Space Ready Microwave Cables: Into the Cosmos

What are the makings of an RF space assembly?

White Paper

History

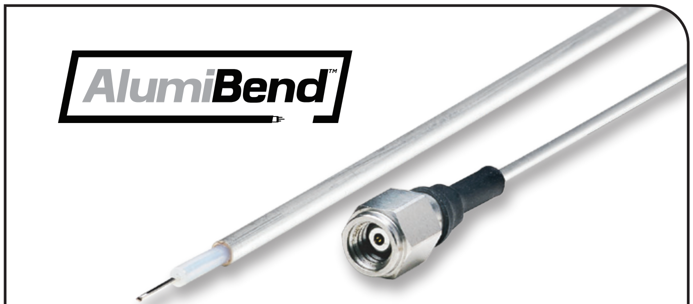
Ever since the launch of the first space vehicle, Sputnik, in 1957, satellites and other celestial craft have utilized antennas to send some form of communication or data back to earth. Today there are nearly 7,000 satellites orbiting the earth, projected to reach nearly 15,000 by 2030 as the number of Low Earth Orbit (LEO) constellations increases. Without the ability to send and receive data to and from the surface of earth, a spacecraft becomes vulnerable and, in most cases, virtually useless. Technological advancements have enabled modern spacecraft and satellites to exchange extremely large volumes of information at incredibly fast rates, making cabling a critical component of a space vehicle's communications system.

Not all microwave cable constructions are created equal and a "one cable fits all" approach simply doesn't work for most space applications. The complexity of spaceflight demands a unique cabling solution tailored to specific mission conditions. Each type of orbit—GEO, LEO, MEO, SSO and GTO—as well as Lagrangian orbital positions and deep space missions all have unique environmental conditions to consider. Some of these are: the flexibility needed in flight and during installation or integration, the electrical performance (insertion loss, phase stability, shielding, multipaction, PIM), the environmental performance (radiation, mission duration), and weight. The goal is to select a cable that can meet these various operating conditions and contribute to lowering mission risk.

Flexibility

RF microwave cables come in two basic forms: flexible and semi-rigid. Both have different advantages. A flexible cable can be easily bent by hand into an installation while a semi-rigid cable offers better shielding with respect to EMI (electromagnetic interference) shielding and radiation breakdown. A semi-rigid cable typically has a solid copper outer conductor and is more akin to a pipe. It is somewhat difficult to install and typically needs fixture tooling to bend it into fixed shapes. A more forgiving version of the standard semi-rigid cable has a soft aluminum solid outer conductor, allowing it to be hand formed into the installation. Neither of these semi-rigid options can be used when the cable must flex after installation, for example, when a panel or antenna is deployed or extended once in flight or in orbit. In those cases, only a flexible cable should be used.

MegaPhase Semi-Rigid Cables



MegaPhase AlumiBend™ Cables

With the right connections, anything is possible.

Electrical Performance

Insertion Loss

The geometry and size of an RF cable has a direct relationship to its insertion loss characteristics. Generally, the larger the cable diameter, the lower its loss will be over the length of the cable. Conversely, the larger the cable, the lower its maximum operating frequency. This conflicting loss-to-frequency limit is bound by the cable geometry and the laws of physics within the RF coaxial structure. The cable size is therefore governed by the maximum operating frequency and sometimes the mass or weight requirements of the mission. Insertion loss characteristics will be limited at higher frequencies because of the loss-to-frequency geometry relationship within the cable structure.

Cable dielectric materials with lower dielectric constants (and higher velocities of propagation) can be used to enhance and improve a cable's insertion loss over its length. Improving or lowering a cable's insertion loss characteristics by lowering its dielectric constant typically changes the mechanical compression strength of the cable. This makes the cable susceptible to crushing. The cable's electrical properties degrade significantly when a cable's cross section is compressed or crushed. This may make it necessary to add mechanical enhancements to the cable to protect it against compression, depending on the application environment. There are several ways this can be achieved. Most cable manufacturers have developed a portfolio of cabling products with various protection enhancements.

Adding crush-resistant protection layers to a cable construction increases its overall diameter, mass, and cost. These factors and tradeoffs should be carefully considered when selecting a cable with enhanced dielectrics that improve the assembly's overall insertion loss.

MegaPhase ThermalVAC Cables

Phase Stability

Array antennas are becoming the standard on larger satellites to support the growing RF channels they are designed to handle. Sophisticated systems may require phase matching each cable assembly within the array grouping of the antennas.

In some phase array systems, it is important that cables track together within a given phase tolerance across temperature ranges to maintain the proper phase angles between antenna elements. It is sometimes important to have a cable that not only tracks well to other cables within the array group but also maintains a tight phase profile over a given temperature range. Selecting a cable that doesn't exhibit what is known as a "Teflon™ Phase Knee" (the abrupt phase change that Teflon dielectric cables go through around 23 degrees C) may be of importance depending on the application's specific operating parameters. There are a variety of dielectric materials and dielectric constructions available that perform well under these conditions. There are also electrical and mechanical differences between these dielectric cable structures.

MegaPhase UltraPhase™ Cables

Other times phase performance over flexing may play a critical role. For such flexing applications, the cable's shielding structure has more of an impact on phase stability than the dielectric material.

Shielding

The shielding effectiveness of a cable differs by its construction. There is a wide range of shielding offerings available for coaxial cables from -70 dB to -150 dB. Increased mechanical shielding increases a cable's mass, adding weight and reducing its flexibility. Shielding effectiveness should be balanced with the spacecraft's RF isolation and liftoff weight requirements.

MegaPhase NextPhase™ Cables

Multipaction

Special connectors are needed when multipactor breakdown is a concern. A multipactor event can cause the disruption of signal within the transmission path. A multipactor event is most likely to occur at elevated power levels. In such cases, it's possible to overheat the internal structure of the transmission line (where the multipation occurs) and burn out the cable assembly. Most connector interface standards were not designed with multipactor breakdown in mind. Venting a connector to allow the flow of gasses trapped within the connector's transmission line structure helps to mitigate a multipactor event from occurring. In highly sensitive systems, connectors that utilize overlapping insulators may need to be used to further protect against a multipactor event. In the most severe environments, wedge type interfaces may need to be considered. Multipaction-resistant connectors also have increased power handling capability by design.

MegaPhase Optimized Super SMA Connectors

Passive Intermodulation

Passive Intermodulation (PIM) distortion can occur in many applications where non-linear signal levels interact or mix. These distortions can interfere with the RF signals being received. Space applications can be especially susceptible to PIM due to the relatively high powers being transmitted from the satellite, combined with relatively low signal levels being received, especially in the portions of the signal chain that are common to both the transmit and receive signals simultaneously. There are a variety of low PIM cable assembly products available that can address the various PIM level requirements for varying applications.

MegaPhase Low PIM Cables

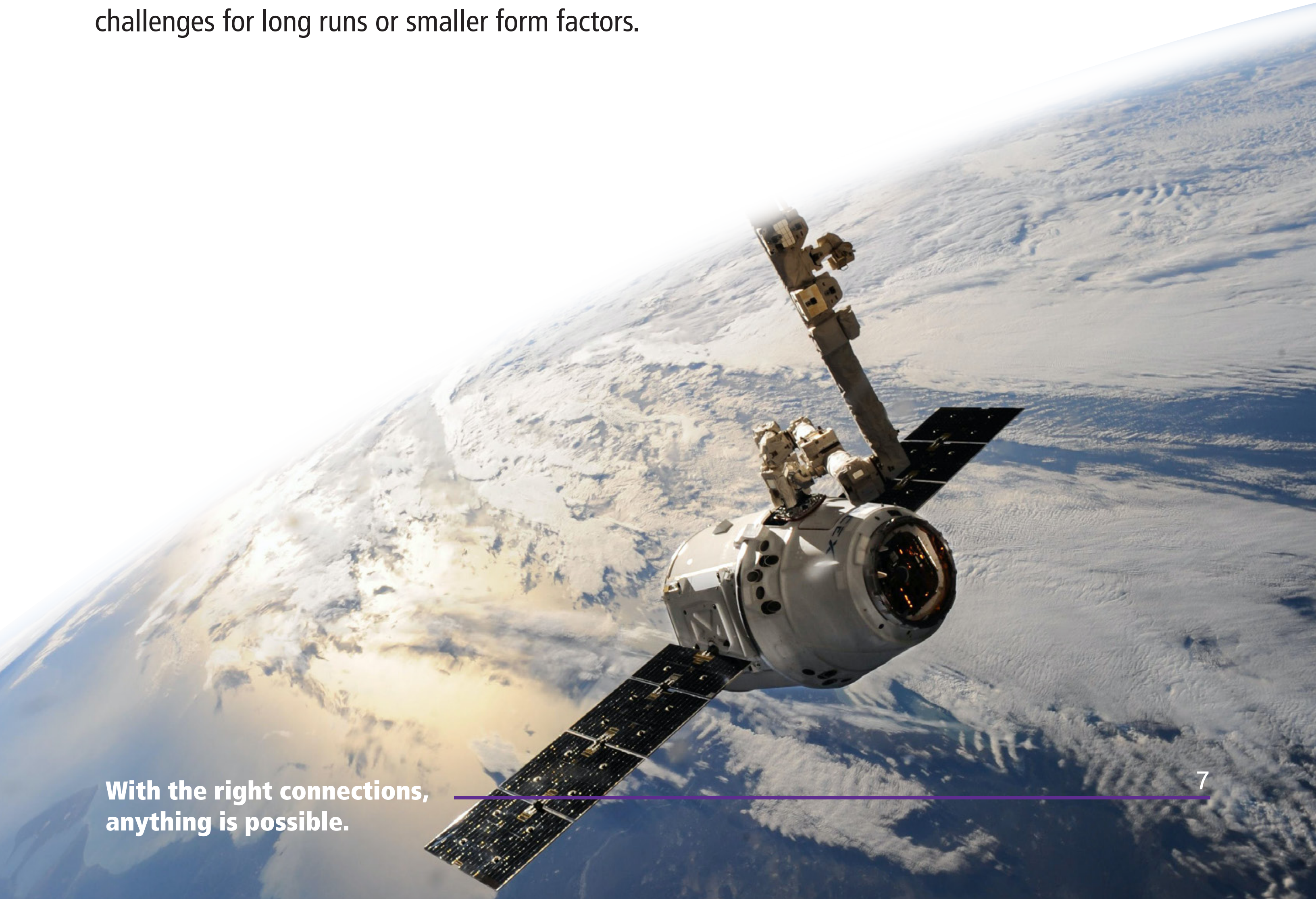
Environmental Performance

Radiation Resistance

Radiation levels can greatly reduce the life of an RF cable assembly by breaking down the polymers in the cable. The intensity of radiation differs by the type of orbit a satellite maintains and its designed service life.

Polymers used for cable jacketing generally don’t have radiation-resistant properties. These polymers may start to break down above 15 Mrad (megarads) exposure. However, that doesn’t necessarily eliminate them from being used in space vehicles. The orbit and location of a cable assembly inside a vehicle’s structure can sometimes provide adequate radiation shielding. Viton™ and Tefzel™ jackets can be added to cables to increase the assembly’s resistance to radiation, which generally enables the cables to survive up to 100 Mrad environments.

Copper or aluminum jacketed cables provide a solid metallic shield around the cable, providing the best radiation shielding, however, as noted above, these are rigid and do present installation challenges for long runs or smaller form factors.



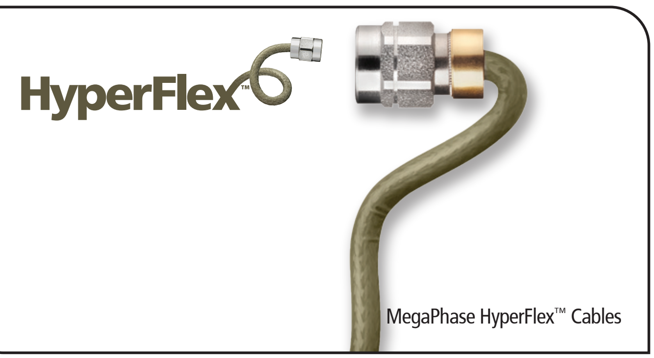
Light Weight (Low Mass)

Cable mass always plays some role in the overall cost of launch. Weight becomes a larger factor as more and longer cable assemblies are added to modern satellite systems, and there is typically some performance tradeoff associated with reducing cable weight. This could be in the form of reduced shielding effectiveness, higher Insertion loss, lower flex life, or a combination of the three. Engineers need to consider the impact and potential tradeoffs of each.

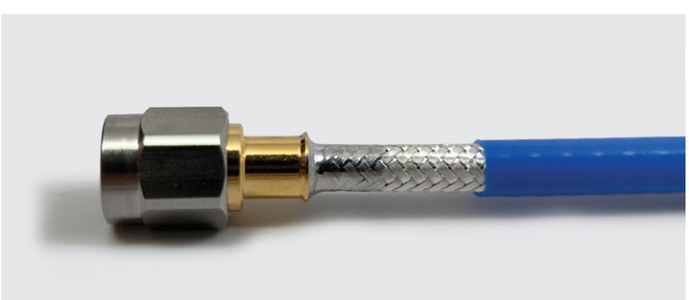
MegaPhase AlumiBend™ Cables

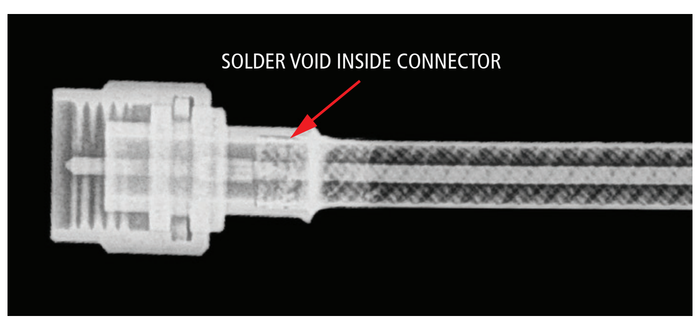
Solder vs. Solderless Termination

A solder termination offers a cost effective and electrically conductive method for attaching a connector to a cable. It is mechanically durable and can withstand extreme temperature changes. However, it also creates a potential fatigue point where the solder transitions into the cable shield at the end of the solder wick (the end of the solder flow in the cable shield structure). This is not typically a concern under normal conditions so long as the cable isn't subjected to stresses during installation. There are times when stressing the cable during installation is unavoidable, for example, in small form factors where short cable assemblies are installed into very tight configurations within box and circuit board assemblies, or if the cable needs to bend near the connector attachment for routing purposes. In these cases, consideration should be given to a solderless type termination that can allow the cable to be bent right behind the connector without transferring fatigue stresses to the connector termination and the cable shield structure.



MegaPhase HyperFlex™ Cables





Conclusion

Engineers face myriad mechanical and environmental challenges when designing cabled systems on space vehicles. Materials and construction geometries play a major role in a cable assembly's survivability in a space environment. Fortunately, there are a variety of coaxial cable offerings available to help engineers optimally balance electrical and mechanical performance parameters.

It is equally important that engineers make sure the quality of the cable's assembly meets the high reliability standards necessary to ensure performance over the mission life, specifically the way a component is manufactured with respect to handling, processing, and the quality of components used. This sometimes includes traceability of those processes and component materials. Carefully selecting a manufacturer helps eliminate the potential for small defects that can jeopardize mission success.

With all these factors in mind, engineers can better understand the key attributes to consider when selecting a cable, connector, and cable assembly for use in space to ensure a long, trouble-free life for a space vehicle's communication system.

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To learn more about the advancements MegaPhase is making in space-qualified products, call (570) 424-8400, email solutions@megaphase.com, or visit megaphase.com/space.

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