Semantic Literary Dynamics Theory

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Abstract. Semantic Literary Dynamics Theory treats text as evolving semantic wavefields rather than as static communication strings. In this framework, meaning is represented by complex semantic phasors whose magnitudes express semantic intensity and whose phases express contextual alignment, allowing coherence, tone, rhetorical movement, and stylistic continuity which are modeled as measurable phase relations across discourse. Building on the spectral representation and operator calculus introduced in the earlier Semantic Phasor Theory papers, this treatment develops a quantitative account of literary flow and literary acceleration as the first and second derivatives of coherence and extends the idea through higher-order semantic operators that act on semantic change and curvature. The result is a unified paradigm that links literary criticism, cognitive modeling, signal processing, and potential AI transformer innovation within a single mathematical conception of meaning.

Keywords. *Semantic Phasor Theory; Semantic Literary Theory; spectral semantics; literary coherence; semantic flow; semantic acceleration; operator calculus; semantic curvature; rhetorical dynamics; complex-valued meaning representation.*

1. Introduction

Over the past century and a half, scholars have repeatedly tried to bring quantitative rigor to literary study. The historical arc runs from nineteenth-century stylometry and authorship attribution, through twentieth-century probabilistic analysis, and into the digital humanities, where literary corpora have been studied for large-scale patterns in genre, form, and historical development. Yet despite these advances, many quantitative approaches have remained descriptive or sociological rather than theoretical in the strong sense, because they offer methods for measurement without a unified mathematical account of meaning itself.[1]

Semantic Literary Dynamics Theory extends the author's earlier semantic phasor theory papers into literary analysis and argues that meaning in texts should be modeled not as a static property of isolated units but as an evolving field distributed across a semantic manifold.[2] In that field, literary effects such as coherence, cadence, tonal shift, rhetorical pressure, and stylistic identity emerge from structured relations of phase and magnitude across semantic modes rather than from isolated sentence-level features alone.

The author's earlier semantic phasor theory papers introduce an operator calculus composed of projection, filtering, and rotation operators that act on semantic configurations in a way structurally analogous to correlation, convolution, and modulation in classical signal processing. The present paper carries this formalism into literary theory and asks what happens when the same mathematics

is applied to discourse-level organization, coherence, voice, rhetorical pacing, and interpretive transformation.

The central intuition is straightforward but far-reaching. Literary criticism has long described texts as unified, fractured, lyrical, tense, ironic, resonant, or rhythmically propelled, but these descriptions usually remain metaphorical. Semantic Literary Dynamics Theory does not discard such language; instead, it attempts to ground it mathematically. Its claim is that many of these effects can be understood in terms of phase stability, interference, spectral concentration, derivative structure, and curvature within a semantic field.[3]

A central concept in what follows is coherence. In wave physics, coherence refers to the degree to which waves maintain a stable phase relationship over space or time. Semantic Literary Dynamics Theory imports this notion into semantics, not by claiming that language is literally a physical wave, but by arguing that if meaning is represented as a complex field, then the mathematics of phase stability, correlation, and interference becomes available for describing semantic connectedness. A text is coherent when its dominant semantic components maintain structured and intelligible phase relations across local and global scales; it is incoherent when those relations break down into destructive interference, instability, or fragmentation.[4]

The paper then moves beyond static coherence by introducing a hierarchy of semantic dynamics. If coherence is treated as a scalar quantity defined over textual progression, its first derivative naturally becomes flow and its second derivative naturally becomes acceleration. This produces a formal language for describing rhetorical movement, narrative quickening, conceptual pivot, emotional surge, and semantic inflection across genres. In this way, the theory aims not only to measure whether a text coheres, but to describe how coherence changes and how the trajectory of meaning bends over time.[5]

2. Quantitative Literary Dynamics Theory and the Problem of Meaning

Quantitative literary study has produced many useful methods, but it has often struggled to explain how meaning itself is organized within a text. Stylometry can identify formal regularities, corpus analysis can detect statistical tendencies, and literary history can reveal large-scale patterns in genre or period, yet none of these by itself provides a sufficiently rich mathematical object for representing semantic alignment, semantic fracture, or the movement of meaning through an extended discourse. The problem is therefore not simply one of missing data or computational weakness, but one of theoretical representation.[6]

Many current models of language represent meaning as symbolic content, vector similarity, or distributional association. These approaches can be useful, but they do not naturally distinguish semantic strength from semantic alignment, nor do they easily model interference, phase inversion, contextual reframing, or higher-order semantic motion. Literary texts repeatedly exhibit such phenomena. A sentence may be intelligible in isolation and yet function ironically inside a broader work; a repeated motif may preserve lexical identity while changing interpretive force; a narrative may maintain thematic continuity while shifting its tonal axis; and a philosophical argument may compress, pivot, and intensify in ways better understood as curvature than as simple addition of propositions.[7]

Semantic Literary Dynamics Theory is therefore framed as a deepening rather than a rejection of quantitative literary study. It preserves the ambition of formal rigor but shifts the center of attention from surface measurement to dynamic semantic organization. The theory asks how meaning is distributed across a field, how semantic components align or interfere, how those relations evolve, and what operators can describe their transformation. In that sense, it aims to provide literary analysis with a mathematical vocabulary adequate not merely to counting features but to describing the structure of meaning itself.

3. Semantic Phasor Representation

The foundational object of the theory focusses on the construct of a semantic phasor field, where a word, phrase, sentence, or discourse segment is represented as a complex-valued expression distributed across a semantic manifold. In its basic form, the field is written as follows:

$$\psi(x) = A(x)e^{i\phi(x)}$$

Here, $A(x)$ denotes semantic magnitude or semantic intensity, $\phi(x)$ denotes semantic phase or contextual orientation, and x indexes conceptual or structural coordinates such as tokens, roles, topics, or latent semantic dimensions. This form is critical because it separates two aspects of meaning that are often fused in ordinary representation: the strength with which semantic material is present, and the way that material is aligned relative to context.

Magnitude measures salience, emphasis, or semantic energy. A large magnitude may indicate that a concept, theme, tone, or affective register is strongly active in a region of discourse. Phase, by contrast, measures orientation within a semantic spectrum. Two passages may activate similar semantic content at comparable strength while differing dramatically in phase, thus producing irony, reversal, contradiction, tonal displacement, or contextual reframing. This inclusion of phase is what allows the model to move beyond simple lexical overlap or static embedding similarity.[8]

We have posited that semantic fields can be analyzed spectrally. This means that a semantic field may be expanded across eigenmodes or basis functions that reveal stable structural patterns in meaning. Literary works can therefore be treated not merely as a sequence of local units, but as a structured distribution of semantic energy across modes. Some works will concentrate energy in a narrow set of dominant modes, thereby producing strong thematic identity or stylistic recognizability, while others will distribute energy broadly, producing fragmentation, experimentation, or semantic diffusion.[9]

In this formulation, the semantic phasor is not a decorative metaphor. It is the formal object that makes possible the entire later development of the theory, including coherence, filtering, projection, derivative structure, curvature, and genre-specific literary application.

4. Coherence as a Phase-Based Property

Coherence is one of the most frequently invoked and least precisely defined concepts in literary and discourse analysis. It ordinarily names the sense that a text hangs together, develops intelligibly, or sustains meaningful connectedness across its parts. Semantic Literary Dynamics Theory retains that intuition but gives it a mathematical basis by borrowing the formal concept of coherence from wave physics.

In its technical origin, coherence concerns stable phase relations among complex waves. High coherence means that amplitude and phase remain correlated across points in space or time; low coherence means that the field is noisy, unstable, or weakly aligned. When translated into the present semantic setting, coherence becomes the stability and alignment of phase across a semantic manifold. The same phasor equation serves as the formal basis of this translation:

$$\psi(x) = A(x)e^{i\phi(x)}$$

In this setting, coherence rises when the phases $\phi(x)$ of dominant semantic contributions remain aligned or vary smoothly across textual progression. When adjacent units contribute energy in compatible directions, their phasors interfere constructively and produce an integrated pattern. When their phases drift abruptly or oppose each other without intelligible relation, interference becomes destructive and the text appears fragmented or unstable.

This framework does not reduce coherence to mere repetition or agreement. A complex work may remain highly coherent while sustaining contrast, ambiguity, irony, or tension, provided these are structurally integrated into a stable phase trajectory. Likewise, a passage may be semantically intense yet weakly coherent if its strongest components pull in incompatible directions without organized relation. The theory therefore distinguishes meaningful complexity from unstructured semantic noise.

Coherence has several scales: a local coherence, where neighboring units maintain stable phase relations; meso-level coherence, where scenes, paragraphs, or thematic clusters develop through recognizable transitions; and global coherence, where the work exhibits stable spectral concentration and a persistent semantic signature. This multi-level structure aligns naturally with the experience of reading, in which readers sense both immediate continuity and long-range unity.[10]

5. Phase, Magnitude, and Eigenmodes

Although coherence depends centrally on phase, we assert that phase is not the only relevant variable. Magnitude and eigenmode structure are also essential if the theory is to capture literary meaning at multiple scales. The relation among these three variables is one of the paper's core conceptual achievements.

Phase is the primary carrier of coherence in the strict wave-theoretic sense. Relative phase determines whether semantic components align constructively or destructively. Smooth variation of phase suggests continuity, measured development, and intelligible transition. Abrupt phase shifts suggest rupture, tonal fracture, irony, or dislocation. In this respect, phase is the most direct indicator of semantic connectedness.

Magnitude, however, determines where coherence matters most. A strong semantic component carries high salience or energy in a passage. If strong components are phase-aligned, they generate a pronounced semantic core; if they are strong but misaligned, they generate vivid conflict, instability, or rhetorical tension. Magnitude therefore modulates the interpretive weight and visibility of coherent and incoherent structures.

Eigenmodes introduce a global dimension. When semantic operators are applied and the relevant structures are diagonalized, the resulting eigenmodes reveal dominant patterns of semantic organization. Coherent texts tend to concentrate energy in a relatively small number of dominant modes, thereby yielding a low-dimensional and structured spectral signature. Incoherent or highly fragmented texts tend to spread energy diffusely across many modes without stable concentration. This gives the theory a mathematically grounded way of talking about unity, style, and long-range thematic organization.

6. Authorial Voice and Spectral Signature

Semantic Literary Dynamics treats authorial voice spectrally. In traditional criticism, voice often names an elusive but recognizable pattern of tone, stance, cadence, and semantic pressure. The theory does not attempt to dissolve that intuition; instead, it proposes a formal language for describing it.

A writer's voice can be understood as a relatively stable pattern in the way semantic energy and phase are distributed across modes over extended stretches of discourse. A measured, lyrical, or formally controlled writer may exhibit narrow spectral support combined with high phase coherence in selected semantic bands. A more experimental writer may disperse energy broadly, introduce abrupt phase rotations, or destabilize expected alignments in a controlled way. In both cases, voice is not merely a matter of vocabulary or syntax; it is a long-range structure in the geometry of semantic motion.

This perspective also clarifies why voice often survives paraphrase. The wording of a passage may change while a characteristic distribution of semantic phase and energy remains intact. Conversely, lexical similarity may fail to capture voice if the underlying spectral organization changes significantly. The theory therefore suggests that style analysis should be sensitive not only to which semantic materials appear, but to how they are phased, weighted, and distributed across the work's dominant modes.

7. Operator-Theoretic Tools for Literary Analysis

The operator calculus inherited from the earlier work in semantic phasor theory turns the current model from a descriptive proposal into an analytic framework. Implicitly we identify three principal operator families already established in the earlier theory: rotation operators, semantic filters, and projectors.[11] Each receives a natural literary interpretation.

Rotation operators alter phase while preserving magnitude. In literary terms, they model contextual shift, reframing, tonal inversion, change of stance, or reinterpretive realignment. Filters redistribute spectral energy across semantic modes. In literary terms, they model thematic emphasis, register control, narrowing to a conceptual core, or the foregrounding of emotional,

ethical, or technical dimensions. Projectors isolate analytically relevant subspaces. They make it possible to examine a text with respect to specific themes, roles, affective bands, or discourse functions without collapsing the work into a single scalar measure.

Taken together, these operators provide formal vocabulary for literary analysis. Instead of speaking impressionistically or subjectively of tonal shift, narrowing focus, or thematic isolation, criticism can describe these operations as mathematically objective tractable transformations within a semantic phasor field.

8. Rotation Operators as Contextual Shifts

Rotation deserves special attention because it offers one of the clearest bridges between the formal calculus and ordinary literary interpretation. In the phasor framework, rotation changes phase while leaving magnitude fixed. This means that semantic content may remain strongly present while its contextual alignment changes.

Such formalism proves especially useful for understanding irony, reframing, tonal inversion, or perspectival change. A phrase may carry nearly identical lexical material in two contexts while meaning something very different because its semantic phase has rotated. Political rhetoric often works by reorienting familiar terms into new ideological alignments, and literary repetition often works by returning to a motif whose semantic energy is preserved but whose phase is altered by narrative context.

The degree of rotation quantifies movement away from prior alignment. Small rotations may correspond to subtle modulation or tonal shading, while larger rotations may correspond to rupture, parody, contradiction, or reinterpretive shock. What criticism often perceives as a turn can therefore be modeled more precisely as measurable phase rotation in semantic space.

9. Semantic Filters and Selective Emphasis

Filters are equally important because literary texts rarely activate all semantic bands equally. Works suppress some dimensions, amplify others, and often guide interpretation by changing the relative weighting of thematic, affective, ethical, or conceptual content. Semantic filters provide a natural model for the selective redistribution of energy.

A filter can narrow a dense passage into its argumentative core, foreground emotional resonance over technical explanation, isolate ethical pressure within a descriptive field, or adapt discourse to a specific domain or audience. These operations do not necessarily change the semantic inventory of a passage; rather, they change the spectral weighting of what is already present. That shift in weighting changes perceived significance and interpretive force.

Filters also help explain longer trajectories in texts. Literary works may begin with broad spectral distribution and gradually narrow toward a climax, or it may expand from a sharply focused premise into wider thematic diffusion. Filtering therefore contributes both to local interpretive emphasis and to global formal development.

10. Projectors as Analytic Probes

Projectors make the theory particularly powerful for criticism and computation because they allow a high-dimensional semantic field to be inspected without flattening. A projector extracts the portion of a semantic field lying within a chosen subspace. That subspace may correspond to theme, role, viewpoint, affective charge, discourse function, or any other semantically defined band.

The advantage of projection is that it allows multiple semantic dimensions to be studied in parallel. A critic may project onto thematic, ethical, and emotional subspaces and compare their magnitudes, phases, and derivative behavior across the course of a text. This makes it possible to examine overlap and divergence among semantic layers without reducing the work to one dominant interpretation.

Projectors thus operate as analytic probes into a complex semantic field. They are especially important for future computational implementation, because they make the model inspectable and provide a pathway toward interpretable semantic analysis rather than opaque vector manipulation.

11. The Algebra for Quantifying Literary Coherence

Our thesis rests on the developing a formal path for quantifying literary coherence by drawing on the signal-processing notion of magnitude-squared coherence. Let us map a semantic phasor signal, $\psi(t)$ i.e., the mathematical representation of a sentence, paragraph, or discourse in a form as follows:

$$\psi(t) = A(t)e^{i\phi(t)}$$

Here t indexes textual position, $A(t)$ denotes semantic magnitude, and $\phi(t)$ denotes semantic phase. One may then compare two related semantic signals, such as local and global representations, or two segments of the same discourse as:

The cross-spectral density as defined by:

$$S_{12}(\omega) = \mathbb{E}[\Psi_1(\omega)\Psi_2\tilde{}(\omega)]$$

Where the auto-spectra defined by:

$$S_{11}(\omega) = \mathbb{E}[|\Psi_1(\omega)|^2], S_{22}(\omega) = \mathbb{E}[|\Psi_2(\omega)|^2]$$

Given the above, magnitude-squared coherence is then given by:

$$\gamma_{12}^2(\omega) = \frac{|S_{12}(\omega)|^2}{S_{11}(\omega)S_{22}(\omega)}$$

Finally, a literary coherence score may be defined by integrating across semantic frequencies or modes with an appropriate weighting function:

$$\mathcal{C} = \int W(\omega)\gamma_{12}^2(\omega)d\omega$$

This scalar $\mathcal{C}$ summarizes how strongly local semantic structures lock into broader discourse-level organization. High values indicate strong semantic alignment, while low values indicate fragmentation or weak integration. The weighting function keeps the model interpretively flexible by allowing some frequencies or semantic bands to matter more than others depending on the analytic purpose.

12. Coherence as a Differentiable Field

Once coherence has been formalized as a measurable scalar, the next step is to treat it as a function over textual progression. This is a crucial move, because it transforms coherence from a static evaluation into a dynamical field. If $C(x)$ denotes coherence as a function of textual position x, then the theory can examine not only whether a text is coherent but how its coherence changes and with what degree of curvature.

The significance of this step places literary analysis within the same formal universe as dynamical systems, where rates of change and higher-order structure matter as much as values themselves. A text may be locally coherent yet dynamically stagnant, globally coherent but locally volatile, or globally unstable while exhibiting strong local pockets of alignment. These distinctions require a theory of change, not just a theory of state.

We therefore next prepare the groundwork for flow and acceleration by asserting that once coherence is treated as a smooth continuous quantity on a semantic manifold, its derivatives acquires direct mathematical meaning. That move is not an ornamental analogy imported from physics; it is the ordinary logic of differentiable fields applied to semantics.

13. Literary Flow as the First Derivative of Coherence

Within this framework, literary flow is defined as the first derivative of coherence with respect to textual position. The formal expression is:

$$F(x) = \frac{dC}{dx}$$

This quantity measures how rapidly semantic alignment strengthens or weakens as discourse unfolds. In mathematical language, it is the rate of change of coherence; in literary language, it models rhetorical movement, pacing, or semantic glide.

When $F(x)$ is small, the text evolves gradually. Transitions feel smooth, tonal shifts are measured, and the reader experiences continuity rather than jolt. When $F(x)$ is large, the discourse is changing quickly. A speech may gather force, a philosophical argument may tighten rapidly, or a narrative may suddenly reorient its movement. When $F(x)$ changes sign, the text may be pivoting, reversing, or moving into a new semantic region altogether.

This formalization is valuable because it translates long-standing critical descriptions of pacing and movement into a mathematically grounded quantity. Flow is not an added metaphor; it is the natural first derivative of coherence once coherence itself has been formalized as a field.

14. Literary Acceleration as the Second Derivative of Coherence

The theory extends naturally to second order. If flow is the first derivative of coherence, then semantic or literary acceleration is the second derivative:

$$A(x) = \frac{d^2C}{dx^2}$$

This quantity measures how rapidly the rate of change coherence itself is changing. In literary terms, it captures inflection, surge, compounding motion, and semantic curvature.

We argue that this second-order quantity is indispensable because many strong reading experiences are experiences not merely of change, but of accelerating change. A speech may become more urgent, a narrative may turn with force rather than drift, a poem may thicken in resonance, and an argument may leap from exposition into indictment. These are better modeled by acceleration than by coherence or flow alone.

The source material makes a useful analogy to mechanics. Coherence corresponds to position, flow to velocity, and semantic acceleration to force or curvature acting on the semantic field. The analogy is structural rather than literal, but it clarifies why acceleration matters: readers do not only perceive semantic location and motion, but also the bend, pressure, and quickening of that motion.

15. Why Higher-Order Dynamics Matter

We assert that higher-order dynamics are not optional refinements but necessary tools for a serious mathematics of literary movement. Coherence alone cannot distinguish among a stable text, an intensifying text, a loosening text, or a text about to rupture. Flow adds the rate of change, but acceleration adds the curvature of that change, which is often what readers feel as urgency or turn.

This becomes especially important across genres. In speeches, acceleration can mark crescendos, emotional surges, and shifts in moral or political framing. In screenplays, it can identify turning points, pacing inflections, and scene-to-scene tension arcs. In philosophical prose, it can reveal conceptual leaps and intensifications of claim. In lyrical writing, it can model semantic meter, oscillation, and resonance.

These applications matter because literary theory has long possessed a rich descriptive vocabulary for movement but has rarely tied that vocabulary to explicit mathematics. This theory proposes that at least some of those effects can be formalized through derivatives of coherence without thereby reducing literature to simplistic metrics.

16. Spectral Rhythm and Semantic Meter

One of the more suggestive developments in the source text is the idea that derivative structure can reveal rhythm-like behavior in literary language. If coherence oscillates through a text, then its derivative reveals a pattern of rise and fall, approach and release, intensification and relaxation. This makes it possible to speak of spectral rhythm.

In lyrical forms, readers often experience a passage as moving musically even when no strict metrical scheme is present. We refer to this as cadence, where this theory interprets that experience in terms of evolving phase relations among semantic components. Coherence may be compared to harmonic stability, while flow resembles voice leading or harmonic motion. The comparison is not meant to collapse literature into music, but to note that both domains can exhibit mathematically analogous structures of alignment, transition, and recurrence.

This opens an intriguing path for future analysis. cadence, resonance, return, and lyrical propulsion may be studied not only as surface prosody, but as deeper semantic dynamics distributed across a spectral field.

17. Local Operators: Adjacent Unit Dynamics

The appendix extends the theory by introducing local operators that measure how coherence changes between neighboring textual units. These units may be sentences, clauses, beats, or shots depending on genre and analytic scale. The local flow operator is written as:

$$\mathcal{D}_1 C(x) = C(x + \Delta x) - C(x)$$

The local acceleration operator is written as:

$$\mathcal{D}_2 C(x) = C(x + \Delta x) - 2C(x) + C(x - \Delta x)$$

These are finite-difference approximations to velocity and curvature. They are especially useful for modeling micro-pivots in argument, beat-level emotional shifts, scene-to-scene tension changes, and rhetorical transitions that emerge from adjacency rather than from long-range trajectory alone.

18. Global Operators: Curvature of Extended Semantic Trajectories

Our approach has been to complement these local operators with global operators that treat the text as a continuous semantic curve. These are written as:

$$\mathcal{F}[C] = \frac{dC}{dx}, \mathcal{A}[C] = \frac{d^2C}{dx^2}$$

Global operators reveal long-range thematic arcs, narrative acceleration toward a climax, philosophical inflection, and rhetorical crescendo. They are the proper tools when the question concerns the overall shape of a discourse rather than only its immediate steps.

The distinction between local and global derivative operators parallels important distinctions in literary reading. Some effects are felt from one sentence to the next, while others only become visible when the work is viewed as an extended path through semantic space. A complete theory requires both scales.

19. Differential Operators on Semantic Phasor Fields

The theory does not stop with differentiating the scalar coherence function. It also extends differential structure to the semantic phasor field itself. If the field is written as $\Psi(x) = A(x)\, e^{i\phi(x)}$, then the first- and second-order semantic differential operators are introduced as follows:

$$\hat{D}_1 = \frac{d}{dx},\ \hat{D}_2 = \frac{d^2}{dx^2}$$

Applied to the phasor field, $\hat{D}_1$ measures phase velocity and amplitude velocity, while $\hat{D}_2$ measures curvature of phase and curvature of amplitude. This is important because literary change may arise through changing intensity, changing alignment, or their interaction. Meaning does not simply sit at a point in semantic space; it moves, bends, and interferes over time.

20. Hessian Structure and Second-Order Semantic Geometry

A major extension in the appendix concerns the Hessian, which introduces second-order geometry on a multidimensional semantic manifold. In standard mathematical form, the Hessian of a scalar function is given by:

$$H_{ij} = \frac{\partial^2 f}{\partial x_i \partial x_j}$$

This matrix collects all second-order partial derivatives and therefore describes how a function bends, twists, or changes shape across several dimensions. In the present theory, the same idea is carried into semantics. The Hessian becomes a way of describing the curvature of meaning across a conceptual manifold.

This gives the theory a genuine geometric extension. Meaning is no longer only a distribution of spectral energy with phase structure; it also occupies a landscape with curvature, basins, ridges, and saddle points. Such geometry matters because semantic systems exhibit stability, instability, ambiguity, and direction-dependent change.

We emphasize four implications of the Hessian. First, it measures the sensitivity of meaning to conceptual perturbation. Second, it identifies semantic basins or attractors and unstable regions. Third, off-diagonal terms measure coupling between semantic axes. Fourth, spectral diagonalization yields principal curvatures and principal semantic directions.

21. Semantic Gradient and Hessian of a Phasor Field

Let a semantic state be represented as a complex field on a semantic manifold $\mathcal{M}$. We write this as:

$$\psi: \mathcal{M} \to \mathbb{C}, \psi(x) \in \mathcal{H}$$

The semantic gradient and Hessian of ψ are then defined by:

$$\nabla\psi(x) = \begin{bmatrix} \frac{\partial\psi}{\partial x_1} \\ \vdots \\ \frac{\partial\psi}{\partial x_n} \end{bmatrix}, H_\psi(x) = \left[\frac{\partial^2\psi}{\partial x_i \partial x_j}(x)\right]_{i,j=1}^{n}$$

This extends the earlier spectral calculus into a curvature-sensitive operator framework. A second-order semantic operator can then be introduced as:

$$\hat{(H\psi f)}(x) = \sum_{i,j} h_{ij}(x) \frac{\partial^2 f}{\partial x_i \partial x_j}(x)$$

The coefficient functions $h_{ij}(x)$ are derived from the Hessian of the field and may encode its real, imaginary, or spectrally projected structure. This curvature operator joins projection, filtering, and rotation as part of a broader semantic calculus.

22. Semantic Curvature Tensor

To make this geometry explicit, the source text introduces a semantic potential $V(x)$ associated with a meaning configuration. The semantic curvature tensor is then defined by:

$$\mathcal{K}_{ij}(x) = \nabla_i \nabla_j V(x)$$

This is a $(0,2)$ tensor field on the semantic manifold. It measures the local curvature of the semantic landscape and can therefore distinguish stable, unstable, and mixed-sign regions of meaning.

A corresponding curvature operator on semantic phasor fields is defined as:

$$(\hat{\mathcal{K}}\psi)(x) = \sum_{i,j} \mathcal{K}_{ij}\,(x)\nabla_i\nabla_j\psi(x)$$

The eigenvalues of $\mathcal{K}(x)$ yield principal curvatures of the semantic landscape, while the eigenvectors yield principal semantic directions. Positive curvature corresponds to locally stable semantic basins or attractors, negative curvature corresponds to unstable or repulsive regions, and mixed signs correspond to saddle-like zones naturally associated with ambiguity or polysemy.

23. Amplitude-Phase Decomposition of Curvature

Our approach is to follow the path where if the phasor field is written in amplitude-phase form, its Hessian can be decomposed into contributions from amplitude curvature, phase curvature, and mixed interaction terms. In schematic form, the decomposition is written as:

$$H_\psi(x) = e^{i\phi(x)}(H_A(x) + i(\nabla A(x)\nabla\phi(x)^\top + \nabla\phi(x)\nabla A(x)^\top) - A(x)\nabla\phi(x)\nabla\phi(x)^\top + iA(x)H_\phi(x))$$

This decomposition is conceptually important because it shows that semantic curvature can arise in several distinct ways. Meaning may bend because semantic intensity is concentrating or diffusing, because phase alignment is curving, or because changes in magnitude and phase are coupled together anisotropically. Many literary effects likely arise through such mixed interactions rather than from a single isolated source.

24. Worked Example: Two-Dimensional Semantic Basin

To anchor the formalism, the appendix provides concrete two-dimensional examples. Let the semantic manifold be $\mathbb{R}^2$ with coordinates (x_1, x_2), and define the semantic potential by:

$$V(x_1, x_2) = \frac{1}{2}(\alpha x_1^2 + \beta x_2^2), \alpha, \beta > 0$$

Then the resulting curvature tensor is:

$$\mathcal{K}(x) = \begin{bmatrix} \alpha & 0 \\ 0 & \beta \end{bmatrix}$$

Its eigenvalues are $\lambda_1 = \alpha$ and $\lambda_2 = \beta$, and the corresponding eigenvectors are the standard coordinate directions. This means that the origin is a stable semantic attractor and that the sharpness of the semantic basin along each axis is governed by the size of α and β. The associated curvature operator may be written as:

$$(\hat{\mathcal{K}}\psi)(x_1, x_2) = \alpha\frac{\partial^2\psi}{\partial x_1^2}(x_1, x_2) + \beta\frac{\partial^2\psi}{\partial x_2^2}(x_1, x_2)$$

This example models a stable semantic basin in which a phasor field is more tightly confined along directions of higher curvature.

25. Worked Example: Two-Dimensional Semantic Saddle

The second example models ambiguity through a saddle geometry. Again let $\mathcal{M} = \mathbb{R}^2$, but define the semantic potential by:

$$V(x_1, x_2) = \frac{1}{2}(\alpha x_1^2 - \beta x_2^2), \alpha, \beta > 0$$

The corresponding curvature tensor becomes:

$$\mathcal{K}(x) = \begin{bmatrix} \alpha & 0 \\ 0 & -\beta \end{bmatrix}$$

Here one eigenvalue is positive and the other negative. The origin is therefore a saddle point: stable along one conceptual direction and unstable along another. The associated curvature operator is:

$$(\hat{\mathcal{K}}\psi)(x_1, x_2) = \alpha \frac{\partial^2 \psi}{\partial x_1^2}(x_1, x_2) - \beta \frac{\partial^2 \psi}{\partial x_2^2}(x_1, x_2)$$

We interpret this as a natural model for semantic ambiguity or polysemy. Perturbations along one axis stabilize meaning, while perturbations along the other destabilize it. This provides a geometrically precise way to discuss context-dependent semantic resolution.

26. Genre Applications

We emphasize that the framework is not confined to one literary form. Because coherence, flow, and acceleration are treated as abstract properties of semantic organization rather than genre-specific conventions, they can be applied across speeches, screenplays, argumentative prose, philosophy, poetry, and lyrical writing.

In speeches and persuasive arguments, acceleration identifies crescendos, emotional surges, rhetorical pivots, and shifts in advocacy or political framing. In screenplays and narrative writing, it maps turning points, tension arcs, emotional beats, and pacing curvature. In argumentative and philosophical prose, it reveals conceptual leaps, transitions from exposition to indictment, and the intensification of claims. In poetry and lyrical prose, it becomes a model for semantic meter, oscillatory curvature, and phase-driven emotional resonance.

This breadth matters because it suggests that the theory is not tied to one literary school or one corpus-specific application. Rather, it aims to provide a general mathematics of textual movement that can accommodate diverse forms while preserving their differences.

27. Semantic Literary Dynamics as a Foundation for Transformer Innovation

Semantic Literary Dynamics proposes that literary meaning is not a static property of text, but a continuously evolving field characterized by coherence, flow, curvature, and higher-order semantic motion. By modeling discourse as a phasor-based signal—complete with amplitude, phase, and spectral structure—the theory reframes meaning as a trajectory through a multidimensional semantic manifold. This perspective opens a path toward computational systems that do more than encode local lexical associations; it encourages architectures capable of tracking how meaning bends, accelerates, stabilizes, or destabilizes across the span of a narrative. In this view, literary interpretation becomes a problem of modeling semantic dynamics rather than merely semantic content.

Because the theory formalizes meaning as a differentiable field with measurable curvature and coherence structure, it suggests new directions for transformer-based technologies. Current models excel at capturing contextual embeddings but have no explicit representation of semantic flow, phase alignment, or second-order curvature. Semantic Literary Dynamics points toward architectures that incorporate derivative-aware representations, spectral operators, or curvature-sensitive attention mechanisms—allowing models to track not only *what* a text means at each moment, but *how* that meaning moves. Such innovations could enable transformers to recognize thematic arcs, detect narrative inflection points, model rhetorical acceleration, and represent long-range semantic structure with greater fidelity. In this sense, the theory does not merely interpret literature; it outlines a conceptual blueprint for the next generation of meaning-aware language models.

28. Analogy to Optimization Theory

We draw a structural analogy between literary dynamics and optimization theory. For example, in gradient descent, a system follows the first derivative of a loss function, while second-order information captures curvature of the loss landscape. Semantic Literary Dynamics Theory maps this pattern onto textual development. The structural correspondence is as follows:

- Coherence corresponds to semantic position.
- Flow corresponds to semantic gradient.
- Acceleration corresponds to semantic curvature.
- Attractors correspond to thematic or narrative endpoints.
- The semantic landscape functions analogously to a potential or loss surface.

This analogy is not meant literally, but it is analytically suggestive. Both texts and optimization processes involve trajectories through high-dimensional spaces, first-order motion, second-order

curvature, and movement toward structured endpoints. The analogy therefore helps explain why semantic acceleration may be thought of as Hessian-like in literary space.

29. Conclusion

Semantic Literary Dynamics Theory offers a framework in which literary criticism, cognitive modeling, signal processing, and machine reasoning are brought under a shared formal language centered on phasors, operators, derivatives, and semantic geometry. This is unusual because most theories remain confined to either humanistic interpretation or computational technique, whereas we claim it bridges both.

Its ambition is also methodological. The theory does not merely propose one new metric or one new model architecture. It proposes a different way of thinking about meaning as a structured, evolving, phase-sensitive field whose organization is spectral and whose development is geometric. That shift has implications for close reading, quantitative criticism, semantic representation, and future computational design.

Semantic Literary Dynamics Theory proposes that text can be understood as evolving semantic wavefields whose structure is governed by phase, magnitude, spectral concentration, and operator-based transformation. By extending the theory into literary analysis, it offers a formal account of coherence as phase alignment, reinterprets rhetorical and narrative movement in terms of flow and acceleration, and enlarges the original operator calculus through higher-order differential and curvature operators.

The theory's strongest claim is that features long described metaphorically in literary discourse—unity, cadence, resonance, rupture, movement, voice, and turn—may be reformulated as measurable properties of structured phase relations in semantic space. Whether taken as a literary theory, a semantic formalism, or a speculative bridge to transformer innovation, we propose a coherent mathematical program for understanding meaning as evolving geometry.

Appendix: Worked Example – "October"

This appendix uses the prose fragment "October" as a concrete test case, illustrating an operation applying the theory to coherence, flow, acceleration, and phase dynamics, on a simple semantic manifold, without the added Hessian treatment.

1. Text and segmentation

Source paragraph:

"Come late October, a chill descends upon the hour I watch the sun drop behind the western peaks. I'm reminded that even at this elevation the world around me came from the depths of a cold ocean millions of years ago, perhaps for no other reason but for sea life to ogle the sizzling sunrises, muted sunsets, the star-filled nights. I'm sure when life has a choice it chooses to live

where it can embrace the calm that blankets places like this, where the mind contemplates the eternity passed, the eternity ahead, and lets the hand record its lasting impressions.

It's between the eternities of what was and what's to come that we materialize from nothingness to a being that joins Nature in all its vibrancy, left to marvel, to wonder, to acquire knowledge, find truth, discover our essence, and for some attain wisdom, that ineffable insight that emerges from the harvest of the whole. I left home in my mid-teens embarking on an odyssey, traveling throughout the U.S. and a goodly part of the world, where I encountered challenges, obstacles and choices. In coming full circle, life has taught me that when in doubt, listen to your heart.

During my decades-long wandering I have bedded down in many places, done countless jobs, some memorable, some forgotten. I've loved hard, hated hard, laughed and cried hard. I've met folks bent by life. I too have been bent by life, its storms, long winters and fires, real and figurative. I've often hungered for the wrong things, exposing in me the blemish of cowardice or the occasional potency of pluck, and in either case often bordering on recklessness, as I fought my demons. I've been afraid of tomorrow when I knew it wouldn't come for someone I loved. I've held new life close to my heart and buried the dead with whom I shared my soul."

For analysis, the process begins by segmenting the paragraph into three macro-units, which are determined by shifts in experiential frame and discourse function. This satisfies computational implementation of the phasor-based framework, as the text must be discretized into analyzable units and mapped into a semantic feature space. This does not require committing to any particular notion of a "token": words, lemmas, phrases, or clauses can all serve as sampling points of the evolving semantic field, depending on the granularity appropriate to the analysis. Likewise, the semantic vectors associated with these units need not be drawn from standard distributional embeddings such as word2vec or GloVe. Any representational scheme—hand-crafted feature bundles, transformer-based encodings, or a bespoke semantic space aligned with the theory's primitives—can serve as the coordinate system in which phasor amplitude, phase, coherence, and curvature are computed. When quantitative measures are desired for larger macro-units such as U_1–U_3, these token-level representations are aggregated into centroids, covariance structures, or spectral summaries, but the theory itself remains agnostic about the specific embedding technology used.

Within this computational framing, tokens can be treated as discrete observations of an underlying semantic signal, analogous to samples drawn from a continuous waveform. Each token captures a local configuration of meaning, and sequences of tokens trace the trajectory of the discourse through semantic space. Unlike physical sampling, however, the semantic signal is not metrically fixed or band-limited; segmentation and representation choices actively shape the signal being analyzed. Nevertheless, the analogy is productive: macro-units such as U_1, U_2, and U_3 below function as windows over which integrals, spectral densities, coherence measures, or curvature operators can be computed. A practical workflow therefore begins by defining a semantic feature space aligned with the theory's conceptual axes, encoding each token or clause into that space, and then deriving aggregated quantities—semantic energy, directional curvature, principal axes, or coherence gradients—that can be interpreted back into literary-theoretic terms.

1. Segmentation

- Unit 1 (U_1): Cosmic / natural frame
  "Come late October a chill descends … lets the hand record its lasting impressions." Connotes outer, cosmological/natural frame, observational and contemplative, grounding the "world" and the writing self.

- Unit 2 (U_2): Emergence and life-odyssey
  "It's between the eternities … when in doubt, listen to your heart." Connotes metaphysical emergence plus life-odyssey, bridging cosmic frame and individual biography; high density of teleological and axiological predicates (purpose, truth, essence, wisdom).

- Unit 3 (U_3): Trials, love, and loss
  "During my decades-long wandering … buried the dead with whom I shared my soul." Connotes concrete experiential inventory of trials, relationships, losses, with strong affective and episodic content.

Semantic segmentation is driven formally by segmentation is driven by changes in: Deictic center (from world/landscape → metaphysical between-eternities self → concrete autobiographical "I"); Dominant process type (descriptive/existential → evaluative/gnomic → narrative/episodic) and Thematic role of "I" (observer and scribe → emerging agent seeking meaning → sufferer/lover/actor in specific events).

Intuitively and specifically in this case results in:

- U_1: contemplative, cosmological, high alignment with "eternity + nature + reflection."
- U_2: bridge between eternity and biography, strong thematic integration.
- U_3: biographical intensity, still anchored in the earlier frame but more turbulent.

So the separation into U_1–U_3 is grounded in systematic shifts in semantic role configuration and aspectual/temporal profile, not just superficial paragraph breaks.[

2. A simple semantic phasor model

We model a low-dimensional semantic manifold with two axes:

- Axis N: Nature–Cosmos
- Axis B: Personal–Biographical

Each unit is represented by a semantic phasor

$$\psi_k = A_k e^{i\varphi_k}$$

where

- $A_k \geq 0$ is semantic intensity (magnitude),
- φ_k is phase (orientation) in the N–B plane,
- index $k \in \{1,2,3\}$ labels U_1, U_2, U_3.

We also introduce a global "theme" phasor representing the overall discourse:

$$\Psi\_global = 1.0\ e^{i60^\circ}$$

This reflects a balanced but slightly "biographical-tilted" cosmic meditation: nature and eternity framing a life story.

For a toy numerical example, choose:

U_1 (cosmic, less biographical):

$$\psi_1 = 0.9\ e^{i30^\circ}$$

U_2 (bridge, maximally aligned with the theme):

$$\psi_2 = 1.0\ e^{i60^\circ}$$

U_3 (biographical, intense, slightly beyond the global tilt):

$$\psi_3 = 1.1\ e^{i80^\circ}$$

Here Phase φ_k encodes the relative mix of N vs. B and Amplitude A_k encodes semantic energy or intensity i.e., the strength of the unit in the global discourse.

These values are illustrative, not fitted; they are chosen to mirror the intuitive reading: U_1 is more cosmic than personal, U_2 aligns strongly with the overall theme, U_3 leans farther into biographical experience while remaining close in direction.

3. Local with respect to global coherence

In the main theory, coherence is defined spectrally via cross- and auto-spectra and magnitude-squared coherence.[12] For two signals with spectra $\Psi_1(\omega)$, $\Psi_2(\omega)$:

$$S_{12}(\omega) = E[\ \Psi_1(\omega) \cdot \overline{\Psi_2}(\omega)]$$

$S_{11}(\omega) = E[\,|\Psi_1(\omega)|^2], \quad S_{22}(\omega) = E[\,|\Psi_2(\omega)|^2]$

$\gamma_{12}^2(\omega) = |S_{12}(\omega)|^2 \,/\, (\, S_{11}(\omega) \cdot S_{22}(\omega)\,)$

A scalar coherence is then obtained by weighting and integrating:

$C = \int W(\omega) \cdot \gamma_{12}^2(\omega)\, d\omega$

where:

- $S_{12}(\omega)$ is cross-spectral density between two semantic signals,
- $S_{11}(\omega)$, $S_{22}(\omega)$ are auto-spectra,
- $W(\omega)$ is a weighting function over modes.

For a compact appendix example, we approximate coherence between a local unit ψ_k and the global theme Ψ_global by phasor alignment in the N–B plane:

$C_k \approx A_k \cdot \cos(\, \varphi_k - \varphi\_global\,)$

This approximation captures two core factors:

- amplitude A_k (how strong the unit is),
- angular alignment $\cos(\varphi_k - \varphi\_global)$ (how well its direction matches the global theme).

Using the toy values with φ_global = 60° and the illustrative values above:

- U_1:

  $\Delta\varphi_1 = 30° - 60° = -30°$
  $C_1 \approx 0.9 \cdot \cos(30°) \approx 0.9 \cdot 0.866 \approx 0.78$

- U_2:

  $\Delta\varphi_2 = 60° - 60° = 0°$
  $C_2 \approx 1.0 \cdot \cos(0°) = 1.0$

- U_3:

  $\Delta\varphi_3 = 80° - 60° = 20°$
  $C_3 \approx 1.1 \cdot \cos\,(20°) \approx 1.1 \cdot 0.94 \approx 1.03$

Thus, as a discrete coherence field over textual position $x \in \{1,2,3\}$:

$C(1) \approx 0.78$
$C(2) \approx 1.00$
$C(3) \approx 1.03$

This aligns with the phenomenology of the paragraph:

- U_1 is coherent but slightly "off-axis" compared to the main life lesson.
- U_2 tightens into the thematic center ("when in doubt, listen to your heart").
- U_3 further intensifies biographically while remaining strongly aligned.

4. Discrete flow and acceleration

In the body of the paper, literary flow is defined as the first derivative of coherence with respect to textual position:

$$F(x) = \frac{dC}{dx}$$

and literary acceleration as the second derivative:

$$A(x) = \frac{d^2C}{dx^2}$$

In a discrete setting with macro-units, we approximate derivatives by finite differences.

Let $\Delta x = 1$ unit between U_1, U_2, U_3. Define:

$D_1C(x) = C(x + 1) – C(x)$
$D_2C(x) = C(x + 1) – 2\ C(x) + C(x – 1)$

4.1 Flow (first difference)

Between U_1 and U_2:

$D_1C(1) = C(2) – C(1) \approx 1.00 – 0.78 = 0.22$

Between U_2 and U_3:

$D_1C(2) = C(3) – C(2) \approx 1.03 – 1.00 = 0.03$

Interpretation:

- $U_1 \rightarrow U_2$: flow is strongly positive (≈ 0.22). Coherence rises sharply as the text moves from a largely cosmic reflection into a fully integrated, life-philosophical assertion ("listen to your heart"). This is the major tightening of the discourse.
-
- $U_2 \rightarrow U_3$: flow remains positive but small (≈ 0.03). Coherence still increases, but much more gently. The text deepens and particularizes the established theme rather than pivoting away from it.

4.2 Acceleration (second difference)

We can compute a discrete acceleration centered at U_2:

$D_2\, C(2) = C(3) - 2\, C(2) + C(1)$

Numerically:

$D_2\, C(2) \approx 1.03 - 2(1.00) + 0.78$
$D_2\, C(2) \approx 1.03 - 2.00 + 0.78$
$D_2\, C(2) \approx -0.19$

Interpretation:

Flow is large into U_2 and small into U_3.

- The first difference $D_1\, C$ is large between U_1 and U_2 and small between U_2 and U_3.

The negative second difference at $x = 2$, $D_2\, C(2) \approx -0.19$ indicates that the rate of coherence increase is slowing as we move past U_2. The main semantic "turn" occurs in U_2; U_3 continues along the same trajectory but with less curvature.

This matches the general claim that semantic acceleration captures inflection, surge, and curvature in the coherence field: the surge is into the heart-guided life lesson; after that, the curve flattens.

In narrative terms:

- $U_1 \rightarrow U_2$ is the main semantic turn: coherence accelerates into the heart-guided life lesson.
- By the time we reach U_3, the "speed" of tightening has diminished; the text continues in the same direction but with less curvature. The trajectory has entered a kind of thematic cruise rather than further steepening.

This matches the theoretical claim that semantic acceleration captures inflection, surge, compounding motion, and curvature in the coherence field.

5. Phase dynamics and spectral rhythm

The paper notes that if coherence oscillates through a text, its derivative structure reveals a pattern of rise and fall, approach and release, intensification and relaxation—a spectral rhythm.

In this example, the phases of the local unit phasors evolve as:

$\varphi_1 = 30° \rightarrow \varphi_2 = 60° \rightarrow \varphi_3 = 80°$

Relative to the global phase φ global = 60°:

From $U_1 \rightarrow U_2$: phase rotates or shifts from 30° to 60°. This is a substantial rotation toward the global thematic direction. Semantically, the text moves from an introductory cosmic observation toward a statement that fully aligns "eternity" with biographical meaning and moral insight fuses "when in doubt, listen to your heart."

From $U_2 \rightarrow U_3$: phase shifts from 60° to 80°. The discourse tilts further into personal biography—love, loss, fear of tomorrow—while remaining close in phase to the global theme.

We can summarize the phase movement qualitatively:

- Large corrective rotation into U_2 (strong realignment; the paragraph "locks in" to its central thesis).
- Smaller additional rotation into U_3 (deepening the personal stakes without breaking coherence).

If we were to approximate phase velocity and phase acceleration with finite differences on $\varphi(x)$, we would see:

- High phase velocity into U_2, reflecting a strong reorientation.
- Reduced phase velocity into U_3, consistent with continued deepening rather than a new turn along the established direction rather than a new turn. Phase curvature changes sign as the main turn gives way to elaboration.

From the standpoint of Semantic Literary Dynamics Theory, this is precisely the kind of "approach and release" pattern that underlies spectral rhythm:

- Coherence rises and then levels off.
- Phase approaches the global direction, then overshoots slightly and settles nearby.
- Flow peaks around the central insight and declines thereafter.
- Acceleration changes sign, marking an inflection where the major turn has already been made.

In short, the "October" paragraph fragment thus functions as a miniature wavefield to illustrate how a short piece of lyrical prose can be viewed as a semantic trajectory: coherence tightens into

a central life lesson, flow and acceleration articulate the strength and timing of that tightening, and phase dynamics reveal how the discourse moves within a low-dimensional semantic plane shaped by nature and biography.

REFERENCES

[1] Kovalev B. V. From Classics to Digital Philology: On the Origin and Growth of Stylom etry. Philologia Classica 2024, 19 (2), 347–360. https://doi.org/10.21638/spbu20.2024.211

[2] Carvalko, Jr., J. R. (2026). Semantic Phasor Theory: A Unified Spectral Model of Meaning and Cognitive Structure (Pre Publication). Mar. 11, 2026' https://zenodo.org/records/18965947; Carvalko, J. R., The Operator Calculus of Semantic Phasors: Formal Foundations and Spectral Analysis (Pre Publication). March 16, 2026, https://zenodo.org/records/19055628.

[3] Wikipedia contributors, "Coherence (signal processing)," *Wikipedia, The Free Encyclopedia*, Mar. 31, 2026. Accessed: Mar. 31, 2026. [Online]. Available: https://en.wikipedia.org/wiki/Coherence_(signal_processing).

[4] Wave Superposition, Interference, Phase Difference and Coherence, Mar. 31, 2026. Accessed: Mar. 31, 2026. [Online]. Available https://sciencready.com.au/pages/wave-superposition-interference-phase-difference-and-coherence.

[5] Cui D, Qi S, Gu G, Li X, Li Z, Wang L, Yin S. Magnitude Squared Coherence Method based on Weighted Canonical Correlation Analysis for EEG Synchronization Analysis in Amnesic Mild Cognitive Impairment of Diabetes Mellitus. IEEE Trans Neural Syst Rehabil Eng. 2018 Oct;26(10):1908-1917. doi: 10.1109/TNSRE.2018.2862396. Epub 2018 Aug 2. PMID: 30072334.

[6] Hughes JM, Foti NJ, Krakauer DC, Rockmore DN. Quantitative patterns of stylistic influence in the evolution of literature. Proc Natl Acad Sci U S A. 2012 May 15;109(20):7682-6. doi: 10.1073/pnas.1115407109. Epub 2012 Apr 30. PMID: 22547796; PM□ID: PM□3356644.

[7] Authorship Attribution of Late 19th Century Novels using GAN-BERT, Proceedings of the 61st Annual Meeting of the Association for Computational Linguistics- Student Research Workshop, pages 310–320 July 10-12, 2023, Association for Computational Linguistics, [Online]. Available: https://aclanthology.org/2023.acl-srw.44.pdf.

[8] Ibid, 4.

[9] Ibid, 3.

[10] Ibid, 7.

[11] Ibid, 2.

[12] Cross Spectrum and Magnitude-Squared Coherence, Accessed: Mar. 31, 2026. Available: [Online]. https://www.mathworks.com/help/signal/ug/cross-spectrum-and-magnitude-squared-coherence.html.