MegaPhase®

Overcoming Miniaturized Routing Challenges with Solderless Terminations

White Paper

Introduction

The electro-mechanical method used to attach an RF connector to a coaxial cable is called the "cable termination." Cable termination methods have evolved over the years to improve assembly performance in demanding applications. Military, space, telecommunications, and test and measurement industries design system upgrades to meet market needs and advancements in technologies. These advancements typically require higher bandwidth or higher frequency transmission which translates into a smaller system footprint. In some cases, the system's footprint is reduced to make room to add additional technologies to further enhance system performance, but these evolving system enhancements pose new challenges for coaxial cable assembly terminations.

Flexible coaxial cable terminations must adapt to evolving system designs where form and fit are reduced while function is greatly expanded. New, innovative coaxial products are emerging to address these increasingly rigorous requirements. This paper examines the limitations of using traditional style terminations in high density, small form factor applications, and the technological advancements that enable flexible cable assemblies to be installed in these very tight spaces.

The MegaPhase HyperFlex cable series utilizes solderless terminations

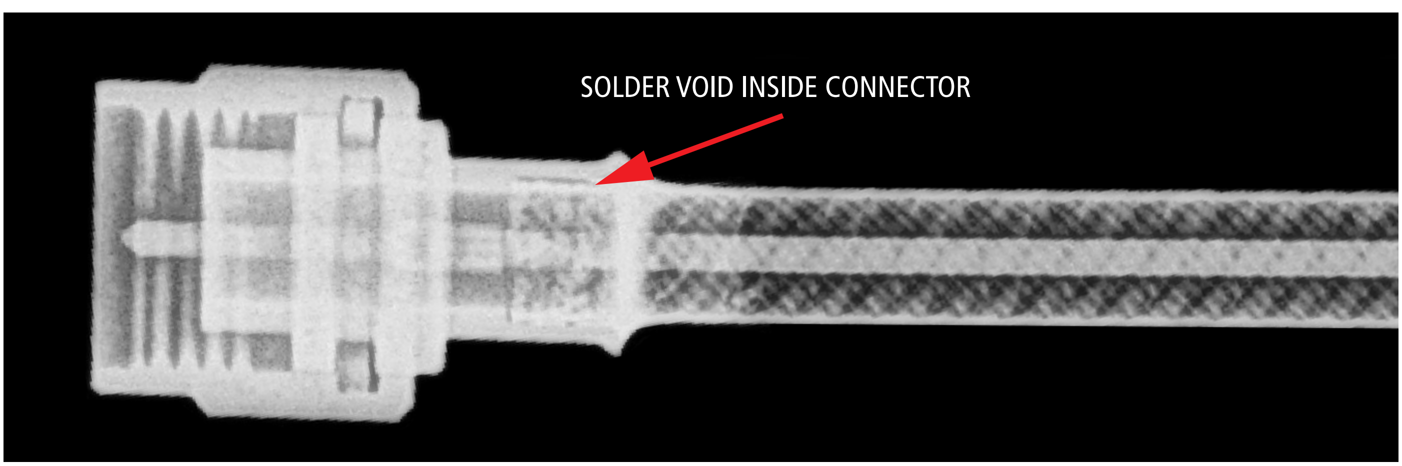
History and Types of Coaxial Terminations on Flexible Cable

A coaxial connector consists of a connector housing, center contact, and an insulating dielectric. Flexible coaxial terminations consist of attaching the cable shields or braid structure to the connector housing and then the cable center conductor to the center contact of the connector. Crimp and clamp terminations were the first types of braid attachments developed for flexible cable assemblies, and the connector contact was terminated using a solder or crimp method. These early termination methods were typically dictated by operating frequency and environmental requirements for the cable assembly. The use of solder to terminate cable outer conductor shields was a natural transition, widely influenced by solder-terminated semi-rigid cables, which have a solid outer conductor rather than braid and foil.

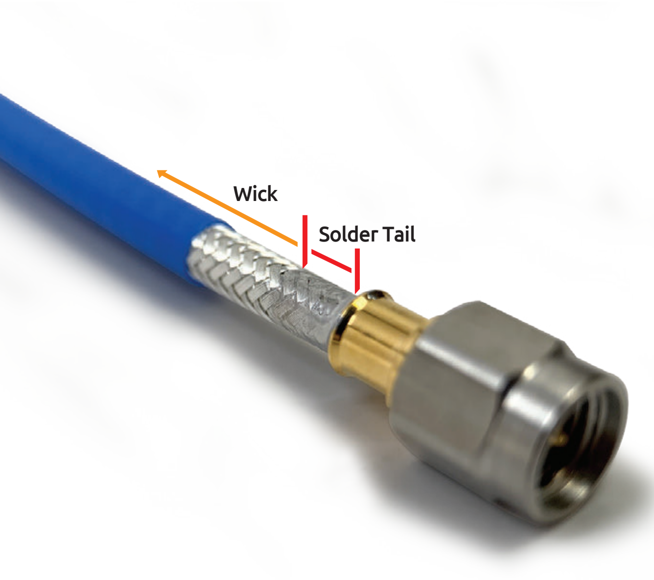
The introduction of solder termination for flexible cables was a silver bullet for the coaxial cable assembly industry. The solder termination has proven, through many decades and in diverse system applications, to be rugged in high shock, vibration, and thermal conditions. This method quickly became the high-performance coaxial RF assembly standard for inside-the-box and between modules in the complex, high performance RF system infrastructures we know today.

Advantages and Disadvantages of a Solder-Terminated RF Assembly

The robust solder termination is well suited for military and other high reliability applications because it maintains excellent electrical grounding and bonding integrity for optimum RF transmission and is rugged mechanically under stress. The challenge with solder terminations is the application process. Solder joint integrity can be jeopardized prematurely under stress if not done correctly by an experienced technician. A reliable solder joint is achieved by controlling solder volume, dwell time, and consistent heat distribution in the target area. When solder application parameters are not controlled properly, it is possible to create a deceptive solder joint appearance that does not have adequate adhesion structurally. Cold solder, porous volume, and improper flow are common issues often not visible to the human eye. High-reliability applications often require X-ray inspection to examine solder fill and ensure structural integrity.



The Evolution of Small Form Factor System Modules

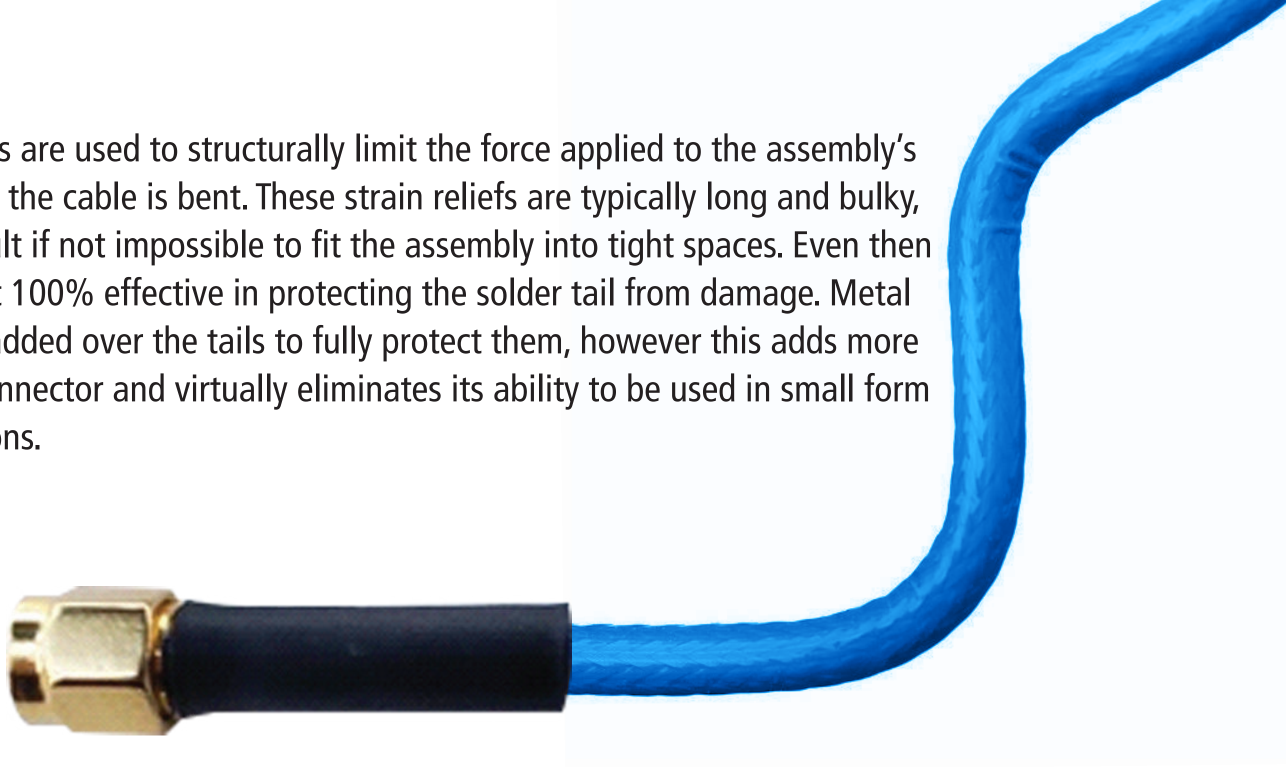


Technological advancement in component designs and manufacturing have enabled architectures and system envelopes to shrink in size while increasing the component's overall throughput performance, enabling system engineers to shrink overall package sizes and/or add additional functionality. This is key to adding capabilities to advanced systems in modern airborne electronic warfare and space platforms, where real estate is at a premium. More capability often requires more RF channels, increasing the number of cable assemblies that are packed into a given area. Furthermore, these smaller form factors also make it more challenging to route RF cabling.

Despite their benefits, solder-terminated flexible assemblies have a particular disadvantage in small form factor applications. These assemblies have a rigid section of cable just behind the connector, created during the termination process when solder wicks into the cable shield as solder and heat are applied to attach the connector housing. The solder is drawn up the cable braid by a naturally occurring phenomenon called capillary force, as it travels to fill the cracks and voids within the braid structure. This rigid section created in a cable braid structure at the connector termination is referred to as a "solder tail."

If a solder tail is forced into a bend, it will fracture; a solder-terminated cable assembly is on borrowed time once a crack forms in a solder tail. The crack will continue to grow under vibration and thermal changes, eventually reaching a point where it affects system performance and finally to outright failure.

Stiff strain reliefs are used to structurally limit the force applied to the assembly's solder tail when the cable is bent. These strain reliefs are typically long and bulky, making it difficult if not impossible to fit the assembly into tight spaces. Even then they are still not 100% effective in protecting the solder tail from damage. Metal sleeves can be added over the tails to fully protect them, however this adds more length to the connector and virtually eliminates its ability to be used in small form factor applications.



Another technique used to solve this challenge is to change the connector from a straight configuration to a right angle. This is needed when the cable must turn ninety degrees relative to the connector mating interface behind the box interface wall or bulkhead. System performance is typically negatively impacted when using right angle connectors, raising VSWR and insertion loss. Engineers must accept reduced electrical performance when using right angle connectors when no other option is available to fit the assembly into a small footprint.

Right angle connectors have fixed geometries. If multiple cables must bend into right angles at varying distances behind each channel interface, a different right angle connector configuration will be needed for each cable assembly. This uniqueness per right angle connector significantly drives up the cable assembly price, often making it economically unfeasible. Furthermore, it adds more complexity to the overall cable management within a system and results in longer lead times from the cable assembly supplier.

Some manufacturers use bent tubes to simulate right angle connectors that bend at various degrees. This helps to control the significant pricing increases associated with using different fixed right angle connector configurations but does little to alleviate the complexity in system cable routing, configuration, and procurement. Furthermore, bent tubes need to have large sweeping bends to maintain system electrical parameters thus making them unqualified for use in high density, small form factor applications.

The cable itself also needs to be evaluated for use in high density, small form factor applications. Coaxial cables need to be able to handle very tight static bends and be large enough in cross section to meet system RF performance requirements for power handling and insertion loss. These cables also need to have good shielding characteristics, particularly when bent. Most cables currently on the market do not have good electrical characteristics when bent below a 0.250in (2.65mm) radius. This is because shield layers are not adequate to limit aperture exposure when in tight bends, compromising signal isolation.

Right angle connectors and minimum bend radii limitations force system engineers to design around the cable assembly geometries, sometimes forcing them to increase the overall size of the box envelope just to accommodate the RF channels. This potentially increases the overall weight of the package and/or reduces the space available for additional system enhancement and channels.

Cable Assembly Termination Advancements Give Engineers the Freedom to Further Shrink Form Factors

The evolution of system miniaturization requires the evolution of the cable assembly termination. Solder terminations have proven to be problematic when package sizes shrink below the mechanical limits of a solder tail. As such, it is essential for any new termination methods to perform electrically and mechanically as well as their soldered predecessors.

RF connector manufacturers have developed innovative solderless solutions to specifically address the requirements of small form factor environments. These new terminations have all the same performance characteristics of solder-terminated assemblies without using any solder. This makes the cable assemblies RoHS compliant and eliminates the need for X-ray verification of the termination. These advanced solderless terminations have been engineered to hold up under the same extreme mechanical environments as high performance solder-terminated assemblies. This makes them ideal for use in military airframes, space vehicles, and ground-based military platforms.

Cables with exceptionally small bend radii are better suited for use in tight environments and have been reengineered to improve their static bend characteristics to further enhance solderless terminated assemblies. Similarly, shield constructions have been enhanced to protect signals in today's hostile RF environments. RF shielding is typically >100 dB even when put into a tight bend.

Advanced solderless cable-connector systems perform electrically as well or better than solder-terminated assemblies even when the cable is bent tightly behind the connector body; some cables can be put into a radius as small as 0.100in (2.54mm). This eliminates the need to have a right-angle connector design for these cables. The cable can be bent tightly enough to the connector to produce a right-angle connector geometry while maintaining both mechanical and electrical performance. Additionally, advanced solderless assemblies can be made as short as a few inches, and still bend into a configuration shape.

Advanced solderless cable attachments address all the challenges system engineers have been facing for years with using solder-terminated assemblies in a shrinking system footprint. Solderless terminated assemblies are also good candidates for upgrading legacy systems that use traditional solder terminations because they put an end to potential field failures caused by solder tail fractures that can develop during system installation. Assemblies having tight bend radii make mechanical routing easier and eliminates the need to manage right angle connector geometries.

Conclusion

Solder-terminated flexible cable assemblies have been the primary choice for use in extreme electro-mechanical environments including military and space applications for many years. They have earned their place in high end applications because of their good electrical and mechanical properties, however the solder tails of these assemblies present routing challenges inside boxes that are becoming increasingly miniaturized. The cables cannot be bent in close proximity to the connector without compromising the integrity of the termination. A fractured solder joint can lead to a field failure that can disable a system during its most critical use. Until recently, engineers have had few options other than to design systems around the mechanical constraints of connector solder tails, greatly impacting the size of the overall box footprint.

New innovative coaxial products such as high reliability solderless terminated cable assemblies provide a solution to these in-box routing challenges. System engineers now have flexible cable assembly options that allow them to shrink system packaging smaller than ever before, making room for added capabilities and technologies to a given platform, or move it to a smaller operational platform altogether. Using solderless terminated cable assemblies also allows engineers to replace legacy (solder-terminated) box assemblies to reduce costs through configuration synergy. Solderless terminated assemblies increase the ease of installation and eliminate solder tail installation fracture, providing engineers with peace of mind with respect to field failures.

To learn more about the advancements
MegaPhase is making in solderless terminated assemblies,
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