Problem Set 3 Wednesday June 18, 2003

Problem 1:

The difference orbit shown in the figure resulted from subtracting the orbit after changing corrector S8B:V4 by + 2 Amps from the orbit taken just before making this change

Given:

* The value of the vertical beta function at the location of corrector S8B:V4 is 25 meters
* The machine energy is 7.00 GeV
* Note 1 Tesla = 10 kGauss = 10,000 Gauss

5a) What is the integer part of the vertical tune?

Answer: Counting oscillations it is 19.

5b) Is the fractional part of the tune less than 0.5 or greater than 0.5 ?

Answer: Since positive current change results in positive corrector kick and the orbit change at the corrector is positive, the tune is below the half integer < 0.5.

5c) What is the approximate corrector calibration in, Gauss-meters / Amp, milliradians / Amp

Answer:

$\theta_\kappa = 2\, \mathbf{u_k} \,/\, (\beta_\kappa \mathbf{cot}(\pi\nu)) = 2\ (0.1\ \mathbf{x}\ \mathbf{10^{-3} m}) \,/\, ((\mathbf{25\ m})(\mathbf{cot}(\pi\ (19.25)))) = 8.0\ \mathbf{x}\ \mathbf{10^{-6}}$ **radians = 8.0 μrad.**

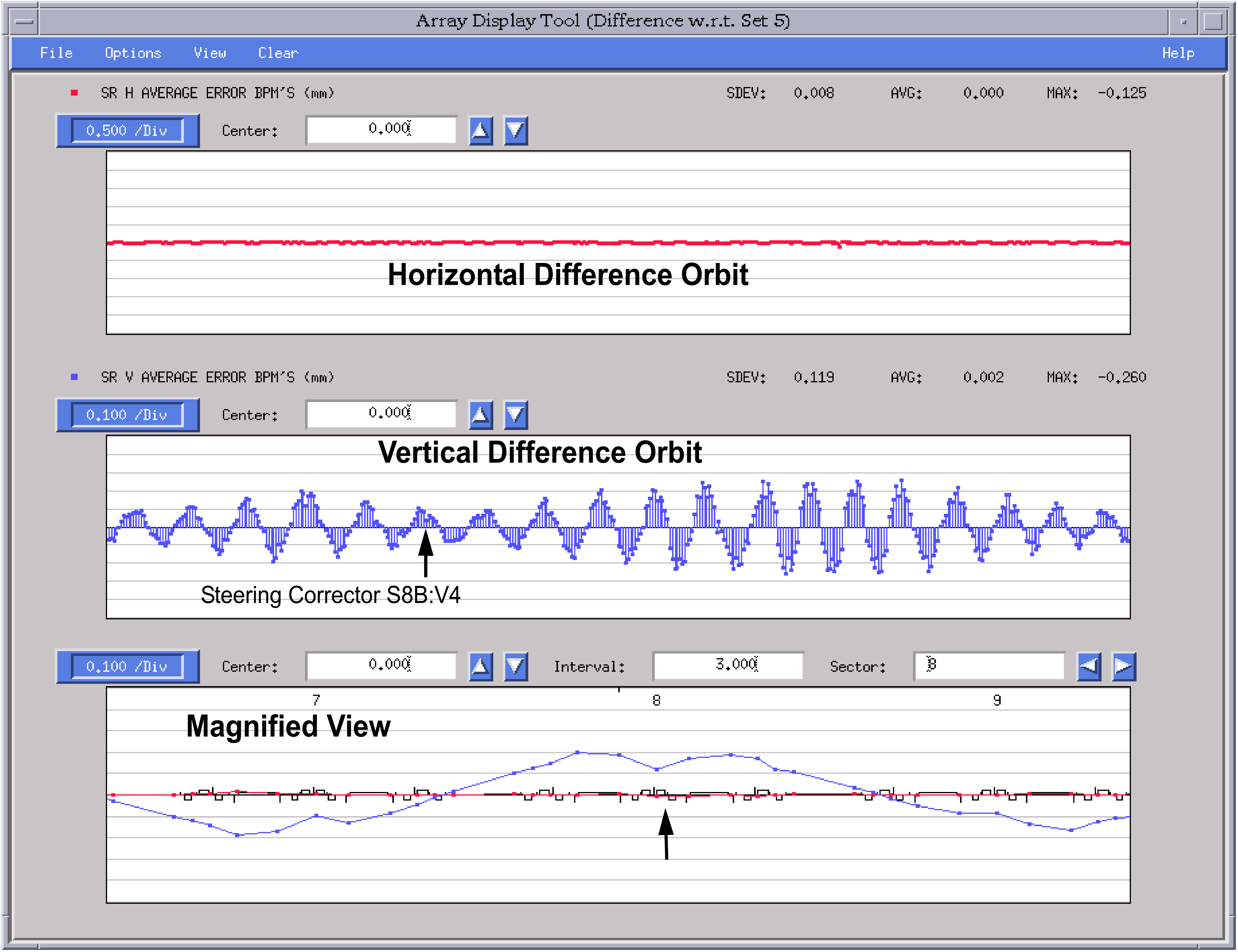
θ_k = **kI => k =** 8.0 **x 10^{-6} radians / 2 Amps = 4.0 x 10-6 radians / Amp = 4.0 x 10^{-3} mrad / Amp.**

BL / I = (p / e)θ_κ = (3.3356) (7 **GeV) (**8.0 **x 10^{-6} radians) / 2 Amperes =** 9.34 **x 10^{-5} T m / Amp = 0.934 G m / Amp.**

5d) The full-scale range of the steering correctors is +- 150 Amps. How many milliradians is this?

Answer:

θ_{max} = **k I_{max}= (4.0 x 10^{-3} mrad / Amp)(150 Amps) = 0.6 mrad.**



Array Display Tool (Difference w.r.t. Set 5)
File
Options
View
Clear
Help
SR H AVERAGE ERROR BPM'S (mm)
SDEV: 0.008
AVG: 0.000
MAX: -0.125
0.500 /Div
Center: 0.000
Horizontal Difference Orbit
SR V AVERAGE ERROR BPM'S (mm)
SDEV: 0.119
AVG: 0.002
MAX: -0.260
0.100 /Div
Center: 0.000
Vertical Difference Orbit
Steering Corrector S8B:V4
0.100 /Div
Center: 0.000
Interval: 3.000
Sector: 8
7
8
9
Magnified View

Problem 2:

2a) Consider the three quadrupoles mounted on a typical APS girder, Q1, Q2, Q3, of effective length $l_1 = l_3 = l = (5/8)\, l_2 = 0.5$ m separated by distances L = 0.6 m. The quadrupole strengths $k1 = k3 = k_f = 0.5 / m^2$, $k2 = k_d = -0.7 / m^2$. Given the separation L, use the thin lens approximation (assuming the thin lenses act at the center of each quad) to obtain a formula for the effective focal length of the triplet (don't put numbers in yet).

Answer: The matrix for the right half of the triplet from symmetry point:

$$\begin{bmatrix} 1 & 0 \\ -\frac{1}{f_f} & 1 \end{bmatrix} \begin{bmatrix} 1 & L \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \frac{1}{2f_d} & 1 \end{bmatrix} = \begin{bmatrix} 1 + \frac{L}{2f_d} & L \\ \frac{1}{2f_d} - \frac{1}{f_f} - \frac{L}{2f_f f_d} & 1 - \frac{L}{f_f} \end{bmatrix}$$

Similarly, the matrix for the left half of the triplet from the symmetry point is:

$$\begin{bmatrix} 1 & 0 \\ \frac{1}{2f_d} & 1 \end{bmatrix} \begin{bmatrix} 1 & L \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ -\frac{1}{f_f} & 1 \end{bmatrix} = \begin{bmatrix} 1 - \frac{L}{f_f} & L \\ \frac{1}{2f_d} - \frac{1}{f_f} - \frac{L}{2f_f f_d} & 1 + \frac{L}{2f_d} \end{bmatrix}$$

Multiply the results of the last two matrix multiplications only for the M_{21} matrix element which is $1/f_{eff}$.

$$M_{21} = 2\left(1 - \frac{L}{f_f}\right)\left(\frac{1}{2f_d} - \frac{1}{f_f} - \frac{L}{2f_f f_d}\right) = \frac{1}{f_{eff}}$$

2b) Calculate to the focal lengths of the three magnets individually and compare to the focal length of the triplet using the numerical parameters given in 2a.

Answer: For the individual magnets:

$f_f = 1 / k_f l = 1 / (0.5 / m^2\ 0.5\ m) = 4\ m = f_1 = f_3$.

$f_d = -1 / k_d l_2 = 1 / (-0.7 / m^2\ 0.8\ m) = 1.786\ m = f_2$.

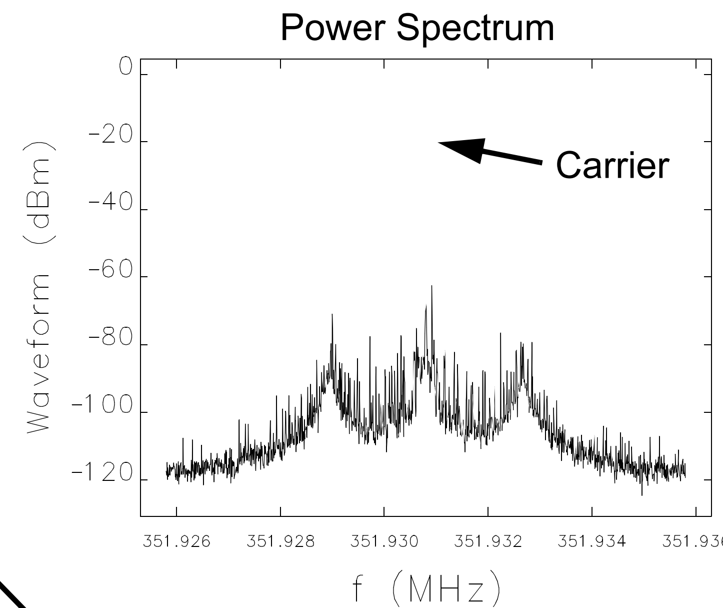
For the triplet configuration the quadrupole separation length:

L = 0.6 m + 0.25 m + 0.4 m = 1.25 m.

$f_{eff} = 1 / (2(1 + 1.25 / 4)(1/ (2(1.786)) - 1 / 4 - 1.25 / (2(4)(1.786)))) = -12.64\ m$

So, $f_{eff} >> f_f$, f_d.

Computer Lab Problem



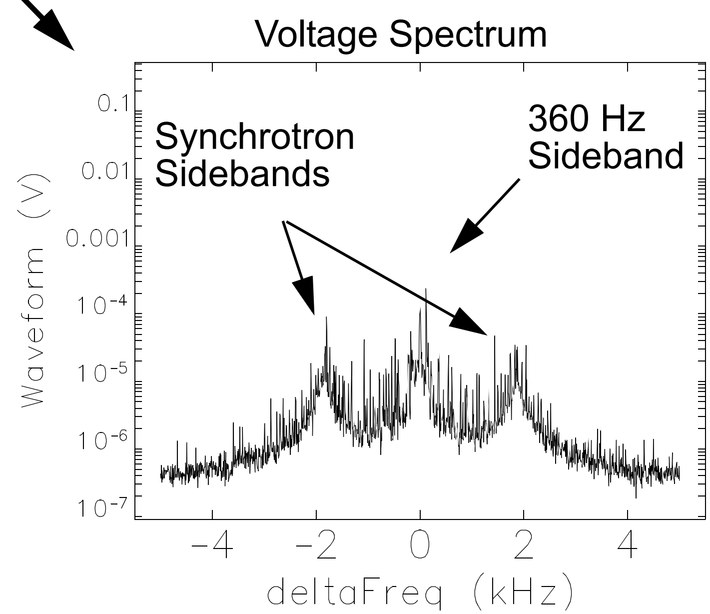
Given the power spectrum shown, together with the “voltage spectrum” (.xls file) -

1) Is this a peak voltage spectrum, rms, or something else?
Hint 0 dBm = 1 mW rms into a 50 ohm load.

2) What is the relation between the given voltage spectrum and $|V_k|$?

3) Plot the power spectral density in (Volts^2 / Hz) vs. deltaFreq

4) What is the voltage variance and standard deviation in the full 10 kHz frequency span, not counting the carrier.?
Note - deltaFreq < 0 does not imply $V_k \rightarrow V_k{}^* = V_{-k}$



5) What is the ratio of rms voltage in the upper 360 Hz sideband to the overall rms voltage corresponding to deltaFreq > 0 ?

6) What is the ratio of the rms voltage in the 360 Hz sidband to the rms voltage associated with the upper synchrotron sideband between 1.5 and 2.5 kHz.

7) Plot the square root of the reverse-integrated power spectral density from 5 kHz down to, but not including, deltaFreq=0, in volts rms. Simpson rule integration is good enough.