Tachyons for Interstellar Communication

G. L. Harnagel *

December 14, 2020

Abstract

Concerns that tachyons, which have imaginary mass, may violate causality have been been discussed in the context of two distinct embodiments for constructing a message loop. One employs transmitters in motion relative to receivers, while the other has transmitters and receivers at rest with each other and messages are passed between moving observers using electromagnetic signals. The latter (Method II) is of interest only to those who seek to disprove the existence of faster-than-light phenomena by constructing hypothetical thought experiments based solely upon kinematics that purportedly violate causality, often by specious means. The former (Method I), on the other hand, is based upon the wider foundation of both kinematics *and* dynamics, and sound analysis proves that causality is not violated. For Method I, the relative speed between transmitter and receiver limits the propagation speed according to $u = c^2/v$, where u is the maximum possible propagation speed and v is the relative speed between transmitter and receiver. This paper discusses this paradigm for communicating between outposts in different star systems. Techniques will be discussed for increasing propagation speed beyond that limited by the relative motion between earth and a planetary base in orbit around a distant star.

*Retired Physicist

1 Introduction

Bilaniuk et al. considered that particles could be divided into three different classes.[1] Class I includes those which travel slower than the speed of light, Class II are those which travel *at* the speed of light, and Class III are those that travel *faster* than the speed of light. Indeed, Class III particles cannot travel *at or slower* than the speed of light. G. Feinberg coined the name "tachyon" for Class III particles.[2]

Much has been written on whether or not tachyons violate causality. A paper[3] discusses the physics of tachyons and concludes that neither embodiment defined in the Abstract violates causality; however, the proof of Method I is straightforward and simple, whereas that of Method II is fraught with difficulties. Because Method II has many speculative premises and is prone to erroneous analysis leading to the false conclusion that tachyons violate causality, it has been used as a fallacious argument that Method I is no better. This is a false assertion because Method I is based upon kinematics *and* dynamics, whereas Method II is based solely on kinematics.[4]

Because tachyons obey special relativity, they

[1] O. M. P. Bilaniuk, V. K. Deshpande and E. C. G. Sudarshan, "'Meta' Relativity," American Journal of Physics, 30, (10): 718-723 (1962)

[2] G.Feinberg, "Possibility of Faster-Than-Light Particles," Physical Review, 159, (5): 1089-1105 (1967)

[3] G. L. Harnagel, "Tachyons from a Laboratory Perspective," vixra 2011.0076 (2020)

[4] W. N. Matthews, Jr., "Seven formulations of the kinematics of special relativity," American Journal of Physics, 88, 269 (2020)

would obey the relativistic energy equation,[5]

$$E^2 = p^2c^2 + m^2c^4 \tag{1}$$

where m is imaginary for tachyons, $p = \gamma mu$ and u is the velocity of the tachyon. Rewriting Equation (1) with m replaced by im, since tachyons have imaginary mass, it becomes

$$E^2 = \frac{m^2u^2c^2}{u^2/c^2 - 1} - m^2c^4 \tag{2}$$

The m in Equation (2) is the absolute value of the tachyon mass. This shows that E, the energy of a tachyon, approaches zero as the tachyon velocity, u, approaches infinity. As a practical matter, any signal transmission requires at least *some* expenditure of energy, hence it is not physically possible to send a tachyon signal at infinite speed. Infinite speed represents a barrier which cannot be breached, even by a tachyon. Furthermore, infinite speed would mean that the tachyon would be everywhere at once, which would present an analytical and philosophical conundrum. When this paper refers to infinite speed it is to be understood as an idealization with the awareness that it will signify some speed that approaches but does not attain infinity.

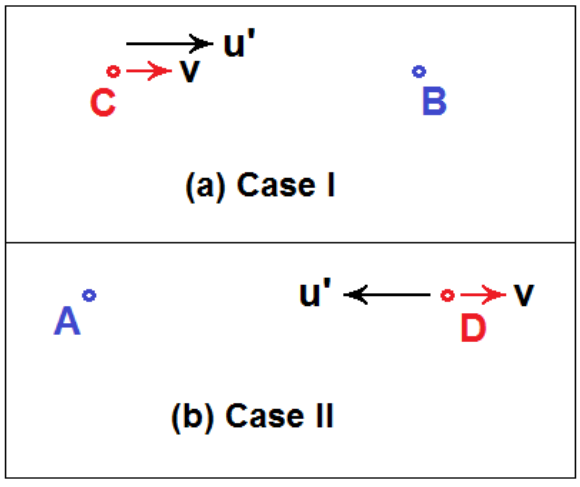

Figure 1: The two cases of direct superluminal communication.

Figure 1 presents the two situations that can occur with direct tachyon communication between tachyon transmitters and receivers in relative motion. The signal moves in the same direction as the source (Figure 1a), referred to as Case I, or it moves in the opposite direction (Figure 1b), which is called Case II. In Figure 1a, observer C is moving toward stationary observer B at velocity, v, and C sends an (almost) infinitely-fast signal (u') directly to B. The signal has almost no energy relative to C, but it is observed by B as having significantly more energy since the energy of C's motion is added (relativistically) to the signal's energy. Consequently, the signal travels *slower* relative to B according to Equation (2). When an observer moving at velocity v with respect to a stationary observer sends out a signal or object at velocity u' (with respect to the moving observer), the velocity of said signal or object with respect to the stationary observer, according to the kinematics of the Lorentz transformation, is[6]

$$u = \lim_{u' \to \infty} \frac{u' + v}{(1 + \frac{u'v}{c^2})} = \frac{c^2}{v} \tag{3}$$

This equation, valid for v and u' having the same sign, shows that when the signal velocity relative to the moving frame, u', is (nearly) infinite, the velocity relative to the stationary frame is (nearly) $u = c^2/v$. This kinematic result is in agreement with energy considerations and is clearly a consequence of the Relativity of Simultaneity.

In Figure 1b, observer D moves away from observer A and sends an infinitely-fast signal back to A. The signal has almost no energy relative to D, but its energy relative to A must be *subtracted* from its energy relative to D. Unfortunately, it cannot have negative energy so A cannot detect the signal from D. D must give the signal more energy so it will have positive energy when it reaches A, which means that the signal velocity relative to D is slower. The maximum velocity can be determined from the relativistic velocity composition equation for the signal moving in the opposite direction from Equation (3):

[5] http://hyperphysics.phy-astr.gsu.edu/hbase/Relativ/releng.html

[6] J. D. Jackson, Classical Electrodynamics, (1965), p.361

$$u = \frac{-u' + v}{1 - u'v/c^2} \tag{4}$$

where u' is positive for propagation in the negative x' direction for illustration purposes. Equation (4) shows that for leftward-going u', it is limited to c^2/v, at which point u becomes infinite. This is exactly the limit needed for D to send a signal to A successfully.

Direct tachyon communication between observers in relative motion is very simple, straightforward and does not violate causality, in the sense that messages *cannot* be received before they are sent.[3] Consequently, tachyons should be able to facilitate communication over astonomical distances much, much faster than the speed of light. This would allow far-away outposts to keep in close touch with earth.

2 The Physics of Tachyon Communication Speed

Since the maximum propagation speed of tachyons by Method I is $u = c^2/v$ in one frame and $u = \infty$ as observed from the other frame, the time delay for one-way communication between transmitter and receiver in relative motion is $\Delta t > vL/c^2$ for one and $\Delta t > 0$ for the other. Thus the round-trip time delay time is $\Delta t > vL/c^2$.

For example, communication between Earth and a base on a planet circling Tau Ceti depends upon the relative velocities between the Sun and Tau Ceti in addition to the velocities of Earth around the Sun and the velocity of the base around Tau Ceti. Tau Ceti is moving toward the Sun at -16.7 km/sec,[7] and the Earth orbits the Sun at about 29.8 km/sec. The relative orientation between the plane of Earth's orbit and that of the base is also important, but a planet in the habitable zone of Tau Ceti might have an orbital velocity of about 36 km/sec.

[7] https://en.wikipedia.org/wiki/Tau Ceti

The relative velocity between a transmitter on Earth and a receiver at the Tau Ceti base might vary from about -82 km/sec to about +49 km/sec. Tau Ceti is 11.9 lightyears from us, or about $1.13x10^{14}$ km, so the round-trip communication delay time, Δt, would vary between 5.8 hours and 29.7 hours, nominally, but if the orbital phases were just right, the time delay could approach zero at certain times.

Although the delay of a day or so to send and receive information from a base twelve lightyears away is very good, the time delay *could* be reduced to nearly zero on a consistent basis. A constellation of satellites could be placed in orbit around the Sun. A similar constellation could be placed in orbit around Tau Ceti, as shown in Figure 2. The orbital distances of each ring from the sun and Tau Ceti could be arranged such that the orbital velocities were $v_{Sun} - v_{Base} - v_{TauCeti} = 0$. Figure 2 depicts eight satellites in orbit, but as many satellites could be included to reduce the time delay between a pair of satellites arriving in the proper position for transmission and reception to an acceptable value. Of course, sending the signal between satellite to earth or satellite to base by electromagnetic means may be unacceptable, but short-haul tachyon transceivers between satellites and earth (or base) could reduce that delay significantly.

Figure 2: Satellite Constellations for Reduced Communication Time.

3 Conclusion

Previous work has demonstrated definitively that direct tachyon communication around a loop between transmitters and receivers in relative motion always obeys causality. Provided

that tachyons aren't imbued with unreasonable properties, it was also shown that adding additional participants canot violate causality, either. Enlistment of tachyon properties for long-distance communication has been shown to be feasible, provided that tachyons actually exist and can be suitably controlled.

Although there is no solid experimental evidence at present for faster-than-light physical phenomena, it has been hypothesized that the electron antineutrino may be tachyonic.[8] [9] This line of thought is still very much active,[10] [11] and the initial results from the KATRIN experiment do not refute this since the most likely value obtained for the neutrino mass is imaginary.[12]

Thus it appears that tachyons may be a viable means of communication over interstellar distances with very much less round-trip time delay than possible with radio or light. Time delays on the order of hours, or even minutes, seem possible if tachyons can be identified and harnessed for this enterprise.

It has been hypothesized that many extraterrestrial civilizations exist in our galaxy alone.[13] Given that there are many, the question of why none has been discovered is known as the Fermi paradox.[14] Many believe that we are alone, but we may be missing all the conversations going on because we're too primitive to implement tachyon communication for ourselves.

4 Acknowledgments

The author thanks R.T. Longo for helpful discussions and members of the Google sci.physics.relativity discussion group for ardently presenting the mainstream view.

[8] A. Chodos, A. I. Hauser and V. A. Kostelecky, "The Neutrino as a Tachyon," Physics Letters B 150, 431 (1985)

[9] J Ciborowski and J. Rembielinski, "Tritium Decay and the Hypothesis of Tachyonic Neutrinos," arXiv 9810355 (1998)

[10] C. Schwartz, "Tachyon Dynamics - for Neutrinos?" Int. J. Mod. Phys A 33, 1850056 (2018) https://arxiv.org/abs/1710.09904v2

[11] R. Ehrlich, "Review of the Empirical Evidence for Superluminal Particles and the 3 + 3 Model of the Neutrino Masses," Advances in Astronomy, 2019, Article ID 2820492

[12] M. Aker et al., "An improved upper limit on the neutrino mass from a direct kinematic method by KATRIN," Phys. Rev. Lett. 81, 1562 (2019), arXiv 1909.06048

[13] http://www.setileague.org/general/drake.htm

[14] https://www.seti.org/seti-institute/project/fermi-paradox