TUP062

Development of iterative learning and disturbance observer-based low-level radio-frequency control system for international linear collider

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Abstract

This paper shows the development of a iterative learning control (ILC) combined with a disturbance observer (DOB)-based control for the digital low-level radio-frequency (LLRF) system of international linear collider (ILC) project. The motivation of this study is to compensate for the repetitive (or predictable) and unpredictable disturbances in the radio-frequency (RF) system such as beam loading, Lorentz force detuning (LFD) and microphonics. Results in a cavity simulator-based test bench demonstrate the possibility of the presented control approach. We have a plan to further generalize this approach to LLRF systems at superconducting test facility (STF) and future ILC project.

Introduction

- ILC project: 1.3 GHz Superconducting (SC) cavity, pulse mode operation, 400 RF stations, 10 MW multi-beam klystron (MBK).
- **LLRF** system: Stabilize the RF field in the RF cavity with PI (or P) feedback control in the presence of disturbances.
- Disturbances source: Repetitive error (beam-loading, Lorentz force detuning), and unpredictable error (microphonics).

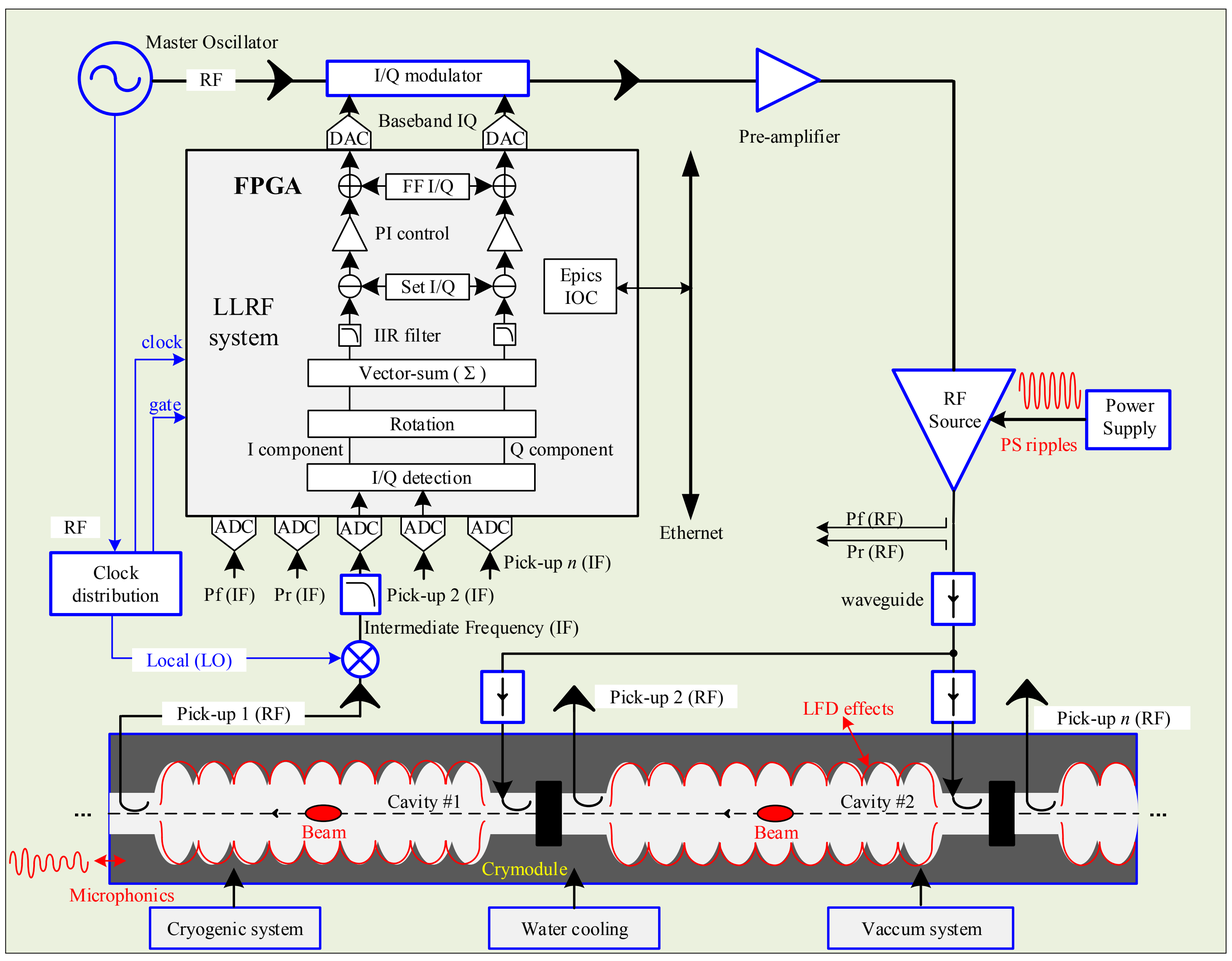

Figure 1: Schematic of the LLRF system and the typical disturbance sources.

ILC algorithm

- Iterative learning control (ILC): Using the error information of last pulse to improve control signal of the current pulse.

$$u_{j+1}(k) = Q_{ILC}\left[u_j(k) + L\left(e_j(k)\right)\right]$$

- The subscript " j " is iteration index, " k " is the time index.
- u_j : Control signal, e_j : Error signal.
- Q_{ILC}: Q-filter, L: Learning function.
- **Valid for the repetitive** disturbances in a pulse mode machine, **incapable** of unpredictable disturbances.

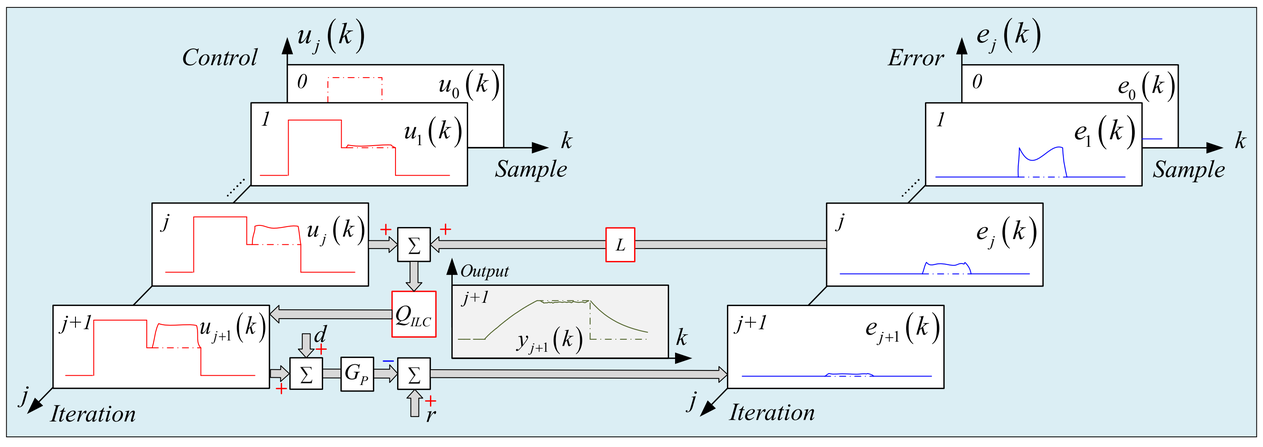

Figure 2: Learning process of ILC algorithm

DOB control

- Disturbance observer-based (DOB) control: estimate the disturbances at first and remove it.
- Model-based method (inverse model G_n^{-1} is needed).
- Q_{DOB} is the Q-filter to make the $Q_{DOB}G_n^{-1}$ realizable.
- Effective in both **repetitive and unpredictable** errors.

$$\hat{d} = Q_{DOB}\left[\left(\varepsilon + d\right)G_p G_n^{-1} - \varepsilon\right]$$

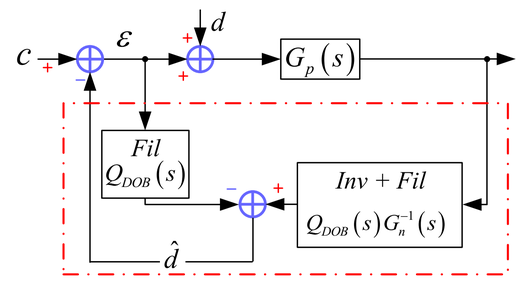

Figure 3: DOB control with Q-filter.

Combined controller (P+DOB+ILC)

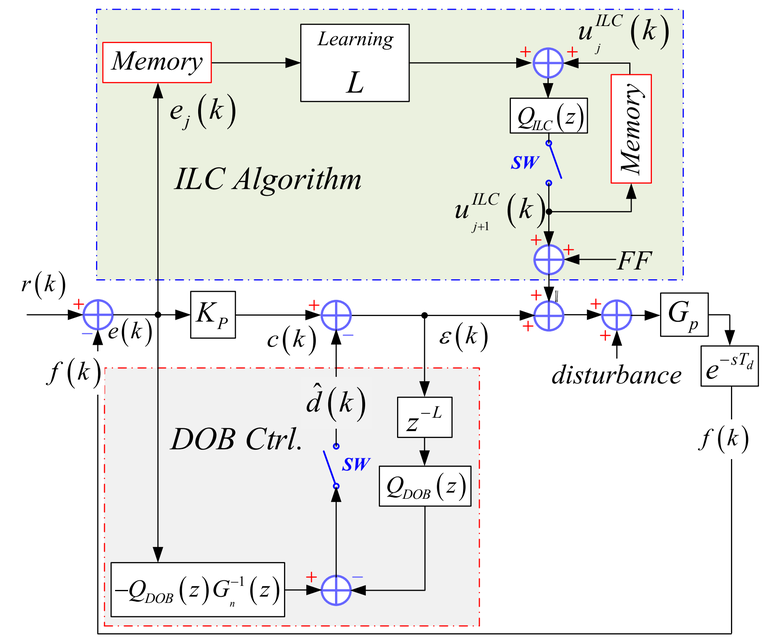

Figure 4: Combined control algorithm including P control, ILC algorithm and DOB control.

Experiments on cavity simulator

- Simulators of beam-loading, Lorentz force detuning and microphonics, pulse mode operation.
- "**P+DOB+ILC**" is valid for all of these disturbances.

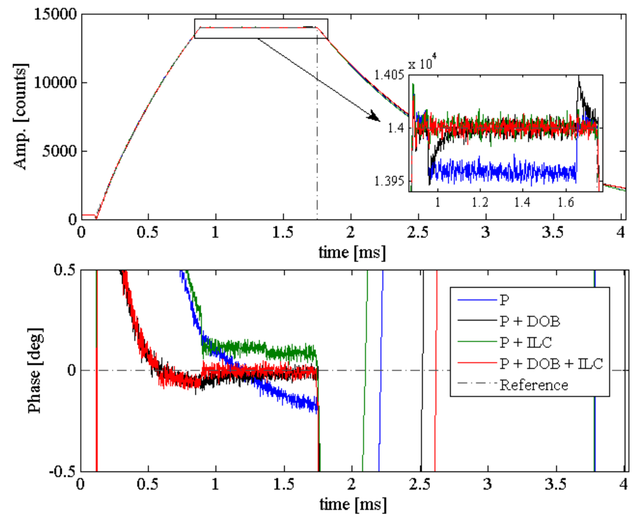

Figure 5: Comparison of P control (blue), "P+DOB" control (black), "P+ILC" control (green) and "**P+DOB+ILC**" control.