Quantum Control Techniques for High Fidelity Pulses

Assumptions made:
- Qubit is in a noisy environment with the maximum amount of noise
- Unknown rabi rate
- A detuning error that we are accounting for
- Amplitude error in the I and Q channels in the complex rabi rate
- Sudden signal changes won't work really well (applying bandwidth limits into control lines)
- SPAM errors

Summary of Approach used: Optimal Control

Why?:
- Most environmental conditions stating the qubit is given in the simulation
- Each optimization technique removes a certain amount of noise while affecting the qubit in a different way

The approach I used bordered around optimal control due to the understanding that I had good information about the model of the system that I was trying to improve. For example, the simulation for the realistic qubits consisted of knowledge of limitations for drive amplitudes, dephasing and amplitude error, control line bandwidth limit, and a SPAM error confusion matrix which outlined all possible information about the noise.
However, with a real device, we have no information about the system's hamiltonian and other parameters for the system I have taken into the account using the rabi rate detuning error to be negligible over time.

<u>How I used BOULDER OPAL:</u>
- Used system identification feature to identify the known terms of the hamiltonian to derive the optimized control.

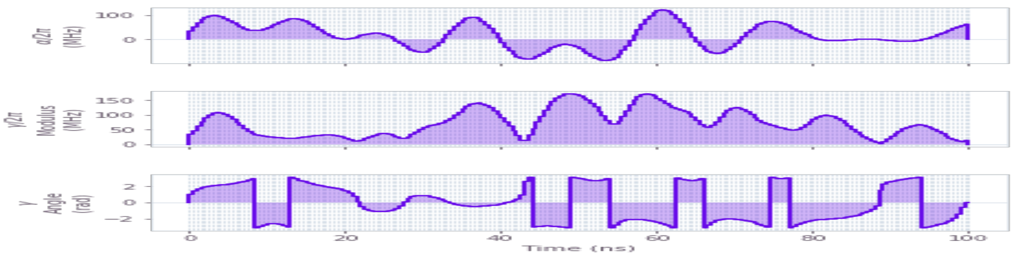
<u>The Quantum Control techniques I used were:</u>
- Band-Limited Pulses with Filters
- Crab optimization

Step 1: Defined the matrices and physical constraints
Step 2: Set initial segment count to 40 and the duration to 200 nanoseconds per pulse
Segment count to 200 and the duration 100 nanoseconds per pulse
Step 3: Used repetition of values

To reduce quantum noise the possible quantum control techniques to use for a NOT and Hadmard gates on the Qubit in the cloud are:

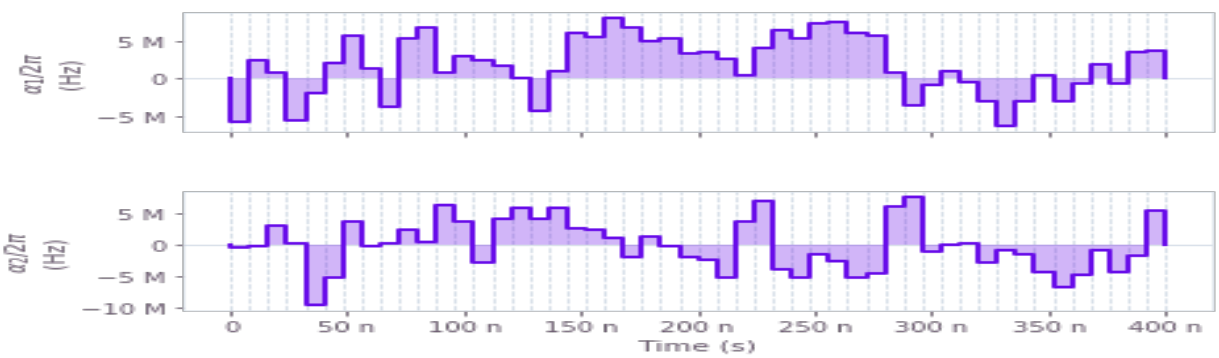
Overall Crab optimization was to adjust the parameters to reduce noise for high fidelity pulses for the Hadmard gates:

- Crab optimization helps refine the pulses in a way that can be optimizable using linear combinations from a set of basis functions by reducing the dimensionality of the search space.
- Used crab optimization to adjust the pulse for exact parameter values to be adjusted based on the output received by the state of the qubit.



Overall Band-Limited Pulses with filers was to adjust the parameters for the NOT gates due to the ideal value being 0 or 1 in the sparse matrix

- Filtering can enable to put band limits on pulses which ensure that optimized controls can be reliably implemented on physical hardware.
- This technique can be applied for a single qubit that touches upon the signal to exhibit an upper bound in the frequency domain and is subject to reduce dephasing noise.



Conclusion:
Crab optimization technique can be scaled for a multi-qubit system due to its nature of linear combination optimization and its ability to reduce the dimensionality of a given search space. This approach was considered due to its nature of optimization for the given knowledge on the qubit.