Asymmetric Source Field Model (ASFM): Residual-Interference Mechanism and Josephson Mapping with Spatially Varying Coupling

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Abstract

We develop the Asymmetric Source Field Model (ASFM) as an effective, symmetry-based description of matter-like residual fields arising from the interference of two coherent source components, denoted Ψ_M ("material") and Ψ_A ("auxiliary"). In the harmonic regime the spatial envelopes obey inhomogeneous Helmholtz equations with effective sources. The residual-interference energy density contains the phase-sensitive term $-\alpha(r)A_M(r)A_A(r)\cos\Delta\phi(r)$, where $\alpha(r)$ is a spatial coupling field. For weak links this maps to the Josephson form $E(\Delta\theta) = E_0 - K\cos\Delta\theta$ with $K \propto \int \alpha(r)A_L A_R\, d^3r$. A structured (possibly multifractal) $\alpha(r)$ produces non-sinusoidal current–phase relations and asymmetric Shapiro steps. We present a controlled route from a minimal effective action to Helmholtz envelopes, provide quantitative estimates for CPR harmonics, outline an experimental program to extract $\alpha(r)$, and discuss scope and limitations. A microscopic derivation of the effective action is deferred to future work.

1 Introduction

The central working hypothesis of ASFM is that a phase-coherent many-body medium can be represented by two slowly varying complex envelopes, $\Psi_M(r,t)$ and $\Psi_A(r,t)$, whose residual interference forms an effective "material" field. This paper develops a minimal and falsifiable formulation sufficient to connect the residual-interference term to Josephson weak-link physics, while keeping the full microscopic derivation for a dedicated follow-up.

2 Helmholtz-type envelope description

In the single-frequency regime with angular frequency ω we write $\Psi_X(r,t) = \Psi_X(r)e^{-i\omega t}$ for $X \in \{M, A\}$. At the level of envelopes the spatial structure is captured by inhomogeneous Helmholtz equations,

$$(\nabla^2 + k^2)\Psi_{M/A}(r) = S_{M/A}(r), \quad k = \frac{\omega}{c_{\text{eff}}}.$$

With the scalar Green function $G_k(R) = e^{ikR}/(4\pi R)$, $R = |r - r'|$, the fields read

$$\Psi_{M/A}(r) = \int G_k(r - r')S_{M/A}(r')\, d^3r'.$$

Point-like or strongly localized sources generate spherical-wave envelopes; boundary conditions in solid-state geometries select guided, bound, quasi-planar or evanescent modes.

3 Residual-interference energy density

Let $\Psi_{M/A} = A_{M/A}(r)e^{i\phi_{M/A}(r)}$. The phase difference is $\Delta\phi = \phi_M - \phi_A$. The residual-interference energy density takes the generic form

$$E_{\text{int}}(r) = -\alpha(r)A_M(r)A_A(r)\cos\Delta\phi(r),$$

where $\alpha(r)$ collects local mixing processes. Upon spatial coarse-graining Eq. (3) yields the weak-link coupling energy discussed below.

4 Josephson mapping for weak links

Consider left/right envelopes $\Psi_{L/R} = A_{L/R}e^{i\theta_{L/R}}$ with phase difference $\Delta\theta = \theta_L - \theta_R$ across a weak link. The overlap integral

$$K \propto \int \alpha(r)A_L(r)A_R(r)\,d^3r$$

leads to the Josephson coupling energy

$$E(\Delta\theta) = E_0 - K\cos\Delta\theta.$$

The corresponding current–phase relation (CPR) is

$$I_s(\Delta\theta) = \frac{2e}{\hbar}\frac{\partial E}{\partial\Delta\theta} = I_c\sin\Delta\theta, \quad I_c = \frac{2e}{\hbar}K.$$

Under a bias voltage $V(t)$ the phase obeys the AC Josephson relation

$$\frac{\hbar}{2e}\frac{d\Delta\theta}{dt} = V(t).$$

A washboard potential results if a DC bias force is included,

$$U(\Delta\theta) = -K\cos\Delta\theta - F\Delta\theta,$$

which underlies macroscopic quantum tunnelling in Josephson junctions.

4.1 Controlled harmonics from inhomogeneous $\alpha(r)$

Let $\alpha(r) = \bar{\alpha} + \delta\alpha(r)$ with $\langle\delta\alpha\rangle = 0$. For a short link the CPR admits

$$I_s(\Delta\theta) = \sum_{n\geq 1} I_n \sin(n\Delta\theta),$$

where, to leading order,

$$\frac{I_2}{I_1} \sim c_2\frac{\int \delta\alpha(r)A_LA_R\cos(2\phi(r))\,d^3r}{\int \bar{\alpha}A_LA_R\,d^3r}, \quad \frac{I_3}{I_1} \sim c_3\frac{\int[\delta\alpha(r)]^2A_LA_R\cos(3\phi(r))\,d^3r}{\int \bar{\alpha}A_LA_R\,d^3r}.$$

Here $\phi(r)$ captures local phase twists from geometry; $c_{2,3}$ are dimensionless geometry factors. Thus a structured or multifractal $\alpha(r)$ quantitatively enhances higher harmonics.

5 From a minimal effective action to Helmholtz envelopes

A coarse-grained, symmetry-allowed effective action for the two-component envelope reads

$$S_{\text{eff}} = \int dt\,d^3r\left[\sum_{X=M,A}\left(\frac{i\hbar}{2}(\Psi_X^*\partial_t\Psi_X - \Psi_X\partial_t\Psi_X^*) - \frac{\hbar^2}{2m_{\text{eff}}}|\nabla\Psi_X|^2 - V(r)|\Psi_X|^2\right) - g(r)(\Psi_M^*\Psi_A + \Psi_A^*\Psi_M)\right].$$

Variation with respect to Ψ_X^* at fixed frequency gives

$$-\frac{\hbar^2}{2m_{\text{eff}}}\nabla^2\Psi_X + V(r)\Psi_X - \hbar\omega\Psi_X - g(r)\Psi_{\bar{X}} = 0, \quad X\in\{M,A\},$$

which reduces to Eq. (1) in the envelope limit with sources $S_{M/A} \sim g(r)\Psi_{A/M}(r)$. Identifying

$$\alpha(r) = 2g(r)$$

connects the phenomenology of Eq. (3) to the action parameterization.

6 Fractal spherical-wave hierarchy: possible origins

A compact parametrization of multi-scale mode families is

$$k_j = k_0 2^j, \quad A_j = A_0 2^{-j} \quad (j = 0, 1, 2, \dots).$$

Such a hierarchy can emerge from (i) multi-scale interface roughness that cascades momenta, (ii) proximity to localization/percolation thresholds generating multifractal eigenmodes, or (iii) nonlinear self-organization balancing gradient energy and the mixing energy $-\alpha A_M A_A \cos \Delta\phi$. Each route implies distinct scaling exponents in nodal statistics and CPR harmonic roll-off.

7 Experimental program to extract $\alpha(r)$

Step 1: CPR spectroscopy. Measure $I_s(\Delta\theta)$ for controlled link families; fit $(I_2/I_1, I_3/I_1)$ via Eqs. (9)–(10).
Step 2: Shapiro asymmetry maps. Under RF at frequency f, record step heights and left–right asymmetries versus power; compare with simulations with skewed $\alpha(r)$.
Step 3: Imaging proxies. Map $A_{L/R}(r)$ (e.g., nano-SQUID, tunneling) and invert Eq. (4) with regularization to estimate α.
Step 4: Cross-geometry scaling. Verify collapse of I_n/I_1 across geometries when a single physical mechanism dominates α.

8 Scope, limitations, and outlook

The present work intentionally focuses on an effective, symmetry-led description that is directly testable in weak links. A material-specific microscopic derivation of S_{eff} and $g(r)$ is deferred to a dedicated paper. Extrapolations to atomic or nuclear scales remain a hypothesis outside the operational scope of the Josephson tests proposed here.

9 Extensions to Atomic Valence and Radioactive Decay (New Section from Fractal Interference Model)

Based on the fractal interference principles discussed in the complementary work on atomic valence [5], we extend the ASFM to atomic scales. The fractal interference model treats protons and neutrons as coherent sources of spherical harmonics, superposing matter and antimatter components to derive electron-equivalent interference nodes.

The residual field $\Psi_{\text{residual}}(r)$ emerges from the imbalance between constructive (proton) and destructive (neutron) contributions, encoding spatial and temporal coherence. Nodes in this field represent valence-relevant structural zones.

Through recursive phase ($\Delta\phi$) and amplitude (α) modulation, the model reproduces valence node counts across $Z = 1$–118. Benchmark elements like C ($Z = 6$, 4 nodes), O ($Z = 8$, 6 nodes), Ne ($Z = 10$, 8 nodes), and Na ($Z = 11$, 1 node) confirm the framework's predictive power.

This extension provides a continuous field-theoretic interpretation of electronic valence, with potential applications to isotopic behavior, decay paths, and quantum coherence, bridging the ASFM to atomic and nuclear phenomena.

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