Feasibility of RF feedback control loops in heavy-ion synchrotrons by means of derivative estimation *

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Damping of longitudinal coherent bunched-beam oscillations is needed in SIS18 and SIS100 to stabilize the beam, prevent emittance growth and keep beam loss low during acceleration. In last year's work several approaches of digital filters for beam-phase control have been examined. An FIR (finite impulse response) filter with 3 taps, cf. [1], has been successfully used at GSI in several machine experiments for a beam-phase control system and a longitudinal feedback system. In this report an alternative FIR filter approach based on derivative estimation leads to better results as it damps dipole oscillations *within* one oscillation period whereas the former filter approach unveils its full potential only *after* one oscillation period.

Requirements and filter properties

A numerical differentiator approach [2] has been chosen as an alternative to the established 3-tap filter. Both filters share the same control topology, but have different coefficients. The results obtained so far indicate that the optimal filter gain is approximately a constant divided by the synchrotron frequency. Therefore the derivative estimation filter has to be adapted to varying synchrotron frequency.
A filter bank will be used to select different filters based on available parameters such as the synchrotron frequency and bunch length. Alternatively, a continuous tuning of the coefficients will be possible [3].

Experiment, simulations

Both the experiment and the nonlinear tracking simulations were performed for $^{238}U^{73+}$ as ion species at an energy of 300 MeV/u for a stationary operation with a linear synchrotron frequency of 422 Hz at h=2. The beam-phase measurement varies with white Gaussian noise with about $3\sigma = \pm 0.66^\circ$. In this case the derivative estimator has a length of L = 10 non-zero taps without additional zero-taps and is tuned to a high damping rate.
Figure 1 shows the experimental and the simulated results where a disturbance of 2° on the beam phase is applied to intentionally excite a feedback reaction. The results indicate that the experiment is in very good agreement with the nonlinear tracking simulation for the derivative estimation approach. Compared to the 3-tap filter approach, there is no overshoot and the dipole oscillation is damped within one oscillation period for the derivative estimation approach. Also the RMS-emittance does not increase while using the derivative estimation approach, which is a second quality criterion besides the damping rate. Furthermore, this approach can be put into practice easily with the existing control topology.

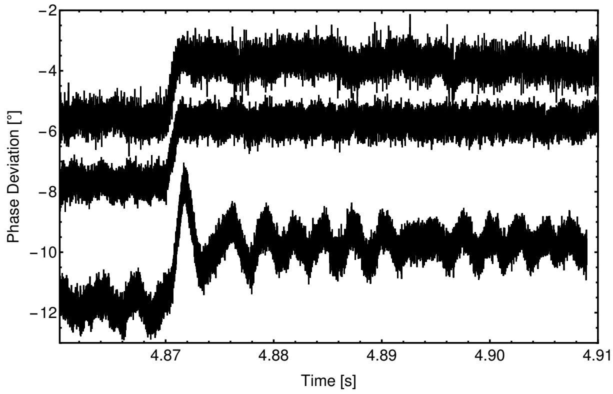

Figure 1: Beam-phase with respect to uncorrected Group-DDS: Experimental data (top), simulated data with arbitrary offset for a controller with derivative estimator (middle) and 3-tap filter (bottom) with a 2° distortion at 4.87s.

Outlook

Under current investigation is the critical signal to noise ratio (SNR), at which the derivative estimator approach delivers better results than the 3-tap filter. Another important investigation regards the implementation of the new approach for operation during acceleration ramps.

References

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DOI:10.15120/GR-2017-1