

Superluminal Signalling without the use of Entangled Particles

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Abstract

Entanglement studies dwell on multi-particle systems by definition – one particle, via a global symmetry/conservation law is correlated to another. It has often been wondered via EPR/Bell/Aspect/Dopfer-Zeilinger/Zbinden whether: first, a communication scheme is possible by entangled quantum state collapse and secondly, whether such a scheme would work over spacelike separations. This study follows on from the author's earlier scheme of sending classical data over a Bell Channel, to now, using an unentangled source. The rationale for this is that beams from a three-way or n-way splitter (even with single photons) are in a sense “entangled” with themselves via the principle of conservation of probability: measurement of a photon in one beam causes a collapse of the wavefunction in all the others. The new communication scheme represents an improvement over using expensive and complicated entangled sources of poor purity, for common-or-garden coherent sources.

1. Introduction

The arrival of the New Quantum Theory[1] in the period of 1925, 1926 by Schrodinger, Heisenberg and Jordan, had from its inception the idea of the tensor product to deal with multi-particle systems. However the procedure of measurement and “wavefunction collapse” and indeed physical reality seemed to be at odds with Relativity[2]. In the celebrated EPR paper, wavefunction collapse was looked at in the context of multi-particle systems and conservation laws. The conclusion was shocking: because wavefunction collapse appeared instantaneous it was in abeyance of Relativity; this led to the belief that Quantum Mechanics was incomplete and must have “hidden variables”.

Bell[3, 4] analysed this paradox and noted that due to the indeterminacy of quantum measurement, it wasn't just a case of classical correlation in relation to a conservation law; for instance: if there was a “law” that for two snooker balls in a bag that one had to be black, the other white, a person choosing from the bag on picking black would know the other was immediately white and vice versa. There is obviously no transmission of information at the instant of measurement, in this case, because although the measurement is random, the outcomes are predetermined.

In the quantum case, it is incorrect to speak of the contents of the bag as being two balls one black, the other white, as they are in superposition (it is *almost* as if they were grey). The very act of measurement determines the outcome of not just one ball *but both*. Clearly over a spacelike separation something *physical* is occurring and the initial thoughts were to whether there were hidden variables and if information could be passed by wavefunction collapse.

To the first, Bell showed that a hidden variables theory would obviously fail: over a spacelike separation, when performing coincidence counting, a parameter could be continuously altered which must be communicated over a spacelike separation to yield consistent results for the global conservation law. Ironically an hidden variables theory would have to be superluminal too or somehow *prescient* of the experimenter's intentions as to how he moved the parameter, so that the other experimenter received consistent results!

Discussion of the matter soon descended into pseudo-philosophic or even metaphysical arguments unworthy to be called Physics and are not worth citing (just watch the Sci-Fi channel), to evade the conundrum thrust into the face of Relativity:- multiple universes to cope with every measurement outcome, observer determined reality, information travelling backwards in time or super-determinism (more so than even the Newtonian “clockwork universe”) to ensure a consistent result of global conservation laws trumping the locally formulated Relativity. Clearly something has to give.

Meanwhile in the early 1980s, EPR/Bell's thought experiment was actually performed[5] to an astounding level of confidence. Furthermore, retrospective analysis of experimental data suggests that this consistency in the outcomes of wavefunction collapse by coincidence counting is extremely rapid[6].

In light of the Aspect experiment, physicists doing *real* Physics (not metaphysics or scriptwriters for Star Trek) and not heading down the road to nowhere of quasi-religioso-metaphysical navel gazing but trying to salvage the losing battle of

Relativity, have looked at the idea of whether there was some prohibitive principle barring information transfer by some scheme of signalling by wavefunction collapse. This is the source of the so-called “No communication theories”[7-9]. Quite correctly and nobly (in the sense of Cervante’s Don Quixote or even St Jude, the patron saint of lost causes) they note that after taking the partial trace on a multi-particle system to perform the act of measurement, that there is no change in the measurement of observables ie: $\langle \psi | A | \psi \rangle$ or $Tr(\rho A)$; no change means no transmission of mass-energy and the belief that no information could be sent. However in the light of experiments showing the remote change of distribution of entangled wavefunctions over spacelike intervals[10, 11] and the author’s contribution to utilise such an effect for communication[12, 13][†], it became apparent that there was a flaw in these “No Communication” theories ([13], appendix 1) where the distribution change could be used to communicate, though *no mass-energy* is transmitted at the actual time of measurement (though the particles did previously travel to their locations for the act of measurement). The author was able to discern this change in distribution by use of a Mach-Zehnder type interferometer setup. The author is also developing a transform to deal with transmission of signals of *pure information* of quantum state without mass-energy, by the simple device of removing the retarded time from the Lorentz transform, which is caused by the finite speed of propagation of light[12-14]. This seems to lead to a very rational view of matters, consistent with Relativity but putting space and time back on an almost Newtonian footing.

As an aside: the notion of superluminal or even *instantaneous* effects seems completely unphysical - “spooky action at a distance”, however the author is currently developing ideas that might show that wavefunction collapse happens at finite speed (albeit much faster than light), coming from the realm of quantum field theory. This doesn’t affect the author’s notions of absolute space and time as a backdrop to the dynamic metric, by this new, faster means of communication proving only finite *too*, just a limit to the method of communication. As a hint to the author’s nascent thoughts and as we shall see in the next section, the frustration in this method must come from the generation of particles from the vacuum state by the measurement process.

We ask now, is it possible to affect a communication scheme via quantum state collapse

[†] Note the latter reference has the correct treatment of the non-factorisable/separable wavefunction in appendix 1, despite the naïve/condensed/easy explanation in the table 1 in the former reference.

with single, unentangled particles, using much of the language and rationale for entangled particles?

2. Whence entanglement in single particle systems?

The phenomenon of Quantum Entanglement is the fascinating and logical interplay of global conservation laws and indeterminacy in measurement. For instance Bell’s analysis[3, 4] and Aspect’s experiment[5] focused on spin, which corresponds to angular momentum and its conservation. Franson[15] utilised entanglement resulting from a two level system and this is a manifestation of the conservation of energy.

In non-Relativistic Quantum Theory there is “Conservation of Probability”. Recounting the author’s earlier paper[12]:

“The probability density of a normalised wavefunction in QM is given by the square of the wavefunction:

$$\rho(\mathbf{r}, t) = |\psi(\mathbf{r}, t)|^2 \quad \text{and} \quad \int \rho(\mathbf{r}, t) d^3r = 1$$

If there is any sense in the concept, probability is conserved and would obey the continuity equation:

$$\frac{\partial \rho(\mathbf{r}, t)}{\partial t} + \nabla \cdot \mathbf{j}(\mathbf{r}, t) = 0$$

Where the probability current density \mathbf{j} is derived on application of the Schrödinger equation to the above relations as:

$$\frac{\hbar}{2mi} (\psi^* \nabla \psi - \psi \nabla \psi^*)$$

Take a spherical source of particles (figure 1) emitted slowly enough to be counted one at a time. Arranged on a sphere one light-year in diameter (say) is a surface of detectors. Only one particle will be counted per detection event as the light-year diameter wavefunction collapses (becomes localised) randomly so that probability is conserved. The wavefunction, in current thought, is not perceived as something that is ‘real’ but is then discarded and a classical path is ascribed from the source to the detector that registered the event to say the particle, *retrospectively* went along that path.”

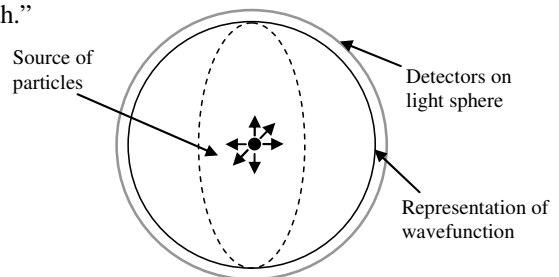


Figure 1 – Conservation of probability

So it might seem that one could write the wavefunction for an n-way splitter (such as a diffraction grating), whose outputs have equal probability at positions x :

$$\psi = \frac{1}{\sqrt{n}}(|x_1\rangle + |x_2\rangle + \dots + |x_n\rangle) \quad \text{eqn. 1}$$

As “being entangled with the vacuum state”:

$$\psi = \frac{1}{\sqrt{n}}(|0\rangle|x_1\rangle + |0\rangle|x_2\rangle + \dots + |0\rangle|x_n\rangle) \quad \text{eqn. 2}$$

We are not saying this is literally true but wish to point out formal similarity with the arguments of wavefunction collapse in entangled systems - measurement of any one of the pairs results in a mixed state *and all that entails in similarity to the arguments with entangled systems.*

3. The “Single” Photon Communication Scheme

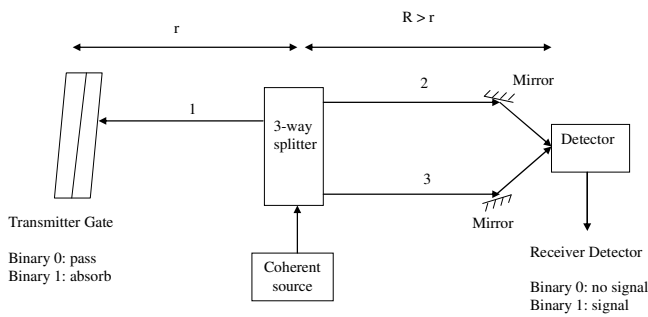


Figure 2 – The Communication Setup

Depicted above is the method of communication by single photon wavefunction collapse. A coherent source is incident on a 3-way splitter[16] which produces the following wavefunction:

$$\psi = \frac{1}{\sqrt{3}}(|x_1\rangle + |x_2\rangle + |x_3\rangle) \quad \text{eqn. 3}$$

Beam 1 is diverted away to a distant signalling station located “ r ” units away from the splitter. The action of the “transmitter” gate is to either pass (binary 0) or absorb (binary 1) beam 1. Beams 2 and 3 are directed and converged to add destructively at a detector located “ R ” units away from the splitter, where to prove the point, R is just greater than r , such that any influence by measurement on the LHS, is perceived much faster than the transit of a conventional mass-energy signal could via the distance $r+R$.

The destructive interference at the detector on the RHS renders the protocol of classical digital data sent over a quantum channel:

LHS	RHS
0: No measurement	No signal
1: Measurement	Normalised 2/3 $\left\{ \begin{array}{l} \text{either } \psi = \frac{1}{\sqrt{3}} x_2\rangle \\ \text{or } \psi = \frac{1}{\sqrt{3}} x_3\rangle \end{array} \right\}$

Table 1

Of course, the argument has been made to single photons but the results follow to many photons and an average measurement. The scheme can be extended to an n-way splitter:

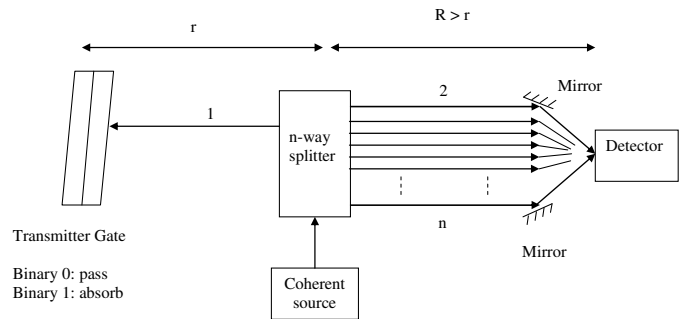


Figure 3 – Generalisation to an n-way splitter

Whereupon the scheme is rendered particularly effective.

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