The Sagnac Effect Falsifies Special Relativity Theory

Ramzi Suleiman [1,2,3, a)]

1. Triangle Research & Development Center, PO-Box 2167, Kfar Qari, 30075, Israel.
2. Department of Psychology, University of Haifa, Abba Khoushy Avenue 199, Haifa, 3498838, Israel.
3. Department of Philosophy, Al Quds University, East Jerusalem and Abu Dies, P.O.B. 51000, Palestine.

Abstract

It is believed that the Sagnac effect does not contradict Special Relativity theory because it is manifest in non-inertial rotational motion; therefore, it should be treated in the framework of General Relativity theory. However, several well-designed studies have convincingly shown that a Sagnac Effect identical to the one manifest in rotational uniform motion is also manifest in transverse uniform motion. This result should have been sufficient to falsify Special Relativity theory. In the present article, we offer theoretical support to the experimental results by elucidating the notion that the dynamics of transverse and rotational types of motion are completely equivalent. Since the transverse Sagnac effect contradicts Special Relativity theory, it follows that the rotational Sagnac effect contradicts Special Relativity theory as well. In addition, we show that our recently proposed Information Relativity theory, in which we abandoned the constancy of the velocity of light axiom, theoretically accounts for the Sagnac effect.

Key words: Sagnac effect, Special Relativity, Information Relativity, Systems equivalence, GPS.

a) suleiman@psy.haifa.ac.il

I. Introduction

The Sagnac effect, called after its discoverer in 1913 [1], has been replicated in many experiments (for reviews see [2-5]). It is well known that the Sagnac effect has crucial applications in navigation [2, 3, 6] and in fiber optic gyroscopes (FOGs) [7-11]. In the Sagnac effect, two light beams sent clockwise and counterclockwise around a closed path on a rotating disk take different time intervals to travel the path. For a circular path of radius R, the difference can also be represented as $\Delta t = \frac{2\,v\,l}{c^2}$, where $v = \omega\, R$ is the speed of the circular motion and l=$2\pi R$ is the circumference of the circle. Today, FOGs have become highly sensitive detectors for measuring rotational motion in navigation [2, 6, 10, 11]. In the GPS system, the speed of light relative to a rotating frame is corrected by $\pm\,\omega\, r$, where ω is the radial velocity of the rotating frame and r is the rotation radios. A plus/minus sign is used depending on whether the rotating frame is approaching the light source or departing from it, respectively.

It is claimed that the Sagnac effect does not contradict Special Relativity theory, since it is manifest in rotational motion, which is considered an accelerated motion (c.f., [12-14]); thus, the effect should be treated in the framework of General Relativity (c.f., [15-16]). Despite the abovementioned claim, a correction for Special Relativity's time dilation is still implemented in GPS system (alongside with a rotational Sagnac correction)!

More importantly, the findings of well-designed experiments ([17-19], see also [20-21]) contradict the aforementioned claim by demonstrating, unambiguously, that the effect manifest in rotational motion, which is identical to Sagnac effect, is also manifest in transverse uniform motion. The manifestation of a Sagnac effect in the latter type of motion should have raised very serious doubts about the validity of Special Relativity's second axiom. However, given its central place in all physics, the aforementioned axiom continues to be an "untouchable" exception that defies falsification.

II. On the equivalence between transverse and rotational dynamics

In this article, we give further support to the experimental refutation of Special Relativity by restating that the theoretical descriptions of the dynamics of transverse and rotational systems are identical, implying that the two types of motion are completely equivalent. In systems sciences (c.f., [22-23]), the equivalence of two dynamical systems implies that their mathematical descriptions must be indistinguishable. On the one hand, the dynamics of a transversely moving body is completely described by the variables t (time), x (distance), v (transverse velocity), m (mass), F (Force), and their interdependencies, as formulated by the laws of transverse motion (see left-side column in Table 1). On the other hand, the dynamics of a rotating body is completely described by the variables t (time), θ (angular position), w (angular velocity), I (radial inertia), τ (torque), and their interdependencies, as formulated by the laws of rotational motion (see middle column in Table 1). A short inspection of the table reveals that the two sets of equations are equivalent. A general representation of the two systems is depicted in the right-side column of Table 1. Confronted with the set of equations appearing in the right-side column of the table, we will have no way of knowing whether the system's parameters $\{p_i\}$ and their interdependencies represent a system in transverse or rotational motion (Q.E.D).

Note that in the table, we did not specify that the parameter p_1 should represent position; that the parameter p_2 should represent velocity, and so forth. This is because any physical, biological, or other dynamic system with the same set of parameters $\{p_i\}$ and the same interdependencies described in the right-side column of Table 1 is equivalent to the two systems of motion discussed here.

If the reader is convinced that, in general, the transverse and rotational systems are completely equivalent, then the equivalence between the special cases of uniform motion with constant velocities v and w, respectively, follows as a corollary. It follows immediately that the claim that the rotational Sagnac effect does not contradict Special Relativity is a false claim.

Table 1

Dynamical equations of transverse and rotational systems

Translational	**Radial**	**General** $\boldsymbol{p_i}$ – system parameter i
x - Transverse position	θ - Angular position	p_1
$v = \frac{dx}{dt}$ - Transverse velocity	$\omega = \frac{d\theta}{dt}$ - Angular velocity	$p_2 = \frac{dp_1}{dt}$
$a = \frac{dv}{dt}$ - transverse acceleration	$\alpha = \frac{d\omega}{dt}$ - Angular acceleration	$p_3 = \frac{dp_2}{dt}$
M - Mass	I - Radial inertia	p_4
$F = ma$ - Newton's second law	$\tau = I\,\alpha$ - Newton's second law	$p_5 = p_4\, p_3$
$W = \int F dx$ – Transverse work	$W = \int \tau \; d\theta$ – Angular Work	$p_6 \int p_5 dp_1$
$E = \frac{1}{2} mv^2$ - Transverse kinetic energy	$E = \frac{1}{2} I\, \omega^2$ - Angular kinetic energy	$p_7 = \frac{1}{2} p_4\, {p_2}^2$
…….	…….	…….

Another, indirect support for our claim that the Sagnac effect contradicts Special Relativity theory is the fact that the Sagnac effect can be derived theoretically from our recently proposed Information Relativity theory (c.f., [24-25]) in which we abandoned the second axiom of Einstein's Special Relativity. For a transversely moving detector with velocity v relative to light source, the theory prescribes that the time duration, as measured by the detector, of an event with duration $\Delta t'$ taking place at the light source, is given by the following Doppler-like formula:

$$\Delta t \;=\; \frac{1}{1 \pm \frac{v}{c}} \Delta t' \tag{1}$$

Where the "+" sign applies when the detector approaches the light source and the "-" applies when it is moving away from the light source. For a path of length l, we have: $\Delta t' = \frac{l}{c}$. Substitution in eq. 1 yields:

$$\Delta t \;=\; \frac{1}{1 \pm \frac{v}{c}} \; \frac{l}{c} = \frac{l}{c \pm v} \tag{2}$$

The difference between the arrival times of two light beams propagating in opposite directions along the same path is given by:

$$\Delta T = \left(\frac{c}{c-v} - \frac{c}{c+v}\right)\frac{l}{c} = \frac{(c+v)-(c-v)}{(c-v)(c+v)}\, l = \frac{2v\,l}{(c-v)(c+v)} = \frac{2v\,l}{c^2 - v^2} \approx \frac{2v\,l}{c^2} \tag{3}$$

The above result is identical to the formula which describes the rotational and transverse Sagnac effect (see [17-18]).

III. Summary and conclusions

It is commonly accepted that the manifestation of the Sagnac effect in rotational motion does not contradict Special relativity, since the latter applies only to transverse uniform motion and not to rotational motion, which involves acceleration. The fact that a Sagnac Effect, identical to the one manifest in rotational motion, was also detected in transverse uniform motion [17-20] strongly refutes Special Relativity Theory. However, given the central role of the theory's second axiom in all physics, the above-mentioned results concerning the existence of a Sagnac effect in transverse uniform motion has been until now widely neglected. In the present paper, we provided further support to the experimental refutation of Special Relativity by showing theoretically that the transverse and rotational types of motion are completely equivalent dynamical systems. In principle, we elucidated the fact that when the set of equations describing the interdependencies between the variables of a rotational (or transverse) dynamic system are written using a set of uninformative symbols $\{p_i\}$, $i = 1,2,\ldots n$, then we will have no way of knowing whether the system's parameters $\{p_i\}$ and their interdependencies describe a transverse or a rotational motion. Accordingly, it follows that both the rotational and transverse types of Sagnac effects contradict Special Relativity. If we accept the principle that theories are falsified by contradictory empirical evidence [26-27], then Special Relativity's second axiom must be abandoned, no matter how dramatic the consequences might be.

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