New ADT signal processing for large tune spread acceptance

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LHC ADT

• Bunch by bunch filters
  • Phase and gain linearization for the power amplifiers and kickers
  • E.g. “standard bandwidth”, “enhanced bandwidth”

• Turn by turn filters
  • Closed orbit suppression
  • Pickup to kicker betatron phase advance correction

Two families of digital filters

MD for new turn by turn filters
New turn by turn filters

- Currently used ADT filter scheme (Notch+Hilbert) is 8 taps long
- 3-tap filters allow larger tune acceptance and gain margins
- Test for 16-tap filter (possible noise reduction)
- MD procedure
  - Single pickup (BPMCS.9R4.B1) and kicker in vertical plane
  - Damping time measured as a function of tune
    - Injection machine settings, low chromaticity (2-4 units) and no octupoles
    - Fractional tune varied between 0.25 and 0.33
    - Beam kicked with the ADT
    - Data from ObsBoxB.LHC.ADT.B1V.Q9.Tune2k buffer
    - Reference tune for tune shifts from the kicks with >200 turns damping time
• Observations
  • 3-tap filter provides flat response in the studied tune range
  • 3-tap filter induces less tune shift
    • In general, ADT amplifies tune shifts
    • Amplification depends on ADT gain (damping time) and filter
  • Good agreement between the PyHEADTAIL simulations and the measurements
Additional tests

- Bunch train injection with the 3-tap filter
  - 10 turns damping time demonstrated with the nominal injection settings

- 16 tap filter
  - Tune acceptance measured
  - <15 turns damping times demonstrated for single bunch injections

Note: Gain varied between the indiv injections
Ready for operational use?

- **3-tap filter**: no drawbacks found so far
  - **Tune acceptance**: Better for all the tunes and pickup locations
  - **Noise performance**: Similar to the currently used scheme
  - **Flexibility**: Analytical equation for all the operational schemes

- **16-tap filter?**
  - MD demonstrated technical feasibility for operational testing after the LS2
  - Better noise performance is not obvious
    - Fundamental challenges to suppress beam noise at the betatron frequency (error propagation)
    - Noise and damping can be modified around the betatron frequency
      - Open question: any effects when operated with chromaticity and octupoles?
Thank you!
Filter frequency responses

3-tap filter coefficients

![Graph showing 3-tap filter coefficients](image)

- Coefficient values plotted against pickup to kicker phase advance in degrees.
- Curves represent different values of $Q_{frac}$: $Q_{frac}=0.275$ (solid orange), $Q_{frac}=0.295$ (dashed orange), $Q_{frac}=0.31$ (solid green), $Q_{frac}=0.32$ (dashed green).
- Coefficients $b_0$, $b_1$, and $b_2$ are indicated.

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