG) for the video industry. SMPTE 424M, SMPTE RP184, SMPTE RP194 were considered in the actual Jitter Measurement.

6.3 Measurement Results

6.3.1 Neutrik NBNC75BTU11 with Belden 1694A coax cable

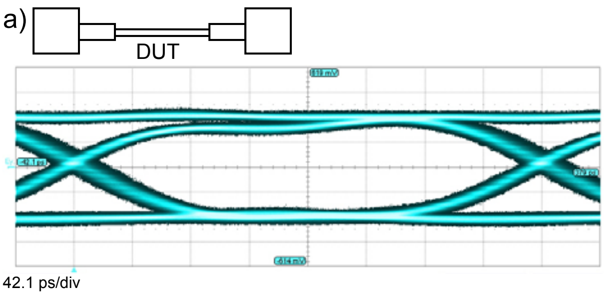


Figure 6

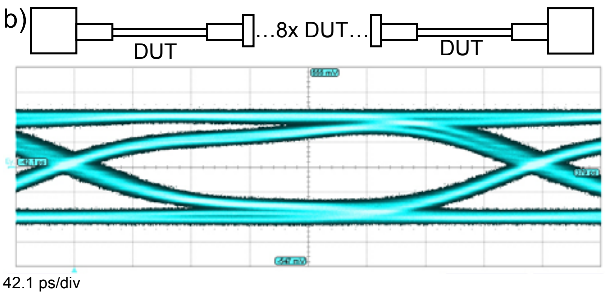


Figure 7

Connector type	Timing jitter pk – pk [ps]	[UI]	Rise time [ps]	Fall time [ps]
a) Neutrik NBNC75BTU11	34.47	0.10	126	112
b) Neutrik NBNC75BTU11	37.71	0.11	205	158
Adapter: Neutrik NBB75FG				

6.3.2 European Manufacturer HD optimized product with Belden 1694A coax cable

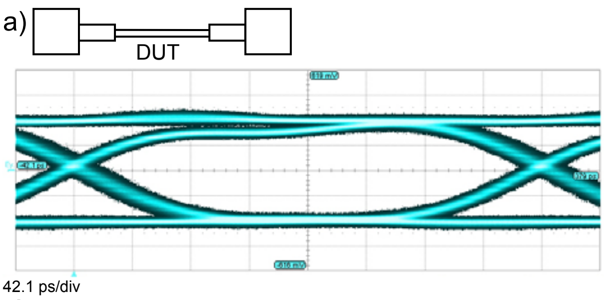


Figure 8

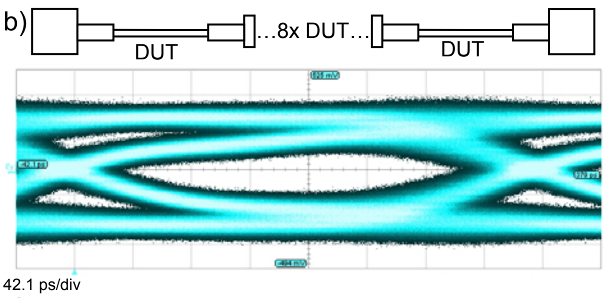


Figure 9

Connector type	Timing jitter pk – pk [ps]	[UI]	Rise time [ps]	Fall time [ps]
a) European Manufacturer HD optimized	35.26	0.10	133	118
b) European Manufacturer HD optimized	83.55	0.25	302	233
Adapter: European Manufacturer				

6.3.3 European Manufacturer Standard product with Belden 1694A coax cable

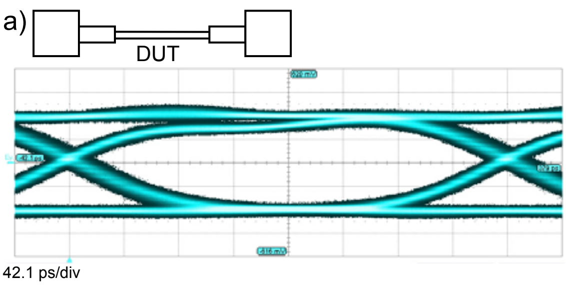


Figure 10

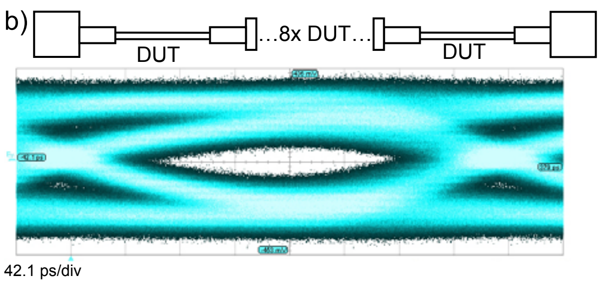


Figure 11

Connector type	Timing jitter pk – pk [ps]	[UI]	Rise time [ps]	Fall time [ps]
a) European Manufacturer Standard series	36.72	0.11	139	121
b) European Manufacturer Standard series	168.83	0.50	543	280
Adapter: European Manufacturer				

6.4 Conclusion

As written in section 2.2, jitter cannot be eliminated completely.
However, in order to reduce the potential jitter to a minimum, Neutrik concentrates on getting to the heart of the problem by optimizing connectors and its material.

Transmission line Timing Jitter (Method b):

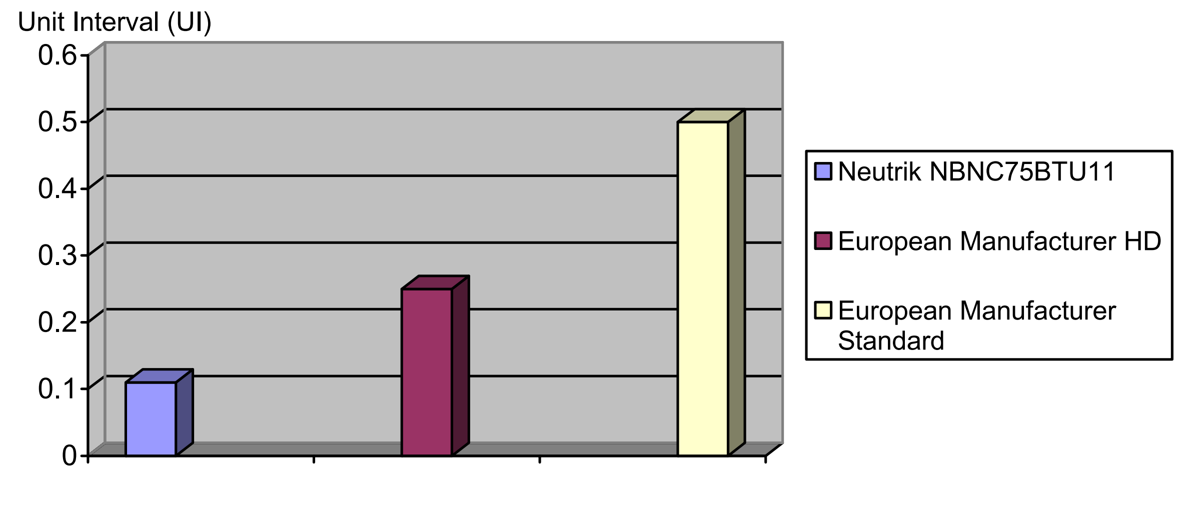


Figure 12

Figure 12: After a signal path of 10 test cables (including 9 adapters), connected in series, the Neutrik BNC connectors do only add 0.11 Unit Interval (UI) of jitter to the signal, whereas the compared test specimens under the same conditions add 0.25, respectively 0.5 UI of jitter.

Actually, the Neutrik BNC connectors offer considerable jitter budget to enable longer cable runs and/or a higher number of patch connections without causing the signal to be undeterminable.
Neutrik true 75 Ω BNC connectors deliver best performance, especially when routed signals in transmission paths spreads via a considerable number of connections (Patch Panels, Patch cords and adapters).

From their beginning, the Neutrik rearTWIST® BNC connectors were designed under stringent specifications with regards to impedance and screening. In the actual jitter measurement the Neutrik rearTWIST® BNC again proved to have been and continue to be the best choice even for the 1080p/60 higher frame rate HD data format transmission lines.

References / Literature:

1 SMPTE RP 184-2004, Specification of Jitter in Bit-Serial Digital Systems
2 Bell Communications Research, Inc (Bellcore), “Synchronous Optical Network (SONET) Transport Systems: Common Generic Criteria, TR-253-CORE”, Issue 2, Rev No. 1, December 1997
3 SMPTE 424M-2006, SMPTE Standard for Television – 3Gb/s Signal/Data Serial Interface
4 Tektronics, Guide to understanding and characterizing Timing Jitter

Additional Literature:
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