Chapter 3

The Spinning Of Spacetime As Seen In The Inverse Faraday Effect

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Abstract

The inverse Faraday effect is the observation of spinning spacetime in general relativity. The spinning gives rise to a spin connection in the Palatini variation of general relativity and in the Evans unified field theory. For the free electromagnetic field the spin connection is the dual of the tetrad field in the tangent spacetime, and from this inference the Evans spin field $\mathbf{B}^{(3)}$ is deduced straightforwardly. The spin field is a magnetic flux density which is observed in the reproducible and repeatable inverse Faraday effect as a magnetization occurring in all materials, in the simplest instance one electron.

Key words: Inverse Faraday effect; Evans field theory, general relativity, Evans spin field, spin connection, tetrad field, Palatini variation.

3.1 Introduction

In the Evans unified field theory [1]– [5] the electromagnetic field is spinning spacetime in general relativity and the gravitational field is curving spacetime in general relativity. The two fields are unified and inter-related by standard differential geometry as first developed by Cartan and others. The fundamental field is the tetrad form of the standard Palatini variation [6]– [9] of general relativity. In this paper the concept of spinning spacetime is established experimentally by reference to the reproducible and repeatable inverse Faraday effect [10]– [12], the magnetization of matter by the circularly polarized component of electromagnetic radiation at any frequency. In the standard model the electromagnetic sector is Lorentz covariant only, and is not therefore objective to all observers, or generally covariant. In consequence, the effect of gravitation on electromagnetism and vice versa cannot be analyzed with the standard model. In the latter, electromagnetism is a spinning and propagating entity superimposed on the Minkowski spacetime of special relativity. The Minkowski spacetime itself does not spin, and in consequence there is no spin connection in the standard models description of electromagnetism. The result is that there is no Evans spin field $\mathbf{B}^{(3)}$ [1]– [5] in the standard model, and no generally covariant or objective explanation in the standard model for the inverse Faraday effect. Available explanations [13, 14] of the inverse Faraday effect in the standard model rely on the conjugate product of transverse potentials or transverse electric or magnetic fields. The conjugate product is introduced empirically [15] and in the standard model it is not realized that the conjugate product defines the Evans spin field. For this, general relativity is needed as explained straightforwardly and simply in this paper.

In Section 3.2 the spin field is defined for the free electromagnetic field using the first Maurer Cartan structure equation of standard differential geometry. In Section 3.3 the inverse Faraday effect is explained from first principles of Evans unified field theory for one electron, and suggestions made for further work on atomic and molecular materials, where the inverse Faraday effect is mediated by a hyperpolarizability which is also a property of differential geometry in the Evans field theory. In this way a self consistent unified field theory of non-linear optics in general can be built up from differential geometry.

This paper therefore emphasizes a key difference between Evans field theory and the obsolete standard model, the spin field exists in the former but not in the latter. The spin field is observed experimentally, so the Evans field theory is preferred because it explains the spin field in a generally covariant manner as required of any valid theory of physics. To be valid, a theory must be objective to all observers, the principle of general relativity.

3.2 Derivation of the Evans Spin Field from First Principles

The starting point is the first Maurer Cartan structure equation of standard differential geometry [1]– [5], which defines the torsion form (T^a) as the covariant exterior derivative ($D\wedge$) of the tetrad form (q^a). In the standard Palatini variation of general relativity the tetrad form becomes the fundamental field. (In the Einstein Hilbert variation of general relativity the symmetric metric becomes the fundamental field.) In the standard notation [16] of differential geometry the first Maurer Cartan structure equation is:

$$T^a = D \wedge q^a = d \wedge q^a + \omega^a{}_b \wedge q^b \tag{3.1}$$

where $\omega^a{}_b$ is the spin connection one-form and where $d\wedge$ denotes the exterior derivative of Cartan. The indices in Eq.(3.1) are those of the tangent spacetime. The indices of the base manifold in differential geometry are always the same on both sides of any equation of differential geometry, so are customarily omitted [16]. Reinstating the base manifold indices we obtain:

$$T^a{}_{\mu\nu} = (d \wedge q^a)_{\mu\nu} + \omega^a{}_{\mu b} \wedge q^b{}_\nu . \tag{3.2}$$

Therefore differential geometry consists of equations of the tangent bundle valid for each and every index such as μ and ν of the base manifold. This inference provides us with one of the fundamental principles of Evans field theory: equations of physics such as the Dirac equation can be written in the tangent bundle and the effect of gravitation on these equations is measured by the way in which the tangent bundle and base manifold are related geometrically. The fundamental field is the tetrad because the latter is defined by:

$$V^a = q^a{}_\mu V^\mu \tag{3.3}$$

where V^a is any vector or spinor in the tangent bundle and where V^μ is the corresponding vector or spinor in the base manifold. The latter is defined by Evans spacetime [1]– [5] and the tangent bundle by the Minkowski spacetime. So the tetrad inter-relates the tangent bundle and base manifold and gives the information required to measure the effect of a curving base manifold: gravitation; or the effect of a spinning base manifold: electromagnetism.

In electromagnetism and electrodynamics the Evans Ansatz [1]– [5] defines the potential field $(A^a{}_\mu)$ as the tetrad field within a scalar-valued factor $A^{(0)}$ with the units of volt s/m. Thus $cA^{(0)}$ has the units of volts, and $cA^{(0)}$ is a primordial quantity (analogous to Feynman′s well known [17] description of electromagnetic potential in special relativity as the universal influence). Thus:

$$A^a{}_\mu = A^{(0)} q^a{}_\mu \tag{3.4}$$

from which the anti-symmetric electromagnetic field tensor is defined as:

$$\begin{aligned} F^a{}_{\mu\nu} &= (d \wedge A^a)_{\mu\nu} + \omega^a{}_{\mu b} \wedge A^b{}_\nu \\ &= \partial_\mu A^a{}_\nu - \partial_\nu A^a{}_\mu + \omega^a{}_{\mu b} A^b{}_\nu - \omega^a{}_{\nu b} A^b{}_\mu . \end{aligned} \tag{3.5}$$

In the standard model the Lorentz covariant equivalent of Eq.(3.5) is:

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu \tag{3.6}$$

In the correctly objective or generally covariant description of electrodynamics (Eq.(3.5)) there appears an extra magnetic flux density for the free field:

$$B^a{}_{\mu\nu} = \omega^a{}_{\mu b} A^b{}_\nu - \omega^a{}_{\nu b} A^b{}_\mu . \tag{3.7}$$

When the magnetic flux density (3.7) interacts with matter it produces the magnetization of the inverse Faraday effect [1]– [5]. Evidently, the standard model's Eq.(3.6) does not produce an inverse Faraday effect. The latter is due to the Evans spin field (3.7) and to the spin connection $\omega^a{}_{\mu b}$ set up by the spinning spacetime that we know as electromagnetism.

By free electromagnetic field we mean the propagating field in the absence of mass (material matter). The free field is defined by the homogeneous Evans field equation, (HE), which is simply Eq.(3.5) developed into the Bianchi identity [1]– [5]:

$$\begin{aligned} d \wedge F^a &= \mu_0 j^a \\ &= A^{(0)} \left(R^a{}_b \wedge q^b - \omega^a{}_b \wedge T^b \right). \end{aligned} \tag{3.8}$$

The HE is a combination [18] of the Gauss Law applied to magnetism and the Faraday law of induction. Both laws are well known to hold to high precision in the laboratory, from which it is deduced that the homogeneous current j^a is zero within contemporary experimental precision in the laboratory. (In cosmological contexts in contrast j^a may be measurable experimentally.) Therefore we may write:

$$j^a \sim 0. \tag{3.9}$$

Eq.(3.9) in geometrical terms is:

$$(D \wedge \omega^a{}_b) \wedge q^b = \omega^a{}_b \wedge \left(D \wedge q^b \right) \tag{3.10}$$

and a solution of Eq.(3.10) is [1]– [5]:

$$\omega^a{}_{\mu b} = -\frac{\kappa}{2} \epsilon^a{}_{bc} q^c{}_\mu \tag{3.11}$$

where κ is the free space wavenumber of the electromagnetic radiation. It follows [18] from Eq.(3.11) that for the free field the Evans spin field is:

$$\mathbf{B}^{(3)*} = -i \frac{\kappa}{A^{(0)}} \mathbf{A}^{(1)} \times \mathbf{A}^{(2)} \tag{3.12}$$

in vector notation and in the complex circular basis [1]– [5]. In Eq.(3.12) the vector cross product on the right hand side is the well known conjugate product of non-linear optics [19]. The conjugate product has therefore been derived from the first principles of general relativity and defines the Evans spin field $\mathbf{B}^{(3)}$. In the standard model the conjugate product is introduced empirically and cannot be related to the Evans spin field because in special relativity the spin field does not exist (Eq.(3.6)). It does not exist because the Minkowski spacetime of special relativity does not spin.

If we accept general relativity we must accept the Evans spin field and objectivity in physics. If we reject the Evans spin field we must reject general relativity and objectivity in physics.

3.3 The Inverse Faraday Effect in One Electron and Atomic and Molecular Material

The interaction of the spin field with one electron produces the observable magnetization of the inverse Faraday effect as follows:

$$\mathbf{M}^{(3)*} = -\frac{i}{\mu_0}\frac{\kappa'}{A^{(0)}}\mathbf{A}^{(1)} \times \mathbf{A}^{(2)} = \frac{1}{\mu_0}\frac{\kappa'}{\kappa}\mathbf{B}^{(3)*} \tag{3.13}$$

where [15]:

$$\frac{\kappa'}{\kappa} = \frac{N}{V}\left(\frac{\mu_0 e^2 c^2}{2m\omega^2}\right). \tag{3.14}$$

Here N is the number of electrons in a sample of volume $V, -e$ is the charge on the electron, m is the mass of the electron, and ω is the angular frequency $2\pi f$ of the electromagnetic radiation where f is its frequency in hertz. (Here ω should not be confused with the spin connection $\omega^a{}_{\mu b}$.) In order to calculate Eq.(3.14) in the Evans field theory a minimal prescription method may be used as follows:

$$p^a{}_\mu = p^a{}_\mu + eA^a{}_\mu \tag{3.15}$$

and the angular momentum imposed to the electron by the circularly polarized electromagnetic field calculated in the non-relativistic limit [15]. If we wish to include relativistic effects the Hamilton-Jacobi method may be used [15].

The key point is that the observable magnetization of the one electron inverse Faraday effect directly observes the Evans spin field from Eq.(3.13) within the factor κ'/κ.

It is observed from Eq.(3.11) that the inverse Faraday effect in samples of many electrons, such as atomic and molecular samples, arises from the particular form taken by the three index spin connection in the atom or molecule. Only in free space is the spin connection dual to the tetrad through Eq.(3.11). In the interaction of a circularly polarized field with one electron Eq.(3.11) becomes:

$$\omega^a{}_{\mu b} = -\frac{1}{2}\kappa' \epsilon^a{}_{bc} q^c{}_\mu \tag{3.16}$$

but in more complicated samples the simple Eq.(3.16) no longer applies, and the inverse Faraday effect is defined by hyperpolarizabilities constructed from the spin connection. In other words hyperpolarizabilities are properties of differential geometry. This deduction is generalized finally to the basic principle of Evans unified field theory: physics is differential geometry.

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