SPS High Bandwidth Transverse Feedback System MD

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Nov. 29 – Dec. 1, 2012

1. Nov. 29, 2012 - Measure amplifiers to check their output levels

- (a) Need a -11 dBm (89 mV_p) signal at the input of the wide band gate (recall there is a -10 dB attenuator at input of WBG). With the excitation system, we need to remove 3 dB of attenuation from the DAC output chain to achieve 82 mV_p. Replace the 4 dB attenuator after the programmable delay with a 1 dB attenuator.
- (b) For the feedback system we must also reduce the attenuation by 3 dB. Replace the 6 dB attenuator with a 3 dB attenuator. Measure 84 mV_p at the end of the DAC chain (just before the -10 dB attenuator at the WBG). Note: For some reason, the attenuator was switched back to 6 dB. Claudio nor Johnny remember why this was done and is a mistake, should have used 3 dB attenuation. Check this again before Jan 2013 MDs. Figure 1 shows the DAC output chain with the new attenuation values.

Figure 1: Back end DAC chain for the excitation and feedback systems used in the MD.

2. Back end synchronization of excitation signal with beam using excitation system

- (a) To get an idea of where we are aligned, monitor the kicker load, MUX 2.
 - i. Excitation signal - sine 200 MHz, no modulation, Warmup turns: 2000, Turns: 15000, Nov29_218.cfg
 - ii. GUI settings - INJECTION DELAY: 2000, BUNCH DELAY: 4089. Programmable delay: 0.0 ns
 - iii. 121129.030827.wfm, recorded for 20000 turns.
 - iv. Initial alignment looks pretty good as shown in Figure 2. Crossing point of the bunch signal and excitation signal near 0V, which implies proper time alignment.
 - v. Adjust the BUNCH DELAY to 4088 and programmable delay to 5.0 ns, in order to have range to decrease time delay.
 - vi. The signal level of the load is 60 mV_p, which is 1/2 of what is expected at the MUX out for a input sine 200 MHz, 82 mV_p signal at the entrance of the wide band gate. Could this be because the signal we are applying is a burst, not steady state continuous signal? This

Figure 2: Kicker load signal via MUX 2 showing the bunch, bunch + excitation, and excitation signals. The excitation signal was computed by subtracting the bunch signal from the bunch + excitation signal.

is something we must check/recheck. Could be related to the hybrid attenuating the burst signal more than a continuous signal as we observed in setup.

vii. Table 1 displays the data taken monitoring MUX 2 on Ch3 in the scope.

Table 1: Kicker load signal measurements via MUX 2 for beam-excitation synchronization measurement on 11/29/2012

File (121129_)	BUNCH DELAY	Prog. delay (ns)	Notes
030827	4089	0.0	
041433	4089	0.0	
042245	4088	5.0	No beam, measurement of excitation only
042351	4088	5.0	
042749	4088	4.0	
042950	4088	6.0	
043725	4088	4.8	

(b) Use the beam-excitation synchronization method developed this past year. Drive the beam with a mode 1 (sine 200 MHz) AM chirp signal. Chirp through the betatron frequency and first synchrotron side band. Monitor the beam response with the pickup. A properly synchronized signal should minimally excite the mode 0 or barycentric motion of the beam, and maximally excite the mode 1 or head-tail motion.

- i. Excitation signal - sine 200 MHz, AM, chirp: $0.185 \pm 5\%$, Warmup turns: 2000, Turns: 15000, Nov29_524.cfg
- ii. GUI settings - INJECTION DELAY: 2000, BUNCH DELAY: 4088, Programmable delay: 4.8 ns
- iii. Table 2 lists the data files acquired. However, for some reason, the .cfg file did not load probably in VB GUI and the chirp signal was not playing out for the full 15000 turns. We did not realize this until datum 121129.054544 was acquired. This data may or may not be useful.
- iv. Upon loading the Nov29_524.cfg again, the system played out the correct number of turns. This is strange and must be fixed.

Table 2: Initial synchronization measurements. Problem with .cfg file not loading properly. Does not play out all 15 k turns.

File (121129_)	Prog. delay (ns)	Notes
052824	4.8	
052939	.	
053021	.	
053100	.	
053143	.	
053349	4.9	
053439	.	Orbit shift
053555	.	Orbit shift
053670	.	
053719	.	
053801	.	
053843	5.0	
053925	.	
054007	.	
054049	.	Orbit shift
054132	.	Orbit shift
054243	.	Orbit shift
054338	.	
054417	.	
054501	5.1	
054544	.	

(c) Start the synchronization measurement.

- i. Excitation signal - sine 200 MHz, AM, chirp: 0.175 – 0.195 (increase chirp range to cover for tune shifts), Warmup turns: 2000, Turns: 15000, Nov29_606.cfg.
- ii. GUI settings - INJECTION DELAY: 2000, BUNCH DELAY: 4088, Programmable delay: 5.1 ns
- iii. Table 3 lists the data files acquired with .cfg file properly loaded. We did not finish the measurement, since we lost beam at 7AM for the ion run. Start from here on our next shift.
- iv. The resulting mode 0 beam motion is plotted vs. fine delay in Figure 3.

Figure 3: Mode 0 beam motion from the data listed in Table 3

3. **Nov. 29, 2012 - 20:44** - Have beam again, continue with beam-excitation synchronization measurement with excitation system.

- (a) First check injection trigger level: 600 mV
- (b) The excitation system power was cycled by mistake. Since the DAC can boot up in one of four states, we will have to restart the timing measurement.
- (c) Lost bunch alignment with our scope trigger. Wolfgang investigates and figures out the problem. (JC - I'm not sure what the problem was. Something needed to be reset in Faraday cage, talk with Wolfgang)
- (d) Date change - **Nov. 30, 2012**. Monitor kicker load signal via MUX 4:
 - i. Excitation signal - sine 200 MHz, no modulation, warmup turns: 2000, Turns: 15000, Nov29-218.cfg
 - ii. GUI settings - INJECTION DELAY: 2000, BUNCH DELAY: 4088, Prog. delay 5.0 ns
 - iii. Table 4 lists the data files acquired by the scope of the kicker load signal

Table 3: Pickup data from the beam-excitation synchronization measurement. The .cfg file properly loaded for these measurements.

File (121129_)	Prog. delay (ns)	Notes
062127	5.1	
062658	.	
062842	.	
062948	.	
063029	.	
063112	.	
063237	5.2	
063327	.	
063813	.	
063853	.	
063935	.	mode -1 visible
064103	.	
064209	.	
064305	.	
064433	5.0	
064522	.	
064635	.	
064719	.	
064801	.	
064844	.	
064925	.	
065007	.	
065202	4.9	
065254	.	
065337	.	
065540	.	
065624	.	
065715	.	
065803	.	
065917	4.8	
065955	.	
070037	.	
070120	.	
070202	.	
070244	.	
070331	.	
070447	.	
070901	.	

Table 4: Files of the kicker load signal via MUX 4 from the beam-excitation synchronization measurement on 11/30/2012.

File (121130_)	Prog. delay (ns)
021504	5.0
022040	5.15
022444	5.35
022530	5.85
022646	4.95
022727	4.45

(e) Monitor pickup for beam motion

- i. Excitation signal - sine 200 MHz, AM, chirp, 0.175 – 0.195, Warmup turns: 2000, Turns: 15000, Nov29_606.cfg.
- ii. GUI settings - INJECTION DELAY: 2000, BUNCH DELAY: 4088, Prog. delay: 4.45 ns
- iii. Table 5 lists the data files acquired by the scope of the pickup signal.

Table 5: Data files of pickup signal for the beam-excitation synchronization measurement on 11/30/2012

File (121130_)	Prog. delay (ns)	Notes
022919	4.45	Strong mode 0
023028	.	
023107	.	
023233	.	
023349	.	
023430	.	
023549	.	
023631	.	
024602	4.95	See mode 0 and mode 1
024644	.	
024723	.	
024807	.	
024846	.	
024928	.	
025010	.	
025614	5.15	
025739	.	
025816	.	
025857	.	
025940	.	
030020	.	
030101	.	
030141	.	
030749	5.35	
030911	.	
030951	.	
031037	.	

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Table 5 – continued from previous page

File (121130_)	Prog. delay (ns)	Notes
031151	.	
031235	.	
031315	.	tune shift, excluded from analysis
031402	.	
031515	.	
031557	.	
032033	5.85	
032123	.	
032205	.	
032245	.	
032326	.	
032406	.	chirp has sidebands
032449	.	tune shift, excluded from analysis
032529	.	
032611	.	
032687	.	
033015	5.10	tune shift, excluded from analysis
033053	.	
033134	.	
033357	.	
033500	.	
033541	.	
033623	.	
034441	.	800 MHz RF added to reduce chromaticity, tune shift
034625	.	
034713	.	
034756	.	
034838	.	

- iv. The resulting mode 0 beam motion is plotted vs. programmable delay in Figure 4. Prog. delay of 5.10 ns seems to be the proper time.
 - v. Example spectrograms of the properly timed signal at fine delay 5.10 ns are shown in Figure 5. Notice that the chirp frequency hits the betatron frequency and minimally excites mode 0.
4. Synchronize beam-excitation with the feedback system in excitation mode. However, we have a serious problem. We cannot detect any of the trigger signals to the new system. Without triggers, we can not run the excitation function, or anything for that matter. Emails to John F. and John D., sleep for us.
 5. **Nov. 30, 2012 Mid afternoon** - Diagnosing the problem with the feedback system. While in email communication with John F. and John D. we were able to figure out the problem with the system. A 5A fuse on the FPGA motherboard blew. It fused the +12VDC supply to the DAC daughterboard, and thus the triggers stopped working. We are not sure what caused this to happen. The feedback system was continuously powered since Nov. 26, so it doesn't appear that some kind of start up surge could have killed it. Instead of messing with the fuse, we found an external, current regulated power supply to directly power the DB, drawing 84 mA initially, and increased to 98 mA

Figure 4: Mode 0 beam motion from data set in Table 5. Prog. delay of 5.10 ns seems to be the proper time.

Figure 5: Two spectrograms showing beam motion from excitation with a sine 200 MHz AM chirp signal. There is minimal mode 0 excitation from the chirp signal showing the beam and excitation signal are properly synchronized.

Figure 6: Left: New and old excitation signals with good time alignment. Right: New and old excitation signal one bucket apart.

6. With the system is up and running again, synchronize back end of new system with beam.

(a) Setup feedback system

- i. Excitation signal - sine 200 MHz, no modulation, 2000 warmup turns, 15000 turns, Nov30_1917.cfg
- ii. Thresholds set to 0.3 V for both the fiducial and injection triggers.
- iii. Adjust FIDUCIAL DELAY to 4610, which puts the signal very close to the scope trigger. Acquire excitation signal through full back end chain. Seems to be working well.

(b) Setup excitation system

- i. Configuration same as earlier in the day (before the problems) Nov29_606.cfg..
- ii. BUNCH DELAY: 4088, Prog. delay: 5.10 ns, TRIGGER THRESHOLD: 0.15, INJECTION THRESHOLD: 0.4
- iii. Change BUNCH DELAY to 0 in order to move the signal close to scope trigger. Seems to work fine.

(c) Match the feedback system excitation signal to the excitation system signal.

- i. Initially, we changed the FIDUCIAL DELAY of the new system to 4617, which moved the signal within 0.45 ns of the excitation system signal. However, we were losing the signal at every other fiducial. Remember that the harmonic number of SPS is 4620, it seems that we are too close to this value, which is causing the loss of signal. We study this and see that we cannot set the FIDUCIAL DELAY above 4615.
- ii. Change excitation system BUNCH DELAY to 4088. If a fiducial delay of 4617 was close in timing and is 3 buckets from 4620 or 0 (used to setup the old system), the feedback system FIDUCIAL DELAY should be 4085. Prog. delay: 0.45 ns. See Figure 6 for timing alignment between both systems. Looks good.

7. Excite beam with feedback system and check synchronization

(a) Monitor the kicker load signal via MUX 4.

- i. Settings - FIDUCIAL DELAY: 4085, Prog. delay: 0.45 ns
- ii. 121130_214615, 20k turns recorded. Response looks terrible. Burst signal is riding on a DC offset!!

- iii. Must have had a problem loading the configuration file. The default drive, which is normally set to 127 was set to 0. More .cfg loading problems.
- iv. Things now working. But no beam. Monitor kicker load, recored excitation signals with no beam for each amplifier: 121130_222417 - MUX1, _222459 - MUX2, _222544 - MUX3, _222635.
- v. With beam, monitor kicker load MUX4 - _223209. Timing looks a little off.
- vi. Check excitation system synchronization again (settings from earlier in the day). Monitor kicker load MUX 4. Table 6 lists the files acquired and corresponding programmable delay settings. It looks like the fine delay should be 5.05 instead of 5.1 from earlier in the day. (Look at these kicker load signal plots closer. It seems that there is more than a 0.05 ns time difference between 5.05 and 5.1. Problem with the delay box?)

Table 6: Files of the kicker load signal via MUX 4, when checking the excitation system beam-excitation synchronization (late 11/30/2012).

File (121130_)	Prog. delay (ns)
223500	4.6
224052	4.6
224335	4.7
224521	4.85
224742	4.95
225147	5.10
225313	5.05
225534	5.0

- vii. Now repeat for the feedback system. The excitation signal is one bucket too early, change FIDUCIAL DELAY to 4084. Monitor kicker load signal via MUX 4. Table ?? lists the files acquired and corresponding programmable delay settings.

Table 7: Files of the kicker load signal via MUX 4, when checking the feedback system beam-excitation synchronization (late 11/30/2012).

File (121130_)	Prog. delay (ns)
230408	3.2
230451	3.5
230537	3.7
230803	3.6

- (b) Monitor the pickup signal while exciting with the feedback system.
 - i. Programmable delay: 3.55 ns.
 - ii. Excitation signal: sine 200 MHz, AM, chirp 0.175 – 0.195, Nov30_2125.
 - iii. First driven beam with feedback system excitation function _231645
 - iv. Spectrogram shows chirp moving through mode 0 and mode 1 with very little excitation of mode 0, strong excitation of mode 1.
 - v. Files recorded (121130_): 231913, 232014, 232122, 232210, 232912, 232959, 233045, 233212, 233314.
 - vi. RMS $\Delta y = 1.25 \pm 0.43 \times 10^{-3}$ a.u.

- (c) **Dec. 1, 2012:** Check the excitation system
- Fine delay set to 5.05 ns.
 - Files recorded (121201-): 000524, 000637, 000723, 000822, 000856, 000944, 001116, 001219.
8. Set up front end timing (JC - My notes were a bit hard to decipher at this point.)
- With the FIR filter in pass through mode, monitor the equalized pickup signal. Try to locate the bunch centroid in the center of the sampling region of the ADC.
 - Set ADC FIDUCIAL DELAY to 27, Prog. delay: 6.1 ns
 - Monitor the DAC signal, bunch looks nicely centered: 121201.012744.
 - The separation between the fiducial strobe and the DAC signal is $\Delta t = 42$ ns as shown in Figure 7: 121201_013216.wfm, 121201_013308.png, 121201_013526. wfm

Figure 7: Ch1 is the DAC signal with an equalized pickup signal input passed through the FIR filter. Ch3 is Fiducial strobe. 121201_013308.png

- Find the width of the bucket by scanning the prog. delay at ADC input. Seems like limits are with 2 ns and 7 ns on fine delay.
 - 014134 - 5 ns
 - 014309 - 7.5 ns
 - 014522 - 5.5 ns
- Observe passed through pickup signal out of DAC and excitation signal from excitation system to make sure timing is still correct in Figure 8 Play excitation file with excitation system. Set Feedback DAC FIDUCIAL DELAY to 4084 and Excitation DAC BUNCH DELAY to 4088. Screen capture: 023106.png, wfm: 023124.wfm. Set bunch delay on scope trigger from 1827 to 1302.
- Apply 5 tap filter, gain 1, frequency 0.18, phase 90°

Figure 8

- i. 023258.wfm, 023322.png
- ii. 023441.wfm, 023425.png
- (h) Apply pass through filter, 024219.png
- (i) Apply 5 tap filter, gain 1, frequency 0.18, phase 90°
 - i. 024412.wfm
 - ii. 024542. wfm
 - iii. 024720
- (j) Increase gain to 10.
 - i. 025105
 - ii. 025233
 - iii. 025336
 - iv. 025458
 - v. 025637
 - vi. 025730
- (k) No changes with filter, but we may have changed the prog. delay timing on the Feedback DAQ to 3.50 ns.
 - i. 025845
 - ii. 030110
 - iii. 030349 - include pickup signals
- (l) Change feedback system FIDUCIAL DELAY to 4615. Change static trigger bunch delay for the scope trigger back to 1827. Record 20k turns, Ch2 - delta (raw), Ch1 - Feedback DAC signal
 - i. 030819

- ii. 030907
 - iii. 030958
 - iv. 031127
 - v. 031215
 - vi. 031300
- (m) Filter in pass through mode, gain 1.
 - i. 031523
 - ii. 031656
 - iii. 031749
 - iv. 031828
- (n) Monitor hybrid signal with both excite systems. Change static trigger bunch delay to 1302. Feedback fiducial delay: 4084, excitation bunch delay: 4088.
- (o) Set filter to phase 0° for 30 turns, then open. Monitor for 3k turns: 033008
- (p) Wait 10k turns, 0° filter for 30 turns, can see response for 30 turns.
- (q) Back to pickup mode, scope trigger bunch delay to 1827 $\rightarrow$ now close the loop!
- 9. Start closed loop tests, monitor pickup signals
 - (a) 5 tap filter, gain 1, frequency 0.18, phase 0° . 3k turns recorded, injection delay 2k turns(?), play signal 30 turns
 - i. 034835
 - ii. 035052
 - iii. 040214
 - (b) Change filter phase to 180°
 - i. 040256
 - ii. 040342
 - iii. 040430
 - iv. 040518 - 20k turns recorded
 - v. 040607
 - (c) Increase filter play on beam to 60 turns
 - i. 040649
 - ii. 040736
 - iii. 040823
 - iv. 040911
 - v. 040957
 - vi. 041044
 - vii. 041133
 - (d) Increase gain to ?
 - i. 044852
 - ii. 045011
 - (e) Pause, check the DAC out, nice correction signal at betatron frequency, Claudio happy! 051056.wfm
 - (f) Back to playing feedback on beam, gain 8, phase 180° , play out 60 turns

- i. 051459
 - ii. 051546
 - iii. 051639
- (g) Increase gain to 16, 60 turns
 - i. 051725
 - ii. 051831
 - iii. 051941
 - iv. 052008
- (h) Increase turns to 100, gain 16
 - i. 052116
 - ii. 052234
- (i) Increase turns to 150, gain 16 - 052339
- (j) Increase turns to 200, gain 16
 - i. 052444
 - ii. 052522
- (k) Change filter phase to 0° , gain 16, 60 turns - 052730
- (l) Increase turns to 120
 - i. 052814
 - ii. 052901
- (m) Increase turns to 200
 - i. 052948
 - ii. 053037
- (n) Pause, monitor kicker load, phase 180°
 - i. 054417 - Can definitely see amplifier response
 - ii. 054644
- (o) Monitor pickups again
 - i. 054746 - yes, we can see motion, seems that we drive the beam with phase 180°
 - ii. 054835
 - iii. 055230
- (p) Increase turns to 600, 5k turns recorded
 - i. 055316
 - ii. 055403 - DSP filter saturate indicator (front panel) illuminated
 - iii. 055449
 - iv. 055622
 - v. 055713
- (q) Reduce gain to 8, 900 turns
 - i. 060325
 - ii. 060458
 - iii. 060544
 - iv. 060632

- v. 060719
- vi. 060808
- vii. 060851

- (r) At this point, we will drive the beam then try to damp the motion. Create two excitation files.
 - i. Mode 0 excitation, injection delay 1000, drive for 10k turns, AM, chirp 0.175 – 0.181, Dec01-613
 - ii. Mode 1 excitation, injection delay 1000, drive for 10k turns, AM chirp 0.181 – 0.187, Dec01-614

- (s) Beam stopped to fill LHC, must wait. Looking to drive and damp when our MD cycle returns.

- 10. Beam is back, continue with closed loop tests. Looking at kicker load MUX 4. See Table 8. However, it seems that we are driving the beam regardless of the phase. Not able to resolve this before the end of the MD, and we are very tired. End of MD.

Table 8: Kicker load MUX 4 measurements with active feedback

File (121201_)	Gain	Phase @ 0.18 (°)	Turns	Notes
073645	8	0	500	
073806	8	0	700	
073919	8	0	900	
074035	8	0	1200	Large kicker response
074144				
074535	8	90	500	Large kicker response
074611				
074654				
074754	8	90	900	Large kicker response
075022				
075144	1	-90	500	Not much response
075235				
075417	8	-90	500	
075554	4	-90	500	
075728	4	-90	1000	
075914	4	0	1000	less motion than previous
080007	4	0	1000	
080145	4	0	1500	
080246	4	180	1000	
080454	4	180	2000	
080736	4	180	2000	
080952	4	0	2000	
081113	4	90	2000	lots of motion
081212				
081559	4	-90	2000	little motion
081848	4	-90	4000	