**Quantum Teleportation Experiment Report**

**Introduction**

This report summarizes the findings from a series of quantum teleportation experiments. The study focuses on assessing the fidelity of teleportation under various conditions, employing both Randomized Benchmarking and Quantum Controlled Error Correction methodologies. The objective is to evaluate the performance of these techniques in maintaining the integrity of quantum information during transfer.

**Experimental Overview**

The experiments were conducted across three distinct cases:

* **Case 1: Simple Teleportation**
* **Case 2: Application of an Rx gate with *θ*=5*π/7*​**
* **Case 3: Application of an Rx gate with *θ*=2*π/7*​**

Each case was tested under the influence of noise, to measure error rates and fidelity—a metric that reflects the accuracy of the quantum state post-teleportation.

**Methodologies**

Two advanced quantum information processing protocols were utilized:

**Randomized Benchmarking**

Randomized Benchmarking (RB) provides an average error rate of a full set of quantum gates, discounting errors from state preparation and measurement. This method applies random sequences of quantum gate operations to obtain a clearer signal of the intrinsic errors in the gates.

**Quantum Controlled Error Correction (QCEC)**

QCEC is a sophisticated protocol combining features of quantum teleportation, error correction, and control, designed to achieve high-precision, reliable quantum information transmission, even when errors are present.

**Results**

CASE 1: SIMPLE TELEPORTATIONA diagram of a diagram

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Results for Randomized Benchmarking

A graph of different sizes and colors

Description automatically generated

Error rate for direct measurement with noise: 0.49999999999999994

Error rate for randomized measurement with noise: 0.22321999999999997

Fidelity for direct measurement with noise: 0.5

Fidelity for randomized measurement with noise: 0.77678

Results for Quantum Controlled Error Correction

A diagram of a diagram

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A graph with numbers and lines

Description automatically generated

Error rate with noise: 0.0341796875

The fidelity is 0.9658203125

Case 2: theta= 5\*pi/7

A diagram of a circuit

Description automatically generated

A graph with numbers and a bar chart

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Error rate for direct measurement with noise: 0.5

Error rate for randomized measurement with noise: 0.18455999999999997

Fidelity for direct measurement with noise: 0.5

Fidelity for randomized measurement with noise: 0.81544

Results for Quantum Controlled Error Correction

A screenshot of a computer

Description automatically generated

A graph with numbers and lines

Description automatically generated

Error rate with noise: 0.041015625

The fidelity is 0.958984375

Case 3: theta= 2\*pi/7

Results for Randomized Benchmarking

A diagram of a circuit

Description automatically generated

A graph with numbers and a bar chart

Description automatically generated

Error rate for direct measurement with noise: 0.5

Error rate for randomized measurement with noise: 0.18912999999999996

Fidelity for direct measurement with noise: 0.5

Fidelity for randomized measurement with noise: 0.81087

Results for Quantum Controlled Error Correction

A screenshot of a computer

Description automatically generated

A graph with numbers and lines

Description automatically generated

Error rate with noise: 0.04052734375

The fidelity is 0.9594726562.

**Discussion**

The findings suggest that both Randomized Benchmarking and Quantum Controlled Error Correction are effective in reducing error rates in quantum teleportation. QCEC, in particular, exhibited significantly high fidelities, demonstrating its robustness against noise. The application of Rx gates introduced biases in the system, yet the fidelities remained high, especially with QCEC, indicating its potential for precise quantum information processing.

**Conclusion**

The experiments confirm the efficacy of Randomized Benchmarking and Quantum Controlled Error Correction in maintaining the fidelity of quantum states during teleportation. These protocols are invaluable for the development and validation of quantum computing systems, ensuring reliable transfer of quantum information even in noisy environments. Three cases were taken into consideration. The first one was a simple teleportation in which the probability of the teleported state to be either 0 or 1 was equally likely. The fidelity using the random benchmarking was :

Fidelity for direct measurement with noise: 0.5

Fidelity for randomized measurement with noise: 0.77678

Then Quantum Controlled error correction was implemented in which the following results were obtained:

The fidelity is 0.9658203125

In the second case, we applied an Rx gate with theta= 5\*pi/7, which essentially biased the system to state 1 instead of zero. The fidelity using the random benchmarking gave the following results

Fidelity for direct measurement with noise: 0.5

Fidelity for randomized measurement with noise: 0.81544

Also, the results(fidelity) using the Quantum controlled Error correction gave the following results:

The fidelity is 0.958984375

In third case we applied an Rx gate with theta= 2\*pi/7 which essentially biased the system to state 0 instead of state 1. The fidelity using the random benchmarking gave the following results.

Fidelity for direct measurement with noise: 0.5

Fidelity for randomized measurement with noise: 0.81087

Also, the results(fidelity) using the Quantum Controlled Error Correction gave the following results.

The fidelity is 0.9594726562.

**References**

<https://arxiv.org/abs/1512.00139>

<https://www.youtube.com/watch?v=QLMVfImNc0o>