

Author(s)

First Name	Middle Name	Surname	Role	Email	SMPTE Member?
Owen	Robert	Barthelmes	Director of Engineering	obarthelmes@amphenolrf.com	Y

Affiliation

Organization	Address	Country
Amphenol RF	4 Old Newtown Road Danbury, CT 06810	USA

Author(s) – repeat Author and Affiliation boxes as needed—

First Name	Middle Name	Surname	Role	Email	SMPTE Member?
David	Ivan	Weinstein	Principal RF Engineer	dweinstein@amphenolrf.com	N

Affiliation

Organization	Address	Country
Amphenol RF	4 Old Newtown Road Danbury, CT 06810	USA

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SMPTE Meeting Presentation

High Density Interconnect Standards for Next Generation Broadcast Networks

Owen Barthelmes, Director of Engineering

Amphenol RF, 4 Old Newtown Rd, Danbury, CT 06810, obarthelmes@amphenolrf.com

David Weinstein, Principal RF Engineer

Amphenol RF, 4 Old Newtown Rd, Danbury, CT 06810, dweinstein@amphenolrf.com

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Abstract. HD-BNC is a high density interconnect standard which satisfies space constraints in next generation system architectures. The configuration maintains expectations relative to user experience, mechanical robustness and low loss at extended frequencies to support higher data rates. BNC connectors per IEC 169-8, having been deployed in systems for over 50 years, offers robust performance and user friendly quarter turn bayonet style coupling. HD-BNC is therefore proposed as an open standard solution preserving all of the benefits of BNC with a fourfold footprint reduction. HD-BNC was developed from inception as a 75 Ohm interface with extensive simulation and test validation to optimize signal transmission per SMPTE-292M and 424M standards in both analog and digital video and audio signals. This paper will detail the development process and contrast this interconnect solution to others in the industry in key areas such as mechanical robustness and electrical performance of real world applications.

Keywords. *high density; interconnect; analog video; digital video; high bandwidth; connector*

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Introduction

Modern Broadcast systems and components demand a higher density in interconnect arrays allowing for more bandwidth in existing or shrinking footprints. The current de facto standard for interconnect is the BNC which was developed by a collaboration between Bell Labs and Amphenol in the 1950's. The BNC originated as a 50 Ohm transmission line and was highlighted with a bayonet coupling mechanism that allowed for quick mating and de-mating.

Based mainly on its size and mating efficiency, the BNC began to be adopted in broadcast systems. Early systems had very low frequency requirements and therefore the 50 Ohm interface could be used with acceptable loss characteristics. As systems became more advanced and bandwidth requirements increased, the 75 Ohm BNC emerged. At first many of the connectors branded 75 Ohm were little more than 50 Ohm connectors with a portion of the interface dielectric removed to increase impedance. The design variants continued to evolve and the highest performing variants were given names like "True-75Ohm BNC". In the end, many of these connectors perform satisfactorily even with the current demands of SMPTE-292M and 424M, but will always be adaptations of the 50 Ohm original.

Next generation Broadcast systems have reached the limits of what the BNC can offer mostly because of physical real estate. The BNC shows its age and limits density. With the real industry demand for higher density, alternatives have emerged but are still in their infancy with respect to large scale adoption. The Broadcast industry is in a critical juncture to adopt a new standard to move forward. It is in the best interest of the industry as a whole to settle on one standard to reduce complexity and associated cost of non-interchangeable systems and cable infrastructure.

The industry now has choices of connectors such as 1.0/2.3 (75 Ohm), Mini-BNC and HD-BNC. Each has their own features and benefits but to determine which is best suited for large scale deployment, several key performance factors must be reviewed and balanced. They are:

1. Density
2. Robustness
3. Bandwidth
4. User Experience

Amphenol is uniquely positioned to compare these products as a manufacturer and supplier of all of them in the industry.

HD-BNC

Amphenol RF developed the HD-BNC to provide the best balance of performance factors. The interface and product line were enhanced through a close collaboration with Harris Broadcast Communications. Harris injected industry experience to assist in fine tuning the product to meet real world applications and requests from the users.

The HD-BNC features a bayonet style coupling system but in a dramatically reduced package size. It was designed from inception as a 75 Ohm interface optimized for modern systems up to 3GHz but with an extended ceiling of 6 GHz for the high bandwidth requirements of future systems.

The interface itself had been proposed as an open source industry standard in IEC. The Amphenol version of the HD-BNC mating sleeve features a unique geometry with a visual

indicator to confirm positive mating as well as integrate with the special installation tool. These unique features are described in US Patent Number 7,553,177.

1.0/2.3

The 1.0/2.3 is a connector series that originated in Europe which gets its name from the outer diameter of the center contact (1 mm) and inner diameter of the outer contact (2.3 mm). It is controlled by industry specifications including DIN 47297, CECC 22230 and IEC 61169-29. It is inherently a 50 Ohm interface and built around the concept of three mating styles. These include a push on version for connectors mounted in housings, as well as both a snap-lock version and threaded version for discreet cabled applications. Within the Broadcast market, the connector is often referred to as a “Mini-DIN”.

Over the years, the 1.0/2.3 has been applied in telecom central office application and more recently broadcast systems with 75 Ohm variants. Since 1.0/2.3 is an air dielectric interface, it is more difficult to achieve 75 Ohm. Most 75 Ohm 1.0/2.3 are not “True 75 Ohm” as to achieve such performance, the size of the center contact must be significantly reduced which compromises mechanical robustness.

The connector is easy to mate with a simple push action but requires that the coupling sleeve be retracted to de-mate. This can be an issue in dense applications as access to the sleeve can be difficult.

Mini-BNC

Mini-BNC is a scaled down BNC style connector which offers a 40% increase in density over standard BNC. It was originated as a 75 Ohm interface but is not controlled by any industry standard. Although there are multiple suppliers of Mini-BNC there are no published specifications which guarantee intermateability, only catalog documents which are not industry approved and are subject to change.

The Mini-BNC has limited patent protection for one variation of construction by Patent 6,561,841. The known design variations produced by other suppliers including Amphenol use a different construction.

Density

HD-BNC can be configured with a centerline spacing of 8 mm minimum compared to BNC at 15.5 mm. This allows for density improvements of 400% over standard BNC. The product portfolio includes an installation tool which allows for mating and de-mating even in a dense array of cabled connections at the minimum 8mm pitch. It is important to note that density is being used to describe connectors mounted in an array not simply a straight line. Arrays are commonly configured in broadcast systems and introduce more installation concerns than single row applications.

In practical application, the HD-BNC offers the highest level of density of any currently available solution while allowing for easy installation using the associated tool. The density offered by the 1.0/2.3 is somewhat variable and difficult to specify due to a large variation in the dimensions of the plug coupling mechanism. Most published density specifications for 1.0/2.3 are for single row applications. For Amphenol products, when applied to an array, the minimum density practical limitation has been determined to be 10 mm.

A relative comparison of high density options are shown in Figure 1.

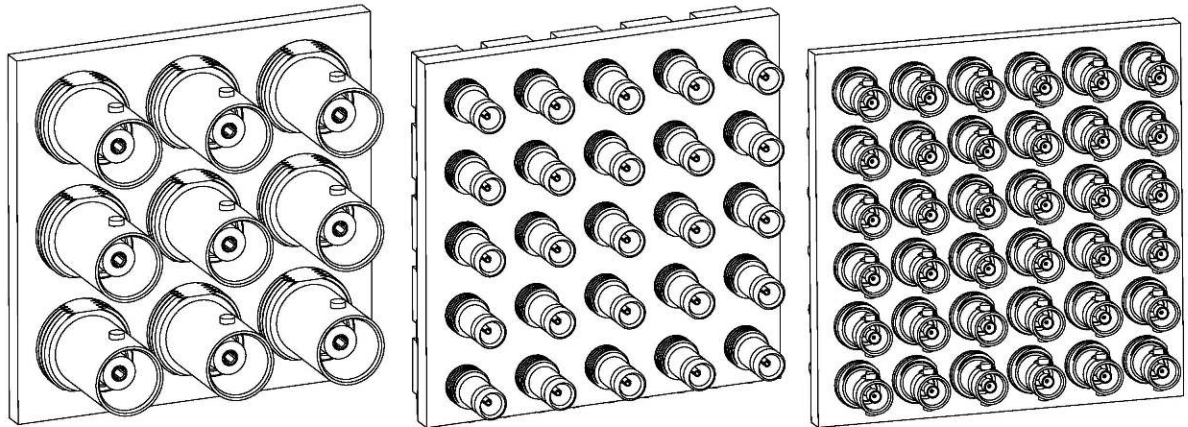


Figure 1: BNC (15.5mm), 1.0/2.3 (10mm) and HD-BNC (8mm)

It should be noted that density can be cable limited. For instance, Belden 1694 cable is larger in diameter than both the HD-BNC and 1.0/2.3 interface and therefore it becomes the limiting factor. The HD-BNC connectors for 1694 cable have been optimized to limit overall size but even with this optimization are limited to a pitch of 9.5 mm.

The bayonet style mating of the HD-BNC improved density in tight arrays because of its interaction with the installation tool. As a “twist to mate” interface, the tool can engage from the rear or cable side to the coupling mechanism to assist in turning the mating sleeve. Unlike HD-BNC, the 1.0/2.3 interface must be pulled to de-mate and the removal tool must be configured so that it must be engaged from the side. This is the primary limitation in density for the 1.0/2.3 as in any arrangement besides single row, there must be additional clearance for the tool or even greater for finger engagement.

Robustness

This is a broad category that refers to the connector’s ability to resist damage and perform under a high degree of mechanical stress. Typical connector standards and specifications do not account for applications such as Broadcast systems. These systems are comprised of large but dense bundled cable assemblies which translate significant in-line and side loads to the connector. The density also results in a semi-blind mating condition which can lead to connectors being mated at an off angle which can damage contact systems.

The application stresses have been considered in the design of the HD-BNC connector series. Key features of the connector include a closed entry center contact system. The center contact in the plug side is completely surrounded by dielectric material which includes a guide “funnel” to ensure that the center contacts do not suffer from mis-mating or “slide-by”. This is a condition where the male pin does not enter the female socket and instead slides along the side of the contact. Not only does this result in poor electrical performance but it can permanently damage the connector. The HD-BNC closed entry interface as shown in Figure 2 eliminates this concern as compared to 1.0/2.3 shown in Figure 3.

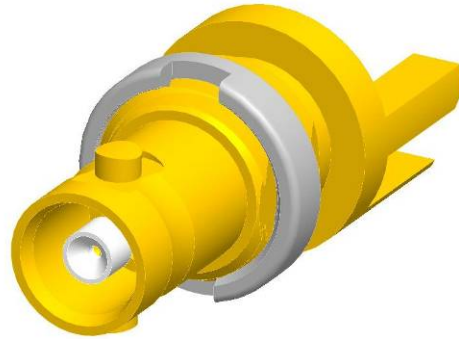


Figure 2: HD-BNC Closed Entry Interface

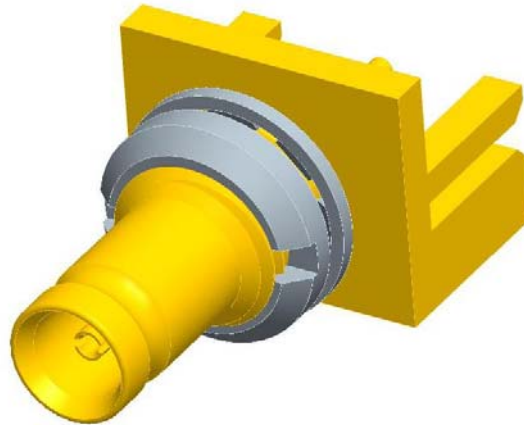


Figure 3: 1.0/2.3 Interface

Another concern with high density alternatives is the amount of splay or “wobble” the interface displays when a side to side cable movement is applied. With the HD-BNC the interface has been designed to limit this movement. The outer contact has also been configured to withstand higher side load forces without damage. Figure 4 shows the relative movement of each of the three interfaces. Measurements as shown in Figure 5 were made using an optical comparator and a slight side load applied to each connector.

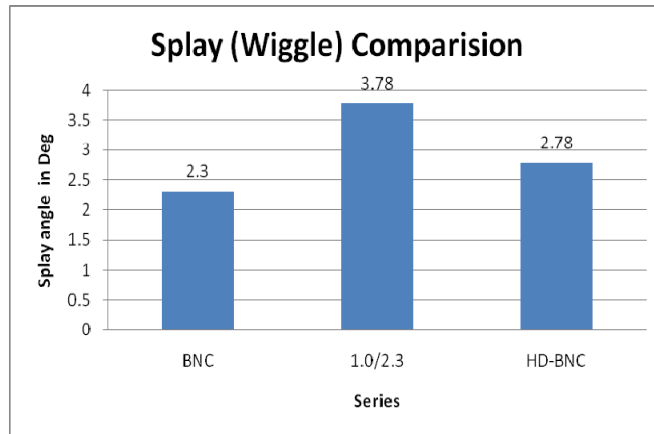


Figure 4: Comparison Chart of Splay Angle: BNC, HD-BNC to 1.0/2.3

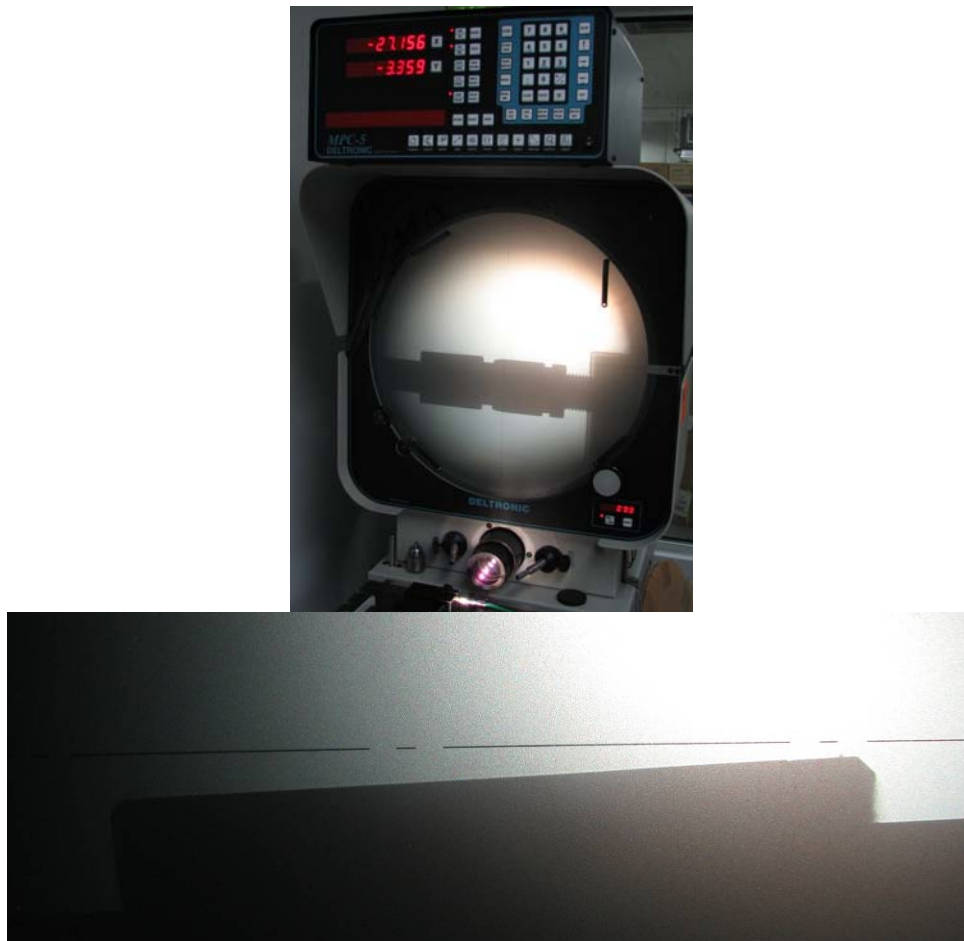


Figure 5: Splay Angle Measurement

To better define the robustness of the various interface options in real applications, a set of experiments were structured to measure relative performance. The results of these tests are shown in Figures 6 to 12, illustrating relative performance of HD-BNC, 1.0/2.3 and BNC. It should be noted that this testing did not compare all variations of the 1.0/2.3 and BNC connectors in the industry, only that of readily available and common products with known field

deployment. There can be a lot of variation from one manufacturer to another especially with the 1.0/2.3 interface. The test results are not intended to single out any one product, but instead to show typical and relative performance of the different interconnect options.

The first comparison is the base Return Loss of the three interfaces. The test setup for each is a cable plug mounted to Belden 1855 cable and then mated to a precision adapter on an Agilent ENA E5071C. The low loss adapter is included in each measurement. It can be seen that all of the connectors will meet the SMPTE specification as a component but there is significantly more margin offered by the HD-BNC product.

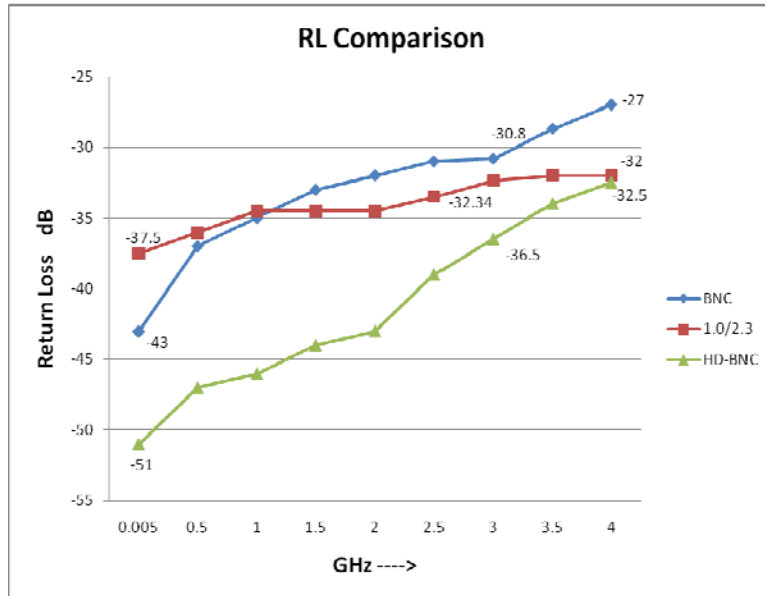


Figure 6: Return Loss Comparison Chart: BNC, HD-BNC to 1.0/2.3

The next test measures the change in return loss when an axial load is applied during the test. In all cases there is some change in return loss but none generate any level of concern. It is expected that all of these interfaces would vary under load. Again, the HD-BNC displayed the best overall Return Loss as shown in Figure 7. Interestingly, the Return Loss of the HD-BNC improved with a load applied. With both the standard BNC and the 1.0/2.3 the Return Loss degraded under load.

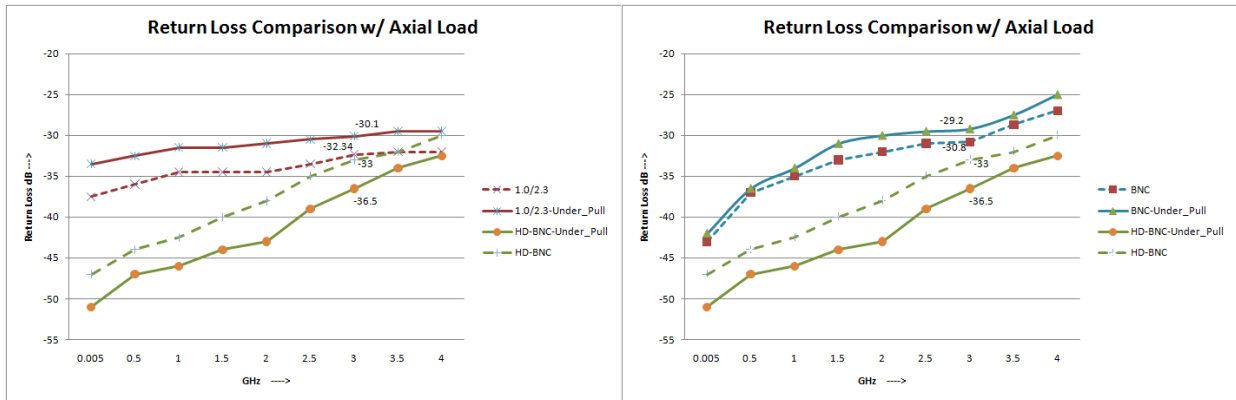


Figure 7: Return Loss with Axial Load Chart: HD-BNC vs. BNC and 1.0/2.3

In addition to axial load, Return Loss performance can be impacted by a side load. In the next test, a side load was applied to both the 1.0/2.3 and the BNC and the Return Loss was recorded as shown in Figure 8. Again, the base Return Loss of the HD-BNC was superior to the 1.0/2.3 and under load the performance increased for the HD-BNC but degraded for the 1.0/2.3. This is important to consider as in a real world environment, the connector is almost always subjected to a side load due to cable routing.

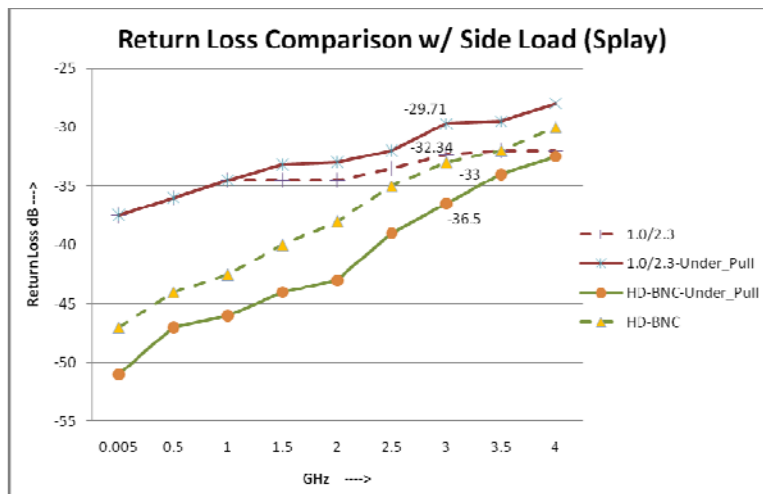


Figure 8: Return Loss with Side Load

Coupling strength is a critical mechanical feature. A test was configured to compare the axial load resistance of the interface to separation. Mated pairs of connectors were subjected to an axial load by pulling on the cable with results shown in Figure 9. Failure was noted when the connectors separate. The industry standard for BNC is to achieve a minimum of 100 lb (445 N). The BNC connectors in this test exceeded the requirement by 100%. The HD-BNC also passed the industry requirement with a result of 122 lb. (543 N). It is to be expected that the HD connector not be as strong as the BNC as it is considerably smaller but very good that it continues to meet the performance specification. 1.0/2.3 fell considerably below the standard. This separation force would be concerning in a field deployment with real world cable bundling.

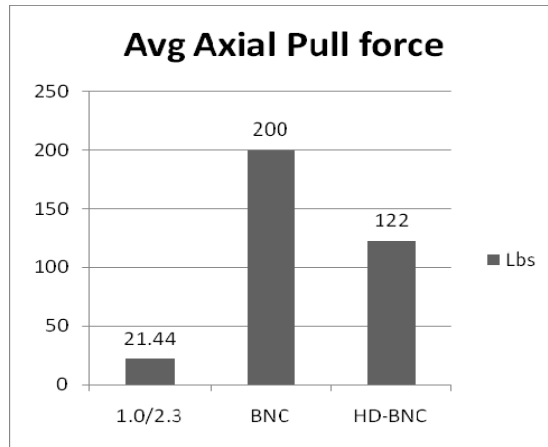


Figure 9: Coupling Axial Strength Chart: HD-BNC to 1.0/2.3

The final mechanical test compares the side load resistance of the high density interfaces. The test setup featured a bulkhead jack connector mounted to a panel. A side load was applied in perpendicular direction with a test pin positioned the same distance from the panel in each test. Using a Zwick/Roell Z2.5 tensile tester, the forces were increased in increments of 5 lbs. (22 N) and the force versus displacement was recorded along with the condition of the interface. The test setups and results are shown in Figure 10, 11 and 12. The HD-BNC resisted 63% more side load than the 1.0/2.3 further illustrating its robustness and suitability for complex cable routing and larger cable types.

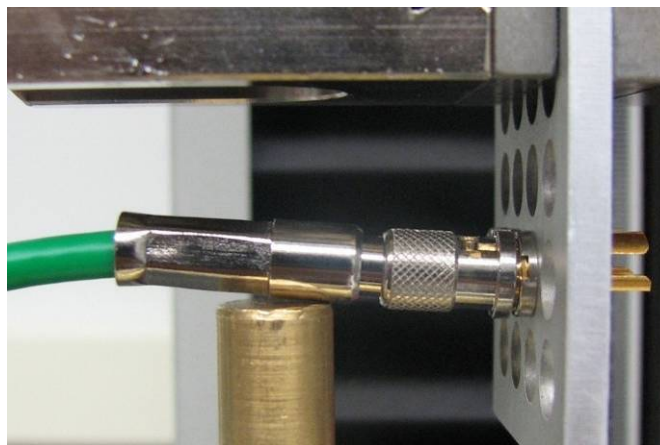


Figure 10: HD-BNC

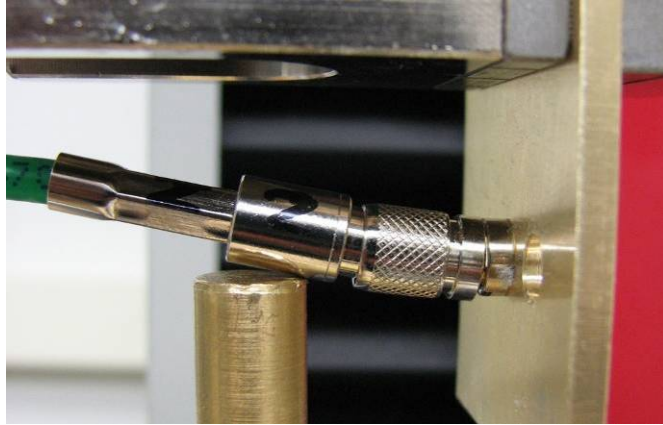


Figure 11: 1.0/2.3

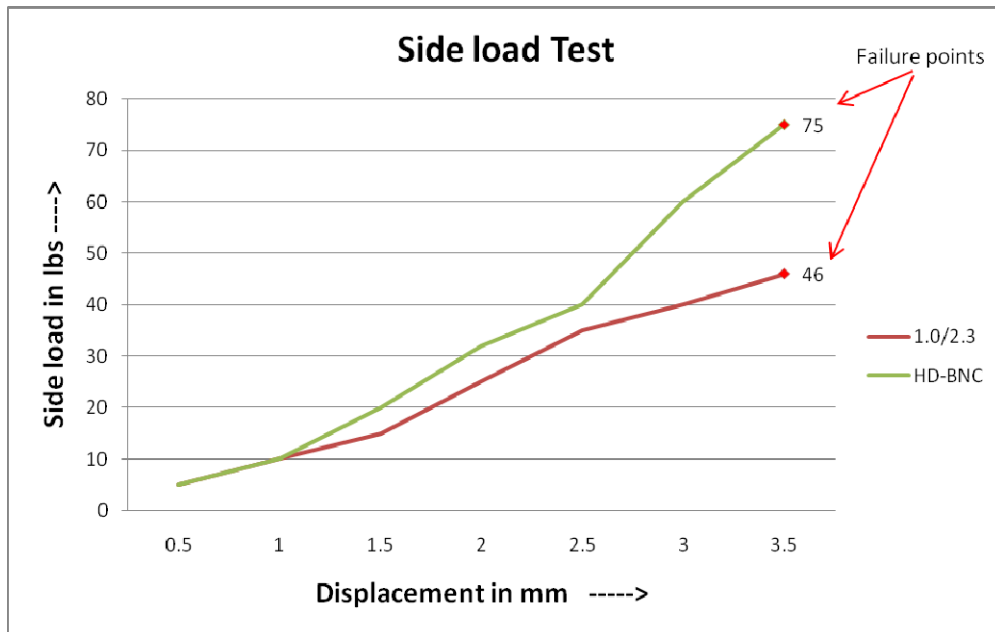


Figure 12: Side Load Resistance Chart: HD-BNC to 1.0/2.3

Bandwidth

To ensure high bandwidth performance, one must first understand the definition of bandwidth as it is applied to interconnect products. It is then important to understand how RF performance capabilities at the component level, such as connectors, combine to influence the system level specifications. In the end, each connector must be designed and tested accurately to ensure that the industry requirements for bandwidth are met.

Definition

HD-BNC was developed from inception as a 75 Ohm interface with extensive simulation and test validation to optimize signal transmission per SMPTE-292M and 424M standards in both

analog and digital video and audio signals. The SMPTE 292M standard is a nominally 1.5 Gbit/s interface. In addition, looking forward, SMPTE-424M specifies the standards for a 3 Gb/s Signal/Data Serial Interface.

Current SMPTE requirements for Return Loss are -15 dB from 5 MHz to 1.5 GHz and -10 dB from 1.5 GHz to 3 GHz. Looking forward, many hardware manufacturers are developing systems with better resolution that require components capable of even higher bandwidth performance and as a result of this, the Amphenol RF HDBNC series has been optimized for excellent performance to 6 GHz. See Figure 13 showing a typical Return Loss plot for an HD-BNC connector with performance better than -35 dB DC-3 GHz and -26 dB 3-6 GHz.

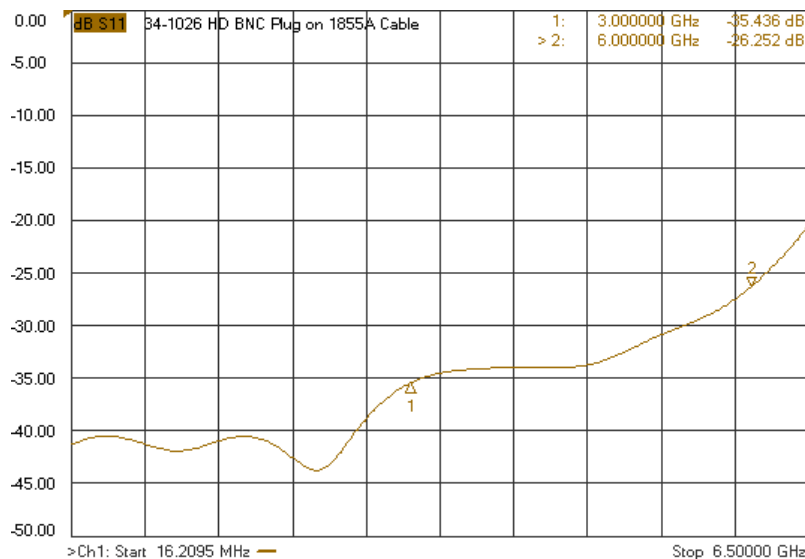


Figure 13

System vs. Component Requirements

The system requirements per SMPTE-292M and 424M are for the total system return loss. In any RF transmission line system, the individual component losses will add as vectors to create maximum and minimum return losses as a function of frequency depending on the distance between them and the velocity of propagation of the transmission line.

In the simplest case, a cable assembly that has 2 connectors with equal return losses of 30 dB will add and subtract with maxima and minima every $\frac{1}{2}$ wavelength. When they subtract, theoretically, the results will be an infinite return loss, and when they add, the results will be approximately 6 dB worse or 24 dB if we ignore the effects of the cable. Typical systems may have cable assemblies as well as connectors launched onto a PCB that contains significant RF circuitry. In order to minimize the effects of the connectors, the design goal for return loss is 30 dB at 3 GHz with performance typically 35 dB and much better than that at lower frequencies.

In fact, systems are usually much more complex than 2 connectors on a cable assembly. The system level challenge can be exemplified by expanding the theoretical case to 3 connectors with -25 dB Return Loss. The best method to calculate the impact of multiple components is to first convert the Return Loss to the Reflection Coefficient. In this case, -25 dB is equal to a Reflection Coefficient of .056. If the design of the system was such that at some frequency, all

of the reflections added in phase, then the resultant Reflection Coefficient would be $.056 \times 3 = .168$ which translates to a Return Loss of -15.49 dB. This leaves little margin and is why the individual component design must be optimized to have the lowest possible Return Loss. If the connectors were -35 dB, then the resultant would be -25.35 dB. The design goal of -30 dB for HD-BNC products allows for significant margin for system and hardware manufacturers.

Another system level factor to consider is transmission distance. Data transmitted over an RF carrier signal is primarily limited by the transmitter circuitry and the overall loss of the transmission line. In reality, a connector with reasonable Return Loss will have little impact in distance but validation is still important. Amphenol worked with Embrionix, a Canadian based company for Broadcast equipment, to confirm the ability of HD-BNC to allow industry leading data transmission. Embrionix manufactures the world's first production application of the HD-BNC in their EB30HD2R-LNR which is a 3Gbps dual receivers coaxial SDI reclocked SFP. Using this product a test was configured with a checkfield (pathological SDI test pattern) at 3G-SDI as shown in Figure 14. Even with the non-ideal test setup including 4 additional BNC cable adapters to construct the total distance, the test results showed a very positive result of 136.5 meters. With a continuous run of 1694A cable, 140 meters would be achieved.

Belden 1694A – Cable length test setup

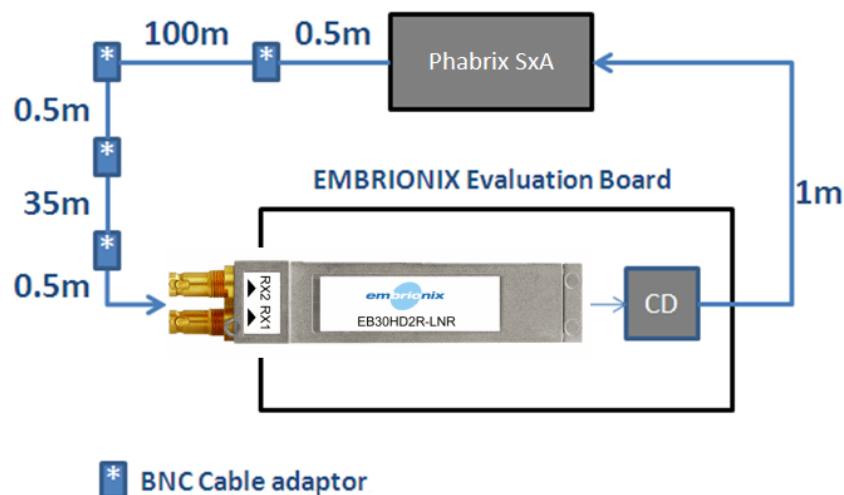


Figure 14

Design Analysis

In high bandwidth applications, it makes sense to select a connector that was designed from inception as a 75 Ohm interface and optimized with sophisticated finite element analysis software to adapt to standard cables and PCB configurations. Amphenol performs analysis on 100% of all connector products early in the design phase prior to prototyping or validation.

For cabled connectors the analysis consists of generating a 3D model of the connector transmission line attached to a model of the cable. Assumptions are made based on experience of how the connector and cable will fit together in the assembled state. Amphenol uses the FEA software, Ansoft HFSS to model and predict the RF performance through the combined transmission line. By using the advanced TDR (Time Domain Reflectometer) function of the software, the RF Engineers are able to tune out impedance mismatches. This results in

the lowest possible Return Loss and Insertion Loss in the final product. This low Return Loss allows the system to conform to SMPTE 292M and 424M standards with added margin.

The figure 15 shows a typical HFSS model. Figure 16 shows a TDR and Figure 17 depicts the iterative improvements in Return Loss through optimization of the transmission line geometry.

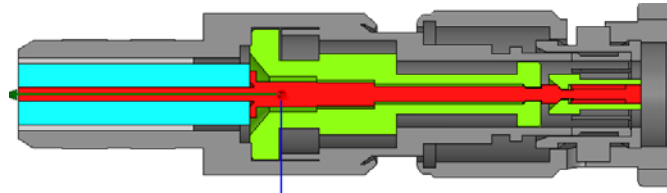


Figure 15: HFSS Model

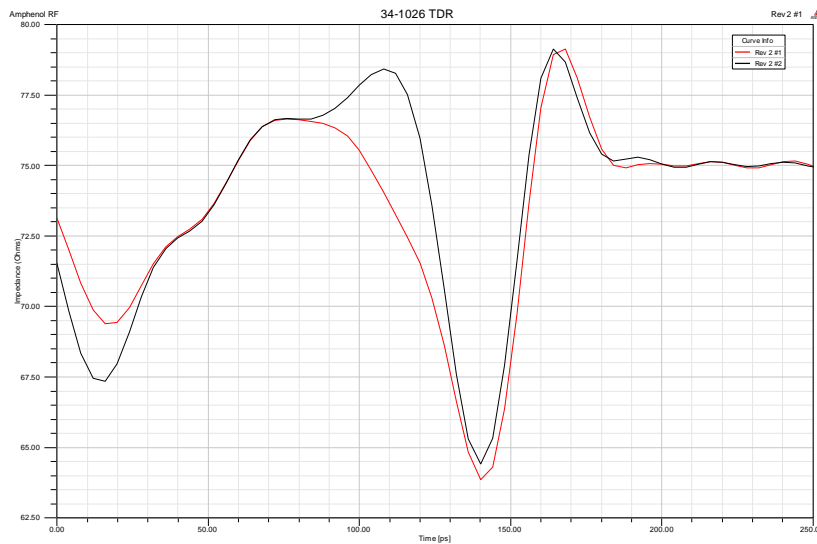


Figure 16: TDR

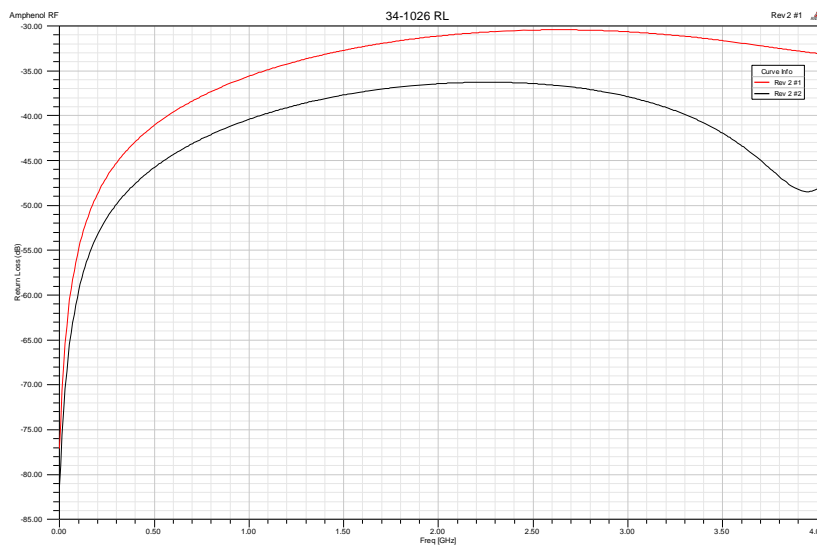


Figure 17: Return Loss

Most system designs require some sort of PCB connector implementation. This generally creates a problem since the connector manufacturer can only guarantee the performance of the connector up to the point of its launch onto the PCB. Impedance mismatches will occur at the launch and steps must be taken to minimize these mismatches. To achieve density, the proven PCB launch configurations used today for BNC connectors cannot be reused as they themselves are too large. High density connector alternatives require new smaller launches.

PCB Launches are difficult to specify and standardize because PCB construction can vary greatly from system to system and every different configuration of connector will require a custom launch design. Edge launch, through hole or SMT will all require different configurations and these will depend on the customer board configuration such as microstrip, grounded coplanar or stripline. Within those parameters there are additional variables such as whether the connector signal trace is on the same side of the board where the connector is mounted. Additionally, specific details such as board material, ground plane spacing, and the number of ground planes, board thickness and via requirements will all affect the impedance and thus the specific configuration of the launch.

Typically, connector manufacturers leave the PCB design up to the system designers. In this case, and to ensure a successful transition to a high density solution, Amphenol performed extensive FEA analysis using Ansoft HFSS to optimize each configuration. To build a library, Amphenol worked closely with Harris Broadcast to document the most common configurations in the industry. Each combination of PCB and connector were simulated and the optimum configuration was published for all customers to access.

Historically, the system designer must integrate a passive impedance matching circuit into a PCB to compensate for a poor launch or connector. With the design of the HD-BNC product line and the corresponding optimized launches Harris Broadcast Communications has been able to eliminate the matching circuit in at least one case. This was accomplished by optimizing both the connector and the launch for real world PCB applications. Figure 18 shows a typical return loss plot on a PCB from Harris Broadcast Communication with a 75 Ohm chip termination applied to the PCB trace.

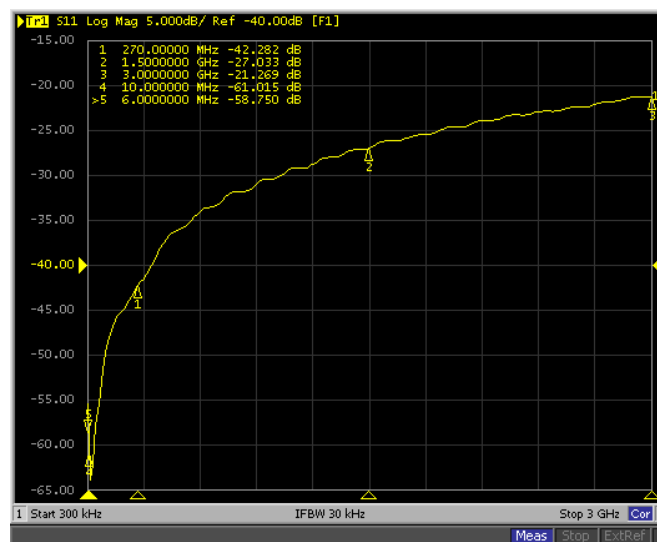


Figure 18: HD-BNC on System Board

For a PCB optimization, the process is similar to a cabled connector but more involved due to the complex geometry of the board and layers. First a 3D model is created as shown in Figure 19.

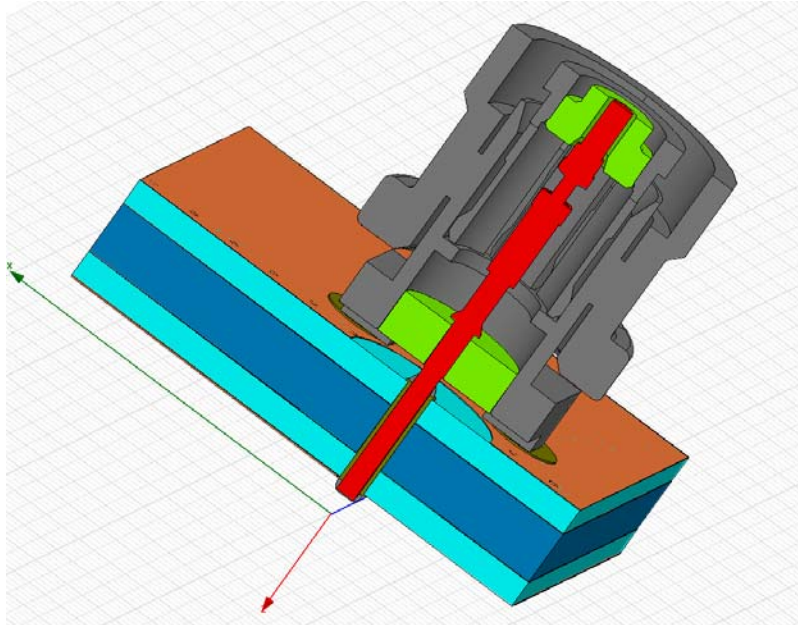


Figure 19: HFSS Model

Then, using Ansoft HFSS, a TDR and Return Loss (S11) plot is generated. The RL shows the true performance while the TDR acts as a design tool for the engineer to pinpoint impedance mismatches that can be tuned. Both Figures 20 and 21 show the performance improvements gained through optimization.

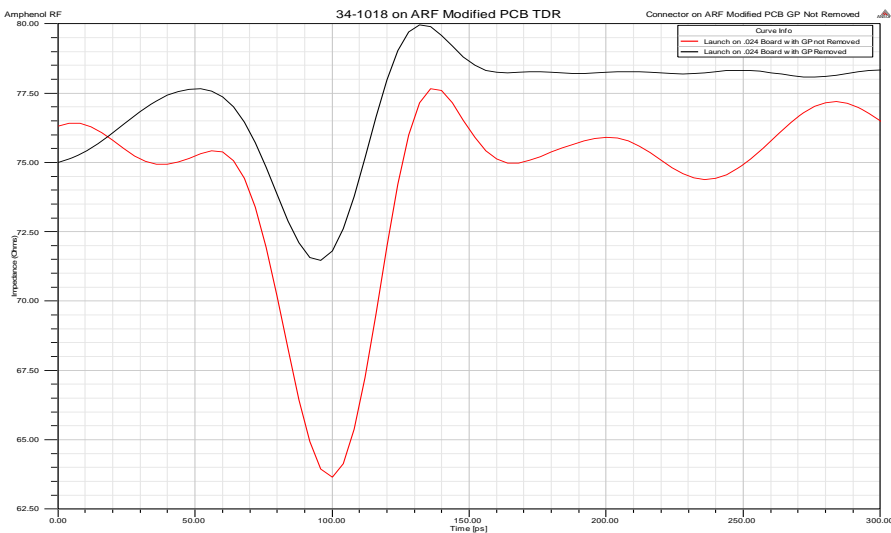


Figure 20: TDR

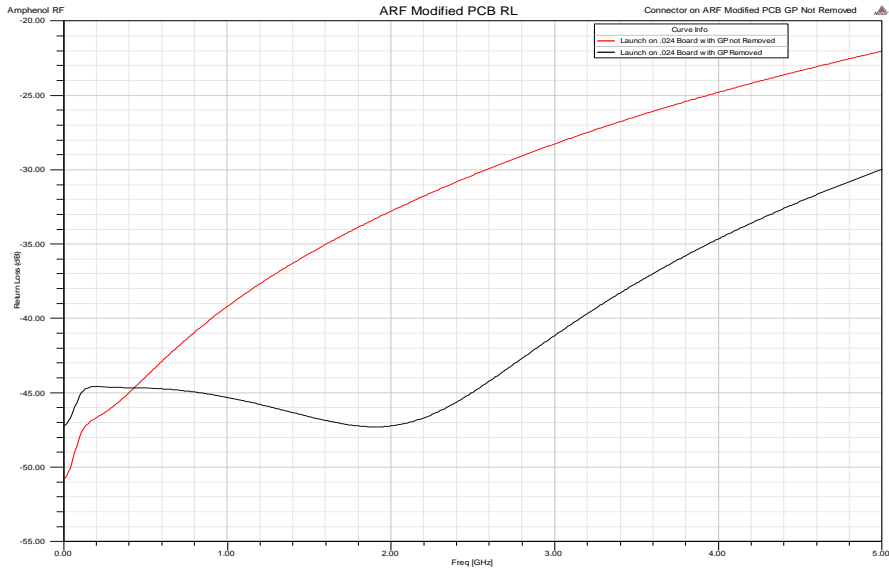


Figure 21: Return Loss

Once the PCB and connector are optimized, a highly detailed PCB footprint is published as shown in Figure 22. It is critical to note that the recommended launch only applies for the specific PCB configuration shown. Since a PCB is a transmission line, any change in the materials, geometry or dimensions of that line will result in a change in the loss characteristics. For applications that require variation from the published footprint, a new simulation must be performed to ensure optimum performance. Amphenol performs this simulation as a value added service to customers.

RECOMMENDED PCB LAUNCH FOR OPTIMAL RF PERFORMANCE

VARIATIONS IN BOARD SUBSTRATE AND TRACE MAY REQUIRE DIFFERENT GEOMETRY

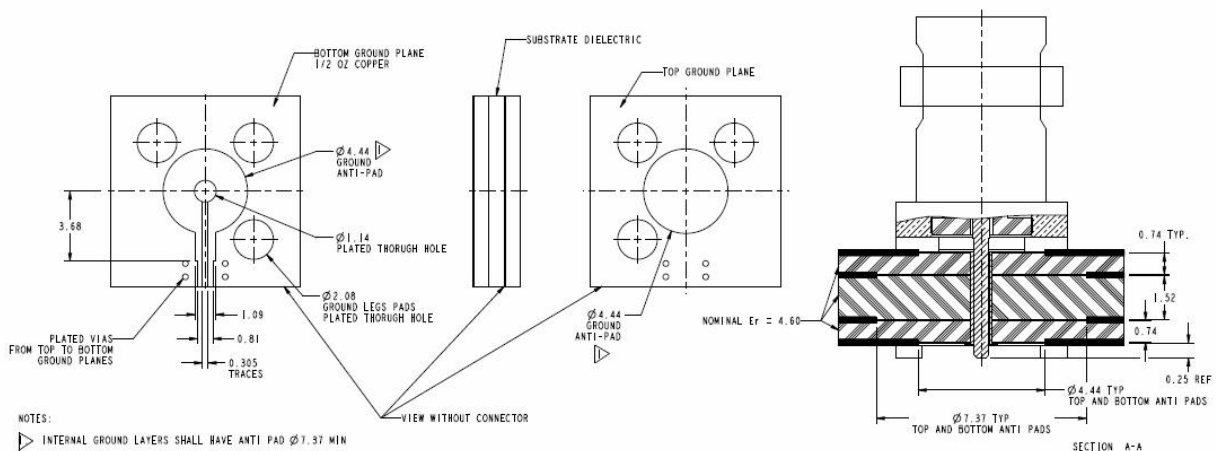


Figure 22

Connector Measurement

Evaluating the performance of connectors involves measuring their S parameters on a network analyzer. Network analyzers are available with various interfaces on the test ports. In 75

Ohms, the most common one is 75 Ohm Type N as this connector is a robust, repeatable, air interface for which there are well designed calibration kits available.

When calibration kits are not available for a particular series, well designed, low loss adapters are typically used to interface between the network analyzer test port and the connector under test. In addition, a verification kit may be used. A verification kit is one that has components that are not precise enough to meet the stringent requirements for a traceable calibration kit but acceptable for determining accurate performance while eliminating the errors introduced by an adapter. With the standard 75 Ohm BNC interface, some engineers prefer using well designed adapters while others prefer commercially available "calibration or verification" test kits.

Designing and manufacturing a true calibration kit is a very difficult and expensive undertaking involving precision modeling, simulation and manufacturing. In addition, determining the calibration constant/coefficients can be extremely difficult, especially parameters such as capacitance and inductance. Repeatability is also especially important and the standard BNC interface is known to be somewhat noisy as the interface is controlled by wave washers in the bayonet sleeve and tolerances can be difficult to control. The currently available "BNC Calibration Kits" generally leave a lot to be desired as true calibration standards with movement and fluctuations in the measurements a fairly common occurrence. Precise measurements in any connector series that is not threaded and tightened are difficult and not extremely repeatable particularly at low loss levels.

The HD-BNC connector, due to its bayonet twist and turn mating as well as closed entry insulator and smaller size than BNC makes it a more stable interface. In order to best confirm the performance of HD-BNC, several different methods of testing have been devised and implemented. Initially, precision designed test adapters were made from both Type N and BNC to HD-BNC. These adapters were then tested using the standard 75 Ohm Type N and 75 Ohm BNC cal kits commercially available. In addition, we designed various standards to be utilized in verification kits to duplicate and confirm these measurements.

Cal standards such as short, offset short, open, load and line were designed and manufactured. These components have been configured in several different styles of kits to allow calibrations to SOLT (short, open, load, thru), OSLT (offset short, short, load thru), TRL (thru, reflect, line) and TRM (thru, reflect, match). Each kit has various advantages.

The TRL kit is very advantageous for measuring terminations since the load is not one of the standards used in the calibration process. However, due to numerous restrictions on the components, the TRL kit is limited as to its low frequency limit and also may require lines of different lengths to cover the entire frequency range. Also, you must perform a 2 port calibration. Naturally, you can still do 1 port measurements.

The TRM kit is very useful as the 3 standards required are not overly difficult to make and characterize. This calibration will also work down to the minimum frequency capability of the analyzer. It also requires a 2 port calibration.

The OSLT requires 2 short standards instead of 1 short and 1 open as in the SOLT. The open normally has some parasitic capacitance that must be accounted for and is not always easy to characterize or measure.

Rigorous testing has shown that the adapters meet the simulated results very closely. The most difficult part of the process is the repeatability of the measurement due to variations when mating and un-mating the connector interfaces. However, the HD-BNC test kits are as repeatable in actual use as the commercially available BNC "cal kits".

User Experience

Ultimately, for a new interface to be adopted, the user experience must be positive. The key aspects that impact the user experience are mating style, installation tools, cable compatibility, and termination tooling.

Mating Style

Again, working with Harris Broadcast Communications, the industry preferences in each of these categories were determined and then integrated into the design of the HD-BNC. The most prominent feature of the HD-BNC is the bayonet style mating. Users of the BNC, especially field installers are very familiar and comfortable with this mating style. Incorporating this mating style in a high density variant was a mandatory requirement during the development.

A secondary advantage of the bayonet is the ability to validate the mated condition visually. The HD-BNC features two full axial grooves on the outer surface which are oriented to bayonet lug engagement features as shown in Figure 23. This allows a user to inspect the mating condition of many connectors with a clear visual indication.

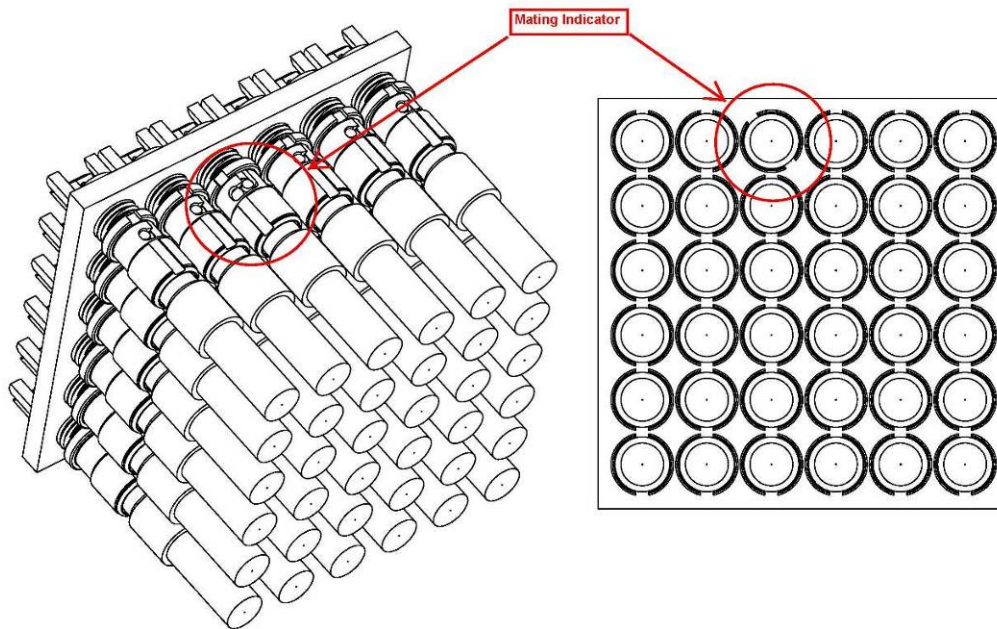


Figure 23: Mating Indicator

The 1.0/2.3 uses a push lock mating mechanism. This means that the connector can be pushed to mate but the outer coupling sleeve must be retracted with a pulling force to disengage the interface. If the sleeve is not engaged, the connector is locked and can resist mild axial cable loads. If the connector is forcefully dislodged the assembly will usually display some sort of cable or interface damage. While this mechanism is effective, it is not familiar to the majority of users in the industry and therefore has limited adoption rates.

The 1.0/2.3 does not offer any visual confirmation of mating condition. This can be a limitation especially in high connector count arrays. The only method to confirm mating is by pulling on the cable after mate.

Installation Tools

The BNC and Mini-BNC product lines are both augmented with an installation tool with very similar function. It slides on from the cable side of the connector along the axis of the cable, fits over the coupling sleeve, and then is actuated by a twisting motion. The HD-BNC tool, as shown in Figure 24, maintains this basic operability whereas the 1.0/2.3 requires a pulling motion to de-mate the interface. Therefore commonly available tools for the 1.0/2.3 series are engaged from the side of the coupling sleeve and then pulled with an axial force away from the mated pair to disengage the mechanism.

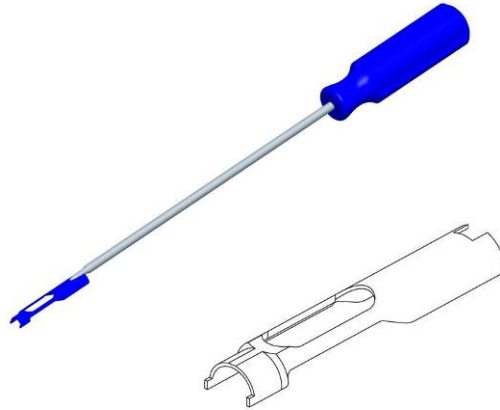


Figure 24: HD-BNC tool

Cable Compatibility

The market investigation revealed that there are four commonly available cables used in the market. They are Belden® types 1694A, 1855A, 1695A, and 1505A. As legacy products, the BNC and Mini-BNC series have broad offerings for these standard cable types. HD-BNC also supports all of these cables. In markets outside North America, there is great variation in popular and available cable types. The HD-BNC product line will be expanded to all cable types as systems are deployed in those regions.

It should be noted that the most challenging cable to accommodate in a high density interface is the 1694A type but compatibility with this cable is key to user experience and product acceptance. The larger cable types like 1694A are needed for transmitting data over longer distances but the size can pose issues with the connector and density. This cable has an outer diameter of .275" (7 mm). This is a limiting factor when considering the size implication in the mechanism used to attach a connector to cable. The most common configuration in the industry consists of a loose tubular "crimp ferrule" which is positioned over the cable outer braid and crimped using a hex die tool to compress and therefore attach the braid to the connector body. This adds considerably to the connector diameter. With the HD-BNC series, much effort was taken to minimize this increase. Also, the tool shape was optimized to accommodate this larger cable even in a dense array. Even with this optimization, the minimum density in an array is 9.5mm using 1694A cable.

There is no broadly available 1694A compatible product in the 1.0/2.3 series today.

Termination Tooling

Another crucial user experience is the termination of the connector onto cable. Especially with respect to the field installers, the tools, techniques and procedures used to attach connectors in the field has been established by BNC and Mini-BNC in the market. HD-BNC has been designed to use all industry standard tools and procedures existing today. This includes, cable strip dimensions, strip tooling, and hex crimp dies.

Conclusion

Modern Broadcast equipment and systems require higher connector density to meet the latest technology demands. There are multiple options available to achieve higher density but it is critical that manufacturers understand the benefits and limitations of each. It is in the best interest of the industry to standardize on one interface to minimize wiring in the plant and to achieve compatibility with equipment.

In the critical categories of density, robustness, bandwidth, and user experience, HD-BNC is a superior option for next generation Broadcast systems. However, the 1.0/2.3 connector has been deployed in some system platforms over the past years. Manufacturers and the industry as a whole must make a decision on which interconnect standard will offer the greatest benefit to current and future system architectures.

Acknowledgements

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SMPTE-424M-2006 "3 Gb/s Signal/Data Serial Interface"



HIGH DENSITY INTERCONNECT STANDARDS FOR NEXT GENERATION BROADCAST NETWORKS

Owen Barthelmes, Amphenol RF

Introduction

Interconnect Solutions

- BNC
- Mini-BNC
- 1.0/2.3
- HD-BNC

Industry Challenges

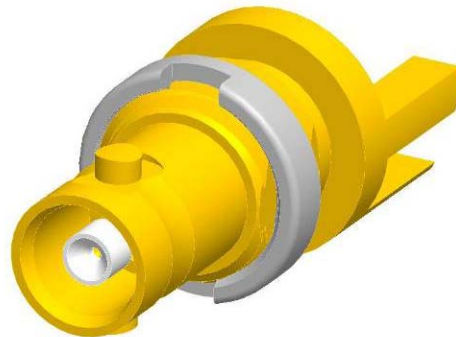
- SMPTE 292M & 494M
- Technologies – 3G SDI/3D
- Higher Bandwidth
- Reduced Footprint



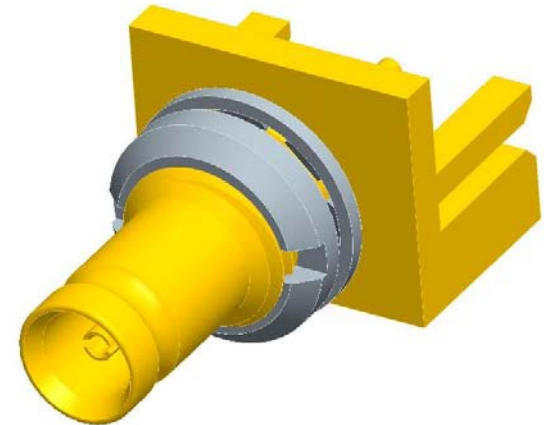
Advancing the
Global Professional
Standards of the
Industry

Key Performance Factors

- Density
- Robustness
- Bandwidth
- User Experience



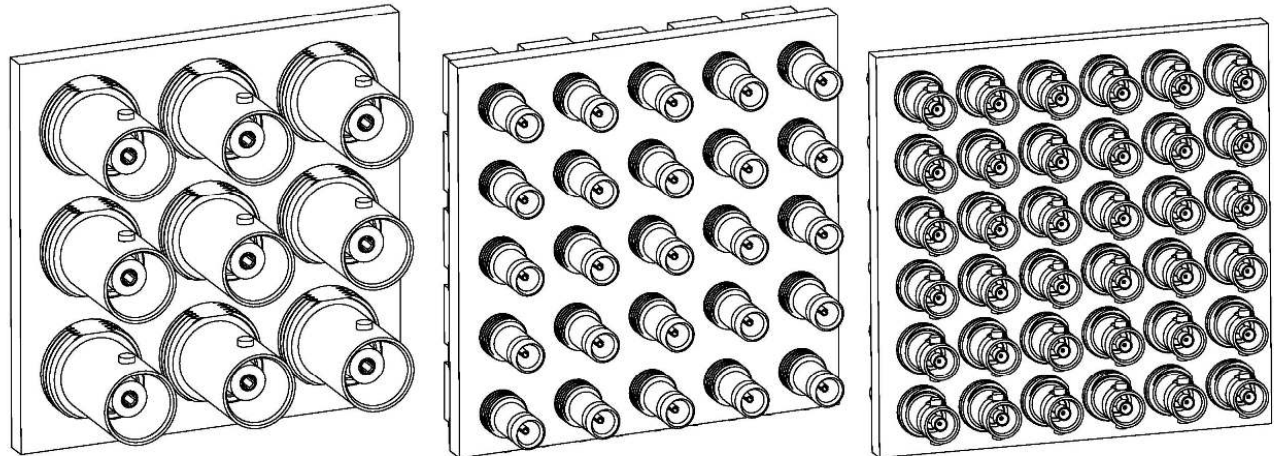
HD-BNC



1.0/2.3

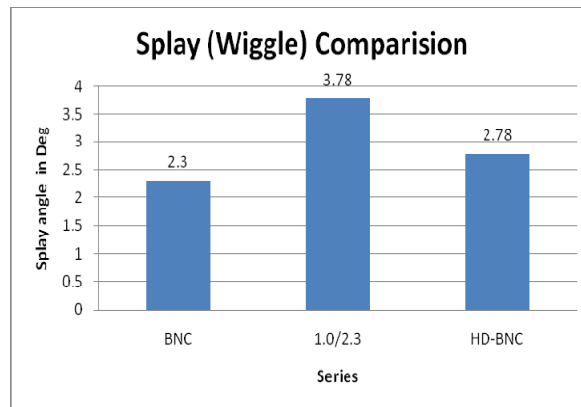
Density

- BNC
 - 15.5mm
- Mini-BNC
 - 13.1mm,
 - 40% density
- 1.0/2.3
 - 10mm
 - 250% density
- HD-BNC
 - 8mm
 - 400% density



Robustness - Mechanical

- Angle Splay
- Wiggle
- Side to Side Movement

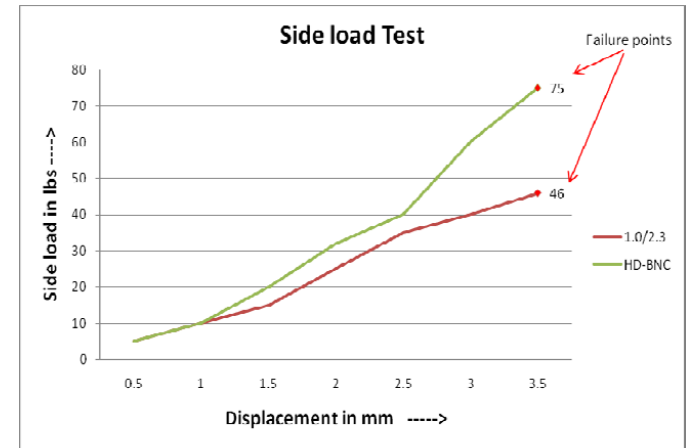
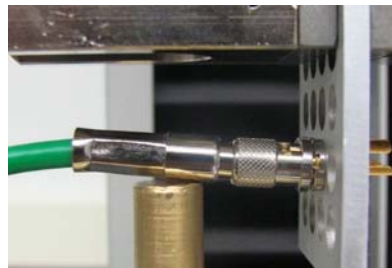
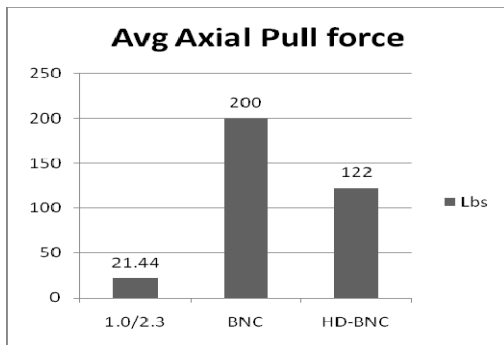


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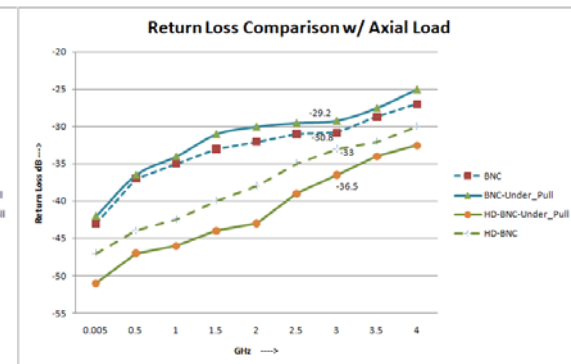
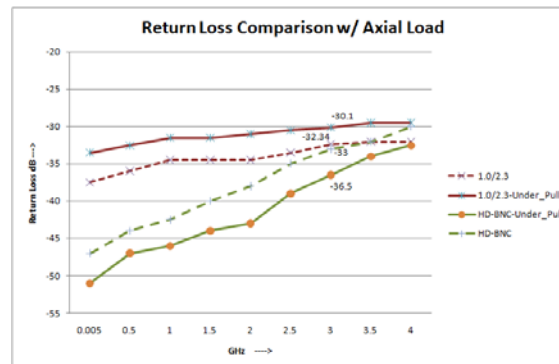
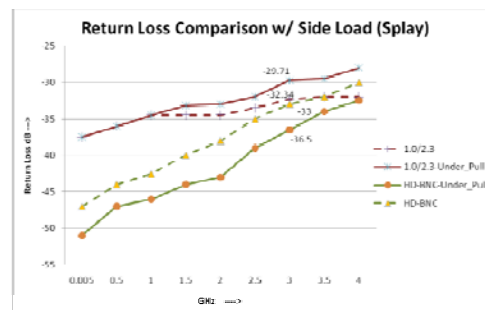
Robustness - Mechanical

- Axial Pull Force
- Side Load Resistance



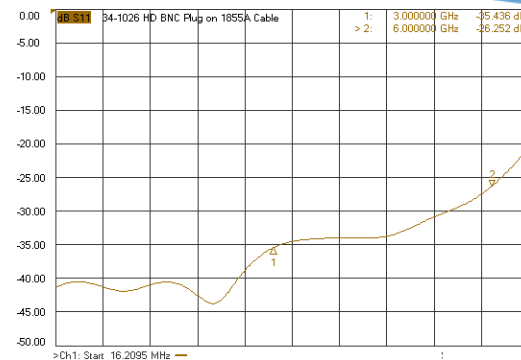
Robustness - RF

- Performance under mechanical stress
- Side Load
- Axial Load
- RL Variation

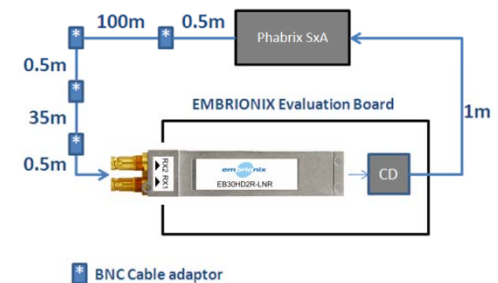


Bandwidth

- SMPTE 292M & 424M RL
 - -15 dB from 5 MHz to 1.5 GHz
 - -10 dB from 1.5 GHz to 3 GHz
- System vs. Component
 - -30dB Design Goal
 - 3 connectors with -25dB RL
 - $RC = .056 * 3 = .168 = -15.5\text{dB}$
- Data Transmission Length
140meter+

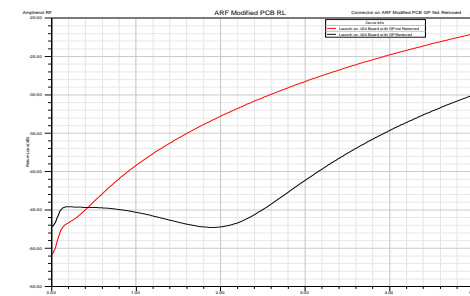
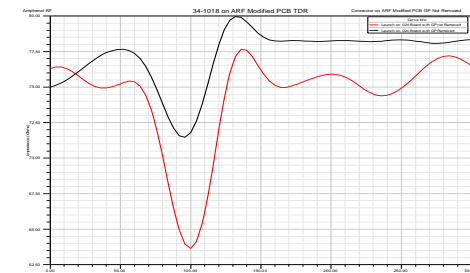
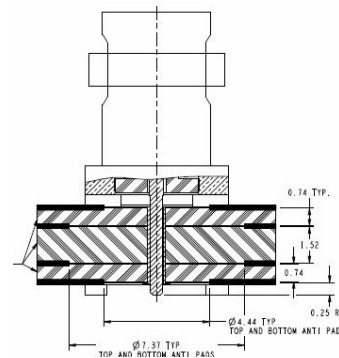
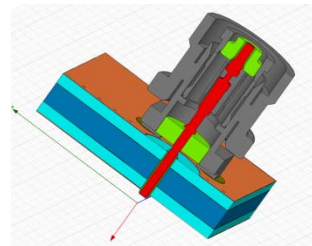


Belden 1694A – Cable length test setup



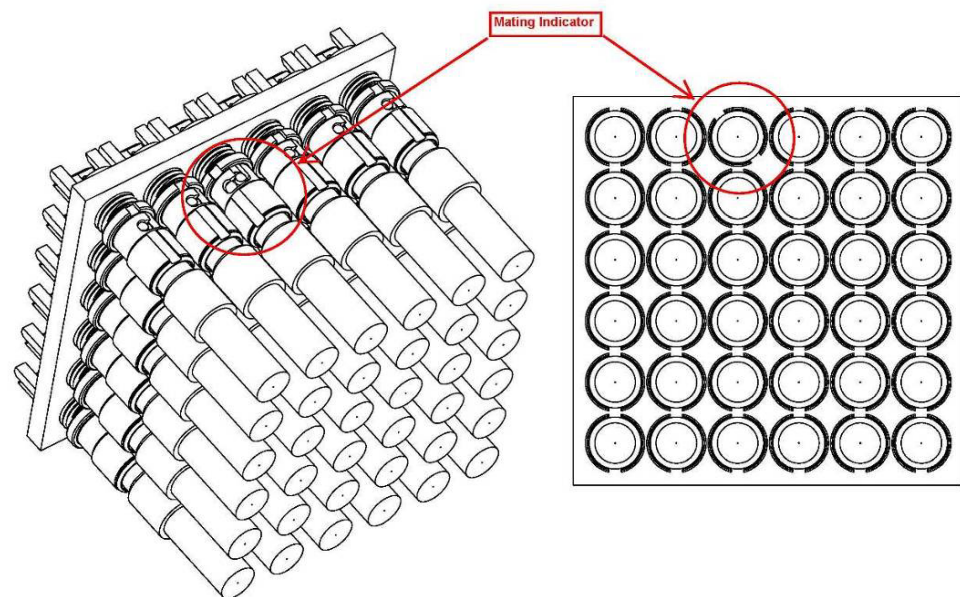
Analysis and Measurement

- HFSS 3D Model
- TDR
- Return Loss
- PCB Launch Optimization
- Test Kits
 - SOLT, OSLT, TRL, TRM
 - Insertable Adapters



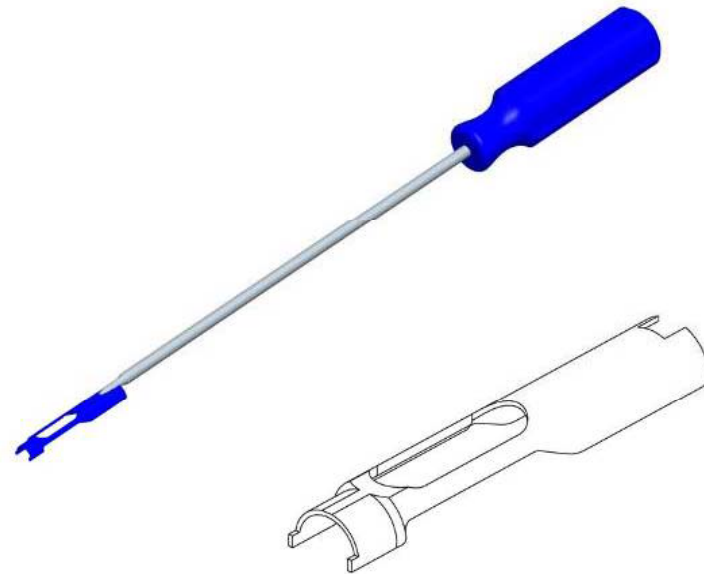
User Experience

- Mating Style
 - Bayonet
 - Push-Pull
- Visual Indicator



User Experience

- Installation Tool
- Cable Compatibility
 - Belden 1694A
 - Image 1000
- Field Termination Tooling
 - Industry Standard



Conclusion

- Clear requirement for higher density
- HD-BNC outperforms
 - Density
 - Robustness
 - Bandwidth
 - User experience
- The industry must decide

