The homogeneous and inhomogeneous ECE current, Part III

Horst Eckardt[1], Anil Goel[2]
A.I.A.S. and UPITEC
(www.aias.us, www.upitec.org)

March 9, 2024

Abstract

In the previous papers of this series, we have shown that the homogeneous current of ECE theory can be interpreted as an electric polarization. In this paper, we continue this investigation, and show that it is a flow of potentials. This further corroborates the experiments of Tesla. The well-known wave equations are expanded to include conductivity terms for electrical conductivity and for conductivity evoked by the flow of potentials. This is not an ad-hoc assumption, but instead follows from ECE theory. As a result, the Poynting vector contains additional terms describing what is known as the Heaviside flow, which is present outside of electric conductors. The propagation velocity of electromagnetic waves can take values smaller and even greater than its value in vacuo.

Keywords: ECE theory, ECE2 theory, electrodynamics, homogeneous current, Tesla technology, potential area flux density, electromagnetic wave propagation.

1 Introduction

In Parts I and II of this article series [5,6], we have described the two currents of ECE theory [1–4], the homogeneous and inhomogeneous current. The inhomogeneous current is the current appearing in the Maxwell-Heaviside equations as an external quantity. In ECE theory, the homogeneous current is the symmetric counterpart to the inhomogeneous current, and is normally assumed to be zero, because it describes magnetic monopoles and their magnetic current densities. However, new experimental results give strong indications that this type of current really exists [7, 8]. According to the preceding two articles and [9], the homogeneous current can be explained by electric polarization effects, and is therefore an electric phenomenon rather than a magnetic one. In addition, we have explained that Tesla's experiments on wireless communication and energy transfer can be put on a scientific basis by using this type of current.

[1]email: mail@horst-eckardt.de
[2]email: anil@anilgoel.com

In this paper, we further develop the homogeneous current, and show that it is a flow of a potential density. In ECE theory, the currents are not external quantities, but instead consist of field terms. In particular, a conductivity term can be derived, which will lead to expanded electromagnetic wave equations for both types of currents, and the power density will contain a term formerly unaccounted for. Furthermore, we will show that the propagation velocity of the fields can be different from their value c in vacuo. This velocity can even become greater than c, a surprising result that requires general relativity in order to be understood. To explain this, we will apply m-theory [2], and one resulting interpretation could be that energy is transferred from spacetime to technical systems.

2 Field equations with homogeneous and inhomogeneous currents

2.1 Symmetrized Maxwell field equations

The original Maxwell-Heaviside equations in the vacuum read:

$$\boldsymbol{\nabla} \cdot \mathbf{B} = 0, \tag{1}$$

$$\frac{\partial \mathbf{B}}{\partial t} + \boldsymbol{\nabla} \times \mathbf{E} = \mathbf{0}, \tag{2}$$

$$\boldsymbol{\nabla} \cdot \mathbf{E} = \frac{\rho_e}{\epsilon_0}, \tag{3}$$

$$-\frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t} + \boldsymbol{\nabla} \times \mathbf{B} = \mu_0 \mathbf{J}, \tag{4}$$

where $\mathbf{E}$ is the electric field, $\mathbf{B}$ is the magnetic induction, $\mathbf{J}$ is the electronic current density vector, and ρ_e is the volume charge density. The equations are the Gauss law, the Faraday law, the Coulomb law, and the Ampère-Maxwell law.

Instead of using $\mathbf{E}$ and $\mathbf{B}$, we can use an alternative notation with the dielectric displacement $\mathbf{D}$ and the magnetic field $\mathbf{H}$:

$$\boldsymbol{\nabla} \cdot \mathbf{H} = 0, \tag{5}$$

$$\frac{1}{c^2}\frac{\partial \mathbf{H}}{\partial t} + \boldsymbol{\nabla} \times \mathbf{D} = \mathbf{0}, \tag{6}$$

$$\boldsymbol{\nabla} \cdot \mathbf{D} = \rho_e, \tag{7}$$

$$-\frac{\partial \mathbf{D}}{\partial t} + \boldsymbol{\nabla} \times \mathbf{H} = \mathbf{J}. \tag{8}$$

Notice that the factor $1/c^2$ now appears in the Faraday law instead of the Ampère-Maxwell law.

2.2 Symmetrized ECE field equations

The electromagnetic field equations of ECE theory are

$$\boldsymbol{\nabla} \cdot \mathbf{B} = -\mu_0 j^0, \tag{9}$$

$$\frac{\partial \mathbf{B}}{\partial t} + \boldsymbol{\nabla} \times \mathbf{E} = c\,\mu_0\,\mathbf{j}, \tag{10}$$

$$\boldsymbol{\nabla} \cdot \mathbf{E} = \frac{\rho}{\epsilon_0}, \tag{11}$$

$$-\frac{1}{c^2}\frac{\partial \mathbf{E}}{\partial t} + \boldsymbol{\nabla} \times \mathbf{B} = \mu_0\,\mathbf{J}, \tag{12}$$

with the homogeneous current density $\mathbf{j}$ and the homogeneous charge density j^0. According to Eqs. (24-27) in the first paper [5], the right sides can be written as

$$-\mu_0 j^0 = 2\boldsymbol{\kappa}_{(\Lambda)} \cdot \mathbf{B}, \tag{13}$$

$$c\,\mu_0\,\mathbf{j} = 2\left(c\kappa_{(\Lambda)0}\mathbf{B} - \boldsymbol{\kappa}_{(\Lambda)} \times \mathbf{E}\right), \tag{14}$$

$$\frac{\rho}{\epsilon_0} = -2\boldsymbol{\kappa} \cdot \mathbf{E}, \tag{15}$$

$$\mu_0\,\mathbf{J} = 2\left(\frac{1}{c}\kappa_0\mathbf{E} + \boldsymbol{\kappa} \times \mathbf{B}\right). \tag{16}$$

The κ's are wave numbers that are determined by the curvature and torsion of spacetime.

Using the symmetrized Maxwell equations (5-8), we have to redefine j^0 and $\mathbf{j}$ in a way that satisfies the ECE equations (9-12). Equations (7-8) already have the desired form. For equations (5-6), we have two options: either we use the $\mathbf{E}$ and $\mathbf{B}$ fields as in (9-10), or we rewrite them using the alternative notation with the dielectric displacement $\mathbf{D}$ and the magnetic field $\mathbf{H}$. Each option will have different physical dimensions of j^0 and $\mathbf{j}$. For the Gauss law, the first option gives us

$$\boldsymbol{\nabla} \cdot \mathbf{B} = \rho_p, \tag{17}$$

where ρ_p has the units $T/m = Vs/m^3$. This is a volume density and compares well with the electronic charge density, which has the units $C/m^3 = As/m^3$. Selecting the second option would give us

$$\boldsymbol{\nabla} \cdot \mathbf{H} = \rho_p, \tag{18}$$

but we would obtain for ρ_p the units A/m^2, which is an area current density and is not meaningful here. Using the same arguments, we will define the Faraday law of ECE theory by

$$\frac{\partial \mathbf{B}}{\partial t} + \boldsymbol{\nabla} \times \mathbf{E} = \mathbf{V}. \tag{19}$$

The current density of the homogeneous current was renamed $\mathbf{V}$, because it has the units of V/m^2, which is the same as $Vs/(m^2s)$, and represents an area flux density of a potential. The ECE field equations now read:

$$\boldsymbol{\nabla} \cdot \mathbf{B} = \rho_p, \tag{20}$$

$$\frac{\partial \mathbf{B}}{\partial t} + \boldsymbol{\nabla} \times \mathbf{E} = \mathbf{V}, \tag{21}$$

$$\boldsymbol{\nabla} \cdot \mathbf{D} = \rho_e, \tag{22}$$

$$-\frac{\partial \mathbf{D}}{\partial t} + \boldsymbol{\nabla} \times \mathbf{H} = \mathbf{J}. \tag{23}$$

The factor of $1/c^2$ is no longer in front of any time derivative, and the Gauss and Faraday laws are now fully equivalent to the Coulomb and Ampère-Maxwell laws – except for a sign change in the time derivatives. These equations have physically meaningful charge and current units, and both pairs are dual to each other (see Table 1). The Gauss and Faraday laws now correspond to the Coulomb and Ampère-Maxwell laws through the following mappings:

$$\mathbf{D} \longleftrightarrow \mathbf{B}, \tag{24}$$

$$\mathbf{E} \longleftrightarrow \mathbf{H}, \tag{25}$$

$$\mathbf{J} \longleftrightarrow \mathbf{V}, \tag{26}$$

$$\rho_e \longleftrightarrow \rho_p. \tag{27}$$

As we can see from Table 1 (below), it follows that the units in the left and right columns can be transformed into one another by simply replacing V with A, and vice versa. The "magnetic" charge q_p has units of Volt-seconds and is an electric property rather than a magnetic one. The reverse holds for the electric charge q_e which contains the Ampère that appears in all magnetic units. Thus, an electric charge has a magnetic character, even if this may seem quite unusual.

Electric	Unit	Magnetic	Unit
μ_0	$\frac{Vs}{Am}$	ϵ_0	$\frac{As}{Vm}$
$\mathbf{E}$	$\frac{V}{m}$	$\mathbf{H}$	$\frac{A}{m}$
$\mathbf{B}$	$\frac{Vs}{m^2}$	$\mathbf{D}$	$\frac{As}{m^2}$
$\mathbf{V}$	$\frac{V}{m^2}$	$\mathbf{J}$	$\frac{A}{m^2}$
q_p	Vs	q_e	As
ρ_p	$\frac{Vs}{m^3}$	ρ_e	$\frac{As}{m^3}$
η_0	$\frac{V}{Am}$	σ_0	$\frac{A}{Vm}$

Table 1: Physical units of electric and magnetic quantities.

From Eqs. (13-16), we obtain the the charge and current densitiy terms:

$$\rho_p = -2\boldsymbol{\kappa}_{(\Lambda)} \cdot \mathbf{B}, \tag{28}$$

$$\mathbf{V} = 2\left(c\kappa_{(\Lambda)0}\mathbf{B} - \boldsymbol{\kappa}_{(\Lambda)} \times \mathbf{E}\right), \tag{29}$$

$$\rho_e = -2\epsilon_0 \boldsymbol{\kappa} \cdot \mathbf{E}, \tag{30}$$

$$\mathbf{J} = \frac{2}{\mu_0}\left(\frac{1}{c}\kappa_0\mathbf{E} + \boldsymbol{\kappa} \times \mathbf{B}\right). \tag{31}$$

In ECE theory, all charge and current terms are expressed by fields. **V** and **J** consist of a conductivity term and a Lorentz force term, as was already worked out in paper [5].

2.3 Conductivity terms

In electrical engineering, Ohm's law is used extensively. It is not included in the Maxwell-Heaviside equations, but it has been recognized as an empirical law. It connects the current density with the electric field strength by a conductivity factor σ_0:

$$\mathbf{J} = \sigma_0 \mathbf{E}. \tag{32}$$

σ_0 is a tensor in the most general case, but it will be handled as a scalar constant here. As already stated in the first paper of this series [5], Ohm's law is contained in the ECE equations via a conductivity term. From Eq. (31), we can directly see that the conductivity can be defined by

$$\sigma_0 = \frac{2\epsilon_0}{\mu_0 c}. \tag{33}$$

If the Lorentz term in (31) is neglected, we immediately get Eq. (32), and then substituting

$$\mathbf{D} = \epsilon_0 \mathbf{E} \tag{34}$$

into (32) gives us

$$\mathbf{J} = \frac{\sigma_0}{\epsilon_0}\mathbf{D}. \tag{35}$$

The quotient σ_0/ϵ_0 has the units of inverse seconds and is a frequency. We denote this by

$$\omega_e = \frac{\sigma_0}{\epsilon_0}, \tag{36}$$

giving us

$$\mathbf{J} = \omega_e \mathbf{D}. \tag{37}$$

ω_e is the frequency of an inwardly spiralling electric induction.

An analogous effect can be found in the following way. We can define a conductivity for the potential density **V** by an equation that is dual to Ohm's law:

$$\mathbf{V} = \eta_0 \mathbf{H}. \tag{38}$$

By comparing this equation with (29) we find that

$$\eta_0 = 2c\kappa_{(\Lambda)0}\mu_0, \tag{39}$$

and by substituting

$$\mathbf{B} = \mu_0 \mathbf{H} \tag{40}$$

into (38), we find that

$$\mathbf{V} = \frac{\eta_0}{\mu_0}\mathbf{B}. \tag{41}$$

The quotient η_0/μ_0 has the units of a frequency, again. We denote this by

$$\omega_p = \frac{\eta_0}{\mu_0}, \tag{42}$$

leading to

$$\mathbf{V} = \omega_p \mathbf{B}. \tag{43}$$

ω_p is the frequency of an outwardly spiralling magnetic induction.

3 Poynting vector and power density

The potential density causes additional terms to appear in the Poynting vector, terms that have been unaccounted for so far. The Poynting vector (with units of W/m^2) describes the flow of power per unit area and is defined by

$$\mathbf{S} = \mathbf{E} \times \mathbf{H}. \tag{44}$$

In a given volume that contains electromagnetic fields, it counts the energy flow through the boundaries. The field energy density in the volume is given by

$$u = \frac{1}{2}\left(\mathbf{E}\cdot\mathbf{D} + \mathbf{B}\cdot\mathbf{H}\right) \tag{45}$$

(see section 5.3.1 of [2], or any electrodynamics textbook). The Poynting theorem states that the change in time of u and the divergence of $\mathbf{S}$ are related by

$$\frac{\partial u}{\partial t} + \boldsymbol{\nabla}\cdot\mathbf{S} = -\mathbf{J}\cdot\mathbf{E}. \tag{46}$$

This is the conservation law for the field energy. The divergence term of $\mathbf{S}$ can be rewritten by using the vector algebra rule,

$$\boldsymbol{\nabla}\cdot(\mathbf{A}\times\mathbf{B}) = (\boldsymbol{\nabla}\times\mathbf{A})\cdot\mathbf{B} - (\boldsymbol{\nabla}\times\mathbf{B})\cdot\mathbf{A}, \tag{47}$$

to give us

$$\boldsymbol{\nabla}\cdot\mathbf{S} = (\boldsymbol{\nabla}\times\mathbf{E})\cdot\mathbf{H} - (\boldsymbol{\nabla}\times\mathbf{H})\cdot\mathbf{E}. \tag{48}$$

The terms $\boldsymbol{\nabla} \times \mathbf{E}$ and $\boldsymbol{\nabla} \times \mathbf{H}$ can be replaced with Eqs. (21) and (23):

$$\boldsymbol{\nabla} \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} + \mathbf{V}, \tag{49}$$

$$\boldsymbol{\nabla} \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}. \tag{50}$$

Then, from (48), it follows that

$$\boldsymbol{\nabla} \cdot \mathbf{S} = \left(-\frac{\partial \mathbf{B}}{\partial t} + \mathbf{V} \right) \cdot \mathbf{H} - \left(\frac{\partial \mathbf{D}}{\partial t} + \mathbf{J} \right) \cdot \mathbf{E}. \tag{51}$$

Inserting the conductivity equations

$$\mathbf{J} = \sigma_0 \mathbf{E}, \tag{52}$$

$$\mathbf{V} = \eta_0 \mathbf{H}, \tag{53}$$

then gives us

$$\boldsymbol{\nabla} \cdot \mathbf{S} = \left(-\frac{\partial \mathbf{B}}{\partial t} + \eta_0 \mathbf{H} \right) \cdot \mathbf{H} - \left(\frac{\partial \mathbf{D}}{\partial t} + \sigma_0 \mathbf{E} \right) \cdot \mathbf{E}, \tag{54}$$

which in vacuo is

$$\begin{aligned} \boldsymbol{\nabla} \cdot \mathbf{S} &= \left(-\mu_0 \frac{\partial \mathbf{H}}{\partial t} + \eta_0 \mathbf{H} \right) \cdot \mathbf{H} - \epsilon_0 \left(\frac{\partial \mathbf{E}}{\partial t} + \sigma_0 \mathbf{E} \right) \cdot \mathbf{E} \\ &= -\mu_0 \frac{\partial \mathbf{H}}{\partial t} \cdot \mathbf{H} + \eta_0 \mathbf{H}^2 - \epsilon_0 \frac{\partial \mathbf{E}}{\partial t} \cdot \mathbf{E} - \sigma_0 \mathbf{E}^2. \end{aligned} \tag{55}$$

The scalar product of the fields with their time derivatives can be rewritten via the product rule,

$$\frac{\partial \mathbf{A}^2}{\partial t} = 2 \frac{\partial \mathbf{A}}{\partial t} \mathbf{A}, \tag{56}$$

to give the final result:

$$\boxed{\boldsymbol{\nabla} \cdot \mathbf{S} = -\frac{\epsilon_0}{2} \frac{\partial \mathbf{E}^2}{\partial t} - \frac{\mu_0}{2} \frac{\partial \mathbf{H}^2}{\partial t} - \sigma_0 \mathbf{E}^2 + \eta_0 \mathbf{H}^2.} \tag{57}$$

The first three terms are negative and effect a decrease of the energy flow, while the fourth term $\eta_0 \mathbf{H}^2$ is positive and increases the energy flow when the magnetic field is increased. This is the long-sought Heaviside energy flow, which describes an energy flow from spacetime.

Additional contributing factors to this energy flow become visible when electrodynamics is placed on a broader basis, for example, when it is based on Clifford algebra [9].

4 Wave equations

4.1 Wave equations from symmetric ECE field equations

The standard wave equations of electrodynamics are well known. They are found by taking the time derivative and curl of the Faraday and Ampère-Maxwell laws in different combinations. We can also do so with the symmetric ECE field equations (21) and (23). Taking the curl of (21) and the time derivative of (23) leads us to

$$\frac{1}{c^2}\frac{\partial}{\partial t}\boldsymbol{\nabla}\times\mathbf{H}+\boldsymbol{\nabla}\times\boldsymbol{\nabla}\times\mathbf{D}=\epsilon_0\boldsymbol{\nabla}\times\mathbf{V}, \tag{58}$$

$$-\frac{\partial^2\mathbf{D}}{\partial t^2}+\frac{\partial}{\partial t}\boldsymbol{\nabla}\times\mathbf{H}=\frac{\partial\mathbf{J}}{\partial t}. \tag{59}$$

Then, using the identity

$$\boldsymbol{\nabla}\times\boldsymbol{\nabla}\times\mathbf{A}=-\nabla^2\mathbf{A}+\boldsymbol{\nabla}(\boldsymbol{\nabla}\cdot\mathbf{A}), \tag{60}$$

and assuming that the fields are divergence-free gives us for the first equation:

$$\frac{1}{c^2}\frac{\partial}{\partial t}\boldsymbol{\nabla}\times\mathbf{H}-\nabla^2\mathbf{D}=\epsilon_0\boldsymbol{\nabla}\times\mathbf{V}. \tag{61}$$

From the second equation we obtain

$$\frac{\partial}{\partial t}\boldsymbol{\nabla}\times\mathbf{H}=\frac{\partial^2\mathbf{D}}{\partial t^2}+\frac{\partial\mathbf{J}}{\partial t}. \tag{62}$$

By inserting this into Eq. (61), we find that

$$\boxed{\frac{1}{c^2}\frac{\partial\mathbf{D}}{\partial t}-\nabla^2\mathbf{D}=-\frac{\partial\mathbf{J}}{\partial t}+\epsilon_0\boldsymbol{\nabla}\times\mathbf{V}.} \tag{63}$$

Under the assumption that **J** and **V** are predefined, this is an inhomogeneous wave equation for **D**.

Similarly, we find a wave equation for **H** when we take the time derivative of (21) and the curl of (23):

$$-\frac{1}{c^2}\frac{\partial^2\mathbf{H}}{\partial t^2}+\frac{\partial}{\partial t}\boldsymbol{\nabla}\times\mathbf{D}=\epsilon_0\frac{\partial\mathbf{V}}{\partial t}, \tag{64}$$

$$-\frac{\partial}{\partial t}\boldsymbol{\nabla}\times\mathbf{D}+\boldsymbol{\nabla}\times\boldsymbol{\nabla}\times\mathbf{H}=\boldsymbol{\nabla}\times\mathbf{J}. \tag{65}$$

The second equation can again be rewritten as

$$-\frac{\partial}{\partial t}\boldsymbol{\nabla}\times\mathbf{D}-\nabla^2\mathbf{H}=\boldsymbol{\nabla}\times\mathbf{J}, \tag{66}$$

and then inserting it into (64) gives us

$$\boxed{\frac{1}{c^2}\frac{\partial^2\mathbf{H}}{\partial t^2}-\nabla^2\mathbf{H}=\boldsymbol{\nabla}\times\mathbf{J}+\epsilon_0\frac{\partial\mathbf{V}}{\partial t}.} \tag{67}$$

This is an inhomogeneous wave equation for the **H** field. Both wave equations (63) and (67) differ from standard theory by the fact that a potential density **V** appears as an additional source term.

4.2 Wave equations with conductivity terms

In the following discussion we will replace **J** and **V** by their conductivity terms. This will lead to homogeneous wave equations, in contrast to the former versions where **J** and **V** represented inhomogeneous terms, which acted as sources. We will proceed similarly to how we did in the preceding section.

4.2.1 Wave equations for E and J

With the electric conductivity (37), $\mathbf{J} = \omega_e \mathbf{D}$, the Ampère-Maxwell law (23) reads

$$\boldsymbol{\nabla} \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \omega_e \mathbf{D} = \epsilon_0 \left(\frac{\partial \mathbf{E}}{\partial t} + \omega_e \mathbf{E} \right). \tag{68}$$

The Faraday law (21) with the potential density (43), $\mathbf{V} = \omega_p \mathbf{B}$, is

$$\boldsymbol{\nabla} \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} + \omega_e \mathbf{B} = -\mu_0 \left(\frac{\partial \mathbf{H}}{\partial t} - \omega_p \mathbf{H} \right). \tag{69}$$

Taking the curl of the last equation gives us

$$\boldsymbol{\nabla} \times \boldsymbol{\nabla} \times \mathbf{E} = -\mu_0 \left(\frac{\partial}{\partial t} \boldsymbol{\nabla} \times \mathbf{H} - \omega_p \boldsymbol{\nabla} \times \mathbf{H} \right). \tag{70}$$

Inserting Eq. (68) then leads to

$$\begin{aligned} \boldsymbol{\nabla} \times \boldsymbol{\nabla} \times \mathbf{E} &= -\mu_0 \epsilon_0 \left(\frac{\partial}{\partial t} \left(\frac{\partial \mathbf{E}}{\partial t} + \omega_e \mathbf{E} \right) - \omega_p \left(\frac{\partial \mathbf{E}}{\partial t} + \omega_e \mathbf{E} \right) \right) \\ &= -\frac{1}{c^2} \left(\frac{\partial^2 \mathbf{E}}{\partial t^2} + \omega_e \frac{\partial \mathbf{E}}{\partial t} - \omega_p \left(\frac{\partial \mathbf{E}}{\partial t} + \omega_e \mathbf{E} \right) \right) \\ &= -\frac{1}{c^2} \left(\frac{\partial^2 \mathbf{E}}{\partial t^2} + (\omega_e - \omega_p) \frac{\partial \mathbf{E}}{\partial t} - \omega_p \omega_e \mathbf{E} \right). \end{aligned} \tag{71}$$

As before, we assume that the fields are divergenceless, so that

$$\boldsymbol{\nabla} \times \boldsymbol{\nabla} \times \mathbf{E} = -\nabla^2 \mathbf{E}. \tag{72}$$

Eq. (71) can then be written in the form

$$\boxed{\frac{1}{c^2} \left(\frac{\partial^2 \mathbf{E}}{\partial t^2} + (\omega_e - \omega_p) \frac{\partial \mathbf{E}}{\partial t} - \omega_p \omega_e \mathbf{E} \right) - \nabla^2 \mathbf{E} = \mathbf{0}.} \tag{73}$$

This is a homogeneous partial differential equation of second order for $\mathbf{E}$. If there is no conductivity,

$$\omega_e = \omega_p = 0, \tag{74}$$

then Eq. (73) becomes the standard wave equation of electromagnetic fields in the vacuum:

$$\frac{1}{c^2} \frac{\partial^2 \mathbf{E}}{\partial t^2} - \nabla^2 \mathbf{E} = \mathbf{0}. \tag{75}$$

We can also easily derive a wave equation for $\mathbf{J}$. From (37) we have the linear relation

$$\mathbf{E} = \frac{\mathbf{J}}{\omega_0 \epsilon_0}, \tag{76}$$

and because (73) is linear in $\mathbf{E}$, it follows directly that

$$\boxed{\frac{1}{c^2} \left(\frac{\partial^2 \mathbf{J}}{\partial t^2} + (\omega_e - \omega_p) \frac{\partial \mathbf{J}}{\partial t} - \omega_p \omega_e \mathbf{J} \right) - \nabla^2 \mathbf{J} = \mathbf{0}.} \tag{77}$$

4.2.2 Wave equations for H and V

We now proceed in an analogous way to derive a wave equation for **H**. Using the potential density (43), $\mathbf{V} = \omega_p \mathbf{B}$, the Faraday law (21) reads

$$\boldsymbol{\nabla} \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} + \omega_p \mathbf{B} = -\mu_0 \left(\frac{\partial \mathbf{H}}{\partial t} - \omega_p \mathbf{H} \right). \tag{78}$$

The Ampère-Maxwell law (23) with the current density (37), $\mathbf{J} = \omega_e \mathbf{D}$, is

$$\boldsymbol{\nabla} \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \omega_e \mathbf{D} = \epsilon_0 \left(\frac{\partial \mathbf{E}}{\partial t} + \omega_e \mathbf{E} \right). \tag{79}$$

Taking the curl of the last equation gives us

$$\boldsymbol{\nabla} \times \boldsymbol{\nabla} \times \mathbf{H} = \epsilon_0 \left(\frac{\partial}{\partial t} \boldsymbol{\nabla} \times \mathbf{E} + \omega_e \boldsymbol{\nabla} \times \mathbf{E} \right). \tag{80}$$

Inserting Eq. (78) then leads to

$$\begin{aligned} \boldsymbol{\nabla} \times \boldsymbol{\nabla} \times \mathbf{H} &= -\mu_0 \epsilon_0 \left(\frac{\partial}{\partial t} \left(\frac{\partial \mathbf{H}}{\partial t} - \omega_p \mathbf{H} \right) + \omega_e \left(\frac{\partial \mathbf{H}}{\partial t} - \omega_p \mathbf{H} \right) \right) \\ &= -\frac{1}{c^2} \left(\frac{\partial^2 \mathbf{H}}{\partial t^2} - \omega_p \frac{\partial \mathbf{H}}{\partial t} + \omega_e \left(\frac{\partial \mathbf{H}}{\partial t} - \omega_p \mathbf{H} \right) \right) \\ &= -\frac{1}{c^2} \left(\frac{\partial^2 \mathbf{H}}{\partial t^2} + (\omega_e - \omega_p) \frac{\partial \mathbf{H}}{\partial t} - \omega_p \omega_e \mathbf{H} \right). \end{aligned} \tag{81}$$

As before, we assume that the fields are divergenceless, so that

$$\boldsymbol{\nabla} \times \boldsymbol{\nabla} \times \mathbf{H} = -\nabla^2 \mathbf{H}. \tag{82}$$

Eq. (81) can then be written in the form

$$\boxed{\frac{1}{c^2} \left(\frac{\partial^2 \mathbf{H}}{\partial t^2} + (\omega_e - \omega_p) \frac{\partial \mathbf{H}}{\partial t} - \omega_p \omega_e \mathbf{H} \right) - \nabla^2 \mathbf{H} = \mathbf{0}.} \tag{83}$$

This is a homogeneous partial differential equation of second order for **H**. If there are no conductivities,

$$\omega_e = \omega_p = 0, \tag{84}$$

then Eq. (83) becomes the standard wave equation of magnetic fields in the vacuum:

$$\frac{1}{c^2} \frac{\partial^2 \mathbf{H}}{\partial t^2} - \nabla^2 \mathbf{H} = \mathbf{0}. \tag{85}$$

We can now easily derive a wave equation for **V**. From (43) we have the linear relation

$$\mathbf{V} = \frac{\mathbf{H}}{\omega_p \mu_0}, \tag{86}$$

and because (83) is linear in **H**, it follows directly that

$$\boxed{\frac{1}{c^2} \left(\frac{\partial^2 \mathbf{V}}{\partial t^2} + (\omega_e - \omega_p) \frac{\partial \mathbf{V}}{\partial t} - \omega_p \omega_e \mathbf{V} \right) - \nabla^2 \mathbf{V} = \mathbf{0}.} \tag{87}$$

5 Field velocities

5.1 General calculation

The expansion velocity of standard electromagnetic waves is the velocity of light c in vacuo. In the following, we will show that the wave equations derived in the preceding section can lead to velocities different from c.

We compute the expansion velocity in the following way. For simplicity, we restrict ourselves to one dimension, X. Then, the time derivative of a field component E_X is

$$\frac{\partial E_X}{\partial t} = \frac{\partial E_X}{\partial X}\frac{\partial X}{\partial t} = v_X \frac{\partial E_X}{\partial X}. \tag{88}$$

In special relativity, the speed v_X is assumed to be constant. Consequently, the second time derivative is

$$\frac{\partial^2 E_X}{\partial t^2} = v_X \frac{\partial}{\partial t}\left(\frac{\partial E_X}{\partial X}\right) = v_X \frac{\partial X}{\partial t}\frac{\partial}{\partial X}\left(\frac{\partial E_X}{\partial X}\right) = v_X^2 \frac{\partial^2 E_X}{\partial X^2}. \tag{89}$$

Generalized to vector form, this equation reads

$$\frac{\partial^2 \mathbf{E}}{\partial t^2} = \mathbf{v}^2\ \nabla^2 \mathbf{E} \tag{90}$$

or

$$\nabla^2 \mathbf{E} = \frac{1}{\mathbf{v}^2}\frac{\partial^2 \mathbf{E}}{\partial t^2}. \tag{91}$$

After we insert this into the standard wave equation (75), the time derivatives of $\mathbf{E}$ cancel out, and we obtain

$$v^2 = c^2 \quad \text{or} \quad v = c. \tag{92}$$

We use the same procedure for determining the wave velocities of the extended wave equations (73, 77, 83, 87), which are all identical in structure. Eq. (73) then becomes

$$\frac{1}{c^2}\left(\frac{\partial^2 \mathbf{E}}{\partial t^2} + (\omega_e - \omega_p)\frac{\partial \mathbf{E}}{\partial t} - \omega_p \omega_e \mathbf{E}\right) - \frac{1}{\mathbf{v}^2}\frac{\partial^2 \mathbf{E}}{\partial t^2} = \mathbf{0}. \tag{93}$$

Thus, that the equation has been reduced to a differential equation of only one variable t, multiplying by $c^2 v^2$ gives us

$$\left(v^2 - c^2\right)\frac{\partial^2 \mathbf{E}}{\partial t^2} + v^2\left((\omega_e - \omega_p)\frac{\partial \mathbf{E}}{\partial t} - \omega_p \omega_e \mathbf{E}\right) = \mathbf{0}. \tag{94}$$

This is a quadratic equation in v and can be solved when certain model forms of $\mathbf{E}$ are assumed. Furthermore, we can consider conductors and nonconductors separately by choosing ω_e and ω_p appropriately.

To obtain a suitable equation for determining v, we transform this equation into a form where only spatial derivatives of $\mathbf{E}$ appear. To avoid complications with vector algebra, we restrict consideration to a one-dimensional case $E(r,\, t)$ with space coordinate r. Then we have

$$\frac{\partial E}{\partial t} = v\frac{\partial E}{\partial r}, \tag{95}$$

$$\frac{\partial^2 E}{\partial t^2} = v^2\frac{\partial^2 E}{\partial r^2}, \tag{96}$$

and Eq. (73) takes the form

$$\frac{1}{c^2}\left(v^2\frac{\partial^2 E}{\partial r^2} + v\left(\omega_e - \omega_p\right)\frac{\partial E}{\partial r} - \omega_p\omega_e E\right) - \frac{\partial^2 E}{\partial r^2} = 0 \tag{97}$$

or

$$(v^2 - c^2)\frac{\partial^2 E}{\partial r^2} + v\left(\omega_e - \omega_p\right)\frac{\partial E}{\partial r} - \omega_p\omega_e E = 0. \tag{98}$$

This is a quadratic equation in v again. The same equation holds for any of the fields E, H, J, of V. Therefore, we denote these field with F in the following discussion.

We can make three different assumptions about the spatial structure of the fields:

1. Exponentially decreasing:

$$F = F_0 e^{-kr}, \tag{99}$$

2. Exponentially increasing:

$$F = F_0 e^{kr}, \tag{100}$$

3. Oscillating:

$$F = F_0 e^{-ikr}, \tag{101}$$

where F_0 is an amplitude and k is a wave number. When we apply these assumptions to Eq. (98), the amplitudes and exponential factors cancel out, and for the three cases above we obtain the general solutions:

1. Exponentially decreasing:

$$v = \frac{\pm\sqrt{(\omega_e + \omega_h)^2 + 4c^2\, k^2} + \omega_e - \omega_h}{2k}, \tag{102}$$

2. Exponentially increasing:

$$v = \frac{\pm\sqrt{(\omega_e + \omega_h)^2 + 4c^2\, k^2} - \omega_e + \omega_h}{2k}, \tag{103}$$

3. Oscillating:

$$v = \frac{\pm\sqrt{-(\omega_e + \omega_h)^2 + 4c^2\, k^2} + i(\omega_e - \omega_h)}{2k}. \tag{104}$$

To make the solutions more specific, we consider three cases for the frequencies ω_e and ω_h that determine the conductivity behavior of the material in which the waves propagate:

1. Conductor: this is defined by

$$\omega_e \neq 0, \qquad \omega_h = 0, \tag{105}$$

   and the corresponding wave vector in the velocity is

$$k = \frac{\omega_e}{c}. \tag{106}$$

2. Non-conductor: similarly to the first case, we obtain

$$\omega_e = 0, \qquad \omega_h \neq 0, \tag{107}$$

$$k = \frac{\omega_h}{c}. \tag{108}$$

3. Equilibrium wave: in special cases, for example to describe quantum systems, both conductivities are equal:

$$\omega_e = \omega_h =: \omega_0, \tag{109}$$

$$k = \frac{\omega_0}{c}. \tag{110}$$

Once we specify all of these cases, the computer algebra code delivers results for the velocities (102 - 104) that contain no constants other than c. The resulting velocities are listed in Table 2, and the numerical values are also shown. We assume that the negative values describe backward motion, and can be sorted out. We obtain values that are smaller or even larger than c. The latter result is discussed in more detail below. Interestingly, the exponential waves in the conductor and non-conductor follow the golden ratio. For oscillating waves, we obtain a real and an imaginary part. The imaginary part may indicate oscillations [9].

	v(conductor)	v(non-conductor)	v(equilibrium wave)
Exponential decreasing	$\frac{(\pm\sqrt{5}+1)c}{2}$	$\frac{(\pm\sqrt{5}-1)c}{2}$	$\pm\sqrt{2}c$
	$-0.618c$	$-1.618c$	$-1.414c$
	$1.618c$	$0.618c$	$1.414c$
Exponential increasing	$\frac{(\pm\sqrt{5}-1)c}{2}$	$\frac{(\pm\sqrt{5}+1)c}{2}$	$\pm\sqrt{2}c$
	$-1.618c$	$-0.618c$	$-1.414c$
	$0.618c$	$1.618c$	$1.414c$
Oscillating	$\frac{(\pm\sqrt{3}+i)c}{2}$	$\frac{(\pm\sqrt{3}-i)c}{2}$	0
	$(-0.866+0.5i)c$	$(-0.866-0.5i)c$	0
	$(0.866+0.5i)c$	$(0.866-0.5i)c$	0

Table 2: Expansion velocities of electromagnetic fields with conductivity terms.

In the equilibrium case, the propagation velocity for decreasing and increasing waves is identical, and greater than c. When we have an oscillation, the velocity is zero, i.e., there is no wave propagation: it is a standing wave. This is the case for quantum mechanical systems, for example, for electrons in atoms.

5.2 Interpretation of $v > c$

In special relativity, which is the basis of standard quantum mechanics, the velocity of light in vacuo, c, is an absolute limit for any kind of motion. To understand the breaking of this rule, we have to advance to general relativity. In ECE theory, spacetime is identified with the flow of aether, which has local variations in density. This density variation is described by m theory [2]. There it was shown that general relativity, and in particular m theory, allows velocities greater than c.

In m theory, a generalized relativistic γ factor is used, which has the form:

$$\gamma = \left(\mathrm{m}(r) - \frac{v^2}{\mathrm{m}(r) c^2} \right)^{-1/2} . \tag{111}$$

$\mathrm{m}(r)$ is a function that is dependent on the space coordinate r, and describes the variation of the spacetime density. In the case of a spherically symmetric spacetime, this is the radial coordinate. When γ is predefined, the above equation can be solved for $\mathrm{m}(r)$. The solution is

$$\mathrm{m}(r) = \frac{\pm\sqrt{4 \frac{v^2}{c^2} \gamma^4 + 1} + 1}{2\gamma^2} . \tag{112}$$

In the limit $\gamma \to \infty$,

$$\frac{1}{\gamma} \to 0, \tag{113}$$

and from Eq. (111) we obtain

$$m(r) \to \pm \frac{v}{c}, \tag{114}$$

which is a constant function. The asymptotes of γ with respect to $\mathrm{m}(r)$ can be seen in Fig. 1, where the values of v/c appearing in Table 1 have been used. $\mathrm{m}(r) = 1$ corresponds to the limit of special relativity.

Alternatively, $v > c$ can be derived from an extension of special relativity. As described in [9], the relativistic γ factor can be developed in the form

$$\mathbf{E} = \left(1 + \frac{v^2}{c^2} + \left(\frac{v^2}{c^2} \right)^2 + \left(\frac{v^2}{c^2} \right)^3 + \dots \right) \mathbf{E}_0, \tag{115}$$

which is a series expansion for the transformation law $\mathbf{E}_0 \to \mathbf{E}$. This series is convergent for $v < c$, but divergent for $v \geq c$. In the latter case, this means that energy is transferred from spacetime.

To summarize the main point of this section, velocities $v > c$ are possible in generally relativistic theory. The velocities that we obtained for the wave equations with conductivity terms directly show the limits for the corresponding m function.

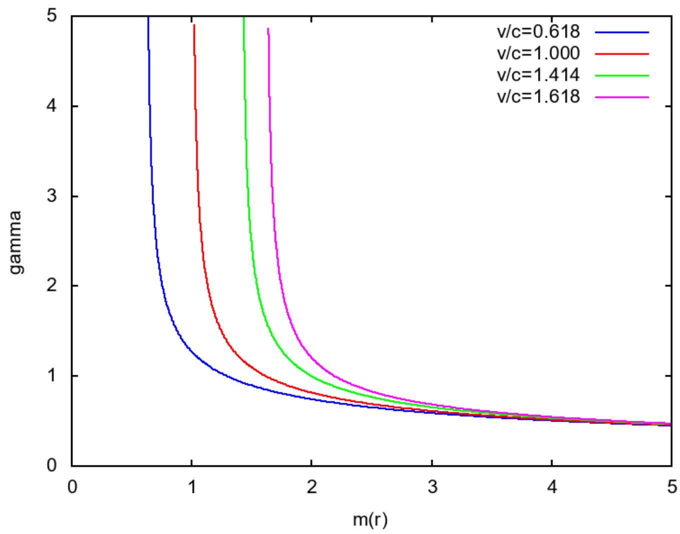

Figure 1: γ as a function of m(r) for different ratios v/c.

5.3 Experimental verification

Experiments by Aichmann and Nimtz [10] have shown that electromagnetic signals can propagate with superluminal velocity through barriers. This is not an artifact of the phase velocity, which is known to be able to be greater than the group velocity. Information is transferred by the group velocity, and measurements show that the group velocity is greater than c. Thus, the researchers were able to transfer large amounts of information with superluminal speed.

There is a continuing debate about whether these results are actually possible. When the quantum mechanical tunneling effect is considered, tunneling of single particles takes place in zero time, and wave packets can tunnel through a barrier much faster than they move in vacuo. This is not a break of causality because the effect does not allow loops in the direction of time. The only consequence is that for superluminal processes the ratio v/c in special relativity has to be changed to v/c', where c' is the increased signal velocity.

Critics frequently argue that a luminal front velocity of wave fronts can explain the experimental results. However, this is not possible since such a concept requires mathematically exact jumps in amplitude, and therefore the existence of an infinite frequency in the frequency spectrum, which would require infinite energy [10].

As a final remark, we state that Aichmann and Nimtz are not the only ones who have measured superluminal speed. In their paper, they reference other experiments which have not been given much attention in the past.

Acknowledgment

We would like to thank John Surbat for proofreading this paper and suggesting improvements.

References

[1] M. W. Evans, “Generally Covariant Unified Field Theory: The Geometrization of Physics”, Vols. 1 to 7, Abramis Academic, Bury St Edmunds, 2005 ff.

[2] H. Eckardt, “ECE UFT - The Geometrical Basis of Physics, Vol. I - Classical Physics”, textbook, epubli, Berlin, 2022, freely available as UFT Paper 438, Unified Field Theory (UFT) section of www.aias.us.

[3] H. Eckardt, “ECE UFT - The Geometrical Basis of Physics, Vol. II - Quantum Physics”, textbook, in preparation, freely available as UFT Paper 448, Unified Field Theory (UFT) section of www.aias.us.

[4] Scientific and popular articles on Unified Field Theory (UFT), Unified Field Theory (UFT) and Publications sections of www.aias.us.

[5] H. Eckardt, “Properties of the homogeneous and inhomogeneous ECE current, Part I”, UFT Paper 454, Unified Field Theory (UFT) section of www.aias.us.

[6] H. Eckardt, “Properties of the homogeneous and inhomogeneous ECE current, Part II”, UFT Paper 455, Unified Field Theory (UFT) section of www.aias.us.

[7] A. K. C. Tan et al., “Revealing emergent magnetic charge in an antiferromagnet with diamond quantum magnetometry”, 5 December 2023, Nature Materials. DOI: 10.1038/s41563-023-01737-4

[8] https://www.london-nano.com/research/magnetic-monopoles-discovered-lcn-scientists

[9] A. Goel, “RA-DIANT Next Generation Renewable Energy Device”, Publications section of www.aias.us.

[10] H. Aichmann, G. Nimtz, “On the Traversal Time of Barriers”, Foundations of Physics 44 (6), 678-688 (2014).