White Paper

TAKE OFF AND STAY CONNECTED: SEAMLESS INTERNET SERVICE THROUGH SUPERIOR CABLE TECHNOLOGY

Introduction

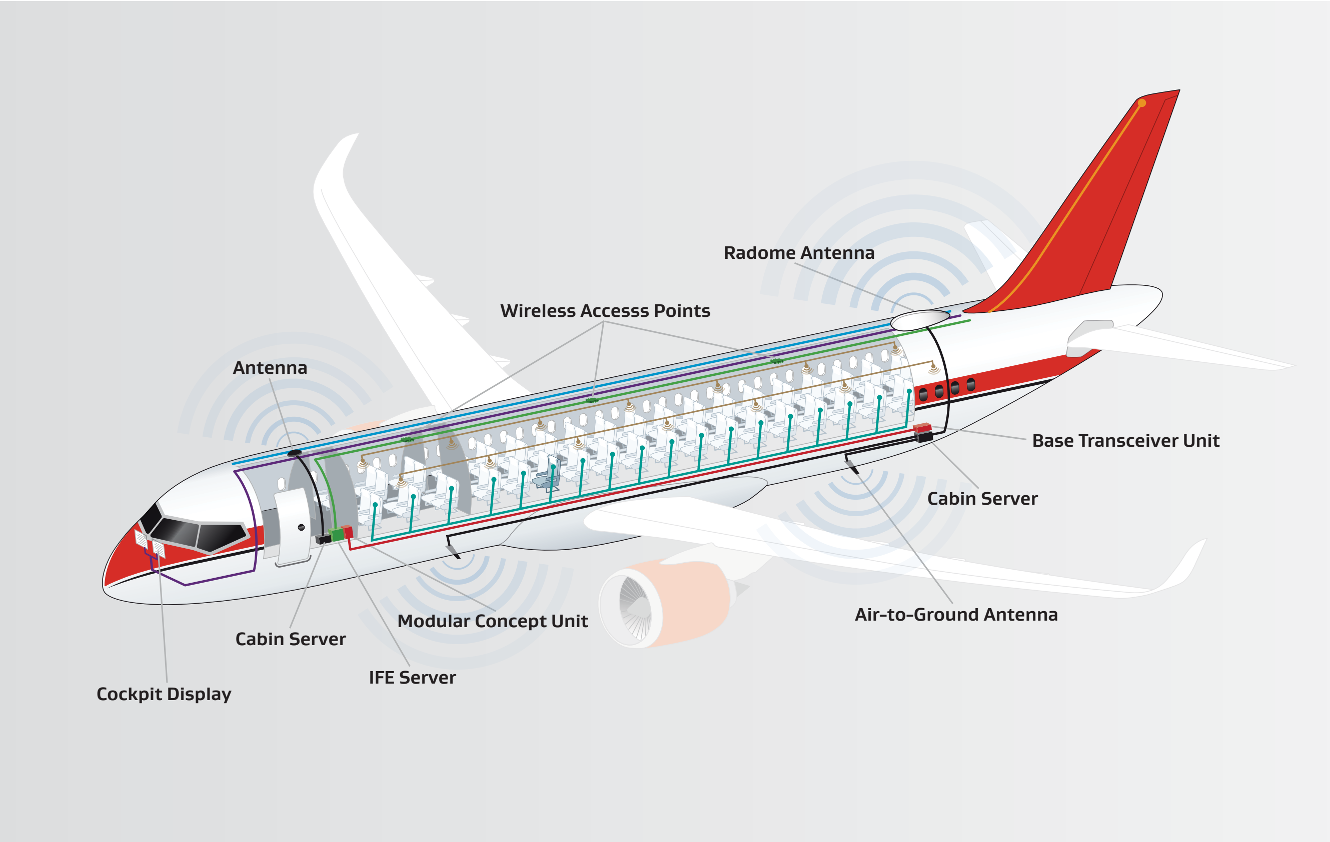
Today's airline passengers have a growing expectation that they can use their hand-held devices during the flight, either for business or fun, as they want to stay connected with work colleagues, family, and friends. As this demand for in-flight connectivity grows, passengers' expectations are also rising, demanding higher speeds and a better quality of service. If the airlines use the WiFi as a revenue stream, they must be able to provide a reliable connection to maintain customer satisfaction. If the service is poor, passengers will ultimately vote with their money and choose a carrier with a more reliable connectivity solution. On the aircraft, connecting the WiFi system antenna to the transceiver is achieved using a 50-ohm coaxial cable. Failure or degradation of this single cable can cause the system to be unavailable and lead to frustrated passengers.

"Good afternoon, passengers. On behalf of the crew, I'd like to welcome everyone to today's flight. Unfortunately, the on-board WiFi service is unavailable due to technical reasons, so you will not be able to access the Internet or send messages using your hand-held devices during the flight. We apologize for the inconvenience."

Why are cables failing?

Sealed coaxial cable assemblies have been used for decades in underground or "direct burial" applications such as cable TV. Cable TV providers found early on that burying a cable subjected it to a variety of temperatures and high moisture environments. Over time, their precious cable infrastructure corroded away from the inside out, necessitating costly replacement campaigns as well as contending with signal degradation and ultimately service outages. The corrosion process is hastened by the fact that in cable TV applications, a DC voltage is continuously present between the inner and outer conductor, accelerating the cathode/anode effect initiated by the presence of moisture within the cable. Under these conditions, a cable using dissimilar conductor materials can literally disintegrate in weeks once moisture permeates the cable's structure.

Figure 1: Key IFEC Areas in Civil Aircraft



In the airborne environment, coaxial cables often occupy areas of the airframe where various fluids, including fuel and hydraulic fluid vapor, along with particulate debris are present (Figure 1). These areas are particularly problematic for airborne applications where the cable occupies an unpressurized portion of the aircraft. As the aircraft ascends and descends, atmospheric pressure changes will cause an unsealed cable to aspirate. When the external pressure is greater than the cable's internal pressure, moisture-laden air is forced into the cable and will change its dielectric properties, thus impacting the cable's phase length. As the external pressure drops, the moisture-laden air migrates out of the cable, again impacting the dielectric's properties and further changing the cable's phase length. The effects of aspiration are compounded when warm, humid air enters a colder, unsealed cable, resulting in the formation of condensation. Once liquid is present within the cable's structure and its dielectric, the process is not likely to completely reverse itself. When contaminates have penetrated a coaxial cable's structure, the following performance-inhibiting results can be expected:

- **Instability under flexure —** continuity through the cable's outer conductor is affected due to corrosion, a reduction in conductivity or both, which manifests itself as amplitude instability with movement.
- **Progressively increasing insertion loss —** in this case, moisture introduces two separate signal loss phenomena: (1) Corrosion of the outer conductor, which in turn increases signal loss over the cable's length; (2) In cables using porous dielectrics, the moisture permeates the dielectric material, effectively increasing its dielectric constant and loss tangent, increasing the dielectric loss.
- **Capillary action —** coaxial cables employ either a braided outer conductor or a braid over flat wire outer conductor construction. In either case, the braid's intricate structure can allow water to migrate throughout the cable via capillary action, further spreading the water's corrosive action. Water entering the cable at some midpoint location will eventually wick to the connectors.
- **Dielectric contamination / modification of dielectric constant —** the previously mentioned bullet points address water ingress as applied to an unsealed cable assembly. When salt or other corrosives are added to the equation, damage progresses at an accelerated rate. Fluids other than water pose a threat to cable performance. In-flight applications, cables can be exposed to lubricants, hydraulic fluid, jet fuel, and deicing agents. None of these carry the potential for corrosion, but if allowed to penetrate the cable's construction, all will seriously compromise a cable's loss, stability, and dielectric properties simply because they can cause high resistance within the cable's outer conductor and contaminate its dielectric.

How can failures be prevented?

The use of vapor-sealed cable assemblies in airborne applications is not new (Figure 2). The military has demanded their use for over 50 years, connecting high-frequency, mission-critical systems such as Radar Warning Receivers and Electronic Countermeasures to ensure the safety of the aircraft and its crew. With rapid changes in altitude and the presence of fluids or condensation, a cable signal can be corrupted by the penetration of these contaminants into the cable jacket or the connector interface. With repeated pressure changes and the presence of moisture, corrosion is created, ultimately resulting in cable failure.

In commercial and general aviation, system requirements have generally not demanded higher frequency and lower attenuation coaxial cables, but now, with the advent of Ku and Ka-band WiFi, this has driven the need to consider the use of vapor-sealed cable assemblies. MIL-DTL-17 cables are no longer the “go-to” choice as frequencies increase and loss budgets tighten. There are two ways of providing WiFi connectivity to the plane.

For satellite-based systems, planes connect to satellites in geostationary orbit through a roof-mounted antenna located under a protective radome. When aircraft have been on the ground sitting in heat and humidity and then take-off on their next flight, condensation builds up within the radome and can be transferred to the cable assembly. De-icing fluids, cleaning agents and rain can also penetrate the radome if it is poorly sealed, which also can create potential contamination of the cable assembly. Air-to-ground (ATG) works via ground-based mobile broadband towers, which send signals up to an aircraft’s antennas that are usually located on the base of the fuselage. The cable sits at the lowest point in the airframe and is vulnerable to leaked fluids such as hydraulic oil, fuel, galley spillages, and toilet waste. Cable replacement and servicing constitute a serious aircraft downtime issue that will directly impact an airline’s profitability, with an estimated Aircraft On Ground (AOG) cost of $20,000 (US) per day.

In addition, there are the intangible costs of reduced customer comfort, missing customer expectations, overall customer satisfaction, and the risk of losing return business.

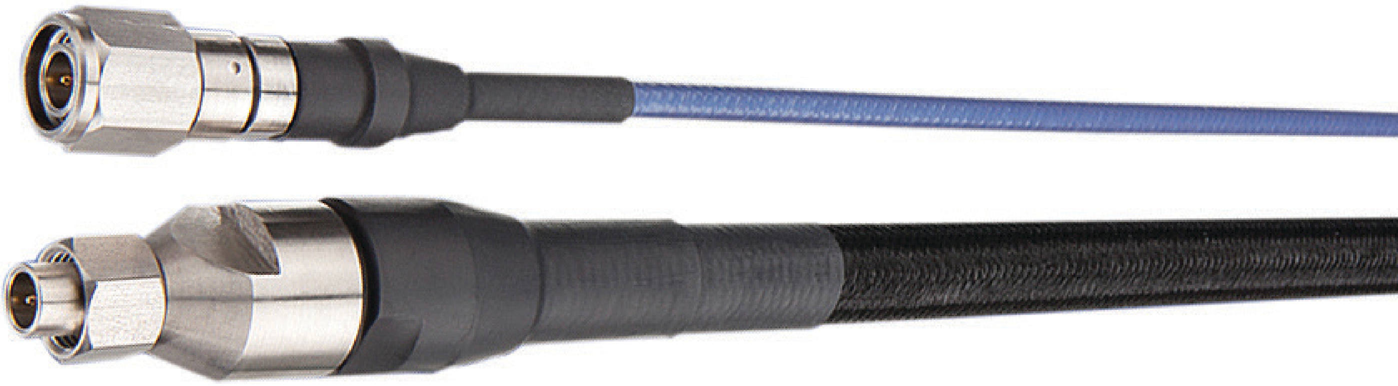
What are vapor-sealed cable assemblies?

Vapor-sealed cable assemblies are engineered specifically to prevent the ingress of fluids or vapors. The only reliable protection method for the cable assembly is to use a continuous metallic layer along its length. This layer, known as the vapor barrier prevents the transmission of gases through to the dielectric: plastics are micro-porous and do not provide an effective barrier.

Connectors need to be sealed at the interface and also at the rear of the termination to ensure a hermetic seal. Different methods are available, with the most effective being a glass-to-metal seal, but this has a negative impact on electrical performance because of the relatively high dielectric constant of glass. The more common method, for electrical performance and cost-effectiveness, is to use o-rings on all potential leak paths within the connector. These have negligible impact on electrical performance if integrated into the electrical design of the connector.

For a vapor seal, a military standard test must be completed in the absence of any standard commercial test method. Testing a vapor seal is fully described in MIL-STD 202, Method 112E and involves the use of a Helium Mass Spectrometer leak detector. As helium will diffuse through a solid three times faster than air, it is useful as a tracer gas to detect leaks. The cable assembly is backfilled with a helium/nitrogen mix before placed inside a vacuum chamber and then evacuated. The helium that is drawn from the cable under vacuum is detected by the helium mass spectrometer and, in the case of a vapor-sealed cable assembly, must not exceed a leakage rate of 1.0 x 10-5 cubic centimeters per second per foot of length.

Figure 2: Vapor-Sealed Cable Assembly



Why choose Gore?

Gore offers a broad portfolio of rugged, vapor-sealed microwave cable assemblies for various aircraft applications such as WiFi connectivity. Products include GORE® Microwave/RF Assemblies, 7 Series and GORE-FLIGHT™ Microwave Assemblies, 6 Series (Figures 3 and 4).

The 7 Series is engineered precisely to prevent the ingress of water vapor, fuel, and other hazardous contaminants. They are a lightweight solution and provide consistent performance over time with low insertion/return loss and excellent phase stability at frequencies up to 40 Gigahertz (GHz). Not only that, they provide outstanding shielding effectiveness against electromagnetic interference that can compromise signal integrity and reduce the quality of signal transmission. Gore also offers robust, low-profile connector options designed specifically to complement assembly performance, minimizing loss and reflection for optimized signal transmission.

When it comes to installation, aircraft maintainers will find it much easier to route our assemblies in confined areas because they are smaller and more flexible with a tighter bend radius. You can be confident that our 7 Series will not break or fail during routing like other standard assemblies that are more rigid.

Gore's award-winning 6 Series provides all the benefits and features of the 7 Series in a similar lightweight, flexible cable construction. However, it has an additional feature of an internal crush-resistance layer that provides enhanced protection against damage caused during maintenance activities and repeated shock/vibration in the flight environment.

All of our microwave cable assemblies have been thoroughly tested and qualified to meet stringent industry specifications and requirements for current and future generation commercial aircraft.

Whichever series you choose for your specific application, our products are the proven, long-lasting solution for easier installation, reliable signal integrity, reduced downtime, improved fuel efficiency, increased payload, and lower total costs.

For more information about proving installed performance of airframe microwave assemblies using a Gore-developed installation simulator, visit gore.com/resources/proving-installed-performance-of-airframe-microwave-assemblies.

For more information about our portfolio of microwave cables assemblies for aerospace applications, visit gore.com/products/categories/cables-cable-assemblies/aerospace

Figure 3: Vapor-Sealed Construction of GORE® Microwave/RF Assemblies, 7 Series

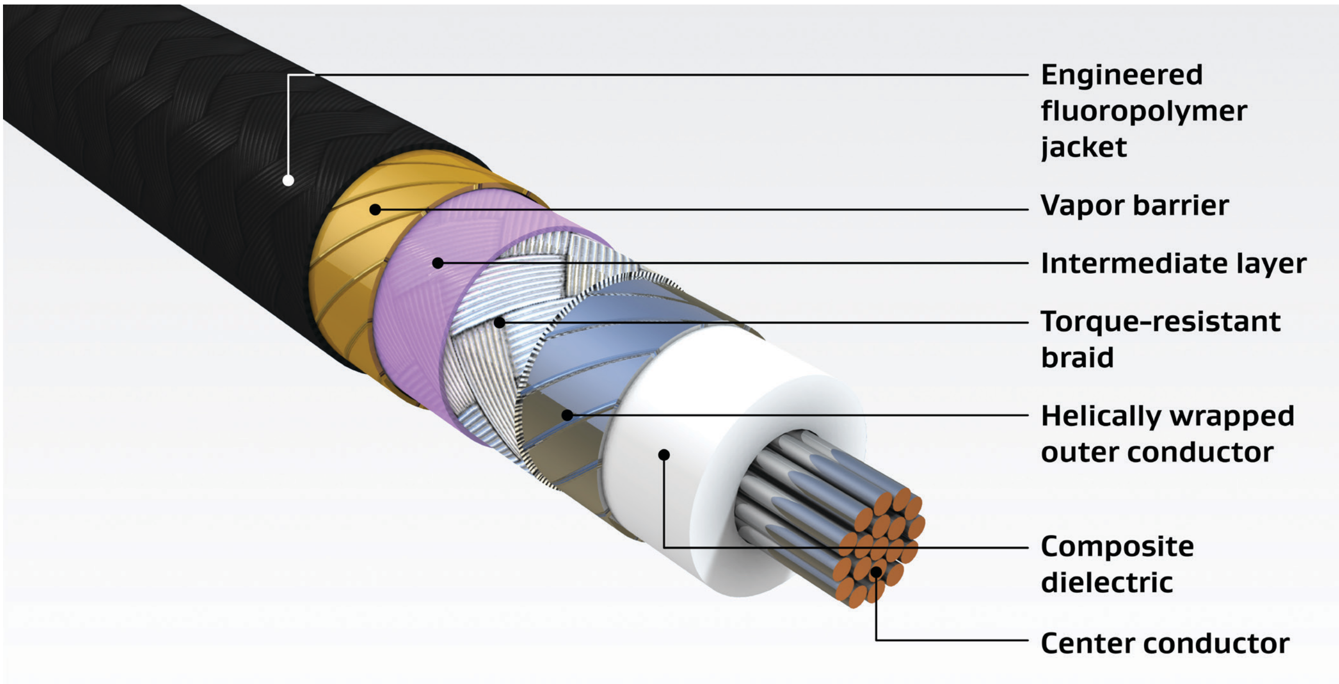
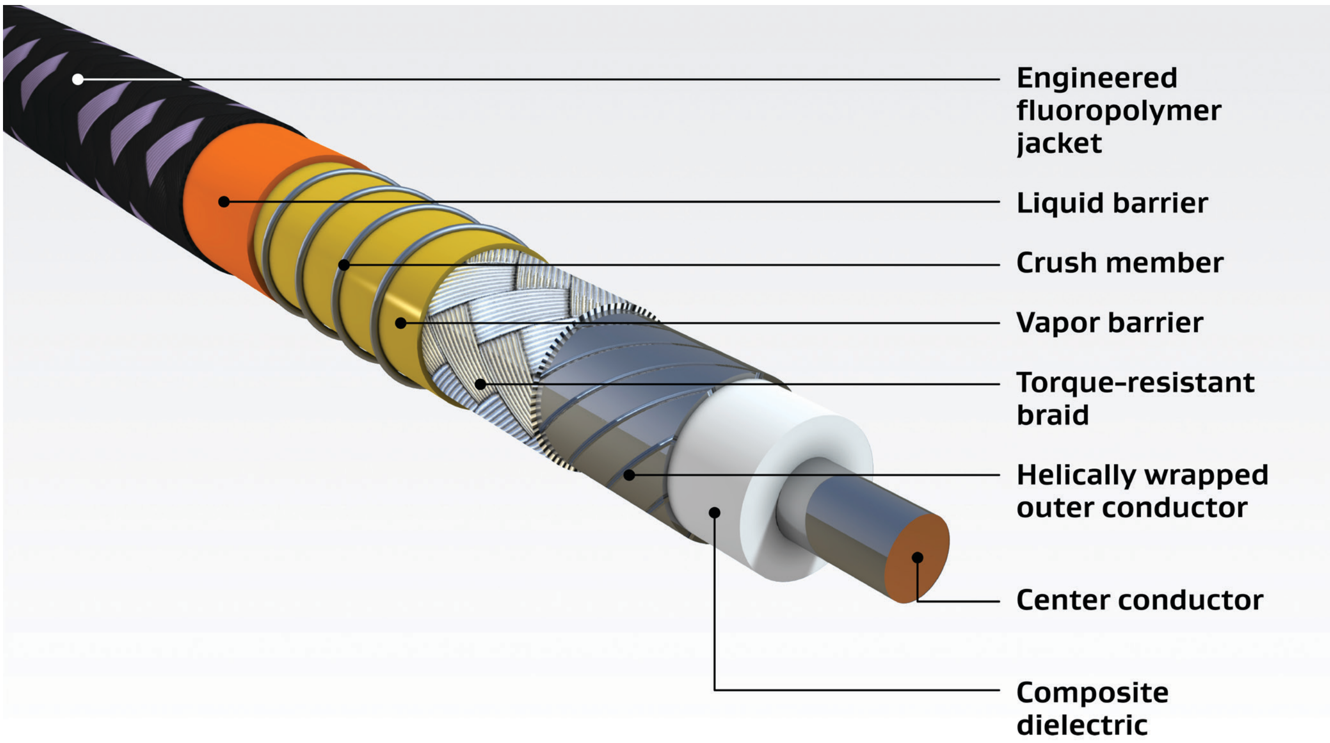


Figure 4: Rugged Construction of GORE-FLIGHT™ Microwave Assemblies, 6 Series



Summary

On-board WiFi is creating new challenges for the commercial and general aviation community. Passengers are demanding reliable, high-speed connections to allow them to continue to use their phone or tablet for business or pleasure at 36,000 feet. Microwave coaxial cable assemblies are a key component to system performance because if the cable assembly becomes degraded, customer satisfaction will rapidly decline. Selecting an inferior MIL-DTL-17 cable assembly that was "good enough" in the past is now a false economy. There is a growing need for reliable high-frequency, vapor-sealed cable assemblies that are precisely designed for aircraft systems.

Selecting the wrong cable assembly has the potential to impact service performance, customers' on-board experience, and ultimately impact your revenue. Proven and reliable vapor-sealed cable assemblies already exist and are now the right choice for WiFi connectivity in the sky.

"Ladies and gentlemen, we'll be arriving at our destination soon. We thank you for flying with us today and hope you have enjoyed your flight, including our in-flight WiFi service. We look forward to seeing you again in the future."