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## Next-Gen RF/Microwave Interconnects for Counter-UAS and Air-Defense Systems

### Enabling Rapid Detection and Engagement of Drones and Hypersonic Threats

#### Executive Summary

The rapid proliferation of unmanned aerial systems (UAS) and the emergence of hypersonic vehicles pose unprecedented challenges for modern defense architectures. Counter-UAS (C-UAS) and integrated air-defense systems must detect, track, identify, and neutralize these threats in fractions of a second. At the heart of these systems are radiofrequency (RF) and microwave subsystems, from sensor arrays and phased-array radars to data links and electronic warfare (EW) suites. Critical to the fidelity and responsiveness of these subsystems are **high-frequency interconnect solutions** — cabling, connectors, and transmission media capable of preserving signal integrity at ever-higher frequencies under extreme environmental conditions.

This whitepaper explores the role of next-generation RF/microwave interconnects in advancing C-UAS and air-defense capabilities. It also examines technical challenges and enabling technologies outlining future directions for system-level integration supporting rapid detection and engagement of both low-signature drones and high-speed hypersonic threats.

#### Introduction

Modern battlefields demand rapid situational awareness and decisive action. The widespread availability of commercial drones, often operated with minimal training and low radar cross sections, has made airspace insecurity pervasive, from military theaters to urban environments. Meanwhile, hypersonic vehicles present a radically compressed engagement timeline, making early detection and high-precision tracking imperative.

At the core of these detection and engagement systems are RF and microwave technologies — especially **high-frequency radar, communication, and EW subsystems**. The performance of these RF front ends is governed not only by the active components (e.g., transmit/receive modules, digital signal processors) but by the **interconnect infrastructure** that links them: coaxial cabling, precision microwave connectors, waveguide feeds, and increasingly, high-speed digital links.

Traditional interconnects designed for legacy radar and communications, optimized for lower frequency ranges and moderate data throughput, cannot keep pace with the requirements of next-generation threats. As operational frequencies migrate into the millimeter-wave spectrum and data links demand



multi-gigabit performance, interconnect losses, impedance mismatches, and environmental vulnerabilities become limiting factors in system performance.

The sections that follow discuss how **advances in high-frequency interconnect technology** — including low-loss cabling, precision connectors, integrated RF assemblies, and novel materials — are foundational to C-UAS and air-defense effectiveness. Information will demonstrate how optimized interconnects support rapid RF signal propagation, reduce latency, minimize insertion loss, and preserve phase coherence essential for high-resolution radar imaging and rapid threat engagement.

### **C-UAS and Air-Defense System Requirements**

- **Evolving Threat Landscape**
- **Small UAS (sUAS):** Low radar cross section, agile flight patterns, often employing commercial off-the-shelf RF communications.
- **Hypersonic Threats:** Speeds > Mach 5 compress detection-to-engagement timelines; require high-bandwidth, low-latency sensor networks.
- **Electronic Warfare Countermeasures:** Adversaries employ RF jamming, deceptive GPS spoofing, and communication encryption.

### **System Functional Imperatives**

- **High-Resolution Sensing:** Wide bandwidth and high dynamic range for accurate target discrimination.
- **Fast Data Transport:** Ultra-low latency between sensors, processors, and effectors.
- **Environmental Robustness:** Military-grade interconnects capable of vibration, shock, temperature extremes, and EMI/EMP environments.

### **RF/Microwave Interconnect Challenges**

- **Signal Integrity at High Frequencies**
- **Attenuation and Phase Distortion:** Increases with frequency; critical in millimeter-wave bands used for high-resolution radar.
- **Impedance Control:** Mismatches cause reflections, degrading radar sensitivity and communication reliability.



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## Connector and Cable Performance

- **Insertion Loss:** Every connection introduces loss; minimized by precision machined interfaces and advanced dielectric materials.
- **Return Loss and VSWR:** High return loss degrades power transfer and system sensitivity; precision connectors maintain consistent characteristic impedance.

## Environmental and Mechanical Considerations

- **Flex Life and Mechanical Wear:** Tactical systems require ruggedized interconnects that withstand repeated mating cycles.
- **Thermal Stability:** Materials must maintain electrical performance across extremes typical in defense deployments.

**Enabling Technologies** – Coaxial cables are the backbone of most high-frequency systems because they maintain characteristic impedance and low-loss up through microwave and millimeter-wave bands, which is essential for radar and sensor frontends that detect drones and hypersonic vehicles.

- **Low-Loss Cabling Solutions** - Advanced coaxial and semi-rigid cables with **low-dielectric constant materials** and **surface-treated conductors** reduce skin-effect losses at microwave and millimeter-wave frequencies. These cables preserve signal integrity over longer runs between radar front ends and processing modules.
- **High-frequency assemblies** optimized for frequencies beyond GHz for advanced radar, imaging, and communications links.
- **Phase-matched and phase-stable coax assemblies** – Typical for phased-array electronics where precise timing yields rapid beam steering and target tracking.

## Precision Microwave Connectors

High-performance connectors such as **2.92 mm, 1.85 mm, and 1.0 mm interfaces** support frequencies beyond 40–110 GHz with minimal reflection coefficients. Precision tolerances and controlled contact surfaces maintain tight impedance control crucial for phased array and broadband systems.

- SMA (SubMiniature A) connectors – versions widely used in radar and RF test links.
- Type N Connectors – rugged threaded RF connectors common in outdoor sensors and ground radar installation.



- Precision mmWave connectors – designed for millimeter-wave systems used in modern high-resolution radar for fine target discrimination and rapid beamforming.

**Advanced and Rugged Interconnects** – Defense systems often require more than just basic connectors.

- Blind-mate and locking miniature connectors allow rapid, reliable mating under vibration/shock without threaded coupling, useful in modular radar/EW arrays.
- MIL-spec coaxial assemblies provide rugged, sealed connections in airborne and ground platforms.
- Hybrid cables (combining fiber optic with RF/power) carry both high-bandwidth optical data and electrical signals, minimizing latency and physical footprint in complex sensor arrays.

**How high-frequency cables and Connectors enable Rapid Detection and engagement:**

- Wide operational frequency range – Extending into millimeter-wave bands increases resolution and bandwidth, improving detection of small or fast-moving targets.
- Low-loss and phase stability – Critical for high-performance radar and phased arrays, ensuring signal can be processed quickly and accurately.
- Environmental ruggedness – Military cables and connectors are built to withstand temperature extremes, shock/vibration, and EMI, essential for field and airborne systems.
- Tight impedance matching – Reduces reflections and preserves signal fidelity at high speeds and across wide bandwidths, supporting rapid engagement decisions.

**Novel Materials and Additive Manufacturing**

Materials like **PTFE composites, liquid crystal polymers (LCPs), and nanostructured conductors** yield improved high-frequency performance and mechanical resilience. Additive manufacturing facilitates complex waveguide geometries and integrated RF pathways directly within structural components, reducing interconnect count and insertion points.

**Systems Integration and Performance Gains**

- **Rapid Detection and Tracking**
- **Preserved Phase Coherence:** High-quality interconnects enable accurate beamforming and Doppler processing essential to distinguish small targets.



- **Reduced Latency:** Low-loss, high-speed links shorten signal travel times, enabling faster target updates and quicker weapon cueing.

### Enhanced Engagement Accuracy

- **Data Fusion:** High-bandwidth interconnects support real-time fusion of radar, EO/IR, and EW sensor data.
- **Predictive Tracking:** Reduced signal degradation enhances algorithms that extrapolate target motion, vital for hypersonic object interception.

### Future Directions

- **Integrated RF Photonics**

Optical interconnects with RF over fiber extend high-frequency capability across longer distances with negligible loss and immunity to EMI.

- **Smart Interconnects**

Embedded diagnostics and self-healing network paths that automatically optimize signal routes and identify failing components in real time.

- **Standardization and Modularity**

Open standards for high-frequency interconnects accelerate technology refresh cycles and cross-platform interoperability across allied defense systems.

### Conclusion

The next generation of counter-UAS and air-defense systems operates in an environment defined by speed, stealth, and signal complexity. Effective engagement of rapidly maneuvering drones and hypersonic threats depends not just on sophisticated radar and processing algorithms, but on the often-underappreciated backbone of **high-frequency RF/microwave interconnects**.

Advanced cabling and connector technologies — optimized for minimal loss, consistent impedance, ruggedization, and high bandwidth — are foundational to preserving signal integrity from sensor to processor to effector. These interconnect solutions enable reduced latency, enhanced sensitivity, and



superior system robustness, directly translating into quicker detection, more accurate tracking, and more effective engagements.

As threats continue to evolve, investments in interconnect innovation — including integrated assemblies, novel materials, and smart diagnostics — will be pivotal in maintaining airspace superiority. Delivering reliable performance at the frontlines of electromagnetic and physical engagement domains ensures that defense systems remain agile, resilient, and decisive in the face of emerging aerial threats.