MIA (Model Independent Analysis) for Booster

October 2, 2003

1 Review of MIA

Form turn by turn data (P turns) from all M BPMs into a matrix [1]

$$\mathbf{B} = \frac{1}{P}\begin{pmatrix} x_{11} & x_{12} & \cdots & x_{1M} \\ x_{21} & x_{22} & \cdots & x_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ x_{P1} & x_{P2} & \ldots & x_{PM} \end{pmatrix}$$

where $x_{pm} = X_{pm} - X^0_{pm}$, i.e., the reference orbit is subtracted.

SVD of matrix B

$$\mathbf{B} = \mathbf{USV^T} = \sum_i^d \sigma_i u_i v_i^T$$

Each non-trivial singular value corresponds to a mode. u_i is "temporal pattern". v_i is "spatial pattern"

For ideal betatron motion

$$x_p^m = \sqrt{2J_p\beta_m}\cos(\phi_p + \psi_m)$$

where β_m and ψ_m depend on model.

$$\mathbf{B} = \sigma_+ u_+ v_+^T + \sigma_- u_- v_-^T$$

and

$$\begin{aligned} \beta &= < J >^{-1} [(\sigma_+ v_+)^2 + (\sigma_- v_-)^2] \\ \psi &= \tan^{-1}\left(\frac{\sigma_- v_-}{\sigma_+ v_+}\right) \end{aligned}$$

BPM noise reduction

[1] Chun-xi Wang, PhD dissertation, Standform University, SLAC-R-547

2 Booster turn-by-turn data

2.1 a description of data

2.2 Decomposition

2.3 Lattice function

2.4 BPM noise

2.5 Degree of freedom analysis

3 summary

3.1 Discussions

1 Δx and Δy doesn't fit in the betatron motion model well because

- reference orbit (X_0) is not stable due to injection, feedback, etc
- coupling between the two planes introduces more physical modes.
- ...

2 BPM gains are needed. Assuming identical kicker gains (except for V01L), ORM data can provide vertical BPM gains without the complication of a lattice model. How to get better information of BPM gains?

3.2 Conclusion

MIA method has the potential to extract lattice information about the Booster throught the cycle. But we need better and more data.

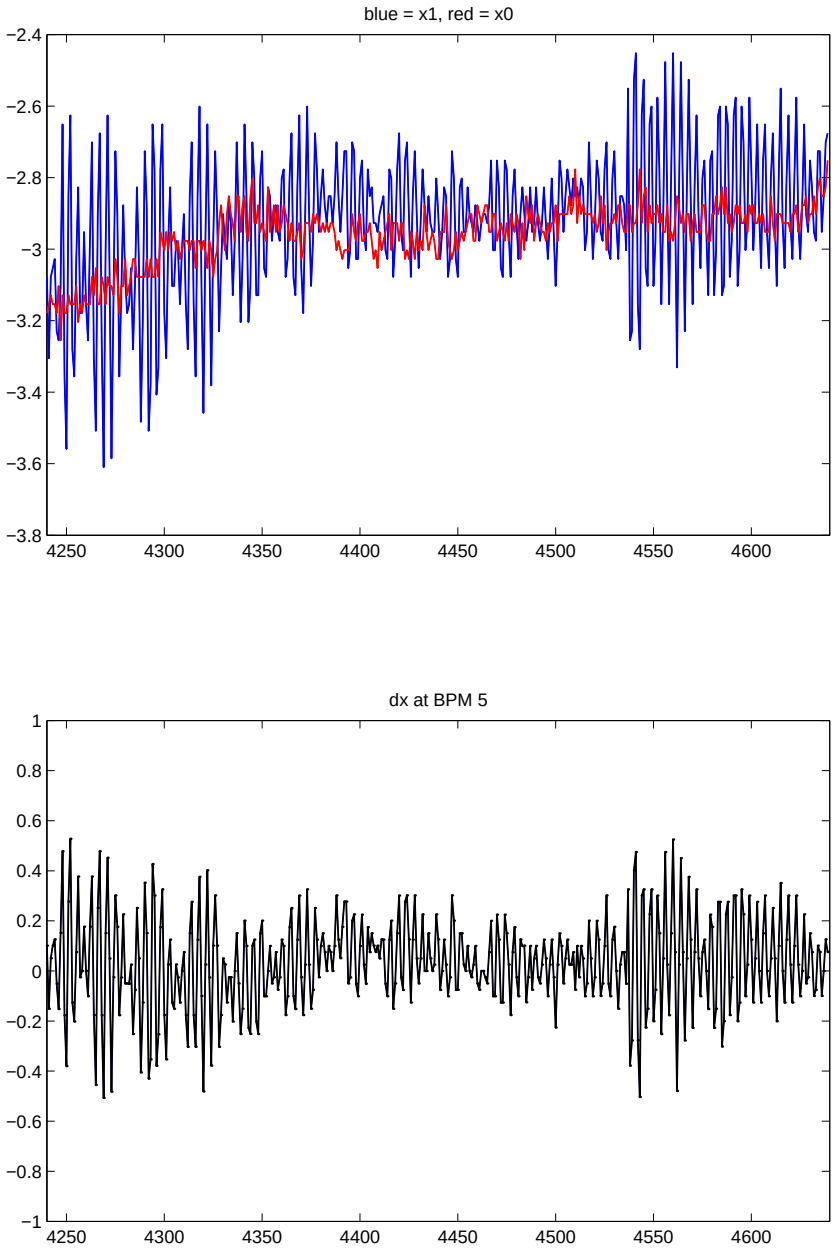


Figure 1: Horizontal Δx at BPM HST03L from 4250 turn.

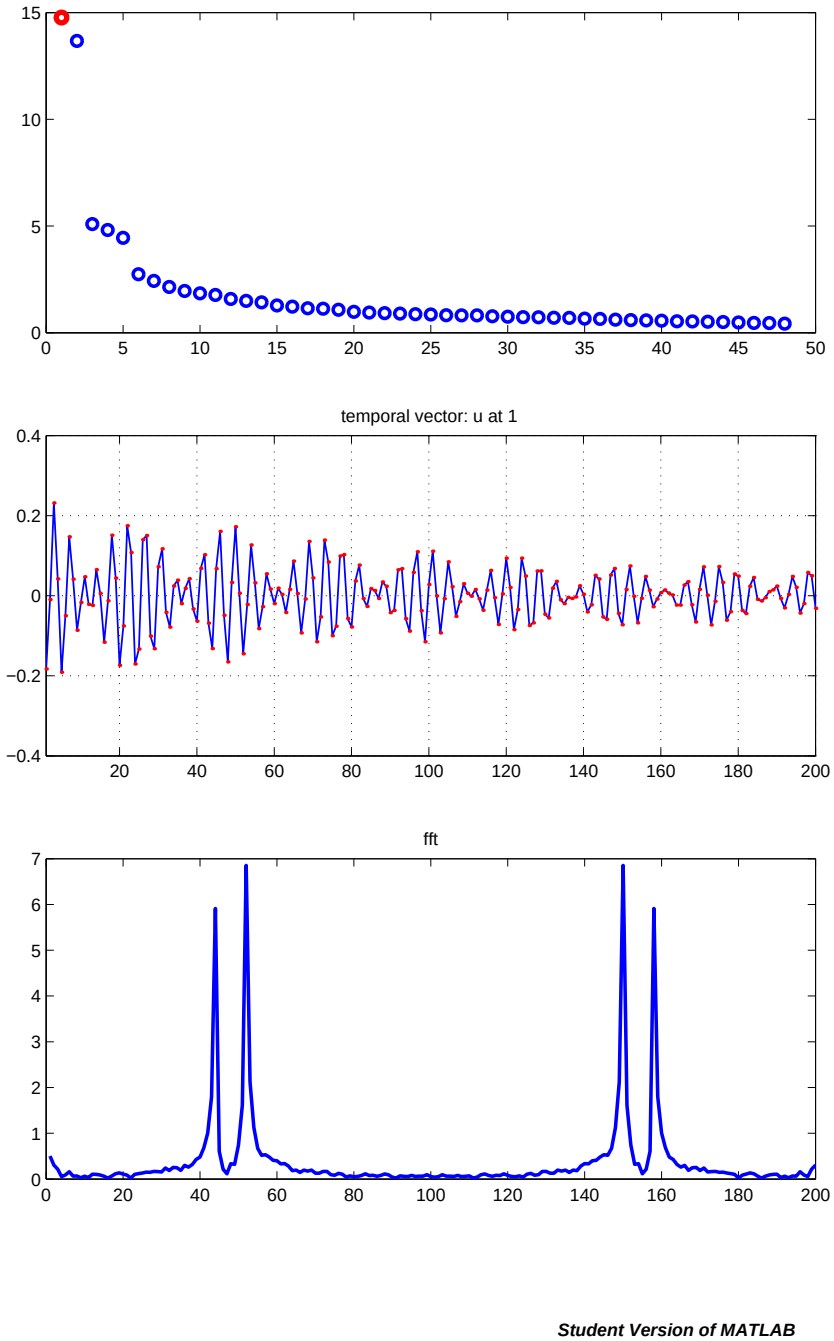


Figure 2: Singular values and temporal pattern of mode 1, Horizontal, turns [4250,4449]

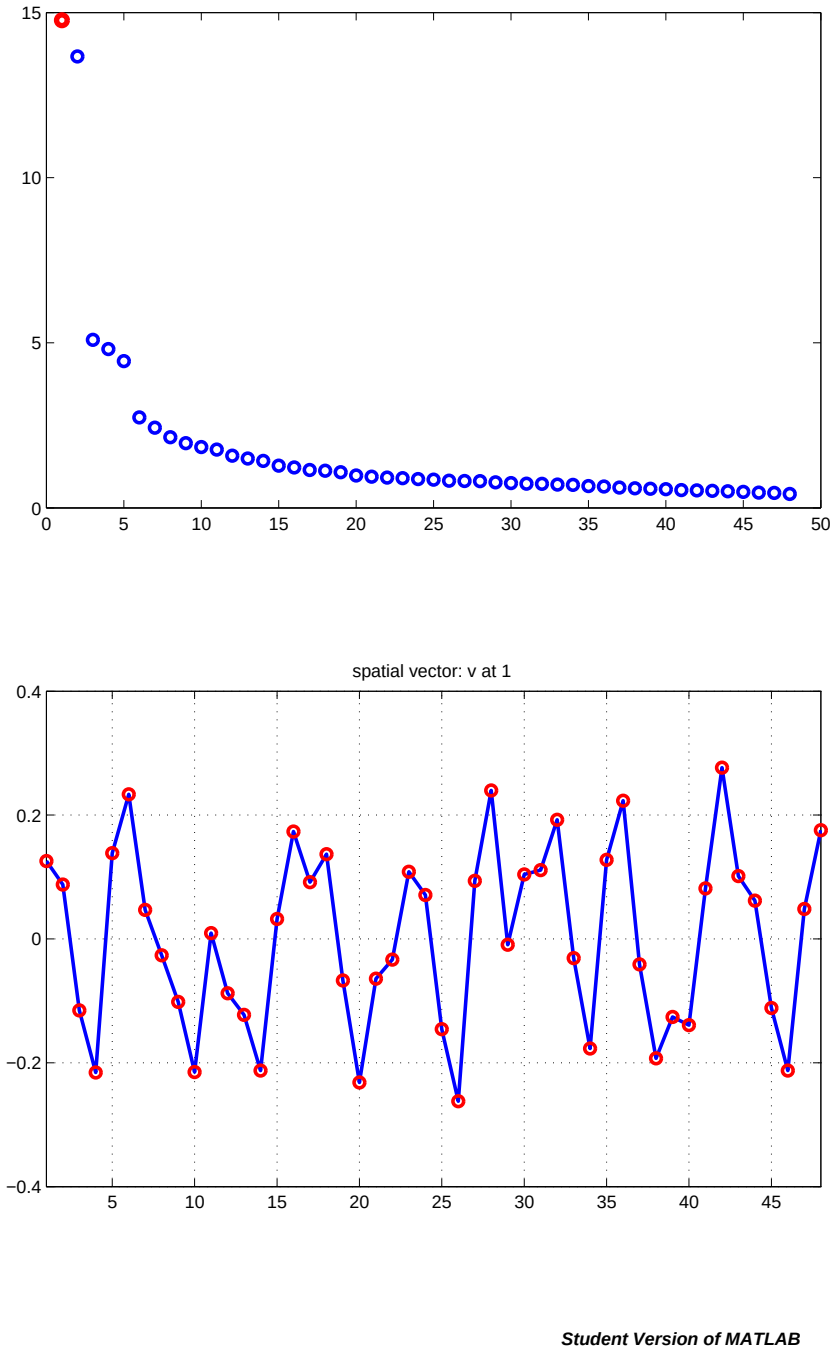


Figure 3: Singular values and spatial pattern of mode 1, Horizontal, turns [4250,4449]

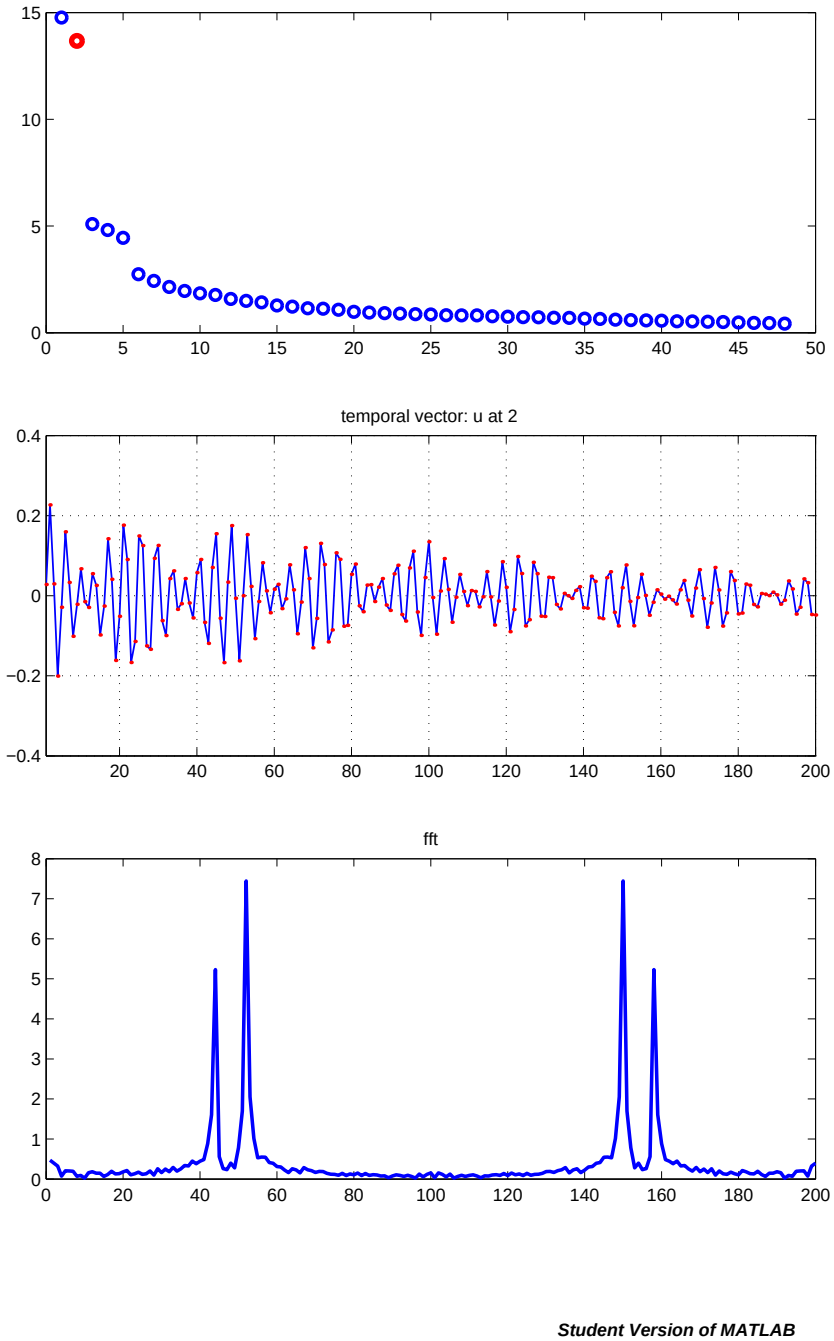


Figure 4: Singular values and temporal pattern of mode 2, Horizontal, turns [4250,4449]

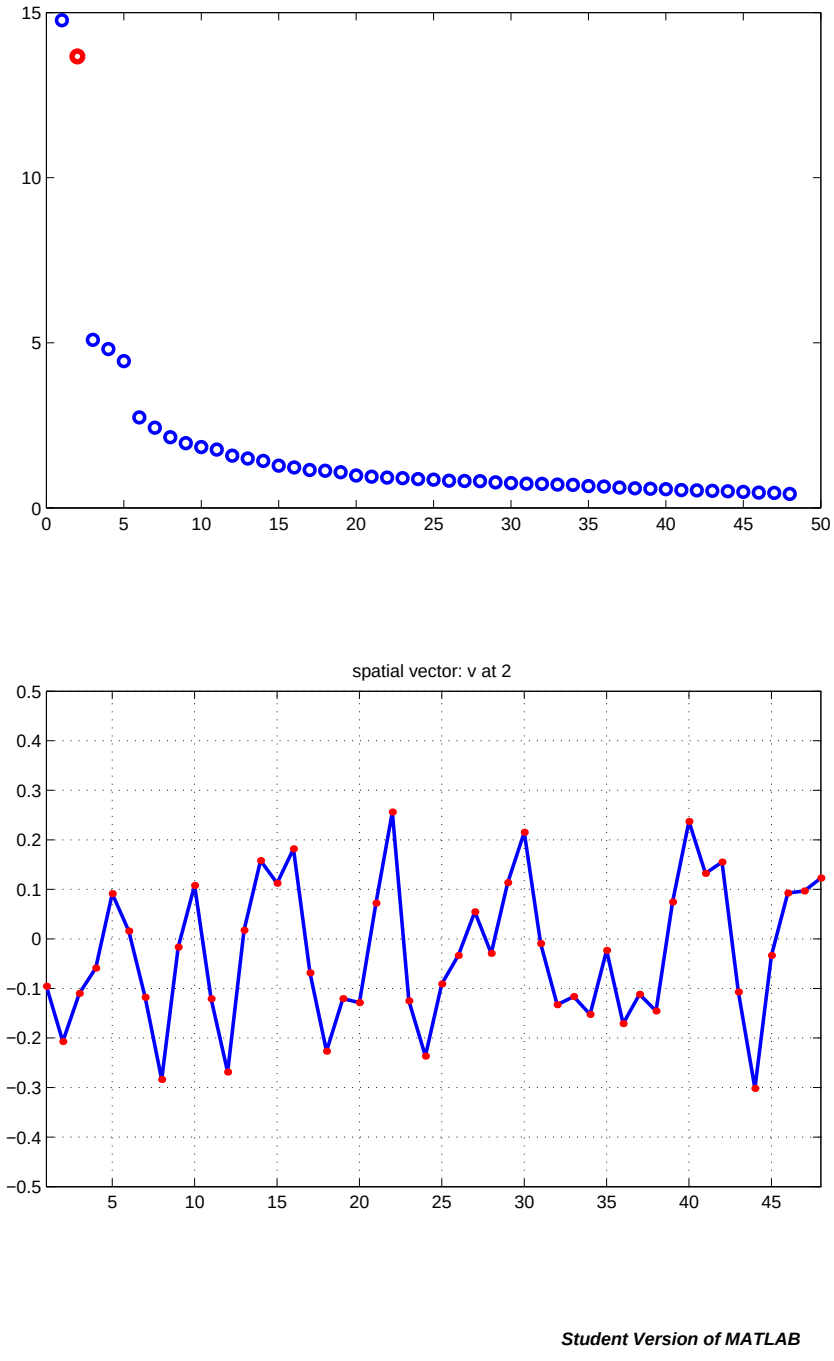


Figure 5: Singular values and spatial pattern of mode 2, Horizontal, turns [4250,4449]

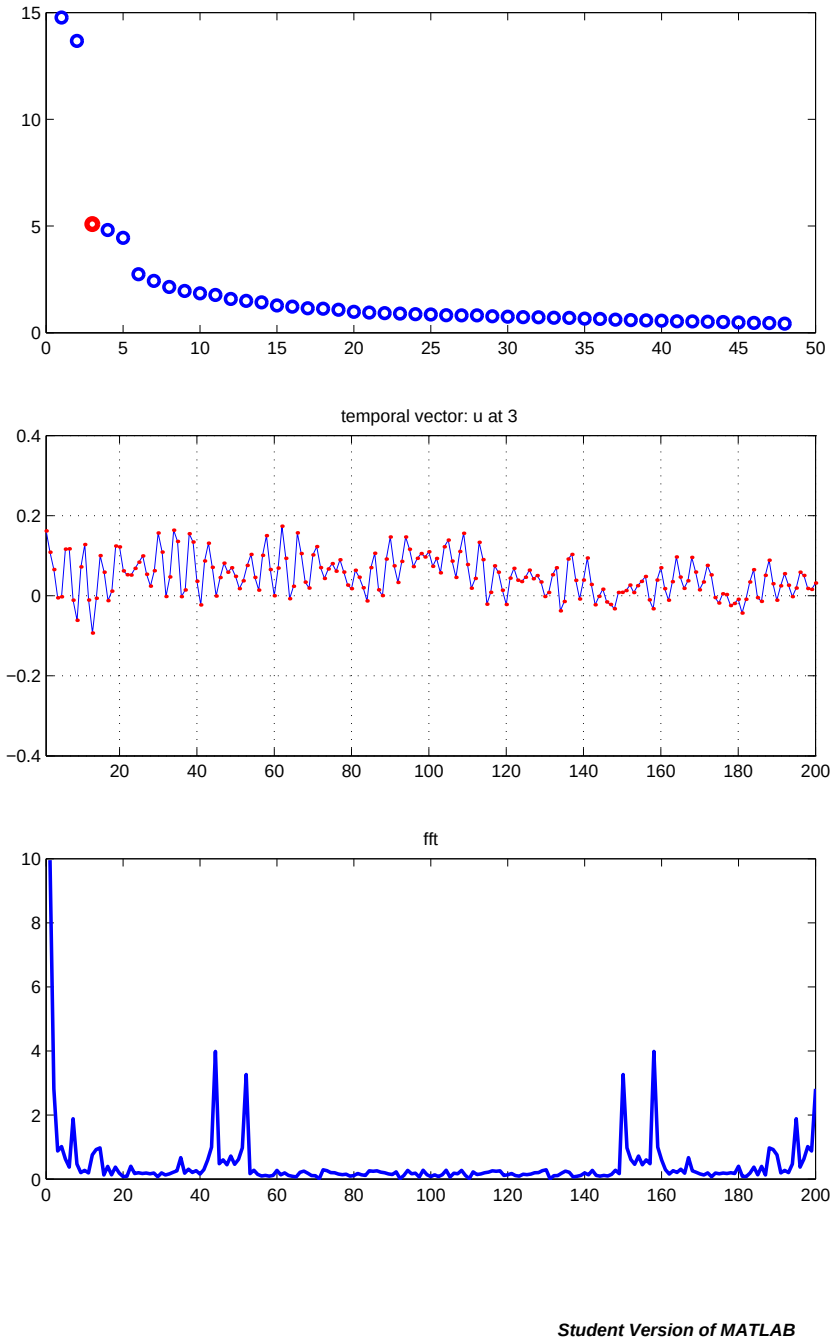


Figure 6: Singular values and temporal pattern of mode 3, Horizontal, turns [4250,4449]

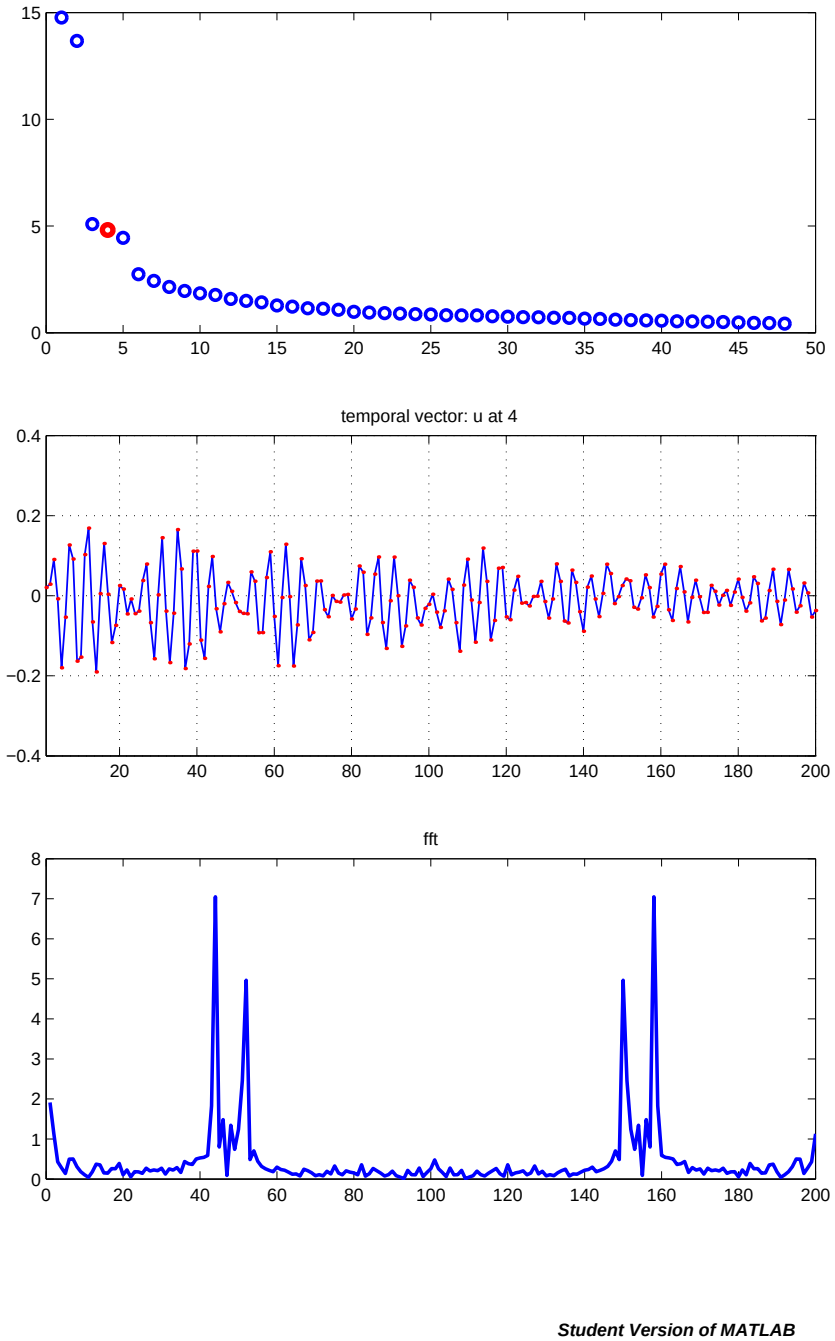


Figure 7: Singular values and temporal pattern of mode 4, Horizontal, turns [4250,4449]

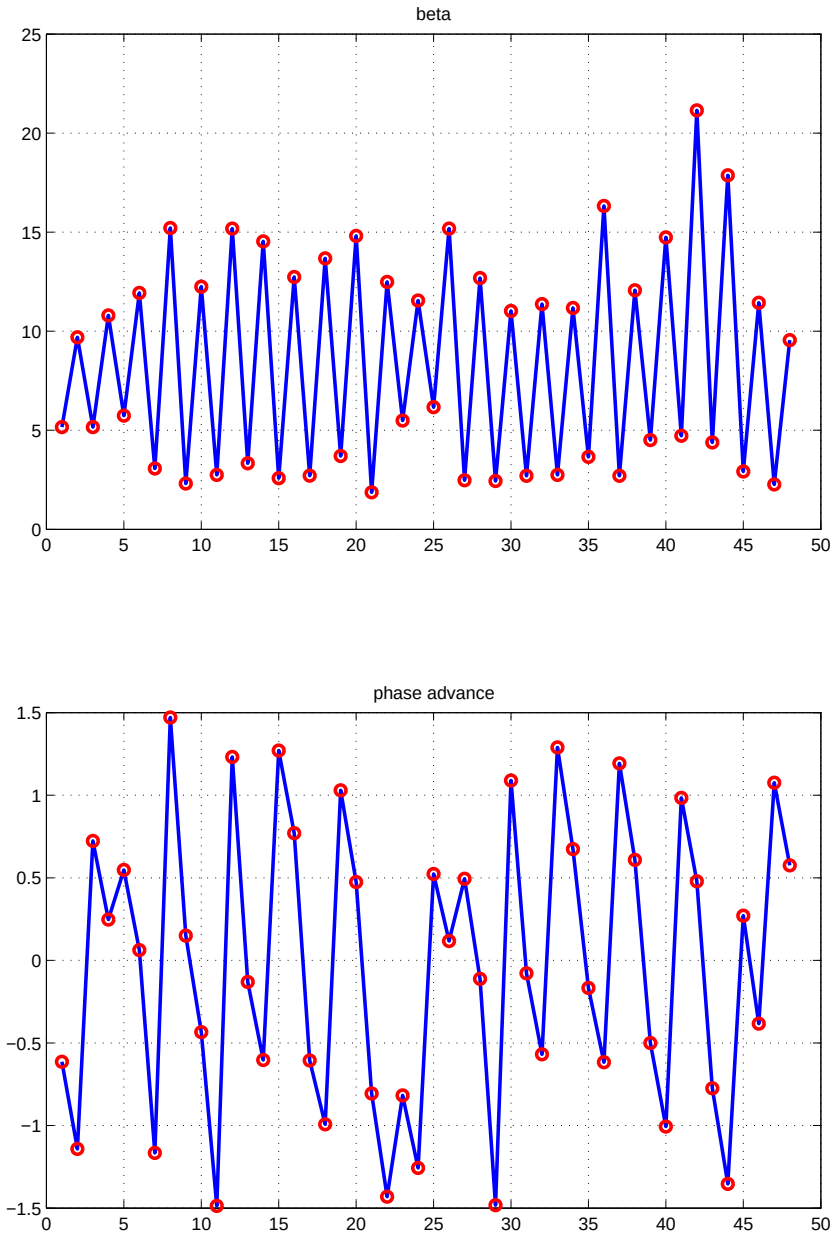


Figure 8: Beta and phase obtained by the 2 leading mode. Horizontal

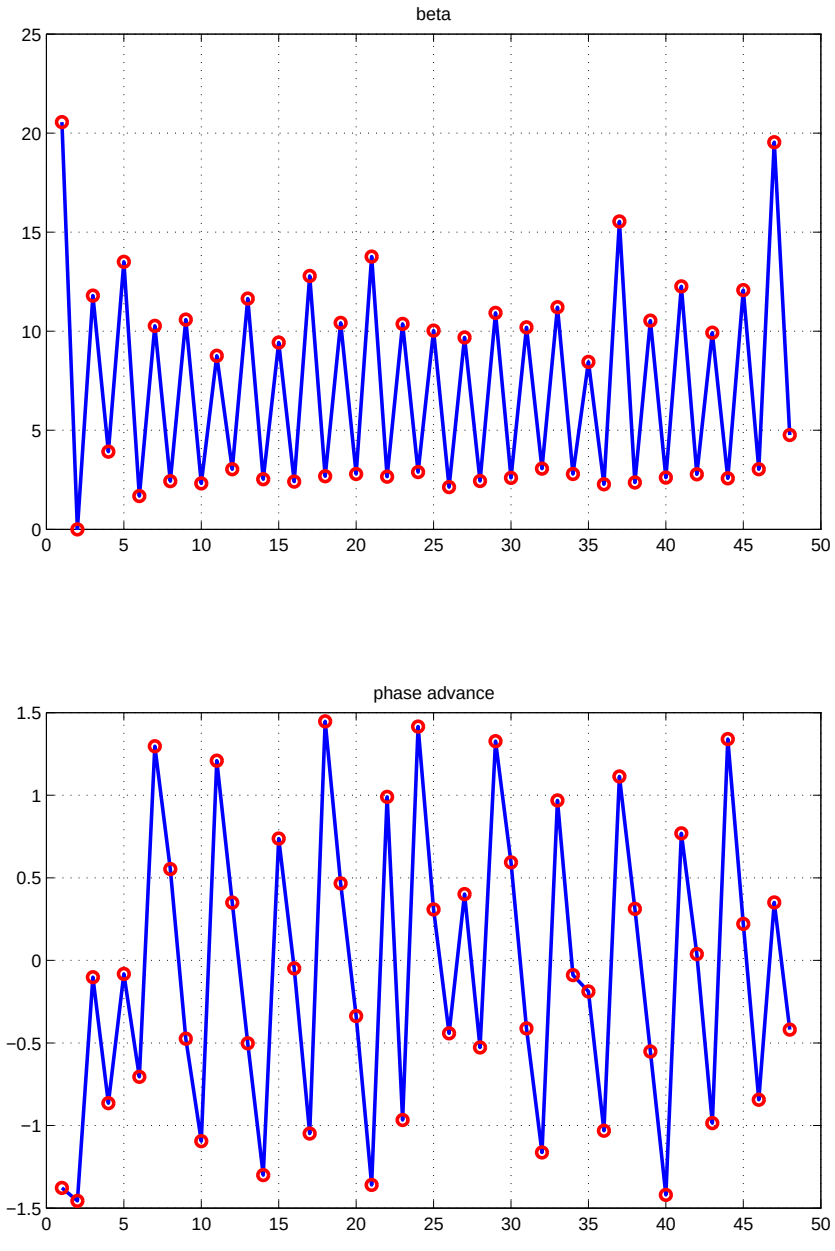


Figure 9: Beta and phase obtained by the 2 leading mode. Vertical, corrected with BPM gain

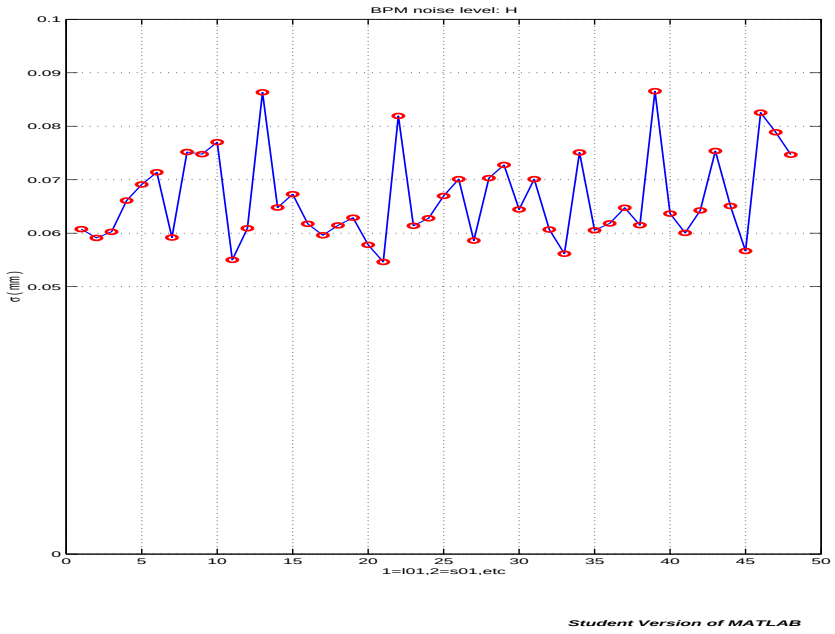


Figure 10: BPM noise. Taken from modes other than the leading 5; Horizontal

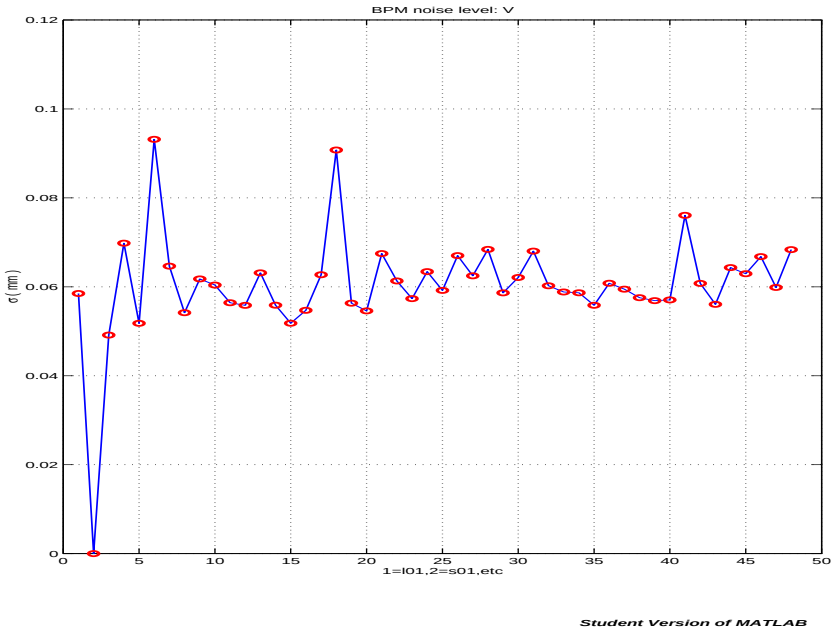


Figure 11: BPM noise. Taken from modes other than the leading 5; Vertical, corrected with BPM gain

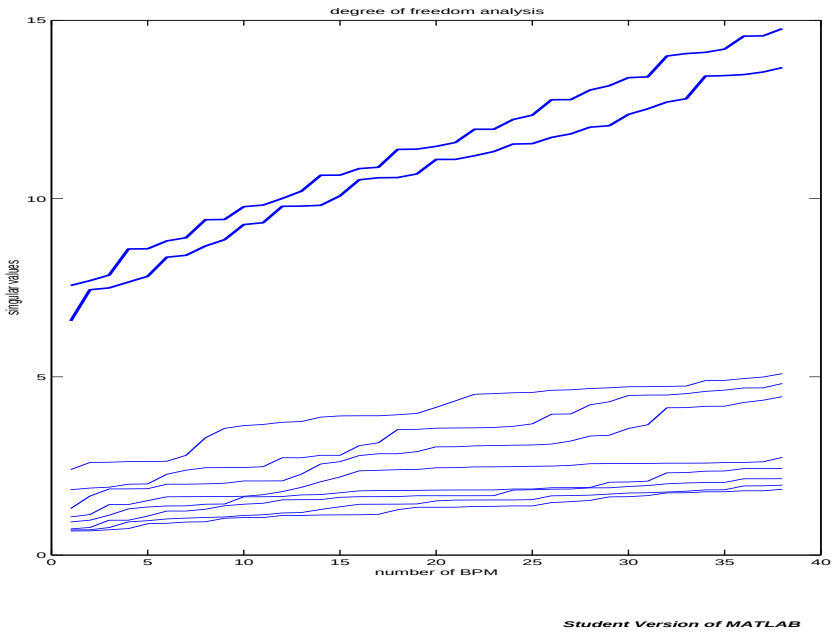


Figure 12: Horizontal, degree of freedom. A plot of singular values of the leading 10 modes as the number of BPMs increases.

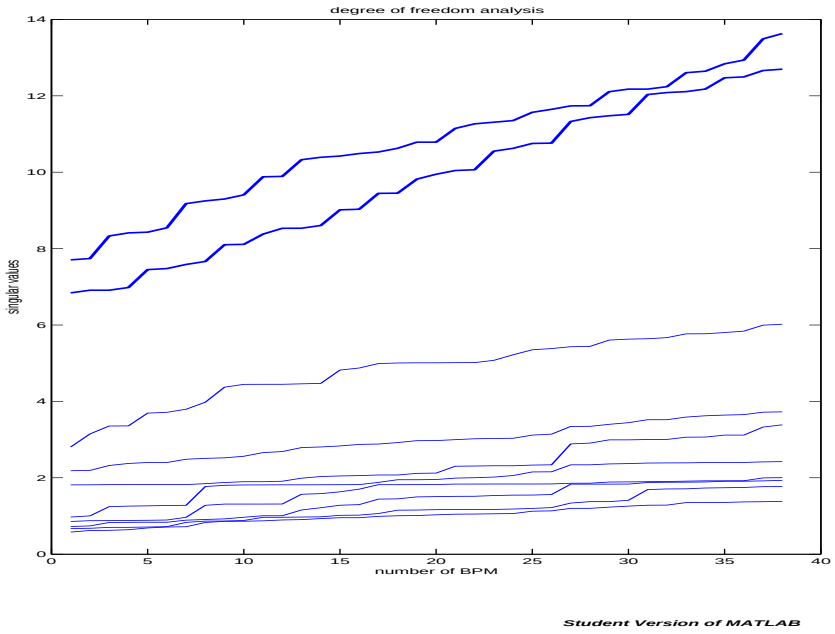


Figure 13: Vertical, degree of freedom.

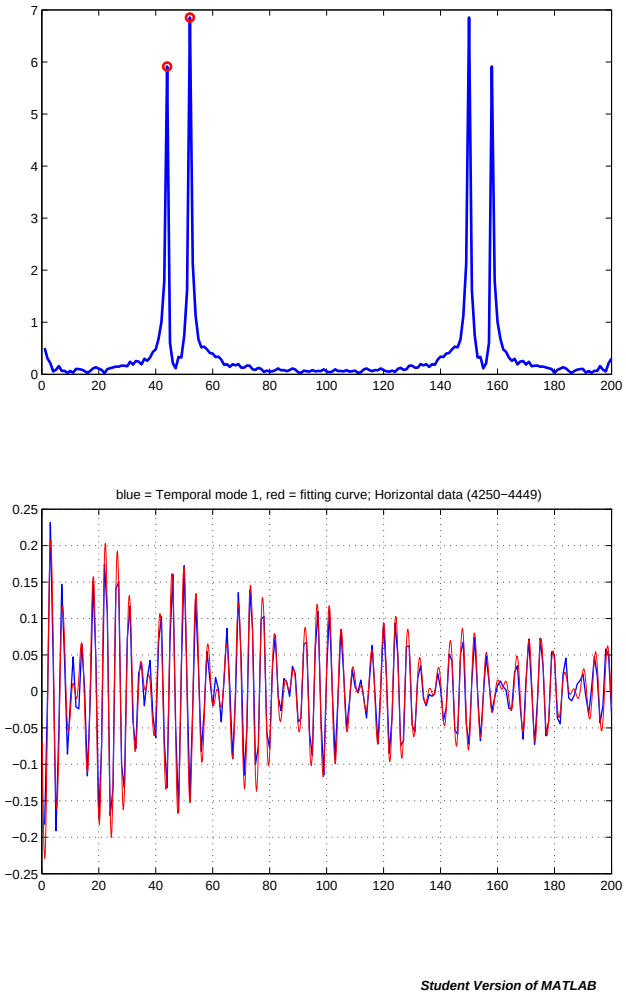


Figure 14: Fit temporal mode into a model $x = a_0 + A\exp(-\alpha t)(\sin(\omega_1 t + \phi_1) + \sin(\omega_2 t + \phi_2))$. Horizontal mode 1

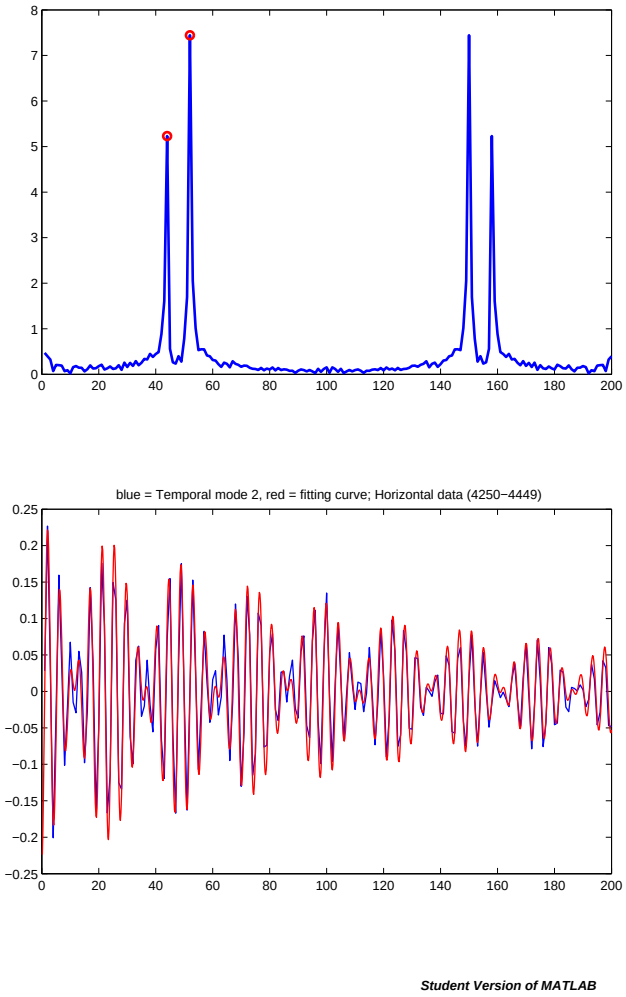


Figure 15: Fit temporal mode into a model $x = a_0 + A\exp(-\alpha t)(\sin(\omega_1 t + \phi_1) + \sin(\omega_2 t + \phi_2))$. Horizontal mode 2

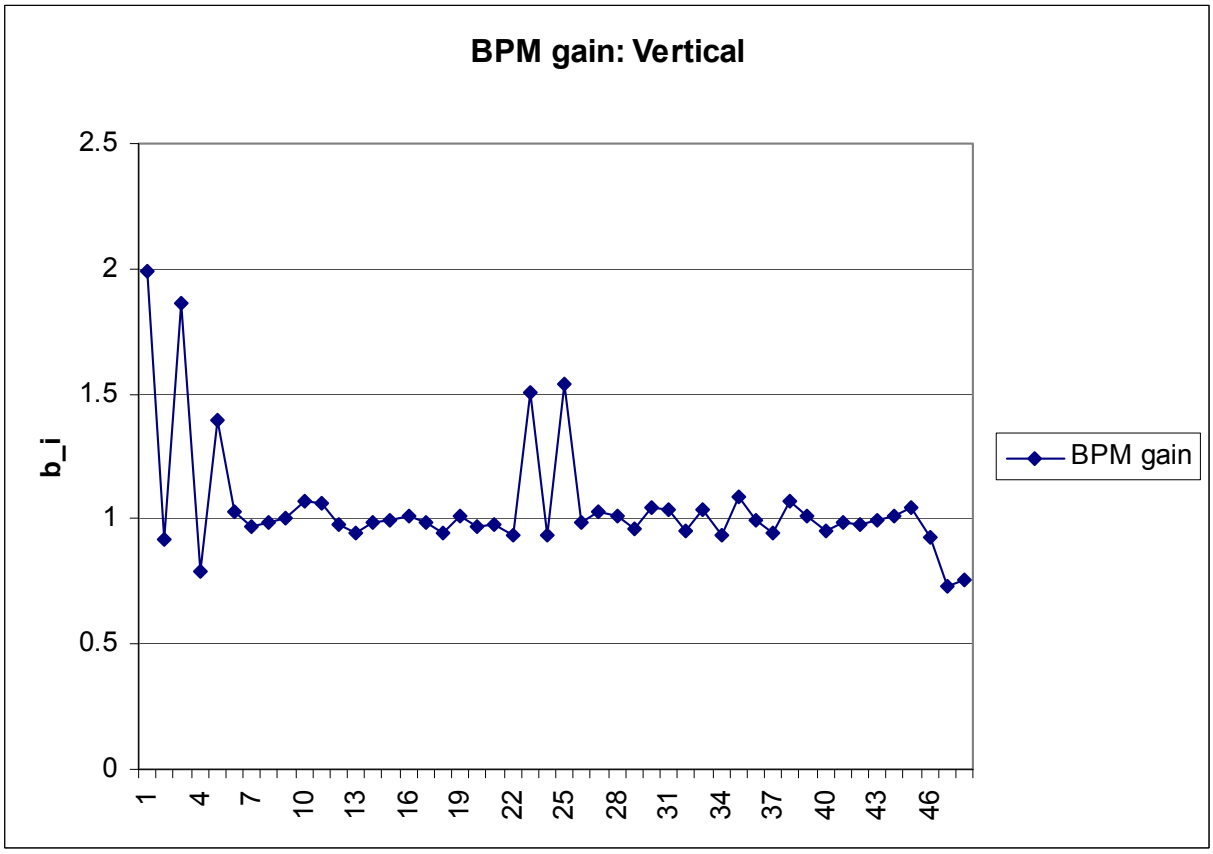
Frequencies:,

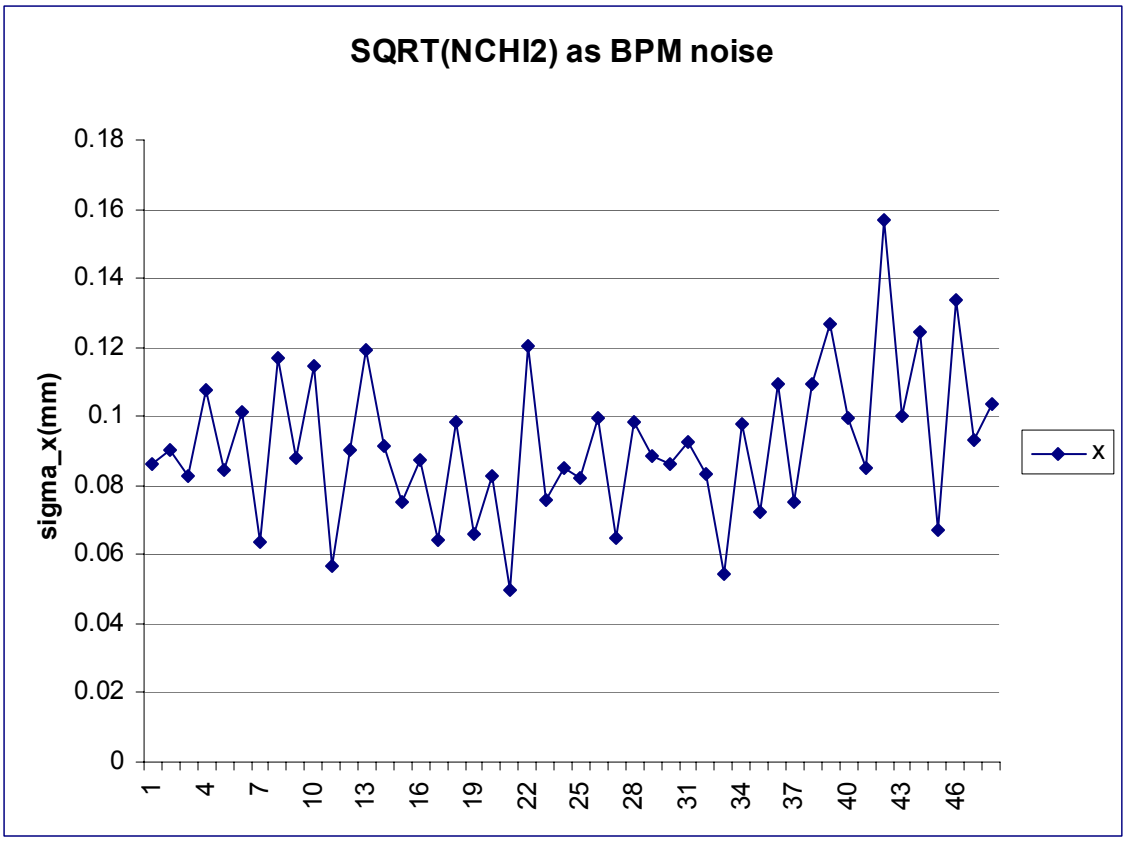
Horizontal	Freq 1	Freq 2	Tune
Mean(w)	1.352249	1.60434	6.76472
Stdev(w)	0.001961	0.002823	0.00055

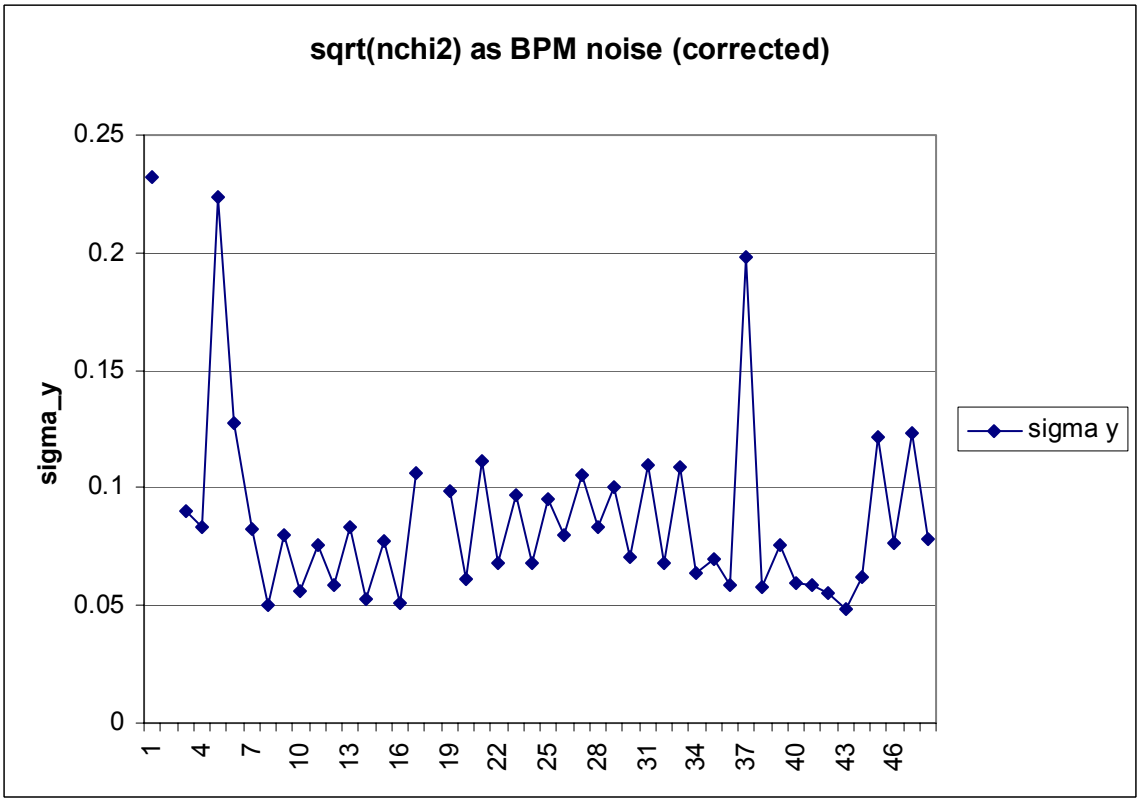
Vertical	Freq 1	Freq 2	Tune
Mean(w)	1.352238	1.603832	6.76476
Stdev(w)	0.001584	0.002154	0.00042

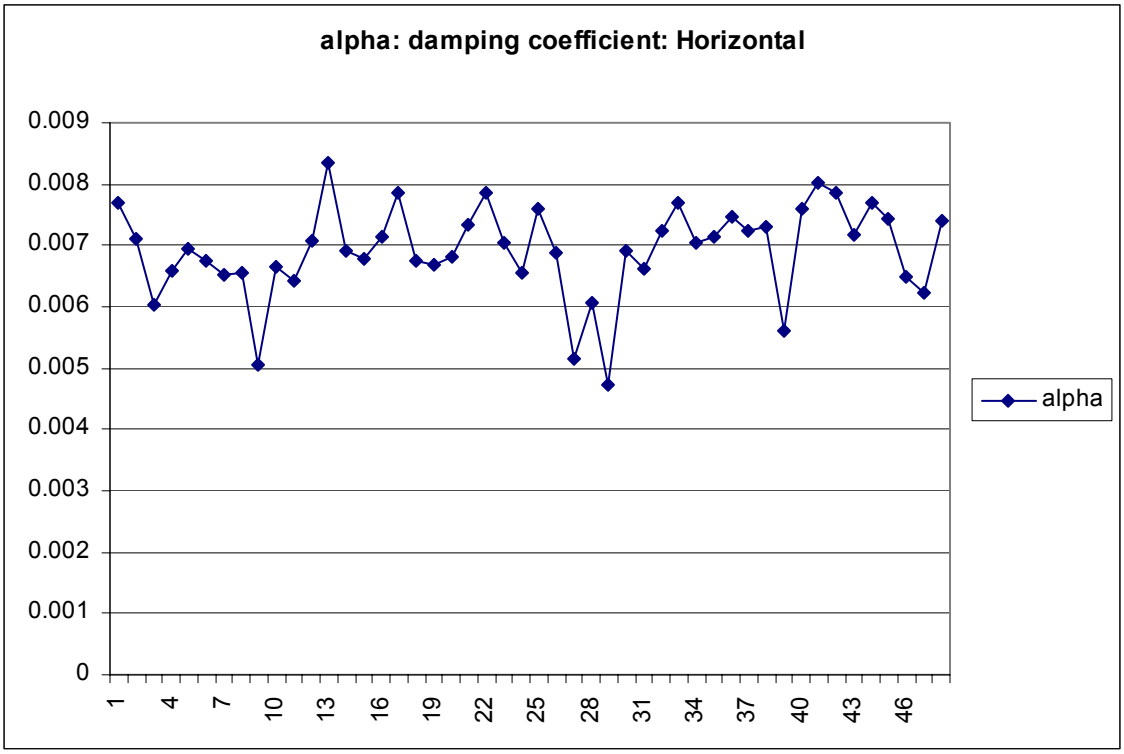
Fitting Model

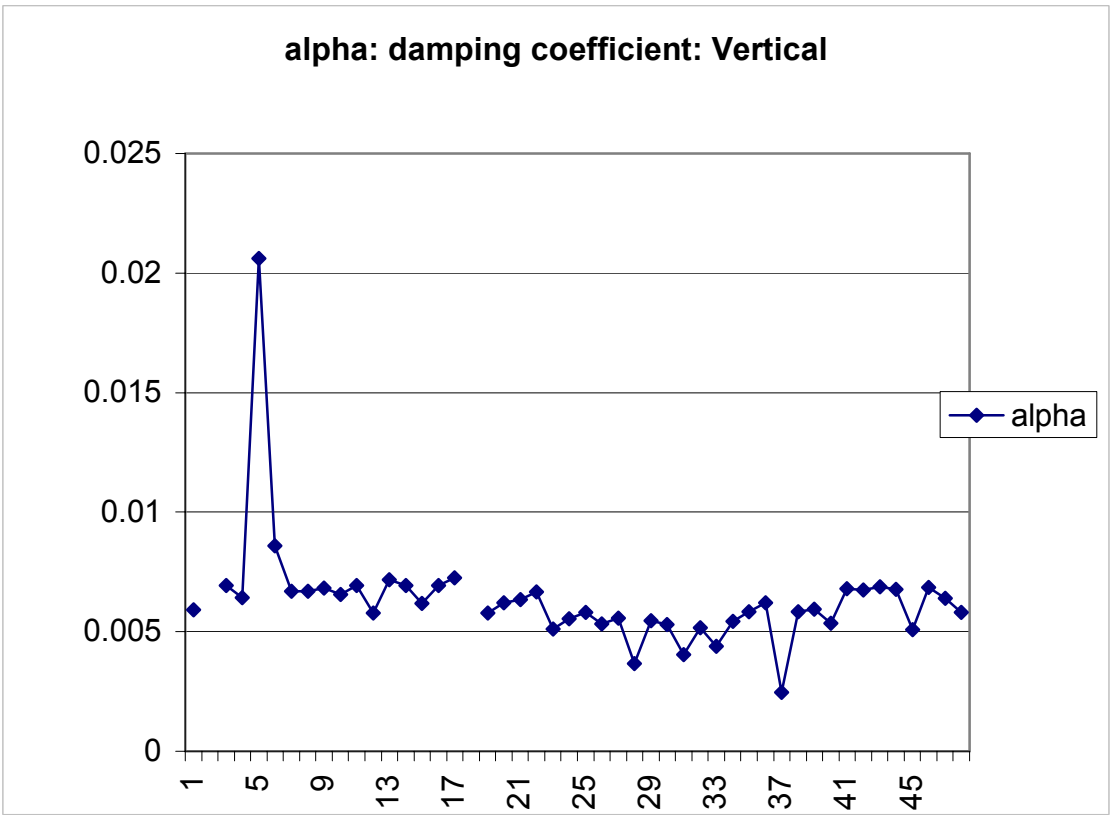
$$x = a_0 + A\exp(-\alpha t)[\sin(\omega_1 t + \phi_1) + \sin(\omega_2 t + \phi_2)]$$

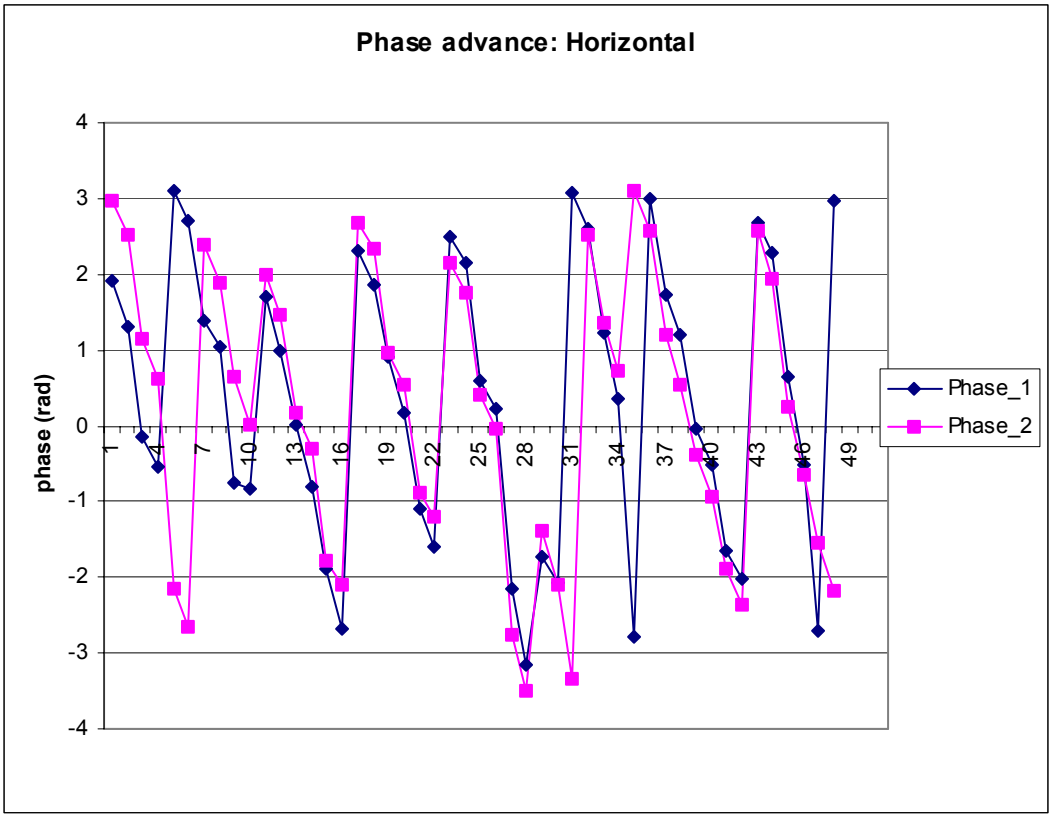


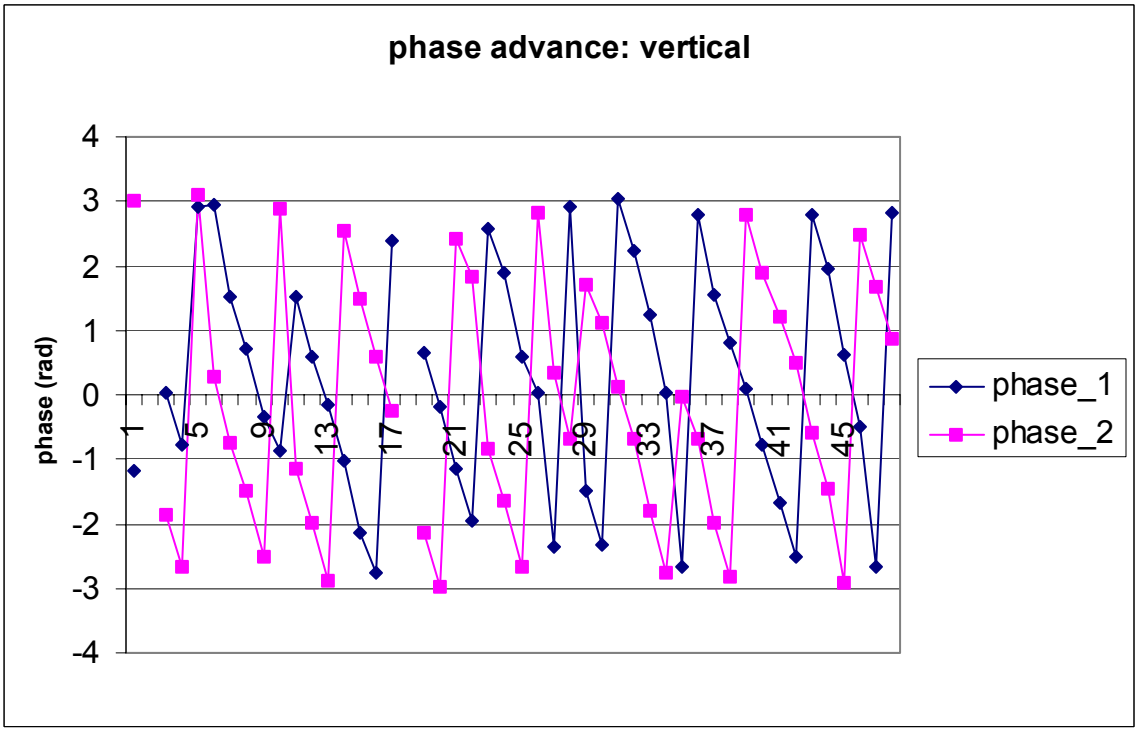

SQRT(NCHI2) as BPM noise
sigma_x(mm)
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
x


sqrt(nchi2) as BPM noise (corrected)
sigma_y
0.25
0.2
0.15
0.1
0.05
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
sigma y


alpha: damping coefficient: Horizontal
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
alpha


alpha: damping coefficient: Vertical
0.025
0.02
0.015
0.01
0.005
0
1
5
9
13
17
21
25
29
33
37
41
45
alpha


Phase advance: Horizontal
phase (rad)
4
3
2
1
0
-1
-2
-3
-4
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
Phase_1
Phase_2


phase advance: vertical
phase (rad)
4
3
2
1
0
-1
-2
-3
-4
1
5
9
13
17
21
25
29
33
37
41
45
phase_1
phase_2

Fit mode 1&2 of Horizontal data to the model

	W1	W2	Nchi^2
Mode 1	1.353014	1.604340	0.00017
Mode 2	1.352549	1.603710	0.00027