Hybrid Neural Networks + Quantum Field Theory-inspired Signal Processing System

# 1. Introduction

This document outlines the design and implementation of a Hybrid Neural Networks and Quantum Field Theory (QFT) inspired signal processing system. The goal is to create an intelligent, adaptive platform capable of interpreting signals in both laboratory and field environments, leveraging classical neural networks (CNN, RNN, Transformer), quantum neural networks (QNN), and signal physics models from QFT.

# 2. System Overview

The system integrates components for signal acquisition, frequency/time domain analysis, and dynamic model selection based on signal properties. It supports environmental adaptability, operating in controlled (lab) and dynamic (field) conditions.

# 3. Architecture and Components

The system consists of the following modules:  
- Environment Detection Module  
- Signal Interpretation (FFT, amplitude, frequency, SNR)  
- Hybrid Neural Network Engine (Classical + Quantum)  
- Quantum Field Theory Module Library  
- Interaction Modeling using Feynman Diagrams  
- Security and Adaptive Communication Layers

# 4. Signal Processing Demo

A sample demo was implemented simulating a noisy composite signal composed of 50 Hz and 120 Hz sine waves. The FFT analysis was performed to extract peak frequency and energy metrics, which were then used as input features for a dummy classical neural network classifier. The classifier predicted whether to use classical NN (lab mode) or quantum NN (field mode).

# 5. Features and Benefits

- Adaptive to both lab and field environments  
- Uses FFT and spectrum analysis for real-time signal profiling  
- Dynamically selects neural network type based on environment and signal  
- Supports theoretical QFT modeling including Feynman diagram logic  
- Embeds security through firewall-like NN classifiers and QKD protocols

# 6. Future Enhancements

The next steps will include:  
- Integration with real QNN platforms like PennyLane or Qiskit  
- Deployment as a microservice or simulation toolkit  
- Expansion of the QFT module library with additional field theories  
- Visualization interfaces for interaction diagrams and spectrum analysis

# 7. Sample Code Summary

The provided code demonstrates an end-to-end pipeline:  
- Signal Simulation → FFT Analysis → Feature Extraction → NN Inference → Visualization  
The mode selected (Lab or Field) informs which type of neural processing pipeline to activate.