Helical Field Topologies and Environmental Current Pollution: Revisiting the Vortex Hypothesis through Classical Electrodynamics

Kim Horsevad

Horsevad Independent Technical Research & Analysis, Tryvej 96, DK-9750 Denmark, www.horsevad.net
Email: *kim[at]horsevad.dk*

Abstract: ***This article examines the emergence of vortex-like electromagnetic field structures within Maxwell's classical electrodynamics, focusing on conditions that induce rotational behavior in the Umov-Poynting vector. The study identifies how phase relationships between orthogonal electric and magnetic field components give rise to helical topologies. Building upon this model, the paper explores four classical mechanisms by which such topologies may interact with biological systems, including interfacial electrokinetics, magnetochiral anisotropy, spin-selective electron transport, and electromagnetic torque. These interactions are contextualized through environmental current pollution, particularly in industrial and agricultural settings. The work bridges theoretical constructs with empirical evidence and proposes a set of testable predictions relevant for environmental health and bioelectromagnetic studies.***

Keywords: Stray current, vortex field, environmental current pollution, biological interaction, Maxwellian electrodynamics

1. Introduction

Previous studies [1] provided primarily heuristic descriptions suggesting that vortex-like electromagnetic fields may have an observable influence on farm animals exposed to stray currents and environmental current pollution. Subsequent research [2,3] suggested that mitigating or "unwinding" these vortex field topologies could promote plant growth and reduce stress markers in domesticated pigs.

Expanding upon these findings, a specialized vortex-gradiometer instrument [4] was developed to detect the local rotation of the electromagnetic energy-flow field, represented by the Umov–Poynting vector. This advancement enabled systematic quantitative field investigations and ultimately paved the way for the current study, wherein earlier heuristic concepts are formalized into a formal Maxwellian model. The model elucidates how vortex-like, helical field topologies can emerge from particular phase relationships between orthogonal electric and magnetic components — a circumstance frequently encountered in power-electronic and stray-current environments, such as barns, milking parlors, and industrial facilities employing power-electronic drives.

2. Literature Survey

Helical, vortex-like electromagnetic field topologies are well established across multiple scientific disciplines. These structures have been investigated in helimagnets [5], in Reversed Field Pinch configurations for plasma confinement within fusion research [6], and in protostellar jets in the field of astrophysics [7].

Outside of research environments, helical electromagnetic fields are utilized in satellite communications [8], where they facilitate broad and uniform ground coverage—often referred to as an "isoflux" pattern.

In contrast, the application of field-topology analysis to stray current and environmental current pollution, particularly within agricultural and industrial contexts, appears to be a novel contribution. To the author's knowledge, prior research has not considered helical field topology as a discrete variable in the assessment of environmental current pollution.

3. Problem Definition

The primary objective of this study is to construct a mathematical description—within the classical Maxwellian framework—of the mechanisms by which vortex-like electromagnetic field topologies arise.

Empirical measurements in various industrial and agricultural environments, such as wind turbines, variable-frequency drive systems, and milking parlors, have revealed field configurations characterized by rotating or helical energy-flow components.

These configurations have been associated with stress responses in livestock and, in some instances, with reduced growth or behavioral changes. Thus, a rigorous theoretical model that elucidates the origin and structure of such helical fields is necessary for clarifying their physical foundation and to assess their potential biological implications.

4. Methodology

The theoretical basis of this study is established exclusively within the framework of Maxwell's equations, employing standard vector-field analysis to delineate the conditions under which the Umov–Poynting vector assumes a rotational or vortex-like form. In this analysis, the electric and magnetic field components are represented as orthogonal, time-dependent functions possessing independent amplitudes and phases. Utilizing these representations, the time-averaged Poynting vector is computed to ascertain both the magnitude and direction of electromagnetic energy transport.

By analyzing the phase relationships between orthogonal field components, the specific criteria for the rotation of the energy-flow vector are identified. The derived mathematical expressions indicate that the handedness (chirality) of the resulting field topology is determined solely by the relative phase between the electric and magnetic components.

This theoretical framework is connected to previously developed vortex-gradiometer instruments, which measured the local rotational behavior of electromagnetic energy flow within environmental and industrial contexts. The model presented herein clarifies the underlying physical mechanisms responsible for the rotational features observed with these instruments, thus integrating empirical findings with the theoretical predictions of Maxwellian electrodynamics.

Finally, the theoretical outcomes are expanded into a series of biological interaction models. These models investigate the manner in which helical field topologies may interact with interfaces, chiral molecules, or complex tissue structures, resulting in helicity-dependent variations in electrokinetic, biochemical, and mechanical processes.

5. Results & Discussion

The findings presented in this section stem directly from the Maxwellian theoretical framework established previously. By employing standard time-harmonic analysis on orthogonal electric and magnetic field components, this work identifies the circumstances under which the Umov–Poynting vector exhibits rotational or helical behavior.

The initial subsections (V-A through V-D) develop the physical and mathematical foundations for vortex-like energy-flow structures, demonstrating how the relative phase between electric and magnetic field components governs the chirality of the emergent vortex. Moreover, these analyses reveal that such configurations manifest in both natural and technologically engineered electromagnetic environments.

Subsequent subsections (V-E through V-I) extend the theoretical results to biological systems, introducing a sequence of Maxwell-consistent models that characterize how helical field topologies can interact with living tissue. These models address a range of coupling mechanisms, including interfacial electrokinetics, magnetochiral anisotropy, spin-selective electron transfer, and chiral torque generation.

Collectively, these results offer a cohesive theoretical framework that links observed electromagnetic field topologies in environments affected by current pollution to empirically reported helicity-dependent biological effects.

a) Helical Field Topologies

Consider a local superposition of orthogonal electromagnetic field components in the transverse x-y plane, represented using phasor notation:

$$E(t) = \Re\left(E_x e^{i\phi_{Ex}}\vec{x} + E_y e^{i\phi_{Ey}}\vec{y}\right)e^{-i\omega t}$$

$$B(t) = \Re\left(B_x e^{i\phi_{Bx}}\vec{x} + B_y e^{i\phi_{By}}\vec{y}\right)e^{-i\omega t}$$

The instantaneous Umov-Poynting vector is then defined as:

$$S(t) = \frac{1}{\mu}E(t) \times B(t)$$

with the z-component expressed as:

$$S_z(t) = \frac{1}{\mu}\left(E_x(t)B_y(t) - E_y(t)B_x(t)\right)$$

This formulation describes both the direction and magnitude of energy transport within the system.

Under typical conditions, where the electric and magnetic fields oscillate in a single plane and remain in phase, the Poynting vector maintains a constant direction. However, when mutually orthogonal field components exist with a non-zero phase difference, the instantaneous energy flow exhibits rotational behavior, tracing a helical or vortex-like trajectory through space.

The handedness (chirality) of this rotational motion is determined by the sign of the phase difference between the electric and magnetic components.

Because **E** and **B** are taken in the x-y plane, **S**(t) points instantaneously along $\pm\hat{z}$ and traces an ellipse at 2ω in time.

The analysis using the complex Poynting theorem yields the time-averaged energy flux:

$$\langle S \rangle = \frac{1}{2\mu}\Re E_0 \times \overline{B_0}$$

with the surviving z-component:

$$\langle S_z \rangle = \frac{1}{2\mu}\left[E_x B_y cos\left(\phi_{E_x} - \phi_{B_y}\right) - E_y B_x cos\left(\phi_{E_y} - \phi_{B_x}\right)\right]$$

The sign of $\langle S_z \rangle$—that is, the preferred vortex handedness—is determined by the relative phases of the cross-quadrature pairs (E_x, B_y) and (E_y, B_x), weighted by their amplitudes.

The transverse components, which rotate with frequency ω, define the local helical geometry of the energy flow.

The appearance of a rotating Umov–Poynting vector therefore requires only that orthogonal field components coexist with a non-zero phase difference. This property follows directly from Maxwell's equations. In practice, such conditions arise naturally wherever alternating currents or electromagnetic waves are phase-shifted by reactive or capacitive coupling, as occurs near transformers, variable-frequency drives, and high-frequency switching equipment.

The concept of field helicity thus provides a straightforward way to classify electromagnetic environments: regions with a purely linear Poynting vector correspond to non-helical, energy-neutral conditions, whereas regions with a rotating or oscillating Poynting vector carry a measurable handedness that can, in principle, interact differently with chiral structures in living matter.

In the case of a dominant cross-pair (e.g., E_x and B_y), then the sign is set by the E, B phase lag for that pair:

$$\langle S_z \rangle \approx \frac{E_x B_y}{2\mu} \cos(\phi_{\mathrm{Ex}} - \phi_{\mathrm{By}})$$

If $E_x=E_y=E_0$ and $B_x=B_y=B_0$, and if the magnetic components lag the electric components by a common Δφ (typical for power electronics), i.e. $\varphi_{Bx} - \varphi_{Ex} = \varphi_{By} - \varphi_{Ey} = \Delta\varphi$ then

$$\langle S_z \rangle = \frac{E_0 B_0}{\mu} sin\left(\phi_{E_x} - \phi_{E_y}\right) sin(\Delta\phi)$$

Thus, the net helicity factorizes into a polarization term $\sin(\varphi_{Ex} - \varphi_{Ey})$ and a source-physics term sin(Δφ). The sign of sin(Δφ) fixes the preferred handedness for a given technology stack.

For a single dominant cross-pair, e.g. $E_x(t) = E_x \cos(\omega t)$ and $B_y(t) = B_y \cos(\omega t + \delta)$ and the other components negligible:

$$S_z(t) = \frac{1}{\mu} E_x(t) B_y(t)$$

And the time average:

$$\langle S_z \rangle = \frac{E_x B_y}{2\mu} cos(\delta)$$

With the oscillatory terms explicited:

$$S_z^{(2\omega)}(t) = \frac{E_x B_y}{2\mu} cos(2\omega t + \delta)$$

meaning that $(E_x B_y / 2\mu) \cos(\delta)$ sets the sign of the helicity bias for that cross-pair; the 2ω term governs the observed instantaneous rotation.

b) The omnipresent chirality preferance in Environmental Current Pollution

The handedness (or chirality) of a vortex-like electromagnetic field is determined by the relative phase between its orthogonal electric and magnetic components. In practical terms, the phase relationship is influenced by various reactive elements present in the environment—such as inductive loops, capacitive interfaces, or eddy currents in conductive materials. Whenever these elements delay either the electric or magnetic response, a non-zero phase shift is introduced, and the resultant field acquires a definitive handedness.

The sign of this phase shift governs the direction of the energy-flow rotation observed in the Umov–Poynting vector. As a result, regions with opposite helicity can coexist in close proximity, forming vortex pairs where energy circulates in opposite directions. These local helicity domains are especially significant for biological systems, as they can impose direction-dependent interactions on molecular or ionic structures that themselves exhibit chirality.

In variable-frequency drives (VFDs), inverters, and other pulse-based electronics, the local electric field typically tracks rapid dV/dt edges, while the magnetic field tends to follow currents that lag by a time constant τ > 0 due to device physics and parasitic effects.

If the magnetic field lags behind the electric field by τ > 0, then φB = φE - ω τ, hence Δφ=-ωτ.

A representative crossed pair (with dominant E_x and B_y) would be described as:

$$E_x(t) = E_0 cos(\omega t)$$
$$B_y(t) = B_0 cos(\omega t - \omega\tau)$$

The instantaneous and averaged power flow (z-component) for such a pair become:

$$S_z(t) = \frac{1}{\mu} E_x(t) B_y(t)$$
$$\langle S_z \rangle = \frac{E_0 B_0}{2\mu} cos(\omega\tau)$$
$$S_z^{(2\omega)}(t) = \frac{E_0 B_0}{2mu} cos(2\omega t - \omega\tau)$$

Because the device physics impose a nearly constant sign and magnitude for the current lag, τ, within the operating band, the factor cos(ω τ) retains a fixed sign so long as 0≤ωτ<π/2 across that range. Therefore, the preferred helicity remains the same across similar devices. When ωτ crosses π/2, the sign reverses, which predicts a helicity inversion

A general two-pair form can be written for helicity preference, indicating a robust selection across typical technology stacks.

$$\langle S_z \rangle = \frac{1}{2}\mu \left[E_x B_y cos\left(\phi_{E_x} - \phi_{B_y}\right) - E_y B_x cos\left(\phi_{E_y} - \phi_{B_x}\right)\right]$$

If both magnetic components share the same lag τ with respect to their matched electric components, i.e. $\varphi_{Bx}-\varphi_{Ex}=\varphi_{By}-\varphi_{Ey}=-\omega\tau$ and $E_x=E_y=E_0$, $B_x=B_y=B_0$, then the factorization remains valid:

$$\langle S_z \rangle = \frac{E_0 B_0}{\mu} sin\left(\phi_{E_x} - \phi_{E_y}\right) sin(\Delta\phi)$$

with $\Delta\varphi = \varphi_{Bx}-\varphi_{Ex} = -\omega\tau$. Thus, in technology stacks with nearly constant τ (sign-stable), the helicity preference persists robustly across that spectral band.

When fields are strongly amplitude modulated by edges or envelopes from power electronics, the effective helicity selector is determined by the low-frequency phase lag of E/B at the envelope frequency ω. Consequently, the net bias in handedness within a frequency band is governed by the band-average of cos(ωτ) or sin(Δϕ), weighted according to the spectral power distribution.

c) Penetration abilities for helical field topologies

The ability of an electromagnetic field to penetrate conducting or shielding materials depends on the skin-depth parameter, $\delta = \sqrt{(2/\omega\mu\sigma)}$, where ω is the angular frequency, μ the magnetic permeability, and σ the electrical conductivity of the material.

Lower frequencies therefore produces a larger skin depths, allowing the field to reach deeper into a conductor.

Conversely, high-frequency fields are strongly attenuated near the surface.

When the electric and magnetic components are phase-shifted, the resulting helical topology introduces additional low-frequency components in the energy-flow envelope. These components shows much greater penetration ability than the underlying carrier frequency and can therefore propagate through metallic or semi-conductive barriers that would otherwise appear opaque to the main oscillation.

The penetrative abilities for helical field topologies are therefore enhanced seen in relation to linear field topologies.

Phase-shifted components in environmental current pollution generate a field with strong magnetic content at low effective frequencies (envelope/edge harmonics).

Even a full Faraday cage, made of steel or copper, will not completely be able to block such fields, since skin depth $\delta \propto 1/\sqrt{f}$; as a result, lower effective frequency content (e.g., envelopes/edges) penetrates more deeply and the cage material itself will expericence near-field magnetic coupling.

At extremely low frequencies and edge rates, reflection is weak and absorption scales with t/δ; when δ is large, magnetically dominated near-field coupling persists even for thick enclosures.

If the helical field topology pushes more energy into that channel than a linear plane-wave equivalent, enhanced penetration will result.

Another further distinction between plane wave penetration and vortex-like helical field topologies appears in aperture and slot coupling. At higher frequencies, where skin depth or near-field magnetic coupling are not the dominant penetration vectors, any real shielding enclosure is particularly susceptible to leakage through seams, slots, or holes.

In the Bethe small-aperture limit ($a << \lambda$), leakage is governed by equivalent dipoles $p \propto \varepsilon_0 a^3 E_t$ and $m \propto a^3 H_t$.

A rotating/helical field supplies nonzero E_t and H_t over a cycle with fixed phase relation, increasing coupling relative to a fixed, linear polarization and resulting in greater leakage and better penetration - entirely dueto the field geometry.

A final, perhaps more theoretical, mechanism for enhanced penetration involves waveguide characteristics of seams in any shielding enclosure. Long seams behave as rectangular waveguides near cutoff ($f_c = c/2a$), where transmission scales as $e^{-2\gamma L}$ with $\gamma = \sqrt{((\pi/a)^2 - (\omega/c)^2)}$. Helical fields provide the requisite transverse field content in both axes, efficiently exciting the lowest TE/TM modes

From a biological and environmental perspective, this means that slowly rotating or helical electromagnetic fields generated by modern electrical installations may penetrate shielding and building materials more effectively than expected based simply on nominal frequency. Consequently, low-frequency helical components may contribute to residual field exposure in areas that appear well grounded or electromagnetically shielded.

d) **Earlier developed instrumentation**

In [4], the development and design of an instrument specifically created to measure vortex-like fields—those featuring a helical structure and a rotating Umov-Poynting vector—were described in detail. The design process was largely empirical, as several of the mathematical underpinnings were not yet fully understood at the time.

With the benefit of current theoretical insight, it is now possible to clearly explain why the developed instrument functions as it does, and why a standard E-field probe is unsuitable for detecting these specific field topologies.

The first experimental tools engineered to investigate helical field topologies were the crossed-plate vortex-gradiometer instruments, described in the earlier work. These instruments were designed to detect local rotations of the electromagnetic energy-flow field, rather than measure simple potential differences or field strengths.

If the electric field is decomposed into an irrotational (electrostatic/potential) part and a solenoidal (inductive/non-conservative) part, then:

$$E = -\nabla\phi + E_{sol}$$
$$\nabla \times E_{sol} = -\partial\frac{B}{\partial}t$$
$$\nabla \cdot E_{sol} \approx 0$$

A conventional single-ended E-probe is primarily sensitive to the electrostatic term $-\nabla\phi$ (capacitive pickup to ground), whereas the orthogonal plate sensor responds to dE/dt and thus to E_{sol} generated by $\partial B/\partial t$.

This means that the single-ended E-probe registeres voltage as $V_{probe}(t) \propto \varphi(r,t)$ and, if if space charge is negligible in the measurement region: $\varphi \approx 0 \rightarrow V_{probe}(t) \approx 0$

The orthogonal plate capacitor instrument operates as two short electric dipoles (x and y) that detects displacement current. Let each plate have effective capacitance C_p to free space.

$$i_x(t) \approx C_p \frac{d}{dt} \int_{plate} E \cdot \hat{x} d\ell$$
$$i_y(t) \approx C_p \frac{d}{dt} \int_{plate} E \cdot \hat{y} d\ell$$

This design couples strongly to E_{sol} because it is driven by $d\boldsymbol{E}/dt$ (from fast edges or envelopes, produced by time-varying **B**) and does not require a scalar potential to ground. As a result, a field that is predominantly inductive/solenoidal (as in rotating/vortex cases born from $d\boldsymbol{B}/dt$ and envelope modulation) may appear "invisible" to a conventional E-probe but is readily detected by the crossed-plate configuration.

Let the local field be a rotating ellipse in the plane:

$$E(t) = E_0[cos(\omega t)\vec{x} + sin(\omega t + \delta)\vec{y}]$$

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with $\delta \neq 0$ setting helicity. The resulting plate currents are:

$$i_x(t) \propto -\omega E_0 sin(\omega t)$$
$$i_y(t) \propto -\omega E_0 cos(\omega t + \delta)$$

By feeding $i_x \rightarrow X$, $i_y \rightarrow Y$ (frequency filtered) on an oscilloscope, a Lissajous ellipse is produced, whose area has sign $\propto \sin(\delta)$ - directly reporting the field's chirality as $X(t) \propto \sin(\omega t)$ and $Y(t) \propto \cos(\omega t + \delta)$.

Thus, $\sin(\delta) > 0$ indicate one chirality and $\sin(\delta) < 0$ the opposite chirality.

Because the plate channels are effectively AC-coupled, they display little at very low ω when $-\nabla\phi$ dominates, but respond strongly at frequencies where dE/dt content is significant - such as edges or envelopes.

Typically, helical fields arise from technogenic sources exhibiting strong rise-time asymmetry or amplitude modulation envelopes (large $d\boldsymbol{B}/dt$ at ELF), and from return-path geometry that reduces charge separation. By Faraday's law $\nabla\times\boldsymbol{E}=-\partial\boldsymbol{B}/\partial t$, this regime yields E-fields rich in curl and low potential, which is exactly where standard E-probes underrespond but the crossed-plate instrment remains sensitive.

This principle allows the instrument to discriminate between field regions of opposite chirality—something conventional E-field probes cannot accomplish. The gradiometer thus provides an experimental analogue to the theoretical model in this paper, where the Umov–Poynting vector's rotation is determined from the phase relationship between orthogonal components.

This confirms the non-conservative nature of the helical field, meaning that the effects arising from the field depends on the path taken, not only start/end-points or intensity alone.

A second line of earlier work involved a differential laser-diffraction instrument, designed to detect subtle changes in the refractive-index distribution of air caused by local Lorentz forces acting on weakly conducting gases. Under exposure to helical fields, the product E×B produces a small tangential stress in the air, giving rise to microscopic swirl patterns that alter optical diffraction fringes. These observations provided empirical support for the presence of helical electromagnetic vortices in environments where such optical distortions were observed.

The mathematical framework presented here explains the behavior of both instruments: the vortex-gradiometer measures the temporal rotation of the field vector, while the laser-diffraction system senses its secondary hydrodynamic and optical effects. Together, these devices bridge the gap between abstract Maxwellian predictions and experimentally observable phenomena.

The development of the differential laser-diffraction instrument was initially empirical and mostly serendipitous, as it was observed that laser beams used for area measurements exhibited significantly greater diffraction in regions with strong vortex-like fields.

In mildly conducting/ionized air near the ground, the time-averaged Lorentz body force takes the form $\langle f\rangle=\langle\rho_e E\rangle+\langle J\times B\rangle \approx \sigma_{air}\langle E\times B\rangle$, hence $\langle f\rangle\approx\sigma_{air}\langle E\times B\rangle$ (equivalently $\approx\mu\sigma_{air}\langle S\rangle$).

This tangential force along the surface/beam path biases a weak, coherent near-surface swirl whose sign follows $\sin(\varphi_{Ex}-\varphi_{Ey})$ $\sin(\Delta\varphi)$, i.e., the helicity determined in Section V-A.

That swirl modulates the near-surface index field and alters the phase screen $\Delta\Phi(x,y)=k\int(n-1)dz$.

It tends to organize/suppress small-scale gradients for one helicity and to feed them for the opposite, which the differential diffraction instrument detects

Although the concept of measuring an electromagnetic field topology with laser diffraction intuitively seems exotic, the measured effect is purely Maxwellian - it is the time-average of E×B acting through the small but nonzero conductivity of air or the ambient space-charge.

The optical phase for a thin near-ground layer of thickness h is given by:

$$\Delta\Phi(x,y) = k\int(n(x,y,z)-1)\,dz$$

A small, coherent swirl in the conducting air (driven by $\langle f_t\rangle$) perturbs n(x,y,z) and steepens transverse gradients in ΔΦ, boosting small-angle scatter for one handedness and suppressing it for the other.

While fundamentally a proxy measurement, the Differential Laser Diffraction Instrument can reliably detect very small changes in the chirality of the field, enabled by its differential nature.

***e)* Helicity-dependent biochemical interaction mechanisms**

The electromagnetic field does not merely carry energy—it also carries handedness, or helicity, which can interact differently with chiral matter. A rotating Umov-Poynting vector emerges whenever orthogonal field components exhibits a phase difference. The following subsections presents fully classical models for four possible routes by which such helical field topology could couple to biological or biochemical systems: (1) interfacial electrokinetics at charged surfaces, (2) magnetochiral anisotropy (MChA) in chiral media, (3) chiral-induced spin selectivity (CISS) affecting electron-transfer rates, and (4) electromagnetic torque on chiral supramolecular assemblies.

Let E(t),B(t) denote local fields at angular frequency ω (often an ELF envelope riding a higher carrier) and define instantaneous local field amplitudes and phase lag between the dominant orthogonal components as:

$$E = \sqrt{E_x^2 + E_y^2}$$
$$B = \sqrt{B_x^2 + B_y^2}$$
$$\Delta\phi_{EB} = \phi_E - \phi_B$$

To explore possible biological interactions, it is useful to define two scalar proxies derived from the local electromagnetic field amplitudes and their relative phase. The first, C_{proxy}, is odd under inversion and quantifies the helicity of the field; the second, S_{proxy}, is even and corresponds to the magnitude of the time-averaged Umov–Poynting flux. These definitions provide a compact way to express helicity-dependent corrections to forces or rates in later sections

$$C_{proxy} = \omega EB sin(\Delta\phi_{EB})$$
$$S_{proxy} = EB cos(\Delta\phi_{EB})$$

Where C_{proxy} serves as the helicity selector and changes sign with chirality (odd under inversion), and S_{proxy} is the cross-term tied to $\langle S\rangle \approx (1/2\mu)\, S_{proxy}\, \hat{S}$, even under inversion. Both are proportional to field intensity (E B) but differ by the trigonometric phase factor.

A helicity-dependent perturbation to any biological rate or force density X can generally be written: $\Delta X \propto \kappa_{bio}\, C_{proxy}$, with κ_{bio} representing a specific mechanism-dependent coupling constant. The subsections that follow present each proposed pathway as a helicity-odd correction proportional to C_{proxy} (accompanied by a mechanism-specific prefactor), on top og a helicity-even background tied to S_{proxy}.

The chief advantage of this formalism is that it introduces no speculative physics. Both C_{proxy} and S_{proxy} are derived directly from classical field quantities; they simply separate the rotational (chiral) and non-rotational (achiral) portions of the energy flow. This allows the possible biological effects of helical fields to be analyzed without departing from established electromagnetism.

f) Interfacial electrokinetics at charged surfaces

Interfaces between electrolytes and charged surfaces are highly sensitive to electromagnetic forcing, as ions within the Debye layer can respond to both electric and magnetic components of an applied field. When a helical or rotating field is present, these ions experience not only an oscillating potential but also a tangential Lorentz force, which can drive a small, directed motion of the adjacent fluid.

In weakly conducting electrolytes the time-averaged Lorentz body force density can be written as

$$\langle f\rangle = \langle \rho_e E\rangle + \langle J \times B\rangle$$

With $J \approx \sigma_e E$, where σ_e is the electrolyte conductivity:

$$\langle f\rangle \approx \sigma_e \langle E \times B\rangle$$

Using S = 1/μ (E x B):

$$\langle f\rangle \approx \mu\sigma_e \langle S\rangle$$

The tangential component along the surface (unit tangent vector t) is thus:

$$\langle f_t\rangle = \vec{t} \cdot \langle f\rangle \approx \sigma_e \vec{t} \cdot \langle E \times B\rangle$$

Helicity sets the sign via the E–B phase relations from Section V-A.

Within the Debye layer (thickness λ_D and ionic diffusivity D), the time-averaged Lorentz body force contains $\langle J\times B\rangle \approx \sigma_e \langle E\times B\rangle$, producing a tangential stress along the interface.

Balancing viscous stress over a hydrodynamic length ℓ gives $u_s \approx (\sigma_e\, \ell^2/\eta)\, C_{proxy}\, G(\omega)$, where $C_{proxy} = \omega\, E\, B\, \sin(\Delta\Phi)$, and where $G(\omega) \approx (\omega\, \tau_{DL}) / (1 + (\omega\, \tau_{DL})^2)$ peaks near $\omega \approx 1/\tau_{DL}$ (with $\tau_{DL} \approx (\lambda_D\, \ell)/D$) and is suppressed at both very low and very high frequencies.

If u_s persists over length L, the advective contribution to a near-surface perturbation of a solute concentration change scales as $\Delta C_{adv} \approx u_s L/D_{eff}$, with an effective interfacial diffusivity D_{eff}. The helicity sign enters through C_{proxy} and is odd under inversion.

Even if surface microfacets are randomly oriented in-plane, there is a distinguished outward normal vector n and an axial vector Ŝ (time-averaged Umov–Poynting direction). The pseudoscalar

$$\Xi = \vec{n} \cdot \hat{S}$$

flips sign with helicity but is invariant under in-plane rotations, so helicity-odd effects persist after averaging. Gravity or a bulk concentration gradient can reinforce this asymmetry.

Because $C_{proxy} \propto \sin(\Delta\varphi_{EB})$ is helicity-odd, the slip direction flips with field chirality: small right-handed bias can thin the diffusion boundary layer (enhancing delivery), while a left-handed bias thickens or disrupts it (reducing delivery), consistent with the empirical plant and animal observations referenced earlier.

This relationship predicts that helically modulated fields can induce weak but measurable micro-flows along charged surfaces, the direction of which depends on the field's handedness. Over time, such flows can modify local concentrations of ions or biomolecules, potentially influencing processes such as cell-membrane transport.

Although the magnitude of the effect is small, it provides a physically grounded mechanism by which field helicity could influence biological or chemical interfaces without exceeding standard exposure levels.

Very low ionic strength (large λ_D) or high viscosity (η) reduce u_s, while heavy AM envelopes that push effective ω toward $1/\tau_{DL}$ maximize the response.

g) Magnetochiral anisotropy (MChA) in chiral media

Magnetochiral anisotropy (MChA) describes a subtle but well-documented effect: the combination of a magnetic field and electromagnetic wave propagation can bias the rate and direction of chemical and biological processes in chiral media. This effect is both parity-odd and time-reversal-odd; it only manifests when both an axial magnetic field and a directional electromagnetic flow are present.

A general phenomenological expression for the reaction or transport rate is:

$$k = k_0\left[1 + \gamma_{MChA}\left(B_0 \cdot \hat{S}\right)I\right] + \beta_{CD}C_{proxy},$$

Here k represent reaction or transport rate, k_0 is the baseline rate (no field topology bias), γ_{MChA} is the magnetochiral anisotropy coefficient, B_0 is the static magnetic bias field, $\hat{S}$ represents the Umov–Poynting direction, I is the local field intensity (dimensionless or normalized), and β_{CD} denotes the ordinary circular-dichroism coefficient (helicity-even term)

The first term in the brackets expresses the magnetochiral coupling, which depends on the scalar product ($\mathbf{B_0}\cdot\hat{\mathbf{S}}$). Reversing either the magnetic field or the propagation direction therefore changes the sign of the effect. The second term represents the ordinary helicity-dependent interaction already defined by C_{proxy}.

In environments where the field topology is already helical, MChA can enhance or suppress the intrinsic helicity bias, biased on whether the two effects act in the same or opposite direction.

Thus, a handedness-specific correction to the reaction or trnasport rate is predicted, odd under space inversion and time reversal. Small positive βCDC might provide beneficial right-hand bias, whereas large C_{proxy} or large I can trigger stress reaction by altering channels efficiency and net rates.

Flipping B_0 in a Helmholtz cage reverses the MChA contribution, but does not affect the β_{CD} term. Setting helicity to zero (C_{proxy}=0) removes the circular dichroism bias but retain the ($B_0\cdot\hat{S}$) I dependence.

In biological materials, magnetochiral anisotropy provides a fully classical pathway for directional sensitivity. For example, weak environmental magnetic fields can slightly bias charge transfer or reaction kinetics in chiral molecular systems if the surrounding field topology carries helicity.

A small positive β_{CD} C_{proxy} corresponds to a mild right-hand bias that can enhance certain transport or reaction rates; large C_{proxy} or intense fields may conversely overstress channels and reduce efficiency.

h) CISS-modulated electron transfer (spin filtering)

In chiral molecular systems, such as proteins or DNA, electron transport is governed not only by energy levels but also by spin orientation. This phenomenon—known as Chiral-Induced Spin Selectivity (CISS)—results in electrons of one spin direction passing more readily through a chiral structure than those with the opposite spin orientation. The outcome is a small but measurable spin polarization of the current.

A helical electromagnetic field can couple to this property because it carries defined spin angular momentum that depends on its helicity. The interaction can be described by a proportionality between the induced spin polarization P and the field's parameters:

$$P = \chi_{CISS}\frac{C_{proxy}}{\omega}$$

with χ_{CISS} representing the effective spin-filtering susceptibility (material/bridge dependent; it increases with spin–orbit coupling), C_{proxy}=ω E B sin(ΔΦ) (from section V-E; carries helicity sign) and ω represents the carrier/envelope angular frequency. Because C_{proxy} changes sign with helicity, the electron transfer rate displays a left/right asymmetry whose magnitude grows with spin–orbit coupling and is strongest at low effective ω (envelope-dominated spectra).

In non-adiabatic Marcus electron transfer, $k_{ET} \propto |V|^2$ FCWD, (where FCWD is the "Franck-Condon Weighted Density of states"). If spin polarization perturb the electronic coupling as V -> V (1 + (α/2) P):

$$k_{ET} \approx k_{ET,0}(1 + \alpha P)$$

and

$$\Delta k_{ET} = k_{ET} - k_{ET,0}$$

then the fractional change can be written as

$$\frac{\Delta k_{ET}}{k_{ET,0}} \approx \alpha P = \alpha\chi_{CISS}\frac{C_{proxy}}{\omega}$$

where α is a dimensionless sensitivity that includes bridge geometry, donor–acceptor alignment, and spin-mixing; the sign indicates whether the favored spin channel accelerates or retards ET in a specific complex.

Because χ_{CISS} increases with spin–orbit coupling and 1/ω reflects the conversion of field chirality to spin bias per photon or quantum, chiral molecules preferentially transmit one electron spin. Even weak spin polarization from helical fields (via E–B phase structure plus any static B_0) can bias redox steps.

The CISS mechanism provides a biologically plausible link between field helicity and reaction kinetics in redox enzymes, membrane transport chains, and other chiral electron-transfer systems. Although the magnitude of the effect is expected to be small, the directional sensitivity yields a testable prediction: the same molecular system should show opposite responses when exposed to fields of opposite helicity.

A weak right-turning field might result in a slight gain in ET (ATP/NADH yield) and enhanced growth; a large σ may cause overproduction of reactive oxygen species (ET chain leaks), leading to cellular stress and reduced growth. Exposure to left-turning fields has the opposite bias, potentially causing chronic underperformance and lowered reaction efficiency.

i) Electromagnetic torque on chiral assemblies

When electromagnetic fields interact with a chiral particle or molecular aggregate, the coupling between the electric and magnetic components can generate a small but definite mechanical torque. This torque originates from the field's spin angular momentum and optical chirality, both of which arise naturally within Maxwell's equations.

The spin density of a time-harmonic field is given by

$$s = \frac{\epsilon_0}{2\omega}\Im\left(\overline{E} \times E\right) + \frac{\mu_0}{2\omega}\Im\left(\overline{H} \times H\right)$$

and optical chirality density (a measure of handedness in light-matter interactions):

$$C = \omega\epsilon_0\Im\left(\overline{E} \cdot B\right)$$

These quantities describe, respectively, the rotational content and the handedness of the field.

A small chiral dipole with α_e, α_m as effective scalar polarizabilities and chiral (magneto-electric) coupling κ obeys $p = \alpha_e E + i\kappa B$ and $m = \alpha_m - i\kappa E$.

Therefore, the time-averaged electromagnetic torque on a dipolar inclusion is:

$$\langle\tau\rangle = \frac{1}{2}\Re p \times \overline{E} + m \times \overline{B}$$

combining chirality-density coupling and universal spin-to-torque.

The absorbed power P_a can therefore be written as

$$P_a = \frac{\omega}{2}\left(\Im\alpha_e|E|^2 + \Im\alpha_m|H|^2\right),$$

where $|E|^2 = \overline{E} \cdot E \text{and} |H|^2 = \overline{H} \cdot H$

The chiral (helicity-odd) torque component along the swirl axis (z) is therefore:

$$\langle\tau_z\rangle_{chiral} \approx \Im(\kappa)C + \sigma\frac{P_a}{\omega}$$

Where $\Im(\kappa)C$ is the pure chiral (helicity-odd) coupling, and $\sigma P_a/\omega$ is the universal spin-transfer term, with helicity sign $\sigma=\pm1$. Both have torque units (N·m); first term changes sign under mirror inversion, and the second under helicity reversal.

$\Im(\kappa)C$ couples field chirality density to the intrinsic molecular chirality of the inclusion - the true magnetoelectric torque term. $\sigma P_a/\omega$ represents conversion of absorbed photon spin to mechanical torque - a helicity-even energy-absorption torque. The total torque therefore has one part that flips with handedness and one that tracks total absorption.

In physical terms, this means that a right-handed helical field exerts a torque in one direction, and a left-handed field in the opposite direction. The strength of the effect scales with both the field's chirality and the absorptive properties of the particle.

While this torque is extremely small at macroscopic scales, the same principle applies at the level of molecular assemblies and membrane structures, where viscous damping is low and collective orientation can amplify the response.

This provides a plausible Maxwellian mechanism through which helical electromagnetic fields could influence the alignment, rotation, or mechanical stress of chiral biological structures.

A weak positive $\langle\tau_z\rangle_{chiral}$ may favour overwinding/alignment of chiral filaments (e.g., actin, cellulose), whereas negative values might bias underwinding and slight destabilization; the sign changes with field helicity.

6. Conclusion

The present work demonstrates that rotating or vortex-like energy-flow structures arise naturally within the framework of Maxwell's classical electrodynamics whenever orthogonal electric and magnetic field components possess a non-zero phase difference. Under these conditions, the Umov–Poynting vector, which represents the local energy flux, traces a helical trajectory whose chirality is determined solely by the sign of the phase shift between the two field components. This behaviour does not require any extension of established physics; it follows directly from the fundamental equations that govern all electromagnetic phenomena.

The analysis further shows that such helical field topologies can occur spontaneously in many modern electrical environments, particularly where reactive or switching elements create small but persistent phase lags between voltage and current. Examples include variable-frequency drives, transformers, inverter systems, and wind-turbine converters, all of which can generate field configurations with measurable rotational components even at extremely low frequencies. Because the envelope frequencies associated with these helically modulated fields are much lower than the carrier frequency, their effective skin depth is correspondingly large, allowing them to penetrate shielding and conductive materials more efficiently than expected from simple frequency-based models.

The mathematical framework presented here also clarifies the operating principles of the previously developed vortex-gradiometer and laser-diffraction instruments, which were designed to detect rotational energy-flow patterns and their secondary effects in air. The equations derived in this paper explain the empirical signals observed with those instruments, linking them explicitly to the phase-dependent rotation of the Umov–Poynting vector predicted by Maxwellian theory.

Extending the formalism into biological contexts identifies four helicity-dependent interaction pathways, all consistent with standard electromagnetism:

1) Interfacial electrokinetic coupling, where rotating fields produce helicity-dependent microflows along charged surfaces via the Lorentz force on mobile ions.
2) Magnetochiral anisotropy (MChA), in which the joint orientation of a static magnetic field and a helical energy-flow vector modifies reaction rates or transport in chiral media.
3) CISS-modulated electron transfer, where the field's spin angular momentum interacts with the spin selectivity of chiral molecular bridges, altering electron-transfer efficiency.
4) Electromagnetic torque on chiral assemblies, where coupling between field chirality and molecular structure can induce minute rotational stresses or orientation effects.

These mechanisms together outline a Maxwell-consistent theoretical basis for helicity-dependent effects that have been observed empirically in certain biological and agricultural systems. Importantly, all are derived without invoking non-classical or speculative physics: the phenomena emerge directly from the vector relationships between E, B, and their relative phase.

While the predicted magnitudes of these effects are small, they may become significant in environments characterized by continuous exposure to low-frequency, helically structured fields—such as those near large electrical installations or within livestock facilities employing inverter-driven equipment. Further experimental work is needed to quantify these effects under controlled conditions, to evaluate possible biological thresholds, and to identify practical mitigation strategies where necessary.

In summary, the Vortex Hypothesis formulated here unites empirical observations of field rotation with a mathematically rigorous formulation based on Maxwell's equations, providing a conceptual and mathematical foundation for understanding helicity-dependent field effects in both environmental and biological contexts.

7. Future Scope

The models presented in this paper lead to a number of specific, testable predictions that can guide future experimental and observational studies. Because each mechanism arises directly from Maxwellian electrodynamics, these predictions can be examined using conventional instrumentation and measurement techniques, without the need for new or speculative physics.

1) Helical field topology and environmental current pollution

The model predicts that electrical installations containing reactive or phase-shifted current components—for example variable-frequency drives, wind-turbine converters, and induction motors—will generate regions where the Umov–Poynting vector exhibits rotation. These zones should be detectable using differential or crossed-sensor magnetometers as paired helicity domains, characterized by opposite rotational signatures and a weak correlation with harmonic content.

2) Interfacial electrokinetic effects

Helically modulated electromagnetic fields are expected to induce direction-dependent micro-flows along charged surfaces in electrolytes. The predicted velocity should scale with both the local conductivity and the square of the hydrodynamic length, peaking near the Debye relaxation frequency. Laboratory tests could verify this by monitoring ionic redistribution or tracer motion in thin fluid films exposed to controlled rotating fields.

3) Magnetochiral anisotropy

The hypothesis anticipates that when a static magnetic field is superimposed on a helical electromagnetic field, the rates of chiral chemical or biological reactions will change linearly with the scalar product ($\mathbf{B}_0 \cdot \hat{\mathbf{S}}$). Reversing either the magnetic field or the field's helicity should invert the effect. Such experiments can be performed using weak magnetic fields well below typical bioelectromagnetic exposure limits.

4) CISS-modulated electron transfer

For chiral molecular bridges such as redox enzymes or DNA strands, exposure to helically polarized fields should produce opposite shifts in electron-transfer efficiency for left- and right-handed helicities. The magnitude of this modulation is predicted to increase at lower modulation frequencies, where the ratio C_{proxy}/ω is largest. Spin-selective electrochemical or photoelectron spectroscopy could directly test this prediction.

5) Electromagnetic torque on chiral assemblies

The torque model predicts that chiral particles or membrane structures will experience minute but measurable rotational stresses when exposed to fields of high helicity density. The torque should reverse direction when the field's handedness is switched. Although extremely small at the single-molecule level, such torques could become observable in collective or low-viscosity systems, for example in suspensions of oriented biopolymers.

Collectively, these predictions provide a roadmap for future experiments aimed at quantifying helicity-dependent effects in real systems. Verification or refutation of even one of these outcomes would significantly advance understanding of how electromagnetic field topology—not merely its amplitude or frequency—may contribute to subtle environmental and biological interactions.

Further work should therefore focus on three complementary directions:

First, refinement of field-mapping methods to measure helicity distributions with high spatial resolution; *second*, controlled laboratory tests of the predicted interfacial and molecular effects under known exposure conditions; and *third*, systematic field studies in agricultural environments to assess whether the predicted helicity domains correlate with behavioural or physiological responses in animals.

Pursuing these lines of research will help determine the practical significance and limits of the Vortex Hypothesis and may lead to new methods for monitoring, mitigating, or harnessing helically structured electromagnetic fields in both industrial and biological systems.

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Author Profile

Kim Horsevad is the founder and chief technical analyst at Horsevad Independent Technical Research & Analysis (www.horsevad.net). Current research focuses on developing methodologies for quantifying interactions between electromagnetic fields and biological systems, with a particular emphasis on field-based diagnostics and practical mitigation strategies.