4 Gs/s Excitation System for SPS Machine Physics

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Abstract

We present an electronic excitation system used to study single-bunch vertical dynamics in the CERN SPS. The system uses a 4 GS/sec/ fast digital excitation system, in conjunction with 400 W of 20 - 1000 MHz amplifiers and a vertical kicker to excite vertical motion. A related beam receiver system digitizes the beam response on 4 strip-line electrodes and we record the beam response. Our long-term goal is to design a wide-band feedback system to control/stabilize the bunch in the presence of e-cloud and transverse mode coupling instabilities (TMCI). This initial work validates the back-end functions and is part of a dynamics effort to characterize how the presence of electron clouds impacts the proton bunch dynamics.

Identification of Bunch Dynamics for CERN SPS Ring

- The identification of the individual bunch dynamics in the SPS ring involves the development of wide-bandwidth hardware to be able to drive the individual sections of the bunch.
- Starting with August 2011 MD, we've started to use a deterministic excitation system that can create an arbitrary synchronized excitation signal.
- This approach allows new beam diagnostic techniques which give us an opportunity to validate nonlinear macroparticle simulation codes with real measurements taken from machines.

Hardware Development for Excitation System

To allow arbitrary wide-band synchronized excitation we have developed a system (figure 1) capable of driving user-defined 4 GS/sec. waveforms on selected bunches during the SPS machine cycle. This was installed at the SPS in July/August 2011.
The system uses a synchronized master oscillator to drive data streams at 4 GS/sec. from a local memory.

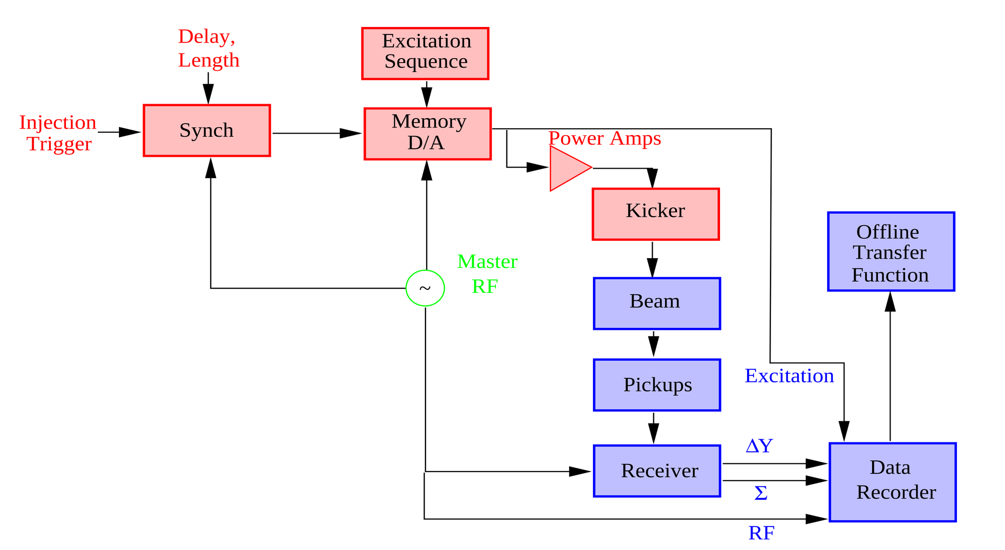

Figure 1: *Hardware configuration for excitation and measurements .*

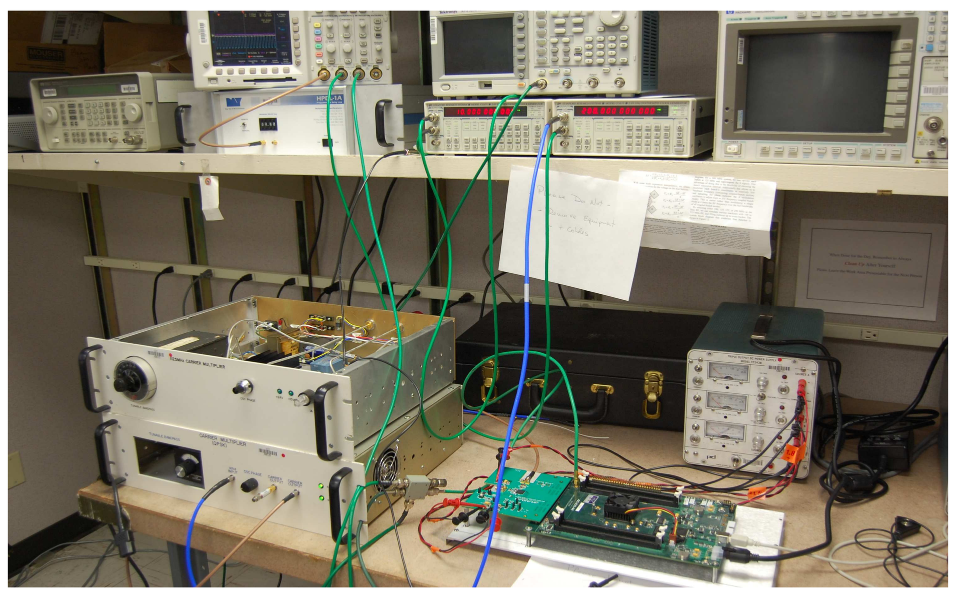

Figure 2: *Excitation system with synchronised master oscillator developed at SLAC for use at CERN*

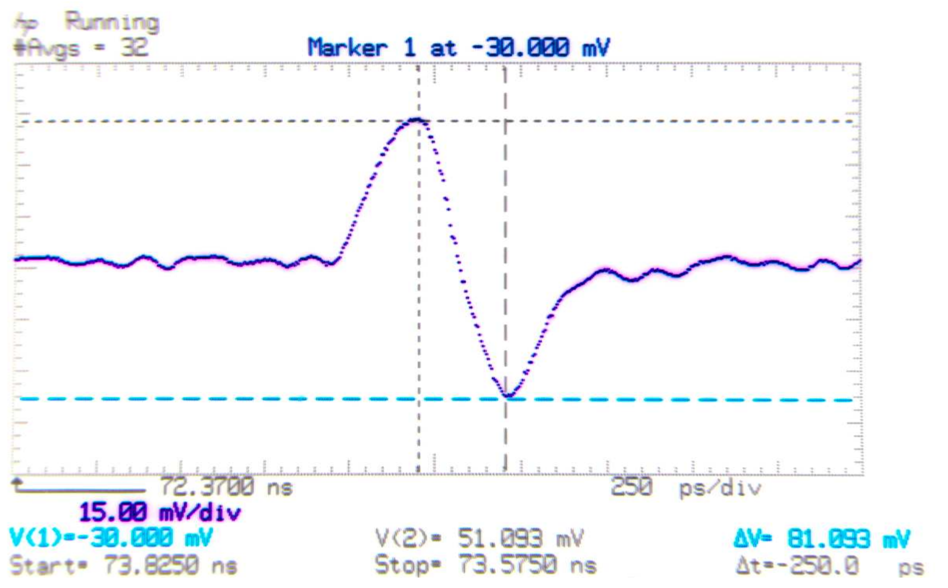

Figure 3: *4 GS/sec. doublet signal showing 250 ps transition*

A trigger and synchronization system allows the selection of a single or multiple bunches in the SPS with respect to a revolution fiducial, and for each bunch a 16 or 32 sample/turn excitation (15,000 turn length) is generated after synchronization to an injection trigger.

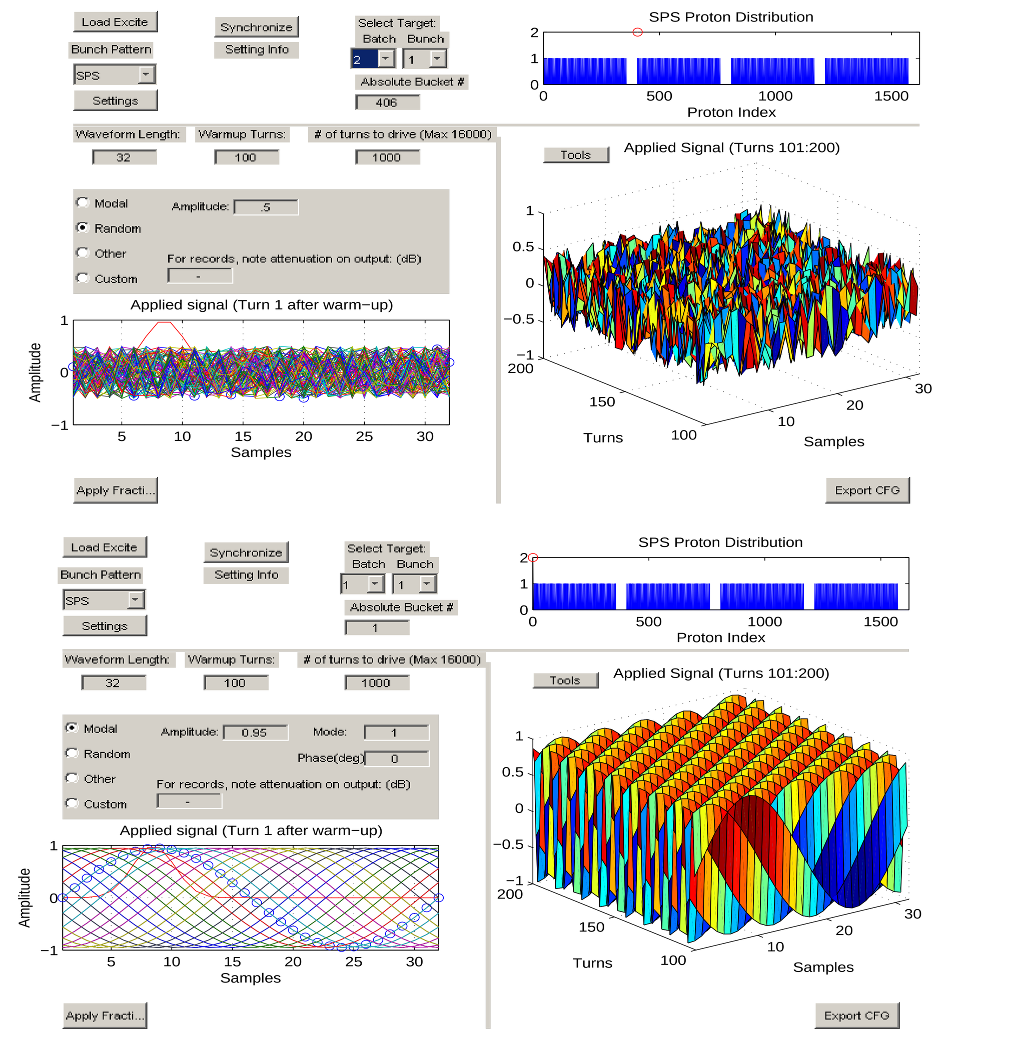

Figure 4: *GUI for excitation system. Random signal (top) and phase modulated signal at a tune of 0.185 (bottom).*

The baseband D/A signal is amplified by four 100W 20–1000 MHz RF amplifiers, which drive an existing wide-band pickup electrode as a vertical kicker.

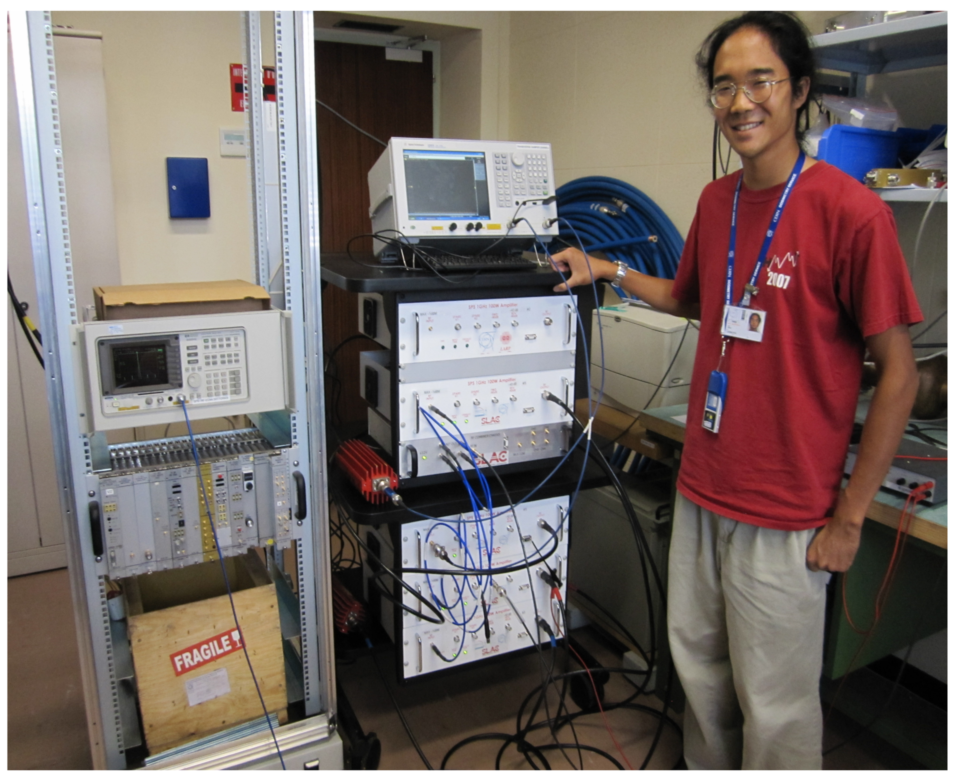

Figure 5: *Power amplifiers in test at CERN.*

Figure 6: *Four 100W amplifiers are placed in the tunnel under a bend magnet.*

Figure 7: *An exponentially-tapered pickup array (BPW 319.01) is used as a kicker in the tunnel for our MD measurements. A similar array (BPW 321) is used as a pickup.*

The basic goal of the first experiment was to excite different internal modes to test our excitation system in the CERN SPS tunnel. We were successful in exciting mode 0 (barycentric motion, in Figure 8) and mode 1 (head-tail motion, in Figure 9).

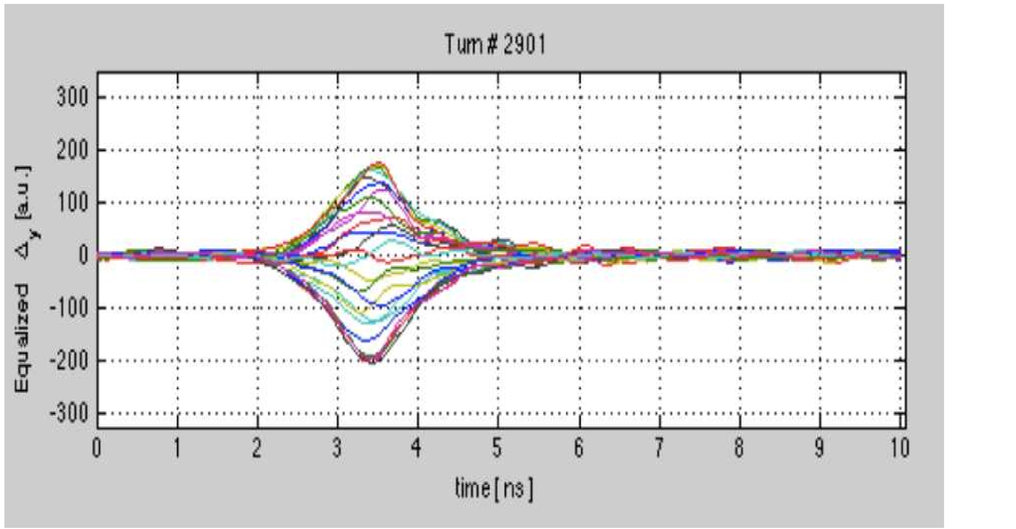

Figure 8: *Excitation of mode 0 motion from a excitation file with all bunch slices in phase. Plot shows vertical dipole moment for 25 turns.*

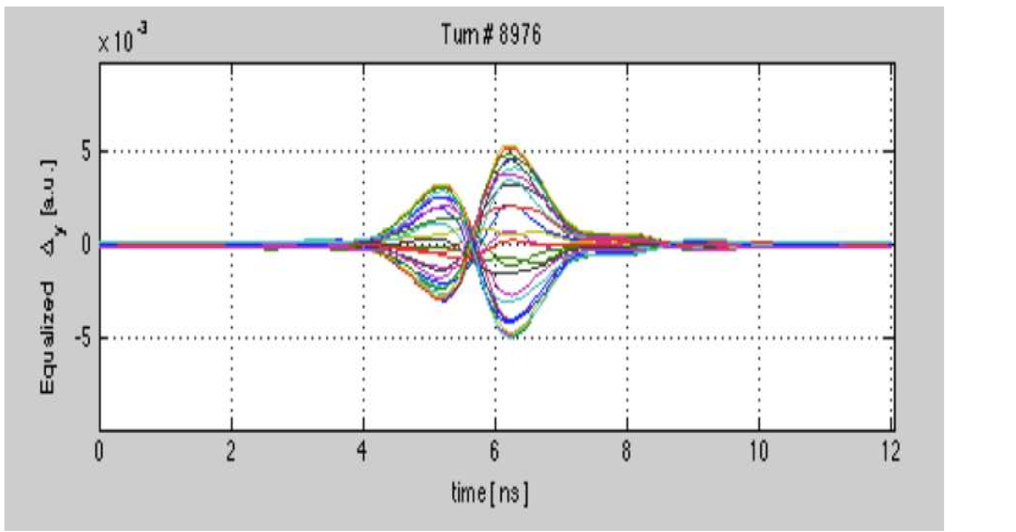

Figure 9: *Excitation of head-tail (mode 1) motion from an excitation file with 180 degrees phase difference between head and tail of bunch. Plot shows vertical dipole moment for 25 turns.*

This is a very promising step that shows we can excite the beam even with the existing kicker structure in the tunnel.

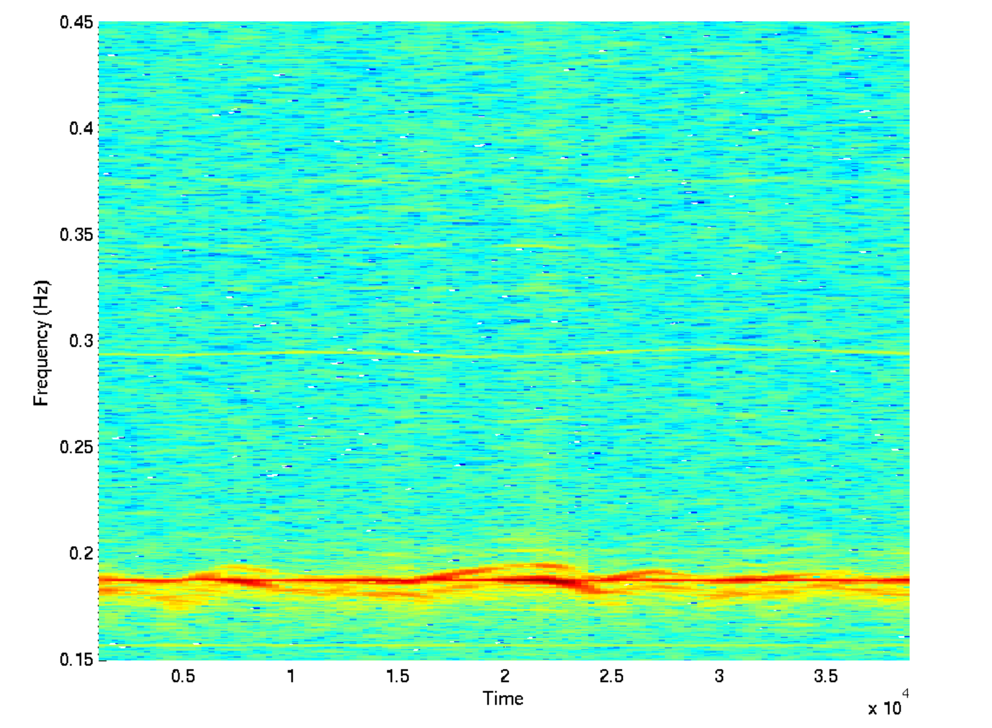

Figure 10: *Spectrogram showing the interaction of the beam modes (wavy bands) with the excitation (red line at 0.185). The different beam modes are excited at different times as tune shifts bring each of the modes into resonance with the excitation.*

Future Work and Conclusion

The immediate next step is to excite the beam again with band-limited noise and use the excitation/response measurements in the identification process. These experiments and data analysis are necessary adjuncts to the design and specification of a useful wide-band feedback system, and help specify critical issues of necessary bandwidth, required amplifier power, specifications of kicker structure parameters, and the overall strategy for a control filter.
Our group is fabricating a proof-of-principle 4 GS/sec. feedback control system, and developing a wide-band vacuum kicker structure for tests at the SPS in 2013.

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