Chapter 2

Einstein Cartan Evans (ECE) Unified Field Theory: The Influence Of Gravitation On The Sagnac Effect

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Abstract

Einstein Cartan Evans (ECE) unified field theory is an extension of the original Einstein Hilbert gravitational field theory of 1915 to all radiated and matter fields. This allows the systematic investigation of the mutual interaction of gravitation and electromagnetism (EMG coupling) and allows the development of a generally covariant quantum field theory in which the wave-function is the tetrad. The latter is the fundamental field of the Palatini variation of general relativity. The ECE field theory is used to investigate the effect of gravitation on the Sagnac effect through a non-zero current of the homogeneous field equation. A frequency shift of the Sagnac effect is predicted due to gravitation, in accord with experimental observation.

Keywords : Einstein Cartan Evans (ECE) unified field theory; effect of gravitation on the Sagnac effect.

2.1 Introduction

The original and well known theory of general relativity was developed independently by Einstein and Hilbert in 1915 and was applied to the gravitational field. It is now known [1] to be precise to about one part in one hundred thousand for the solar system using contemporary Eddington experiments. The Einstein Cartan Evans (ECE) unified field theory was initiated in 2003 and has been tested with a variety of experimental data [2]– [30]. The ECE field theory is based on the most general type of Riemann geometry, developed by Cartan into differential geometry. ECE field theory is a theory of general relativity and thus of rigorously objective physics applied to all radiated and matter fields, it is not confined to the gravitational field. The fundamental wave equation of ECE theory is based on the Evans Lemma [2]– [30], a subsidiary proposition to the Evans wave equation, and an identity of Cartan geometry based on the well known tetrad postulate [31]. Within a C negative potential magnitude $A^{(0)}$, the electromagnetic field has been identified as the torsion form of Cartan, and the electromagnetic potential as the tetrad form of Cartan. The field and potential are inter-related through the first structure equation of Cartan, an inter-relation which involves the spin connection. The latter is missing from special relativity and the Maxwell Heaviside field theory of the standard model. The field equations of electromagnetism have been identified as the first Bianchi identity of Cartan geometry, and the way electromagnetism interacts with gravitation (EMG coupling) has been recognised as being governed entirely by Cartan geometry. The fundamental equations governing this interaction are the two Cartan structure equations and the two Bianchi identities [2]– [31]. The first Cartan structure equation defines the torsion form as the covariant exterior derivative of the tetrad, and the second Cartan structure equation defines the Riemann form as the covariant exterior derivative of the spin connection. The first Bianchi identity relates the covariant exterior derivative of the torsion form to the Riemann form, and the second Bianchi identity asserts that the covariant exterior derivative of the Riemann form vanishes identically.

The Einstein Hilbert (EH) field theory of gravitation has been identified as a limit of the ECE field theory, the limit where the torsion form vanishes. In this case the covariant exterior derivative of the tetrad vanishes and there is no torsion form present in the geometry.

This limit defines the approximation to Riemann geometry used by Einstein and Hilbert to derive their well known field equation of 1915. In consequence of this approximation the EH field theory cannot describe EMG coupling because the electromagnetic field is undefined without the torsion form. In ECE field theory the electromagnetic field is self-consistently defined within general relativity as the spinning of spacetime, the gravitational field as the curving of spacetime. The tetrad of ECE field theory is the fundamental field. The weak and strong fields are tetrads in the appropriate representation space [2]– [30]. The ECE field theory is therefore a straightforward unification scheme based directly on well known and standard Cartan geometry. The latter is rigorously equivalent [2]– [31] to the most general type of Riemann geometry, Riemann geometry in which the torsion tensor and the Riemann tensor are both non-zero, and in which the connection is in general asymmetric in its lower two indices. For rotational motion [2]– [31] the connection of Riemann geometry is anti-symmetric in its lower two indices, the spin connection of Cartan geometry is dual to the tetrad, and the Riemann form is dual to the torsion form. In consequence the homogeneous current of the ECE theory vanishes for pure rotational motion [2]– [30]. For pure translational motion governed by centrally directed forces the EH theory applies, the connection is symmetric in its lower two indices, the torsion form vanishes, and the homogeneous current again vanishes.

In this paper the effect of gravitation on the Sagnac effect in ECE theory is evaluated with a non-zero homogeneous current. In this case the connection in Riemann geometry is asymmetric in its lower two indices and rotational and translational motion are in consequence of this mutually influential. The latter influence is shown to produce a frequency shift of the Sagnac effect, a shift that can be looked for with a high precision ring laser gyro. In Section 2.2 the rigorous theory is given, and in Section 2.3 the rigorous theory is approximated in terms of the vector notation used in electrical engineering, classical electrodynamics and dielectric theory. It is shown that the main prediction of the paper, a frequency shift of the ring laser gyro due to gravitation, is supported by known experimental evidence [32]. Contemporary ring laser gyro technology is much more precise. This type of frequency shift is due to a non-zero homogeneous current of ECE field theory. This is expected to be very tiny and is a novel classical effect different from the well known bending of light by gravity in an Eddington experiment. The latter is a quantum effect which relies on the mass of the photon interacting through pure gravitation (EH theory) with another mass such as that of the sun. The Eddington effect and contemporary developments thereof [1] are described in the torsion free limit when ECE field theory reduces to EH field theory. In order to describe the effect of gravitation on an optical effect such as the Sagnac effect, the rigorous ECE unified field theory is needed. The available data [32] strongly suggest that gravitation does indeed cause a broadening (unresolved frequency shift) in the Sagnac effect, an important verification of ECE field theory if the data [32] are found to be reproducible and repeatable. If after further precise experimental testing it is found that there is no shift of the Sagnac effect in a gravitational field it would mean simply that the mutual influence is too small to be measured by the contemporary ring laser gyro. Many other types of experimental verification of ECE theory are already available [2]– [30].

2.2 Rigorous ECE Theory

The effect of gravitation on the Sagnac effect is given in general by the homogeneous field equation [2]– [30] of the ECE theory:

$$d \wedge F^a = \mu_0 j^a \tag{2.1}$$

where

$$F^a = d \wedge A^a + \omega^a{}_b \wedge A^b, \tag{2.2}$$

$$A^a = A^{(0)} q^a. \tag{2.3}$$

Here F^a is the vector valued electromagnetic field two-form, $d\wedge$ denotes the exterior derivative where $\wedge$ is the wedge product, μ_0 is the vacuum permeability, j^a is the homogeneous current three-form, A^a is the electromagnetic potential one-form, $\omega^a{}_b$ is the spin connection, and q^a is the tetrad one-form. The Sagnac effect is due [30] to a rotating tetrad, so gravitation affects q^a and therefore the Sagnac effect when:

$$j^a \neq 0. \tag{2.4}$$

Some early experimental support for such an effect is given in ref. (32). Conversely the observation of the influence of gravitation on the ring laser gyro would be a confirmation of the existence of the homogeneous current . The latter is defined by [2]– [30]:

$$j^a = \frac{A^{(0)}}{\mu_0} \left(R^a{}_b \wedge q^b - \omega^a{}_b \wedge T^b \right) \tag{2.5}$$

where $R^a{}_b$ is the tensor valued Riemann or curvature two-form. For pure electromagnetism or for pure gravitation [2]– [30]:

$$j^a = 0. \tag{2.6}$$

In order for j^a to be non-zero a spin connection $\omega^a{}_b$ is needed which is neither symmetric nor anti-symmetric in its a and b indices. This is the geometrical condition needed for gravitation to influence electromagnetism.

In tensor notation Eq.2.1 is [2]– [30]:

$$\begin{aligned} \partial_\mu F^a{}_{\nu\rho} + \partial_\nu F^a{}_{\rho\mu} + \partial_\rho F^a{}_{\mu\nu} = A^{(0)} (& R^a{}_{\mu\nu\rho} + R^a{}_{\nu\rho\mu} + R^a{}_{\rho\mu\nu} \\ & - \omega^a{}_{\mu b} T^b{}_{\nu\rho} - \omega^a{}_{\nu b} T^b{}_{\rho\mu} - \omega^a{}_{\rho b} T^b{}_{\mu\nu}) \end{aligned} \tag{2.7}$$

the Hodge dual of which is:

$$\partial_\mu \widetilde{F}^{a\mu\nu} = \mu_0 \widetilde{j}^{a\nu} = A^{(0)} \left(\widetilde{R}^a{}_\mu{}^{\mu\nu} - \omega^a{}_{\mu b} \widetilde{T}^{b\mu\nu} \right). \tag{2.8}$$

Note that the Hodge dual current is a vector valued one-form. In EH theory:

$$\widetilde{R}^a{}_\mu{}^{\mu\nu} = \widetilde{T}^{b\mu\nu} = 0 \tag{2.9}$$

because the first Bianchi identity (or cyclic identity) in EH theory vanishes:

$$R^a{}_b \wedge q^b = 0 \tag{2.10}$$

and in EH theory there is no torsion. For pure electromagnetism uninfluenced by gravitation:

$$R^a{}_b = \epsilon^a{}_{bc} T^c, \qquad \omega^a{}_b = \epsilon^a{}_{bc} q^c, \tag{2.11}$$

in consequence of which [2]– [30]:

$$\widetilde{R}^a{}_\mu{}^{\mu\nu} = \omega^a{}_{\mu b} \widetilde{T}^{b\mu\nu} \tag{2.12}$$

So in the absence of EMG coupling the homogeneous current vanishes and:

$$\partial_\mu \widetilde{F}^{a\mu\nu} = 0. \tag{2.13}$$

In vector notation Eq.2.13 becomes two simultaneous equations:

$$\nabla \cdot \mathbf{B}^a = 0, \tag{2.14}$$

$$\nabla \times \mathbf{E}^a + \frac{\partial \mathbf{B}^a}{\partial t} = \mathbf{0}, \tag{2.15}$$

where $\mathbf{B}^a$ is the magnetic flux density (in tesla or weber per meter squared) and $\mathbf{E}^a$ is the electric field strength (in volts per meter). Eq.2.14 for each polarization index a is the Gauss law applied to magnetism, and Eq.2.15 is the Faraday law of induction. Therefore Eqs.2.14 and 2.15 are true when the ring laser gyro is not influenced by gravitation.

In the presence of EMG coupling Eqs.2.14 and 2.15 become:

$$\nabla \cdot \mathbf{B}^a = \mu_0 \widetilde{j}^a, \tag{2.16}$$

$$\nabla \times \mathbf{E}^a + \frac{\partial \mathbf{B}^a}{\partial t} = \mu_0 \widetilde{\mathbf{j}}^a, \tag{2.17}$$

where:

$$\widetilde{j}^{a\nu} = \left(\widetilde{j}^a, \widetilde{\mathbf{j}}^a \right). \tag{2.18}$$

Thus EMG coupling produces a shift in the frequencies of $\mathbf{B}^a$ and $\mathbf{E}^a$ through the scalar current $\widetilde{j}^a$ and vector current $\widetilde{\mathbf{j}}^a$. This means that the frequency of $\mathbf{A}^a$ and $\mathbf{q}^a$ are also shifted, and there is a shift (Section 2.3) in the Sagnac effect or ring laser gyro. This is the qualitative explanation of such a shift in ECE theory.

A quantitative or numerical calculation of such a shift requires the definitions of the scalar and vector currents appearing in Eqs.2.16 and 2.17. The scalar current is defined by the indices:

$$\nu = 0, \qquad \mu = 1, 2, 3 \tag{2.19}$$

and so:

$$\widetilde{j}^a = \frac{A^{(0)}}{\mu_0} \left(\widetilde{R}^a{}_i{}^{i0} - \omega^a{}_{ib} \widetilde{T}^{bi0} \right), \quad i = 1, 2, 3. \tag{2.20}$$

In Eq.2.20 summation is implied over repeated indices i as usual. The scalar and vector currents are non-zero if and only if Eq.2.11 is not true, i.e. if and only if the spin connection is not dual to the tetrad and if and only if the curvature form is not dual to the spin connection. This means that EMG coupling originates in an influence of spacetime curving on spacetime spinning and vice-versa. If the ring laser gyro can detect this influence, as suggested by ref. [32], then novel technologies could emerge. The most important of these would be the acquisition of electric power from ECE spacetime. The vector current is defined by [2]– [30]:

$$\widetilde{\mathbf{j}}^a = \widetilde{j}^a{}_X \mathbf{i} + \widetilde{j}^a{}_Y \mathbf{j} + \widetilde{j}^a{}_Z \mathbf{k}, \tag{2.21}$$

where the three components are given by:

$$\begin{aligned} \widetilde{j}^a{}_X = \frac{A^{(0)}}{\mu_0} (& \widetilde{R}^a{}_0{}^{10} + \widetilde{R}^a{}_2{}^{12} + \widetilde{R}^a{}_3{}^{13} \\ & - \omega^a{}_{0b} \widetilde{T}^{b10} - \omega^a{}_{2b} \widetilde{T}^{b12} - \omega^a{}_{3b} \widetilde{T}^{b13}) \end{aligned} \tag{2.22}$$

$$\widetilde{j}^a{}_Y = \frac{A^{(0)}}{\mu_0}(\widetilde{R}^a{}_0{}^{20} + \widetilde{R}^a{}_1{}^{21} + \widetilde{R}^a{}_3{}^{23} \\ -\omega^a{}_{0b}\widetilde{T}^{b20} - \omega^a{}_{1b}\widetilde{T}^{b21} - \omega^a{}_{3b}\widetilde{T}^{b23}) \tag{2.23}$$

$$\widetilde{j}^a{}_Z = \frac{A^{(0)}}{\mu_0}(\widetilde{R}^a{}_0{}^{30} + \widetilde{R}^a{}_1{}^{31} + \widetilde{R}^a{}_2{}^{32} \\ -\omega^a{}_{0b}\widetilde{T}^{b30} - \omega^a{}_{1b}\widetilde{T}^{b31} - \omega^a{}_{2b}\widetilde{T}^{b32}). \tag{2.24}$$

Therefore a quantitative calculation would require knowledge of the scalar elements in Eq.2.21. In general it can be seen that the vector current depends on the spin connection, curvature and torsion. These are not mathematically independent quantities because they are related by the fundamentals of Cartan geometry, the two Cartan structure equations:

$$T^a = D \wedge q^a = d \wedge q^a + \omega^a{}_b \wedge q^b, \tag{2.25}$$

$$R^a{}_b = D \wedge \omega^a{}_b = d \wedge \omega^a{}_b + \omega^a{}_c \wedge \omega^c{}_b, \tag{2.26}$$

and the two Bianchi identities:

$$D \wedge T^a = R^a{}_b \wedge q^b, \tag{2.27}$$

$$D \wedge R^a{}_b = 0. \tag{2.28}$$

The tetrad is always defined by the Evans Lemma [2]– [30]:

$$\Box q^a{}_\mu = R q^a{}_\mu, \tag{2.29}$$

where

$$R = -kT, \tag{2.30}$$

is the scalar curvature, where T is the index contracted energy - momentum tensor and k is Einstein's constant [2]– [30]. In ECE theory Eq.2.30 applies to all radiated and matter fields as intended by Einstein [33]. Thus for a given T the eigenvalues of the tetrad can be calculated. The spin connection obeys the second Bianchi identity 2.28 and is related to the gamma connection by the tetrad postulate [2]– [30]:

$$D_\mu q^a{}_\nu = 0. \tag{2.31}$$

From a knowledge of the spin connection and tetrad, the torsion and Riemann forms can be found, and finally the scalar and vector currents.

2.3 Inferences From Dielectric Theory Of ECE Spacetime

It is necessary to prove using dielectric theory that Eq.2.17 results in a frequency shift of the Sagnac effect. It is first shown that Eq.2.17 can always be rewritten as:

$$\nabla \times \mathbf{D}^a + \frac{1}{c^2}\frac{\partial \mathbf{H}^a}{\partial t} = \mathbf{0}, \tag{2.32}$$

where

$$\mathbf{D}^a = \epsilon_0 \mathbf{E}^a + \mathbf{P}^a, \tag{2.33}$$

$$\mathbf{H}^a = \frac{1}{\mu_0}\mathbf{B}^a - \mathbf{M}^a. \tag{2.34}$$

Here $\mathbf{D}^a$ is the displacement, $\mathbf{H}^a$ the magnetic field strength, $\mathbf{P}^a$ the polarization, $\mathbf{M}^a$ the magnetization, and ϵ_0 the vacuum permittivity [34] for each polarization index a. using Eqs.2.33 and 2.34 in Eq.2.32:

$$\nabla \times (\epsilon_0 \mathbf{E}^a + \mathbf{P}^a) + \mu_0\epsilon_0 \frac{\partial}{\partial t}\left(\frac{1}{\mu_0}\mathbf{B}^a - \mathbf{M}^a\right), \tag{2.35}$$

where:

$$\epsilon_0\mu_0 = \frac{1}{c^2}. \tag{2.36}$$

It follows that:

$$\nabla \times \mathbf{E}^a + \frac{\partial \mathbf{B}^a}{\partial t} = \mu_0 \widetilde{\mathbf{j}}^a \tag{2.37}$$

where:

$$\widetilde{\mathbf{j}}^a = \frac{\partial \mathbf{M}^a}{\partial t} - \frac{1}{\epsilon_0\mu_0}\nabla \times \mathbf{P}^a \tag{2.38}$$

Q.E.D. Thus Eq.2.38 is an expression for the vector current of ECE spacetime in terms of dielectric polarization and magnetization. Thus EMG coupling can be understood in terms of a polarization and magnetization of ECE spacetime.

If the EMG coupling is weak, as expected experimentally, then:

$$\widetilde{\mathbf{j}}^a \longrightarrow \mathbf{0}. \tag{2.39}$$

Thus:

$$\frac{\mathbf{M}^a}{\partial t} - \frac{1}{\epsilon_0\mu_0}\nabla \times \mathbf{P}^a \sim \mathbf{0}. \tag{2.40}$$

Now introduce the permeability μ and permittivity ϵ of the ECE spacetime. In standard dielectric theory the polarization is related to the electric field strength as follows:

$$\mathbf{P}^a = (\epsilon_r - 1)\,\epsilon_0 \mathbf{E}^a \tag{2.41}$$

and the magnetization is related to the magnetic flux density by

$$\mathbf{M}^a = \frac{1}{\mu_0}\left(\frac{\kappa}{1+\kappa}\right)\mathbf{B}^a \tag{2.42}$$

Here

$$\epsilon_r = \frac{\epsilon}{\epsilon_0} \tag{2.43}$$

is the relative permittivity or dielectric constant and

$$\mu_r = \frac{\mu}{\mu_0} = 1 + \kappa \tag{2.44}$$

is the relative permeability, κ being the volume magnetic susceptibility (not to be confused with the wavenumber κ). It follows that the polarization and magnetization both vanish when:

$$\epsilon = \epsilon_0, \tag{2.45}$$

$$\mu = \mu_0, \tag{2.46}$$

i.e. vanish in the vacuum, for which $\widetilde{\mathbf{j}}^a$ also vanishes. In a dielectric (the ECE spacetime):

$$\widetilde{\mathbf{j}}^{\mathbf{a}} = \kappa \frac{\partial \mathbf{B}^a}{\partial t} - (\epsilon_r - 1)(1 + \kappa) \nabla \times \mathbf{E}^a \tag{2.47}$$

so ECE spacetime is a dielectric with relative permittivity ϵ_r and relative permeability μ_r. Thus EMG coupling changes ϵ_0 to ϵ and changes μ_0 to μ. This means that EMG coupling changes the refractive index defined [35] by:

$$n^2 = \frac{\epsilon\mu}{\epsilon_0\mu_0} = \epsilon_r\mu_r. \tag{2.48}$$

In the presence of absorption the refractive index and relative permittivity and permeability become complex valued with frequency dependent real and imaginary parts [36]. In general therefore novel optical and spectroscopic effects are expected from EMG coupling. The phase velocity of the electromagnetic wave is changed by EMG coupling from its vacuum value c to:

$$v = \frac{c}{n}. \tag{2.49}$$

The phase of the Sagnac effect is shifted in consequence to

$$\phi = \frac{4\Omega Ar}{\lambda v} \tag{2.50}$$

from

$$\phi = \frac{4\Omega Ar}{\lambda c}. \tag{2.51}$$

The time delay [30] of the Sagnac effect is shifted by EMG coupling to:

$$\Delta t = \frac{4\Omega Ar}{v^2} \tag{2.52}$$

from

$$\Delta t = \frac{4\Omega Ar}{c^2} \tag{2.53}$$

in the absence of EMG coupling. Here Ar is the area of the Sagnac platform, λ is the wavelength of the light, and Ω the angular rotation frequency of mechanical rotation of the Sagnac platform.

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