Experiment 5

Aim

Implementation of Quantum Teleportation circuit in IBM Quantum Composer.

Theory

Quantum teleportation is a fundamental concept in quantum information science that enables the transfer of quantum information from one qubit to another over a distance without actually transmitting the qubit itself. It relies on the phenomenon of quantum entanglement, whereby two or more qubits can become correlated in such a way that the state of one qubit can affect the state of another, even when they are separated by large distances.

The process of quantum teleportation involves three qubits: the input qubit, the sender's qubit, and the receiver's qubit. The goal is to transfer the state of the input qubit to the receiver's qubit without actually transmitting the qubit itself. The sender and receiver share an entangled pair of qubits, which is used to transmit the information about the input qubit from the sender to the receiver.

The quantum teleportation circuit can be implemented using the following steps:

Prepare an entangled pair of qubits in the Bell state:

$$|\Psi^+\rangle = \frac{1}{\sqrt{2}}(|0\rangle \otimes |1\rangle + |1\rangle \otimes |0\rangle) \tag{1}$$

The input qubit to be teleported is prepared in an arbitrary state:

$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle \tag{2}$$

The input qubit is entangled with the sender's qubit by applying a CNOT gate with the input qubit as the control and the sender's qubit as the target:

$$|\Psi\rangle = \frac{1}{\sqrt{2}}(\alpha|00\rangle + \alpha|01\rangle + \beta|10\rangle + \beta|11\rangle) \tag{3}$$

A Hadamard gate is applied to the input qubit:

$$|\Psi\rangle = \frac{1}{2}(\alpha|00\rangle + \alpha|01\rangle + \alpha|10\rangle + \alpha|11\rangle + \beta|00\rangle + \beta|01\rangle - \beta|10\rangle - \beta|11\rangle) \tag{4}$$

The input qubit and the sender's qubit are measured in the computational basis, and the results are sent to the receiver over a classical channel. The sender's qubit collapses to either $|0\rangle$ or $|1\rangle$, depending on the measurement outcome.
Based on the measurement results, the receiver applies a Pauli-X gate, a Pauli-Z gate, or both to the receiver's qubit:

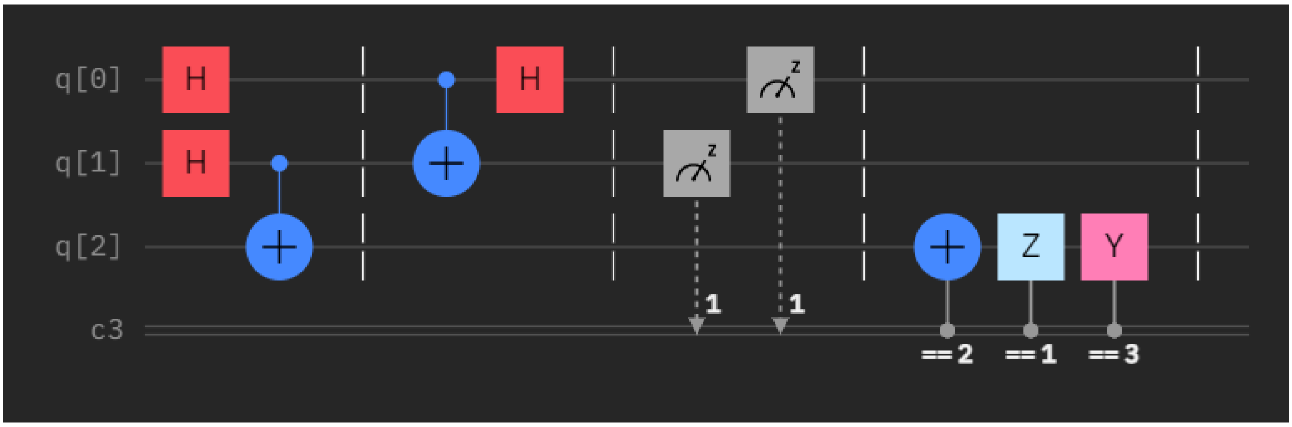
- If the measurement result for the sender's qubit is $|0\rangle$ and the input qubit is $|0\rangle$, no gates are applied to the receiver's qubit.
- If the measurement result for the sender's qubit is $|1\rangle$ and the input qubit is $|0\rangle$, a Pauli-X gate is applied to the receiver's qubit.
- If the measurement result for the sender's qubit is $|0\rangle$ and the input qubit is $|1\rangle$, a Pauli-Z gate is applied to the receiver's qubit.
- If the measurement result for the sender's qubit is $|1\rangle$ and the input qubit is $|1\rangle$, both a Pauli-X gate and a Pauli-Z gate are applied to the receiver's qubit.

The receiver's qubit now has the same state as the original input qubit:

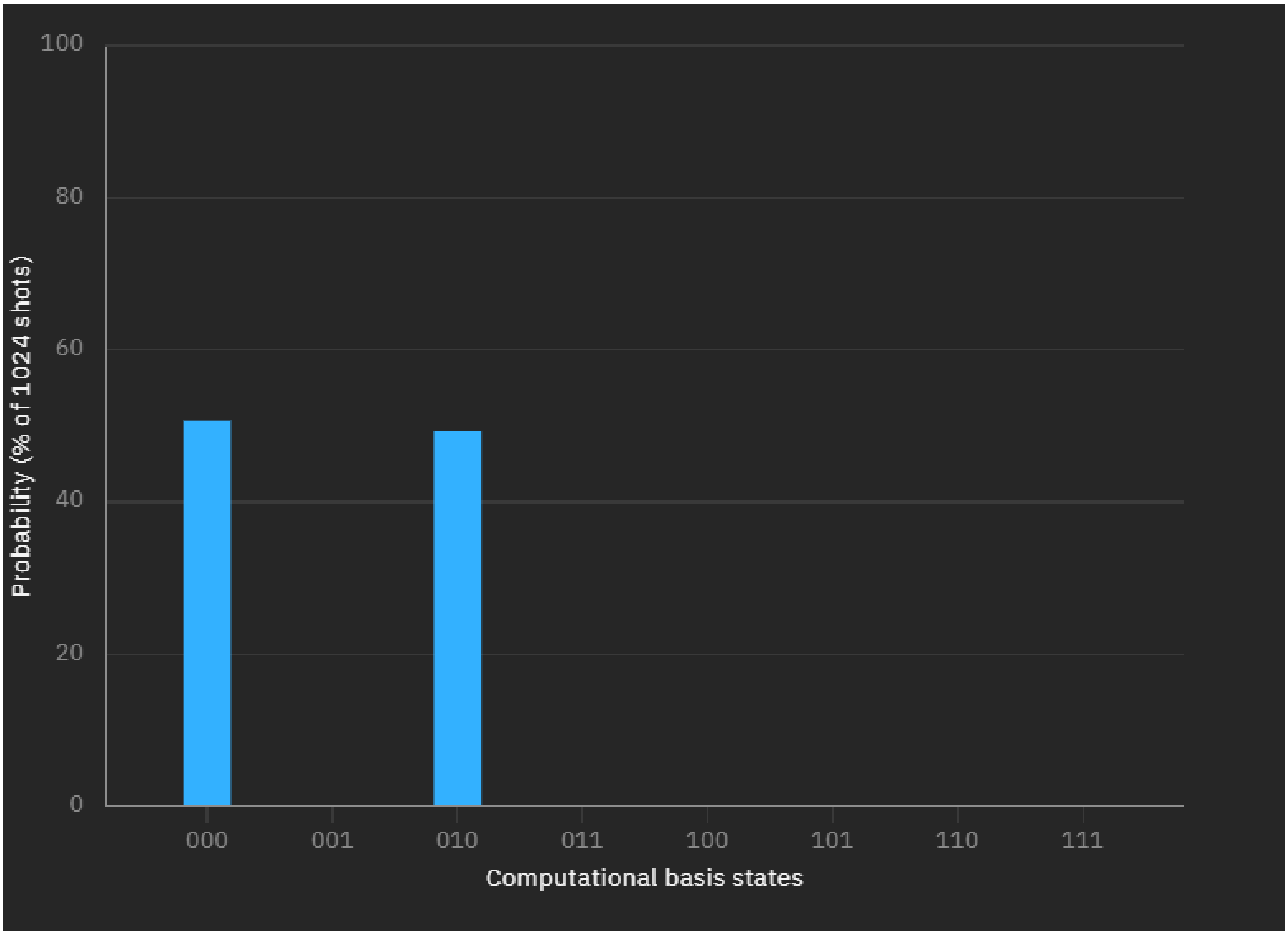
$$|\psi\rangle = \alpha|0\rangle + \beta|1\rangle \tag{5}$$

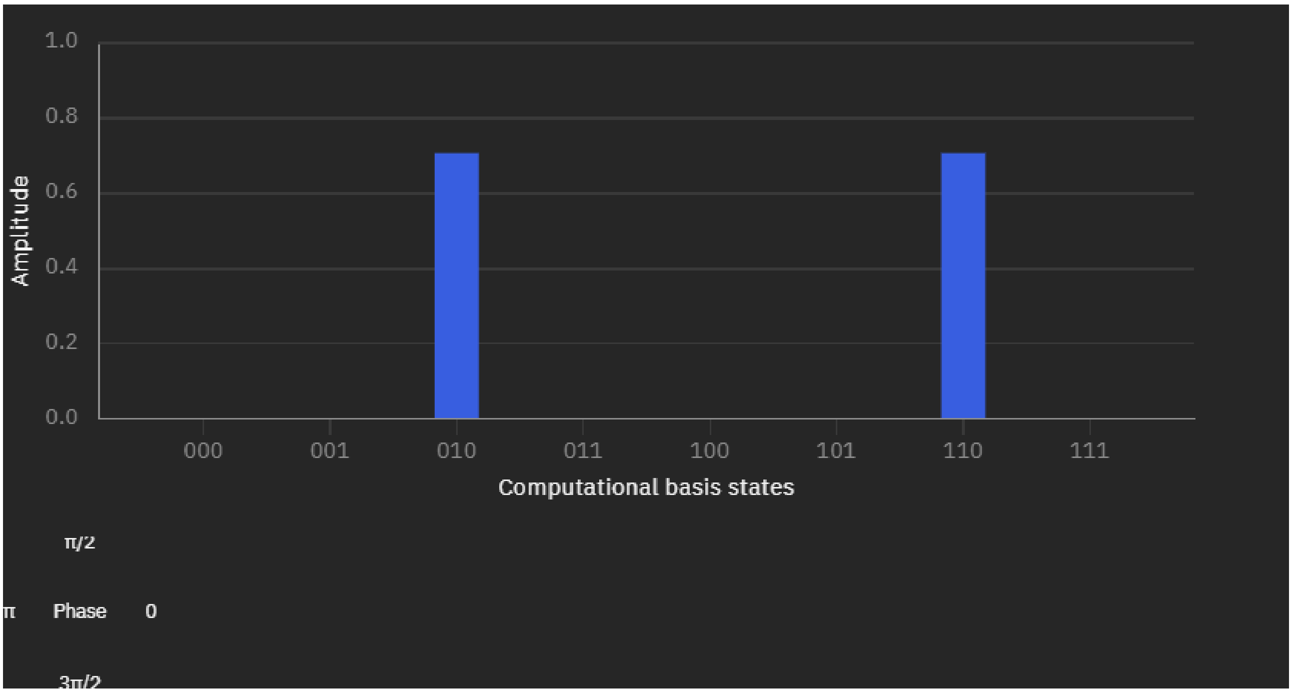
Lab Exercise

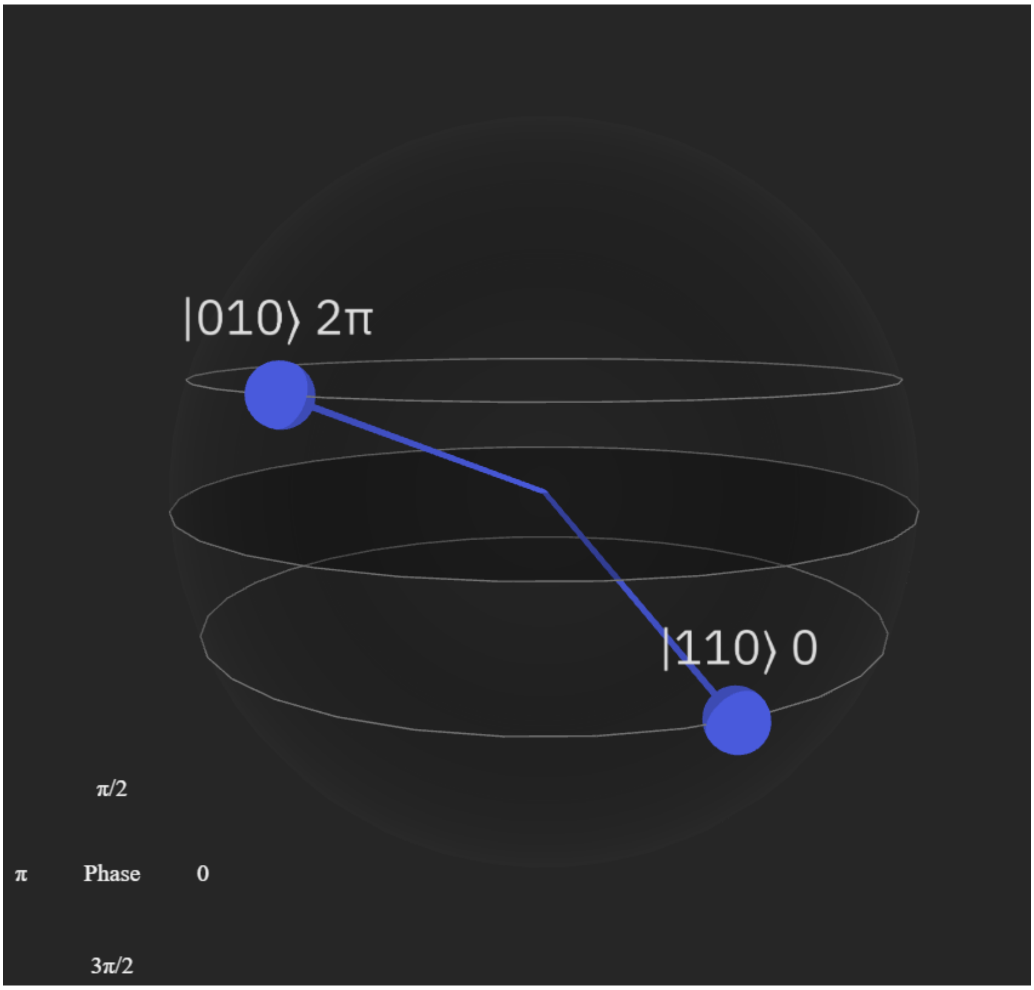
IBM Composer Circuit:



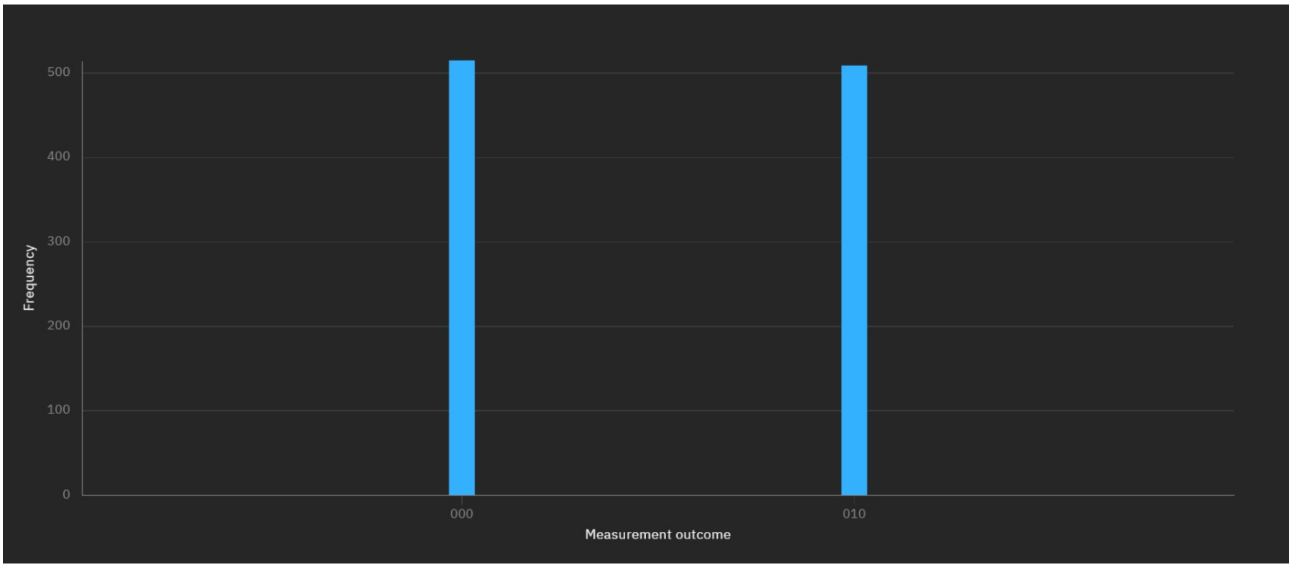
Results:




1.0
0.8
0.6
0.4
0.2
0.0
Amplitude
000
001
010
011
100
101
110
111
Computational basis states
π/2
π
Phase
0
3π/2


|010⟩ 2π
|110⟩ 0
π/2
π
Phase
0
3π/2

Job Results:



Conclusion

In conclusion, quantum teleportation is a fascinating idea in quantum information science that enables the transmission of quantum information over a distance between two qubits without actually sending the qubit itself. There are numerous uses for this intricate procedure in quantum computing, quantum communication, and quantum cryptography. It is based on the entanglement and measurement concepts.

A crucial step towards the realisation of quantum communication networks is the creation of the quantum teleportation circuit employing qubits. Quantum teleportation will be more crucial as quantum computer technology develops since it allows for the distant manipulation of quantum states. The secure transmission of quantum information across great distances is made possible by quantum teleportation, which adds an extra degree of security to quantum communication protocols.

Overall, the development of quantum teleportation is a significant advancement in the field of quantum information science, and it has the potential to revolutionize the way we communicate and process information in the future.