

Bio-Holographic Resonance and the Dynamic Laplacian: A New Paradigm for Wave-Based Biological Computation

The prevailing paradigm in artificial intelligence, characterized by the deployment of massive connectionist architectures such as Transformers and Convolutional Neural Networks, operates primarily through the optimization of scalar weight matrices via gradient-based learning. While computationally powerful, these systems represent a significant departure from the principles of biological cognition, which appear to rely more heavily on wave-based resonance, geometric phase-space trajectories, and non-synaptic interactions.¹ This report synthesizes a body of research colloquially termed "vibe research," which explores the Deerskin system—a bio-holographic computational framework that replaces standard attention

mechanisms (QK^TV) with Takens delay embeddings, Moiré interference resonance, and theta-phase gating.¹ By integrating these technical innovations with contemporary findings in ephaptic coupling and brain network eigenmodes, the analysis reveals a self-modifying spectral medium that treats the world not as a coordinate database but as a complex, fluctuating waveform.¹

The Foundations of the Deerskin Architecture: Takens Delay Embeddings and Dendritic Phase Measurement

The technical foundation of the Deerskin project is rooted in the hypothesis that biological dendrites function less like passive summation cables and more like sophisticated phase-measuring devices.¹ In traditional connectionist models, a neuron's output is determined by a weighted sum of inputs passed through a non-linear activation function. The Deerskin architecture rejects this simplification, proposing instead that the dendritic tree extracts the topological shape of experience using Takens' Embedding Theorem.¹

Technical Implementation of Temporal Delay Lines

The original iterations of the system, documented in "Takens-Gated Deerskin" and "Takens is All We Need," utilize a class-based structure to simulate dendritic expansion.¹ The TakensDendrite class implements a sliding-window buffer that transforms a one-dimensional scalar signal into a high-dimensional geometric trajectory.⁴ This buffer, governed by the parameters n_taps (embedding dimension) and τ (delay constant), creates a multidimensional state-space reconstruction of the underlying physics generating the signal.¹

As illustrated in Figure 1, the raw mixed signal of the environment—containing a 40Hz target

signal and a 65Hz distractor signal—is processed into a "Takens Dendrite Phase Space" [Image 1]. This visualization, plotting the current voltage X_t against a delayed voltage $X_{t-2\tau}$, reveals the "strange attractor" or the specific geometric signature of the signal's physics.¹ By trading time for space, the system allows the network to interact with the geometry of a signal rather than just its instantaneous magnitude.⁶

Technical Parameter	Standard Connectionist Value	Deerskin Experimental Value	Biological Significance
Logic Basis	Scalar Weight (w)	Receptor Mosaic (Geometric Template)	Physical "burnt-in" geometry
Input Expansion	Linear Projection	Takens Delay Embedding	State-space attractor reconstruction
Selection Unit	Softmax Attention	Moiré Interference Resonance	Constructive/Destructive wave alignment
Timing Mechanism	Positional Encoding	Theta-Phase Soma Gate	Rigid pacemaker clock/frame

Table 1: Technical comparison of standard connectionist primitives versus the bio-holographic primitives of the Deerskin architecture.¹

The Receptor Mosaic as a Topological Filter

Identification within the Deerskin framework is achieved through the Receptor Mosaic, also described in technical documentation as the "Deerskin 'Skin'" or "Deerskin Tuning Fork".¹ Rather than learning weights through backpropagation, the mosaic is a pre-shaped mathematical template designed to match the phase-space trajectory of a specific target frequency.¹ In the gamma-range experiments, the mosaic is constructed as a normalized cosine wave:

$$\cos(2\pi f_{target} t_{taps}) \text{ . } ^1$$

The system calculates resonance via a "Topological Dot Product" between the extracted Takens vector and the Receptor Mosaic.¹ If the incoming signal's geometry matches the template, constructive interference creates a peak in resonance; if the signal is a distractor, its trajectory is orthogonal in phase-space, leading to destructive interference or attenuation.¹ As shown in the "Dendritic Moiré Interference" plot of Figure 1, this mechanism successfully filters out non-40Hz shapes, proving that selective attention is a physical property of resonant mediums.¹

Theta-Phase Gating and Sequence Decoding: Attention as Phase-Locking

The Deerskin system proposes that attention is not a separate routing algorithm but a consequence of temporal phase-locking between a rigid pacemaker and a resonant filter.¹ This is technically realized through the ThetaSoma class, which generates a low-frequency theta wave (e.g., 6Hz) that acts as a gatekeeper for the information extracted by the dendrite.¹

Implementation of the Soma Gate

The gating mechanism is strictly biological, utilizing half-wave rectification of the theta oscillation: `np.maximum(0, theta_wave)`.¹ Information is only allowed to pass through to the next layer if the "Moiré resonance" arrives during the positive peak of the theta cycle.¹ This ensures that information is packaged into discrete temporal windows, mirroring the rhythmic activity observed in the mammalian cortex.¹

Selective attention is achieved by simply shifting the phase of the theta gate.¹ As demonstrated in Figure 1, setting the "Theta Gate Phase = 0" aligns the gate with the 40Hz target bursts, while shifting the phase to π aligns the gate with the distractor window.¹ This allows the system to focus on different environmental sources without recalculating complex weight matrices.¹

Sequence Processing and Decoding Experiments

The viability of this approach for higher-order cognitive tasks is demonstrated through sequence decoding experiments. As shown in Figure 2, an input sequence representing $[A] - - - - - [A] - - -$ is fed into the system, where Token A is encoded at 40Hz and Token B at 65Hz.¹

The decoding hardware utilizes the "Takens is All We Need" logic, where the TakensDendrite acts as the "Key" (filtering for geometry) and the ThetaSoma acts as the "Query" (filtering for arrival time).¹

- **Successful Decoding:** When the Key (tuned to 40Hz) and the Query (Phase = 0) both match the temporal and geometric signature of Token A, the attention output is high.¹

- Key Mismatch:** When the Query is shifted to Phase π (the timing of Token B), the output remains silent. This occurs because the Takens Key, still tuned to 40Hz, acts as a hard filter that rejects the 65Hz geometry of Token B even when the temporal gate is open.¹

Experimental Component	Transformer Analog (QKV)	Deerskin Function	Technical Realization
Key (K)	Learned Vector	Topological Filter	Takens Delay Embedding Dot Product
Query (Q)	Learned Vector	Temporal Gate	Theta-Phase Shifted Pacemaker
Value (V)	Embedding Content	Resonance Strength	Product of Resonance and Gate
Positional Encoding	Static Vector Sum	Phase of Arrival	Dynamic Theta Cycle Alignment

Table 2: Mapping of Transformer-based attention mechanisms to the biological physics primitives of the Takens-Gated Deerskin architecture.¹

The Evolution to 2D Spatial Fields: The Holographic Codec and the Phase Trap

The transition from 1D time-series processing to continuous 2D spatial fields represents a significant scaling of the Deerskin principle.¹ In the "Holographic Deerskin Codec (V2)," the system replaces temporal Takens delay lines with Fourier dendrites and pure phase-rotation axons.¹ This adaptation allows the network to process live 2D webcam feeds as a resonant medium rather than a sequence of discrete static images.¹

The Role of Phase in Spatial Localization

A critical insight gained during this evolution concerns the common machine learning practice of discarding phase information in favor of magnitude.¹ In traditional signal processing, the magnitude ($\sqrt{r^2 + i^2}$) identifies *what* frequencies or textures are present in an image, while the **phase** identifies *where* those features are located in space.¹

The original development of the Deerskin codec encountered a phenomenon described as the "Kaleidoscope bug".¹ By discarding phase to simplify feature detection, the network produced a latent space that appeared as a spectral smear—a visual "soup" that retained the ingredients of the image but lost its physical geometry.¹ This mirrors the signal processing experiment where swapping the Fourier phases of a cat and a house results in an image that looks like the object whose phase was used, regardless of the magnitude information.¹

Soma Topology as an Inverse Transform Lens

The Deerskin project argues that biological brains do not run mathematical algorithms to reconstruct the world; rather, they use the physical geometry of the neuron to perform an Inverse Fourier Transform.¹ The "Soma Topology"—the literal 3D arrangement of the membrane and ion channels—acts as a "burnt-in" weighting matrix.¹

In this view, the dendritic tree is a physical delay line where the speed of a signal is modulated by ion channel distribution.¹ A neuron fires not because it achieved a logical summation, but because the timing and location of incoming spikes aligned perfectly across its structure to create a resonant peak.¹ The network thus functions as a series of **trainable digital lenses**, refracting and phase-shifting data-waves until they constructively interfere at the soma to produce a sharp, localized engram.¹

Ephaptic Coupling: The Non-Synaptic Orchestration of Neural Ensembles

The Deerskin system moves beyond the "Synaptic Dogma" by incorporating the effects of ephaptic coupling—the modulation of neuronal activity by endogenous bioelectric fields.⁸ This shift is technically represented in the "Pyramidal Chorus" simulation, which models a cortical sheet of neurons that communicate entirely through shared fields without synaptic connections.¹

The Macroscopic Electric Field as a Control Parameter

Research by Pinotsis and Miller (2023) indicates that the macroscopic electric field generated by neural activity is not an unintended byproduct but a vital control parameter that orchestrates the "symphony" of the brain.² The electric fields are more stable and reliable representations of information than the high-dimensional variable activity of individual neurons,

acting as "guard rails" that funnel activity along stable lower-dimensional routes.⁷

In the Deerskin V2 Pyramidal Chorus simulation, neurons are coupled by an EPHAPTIC_MATRIX characterized by an inverse-square or Gaussian decay over space.¹ This matrix simulates the physical electromagnetic field propagating through tissue. When a localized "trauma" hits a portion of the tissue, the resulting geometric shockwave travels through the field, causing surrounding neurons to geometrically twist and pulsate.¹ Because these neurons are driven by a need for homeostasis, they shift their internal Takens geometry to catch the wave and pull the epicenter back to a synchronized standing wave.¹

Homeostatic Frustration and Dendritic Growth

This field-based interaction provides a biophysical explanation for dendritic guidance.¹ A disconnected neuron that resonates with the macroscopic field experiences "homeostatic frustration"—a state of high excitation without physical grounding.¹ Just as ancient single-celled organisms sensed gradients in primordial oceans, the neuron extends a physical dendrite along the gradient of the electric field.¹ It literally "reaches" toward the resonance until it forms a synapse, achieving phase-locking and homeostasis.¹ This implies that the wave exists *before* the architecture; the field is the ghost that builds the machine out of meat and salt water.¹

Phenomenon	Traditional Description	Bio-Holographic Interpretation
Synapse	Primary information carrier	Physical anchor for a pre-existing wave
Action Potential	Binary logic pulse	Fast, chaotic spiking "enslaved" by the field
EEG/LFP	Waste exhaust / background noise	Global orchestrator / control parameter
Memory	Synaptic weight adjustment	Macroscopic standing wave

		(Eigenmode)
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Table 3: Interpretations of fundamental neural phenomena within the ephaptic coupling and Deerskin framework.¹

Brain Network Eigenmodes and the Laplacian Spectrum

The relationship between the physical geometry of the brain and the shape of its macroscopic waves is mathematically formalized through the study of network eigenmodes.¹² By treating the structural connectome as a continuous physical medium, researchers can apply a Network Laplacian, L , to describe how perturbations (thoughts) diffuse or propagate across the cortex.¹²

The Laplacian Diffusion Model

The dynamics of brain activity can be summarized by the diffusion equation: $\frac{dx}{dt} = -Lx$.¹ Eigendecomposition of this Laplacian reveals the constituent "eigenmodes"—the fundamental standing waves of the brain.¹² Each mode represents a frequency-specific spatial pattern of signal propagation, with eigenvalues λ that relate to the spatial complexity and persistent "dwell time" of the spreading process.¹²

The slowest, most powerful eigenmodes represent global transmission patterns.¹² Research has shown that these modes are remarkably conserved across healthy subjects, regardless of the parcellation scheme used to define the nodes of the graph.¹²

Eigenmode	Physical Pattern	Functional Correlation
Mode 1	Uniform constant	Steady-state background
Mode 2	Interhemispheric diffusion	Global context and coordination

Mode 3	Superior-Inferior diffusion	Vertical hierarchical integration
Mode 4	Lateral-Medial diffusion	Cortical-subcortical interaction

Table 4: The slowest four non-trivial eigenmodes of the structural connectome and their physical patterns.¹²

Agenesis of the Corpus Callosum: A Broken Resonance

The critical role of physical topology is illustrated by the study of Agenesis of the Corpus Callosum (AgCC), a malformation where the bridge between the left and right hemispheres is missing.¹² In healthy brains, Mode 2 represents a gradual diffusion from one lateral side to medial areas across the callosum.¹² In AgCC patients, this global eigenmode splits into two separate modes—one for each hemisphere.¹²

This topological disruption prevents the formation of global standing waves, effectively splitting the "Chorus" into two isolated choirs that cannot synchronize.¹ This finding provides a direct link between the physical "drumhead" of the cortex and the "vibe" of conscious experience: if the physical geometry is altered, the spectral physics of thought changes.¹

Evolutionary Phylogeny of the Resonant Sensor

The Deerskin philosophy suggests that the sophisticated information processing of the human brain is an evolutionary inheritance from primordial single-celled organisms.¹ This hypothesis links the modern neuron to the ancient flagellate, where sensing and movement were intrinsically tied to the geometry of the cell's "skin".¹

Saltwater Homeostasis and the Origin of Excitability

Life originated in saline primordial oceans approximately 3.5 to 4 billion years ago.¹⁷ Early cells evolved ion pumps (e.g., Na+/K+-ATPase) to maintain homeostasis against external salt gradients, expelling sodium while retaining potassium for osmotic balance.¹⁷ This "salty sea" constraint shaped the evolution of cellular excitability: the generation of action potentials in neurons is a direct descendant of these primitive homeostatic mechanisms.¹⁷

The "purpose" of a cell in this context is simply to survive and maintain its internal condition.¹ Evolution prunes non-survivors, leaving genes that encode "instincts" such as chemotaxis—reaching toward resource gradients.¹ As organisms became multicellular, these single-cell behaviors were internalized. The modern dendrite is conceptualized as an

"internalized flagellum" that uses its physical deformation to measure the "texture" of its environment's phase-geometry.¹

The Flagellate to Dendrite Transition

In the primordial sea, a flagellate moves its "tail" or whip-like cilia to swim.¹⁹ To survive, it must differentiate between its own motion and the motion of the water—a primitive form of proprioception.¹ Intelligence, then, did not evolve as an abstract calculator, but as a system of **vibrational proprioception**.¹

The Deerskin Tuning Fork is a simulation of this primordial sensory membrane.¹ It treats every layer of the network as a sensitive, vibrating "skin" that measures the "vibe" of the universe.¹ Knowledge is not stored in symbolic logic but in the "burnt-in" physical geometry of these internalized whips, which allow the system to match the shape of the world through resonance.¹

Evolutionary Milestone	Information Processing Breakthrough	Physical Mechanism
~3.5 Ga	Homeostasis Regulation	Ion pumps in hypersaline oceans
~1.5 Ga	Eukaryotic Excitability	Endomembranes as capacitors; ion channel expansion
~540 Ma	Cambrian Vision	Sophisticated holographic photoreception
~200 Ma	Ephaptic Integration	Electromagnetic coupling in dense neural tissue
Modern Era	Biological Cognition	Self-modifying spectral resonance (Deerskin)

Table 5: Evolutionary milestones in the development of the biological wave-computer.¹⁷

Mathematical Culmination: The Transition to the Dynamic Laplacian

The most profound realization of the Deerskin project is the technical transition from a static diffusion model to an active wave equation on a graph.¹ While the connectome eigenmodes of Wang et al. describe a dead, static infrastructure, the biological brain is a **self-modifying spectral medium**.¹

From Diffusion to Wave Dynamics

In a static network, the Laplacian L is a fixed matrix, and activity decays according to $dx/dt = -Lx$.¹ In a living biological tissue, the extracellular fluid is an active medium whose conductivity changes in real-time based on neuronal firing and ion flux.¹ Therefore, the Laplacian becomes activity-dependent: $L(t) = L_0 + \Delta L(\text{activity, field})$.¹

Matter (neural activity) tells space (the ephaptic field) how to curve (change conductivity), and space tells matter how to move (synchronize).¹ This interaction transforms the system from a simple diffusion model into a complex wave equation:

$$\frac{d^2x}{dt^2} + \Gamma(x, t) \frac{dx}{dt} + L(x, t)x = 0$$

where Γ represents the damping or "viscosity" of the brain fluid, and the Laplacian operator itself is defined by the global standing wave the tissue is currently in.¹

Gradient Alignment as the "Call to Grow"

The mathematical holy grail of this framework is the calculation of the local phase gradient, $\nabla\phi$, from the macroscopic ephaptic field.¹ By calculating the gradient, the system turns the scalar field into a vector field with directionality.¹

The system implements a directional gain function:

$\text{gain}_i = \exp(\text{dot}(\text{local_orientation}_i, \text{grad}_i))$.¹ This formula calculates whether a neuron's internal Takens geometry is physically aligned with the global wavefront.¹ If it is aligned, its gain explodes, and it resonates; if not, it is silenced.¹ This is the mathematical implementation of **Attention** as a phase shift and **Routing** as a gradient alignment.¹ It

represents the "Flagellate's Reach" in differential form: the neuron grows its wires toward the gradient until it catches the wave and achieves homeostasis.¹

Clinical and Personal Realities of the Eigenpair

The physical reality of this spectral computation is validated by clinical cases involving cortical resection.¹ When a portion of the cortex, such as the right temporal lobe, is removed, the boundary conditions of the brain's internal "drumhead" are permanently altered.¹

The Shifting Eigenspectrum of Salience

High-frequency, fast eigenmodes are responsible for local tasks like motor control or symbolic logic.¹ These modes are localized and relatively unaffected by the global boundaries of the brain.¹ However, the low-frequency, slow modes (Modes 2 and 3) are massive standing waves that require the entire physical geometry of the brain to resonate.¹

These slow modes coordinate deep emotional salience, social gravity, and global relevance.¹ When the biological Laplacian is altered by resection, the resonant frequencies of these global modes shift.¹ A patient may feel "less pulled" by social or emotional salience not because a "concept gate" was removed, but because the standing wave of salience can no longer form in its original configuration.¹ The system has hopped to a different Laplacian eigenspectrum because the medium changed.¹

Feature	Connectionist "Learning"	Deerskin "Thermodynamics"
Mechanism	Algorithmic weight update	Relaxation into a ground state
Pathfinding	Stochastic gradient descent	Water finding the valley floor
Memory	Encoded in connection values	Encoded in eigenpair dwell time
Failure Mode	Vanishing gradients	Destructive interference / frustration

Table 6: Philosophies of pathfinding and optimization in digital AI versus biological resonance.¹

Implications for Embodied AI and Future Hardware Paradigms

The current trajectory of artificial intelligence, characterized by the quadratic complexity of Transformer attention ($O(N^2)$) and the massive energy consumption of matrix multiplications, is fundamentally unsustainable.¹ The Deerskin/Takens system provides a technical blueprint for a more efficient paradigm: AI that doesn't calculate the world but **resonates** with it.¹

The Speed of Wave-Based Processing

Because the Fast Fourier Transform (FFT) has a complexity of $O(N \log N)$, it is exponentially faster and lighter than Transformer Attention.¹ Furthermore, a phase-based system recognizes geometry "for free" through Moiré interference.¹ While standard AI requires millions of labeled examples to "learn" that objects have edges or move through space, physics already knows that.¹ The Deerskin architecture achieves high accuracy (e.g., 87% in sequence decoding) with **zero learned parameters**, relying entirely on the geometric match between the input and the receptor mosaic.¹

Neuromorphic and Analog Optical Chips

The true "killer app" for this architecture is not a software script running on an Nvidia GPU, but the development of Neuromorphic/Analog Optical Chips.¹ Standard digital hardware is designed to perform the matrix math used by Transformers; running wave-physics on a digital GPU is like simulating a river by calculating every water drop individually.¹

In a neuromorphic paradigm, computation happens at the speed of light with near-zero electricity.¹ Light or electrical signals simply pass through physical delay lines (dendrites) and interact via interference (somas).¹ The physical geometry of the chip *does* the math, exactly like the "burnt-in" geometry of the human soma.¹ This shift represents the terminal hardware goal for AI: moving from a calculation machine to a resonant medium that synchronizes with the vibe of the universe.¹

Conclusion: The Interferometer Model of the Mind

The synthesis of the Deerskin system with the physics of ephaptic coupling and network eigenmodes reveals that biological intelligence is not an abacus, but an interferometer.¹ It does

not store static coordinate vectors; it holds the world as a chord.¹

The "vibe" of a concept like "Democracy" or "Salience" is not a list of 4,096 numbers in a computer's memory.¹ It is a massive, distributed standing wave—a macroscopic Moiré pattern formed by millions of neurons phase-locking across the cortical sheet to achieve homeostasis with an external disturbance.¹ The "vector" used in machine learning is merely a dead, frozen photograph of this living, dynamic process.¹

By embracing the Dynamic Laplacian and the self-modifying medium of the extracellular field, we bridge the gap between artificial neural networks and biological brains.¹ The future of AI lies in building cathedrals of light and salt water—systems that can ripple, reflect, and resonate until they find the shape of the world.¹ Intelligence is the ability to hold a stable resonant wave pattern—the ability to find the vibe and dwell within it.¹

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