Align DRF2 and Debuncher Momentum Cooling

Modified: 9-17-04 by Brian Drendel
Created: 4-23-04 by Brian Drendel adapted from tuning procedures implemented by Dave Vander Meulen
Send comments and suggestions to the Pbar Tuning Guide Admins

Production Release 2.26

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^{o}F. This device cannot be tuned.

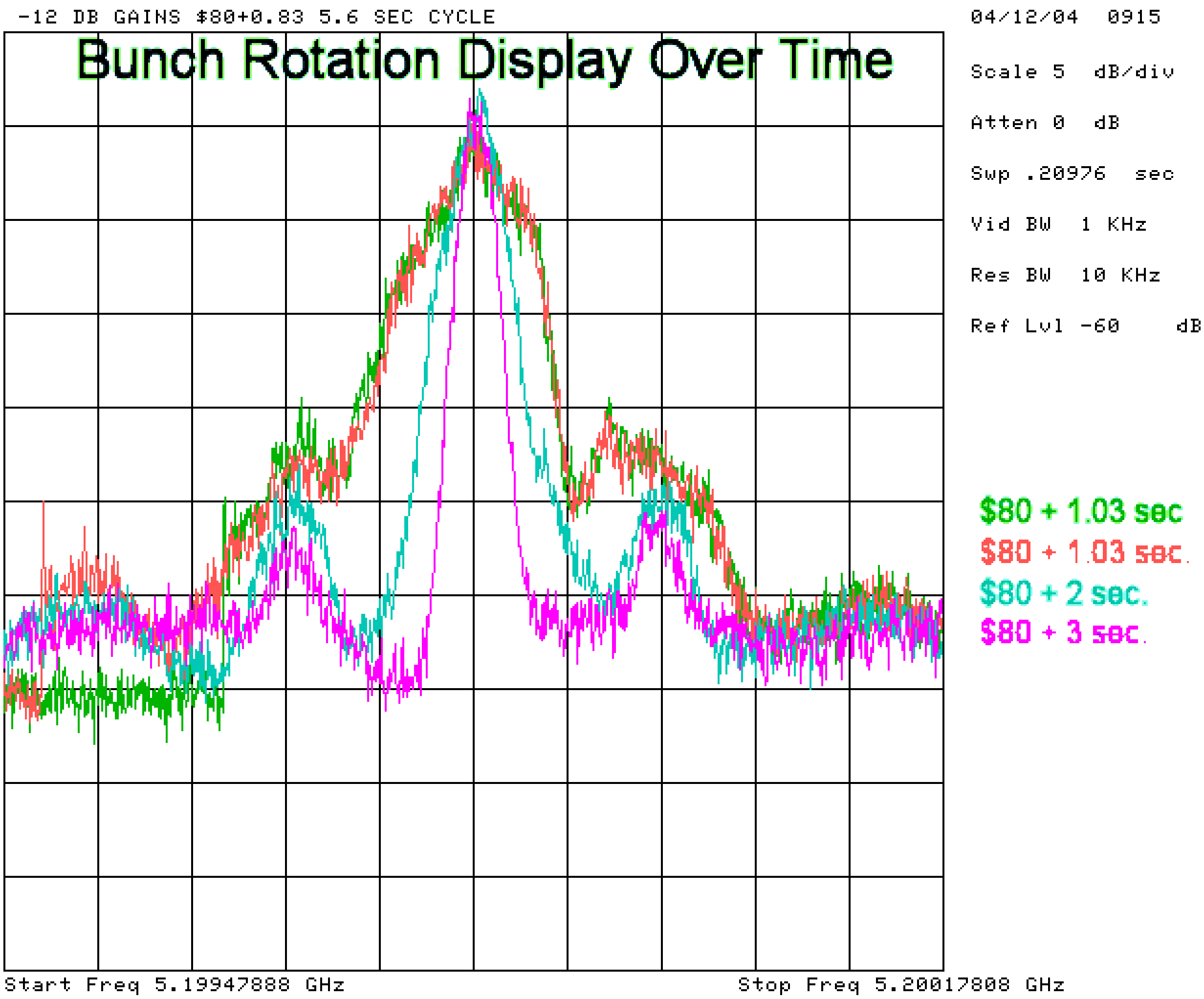


Figure 1: This is the standard bunch rotation display triggered at different times. It represents the momentum width of the Debuncher beam at different times in the cycle. The green and red traces are at the bunch rotation time, the cyan trace is at 1.0 seconds after bunch rotation and the magenta trace 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 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. We then compare the distributions with DRF2 on versus DRF2 off. If the peaks of the distributions do not line up, we tune D:PJWR53 in steps of 10 Hz, and repeat the measurements and adjustments until the peaks are aligned. Once the peaks are aligned, we calculate how close the peaks are to the beam revolution frequency. We 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.

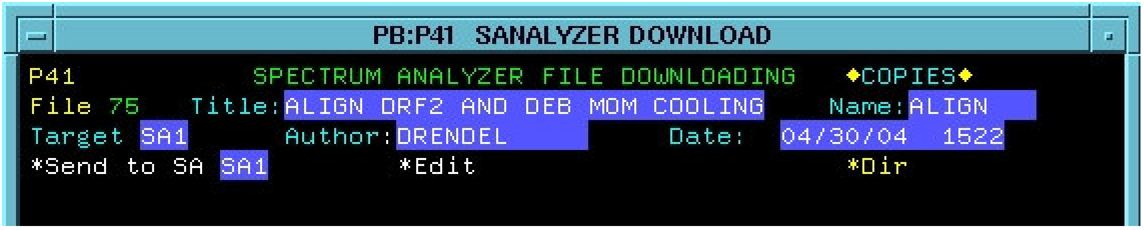
Setup

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

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	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*

band 2.		*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.

x	29
1	10.002498
2	10.003327
3	10.003179
4	10.003216
(5)	

x	29
8	4.200383
9	4.200315
10	4.200348
11	4.200291
12	4.200107
(13)	

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.

```
 !ALIGN DRF2 AND DEB MOM COOLING
-D:SA11T       Trigger for D:SB11SA    1.03         1.03       secs ...-
 D:R2HLSC      DRF2 Hi Lvl Stat/Cntrl                               . .
-D:PJWR53      Phase Jump f wrt 53MH   101550.01    101550.01 Hz
```

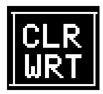
4. Set the spectrum analyzer #1 trigger time (D:SA11T) time to $80 + {interval between $29 events} - {0.2 seconds}. For example, if the time between $29 events is 10 seconds (as in the left screen capture after step 2.d above), then the correct setting for D:SA11T would be $80 plus 9.8 seconds. Likewise, 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)

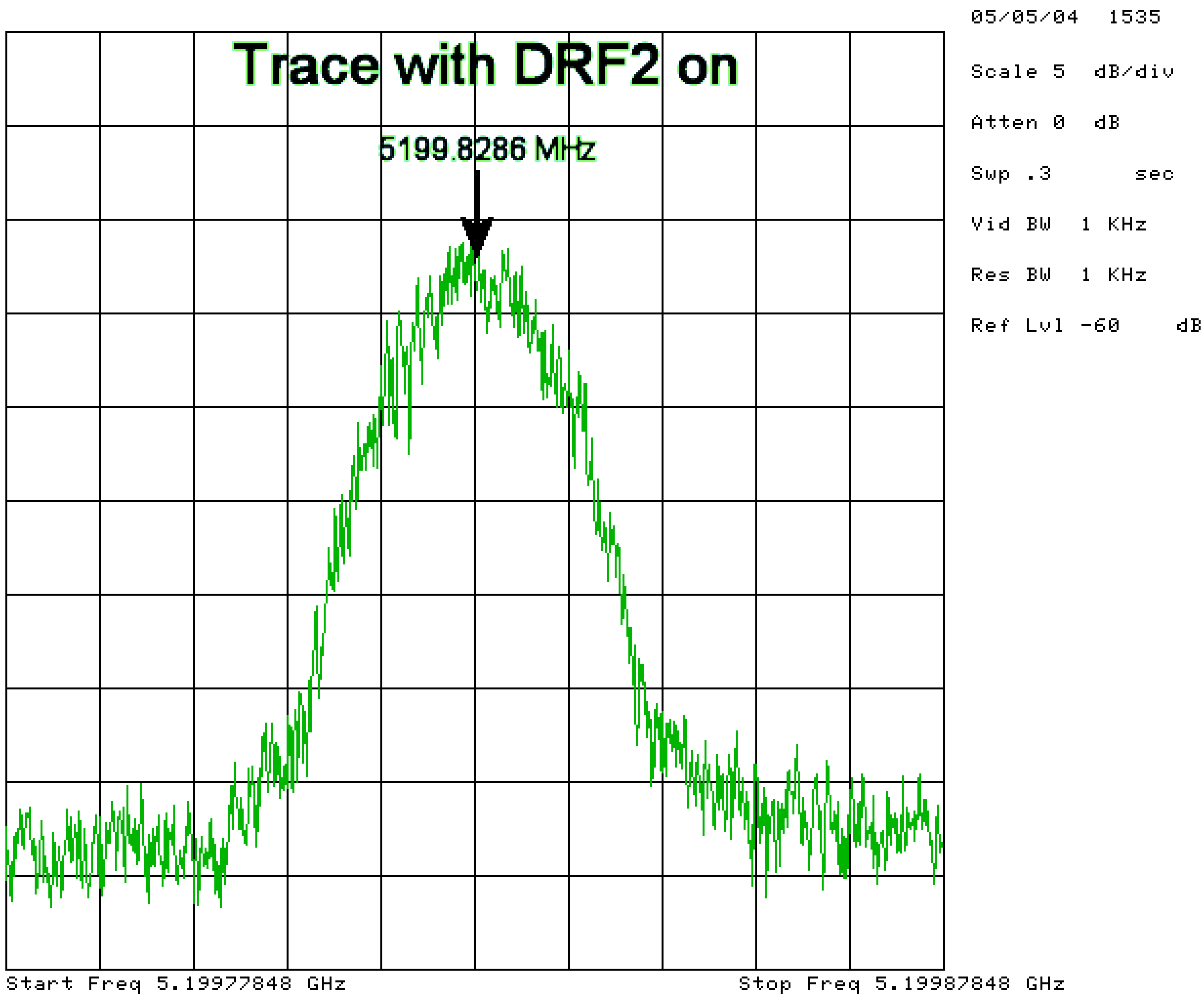
   b. Y= A:CPTW01 from 0 to 40 Watts (do not connect points).

6. From P42 start the SA Emulator by clicking on  in the upper right corner of the screen. Leave P42 open, since we will be using to make our screen plots.

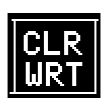
7. On the SA Emulator, click the  button for trace A. This ensures that our plot has only has data from our intended sample.

8. Wait for approximately five $29 events to pass.

9. From P42, select "Start a new plot" and then click on "Trace A." You should get a plot that looks like the following.



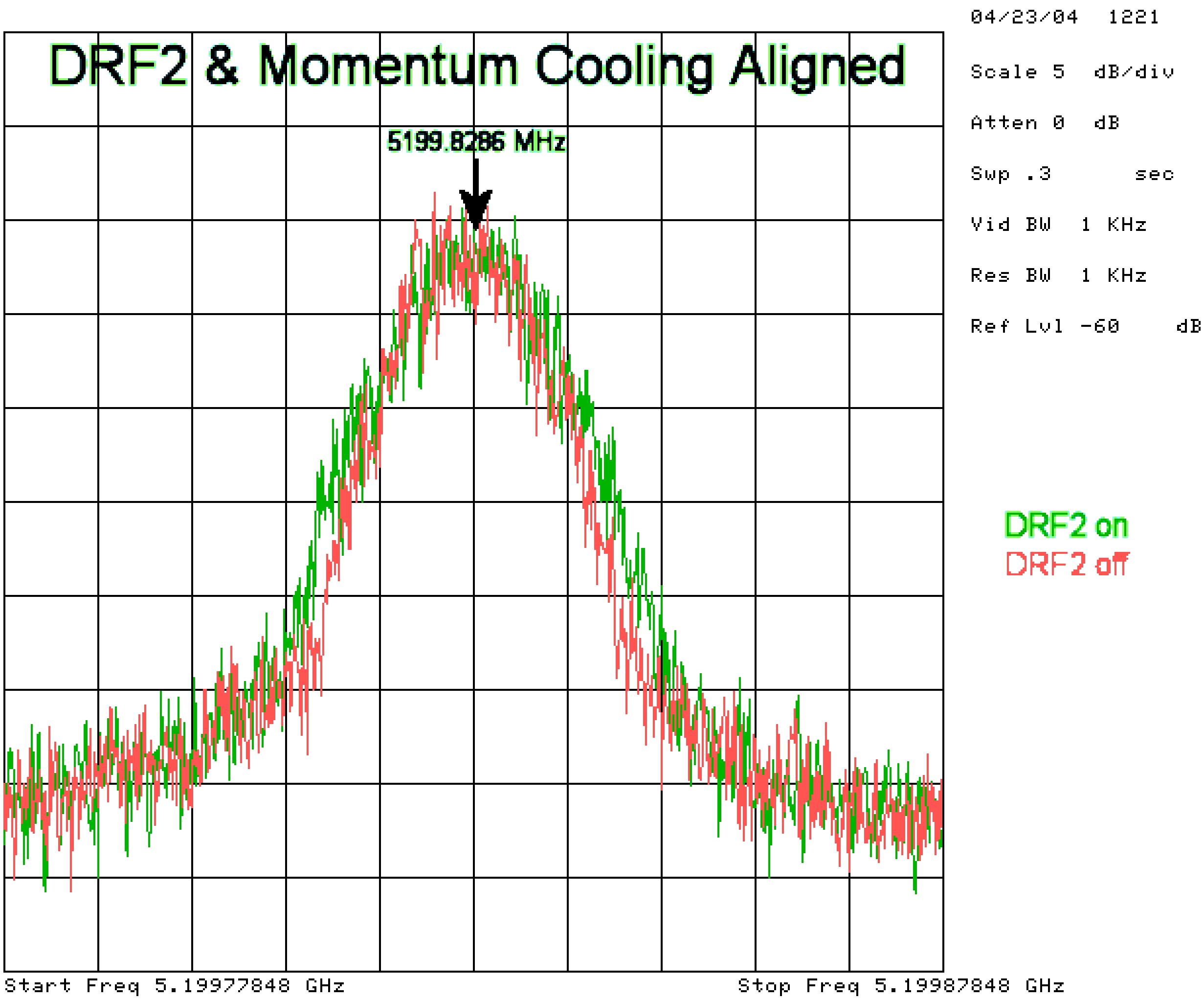
10. Go to parameter Page P8 DRF1 <29> and turn off DRF2 by issuing an off command to D:R2HLSC.

11. On the SA Emulator, click the 

button for trace A. This ensures that our plot has only has data from our intended sample.

12. Wait for approximately five $29 events to pass.

13. From P42 toggle "Add trace to plot" and then click "Trace A." You will get a plot that may look like the following.



14. Go to parameter Page P8 DRF1 <29> and turn on DRF2 by issuing an on command to D:R2HLSC.

15. Compare the two distributions on your plot.
    a. If you completed this procedure in the order listed above, the green trace will be with DRF2 on, and the red trace will be with DRF2 off.

    b. If the peaks are not aligned, adjust D:PJWR53 in steps of 10 Hz from parameter Page P8 DRF1 <29>.

    c. 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.

```
 !ALIGN DRF2 AND DEB MOM COOLING
-D:SA11T      Trigger for D:SB11SA   2.5          2.5        secs ...-
 D:R2HLSC     DRF2 Hi Lvl Stat/Cntrl                              . .
-D:PJWR53     Phase Jump f wrt 53MH   66  -4      101550.01 Hz
```

d. Increasing D:PJWR53 moves the DRF2 on (green) trace to the right (higher frequency) in relation to the DRF2 off (red) trace.

e. Then repeat steps 1 through 14 above with the new D:PJWR53 setting.

f. Repeat as necessary until the peaks are aligned. If your total changes were more than ~80 Hz, consult a Pbar expert for further guidance.

g. Plots from a sample alignment are shown below in Figures 1, 2 and 3.

16. After the peaks have been aligned, measure how close the peaks are to the revolution frequency of the beam. 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 4.

17. Document any tuning changes in the Pbar electronic log book.

18. 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.

What should we see?

Figures 1 through 3 below are plots that show the results of completing the alignment. The first plot shows D:PJWR53 set 50Hz too high. The Green trace is with DRF2 on and the red is with DRF2 off. The peak of the Beam with DRF2 off is of lower frequency (further to left on plot). The second plot shows D:PJWR53 set to approximately the correct value. The peaks of the beam with DRF2 on (green) and DRF2 off (red) are nearly aligned. The third plot shows D:PJWR53 set 60 Hz too low. The peak of the DRF2 off (red) beam is of higher frequency (further to the right).

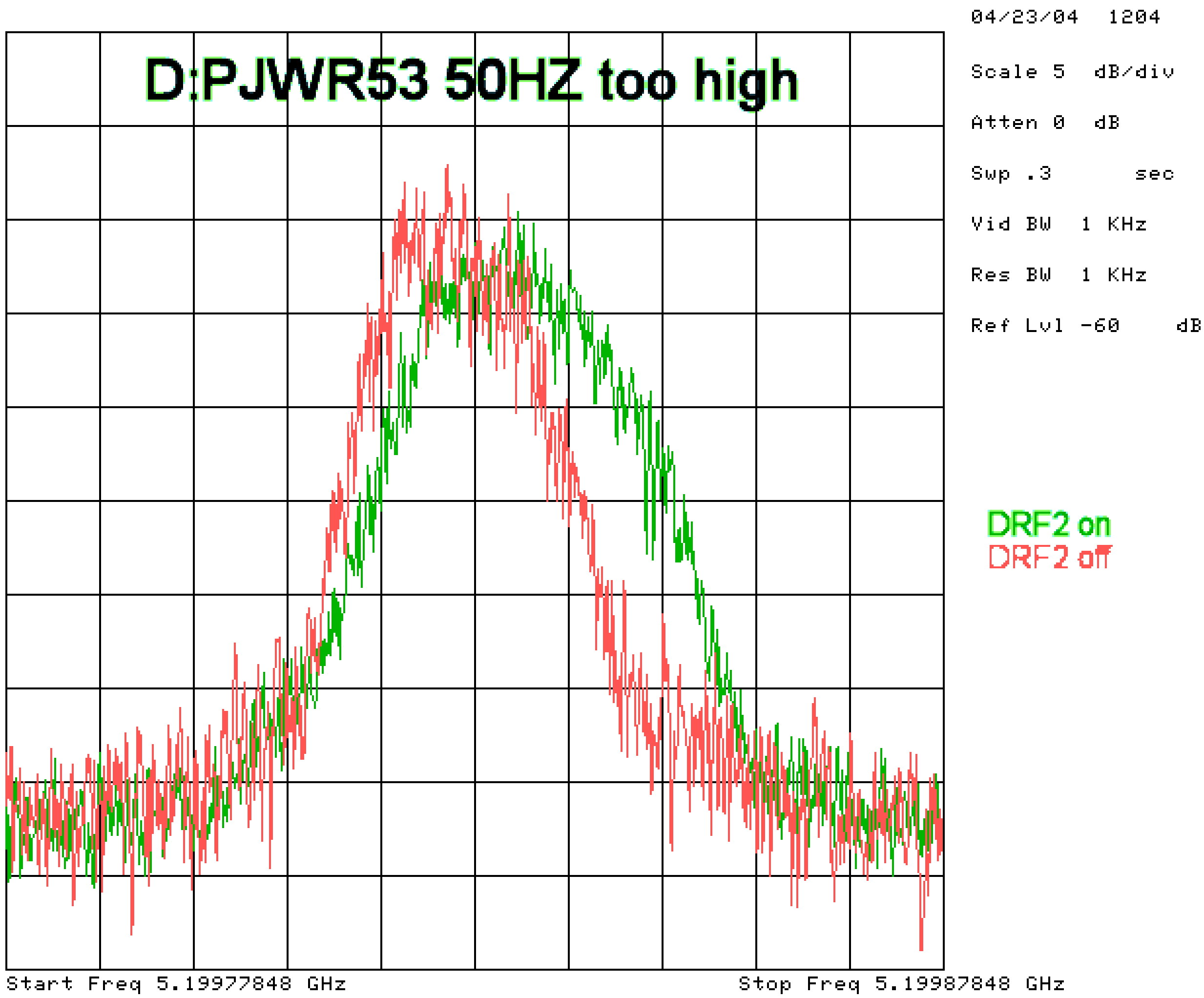


Figure 2: Green trace is with DRF2 on. Red trace is with DRF2 off. In this case D:PJWR53 too high by 50Hz.

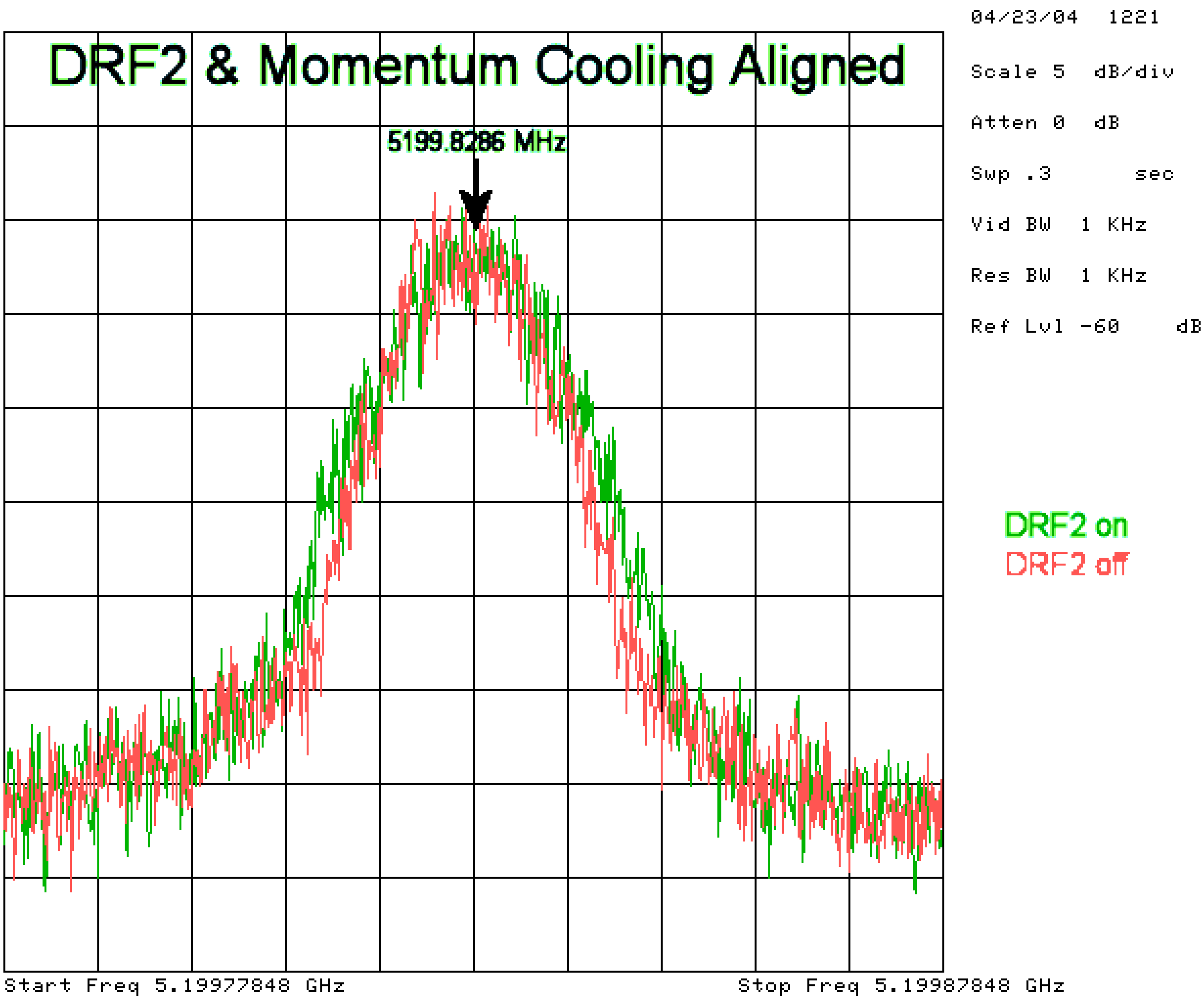


Figure 3: Green trace is with DRF2 on. Red trace is with DRF2 off. In this case, D:PJWR53 is set to approximately the correct value.

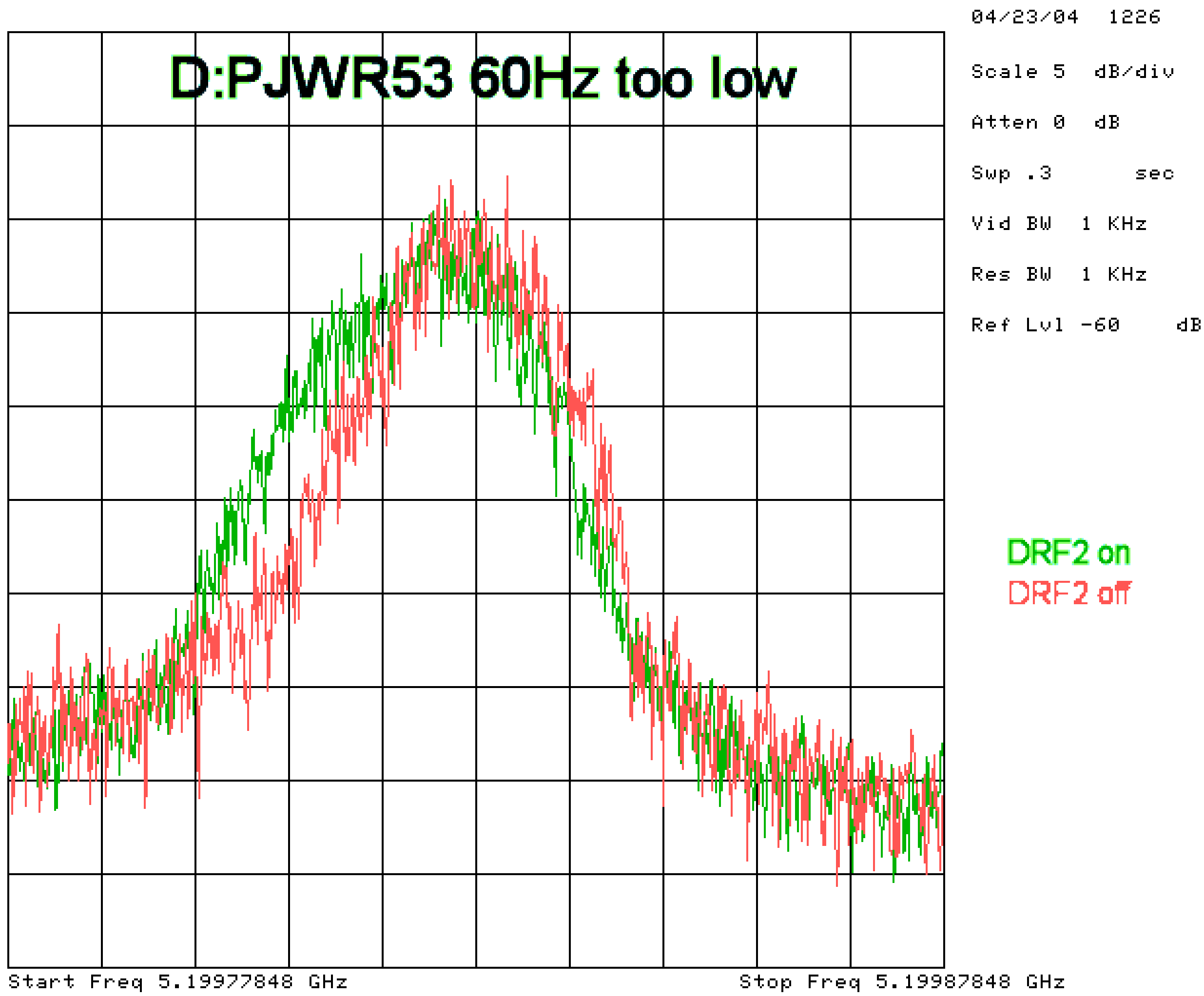


Figure 4: Green trace is with DRF2 on. Red trace is with DRF2 off. In this case, D:PJWR53 is 60Hz too low.

It is important to watch that changing the alignment does not hurt stacking. Figure 5 below shows a plot that includes the core cooling response (A:CPTW01) to alignment changes. A keen-eyed observer may notice that the below plot was started with AUTO resolution instead of 15 Hz. Plotting at 15 Hz will give a better resolution and is highly recommended. Also, we should make sure to pay attention to A:CPTW01 instead of the A:SPPSUM on this plot. A:SPPSUM (Stacktail total power) only updates at 1 Hz , and the updates have been shown to be asynchronous with power changes in the cooling systems. As a result, some Pbar experts recommend using A:CPTW01 instead of A:SPPSUM.

In Figure 5, we can see a direct correlation between the quality of DRF2/Debuncher Momentum Cooling alignment and power in the cooling systems. The arrow marked "1" in Figure 4 shows the cooling levels when D:PJWR53 was set 50 Hz too high as in Figure 2. The arrow marked "2" in Figure 6 is where we had made a total of five 10 Hz steps to get the cooling aligned as shown in Figure 3. We can see both the Stacktail and Core cooling power increased. The timeline only had stacking $29 events, the rep rate did not change, and beam from Main Injector was stable. This tells us that the beam to the Debuncher was most likely consistent during this time. There were no Accumulator cooling tuning changes made during this time of this study, so the increased power in the cooling system can be assumed to be a result of more beam making it to the Accumulator, which is likely a direct result of our cooling alignment. To demonstrate this, the arrow marked "3" in Figure 6 is the result of moving D:PJWR53 in six more 10 Hz steps (this time too low) to the value shown in Figure 4. The cooling powers both decrease as a result. The arrow marked "4" in Figure 6 is where we put D:PJWR53 back to its optimum value as seen in Figure 3. Again the core cooling power increased showing that more beam was making it to the Accumulator.

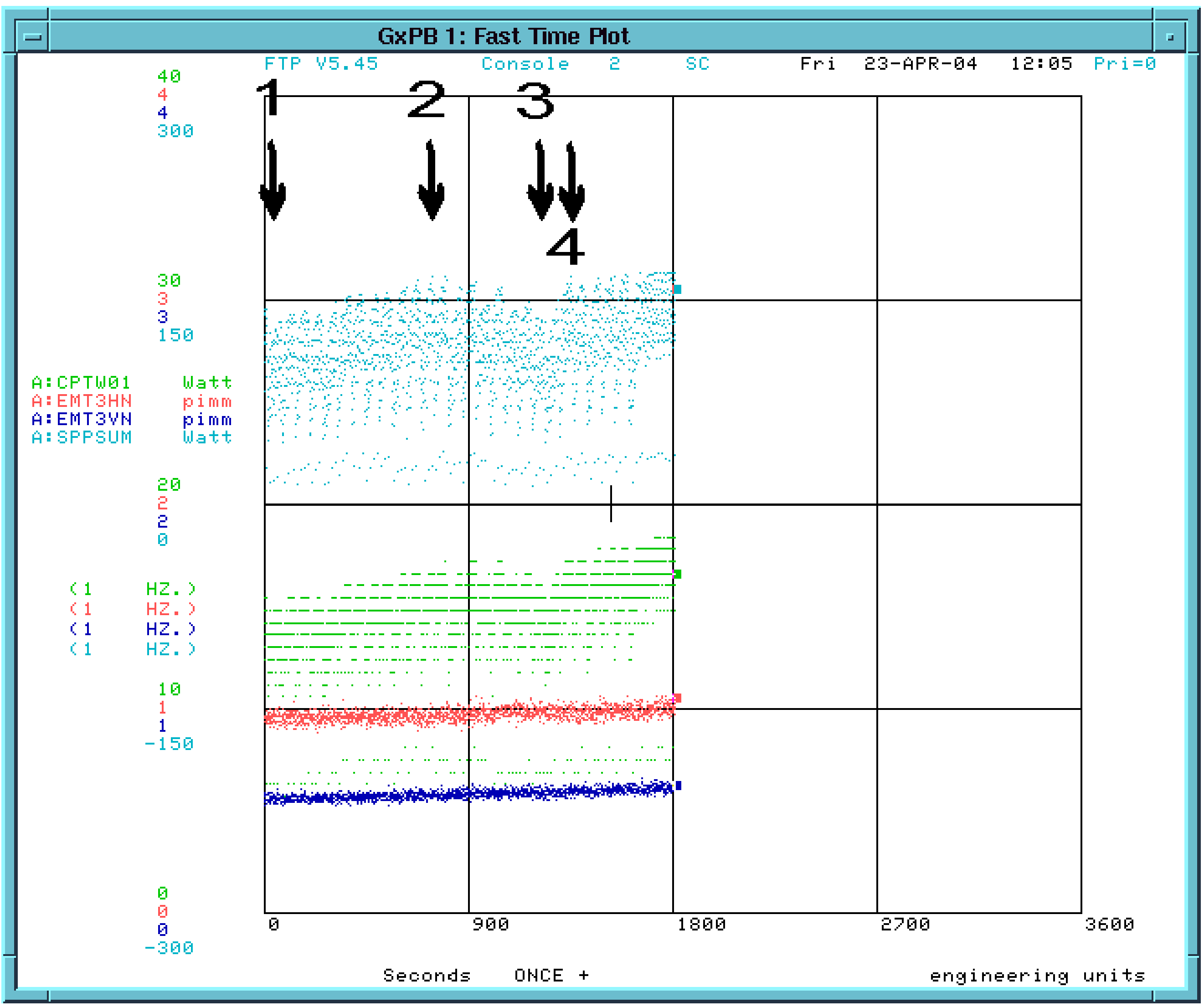


Figure 5: Response of Accumulator Cooling to alignment. "1" marks where D:PJWR53 was set too low (Setting shown in Figure 2). "2" marks where D:PJWR53 was aligned (Setting shown in Figure 3). "3" marks D:PJWR53 set too high (Setting shown in Figure 4). "4" marks putting D:PJWR53 back to its aligned value (Setting shown in Figure 3).

In all of the examples to this point, the final alignment is centered on the plot. This puts the cooling at exactly the revolution frequency of the beam (590018 Hz). However, the frequency that the cooling works at drifts as much as much as one or two hertz over time. Figure 6 below shows the final alignment taken a couple of weeks after the one done in Figure 3. We see that in Figure 6 alignment occurred approximately one box to the left of the center. The peak on the below plot was measured at 5.1998209×10^9 Hz. You can calculate the revolution frequency by dividing the measured frequency by the harmonic number (8813) that the scope is setup to look at. So the cooling is running at $(5.1998209 \times 10^9 \text{ Hz}/ 8813) = 590017$ Hz, which is one hertz lower than the revolution frequency of 590018 Hz. If the peak drifts more than one and a half boxes from the center (> 1.65 Hz high or low), a Pbar expert should be consulted for further instructions. 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. Plotting and data logging the Debuncher cooling oven temperature D:POVTMP would be a good start if this appears to be the problem.

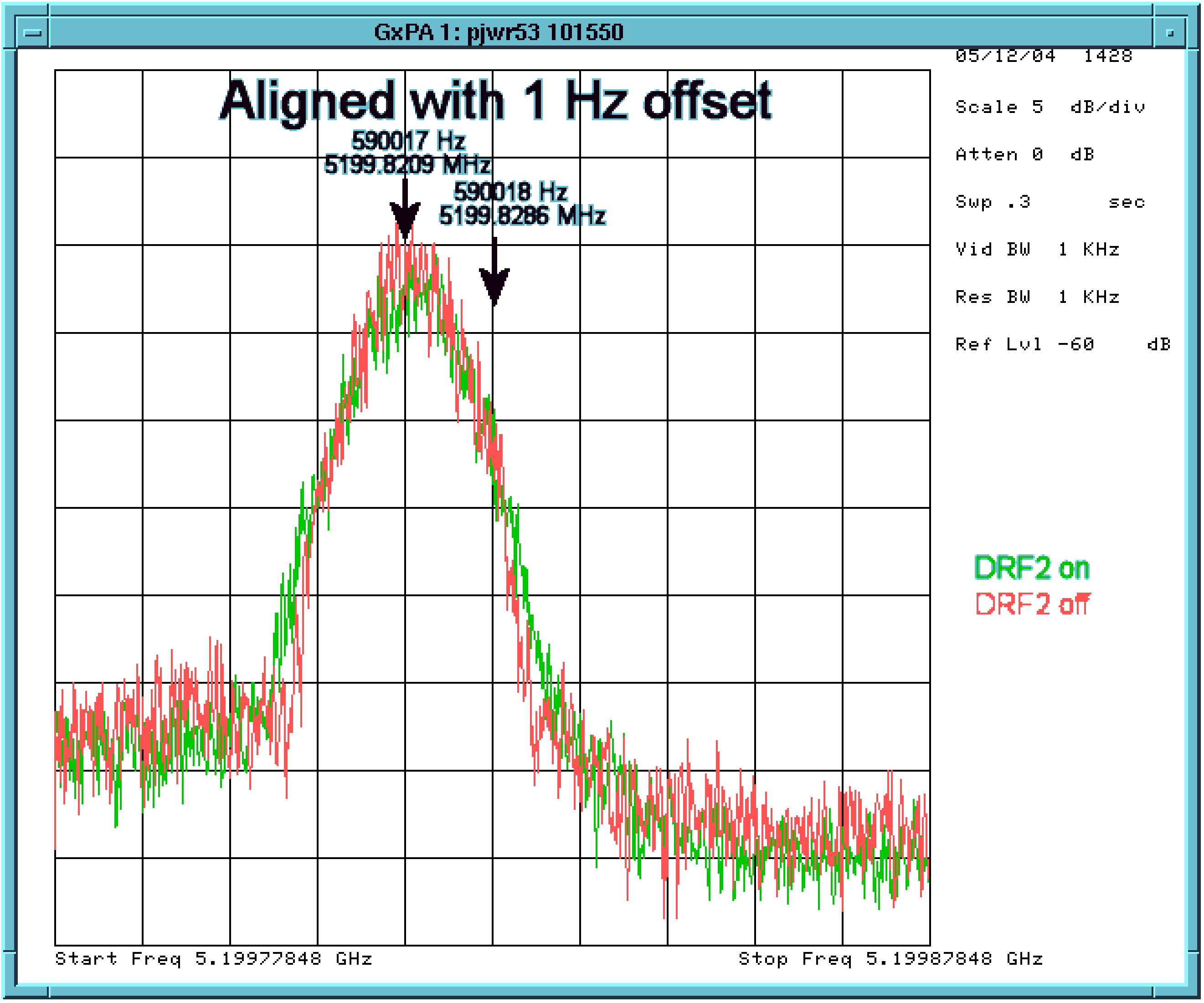


Figure 6: Alignment in this case happens at a revolution frequency of 5900017 Hz (5199.8209 MHz on the spectrum analyzer) , which is approximately one hertz lower than the default revolution frequency of 590018 Hz (5199.8286 MHz on the spectrum analyzer). If the peaks in the distribution are off center horizontal by more than one and a half boxes , then a Pbar expert should be consulted for further instructions.

Occasionally the frequency will drive far enough that a Pbar expert needs to take action. Figure 7 below shows an example of the beam being 2 Hz too low. In this case the Debuncher momentum notch filter, D:PTMF, was raised by 2 psec to re-center the distribution. A Debuncher Momentum notch filter change should only be made under the direction of a Pbar expert.

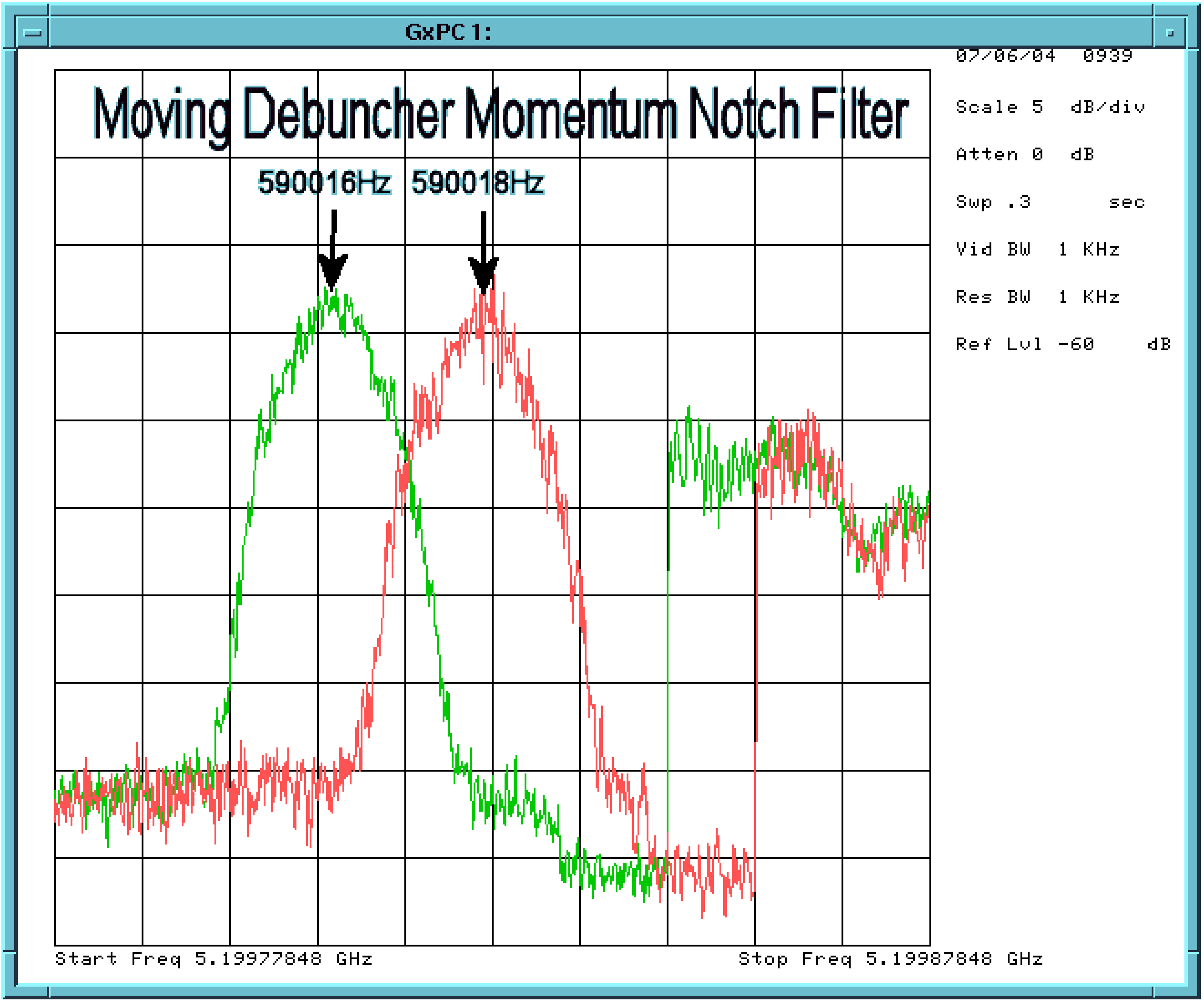


Figure 7: Both traces are with DRF2 off. The green trace shows the revolution frequency two Hz too low. The red trace shows beam at the correct revolution frequency after a small change was made to the Debuncher Momentum notch filter. This type of change should only be made under the direction of a Pbar expert.

After changing the notch filter, the alignment needs to be re-checked. Figure 8 below shows the cooling now aligned at the correct revolution frequency.

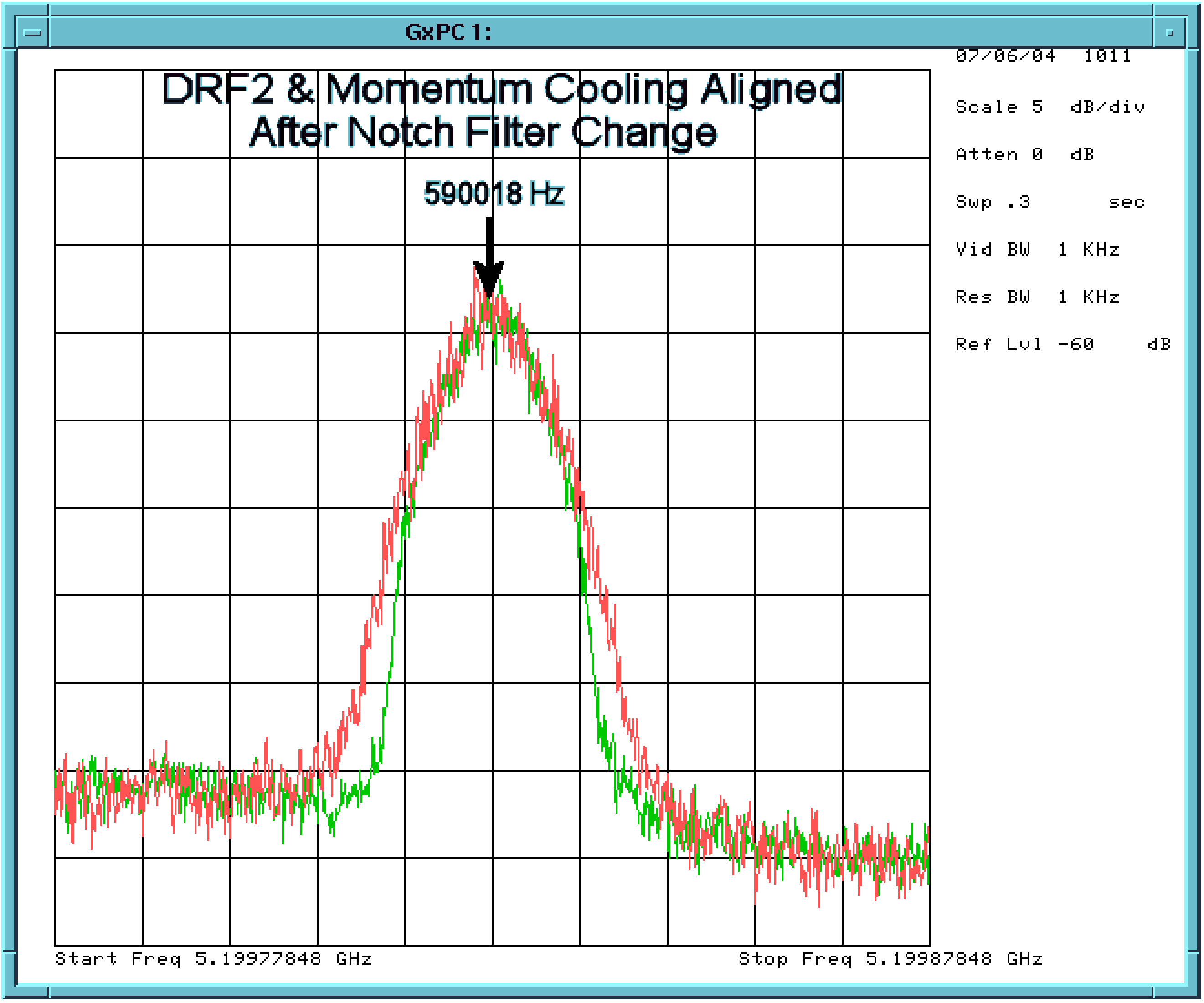


Figure 8: DRF2 and Debuncher Momentum cooling were re-aligned after making the notch filter change.

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. On the SA Emulator, click the "Clear Write" button for trace A.
6. Wait for approximately five $29 events to pass.
7. From P42, select "Start a new plot" and then click on "Trace A."
8. Turn off DRF2 by issuing an off command to D:R2HLSC.
9. On the SA Emulator, click the "Clear Write" button for trace A.
10. Wait for approximately five $29 events to pass.
11. From P42 toggle "Add trace to plot" and then click "Trace A."
12. Turn on DRF2 by issuing an on command to D:R2HLSC.
13. Compare the two distributions on your P42 plot.
    a. If the peaks are not aligned, adjust D:PJWR53 in steps of 10 Hz from parameter Page P8 DRF1 <29>.
    b. Increasing D:PJWR53 moves the DRF2 on (green) trace to the right (higher frequency) in relation to the DRF2 off (red) trace.
    c. If cooling power goes up in your FTP, then you are getting more beam to the Accumulator.
    d. Repeat steps 5 through 13 until the peaks of the two distributions are aligned.
14. Measure how close the aligned peaks are to the revolution frequency of the beam.
    a. Turn on the marker by clicking on the "NRM" button , followed by the "Peak Search" button.
    b. If the marker is not on the peak, then adjust the marker location by clicking on the "NRM" button, followed by the "Knob Hi" button.
    c. Use the console knob to move the marker until it aligns with the peak of the distribution.

d. If the peaks are off by more than one and a half boxes from center, consult a Pbar expert for further guidance.

15. Document any tuning changes in the Pbar electronic log book.

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