Searching for Earth's Trajectory in the Cosmos

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A recollection is presented of a previous work containing a model of the refraction mechanism, which served as a basis for the analysis of Michelson & Morley and Shamir & Fox experiments relating to the search for the ether wind. It was subsequently assumed that the first produced a negative result due to lack of accuracy, as a result of the low refraction index of the air (n = 1.0003). The second, with arms consisting of perspex rods with n = 1.49, made it possible to detect a 6.64km/s ether wind. In that work, an experiment was proposed with fibre-optic coils, in order to increase accuracy.

In the present document, that proposal is again dealt with under the designation of fibre-optic tachymeter (FOT). It takes into account the remarkable development achieved in the last decade in the technology of fibre-optic gyroscopes (FOG). The Sagnac effect, which is the FOG principle, is reviewed by analysing it in accordance with the refraction mechanism model and by putting its precision into the equation. Reference is made to the trend toward using triaxial FOG and the same procedure is proposed for a triaxial FOT.

It is proved that a gyro-tachymeter (FOGT) consisting of a triaxial gyroscope and a triaxial tachymeter is able to detect movements related to Earth's rotation and with its translation around the Sun. In view of the fact that such movements have a specific daily and annual periodicity that characterises them, it would appear possible to detect the velocity of 620km/s of Earth in the cosmos, corresponding to the asymmetry of the fossil radiation detected by the satellite COBE and in case of occurrence of other movements, these will be detected if they are within the precision range of the GT.

1 – INTRODUCTION

In a previous work [1], an analysis was made of the experiment in which Fizeau, in 1851, proved how the velocity of propagation of light in the water varies when the latter is in motion. Also in that equation, he verified that such variation is in agreement with the equation deduced by Fresnel in 1818. Nevertheless, considering that the hypothesis of partial dragging of the ether, from which Fresnel deduced his equation, is poorly convincing, an alternative model of the refraction mechanism was also proposed.

In such refraction mechanism it is assumed that the light travels inside refractional bodies following zigzag ABCDE trajectories (fig. 1.1), under the scattering effect caused in the luminous radiation by the body's atoms. The velocity of propagation of light along each side of the zigzag is constant and equal to the velocity in the vacuum. If the body is in motion under the effect of the inherent *aberration*, the *scattering angle* α changes into α' and the zigzag trajectory becomes A'B'C'D'E', maintaining however the side lengths (Fig. 1.1).

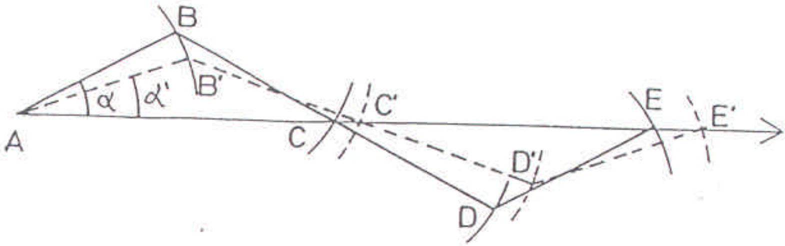

Fig. 1.1 – Zigzag trajectory of light on a refractional body.

Fig. 1.2 shows that c being the velocity of light in the vacuum, due to scattering, its effective velocity w inside the body at rest is c cos α. Also considering that the refraction index n is the relation c/w, there can be obtained:

$$w = c\cos a = \frac{c}{n} \qquad 1.1$$

thus:

$$\cos a = \frac{1}{n} \qquad 1.2$$

If the body is in rectilinear motion with velocity *v*, under the aberration effect, the *apparent scattering angle* becomes α' and the velocity of propagation of light in the body changes from w to w' given by

$$w' = c\cos a' \qquad 1.3$$

α' being given by

$$tga' = \frac{c\,sen\,a}{w+v} \qquad 1.4$$

The difference of velocity of propagation due to the body's movement is given by:

$$w' - w = c(\cos a' - \cos a) \quad 1.5$$

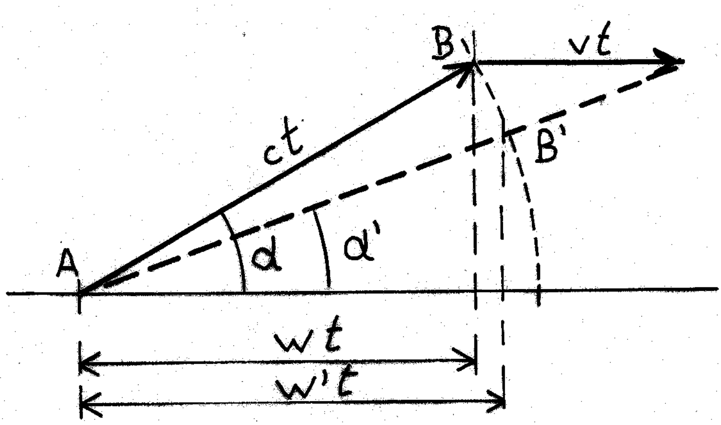

Fig. 1.2 - In a body in motion with velocity *v*, under the aberration effect, the scattering angle changes from α to α' and the velocity of propagation from w to w'.

By comparing equation 1.5 with the famous Fresnel formula:

$$w' - w = \left(1 - \frac{1}{n^2}\right)v \quad 1.6$$

It can be verified that for low values of *v*, the results are almost equal [1].

The model was applied to Fizeau and Michelson's experiment and it was concluded that the accuracy of the latter, considering that the refraction index of the air is very low (1 = 1,0003), was not enough to detect the ether wind. The model was also used in the experiment carried out in 1969, by Shamir & Fox [2]. The latter was similar to Michelson's experiment, but with a significant difference: the propagation of light on the arms of the apparatus, instead of occurring through air, was performed by means of perspex rods with a refraction index n= 1.49. Therefore, in that experiment an ether wind was detected of 6.64 km/s, i.e., about 22% of the orbital velocity of Earth (30km/s).

With such satisfactory result, a modification in Shamir & Fox's interferometer was proposed, which consisted of replacing the arms of the apparatus by fibre-optic coils (Fig. 1.3b), so as to increase its accuracy [1].

On the other hand, taking into account the remarkable development achieved in the 90's, as regards the technology of fibre-optic gyroscopes, it was considered that a study should be done on the feasibility of development of the fibre-optic gyro-tachymeter. This is precisely the subject of the present work.

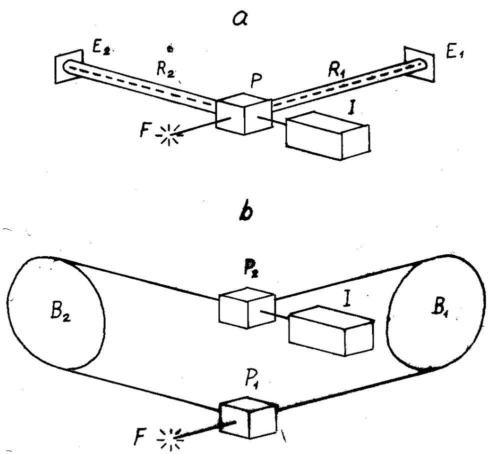

Fig. 1.3 – a) Shamir & Fox's interferometer
F – Light source; P – semi-transparent plate;
R – Perspex rods; E – mirrors; I - interferometer.
b) Fibre-optic tachymeter
B_1 and B_2 – fibre-optic coils

2 – THE FIBRE-OPTIC GYROSCOPE (FOG)

2.1 – Concepts

Sagnac presented in 1914 a memoir about his interferometer [3]. Nevertheless, he had already published in 1910 the corresponding theory and, in 1913, the experimental results obtained.

The Sagnac interferometer consists of the following (Fig. 2.1): the luminous flow emitted by source F is split into two by the semi-transparent plate P, one beam proceeds through mirrors A, B, C and the other, continues in the opposite sense. They are subsequently reunited on P, which is their point of departure to interferometer I. The mirrors and the plate form therefore a closed circuit, which is travelled by light in opposite senses. When all the apparatus, including the light source and the interferometer, is in rotation around point O, the path followed by one of the beams decreases comparatively with the other, thus producing a displacement of the corresponding interference fringes [4].

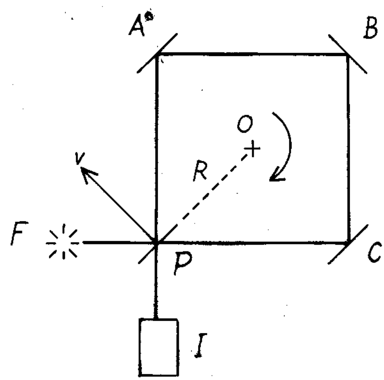

Fig. 2.1 – Sagnac interferometer.

w being the angular velocity of the rotation given to the interferometer (Fig. 2.1), the velocity of P will be $v = wR$. Thus, the time spent by the beam travelling on the side PA (in the same direction as ω) will be:

$$t_{AB} = \frac{R\sqrt{2}}{c - v/\sqrt{2}} = \frac{2R}{\sqrt{2}c - wR}$$

and the time spent by the beam continuing on the side PC (in the opposite sense to w), will be:

$$t_{AD} = \frac{2R}{\sqrt{2}c + wR}$$

c being the velocity of light.

The total time for the two paths in direct sense t and in opposite sense t_c will be therefore:

$$t = \frac{8R}{\sqrt{2}c - wR}$$

$$t_c = \frac{8R}{\sqrt{2}c + wR}$$

and their difference $\Delta t = t - t_c$, having a series development, will be:

$$\Delta t = \frac{8R^2 w}{c^2} \qquad 2.1$$

Or, considering that the area limited by the circuit $PABC$ is $A = 2R^2$:

$$\Delta t = \frac{4Aw}{c^2} \qquad 2.2$$

t and l being the period and wavelength of monochromatic light used, there can be obtained:

$$t = \frac{l}{c} \qquad 2.3$$

and the relative development Δ of the interference fringes will be given by:

$$\Delta = \frac{\Delta t}{t} \qquad 2.4$$

or considering 2.2:

$$\Delta = \frac{4Aw}{c\,l} \qquad 2.5$$

That result has been experimentally tested. The Sagnac interferometer is thus a gyroscope and Michelson and Gayle used it, in 1925, to measure the angular velocity of Earth [4].

As from the 80's, the fibre-optic gyroscope has been developed on basis of the Sagnac interferometer and it can be briefly described as follows [5].

Let us consider in fig. 2.2a, an interferometer, in which from the semi-transparent plate P, a luminous beam split into two and reflected on an infinitive number of mirrors and having followed in opposite senses a circular trajectory, returns subsequently *in phase* to the same point P. Let us assume now that the interferometer is in rotation in the vacuum. Then, the light emitted in point P travels through those mirrors with the same velocity c in opposite senses. However, during the time t_v of that travel, the plate P will be displaced to P' (Fig. 2.2b) and the ray of light that propagates in the same rotation sense as the interferometer has an increased travel of Δl_v, whereas the ray propagated in the opposite sense has a decreased travel of Δl_v. There is therefore a travel difference $2\Delta l_v$ between the two rays and which corresponds to a time difference Δt_v given by:

$$\Delta t_v = \frac{2pR + \Delta l_v}{c} - \frac{2pR - \Delta l_v}{v} = \frac{2\Delta l_v}{c} \qquad 2.6$$

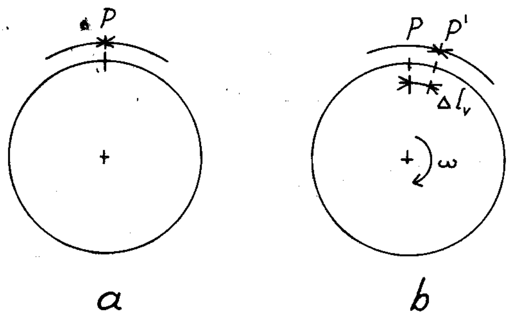

Fig. 2.2 – Sagnac effect on an ideal circular travel in vacuum:
a) motionless interferometer; b) interferometer in rotation.

If the propagation of light, instead of occurring in the vacuum with a refraction index of n= 1, occurs in a medium with n> 1, which is the case of a fibre-optic gyroscope, there is a very low phase difference, as will be demonstrated below, but which is not null as some authors have concluded [5]. The demonstration of the nullity of such phase difference is presented below.

In a motionless fibre-optic circuit both luminous rays travel with a velocity

$$w = \frac{c}{n} \qquad 2.7$$

and return to plate P at the end of time t_m given by:

$$t_m = \frac{2pR}{w} = \frac{2pnR}{c} = nt_v \qquad 2.8$$

When the interferometer is in rotation (Fig. 2.3b) the plate P travels during time t_m through the length

$$\Delta l_m = Rwt_m = n\Delta l_v \qquad 2.9$$

which is n times higher than the length Δl_v corresponding to vacuum, as Fig. 2.3 shows. In this case however, the velocity of light is not equal in both senses. In accordance with the Fresnel formula, the velocities in the sense of rotation v_ρ and in the opposite sense v_{cr} are given by:

$$vr = \frac{c}{n} + a_F Rw \qquad 2.10$$

$$v_{cr} = \frac{c}{n} - a_F Rw \qquad 2.11$$

Rω being the tangential velocity of the fibre-optic and a_F the Fresnel dragging coefficient:

$$a_F = 1 - \frac{1}{n^2} \qquad 2.12$$

Δt_{mF} being therefore given by:

$$\Delta t_{mF} = \frac{2pR + n\Delta l_v}{v_r} - \frac{2pR - n\Delta l_v}{v_c} \qquad 2.13$$

The expression above is *approximately* equal to:

$$\Delta t_m = \Delta t_v n^2 (1 - a_F) \qquad 2.14$$

therefore, considering 2.12:

$$\Delta t_m = \Delta t_v \qquad 2.15$$

This would serve to demonstrate that the Sagnac effect is independent from the refraction index of the medium [5].

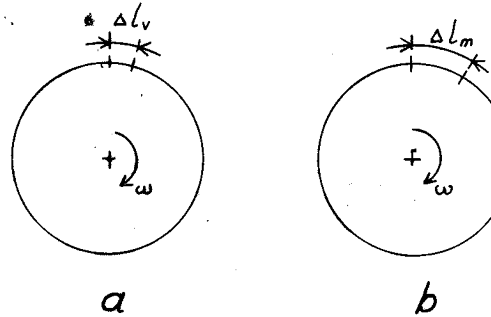

Fig. 2.3 – Sagnac effect: a) in the vacuum; b) in a fibre-optic.

In order to prove otherwise, let us consider again a fibre-optic circuit. When the circuit is at rest, the velocity of light, travelling through it, is given by:

$$w = c\cos\alpha = \frac{c}{n} \qquad 2.16$$

α being the scattering angle at rest.

When the circuit is in rotation, the velocities w_r in the sense of the rotation and w_{cr} in the opposite sense will be given by:

$$w_r = c\cos\alpha_r \qquad 2.17$$

$$w_{cr} = c\cos\alpha_{cr} \qquad 2.18$$

The corresponding scattering angles are given by:

$$tg_{\alpha r} = \frac{c\,sen\,\alpha}{c\cos\alpha + wR} \qquad 2.19$$

$$tg\alpha_{cr} = \frac{c\,sen\,\alpha}{c\cos\alpha - wR} \qquad 2.20$$

The travel time difference will be therefore:

$$\Delta t_m = \frac{2pR + n\Delta l_v}{w_r} - \frac{2pR - n\Delta l_v}{w_{cr}} \quad 2.21$$

Fig. 2.4 shows Δt_m given by Eq. 2.21 and also given by Eq. 2.13 (Δt_{mF}), in accordance with R and ω for the refraction indices n= 1 and n = 1.45.

Thus, the following equation can be deduced:

$$\Delta t = f_G(n)\frac{4pR^2 w}{c^2} \quad 2.22$$

$f_G(n)$ being a function of the refraction index, which, as fig. 2.5 shows, assumes the following form:

$$f_G(n) = n^2 \quad 2.23$$

Thus, the Eq. 2.22 can assume the following form:

$$\Delta t = n^2 \frac{4Aw}{c^2} \quad 2.24$$

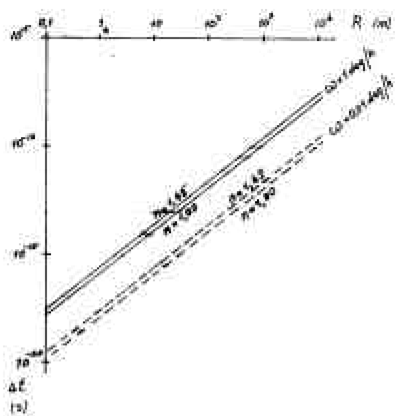

Fig. 2.4 – Travel time difference Δt in accordance with R and w.

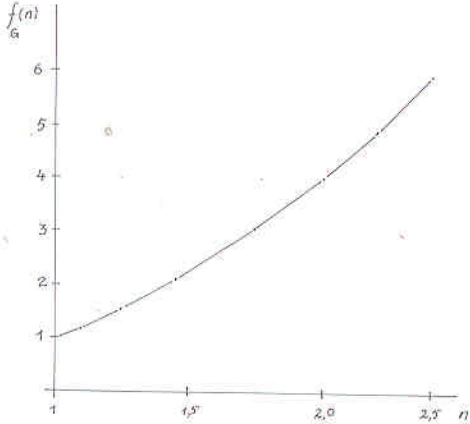

Fig. 2.5 – Function $f_G(n) = n^2$

Which is only different from Eq. 2.2 as regards the factor n^2. Thus, it can be concluded that the Eq. 2.15, according to which, the Sagnac effect is independent from the refraction index of the medium [5], is only a first approach. In fact, it is proportional to the square of the refraction index.

In view of the fact that the length F of fibre-optics is given by:

$$F = NpD \tag{2.25}$$

one will have:

$$A = \frac{1}{4} FD \tag{2.26}$$

Thus, the Eq. 2.24 can assume the form as follows:

$$\Delta t = n^2 \frac{FDw}{c^2} \tag{2.27}$$

2.2 – FOG Accuracy

On the basis of Eq. 2.27, Fig. 2.6 shows Δt, as a result of the angular velocity w in deg/h, n = 1.45 being for F equal to 1m, 10^3m and 10^6m and D = 0.05m.

The same Fig. 2.6 indicates the zone Ac corresponding to the FOG currently used in aircrafts, which require a precision ranging from 10 to 0.1 deg/h and which commonly use 100m to 200m of fibre in coils varying from 30 to 60mm diameter. It is also indicated the zone Hp of higher performance FOG's with 0.5 to 2Km of fibre in coils with 8 to 10 cm diameter, with a precision of 0.01 deg/h [5].

As can be seen, values of Δt from 10^{-15} to 10^{-17}s correspond to the precision above.

This means that the present technology of FOG has embraced measurements of Δt from 10^{-15} to 10^{-17}s corresponding to angular velocities of 10 to 0.01 deg/h.

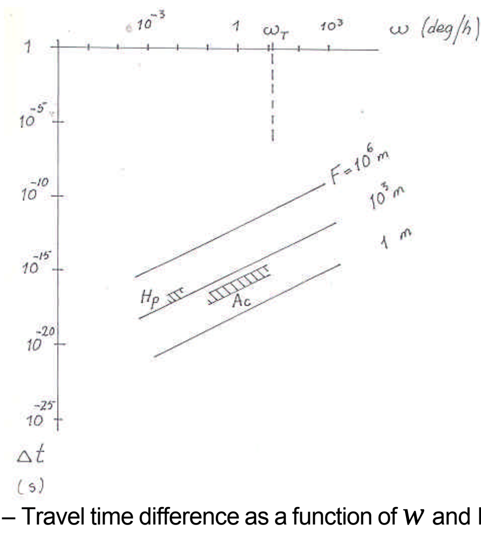

Fig. 2.6 – Travel time difference as a function of w and F.

3 – THE FIBRE-OPTIC TACHYMETER (FOT)

Fig. 3.1 shows a schematic drawing of a FOT different from the one presented in fig. 1.3b. The difference is the fact that in the latter, the fibre-optic is not rolled in circles but rather in a mould formed by a flat zone, with a length l and a thickness D, and having almost cylindrical caps with a diameter equal to the thickness.

Since the tachymetric effect of a coil is proportional to its length:

$$L = N(l + D) \tag{3.1}$$

The length F of a fibre-optic of each coil being given by:

$$F = N(2l + pD) \tag{3.2}$$

and D being very small in comparison with l, will be approximately:

$$F \cong 2L \tag{3.3}$$

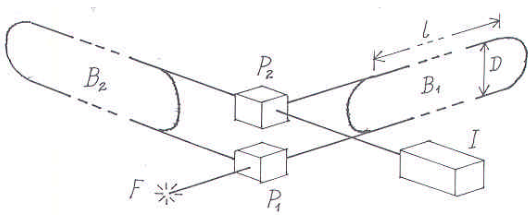

Fig. 3.1 – Schematic drawing of a FOT.

Reference should be made of the fact that the length L of a FOT corresponds to the length of the arms of either Michelson & Morley's or Shamir & Fox's interferometers.

By assuming that the FOT travels at an absolute velocity v in the direction of the coil B_1, the time t_1, spent by the luminous ray in the path $P_1B_1P_2$ is

$$t_1 = \frac{F}{2}\left(\frac{1}{c\cos a'} + \frac{1}{\cos a'_c}\right) \qquad 3.4$$

and the time t_2 spent in the paths $P_1B_2P_2$

$$t_2 = \frac{F}{w} \qquad 3.5$$

a, a' and a'_c being the scattering angles at rest, in the sense of v and in the opposite sense, respectively, given by Eq. 1.1 and 1.4;

$$tga' = \frac{csen\,a}{w+v} \qquad 3.6$$

$$tga'_c = \frac{csen\,a}{w-v} \qquad 3.7$$

The difference Δt will be therefore:

$$\Delta t = t_1 - t_2 \qquad 3.8$$

In accordance with Fresnel formula it will be: $\Delta t_F = t_{F1} - t_{F2}$, Thus,

$$t_{F1} = \frac{F}{2}\left(\frac{1}{w+f_F v} + \frac{1}{w-f_F v}\right) \qquad 3.9$$

$$t_{F2} = \frac{F}{2}\cdot\frac{2}{w} = \frac{F}{W} \qquad 3.10$$

3.2 –FOT Accuracy

Fig. 3.2 shows how Δt varies in accordance with the length of the fibre F of each coil and with the velocity v for coils of $n = 1.45$ and diameter D = 50mm. It can be thus deduced that the Eq. 3.8 can assume the form:

$$\Delta t = f_T(n)\frac{Fv^2}{c^3} \qquad 3.11$$

$f_T(n)$ being a function of the refraction index, which for $n = 1.45$ has the value $f_T(n) = 1.993$.

In the same fig. 3.2, the point SF corresponds to Shamir & Fox's experiment, in which, with $n = 1.49$ and F= 2×0.26, the velocity $v = 6.64$km/s was measured. The point MM represents Michelson & Morley's experiment ($n = 1.0003$, F = 60m) for the orbital velocity of Earth ($v_T = 30$km/s).

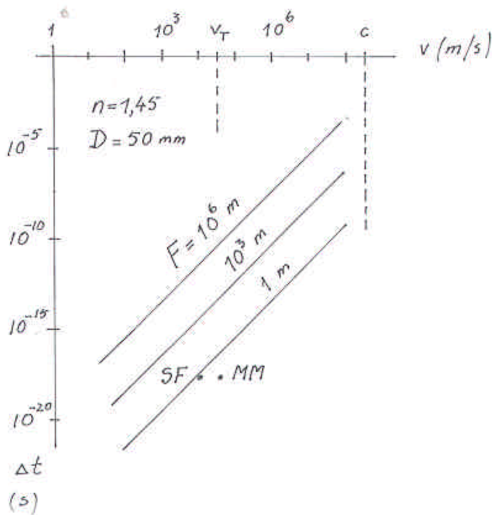

Fig. 3.2 – Difference Δt of travel time in a FOT, in accordance with the velocity *v* and the length F of the fibre-optic of each coil.
SF: Shamir & Fox's experiment
MM: Michelson & Morley's experiment

Fig. 3.3 shows that the function $f_T(n)$ has little variation when the velocity changes from 1km/s to 30km/s. Thus, in a first approach, it can be considered independent from v and with the equation as follows:

$$f_T(n) = n^{2.95} - 1 \qquad 3.12$$

Its values for some refraction indices, including the one of the fibre-optic (1.45) and the one of the diamond (2.417), are also included in the same figure.

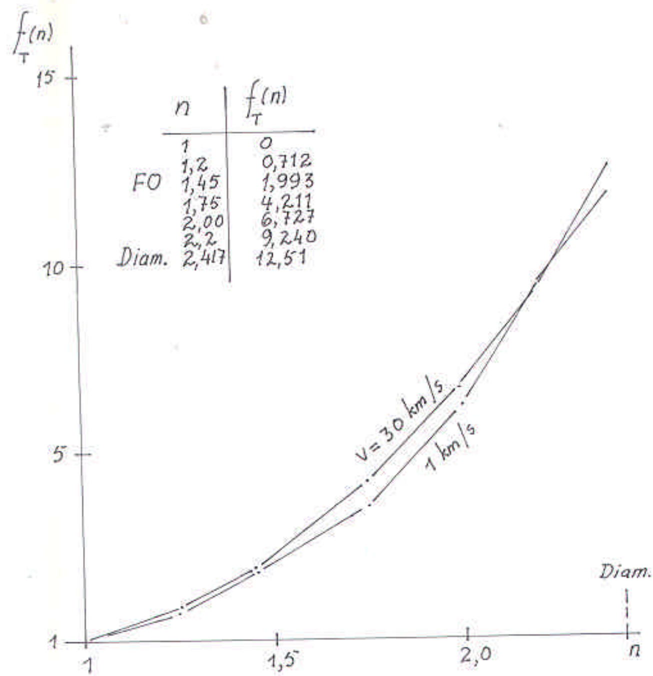

Fig. 3.3 – Function $f_T(n) = n^{2.95} - 1$.

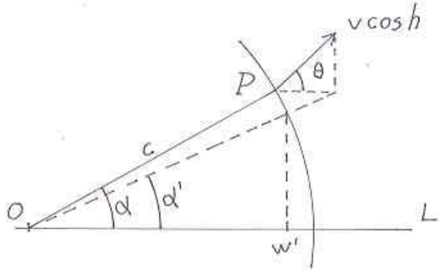

Fig. 4.1 – Scattering angle α’ when the velocity *v* is not parallel to the axis OL.

4 – THE FIBRE-OPTIC GYRO-TACHYMETER (FOGT)

4.1 – The triaxial gyroscope

In order to detect the rotations of a vehicle, not only in relation to an axis with a certain direction, but also in relation to any direction whatsoever, three gyroscopes are required, with the corresponding axis forming an orthogonal trihedron. Nevertheless, there is a tendency to use triaxial gyroscopes with only one source of light, instead of separate uniaxial gyroscopes. Such triaxial gyroscopes, together with special accelerometers, form the inertial measurement units (IMU) [5].

4.2 – The triaxial tachymeter

Fig. 4.1 presents an overview of the problem referring to measurement in a FOT, when the absolute velocity *v* is not parallel to the direction OL of the propagation of light. Thus, one should consider the angular co-ordinates *q* and *h* formed by *v* with a plan defined by OL and by a radius OP of the scattering cone. This example refers to the case presented by Chapter 3, which replaced *v* in Eq. 3.6 and 3.7, by the component v cosh cos$q$ [1]. Thus, it is obtained:

$$tga' = \frac{csen\,a}{w + v\cosh\cos q} \qquad 4.1$$

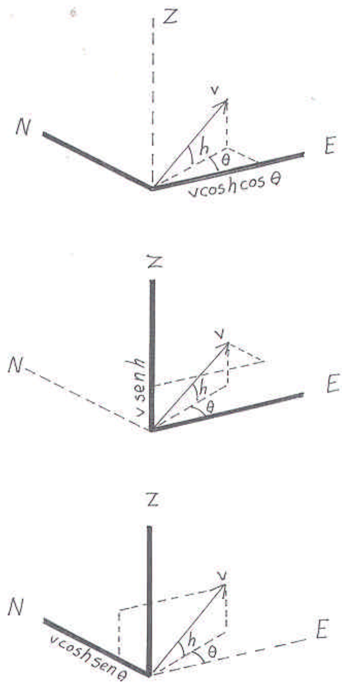

Fig. 4.2 – Three FOT's for determination of the absolute velocity *v* of Earth.
FOT-EN – in the horizontal plan
FOT-EZ – in the vertical plan directed to east
FOT-NZ – in the vertical plan directed to north

Fig. 4.2 shows a schematic drawing of three FOT's, which forms in the whole, an orthogonal trihedron.

The arms of the first are directed to E and N, and it should detect the component of the velocity v given by v cos h cos$q$. The arms of the second are directed to E and Zenith (au Nadir), which is intended to detect the component v sin$h$. Lastly, the arms of the third are directed to N and Zenith (au Nadir), which is intended to detect the component v cos$h$ sin$q$.

Such FOT's are able either to operate separately or to form a triaxial tachymeter, with the same light source, similarly to the triaxial gyroscopes.

4.3 – Searching for Earth's trajectory

Fig. 4.3 presents side-by-side the diagrams of FOT and FOG forming a fibre-optic gyro-tachymeter (FOGT). Fig. 4.4 shows the length l of each FOT coil in accordance with the corresponding length F of the fibre-optic and of the number N of turns of the coil (Eq. 3.2).

As can be seen, with a precision of approximately 10^{-16} within the range of the present FOG technology, the length F of the fibre-optic, which is the necessary for a FOT to detect the orbital velocity of Earth $\left(v_T = 30 km/s\right)$, is about a few ten metres. As Fig. 4.4 shows, that length can be obtained with coils having a length l of about a few metres, with N of only a few tens.

In order to detect the velocity resulting from Earth's rotation at about 40º latitude ($v_{TR} = 355 m/s$) it would be required some coils with F of some kilometres, which implies (Fig. 4.2) Lengths l of about a few ten metres with N of a few hundreds.

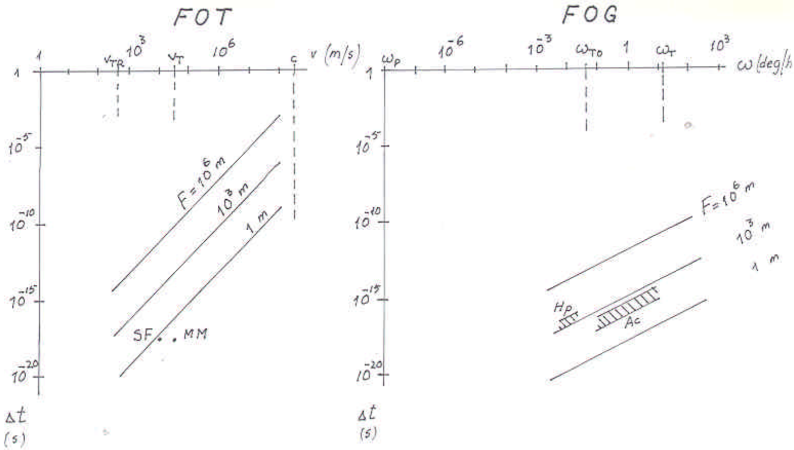

Fig. 4.3 – Diagrams of a fibre-optic gyro-tachymeter (FOGT):
V_T = 30km/s – Orbital velocity of Earth
V_{TR} = 355m/s – velocity resulting from Earth's rotation at 40º latitude
ω_T = 15deg/h – angular velocity of Earth's rotation
ω_{TO} = 0.04 deg/h – angular velocity in Earth's orbit around the Sun.
$\omega_P = 10^{-8}$ deg/h – angular velocity due to the variation of the position of the Pole.

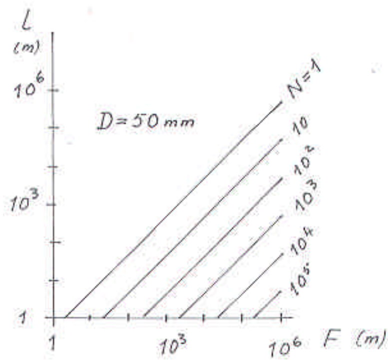

Fig. 4.4 – Length l of the FOT coil as a function of the length F of the fibre-optic.

As regards the FOG, both the angular velocity of Earth's rotation ($w_T = 15\deg/h$) and the angular velocity of Earth in its orbit around the Sun $\left(w_{TO} = 360\deg 365 days/24h \cong 0.04\deg/h\right)$ are within the range of the present technology (Fig. 4.4). Nevertheless, the angular velocity related with the variation in the position of Earth's poles (w_P), which is about ten metres per year [6] and to which corresponds an angular velocity w_P of about 1E-8 deg/h $\left[w_P = (10/6.37E6)(180/p)/365x24 \cong 1E-8\deg/h\right]$. Therefore, they are far beyond the possibilities of the present technology, as Fig. 4.3 and 4.4 show.

In fact, on the one hand, the FOGT has enough precision to detect the movements referring to Earth's rotation and to its orbit around the Sun. On the other hand, such movements of the Earth have a daily and annual periodicity, which clearly identifies them. Thus, it seems that, if there are some movements other than those mentioned previously, these will be detected, provided that their magnitude is within the precision range of the FOGT. This is the case of the velocity of 620km/s of Earth in the cosmos, which corresponds to the asymmetry of fossil radiation detected by the satellite COBE [7].

5 – CONCLUSIONS

From the analysis performed on basis of the model of the refraction mechanism proposed in a former work, the following conclusions can be presented:

1. The Sagnac effect, which is the principle of the fibre-optic gyroscopes (FOG), is proportional to the square of the refraction index of the fibre (Eq. 2.27).

2. The ether wind, which is the principle of the fibre-optic tachymeter, is a function of the refraction index of the fibre (Eq. 3.12).
3. It seems that the detection of the velocity of 620km/s of Earth in the cosmos, corresponding to the asymmetry of the fossil radiation detected by the satellite COBE is within the range of the fibre-optic gyro-tachymeter (FOGT). The construction of that apparatus is proposed on basis of the present technology of fibre-optic gyroscopes (FOG).

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