

Comment and Rebuttal

Comment on “The Case of Absence of Transverse Doppler Effect”

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Abstract—In the above paper [1], an extraordinary claim of experimental absence of the transverse Doppler effect is made. As stated in the abstract, “An experiment … showing that a 33-GHz microwave signal received by rotating antennas is not exhibiting the frequency shift (“transverse Doppler effect”) predicted by the relativistic Doppler formula.” In this comment, we will reanalyze the experiment and show that the correct application of special relativity predicts exactly a zero effect, in perfect coincidence with the observed result.

Index Terms—Relativistic Doppler effect, rotating antennas, transverse Doppler effect.

The experimental setup (Fig. 1) consists of a source of electromagnetic waves in the form of a stationary antenna monopole, a stationary pickup, and two counter-rotating disks that move at tangential speeds of $+v$ and $-v$, respectively. In [1], it is claimed that special relativity predicts a Doppler shift between the input frequency f at the source and the pickup frequency f_3 at the receiver. Since the two discs move at a relative speed of $2v$, it is claimed that the frequency at the second rotating disc is

$$f_2 = \frac{f_1}{\sqrt{1 - \left(\frac{2vc}{c^2 + v^2}\right)^2}}. \quad ([1, \text{eq. (13)}])$$

This is precisely the point where the error is introduced in [1], leading to the final erroneous derivation. Finally, according to [1], the frequency at the receiver is

$$f_3 = f_2 \sqrt{1 - \frac{v^2}{c^2}} = f \frac{1 + \frac{v^2}{c^2}}{1 - \frac{v^2}{c^2}}. \quad ([1, \text{eq. (14)}])$$

The preceding expression predicts a blue shift between the source frequency f and the frequency at the receiver. Nevertheless, no such shift was observed in the experiment. Here, we outline the correct derivation.

The relativistic Doppler effect affects the frequencies as a function of the relative speed between a moving reflecting object, such as the rotating discs in [1], and the light source and between the reflecting object and the pickup since the object acts as a secondary light source by reflecting the incident light. In Fig. 2, f is the frequency emitted by the light source, $f_{\text{reflected}}$ is the frequency reflected by the moving object, and f' is the frequency perceived by the receiver. For an object receding from the light source, $f_{\text{reflected}}$ is red-shifted according to the general expression of the relativistic Doppler effect [2] given by

$$f_{\text{reflected}} = \frac{f \sqrt{1 - \frac{v^2}{c^2}}}{1 + \frac{v}{c} \cos \phi}. \quad (1)$$

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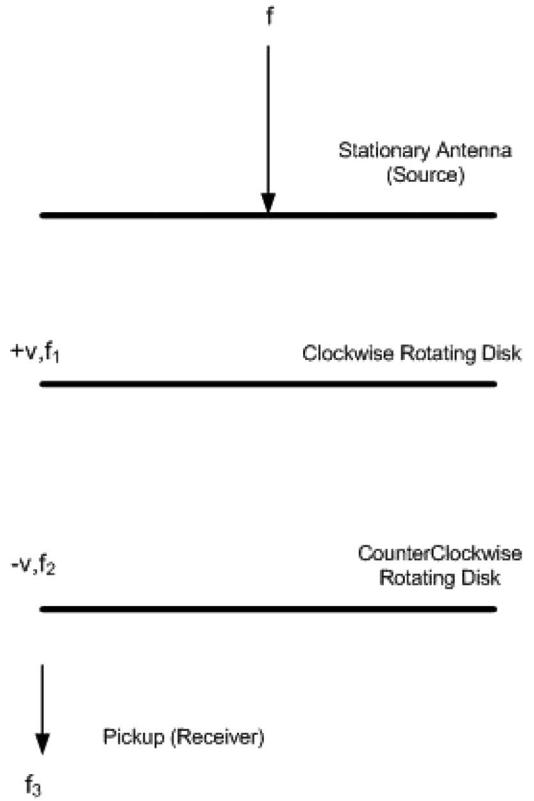


Fig. 1. Experimental setup.

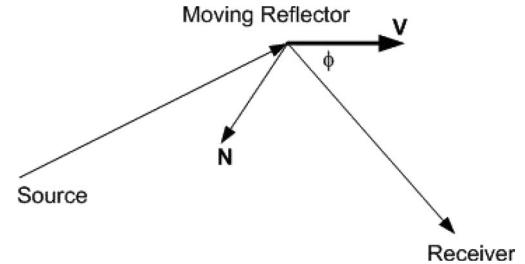


Fig. 2. Relativistic Doppler effect off moving reflectors.

In the preceding expression, v is the speed of the reflecting object with respect to both the source and receiver, and ϕ is the angle between the direction of the electromagnetic wave and the direction of the object. For the case in [1], $\phi = \pi/2$.

Because the object is approaching the pickup, the frequency f' is blue-shifted with respect to $f_{\text{reflected}}$, which is given by

$$f' = \frac{f_{\text{reflected}} \left(1 + \frac{v}{c} \cos \phi\right)}{\sqrt{1 - \frac{v^2}{c^2}}} = f. \quad (2)$$

We have just demonstrated that, contrary to the claims from [1], there is no frequency shift due to the relative motion between the reflector and the receiver, provided that the predictions of special relativity are correctly applied, as previously described. The result is valid for arbitrary ϕ ; therefore, it includes the case described in [1].

In other words, there cannot be any Doppler effect in the case when there is no relative motion between the source and the receiver. The presence of the rotating discs in [1] is *then irrelevant*. Thus, the equation in [1] is incorrect. This explains why no effect was observed. In the published literature [3]–[5], there is ample experimental confirmation of the relativistic Doppler effect, in perfect agreement with special relativity.

We have derived the correct relativistic equations that describe the expected null outcome reported in [1] and conclude that no contradiction between the outcome of the experiment and the predictions of special relativity exists.

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Response: The Case of Absence of Transverse Doppler Effect

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In the comment, the relativistic Doppler shift equation [see (1)] has not correctly been copied from [1], since (1) does not at all appear in [1]. It is well known that there is only one relativistic Doppler shift equation, as shown in [1, p. 914], and it reads

$$f' = f \frac{1 \pm v/c \cdot \cos \varphi}{\sqrt{1 - v^2/c^2}}. \quad (1)$$

The positive sign is valid for an approaching object, and the negative sign is for a receding object.

However, in the Comment, the inverse expression of (1) is shown for a receding object, namely

$$f' = f \frac{\sqrt{1 - v^2/c^2}}{1 + v/c \cdot \cos \varphi}. \quad (2)$$

Equation (1) in the Comment is thus incorrect. Instead, the third equation in [1, p. 915] should have been used, where the relativistic

Doppler shift equation for a receding reflector is derived, which reads

$$\begin{aligned} \omega'' &= \frac{\omega' - v k'_x}{\sqrt{1 - (v/c)^2}} \\ &= \frac{\omega[1 + (v/c)^2] - 2v k_x}{1 - (v/c)^2} \\ &= \omega \frac{[1 + (v/c)^2] - 2(v/c) \cos \varphi}{1 - (v/c)^2}. \end{aligned} \quad (3)$$

For $\varphi = 90^\circ$ (transverse direction), this equation reduces to the expression in [2, eq. 14], i.e.,

$$\omega'' = \omega \frac{1 + (v/c)^2}{1 - (v/c)^2}. \quad (4)$$

A second error appears in the Comment: only one moving object (one rotating disk) had been considered according to Fig. 2. However, two moving objects (two disks rotating in opposite directions v and $-v$) had been used in [2], and special relativity predicts Doppler shifts between all moving objects. Hence, a shift is expected to occur for a signal emitted from a moving object (rotating disk 1) and received by another moving object (disk 2 in [2]), and this shift has correctly been calculated in [2] by using the relativistic addition theorem for velocities, yielding the equations in [2, eqs. 13 and 14].

Ives and Stillwell [3] have done a completely different experiment not comparable with the experiment in [2]. Their measurement yielded a gamma factor due to the quantum-mechanical absorption of photons in the detectors, thereby transferring the mass of photons into the detectors. If they had used reflectors instead of detectors, then no gamma factor would have been obtained, as was shown by Engelhardt [4].

Hence, it has not been demonstrated in the Comment that in [2] the equations of the relativistic Doppler effect had been misapplied. In fact, it seems that those equations may have been improperly applied in the Comment.

REFERENCES

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