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P3_10 Red-shifted Speed Cameras

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Abstract

This paper investigates whether a car could travel fast enough to be red-shifted out of a speed cameras range of vision. It also calculates the observed length contraction of such a car if it could go at this velocity. It was calculated that a car would need to travel at 0.178 times the speed of light to avoid being caught by the speed camera via the Doppler Effect. It was also calculate that a Ferrari 458 would contract by 7.3cm at this velocity.

Introduction

There are several thousand speed cameras in the UK, catching millions of motorists as they break the speed limit every year. The majority of these cameras use either RADAR (RAdio Detection And Ranging) or LIDAR (LIght Detection And Ranging) to measure a cars instantaneous speed and then capture an image of any offending vehicles. This image is then use to identify and prosecute the driver. This paper investigates the speed at which a car would have to travel in order for the image to be Doppler shifted beyond the visible spectrum of the camera. It will also calculate the apparent observed length contraction of the car at this speed.

The Doppler Effect

The Doppler Effect is the change in frequency of a wave (either sound or light), as viewed by a stationary observer, as the source moves past the observer. Within this paper it will be assumed that the speed camera is a reverse facing camera. This means that the car will be receding from the camera and hence will be red-shifted. The equation for the receding Doppler Effect [1] is

$$f' = \frac{\sqrt{1 - V^2/c^2}}{1 + V/c} f_0, \tag{1}$$

where f' is the observed frequency, V is the velocity of the source, c is the speed of light, and f_0 is the emitted frequency. This can be rearranged to make the velocity the subject of the equation,

$$V = c\frac{(f'/f_0)^2 \pm 1}{(f'/f_0)^2 + 1}. \tag{2}$$

Note that the $\pm$ will give two values of the velocity. However, if it is taken as + then the velocity would be c, which when substituted into equation (1) will result in a division by 0, hence the only solution is for the numerator is $(f'/f_0)^2 - 1$.

Length Contraction

Another calculation was carried out to find out how the length of a car travelling at this velocity would change. Length contraction is a phenomenon where the length measured by an observer of an object travelling at a relative velocity is decreased in comparison to the length in the reference frame of the object. This is only usually noticeable at relativistic speeds. The equation for length contraction [1] is,

$$L = \frac{L_p}{\gamma} = L_p\sqrt{1 - \frac{v^2}{c^2}} \tag{3}$$

where L is the measured length, v is the velocity of the object and L_p is the proper length of the object.

Discussion

It will be assumed that the frequencies observed by the camera are the same as the human eye. The minimum frequency observed is 430THz (red) [2]. The number plate of the car is the area that needs to be red-shifted in order to avoid detection. Typically a rear UK number plate is yellow, the frequency of yellow light is between 525 and 505 THz, hence f_0 will be taken to be 515THz. When these frequencies are submitted into equation (2), the required velocity is 0.178c or $5.34\times10^7\text{ms}^{-1}$.

Using equation (3) and the velocity of the object, the length of a Ferrari 458 Italia [3], 4527mm, would contract by 73mm to 4454mm. Hence if the camera were capable of capturing an image, the reading would be incorrect as the car would be significantly shorter.

It should be noted that this paper has ignored any delay in taking the photo or the time taken to image the car. As at such high velocities the car would probably escape the range of the camera by the time the electronics have reacted. It has also been assumed that any other light that is emitted from the car is of a lower frequency (i.e. there may be some infrared radiation but no UV or x-ray radiation).

Conclusion

The required velocity of the car is beyond realistic. The fastest man-made object, the Helios Probe, is 2.29×10^{-4}c [4]. This car would need to go several magnitudes faster than this space probe and this is not possible. Hence it would be impossible to avoid a speeding ticket by taking advantage of the Doppler Effect.

References

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[4] http://www.popularmechanics.com/technology/engineering/extreme-machines/worlds-top-12-fastest-vehicles#slide-1 accessed on 19-11-13