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One-turn delay filters in LLRF feedback controllers applied to circular accelerators: Impact on the RF station and beam dynamics and optimal configuration

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High beam currents in circular accelerators lead to stability and performance limits associated with static and dynamic beam loading. Sophisticated techniques in the feedback control system of the RF stations are necessary to mitigate these effects. One-turn delay filters have been commonly included in the low-level RF feedback loops, to reduce the impedance presented to the beam by the closed loop RF station.

This paper analyzes different configurations for the one-turn delay filters and evaluates the impact in both the impedance reduction and the beam dynamic characteristics of the parameters of the comb filter and LLRF feedback system. With the introduction of narrow band comb filters, small changes in LLRF parameters can have significant effects on the stability and performance of both the RF station and beam dynamics.

This work summarizes previous designs, including comb filters in the PEP-II LLRF system, and addresses the optimal settings of LLRF parameters and configuration tools for the CERN LHC LLRF system including one-turn delay filers. In particular, for the LHC RF stations, it justifies the resolution in the measurement techniques to identify the parameters of the LLRF stations and presents algorithms developed to maximize the phase margin, taking into consideration the phase behavior of the closed loop system. Results from simulations and measurements are presented to validate the procedure followed. Predictions for operation and performance limitations on the RF station and beam dynamics at high beam current operation will be analyzed.

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