



Ruggedized RF Coaxial Cables for Radar Applications

Technical Considerations for High-Performance RF and Microwave Interconnects

1. Introduction

Radar systems place exceptional demands on their RF coaxial interconnects. As architectures evolve toward wider bandwidths, higher operating frequencies, and increasingly complex phased-array configurations, the coaxial cable assembly becomes a critical component of system performance. These assemblies must preserve signal fidelity under conditions involving high peak power, thermal cycling, mechanical stress, and exposure to harsh environments such as salt fog, UV radiation, and extreme temperatures.

This white paper examines the engineering principles that govern radar-qualified coaxial cable performance. It focuses on the characteristics that influence signal integrity—frequency response, phase stability, attenuation, power handling, shielding effectiveness, and environmental survivability—and offers a technical perspective on how cable design choices affect radar capability.

2. Frequency Range and High-Frequency Performance

Radar systems occupy a wide span of the RF spectrum, from lower microwave bands used in long-range air and surface surveillance to millimeter-wave frequencies that support high-resolution imaging and targeting. Coaxial cables serving these systems must maintain predictable impedance and low VSWR across the radar's operating band. As frequencies increase, issues such as dielectric uniformity, conductor surface quality, and shielding geometry become increasingly important, since higher-order mode propagation and increased attenuation can degrade system performance.

Well-designed microwave and millimeter-wave coaxial cables control these phenomena through precise manufacturing tolerances, high-quality dielectrics, and carefully engineered conductor geometries. These factors help ensure consistent signal propagation and stable electrical performance even in challenging frequency environments.

3. Phase Stability and the Demands of Phased-Array Radar

In Electronically Scanned Array (ESA) radar architectures, phase stability is critical. Phased-array antennas steer their beams by adjusting the phase and amplitude of signals feeding each radiating



element. Any variation in the electrical length of coaxial interconnects—whether caused by temperature changes, mechanical stress, or material aging—can degrade beamforming accuracy, introduce direction-finding errors, and reduce overall system performance.

Achieving stable phase behavior requires attention to the thermal coefficient of phase (TCP), mechanical stability of the dielectric, and uniformity of the cable's physical structure. Materials that resist expansion and contraction under temperature cycling help maintain consistent electrical length. The balance between mechanical characteristics and phase stability must be carefully managed, especially in airborne and mobile systems where cables experience continuous vibration or thermal changes.

4. Attenuation, Loss Mechanisms, and Low-Loss Design

Insertion loss affects both the transmit and receive functions of a radar. As RF signals traverse the coaxial cable, they experience conductor loss, dielectric loss, and in some cases radiation loss. These mechanisms increase with frequency and can significantly influence the radar's range and sensitivity. In high-frequency or long-run applications, excessive attenuation can reduce detection capability or transmitter power.

Low-loss coaxial cables typically address these challenges through the use of low-dielectric-constant insulation materials, smooth and highly conductive plating on the center conductor, and optimized shield constructions that reduce energy leakage. The design of low-loss cables often involves tradeoffs between mechanical flexibility, shielding effectiveness, and attenuation performance, which must be balanced according to the radar system's mission requirements.

5. Power Handling and Thermal Performance

Many radar systems operate with high peak and average power levels, which impose significant thermal stresses on coaxial assemblies. If heat is not effectively managed, the dielectric can degrade, the conductor can soften, or the assembly may experience long-term performance drift.

The power-handling capability of a coaxial cable is influenced by dielectric strength, thermal conductivity, conductor dimensions, and the ability of the cable to dissipate heat to the surrounding environment. Designs often incorporate materials with high breakdown voltage and stable thermal performance, along with geometries that limit electric field concentration (V.S.W.R "hot spots") and minimize localized heating. Careful matching of cable type to the expected power levels is essential to maintaining reliable operation.



6. Environmental Survivability and Mechanical Ruggedness

Radar installations frequently operate in harsh, exposed environments. Naval systems must withstand salt spray, humidity, and continuous weather exposure. Airborne platforms experience rapid temperature changes, vibration, and pressure variation. Ground-based radars may contend with dust, sand, moisture, and direct sunlight.

To ensure survivability under these conditions, coaxial cable assemblies must be constructed with robust jacketing materials, corrosion-resistant shielding, and mechanical designs that maintain electrical integrity over the life of the system. UV-resistant jackets, moisture-blocking layers, and reinforced shielding structures help protect against environmental degradation, while flexible yet stable mechanical constructions allow the cable to endure vibration, bending, and repeated movement.

7. Shielding Effectiveness and Electromagnetic Compatibility

Radar systems operate in increasingly dense electromagnetic environments, and the integrity of the coaxial interconnect plays an important role in preventing unwanted coupling and interference. High shielding effectiveness minimizes susceptibility to external electromagnetic fields and reduces emissions that could interfere with other system components or adjacent radar channels.

The choice of shielding architecture—whether foil, braid, composite layers, or rigid outer conductors—depends on the required level of EMI protection, mechanical flexibility, and environmental durability. Semi-rigid constructions offer excellent shielding due to their continuous metal outer conductor, while advanced braided and laminated shields can provide a balance of flexibility, ruggedness, and EMI resistance suitable for dynamic platforms.

8. Application-Specific Cable Architectures

Different radar platforms impose distinct mechanical and electrical requirements on their coaxial interconnects. Semi-rigid cables may be preferred in fixed installations where routing is stable and shielding demands are high. Flexible low-loss cables are advantageous in systems requiring frequent movement, vibration isolation, or complex routing paths. Temperature-stable constructions are indispensable for phased-array architectures, where even minor shifts in phase can impact beamforming precision. Outdoor and shipboard installations often prioritize ruggedized, low-smoke, low-halogen jacketing and environmental resistance to ensure long-term reliability under continuous exposure.



Selecting the appropriate coaxial cable architecture requires a clear understanding of the radar system's operating frequency, power levels, environmental conditions, and phase stability requirements. In most cases, no single cable type addresses all needs; instead, each application benefits from a tailored approach that balances electrical, mechanical, and environmental considerations.

9. Conclusion

The performance of a radar system is closely tied to the quality and suitability of its RF coaxial interconnects. High-frequency operation, demanding environmental exposure, and increasingly complex antenna architectures place unprecedented requirements on cable assemblies. By understanding the principles of frequency behavior, phase stability, attenuation control, power handling, shielding effectiveness, and mechanical ruggedness, system designers can specify coaxial solutions that preserve signal integrity and ensure long-term reliability.

As radar technology continues to advance, the interconnect will remain a critical component—one that must evolve in material science, mechanical design, and manufacturing precision to support next-generation performance requirements