Unravelling the potentials puzzle and corresponding case for the scalar longitudinal electrodynamic wave

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Abstract This paper will attempt to demonstrate, through a wide range of recent empirical evidence and theoretical considerations, the viability of the scalar longitudinal wave (SLW) concept as presenting a new challenge to the science of classical electrodynamics (CED). Contributing developments underlying the existence of this field effect are introduced underscoring the many principal exhibits of the curl-free (irrotational) vector potential, especially in regards to the compelling Maxwell-Lodge effect, certifying the long-debated physical significance of the potentials in CED. This will naturally lead to the novel concept of “gradient-driven” current, a key feature of the 2016 L.M. Hively US Patent 9,306,527, providing the missing element in standard CED resulting in a consistent understanding of this discipline. In accordance with these imperatives, institution of a full gauge-free electrodynamics model will be postulated implying the complete independence of scalar and magnetic vector potentials. Through these directives, the SLW is then revealed. Due to the unique characteristic of its minimal attenuation the SLW is then shown to be a potential harbinger of new technology, and a forerunner of future possible paradigm revolutions.

1. Introduction
For more than a century and a half Maxwell’s equations have served as a bastion for classical electrodynamics. These four vectoral wave equations have stood the test of time, not only in regards their principal utility, representing the scaffolding from which has emerged the vast electromagnetic technological infrastructure of our current world power grid, but their veracity in correctly and accurately predicting field effects in uncountable numbers of experimental test protocols. Indeed, our knowledge of the properties and dynamics of electrodynamic systems is believed to be the most solid and firmly established in all of classical physics.

By its extension, the application of quantum electrodynamics, describing the interaction of light and matter at sub-atomic realms, has produced the most successful scientific theory yet produced to date, agreeing with corresponding empirical findings to astounding levels of precision. With such a longevity of success, it is no wonder that mainstream physics considers that standard classical electrodynamics is complete and that it is virtually a closed subject.

However, these facts have understandably, albeit unfortunately, lulled contemporary physics into the false security of the perceived notion that the theoretical structure of modern classical electrodynamics is now written in stone and there is no compelling reason, empirical or theoretical, for considering the possible need for its re-evaluation or alteration. These beliefs have even reached the
levels of a religious fervor on the part of many contemporary physicists, who are wont to summarily dismiss any claims to the contrary, to the extent of branding those suggesting possible missing elements as heretics.

Nevertheless, as we hope to demonstrate through forthcoming argument in this paper, there is a key missing dimension of electrodynamics that can be attributed to the failure to include what can be termed the electro-scalar force in its structural edifice. Now, as an offshoot to this process, we also wish to transcend and dispel the derision this subject has engendered over the years by mainstream physics, having associated it with cultish groups of researchers/hobbyists who for many years have unfortunately been unable to present much solid evidence of the dynamics of this field structure in electrodynamics, instead relying principally on mostly unfounded anecdotal evidence to support these claims.

However, we will present cogent arguments, both from theoretical first-principle considerations as well as compelling recent empirical findings, examining the embodiments of various patented technology, which will be shown to warrant a thorough re-evaluation of the current structure of classical electrodynamics both in regards to model consistency and completeness.

The paper is arranged in the following manner – section 2 covers the historical developments in connection with the origin of the magnetic vector potential from the fertile mind of Faraday coupled with the mathematical expertise/ingenuity of Maxwell. The controversy surrounding the role of the vector potential is discussed, with special attention given to the physical significance of the so-called curl-free vector potential, apart from as well as including its usual quantum context associated with the celebrated Aharonov-Bohm effect. Accordingly, the case will be built with the aim of putting to rest the worldview by physicists which, unlike the electric and magnetic field intensities, assigns a purely secondary mathematical utility for the magnetic vector potential in classical electrodynamics, and not a primary physical status. Thus, appreciation of the phenomenological import of the curl-free vector potential in many experimental protocols in classical physics, will then naturally lead to two interdependent imperatives: the promotion of the potentials to their full birthright physical status in CED, and the corresponding novel theoretical prescription of the total (manifest) independence of the potentials (electric and magnetic), culminating in a completely gauge-free model for CED, which is given the appellation Extended Electrodynamics (EED). Through the advancement of these directives, as a natural progression as will be shown in section 3, subsequently will be ascertained the disclosure of the scalar longitudinal field, and its hitherto unsuspected role in classical electrodynamics. Central to this view will be an examination of the recent patent granted to physicist Lee M. Hively, demonstrating how the novel concept of gradient-driven electrical current, as a natural implication of the curl-free vector potential, not only sets the stage for the scalar longitudinal wave (SLW) dynamics, but provides the missing element in standard Maxwellian electrodynamics which will establish the basis for a consistent understanding of this discipline. The unique feature of the lack of attenuation of the SLW, as not being subject to the “skin effect”, will round off our investigation in section 4, revealing the vast potential applications of scalar wave dynamics not only in future technological infrastructure, but as possibly already exhibited in both inanimate and biological systems in nature.

2. The physical significance of the magnetic vector potential

Historically, a great degree of controversy has surrounded the conceptual interpretation of the role the magnetic vector potential should play in classical electrodynamics [1]. This can be attributed to the fundamental mathematical relationship between the scalar potential ($\phi$) and the vector potential ($A$), and the electric ($E$) and magnetic ($B$) fields. Any electromagnetic field may be described by giving $E$, $B$, or by giving potentials $A$, $\phi$, from which $E$ and $B$ are derivable, via:

$$B = \nabla \times A, \quad E = -\nabla \phi - \partial A / \partial t.$$  \hspace{1cm} (1)

However, only $E$, $B$ are usually regarded as “real” physical fields, whereas to consider the introduction of the vector potential as no more than a mathematical convenience, useful as an aid in solving the Maxwell’s equations for $E$, $B$. This interpretation derives from the “operational” definitions
of $E$ and $B$, their detectability through forces $qE$ and $\mathbf{v} \times (qB/c)$ on a test charge $q$, that is supposed to lend them reality through the Lorentz-force equation:

$$d(M\mathbf{v})/dt = qE + \mathbf{v} \times \mathbf{B}/c,$$

with $E$, $B$ to be evaluated at positions $r(t)$ of the point particle.

However, this practice of attributing non-physical significance to the magnetic vector potential couldn’t have been further from the thoughts of the original architects of what eventually became modern classical electrodynamics. Particularly, from the astute intuitive observations of Faraday, of electromagnetic phenomena in the early 19th century, the magnetic vector potential was originally christened by him as the “electrotonic state”[2]. It was to Maxwell’s great credit to recognize the key import of these nascent, metaphysically inspired intuitions of Faraday and reframe this electrotonic state in precise mathematical formalism, the measure of which he renamed the magnetic vector potential [3]

This turned out to be a turning point in the formalistic development of the theory.

Now, before Maxwell, the only extant mathematical representations of electric and magnetic dynamics was derived from the work of Ampere-Weber, describing forces between current elements which assumed direct action-at-a-distance, without the aid of a material medium [4]. However, basing the new model of electrodynamics on causality of interactions, it was due to this alternate structure originally proposed by Faraday – with the electrotonic state as its centerpiece, that later through Maxwell’s codification, brought to the fore the first theory of action by local contact - the precursor to the modern field conception of electrodynamics [5].

The electrotonic state could be best described as the ability for the field medium surrounding a (primary) electrical conductor, to possess the latent readiness to respond with current flow in a (secondary) circuit, if the magnetic flux linking the primary conductor changed in time. Thus, the electrotonic state became an intensity of a level previous to electric and magnetic field properties and measurable forces, and consequently represented to Faraday and Maxwell, a “store” of potential dynamism, playing a role on the same physical footing as that of the fields [6].

Yet these potentials, introduced by Maxwell as physical, were summarily unceremoniously discarded by Heaviside [7] as “non-physical”. He argued, basically from his engineering background in telegraphy, that they they rendered the equations of propagation, in his words “unmanageable and also not sufficiently comprehensive”. Heaviside (and Hertz independently) stated that the standard “duplex” field equations (now known as Maxwell’s equations) and the associated two field vectors ($E$, $B$) were the sole basis of electromagnetism.

However, the original descriptive conception of the magnetic vector potential, and its corresponding physical significance, has recently been brilliantly articulated in the insightful modern under-appreciated dissertation by Konopinski [8]. Quite close to the spirit of Faraday’s inspiration, Konopinski’s views the vector potential as a “store” of field momentum available for exchange with the kinetic momentum of charged matter or charges in a conductor [9]. Konopinski then proceeds to show that operational definitions of $\phi$, $A$ can now be ascertained from the equation of motion (2) when it is reexpressed in terms of the field description by the potentials, through substitutions from (1):

$$\frac{d}{dt} [M\mathbf{v} + (q/c)A] = -\nabla q[\phi - (\mathbf{v}/c) \cdot A].$$

This is also the form that follows most directly from the variational principle, and the Lagrangian or Hamiltonian representations of mechanics, all dealing with energy and momentum exchanges without regarding an explicit conception of forces. Equation (3) gives changes in “conjugate momentum” $p = M\mathbf{v} + qA/c$, that are generated wherever there are gradients in an “interaction energy” $q[\phi - \mathbf{v} \cdot A/c]$. To demonstrate that $A$ can be measured at all points in space Konopinski introduces the engaging gedanken experiment involving a solenoid outside of which a macroscopic bead of unit charge slides freely on a circular fiber of insulator material concentric with the cross-section of the solenoid. Since $A$ everywhere has only an azimuthal component parallel to the current flow, the gradients of $\phi$ and $A$ vanish making the right side of (3) zero. Consequently, the generalized momentum $p$ is a conserved quantity. The vector
potential is then obtained by monitoring the associated changes in the bead’s momentum $Mv$ arising from changes in the solenoid’s current and by applying conservation of momentum. Thus $qA/c$ is the momentum “stored” in the system comprised of a unit test charge in an external magnetic field.

Consequently, just as $q\phi$ serves as a store of field energy, so $qA/c$ measures a store of field momentum available to a charge’s motion [10]. The potentials thus represent field energies and field momenta, per unit charge, as those participate in the universal conservation of energy and momentum, whereas force and work rate per unit charge, can be regarded as convenient terms for the transfer rates. The $q\phi$ and $qA/c$ are joint properties of the superposed fields arising from their interference – important because they determine the processes through which fields and charges become observable.

Apart from such theoretical considerations, there has been a host of empirically-based evidence surrounding the phenomenon of the curl-free magnetic vector potential that continues to emerge. Observations of this nature have been reported across the board of both microscale and macroscale domains, as well as spanning across the historical spectrum of both modern and antiquarian research. For instance, the well-plumbed Aharonov-Bohm (A-B) effect [11] has certainly certified the inextricable link of the magnetic vector potential to quantum effects. This phenomenon demonstrated that the wavefunction of electrons passing around a long solenoid, accumulates a phase determined by the line integral of the vector potential in the space along a path from the source to the screen [12]. This is a quantum-mechanical phenomenon in which a quantum particle is affected by static electromagnetic fields which are topologically confined to regions not accessible to the particle. Consequently the particle sees only null magnetic field (curl-free vector potential) during its transit [13].

When this was first discovered, physicists were incredulous, since the A-B effect went against the prevailing dogmatic wisdom which held that the magnetic vector potential could not have any physical effect [14]. Now, the A-B effect, dealing with quantum effects at the microscale, was predicted and verified in the mid 20th century. Yet very recently, Varma et al. [15] has demonstrated the existence of a similar effect, the observation of a static curl-free vector potential on the macroscale as well, in a system of charged particle dynamics in an external magnetic field. This new phenomenon, albeit as of this writing yet to be duplicated, is demonstrated by observing the effect in the variation of a curl-free vector potential by varying the current in a toroidal solenoid (which produces it) on a very low current electron beam of a few tens of nano-amperes, of a given energy propagating linearly along a magnetic field, as detected by a detector plate [16]. Contrary to what would be expected to be observed on the macroscale as a flat current, as per the classical view, the detector-plate current was found to vary in a periodic manner with the linear variation of the vector potential [17]. This undulatory behavior thus signals the detection of a curl-free vector potential on the macroscale. However, according to Varma [18] though on the macroscale, the observation does not belong to classical physics. Rather, it is mediated through a matter wave which is on the macroscale, similar to the A-B effect being modulated by the de Broglie matter wave. Although in the Varma protocol, it is essentially a quantum modulation of the de Broglie matter wave along the magnetic field lines of force, which is brought about by a scattering-induced transition across electron Landau levels [19].

In commenting on this result, Shukla [20] states that the matter wave is surprisingly shown to be on the macroscale of a few centimeters for typical laboratory parameters, and thus could be considered a classical effect. But then he remarks that it is not since a curl-free vector potential would not affect a particle or electrical system ‘classically’. However, as we will see, even this supposed assumed tenet of electrodynamics may also be in need for a major re-tooling. Indeed, recent studies as well as those in the distant past have determined that a curl-free vector potential may cause robust unexpected physical effects (e.m.f.’s) in classical electromagnetic systems via what has been recently coined the “Maxwell-Lodge” effect [21].

As a matter of fact, nowhere in the pantheon of electromagnetic protocols that shall be cited, has the impact of the curl-free vector potential most clearly been shown to be felt, than with the Maxwell-Lodge effect. So much so, that when the significance of this phenomenon is duly appreciated by mainstream physics, it might represent the underpinnings to finally elevate the vector potential to its natural birthright physical status in CED; for this was the mantle it was originally intended to take on according to the
worldviews of Maxwell and Faraday in the 19th century.

It derives from a key observation from Oliver Lodge harkening back to the beginnings of the original formulation of CED. From the results of an electromagnetic experiment, Lodge was confronted with a conundrum based upon an apparent paradox, in connection with standard effects expected from the canonized tenets of Maxwellian electrodynamics. Unfortunately, his findings were essentially ignored, and a fluke attributed to deficiencies in precision due to relatively primitive 19th century electrical equipment. Specifically Lodge used a torus solenoid wound on to a ring shaped iron core; stray magnetic fields could only be detected by the use of iron filings, alternating voltage was simulated by including a reversing key in a direct current circuit, and induced voltage in the ring was detected by a quadrant electrometer with a movable needle. Nevertheless, despite these obvious shortcomings, taking up the gauntlet, over a century later, Rousseaux et al. [22] emphasized that the Maxwell-Lodge effect still presents a fundamental problem to the foundations of CED. To most simply state it, a very long solenoid is circled in its central plane by a conducting loop (Fig. 1). When a sinusoidal current is applied to the solenoid, there is a corresponding voltage induced in the loop, despite the fact that no sensible magnetic flux exists in proximity to the loop. The magnetic field of an infinitely long solenoid is nonzero only inside the solenoid; however, outside an infinitely long solenoid, the magnetic field is zero. In contrast, because the vector potential is present everywhere around a current-carrying conductor and is parallel to the current, it can exist both inside and outside an infinitely long solenoid. Despite no magnetic field existing outside the solenoid, a secondary voltage appears across a loop secondary coil placed around the outside of the solenoid. Also, it should be noted that Blondel, also performed a similar type of experiment that apparently verified this effect in 1914 (details in [21]).

![Figure 1. Circuits for the Maxwell-Lodge effect representation](image)

The phenomenon associated with the induction of e.m.f. in a magnetic field-free region has then been termed the Maxwell-Lodge effect. The Rousseaux team used for their experiment a diversity of Lodge’s apparatus with voltmeter instead of a movable needle (Fig. 1). Assuming the voltage induced in the ring was due to the dynamics of the vector potential \(\mathbf{A}\) outside the solenoid via the relation, \(\mathbf{E} = -\nabla \mathbf{A}\), they split the vector potential up according to the Stokes-Helmholtz-Hodge decomposition:

\[
\mathbf{A} = \mathbf{A}_{//} + \mathbf{A}_{\perp} + \mathbf{A}_h
\]

(4)

where the third term (the harmonic part) meets the conditions \(\text{div} \ A_h = 0, \text{curl} \ A_h = 0\). It is well known that this harmonic part that it is cause of the Aharonov-Bohm effect. As we will show, the Maxwell-Lodge effect demonstrates its necessity in classical physics as well. However, the harmonic component of the vector potential was conventionally falsely perceived not to induce any effect because it is always possible to "gauge" it away by subtracting the gradient of an appropriate scalar function. Nevertheless, since the space is multiply-connected, this proves to be false since in the quantum/classical protocols above the observables are related to the circulation of the external vector potential (the holonomy), that is associated with the phase differences in the Aharonov-Bohm effect, and the internal magnetic flux in the Maxwell-Lodge effect.
Outside an ideal solenoid of infinite length, the vector potential is precisely equal to the harmonic component (or a gradient) because of its divergenceless/curl-less nature, as expressed by the following formula in cylindrical coordinates, by using Stokes theorem on a closed circular path of radius \( r \):

\[
\mathbf{A} = \mathbf{A}_h = \nabla \left( \frac{\Phi \theta}{2\pi} \right) = \frac{\Phi}{2\pi r} \hat{e}_\theta
\]

where \( \Phi \) is the flux of the magnetic field inside the solenoid or the circulation of the vector potential outside the solenoid. The magnetic field is null outside a perfect solenoid of infinite length in the stationary regime. Moreover, it is pointed out that the supposed mathematical indeterminacy due to the gauge transformations is negated by the boundary conditions which give a physical determination to the vector potential outside a solenoid. If the current varies slowly in time the magnetic field is still null outside the perfect solenoid but because the vector potential is not null outside the solenoid and varies with time, it creates an electric field outside the solenoid:

\[
\mathbf{E} = -\frac{\partial \mathbf{A}}{\partial t} = -\nabla \left( \frac{d\Phi \theta}{dt \ 2\pi} \right) = -\frac{1}{2\pi r} \frac{d\Phi}{dt} \hat{e}_\theta.
\]

Moreover, in their experimental findings on the Maxwell-Lodge effect, Rousseaux et al. have offered the compelling argument that lends support to the view that an electromagnetic influence can be propagated, free of a magnetic field. Thus, given the results that a constant magnetic field plays no role in the mechanism of electromagnetic transmission, Rousseaux et al. have proposed to consider the harmonic part of the vector potential to be the actual agent for propagation.

Besides confirming the findings of Rousseaux et al., in their own follow-up experimental study, the team of Leus and Taylor [23] have added an additional proposal - positing that in electromagnetic transmission, it is not just the harmonic part, but the vector potential in total that should regarded as playing a part in this process; that it is highly plausible that electrodynamic flow of energy, in general, is related to the time variation of the vector potential. By considering the subtle but important distinction between kinematical and dynamic systems, Leus et al. [23] have suggested that the acceleration of a charge which is associated with creating and propagating an electromagnetic disturbance, seems inseparably linked to the ‘trinity’ of vectors (\( \mathbf{A}, \mathbf{E}, \mathbf{B} \)). It is due to the charge’s acceleration that \( \mathbf{A} \) and \( \phi \) are simultaneously varying in parallel with the electromagnetic field. All these entities in total make up the integral parts of a physical unity.

Recently, the operational implementation of the Maxwell-Lodge effect has been embodied in a patent issued to M. Daibo [24]. In an associated paper [25] Daibo et al. have described this surprisingly simple apparatus. In order to disentangle the space to be used where the vector potential and the magnetic field are superimposed, they constructed a nested structure comprising a coiled coil, as depicted in Fig. 2 below. To eliminate the magnetic field and generate a pure vector potential, they constructed a very long flexible solenoid whose current-return wire runs through the core of the solenoid itself. This current-return wire was also oriented coaxially within the flexible solenoid. This so-called vector potential coil (VPC) was then outfitted with several secondary coils passing through the hollow core of the VPC. The VPC was then driven with alternating current causing a voltage difference across these various secondary coils, even though the secondaries were not exposed to any magnetic fields. The whole primary-secondary coil configuration was termed vector potential transformer (VPT).

They found that the VPT has the unique property that the secondary voltage does not depend on the path followed by the secondary coil. Moreover, the secondary voltage appeared even when the secondary coil was enclosed by a conducting material. Other features of the VPC that make it attractive for various industrial applications are that it generates ac electric fields without requiring bare electrodes, which means that it can be used in corrosive media, such as blood. Because of its transparent characteristics, the vector potential can penetrate through conductive materials, such as a living organism, deep sea
water, and even reactor pressure vessels in nuclear power plants. Of course, since the VPT does not generate magnetic fields, this makes it quite suitable for medical or high precision measurements.

Figure 2. VPT with secondary circuit coil configurations

In a recent paper whose subject matter is in connection with another patent that utilizes a curl-free vector potential ansatz, albeit at microwave frequencies, N. Nikolova comments [26] that the non-uniqueness of the potentials as a reason for considering them as non-physical is untenable, and is an opinion that deserves a closer look as it does not seem to have solid foundations. Also, she points out that in antenna theory, where the electric and magnetic vector potentials are common analytical tools, a number of paradoxes can occur, in which the mathematical models predict nonzero propagating potentials with zero field vectors. The most striking example is the expansion of the free-space field in spherical harmonics where the vector potential is radially polarized. The 0th - order solution, which features a spherically symmetric potential, appears to be non-physical because the field vectors are zero everywhere. At the same time the wave impedance remains finite and exactly equal to that of free space. No energy can be coupled to this impedance, however, because the model implies a radially propagating “potential wave” with no power transport (the Poynting vector is zero). In general, the relativistic 4-vector potential $\mathbf{A}, \phi$ results in zero field vectors in the far zone when $\mathbf{A}$ is purely longitudinal (polarized in the direction of propagation).

It is abundantly clear, from the above theoretical and empirical evidence, that the received practice of assigning to the vector potential a purely non-physical status in CED, has been first of all premature, extraordinarily misplaced, and essentially ill-conceived. Accordingly, the related emphasis on placing only the field vectors $\mathbf{E}$ and $\mathbf{B}$ (and their six 3-space components) as the sole basis of electromagnetism, has come to markedly disagree with quantum electrodynamics where the covariant 4-vector potential has the intrinsic ability to describe the momentum-energy state of an electromagnetic system; the inevitable result is a science of electromagnetism unnaturally split into two branches with contradicting views on the basics.

Moreover, make no mistake about it, these discussed experimental protocols outlining the apparent paradoxes with the potentials, are not mere trivial flukes that can be written off as minor peccadillos incapable of changing the standard view of the role of the latter – they represent major flaws preventing a fuller proper understanding of CED. Indeed, as we will show, failure to recognize the import of these relatively simple low-energy processes involving the curl-free vector potential, has totally masked a new dimension of electrodynamics that has yet to be appreciated and exploited.

In order to reveal the hidden frontiers of CED, and repair cracks in its current edifice, two directives must be implemented. First, as we have argued in this paper, is to acknowledge the physical significance of the potentials at all levels of nature. Classical physics has for far too long, taken a non-productive non-holistic - almost schizoid stance - when it comes to interpreting the role of the potentials which, as stated above, and forcefully repeated here, has caused an unnatural separation of electromagnetism into two branches – quantum and classical – with conflicting views on its foundational elements.

Part of the reason for this unsettling split, has been the common practice of assigning specific so-
called “gauge restraints” on the potentials for solving particular problems in electromagnetism in order to fix boundary conditions for either the process of finding proper electric and magnetic fields from given charge and current distributions or for the inverse problem. Accordingly, the usual electromagnetic theory then specifies that the potentials may be chosen arbitrarily, based on the specific so-called gauge that is chosen for this purpose. The gauge is a supplementary condition which is injected into Maxwell’s equations, expressed as a function of the potentials. This convention is now so engrained in the practice of CED that it is now considered to be a de rigueur requirement. Yet, while effective as a mathematical tool, the setting of a gauge places undue restriction on the potentials; for instance the Lorenz gauge, makes the scalar and vector potentials totally dependent on each other.

Consequently, we propose the second directive –confluent with the first – to make the potentials completely independent of one another, resulting in a unique purely “gauge-free” electrodynamics. This novel prescription also closely follows the principle of Occam’s razor, which dictates that a system of scientific knowledge should not introduce concepts or entities that are not strictly necessary, emphasizing the simplicity and conciseness of the model. Consequently, a wholesale reinterpretation of Maxwell’s equations is proposed without gauged potentials. Also, according to Occam’s razor, this reformulation must also of necessity, invoke the constraint that the electromagnetic 4-potential, as per the Minkowski space-time prescription, should be considered as an inseparable single unit entity. This ansatz will give rise to an electromagnetic field composed not only of the six-component classical vectorial electrical field intensity and magnetic flux density, but also by a scalar longitudinal field. This hypothetical entity has often been referred to by various sources with the equivalent alternate terminology as an electroscalar field. Later we will clarify appropriate use for these two designations.

Although few researchers have considered this possibility, notable key exceptions are the work by Bettini [27,28], the Lagrangian given in Aharonov & Bohm [29], and that introduced earlier by Fock & Podolsky [30], papers by Arbab [31,32], Tomlin [33], van Vlaenderen [33,34], Vassallo et al.[36], two papers by Hively [37,38], and the central scholarly recent series of dissertations by the mathematician-physicist Woodside [39-41]. The last two researchers have done yeoman’s work of monumental scope in formulating the basics of this vanguard model. For instance, to touch base with actual viable real-world applications based on this gauge-free CED, we shall focus on the recent revealing groundbreaking 2016 patent issued to physicist Lee M. Hively [42], the embodiments of which receive solid support from from a brilliant rigorous first-principles demonstration of the existence of of the scalar longitudinal field by Dale A. Woodside [39]. The related emergence of the scalar longitudinal wave (SLW) will then be naturally derived, whose existence will be shown to produce many interesting implications and consequences of electrical charges and currents. Although empirical findings of mostly an anecdotal nature of the unconfirmed occurrence of such a non-Hertzian SLW have emerged over the years (e.g., Tesla [43], Monstein & Wesley [44], Meyl [45]), they have been summarily discounted by mainstream physics and efforts of the corresponding researchers generally maligned. However, as technology inexorably drives this understanding forward via the concrete embodiments outlined in the landmark Hively patent, we are certainly approaching a time where these findings can no longer be pushed aside and ignored by orthodox physics, and physics must come to terms with their potential physical and philosophical impacts on our world society.

3 Emergence of the scalar longitudinal electrodynamic wave

Insight into the incompleteness of electrodynamics can begin with the Helmholtz theorem which states that any sufficiently smooth three-dimensional vector field can be uniquely decomposed into two parts: irrotational and solenoidal. By extension, a generalized theorem now exists, certified by the recent work of Dale A. Woodside [39-41], for unique decomposition of a sufficiently smooth Minkowski four-vector field (three spatial dimensions plus time), into four-irrotational and four solenoidal parts, together with the normal and tangential components on the bounding surface. With this background, the theoretical existence of the electroscalar field can be attributed to the failure to include certain terms in the standard Stuckelberg four-dimensional electromagnetic Lagrangian density that are related to the four-irrotational parts of the vector field.:
\[ L = -\frac{e c^2}{4} F_{\mu \nu} F^{\mu \nu} + J_\mu A^\mu - \frac{\gamma e c^2}{2} (\partial_\mu A^\mu)^2 - \frac{e c^2 k^2}{2} (A_\mu A^\mu), \]  
\[ (7) \]

\( F^{\mu \nu} \) is the Maxwell tensor, \( c \) is speed of light, \( c^2 = 1/\mu \varepsilon \) (not necessarily vacuum); the 4-current is \( J_\mu = (\rho c, J) \); the 4-potential is \( A_\mu = (\Phi/c, A) \). Here, \( \varepsilon \) is the electrical permittivity – not necessarily that of the vacuum. Now, \( k = 2\pi mc/\hbar \) must be zero, otherwise the existence of the last term implies massive photons which has been shown to be essentially false, since the upper bound for photon mass, if it exists at all, has determined to be \( \sim 10^{-53} \text{kg} \). Specifically, the electroscalar field becomes incorporated into the structure of electrodynamics if we let \( \gamma = 1 \) and \( k = 0 \). As we can see in this representation, it is the presence of the third scalar-valued term that describes these new features.

\[ L_{EM} = \frac{e c^2}{2} \left[ \frac{1}{c^2} \left( \nabla \Phi + \frac{\partial A}{\partial t} \right)^2 - \left( \nabla \times A \right)^2 \right] - \rho \Phi + J \cdot A - \frac{e c^2}{2} \left( \frac{1}{c^2} \frac{\partial \Phi}{\partial t} + \nabla \cdot A \right)^2 \]  
\[ (8) \]

We can see more clearly how this term arises by writing the Lagrangian density in terms of the standard scalar \( \Phi \) and magnetic vector potentials \( A \) for a massless 4-vector field \( A_\mu \) that is no more than quadratic in its variables and derivatives:

We will see that it is the relationship between the potentials that underscores the disclosure of the missing electroscalar field and its hitherto unsuspected key role in electrodynamics. First, equation 8 allows only two potentially physical classes of 4-vector fields [40]. As case in point, without the last term, equation (8) describes zero 4-divergence of \( A_\mu \) (which we have formally called four-solenoidal above). The second class of four-vector fields has zero 4-curl of \( A_\mu \), \( F^{\mu \nu} = \partial^\mu A^\nu - \partial^\nu A^\mu = 0 \) (four-irrotational vector field). This will emerge if and only if this last scalar factor term is included, as represented by the total Lagrangian density above. In fact the expression in the parentheses in this term, when set equal to zero, describes the Lorenz condition, as was mentioned previously, which restricts the scalar and vector potentials in their usual form, to be mathematically dependent on each other. However, as we have stressed above, the new model allows for a non-zero value for this scalar-valued expression, achieving the directive of making the potentials completely independent of one another. This results in the previously stated gauge-free electrodynamics, where this new scalar-valued component \( C \), is a dynamic function of space and time represented by the following relation:

\[ C = \nabla \cdot A + \frac{1}{c^2} \frac{\partial \Phi}{\partial t}; \]  
\[ (9) \]

As can be clearly seen, application of the Lorenz gauge, where \( C = 0 \), totally denies the status of real physical entity to the scalar field. However, it is this new idea of the independence of the potentials in this gauge-free electrodynamics out of which the scalar value \( C \) is derived, and from which the unique properties and dynamics of the scalar-longitudinal electrodynamic wave arises.

A more complete electrodynamic model may be derived from equation (8) of the Lagrangian density. The Lagrangian expression is important in physics, since invariance of the Lagrangian under any transformation gives rise to a conserved quantity. Now, as is well known, conservation of charge-current is a fundamental principle of physics and nature. Conventionally, in classical electromagnetics charged matter creates an electric \( E \) field. Motion of charged matter creates a magnetic \( B \) field from an electrical current which in turn influences the \( B \) and \( E \) fields. These dynamics produce what is known as transverse wave excitations perpendicular to the direction of propagation. These effects can be modelled by Maxwell’s equations. Now, exactly how and to what degree do these equations and dynamics of \( E \) and \( B \) change when we include the new scalar factor of \( C \).

Those who are familiar with classical electrodynamics will notice the two homogeneous Maxwell’s
equations – representing Faraday’s law and the standard Gauss-Ostragradsky equation for divergenceless magnetic field, are both unchanged from the classical model.

\[ C = \nabla \cdot A + \frac{1}{c^2} \frac{\partial \Phi}{\partial t}; \]  
\[ \nabla \cdot E + \frac{\partial C}{\partial t} = \frac{\rho}{\varepsilon}; \]  
\[ \nabla \times B - \frac{1}{c^2} \frac{\partial E}{\partial t} = \nabla C = \mu J; \]  

However, notice the above three new eqns. incorporate this new scalar component which is labelled \( C \). This formulation as defined by new eqn. (10), whose construction we observed above, creates a radical revision of Maxwell’s equations, with one new term \( (\partial C/\partial t) \) in Gauss-Ostragradsky Law for the electrical field (eqn.11), where \( \rho \) is the charge density, and one new term \( (\nabla C) \) in Ampere’s Law (eqn. 12), where \( J \) is the current density. We see these new eqns. lead to some important conditions. First, relativistic covariance is preserved. Second, the classical fields \( E \) and \( B \) are unchanged in terms of the usual classical potentials (\( A \) and \( \Phi \))-see equations (1),(2). We have the same classical wave eqns. for \( A \), \( \Phi \), \( E \) and \( B \) without the use of a gauge condition (and its attendant incompleteness). The EED theory shows cancellation of \( \partial C/\partial t \) and \( \nabla C/\mu \) in the classical wave equations for \( \Phi \) and \( A \); and a scalar-longitudinal wave (SLW) is revealed, composed of two interdependent agents: the scalar field \( C \) we spoke of above, and a concomitant longitudinal-vectorial electric field whose origin we will speak of next. The term longitudinal wave refers to a wave that has excitations which are parallel to the direction of propagation.

\[ \frac{\partial^2 C}{\partial t^2} = \nabla^2 C \equiv \Box^2 C = \mu \left( \frac{\partial \rho}{\partial t} + \nabla \cdot J \right). \]  

This can be more clearly seen to emerge by examining the new wave equation for \( C \), which is revealed by use of the time derivative of (eqn. 11), added to divergence of (eqn. 12). Now, as is known, matching conditions at the interface between two media with different electrical properties are required to solve Maxwell’s eqns. Interface matching conditions for (13) uses a Gaussian pill box with end faces parallel to the interface in regions ‘1’ and ‘2’. In the limit of zero pill box thickness, the divergence theorem can be used on eqn. (13) will yield interface matching in the normal component (‘\( n \)’) of \( \nabla C/\mu \) as shown in eqn. (14). The subscripts in eqn. (14) denoted by \( \nabla C/\mu \) in medium 1 or medium 2, respectively. (\( \mu \) is magnetic permeability – again not necessarily that of the vacuum). In this regard, with the vector potential (\( A \)) and scalar potential (\( \Phi \)) now stipulated as independent of each other, this significantly changes the usual matching conditions between the two media.

\[ \left( \frac{\nabla C}{\mu} \right)_1 = \left( \frac{\nabla C}{\mu} \right)_2, \]  

For instance, it is now the surface charge density at the interface which produces a discontinuity in the gradient of the scalar potential (\( \Phi \)), which is inconsistent with the standard (CED) discontinuity in the normal component of \( E \). Also, it should be noted that the wave equations for \( A \), \( \Phi \), \( E \), and \( B \) are unchanged under time reversal; \( t \to -t \), produces a sign change on both sides of equation (13) that also involves time invariance. The sign change in \( C \) indicates its pseudoscalar nature. The time reversibility of EED implies that reciprocity holds; a SLW transmitter can also be used as a receiver. Above all, there are truly remarkable properties of this new wave equation. Notice from eqn. (13), the driving factor or source for the scalar field \( C \) implies a violation of charge-current conservation (RHS non-zero), a
instance, focusing on the scalar component, we then use structure then informs the various terminology that has been invoked to describe the phenomenon. For counterpart in a push-pull fashion. Interestingly, the nature of this unique two-fold electrodynamic wave description.

Now, the above noted fact that $B=0$ for the SLW, implies no back electromagnetic field from $\partial B/\partial t$ in Faraday’s law which in turn gives no circulating eddy currents conventionally subject to Lenz’s Law. Accordingly, corresponding experimentation by Hively’s team has shown that the SLW is not subject to the skin effect in media with linear electric conductivity, and travels with minimum resistance in any conductive media. This is unprecedented in the annals of electrodynamics. This significant property of the SLW certainly has great bearing on many practical issues, not only on the future engineering protocol for generating of widespread wireless power efficiently and abundantly, but speaks directly to the current state of weaknesses in the world electrical grid and currently unknown or unsuspected future demands which might be placed on our aging power production and distribution systems by possible extreme climate effects.
In summary Fig. 3 shows the key structural differences in standard CED versus EED (Gauge-Free Electrodynamics). In addition to the standard CED side of things in which a restricted dependence of the potentials necessarily leads to solenoidal (circulating currents) and the concomitant transverse electromagnetic wave, we have this whole new dimension of gauge-free electrodynamics resulting from the assumption of independence of the potentials that is now ripe for exploration. In the above cited protocols, the VPT is just one of these many new innovations that exploits the gradient-driven current SLW and its important feature of lack of attenuation that, as was earlier stated, has the potential to produce a virtual revolution in how electricity is generated and distributed.

From the new EED model, many potential transformational principles have emerged to challenge the current landscape of electrodynamics. Here we summarize some of these unique properties of the scalar-longitudinal wave. Five of these seven properties have been verified by Hively’s team, setting the stage for understanding the specific technological aspects of the Hively patent. Please note: the equation numbers correspond to those of Hively’s specific equations in his patent – not those of this paper.

| Item number and specific SLW property | Equation(s) |
|--------------------------------------|-------------|
| 1) C is a dynamical quantity (scalar field). | EQN. 3-7 |
| 2) C is driven by gradients in J and \( \partial E/\partial t \). | EQN. 6 |
| 3) SLW propagates in conductive media without the skin effect. | EQNS. 8-12 |
| 4) Interface matching involves continuity in (VC/µ),. | EQN. 10 |
| 5) A longitudinal E-field accompanies C, as an SLW. | EQNS. 11-17 |
| 6) C, E, and J exchange energy in conductive media. | EQNS. 11-17 |
| 7) \( C/E \equiv 1/c \) in conductive media, allowing normal instrumentation. | EQN. 13 |

From the above considerations, it can be seen how the SLW has not been acknowledged theoretically as part of the structure of classical electrodynamics. Compounding this issue is corresponding failure to physically detect this phenomenon. The reason this SLW has not been detected can be attributed to the fact that all electromagnetic antennas are of the dipole-type, designed to detect only TEM and the solenoidal current that is its foundation, and not the longitudinal wave which is a function of gradient-driven current dynamics, which requires a monopole antenna, as will now be described. Concerning the specific engineering embodiments in the Hively patent required to reveal these unique effects. Fig. 4 illustrates a cross-sectional view of a linear monopole antenna apparatus. In the middle is a first conductor (202), a tubular second conductor (204) and an annular skirt balun (206). The balun is configured to cancel most or all of the returning current on the outer surface of the second conductor.
This is achieved with the length of the balun being one-quarter of a wavelength corresponding to the first operating frequency. The skirt balun (of ¼ wavelength) causes a phase shift in in the current flow along the guided path from the bottom (inside surface) of the outer balun (0°), to the top (inside surface) of the skirt balun (90°) and back down the outer surface of the coax outer to the end of the balun (180°). The 180° phase shift cancels the return current flow along the outside of the outer coaxial conductor. During operation an electric current on the balun is appx. 180° out of phase relative to the electric current wave on the outer surface of the second conductor adjacent to the balun thereby cancelling the return current on the outer surface of the second conductor, effectively creating a zero magnetic field, which in turn is a necessary and sufficient condition for producing the SLW. Thus, essentially all the electric current goes into charging and discharging the antenna.

![Figure 4: Cross-section of SLW monopole antenna](image)

Also, from Hively’s 2016 patent, Figure 5 illustrates an alternate method to produce the same results - a bifilar coil apparatus configured to transmit and/or receive scalar-longitudinal waves. The first and second conductor making up this coil are conductively coupled such that an electric current in the coil will propagate in opposite directions in adjacent turns of the coil, represented by the alternate dotted (704) and solid (702) lines, thus cancelling any magnetic field so that during the operation the coil transmits or receives only scalar-longitudinal waves. The coil is thus configured to create a gradient-driven current, which arises from the magnetic field cancellation, and has zero inductance due to counter-going electrical currents in adjacent turns of the coil. Also, there is zero capacitance as a result of adjacent coil turns having the same electric charge density. This bifilar coil is a two-dimensional monopole that accumulates positive and negative charge over each sinusoidal cycle. We will return to discuss other interesting potential implications of this patent for power generation and conversion later.

![Figure 5: Bifilar-coil-type SLW monopole antenna](image)

4. Evidence of the SLW in patents, and in nature - both inanimate and biological
For now, let’s look at other patents that may indicate dynamics of an electroscalar nature. Larry Park has invented a device [46] that has apparently detected seismic precursor earthquake signals earlier than any
previous systems of this type. His device detected SPI (single phase impulses) and MPB (multiple phase bursts) signals in strong correlation with earthquakes actually occurring 8 to 80 hours later. These unique impulses are induced by slow pressure variations in the crust of the Earth from the breaking of chemical bonds as the rock fractures, leaving positive and negative charges on opposite sides of the fault. Eventually enough charge builds up to cause current flow (arching) across the fault. This gradient-driven current creates the SLW. Although Park assumed he was detecting TEM, nevertheless, these signals, unlike anything previously detected from movement of the Earth crust as precursor seismic activity manifest as low frequency waves w/ high frequency signals imposed thereon and travelling through matter itself. These scalar longitudinal waves produced are saturated over the frequency spectrum – as being spectrally rich. This description is one reason why these detected signals may be scalar-wave mediated. Another reason why is clearly evident from the depiction of the coil windings in the Park patent [46]. Notice the characteristic flat pancake coils illustrated earlier in the Hively patent, specifically designed to eliminate inductance and capacitance in order to create the gradient-driven current, enabling this detector to be sensitive to scalar longitudinal seismic wave precursor signals from Earth movement.

Figure 6: Possible registration of scalar solar radiation

Thus, we see that the SLW may already be a dynamical feature of natural phenomena. The scalar-longitudinal wave may be a feature of some astrophysical phenomena, particularly highlighting its enormous predicted penetration power. The most favorable conditions for the registration of solar electroscalar radiation was realized by Russian researchers during the eclipse of the sun in Aug. 2008 [47]. During the eclipse the moon shields most of the flux of the transverse electromagnetic solar waves, while the longitudinal waves, having greater penetration power, do reach the Earth’s surface. The incident solar radiation may lead to self-excited radial oscillations in conductive substances. Specifically, the EED theory predicts that a charged sphere, oscillating in a ballooning (monopolar) mode will radiate the SLW, and that higher order (multi-pole) oscillations will also create the SLW. Considering this physics, metallic spheres were used to measure such radiation. This protocol had four copper spheres placed in a metallic box (Faraday cage), connected to each other’s centers by a copper wire. The Faraday cage protocol eliminates any possible registration of TEM radiation. The result of measurements are shown in this Fig. 6. Notice how the maximum effect occurred at the peak of the eclipse. Now, since the detection of solar electroscalar energy should technically occur anytime the moon is between the Earth and the sun, the amplification of the signal would be expected during the regular monthly new moon phase. This result was also seen by the Russian team [47]. Unfortunately, since no other independent groups have attempted to duplicate this expt., there is controversy as to the veracity of these claims.

\[
\frac{\varepsilon \mu}{\partial t} \left( \frac{E \times B}{\mu} - \frac{CE}{\mu} \right) + J \times B + \rho E - CJ + \nabla \times BC = \nabla \cdot \vec{T} + \nabla \frac{C^2}{\mu}. 
\]

\[
\frac{\partial}{\partial t} \left( \frac{B^2}{2\mu} + \frac{C^2}{2\mu} + \frac{\varepsilon E^2}{2} \right) + \nabla \cdot \left( \frac{E \times B}{\mu} + \frac{CE}{\mu} \right) + J \cdot E - \rho \frac{C}{\varepsilon \mu} = 0.
\]
This brings us back to the particulars of the Hively patent that might exploit this solar SLW to generate electrical power. Accordingly, the sun is a very hot ball of charged particles (electrons and ions in a plasma) that undergoes longitudinal oscillations producing a radial gradient-driven current density. A specific application of this patent involves electric power generation on the basis of new terms in the momentum balance eqn. (17). Here $T$ represents the Maxwell stress tensor. More specifically electrical power can be generated by charging a flat-plate capacitor to give a large directed $E$-field. Then SLW emission from the sun will generate force variations across the capacitor plates via the term $(CE/\mu)$ in this equation, corresponding to a voltage to yield a power-producing current. This power is thus proportional to $E$ (and therefore to the capacitor voltage) and the solar SLW emissions $C$. The variable-frequency power can then be rectified, and subsequently be converted to alternating current via an alternator. It is this term $(CE/\mu)$ that implies the possible transmission of wireless power over large distances in a directed fashion. When we add the new energy-balance eqn. (18) to the new momentum-balance equation, we see another practical role for this key term $(CE/\mu)$. It may correspond to an increase (or decrease) in longitudinal electrodynamic momentum in equation. (17) along the direction of motion, with a concomitant decrease (increase) in electrical energy as per equation (18). Because of the sign difference for this term in both eqns. there arises an inverse-intensive relationship. Specifically, longitudinal electrodynamic power loss (or gain) may drive a corresponding kinetic energy gain (loss) in the physically massive object that is emitting these waves. Consequently, EED theory may predict a propulsion mechanism without the use of propellant mass.

Looking at the significance of another key term in these equations, specifically, EED theory predicts a new term $(CJ)$ in eqn. (17). As previously noted, the longitudinal electric field $E$ induces an electric current density ($J$) in any distant conductive object in its path according to their direct proportionality. Thus, the concomitant presence of a scalar field $C$ may interact with this current to produce a force $(CJ)$ on the distant object. By the use of a phased array of SLW emitters, the relative phase of $E$ (and thus $J$) may be shifted with regard to the phase of $C$. This may then produce the engineering equivalent of a “tractor” beam. Another reason for the significance of the new term $(CJ)$, may be in supporting the experimental evidence for what is known as Weber electrodynamics, which involves forces that are parallel to the electrical current density $(J)$. The specific controversial tests which have claimed to justify this thesis included: the force on Ampere’s bridge, the tension to rupture current-carrying wires, the force on the Graneau-Hering submarine, the mercury-driving force in Hering’s pump, and the oscillation-driving force in a current-carrying mercury wedge. These test results [48] are not inconsistent with – and may be implied by - the new force term $(JC)$ in eqn. (17); namely, the force is independent of the electrical current’s direction, since $JC \sim (\text{current})^2$ in the conductor with a gradient-driven current.

![Figure 7: Spectral output of radiation as a function of tape angle](image)

Surprisingly, the protocol for producing the electroscalar field may extend to embrace some of the more mundane phenomena in which very low energy levels of excitation are required. As a possible case
in point, in the 300 or so year history of electrodynamics, tribo-electrification is one of the least understood electrical phenomena and up to present it has not been shown how to derive it from first principles. Triboelectrification refers to the process of separating positive and negative charges by means of mechanical action. Now, over the course of the last 100 years, x-ray imaging has conventionally relied upon the availability of a high-voltage supply to accelerate electrons to sufficient energies for x-ray emission. It is thus no less surprising that in 2008 [49] it was revealed that, hitherto unsuspected, x-ray energies can be generated by the common tribo-electrification process of peeling ordinary adhesive tape in low pressure or vacuum. According to mainstream physics, similar to atmospheric lightning, the precise method of charge separation is still unknown. However, once again we see the theme of chemical bond breaking re-surfacing, which leaves positive and negative charges on opposite sides of the interface. The charge buildup eventually causes arcing and possible production of a gradient-driven current producing the SLW.

Specifically, in this protocol, the mechanical energy of tape peeling creates electrostatic energy due to charge separation, and the breaking of adhesive (chemical) bonds. Electrons that are accelerated, when striking the opposite side of the tape produce photons to conserve momentum. Now, according to the CED view, it is believed these high energy photons produce transverse bremsstrahlung (or braking radiation). However, the transient charge densities of $10^{12}$ electrons/cm$^2$, was more than an order of magnitude greater than is measured in typical tribo-charging systems; This also indicates support for a model including the SLW that may be required for explanation of these observations.

More conundrums surfaced to challenge the current model as to the actual nature of the radiation produced [50]. As case in point, there has been a significant doubt raised as to why the spectral frequency of the radiation does not correspond to that commonly understood to be a signature of bremsstrahlung or polarizational bremsstrahlung. This has been particularly true since the output of spectral radiation frequency is a function of the angle between the tape and normal to the tape surface, as depicted in this graph in Fig. 7, measuring photon count rate as a function of this tape angle. This graph clearly shows that ordinary bremsstrahlung would smoothly bound the angular distribution from below, while polarizational bremsstrahlung bounds the angular distribution from above. However, interestingly, neither mechanism shows the 20% highly discontinuous rise/fall in sharp angular distribution between $80^\circ$ - $100^\circ$. Now, according to theory of electroscalar radiation the SLW is considerably more penetrating in matter due to not being subject to the skin effect, and might explain this anomalous angular radiation distribution. Thus, humble physical objects such as adhesive tape may reveal the existence of electroscalar radiation.

Fig. 8. Alteration of index of refraction on human blood plasma by irradiation from TC (TESLAR chip)

The scalar longitudinal wave may also be an inherent component of human biophysical systems as well, affecting the alpha brain wave rhythm, the parametric resonance of organs, and could be responsible for primary human perception. One of these devices that is claimed to have measurable
biological effects is known as the TESLAR watch. Its inventors have asserted that it produces a SLW at very low frequency. In testing this instrument, Rein [51] has showed that the presence of the TESLAR chip (TC) showed 137% enhancement of human lymphocyte proliferation (immune system). Another test demonstrated that nerve cells could inhibit their uptake of noradrenalin (depression-fighting process) by as much as 19.5% in presence of the TESLAR watch.

The Krasnoholovets comprehensive studies are particularly relevant in this regard. For instance, in Fig. 8 [52], we see the results of laser irradiation on an aqueous highly non-equilibrium solution of human blood plasma, demonstrating the change in the index of refraction ($n$) of the liquid over a short period of time (~1 min.) causing definite changes in fringe patterns of laser light, by operation of a TESLAR watch. The possible effects of temperature on the solution’s index of refraction by the heating of the laser light was ruled out since the maximum change of $n$ of the blood protein solution by the TC was an order of magnitude higher than that predicted from the temp change. It should be noted here that all living processes involve concentration gradient-driven ion currents across the cellular membrane. Imposing a SLW on living cells will alter these currents. The TC apparently alters the currents in a therapeutic fashion.

Also, changes of $n$ are produced by changes in the structure of the network of hydrogen bonds of water. This last effect was demonstrated by the same team in a dramatic fashion when examining effects by the TC [53]. For instance, in another embodiment of an experimental protocol test showed the results of irradiation by the TC on the infrared spectrum of the evaporation of an aqueous solution of hydrogen peroxide. The spectra demonstrated that the TESLAR watch suppresses the vibration of the molecules in the solution and, in particular, strongly freezes vibrations of O–H bonds. Thus it was concluded that the TC can strongly affect a significantly non-equilibrium system. In this regard, the physics here alters the chemical potential in the molecules via a bond angle change, not unlike modifying the nuclear potential in a nucleus.

Other experiments demonstrate the EED feature of irrotational (gradient-driven current) that was discussed in section 3 (for example): arc discharges [49,50], ion-concentration-gradient-driven current across living cell walls [54], atmospheric pressure gradient-driven current [55], and irrotational electroencephalogram current [56].

5. Conclusions and prospects
The above represent adequate examples to show the field of electrodynamics (classical and quantum) is incomplete. In this regard, the experimental evidence shows that classical electrodynamics was seriously remiss in terms of omitting the electroscalar component. Anomalies previously not completely understood may get a boost of new understanding from the operation of electroscalar energy. We have seen in the three instances examined – the mechanism of generation of seismic precursor electrical signals due to the movement of the Earth’s crust, the ordinary peeling of adhesive tape, as well as irradiation by the special TESLAR chip, the common feature of the breaking/altering of chemical bonds. In fact, we may ultimately find that any phenomena requiring the breaking of chemical bonds, in either inanimate or biological systems, may actually be scalar-wave mediated. Thus, we may discover that the scientific disciplines of chemistry and/or biochemistry may be more closely related to physics than is currently thought. It may even turn out that the gradient-driven current, and associated scalar-longitudinal wave could be the umbrella concept under which many of the currently unexplained electrodynamic phenomena might find a satisfying explanation.

Above all, these new findings provide an able challenge to the worldview by physicists that the magnetic vector potential $A$ is just a mathematical device and has no physical reality in the description of electrodynamics, unlike the electric and magnetic field intensities. The Maxwell-Lodge effect, as certified by the empirical evidence of such devices as the VPT, unquestionably now raises the significance of the magnetic vector potential to primary status, not only in quantum mechanics where the Aharanov-Bohm effect holds sway, but boosting its respectability in classical electrodynamics through appreciation of the compelling elements of the gauge-free electrodynamics system. The new scalar longitudinal wave patent itself [42] is a primary example of the type of invention that probably
would not have seen the light of day even ten years ago. Now, its existence may represent a real game changer in this area. It will unquestionably bring the subject of scalar electrodynamics to the sharpest positive focus it has been to date. Not only will it provide the springboard for development of the long sought-for sound theoretical basis for the inclusion of the SLW in electrodynamics, motivate a re-evaluation of the current structure of CED in regards to model completeness and consistency, but is destined to forecast a paradigm revolution in our modes of energy generation and power conversion.

Despite what mainstream physics may claim, the study of classical electrodynamics is by no means a closed book. On a grander panoramic scale, our expanding knowledge gleaned from further examining the electro-scalar wave concept, as applied to areas of investigation such as developing wireless sources of energy, etc., will explicitly shape the future of society as well as science, especially concerning our openness to phenomena that challenge our current belief systems.

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