Align DRF2 and Debuncher Momentum Cooling

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Send comments and suggestions to the Pbar Tuning Guide Admins

Production Release 2.53

Introduction:

This document is divided into multiple sections. Click on the section title to go directly to the corresponding section.

1. Introduction: The introduction outlines all of the sections contained in this document and provides quick links that allow the reader to go directly to any section.
2. Prerequisites: This is a list of what items need to be tuned before you can complete this procedure.
3. Background: The background section gives an overview of DRF2 and the Debuncher Momentum Cooling and explains why we want the two systems aligned.
4. Setup: This section outlines what setup is required prior to starting this procedure.
5. Full Length Procedure: This is the full length version of the procedure, complete with screen captures and detailed discussion.
6. Condensed Procedure: This is a condensed version of the procedure without any screen captures, nor discussion.

Prerequisites:

Before completing this tuning procedure, make sure that you have already verified that the following tuning has been completed:

1. Debuncher Bend Bus

Background

The purpose of this document is to outline how to align DRF2 with the Debuncher Momentum cooling. DRF2 is used to maintain a 200nsec gap in the Debuncher beam by forming a barrier bucket that excludes particles from its interior. When timed properly, the barrier bucket gap passes over the Debuncher extraction kickers during the time that the kickers fire, minimizing beam loss due to the firing of the kicker. The beam is then transferred through the D-to-A line and then to the Accumulator. The Debuncher (53MHz harmonic number of 90) has an approximately 7% larger circumference than the accumulator (53 MHz harmonic number of 84), so the barrier bucket also allows the extracted Debuncher beam to fit exactly into one circumference of the Accumulator. The DRF2 frequency is tied to DRF1 and can be tuned with the variable D:PJWR53.

The Debuncher Momentum cooling further reduces the momentum spread in the Debuncher after bunch rotation and adiabatic debunching. The Debuncher Momentum cooling approaches what is called the asymptotic width (smallest momentum spread that the system can obtain) in approximately 2 seconds. Figure 1 below shows the Debuncher Momentum cooling in action. The figure is the standard bunch rotation display triggered at different times. As the display is triggered later in time (up to about 2 seconds), the frequency spread of beam in the Debuncher gets narrower. This translates to a narrower momentum spread in the beam. The operating frequency of the Debuncher Momentum cooling is maintained via thermal regulation. This regulation can be tracked with the Acnet parameter D:POVTMP, which should regulate to approximately 0.1°F. This device cannot be tuned; however, the operating frequency of the cooling can be changed by moving the Debuncher Momentum cooling notch filter D:PTMF.

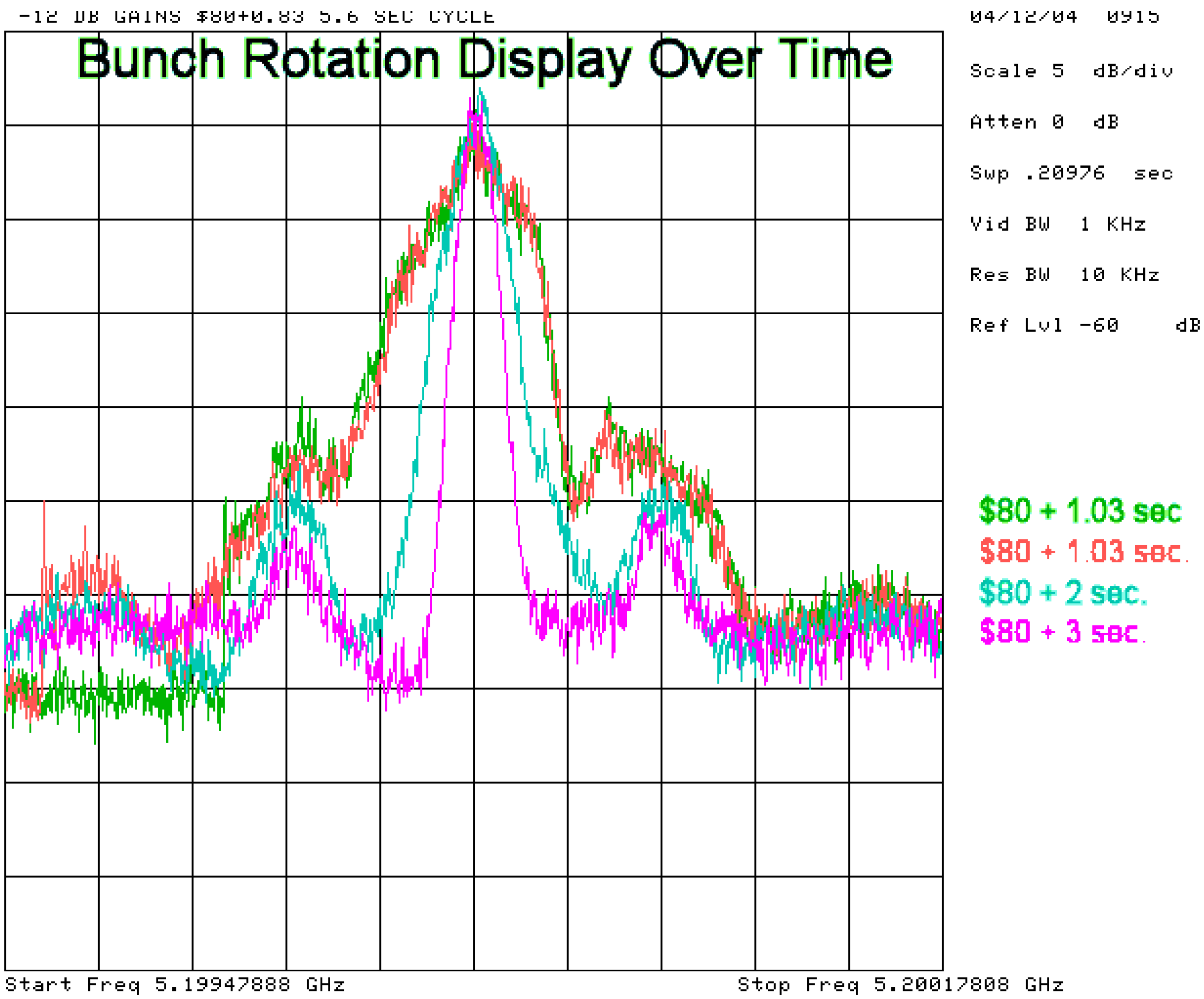


Figure 1: This is the standard bunch rotation display triggered at different times. It represents the momentum width of the Debuncher beam at different times in the cycle. The green and red traces are at the bunch rotation time, the cyan trace is at 1.0 seconds after bunch rotation and the magenta trace is 2.0 seconds after bunch rotation. The distribution gets more narrow over time showing the effect of the Debuncher momentum cooling.

If DRF and the Debuncher Momentum cooling are operating at different frequencies, then the Debuncher Momentum cooling will be fighting DRF. DRF will have the beam at one frequency, while the Debuncher Momentum Cooling try to pull the beam to a different frequency. As a result, the final beam distribution at extraction will have a wider and/or less symmetric momentum distribution when it is injected into the Accumulator. This translates to a wider momentum beam that is less symmetric on the Accumulator injection orbit, more beam left behind by ARF1 and less beam to the Stacktail.

This situation can be avoided if we align DRF2 and the Debuncher Momentum Cooling to the correct frequency. To do this, we look the Debuncher Momentum Band 2 pickup DP2-SCH signal just prior to extraction from the Debuncher. We look at the distribution with a

100 KHz span at the frequency that corresponds to the 8813 harmonic of the revolution frequency, which falls inside the momentum band 2 frequency range. This is the same frequency that we use to look at Debuncher bunch rotation. With DRF2 off, we capture the spectrum analyzer trace. The momentum cooling should have the beam at 590018Hz. If not, we can adjust the Debuncher Momentum Cooling notch filter, D:PTMF in very small steps (a 1 ps change is large) to align the signal. Once the signal is aligned, we turn back on DRF2 and compare the peaks with DRF2 off and on. These two peaks should be aligned. If not, we can tune D:PJWR53 in steps of 10 Hz, and repeat the measurements and adjustments until the peaks are aligned at 590018Hz. One note of caution is that when you change PJWR53, it causes a phase errors in the DRF1 cavities. So anytime we change PJWR53, we should plot the DRF2 rotator phase errors (D:PHERR*, with * =2,3...,7) and do not make another change until the phase signals stabalize close to zero degrees. We should also watch cooling power in the Accumulator to verify that we get more beam to the Accumulator Stacktail and Core after we complete the alignment.

We should align the Debuncher Momentum Cooling with DRF2 when the beam left on the Accumulator injector obit (CATV AP #28) is excessive and tuning ARF1 pickup frequency could not cure the problem. We should be careful not to trust this procedure when the $29 rep rate is very short (i.e. 2.0 seconds or 2.2 seconds), since the cooling may not be done narrowing the beam when we trigger the scope. Under these circumstances, we recommend extending the $29 rep rate to 3.0 seconds or more for the duration of the alignment procedure.

Setup

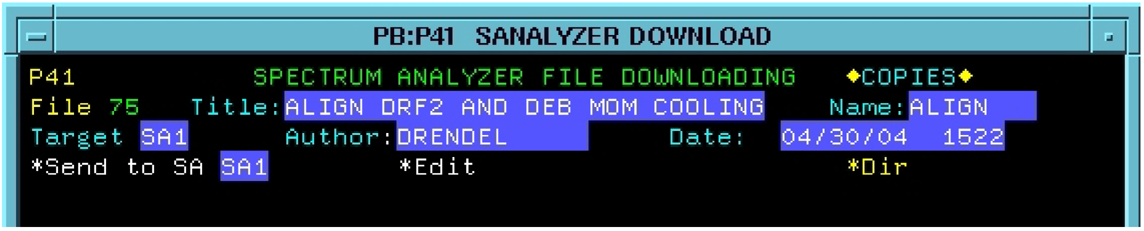
You will need spectrum analyzer #1 to complete this exercise. This exercise can be completed either remotely or at AP10. Verify that nobody is using SA #1 for other common tasks like Bunch Rotation Tuning or Signal Suppression measurements. It is also a good idea to check with tuners and studiers in the MCR and AP10 before beginning. Acnet page D15 will show if the AP10 consoles (12, 13, 14) are in use, or call AP1 control room at extension x4370.

Full Length Procedure: Part 1 - Setup

The following steps should be completed to align DRF2 with the Debuncher momentum cooling. This section contains screen captures and detailed discussion. If you are already familiar with this procedure and would prefer to review a condensed version of this procedure, then click here.

1. From P41 load file #75 to SA #1. To do this, type 75 next to "File" as shown below and then interrupt. Verify SA1 is to the right of "Send to SA" as shown below, then

click on "Send to SA" and take the caution.



a. If the file does not load properly, you can setup SA #1 through P42 or the Spectrum Analyzer emulator. The below table shows how to setup SA #1 from P42 or SA emulator commands. These are the same commands that are loaded above in P41 File #75.

Command	**P42 Commands**	**Emulator Commands**
Connect to SA #1	Go to P42, select SA #1 (D:SB11SA), and enter data into the SET DATA field.	Go to P42, click on ♦Emulate♦ located at the top right-hand portion of the screen, and then select Spectrum Analyzer #1.
Instrument Preset	IP	INS PST
Set the Reference Level	RL -60 DB	Refer Level 6 0 GHz -dB
Set the Attenuation Level	AT 0 DB	ATT 0 MHz +dB
Set the Center Frequency in the center of momentum band 2.	CF 5199.8286 MZ	Center Freq 5 1 9 9 . 8 2 9 MHz +dB *Note: You may notice that the number used above is one significant digit less than what*

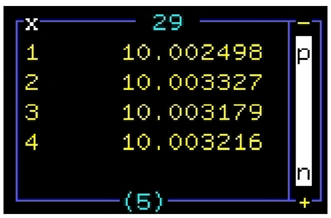
		we send with P41 or P42. This is due to a limitation of the emulator SA. This value will work as it only corresponds to a 0.04Hz offset on the Spectrum Analyzer display. If you want to enter the exact center frequency value, use the P42 "set data" field as shown on the left.
Set the frequency span	SP 100 KZ	Freq Span · 1 · 0 · 0 · KHz m *
Set the video bandwidth	VB 1 KZ	VID BW · 1 · KHz m *
Set a log scale	LG 5 DB	LOG dB/ · 5 · MHz +dB
Set video average to 5 sweeps	KSG 5	SFT · VID BW · 5
Set input signal to Debuncher Momentum Band 2	SIG: DP2-SCH	PORT 1 cannot be used to connect to Debuncher Momentum Band 2. Instead P35 is used as outlined in step "b" below.

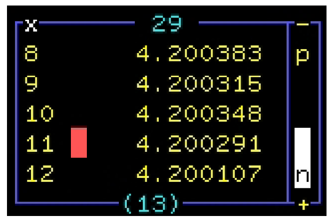
b. If there are any problems connecting SA #1 to the Debuncher Momentum Band 2 signal, you can also make this connection using P35.
   i. Go to Acnet console page P35 and select DEBUNCHER MOMENTUM BAND 2.
   ii. Click ♦Disconnect♦ underneath SA #1 a couple of times.
   iii. Click ↑SA #1↑ and select >DP2-SCH.
   iv. If SA #1 connects to DP2-SCH, you will see the following on P35.

```
 ↑SA  #1↑
 DP2-SCH
♦Disconnect♦
```

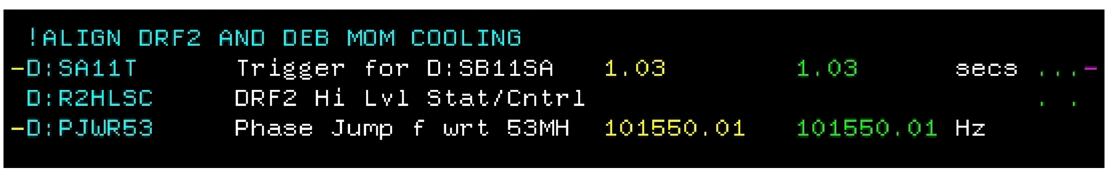
2. Determine the interval between $29 stacking events by completing the below steps.
   a. Go to Acnet console page D33.

b. In the lower left corner, switch from the default ♦Normal ♦ time interval setting to ♦Event Interval ♦.
c. Click on the $29 event.
d. Note the time interval between the $29 events. Below are two screen shots taken with two different timelines. The time between $29 events is 10 seconds in the screen capture on the left, and the time interval between the $29 events is 4.2 seconds in the screen capture on the right. The time interval between $29 events that you will see is determined by your current timeline. If you are at a 3.0 second rep rate, then you will see 3.0 seconds on D33.





3. Go to P8 DRF1 <29>. We will need the three parameters on the bottom of the page (shown here) to complete this tuning procedure. D:SA11T is used to set the Spectrum Analyzer #1 trigger timer, D:R2HLSC is used to turn DRF2 on and off, and D:PJWR53 is used to complete the alignment.



4. Set the spectrum analyzer #1 trigger time (D:SA11T) time to $80 + {interval between $29 events} - {0.2 seconds}. For example, if the time between $29 events is 10 seconds (as in the left screen capture after step 2.d above), then the correct setting for D:SA11T would be $80 plus 9.8 seconds. Likewise, if the time between $29 events is 4.2 seconds (as in the right screen capture after step 2.d above), then the correct setting for D:SA11T would be $80 plus 4.0 seconds. We are looking at the SA just prior to extraction from the Debuncher when the momentum cooling has already cooled the beam.
5. Start a Fast Time Plot (as shown in Figure 5 below) that includes:
   a. X= Time from 0 to 3600 seconds (plot at 15Hz)
   b. Y= A:CPTW01 from 0 to 40 Watts (do not connect points), A:SPTW03 from 0 to 40 Watts, A:PRDCTN from 0 to 24, and D:PTMF from 220 to 240 ps.
6. From P42 start the SA Emulator by clicking on ♦Emulate♦ in the upper right corner of the screen. Leave P42 open, since we will be using to make our screen plots.

Full Length Procedure: Part 2 - Align Momentum Cooling to

590018Hz

7. Go to parameter Page P8 DRF1 <29> and turn off DRF2 by issuing an off command to D:R2HLSC.
8. On the SA Emulator, click the CLR WRT button for trace A. This ensures that our plot has only has data from our intended sample.
9. Wait for approximately five stacking pulses.
10. Measure how close the peak is to the revolution frequency of the beam (590018 Hz). Ideally they would be exactly aligned.
    a. From the Spectrum Analyzer Emulator, find the peak of the distribution. This can be done by doing the following:
        i. In the Marker Section, click on NRM, followed by PK SRC Peak Search.
        ii. Verify that the marker shown on CATV AP #20 is aligned with the peak of the distribution.
        iii. If the marker is not aligned with the peak, then adjust the marker location by clicking on NRM, followed by KNOB Hi. Use the console knob to move the marker until it aligns with the peak of the distribution.
        iv. To read the marker frequency, click on Read which is located in the lower right of the keystroke history window.
        v. Note the value Mrkr freq = in the keystroke history. This is the frequency that where the marker is located.
    b. To convert to revolution frequency, divide the marker frequency by the harmonic number (8813).
    c. The horizontal center of the display is set to 590018 Hz, which is the Debuncher revolution frequency.
    d. Each horizontal box on the Spectrum Analyzer corresponds to approximately a 1.1 Hz offset from the revolution frequency.
    e. If the peaks are off by more than one and a half boxes from center (> 1.65 Hz high or low), consult a Pbar expert for further guidance. A move of more than this might indicate a problem with the cooling and correcting with the RF my lead to problems with D-to-A transfer efficiency.
    f. A plot showing the peaks aligned at 590017 Hz (1 Hz low) is shown below in Figure 1.
11. Adjust the Debuncher Cooling Notch Filter D:PTMF in 2 step intervals by typing < 2s> or < -2s> in the brackets. A step size of 2 corresponds to approximately a 0.5

picosecond change.

a. Do not make changes larger than +/- 4 steps (2 picoseconds).
b. Do not change the notch filter in steps of picoseconds by typing a number in. This creates too large of a change.
c. Increasing D:PTMF will move the beam to the left (lower frequency) on the spectrum analyzer.
d. Decreasing D:PTMF will move beam to the right (higher frequency) on the spectrum analyzer.

12. Repeat steps 9 and 10 until the distribution is aligned to 590018Hz.

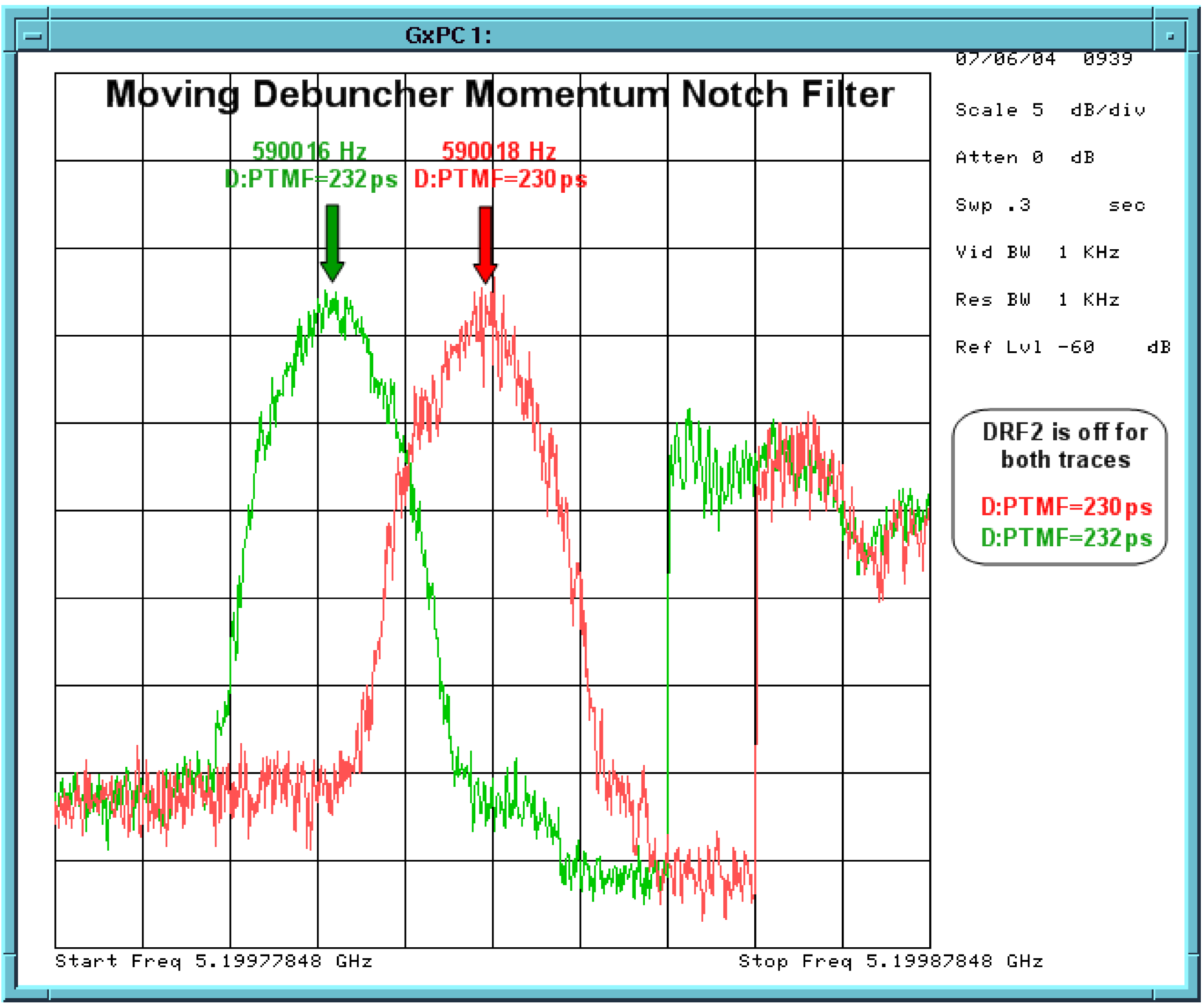


Figure 2: Both traces are with DRF2 off. The green trace shows the revolution frequency two Hz too low. The red trace shows beam at the correct revolution frequency after a small change was made
to the Debuncher Momentum notch filter D:PTMF. Care should be made when making changes to the notch filter.
Consider a one picosecond change to be large. Decreasing D:PTMF moves the distribution to the

right.

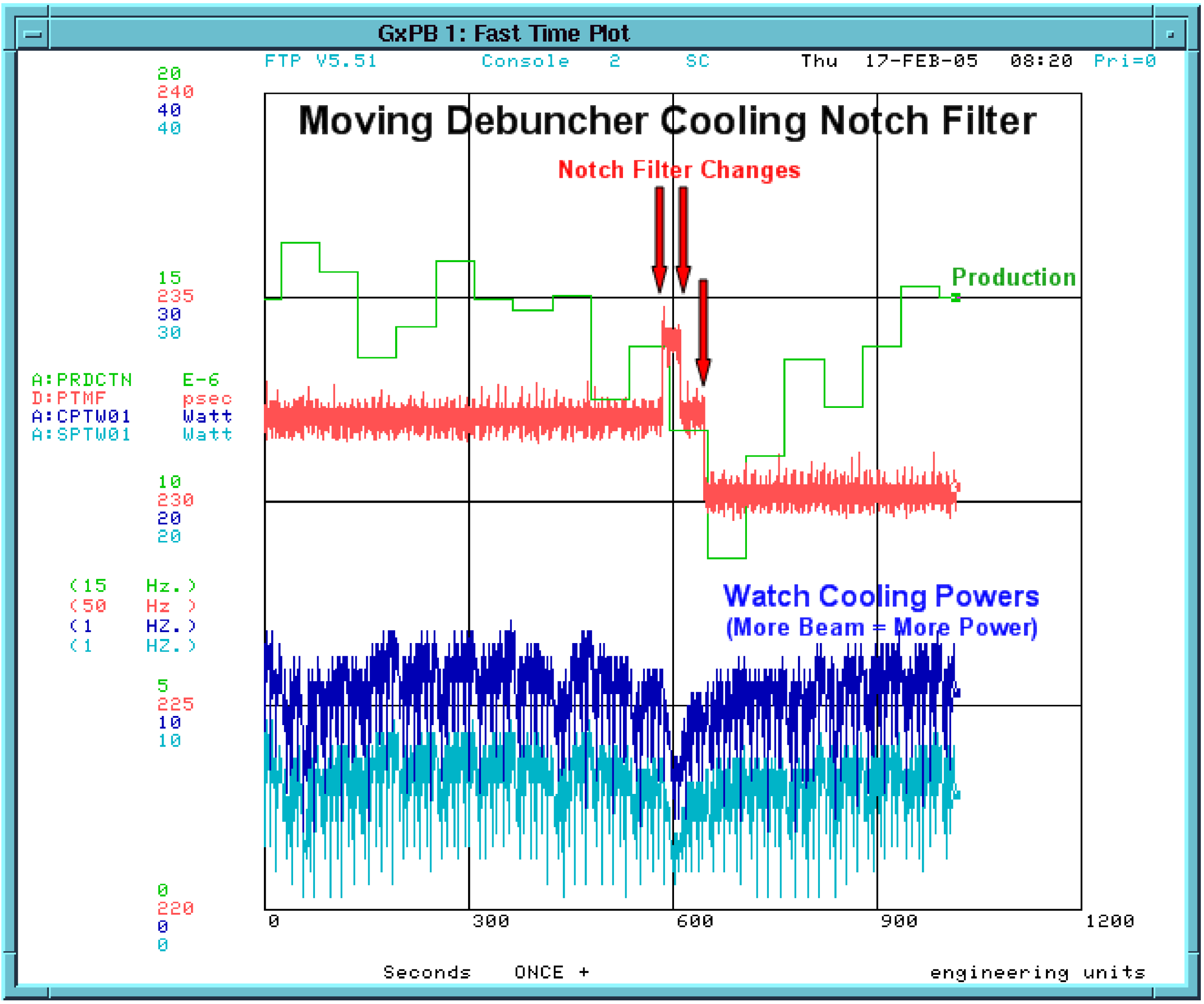


Figure 3: Plotting cooling powers and production while changing D: PTMF allows you to verify that your tuning changes are not adversely effecting stacking.

Full Length Procedure: Part 3 - Align DRF2 with PJWR53

13. Go to parameter Page P8 DRF1 <29> and verify that DRF2 (D:R2HLSC) is still OFF.
14. On the SA Emulator, click the  button for trace A. This ensures that our plot has only has data from our intended sample.
15. Wait for approximately five stacking pulses.
16. From P42, select "Start a new plot" and then click on "Trace A." You should get a plot that looks like the following.
17. Go to parameter Page P8 DRF1 <29> and turn on DRF2 by issuing an on command to

D:R2HLSC.

18. On the SA Emulator, click the 

button for trace A. This ensures that our plot has only has data from our intended sample.
19. Wait for approximately five stacking pulses.
20. From P42 toggle "Add trace to plot" and then click "Trace A." You will get a plot that may look like figure 4 below.

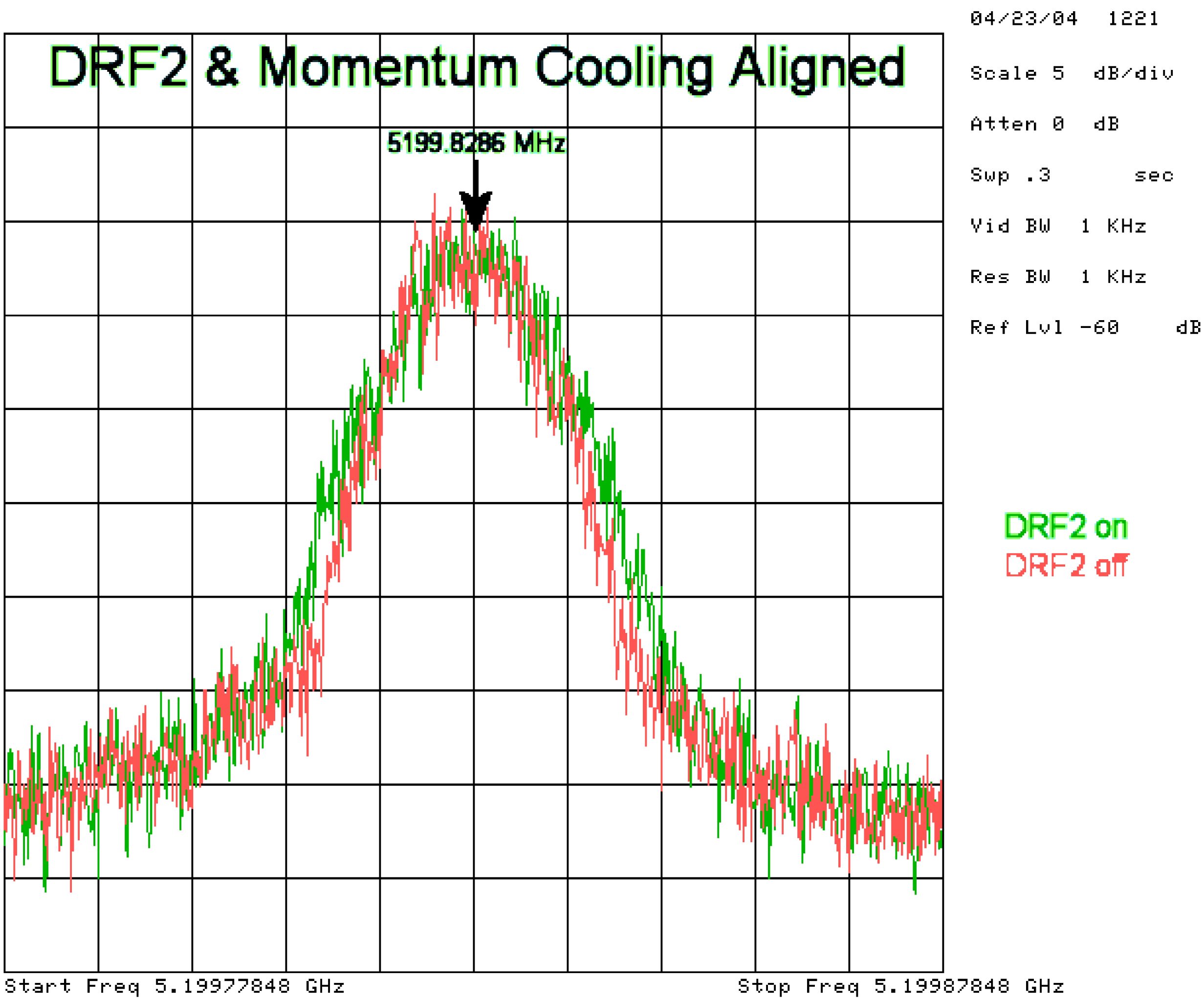


Figure 4: DRF2 and Debuncher Momentum Cooling Aligned.

21. Compare the two distributions on your plot as seen above in Figure 4.
    a. If you completed this procedure in the order listed above, the green trace will be with DRF2 off, and the red trace will be with DRF2 on. If the traces are aligned, then skip to step 22.
    b. If the peaks are not aligned, adjust D:PJWR53 in steps of 10 Hz from parameter Page P8 DRF1 <29>. Figures 6 -8 below show examples of misalignments.

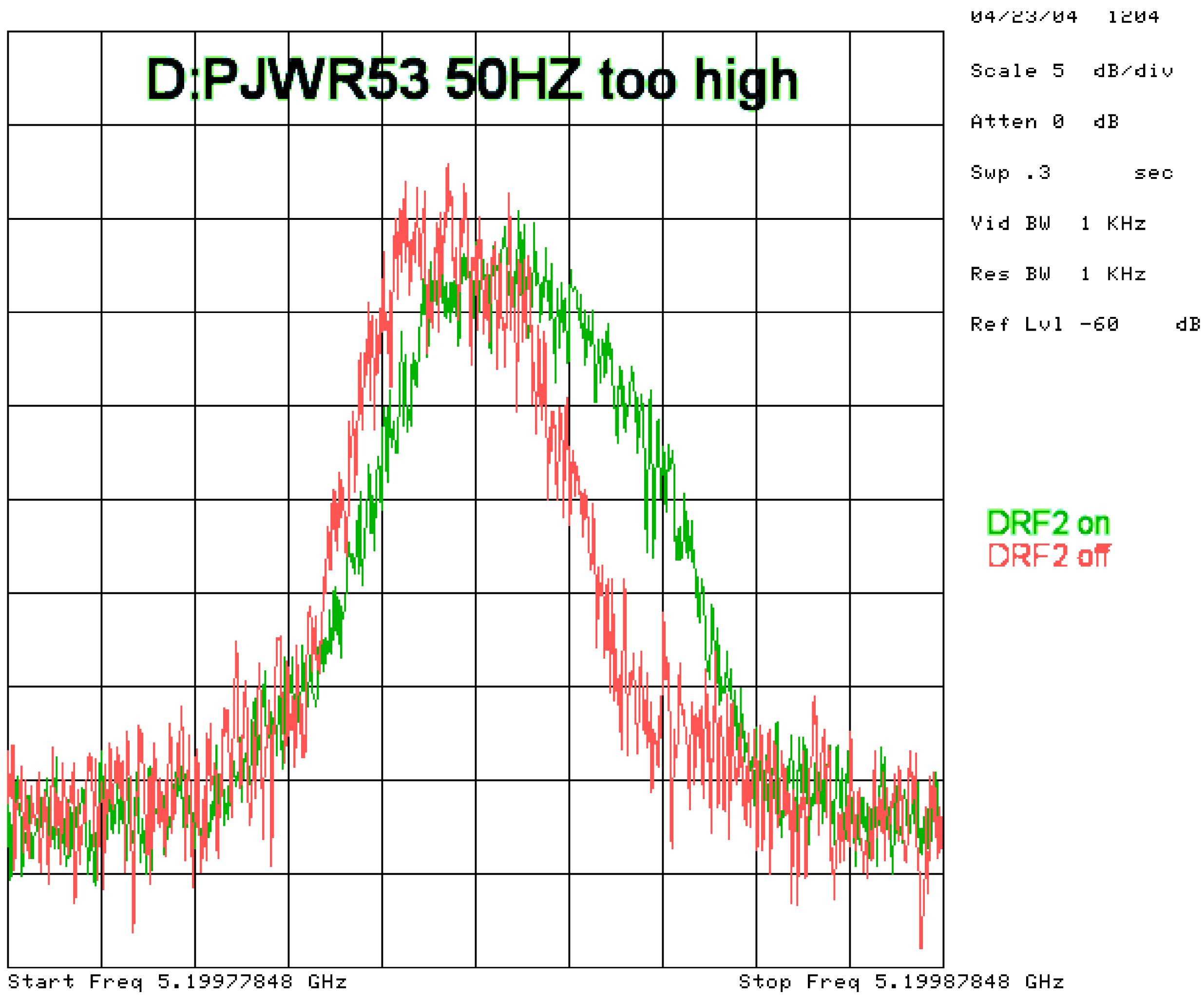


Figure 5: Green trace is with DRF2 on. Red trace is with DRF2 off. In this case D:PJWR53 too high by 50Hz.

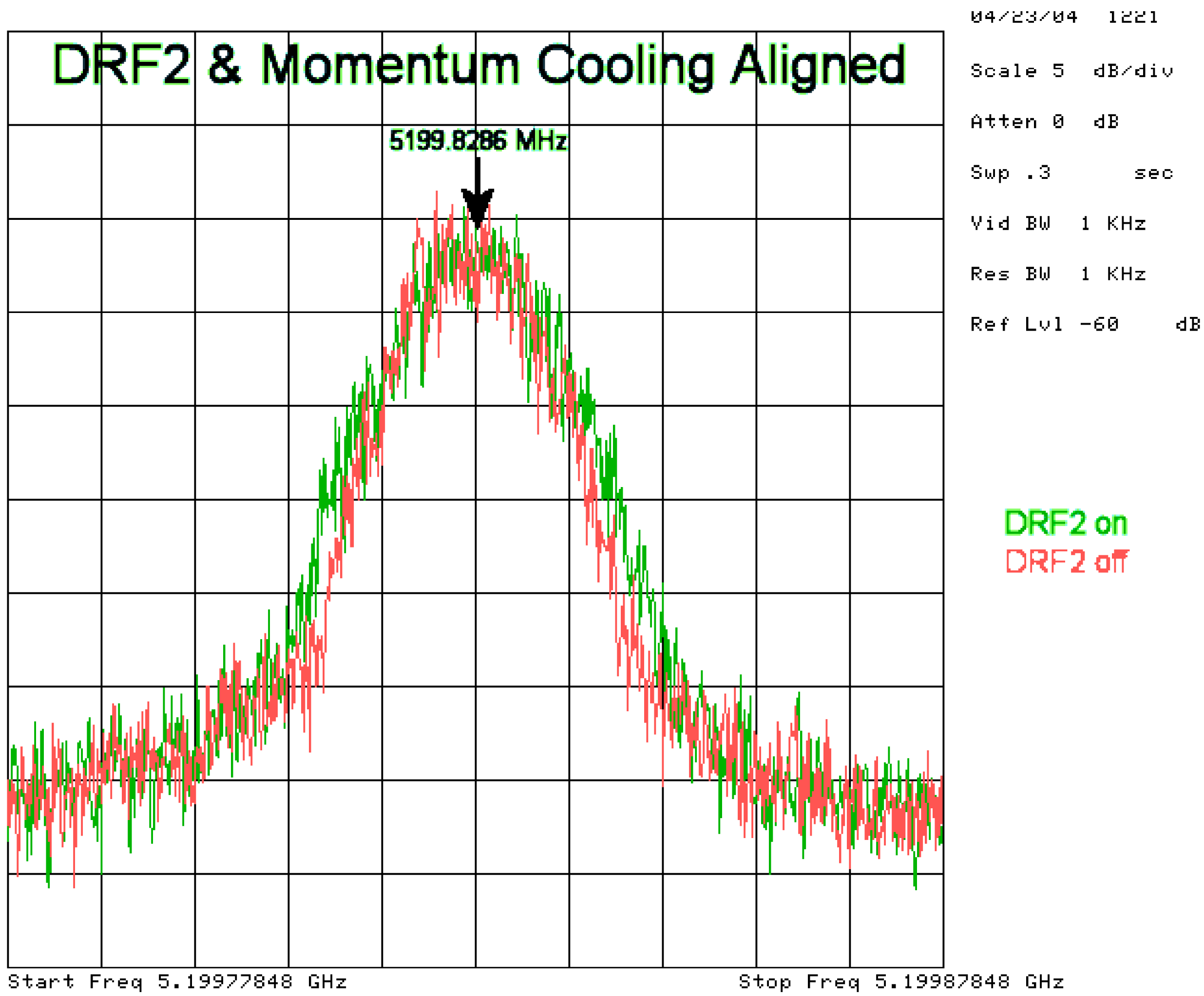


Figure 6: Green trace is with DRF2 on. Red trace is with DRF2 off. In this case, D:PJWR53 is set to approximately the correct value.

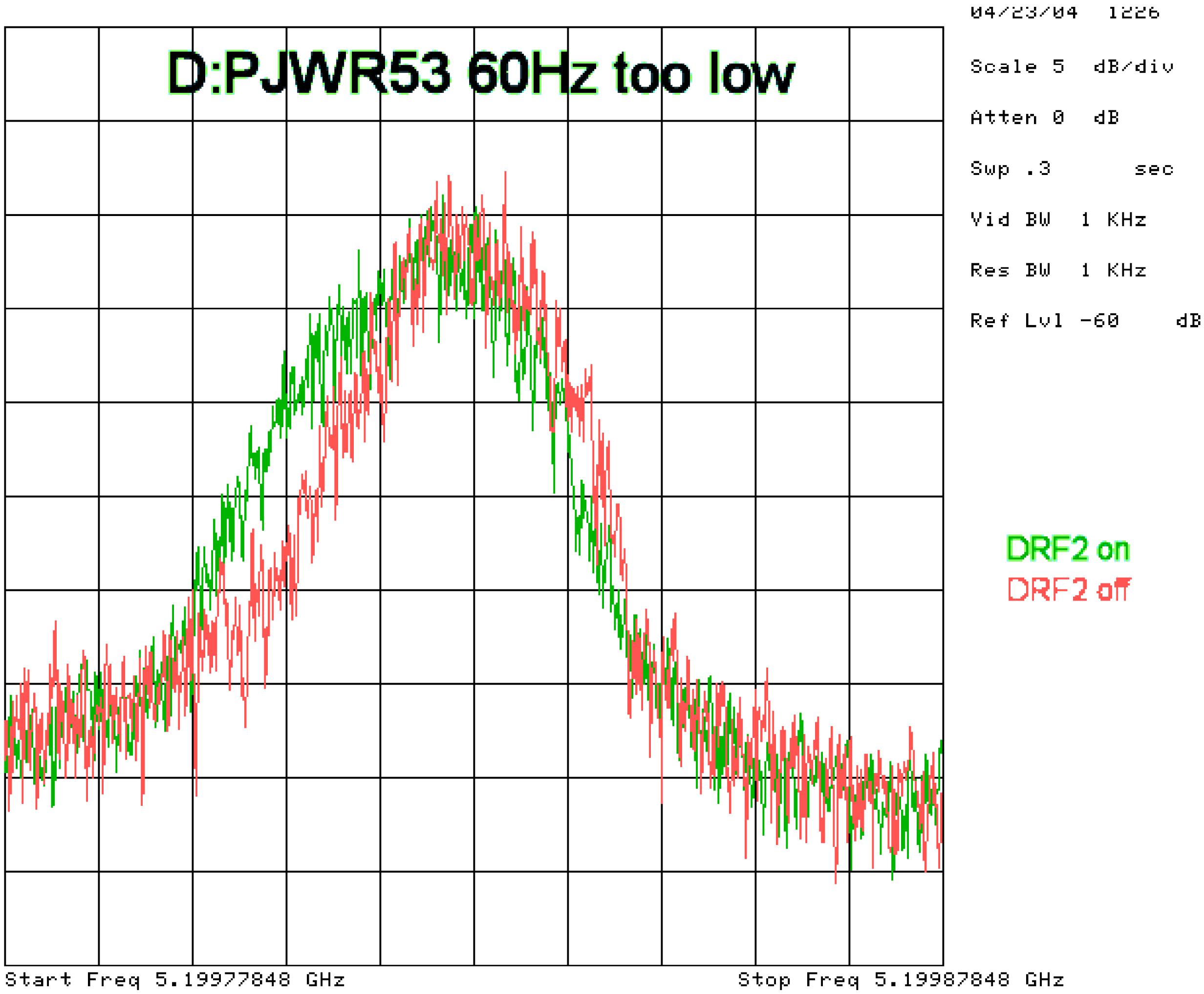


Figure 7: Green trace is with DRF2 on. Red trace is with DRF2 off. In this case, D:PJWR53 is 60Hz too low.

a. After any change to D:PJWR53, plot any four of D:PHERR2 - D:PHERR4 once+ from 0 to 1200 seconds and do not make any further changes until any phase oscillations caused by the change have been damped out. The phase errors should always be plus or minus a half of a degree as shown in Figure 8.

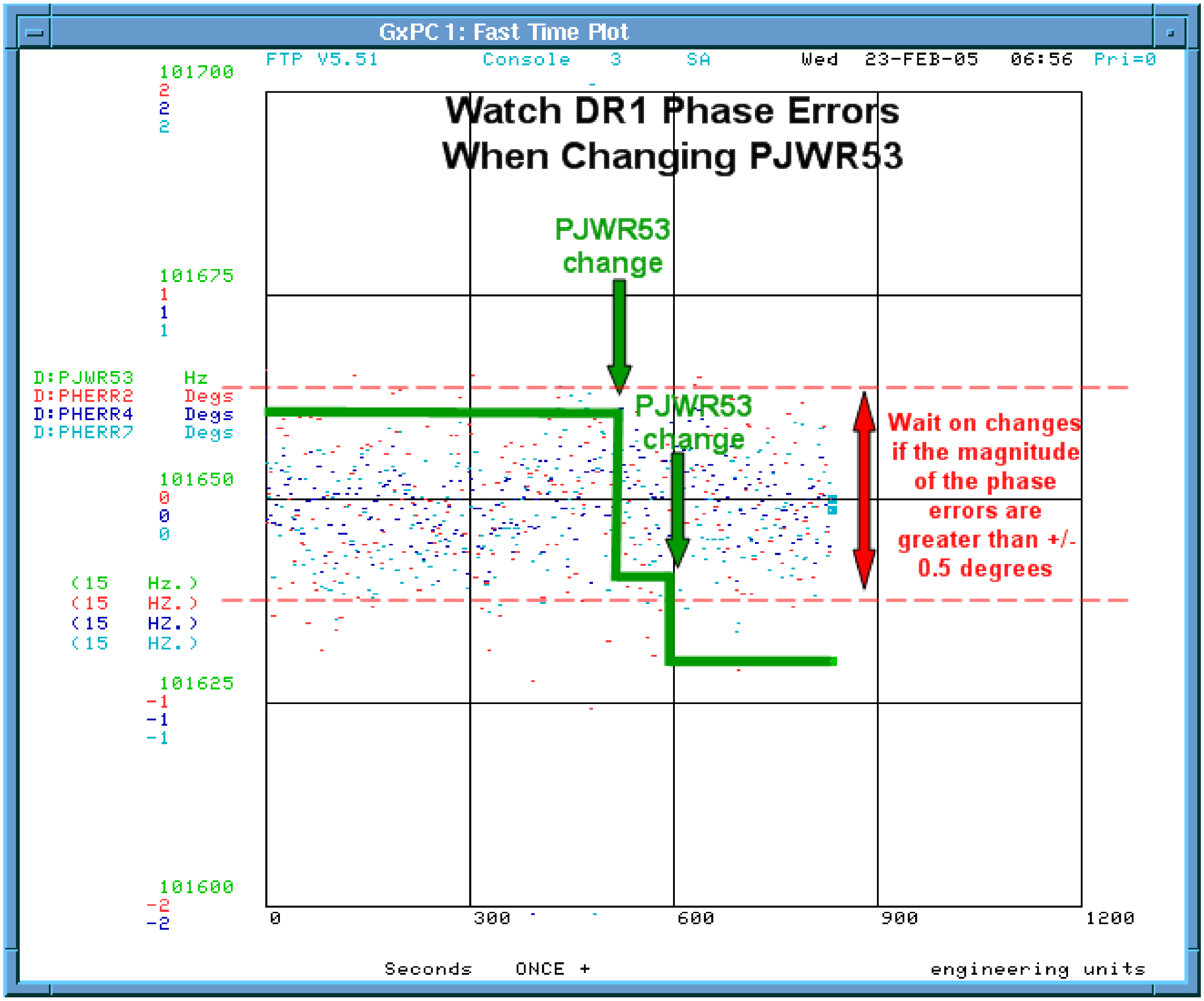


Figure 8:

d. Occasionally, the DRF2 parameters on P8 DRF1 <29> display an Acnet 66 -4 error (DOWNLOADNODATA: Download Source could not acquire the data from the setting's database) in place of the D/A value. The problem can usually be remedied by typing in the appropriate D/A value and interrupting. If this problem is encountered a Pbar expert should be contacted.

e. Increasing D:PJWR53 moves the DRF2 on (green) trace to the right (higher frequency) in relation to the DRF2 off (red) trace.
f. Then repeat steps 13 through 21 above with the new D:PJWR53 setting.
g. Repeat as necessary until the peaks are aligned. If your total changes were more than ~80 Hz, consult a Pbar expert for further guidance.

    h. Plots from a sample alignment are shown below in Figures 1, 2 and 3.
22. Document any tuning changes in the Pbar electronic log book.
23. Return to the default SA #1 bunch rotation display.
    a. Load P41 file #3.
    b. Set D:SA11T to $80 + 1.03 seconds.
    c. Verify that DRF2 (D:R2HLSC) was turned back on.

Do not hurt stacking!

It is important to watch what changing the DRF2 to Debuncher Momentum Cooling alignment does to stacking. Proper alignment between DRF2 and the Debuncher Momentum cooling should result in the narrowest possible momentum spread coming out of the Debuncher. This should translate to more beam making it to the Accumulator, which can be seen in the Stacktail and Core cooling systems in the Accumulator. More beam results in higher power readings on the TWTs. Make sure to watch cooling power and production, as shown in Figure 3 above. Also, watch for changes on the Accumulator injection orbit. Since the beam being delivered to the Accumulator is being changed in this procedure, if the size of the leftover beam on the Accumulator injection orbit increases, ARF1 should be retuned to compensate.

Condensed Procedure:

The following is a condensed checklist of the steps covered in the above procedure. No screen captures nor motivating discussion are provided in this section. For more detail, discussion and screen captures, read the Full Length Procedure above.

1. From P41 load file #75 to SA #1.
2. Go to P8 DRF1 <29>.
3. Set the spectrum analyzer #1 trigger time (D:SA11T) time to $80 + {interval between $29 events} - {0.2 seconds}.
4. Start a Fast Time Plot that includes:
    a. X= Time from 0 to 3600 seconds (plot at 15Hz)
    b. Y= A:CPTW01 from 0 to 40 Watts (do not connect points).
5. Align Notch Filter to 590018HZ, by completing the following steps.
    a. Turn off DRF2 by issuing an off command to D:R2HLSC.
    b. On the SA Emulator, click the "Clear Write" button for trace A.
    c. Wait for approximately five stacking events to pass.
    d. From P42, select "Start a new plot" and then click on "Trace A."
    e. If the peak of the trace is not at the center of the display (590018Hz), then move D:PTMF in plus or minus 1 step increments. Decreasing PTMF moves the

trace to the right, while increasing PTMF moves the trace to the left.
    f. On the SA Emulator, click the "Clear Write" button for trace A.
    g. Wait for approximately five stacking events to pass.
    h. From P42, select "Add trace to plot" and then click on "Trace A."
    i. Repeat steps 9-12 until the peak is aligned to the center of the display.
6. Save the P42 captures to save file for later documentation.
7. Align DRF on and off traces with PJWR53 by completing the following steps.
    a. Leave DRF2 off to get one more plot in steps 16-18.
    b. On the SA Emulator, click the "Clear Write" button for trace A.
    c. Wait for approximately five stacking events to pass.
    d. From P42, select "Start a new plot" and then click on "Trace A."
    e. Turn on DRF2 by issuing an on command to D:R2HLSC.
    f. On the SA Emulator, click the "Clear Write" button for trace A.
    g. Wait for approximately five stacking events to pass.
    h. From P42 toggle "Add trace to plot" and then click "Trace A."
    i. Compare the two distributions on your P42 plot.
        i. If the peaks are not aligned, adjust D:PJWR53 in steps of 10 Hz from parameter Page P8 DRF1 <29>.
        ii. Increasing D:PJWR53 moves the DRF2 on (red) trace to the right (higher frequency) in relation to the DRF2 off (green) trace.
        iii. If cooling power goes up in your FTP, then you are getting more beam to the Accumulator.
        iv. Repeat steps a through i until the peaks of the two distributions are aligned.
8. Document any tuning changes in the Pbar electronic log book.

For a more detailed treatment of this procedure, please see the Full Procedure.