Tune Measurement with Chirped Excitation in the Hera Proton Ring

CERN Tune/PLL Workshop
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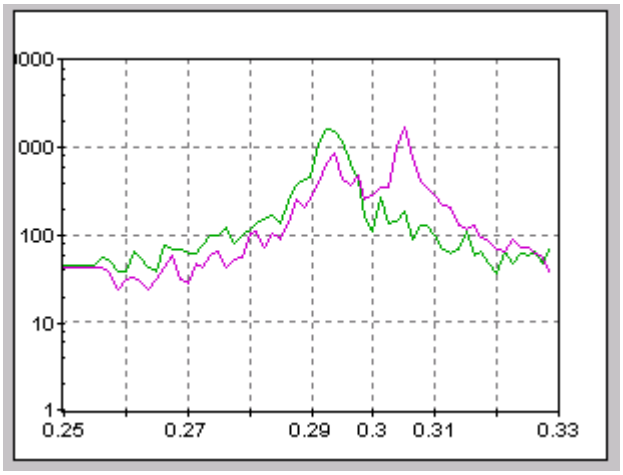


HERA P Ring Parameter Sheet 2002

Parameter	Injection	Luminosity
Circumference (m)	6336	6336
Rev. Freq (Hz)	47,303	47,316
Energy (GeV)	40	920
B Field (T)	0.226	5.2
RF (MHz)	52/208	52/208
Bunch Spacing (MHz)	10.4	10.4
Bunch Length (m, fwhm)	0.36	0.18
dp/p (rms)	.0004	.0001
# Bunches	~ 180	~180
Total Current (A)	~ 0.100	~0.100
Synch Freq (Hz)	~ 40	~ 40
Integer β Tunes	31/31	31/31
Fractional β Tunes	0.293/0.297*	0.293/0.297*
(Hz)	~13,900	~13,900
Natural Chrom.	-60 / -60	-60 / -60
Persistent Current Chrom.	≈ +-40 ??	≈ 0 / 0

HERA P Ring Beam Parameter Control Summary

Problem: **Limited Reproducibility** (day to day and week to week)

Reference Magnet System [2 SC Dipoles in series with Ring]

- NMR Probes [Measure Injection Field]
- Dipole Integration Coil [Measure Field Change during Ramp]
- Rotating Sextupole Coil [Measure Sext field during Injection, Ramp]

Injection Field Control (Compensate Persist. Current decay)

- Reference NMR changes drive Horizontal Correction Coils in Arcs
- Reference Sext drives Sextupole Strings in Arcs

Injection Procedures (Bring to nominal conditions)

Operators have knobs for:
Qx, Qy (drive quad strings in arcs)
Sx, Sy (drive sext strings in arcs)
Sk_a,Sk_b (drive 2 skew quads in West straight)

Inject 10 Bunch Test Shot(s) and
- Measure P offset from Longitudinal Inj Oscillation and correct
- Measure Tunes from Inj Oscillations, stored beam, and correct
- Adjust coupling by 'nearest approach' of Tunes
- Adjust Chromaticity by Peak Width , and/or RF stepping

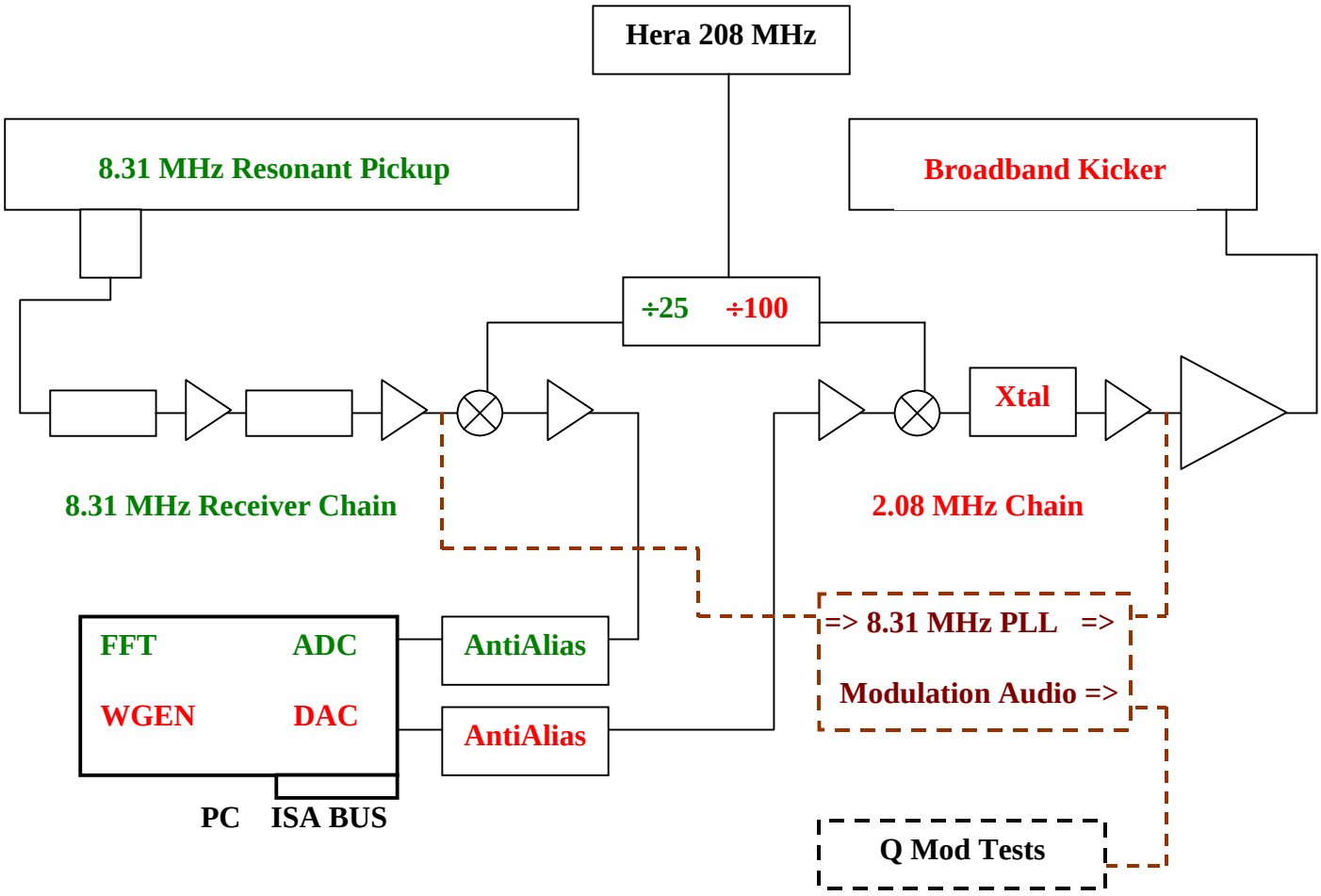
Inject 180 Bunch Train for Ramp

Ramp Field Control

- SC Dipole Circuit Driven by Pulse Generator
- Reference Dipole Integrator coil drives ramp of 'other' magnets
- Reference Sext drives Δs adding to linear current ramp of Sexts
- Tables drive non-linear corrections to Quad Strings
- Tables drive non-linear corrections to Sext Strings
- Operators drive Qx,Qy via knobs and Sx,Sy, Sk_a,Sk_b as necessary

[new tables periodically produced from smoothed knob data]

Hera P Tune System



Comments

- Concept from SPS “Schottky” System (Boussard, Linnecar, Scandale)

- Signal from ALL bunches in Hera but a SINGLE multibunch mode

- Kicker drives ALL bunches in that SAME multibunch mode

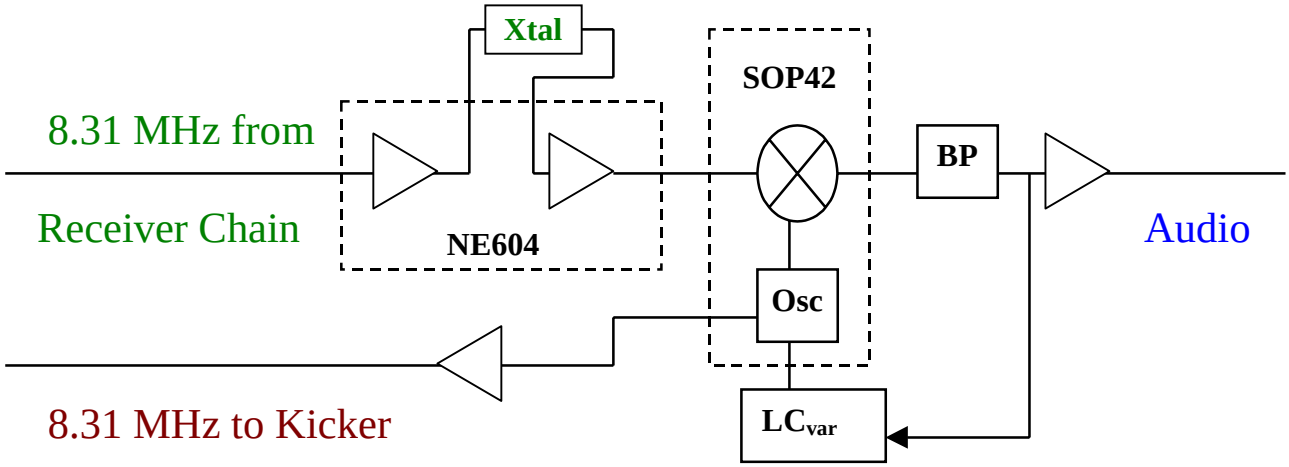
- Monitor Sensitivity ~ 5Ω /mm, Input Sensitivity ~ 3 nV/Hz^{½}
  [For 100 ma, 100 Hz band, S/N~10 for 6 nm *in multibunch mode*]

- Standard Operation uses ‘Chirped’ Excitation during Injection, Ramp Frequency 10 => 20 kHz with Trapezoidal Window, during FFT

fft range 0-30 kHz , 2048 pts, acquisition time 34 msec
fft rate 8 Hz , avg 4 => 2 Hz at console

Simple PLL Module

(L. Becker, DESY, ~1992)



[Used for measuring tune modulation, O. Bruening, 1994 (?)]

Some Comments on Hera Resonant Monitor + Chirped Excitation System

- During early operation of Hera P, the linear chirp was found to be a very simple general purpose excitation, and we have hardly experimented with anything else (very little new development work in past 6 years!)

- What does the excitation look like? Does linear chirp ~~deexcite,~~ as well as excite the bunch oscillations, or are they left ringing after passing through resonance? *[observations suggest something in between]*

- Sensitivity means that kicker can be used without much worry about emittance growth (when machine is reasonably tuned up)

- Sensitivity means that system is useful for diagnosing problems responsible for slow beam emittance growth

- Width and coupling observable (but not always easy to interpret)

- Lots of information for good operators, but **hard to automate!** (peak shapes very different in various machine conditions, coupling & chromaticity correction require 'dithering' tests)

- Tune spectra sensitive to many aspects of machine performance (messenger blamed for bad news?)

Possible Modifications?

- Better fitting of available data [*Wavelets?]*

- More sophisticated signal processing? Now throwing away time/phase information.

- Single Impulse Kick as alternative? (eg 8.3 MHz for 2-3 turns) Would this permit simple coupling measurement via mixed time/frequency domain analysis?

- Use 8.3 MHz system together with Klute digital PLL for tune control? We have not tried to think about how this interacts with coupling and chromaticity in the Hera P.

The real issue is **RELIABLE CONTROL** during the ramp!

With the Hera P Ring, it seems not realistic to require that automatic tune control need work only on a machine which is already in a ‘very well tuned’ condition. The system must also be able to cope with a ‘moderately well tuned’ machine, and must have ‘sane’ responses to states in which clean tune information is not available.