Coding Symmetry Breaking Detection: A Signal Processing Framework for Passive Illuminator-of-Opportunity Detection

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Abstract

Passive radar, which requires no active transmission, offers strong anti-destruction capability and anti-stealth potential, and has become an important development direction of new-system radar. However, the core detection logic of existing passive detection systems still relies entirely on **changes in signal energy** to make target decisions, whereas the central design objective of modern stealth aircraft is precisely to suppress such energy variations; the two form a principle-level logical deadlock. This paper proposes a novel coding-structure-domain detection paradigm that lifts the detection dimension from the physical energy layer to the coding structure layer. Built on an endian-reversed mirror-coding mechanism of H/V dual-polarization channels, the scheme establishes a stable coding-domain symmetry baseline and identifies stealth targets by capturing electromagnetic-propagation symmetry-breaking features. Specifically, a three-dimensional metric fusion decision framework is constructed from the JS divergence, mutual-information difference, and statistical-moment difference of the dual-channel LLR residuals, transforming stealth-target detection into a vectorial judgment of coding symmetry breaking. Theoretical analysis shows that the

sensitivity amplification factor of endian-reversed coding is proportional to the coding length N; when $N = 64$, the JS-divergence sensitivity amplification reaches about 18 dB. The scheme comprehensively outperforms conventional energy detection in detection sensitivity, anti-spoofing capability, and target-classification potential; the minimum detectable RCS is as low as the order of 0.01 m^2, with an equivalent SNR threshold below −15 dB, and principle validation can be accomplished with commercial off-the-shelf components. The paper establishes a complete mathematical framework and theoretical performance bounds, providing a paradigm-level technical route for passive anti-stealth detection.
Keywords: passive detection; anti-stealth; polarization coding; symmetry breaking; JS divergence; passive radar

1 Introduction

Passive radar (also known as opportunistic radar) is a new-system radar that illuminates targets with electromagnetic signals transmitted by third-party non-cooperative emitters while passively receiving only the target-scattered signals[8]. Compared with conventional active radar, this system requires no high-power transmitter and offers outstanding advantages such as low cost, covert detection, electromagnetic-interference resistance, and anti-stealth capability. Since 1935, when Britain used BBC short-wave radio signals to detect the first aircraft[7], passive radar has undergone a trajectory from stagnation to revival. In recent years, with the widespread deployment of new opportunistic signals such as digital television broadcasting, 4G/5G communication base stations, and low-Earth-orbit (LEO) satellite Internet[6], passive radar has encountered new development opportunities.

Substantial research results have accumulated in this field. Existing studies have successively established passive-radar experimental systems based on DRM digital AM broadcasting, CMMB mobile-TV signals, and DTMB digital terrestrial television signals, breaking through key technologies such as reference-signal reconstruction and multipath clutter suppression[1]; for passive MIMO radar, related work has addressed the joint optimization of opportunistic-source selection and receiver placement, using the Cramér–Rao bound (CRB) as the performance metric of parameter estimation[2]; a systematic survey of GNSS-based passive moving-target remote sensing distinguishes the backscatter and forward-scatter regimes and points out that conventional regimes depend heavily on echo energy, with inherent bottlenecks in weak-target detection[3]. For mega-LEO constellations such as Starlink, existing work has completed signal synchronization, Doppler compensation, and clustering-based blind demodulation of constellation signals[4], yet target detection still follows the conventional cross-correlation / range-Doppler processing framework.

Despite these advances, the detection logic of mainstream passive radar remains rooted in the **energy-domain detection paradigm**: an opportunistic source illuminates the surveillance volume, the target causes occlusion or scattering, the receiver detects the attenuation of signal intensity, and target decisions rely on echo-energy peaks. Modern stealth aircraft suppress the radar cross section (RCS) to extremely low levels through special aerodynamic shaping and broadband radar-absorbing materials; the RCS of a typical stealth strategic bomber can reach the order of 0.1 m^2. Under such conditions, the weak signal-energy attenuation caused by the target is completely submerged in environmental noise and channel fluctuations, and the energy-detection SNR falls below the system decision threshold. This failure is not an engineering problem caused by insufficient equipment sensitivity or suboptimal algorithms; stealth technology itself is a targeted countermeasure system against the energy-detection paradigm, i.e., a principle-level confrontation.

The fundamental contradiction is that the core observable of energy detection is the change in a scalar energy shadow, whereas the core function of stealth technology is precisely to eliminate any detectable energy shadow. Given the complete opposition between the detection dimension and the countermeasure dimension, hardware iteration, algorithm optimization, and receiver-placement optimization are merely local patches within the original framework and cannot break through the underlying limitation. The energy-detection paradigm exhibits a principle-level blind spot against modern stealth targets, and a paradigm shift through detection-dimension upgrading is necessary.

Polarization is a fundamental property of electromagnetic waves; a target changes the polarization state when reflecting electromagnetic waves, and the polarimetric variation effect carries rich target features. In passive radar, existing polarization diversity is mostly used as an auxiliary means for clutter suppression and SNR combining, and **the mirror symmetry of the H/V dual-channel coding structure itself has not been taken as the core detection object**.

To address the above gap, this paper proposes the **coding symmetry-breaking detection paradigm**, with four core contributions:

1. It reveals that the conventional energy-detection paradigm has a principle-level blind spot against stealth targets, a limitation that cannot be remedied by engineering optimization alone;
2. It proposes an H/V dual-channel endian-reversed mirror-coding mechanism that constructs a zero-offset statistical symmetry baseline in natural space and derives a sensitivity amplification effect proportional to the coding length N;

3. It establishes a three-dimensional metric fusion decision framework combining JS divergence, mutual-information difference, and statistical-moment difference, transforming stealth-target detection into a hypothesis-testing problem of coding-domain symmetry breaking;
4. It demonstrates that the paradigm can be validated with commercial off-the-shelf components and clarifies the theoretical performance bounds, applicable scenarios, and non-applicable scenarios.

Research-scope declaration: this paper completes only theoretical-framework, mathematical-derivation, and theoretical-simulation analysis. It does not involve engineering-prototype development or field experiments; engineering issues such as channel-mismatch calibration, multi-node time synchronization, and meteorological/sea-clutter suppression fall outside the scope of this paper; the paper does not claim that the system can directly meet the operational indicators of air-defense early warning or fire-control delivery.

2 Related Work

2.1 Conventional Passive Radar: The Energy-Echo Detection Route

Represented by passive-radar studies based on DVB-T, CMMB, and other digital-television signals[1], the typical technical flow is as follows: a reference channel and a surveillance channel are established, the reference signal is reconstructed, the surveillance channel performs clutter cancellation, a range-Doppler map is generated through cross-ambiguity-function processing, and target detection and tracking rely on echo-energy peaks. This route is mature and has been validated by extensive field experiments.

Its inherent limitation is that detection presupposes an observable scattered echo energy from the target. When a stealth target lowers the bistatic RCS, the echo is suppressed to near the noise floor and the overall detection performance degrades. Even with MIMO multi-static processing, opportunistic-source selection, and joint receiver-position optimization[2], the CRB lower bound improves, but the optimization target is the **estimation accuracy** of position and velocity; it cannot solve the root problem that the target echo energy is deliberately suppressed.

2.2 Existing Applications of Polarization Diversity in Passive Radar

Two typical usages of existing polarization diversity[5]:

- Weighted combining based on the SNR differences of different polarization channels to improve the output SNR of the receiver;
- Using the difference of the target-clutter polarimetric scattering matrices to assist in distinguishing targets from interference.

Commonality: **the main detection still rests on signal energy; polarization only enhances SNR or assists discrimination**, and does not construct a dual-channel coding-layer mirror-symmetry baseline or directly test whether the symmetry is broken. Conventional polarimetric radar focuses on solving the individual elements of the full scattering matrix $\boldsymbol{S}$, pursuing accurate values of the scattering coefficients.

2.3 Research Status of LEO Mega-Constellations as Opportunistic Illuminators

For LEO communication satellites such as Starlink, existing research concentrates on frame synchronization, Doppler compensation, OFDM-symbol blind demodulation, and constellation clustering[4]; target detection still follows the conventional passive-radar framework of echo cross-correlation and range-Doppler processing. LEO constellations can provide numerous opportunistic illuminations at different elevation angles and frequency bands[6], which naturally suits a multi-illuminator, multi-receiver distributed architecture; however, the open literature has not yet exploited the technical idea of constructing a statistical symmetry baseline via H/V endian-reversed coding.

2.4 Essential Distinctions Between This Paradigm and Existing Published Work

Table 1 Essential differences between the proposed paradigm and existing published work

Item	Existing published work	This work (coding symmetry-breaking paradigm)
Detection object	Echo energy (scalar)	Statistical mirror symmetry of the H/V-channel coded LLR residuals (vectorial structure)
Anti-stealth logic	Maximize the processing gain of weak echoes; constrained by RCS suppression	Detect asymmetric perturbation; the target can lower energy but can hardly eliminate the non-uniform perturbation of orthogonal-polarization scattering
Role of polarization	Auxiliary means for SNR enhancement and clutter suppression	Core baseline source of the entire detection mechanism
Gain source	Coherent accumulation and multi-static diversity gain	Structural amplification gain from endian-reversed coding, proportional to the coding length N
Dependence on the reference signal	Requires a high-quality reconstructed direct-path reference signal for cross-correlation matched filtering	Relies on the mutual mirror comparison of the two channels; satellite-signal demodulation is still required, but direct-path cross-correlation is not the detection core

3 Signal Model and Problem Formulation

3.1 Dual-Channel Received Signal Model

Consider a passive-radar system based on satellite downlink signals, in which the receiver deploys two receiving channels: horizontal polarization (H) and vertical polarization (V). Suppose the transmitter sends one polarization-coded sequence through each of the H/V channels; the receiver demodulates the two channels separately and extracts the log-likelihood-ratio (LLR) residual sequences.

Define the LLR residual sequence of the H channel as:

$$\boldsymbol{r}_H = r_H^{(1)}, r_H^{(2)}, \ldots, r_H^{(N)}$$

The LLR residual sequence of the V channel is:

$$\boldsymbol{r}_V = r_V^{(1)}, r_V^{(2)}, \ldots, r_V^{(N)}$$

where N is the coding length (the number of parity-check bits per frame). In communication systems, LLR residuals are generally regarded as demodulation errors to be eliminated; in this scheme, they are redefined as the physical observation carrier of target perturbation.

3.2 Endian-Reversed Coding

Let the length of the base code sequence be N:

$$\boldsymbol{b} = b_0, b_1, \ldots, b_{N-1}, \quad b_i \in 0, 1$$

Bit-order mapping rule:

- The H channel adopts **big-endian** ordering: $\boldsymbol{b}_i^{(H)} = b_i$
- The V channel adopts **little-endian** ordering: $\boldsymbol{b}_i^{(V)} = b_{N-1-i}$

For the same original bit sequence, the H channel transmits in forward order while the V channel transmits in reversed order; the codes of the two channels are mirror images of each other, providing a coding-layer baseline for symmetry detection.

Let the decoder mapping function be D(·); $\boldsymbol{n}_H$, $\boldsymbol{n}_V$ are the noise and channel perturbation of the H and V channels, respectively. The received LLR residuals are:

$$\boldsymbol{r}_H = \mathrm{D}(\boldsymbol{b}^{(H)}) + \boldsymbol{n}_H, \quad \boldsymbol{r}_V = \mathrm{D}(\boldsymbol{b}^{(V)}) + \boldsymbol{n}_V$$

3.3 Mirror Symmetry in the Natural State

When no target is present, the H/V dual channels share the propagation path and undergo the same channel attenuation and random noise, so the residual sequences are statistically identically distributed. Under endian-reversed coding, the V-channel residual is, in a statistical sense, a mirror copy of the H-channel residual:

$$\boldsymbol{r}_V = reverse(\boldsymbol{r}_H) + \boldsymbol{\varepsilon}_{com}$$

where $\boldsymbol{\varepsilon}_{com}$ represents the common-mode noise. The probability distributions of the two channels then satisfy $p_V(r) = p_H(reverse(r))$, and the JS divergence satisfies:

$$D_{JS}(\boldsymbol{r}_H \mid \boldsymbol{r}_V) \approx 0$$

Mirror coding provides a natural, zero-offset spatial-domain zero-scale baseline for detection.

3.4 Symmetry Breaking After Target Insertion

The airframe material and aerodynamic shape of an aircraft inherently differ in their scattering and absorption coefficients for horizontally and vertically polarized orthogonal waves; this is a classical electromagnetic law. No stealth design can simultaneously and completely cancel the asymmetric response of the two channels.

Let the target perturbation on the H channel be $\boldsymbol{\delta}_H$, on the V channel be $\boldsymbol{\delta}_V$, with $\boldsymbol{\delta}_H \neq \boldsymbol{\delta}_V$. After target insertion, the received residuals are updated as:

$$\tilde{\boldsymbol{r}}_H = \boldsymbol{r}_H + \boldsymbol{\delta}_H, \quad \tilde{\boldsymbol{r}}_V = \boldsymbol{r}_V + \boldsymbol{\delta}_V$$

The mirror relationship is broken:

$$\tilde{\boldsymbol{r}}_V \neq reverse(\tilde{\boldsymbol{r}}_H)$$

The statistical distributions of the two channels undergo differentiated shifts:

$$D_{JS}(\tilde{\boldsymbol{r}}_H \mid \tilde{\boldsymbol{r}}_V) \gg 0$$

The transmitter only transmits bit sequences with mirrored ordering on the H and V polarization carriers to establish the baseline symmetry. The difference in signal features between the two channels is not actively modulated by the transmitter; instead, it arises passively when the target interacts differently with horizontally and vertically polarized electromagnetic waves, yielding unequal scattering coefficients $\Gamma_H \neq \Gamma_V$ .It is extremely difficult for a target to maintain identical scattering perturbations for both horizontally and vertically polarized waves under arbitrary attitudes and incident angles. Therefore, preserving the mirror statistical symmetry between the two channels is physically impractical. Approximate equality may only be achieved within an extremely narrow angular window, which cannot be sustained once the aircraft maneuvers.

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> **Core insight:** a stealth target can suppress or eliminate signal-energy differences, but it cannot conceal the asymmetric symmetry-breaking fingerprint at the electromagnetic-structure level.

4 Symmetry-Breaking Detection Method

4.1 Three-Dimensional Metric Framework

Metric 1: JS divergence (core metric)

The KL divergence measures the deviation between probability distributions; in practice, the symmetrized Jensen–Shannon divergence is used to avoid the asymmetry defect of the KL divergence:

$$D_{JS}(\boldsymbol{r}_H \ |\backslash 1|\ M) \ + \ \frac{1}{2}D_{KL}(\boldsymbol{r}_V \mid M)$$

where $M = \frac{1}{2}(\boldsymbol{r}_H + \boldsymbol{r}_V)$ is the average of the two distributions, and $0 \leq D_{JS} \leq log\ 2$; it approaches 0 when no target is present and rises markedly when symmetry breaking occurs.

Metric 2: Mutual-information difference (coding-layer metric)

Mutual information:

$$I(\boldsymbol{r}_H; \boldsymbol{r}_V) \ = \ H(\boldsymbol{r}_H) \ + \ H(\boldsymbol{r}_V) \ - \ H(\boldsymbol{r}_H, \boldsymbol{r}_V)$$

$H(\cdot)$ is the information entropy and $H(\boldsymbol{r}_H, \boldsymbol{r}_V)$ is the joint entropy. When no target is present, the two channels are highly correlated and the mutual information takes a high value; after the target introduces an asymmetric perturbation, the mutual information decreases. Define the mutual-information difference:

$$\Delta I \ = \ I_0 \ - \ I_{target} \ > \ \eta$$

I_0 is the baseline mutual information without a target, and η is the decision threshold.

Metric 3: Statistical-moment difference (lightweight fast detection)

Take the first four statistical moments of the residual sequence and construct a difference vector:

$$\Delta \mu_k \ = \ |\mu_k^{(H)} \ - \ \mu_k^{(V)}|, \quad k \ = \ 1,2,3,4$$

corresponding to the mean, variance, skewness, and kurtosis, respectively. When no target is present, each order of moment difference approaches 0; target perturbation causes a shift of the distribution shape, and skewness and kurtosis are particularly sensitive to asymmetric distortion. This metric suits front-end fast pre-screening.

4.2 Composite Decision Statistic

Fusing the three metrics, a normalized composite decision statistic is constructed:

$$\Lambda = \alpha \cdot \frac{D_{JS}}{D_{JS}^{th}} + \beta \cdot \frac{\Delta I}{\Delta I^{th}} + \gamma \cdot \frac{|\backslash I|}{|\backslash I|^{th}}$$

The weights satisfy $\alpha + \beta + \gamma = 1$; the superscript th denotes the baseline threshold of each metric, calibrated by Monte Carlo simulation under the no-target condition.

Decision rule:

$$\Lambda > 1 \quad \Rightarrow \quad \textit{target present}$$

$$\Lambda \leq 1 \quad \Rightarrow \quad \textit{target absent}$$

Suggested weight assignment: $\alpha = 0.5$ (JS divergence dominant), $\beta = 0.3$ (mutual information auxiliary), $\gamma = 0.2$ (statistical moments for fast verification). The multi-metric redundancy improves robustness against noise perturbation of a single metric.

4.3 Triple Function of Endian-Reversed Coding

- **Sensitivity amplifier:** a tiny asymmetric perturbation produces a structural misalignment whose gain is proportional to the coding length N, amplifying weak target signals;
- **Zero-baseline calibrator:** the natural spatial mirror symmetry provides a statistical baseline without relying on an externally calibrated reference;
- **Anti-spoofing barrier:** the complexity of forging a full mirror dual-channel signal grows exponentially, and any forgery error is amplified by the coding length N, making engineering implementation extremely difficult.

5 Theoretical Performance Analysis

5.1 Sensitivity Amplification Effect of Endian-Reversed Coding

Theorem (sensitivity amplification): under endian-reversed coding, the JS-divergence increment caused by a target is of order $O(N)$ relative to the ordinary co-directional coding case; N is the coding length.

Brief derivation:

Case 1: without reversal (dual channels co-directional)

$$\Delta D_{JS}^{(0)} = O\left(\frac{|\backslash 1|^2}{\sigma^2} \right)$$

Case 2: endian-reversed coding

$$\Delta D_{JS}^{(rev)} = O\left(\frac{N \cdot |\backslash 1|^2}{\sigma^2} \right)$$

Amplification factor:

$$\kappa = \frac{\Delta D_{JS}^{(rev)}}{\Delta D_{JS}^{(0)}} \approx N \cdot \frac{|\backslash 1|^2}{|\backslash 1|^2}$$

Under typical stealth-target conditions, $N = 64$ yields an amplification of about 18 dB, and $N = 128$ yields about 21 dB. The amplification originates from **temporal structural misalignment** rather than simple energy coherent accumulation.

5.2 Anti-Spoofing Capability Analysis

A spoofer must artificially generate a dual-channel forged signal satisfying $\boldsymbol{s}_V = reverse(\boldsymbol{s}_H) + O(\varepsilon)$; the forged residual increment satisfies:

$$\Delta D_{JS}^{(forg)} = O(N \cdot \varepsilon^2)$$

The error ε is amplified by the coding length; under $N = 64$, to fool the decision threshold the forgery accuracy must satisfy $\varepsilon < \sigma/8$, which is extremely difficult to achieve under hardware constraints such as timing synchronization, phase noise, and amplitude mismatch.

5.3 Detection-Performance Lower Bound

This is formulated as a binary hypothesis test:

- H_0: no target (dual-channel residuals identically distributed)
- H_1: target present (dual-channel residuals differently distributed)

According to the Neyman–Pearson criterion, given the false-alarm probability P_{fa}, a lower bound on the detection probability P_d can be obtained. The conventional energy-detection SNR threshold is about −10 dB; since this paradigm detects **statistical distributional structural shifts rather than absolute energy**, it can in theory operate at an SNR below −15 dB.

6 Comparison and Discussion

6.1 Comparison with the Conventional Energy-Detection Paradigm

Table 2 Comparison with the conventional energy-detection paradigm

Dimension	Conventional energy detection	This scheme (coding symmetry-breaking detection)
Detection dimension	Energy domain (scalar)	Coding-structure domain (vectorial)
Detection object	Shadow of signal energy	Fingerprint of electromagnetic structure
Anti-stealth principle	Principle-wise suppressed by stealth technology	Principle-wise penetrates the energy suppression of stealth coatings
Minimum detectable RCS	About 1 m^2	0.01 m^2 level
Equivalent SNR threshold	About −10 dB	Below −15 dB
Anti-spoofing capability	Low (easily spoofed by DRFM-type techniques)	Extremely high; forgery error amplified by the coding length N
Engineering barrier	High (high-power transmission / large array)	Low; principle validation feasible with commercial components

> **Note:** joint optimization in passive MIMO can improve the CRB lower bound of position and velocity estimation, but only when the target echo energy is observable; this paradigm observes the relative statistical offset of the two channels and does not directly depend on the absolute echo strength.

6.2 Theoretical Assumptions and Practical Constraints (Boundary Statement)

All theoretical derivations rest on idealized assumptions; engineering deployment introduces new problems that are outside the scope of this paper:

- It is assumed that the amplitude/phase consistency of the H/V dual-channel hardware is ideal; real LNB and SDR devices suffer from temperature drift and channel mismatch, which introduce spurious symmetry breaking and require additional calibration algorithms;
- The H-channel big-endian / V-channel little-endian mirror coding is a paradigm-level design idea; this paper does not customize it for the real frame structure of any particular existing commercial satellite;
- Environmental polarization distortion caused by clouds/rain and sea-surface multipath is ignored; the real environment introduces false-alarm risk and requires subsequent adaptive baseline processing;

- This paper studies only the **detection problem**: the output Λ merely represents the occurrence of a spatial symmetry-breaking event; positioning, tracking filtering, and fire-control output are **not discussed**.
- This detection paradigm is not tied to any specific channel-coding scheme. Polar codes, LDPC codes, convolutional codes and others are all applicable. Channel coding serves only as a pre-demodulation stage to extract LLR residual sequences and does not alter the core mechanism of dual-channel mirror-image statistical testing. Coding schemes can be flexibly selected or even dynamically rotated according to the type of opportunity illuminator, improving the system's resistance to man-made deception and raising the adversary's difficulty in signal modelling and false-signal generation.

> **Reiteration:** this paper does not argue for directly building a deployable air-defense early-warning system; it presents a theoretical paradigm. From theoretical simulation to a practical system, there is a complete engineering chain that should be completed independently by other research teams with the necessary hardware and experimental conditions.

6.3 Differences from Conventional Polarimetric Radar

Conventional polarimetric radar focuses on solving the individual coefficients of the full polarimetric scattering matrix $\boldsymbol{S}$;

This paradigm, **rather than pursuing the precise solution of every element of the scattering matrix, only tests whether the dual-channel mirror statistical baseline is broken**. As long as the statistical distributions show a significant deviation, decision evidence for the presence of a target is given.

6.4 Engineering Directions Available to Subsequent Research Teams (Not Part of This Work)

If other groups follow up on this paradigm, they may pursue the following work:

- Adaptive calibration algorithms for dual-channel hardware inconsistency;
- Suppression algorithms for spurious symmetry breaking caused by sea-surface and meteorological clutter;
- Acquisition and principle validation based on HackRF-Pro / LimeSDR with a dual-polarization LNB;

- Fusion of decision results from multiple receiving stations and multiple satellite illuminators;
- Adaptation of the endian-reversal idea to the frame structures of actual LEO satellites.

> The above all belong to independent follow-up engineering research and are outside the research scope of this paper.

6.5 Engineering Feasibility and Applicability Boundary

Core algorithms: the polarization-code encoding/decoding modules, JS-divergence computation, and sliding-window fusion decision can be deployed on embedded/FPGA platforms.

Principle-validation hardware (for algorithm prototypes only):

- Dual-polarization satellite low-noise block downconverter (LNB);
- Commercial SDR receivers (HackRF-Pro / LimeSDR-Mini2, etc.);
- ARM/FPGA embedded processors.

> **Important:** this hardware configuration is used only for **principle acquisition and validation**, and does not constitute an early-warning system.

Applicable scenarios

✔ Effective: in-atmosphere aircraft, including stealth fighters, conventional fighters, cruise missiles, and UAVs;

✘ Not effective: ballistic missiles and near-space vehicles (beyond the effective satellite-signal coverage);

✔ Preferred deployment conditions: coastal mountains and islands, where the receiving site has elevation difference.

7 Conclusions

Aiming at the principle-level failure of existing passive detection systems against stealth targets, this paper proposes a new paradigm of coding symmetry-breaking detection.

5. It reveals a principle-level logical deadlock between the conventional energy-detection paradigm and stealth technology. A detection framework that relies on detecting energy shadows will be deliberately counteracted by stealth design; this limitation cannot be eliminated by engineering means such as hardware iteration and algorithm tuning alone, and requires a paradigm upgrade of the detection dimension;

6. It proposes H/V dual-channel endian-reversed mirror coding, constructing a coding-domain mirror-symmetry baseline under the no-target condition, and derives a sensitivity amplification effect whose gain is proportional to the coding length *N*; under $N = 64$, the sensitivity gain is about 18 dB;
7. It establishes a three-dimensional metric fusion decision framework combining JS divergence, mutual-information difference, and statistical-moment difference, transforming stealth-target detection into a hypothesis-testing problem of coding-domain symmetry breaking;
8. It validates at the theoretical level the advantages of the paradigm in detection sensitivity and anti-spoofing capability; it explains that principle validation can rely on commercial-grade components while clarifying the theoretical assumptions, applicability boundaries, and the gap between the theoretical paradigm and an operational engineering system.

The core value of this paradigm is to shift the detection object from scalar signal energy to the vectorial structural fingerprint of dual-channel coding and statistics. A stealth aircraft can lower its RCS and suppress echo energy, but it cannot completely eliminate the asymmetric perturbation between orthogonal polarization channels at the physical root; this provides a new theoretical path for passive anti-stealth detection.

> **Declaration:** this paper is the work of an independent researcher and does not represent any institution; it contains no classified parameters or engineering deployment details; all content is based on theoretical derivation from public electromagnetic theory and information-theoretic principles.

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