MD4063 New ADT signal processing for large tune spread acceptance

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LHC ADT

• Beam position measured bunch by bunch, turn by turn
• The oscillatory part is extracted and the correction kick is calculated by means of digital filters
  • Removal of the closed orbit
  • Phase advance between pickups
  • Phase advance to the kicker
  • Multiple pickups (2 (4) per beam per plane)
• Current implementation
  • Notch filter + Hilbert phase shifter (8 taps total, 4.5 turns group delay)
• New proposal – a specially designed 3 tap FIR filter based on analytical solution
• MD goal: demonstrate that the new 3-tap FIR filter approach can replace the old filter approach (Notch + Hilbert) in operational use after the LS2
Motivation

- New filters are shorter (new 3-tap vs old 8-tap)
  - More stable for short damping times
- Phase responses of the new filters are flatter
  - Constant performance for larger tune spread at flat top
- Scheme works also for close to half integer tunes
- Allows a single pickup operation with short group delay
MD preparations

• To be confirmed with operations
  a) What is the maximum coherent tune range which we can scan?
     • This helps to prepare a detailed measurement plan.
     • Delta of ±0.02-0.03 from design tune will already show differences between the filters
  b) Estimation how long time it takes to do a single tune-gain measurement scan with active ADT excitation

• Preparations
  • Calculate the filter coefficients for different scenarios, taking into account the injection optics - DONE
  • ADT signal processing unit firmware change. The Notch and Hilbert phase shifter filter will be replaced by a new 3 tap filter – will be ready by MD3
Required beam

• A “standard” ADT setting up sequence

• One beam only, injection energy

• Few pilots to verify the feedback loop functioning

• Move to few indivs, or a short train

• Kick, kick, kick, kick, change tune, kick, kick, kick, kick, kick...

• Time estimate ~6 hours
Following steps

• If the filter approach works it encourages further development/studies for new ADT functionalities:
  • ADT operation close to the half integer tunes
  • Long filters to damp low frequency motion e.g. 50 Hz
  • Long filters for reduced bandwidth operation to reduce noise

Proof of principle test for the damping of the low frequency oscillation

Possible noise reduction with longer filters up to 24 taps
Backup slides
Steps to be taken during the MD

a) Disable the second ADT module in the selected plane, only one module and one pickup will be used for the test
b) Flash the new ADT signal processing firmware into FPGA, restart the FESA class to initialize it properly
c) Set the filter coefficients for both pickups Q7 and Q9
d) Keep the feedback loop open
e) Inject 1 probe bunch
f) Do few excitations and test the excitation and measurement mechanics
g) Close the loop, verify the damping at nominal tune and nominal gain by ADT-excitation and closed loop transfer function measurement
h) If feedback fully operational, scan the gain-tune parameter space using a single pickup and a single kicker
i) If h) successful turn on both pickups. Do few gain-tune scans.
j) If i) successful, inject a short (or a full length) train of nominal bunches and do a detailed gain-tune scan to demonstrate a proper working with trains
SPS proof of principle test

- SPS MD3391 (6.8.2018)
- Test with the operational firmware inducing some limitations
  - Coefficients normalized down by a factor of three (= gain reduced by a factor of three)
  - Signal processing delay 2 turns (1 turn normally)
  - Only one pickup and kicker
  - Filter tune was varied instead of the machine tune
- In spite of the test limitations, the new filter is significantly less sensitive to the tune variations than the old approach as expected
Damping times from PyHEADTAIL simulations

Phase advance between the pickup and the kicker is 0 deg

Phase advance between the pickup and the kicker is 90 deg