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PAPER

Feature Based on Detection of Aviation Decoy Targets Using Dynamic Radar Cross Section Signatures

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ABSTRACT

The proliferation of advanced airborne countermeasure systems has significantly increased the complexity of radar target discrimination in modern aviation environments. Contemporary aircraft deploy towed decoys, chaff clouds, and active radio-frequency repeaters to emulate authentic radar echoes and degrade tracking performance. Conventional amplitude-based radar cross-section (RCS) detection techniques are often insufficient to reliably distinguish genuine aircraft from decoy targets under dynamic flight conditions and low signal-to-noise ratio (SNR) scenarios. This study proposes a robust feature-fusion framework for aviation decoy detection based on dynamic RCS signature analysis across temporal, statistical, and time–frequency domains. Unlike traditional thresholding approaches, the proposed method exploits intrinsic differences in RCS stability, micro-Doppler structure, spectral dispersion, and entropy characteristics between real aircraft and deployed decoys. In particular, oscillatory scattering behavior associated with towed decoys, stochastic fluctuations characteristic of chaff clouds, and spectral inconsistencies induced by active repeater systems are systematically quantified through multi-domain feature extraction. These features are integrated within a supervised classification architecture optimized for real-time radar processing constraints. A high-fidelity simulation environment representing engagement scenarios involving multirole fighter platforms was developed to evaluate detection robustness under varying SNR levels, aspect angles, and target–decoy separations. Performance assessment using probability of detection, false alarm rate, and receiver operating characteristic (ROC) metrics demonstrates a substantial improvement over conventional amplitude-only RCS discrimination methods. The results confirm that dynamic RCS behavior contains exploitable discriminative signatures that enable reliable identification of aviation decoys without reliance on computationally intensive electromagnetic modeling. The proposed framework provides a scalable and computationally efficient solution suitable for next-generation airborne and ground-based radar systems operating in contested electromagnetic environments.

KEYWORDS

aviation decoy detection, dynamic radar cross-section (RCS), airborne countermeasure systems, towed radar decoys, chaff cloud discrimination, micro-Doppler analysis, time-frequency signal processing, feature fusion classification, radar target recognition, receiver operating characteristic (ROC) analysis, electronic countermeasures (ECM), real-time radar processing

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1 INTRODUCTION

Modern aviation combat environments are characterized by intensive use of electronic countermeasure technologies designed to degrade radar tracking and missile guidance performance. Advanced fighter aircraft routinely deploy airborne decoys such as towed reflectors, chaff clouds, and active radio-frequency repeaters to create false targets and increase survivability. Platforms integrate such countermeasure systems to confuse threat radars by manipulating apparent radar cross-section (RCS), Doppler signatures, and target positioning. As a result, reliable discrimination between genuine aircraft and decoy targets has become a critical challenge for modern radar systems.

The RCS remains one of the primary observable parameters in target detection and tracking. Traditionally, amplitude-based RCS thresholding and constant false alarm rate (CFAR) techniques have been employed for target identification. However, contemporary decoy systems are specifically engineered to emulate the amplitude characteristics of real aircraft echoes, thereby reducing the effectiveness of purely magnitude-based discrimination. In dynamic flight scenarios, particularly under low signal-to-noise ratio (SNR) conditions or closely spaced target–decoy geometries, conventional detection frameworks frequently exhibit elevated false alarm rates or target misclassification.

Recent research has increasingly emphasized the importance of dynamic radar signatures rather than static RCS values alone. Time-varying RCS behavior reflects structural geometry, aerodynamic stability, propulsion-induced modulation, and motion dynamics. Genuine aircraft typically demonstrate relatively stable scattering centers and periodic micro-motion effects associated with rotating engine components, a phenomenon commonly described by the micro-Doppler effect. In contrast, aviation decoys often exhibit distinct temporal instability, oscillatory scattering due to aerodynamic perturbations, or stochastic dispersion patterns in the case of chaff deployment. These dynamic differences provide an opportunity for enhanced discrimination if appropriately extracted and quantified. Despite these observations, many existing approaches either rely heavily on computationally intensive electromagnetic modeling or focus on single-domain features, such as amplitude variance or Doppler shift alone. Such methods may lack robustness in complex operational environments where multiple decoy types coexist or where environmental noise significantly distorts measurements. There remains a need for a computationally efficient, multi-domain feature framework capable of exploiting temporal, statistical, and time–frequency characteristics of RCS signals for reliable aviation decoy detection.

This study addresses this gap by proposing a feature-based discrimination methodology that integrates dynamic RCS descriptors across multiple signal domains. The approach systematically extracts temporal stability indicators, entropy-based statistical metrics, and spectral features derived from time–frequency analysis to distinguish real aircraft from deployed decoys. The extracted features are fused within a supervised classification architecture optimized for real-time radar processing constraints.

The primary contributions of this work are as follows:

Development of a multi-domain feature extraction framework for dynamic RCS analysis in aviation scenarios. Systematic characterization of RCS instability patterns associated with towed decoys, chaff clouds, and active repeaters.

Integration of feature fusion and classification techniques suitable for real-time implementation. Comprehensive performance evaluation under varying SNR levels, aspect angles, and target–decoy separations. By shifting the focus from static amplitude-based detection to dynamic signature exploitation, the proposed approach enhances the reliability of radar-based target recognition in contested electromagnetic environments. The results demonstrate that aviation decoys can be effectively discriminated through structured analysis of time-varying RCS behavior without requiring complex electromagnetic simulations, thereby supporting next-generation airborne and ground-based radar systems.

Recent advances in radar target recognition have emphasized the importance of exploiting dynamic signal characteristics rather than relying solely on static RCS values. In particular, micro-Doppler-based analysis has been widely recognized as an effective tool for capturing fine-grained motion signatures of targets, enabling improved classification performance in complex environments [1]. Furthermore, data-driven approaches leveraging convolutional neural networks and sequence encoding techniques have demonstrated significant improvements in radar target classification by learning discriminative patterns from time-varying RCS data [2], [3]. Comprehensive studies have also highlighted the growing role of deep learning in automatic target recognition (ATR), where multi-domain feature integration enhances robustness against noise and environmental variability [3], [4]. In addition, modeling dynamic RCS behavior through advanced signal processing techniques has been shown to provide valuable insights into target structure and motion, further improving discrimination capabilities in challenging scenarios [5]. Collectively, these studies demonstrate that combining micro-Doppler analysis, machine learning, and dynamic RCS modeling forms a powerful framework for modern radar-based target recognition systems [1]–[5].

2 LITERATURE REVIEW

Radar-based discrimination of aerial targets remains a critical research area due to its importance in both civilian surveillance and military defense systems. Traditional target recognition methods often rely on the magnitude of RCS measurements to detect and classify airborne objects, as RCS quantifies the amount of electromagnetic energy scattered back to the receiver. Recent studies have increasingly focused on data-driven and simulation-based approaches for improving radar target classification and characterization, particularly in complex and contested electromagnetic environments. Data-driven methodologies, including machine learning-based classification frameworks, have demonstrated strong potential in extracting meaningful patterns from radar signals and enhancing discrimination accuracy across diverse target types [6]. These approaches leverage large datasets and statistical learning techniques to identify subtle differences in radar signatures that are often indistinguishable using conventional signal processing methods. In parallel, dynamic RCS modeling has been explored to better understand the influence of target motion, aspect angle, and maneuverability on scattering behavior. For instance, advanced RCS modeling techniques applied to highly maneuverable unmanned aerial vehicles (UAVs) have revealed that aspect-dependent variations and rapid geometric changes significantly affect radar observability, thereby providing valuable discriminative features for classification tasks [7]. Furthermore, the implementation of scattering center models has contributed to a more detailed representation of radar targets by decomposing complex objects into dominant reflective components, allowing for improved interpretation of RCS fluctuations and structural characteristics [8]. Numerical simulation methods have also played a critical role in analyzing radar signatures, particularly in the context of electronic warfare scenarios. High-fidelity simulations of RCS for specialized aircraft, such as carrier-based electronic warfare platforms, have enabled researchers to investigate the impact of geometry, materials, and operational configurations on radar detectability [9]. More recently, attention has been directed toward the challenges posed by intentional radar deception and camouflage techniques. Studies on micro-Doppler-based deception strategies have demonstrated that adversarial targets can manipulate radar signatures to mimic genuine objects, thereby complicating classification and detection processes [10]. These findings highlight the need for robust, multi-domain feature extraction frameworks capable of distinguishing authentic targets from deceptive ones.

Such data-driven methods highlight the benefits of moving beyond single-domain features toward richer representations of dynamic radar signatures. Comprehensive reviews of radar target characterization emphasize the integration of temporal, spectral, and statistical signal characteristics for robust ATR.

Despite these advancements, the explicit problem of discriminating aviation decoy targets—engineered to emulate real aircraft RCS characteristics—remains underexplored. Most existing studies focus on classifying distinct target classes (e.g., UAVs vs. manned aircraft) and do not address the ambiguity introduced by decoy systems designed to mimic authentic RCS traces. This gap motivates the present work, which systematically extracts and fuses dynamic RCS-driven features across multiple signal domains for reliable aviation decoy detection in realistic radar operating conditions. Recent studies have also highlighted the growing importance of advanced mathematical modeling and computational techniques in radar signal analysis and aerospace applications. In particular, dynamic modeling of RCS behavior has been investigated to better capture the complex scattering characteristics of airborne targets under varying flight conditions. For instance, the development of bimodal models for dynamic RCS characterization has demonstrated the ability to represent both stable and rapidly fluctuating scattering components, providing improved insight into target reflectivity patterns and enhancing the accuracy of signal interpretation in radar systems [11]. Such approaches emphasize the need to move beyond static representations of RCS and instead consider time-varying behaviors that reflect realistic operational conditions. In addition to RCS modeling, optimization-based computational frameworks have been widely applied in aerospace system analysis. Advanced numerical modeling techniques implemented in environments such as MATLAB/Simulink enable precise simulation and optimization of complex flight trajectories, facilitating improved prediction of aircraft motion and radar observables [12]. These methods play a critical role in bridging the gap between theoretical signal models and real-world radar measurements, particularly in scenarios involving highly dynamic targets or nonlinear system behavior. Furthermore, stochastic approaches such as Monte Carlo integration have been effectively utilized to address uncertainty in radar-based measurements and trajectory reconstruction. By incorporating probabilistic analysis, these methods allow for the validation of the physical feasibility and robustness of reconstructed flight paths derived from radar data [13]. The integration of stochastic modeling with radar signal processing provides a powerful framework for handling noise, measurement errors, and environmental variability.

3 METHODOLOGY

The proposed methodology is designed to discriminate genuine aircraft from aviation decoy targets through structured analysis of dynamic RCS signatures using a multi-domain feature extraction and classification framework. The overall processing chain consists of radar signal acquisition, pre-processing and RCS estimation, feature extraction across temporal, statistical, and time–frequency domains, feature fusion and normalization, and supervised classification. This architecture is intended to ensure computational efficiency while maintaining high discrimination accuracy under realistic airborne engagement conditions.

To evaluate the proposed approach, a high-fidelity simulation environment was developed to model an operational scenario involving a multirole fighter platform. The simulated radar system operates in the X-band using pulse-Doppler processing and allows variation of SNR, aspect angle, and target–decoy separation distance. Four representative cases were considered: aircraft without countermeasure deployment, aircraft with a towed decoy, aircraft with chaff cloud release, and aircraft employing an active radio-frequency repeater. For each scenario, time-varying RCS sequences were generated to capture realistic scattering dynamics. The received radar echoes were subjected to standard pre-processing procedures, including range gating, Doppler filtering, and clutter suppression. Instantaneous RCS values were estimated from calibrated echo amplitudes to construct dynamic RCS time series. To reduce measurement noise while preserving meaningful fluctuations, a low-order temporal smoothing filter was applied. The resulting signals provided both amplitude-based RCS evolution and corresponding Doppler frequency estimates for subsequent analysis.

Discriminative information was extracted across three complementary domains. In the temporal domain, features such as mean RCS, standard deviation, peak-to-peak variation, and stability indicators were computed to quantify short-term fluctuation behavior. Real aircraft generally exhibit relatively stable scattering patterns with gradual variation due to maneuvering, whereas towed decoys demonstrate oscillatory modulation caused by aerodynamic cable motion. Chaff clouds, in contrast, produce rapid decorrelation and highly unstable amplitude behavior. In the statistical domain, higher-order descriptors including variance, skewness, kurtosis, and Shannon entropy were calculated to characterize distributional properties of the RCS signal. Entropy-based measures are particularly effective in identifying stochastic scattering behavior typical of dispersed chaff clouds. In the time–frequency domain, Short-Time Fourier Transform (STFT) analysis was employed to generate spectrogram representations, enabling extraction of spectral spread, dominant Doppler components, sideband energy, and micro-motion periodicity. Genuine aircraft generate structured micro-motion signatures associated with rotating engine components, a phenomenon known as the micro-Doppler effect. By contrast, decoys exhibit either low-frequency oscillatory modulation, broadband spectral dispersion, or artificially amplified echoes with phase inconsistencies, depending on the countermeasure type.

All extracted descriptors were combined into a unified feature vector and normalized to ensure comparable scaling across parameters. Feature correlation analysis was conducted to eliminate redundant information and improve classification robustness. A supervised machine learning classifier based on a support vector machine (SVM) with a radial basis function kernel was then implemented to perform binary discrimination between aircraft and decoy targets. The classifier was trained and validated using Monte Carlo-generated datasets spanning varying SNR levels, aspect angles, and geometric separations, with cross-validation employed to prevent overfitting.

System performance was evaluated using probability of detection, false alarm rate, overall classification accuracy, precision, recall, and receiver operating characteristic

(ROC) analysis. Comparative assessment against a baseline amplitude-only RCS threshold method was conducted to quantify the benefits of the proposed multi-domain feature fusion strategy. Computational complexity considerations were also examined to ensure that feature extraction, time–frequency analysis, and classifier inference remain compatible with real-time radar signal processing requirements. Through this structured methodology, dynamic RCS signatures are systematically exploited to achieve reliable aviation decoy discrimination without reliance on computationally intensive electromagnetic modeling.

4 RESULTS

The proposed multi-domain feature-based detection framework was evaluated through high-fidelity simulation scenarios representing a multirole fighter platform under various operational conditions. Four scenarios were considered: aircraft without countermeasure deployment, aircraft with a towed decoy, aircraft releasing a chaff cloud, and aircraft employing an active radio-frequency repeater. Each scenario was simulated across a range of SNRs, aspect angles, and target–decoy separation distances to assess the robustness of the feature extraction and classification framework.

Temporal feature analysis revealed distinct differences between real aircraft and decoy targets. The mean RCS of real aircraft exhibited low variance and smooth temporal fluctuations due to stable aerodynamic motion, whereas towed decoys displayed pronounced oscillatory behavior, chaff clouds showed high randomness and rapid decorrelation, and active repeaters generated intermittent amplitude spikes corresponding to artificial signal amplification. These observations confirmed the effectiveness of temporal stability metrics in capturing decoy-induced deviations from genuine aircraft RCS dynamics. Statistical and entropy-based features further highlighted the discriminative potential of the proposed approach. Shannon entropy and higher-order statistical moments effectively differentiated stochastic scattering patterns from structured RCS signals. Chaff clouds consistently exhibited elevated entropy values, indicating greater signal randomness, while real aircraft maintained lower entropy across all simulated SNR levels. Towed decoys demonstrated intermediate entropy values, reflecting partial correlation with the aircraft's motion and the additional oscillatory perturbation introduced by the tow cable.

Time–frequency analysis using STFT provided additional discrimination through micro-Doppler signatures. Real aircraft produced characteristic periodic micro-Doppler components corresponding to engine and structural motions, whereas decoys either lacked such structured micro-motions or exhibited spectral inconsistencies. Towed decoys introduced low-frequency sidebands associated with aerodynamic oscillations, and active repeaters generated spurious spectral peaks resulting from delayed or amplified reflections. These patterns were consistently captured across different aspect angles and SNR conditions, confirming the robustness of the proposed feature set for spectral discrimination.

The extracted multi-domain features were fused into a unified feature vector and processed using a SVM classifier. Monte Carlo simulations with 10,000 randomly generated test cases showed that the proposed method achieved an overall classification accuracy of 94.7%, with a probability of detection (Pd) exceeding 96% for real aircraft and a false alarm rate (Pfa) below 3.5% for decoy targets. ROC analysis demonstrated a strong trade-off between detection sensitivity and false alarms, with the area under the curve (AUC) exceeding 0.97 across all scenarios.

Comparative evaluation against an amplitude-only RCS thresholding method indicated a substantial improvement, with the baseline method achieving only 78.3% classification accuracy and significantly higher false alarm rates, particularly in low SNR conditions.

These results confirm that dynamic RCS behavior contains exploitable discriminative information and that multi-domain feature extraction—integrating temporal, statistical, and time-frequency characteristics—provides a reliable framework for aviation decoy detection. The methodology demonstrated resilience under varying radar operating conditions, including low SNR, varying aspect angles, and closely spaced target–decoy geometries. Furthermore, the computational analysis indicated that feature extraction and SVM inference can be executed within real-time constraints of modern radar signal processors, making the framework suitable for integration into airborne and ground-based radar systems.

5 DISCUSSION

The simulation results demonstrate that the proposed multi-domain feature-based detection framework is highly effective in discriminating aviation decoy targets from genuine aircraft across diverse operational scenarios. Temporal analysis of the RCS signals showed that real aircraft maintain relatively stable scattering profiles, characterized by low variance and smooth fluctuations caused by aerodynamic maneuvers and engine-induced micro-motions. In contrast, decoy targets introduced measurable perturbations in the RCS time series. Towed decoys generated oscillatory patterns due to cable-induced aerodynamic motion, chaff clouds produced highly random and rapidly decorrelating RCS fluctuations, and active radio-frequency repeaters induced intermittent amplitude spikes resulting from artificial signal amplification. These observations are consistent with findings from prior research, which indicates that dynamic RCS behavior captures essential characteristics of target motion and internal structure that can be exploited for classification.

The statistical analysis reinforced the temporal findings by revealing distinct differences in higher-order metrics between aircraft and decoys. Entropy, skewness, and kurtosis were particularly effective in identifying stochastic behaviors typical of chaff clouds, which displayed high entropy values indicative of the random scattering from multiple metallic elements. Towed decoys exhibited intermediate statistical values, reflecting partial correlation with the aircraft motion while introducing additional oscillatory deviations, which demonstrates that statistical descriptors can reliably capture subtle differences in decoy behavior. These results highlight the limitations of amplitude-only detection approaches, as previously discussed in the literature, where single-domain metrics often fail to detect complex decoy signatures. The integration of statistical features into the feature vector improves robustness, particularly under low SNR conditions and in scenarios where target and decoy RCS values overlap significantly. Time-frequency analysis further enhanced target discrimination by capturing micro-Doppler effects associated with real aircraft. Genuine aircraft exhibited structured micro-Doppler patterns corresponding to rotating engines, control surfaces, and aerodynamic vibrations, which are consistent with known physical phenomena observed in ATR studies. In comparison, decoys either lacked structured micro-Doppler components or presented altered spectral patterns due to their design. Towed decoys generated low-frequency sidebands associated with cable oscillations, chaff clouds produced broadband, incoherent spectral distributions, and active repeaters introduced artificial spectral peaks resulting from signal amplification and phase delays. These results confirm that multi-domain feature extraction provides complementary information: temporal and statistical descriptors highlight amplitude fluctuations and randomness, whereas time–frequency analysis captures spectral dynamics that are unique to real aircraft motion or decoy manipulations. This multi-faceted approach aligns with previous studies that advocate combining temporal, spectral, and statistical features for more reliable radar target recognition.

The fusion of these features into a unified vector allowed a SVM classifier to achieve superior discrimination performance. Monte Carlo simulations with 10,000 test cases demonstrated an overall classification accuracy of 94.7%, with probability of detection (Pd) exceeding 96% for real aircraft and false alarm rates (Pfa) below 3.5% for decoys. The ROC analysis yielded an AUC exceeding 0.97, indicating excellent classifier robustness across all scenarios. By comparison, a baseline amplitude-only RCS thresholding method achieved only 78.3% accuracy, with significantly higher false alarms, particularly at low SNR values. These results validate the importance of integrating multi-domain features, as isolated single-domain methods often cannot capture the subtle RCS variations introduced by decoys.

An important observation from the simulation study is the method's resilience under varying operational conditions. Classification accuracy remained high even when target–decoy separation distances were reduced, aspect angles were altered, or SNR was degraded. This suggests that the proposed framework can effectively detect decoys in close-formation flight or contested electromagnetic environments, a key capability for modern airborne radar systems where decoy deployment is intended to exploit proximity and signal confusion. The results also emphasize the role of micro-Doppler and time–frequency features in distinguishing decoys in scenarios where amplitude-based features alone are insufficient, highlighting the critical contribution of spectral analysis in real-time radar decision-making.

From a practical perspective, the computational complexity of the framework was analyzed to ensure compatibility with real-time radar operations. Feature extraction, including temporal metrics, statistical descriptors, and STFT-based spectral analysis, was implemented efficiently, and SVM inference was performed with minimal latency. This indicates that the proposed methodology can be integrated into both airborne and ground-based radar systems without requiring specialized hardware or excessive processing time, a consideration that is increasingly important for modern radar applications facing high data throughput and real-time threat assessment requirements.

While the framework shows strong performance, certain limitations should be acknowledged. Extremely low SNR conditions, highly maneuvering decoys, or complex environmental clutter may reduce classifier confidence. Additionally, the study relied on simulated RCS data, which, while realistic, may not fully capture all propagation and multipath effects present in operational radar environments. Future work should focus on incorporating experimental flight test data and exploring adaptive or deep learning classifiers capable of online learning to accommodate previously unseen decoy designs. The integration of polarimetric RCS analysis or multistatic radar configurations could further enhance discrimination capabilities, particularly against advanced decoys employing complex electronic countermeasures.

As a result of investigation, the proposed methodology provides a robust and computationally efficient solution for aviation decoy detection by leveraging dynamic RCS behavior across multiple signal domains. The approach demonstrates clear advantages over traditional amplitude-based methods, enabling accurate discrimination under challenging operational conditions. By systematically exploiting temporal, statistical, and spectral characteristics, the framework addresses a key gap identified in the literature regarding decoy detection and offers a practical pathway for next-generation radar systems to maintain target recognition reliability in the presence of sophisticated airborne countermeasures.

6 CONCLUSION AND RECOMMENDATIONS

This study presented a comprehensive framework for the detection and discrimination of aviation decoy targets based on dynamic RCS signatures. The methodology integrates temporal, statistical, and time–frequency features extracted from radar returns, which are fused into a unified feature vector and classified using a SVM. Simulation scenarios modeled a multirole fighter platform and included four representative cases: aircraft without countermeasures, aircraft with a towed decoy, aircraft releasing chaff clouds, and aircraft employing active radio-frequency repeaters. These scenarios were evaluated across varying SNRs, aspect angles, and target–decoy separations to ensure realistic operational conditions.

The results demonstrate that real aircraft exhibit stable RCS behavior with predictable temporal fluctuations and structured micro-Doppler signatures, whereas decoy targets introduce measurable deviations. Towed decoys produced oscillatory RCS patterns, chaff clouds generated highly stochastic amplitude fluctuations and high entropy values, and active repeaters created intermittent amplitude spikes and spectral distortions. Multi-domain feature fusion allowed the SVM classifier to achieve an overall accuracy of 94.7%, with a probability of detection exceeding 96% for real aircraft and a false alarm rate below 3.5% for decoys. These results indicate a substantial improvement over traditional amplitude-only RCS thresholding, which achieved only 78.3% accuracy and was particularly sensitive to low SNR conditions. ROC analysis further confirmed the robustness of the proposed framework, with an area AUC exceeding 0.97 across all simulated conditions.

From an operational perspective, the study confirms that multi-domain RCS features provide reliable discrimination even in challenging scenarios involving closely spaced target–decoy configurations, varying aspect angles, and low SNR environments. Computational analysis shows that feature extraction and SVM classification can be executed in real-time, making the framework suitable for integration into both airborne and ground-based radar systems. This operational feasibility highlights the practical significance of the proposed approach, enabling radar operators to maintain high target recognition performance despite increasingly sophisticated airborne countermeasure technologies.

Based on the findings, several recommendations can be made for future research and practical implementation:

Experimental Validation: While simulations provide high-fidelity RCS data, experimental validation with actual flight tests is recommended to capture environmental effects such as multipath, atmospheric attenuation, and radar clutter, which may influence feature behavior in operational radar systems. Adaptive Learning Algorithms: Future work should explore adaptive or incremental machine learning techniques, including deep neural networks and online learning frameworks, to accommodate previously unseen decoy types or evolving countermeasure strategies in real-time radar environments.

Polarimetric and Multi-Static Radar Integration: Incorporating polarimetric RCS analysis or multi-static radar measurements could enhance discrimination capability by providing additional independent features related to scattering mechanisms, target orientation, and propagation effects. Operational Deployment Guidelines: Radar system designers and operators should consider implementing multi-domain feature extraction modules in real-time processing pipelines, optimizing computational resources to ensure low-latency decision-making, particularly in high-density airspaces or contested electromagnetic environments. Robustness Against Novel Countermeasures: Continuous monitoring of emerging decoy technologies is necessary to update feature extraction strategies. The inclusion of time-frequency anomaly detection and entropy-based monitoring can further improve resilience against sophisticated electronic countermeasures.

In conclusion, this study demonstrates that dynamic RCS-based feature fusion is a powerful and practical approach for aviation decoy detection. By systematically exploiting temporal stability, statistical descriptors, and spectral characteristics, the framework achieves high classification accuracy and robustness across realistic radar operating conditions. The methodology addresses a critical gap in current radar target recognition research, providing a scalable solution for next-generation radar systems tasked with detecting and discriminating increasingly sophisticated airborne countermeasures. Implementing the recommended enhancements, including experimental validation, adaptive learning, and multi-static radar integration, will further strengthen detection performance and operational applicability, ensuring that radar operators can maintain reliable situational awareness in modern complex airspace environments.

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