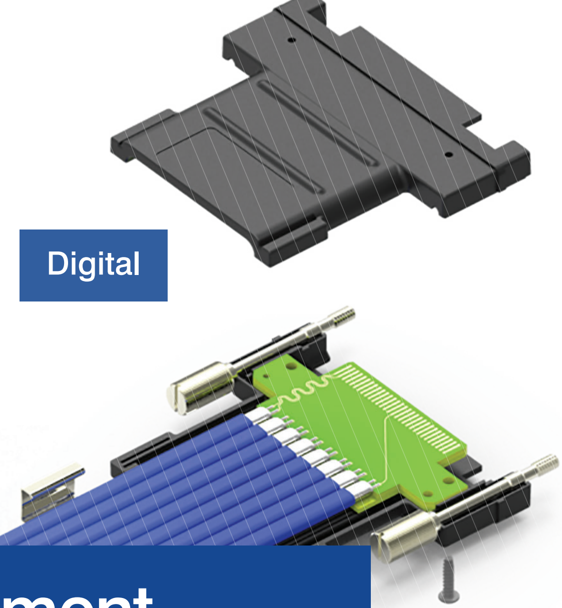

Test & Measurement
Applications & Design Guide

That's **Performance** with **Purpose**

CARLISLE®
INTERCONNECT TECHNOLOGIES

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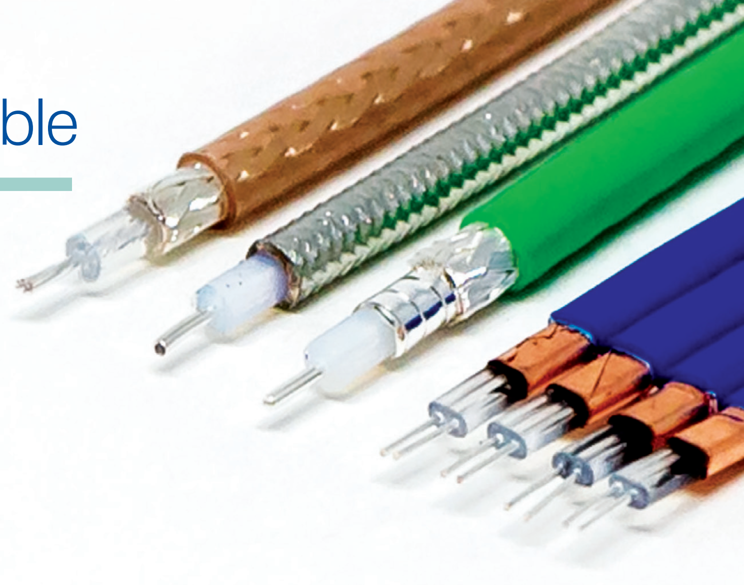
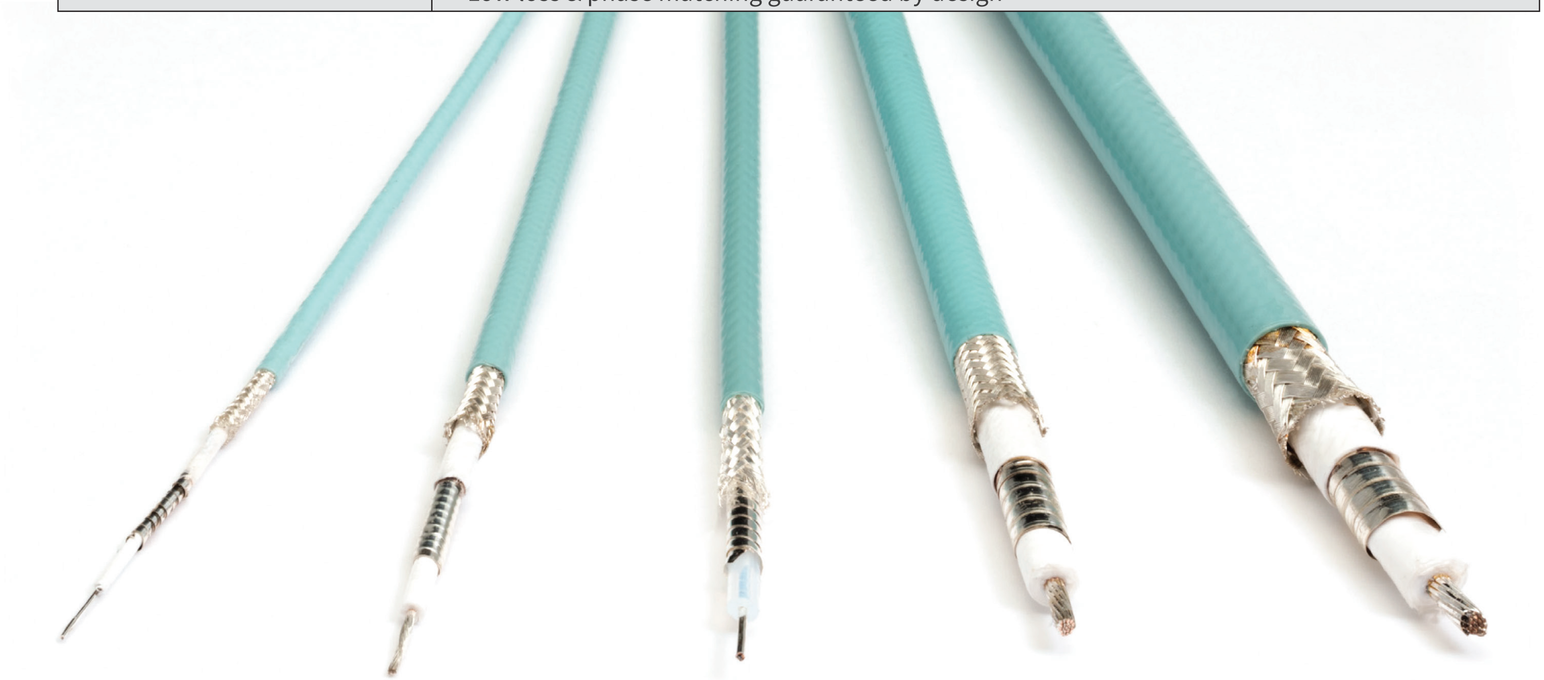
CARLISLE INTERCONNECT TECHNOLOGIES

High-Performance Wire & Cable



Carlisle Interconnect Technologies offers a complete line of high-performance, flexible microwave cables with excellent loss characteristics, outstanding phase stability, and unsurpassed flexibility compared to standard flexible cables—all without sacrificing mechanical integrity. CarlisleIT has greatly increased connector reliability through a unique connector attachment that withstands mechanical and thermal stresses far better than standard connectors. Features and benefits of RF cables typically used in Test & Measurement applications are summarized in the table below:

Product Type	Customer Features & Benefits
Flexible Cables	» Versatile low-loss cables operating up to 70 GHz » Excellent shielding effectiveness & precision phase matching
Semi-Flex/Conformable Cables	» Hand-formable cables with lower leakage & improved bending radius compared to semi-rigid types
Semi-Rigid Cables	» Benchmark by which all other RF cables are measured » Highest RF shielding & lowest attenuation
RG Cables	» High reliability with excellent crush, torque & kink resistance for rugged use
Armor Braid	» Excellent crush, torque & kink resistance for use in rugged environments
Twinax	» Suitable for 100 Ohms differential signaling » Low loss & phase matching guaranteed by design



UTi-FLEX-HF Coaxial Cables

High-Performance Wire & Cable

Overall length of a coax cable assembly is measured from connector reference plane to connector reference plane as shown in Figure 1 below:

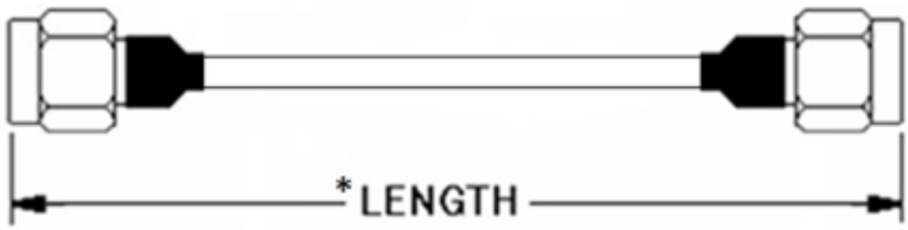


Fig. 1

Typical insertion loss and return loss for a 12-inch high-performance .079-inch RF coax cable with a 1.85 mm connector on each is shown in Figures 2 and 3, respectively. It is a coax cable with a solid center conductor and a .079-inch outer shield. With very low insertion and return losses, it offers excellent signal integrity over a wide range of operating frequencies (DC to 65 GHz).

Fig. 2: Insertion loss of a .079-inch RF coax

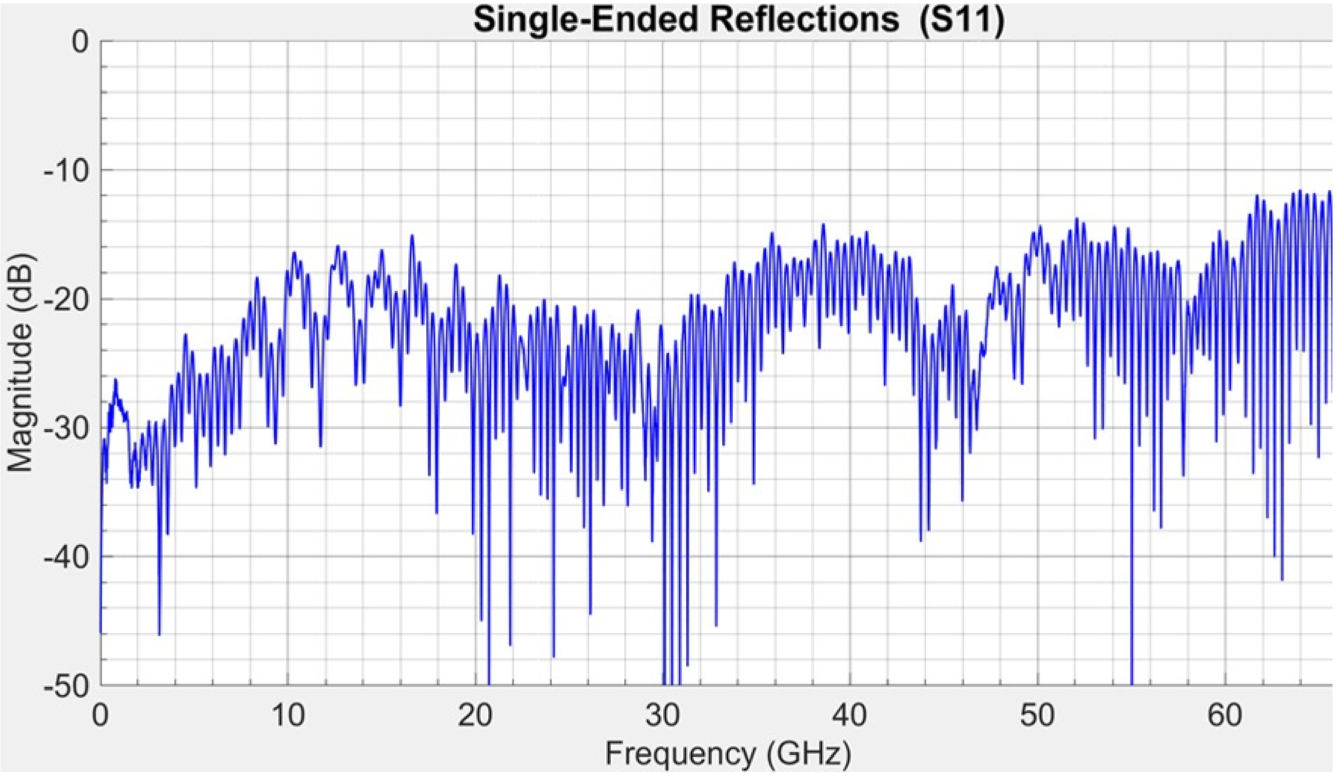


Fig. 3: Return loss of a 0.079-inch RF coax

In electronic signaling, phase is defined as the position of a point in time (instant) on a waveform cycle.

A complete cycle is defined as 360 degrees of phase as shown in Figure 4. Phase can also be an expression of relative displacement between or among waves with the same frequency.

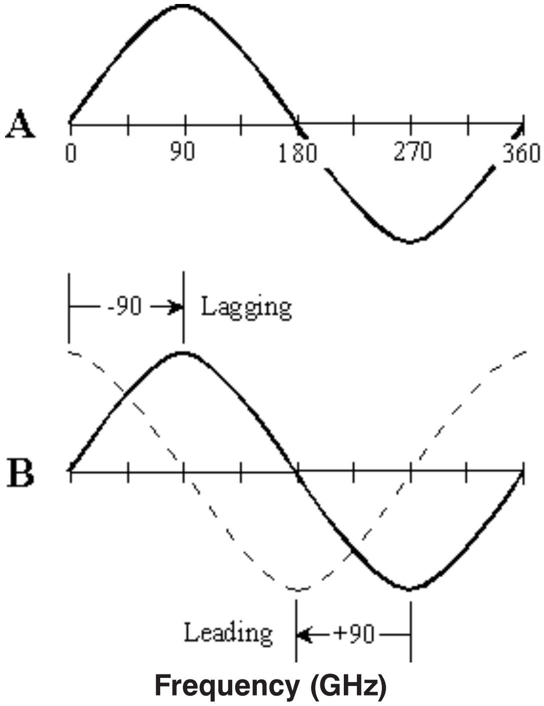


Fig. 4: Phase cycle of signal

Phase difference between two signals, also known as phase angle, is typically defined in degrees. It can be greater than -180 degrees and less than or equal to 180 degrees. Leading phase refers to a wave that occurs “ahead” of another wave of the same frequency. Lagging phase refers to a wave that occurs “behind” another wave of the same frequency. Phase or Phase Shift is the amount of time taken by a wave front to travel a certain distance in a medium.

For a certain physical length of cable, there is electrical length as well. Electrical length of a cable depends on the velocity of propagation (Vp), wavelength, and physical length. Cables that have identical physical lengths but different Vps will have different electrical lengths. Consider this as an example: You have a 10-foot cable assembly for use up to 18 GHz. Further, assume that it has a nominal Vp of 82% but, due to manufacturing or material variations, the Vp can range from 81% to 83%.

Recall that in free space C=f*λ, where C is the speed of light (approximately 3* 108m/sec), f is the frequency in Hertz, and λ is the free space wavelength in meters.

At 18 GHz, the wavelength is 0.0167 meters. Within the coaxial cable, the effective wavelength is Vp * λ, or 0.0137 meters. Our hypothetical 10-foot cable with a Vp of 82% is 223.1 wavelengths long. Each wavelength is a 360-degree phase shift, so the electrical length is about 80,316 degrees.

If we repeat the calculation with the Vp reduced to its 81% limit, the effective wavelength is 0.0135 meters. The same 10-foot length is now 225.8 wavelengths long with a corresponding phase shift of about 81,288 degrees.

Phase matching in coaxial cables depends on many variables such as highest frequency of operation, length of cable assembly, variation of velocity of propagation, temperature, connectors, and test equipment accuracy. The electrical length of a Teflon dielectric coaxial cable assembly changes as a complex function of temperature. Over most temperature ranges, the higher Vp cables exhibit smaller phase changes than the lower Vp cables.

There are two ways to phase match cables:

1. Match to a standard
2. Match to other cables in the set

The cable assemblies can be phase matched to a gold standard with a known electrical length in degrees at a specific frequency. Such cable assemblies are totally interchangeable. With this approach, any cable within a set can be replaced without having to replace the remaining cables within the set. However, yield can be low and the price can be high.

Cable assemblies matched as a set are only guaranteed to be matched to other cables in the same set. There is no guarantee that the cables in any one set will match those of another set, especially if they are manufactured at different times. This approach results in the lowest cost because cable yields are highest. The drawback is that if any one cable of a set needs to be replaced, the entire set must be replaced.

High-Performance Wire & Cable

CarlisleIT offers cable assemblies that are extremely phase-stable over a wide range of temperatures. Thermal chambers are used to test the phase variation over a range of temperatures.

At CarlisleIT, cable assemblies are also tested for any phase, loss, and impedance changes with bending and flexing using VNA and/or PNA. Several sizes of mandrels are used to wrap the flexible assemblies and retest for phase changes. High-stress flex cycle testing is done using 1-inch mandrels on the Dual Mandrel Flex Fixture. The tensioner is adjusted for an equivalent pull force of 1 pound or a 1-pound weight is attached to one end of the cable, and the cable under test is installed on the test fixture. The cable is flexed for 500 cycles of +/- 90 degrees around the mandrels. The cable is then removed from the fixture and is measured for insertion loss, VSWR, and phase. The results are found to be within the specified limits. The above procedure is repeated for increments of 500 up to 2,000 cycles, and then in increments of 1,000 up to a total of 10,000 cycles, provided no degradation is visible in the electrical performance of the AUT (500, 1000, 1500, 2000, 3000, 4000, 5000, 10000).

As an example, Figure 5 shows the test setup and Figure 6 shows the variation in characteristic impedance of 50 ohms for an ETD105E coax cable after 5,000 and 10,000 bend cycles over a certain period of time. ETD105E is a high-quality coax cable from CarlisleIT with a stranded center conductor and a tape-wrapped dielectric. The comparison with initial reference of 50 ohms impedance shows minimal/ negligible variation in characteristic impedance of 50 ohms after 5,000 and 10,000 bend cycles, making it an extremely stable coax cable for high-stress applications.

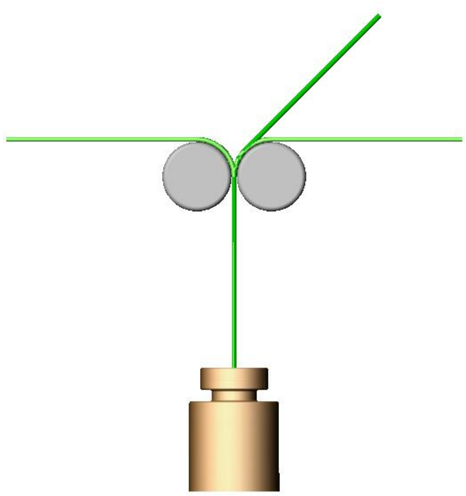


Fig. 5: Test setup for high-stress flex testing

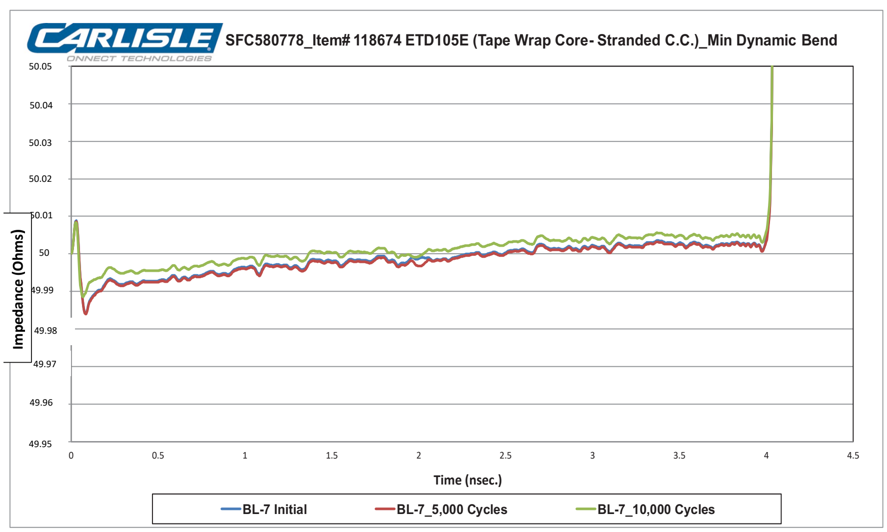


Fig. 6

Phase change can also be measured in degrees by bending and flexing the cable assemblies. For example, Figure 7 shows the typical phase change vs. bending of a .079-inch coax cable when it is wrapped 360 degrees around a 3-inch mandrel.

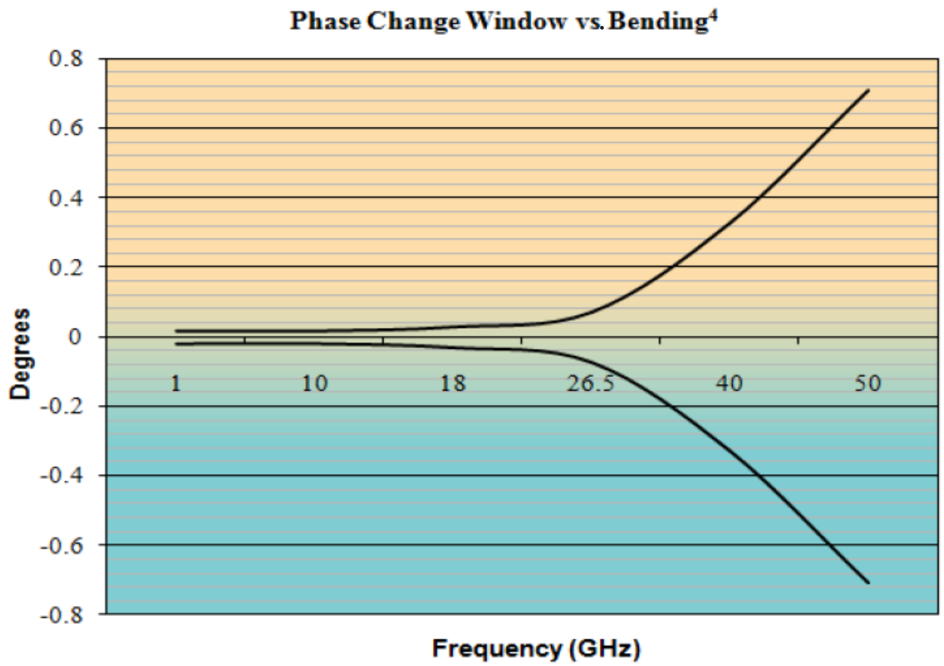


Fig. 7

For complete RF Cable assemblies portfolio, please visit:
carlisleit.com/products/cable-assemblies-harnesses/rf-microwave-cable-assemblies

RF Products

The extraordinary phase stability seen at high frequencies makes the .079-inch coax cable an ideal choice for high-stress applications.

CarlisleIT offers multiple configurations for RF cable jumpers with 1.85 mm, 2.40 mm, 2.92 mm, and 3.50 mm connector types on .079-inch coax. This product offering is part of our Supermarket Products portfolio, which makes them ready to ship within two weeks. The part number ordering nomenclature for coax jumpers is shown below for reference:

Fill in the part number to the right

TM [7] - [ ] [ ] [S] - [ ] [ ] [S] - [ ]

Cable Type

7	.079-inch Coax

Connector 1

4	2.40 mm (50 GHz)
5	3.50 mm (26.5 GHz)
8	1.85 mm (65 GHz)
9	2.92 mm (40 GHz)

Connector 1 Gender

M	Male
F	Female

Connector 1 Orientation

S	Straight

Connector 2

4	2.40 mm (50 GHz)
5	3.50 mm (26.5 GHz)
8	1.85 mm (65 GHz)
9	2.92 mm (40 GHz)

Connector 2 Gender

M	Male
F	Female

Connector 2 Orientation

S	Straight

Length (in inches)*

031	12 inches of
046	18 inches of cable
061	24 inches of cable
091	36 inches of cable
100	39 inches of cable
122	48 inches of cable

CONNECT WITH US TODAY

See CarlisleIT's line of Test & Measurement products at:
carlisleit.com/markets/test-measurement

Applications of RF Cable Assemblies

RF cables are used in a variety of applications, including ATE systems, emulation systems, adapters and pitch translators, antenna systems, navigation, and feedback. They are also used in amplifiers, microwave antennas that need high shielding, and RF test enclosures with tight spacing. When it comes to electronic systems, these cables are used to create short delays in RF/microwave systems, carry RF signals on PCB, used for board-to-board signal transmission, for radar and differential signal propagation, and to transmit/receive high-frequency signals in oscillators, amplifiers, and subsystems. Other common applications include satellite and security camera systems, home cable TV systems, and lab test environments.

For complete RF cable assemblies portfolio, please visit:
carlisleit.com/products/cable-assemblies-harnesses/rf-microwave-cable-assemblies

RF Products

High-Density RF Ganged Interconnects

CarlisleIT offers high-density CoreHC™ and CoreGD™ multichannel test-point systems targeted for high-density boards where space is limited. These products result in reduced trace lengths and higher signal integrity compared to boards using traditional SMA-type connectors.

CoreHC is a compression force interconnect system with a 2.5 mm channel spacing that can be attached directly to the board without a connector. CoreGD is a typical male/female, mate/demate-type interface using SSMP and WMP connectors (Figure 8).

CoreHC™	CoreGD™
Compression force type board interface	SSMP & WMP type board interface
2.92 mm & 1.85 mm cable side connectors; 2.5 mm pitch	1.85, 2.92 & 2.4 mm cable side connectors; 4 mm pitch
Vertical, edge mount & board-to-board options	Vertical, edge mount & board-to-board options

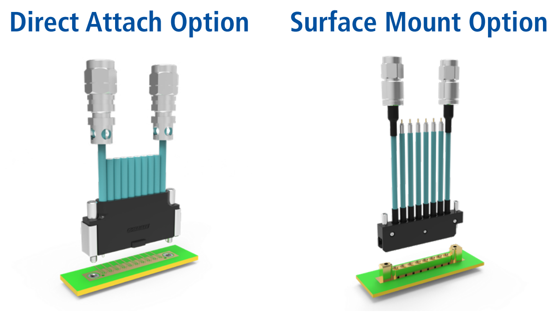


Fig. 8

Both CoreHC and CoreGD solutions are available in .047-inch and .087-inch flexible coax cables. Availability of two different types of coax cables allows the customer to have the design flexibility to choose a desired combination of cable flexibility and target loss profile for the interconnect. CarlisleIT offers phase matching between cables in a pair or in a set of desired number of cables down to pico seconds for designs with tight timing tolerances and budgets at high frequencies. Figure 9 shows the insertion loss of a 28 cm (.079-inch) coax cable assembly and cable assembly along with the trace loss. Return loss for the same CoreHC coax assembly is shown in Figures 11 and 12.

CoreHC Interconnect Solutions

CarlisleIT uses a unique compression-type connector interface in its CoreHC interconnect products. The connector is designed with a cutout in the outer shell so that PCB traces can make contact with the center conductor in the coax structure in Coplanar Waveguide designs. However, the same connector is used for stripline designs, where traces are buried in layers inside the PCB and not on the surface. With compliance of approximately 1/25000th of an inch on both the center conductor and outer GND shells moving independently from each other, the CoreHC makes an effective contact with the traces in both CPW and stripline designs, resulting in excellent signal integrity. Figure 13 shows the cross-section of a CPW board and CoreHC connectors making the contact with the traces. Use of a common connector body for CPW and stripline designs results in economies of scale, yielding better cost and lower lead times.

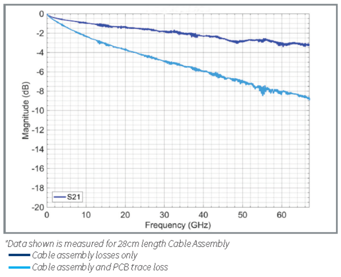


Fig. 9: Insertion loss of a 28 cm .079-inch coax CoreHC channel and cable assembly along with the trace

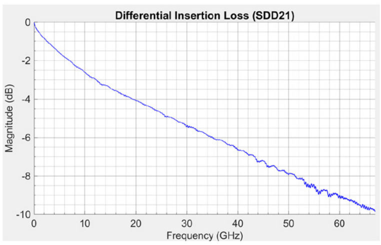
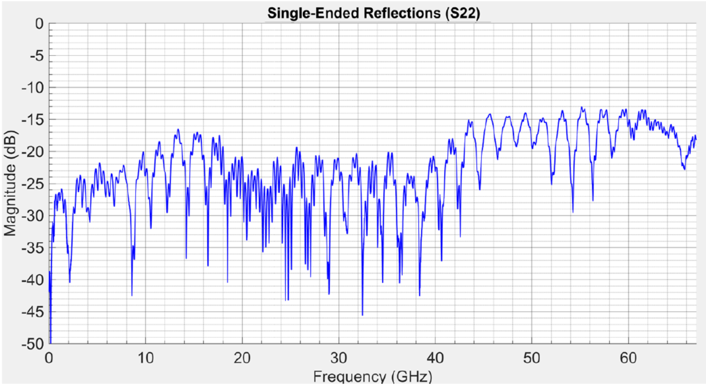


Fig. 10: Differential insertion loss of a CoreHC interconnect using a .079-inch coax cable

The measured differential insertion loss for the CoreHC cable assembly is shown in Figure 10. Note the smoothing of the insertion loss curve in the graph with no spikes.

RF Products

When it comes to return losses, it can be seen from Figure 12 that less reflections from load and source side are seen traveling on the channel in case of differential traces compared to the single-ended design.



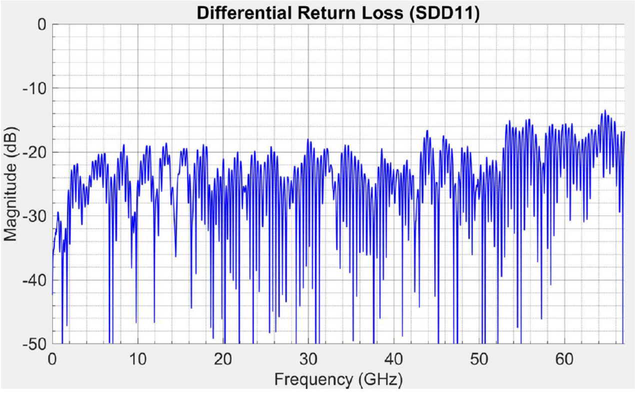


Fig. 11 (Left) and Fig. 12 (Right): Comparison of single-ended and differential return losses of the CoreHC assembly

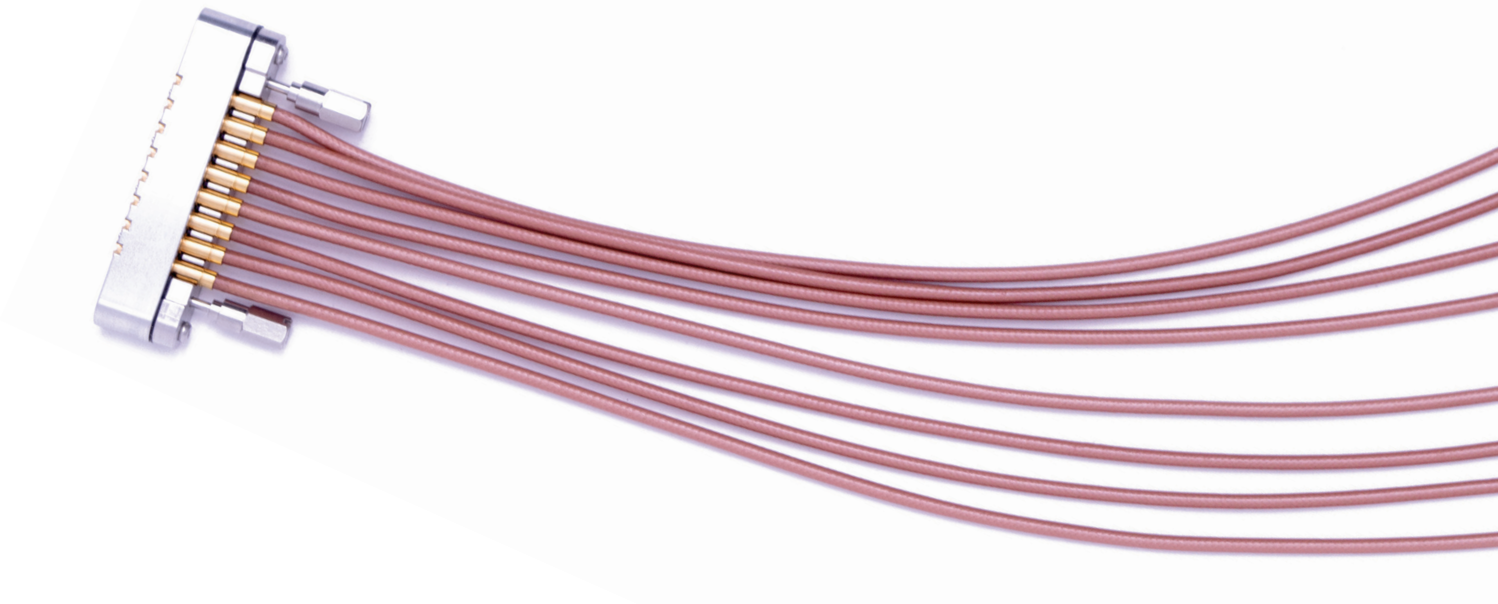


Figure 13 shows a PCB section of a CoreHC interconnect and coplaner waveguide traces.

Fig. 13: CoreHC interconnect on a CPW PCB cross section

Near-end crosstalk can be defined as the coupling of unwanted signals between the two adjacent ports on the same side of the interconnect network as shown in Figure 14 below.

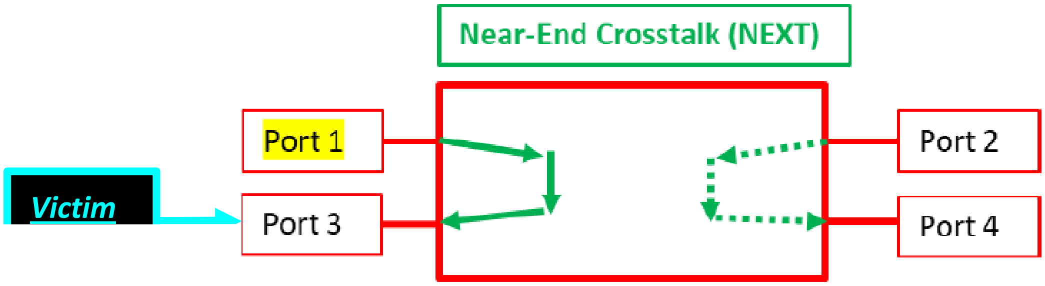


Fig. 14: Near-end crosstalk in two-port interconnect network

In this case, ports 1 or 2 are aggressor ports and ports 3 and 4 are victim ports since the active signals from ports 1 and 2 get coupled to idle ports 3 and 4.

Similarly, far-end crosstalk can be seen as the unwanted coupling of signals from an input port on one side to the output port on the other side of an interconnect as shown in Figure 15.

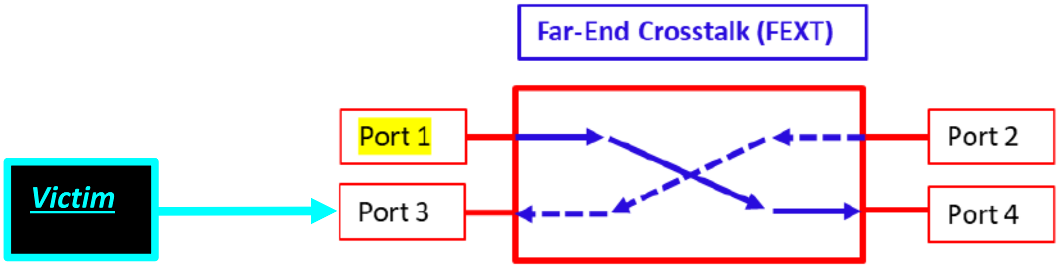


Fig. 15: Far-end crosstalk in two-port interconnect network

Figure 16 shows the same two-port CoreHC interconnect setup on a coplaner waveguide PCB. CarlisleIT optimizes the board layout to minimize both the near-end and far-end crosstalks. Size (i.e., length, width) and spacing of the trace are controlled along with the size and spacing of stitching vias alongside the trace lengths. CarlisleIT offers complete board stackup and layout database in ODB++ format for both CPW and stripline designs to achieve low losses and crosstalk in customer systems.

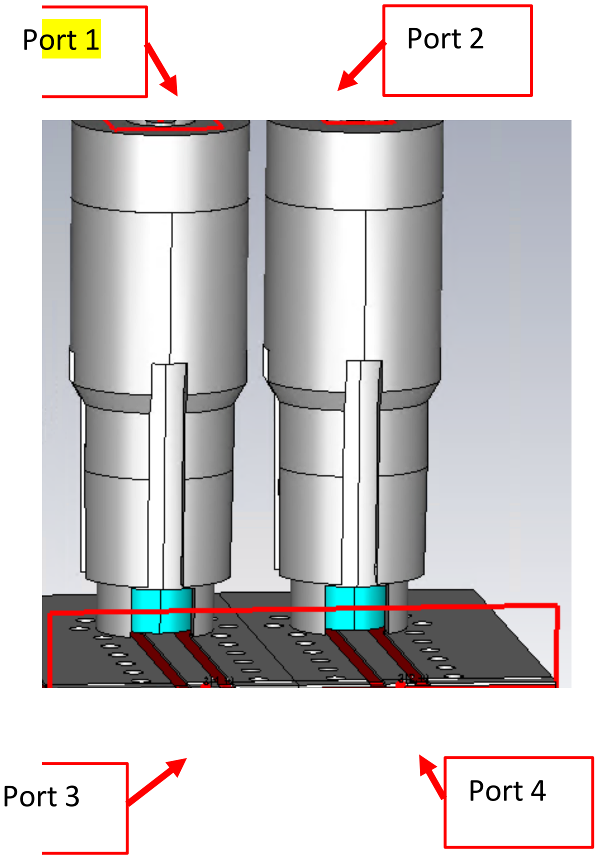


Fig. 16: Two-port CoreHC interconnect setup on a coplaner waveguide PCB

RF Products

Resulting near-end crosstalk for the CoreHC interconnect and PCB is shown in Figure 17 below:

Near-End Crosstalk (NEXT) Port1

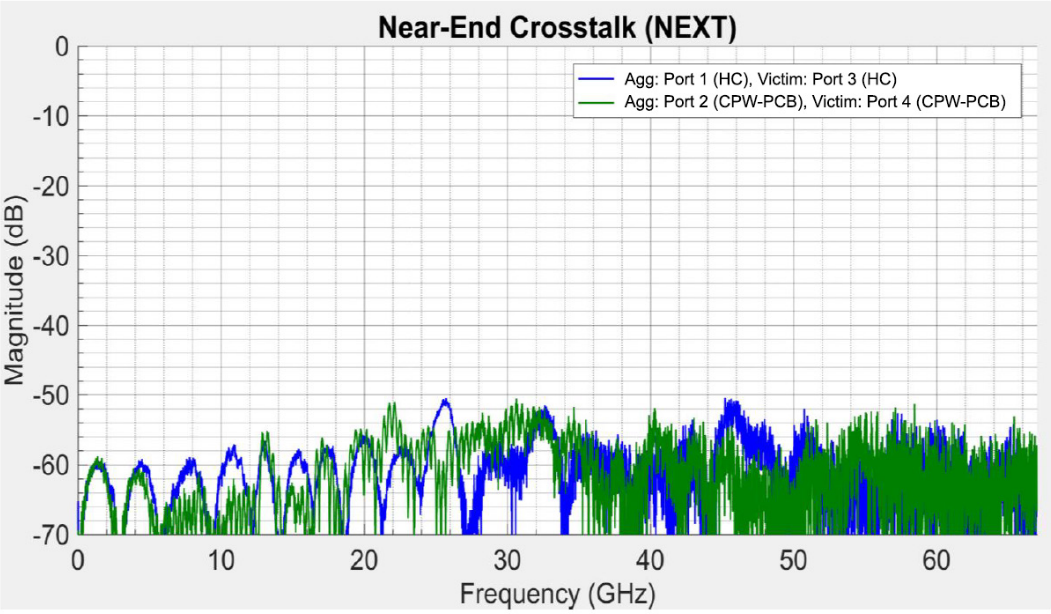


Fig. 17: Near-end crosstalk of the CoreHC interconnect and PCB in CPW PCB

Similarly, the far-end crosstalk is shown in Figure 18 below when the CoreHC interconnect meets the coplaner waveguide PCB:

Far-End Crosstalk (FEXT) Port 1 (HC) → Port 4 (VMCPW/PCB) & Port 2 (VMCPW/PCB)→ Port3(HC)

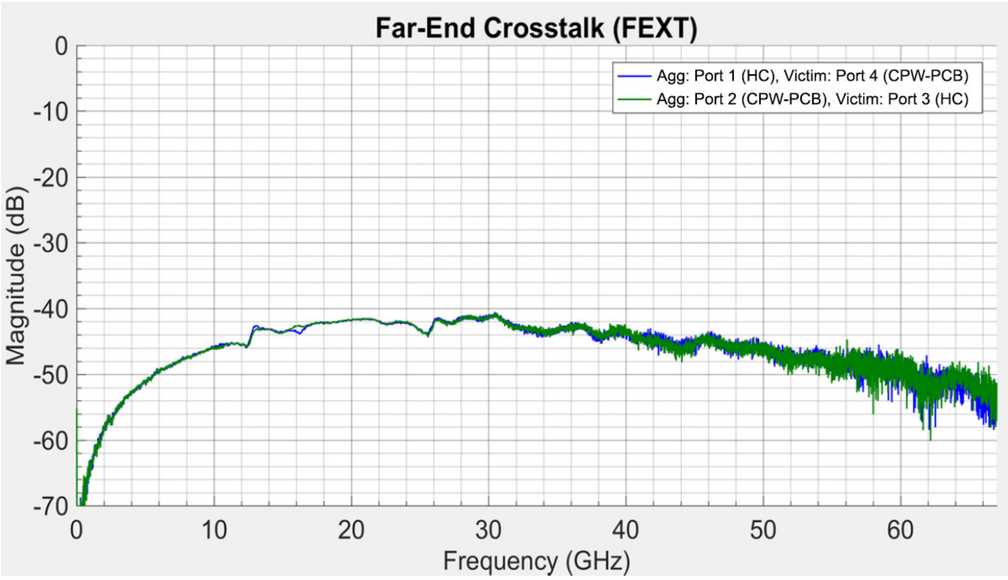


Fig. 18: Far-end crosstalk of the CoreHC interconnect and PCB in CPW PCB

RF Products

Crosstalk in stripline traces of PCBs is lower compared to crosstalk in the CPW designs. Board traces are embedded in the inner layers, resulting in less coupling between themselves since the electric field is more confined to individual board traces. Figure 19 shows the simulation setup of a two-port PCB with stripline traces using the CoreHC interconnect.

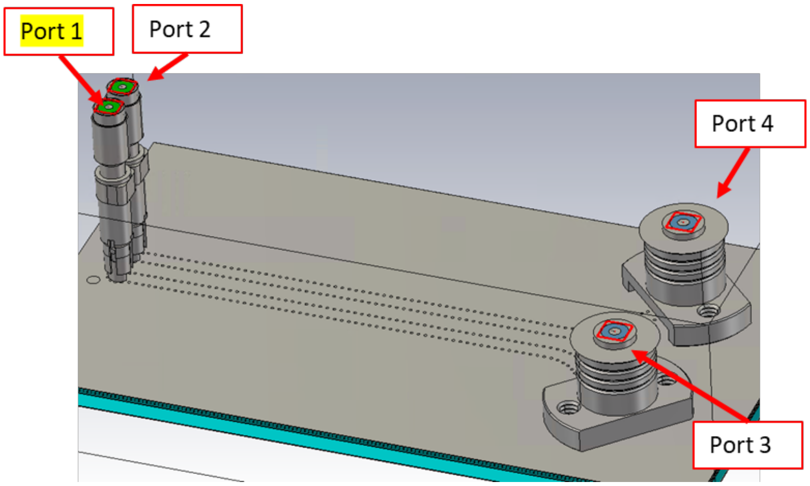


Fig. 19: Simulation setup of a two-port PCB with stripline traces using a CoreHC interconnect

Near-end crosstalk seen for ports 1 and 2 in this case is smaller than the crosstalk seen for CPW board design, as shown in Figure 20 below:

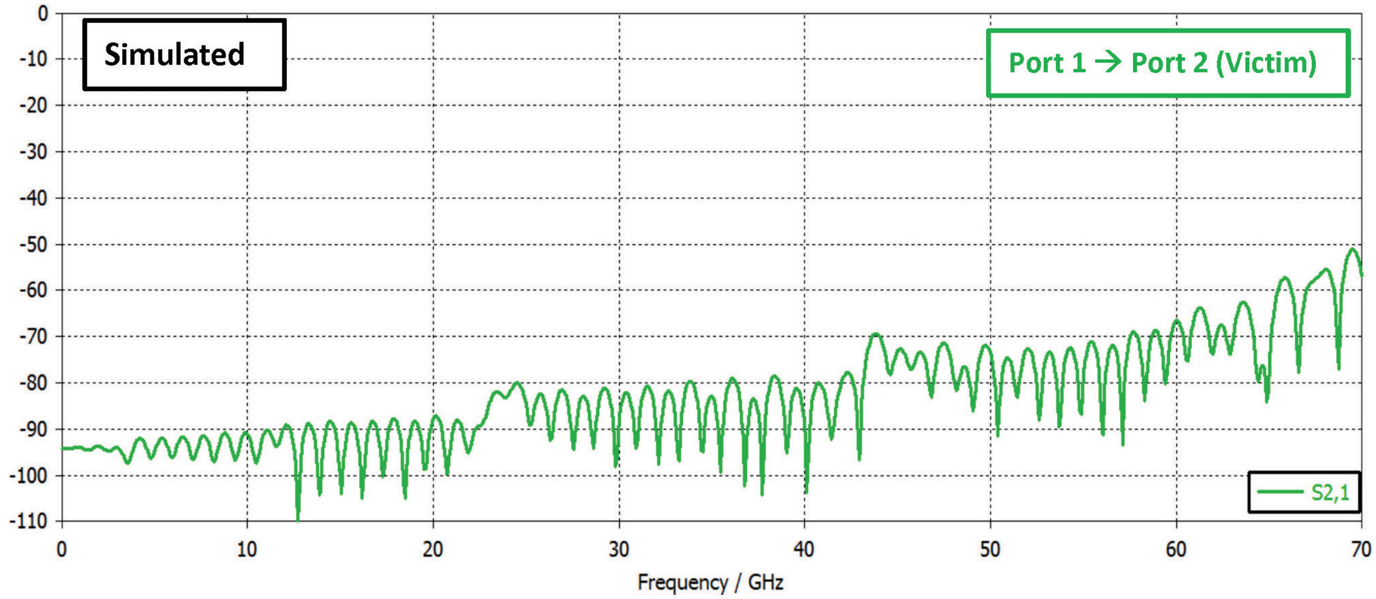


Fig. 20: Near-end crosstalk of a stripline PCB using a CoreHC interconnect

Far-end crosstalk seen is also quite low and confirms the observation that stripline designs tend to have lower crosstalk compared to CPW designs in Figure 21:

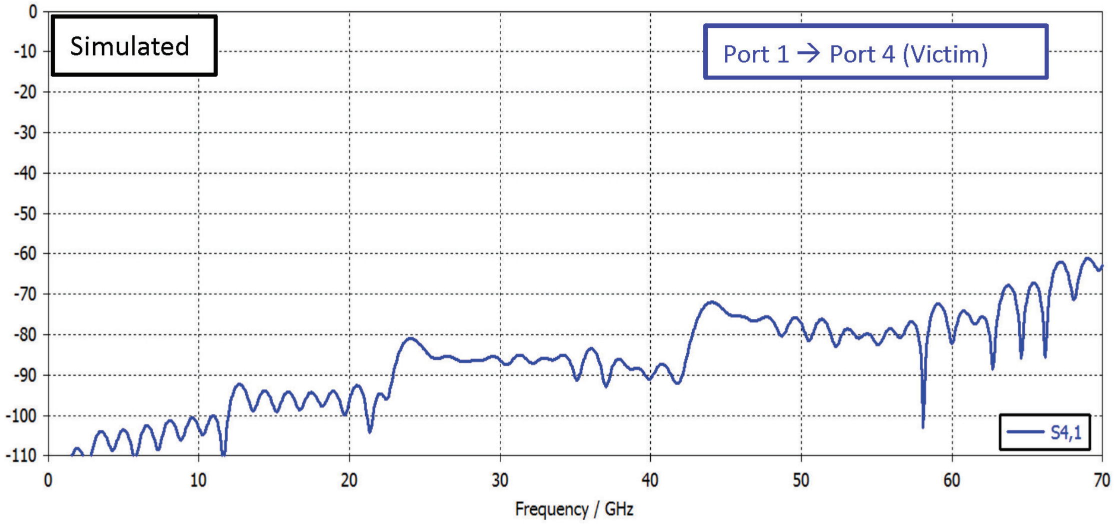


Fig. 21: Far-end crosstalk in a stripline PCB using a CoreHC interconnect

Minimizing crosstalk in high-density and extremely small board design is important. With low crosstalk at high frequencies, excellent signal integrity can be assured with maximum flexibility in layout and routing of traces on the board. Figures 22 and 23 compare the crosstalk performance between the stripline and CPW boards across the frequency range of DC to 70GHz for reference:

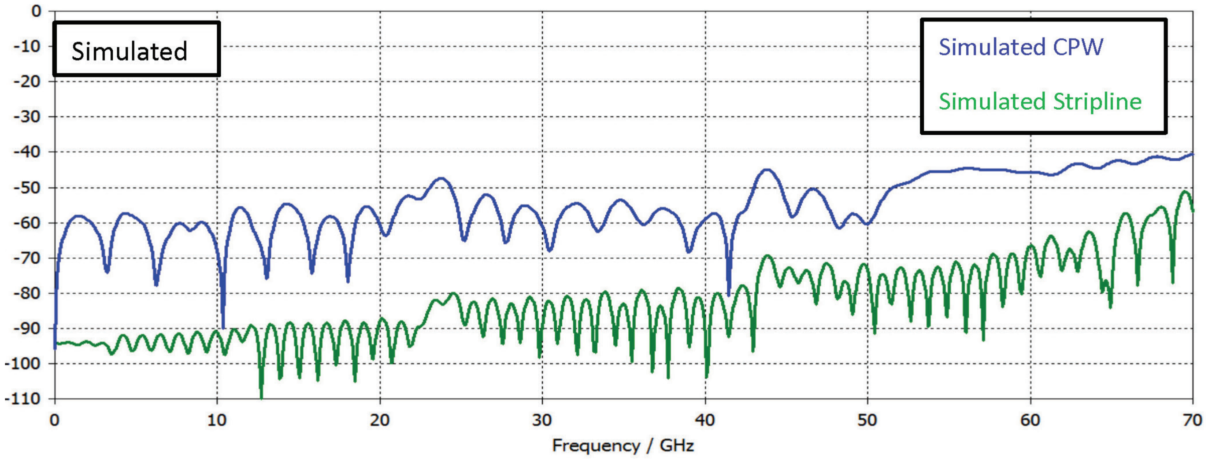


Fig. 22: Comparing near-end crosstalk of a CoreHC interconnect in stripline and CPW designs

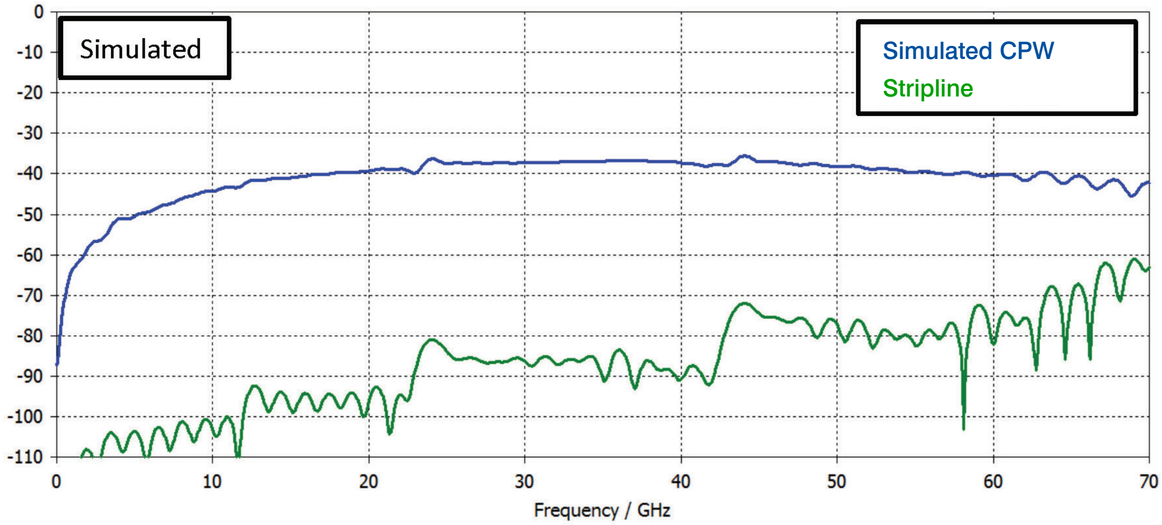


Fig. 23: Comparing far-end crosstalk of a CoreHC interconnect in stripline and CPW designs

The CoreHC interconnect solution can be customized depending on a specific board layout. Figure 24 shows CoreHC interconnect channels in custom housing that allows the assembly to be placed very close to the DUT. In this case, traces from the DUT to the CoreHC contacts are kept very short, minimizing insertion loss and resulting in high density and excellent signal integrity. Overall board size and cost are also reduced.

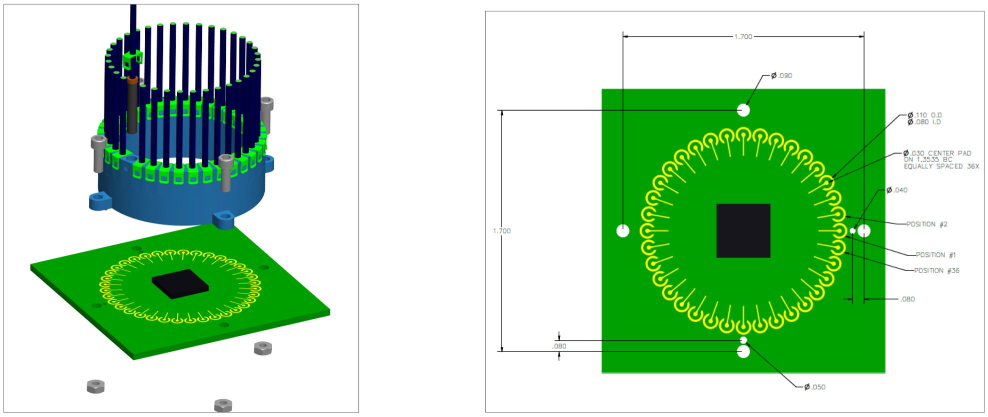


Fig. 24: Vertical-mount CoreHC interconnect with custom housing

Edge-mount interconnect solutions are useful when the DUT is placed closer to the edge of the PCB. The idea is to minimize the length of traces between the interconnect contacts and the DUT so that the losses due to trace impedance are minimized. Figure 24(b) shows the edge launch CoreGD interconnect on a PCB, where the DUT can be placed closer to the edge of the board.

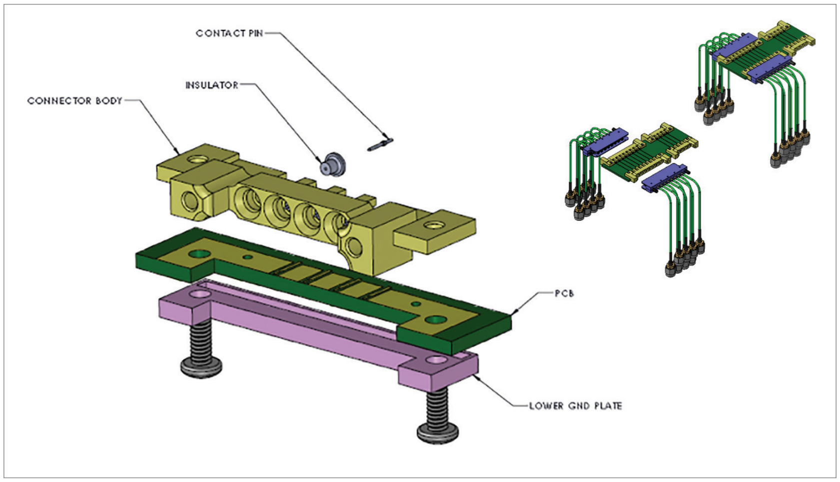


Fig. 24 (b): Edge Launch CoreGD Interconnect

Both CoreHC and CoreGD interconnect solutions offer excellent signal integrity up to 65 Ghz. CoreHC can be more useful in applications that need more density and have smaller PCBs with space constraints. On the other side, CoreGD is more suitable for applications that need a highly robust solution for harsh operating conditions, including shock, vibrations, and high-stress and strain forces. With standard SSMP male and female type interface and a soldered connector on board, CoreGD offers high-reliability for such operating conditions. Both CoreHC and the CoreGD interconnects can operate from -55°C to 165°C.

CarlisleIT has introduced a single-channel, secure-thread CoreHC-based interconnect. The solution uses a compression mount spring pin with a coax cable and a coupling nut to secure the assembly in place on a hollow plastic body with threads. The solution needs the corresponding footprint on the PCB where the spring pin and metal body of the assembly make the contact. By using a coupling nut, the assembly is held securely in place and does not move or demate in shock, vibration, or high-stress conditions. At the same time, the solution offers the same low losses and excellent signal integrity as seen with the CoreHC solution. Another advantage of this solution is that the PCB footprint required for a hollow plastic body is fully compatible with field-replaceable 3.5 mm, 2.92 mm, and 1.85 mm RF connectors. Figure 25 shows the interconnect solution and PCB footprint:

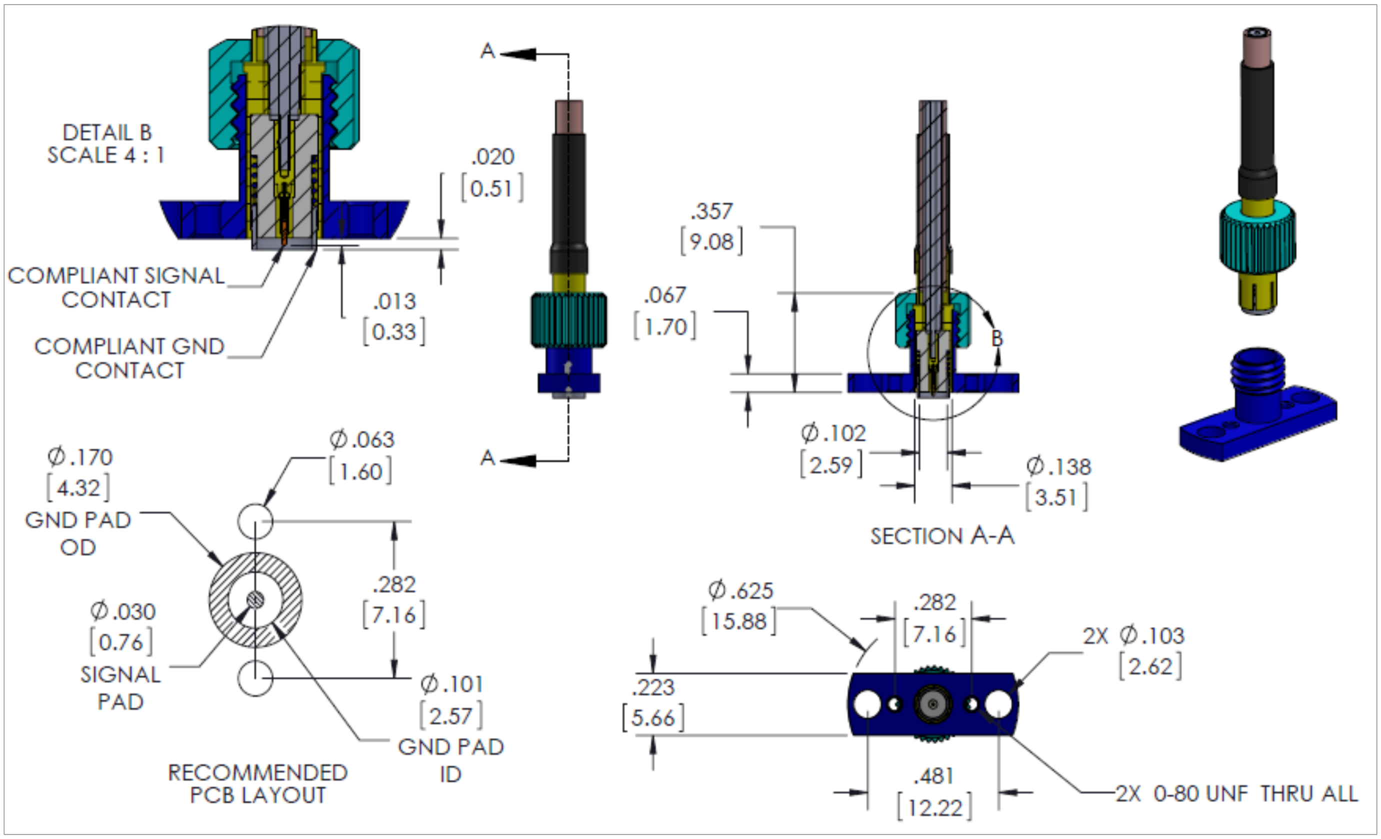
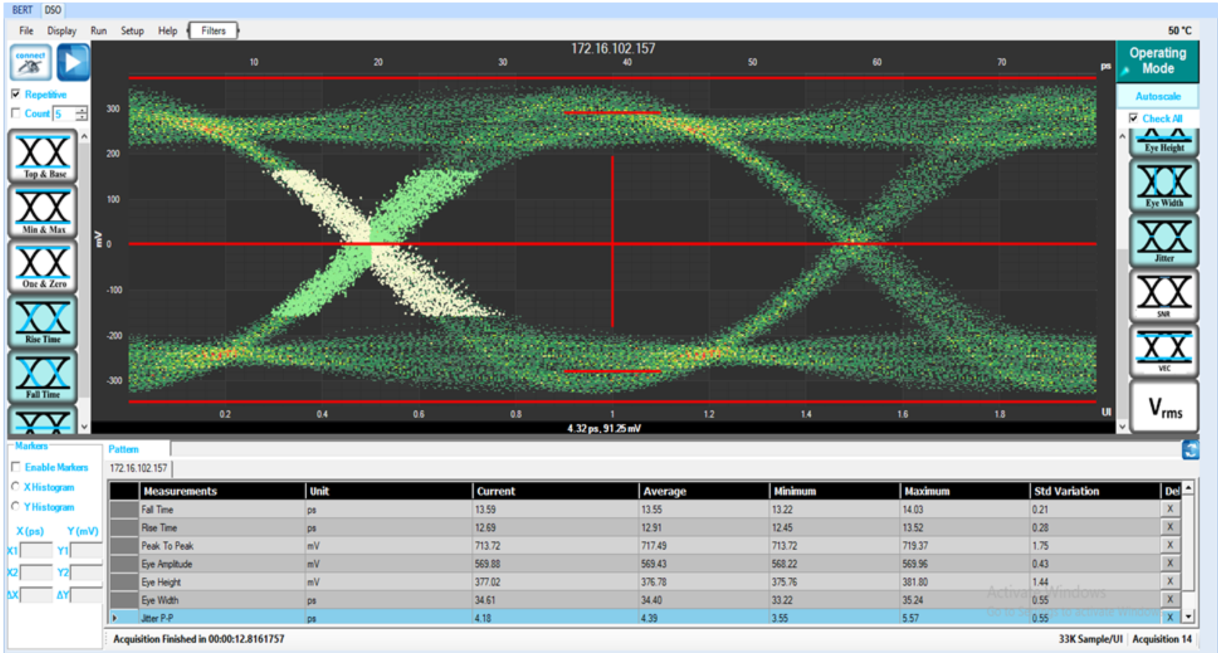


Fig. 25: Single-channel CoreHC-based secure interconnect solution

RF Products

Semiconductor manufacturing companies use eye tests to characterize and qualify the reference designs for optical and electrical functions. An eye test is a time domain signal integrity test that measures key parameters such as rise and fall times, eye amplitude, eye width, eye height, and jitter, and compares them to the bench mark / mask in the test. Figure 26 shows a typical eye test pattern of a 1-foot-long .079-inch coax cable jumpers with 1.85 mm to 2.92 mm adapters along with the measured key parameters. The data rate used for the eye test is a 25 Gbps PRBS7 pattern.



Measurements	Unit	Current	Average	Minimum	Maximum	Std Variation
Fall Time	ps	13.59	13.55	13.22	14.03	0.21
Rise Time	ps	12.69	12.91	12.45	13.52	0.28
Peak To Peak	mV	713.72	717.49	713.72	719.37	1.75
Eye Amplitude	mV	569.88	569.43	568.22	569.96	0.43
Eye Height	mV	377.02	376.78	375.76	381.80	1.44
Eye Width	ps	34.61	34.40	33.22	35.24	0.55
Jitter P-P	ps	4.18	4.39	3.55	5.57	0.55

Fig. 26

The CoreHC interconnect solution from CarlisleIT offers excellent time domain signal integrity with an eye pattern that is almost identical to the low-loss coax cables used in the same operating conditions. In order to demonstrate the high-performance time domain signal integrity of the CoreHC solution, the test PCB and CoreHC cables are added in the test path (6 inches of .079-inch RF coax jumpers, 6 inches of CoreHC cable, and 1.5 inches of Cu trace on PCB are used as the DUT instead of 1-foot-long .079-inch RF coax jumpers as shown in Figure 27).

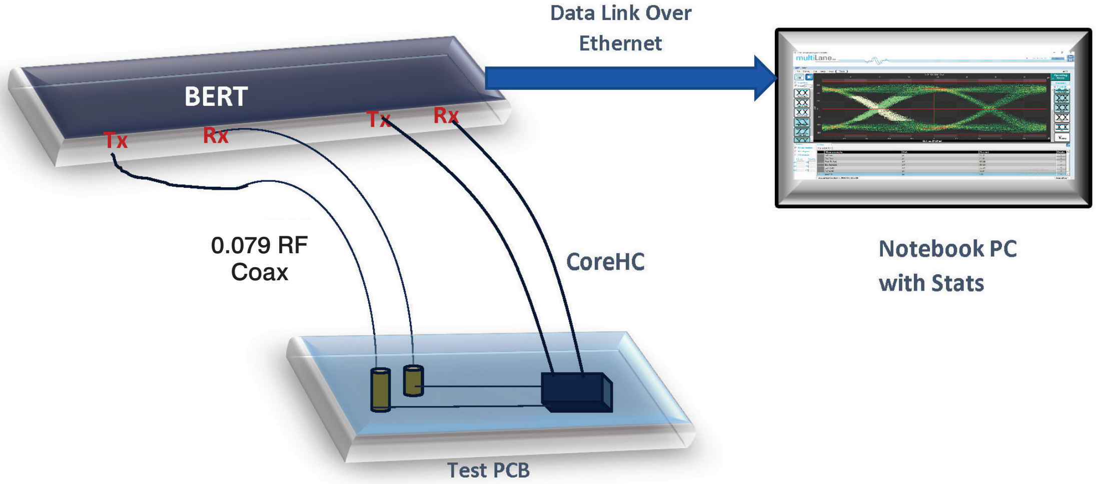


Fig. 27: Test setup using CoreHC, PCB, and .079-inch RF coax jumpers

RF Products

Again, the data rate for the test stays the same (i.e., 25 Gbps using PRBS 7-bit pattern). Slight closing of the eye is seen when the PCB and CoreHC 2.5 cable are added in test path as shown in the figure below. Closing of the eye means an increase in rise and fall times, reduction in eye amplitude and height, and an increase in eye width of signals going through the complete channel (i.e., from Tx to Rx and Rx to Tx path). Figure 28 compares the eye pattern from this test setup with the eye pattern of 1-foot-long .079-inch RF coax cables:

1-Foot-Long .079-Inch RF Coax Jumpers

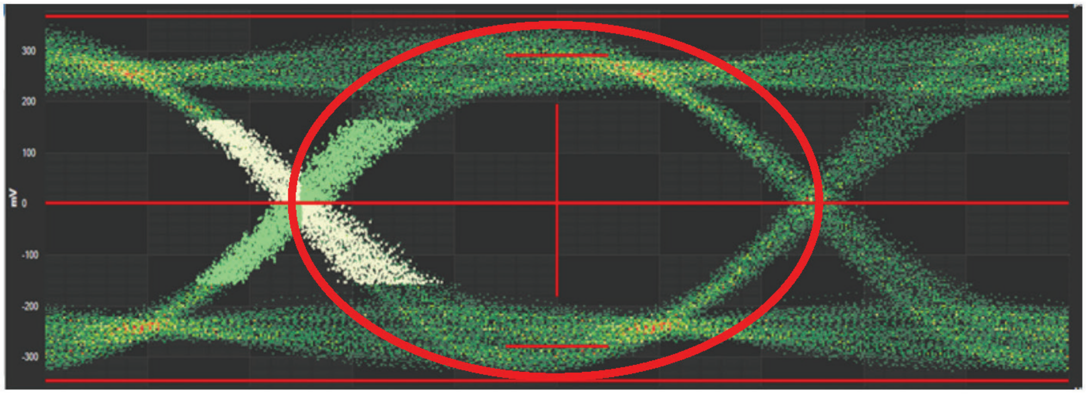


Fig. 28

6-Inch .079-Inch RF Coax Jumpers + 6-Inch CoreHC 2.5 + 1.5-Inch Cu Trace on Magtron 6 Board

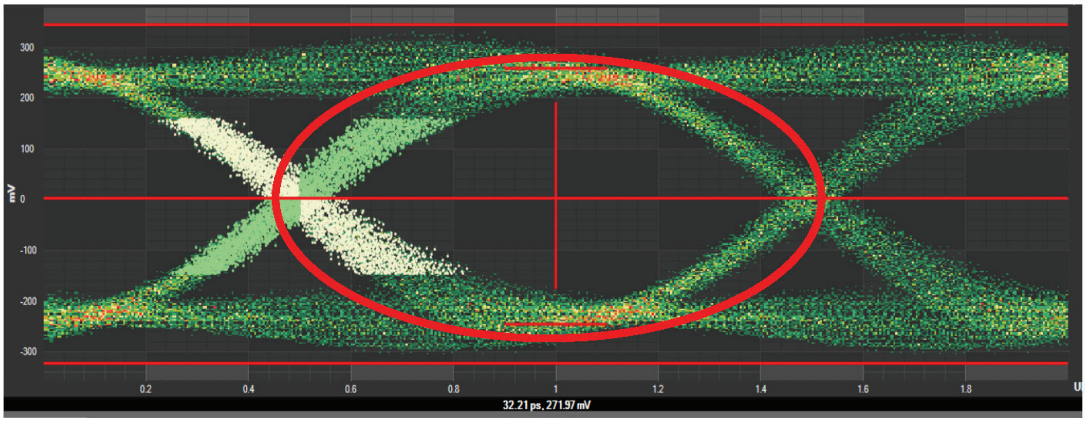


Fig. 29

The key parameters are measured in both cases and are shown as follows:

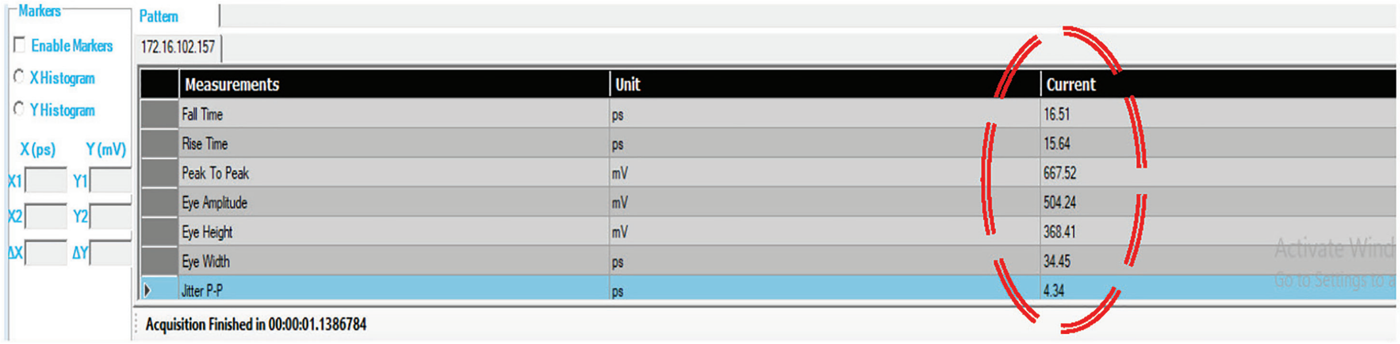
1-Foot-Long .079-Inch RF Coax Cable

Pattern 172.16.102.157

Measurements	Unit	Current	Average	Minimum	Maximum	Std Variation
Fall Time	ps	13.59	13.55	13.22	14.03	0.21
Rise Time	ps	12.69	12.91	12.45	13.52	0.28
Peak To Peak	mV	713.72	717.49	713.72	719.37	1.75
Eye Amplitude	mV	569.88	569.43	568.22	569.96	0.43
Eye Height	mV	377.02	376.78	375.76	381.80	1.44
Eye Width	ps	34.61	34.40	33.22	35.24	0.55
Jitter P-P	ps	4.18	4.39	3.55	5.57	0.55

Acquisition Finished in 00:00:12.8161757 | 33K Sample/UI | Acquisition 14

6-Inch UFC092 + 6-Inch CoreHC 2.5 Cable Assembly + 1.5-Inch Cu Trace on Magtron 6 Board



Measurements	Unit	Current
Fall Time	ps	16.51
Rise Time	ps	15.64
Peak To Peak	mV	667.52
Eye Amplitude	mV	504.24
Eye Height	mV	368.41
Eye Width	ps	34.45
Jitter P-P	ps	4.34

It can be concluded that the closing of the eye with the replacement of 6 inches of the coax cable section (in 1-foot test path) with a CoreHC cable assembly and PCB trace is almost negligible and does not affect the sampling of high-speed signals in electronic systems. Therefore, in a complex, highly-dense board layout, the coax cables can be replaced without the CoreHC interconnect time or frequency domain signal integrity concerns.

CarlisleIT offers the optimized footprints for CoreHC solutions in CPW and stripline PCB designs as shown in Figures 30 and 31.

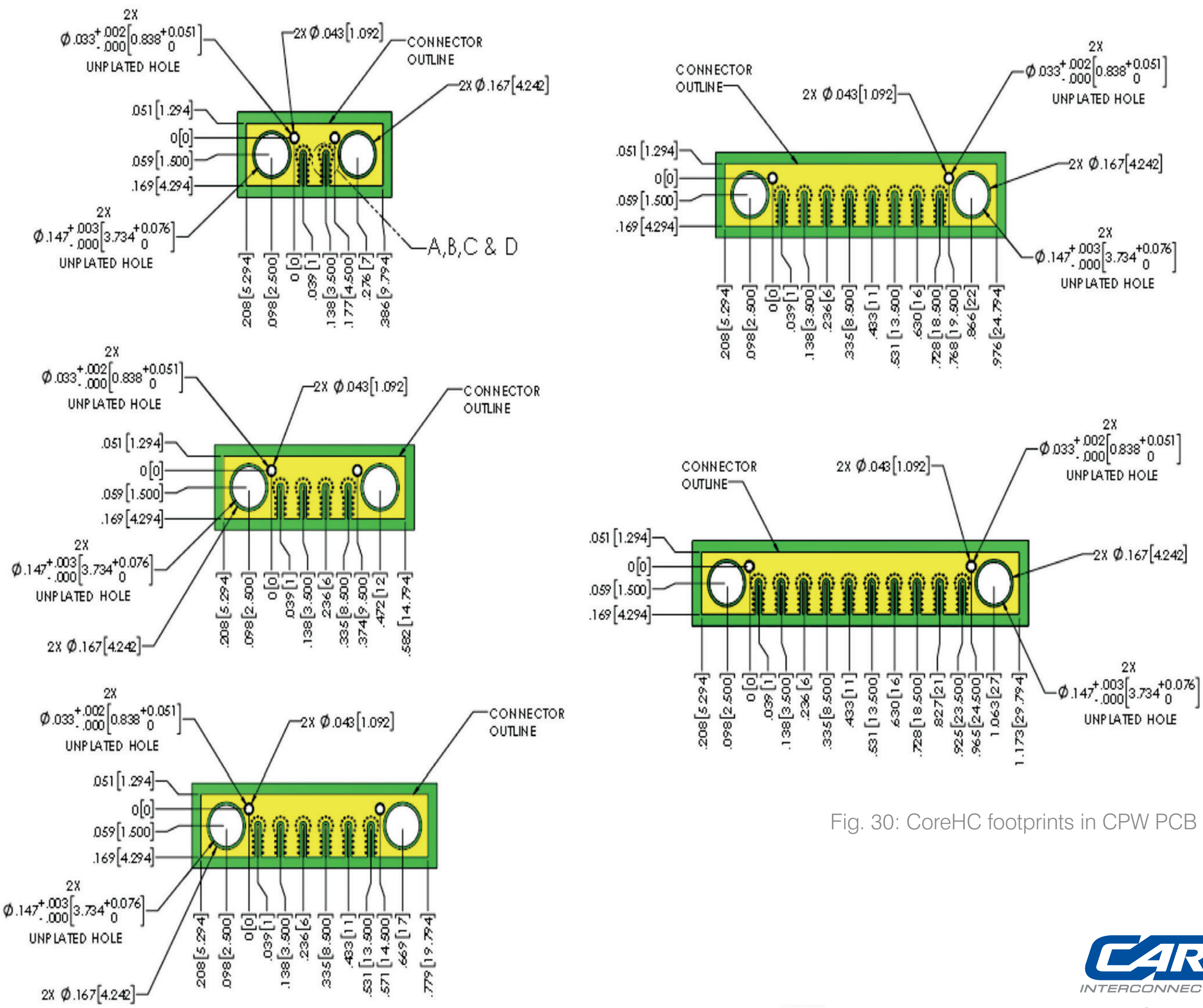


Fig. 30: CoreHC footprints in CPW PCB

RF Products

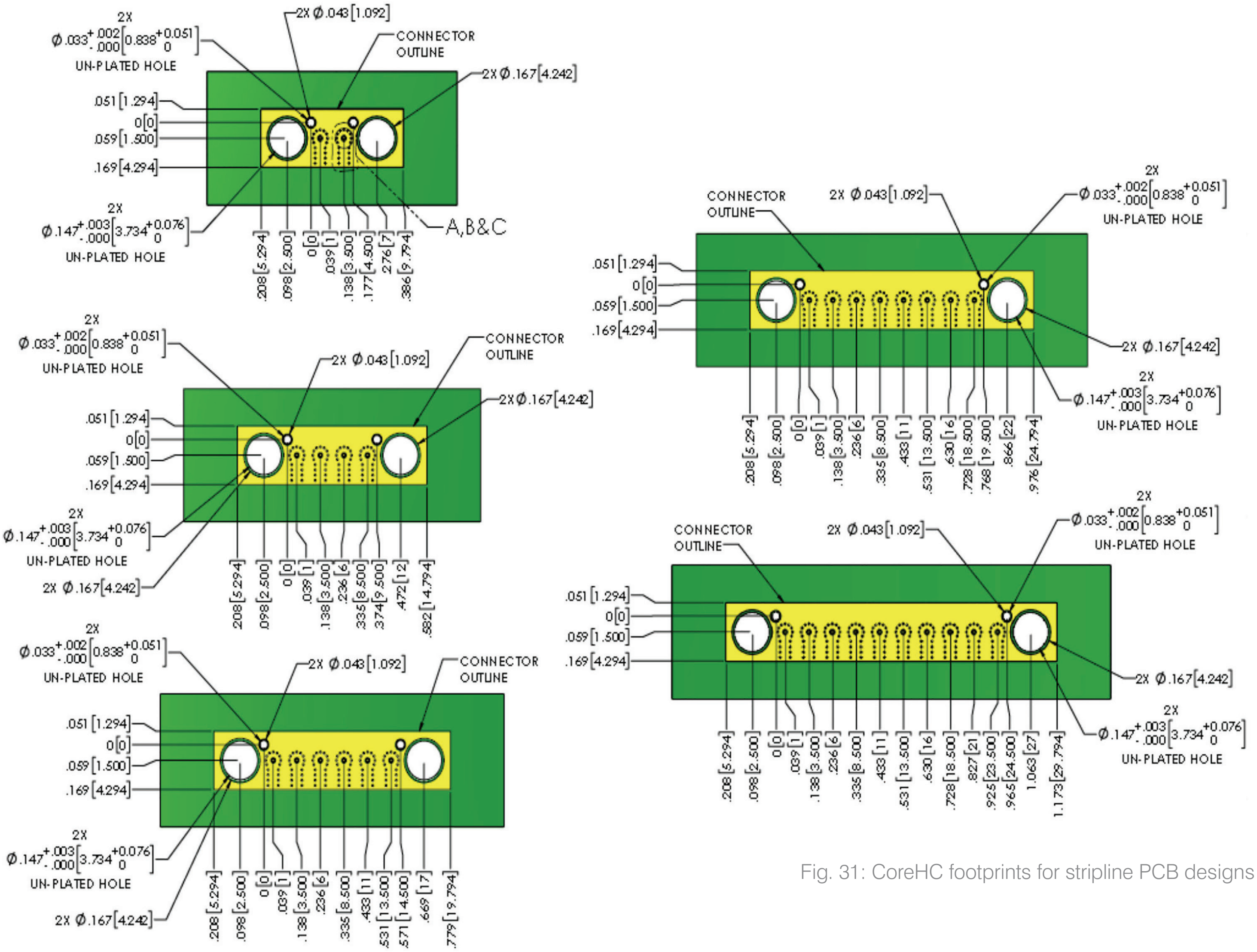


Fig. 31: CoreHC footprints for stripline PCB designs

Additionally, CarlisleIT can review and optimize the customer's PCB designs for the lowest losses and best possible system performance and signal integrity.

For the complete portfolio of ganged RF high-density interconnect solutions, visit:
carlisleit.com/markets/test-measurement/rf-products/

Precision RF Connectors

Precision RF Connectors

CarlisleIT offers a wide portfolio of low-loss, high-frequency precision RF connectors in various configurations for design flexibility and multiple applications.

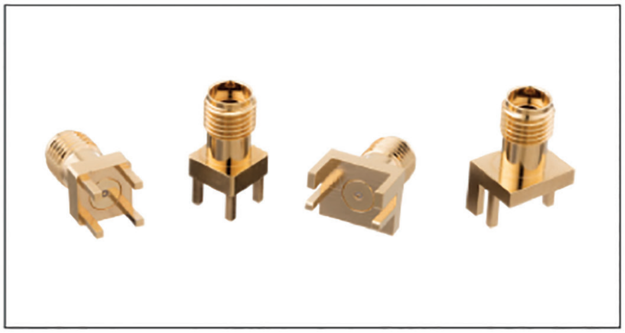
The following table shows featured board mount connectors with key specifications and ordering information.

- 50 ohm impedance
- Frequencies ranging from DC to 65 GHz
- 1.85 mm, 2.42 mm, 2.92 mm, and 3.50 mm mating interfaces
- Field-replaceable options available

Size	Part No.	Description	Termination	Orientation	Freq.	Body	Insulator	Contact
1.85 mm	TMB-V8F2-1L1	1.85-mm Female, 2-Hole-Flange, Post Contact, 0.016 Pin	Field-Replaceable	Vertical	DC - 65 GHz	Passivated Stainless Steel	PCTFE	Gold-Plated BeCu
	TMB-E8FS-1S1	1.85-mm Female Straight, Edge-Mount (Manual Solder)	Manual Solder	Edge-Mount		Gold-Plated Brass		
	TMB-V8FS-2SM	1.85-mm Female Straight, Vertical Solder (Signal Pad)	Mixed-Technology Solder	Vertical				
	TMB-E8F2-1L1	1.85-mm Female Straight, Edge-Mount (Solderless)	Field-Replaceable	Edge-Mount		Passivated Stainless Steel		
2.40 mm	TMB-V4F2-1L1	2.40-mm Female, 2-Hole-Flange, Post Contact, 0.016 Pin	Field-Replaceable	Vertical	DC - 50 GHz	Passivated Stainless Steel	PCTFE	Gold-Plated BeCu
	TMB-E4FS-1S1	2.40-mm Female Straight, Edge-Mount (Manual Solder)	Manual Solder	Edge-Mount		Gold-Plated Brass		
	TMB-V4FS-2SM	2.40-mm Female Straight, Vertical Solder (Signal Pad)	Mixed-Technology Solder	Vertical				
	TMB-E4F2-1L1	2.40-mm Female Straight, Edge-Mount (Solderless)	Field-Replaceable	Edge-Mount		Passivated Stainless Steel		

Typical operating temperature range for precision RF connectors is from -55°C to 165°C. CarlisleIT uses unique design and high-performance gold-plated body and contacts for these connectors. As a result, precision RF connectors have very low insertion and return loss over a wide operating frequency range of DC – 65 GHz as shown in the performance specifications in the table below:

Field-Replaceable



Solderable

PERFORMANCE SPECIFICATIONS

Connector Series	Frequency Rating	Connector Only		Connector & PCB	
		Return Loss (-20 dB max)	Insertion Loss (-0.2 dB max)	Return Loss (-15 dB max)	Insertion Loss (-0.6 dB max)
1.85 mm	DC - 65 GHz	67 GHz		67 GHz	
2.40 mm	DC - 50 GHz	50 GHz		50 GHz	
2.92 mm	DC - 40 GHz	40 GHz		40 GHz	
3.50 mm	DC - 34 GHz	34 GHz		34 GHz	

CARLISLE INTERCONNECT TECHNOLOGIES

Precision RF Connectors

Signal Integrity Performance

Precision RF connectors from CarlisleIT have a consistent impedance profile and perform well on a component level with no resonances. Figure 32 shows the insertion loss and return loss of a vertical-mount field-replaceable 2.92-mm connector. Minimum return loss of -25dB and maximum insertion loss of -0.02dB is seen at 70 GHz, making these connectors suitable for use in high-frequency applications. Since these connectors can be moved easily between the connector footprints on the same or different PCBs, they provide excellent design and maintenance flexibility in RF systems.

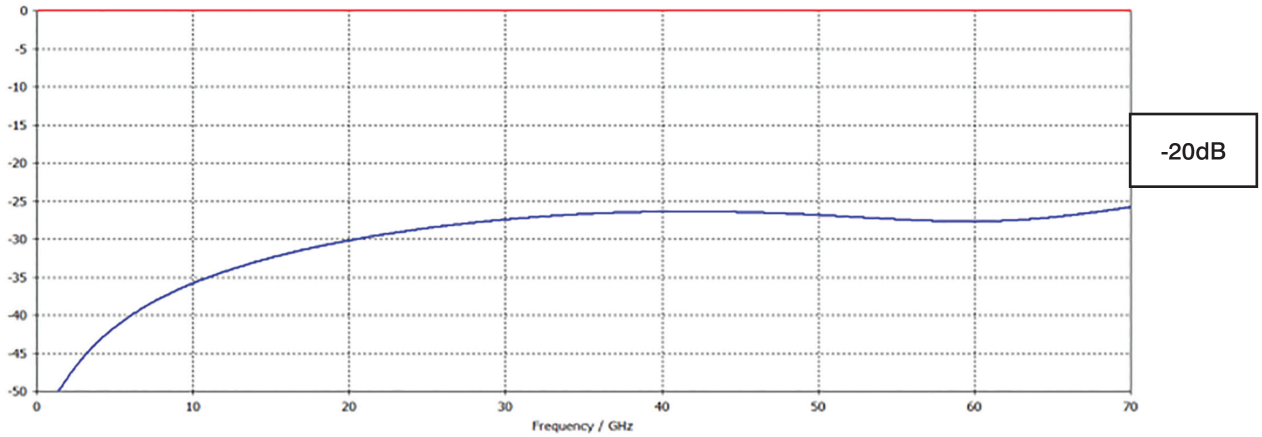


Fig. 32: Insertion loss and return loss of a vertical-mount field-replaceable 2.92-mm connector

Similarly, the time domain response of the same connector is shown in Figure 33 below, which indicates that the impedance profile remains consistent at 50 ohms with minimal variations seen at transition interfaces.

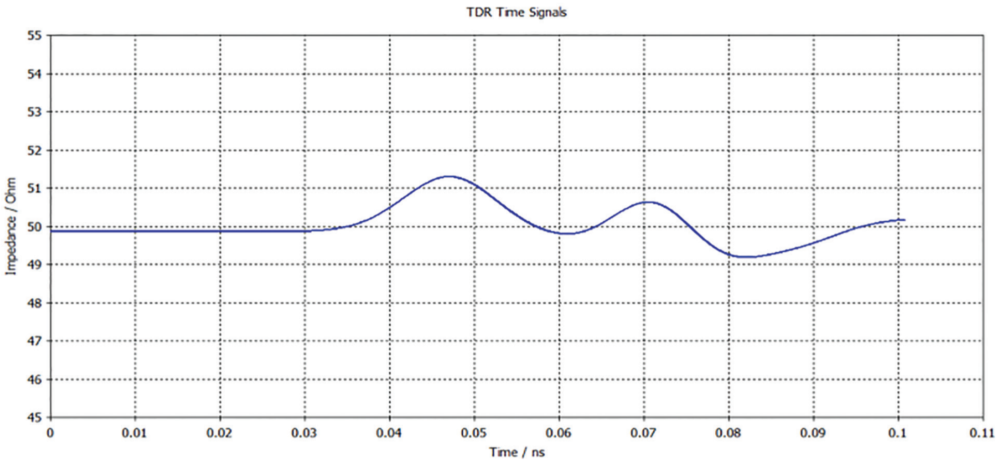


Fig. 33: Time domain response of a vertical-mount field-replaceable 2.92-mm connector

Precision RF Connectors

Soldered RF connectors are more suitable for applications with fixed RF interfaces with practically no requirements of field replacement or changes of RF channels on boards. Soldered RF connectors also provide more ruggedness and reliability, especially for operations in harsh conditions like vibrations, high-speed movement, law enforcement, military use, etc. Figure 34 shows the insertion loss and return loss of a soldered 2.92 mm connector. Minimum return loss of -20dB and maximum insertion loss of -0.06dB is seen at 70 GHz. Note that the losses are slightly higher compared to field-replaceable connectors due to additional discontinuities introduced by soldering and mounting pins.

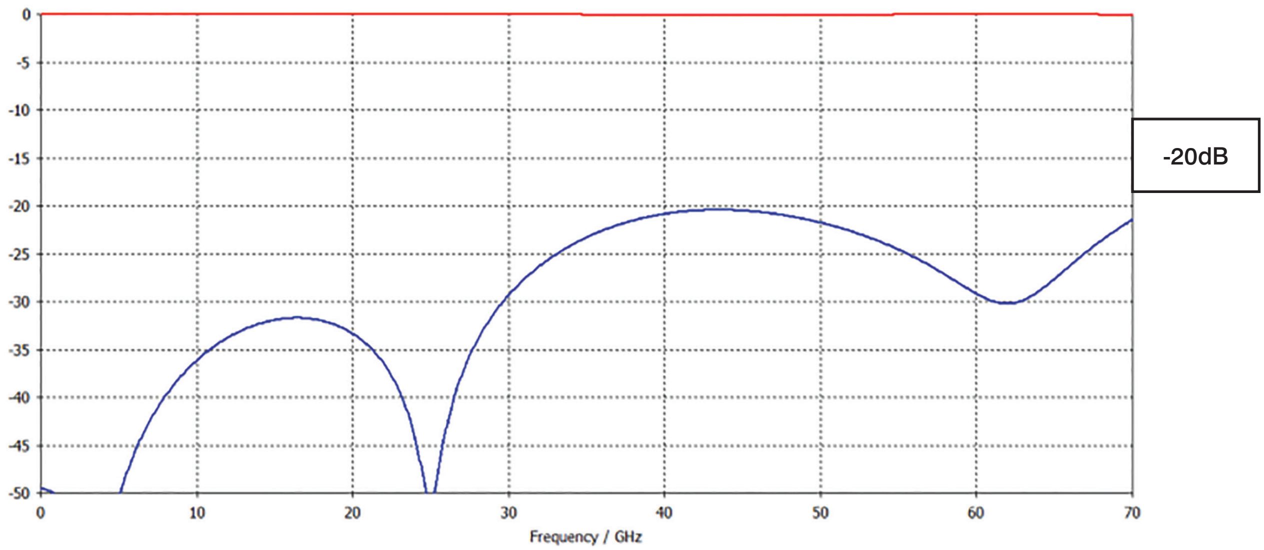


Fig. 34: Insertion loss and return loss of a vertical-mount soldered 2.92-mm connector

Similarly, the time domain response of the same connector is shown in Figure 35 below, which indicates that the impedance profile remains consistent at 50 ohms and is very similar to the profile of field-replaceable connectors.

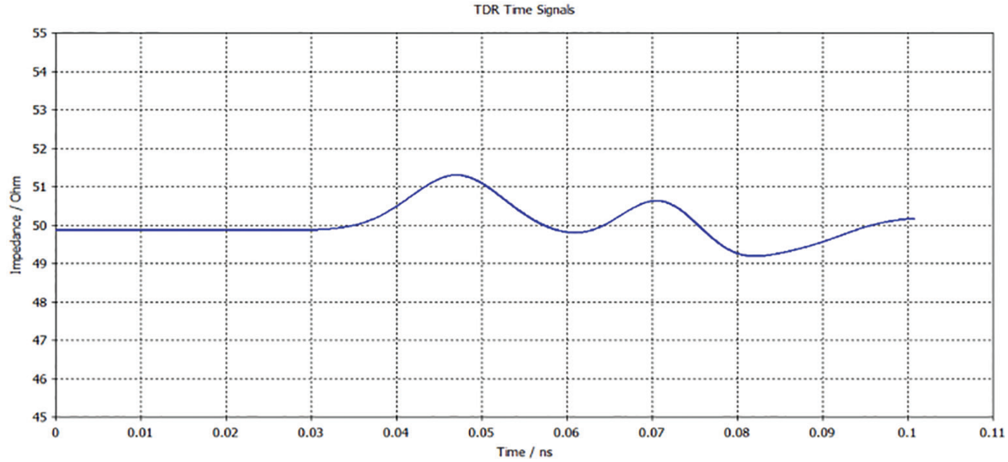


Fig. 35: Time domain response of a vertical-mount soldered 2.92-mm connector

Precision RF Adapters

RF Adapters

CarlisleIT offers a wide portfolio of high-precision, low loss, in-series and inter-series RF adapters for different applications ranging from DC – 65 GHz

- Complete family of in-series and inter-series adapters
- These adapters come standard in a passivated stainless steel body with a captivated beryllium copper center conductor to ensure mating reliability
- 50 ohms impedance, low VSWR, and insertion loss for high signal integrity

Series	Type	Series	Type	Series	Type	Series	Type
1.85 mm	Male to Male Female to Male Female to Female	2.4 mm	Male to Male Female to Male Female to Female	2.92 mm	Male to Male Female to Male Female to Female	3.5 mm	Male to Male Female to Male Female to Female
1.85 mm to 2.4 mm	Female to Female Male to Female Female to Male Male to Male	1.85 mm to 2.92 mm	Female to Female Male to Female Female to Male Male to Male	1.85 mm to 3.5 mm	Female to Female Male to Female Female to Male Male to Male	2.4 mm to 2.92 mm	Female to Female Male to Female Female to Male Male to Male
		2.4 mm to 3.5 mm	Female to Female Male to Female Female to Male Male to Male	2.92 mm to 3.5 mm	Female to Female Male to Female Female to Male Male to Male		

Fig. 36: In-Series and Inter-Series RF Adapters

CarlisleIT offers precision RF adapters with color-coded rings to identify the type of connector on each side of the adapter. The color-coding scheme from CarlisleIT is shown as follows:

	Orange	DC – 26.5 GHz	3.5 mm Connector
	Yellow	DC – 40 GHz	2.92 mm (K) Connector
	Green	DC – 50 GHz	2.4 mm Connector
	Blue	DC – 67 GHz	1.85 mm (V) Connector

Fig. 37: Color Codes for RF Adapters

These adapters offer excellent signal integrity with low VSWR and low insertion loss. Figure 38 shows the insertion loss and VSWR data of a 2.92-mm female to 2.92-mm female adapter. It can be seen that the adapter introduces minimal insertion loss in the channel and exhibits excellent VSWR performance of approximately 1.12 (around 40 GHz).

Precision RF Adapters

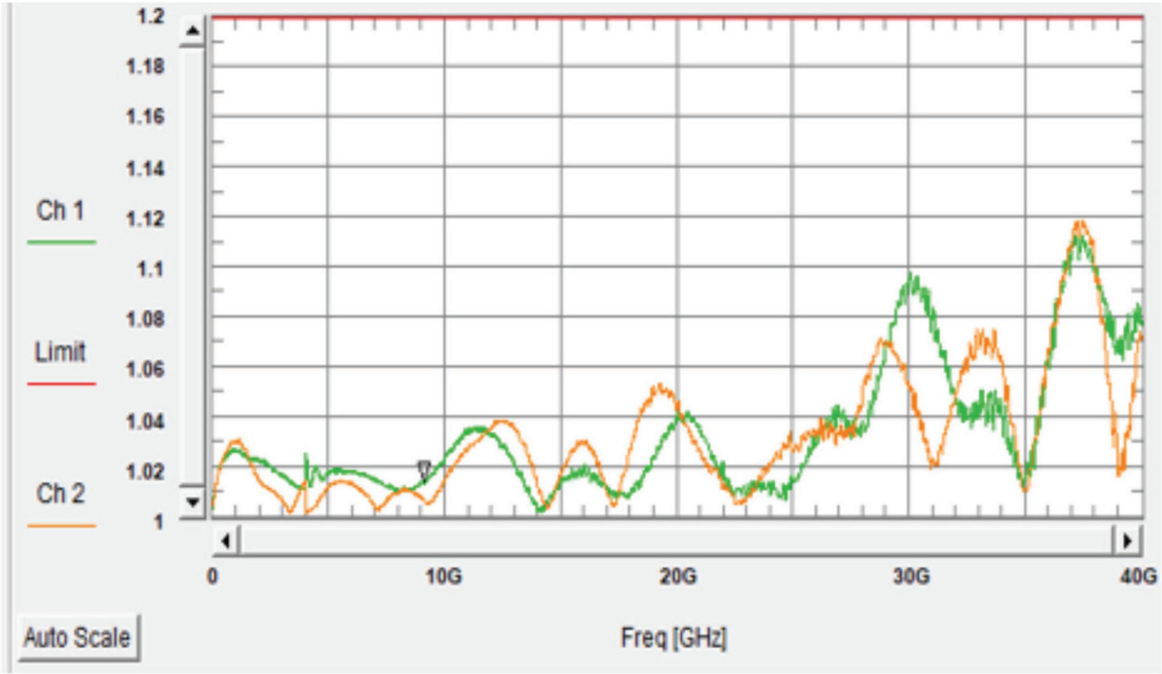


Fig. 38: VSWR performance of a 2.92-mm female to 2.92-mm female adapter

Similarly, insertion loss of the adapter is shown in Figure 39.

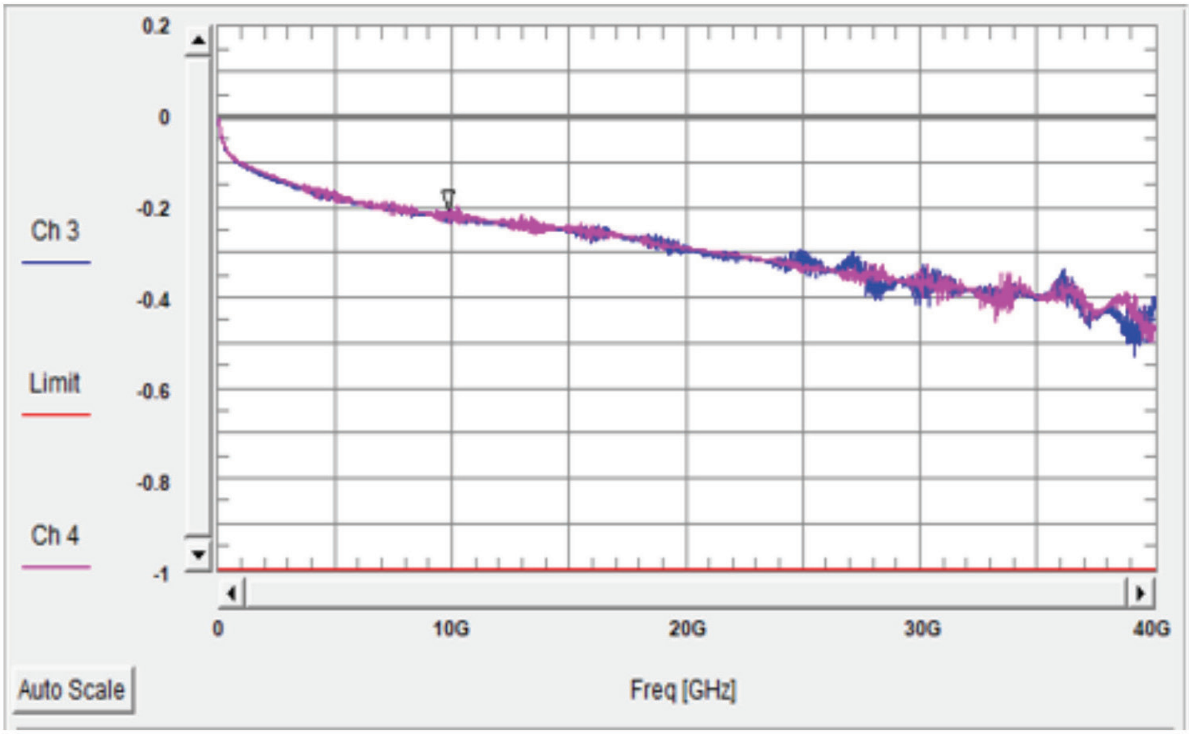


Fig. 39: Low insertion loss of a 2.92-mm female to 2.92-mm female adapter

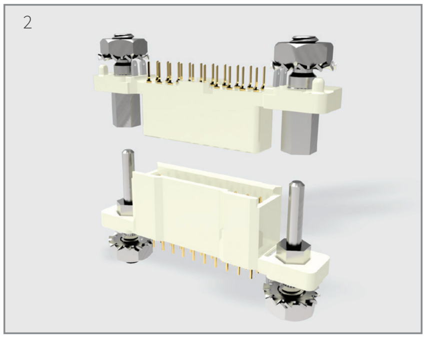
Precision RF adapters from CarlisleIT are readily available within two weeks after receiving the order.

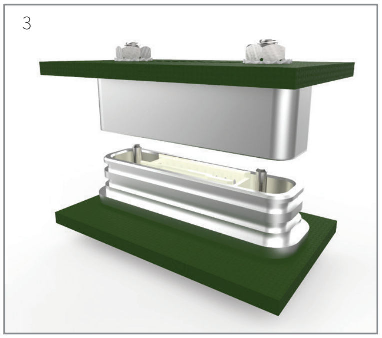
Digital Products

AltaVel: Open Pin Field Interconnect Solution

CarlisleIT's AltaVel™ family of open pin field high-speed digital (up to 56 Gbps) interconnect is optimized to provide scalability and reliability in dense, high-mate/demate cycle applications. The broad family of connectors is available in the following configurations: Board-to-Board, Board-to-Cable, Cable-to-Cable, and Cable-to-Panel. All configurations are available in the following styles: Vertical-to-Vertical, Right-Angle-to-Vertical, and Right-Angle-to-Right-Angle.

Features	Customer Benefits
10,000 mate/demate cycles	High signal integrity and reliability in a long-life package ensures high performance and lower cost of ownership
Flexible, scalable design	High-density, scalable design provides multiple configurations, enabling optimum performance at the lowest total cost
With or without metal shells	Rugged/EMI housing is available for use in harsh environments
Differential - 85 and 100 ohm Single ended - 50 and 75 ohm	Multiple impedance options meet your application needs
Board mounting options	Surface Mount (SMT), Paste-in-Hole (PIH) & Paste-through-Hole (PTH)
Open pin field design	Allows for flexibility in routing and coding schemes, including single-ended, differential pair, power, ground & sideband signals





1) High-reliability contact system featuring three points of contact. Available in SMT, PIH & PTH termination styles.

2) Connector without metal shell

3) Connector with metal shell

Performance specifications for AltaVel connectors:

Parameters	Specifications
Insertion Loss	<0.8 dB to 26 GHz (interconnect only)*
Data Rate	FDR - 14Gb/s, EDR - 28 Gb/s & PCIe Gen4 - 16Gb/s, PCIe Gen5- 32 Gb/s, PAM4 - 56 Gb/s
Impedance	85 or 100 ohm differential impedance; 50 or 75 ohm single-ended impedance
Contact Rating	3 amp max, at ambient with 30° rise
Operating Temperature	-55°C to +125°C
Minimum Contact Wipe	1 mm (0.039") typical
Contact Mating Force	40 grams typical
Insulation Resistance	5,000 megaohms minimum @ 500 VDC
DC Resistance (mated pair)	8.5 milliohm @ 8mm stack height
Durability	Min 1,000 cycles and up to 10,000 mate/demate cycles
Sinusoidal Vibration	20g (EIA-364-28, condition IV)
Shock	50g (EIA-364-27, condition E)
Operating Voltage	200 V, RMS, 60 Hz typical

**Simulated data only*

Digital Products

The AltaVel connector system is available in board-to-board configurations in various sizes from 8 mm to 20 mm. Board spacers are used to offer different board-to-board heights as shown in the figures below:

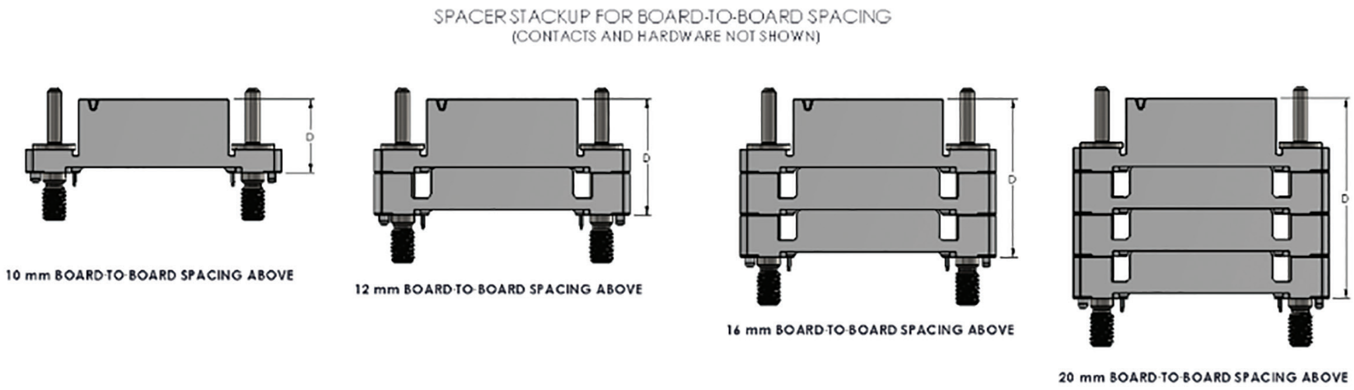
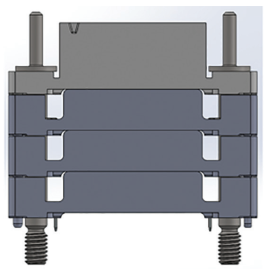
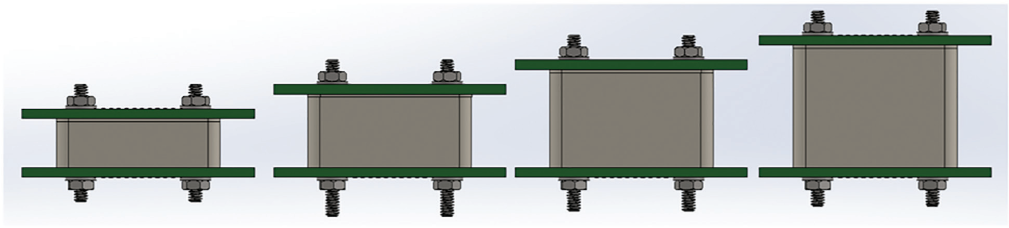


Fig. 40





Digital Products

Figure 41 shows different ways in which RF cables can be terminated on AltaVel connectors. Typically, Twinax cables up to 26AWG and coax cables up to .087 inches can be terminated on AltaVel connectors for cable-to-cable or cable-to-board connectivity.

Fig. 41: AltaVel Connector Configurations

Insertion loss and return loss performance of the AltaVel connector system is shown in Figure 42 below.

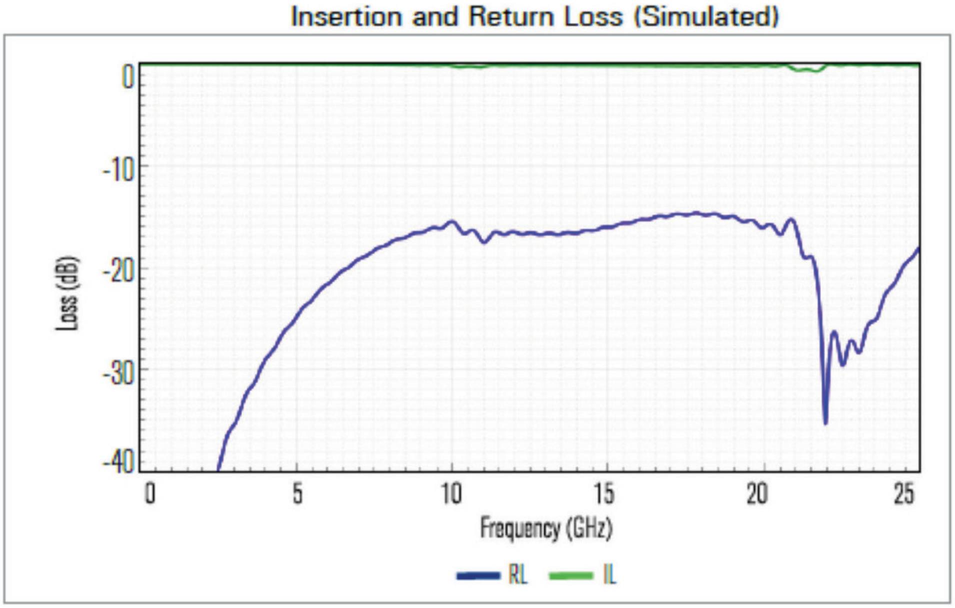


Fig. 42: Insertion loss and return loss performance of the AltaVel connector system

Similarly, the near-end and far-end crosstalk performance of AltaVel connectors is shown in Figure 43 below.

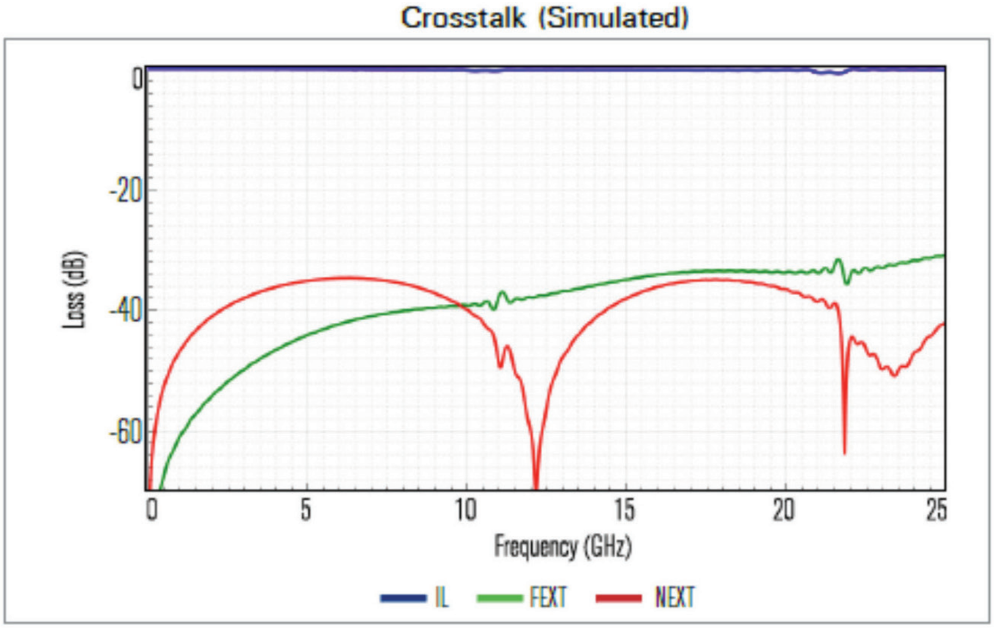


Fig. 43. Near-end and far-end crosstalk performance of a AltaVel system

Low losses and low crosstalk performance of AltaVel connectors make them an excellent choice for high-speed and high-density PCBs.

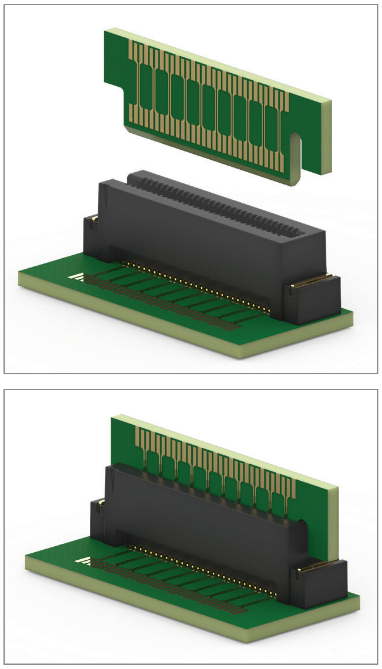
Digital Products

Card Edge Connectors

CarlisleIT's Card Edge Connectors contact system is designed for high-speed, high-density applications. Card Edge Connectors have a smooth mating surface area, which reduces the wear and tear of contacts and increases the durability and life span of the contact system.

They also lower insertion and withdrawal forces, while supporting data rates up to 56 Gbps with excellent signal integrity.

Features	Customer Benefits
High-Speed Differential Data Rate	Offers excellent signal integrity and performance up to 56 bps
Multiple PCB Thicknesses (0.062 & 0.093 inches)	Allows for complex PCB designs
Surface Mount and Edge Mount Options	Enable high-speed, pick-and-place assembly
0.8 mm Pitch	Access signals in dense environments and save PCB space
8.5 mm Max Height	Up to 30 pins for low-profile system designs
500 Mate/Demate Cycles	High reliability and low cost of ownership
Wide Operating Temperature	-55°C to 155°C



Card edge connectors contact system

Key specifications and performance parameters for CarlisleIT's Card Edge Connectors are as shown in the table below:

<table>
<tr><th>Parameters</th><th colspan="2">Specifications</th></tr>
<tr><td>Frequency Range</td><td colspan="2">DC to 25 GHz</td></tr>
<tr><td>Impedance</td><td colspan="2">100 Ω ± 2.5</td></tr>
<tr><td rowspan="3">Return Loss</td><td>Frequency Range</td><td>Return Loss</td></tr>
<tr><td>DC - 20GHz</td><td>>= -38dB</td></tr>
<tr><td>20 GHz - 25GHz</td><td><= -10dB</td></tr>
<tr><td>Insertion Loss</td><td colspan="2">-2dB (max) at 25GHz</td></tr>
<tr><td>Contact Pitch</td><td colspan="2">0.8mm</td></tr>
<tr><td>PCB Thicknesses Supported</td><td colspan="2">0.062 in, 0.093 in</td></tr>
<tr><td>Max Height</td><td colspan="2">7mm</td></tr>
<tr><td>Mate/Demate Cycles</td><td colspan="2">500</td></tr>
<tr><td>Temperature Range</td><td colspan="2">-55°C to 155°C</td></tr>
</table>

Unique design of signal and GND pins of the card edge connector results in low insertion loss. Edge plating of contact PCBs also results in low overall return loss for the Card Edge Connector system. Figure 44 shows the measured insertion and return loss for the Card Edge Connector system. Both de-embedded and raw measured data for the Card Edge Connector system up to 18 GHz is shown.

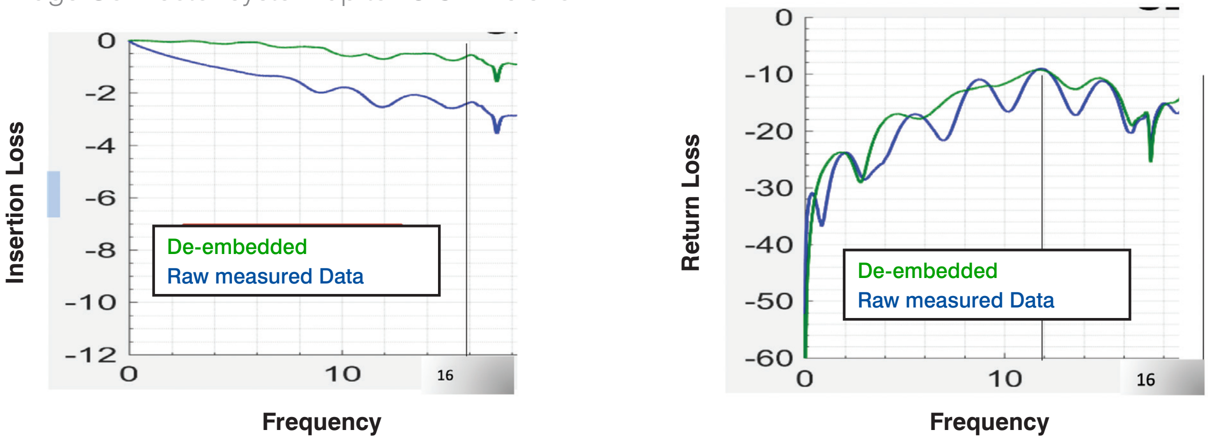


Fig. 44: Insertion and return loss of the Card Edge Connector system

Card edge-based coax and Twinax cable assemblies from CarlisleIT offer excellent signal integrity with low insertion and return loss. These high-performance cable assemblies provide a cable-to-board solution in high-speed interconnect applications like PCIe Gen 5 connectivity. Figure 45 shows the insertion loss of different channels in a 28AWG twin ax cable assembly using a card edge PCB and operating up to 18 GHz. Please note the low loss performance across the complete frequency band, making it suitable for high-speed PCIe Gen 5 and other similar interconnect applications.

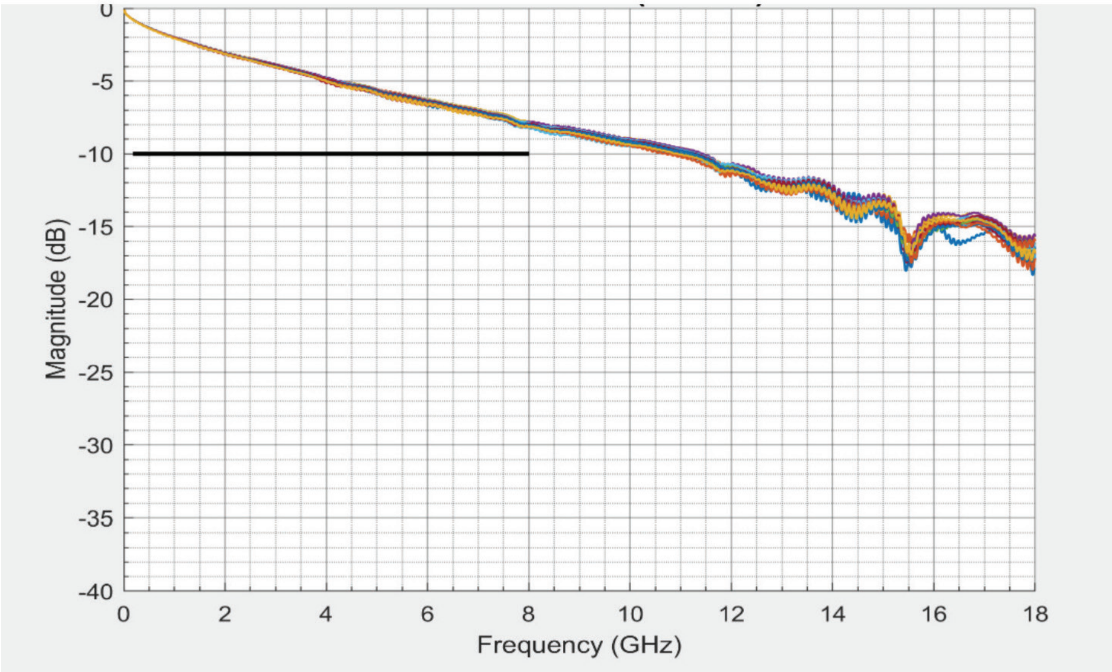


Fig. 45: Insertion loss of a card edge-based Twinax cable assembly

Digital Products

Similarly, the low-return loss performance for Twinax cable assembly comes from high-precision termination of cables on card edge PCB. An example of such cable assembly is shown in Figure 46 below. Another factor contributing to low return loss is the accurate impedance matching of Twinax cable channels with the impedance of card edge PCB traces. Return loss of different channels in card edge-based Twinax cable assembly is shown in Figure 47 below.

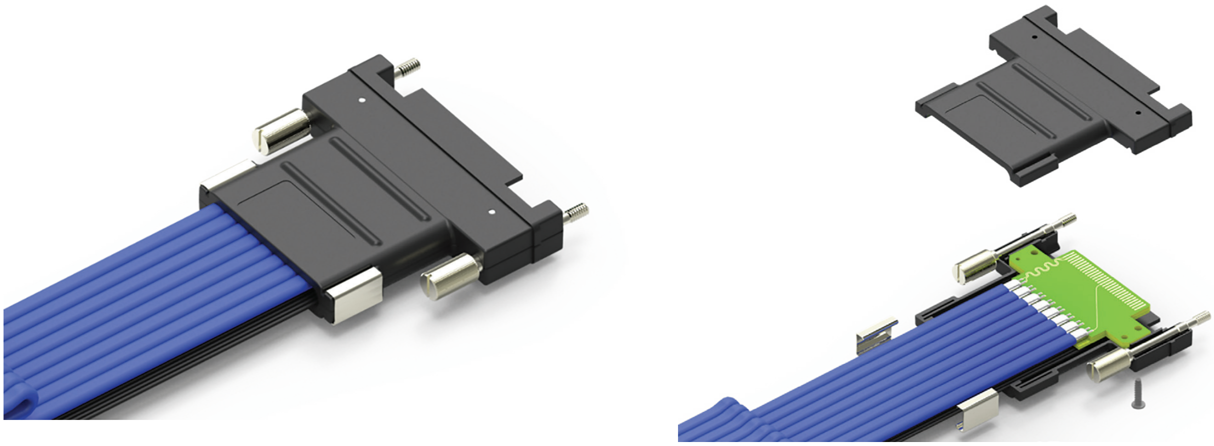


Fig. 46: Twinax-based card edge cable assembly

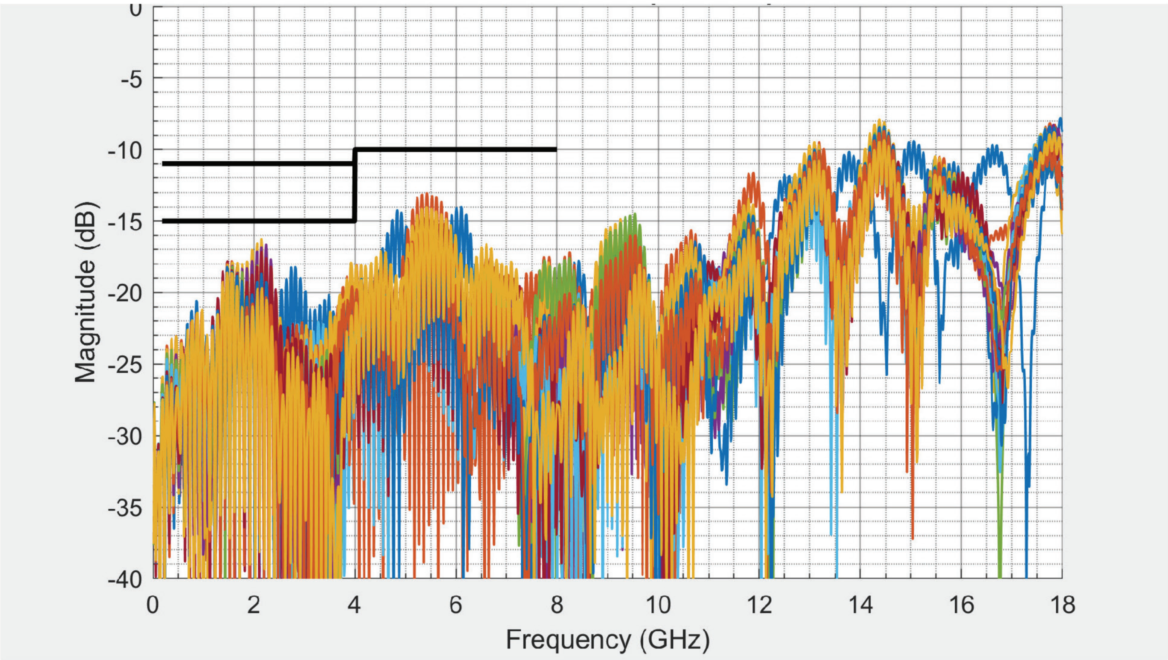


Fig. 47: Return loss of different channels in a card edge-based Twinax cable assembly

Probes

Passive Probes

CarlisleIT offers low-cost high-performance compact CAT III and CAT IV rated probes in a UL-certified plastic body suitable for a variety of applications. The passive probe is a standard, commercial off-the-shelf system engineered to deliver consistent, repeatable, and dependable results. The passive probe provides an industry-leading combination of high bandwidth and high voltage in a low-cost, rugged, general-purpose probing solution.

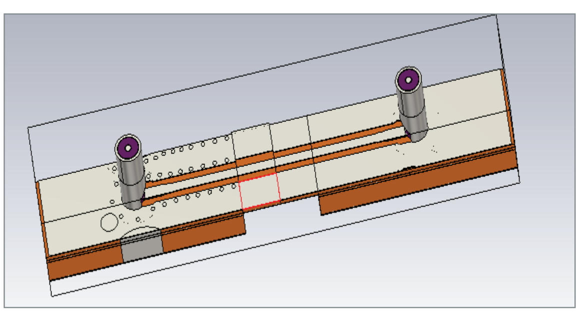
Features	Customer Benefits
500 MHz bandwidth AND 1,000 V Cat III, 600 V CAT IV	A combination of high bandwidth and high voltage reduces the number of probes needed for a variety of applications, simplifying the toolkit and lowering costs
1X, 10X, and 100X configurations	Multiple configurations give customers the flexibility to choose the passive probe that fits their application
Third-party certified, exceeds UL61010-31, IEC61010-31	Superior product quality and safety greatly reduce risk in high-voltage applications
Small, compact probe head and body	Enhanced visibility to small, dense geometry circuit elements within the device-under-test (DUT) ensures correct and accurate test-point contact

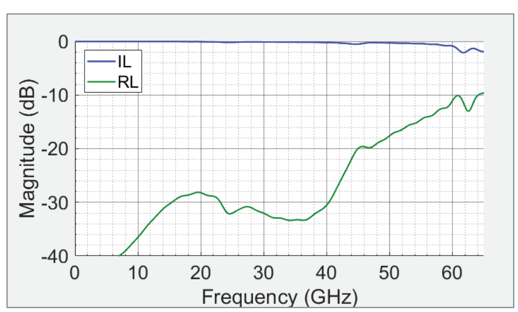
Passive Probes

Signal Integrity Services

CarlisleIT offers signal integrity services to its customers in order to optimize the complex designs made for best possible system performance. CST, Solidworks, and ProE are some of the tools used to simulate the customer's printed circuit board stackups integrated with CarlisleIT's RF connector footprints. Board designs are optimized for the lowest return loss, insertion loss, and crosstalk. Effects of materials for boards like Megtron, Nelco, Rogers, and High-Speed FR4, vias, and layout of signal traces relative to ground plane in board-layer stackup can also be seen and optimized for frequency range of interest.

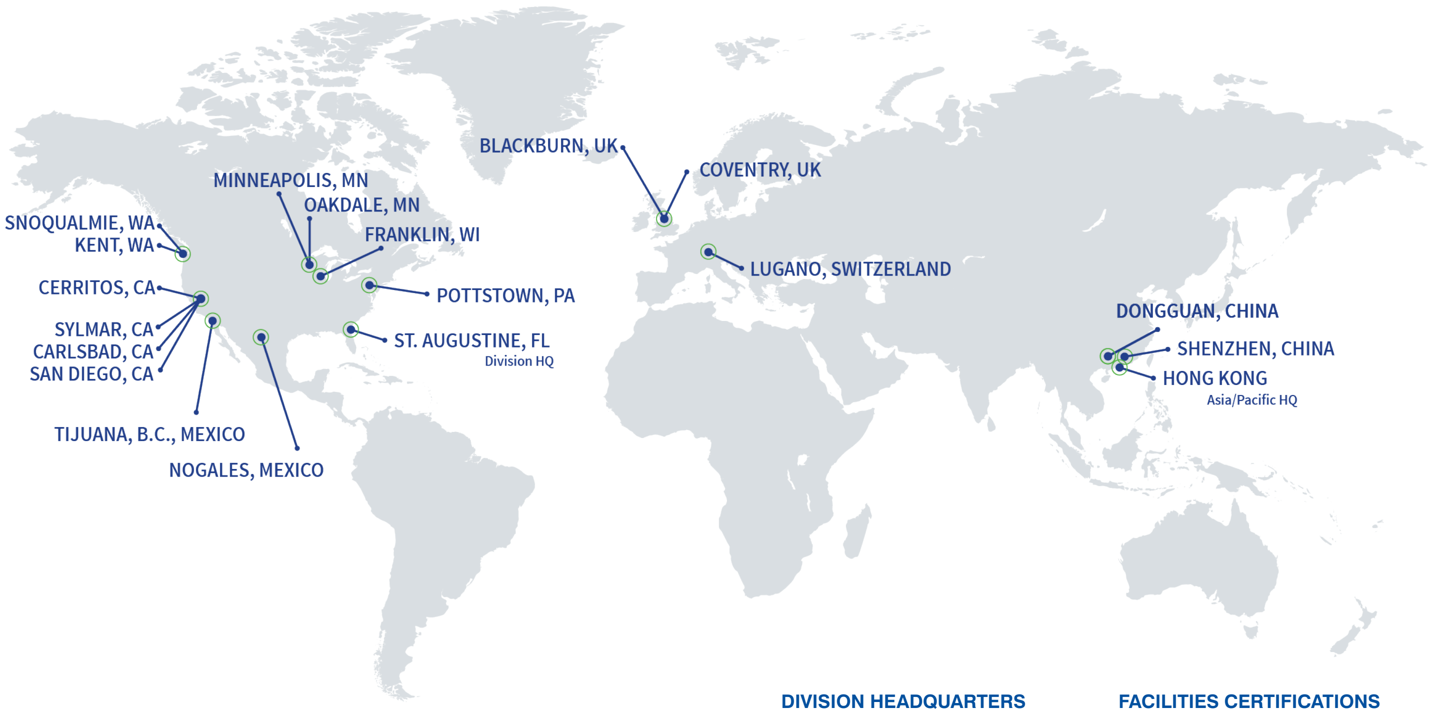
VNA and time domain reflectometry measurements are also performed to validate the simulations and characterize the designs.





Global Manufacturing. **Local Support.**

Wherever you are, so are we. With manufacturing centers around the globe, our highly qualified team of engineers is up to any challenge. Our extensive worldwide manufacturing capabilities, coupled with end-to-end local project management and engineering support, allow us to design, build, test, and certify your product in-house, saving you the time and hassle of managing multiple vendors.



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» MIL-SPEC/SAE
» RoHS compliance

CARLISLE
INTERCONNECT TECHNOLOGIES

Performance with **Purpose**

BR-10186-050521