CONSERVATION LAWS -LIMITS OF THE EQUIVALENCE OF INERTIAL FRAMES

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EQUIVALENCE OF INERTIAL FRAMES

ISSUES WITH CONSERVATION LAWS

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ABSTRACT

The Doppler RADAR frequency ratio derived using Lorentz Transformations between two inertial frames, if measured in the RADAR's inertial frame, results in the creation of excess energy. This phenomenon, if both frames are kept inertial, infringes upon conservation laws. Therefore, the results obtained using Lorentz Transformations are merely approximations, which become just inaccurate at high speeds. Description of the effect must rely on energy and momentum conservation, accounting for radiation recoil, necessitating that at least one frame is not inertial. Only first-order approximations are acceptable when assuming the equivalence of inertial frames, making them unsuitable for exact solutions.

INTRODUCTION

Consider two inertial frames, IRF0 and IRF1, approaching each other at a relative speed v. Imagine ideal mirrors and an emitter of electromagnetic (EM) waves in IRF0. When EM waves are emitted, they can bounce back and forth between the mirrors during the approach. The longitudinal Doppler effect, an experimentally verified phenomenon, shows that the frequency of the radiation increases after each detection for approaching bodies.

The Doppler RADAR formula was found, for the first time in Einstein's famous paper in 1905, as an application of Lorentz Transformations derived in his same famous script. The formula below is the simples one dimensional case [1], experimentally verified to a certain order of accuracy,

$$fr= f_0(1+\beta)/(1-\beta) \tag{1}$$

were f_o is the frequency of emission in one frame and fr is the reception frequency in the same frame and β=v/c. It is used in all Doppler RADAR applications where the speed of a moving object is the quantity to be estimated as in figure 1.

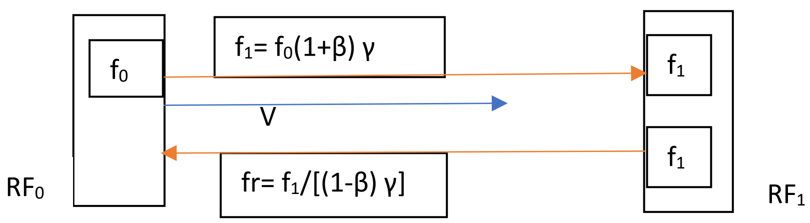

Fig. 1. The Doppler Radar found with Relativistic Doppler formulas

The energy content of the initially emitted radiation is E_{ph} = nhf_0 hence From Eq.(1) it is

$$E_r \approx nhf_0(1+\beta)/(1-\beta) =E_{ph}(1+\beta)/(1-\beta) \tag{2}$$

since the RADAR is an inertial frame it is possible to compare the energy emitted with the one received back : $\Delta E \equiv Er-E_{ph} = 2E_{ph}\,\beta/(1-\beta)$ (3)

In the case of the object approaching to the RADAR, $\beta > 0$, as the frequency of the radiation increases, in each inertial frame, increases progressively in the RADAR's frame. At every bounce of the radiation, an excess energy is detected in each inertial frame, [1] such that: $\Delta E > 0$ from Eq.(2). At low speeds where β is much less than one, and E_0 is small, it is reasonable to consider $\Delta E \approx 0$. This approximation is typically sufficient for practical purposes.

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In general, the energy difference expressed in Eq.(3), for $\beta > 0$ comparable to unity (high speeds), is not negligible and would represent additional energy absorbed by an object stationary in IRF0. This energy comes out from nothing, as the system of the two inertial frames is isolated with no other variations involved. This situation describes a "perpetuum mobile" of the first kind, highlighting the impossibility of maintaining a constant relative speed in the presence of radiation exchange between objects in the same physical problem without violating conservation laws. This would imply the extraction of net energy from the void (capacity to perform work). To maintain a constant speed in the presence of interactions, an unrealistic requirement of infinite masses would be necessary, making the formula non-physical and unacceptable.

A realistic scenario involves at most one inertial frame in every physical problem to avoid this issue in presence of emission and absorption of Radiation. Radiation recoil (supported by experimental evidence) due to momentum-energy conservation of the absorbed radiation, draws its energy from the kinetic energy of the non-inertial mirror, a finite mass object. This object slows down diminishing the relative speed, thus providing energy to increase the radiation frequency of the EM wave, and consequently its energy.

Consider a scenario where one mirror is fixed on an embankment (IRF0) and the other is on a wagon with negligible mass compared to the embankment (attached to Earth). With m as the mass of the wagon, it must be affected by radiation recoil in a small but tangible way.

TO COMPLY WITH CONSERVATION LAWS

Assuming energy and momentum conservation of radiation and the variation of the status of motion of bodies, the result can be found in appendix. It is also in Ref [2] in Equation 7.

With some algebraic manipulation, it becomes (SEE APPENDIX):

$$f = f_0 (1+\beta)/(1-\beta+2E_{ph}/\gamma_0 mc^2) \qquad (4)$$

1) $\beta = 0$, negligible relative speed with the mirror → Compton Effect
2) Negligible mass of the absorbed radiation $E_{ph} / \gamma_0 mc^2 << 1$, → Doppler Radar Eq.(1)

With $E_0 = mc^2$, the rest energy of the mirror or wagon

The excess energy ratio is $\Delta E/E_0 = \Delta f/f_0 = 2 (\beta - E_{ph}/(\gamma_0 E_0))/(1- \beta +2E_{ph}/(\gamma_0 E_0))$ (5)

The speed cannot remain constant $c\beta$ after every bounce of radiation. In this case, the same energy is present, but it is taken from the wagon of mass m_0, slowing down by $c*2E_0/mc^2 = 2E_0/mc$.

Delta E = $(\gamma_0-\gamma_1)E_0 = 2 (\beta - E_{ph}/(\gamma_0 E_0))/(1- \beta +2E_{ph}/(\gamma_0 E_0))$

the energies variation must be the same $(\gamma_0-\gamma_1)E_0 = nh(f_1-f_0)$ where $E_0=mc^2$

The wagon slows down slightly, diminishing its kinetic energy by ΔE in the centre of mass (COM) of the system, thus reducing its relative speed v in the COM by $2E_0/mc^2$. The effect of radiation recoil on the embankment is orders of magnitude smaller, virtually negligible, making it acceptable for IRF0. This scenario avoids the perpetuum mobile of the first kind, providing a sound physical framework for the Doppler effect.

That means basically that infinite mass does not at all involve a Doppler effect, because the radiation change is strictly dependent on an exchange of energy if a body of a certain mass loses some kinetic energy in the COM of the system.

The Doppler effect can rely only on energy and momentum conservation as a physical foundation. The solution found can be approximated by the formula used for practical purposes. Using Lorentz Transformations instead, relying on the principle of inertial frames, the compliance with the non-negotiable principle of physics is missing. The energy of an isolated system cannot increase over time, even for a limited but finite amount of time, allowing to extract a net energy amount form nothing.

Lorentz Transformations used to find the Doppler RADAR formula, where radiation exchange is present, are thus non usable in such a configuration. The principle of equivalence of inertial frames, upon which they are based, is invalidated for application involving higher order accuracy. The Doppler Radar formula derived from Lorentz Transformations infringes upon conservation laws and can only serve as a good approximation in real problems, where radiation recoil effects can be neglected, although the recoil must always be present (although negligible) and it is the real reason of the effect. The Eq.(3) can be valid only at low speeds and or where the energy of radiation is negligible in comparison to the rest energy of the massive reflector: low momentum of radiation.

CONCLUSIONS

Applying Lorentz transformations to a problem involving an exchange of EM radiation between inertial frames leads to the Doppler Radar. It is then configured as a violation of energy conservation laws in each inertial frame. It is impossible to relate two inertial frames with light signals and obtain reliable information at any level of accuracy using Lorentz Transformations, thus the equivalence of inertial frames is falsified by a noncompliance with energy conservation laws. Doppler effect and every problem involving radiation frequency shift, should be treated with at most one inertial frame. Considering a very superficial analysis, Doppler effect might look like an observer dependent phenomenon, but its origin is the exchange of energy momentum between mass and radiation alone. Radiation recoil and variation of momentum and kinetic energy of the reflectors are necessary for any realistic scenario.

REFERENCES

[1] G. Goedeke, V. Toussaint, C. Cooper: "On energy transfers in reflection of light by a moving mirror" Am. J. Phys. 80, 684 (2012).

[2] P. Valenta, T. Zh. Esirkepov, J. K. Koga, A. S. Pirozhkov: "Recoil effects on reflection from relativistic mirrors in laser plasmas." (2020) https://doi.org/10.1063/1.5142084

APPENDIX

ENERGY PRIOR AND AFTER THE ABSORPTION AT THE RADAR

$E_{ini} = h\cdot f_0+\gamma_0\cdot M\cdot c^2$, $E_{final} = h\cdot f_1+\gamma_1\cdot M\cdot c^2$

ENERGY PRIOR AND AFTER THE ABSORPTION AT THE RADAR

$P_{ini}= h\cdot f_0/c -\beta_0\cdot\gamma_0\cdot M\cdot c$ $P_{final} = -h\cdot f_1/c-\beta_1\cdot\gamma_1\cdot M\cdot c$

CONSERVATION LAWS OF ENERGY AND MOMENTUM

a) $E_{ini} = E_{final}$; $hf_0+\gamma_0 Mc^2 = hf_1+ \gamma_1 Mc^2$
b) $P_{ini} = P_{final}$: $hf_0/c - \beta_0\gamma_0 Mc = - hf_1/c - \beta_1\gamma_1 Mc$

From a) $f_1 = f_0 + Mc^2 (\gamma_0\cdot - \gamma_1)/h$; $f_1- f_0 = M\cdot c^2 (\gamma_0\cdot - \gamma_1)/h$

From b) $f_1 = - f_0 - Mc^2 (\beta_0\gamma_0 + \beta_1\gamma_1)/h$; $f_1+f_0 = - Mc^2 (\beta_0\gamma_0 + \beta_1\gamma_1)/h$

$0 = 2hf_0 / Mc^2 + (\gamma_0 - \gamma_1) - (\beta_0\gamma_0 + \beta_1\gamma_1)$;

$2hf_0 / Mc^2 = \gamma_0 (\beta_0 - 1) + \gamma_1 (\beta_1 + 1)$;

$\gamma_1= (2hf_0 / Mc^2 - \gamma_0 (\beta_0 -1))/ (\beta_1 + 1)$;a

$f_1- f_0 = M\cdot c^2 (\gamma_0\cdot - \gamma_1)/h = M\cdot c^2 (\gamma_0\cdot - (2hf_0 / Mc^2 - \gamma_0 (\beta_0 -1))/ (\beta_1 + 1))/h$

$(f_1- f_0)h = M\cdot c^2 (\gamma_0\cdot - (2hf_0 / Mc^2 - \gamma_0 (\beta_0 -1))/ (\beta_1 + 1))$

$\beta_1 = \gamma_0 (\beta_0 -1) Mc^2/ [(f_1-f_0)h- Mc^2\gamma_0 +2hf_0]$

hence

$\gamma_1= (2hf_0 / Mc^2 - \gamma_0 (\beta_0 -1))/ (\gamma_0 (\beta_0 -1) Mc^2/ [(f_1-f_0)h- Mc^2\gamma_0 +2hf_0] + 1)$;

f1-f0 $= M\cdot c^2 (\gamma_0\cdot - \gamma_1)/h$