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Measuring and Adjusting Accumulator Tunes

Last Modified: 10/13/2005 14:39:47 by Brian Drendel
Created: 7-30-04 by Brian Drendel
Portions adapted from *"Adjusting Accumulator Tunes"* by J. Morgan - May 5, 1994
Send comments and suggestions to the **Pbar Tuning Guide Admins**

Production Version 1.04

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. Revision History: The revision history lists the dates and changes made in each major revision of this document.
3. Prerequisites: This is a list of what items need to be tuned before you can complete this procedure.
4. Background: The background section gives an overview of what a tune is, how to measure a tune and how quadrupoles are used to control the tune. The background section is divided into the following three sub-sections.
   a. What is a tune? This section provides an accelerator physics background on tunes and resonance lines.
   b. Measuring the tune. This section outlines how we can measure the tunes in the Accumulator.
   c. Quadrupoles: This section outlines what quadrupole circuits are used to control the tune in the Accumulator.
5. Setup: This section outlines what setup is required prior to starting this procedure.
6. Full Length Procedure: This is the full length version of the procedure, complete with

screen captures and detailed discussion. We divide the procedure into the following sections.

a. Measuring the Tunes: We present three different methods that can be used to measure the tunes.
   i. Measure the Tunes using P43: Explains the standard method of using P43 to measure the tunes.

   ii. Speeding up the Tune measurement: This section explains how to use the SCITEQ to speed up the tune measurement process.

   iii. Measuring the Tunes manually: This section shows how you would measure the tunes using the spectrum analyzers.

b. Adjusting the Accumulator Tunes: Once the Accumulator tunes have been measured using one of the above methods, this section shows how to properly adjust the tunes.

7. **Special Cases**: There are times when care must be taken when adjusting the Accumulator Tunes. Two examples are covered below:
   i. Tunes during shot setup: The material for this section already exists in Jim Morgan's document "Some Pbar Guidelines that help maximize Luminosity," which provides guidelines for adjusting the Accumulator tunes during a Collider Run II shot setup.

   ii. Tunes during Accumulator emittance instabilities: The tunes can be very sensitive at larger stacks, leading to emittance instabilities. This section shows how to adjust the tunes during these conditions.

8. Condensed Procedure: This is a condensed version of the procedure without any screen captures, nor discussion.

9. Printable Version: The HTML version of this document is optimized for viewing. Go to the printable version for a PDF file optimized for printing.

Revision History:

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

1. Draft Release v0.00 (5-5-94 by Jim Morgan): Completed the original procedure.

2. Draft Release v0.20 (7-30-04 by Brian Drendel): Completed updated version of

document including new detailed background section.

3. Production Release v1.00 (9-17-04 by Brian Drendel): Passed review of pbar on-call and Mike Syphers. Document graduates from Draft to Produciton.
4. Production Release v1.01 (11-11-04 by Brian Drendel): Added to Document Database Document 1453.
5. Production Release v1.02 (7-18-05 by Brian Drendel): The nominal tunes on both the stacking and shot lattices were changed to $\nu_x = .683$ and $\nu_y = .681$.
6. Production Release v1.03 (10-13-05 by Brian Drendel): Modified procedure to match new template. Added Revision History and Printable Documents sections.
7. Production Release v1.04 (10-13-05 by Brian Drendel): Updated Document Database Document 1453.

Prerequisites:

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

1. Accumulator Bend Bus

Background: What is a tune?

A detailed accelerator physics orient background on tunes was already covered in the Measuring and Adjusting Debuncher Tunes Document. You can review that document for an in-depth treatment of the theory. As a result, we will only cover material specific to the Accumulator tune measurement and changing process.

The default tunes in the accumulator are $\nu_x = .696$ and $\nu_y = 8.684$ and are normally kept within 0.0005 of these values **(NOTE: On 7-18-05 the nominal tunes on both the stacking and shot lattices were changed to $\nu_x = .683$ and $\nu_y = .681$.)**. Figure 1 shows a tune space diagram with up to 10th order resonance lines. The 10th order sum resonance lines are the red lines that intersect at $\nu_x = .7$ and $\nu_y = .7$. The 5/7 resonance is represented by the vertical red line at $\nu_x = .714$.

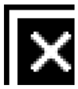


Figure 1: Resonance diagram generated from Acnet Page P192 showing the default Accumulator tunes at ν_x = .696 and ν_y = 8.684

(NOTE: On 7-18-05 the nominal tunes on both the stacking and shot lattices were changed to ν_x = .683 and ν_y = .681.).

One important point to remember is that when we measure the tunes in the Accumulator, we are doing so at the core. The tunes at other locations in the Accumulator aperture, like the injector orbit or deposition orbit, can have different tune values. Figure 2 shows the results of a beam measurement study that examined the behavior of the tunes across the entire Accumulator aperture.

Figure 2: Beam Measurement of tunes across the Accumulator aperture. As beam was moved across the Accumulator aperture with ARF3, the upper horizontal and vertical sideband signals were measured from the horizontal and vertical Schottky pickups to calculate the horizontal and vertical tunes.

The top and bottom plots in Figure 2 represent the horizontal and vertical tunes respectively. The x-axis is the accumulator frequency and the y-axis is the tune value. The thin green line is the familiar Accumulator longitudinal profile, which was added to the diagram to give the reader a reference for the Accumulator frequencies on the x-axis of the two plots. Three vertical blue lines were added to this drawing to represent the locations of the injection, deposition and core orbits. Looking at the horizontal tune (top plot) from the injection orbit to the deposition orbit, we see that the tune starts somewhere above 0.7 and increases to .714, which is the 5/7 resonance line, and then decreases back down to around the default value of .696. Efforts have been made by Pbar experts to minimize this tune excursion. Luckily, beam is being moved by ARF1 at the time of the tune excursion and does not spend any significant time near the 5/7 resonance. Looking at the horizontal tune through the Stacktail and into the core, beam appears to have a fairly constant tune close to the default value of 0.696. The vertical tune also changes across the aperture, but not as severely. Going from the injection to the deposition orbit, the tune moves from about .686 to about .680 and then back up to about .682. From the deposition orbit to the core, the tune is fairly constant though increases slightly at the end to the default value of .684.

Another way to look at this is to combine Figures 1 and 2 to show the path that the tunes traverse on the tune space diagram. Figure 3 was generated by Steve Werkema and shows an accelerator physics model of the tune path from the injection/extraction orbit to the core orbit. Only the center tune is displayed as no tune width is shown in this diagram. Labeled are the 7th, 10th and 13th order resonances. If you carefully compare Figures 2 and 3, you will see that the tune paths are very similar. The biggest difference is the beam measurement in Figure 2 shows that we approach the 5/7 horizontally closer than that depicted in the theoretical model of Figure 3.

Figure 3: Physics model of the tune trajectory across the Accumulator aperture.

When quadrupoles are changed to adjust the tune, the tunes are changed across the entire aperture. If you increase the horizontal tune at the core, you are also increasing the horizontal tune across the entire aperture. Likewise, if you decrease the horizontal tune at the core, you are also decreasing the horizontal tune across the entire aperture. You can visualize a tune change in one plane (horizontal or vertical) by this by looking at Figure 2 and imagining that you are moving the entire tune distribution for that plane up or down without changing the shape or slope of the distribution. You can also visualize a tune change in one plane (horizontal or vertical) by looking at Figure 3 and imaging moving the blue line right and left for a horizontal tune change and up and down for a vertical tune change.

After examining Figures 2 and 3, it should not be overly difficult to imagine cases where a tune change could put the core at a more stable tune, but another part of the Accumulator aperture at a less stable tune. For example, if you moved the horizontal tune high enough you may be able to get the injection orbit to sit on the unstable 5/7 resonance while the core sits at a slightly lower and more stable area. Correcting the tune variation across the aperture involves higher order correction elements and is beyond the scope of this document. Changing the slope of the tune distribution across the diagram in Figure 2 would involve sextupoles, changing the end points would involve octupoles and changing more detailed structure would involve more complicated changes.

Background: Measuring the tune.

In order to measure the tunes Acnet page P43 connects a spectrum analyzer to Accumulator Schottky detectors in the Pbar tunnel. There are three Accumulator Schottky detectors: longitudinal, vertical and horizontal. The longitudinal detector can be used to determine the revolution frequency of the beam, the horizontal Schottky detector can be used to determine the horizontal tune, and the vertical Schottky detector can be used to determine the vertical tune.

Figure 4 below shows the output of a P43 tune measurement. P43 first connects to the Accumulator Longitudinal Schottky to measure the revolution frequency of the beam. This is the plot on the lower center of Figure 4. The Schottky Detectors are most sensitive to beam signals at the 126th harmonic of the revolution frequency. Since we know the revolution frequency of the Accumulator Core is approximately 628890 Hz, then we know that the 126th harmonic is located at approximately 628890 Hz * 126 = 79.2401MHz. P43 sets the center frequency of the spectrum analyzer equal to that value and looks for a peak. P43 then divides the frequency where the peak is located by 126 to get the revolution frequency of the beam.

Figure 4: Typical P43 tune measurement

Once the revolution frequency has been calculated, P43 connects to two separate sidebands in each plane to calculate the tune. We already know that the Schottky Detectors are most sensitive to beam signals at the 126th harmonic of the revolution frequency. The sidebands actually overlap with each other, so the closest sidebands to the 126th harmonic are the lower sideband of the 127th harmonic and the upper sideband of the 125th harmonic. As a result, we should get our best tune measurements from these sidebands. P43 connects a spectrum analyzer to the appropriate Schottky (horizontal or vertical) and sets the center frequency on the spectrum analyzer to the approximate sideband frequency. How does P43 calculate the sideband frequency?

A generic equation for the upper sideband frequency is

(1)

where f_s is the sideband frequency, ν is the fractional portion of the tune (horizontal or vertical), h is the harmonic, and f_{rev} is the revolution frequency of the beam.

Likewise, a generic equation for the lower sideband frequency using the same variables is:

(2)

As discussed earlier, P43 determines the revolution frequency f_{rev} from the longitudinal Schottky measurement, where f_{rev} = 628890 Hz in our example from Figure 4. We also know we want to measure the lower sideband of h =127 the upper sideband of h =125. The default horizontal tune is ν_x = .696 and vertical tune is ν_y = .684. Putting all of this together, we use equations (1) and (2) to get an equations for the upper and lower sideband frequencies in each plane.

The equations for the sidebands are

(horizontal lower sideband) (3)

(vertical lower sideband) (4)

(horizontal upper sideband) (5)

(vertical upper sideband) (6)

P43 then completes four sideband measurements, one at a time in the following order.

1. Connects the horizontal Schottky to the spectrum analyzer, sets the center frequency to that shown in equation (3) and then measures the horizontal lower sideband frequency f_s. This is the upper right-hand plot in Figure 4.

2. Connects the vertical Schottky to the spectrum analyzer, sets the center frequency to that shown in equation (4) and then measures the vertical lower sideband frequency f_s. This is the lower right-hand plot in Figure 4.

3. Connects the horizontal Schottky to the spectrum analyzer, sets the center frequency to that shown in equation (5) and then measures the horizontal upper sideband frequency f_s. This is the upper left-hand plot in Figure 4.

4. Connects the vertical Schottky to the spectrum analyzer, sets the center frequency to that shown in equation (6) and then measures the vertical upper sideband frequency f_s. This is the lower left-hand plot in Figure 4.

P43 then calculates the tune from each sideband using the following equations:

(Tune from horizontal lower sideband) (7)

(Tune from vertical lower sideband) (8)

(Tune from horizontal upper sideband) (9)

(Tune from vertical upper sideband) (10)

where f_s is the sideband frequency measured from the transverse Schottky sideband, ν_x and ν_y are the fractional portion of the horizontal and vertical tunes respectively, and f_{rev} is the revolution frequency of the beam measured from the longitudinal Schottky.

P43 actually provides two different measures of the sideband frequency. The peak tune (PK TUNE) uses the peak of the sideband frequency f_s.. This is basically the same as taking the spectrum analyzer marker and finding the peak value. The center of mass tune (CM TUNE) uses the center of mass of the sideband frequency f_s. This involves integrating the area under the curve and picking the center of that distribution. The tunes in the Accumulator are somewhat coupled, so the center of mass tune skews the results due to the tune reflection from the other plane. When in doubt, trust the peak tunes more than the center of mass tunes as long as the marker peaks line up with the true peaks of distribution. If the peaks of the four sidebands are chosen incorrectly, the center of mass tune can give you an idea of the tune. If the peak on the longitudinal distribution is off, the entire tune measurement should be discarded since that error will be propagated into all four tune calculations.

The final tune value that P43 displays in each plane is an average of the center of mass tune for each sideband. To obtain a tune value based on the peak tunes, just average the upper and lower PK TUNE value listed on the tune plot. Comparing the center of mass and peak tune values in the horizontal plane for our example in Figure 4, we get

In this case, the values are only 0.0003 apart.

Background: Quadrupoles change the tune.

Once it has been determined that the tunes need to be moved, it is important to understand what devices are changed when moving the tune. We know that quadrupoles are used to change the tune. The Accumulator has three quadrupole busses and shunts on many of the quadrupoles.

A:LQ powers all of the "large quadrupoles" on either side of the high dispersion straight sections with numbers AnQ10 to AnQ14, where n is the sector number which can from be 1 to 6. For example in sector 10, A:LQ would power A1Q10, A1Q11, A1Q12,A1Q13, and A1Q14. Due to the mirror symmetry in the number scheme, A:LQ powers the same numbered quadrupoles in all sectors.

A:QT powers all of the smaller quads on either side of the lower dispersion straight sections with numbers AnQ1 to AnQ3 as well as AnQ6, where n is the sector number which can from be 1 to 6. For example in sector 10, A:QT would power A1Q1, A1Q2, A1Q3, and A1Q6. Due to the mirror symmetry in the number scheme, A:QT powers the same numbered quadrupoles in all sectors.

A:QDF powers all of the quadrupoles not powered by A:LQ and A:QT. These are quadrupoles outside of the straight sections with numbers AnQ4 to AnQ9, except for AnQ6, where n is the sector number which can from be 1 to 6. For example in sector 10, A:QDF would power A1Q4, A1Q5, A1Q7, A1Q8, and A1Q9. Due to the mirror symmetry in the number scheme, A:LQ powers the same numbered quadrupoles in all sectors.

Neither A:LQ, A:QT nor A:QDF are used to change the tune in the Accumulator. Instead a set of quad shunts on the A:QDF quads are used. A:QSF1 is used to change the horizontal tune of the Accumulator, and A:QSD is used to change the vertical tune of the Accumulator.

Setup:

You will need spectrum analyzer #4 or #5 to complete this exercise. This exercise can be completed either remotely or at AP10. Verify that nobody is using SA #4 for other common tasks like measuring the Debuncher tunes. 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. Stacking can proceed normally during the tune measurements and adjustments.

Full Length Procedure: Standard Procedure for Measuring the Tunes

1. Start P43 verify the setup before starting the measurement. Settings should match what is shown in Figure 5 below.
    a. Select Spectrum Analyzer: **D:SB12SA <2>** : This is the default setting of Spectrum Analyzer #4 channel two. Alternately, you could use:
        a. D:SB12SA <1> (Spectrum Analyzer #4 channel 1)
        b. D:SB13SA <2> (Spectrum Analyzer #5, channel 2)
        c. Spectrum Analyzer #5, channel 1 is not currently available for tune measurements.
    b. Select Accelerator: **Accumulator**: Accumulator is selected by default.
    c. Select measurement method: **8GeV LONG SCAN**.
    d. Select measurement granularity: **FINE**. **FINE** works in all cases. Quick may work with large stacks, but does not give as accurate a measurement for small stacks. Slow takes too long to be useful.

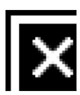


Figure 5: Default P43 Settings

2. Click the **MEASURE TUNE** button to begin the measurement.
3. If the spectrum analyzer MUX switch is in local, you will receive the error shown in Figure 6. The only solutions are to use another spectrum analyzer channel or to flip the MUX switch at AP10 back in remote.

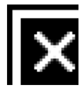


Figure 6: MUX switch in local

4. P43 takes about two minutes to complete the tune measurement. As the application is making the measurement, you will observe several displays being generated.
    a. The first is a longitudinal Schottky signal from which the core's revolution frequency is calculated.

    b. The other four are the upper and lower sidebands of both the horizontal and vertical tunes.

    c. For details on what steps P43 makes to complete the measurement, see the background section of this document.

5. The output of a typical tune measurement is shown in Figure 7.

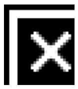


Figure 7: P43 tune measurement

6. Examine the marker position on each of the five plots, and make sure that each marker position is truly close to the peak. If the peak is not well centered, then the measurement should be discarded. This is especially true of the Longitudinal Schottky measurement, since that measurement determines the center frequency which is used in the tune calculation that is completed from the other four sideband measurements.

7. It's a good idea to repeat the measurement 3 or 4 times to get a more accurate tune measurement.

8. The tune values in the center top of Figure 7 are calculated by taking the average of the center of mass tune (CM TUNE).

9. For comparison, also look at the peak tune measurement (PK TUNE) displayed on the upper right of each display. Average the measured tune from both the upper and lower sideband to calculate a value for the tune.

10. Trust the peak tune value more than the center of mass tune value.

11. The fractional portion of the default tunes are ν_x = .696 and ν_y = .684. **(NOTE: On 7-18-05 the nominal tunes on both the stacking and shot lattices were changed to ν_x = .683 and ν_y = .681.)**
    a. If either tune is off by more than 0.0005, then a tune adjustment is in order. Go to the "Adjust the Tunes" section of this document.

    b. If shot setup is in progress, go to the "Adjust the Tunes During Shot Setup" portion of this document.

    c. If the accumulator has a large stack (>150ma) OR if the accumulator is experiencing emittance problems, go to the "Adjust the Tunes During Emittance Instabilities" portion of this document.

Full Length Procedure: Speeding up the tune measurement by using the SCITEQ.

This section provides an alternate to the standard tune measurement procedure listed above. This tune measurement is not only faster when you doing repeated tune measurements, but it also provides a more consistent measurement. The procedure starts by measuring the revolution frequency of the core. That value is used to setup the SCITEQ, which will in turn manually feed the revolution frequency to P43. This provides a more consistent reading of the revolution frequency than is provided by the standard tune measurement. P43 then only needs to make the sideband measurements.

1. Obtain the revolution frequency of the beam. There are a number of possible ways to complete this task. Here are a few examples.
    a. Repeatedly take a standard P43 tune measurement until you get a good longitudinal measurement. The disadvantage of this method, is that each P43 measurement takes a couple of minutes, which means that you could easily spend on the order of ten minutes to get a good set of longitudinal measurements.

    b. Manually measure the peak on the Accumulator Longitudinal Schottky as shown in the Manual Tune Measurement portion of this document. There is a time overhead with getting the spectrum analyzer setup to complete this measurement.

    c. Use the VSA to obtain a value for A:CENFRQ. This method is fastest of three and is covered in the next few steps.

2. Go to Acnet Page P142

3. Click Start VSA
    a. Note: We are not changing the state of Thermostating. We are only starting the

SA.

4. A longitudinal profile plot will be started as shown in Figure 8.

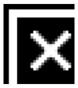


Figure 8: Longitudinal Profile seen by VSA

5. Go to P38 MISC <1>. On the bottom of the page are the two parameters that will be used to setup the SCITEQ. The top of the page has parameters that are updated every time that P43 is run.

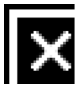
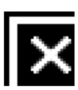


Figure 9: SCITEQ setup on P38 MISC <1>

6. Verify that A:CENFRQ is updating. If not, go back to step 3.

7. Use Equation 11 to set the value of A:R1LLFS.



(11)

8. Open P43 and select the following settings . The settings should match what is shown in Figure 10 below.
    a. Select Spectrum Analyzer: **D:SB12SA <2>** : This is the default setting of Spectrum Analyzer #4 channel two. Alternately, you could use:
        a. D:SB12SA <1> (Spectrum Analyzer #4 channel 1)
        b. D:SB13SA <2> (Spectrum Analyzer #5, channel 2)
        c. Spectrum Analyzer #5, channel 1 is not currently available for tune measurements.
    b. Select Accelerator: **Accumulator**: Accumulator is selected by default.
    c. Select measurement method: **SCITEQ**.

   d. Select measurement granularity: **FINE**. **FINE** works in all cases. Quick will work with large stacks, but does not give as accurate a measurement. Slow takes too long to be useful.

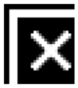


Figure 10: Tune measurement using the SCITEQ

9. P43 will make the tune measurement. This measurement will be noticeably faster than the standard tune measurement. As the application is making the measurement, you will observe the following.
   a. No longitudinal (lower center) profile is generated since we are using the SCITEQ to obtain the revolution frequency.

   b. The four are the upper and lower sidebands of both the horizontal and vertical tunes are calculated as expected.

   c. The output of a typical tune measurement is shown in Figure 11.

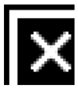


Figure 11: Results of a tune measurement using the SCITEQ.

10. The tune values in the center top of Figure 11 are calculated by taking the average of the center of mass tune (CM TUNE).

11. For comparison, also look at the peak tune measurement (PK TUNE) displayed on the upper right of each display. Average the measured tune from both the upper and lower sideband to calculate a value for the tune.

12. Trust the peak tune value more than the center of mass tune value.

13. The fractional portion of the default tunes are $\nu_x = .696$ and $\nu_y = .684$. **(NOTE: On 7-18-05 the nominal tunes on both the stacking and shot lattices were changed to ν_x = .683 and ν_y = .681.)**
    a. If either tune is off by more than 0.0005, then a tune adjustment is in order. Go to the "Adjust the Tunes" section of this document.

    b. If shot setup is in progress, go to the "Adjust the Tunes During Shot Setup" portion of this document.

c. If the accumulator has a large stack (>150ma) OR if the accumulator is experiencing emittance problems, go to the "Adjust the Tunes During Emittance Instabilities" portion of this document.

Full Length Procedure: Measuring the Tunes manually

It is possible to measure the Accumulator tunes without the help of P43. As an exercise, we will go through the steps required to complete this task. You can either look at each plane separately using a single spectrum analyzer, or you can look at both planes at the same time using two spectrum analyzers.

1. We first need the Accumulator Longitudinal Schottky signal to calculate the revolution frequency of the beam. From P41 load the Accumulator Longitudinal Schottky file.
   a. Load file #76 to SA#4 (or SA #5). To do this, type 76 next to "File" as shown below and then interrupt. Verify SA4 (you can change this to SA5 if you wish to use SA #5 instead) is to the right of "Send to SA" as shown below, then click on "Send to SA" and take the caution.

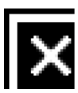


Figure 12: Accumulator longitudinal setup on P41 file #76.

   a. Currently you will get an "Illegal SA for Mux" error when loading the P41 file. This error occurs because the P41 command that connects Spectrum Analyzer Port 2 (the default port on SA #4 and SA #5) to the correct Schottky pickup currently does not work. Until it does work, we will have to connect the Spectrum Analyzer to the Schottky locally, via the SA emulator (see Step 2 below), or by setting the appropriate switch tree parameter from P38 Diagnostic MUX <1>.
      i. Spectrum Analyzer #4: Set A:MX8T02 to 1 for Accumulator Longitudinal Schottky.
      ii. Spectrum Analyzer #5: Set A:MX8T04 to 1 for Accumulator Longitudinal Schottky .

Figure 13: Mux switch positions are displayed on P38 MISC <1>.

iii. In the above example, SA #4 is set to the Accumulator Horizontal Schottky pickup and SA #5 is set to the Accumulator Vertical Schottky pickup. The value that you set depends on which Schottky pickup you want to connect to which Spectrum Analyzer.

2. If the P41 file does not load properly, you can setup Spectrum Analyzer #4 or Spectrum Analyzer #5 through P42 or the Spectrum Analyzer emulator. The below table shows how to setup Spectrum Analyzer #4 or Spectrum Analyzer #5 from P42 or SA emulator commands. These are the same commands that are loaded above in P41 File #76.

Command	P42 Commands	Emulator Commands
Connect to SA #4 or SA #5.	Go to P42, select SA #4 (D:SBSB12A) or SA #5 (D:SB13SA) and enter data into the field.	Go to P42, click on located at the top right-hand portion of the screen, and then select Spectrum Analyzer #4 or Spectrum Analyzer #5.
Instrument Preset	IP	
Set a Log Scale	LG 10 DB	
Set the Reference Level	RL -30 DB	
		Longitudinal Measurement:

Set the Center Frequency (This is Revolution frequency * 126).	CF 79.24014 MZ	*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 small 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 20 KZ	
Set the Attenuation Level	AT 50 DB	
Set the Resolution Bandwidth	RB 300 HZ	
Set Video Bandwidth	VB 30 HZ	
Connect the Spectrum Analyzer port 2 to the Schottky Pickup. *Note: Port 2 is the default on both SA #4 and SA #5.*	SIG: MUX1 2 *NOTE: This command does not current load from P41 or P42. Use the SA emulator or set manually from a parameter page as outlined in step 1.c.*	Click on Port 2, then click on AcL
Clear Screen	HD	(for channel A)

3. You can view the Spectrum Analyzer traces on the CATV system.
    a. Spectrum Analyzer #4: CATV AP 21

    b. Spectrum Analyzer #5: CATV AP 22

4. From P42 start the SA Emulator by clicking on in the upper right corner of the screen. Chose either Spectrum Analyzer #4 or Spectrum Analyzer #5, depending on which Spectrum Analyzer you are using.

5. After a few pulses, a longitudinal profile should be present. We can calculate the revolution frequency of the beam by measuring the frequency of the peak and dividing it by 126. This can be done by doing the following:

   a. In the Marker Section, click on , followed by Peak Search.

   b. Verify that the marker shown on CATV AP #21 (if your are using SA #4) or CATV AP #22 (if you are using SA #5) is aligned with the peak of the distribution.

   c. If the marker is not aligned with the peak, then adjust the marker location by clicking on , followed by . Use the console knob to move the marker until it aligns with the peak of the distribution.

   d. The marker frequency will be listed on the left side of the Spectrum Analyzer CATV display as seen in Figure 14.

Figure 14: Accumulator Longitudinal signal
The marker is a small dot on the trace. After
the marker is centered on the peak of the distribution
Read the marker frequency on the left of the screen
The marker frequency in this example is 79.23974
MHz

   e. If you cannot read the marker frequency value from the CATV, you can read it from the emulator.

i. To read the marker frequency, click on which is located in the lower right of the keystroke history window.

ii. Note the value in the keystroke history. This is the sideband frequency that we will use to calculate the tune.

6. Divide the peak frequency value by 126. This is the revolution frequency that we will need shortly. In our example from Figure 14, our revolution frequency would be 79.23974MHz/126=628887Hz.
   a. NOTE: If you prefer, the spreadsheet located at http://www-bdnew.fnal.gov/pbar/documents/TuningGuide/Accumulator-Tunes/Manual-Accumulator-Tunes.xls can complete the math for you. To use the spreadsheet, do the following.
      i. Click on the above link and choose to save the file to your hard drive.
      ii. Open the spreadsheet.
      iii. Enter the number determined from step 5 above in the "Longitudinal Schottky Peak (MHz) =" field.
      iv. The revolution frequency is then listed in the "Revolution Frequency (Hz) =" field.

7. Now that we have the revolution frequency, we can measure the upper or lower sideband frequency of either the horizontal or vertical plane to determine the tune in that plane.

8. From P41 load the tune file.
   a. If you want to look at the Horizontal tune, then load file #38 to SA#4 (or SA #5). To do this, type 38 next to "File" as shown below and then interrupt. Verify SA4 (you can change this to SA5 if you wish to use SA #5 instead) is to the right of "Send to SA" as shown below, then click on "Send to SA" and take the caution. This file puts the default tune in the center of the spectrum analyzer, assuming that the revolution frequency of the beam is close to 628890 Hz. This file is looking at the upper horizontal sideband. To look at the lower sideband you would have to change the center frequency of the spectrum analyzer as will be shown shortly.

Figure 15: Accumulator horizontal tune setup on P41 file #38

b. If you want to look at the Vertical Tune, then load file #39 to SA #4 (or SA #5). To do this, type 60 next to "File" as shown below and then interrupt. Verify SA4 (you can change this to SA5 if you wish to use SA #5 instead) is to the right of "Send to SA" as shown below, then click on "Send to SA" and take the caution. This file puts the default tune in the center of the spectrum analyzer, assuming that the revolution frequency of the beam is close to 628890 Hz. This file is looking at the upper vertical sideband. To look at the lower sideband you would have to change the center frequency of the spectrum analyzer as will be shown shortly.

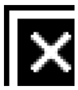


Figure 16: Accumulator vertical tune setup on P41 file #39

c. Currently you will get an "Illegal SA for Mux" error when loading the P41 file. This error occurs because the P41 command that connects Spectrum Analyzer Port 2 (the default port on SA #4 and SA #5) to the correct Schottky pickup currently does not work. Until it does work, we will have to connect the Spectrum Analyzer to the Schottky locally, via the SA emulator (see Step 2 below), or by setting the appropriate switch tree parameter from P38 Diagnostic MUX <1>.
   i. Spectrum Analyzer #4: Set A:MX8T02 to 3 for Accumulator Horizontal Schottky or 5 for Accumulator Vertical Schottky.

   ii. Spectrum Analyzer #5: Set A:MX8T04 to 3 for Accumulator Horizontal Schottky or 5 for Accumulator Vertical Schottky .

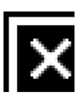


Figure 17: Mux switch positions are displayed on P38 MISC <1>.

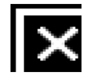
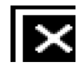
   iii. In the above example, SA #4 is set to the Accumulator

Horizontal Schottky pickup and SA #5 is set to the Accumulator Vertical Schottky pickup. The value that you set depends on which Schottky pickup you want to connect to which Spectrum Analyzer.

9. If the P41 file does not load properly, you can setup Spectrum Analyzer #4 or Spectrum Analyzer #5 through P42 or the Spectrum Analyzer emulator. The below table shows how to setup Spectrum Analyzer #4 or Spectrum Analyzer #5 from P42 or SA emulator commands. These are the same commands that are loaded above in P41 File #38 (or #39). Note that there are four possible setups for four different measurements:
    a. Horizontal lower sideband measurement
    b. Vertical lower sideband measurement
    c. Horizontal upper sideband measurement
    d. Vertical upper sideband measurement

Command	P42 Commands	Emulator Commands
Connect to SA #4 or SA #5.	Go to P42, select SA #4 (D:SBSB12A) or SA #5 (D:SB13SA) and enter data into the field.	Go to P42, click on located at the top right-hand portion of the screen, and then select Spectrum Analyzer #4 or Spectrum Analyzer #5.
Instrument Preset	IP	
Set a Log Scale	LG 5 DB	
Set the Reference Level	RL -65 DB	
		Horizontal Tune (Upper Band) Measurement: **Horizontal Tune (Lower Band) Measurement:**

Set the Center Frequency. The upper and/or lower sidebands can be used for both horizontal and vertical tune measurements. Each has a different frequency setting on the spectrum analyzer.	**Horizontal Upper Band:** CF 79.048957 MZ **Horizontal Lower Band:** CF 79.430694 MZ **Vertical Upper Band:** CF 79.040971 MZ **Vertical Lower Band:** CF 79.438995 MZ	**Vertical Tune (Upper Band) Measurement:** **Vertical Tune (Lower Band) Measurement:** *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 small 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 20 KZ	
Set the Attenuation Level	AT 0 DB	
Set the Resolution Bandwidth	RB 300 HZ	
Set Video Bandwidth	VB 30 HZ	
Connect the Spectrum Analyzer port 2 to the Schottky	Horizontal Tune Measurement: SIG: MUX3 2 Vertical Tune Measurement: SIG: MUX5 2	Horizontal Tune Measurement: Click on Port 2, then click on AcH

Pickup. *Note: Port 2 is the default on both SA #4 and SA #5.*	*NOTE: This command does not current load from P41 or P42. Use the SA emulator or set manually from a parameter page as outlined in step 1.c.*	Vertical Tune Measurement: Click on Port 2, then click on AcV  
Clear Screen	HD	 (for channel A)

10. You can view the Spectrum Analyzer traces on the CATV system.
    a. Spectrum Analyzer #4: CATV AP 21

    b. Spectrum Analyzer #5: CATV AP 22

11. From P42 start the SA Emulator by clicking on in the upper right corner of the screen. Chose either Spectrum Analyzer #4 or Spectrum Analyzer #5, depending on which Spectrum Analyzer you are using.

12. After a few pulses, a sideband profile should be present. Figures 18 through 21 show typical sideband profiles for each of the four possible tune measurements.

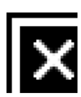


Figure 18: Horizontal Lower Band

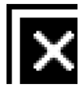


Figure 19: Vertical Lower Band

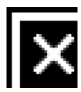


Figure 20: Horizontal Upper Band

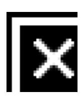


Figure 21: Vertical Upper Band

10. Next, we find the peak of the sideband signal for our spectrum analyzer traces (Figures 18 through 21). We will then use the peak frequency of each plot to measure the

tune. To measure the peak of the spectrum analyzer plot, do the following.

a. In the Marker Section, click on , followed by Peak Search.

b. Verify that the marker shown on CATV AP #21 (if your are using SA #4) or CATV AP #22 (if you are using SA #5) is aligned with the peak of the distribution.

c. If the marker is not aligned with the peak, then adjust the marker location by clicking on , followed by . Use the console knob to move the marker until it aligns with the peak of the distribution.

d. The marker frequency will be listed on the left side of the Spectrum Analyzer CATV display as seen in Figures 18 through 21 above.

e. If you cannot read the marker frequency value from the CATV, you can read it from the emulator.

   i. To read the marker frequency, click on which is located in the lower right of the keystroke history window.

   ii. Note the value in the keystroke history. This is the sideband frequency that we will use to calculate the tune.

11. Recall the revolution frequency that was calculated in step 6, and the sideband frequency that we measured in step 10. Use these two values to calculate the tune. The equation used to calculate the tune depends on which sideband (upper or lower) and which plane (horizontal or vertical) we are measuring. Each of the four equations are given below.

(Tune from horizontal lower sideband) (7)

(Tune from vertical lower sideband) (8)

(Tune from horizontal upper sideband) (9)

(Tune from vertical upper sideband) (10) where f_s is the sideband frequency measured in step 10, ν_x and ν_y are the fractional portion of the horizontal and vertical tunes respectively, and f_{rev} is the revolution frequency measured in step 6.

a. NOTE: If you prefer, the spreadsheet located at http://www-bdnew.fnal.gov/pbar/documents/TuningGuide/Accumulator-Tunes/Manual-Accumulator-Tunes.xls can complete the math for you. To use the spreadsheet, do the following:
   i. Click on the above link and choose to save the file to your hard drive.

   ii. Open the spreadsheet.

   iii. Enter the number determined from step 10 above in the appropriate field.

   iv. The tune is then listed at the bottom of the spreadsheet.

12. Repeat steps 8 through 11 until you have completed all four sideband measurements.

13. Average the value obtained from equations (7) and (9) to obtain your horizontal tune, and average the values obtained in equations (8) and (10) to obtain your vertical tune.

13. The fractional portion of the default tunes are ν_x = .696 and ν_y = .684. **(NOTE: On 7-18-05 the nominal tunes on both the stacking and shot lattices were changed to ν_x = .683 and ν_y = .681.)**
   a. If either tune is off by more than 0.0005, then a tune adjustment is in order. Go to the "Adjust the Tunes" section of this document.

   b. If shot setup is in progress, go to the "Adjust the Tunes During Shot Setup" portion of this document.

   c. If the accumulator has a large stack (>150ma) OR if the accumulator is experiencing emittance problems, go to the "Adjust the Tunes During Emittance Instabilities" portion of this document.

Full Length Procedure: Adjusting the Tunes

Once the tune has been measured, if either tune is off by more than 0.0005, then a tune adjustment is in order. This portion of the document outlines how to make this change. If shot setup is in progress, go to the "Adjust the Tunes During Shot Setup" portion of this document. If the accumulator has a large stack (>150ma) OR if the accumulator is experiencing emittance problems, go to the "Adjust the Tunes During Emittance Instabilities" portion of this document. If the measured tunes are more than about .006 from their nominals, a Pbar expert should be consulted.

1. The quad shunts used to change the Accumulator tune are on P60 ACC50 <11> as shown in Figure 22.

Figure 22: Shunts used to change the Accumulator Tune

2. A:QSF1 is used to adjust the horizontal tune, and A:QSD is used to adjust the vertical tune.
   a. Make small changes on the order of a few hundredths of an amp between tune measurements.

   b. A Counter-clockwise knob rotation will result in a positive tune change in both planes.

   c. Be careful with large stacks.

3. Repeat your tune measurements and tune changes until you reach the desired values for the tunes. Sometime with larger stacks, the tune is very sensitive and sometimes is not stable at the default values.

4. Document any significant tuning changes in the Pbar electronic log book.

Special Cases: Adjusting the Tunes during Shot Setup

The material for this section already exists in Jim Morgan's document "Some Pbar Guidelines that help maximize Luminosity," which provides guidelines for adjusting the Accumulator tunes during a Collider Run II shot setup. Click on the above title to go to that document.

Special Cases: Adjusting the Tunes during Emittance Instabilities

There are times when the core is not stable at the default tune values, and the tunes become very sensitive.   This usually occurs when the stack size is greater than 160ma. When this occurs, use the following guidelines.

1. Make sure ARF1 stays on if you have to stop stacking.
2. Start a once+ 15Hz FTP that contains the stack rate, production efficiency, horizontal and vertical emittances as shown in Figure 23.
3. When changing the tune, make very small shunt changes on the order of 0.01 to 0.02 amps.
4. Watch patiently for slope changes in the emittance and changes in your stack rate and production.
5. Be careful not to make changes too rapidly.
6. If tune changes do not work, consult Pbar experts.
7. Document any significant occurrences in the Pbar electronic log book.

Figure 23: Example of emittance growth when stacking. Tune changes stop the upward climbing emittances. One final tune change turned the emittances around. Stacking and production do not recover on this plot. This is because Booster had tripped off about mid-way across the plot and did not restore operation in time to be seen on this plot.

Condensed Procedure:

1. Start P43 verify the setup before starting the measurement. Settings should match the following
   a. Select Spectrum Analyzer: **D:SB12SA <2>** :
   b. Select Accelerator: **Accumulator**: Accumulator is selected by default.
   c. Select measurement method: **8GeV LONG SCAN**.
   d. Select measurement granularity: **FINE**.

2. Click the **MEASURE TUNE** button to begin the measurement.

3. P43 takes about two minutes to complete the tune measurement. As the application is making the measurement, you will observe several displays being generated.

4. Examine the marker position on each of the five plots, and make sure that each marker position is truly close to the peak. If the peak is not well centered, then the measurement should be discarded.

5. It's a good idea to repeat the measurement 3 or 4 times to get a more accurate tune measurement.

6. The tune values in the center top of Figure 7 are calculated by taking the average of the center of mass tune (CM TUNE).

7. For comparison, also look at the peak tune measurement (PK TUNE) displayed on the upper right of each display. Average the measured tune from both the upper and lower sideband to calculate a value for the tune.

8. Trust the peak tune value more than the center of mass tune value.

9. The fractional portion of the default tunes are ν_x = .696 and ν_y = .684. **(NOTE: On 7-18-05 the nominal tunes on both the stacking and shot lattices were changed to ν_x = .683 and ν_y = .681.)**
   a. If either tune is off by more than 0.0005, then a tune adjustment is in order. Go to the "Adjust the Tunes" section of this document.

   b. If shot setup is in progress, go to the "Adjust the Tunes During Shot Setup" portion of this document.

   c. If the accumulator has a large stack (>150ma) OR if the accumulator is experiencing emittance problems, go to the "Adjust the Tunes During Emittance Instabilities" portion of this document.

10. The quad shunts used to change the Accumulator tune are on P60 ACC50 <11>.

11. A:QSF1 is used to adjust the horizontal tune, and A:QSD is used to adjust the vertical tune.
    a. Make small changes on the order of a few hundredths of an amp between tune measurements.

    b. A Counter-clockwise knob rotation will result in a positive tune change in both planes.

    c. Be careful with large stacks.

12. Repeat your tune measurements and tune changes until you reach the desired values for the tunes. Sometime with larger stacks, the tune is very sensitive and sometimes is not stable at the default values.

13. Document any significant tuning changes in the Pbar electronic log book.

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

Printable Version:

The html version of this document is best for viewing, but not necessarily the best for printing. A printable version of this document is located in the Accelerator Division Documents Database Document 1453.
