PROTOTYPING OF A WIRELESS COMMUNICATION SYSTEM WITH CHANNEL ESTIMATION BASED ON QUANTUM SUPPORT VECTOR MACHINES

Caio Neves e João Dias

***Abstract*—This work presents the development of a wireless communication prototype using GNU Radio and HackRF for OFDM transmission. We investigate channel estimation based on Support Vector Regression (SVR), extended with quantum kernels. The proposal aims to integrate classical OFDM prototyping with quantum-enhanced machine learning estimators. Partial results indicate feasibility of the SDR implementation and ongoing integration of the estimator. The study highlights the potential of quantum-assisted learning in real-world communication systems.**

***Keywords*—SDR, OFDM, channel estimation, support vector regression, quantum machine learning.**

I. INTRODUÇÃO

Future wireless systems demand high reliability and efficient use of the spectrum [1]. Orthogonal Frequency Division Multiplexing (OFDM) is widely adopted for its robustness against multipath fading [2]. However, its performance strongly depends on accurate channel estimation [3]. While classical estimation techniques are well studied, to our knowledge, no work has explored the application of quantum machine learning in real prototypes of wireless communications systems. This paper proposes the integration of Quantum Support Vector Regression (QSVR) [4], [5] into a GNU Radio-based Software-Defined Radio platform [6] for OFDM channel estimation.

II. SYSTEM MODEL

The OFDM transmission chain was developed in GNU Radio Companion and implemented using HackRF One as SDR hardware. Unlike simulated approaches, the propagation channel is given by the real over-the-air environment, which naturally includes multipath fading, noise, and hardware impairments.

In the default GNU Radio OFDM example, channel estimation is carried out by the `OFDM Channel Estimation` block [6]. This block uses the sync words to compute coarse carrier offset and a set of pilot tones across OFDM subcarriers for the purpose of channel estimation. The estimated channel are then passed as tags to the equalizer block, which compensates for channel distortions and recovers the transmitted data.

Caio Neves, Engenharia de Computação, CEFET, Petrópolis-RJ, e-mail: caio.silva.1@aluno.cefet-rj.br; João Dias, Coordenação de Telecomunicações, CEFET-RJ, Rio de Janeiro-RJ, e-mail: joao.dias@cefet-rj.br Este trabalho foi parcialmente financiado por Cefet/RJ, Faperj and CNPq.

Our proposal consists in replacing this classical estimator based on Least Squares with a machine learning-based approach. In particular, we integrate a Support Vector Regression (SVR) estimator with quantum kernels, aiming to improve channel estimation accuracy in real transmission scenarios. The GNU Radio Companion OFDM receiver chain can be seen in Fig. 1

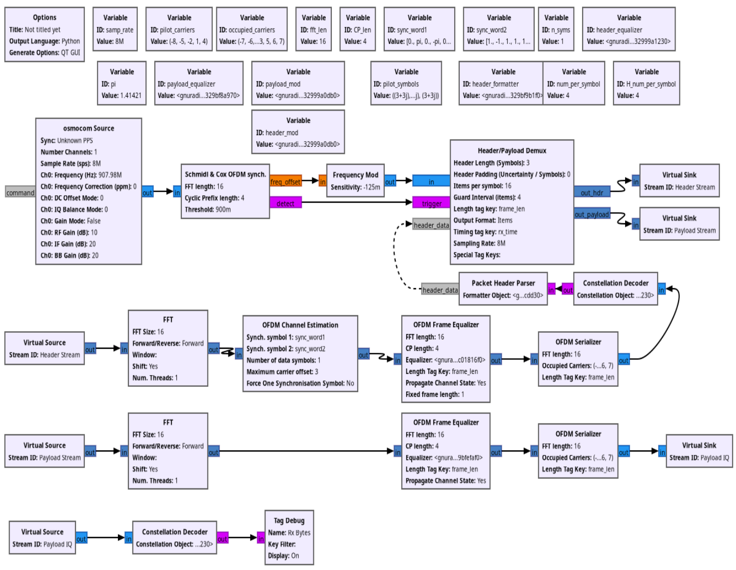

Fig. 1. GNU Radio Companion OFDM receiver chain.

A. QSVR for Channel Estimation

In previous work, we evaluated Support Vector Regression (SVR) with quantum kernels (QSVR) for OFDM channel estimation through simulations, showing improvements over classical estimators in terms of BER and MSE, as can be seen in Figs. 2 and 3. The key idea is to exploit quantum feature maps to embed pilot-based channel observations into high-dimensional Hilbert spaces, enabling the regression model to capture complex non-linear dependencies.

The QSVR estimator replaces the classical `OFDM Channel Estimation` block in GNU Radio. Instead of directly dividing the received sync words by the known reference, our method trains a regression model using pilot tones as input features. A quantum kernel, implemented via

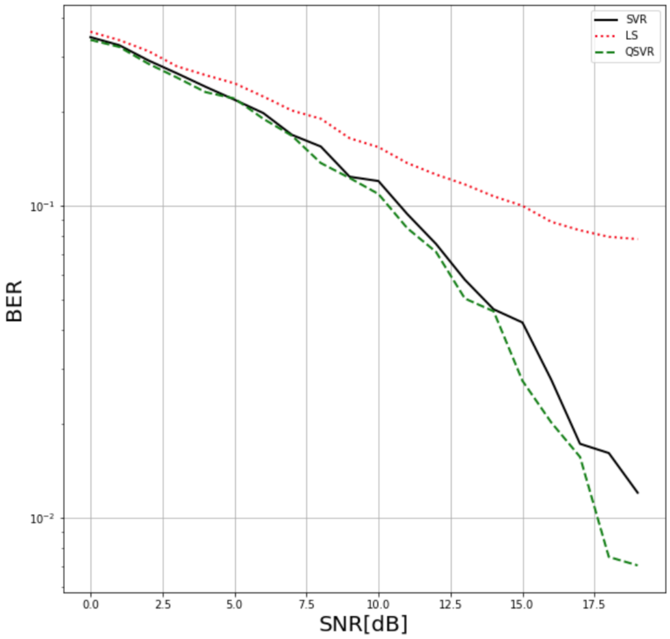

Fig. 2. BER performance comparison between Least Squares, SVR and Quantum SVR Methods.

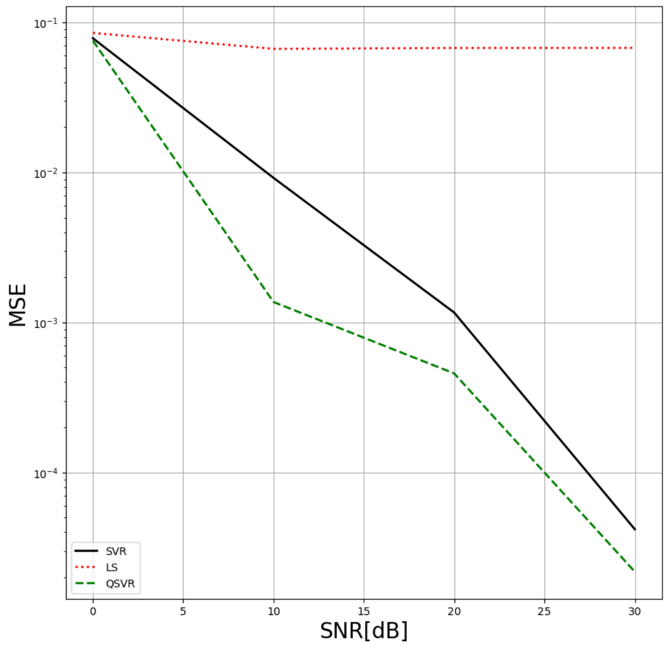

Fig. 3. MSE performance comparison between Least Squares, SVR and Quantum SVR Methods.

Qiskit's `PauliFeatureMap` [5], [7], provides the similarity measure between pilot observations, enhancing the learning capacity of the SVR.

While extensive configurations (encoding functions, Pauli sequences, entanglement strategies, repetitions) were tested in simulation, the best performance was achieved with a ZZFeatureMap, linear entanglement, and a single repetition. The present work extends these results into a real SDR testbed with HackRF One, validating whether the quantum advantage observed in simulations can be sustained in practical transmission scenarios.

III. Partial Results and Ongoing Work

The SDR prototype for OFDM transmission and reception with HackRF One is fully operational, including the standard GNU Radio channel estimation chain. Classical SVR-based estimators were already validated in simulation, showing lower mean squared error compared to linear interpolation methods. The current stage focuses on replacing the `OFDM Channel Estimation` block with the proposed QSVR estimator, enabling experimental tests under real wireless channel conditions. Ongoing work includes integrating the quantum kernel functions into GNU Radio and assessing computational feasibility in practice.

IV. Conclusions

This work presents a prototype for OFDM transmission integrating quantum-enhanced channel estimation based on Support Vector Regression. By extending previous simulation studies to a real SDR testbed, we aim to validate the effectiveness of quantum kernels in practical wireless scenarios. Preliminary results demonstrate feasibility of the implementation, and future work will evaluate bit error rate, mean squared error, and computational cost, determining whether quantum machine learning provides tangible benefits for next-generation communication systems.

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