A GENERALISATION OF CLASSICAL ELECTRODYNAMICS FOR THE PREDICTION OF SCALAR FIELD EFFECTS

Koen J. van Vlaenderen
Institute for Basic Research
P. O. Box 1577, Palm Harbor, FL 34682, USA
koenvanvlaenderen@wanadoo.nl

Within the framework of Classical Electrodynamics (CED) it is common practice to choose freely an arbitrary gauge condition with respect to a gauge transformation of the electromagnetic potentials. The Lorenz gauge condition allows for the derivation of the inhomogeneous potential wave equations (IPWE), but this also means that scalar derivatives of the electromagnetic potentials are considered to be *unphysical*. However, these scalar expressions might have the meaning of a new physical field, S. If this is the case, then a generalised CED is required such that scalar field effects are predicted and such that experiments can be performed in order to verify or falsify this generalised CED. The IPWE are viewed as a generalised Gauss law and a generalised Ampère law, that also contain derivatives of S, after reformulating the IPWE in terms of fields. Since charge is conserved, scalar field S satisfies the homogeneous wave equation, thus one should expect primarily sources of dynamic scalar fields, and not sources of static scalar fields. The collective tunneling of charges might be an exception to this, since quantum tunneling is the quantum equivalent of a classical local violation of charge continuity. Generalised power/force theorems are derived that are useful in order to review historical experiments since the beginning of electrical engineering, for instance Nikola Tesla's high voltage high frequency experiments. Longitudinal electro-scalar vacuum waves, longitudinal forces that act on current elements, and applied power by means of static charge and the S field, are predicted by this theory. The energy density and field stress terms of scalar field S are defined. Some recent experiment show positive results that are in qualitative agreement with the presented predictions of scalar field effects, but further quantitative tests are required in order to verify or falsify the presented theory. The importance of Nikola Tesla's pioneering research, with respect to the predicted effects, cannot be overstated.

1. Introduction

In general, the Maxwell/Heaviside equations, completed by the Lorentz force law, are considered to be a complete theory for classical electrodynamics [12]. In differential form these equations are:

$$\vec{\nabla}\cdot\vec{E} = \frac{\rho}{\epsilon_0} \qquad \text{Gauss law} \tag{1}$$

$$\vec{\nabla}\times\vec{B} - \epsilon_0\mu_0\frac{\partial\vec{E}}{\partial t} = \mu_0\vec{J} \qquad \text{Ampère law} \tag{2}$$

$$\vec{\nabla}\times\vec{E} + \frac{\partial\vec{B}}{\partial t} = \vec{0} \qquad \text{Faraday law} \tag{3}$$

$$\vec{\nabla}\cdot\vec{B} = 0 \tag{4}$$

The electric and magnetic field can be defined in terms of the electromagnetic potentials, Φ and $\vec{A}$:

$$\vec{B} = \vec{\nabla}\times\vec{A} \tag{5}$$

$$\vec{E} = -\vec{\nabla}\Phi - \frac{\partial\vec{A}}{\partial t} \tag{6}$$

The Maxwell/Heaviside equations are *invariant* with respect to a gauge transformation, defined by a scalar function χ:

$$\Phi \longrightarrow \Phi' = \Phi + \frac{\partial\chi}{\partial t} \tag{7}$$

$$\vec{A} \longrightarrow \vec{A}' = \vec{A} - \vec{\nabla}\chi \tag{8}$$

$$\vec{B} \longrightarrow \vec{B}' = \vec{B} \tag{9}$$

$$\vec{E} \longrightarrow \vec{E}' = \vec{E} \tag{10}$$

because the electromagnetic fields $\vec{E}$ and $\vec{B}$ are invariant with respect to this transformation. This means that for each physical situation there is not a unique solution for the potentials Φ and $\vec{A}$, because a particular solution for Φ and $\vec{A}$ can be transformed into many other solutions via an arbitrary scalar function χ. From the set of all equivalent electromagnetic potential functions, one can choose freely a particular subset such that these potentials satisfy an extra gauge condition, such as

$$S = -\lambda_0\epsilon_0\mu_0\frac{\partial\Phi}{\partial t} - \vec{\nabla}\cdot\vec{A} = 0 \tag{11}$$

When $\lambda_0 = 1$ this condition is known as the Lorenz gauge condition [11], and when $\lambda_0 = 0$ one speaks of the Coulomb gauge condition. This generalised gauge condition was introduced by H. Helmholtz, (see, e.g., [4,7]. A similar gauge condition was used by A.E. Chubykalo and V. Onoochin [3] for the derivation of potential wave equations with arbitrary speed. For potentials that satisfy $S = 0$, we can cast the Gauss law and the Ampère law in the form of two decoupled inhomogeneous potential wave equations:

$$\lambda_0\epsilon_0\mu_0\frac{\partial^2\Phi}{\partial t^2} - \vec{\nabla}^2\Phi = \frac{\rho}{\epsilon_0} \tag{12}$$

$$\lambda_0\epsilon_0\mu_0\frac{\partial^2\vec{A}}{\partial t^2} + \lambda_0\vec{\nabla}\times\vec{\nabla}\times\vec{A} - \vec{\nabla}\vec{\nabla}\cdot\vec{A} = \lambda_0\mu_0\vec{J} \tag{13}$$

which are the inhomogeneous potential wave equations (IPWE). For $\lambda_0 = 1$, a class of solutions of these differential equations are the retarded potentials, and in particular the Liénard-Wiechert potentials [10, 25]. For $0 < \lambda_0 < 1$ the longitudinal $\vec{A}$ potential waves and the Φ potential waves are superluminal. The Coulomb gauge can be interpreted as potential waves with infinitely great speed, or instantaneous action at a distance.

This philosophy of gauge transformation seems to be reasonable, but a verification/falsification of it by means of experiments is impossible, which is in sharp contrast with the idea of physics as an emperical science. A very different approach is to regard the IPWE as generalised Gauss and Ampère laws. Like James C. Maxwell, who added the famous displacement current term to the Ampère law, one can add derivatives of expression S to the Maxwell/Heaviside equations:

$$\vec{\nabla}\cdot\vec{E} - \frac{\partial S}{\partial t} = \frac{\rho}{\epsilon_0} \tag{14}$$

$$\vec{\nabla}\times\vec{B} + \frac{1}{\lambda_0}\vec{\nabla}S - \epsilon_0\mu_0\frac{\partial\vec{E}}{\partial t} = \mu_0\vec{J} \tag{15}$$

$$\vec{\nabla}\times\vec{E} + \frac{\partial\vec{B}}{\partial t} = \vec{0} \tag{16}$$

$$\vec{\nabla}\cdot\vec{B} = 0 \tag{17}$$

The addition of these derivatives of S automatically yield the decoupled potential wave equations without the need for an extra gauge condition. These field equations are a generalisation of classical electrodynamics, since the special case $S = 0$ results into the usual Maxwell/Heaviside equations, and they are variant with respect to an arbitrary scalar gauge transformation χ:

$$S \longrightarrow S' = S - \left(\lambda_0\epsilon_0\mu_0\frac{\partial^2\chi}{\partial t^2} - \vec{\nabla}^2\chi\right) \tag{18}$$

unless χ is a solution of the homogeneous wave equation. The expression S now has the meaning of a physical and observable scalar field. This scalar field interacts with the vector fields $\vec{E}$ and $\vec{B}$, as described by the generalised field equations. The question: "Is classical electrodynamics a *complete* classical field theory, with respect to scalar expression S?", can not be answered within the context of the standard Maxwell/Lorentz theory, since this theory treats S as a non-observable non-physical function, and this is premature. The usual gauge freedom and gauge condition $S = 0$ are based on the presumption that partial derivatives of S are not part of complete set of field equations in the first place, which implies that S is disregarded as a physical field even before the theoretical development of the gauge transformation. In other words, the assumed gauge freedom and free choice of gauge conditions are part of a sequence of *circular* arguments, that seem to "prove" that S has no physical relevance. Oliver W. Heaviside did not like the abstract electromagnetic potentials and he preferred the concept of observable fields. In this spirit it is assumed that S can cause observable field effects. This is required for a testable theory. According to this philosophy, the Lorenz gauge condition and the Coulomb gauge condition are special physical conditions, similar to: 'the electric field is zero'.

Next, the induction of scalar fields is discussed, followed by the derivation of generalised force/power theorems in order to predict the type of observable phenomena attributable to the presence of scalar fields.

2. The induction of scalar fields

Considering the definition of S ($S = -\lambda_0 \epsilon_0 \mu_0 \frac{\partial \Phi}{\partial t} - \vec{\nabla} \cdot \vec{A}$), one might design an electrical device such that factor ${}^{\partial\Phi}/_{\partial t}$ or factor $\vec{\nabla} \cdot \vec{A}$ is optimised, and such that these two scalar factors do not cancel each other. With ${}^{\partial\Phi}/_{\partial t}$ we can associate systems of high voltage and high frequency, such as *pulsed power* systems. With $\vec{\nabla} \cdot \vec{A}$ we can associate a source of divergent/convergent currents, which is similar to the induction of a magnetic field by rotating currents, $\vec{B} = \vec{\nabla} \times \vec{A}$. For instance, a spherical or cylindrical capacitor can show currents with non-zero divergence/convergence. If the capacity is high, then we can expect a high $\vec{\nabla} \cdot \vec{A}$, since strong currents need to charge/discharge the capacitor. If the capacity is low, then a higher factor ${}^{\partial\Phi}/_{\partial t}$ can be expected, since then it takes less time to charge and discharge the capacitor to high voltages.

Electromagnetic fields are of static or dynamic type. Considering the inhomogeneous field wave equations:

$$\lambda_0 \epsilon_0 \mu_0 \frac{\partial^2 \vec{E}}{\partial t^2} + \lambda_0 \vec{\nabla} \times \vec{\nabla} \times \vec{E} - \vec{\nabla} \vec{\nabla} \cdot \vec{E} = \lambda_0 \mu_0 \left(-\frac{\partial \vec{J}}{\partial t} - \frac{\vec{\nabla} \rho}{\lambda_0 \epsilon_0 \mu_0} \right) \tag{19}$$

$$\epsilon_0 \mu_0 \frac{\partial^2 \vec{B}}{\partial t^2} - \vec{\nabla}^2 \vec{B} = \mu_0 (\vec{\nabla} \times \vec{J}) \tag{20}$$

$$\lambda_0 \epsilon_0 \mu_0 \frac{\partial^2 S}{\partial t^2} - \vec{\nabla}^2 S = \lambda_0 \mu_0 \left(-\vec{\nabla} \cdot \vec{J} - \frac{\partial \rho}{\partial t} \right) \tag{21}$$

that are deduced from the generalised Maxwell/Heaviside field equations, we can expect primarily *dynamic* scalar fields, because of the conservation of charge. This is the reason why the discovery of scalar field S is not as easy as the discovery of the electromagnetic fields via simple static field type experiments. Quantum tunneling of electrons can be understood on the classical level as a local violation of charge conservation, for instance at Josephson junctions. Hence, collective quantum tunneling devices might induce a new type of classical field: a static scalar field. A dynamic scalar field is induced by a charge/current density wave: set $\vec{E} = \vec{0}$ and $\vec{B} = \vec{0}$, then Eq.(14) and Eq.(15) become:

$$-\frac{\partial S}{\partial t} = \frac{\rho}{\epsilon_0} \tag{22}$$

$$\vec{\nabla} S = \lambda_0 \mu_0 \vec{J} \tag{23}$$

Since S satisfies wave Eq.(21), also the charge density ρ and current density $\vec{J}$ are wave solutions, and for $\lambda_0 > 1$ these wave solutions are sub-luminal. Charge/current density waves are known phenomena in superconductors. The factor λ may differ for non-vacuum media, depending on a new type of charge/current polarisation property of a macroscopic medium. A new type of scalar field boundary condition can be defined for scalar fields, expressed by parameter λ.

3. Generalised power/force laws

First, a source transformation is defined in order to generalise the standard electrodynamic force and power theorems:

$$\rho \longrightarrow \rho' = \rho + \epsilon_0 \frac{\partial S}{\partial t} \tag{24}$$

$$\vec{J} \longrightarrow \vec{J}' = \vec{J} - \frac{1}{\lambda_0 \mu_0} \vec{\nabla} S \tag{25}$$

This source transformation transforms the Maxwell equations into the generalised Maxwell equations. The electrodynamic power theorem and force theorem are given by:

$$\mu_0 \left(\vec{J} \cdot \vec{E} \right) = -\frac{\partial \left(\epsilon_0 \mu_0 E^2 + B^2 \right)}{2\, \partial t} - \vec{\nabla} \cdot \left(\vec{E} \times \vec{B} \right) \tag{26}$$

$$\begin{aligned} \mu_0 \left(\rho \vec{E} + \vec{J} \times \vec{B} \right) = {} & \epsilon_0 \mu_0 \left((\vec{\nabla} \cdot \vec{E}) \vec{E} + (\vec{\nabla} \times \vec{E}) \times \vec{E} \right) + (\vec{\nabla} \times \vec{B}) \times \vec{B} \\ & - \epsilon_0 \mu_0 \frac{\partial (\vec{E} \times \vec{B})}{\partial t} \end{aligned} \tag{27}$$

Next, the left hand side of these theorems is transformed:

$$\begin{aligned} \mu_0 \left(\vec{J} \cdot \vec{E} \right) \longrightarrow {} & \mu_0 \left(\vec{J} - \frac{1}{\lambda_0 \mu_0} \vec{\nabla} S \right) \cdot \vec{E} = \\ & \mu_0 \left(\vec{J} \cdot \vec{E} \right) - \frac{1}{\lambda_0} (\vec{\nabla} S) \cdot \vec{E} = \\ & \mu_0 \left(\vec{J} \cdot \vec{E} \right) - \frac{1}{\lambda_0} \vec{\nabla} \cdot (\vec{E} S) + \frac{1}{\lambda_0} S \vec{\nabla} \cdot \vec{E} = \end{aligned} \tag{28}$$

$$\mu_0\left(\vec{J}\cdot\vec{E}\right) - \frac{1}{\lambda_0}\vec{\nabla}\cdot(\vec{E}S) + \frac{1}{\lambda_0}S\left(\frac{\rho}{\epsilon_0}+\frac{\partial S}{\partial t}\right) =$$
$$\mu_0\vec{J}\cdot\vec{E} + \frac{1}{\lambda_0}\frac{\rho}{\epsilon_0}S - \frac{1}{\lambda_0}\vec{\nabla}\cdot(\vec{E}S) + \frac{1}{\lambda_0}\frac{\partial(S^2)}{2\partial t}$$

$$\mu_0\left(\rho\vec{E}+\vec{J}\times\vec{B}\right) \longrightarrow \tag{29}$$
$$\mu_0\left((\rho+\epsilon_0\frac{\partial S}{\partial t})\vec{E}+(\vec{J}-\frac{1}{\lambda_0\mu_0}\vec{\nabla}S)\times\vec{B}\right) =$$
$$\mu_0\left(\rho\vec{E}+\vec{J}\times\vec{B}\right) + \epsilon_0\mu_0\frac{\partial S}{\partial t}\vec{E} - \frac{1}{\lambda_0}(\vec{\nabla}S)\times\vec{B} =$$
$$\mu_0\left(\rho\vec{E}+\vec{J}\times\vec{B}\right) + \epsilon_0\mu_0\frac{\partial(S\vec{E})}{\partial t} - \frac{1}{\lambda_0}(\vec{\nabla}S)\times\vec{B} - \epsilon_0\mu_0\frac{\partial\vec{E}}{\partial t}S =$$
$$\mu_0\left(\rho\vec{E}+\vec{J}\times\vec{B}\right) + \epsilon_0\mu_0\frac{\partial(S\vec{E})}{\partial t} - \frac{1}{\lambda_0}(\vec{\nabla}S)\times\vec{B} - \left(\vec{\nabla}\times\vec{B} + \frac{1}{\lambda_0}\vec{\nabla}S - \mu_0\vec{J}\right)S =$$
$$\mu_0\left(\rho\vec{E}+\vec{J}\times\vec{B}+\vec{J}S\right) + \epsilon_0\mu_0\frac{\partial(S\vec{E})}{\partial t} - \frac{1}{\lambda_0}(\vec{\nabla}S)\times\vec{B} - \left(\vec{\nabla}\times\vec{B} + \frac{1}{\lambda_0}\vec{\nabla}S\right)S$$

The power theorem and force theorem are transformed into:

$$\mu_0\vec{J}\cdot\vec{E} + \frac{\rho}{\lambda_0\epsilon_0}S = -\frac{\partial\left(\epsilon_0\mu_0 E^2 + B^2 + \frac{1}{\lambda_0}S^2\right)}{2\,\partial t} - \vec{\nabla}\cdot\left(\vec{E}\times\vec{B} - \frac{1}{\lambda_0}\vec{E}S\right) \tag{30}$$
$$\mu_0\left(\rho\vec{E}+\vec{J}\times\vec{B}+\vec{J}S\right) = \epsilon_0\mu_0\left((\vec{\nabla}\cdot\vec{E})\vec{E} + (\vec{\nabla}\times\vec{E})\times\vec{E}\right) \tag{31}$$
$$+ (\vec{\nabla}\times\vec{B} + \frac{1}{\lambda_0}\vec{\nabla}S)S + (\vec{\nabla}\times\vec{B} + \frac{1}{\lambda_0}\vec{\nabla}S)\times\vec{B}$$
$$- \epsilon_0\mu_0\frac{\partial(\vec{E}\times\vec{B}+\vec{E}S)}{\partial t}$$

The new terms in these theorems need to be interpreted. The generalised Poynting vector is: $\vec{P} = \vec{E}\times\vec{B} - \frac{1}{\lambda_0}\vec{E}S$. The power flow vector $\frac{1}{\lambda_0}\vec{E}S$ belongs to a new type of vacuum wave, and by setting $\vec{B} = \vec{0}$ we can deduce the following wave equations from the generalised Maxwell/Heaviside equations:

$$\lambda_0\epsilon_0\mu_0\frac{\partial^2 S}{\partial t^2} - \vec{\nabla}\cdot\vec{\nabla}S = 0 \tag{32}$$
$$\lambda_0\epsilon_0\mu_0\frac{\partial^2 \vec{E}}{\partial t^2} - \vec{\nabla}\vec{\nabla}\cdot\vec{E} = 0 \tag{33}$$

The solution of these wave equations is a *longitudinal electro-scalar wave*, or LES wave. The term S^2 represents the energy density of scalar field S. The interesting term $\frac{\rho}{\lambda_0\epsilon_0\mu_0}S$ can be interpreted as the *applied power by means of static charge* ρ *and a scalar field* S, which is by definition a dynamic electric potential and divergent magnetic potential. The new force term $\vec{J}S$ is a *longitudinal force* that acts on a current element $\vec{J}$. Also new *magneto-scalar stress terms* appeared in the force theorem. The scalar field is like a scalar form of magnetism: it acts on current elements and it interacts with the electric field in vacuum. The derivation of these theorems was already published in [23] by means of the biquaternion calculus [6], in case $\lambda_0 = 1$.

4. Experimental evidence

4.1. *Longitudinal vacuum waves*

Nikola Tesla was one of the first scientist who mentioned the existence of longitudinal electric vacuum waves. Initially he did not believe that the wireless signals discovered by Hertz were the transversal electromagnetic (TEM) waves as predicted by Maxwell. Later Tesla acknowledged TEM waves, but he also insisted on the existence of energy efficient longitudinal electric waves, applicable for the wireless transport of energy and wireless communication. Longitudinal vacuum waves were (and still are) not accepted by the physics community as a physical reality, because this type of wave vacuum wave is not predicted by the standard theory of electrodynamics. This should be reconsidered. Tesla's patents describe wireless energy systems [22] based on Tesla's resonant transformer [19] and ball-shaped antennas. Tesla optimised [21] the voltage and frequency of the signal of his resonant transformer by using a primary pancake coil [20] with low self-induction and a secondary spherical capacitor with low capacity. The secondary circuit voltage is about a million volt or higher. In order to prevent discharges from the secondary capacitor and secondary coil, Tesla isolated the spherical capacitor in a vacuum tube, and he electrically isolated the secondary coil by submerging the coil in an oil reservoir. The capacitor could be made smaller with reduced capacity, because of the reduced risk of discharge, which further enabled Tesla to apply higher frequencies and higher voltages. Obviously Tesla optimised scalar factor $\partial\Phi/\partial t$, and not scalar factor $\vec{\nabla}\cdot\vec{A}$. Tesla claimed that his resonant transformer system could transmit longitudinal electric waves that carry much higher energy than Hertz waves.

Ignatiev's experiment of longitudinal electric wave transmission, by means of a large spherical antenna, confirmed the existence of longitudinal electric vacuum waves without magnetic component [9]. Ignatiev discovered that the transmitted energy was unusually high. In order to explain the result of longitudinal electric wave transmission Ignatiev concluded that a modification of the Gauss law is necessary. A possible modification of Gauss' law is presented in this paper, see Eq. (14). According to Ignatiev the measured propagation speed was about 1.2c, in fact faster than light. Factor 1.2, is still subject of debate, and the error margin in the measurement data produced by Ignatiev is reviewed. Ignatiev excluded the existence of the magnetic field component in the transmitted wave, and this is enough reason to refer to his experiment.

Recently, Wesley and Monstein published a paper [13] on the wireless transmission of longitudinal electric waves, also by means of a spherical antenna, and again the authors confirmed the existence of such a wave. According to Wesley and Monstein the transmitted energy flux is proportional to:

$$\vec{P} = -\vec{\nabla}\Phi \frac{\partial \Phi}{\partial t} \tag{34}$$

and the field energy density is:

$$D = \frac{1}{2}(\vec{\nabla}\Phi)^2 + \frac{1}{2}\left(\frac{\partial \Phi}{c\partial t}\right)^2 \tag{35}$$

which is in agreement with the defined power flow $\vec{E}S$ and the energy density of the electric and scalar fields, $\frac{1}{2}E^2$ and $\frac{1}{2}S^2$ (except for a factor $\epsilon_0\mu_0$), in case we ignore the magnetic potential $\vec{A}$. Wesley and Monstein determined the polarisation of the received signal, which was indeed longitudinal. However, they did not present a background theory for the presented laws for energy flux and energy density. Wesley and Monstein claim Eq. (34) and Eq. (35) can be derived from Eq. (12). This is not true. Only after the introduction of a physical scalar field $\partial\Phi/c\partial t$ and after the deduction of the power theorem Eq. (30), is it possible to deduce Eq. (34) and Eq. (35). Since the generalised power theorem (30) was published already in year 2001 [23], it is fair to assume Wesley and Monstein reduced power theorem (30) to the restricted form of Eq. (34) and Eq. (35), without any reference to [23].

In [17] a Coulomb wave is described by Tzontchev, Chubykalo and Rivera-Juárez, which is a longitudinal electric wave. According to their measurements the Coulomb interaction is not instantaneous, but it has a finite speed which is approximately c. A Coulomb potential can be decomposed into an integral sum of electric potential waves [24] that all have the same speed. The gradient of one such an electric potential wave is a longitudinal electric wave. The integral sum of all longitudinal waves constitutes the Coulomb electric field. As a consequence, a variation in Coulomb potential spreads with finite velocity, for instance during a discharge. Since the time differential of one such an electric potential wave is a scalar field wave, there is possibly a hidden energetic interaction with the charge in the form of longitudinal electro-scalar waves that have frequencies varying from zero to some cut off frequency. Similar to this is the electro-magnetic wave Zero Point Field interaction with a particle, which is based on Max Planck's second hypothesis on the black body radiation energy spectrum, as an alternative to electro-magnetic wave quantization. A difference with the longitudinal Whittaker waves is the random phase of the ZPF electro-magnetic waves.

4.2. *Longitudinal electrodynamic forces*

Longitudinal electrodynamic forces have been observed in several experiments, for example exploding wire experiments by Jan Nasilowski [15] and Peter Graneau [5]. According to Graneau, the pressure due to longitudinal forces would be substantially greater than the pinch pressure. Assis and Bueno [1] showed that Ampère's force law cannot be discriminated from Grassmann's force law for current elements, for any closed current circuit. They conclude both laws do not describe longitudinal forces, therefore a new theory is necessary in order to explain such forces. The standard field stress tensor does not describe longitudinal forces either, see Eq. (28), because a longitudinal force term at the right hand site would not be balanced by a longitudinal force term at the left hand site, and that would render the force theorem false. Longitudinal forces can be explained by the presence of a scalar field and by the generalised force theorem (32), expressed by the term $\vec{\mathsf{J}}\mathsf{S}$. This force is always parallel to the direction of current density $\vec{\mathsf{J}}$. Then one should verify that a scalar field is involved, that is induced by a source of high frequency high voltage, or by divergent/convergent currents in a conductor or plasma. Periodic longitudinal forces give rise to charge density waves and stress [14, 16] waves, and vice verse: a non-zero current divergence is the source of a scalar field that acts longitudinally on nearby current elements, such that another area of non-zero current divergence is created, etc... Setting $\vec{\mathsf{E}} = \vec{\mathsf{B}} = \vec{0}$ in the generalised Maxwell equations, leads to charge density and current density waves; in this case $-\frac{\partial \mathsf{S}}{\partial \mathsf{t}} = \frac{\rho}{\epsilon_0}$ and $\vec{\nabla}\mathsf{S} = \lambda_0 \mu_0 \vec{\mathsf{J}}$, and since S is a wave solution, also ρ and $\vec{\mathsf{J}}$ are waves. The fraction pattern of an exploded wire is very similar to a wave, perhaps as the direct consequence of a charge/current density wave and the breaking of the metal bond between metal atoms in areas with very low or very high electron density. Also Ampère's hairpin experiment [2] shows areas with divergent and convergent currents: at the exact location where currents enter and leave the hairpin [8]. An interesting patent by R.L. Schlicher [18] describes a three dimensional loop antenna with divergent and convergent pulsed currents. In this antenna a force is developed of about 0.1 Newton that seems to be longitudinal rather than transversal to the current elements on which the force acts. The loop antenna conductors are asymmetrical and connected to a pulsed power source of 1 to 100 Hertz. Schlicher attributes the force effect to a magnetic field gradient, but he also admits that it is very difficult to describe this effect precisely. An alternative explanation would be the induction of a scalar field by the convergent currents in the asymmetrical loop antenna, that gives rise to a longitudinal force.

4.3. *Applied power from static charge and a scalar field*

Usually power theorem (26) describes that an applied power source with density

$\vec{E}\cdot\vec{J}$ is converted into a radiated energy flow with density $\vec{\nabla}\cdot(\vec{E}\times\vec{B})$ and the change in field energy $\frac{1}{2}E^2$ and $\frac{1}{2}B^2$. According to the generalised power theorem (30), a scalar field S can turn an object with charge density ρ into an electrical power source with power density $\frac{1}{\lambda_0\epsilon_0\mu_0}\rho S$. This static charge power source is a remarkable prediction by the theory. When the magnetic potential is ignored, this power density is simply $\rho\frac{\partial\Phi}{\partial t}$. Usually, the electric potential energy of a charge Q in the presence of an electric potential V equals $W = QV$. The electrical power equals $P = \frac{dW}{dt} = \frac{d(QV)}{dt} = \frac{dQ}{dt}V + Q\frac{dV}{dt} = IV + Q\frac{dV}{dt}$. The second term is unusual and it can only be understood as a scalar field effect. A large charge reservoir Q in an electric potential V might absorb or radiate longitudinal electro-scalar radiation, in case the potential is rapidly fluctuating in time, while the charge is rather static. Although rumours exist that this actually has been observed, the author is not aware of any published scientific experiments with respect to this effect.

5. Conclusions

The introduction of gauge conditions in CED implies that scalar derivatives of the electromagnetic potentials are non-physical. This hypothesis cannot be tested, and it should be reversed into the testable and positive hypothesis of measurable scalar field effects, such as longitudinal electric vacuum waves, longitudinal electrodynamic forces, and energy conversions by means of static charge and a scalar field. If these effects cannot be detected in general, then finally a *physical* justification for CED gauge conditions has been obtained. However, some experiments indicate the existance of scalar field effects different from electro-magnetic effects. Further quantitative tests are needed in order to obtain scientific proof for the existence of a physical scalar field S, as defined in this paper. A positive verification has consequences for the science of physics. References to "unphysical" scalar photons or "unphysical" longitudinal photons are incorrect, since the qualification "unphysical" is not testable, and the underlying rational arguments are circular. The neglect of Galileo Galilei's philosophy of physics by the physics community, with respect to gauge conditions, resulted into the rejection of Tesla's observation of longitudinal electric waves. There are urgent reasons to review Tesla's scientific heritage, such as the need for new forms of energy and efficient energy technologies.

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