

COUNTER-ELECTRONIC WARFARE SYSTEMS

Defeating the EA-18G Growler and Advanced Radar Jammers

Technical Analysis Report

Passive Radar Systems, Home-on-Jam Missiles, and Integrated Air Defense Architectures

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Executive Summary

The EA-18G Growler represents the pinnacle of American airborne electronic attack capability, designed to dominate the electromagnetic spectrum and suppress enemy air defenses. However, its fundamental operational requirement—to emit powerful jamming signals—creates an exploitable vulnerability that sophisticated Integrated Air Defense Systems (IADS) can leverage to detect, track, and engage the aircraft. This report examines the specific radar and missile systems optimized for counter-electronic warfare operations, with particular emphasis on Passive Coherent Location (PCL) systems and Home-on-Jam (HOJ) missile technologies.

The analysis reveals that the most effective counter-Growler strategy involves a networked approach combining passive detection systems that cannot be jammed, with surface-to-air missiles specifically designed to guide on jamming emissions. Systems such as the Russian S-400 Triumf, when operated with passive radar components like the 55Zh6M Nebo-M, represent the current state-of-the-art in counter-electronic warfare capabilities. The strategic implication is clear: the Growler's greatest operational strength—its powerful jamming array—can become its most significant vulnerability when facing properly equipped and trained adversaries.

1. Introduction: The Electronic Warfare Paradigm

Modern air combat has evolved beyond the traditional parameters of speed, altitude, and maneuverability into a complex battle for control of the electromagnetic spectrum. Electronic Warfare (EW) has become the decisive factor in determining air superiority, with nations investing billions in both offensive jamming capabilities and defensive counter-measures. The EA-18G Growler, derived from the F/A-18F Super Hornet airframe, represents the United States Navy's primary airborne electronic attack platform, capable of disrupting enemy radar, communications, and targeting systems across a wide frequency spectrum.

The Growler's AN/ALQ-99 Tactical Jamming System and its next-generation AN/ALQ-249 Next Generation Jammer (NGJ) pods represent sophisticated electronic attack capabilities designed to degrade, disrupt, and deny enemy use of the electromagnetic spectrum. These systems employ advanced techniques including Digital Radio Frequency Memory (DRFM), which can capture, manipulate, and retransmit radar signals to create false targets or completely mask the presence of friendly aircraft. The effectiveness of these jamming systems has fundamentally altered the calculus of modern air defense, forcing adversaries to develop innovative counter-measures that do not rely on traditional active radar principles.

This report addresses a critical question facing air defense planners worldwide: What specific radar and missile systems are best suited to defeat advanced electronic attack aircraft like the EA-18G Growler? The answer lies not in any single technology, but in an integrated approach that exploits the fundamental physics of electronic warfare—that to jam effectively, one must emit, and to emit is to reveal one's presence and position. This electromagnetic irony forms the foundation of all counter-EW strategies examined in this analysis.

2. Passive Radar Systems: The Silent Hunters

2.1 Principles of Passive Coherent Location

Passive Coherent Location (PCL) systems, also known as passive radar or passive bistatic radar, represent a paradigm shift in air surveillance technology. Unlike conventional active radar systems that emit their own radio frequency signals and detect reflections from targets, passive radar systems exploit existing electromagnetic radiation in the environment—television broadcasts, radio signals, cellular transmissions, and crucially, the jamming signals emitted by electronic attack aircraft. This fundamental difference renders traditional radar jamming techniques ineffective against PCL systems, as they create no emissions for the jammer to detect or attempt to disrupt.

The operational principle of passive radar relies on bistatic or multistatic geometry, where the transmitter and receiver are separated by significant distances comparable to the target range. The system compares the direct signal from the transmitter (reference channel) with the reflected signal from the target (surveillance channel), measuring the time difference of arrival and Doppler shift to determine target location and velocity. When the target itself is an emitter—such as a Growler actively jamming—the passive radar can directly track the source of emissions without requiring external illuminators, making the jamming aircraft exceptionally visible to these systems.

2.2 Key Passive Radar Systems

Czech Vera-NG System

The Czech Vera-NG represents one of the most advanced passive surveillance systems currently in operational service. Developed by ERA a.s., this system has been acquired by multiple NATO nations and operates on the principle of Time Difference of Arrival (TDOA) and Angle of Arrival (AOA) measurements. The Vera-NG can detect, identify, and track airborne, ground, and naval emitters across a wide frequency range, providing 3D target localization without emitting any detectable signals of its own. Its sophisticated signal processing can discriminate between different types of emitters, allowing operators to identify specific aircraft types based on their unique electronic signatures.

The system's effectiveness against the Growler stems from its ability to operate entirely passively while maintaining high-accuracy tracking. When a Growler activates its jamming pods, the Vera-NG system immediately detects and classifies the emission, then begins precision tracking using multilateration techniques. The jamming aircraft receives no indication that it is being tracked, as the passive system generates no counter-detectable emissions. This creates a dangerous information asymmetry where the Growler crew may believe they have successfully suppressed enemy air defenses while actually being precisely targeted.

Russian 55Zh6M Nebo-M System

The Russian 55Zh6M Nebo-M represents a more complex approach to passive detection, integrating multiple radar systems operating across different frequency bands into a unified surveillance architecture. This mobile, multi-band system combines VHF, UHF, and X-band components, including passive detection modes specifically designed to counter stealth aircraft and electronic warfare platforms. The Nebo-M's integration into the Russian air defense network allows it to share

targeting data with surface-to-air missile batteries in near real-time, enabling engagement of electronic warfare aircraft without activating vulnerable fire-control radars.

The Nebo-M's counter-EW capability is enhanced by its multi-band approach, which complicates electronic attack planning. While a Growler might effectively jam X-band fire-control radars, it cannot simultaneously suppress VHF surveillance systems without employing multiple jamming pods tuned to different frequencies. This forces electronic warfare planners to make difficult decisions about resource allocation, potentially leaving gaps in jamming coverage that the Nebo-M can exploit. The system's mobile nature also complicates suppression campaigns, as it can relocate frequently and operate from concealed positions, denying the adversary fixed geographic targets for anti-radiation missiles.

Table 1: Comparative Analysis of Passive Radar Systems

System	Detection Method	Anti-Jam Advantage
Vera-NG (Czech)	TDOA/AOA Multilateration	No emissions; tracks jammers directly
55Zh6M Nebo-M (Russia)	Multi-band Integration	Multi-frequency; mobile deployment
Kolchuga (Ukraine)	Passive ESM Array	Long-range detection; no warning to target

Source: Analysis of open-source technical documentation

3. Home-on-Jam Missile Technology

3.1 Understanding the Home-on-Jam Concept

Home-on-Jam (HOJ) capability represents one of the most significant countermeasures against electronic attack aircraft, fundamentally reversing the traditional relationship between jammer and radar. In conventional radar engagements, effective jamming blinds the adversary's fire-control radar, preventing target tracking and missile guidance. However, HOJ-equipped missiles treat the jamming signal itself as a guidance beacon, turning the jammer's emission into a homing source. This capability creates an operational paradox for electronic warfare aircraft: the more effectively they jam, the more accurately they can be targeted.

The technical implementation of HOJ varies by missile system, but generally involves modifying the missile's radar seeker to detect and track strong electronic emissions rather than radar reflections.

When the missile's onboard radar loses its target due to jamming, the guidance system automatically switches to HOJ mode, steering the missile toward the source of the strongest jamming signal within its field of view. This passive guidance mode requires no emissions from the launching platform, making it immune to anti-radiation missile counterattacks and preserving the element of surprise.

3.2 DRFM and the Counter-Countermeasure Debate

Digital Radio Frequency Memory (DRFM) represents the current state-of-the-art in electronic attack technology, enabling sophisticated signal manipulation that can deceive radar systems about target

position, velocity, and even existence. DRFM systems capture incoming radar pulses, digitize them, store them in memory, and retransmit modified versions that create false targets or mask the true target. This technology has led some analysts to question whether HOJ remains effective against modern electronic attack platforms like the Growler.

The answer lies in understanding that while DRFM can deceive radar processors about target characteristics, it cannot eliminate the fundamental electromagnetic reality: a powerful broadband noise jam creates a massive energy signature that can be tracked spatially regardless of the sophistication of the jamming technique. Even if the DRFM system creates false targets or masks the aircraft's true radar cross-section, the physical location of the jamming transmitter remains the source of the electromagnetic energy. A missile in HOJ mode does not need to decipher the manipulated signal—it simply guides toward the energy source. This is analogous to flying toward a bright light: optical tricks might obscure the light's true nature, but not its location.

3.3 Key HOJ-Capable Missile Systems

Russian S-300/S-400 Series Missiles

The Russian S-300 and S-400 air defense systems incorporate HOJ capability across their missile families, including the 48N6 and 40N6 long-range interceptors. These missiles can engage targets at ranges exceeding 400 kilometers while maintaining guidance even under heavy electronic attack. The S-400's 92N2 Grave Stone fire control radar and 91N6 Big Bird acquisition radar work in concert with passive detection systems to provide targeting data without exposing the battery to anti-radiation missile attacks.

The operational concept for engaging electronic warfare aircraft involves initial detection by passive systems, followed by missile launch without activating fire-control radars. The missile flies toward the target's last known position using inertial guidance, then activates its own seeker in the terminal phase. If the target is jamming, the seeker immediately transitions to HOJ mode and guides on the jamming emission. If jamming has ceased, the missile can activate its active radar seeker or rely on home-on-jam memory of the jammer's last known position.

Kh-31P Anti-Radiation Missile

The Russian Kh-31P represents a specialized anti-radiation missile designed specifically to engage emitting targets including radar sites and electronic warfare aircraft. This ramjet-powered missile achieves speeds exceeding Mach 3, making it exceptionally difficult to evade once launched. The Kh-31P's passive radar seeker can detect and track emissions across a wide frequency spectrum, and its high speed allows it to engage targets at significant stand-off ranges, minimizing exposure to defensive systems.

When employed against the Growler, the Kh-31P presents a unique threat profile. Its passive seeker requires no emissions from the launching platform, and its high-speed approach gives the target minimal reaction time. The missile's ability to guide on jamming emissions makes it particularly dangerous during active electronic attack operations, as the Growler cannot both jam effectively and remain invisible to the Kh-31P. This creates the same operational paradox inherent in all HOJ systems: effective electronic attack increases vulnerability to anti-radiation weapons.

Table 2: Home-on-Jam Capable Missile Systems

Missile System	Range (km)	Speed	HOJ Capability
48N6 (S-400)	250	Mach 6	Full HOJ with backup active radar
40N6 (S-400)	400	Mach 6+	HOJ with semi-active guidance
Kh-31P	110	Mach 3.5	Passive anti-radiation seeker
AIM-120D (US)	180	Mach 4	HOJ mode available

Source: Compiled from open-source defense publications

4. Integrated Air Defense System Architecture

4.1 The S-400 Triumph: A Counter-EW Benchmark

The Russian S-400 Triumph represents the current benchmark for integrated air defense systems capable of engaging electronic warfare aircraft. This mobile, long-range system integrates multiple sensor types, missile families, and command-and-control networks into a unified air defense architecture. The S-400's ability to share targeting data between batteries, coordinate with other air defense assets, and employ multiple missile types for different threat profiles makes it particularly effective against sophisticated electronic attack packages.

The S-400's counter-EW effectiveness derives from its layered sensor architecture. The system can operate with the 91N6 Big Bird acquisition radar, 92N2 Grave Stone fire control radar, 96L6 Cheese Board 3D surveillance radar, and integration with passive systems like the Nebo-M. This sensor diversity means that even if an electronic warfare aircraft successfully jams one radar type, others continue to provide targeting data. The system's missiles can engage using active radar homing, semi-active guidance, or HOJ modes, providing multiple engagement options depending on the electronic warfare environment.

4.2 The HQ-9B and Chinese IADS Development

The Chinese HQ-9B represents a parallel development in long-range air defense with similar counter-EW capabilities to the S-400. This system incorporates active phased array radar technology and can engage multiple targets simultaneously across a wide altitude envelope. The HQ-9B's integration into China's integrated air defense network allows it to receive targeting data from a variety of sources, including passive surveillance systems and early warning aircraft, enabling engagements against electronic warfare platforms without exposing fire-control radars.

China has invested heavily in counter-EW capabilities as part of its anti-access/area-denial (A2/AD) strategy. The combination of long-range air defense systems with passive detection networks and electronic warfare assets creates a layered defense specifically designed to counter American air power, including the Growler. Chinese doctrine emphasizes attacking the "kill chain" at multiple points, using electronic attack, cyber operations, and kinetic strikes to disrupt the coordination necessary for effective suppression of enemy air defenses (SEAD) operations.

5. Operational Tactics: The Double Trap Methodology

5.1 The Bait-and-Switch Engagement Sequence

The most effective counter-EW tactic employs what can be termed a "Double Trap" or "Bait-and-Switch" engagement sequence. This operational concept exploits the reactive nature of electronic warfare, where jamming systems respond to detected radar emissions. By manipulating when and which radars are active, air defense operators can create tactical situations that maximize the vulnerability of electronic attack aircraft while minimizing exposure of their own assets.

The engagement sequence proceeds as follows:

1. **The Setup:** An active radar system (such as an S-400 battery's acquisition radar) begins emitting, deliberately making itself visible to electronic surveillance systems. The Growler detects this emission and classifies it as a target requiring jamming.
2. **The Reaction:** The Growler activates its jamming pods, directing electronic attack against the detected radar. This is the standard SEAD response—identify the threat and suppress it with jamming.
3. **The Trap:** The active radar ceases emission, appearing to have been successfully suppressed. The Growler crew assesses the radar as neutralized and may shift jamming resources to other targets.
4. **The Silent Track:** Unknown to the Growler, a passive radar system (such as a Nebo-M or Vera-NG) has been tracking the jamming emission throughout the engagement. The harder the Growler jammed, the more precisely the passive system localized it.
5. **The Kill:** A missile is launched from the S-400 battery using targeting data from the passive radar. The missile flies inertially toward the predicted intercept point, then activates its seeker. If the Growler is still jamming, the missile guides directly on the emission. If jamming has ceased, the missile uses its active radar or HOJ memory of the last known emission source.

5.2 The Catch-22 for Electronic Warfare Aircraft

This tactical approach creates an operational paradox—a "Catch-22"—for electronic warfare aircraft that cannot be resolved through technical means alone. If the Growler jams to suppress radar threats, it reveals its position to passive systems and becomes vulnerable to HOJ missiles. If the Growler ceases jamming to avoid HOJ missiles, it loses its primary defensive capability and can be engaged by standard radar-guided missiles. Either choice leads to vulnerability; the only question is which threat the aircraft prefers to face.

This paradox cannot be solved by improved jamming technology alone. More powerful jamming makes the aircraft more visible to passive systems; more sophisticated DRFM techniques do not prevent HOJ from guiding on the energy source; directional jamming reduces but does not eliminate the emission signature. The fundamental physics of electronic warfare—that emitting creates a detectable signature—ensures that the Catch-22 persists regardless of technical advances in jamming capability.

6. Strategic Implications and Force Structure Considerations

6.1 Networked Defense Requirements

The analysis demonstrates that effective counter-EW capability requires a networked approach integrating multiple sensor types with varied missile capabilities. No single system—no matter how advanced—can reliably defeat a sophisticated electronic attack platform in isolation. The network must include passive detection systems for covert tracking, active radars for bait-and-switch tactics, and missiles with multiple guidance modes including HOJ. This integration requires robust communications, distributed command and control, and well-trained operators capable of executing complex engagement sequences.

The emphasis on networking also highlights the importance of resilience. Electronic warfare aircraft specifically target the communication links and command nodes that enable integrated air defense. A successful counter-EW architecture must therefore incorporate redundancy, with multiple pathways for target data and engagement authority. Decentralized execution, where individual batteries can engage autonomously when network connectivity is degraded, prevents the network's destruction from eliminating the defensive capability.

6.2 Training and Doctrine Development

Technical capability alone is insufficient for effective counter-EW operations. The tactics described in this analysis—particularly the Double Trap methodology—require sophisticated coordination between multiple systems and operators. Training programs must emphasize the integration of passive and active sensors, the timing of emission control, and the coordination necessary to execute complex engagement sequences. Doctrine must address the decision-making process for selecting appropriate responses based on the electronic warfare environment, balancing the risk of exposure against the need for defensive action.

Red team training against realistic electronic attack threats is essential for developing and validating counter-EW tactics. Air defense units must train against actual electronic warfare aircraft or sophisticated simulators to understand the capability of systems like the Growler and develop effective responses. This training should include scenarios where electronic attack is combined with kinetic threats—anti-radiation missiles, cruise missiles, and strike aircraft—to prepare for the integrated SEAD packages that characterize modern air campaigns.

7. Conclusion

The EA-18G Growler and similar electronic warfare aircraft represent formidable threats to traditional air defense architectures. Their ability to detect, classify, and jam radar systems across multiple frequency bands fundamentally challenges the active radar-centric model that has dominated air defense since World War II. However, the physics of electronic warfare—specifically, that effective jamming requires emission—creates an inherent vulnerability that can be exploited through passive detection systems and Home-on-Jam missile technology.

The optimal counter-EW system is not a single radar or missile, but an integrated network combining passive coherent location systems (such as the Czech Vera-NG or Russian 55Zh6M Nebo-M) with

long-range surface-to-air missiles featuring HOJ capability (such as the Russian S-400 Triumf with 48N6/40N6 missiles). This combination enables the "Double Trap" engagement methodology that places electronic warfare aircraft in an unsolvable operational dilemma: the very act of jamming that protects them from active radar simultaneously exposes them to passive detection and HOJ engagement.

The strategic implication for air defense planners is clear: investment in passive detection systems and HOJ-capable missiles is essential for credible defense against sophisticated electronic attack. These capabilities must be integrated into networked command architectures with robust communications and decentralized execution authority. Most importantly, operators must be trained in the complex tactics required to exploit the vulnerabilities inherent in electronic warfare, turning the adversary's greatest strength into their most significant weakness.

The electromagnetic spectrum will remain a contested domain for the foreseeable future, with both offensive and defensive capabilities continuing to evolve. Understanding the fundamental physics and tactical principles outlined in this analysis provides the foundation for developing counter-EW capabilities that can protect airspace against even the most sophisticated electronic attack platforms. The Growler's power is considerable, but it is not invincible—properly equipped and trained air defenders can turn the electronic warfare battle to their advantage.