Explanation of Anomalous Unipolar Induction in Corotating Conductor-Magnet Arrangements by Galilean Electrodynamics

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Lorentz covariant electrodynamics breaks down when applied to the induction observed in unipolar generators with corotating *conducting disc and magnetic field source. This unusual induction is explained by means of the generalized, Galilei covariant Maxwell equations and shown to be direct evidence for the existence of the substratum (EM field carrier) of the vacuum. Other ether effects which refute the concept of the physically empty STR vacuum are also discussed.*

Introduction

Physical effects which are based on rotating or in general accelerated motions can serve as evidence for an electromagnetic (EM) or gravitational wave carrier (ether) since rotation and accelerated motions are absolute motions in the ether. Such evidence was provided, *e.g.*, by the rotating interferometer experiment ($\mathbf{v} = \mathbf{\Omega} \times \mathbf{r}$, $\mathbf{\Omega}$ = angular velocity of the optical table rotating about its axis $r = 0$) of Sagnac [1]. In this setup, two simultaneously emitted light signals (±) are sent in opposite directions around closed circular paths of radius $r = R$ so that their travel times are (c_o = vacuum speed of light)

$$T_{\pm} = \frac{2\pi R}{c_0 \mp \Omega R} \begin{matrix} > \\ < \end{matrix} \frac{2\pi R}{c_0} \tag{1}$$

due to their different light speeds for propagation upstream (−) and downstream (+) the ether flow $\mathbf{w} = -\mathbf{\Omega} \times \mathbf{r}$ in the frame of reference corotating with the interferometer. The light signals interfere with the experimentally confirmed fringe shift [1]

$$\begin{aligned} \Delta\lambda &= c_0 (T_+ - T_-) = \frac{4\pi R^2 c_0 \Omega}{c_0^2 - \Omega^2 R^2} \\ &\cong \frac{4\pi R^2 \Omega}{c_0} \propto \Omega^1, \quad \Omega R << c_0 \end{aligned} \tag{2}$$

which gives direct evidence of the anisotropic light propagation in the rotating reference frame caused there by the ether flow $\mathbf{w} = -\mathbf{v}$. This effect can not be explained by the special (STR) or general (GTR) theory of relativity. In GTR the (weak) centrifugal acceleration $\Omega^2 r$ (assumed to be equivalent to a gravitational acceleration) observed in the rotating interferometer frame yields a quantitatively and qualitatively false fringe shift $\Delta\lambda$.

In the Aharonov-Bohm experiment [2,3], an electron beam is split at $r=R, \phi = 0(2\pi)$ into two beams propagating along the semi-circles $r=R, 0<\phi<\pi$ and $r=R, \pi<\phi<2\pi$— which are concentric with a long, active solenoid of radius $a < R$. These beams interfere at their reunion point $r = R$, $\phi = \pi$ with the experimentally confirmed phase difference $\Delta S = (e/\hbar)\Phi$ of their de Broglie waves $\Psi_\pm(r,t)$, where Φ is the magnetic flux inside the solenoid $r \le a < R$! To appreciate the significance of this effect, note that the (long) solenoid has an axial magnetic field $\mathbf{B} = \mathbf{B}_o$ for $r \le a$ and $\mathbf{B} = 0$ for $r > a$, whereas its azimuthal vector potential, $A = B_o r/2$ for $r \le a$ and $A = a^2 B_o/2r$ for $r \ge a$, does not vanish outside the solenoid. Thus, the Aharonov-Bohm effect demonstrates that the dynamics of an electron is affected by the vector potential $\mathbf{A}$ in regions where the force field $\mathbf{B}$ vanishes (in accordance with the Schroedinger equation in which only the vector and scalar potentials appear). Accordingly, the vector potential has a more fundamental meaning than its magnetic field [2].

According to the hydrodynamic formulation of wave mechanics [$\Psi = \rho^{1/2} e^{iS}$, $\rho = \Psi\Psi^*$, $\mathbf{V} = (\hbar/m)\nabla S$] [4,5,6], the velocity fields $\mathbf{V}_\pm$ of the probability density ρ of the two electron beams experience, due to the vector potential $\mathbf{A}$, the variations [6]

$$\mathbf{v}_\pm = -\frac{e}{m} A(r)\mathbf{a}_\phi \qquad 0 \le \phi < \pi, \quad \pi < \phi \le 2\pi, \quad r > a \tag{3}$$

where the unit vector $\mathbf{a}_\phi$ changes direction with ϕ. The phase difference $\Delta S = S_- - S_+$ of the de Broglie waves $\Psi_\pm$ of the two beams, which is caused by the vector potential in Eq. (3), is at the point of interference $(r = R, \phi = \pi)$

$$\Delta S = -\frac{m}{\hbar}\left[\int_0^\pi \mathbf{v}_+ \bullet d\mathbf{r} - \int_{2\pi}^\pi \mathbf{v}_- \bullet d\mathbf{r}\right], r = R \\ = -\frac{m}{\hbar}\oint_{C_R} \mathbf{v} \bullet d\mathbf{r} \tag{4}$$

whence [2]

$$\Delta S = \frac{e}{\hbar}\oint_{C_R} \mathbf{A} \bullet d\mathbf{r} = \frac{e}{\hbar}\Phi \tag{5}$$

where $\Phi = \oint_{C_R} \mathbf{A} \bullet d\mathbf{r} = \int_{C_R} \mathbf{B} \bullet d\mathbf{F}$ is the magnetic flux through the cross section $F = \pi a^2$ of the solenoid. Winterberg proposed this surprising interference phenomenon $\Delta S \propto \Phi$ as an ether effect [7].

As communicated earlier [4,5,6], wave mechanics and the uncertainty relations are effects of a hidden ether medium ($\Delta p_x \Delta x > \hbar$ results from an interaction of the microparticle with the ether, *i.e.*, not from a perturbation by the observer), and the vector potential and the magnetic field are excitations fixed in the ether [8,9,10,11,12]. For these reasons, the nonvanishing vector potential outside the solenoid produces a perturbation in the resting ether in form of the azimuthal vortex field,

$$\mathbf{A} = \frac{a^2 B_o}{2} r^{-1}\mathbf{a}_\phi, \qquad a < r < \infty, \quad 0 \le \phi \le 2\pi \tag{6}$$

with $\nabla \bullet \mathbf{A} = 0$ and $\nabla \times \mathbf{A} = \mathbf{0}$. The electron beams moving counter-clockwise (+) and clockwise (–) around the solenoid experience phase shifts $S_+ = -S_-$ of different sign by Eq. (4), since they propagate downstream (+) respectively upstream (–) the azimuthal ether perturbation (6). Thus, the Aharonov-Bohm effect is an ether effect similar to the Sagnac effect (in the latter, the photons of the two light signals move upstream respectively downstream the ether flow, $\mathbf{w} = -\mathbf{\Omega} \times \mathbf{r} \ne$ perturbation).

One of the oldest EM ether effects observed in rotating motion is the anomalous EM induction in rotating unipolar disc generators with no relative motion between the conducting disc and the magnet or solenoid discovered by Faraday in 1832, and more rigorously investigated by Kennard [13] in 1917. Kennard demonstrated that an EMF was induced when there was absolutely no relative motion between conductor, magnetic field source, and the measuring circuit, *i.e.*, the observed EMF depends only on the absolute rotation of the rigid system as a whole [13]. Kennard clearly recognized that unipolar induction involves magnetic field lines fixed in the ether (frame) and that the concept of moving magnetic field lines attached to a rotating magnet has no physical meaning [13,14]. The most comprehensive experimental investigations on unipolar induction are due to Mueller [15,16], who not only confirmed the results of Kennard but verified the seat of the EMF in generator arrangements with and without relative motion between conductors and magnetic field sources.

Figure 1 exhibits the principal setups for unipolar disc generators employing a uniform axial magnetic field produced (a) in the narrow gap of two permanent (*e.g.*, ceramic) magnetic poles and (b) inside a long solenoid. The conducting disc of radius "a", the magnetic field source (permanent magnet or solenoid), and the open measuring circuit o-O-A-a with ideal voltmeter ($R = \infty$) are rigidly connected and rotate as a whole with a constant angular velocity $\boldsymbol{\omega}^\circ$. The circuit o-O-A-a is required only for the measurement of the open-circuit EMF induced across the disc o-a with the help of a voltmeter, *i.e.*, the EMF across the disc exists also in the absence of the measuring circuit.

The radial electric field $\mathbf{E}^\circ(\mathbf{r}^\circ) = -\mathbf{v}^\circ \times \mathbf{B}^\circ$ induced in the disc under open circuit conditions has its sources in a volume space charge distribution $\rho^\circ(\mathbf{r}^\circ) = -\varepsilon_o \nabla^\circ \bullet (\mathbf{v}^\circ \times \mathbf{B}^\circ)$ which can be verified experimentally without an attached circuit, *e.g.*, by means of a macroscopic test charge suspended to sense nearby charge distributions. The space charge induced in

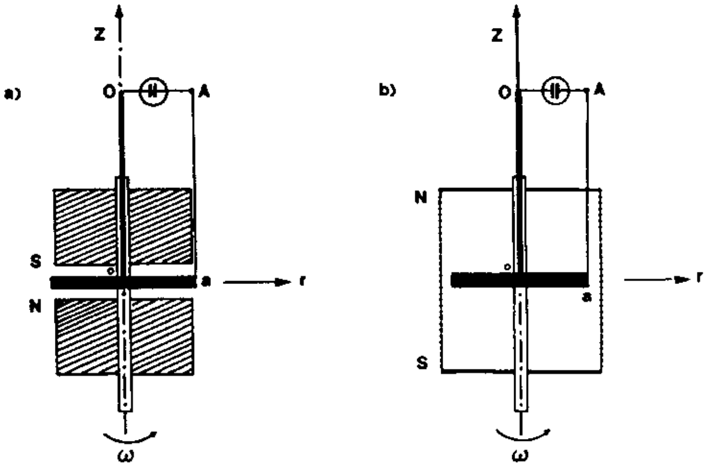

Figure 1.
Cross section of unipolar induction generator with conducting disc, magnetic field source and measuring circuit, corotating: (a) permanent magnet, (b) magnetic solenoid.

the disc gives direct evidence of the absolute rotation $\mathbf{v}^\circ = \boldsymbol{\omega}^\circ \times \mathbf{r}^\circ$ of the rigid unipolar induction system (which could be used as a gyroscope). In the following, we will show that anomalous unipolar induction is (i) readily explained by the generalized, Galilei covariant Maxwell equations [8-10] and (ii) is an effect which provides independent experimental evidence for the existence of the substratum of the vacuum (ether). The unipolar induction theory is developed (i) in the inertial frame in which the generator rotates and (ii) in the quasi-inertial frame corotating with the generator.

2. Theoretical Principles

The theoretical explanation of anomalous unipolar induction is based on the generalized Maxwell equations for inertial frames $\Sigma(\mathbf{r}, t, \mathbf{w})$ with vacuum substratum (ether) flow $\mathbf{w}$ [8,9]. They are generally valid since they are covariant in Galilei transformations between arbitrary inertial frames $\Sigma(\mathbf{r}, t, \mathbf{w})$ and $\Sigma'(\mathbf{r}', t', \mathbf{w}')$ [8-10]. These EM field equations have been applied to a consistent formulation of Galilei covariant quantum mechanics in EM fields [6], the radiation fields of charged particles in uniform (Cerenkov effect) and accelerated motions [10,11,12], and pulsed electrodynamic problems [8]. As a general result, it has been found that electrodynamic phenomena do not depend on the velocity $\mathbf{v}$ of the charged particles relative to the observer (STR) but on their absolute velocity $\mathbf{v} - \mathbf{w} = \mathbf{v}^\circ = \text{inv}$ in the ether (refutation of the STR principle of the relativity of the velocity $\mathbf{v}$ in physics). This outcome is not surprising since (i) EM fields are ether excitations produced by interaction of charges with the ether and (ii) the charges do not interact with the observer.

The generalized, Galilei covariant Maxwell equations for linear, isotropic media in arbitrary inertial frames $\Sigma(\mathbf{r}, t, \mathbf{w})$ with ether flow $\mathbf{w}$ are in standard MKS notation [8-10]:

$$\nabla \times (\mathbf{E} + \mathbf{w} \times \mathbf{B}) = -\left(\frac{\partial}{\partial t} + \mathbf{w} \bullet \nabla\right)\mathbf{B} \tag{7}$$

$$\nabla \times \mathbf{H} = \left(\frac{\partial}{\partial t} + \mathbf{w} \bullet \nabla\right)(\mathbf{D} + \varepsilon \mathbf{w} \times \mathbf{B}) + \mathbf{j} - \rho \mathbf{w} \tag{8}$$

$$\nabla \bullet (\mathbf{D} + \varepsilon \mathbf{w} \times \mathbf{B}) = \rho \tag{9}$$

$$\nabla \bullet \mathbf{B} = 0 \tag{10}$$

where

$$\mathbf{D} = \varepsilon \mathbf{E}, \quad \mathbf{B} = \mu \mathbf{H} \tag{11}$$

$$\mathbf{j} - \rho \mathbf{v} = \sigma(\mathbf{E} + \mathbf{v} \times \mathbf{B}) \tag{12}$$

The Galilei covariance of the EM equations (7)–(12) follows from the field invariants, $\mathbf{E} + \mathbf{w} \times \mathbf{B} = \text{inv}$, $\mathbf{H} = \text{inv}$, $\mathbf{j} - \rho \mathbf{w} = \text{inv}$, $\rho = \text{inv}$, the operator invariants, $\partial/\partial t + \mathbf{w} \bullet \nabla = \text{inv}$, $\nabla = \text{inv}$, and the invariants $\varepsilon = \varepsilon'$, $\mu = \mu'$ $(c = c')$, $\sigma = \sigma'$, in Galilei transformations $\Sigma(\mathbf{r}, t, \mathbf{w}) \leftrightarrow \Sigma'(\mathbf{r}', t', \mathbf{w}')$, where $\mathbf{w} - \mathbf{w}' = \mathbf{v} - \mathbf{v}' = \mathbf{u}$ ($\mathbf{u}$ = velocity of Σ' relative to Σ) [8-10].

Ohm's law (12) assumes that the velocity $\mathbf{v}_c$ of the space charges ρ equals the velocity $\mathbf{v}$ of the conductor, which is applicable to the unipolar generator. Eq. (12) is the most simple form of Ohm's law, which is not valid for arbitrary physical conditions. For the conductors of the unipolar generator (nonmagnetic noble metals), the dielectric permittivity and the magnetic permeability are approximated by their vacuum values, $\varepsilon \cong \varepsilon_0 = 10^{-9}/36\pi$ [As/Vm] and $\mu \cong \mu_0 = 4\pi 10^{-7}$ [Vs/Am].

On the earth, the ether velocity is uniform and of the magnitude $\mathbf{w}_0 \sim 3 \times 10^5$ [m/s] [17]. It can be shown that this uniform ether velocity $\mathbf{w}_0$ has no *net* effect on light or particle propagation in circles (Sagnac and Aharonov-Bohm effects). Similarly, the uniform ether velocity $\mathbf{w}_0$ has no net influence on the EMF induced in the unipolar generator when the latter is in uniform rotation.

Accordingly, we may analyze the unipolar induction generator of Figure 1 either in (i) the laboratory frame Σ_L, which we will identify with the ether rest frame $\Sigma^\circ(\mathbf{r}^\circ, t^\circ, 0)$ or (ii) in the frame of reference $\Sigma(\mathbf{r}, t, \mathbf{w})$ attached to the rotating disc, where $\mathbf{w} = -\mathbf{v}^\circ$ and $\mathbf{v}^\circ = \boldsymbol{\omega}^\circ \times \mathbf{r}^\circ$ is the velocity of rotation of the generator (no relative motion between its parts).

Both the laboratory frame Σ_L and the rotating generator frame Σ are quasi-inertial frames owing to the slow rotation of the earth and the generator. GTR influences are irrelevant on the electrodynamics of the generator, since the possible centrifugal force interference is of the order $(\omega r/c_0)^2$, whereas the induction experiments indicate an EMF of the order $\frac{1}{2}\omega a^2 B_0$.

3. Unipolar Induction Analysis

From the mathematical point of view, the conducting disc, $0 \le r^\circ \le a^\circ, -\delta^\circ \le z^\circ \le +\delta^\circ$, of height $2\delta^\circ$ in the plane $z^\circ = 0$ rotating with a velocity $\mathbf{v}^\circ = \boldsymbol{\omega}^\circ \times \mathbf{r}^\circ$ in a homogeneous external magnetic field $\mathbf{B}_0^\circ = B_0 \mathbf{a}_z^\circ$ (Figure 1) represents a complicated 3-dimensional EM boundary-value problem in the ether rest frame $\Sigma^\circ(\mathbf{r}^\circ, t^\circ, 0)$, with the nature of the boundary conditions changing at the disc rim $r^\circ = a^\circ$. This mixed boundary-value problem leads to dual integral equations for the Fourier amplitudes of the electric potential, which can be solved by the Wiener-Hopf method. Thus, it can be shown that the electric $\mathbf{E}^\circ$ and the magnetic $\mathbf{B}^\circ$ fields are of the form (Σ° frame);

$$\mathbf{F}^\circ = F_r^\circ(r^\circ, z^\circ)\mathbf{a}_r^\circ + F_z^\circ(r^\circ, z^\circ)\mathbf{a}_z^\circ \tag{13}$$

Hence,

$$\mathbf{a}_\phi^\circ \bullet \nabla^\circ \mathbf{F}^\circ(r^\circ, z^\circ) = 0 \tag{14}$$

Note that $\mathbf{B}^\circ = \mathbf{B}^\circ(r^\circ, z^\circ)$ due to the magnetic field produced by the space charge current $\rho^\circ \mathbf{v}^\circ$ in Σ°.

The external magnetic field $\mathbf{B}_o^\circ$ is treated as homogeneous within the disc region, an assumption which is better satisfied in the solenoid (Figure 1a) than in the gap of the magnet poles (Figure 1b). The conducting disc and the source of the magnetic field are rigidly connected and are corotating with the same angular velocity $\boldsymbol{\omega}^\circ = \omega^\circ \mathbf{a}_z^\circ$ in the ether rest frame Σ°.

Since we are mainly interested in calculating the radial electric field and EMF induced in the rotating disc, a simpler analysis is given here, assuming a thin disc, $\Delta z^\circ = 2\delta^\circ \to 0$. The fields in the disc become then functions of r° only. Since the open measuring circuit o-O-A-a in Figure 1 is not needed for the induction of the space charge and electric fields in the disc, it is disregarded in the following analyses. In other words, we do not evaluate the EMF induced in the radial sections of the wires of the open circuit o-0-A-a.

A. Rotating Frame Σ(r, *t*, w). In a frame of reference Σ corotating with the generator, the velocity of the conducting disc and the field source are $\mathbf{v} = 0$, whereas the ether velocity is $\mathbf{w} = -\boldsymbol{\omega}^\circ \times \mathbf{r}^\circ = -\boldsymbol{\omega} \times \mathbf{r} = -\omega r \mathbf{a}_\phi$. The rotating reference frame Σ is of particular interest, since it explicitly exhibits the ether effects $\mathbf{w}\times\mathbf{B}$ and $\rho\mathbf{w}$ in the Galilei covariant Maxwell equations (the *B*-lines frozen into the ether rotate about their axis of symmetry with angular velocity $-\boldsymbol{\omega}$ in Σ, whereas the conductor is at rest there). The EM field equations (7)–(12) are for the stationary ($\partial/\partial t = 0$) operation of the unipolar generator in $\Sigma(\mathbf{r}, t, \mathbf{w})$:

$$\nabla \times (\mathbf{E} + \mathbf{w} \times \mathbf{B}) = 0 \tag{15}$$

$$\nabla \times \mathbf{B} = \mu_o(\mathbf{j} - \rho\mathbf{w}) \tag{16}$$

$$\nabla \bullet (\mathbf{E} + \mathbf{w} \times \mathbf{B}) = \rho/\varepsilon_o \tag{17}$$

$$\nabla \bullet \mathbf{B} = 0 \tag{18}$$

$$\mathbf{j} = \sigma\mathbf{E} \tag{19}$$

since

$$\mathbf{w} \bullet \nabla\mathbf{B} = 0, \quad \mathbf{w} \bullet \nabla(\mathbf{E} + \mathbf{w} \times \mathbf{B}) = 0 \tag{20}$$

by Eq. (14) and the Galilei invariances $\mathbf{B}$ = inv, $\mathbf{E} + \mathbf{w} \times \mathbf{B}$ = inv, ∇ = inv. By Eq. (15), where $\nabla \times (\mathbf{w} \times \mathbf{B}) = \mathbf{B} \bullet \nabla\mathbf{w} \neq 0$,

$$\mathbf{E} + \mathbf{w} \times \mathbf{B} = -\nabla\Phi \tag{21}$$

with

$$\nabla^2\Phi = {-\rho}/\varepsilon_o \tag{22}$$

by Eq. (17). Since $\nabla \times \mathbf{B} = (\partial B_r/\partial z - \partial B_z/\partial r)\mathbf{a}_\phi$, we have $j_{r,z} = 0$ by Eq. (16) and $E_{r,z} = 0$ by Eq. (19) with $E_\phi = 0$ in stationary state (Omic dissipation). Hence,

$$\mathbf{j} = 0, \quad \mathbf{E} = 0, \quad r \le a, \quad |z| \le \delta \tag{23}$$

Thus, Eq. (16) reduces in the disc region to ($\mathbf{w} = -\omega r \mathbf{a}_\phi$)

$$dB_z/dr = -\mu_o \omega r \rho, \quad r \le a, \quad |z| \le \delta \tag{24}$$

since $\partial B_r/\partial z = 0$ for $z = 0$ (symmetry of $\mathbf{B}$ with respect to the plane $z = 0$). Since $\mathbf{E} = 0$, Eqs. (17) and (21) reduce in the disc to

$$r^{-1}\, d(r^2 B_z)/dr = {-\rho}/\varepsilon_o\omega, \quad r \le a, \quad |z| \le \delta \tag{25}$$

$$d\Phi/dr = \omega r B_z, \quad r \le a, \quad |z| \le \delta \tag{26}$$

Elimination of ρ from Eqs. (24) and (25) yields for B_z the differential equation

$$dB_z/B_z = \frac{d\left(\omega^2 r^2/c_o^2\right)}{1 - \omega^2 r^2/c_o^2}, \quad r \le a, \quad |z| \le \delta \tag{27}$$

Hence,

$$B_z(r) = \frac{B_o}{\left(1 - \omega^2 r^2/c_o^2\right)}, \quad r \le a, \quad |z| \le \delta$$
$$\cong B_o, \quad \omega r << c_o \tag{28}$$

since $B_z(r = 0) = B_o$. Substitution of the solution (28) for the magnetic field into Eqs. (24) and (26) yields for the space charge and potential fields:

$$\rho(r) = -\frac{2\varepsilon_o \omega B_o}{\left(1-\omega^2 r^2/c_o^2\right)^2}, \quad r \le a, \quad |z| \le \delta$$
$$\cong -2\varepsilon_o \omega B_o, \quad \omega r << c_o \tag{29}$$

and

$$\Phi(r) - \Phi_o = -\frac{1}{2} c_o B_o \frac{c_o}{\omega} \ln\left(1 - \frac{\omega^2 r^2}{c_o^2}\right), \quad r \le a, \quad |z| \le \delta$$
$$\cong \frac{1}{2}\omega B_o r^2, \quad \omega r << c_o \tag{30}$$

where $\Phi(r = 0) = \Phi_o$. The EMF induced in the conducting disc (o-a) of the unipolar generator is in agreement with experiment [13-16] the open circuit voltage

$$-\Phi_o + \Phi(a) \cong \frac{1}{2}\omega B_o a^2, \quad \omega r << c_o \tag{31}$$

The above developments indicate the induction of the potential $\Phi(r)$ and space charge $\rho(r)$ fields are genuine ether effects, since

$$\nabla\Phi = -\mathbf{w}\times\mathbf{B}, \quad \rho = \varepsilon_o \nabla\bullet(\mathbf{w}\times\mathbf{B}) \tag{32}$$

by Eqs. (21)–(23), where **w** is the ether velocity observed in the rotating frame Σ. Accordingly, unipolar induction is an effect which provides evidence for the existence of the EM substratum of the vacuum. $\Phi(r)$ is an ether potential, which is induced by the ether flow **w** transverse to **B**. The space charge $\rho(r)$ in the disc is the result of the redistribution of the electrons of the conductor in the ether potential gradient $\nabla\Phi$. Note that the ordinary electrostatic field, $\mathbf{E}(r) = 0$, does not exist in the rotating frame Σ for reasons of the Galilei invariance, $\mathbf{E} + \mathbf{w}\times\mathbf{B} = \text{inv}$.

B. Ether Rest Frame Σ°(r°,t°,0). The conducting disc and the magnetic field source rotate with the velocity $\mathbf{v}^\circ = \mathbf{w}^\circ \times \mathbf{r}^\circ = \omega^\circ r^\circ \mathbf{a}_\phi^\circ$ in the ether frame Σ°, whereas the ether velocity vanishes there, $\mathbf{w}^\circ = 0$. The field lines of $\mathbf{B}^\circ$ do not rotate in the ether frame do (in spite of the rotation of the magnetic field source!), since the magnetic field is an excitation of the ether. Accordingly, the induced electric field $\mathbf{v}^\circ \times \mathbf{B}^\circ$ exists in Σ°, and the EM Eqs. (7)–(12) for the unipolar generator in stationary operation ($\partial/\partial t = 0$) are in Σ°(**r**°,t°,0):

$$\nabla^\circ\times\mathbf{E}^\circ = 0 \tag{33}$$
$$\nabla^\circ\times\mathbf{B}^\circ = \mu_o \mathbf{j}^\circ \tag{34}$$
$$\nabla^\circ\bullet\mathbf{E}^\circ = \frac{\rho^\circ}{\varepsilon_0} \tag{35}$$
$$\nabla^\circ\bullet\mathbf{B}^\circ = 0 \tag{36}$$
$$\mathbf{j}^\circ = \rho^\circ\mathbf{v}^\circ + \sigma(\mathbf{E}^\circ + \mathbf{v}^\circ\times\mathbf{B}^\circ) \tag{37}$$

Note that the EM fields in Eqs. (33)–(37) are excitations of the ether, *i.e.*, are fixed in Σ°. By Eqs. (33) and (35)

$$\mathbf{E}^\circ = -\nabla^\circ\Phi^\circ \tag{38}$$
$$\nabla^{\circ 2}\Phi^\circ = -\rho^\circ/\varepsilon_0 \tag{39}$$

Since $\nabla^\circ\times\mathbf{B}^\circ = (\partial B_r^\circ/\partial z^\circ - \partial B_z^\circ/\partial r^\circ)\mathbf{a}_\phi^\circ$ in Eq. (34), Eq. (37) splits up into the relations

$$\mathbf{j}^\circ = \rho^\circ\mathbf{v}^\circ \tag{40}$$
$$\mathbf{E}^\circ + \mathbf{v}^\circ\times\mathbf{B}^\circ = 0 \tag{41}$$

Combining of Eqs. (34) and (40) yields for the magnetic field in the disc ($\mathbf{v}^\circ = \omega^\circ r^\circ \mathbf{a}_\phi^\circ$)

$$dB_z^\circ/dr^\circ = -\mu_o\rho^\circ\omega^\circ r^\circ, \quad r^\circ \le a^\circ, \quad |z^\circ| \le \delta^\circ \tag{42}$$

since $\partial B_r^\circ/\partial z^\circ = 0$ for $z^\circ = 0$ (symmetry of $\mathbf{B}^\circ$ with respect to the plane $z^\circ = 0$). Elimination of $\mathbf{E}^\circ$ from Eqs. (35) and (41) gives for the space charge density in the disc

$$\rho^\circ = -\varepsilon_0\omega^\circ r^{\circ-1} d(r^{\circ 2}B_z^\circ)/dr^\circ, \quad r^\circ \le a, \quad |z^\circ| \le \delta^\circ \tag{43}$$

Substituting Eq. (43) in Eq. (42) yields for the magnetic field the differential equation

$$dB_z^\circ/B_z^\circ = d(\omega^{\circ 2}r^{\circ 2}/c_o^2)/(1-\omega^{\circ 2}r^{\circ 2}/c_o^2)$$
$$r^\circ \le a^\circ, \quad |z| \le \delta^\circ \tag{44}$$

Hence, the magnetic field in the conducting disc is with $B_z^\circ(r^\circ = 0) = B_0^\circ$:

$$B_z^\circ(r^\circ) = B_o^\circ/(1-\omega^{\circ 2}r^{\circ 2}/c_o^2), \quad r^\circ \le a^\circ, \quad |z^\circ| \le \delta^\circ$$
$$\cong B_o^\circ, \quad \omega^\circ r^\circ << c_o \tag{45}$$

Substitution of Eq. (45) in Eqs. (41) and (43) yields for the solutions of the (radial) electric and space charge fields in the disc.

$$E^\circ(r^\circ) = -\omega^\circ r^\circ B_o^\circ/(1-\omega^{\circ 2}r^{\circ 2}/c_o^2), \quad r^\circ \le a^\circ, \quad |z^\circ| \le \delta^\circ$$
$$\cong -\omega^\circ r^\circ B_o^\circ, \quad \omega^\circ r^\circ << c_o \tag{46}$$

and

$$\rho^\circ(r^\circ) = -2\varepsilon_o\omega^\circ B_o^\circ/(1-\omega^{\circ 2}r^{\circ 2}/c_o^2)^2, \quad r^\circ \le a^\circ, \quad |z^\circ| \le \delta^\circ$$
$$\cong -2\varepsilon_o\omega^\circ B_o^\circ, \quad \omega^\circ r^\circ << c_o \tag{47}$$

Integration of Eq. (46) gives for the electric potential in the disc with $\Phi^\circ(r^\circ = 0) = \Phi_o^\circ$:

$$\Phi^\circ(r^\circ) - \Phi_o^\circ = -\tfrac{1}{2}c_o B_o^\circ\left(\frac{c_0}{\omega^\circ}\right)\ln\left(1 - \frac{\omega^{\circ 2}r^{\circ 2}}{c_o^2}\right),$$
$$r^\circ \le a^\circ, \quad |z^\circ| \le \delta^\circ$$
$$\cong \tfrac{1}{2}\omega^\circ B_o^\circ r^{\circ 2}, \quad \omega^\circ r^\circ << c_o \tag{48}$$

The EMF induced in the conducting disc (o-a) of the unipolar generator is in agreement with experiment [13-16] the open circuit voltage

$$-\Phi_o^\circ + \Phi^\circ(a^\circ) \cong \tfrac{1}{2}\omega^\circ B_o^\circ a^{\circ 2}, \quad \omega^\circ r^\circ << c_o \tag{49}$$

In the preceding equations, the velocity of rotation (absolute motion) $\omega^\circ r^\circ = \omega r$, and $r^\circ = r$, $a^\circ = a$, $\delta^\circ = \delta$, $B_0^\circ = B_0$ are invariants in Galilei transformations.

The above solutions agree with experiments on the "one-piece Faraday generator" since in Galilean physics, the rotating disc moves perpendicularly to the B_0-lines, which are fixed excitations in the ether (whereas the magnet is rotating) so that $\mathbf{v}^\circ \times \mathbf{B}^\circ \neq \mathbf{0}$ in Σ°. Accordingly, there is nothing "anomalous" about the observation of an EMF in a unipolar generator with disc and magnet corotating about their common axis of symmetry within Galilean physics.

As the STR denies the existence of the ether as an EM field carrier, the B_0-lines then must be fixed in the rotating magnet (where else?). Since there is no "relative motion" (STR) between magnet and disc, the STR predicts $\mathbf{v}^\circ \times \mathbf{B}^\circ = \mathbf{0}$ and EMF=0, in disagreement with experiment. Accordingly, within the STR the considered induction effect is "anomalous".

In the STR, rotating motions are "relative", too, so that we can view the rotating disc-magnet generator also from the corotating frame Σ, in which both disc and magnet are at rest, so that again $\mathbf{v} \times \mathbf{B} = \mathbf{0}$ and EMF=0, in disagreement with experiment. According to Panofsky and Phillips [18], the unipolar generator with rotating (accelerated) motion requires recourse to the GTR (usual excuse when the STR disagrees with experiment).

C. Galilei Invariance. Comparison of the corresponding solutions for the rotating frame $\Sigma(\mathbf{r}, t, \mathbf{w})$ and the ether frame $\Sigma^\circ(\mathbf{r}^\circ, t^\circ, 0)$, namely Eqs. (23)–(40), (23)–(41), (28)–(45), (29)–(47), (30)–(48), indicates that the following interrelations exist between them (in the same sequence):

$$\mathrm{j} - \rho\mathbf{w} = \mathrm{j}^\circ - \rho^\circ \mathbf{w}^\circ \tag{50}$$

$$\mathbf{E} + \mathbf{v} \times \mathbf{B} = \mathbf{E}^\circ + \mathbf{v}^\circ \times \mathbf{B}^\circ \tag{51}$$

$$\mathbf{B} = \mathbf{B}^\circ \tag{52}$$

$$\rho = \rho^\circ \tag{53}$$

$$\Phi = \Phi^\circ \tag{54}$$

since $\boldsymbol{\omega} = \boldsymbol{\omega}^\circ$, $r = r^\circ$, $z = z^\circ$. Eq. (50) holds since $\mathrm{j} = \mathbf{0}$, $\mathbf{w}^\circ = 0$ and $-\rho\mathbf{w} = \mathrm{j}^\circ$ ($\mathbf{w} = -\mathbf{v}^\circ$). Eq. (51) holds since $\mathbf{E} = \mathbf{0}$ and $\mathbf{v} = 0$,—and $\mathbf{E}^\circ \neq \mathbf{0}$, $\mathbf{v}^\circ \neq \mathbf{0}$ with $\mathbf{E}^\circ + \mathbf{v}^\circ \times \mathbf{B}^\circ = \mathbf{0}$.

Equations (50)–(54) are the known Galilei invariants [8-10] for the reference frames Σ and Σ°. The invariance in Eq. (54) of the potentials in Eqs. (22) and (39) follows from the invariance of space charge density $\rho = \rho^\circ = \mathrm{inv}$.

Thus, we recognize that Galilean electrodynamics [8-10] applied to the unipolar generator with no relative motion between disc and magnet in (i) the corotating reference frame $\Sigma(\mathbf{r}, t, \mathbf{w})$ and (ii) the ether frame $\Sigma^\circ(\mathbf{r}^\circ, t^\circ, 0)$ yields the same solutions for the magnetic field, $\mathbf{B} = \mathbf{B}^\circ = \mathrm{inv}$, the space charge density in the disc, $\rho = \rho^\circ = \mathrm{inv}$, and the scalar potential $\Phi = \Phi^\circ$. These results are in complete agreement with experiment [13-16]. The use of the generalized Maxwell equations [8-10] in the inertial frame Σ° is rigorous, whereas their use in the rotating (quasi-inertial) frame Σ has been justified *a posteriori* [same solutions, Eqs. (50)–(54)].

However, the Maxwell equations and their Galilei covariant generalization are, in general, not applicable to non-inertial or accelerated reference frames. The same holds for the application of the Galilei field invariants (which were derived for inertial frames [8,9]) to non-inertial frames.

4. Breakdown of STR

The simple (approximate) calculations for the thin disc in the frames Σ and Σ° show the essential physics of the unipolar induction problem. The exact solution of the mixed boundary-value problem, for the EM fields (i) inside a non-thin disc and (ii) the surrounding vacuum space is too lengthy to be presented here.

To discuss the breakdown of (i) the Lorentz-covariant Maxwell equations in predicting unipolar generator performance and (ii) the STR principle of the relativity of motion, the experimental observations [13-16] are compared with the Lorentzian (STR) and Galilean electrodynamics (GE) predictions for two crucial unipolar generator arrangements. To avoid misunderstandings, note that EMF refers to the potential difference induced in the conducting disc $r < a$, and that the generator has no open measuring circuit o-O-A-a (which is not required for the induction of the electric field and space charge in the disc).

Disc and Magnet Corotating in Σ°. EXPERIMENT: EMF $\neq$ 0. STR: EMF = 0, since in the corotating frame Σ, the conducting disc does not move in the **B**-field (fixed in magnet), so that $\mathbf{v} = \mathbf{0}$ and $\mathbf{v} \times \mathbf{B} = \mathbf{0}$. GE: EMF$\neq$0, since the disc rotates, in Σ°, in the $\mathbf{B}^\circ$-field (fixed in ether), so that $\mathbf{v}^\circ \times \mathbf{B}^\circ \neq \mathbf{0}$.

Magnet Rotating and Disc at Rest in Σ°. EXPERIMENT: EMF = 0. STR: EMF $\neq$ 0, since in a frame Σ corotating with the magnet the disc moves with velocity $\mathbf{v} = -\boldsymbol{\omega} \times \mathbf{r}$ in the **B**-field (fixed in magnet), so that $\mathbf{v} \times \mathbf{B} \neq \mathbf{0}$. GE: EMF = 0, since in Σ° the disc does not move in the $\mathbf{B}^\circ$-field (fixed in ether), so that $\mathbf{v}^\circ = \mathbf{0}$ and $\mathbf{v}^\circ \times \mathbf{B}^\circ = \mathbf{0}$.

In both cases, the STR predictions have been obtained in a corotating frame of reference Σ, in which the magnet and its attached B-field do not move. This is permitted by the STR principle of the relativity of motion, which thus avoids the conceptual difficulties of rotating magnetic field lines attached to rotating magnets [19].

These two crucial unipolar induction experiments demonstrate that the STR completely fails to predict the experimental observations, whereas Galilei covariant electrodynamics is in full agreement with the experiments. The STR principle of the relativity of motion is invalid, since rotating motion is not relative to an observer but relative to the ether (Σ°).

5. Conclusions

Lorentz covariant electrodynamics and the STR break down in predicting the experimental observations of the induced space charge and EMF in the conducting disc of unipolar generators when (i) magnetic field source and conducting disc corotate about their common axis of symmetry in the laboratory frame (EMF$\neq$0) and (ii) the magnetic field source rotates and the conducting disc is at rest in the laboratory frame (EMF = 0). The STR principle of the "relativity of motion" is not applicable to bodies in uniform rotation, since rotation is absolute motion in the preferred ether rest frame. Galilei covariant electrodynamics, with its concepts of EM fields as excitations of the vacuum substratum (ether) and rotation as absolute motion in the ether frame, correctly predicts the experimental facts in both cases. The presented theory demonstrates that induction in generators with corotating magnetic field source and conducting disc is direct evidence for the existence of the substratum of the vacuum (ether).

For these reasons, this communication represents a theoretical refutation of the STR and Lorentz covariant electrodynamics based on experimental facts. As briefly explained in the introduction, these modern "space-time theories" are also refuted by the Sagnac and Aharonov-Bohm ether effects. The STR is already refuted through Newton's experiments with water buckets in (i) uniform translation and (ii) uniform rotation [20]. Einstein may have anticipated the physical difficulties of Lorentz covariance and the equivalent relativity principle (according to which one and the same light signal propagates not only in the inertial frame of its source but in all (∞^3) conceivable inertial frames with the same speed $c_0 = 3\times10^8$ [m/s]!), and of his principle of the relativity of all motions on 28 March 1949 (six years before his untimely death) when he wrote to his friend Solovine: *"There is not a single concept of which I am convinced that it will survive, and I am unsure, whether I am on the right way at all."*

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