INSTANTANEOUS DATA TRANSFER OVER TEMPORAL BOUNDARIES : A METHOD FOR COMMUNICATING WITH THE PAST AND FUTURE

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ABSTRACT

Using the entanglement principle of Quantum Mechanics it is possible to communicate information instantaneously, and therefore faster than the speed of light. If a communication device utilizing this principle were to travel at a relativistic speed in relation to an integrally connected entangled partner communication device, it would be possible to communicate over temporal boundaries, i.e., with the future and the past., due to the instantaneous communication and time dilation at relativistic speeds.

INTRODUCTION

Utilizing the entanglement principle of Quantum mechanics, described in this paper, it is possible to communicate information faster than the speed of light; instantaneously. A combination of the ability to communicate faster than the speed of light and the effects of special relativity's time dilation allows communication over temporal boundaries that surmounts any previous limitations of communication with the past or future. Let's say a person were to travel at a relativistic speed with a communication device which was integrally connected with another communication device that remained stationary (with respect to the first device). Both of these devices allow faster-than-the-speed-of-light communication, i.e., instantaneous communications. Due to the effects of time dilation for the relativistic traveler and the device, when the traveler returned to the stationary device's world, less time in relation to the stationary device would have passed. Since the traveler's device communicates instantaneously with the partner device, and the partner device (of the same age) is in a "younger" space-time environment, it would be possible for the traveler to talk to the past and for the past to talk to the traveler in the future !

It may not even be necessary to accelerate the traveler at relativistic speeds since the two partner communication devices are the ones that are integrally joined through quantum entanglement which allows instantaneous communication; it might be necessary only to accelerate one device at relativistic speeds in relation to the other in order to communicate with the past and the future.

QUANTUM ENTANGLEMENT

The Einstein-Podolsky-Rosen (EPR) [1] paradox in quantum mechanics reveals that if two particles interact, they become correlated in such a manner that by measuring the position of one particle the wave function of the other will be in a definite position state, regardless of the spatial separation; <u>this</u> is instantaneous. *Singlet* states have a total spin of zero (if one particle is spin up $\uparrow$, the other particle is spin down $\downarrow$, and vice versa). These particles, which are intimately connected by their spin properties could be used to instantaneously communicate information about the spin of each particle, regardless of the distance of separation.

What follows is a simplified version of Bohm's [2] discussion regarding the EPR experiment. To comprehend the essence of the experiment, one must understand some properties of electron spin. Although in subatomic physics the classical conceptual analogies are at best limited, for the purpose of this hypothesis, one can envision particle spin as a rotation about the particle's own axis. The particle spin for an electron is limited to two values. Each electron can spin either in a clockwise or a counter-clockwise direction around a given axis. Physicists often denote these two different directions of spin by "up" or $\uparrow$, and "down" or $\downarrow$.

An important concept is that for any two entangled particles the total spin is zero. So if one particle is spin up, the other is spin down therefore making the total spin equal to zero, since the two opposite spins cancel each other out. Just as electrons exhibit only probabilities to exist in certain places as shown by the Heisenberg uncertainty principle, they also exhibit probabilities to spin about a certain axis. However, when a measurement is performed for any chosen axis of rotation, the electron will be found to spin in one or the other direction about that axis, which has been defined by the observer. Hence, the act of making a measurement about a defined axis, provides the particle with a definite axis of rotation. Before the measurement is performed however, the electron does not have a definite axis of rotation, it merely has a probability or potentiality of assuming any axis of rotation.

With this basic understanding of electron spin, we can now examine the EPR experiment and Bell's theorem. The EPR experiment involves two "entangled" electrons spinning in opposite directions, one up $\uparrow$ and one down $\downarrow$, so that the total spin is zero. Even if these two particles are separated by an arbitrary distance, it is important to note that their total spin will always be zero. If the spin of one particle, say particle 1, is measured along a vertical axis and is found to be $\uparrow$, then the spin of the second particle, particle 2, will be $\downarrow$, but most importantly around the same chosen axis of rotation since the total spin must always be zero. Hence by measuring the spin of particle 1 along a defined axis of rotation, we obtain an indirect measurement of the spin of particle 2 about the same axis, without in any way disturbing the particle. The most significant and somewhat paradoxical aspect of the EPR experiment is that the observer is free to define the axis of measurement. Quantum theory states that the spins of the two electrons about any axis are always opposite, but their spins will exist only as potentialities, until the measurement is taken. Once the observer has chosen a definite axis and has performed the measurement, a definite axis of rotation will be defined for both particles. Another crucial point, as mentioned earlier, is that one can choose the axis of measurement when the particles are any distance apart. The instant particle 1 is measured, particle 2, (which may be thousands of miles away), acquires a definite spin along the chosen axis, instantaneously. If we let a vertical axis = 1 and a horizontal axis = 0, it is possible to pass 1's and 0's instantaneously across large distances by choosing the appropriate axis of measurement. The problem still remains as to when the measurement on the receiving side is to be made, since it must be after the initial measurement has been made on the sending side, but these issues and the process of information transmission can be solved by using polarized entangled particles.

There is a similar type of spin relationship which coincides with a polarized states relationship that can be represented as follows: If, within an entangled particle pair, a particle "A" has a polarized state $|\leftrightarrow\rangle$, then the partner particle "B" will have a polarized state $|\updownarrow\rangle$, and vice versa, post-measurement. The act of measuring the particle will cause the waveform to collapse, but before a single particle is measured, it is even polarized in a general superposition of these two states

$$|\Psi\rangle = a|\leftrightarrow\rangle + b|\updownarrow\rangle \quad (1)$$

were a and b are two complex numbers satisfying $|a|^2 + |b|^2 = 1$.

Bennet et al. [3] realized that by using the entangled particles, one can transport information instantaneously over any distance. During the transmission of information, the quantum state of particle A will be destroyed while the quantum state of particle B is being determined. However, neither the observer of A nor B will obtain any information about the state $|\Psi\rangle$.

An entangled pair is a single quantum system in an equal superposition of the states $|\leftrightarrow\rangle_2|\updownarrow\rangle_3$ or $|\updownarrow\rangle_2|\leftrightarrow\rangle_3$. The pairs initial shared state is represented by:

$$|\Psi^-\rangle_{23} = \frac{1}{\sqrt{2}}\left(|\leftrightarrow\rangle_2|\updownarrow\rangle_3 - |\updownarrow\rangle_2|\leftrightarrow\rangle_3\right) \quad (2)$$

The entangled state contains no information about the individual particles; it indicates only that the two particles are always in opposite states. The important property of an entangled pair is that as soon as a measurement on one particle of the particle pair, projects it, say, onto $|\leftrightarrow\rangle$, the state of the other particle is determined instantaneously to be $|\updownarrow\rangle$, and vice versa. The fact that the measurement of one particle instantaneously influences the state of the other particle was referred to by Einstein as "Spooky action at a distance".

Bouwmeester et al. [4] recently described a method of using the entanglement principle in teleportation. The same method they have described can be used in exchanging information instantaneously. Such an exchange of information by using the entangled particles works as follows. Take three particles: Particle 1 is in the initial state $|\Psi\rangle_1$ and resides in London. Particles 2 and 3 are entangled particles which have been separated. Particle 2 is in London with particle 1, and particle 3 is in New York City. The essential point is to perform specific measurements on particles 1 and 2 which projects them onto the entangled state:

$$\left|\Psi^-\right\rangle_{12} = \frac{1}{\sqrt{2}}\left(\left|\leftrightarrow\right\rangle_1\left|\updownarrow\right\rangle_2 - \left|\updownarrow\right\rangle_1\left|\leftrightarrow\right\rangle_2\right) \qquad (3)$$

This equation describes only one of four possible maximally entangled states into which any state of two particles can be decomposed. The projection of an arbitrary state of two particles onto the basis of the four states is called a Bell-state measurement. The state shown in Eq. (3) is distinguished from the three other maximally entangled states by the fact that it changes sign when particle 1 and particle 2 are interchanged. This unique anti-symmetric feature of $\left|\Psi^-\right\rangle_{12}$ plays an important role in the experimental identification, that is, the measurement of this state.

Quantum physics predicts [2] that once particles 1 and 2 are projected onto $\left|\Psi^-\right\rangle_{12}$, particle 3 is instantaneously projected into the initial state of particle 1. The reason for this behavior is that because we observe particles 1 and 2 in the state $\left|\Psi^-\right\rangle_{12}$, we know that whatever the state of particle 1 is, particle 2 must be in the opposite state, that is, in the state orthogonal to the state of particle 1. But we had initially prepared particle 2 and 3 in the state $\left|\Psi^-\right\rangle_{23}$, which means that particle 2 is also orthogonal to particle 3. This is only possible if particle 3 is in the same state as particle 1 was initially ! The final state of particle 3 is therefore:

$$\left|\Psi\right\rangle_3 = a\left|\leftrightarrow\right\rangle_3 + b\left|\updownarrow\right\rangle_3 \qquad (4)$$

Note that during the Bell-state measurement particle 1 loses its identity because it becomes entangled with particle 2. Therefore the state $\left|\Psi\right\rangle_1$ is destroyed on the London side of the message transmission.

This result (Eq.(4)) deserves some further comments. Quantum information from particle 1 to particle 3 can be transferred over arbitrary distances instantaneously. Also, it is not necessary for one communicating party to know where the other is. Furthermore, the initial state of particle 1 can be completely unknown to everyone.

QUANTUM COMMUNICATION DEVICES

If we replace the states $\left|\leftrightarrow\right\rangle$ and $\left|\updownarrow\right\rangle$ in Eq. (1) by $\left|0\right\rangle$ and $\left|1\right\rangle$, which refer to the states of any two-state quantum system, one can design a device for transmitting binary information over any distance instantaneously. (Superpositions of $\left|0\right\rangle$ and $\left|1\right\rangle$ are called qubits to signify the new possibilities introduced by quantum physics into information science.) Since it is possible to transmit the values of 1 and 0 instantaneously, it is conceivable that large arrays of particles could be so arranged that multitudes of 1's and 0's could be transmitted. This scheme is the basis of Quantum Computing, which allows instantaneous data transfer. The concept of Quantum Computing started as early as 1982, when Richard Feynman considered simulation of quantum-mechanical objects by other quantum systems [5]. However, the true possibilities of Quantum Computing were not really addressed until 1985 [6] in a paper by David Deutsch and then in 1994, Peter Shor from AT&T's Bell Laboratories, finally devised the first quantum algorithm, which could in principle perform factorization[7]. The advancements in the field of Quantum Computing have set the groundwork for the field of Quantum Communication using Quantum Entangled Devices (QEDs). By separating two such devices, it is possible to communicate instantaneously over arbitrary distances (and, of course, these binary messages can be translated into whatever medium is desired).

THE SPECIAL THEORY OF RELATIVITY

By combining the principle of communicating instantaneously with the theory of Special Relativity, one can devise a theory which would allow communications across temporal boundaries, (i.e., with the future and the past). First, it is appropriate that I give a little background on the concept of time dilation used in the theory of Special Relativity.

The theory of Special Relativity developed by Einstein and verified by various experiments (For example, 1976 CERN Muon experiment), states that according to a stationary observer, a moving clock runs slower than an identical stationary clock. This behavior is known as *time dilation.*

From relativity, we know that observers in different inertial frames always measure different time intervals between a pair of events. This fact can be illustrated by using a moving vehicle containing an observer named Speedo and a stationary observer named Nogo along the side of the road. Speedo has a mirror above him in the moving vehicle as it speeds past Nogo. Speedo sends a laser pulse straight up in the vehicle which is reflected from the ceiling mirror as he passes Nogo. Speedo sees the light go straight up and return straight down in his inertial frame (Fig 1).

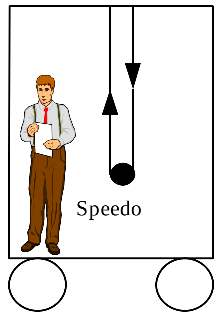

Fig 1

According to Nogo, the mirror and laser are moving with a speed *v*. By the time the light pulse reaches the mirror, the mirror has moved a distance $v\frac{\Delta t}{2}$, where Δt is the time it takes the light to travel from Speedo to the mirror and back to Speedo again as measured by Nogo. In other words, Nogo concludes that, because of the motion of the vehicle, if the light is to hit the mirror, it must leave the laser at an angle with respect to the vertical direction (see Figure 2).

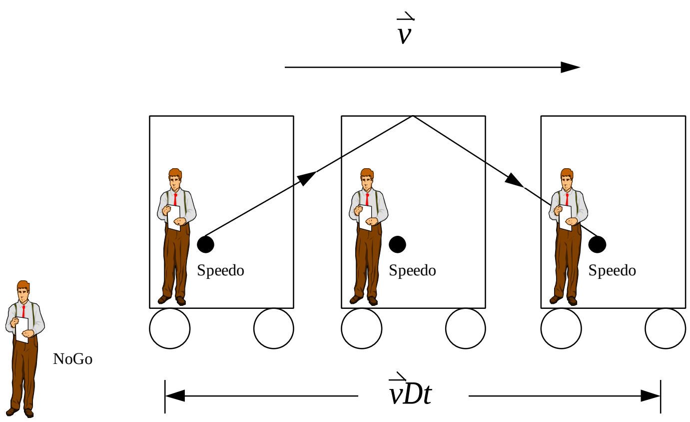

Fig 2

By comparing these two figures, it can be seen that the light must travel farther for Nogo than it does for Speedo.

Since the light travels a farther distance for the stationary observer and since the speed of light is constant *c*, it follows that the time interval Δt measured by Nogo in the stationary frame is longer than the time interval $\Delta t'$ measured by Speedo in the moving frame. To obtain a relationship between these two time intervals, it is convenient use to the right triangle shown in Figure 3.

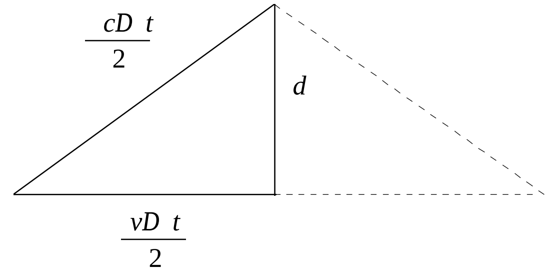

Fig 3

The Pythagorean theorem applied to this triangle gives:

$$\left(\frac{c\Delta t}{2}\right)^2 = \left(\frac{v\Delta t}{2}\right)^2 + d^2$$

Solving for Δt we obtain:

$$\Delta t = \frac{2d}{\sqrt{\left(c^2 - v^2\right)}} = \frac{2d}{c\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

Because $\Delta t' = \frac{2d}{c}$, it follows that

$$\Delta t = \frac{\Delta t'}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

Let $g = \frac{1}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$

Therefore, $\Delta t = g\Delta t'$

So, according to a stationary observer, a moving clock runs slower than an identical stationary clock. This behavior is called time dilation and is true for mechanical clocks as well as for the light clock just described. In fact, all physical processes, including chemical reactions and biological processes, slow down in relation to the movement of a stationary clock when they occur in a moving frame.

SURMOUNTING TEMPORAL BOUNDARIES

The Theory of Special Relativity shows that moving objects slow down in relation to stationary objects. Hence, if two objects start in the same initial time frame and one accelerates and moves for a given period of time, when it returns to the stationary frame, less time will have passed in reference to the object which remained in the stationary frame.

To begin the discussion on communication across temporal boundaries, or with the past or the future, it is best to start with two communicating devices, like walkie-talkies, in reference to the Theory of Special Relativity. Let Speedo be carrying a walk-talkie with him from the stationary frame to the moving frame, and then back to the stationary frame, while NoGo holds another walkie-talkie in the stationary frame, where he remains. When Speedo returns to the stationary frame and talks into the walkie-talkie, he will be talking to an older NoGo and, more important for now, to an older walkie-talkie. This relation will occur since time dilation occurred for Speedo and for the walkie-talkie in the moving frame. The time elapsed for Speedo and his walkie-talkie will be less by a factor of g^{-1} than the time for NoGo and his walkie-talkie.

By constructing the walkie-talkies used by Speedo and NoGo out of quantum entangled particles which convert quibits into communication data, one can achieve instantaneous communication with the entangled walkie-talkie of the same age, or in the same temporal zone. An example of this could be constructed by using the quantum entangled walkie-talkies in the same scenario where Speedo carries one entangled device in the moving frame and returns to NoGo with the other entangled device in the stationary frame. Since Speedo's walkie-talkie always communicates instantaneously with the entangled walkie-talkie of the same age, faster than the speed of light (i.e.: overcoming the Theory of Special Relativity and the limitations of the speed of light), Speedo's walkie-talkie talks to a device that is in the past relative to the present stationary frame he has returned to. The device in the past (representative of how much time dilation occurred while Speedo was traveling) will be speaking to the future.

Hence, Speedo and his walkie-talkie are younger by a factor of g^{-1} than the temporal zone to which they have returned. Thus the entangled walkie-talkie talks from the older temporal zone in which it now exists to its actual-age entangled device which is in a temporal zone that is a factor of g^{-1} in the past.

CONCLUSIONS

By using quantum entangled communication devices (which transfer data instantaneously) and by accelerating one in reference to the other, the accelerated device will be in an earlier time-frame than the stationary device by a factor of g^{-1}. By using these two devices post acceleration, one can communicate over temporal boundaries, i.e., with the past and the future. By using the accelerated device the user will be able to talk to the future, and by using the stationary device the user can talk to the past.

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