Consistency of the Retro-Beam Transactional Framework with the No-Signaling Theorem

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Abstract

This paper demonstrates how the Retro-Beam Transactional Framework (RBTF) adheres to the no-signaling theorem, ensuring no faster-than-light communication. In RBTF, retro-beams (confirmation waves) are statistically dependent on future absorbers and cannot be controlled to send signals. Any attempt to signal averages to no net effect, as established in the Transactional Interpretation (TI) literature. We provide a mathematical proof and three numerical examples illustrating this consistency. ¡grok-card data-id="0f3ce1" data-type="citation$_c$*ard*" >< */grok−card* >< *grok−carddata−id* = "*fad52f*"*data−type* = "*citation$_c$ard*" >< */grok − card* >

1 Introduction

The no-signaling theorem in quantum mechanics states that local measurements on entangled systems cannot be used to transmit information faster than light, preserving causality. In RBTF, which builds on TI, quantum transactions involve offer waves and retro-beams, but the probabilistic nature of absorbers ensures that outcomes average out, preventing controllable signaling.¡grok-card data-id="8aa840" data-type="citation$_c$*ard*" >< */grok−card* > *Retro−beamsoriginatefromfuturemeasurementsbutarenotpre−selectable*; *theyreflectstatisticalboundaryconditionsratherthandeterministicchoices.Thisallowsretro−causalityforcorrelationswithoutviolatingno − signaling.*

RBTF passes this test because any signaling attempt requires manipulating the retro-beam to convey information, but the transaction formation is probabilistic and self-consistent, leading to marginal probabilities independent of distant choices.

2 Proof of No-Signaling

Consider two entangled particles A and B in a general state ρ_{AB}, with local measurements by Alice on A (basis choice X) and Bob on B (basis Y).

In RBTF, the transaction for outcome a on A and b on B is formed by the handshake amplitude $P(a, b|X, Y) = |\langle a, b|U|\psi\rangle|^2$, where U includes the retro-beam influence.

The marginal probability for Alice's outcome a, summed over Bob's outcomes, is:

$$P(a|X) = \sum_b P(a,b|X,Y) = \mathrm{Tr}_A \left[\langle a| \left(\mathrm{Tr}_B[\rho_{AB}] \right) |a\rangle \right], \tag{1}$$

which is independent of Y, as the partial trace over B removes dependence on Bob's measurement. Similarly for Bob.

In transactional terms, the retro-beam from Bob's absorber contributes to the confirmation, but since absorbers respond statistically (via Born rule), the echoed waves average to the reduced density matrix for A, with no net information transfer. Attempted signaling by choosing Y to encode bits fails because Alice's statistics remain unchanged, as proven in TI where advanced waves cancel extraneous signals.¡grok-card data-id="fa2c2a" data-type="citation$_c$ard" >< /grok − card >< grok − carddata − id = "2b37e8"data − type = "citation$_c$ard" >< /grok − card >

This holds for any spacelike-separated measurements, ensuring no violation.

3 Numerical Examples

3.1 Example 1: EPR Singlet State

Consider two spins in the singlet state: $|\psi\rangle = \frac{1}{\sqrt{2}}(|\uparrow\downarrow\rangle - |\downarrow\uparrow\rangle)$.

Alice measures in z-basis ($X = z$), Bob chooses either z ($Y = z$) or x ($Y = x$).

Joint probabilities for $Y = z$: $P(\uparrow, \downarrow |z, z) = 1/2$, $P(\downarrow, \uparrow |z, z) = 1/2$, others 0.

Marginal for Alice: $P(\uparrow |z) = 1/2 + 0 = 0.5$.

For $Y = x$: $P(\uparrow, \pm|z, x) = 1/4$ each for + and -.

Marginal: $P(\uparrow |z) = 1/4 + 1/4 = 0.5$.

Numerically, Alice's probability remains 0.5 independent of Bob's choice, no signaling.

3.2 Example 2: Bell State with Angles

For CHSH setup, state $|\psi\rangle = \frac{1}{\sqrt{2}}(|00\rangle + |11\rangle)$, Alice measures at 0° or 22.5°, Bob at 67.5° or 112.5°.

Correlation $E(\theta_A, \theta_B) = \cos(2(\theta_A - \theta_B))$.

But marginals: For any basis, P(0 for Alice) = 0.5, since reduced $\rho_A = I/2$.

Numerical: Suppose Alice at 0°, P(+—0°) = Tr[(—+⟩⟨+| $\otimes I)\rho$] = 0.5.

Independent of Bob's angle, e.g., for Bob at 67.5°, joint P(+,+)= (1 + cos(135°))/4 (1 - 0.707)/4 0.073, P(+,-)= (1 - cos(135°))/4 0.427, sum 0.5.

No change.

3.3 Example 3: Delayed-Choice Entanglement Swapping

In entanglement swapping, two pairs: photons 1-2 and 3-4 entangled. Bell measurement on 2-3 swaps to entangle 1-4.

Future choice on 2-3 can't signal to past measurements on 1 and 4.

Probabilities: Marginal for photon 1 is always 1/2 for polarization, regardless of whether swapping occurs.

Numerical: Without swapping, P(H for 1) = 0.5.

With swapping, joint with 4 is correlated, but marginal P(H for 1) = P(H—choice) P(choice) = 0.5, averaged over statistical outcomes.

Explicit: In density matrix, $\rho_1 = \mathrm{Tr}_{234}[\rho] = I/2$, unchanged.

Thus, no signaling.

4 References

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