



# CLSORB

## Slow SR Orbit Control in Matlab

7.2.61.6 Rev. 0

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## Revision History

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## 1.0 INTRODUCTION

The CLS has been using an application called CLSORB for performing slow orbit correction in the Storage Ring (SR). CLSORB is written entirely in Matlab by Jeff Corbett of SLAC and consists of a graphical user interface (GUI) as well as helper scripts to perform the calculations. Obtaining data from the control network is calls to the Matlab Channel Access (MCA) libraries. For more information on MCA refer to document Zhang [1].

### 1.1 PURPOSE

The purpose of this document is to highlight the CLSORB features as well as create a basic reference document for those people new to using CLSORB. This document assumes that the reader is familiar with executing Matlab and its use of the Accelerator Object (AO) as the orbit data and corrector control are accessed via the AO.

## 2.0 CLSORB GUI DESIGN

CLSORB was written by Jeff Corbett of SLAC. It is a generic orbit control program that uses whatever AO that has been most recently created. CLSORB uses the family data located in the AO for Beam Position Monitor (BPM) data as well as Horizontal and Vertical Corrector Magnets (HCM/VCM). Based on the AO data, CLSORB calls up functions to perform orbit control. A Graphical User Interface (GUI) is designed to give convenience in operation. A graphic of the CLSORB GUI is given below.

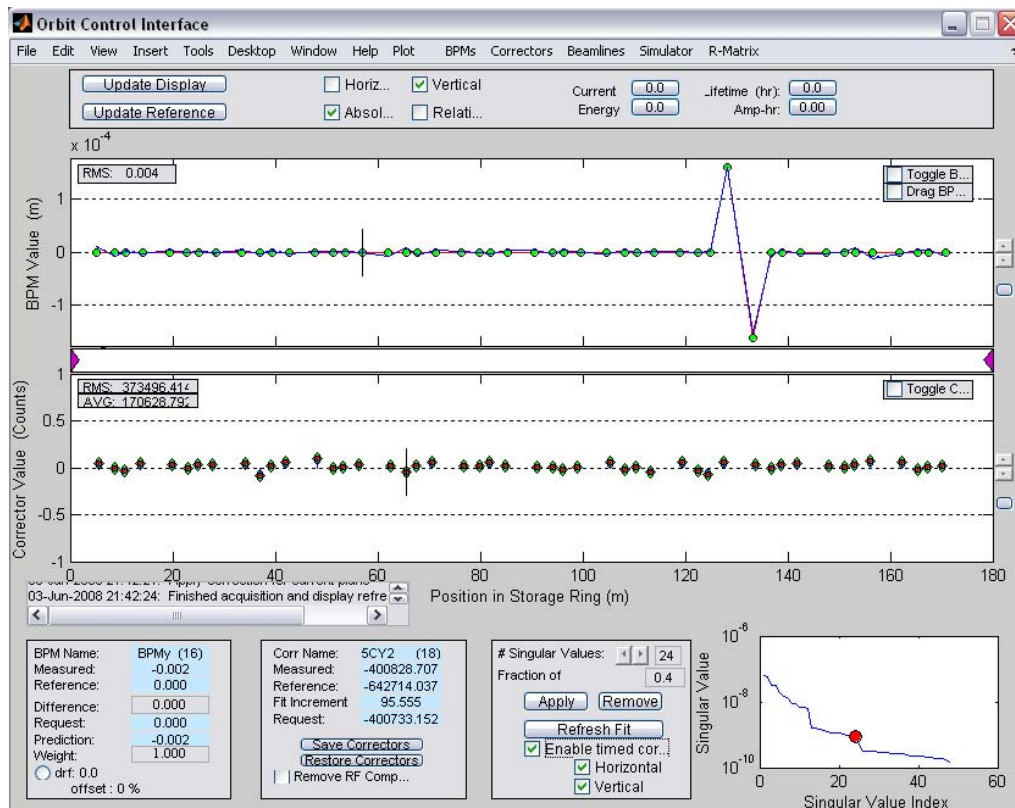


Figure 2.1 CLSORB screen

As shown in Figure 2.1, the CLSORB GUI consists of a set of MatLab GUI widgets, such as Windows menus, pushbuttons, check boxes, and axes. Most of the widgets can trigger callback routines to perform a variety of tasks when manipulated by a user. From a software design point of view, CLSORB calls up four functions to dynamically create those GUI parts, to initialize necessary data structures, and to set up object properties and callback codes to provide orbit analysis and control functionalities. Those functions are described below.

## 2.1 FUNCTION *ORBGUI*

Function *orbgui* consists of a set of functional modules. A MatLab switch/case structure is used to select a certain module being executed. The CLSORB specifies desired *orbgui* module by using its string name as function input parameter.

Some *orbgui* modules are called up during the creation of the GUI to perform setting up or initialization tasks, some of which are:

- Creating the main GUI screen
- Creating the Beam Position Monitor (BPM) display and control panel frame
- Creating the Corrector Magnet (CM) display and control panel frame
- Creating the SVD display and control panel frame
- Creating program information display and element display frame
- Creating upper control panel frame
- Creating menus by calling MatLab *uimenu* function [2]
- Creating user interface controls and setting up properties and callbacks by calling MatLab *uicontrol* function [2]
- Setting up and initializing program data structures

Other *orbgui* modules are used by GUI widgets as callback routines to provide a variety of functionalities after the GUI is created. Some of the functionalities are:

- Refreshing the GUI
- Enabling timed orbit correction
- Loading or saving data
- Switching from different operational modes

Here is an example of using module name *BPMAxes* to call up *orbgui*:

```
orbgui ('BPMAxes')
```

This established the upper axes for the Beam Position Monitor (BPM) display.

## 2.2 FUNCTION *BPMGUI*

Function *bpmgui* has a similar structure to *orbgui*. It consists of a set of functional modules, and uses MatLab switch/case mechanism to select desired module. During the creation of CLSORB GUI, function *bpmgui* is called up to perform the following tasks:

- Creating and initializing circle icons to represent each BPM in the BPM display
- Loading orbit data into BPM data structure
- Setting up, initializing, plotting, and updating the BPM graphics in the BPM display

It is also used by GUI widgets as callback code to provide following functionalities:

- Beam Position Monitor (BPM) selection
- BPM data measurement and processing
- Toggle and Drag modes switching for BPM icon manipulation
- BPM data plotting in the BPM display
- BPM state display in MatLab command window

Here is an example of using module name `PlotIcons_Init` to call up *bmpgui*:

```
bmpgui('PlotIcons_Init')
```

This creates the initial circle icons for each BPM.

## 2.3 FUNCTION *CORGUI*

Function *corgui* is also structured as modules with switch/case mechanism for module selection. It is called during the initialization of the CLSORB GUI to create and initialize patch icons to represent the Corrector Magnets in the corrector display.

Function *corgui* is also used by GUI widgets as callback code to provide following functionalities:

- Corrector Magnet selection
- Corrector Magnet data measurement and processing
- Corrector magnet state display in MatLab command window
- Eigenvector and response matrix display in MatLab command window
- Measuring the response matrix
- Applying or removing orbit correction
- Saving correction data
- Restoring correction data
- Toggle mode selection for Corrector Magnet icon manipulation
- Corrector Magnet data plotting in the corrector display
- Bump generation and restoration

Here is an example of using module name `SaveCorrs` to call up *corgui*:

```
corgui('SaveCorrs',SYS.plane)
```

This saves corrector data for bump generation and restoration.

## 2.4 FUNCTION *RESPGUI*

Function *respgui* consists of a set of functional modules. Desired module is selected by using a switch/case structure. During the creation of the GUI, *respgui* is called up to initialize BPM and corrector eigenvector plots.

Function *corgui* is also used by GUI widgets as callback code to provide following functionalities:

- Building the response matrix and constraint vectors
- Performing inversion and solving the system to calculate corrector values

- Plotting the singular value in the SVD display
- Setting the singular value slider in the SVD display
- Moving the singular value dot to select singular value in the SVD display
- Enabling removal of dispersion component in the horizontal orbit by shifting the SR RF frequency offset

Here is an example of using module name SolveSystem to call up *respgui*:

```
respgui('SolveSystem')
```

This solves the system.

### 3.0 FEATURES

The CLSORB GUI can be divided into several sub screens. Each of them addresses certain aspect of orbit analysis and controls. The following graphic shows the layout of sub screens on the CLSORB main screen.

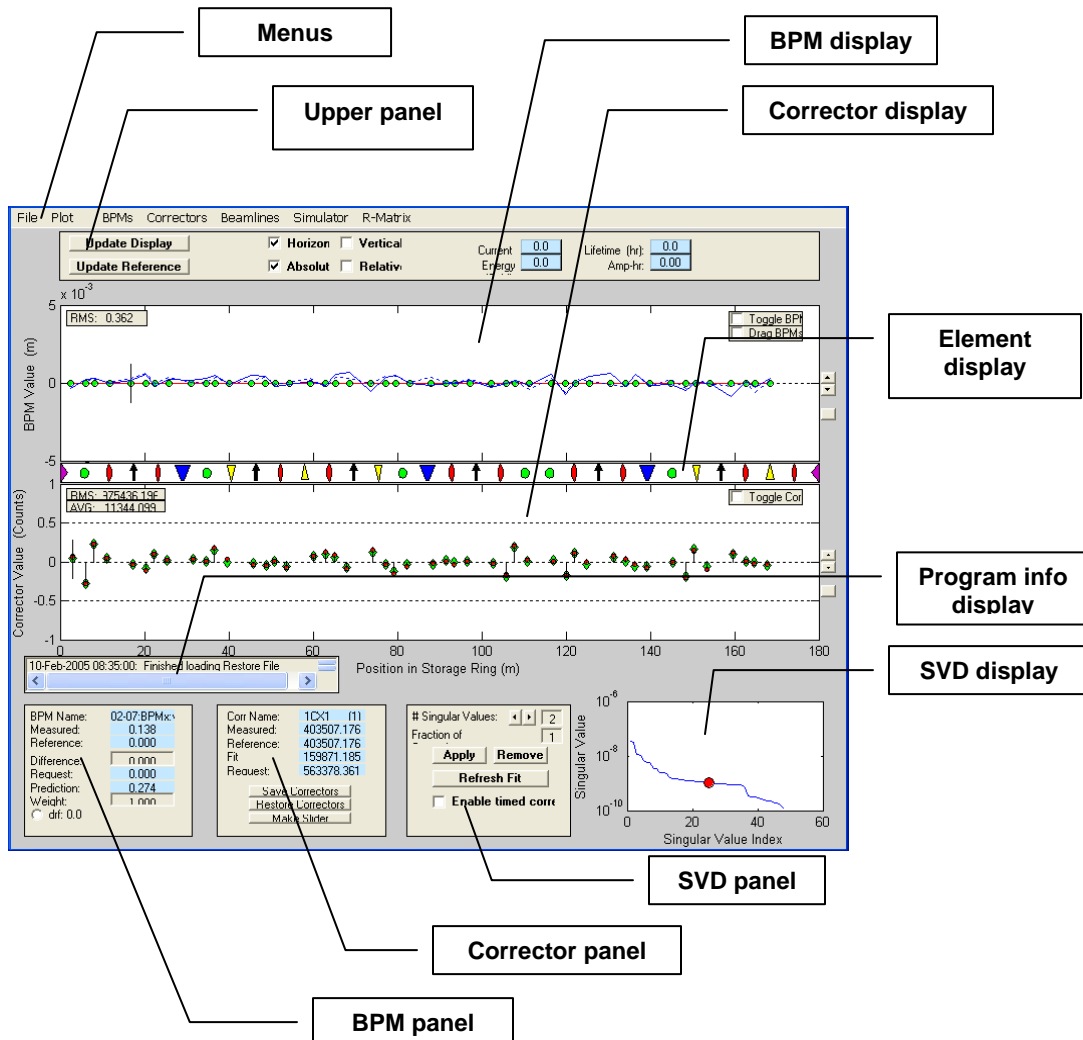


Figure 3.1 CLSORB sub screen layout

### 3.1 UPPER PANEL

A graphic of the upper panel is given in Figure 3.2. The panel consists of following components:



Figure 3.2 Upper Panel

#### 3.1.1 Update Display Pushbutton

The callback routine of this pushbutton is *bpmgui('UpdateAct')*, which executes following steps:

- 1) Measuring and processing the BPM data
- 2) Retrieving corrector set point values
- 3) Performing SVD method to compute the corrector values
- 4) calculating predicted results
- 5) Updating orbit fit, corrector fit, etc
- 6) Updating BPM display
- 7) Updating corrector display
- 8) Updating SVD display

The process from step 1) to 8) is defined as refreshing orbit GUI in this document.

#### 3.1.2 Update Reference Pushbutton

The callback routine of this pushbutton is *bpmgui('UpdateRef')*, which executes following steps:

- 1) Setting a simulated or most recently measured orbit as the reference
- 2) Refreshing orbit GUI

#### 3.1.3 Horizontal Checkbox

The callback routine of this checkbox is *orbgui('Plane')*, which executes following steps:

- 1) Switching to the horizontal plane
- 2) Refreshing orbit GUI

#### 3.1.4 Vertical Checkbox

The callback routine of this checkbox is *orbgui('Plane')*, which executes following steps:

- 1) Switching to the vertical plane
- 2) Refreshing orbit GUI

### 3.1.5 Relative Checkbox

The callback routine of this checkbox is *orbgui('Relative')*, which executes following steps:

- 1) Setting orbit display into relative reference mode:
- 2) Refreshing orbit GUI

### 3.1.6 Absolute Checkbox

The callback routine of this checkbox is *orbgui('Relative')*, which executes following steps:

- 1) Setting orbit display into absolute reference mode
- 2) Refreshing orbit GUI

### 3.1.7 Current Pushbutton

The string on this button shows the electron beam current in Amperes.

### 3.1.8 Energy Pushbutton

The string on this button shows the electron beam energy in GeV.

### 3.1.9 Lifetime Pushbutton

The string on this button shows the electron beam lifetime in hour.

### 3.1.10 Amps-hr

The string on this button shows the electron beam Amps-hours.

## 3.2 BPM DISPLAY

A graphic of the BPM display is given in Figure 3.3.

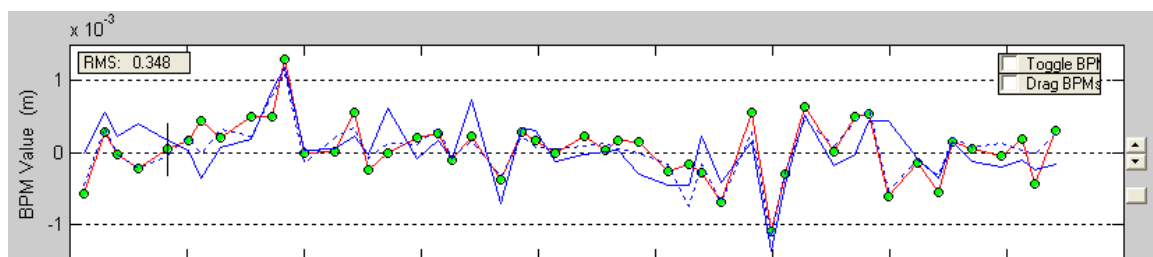


Figure 3.3 BPM display

In the BPM display, X axis is the position in the storage ring. Y axis is the Beam Position Monitor value. The unit for both axes is meter.

The BPM display shows three orbit trajectories: the reference trajectory (red), the measured orbit trajectory (blue), and the predicted fully corrected orbit trajectory (blue-dash). Adjusting the right side slider zooms in/out the display. The Root Mean Square (RMS) of BPM value is shown at the upper left corner of the display.

BPMs are represented by circle-shaped icons. Clicking on a BPM icon brings up a vertical mark on that icon. Information of the marked BPM is displayed on the BPM panel (3.6).

Checkbox Toggle BPM is used to turn on/off the 'toggle' mode. In the 'toggle' mode, BPMs can be selected graphically to specify which BPMs serve as fitting constraints. When a BPM is selected, its surface color is set green; otherwise the surface color is set yellow. BPMs can also be selected/unselected from the BPM menu.

Checkbox Drag BPMs is use to turn on/off the 'drag' mode. In the 'drag' mode, BPMs can be moved graphically to manipulate the predicted fully corrected orbit to desired positions. The CLSORB steers the beam toward the desired position.

### 3.3 ELEMENT DISPLAY

The element display shows lattice elements icons. Figure 3.4 gives a graphic of the element display.



Figure 3.4 the element display

Clicking individual icon brings up a screen displaying family information of that element. Clicking the Show Image button on this screen shows a picture of the hardware.

The family elements and corresponding icons are listed below:







Family Name	Element Icon
BPM	
HCM/VCM	
QFA/QFB/QFC	
SD	
SF	
BEND	

Figure 3.5 family elements and icons

### 3.4 CORRECTOR DISPLAY

A graphic of the corrector display is given below:

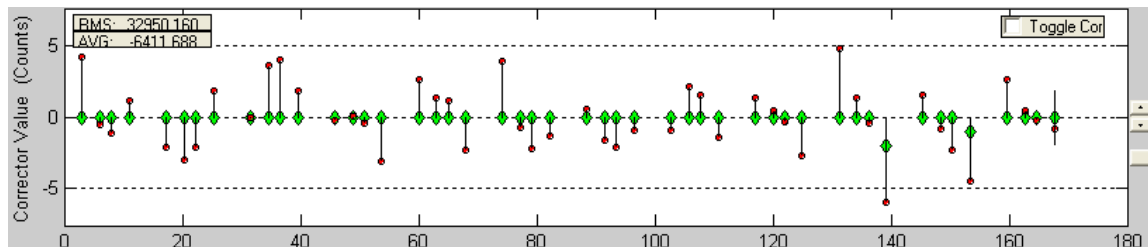


Figure 3.6 the corrector display

In the corrector display, X axis is the position in the storage ring, in the unit of meter. Y axis is the corrector value.

The corrector display shows actual magnet strength and the sum of the actual and fitted magnet strength of each corrector in stem plot form. The actual strength of a corrector is represented by a diamond-shaped icon. The sum of actual and fitted strength of a corrector is represented by a circle-shaped icon. Adjusting the right side slider zooms in/out the display. The Root Mean Square (RMS) and average values are shown at the upper left corner of the display.

Clicking on a corrector's icons brings up a vertical mark on them. Information of the marked corrector will be displayed on the corrector panel (3.7).

Checkbox Toggle Cor is used to turn on/off the 'toggle' mode. In the 'toggle' mode, correctors can be selected graphically to specify which corrector magnets act as variables in the fitting algorithms. When a corrector is selected, the surface color of the diamond-shaped icon is set green; otherwise the surface color is set yellow. The surface color of the circle-shaped icon is always red. Correctors can also be selected/unselected from the corrector menu.

### 3.5 PROGRAM INFORMATION DISPLAY

Program status messages are shown in the program information display. A graphic of the program information display is given below:

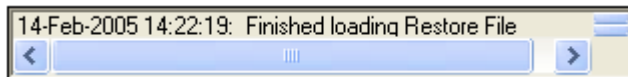


Figure 3.7 program information display

### 3.6 BPM PANEL

When a BPM is marked in the BPM display, the BPM panel displays information of this BPM, which includes:

- BPM name
- Measured value
- Reference value
- Difference from the reference value
- Request value
- Predicted value
- Weight

A graphic of the BPM panel is given in Figure 3.8.

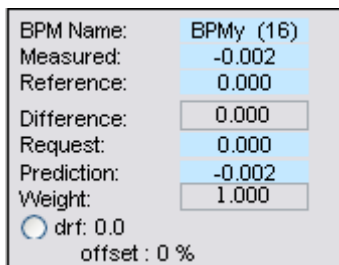


Figure 3.8 BPM display

The drf radio button enables/disables the calculation of the dispersion component of the orbit and calculates the frequency shift needed to correct it. The *offset: %* displays the frequency shift in percent of 5 kHz, the format used by the frequency offset PV.

### 3.7 CORRECTOR PANEL

When a corrector magnet is marked in the corrector display, the corrector panel displays information of this corrector:

- Corrector name
- Measured value
- Reference value
- Fit value
- Request fit value

A graphic of the corrector panel is given below:

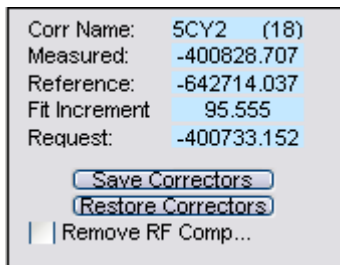


Figure 3.9 corrector panel

The corrector panel also provides two pushbuttons for corrector manipulation and one checkbox to enable/disable dispersion correction.

#### 3.7.1 Save Corrector Pushbutton

The callback routine of this checkbox is *orbgui('SaveCorrs', Sys.plane)*, which saves the corrector read back set points.

#### 3.7.2 Restore Corrector Pushbutton

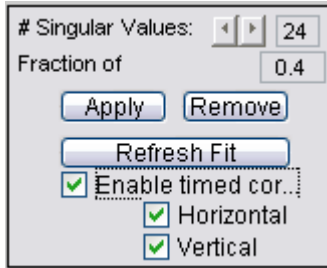
The callback routine of this checkbox is *orbgui('RestoreCorrs')*, which restores correctors to saved values.

#### 3.7.3 Remove RF Component

Checking this box enables the dispersion correction. A maximum frequency shift of 0.2% (100% corresponds to 5 kHz) is allowed each time a horizontal orbit correction is performed.

### 3.8 SVD PANEL

The SVD panel consists of a set of user interface controls for SVD manipulation. A graphic of the SVD panel is given below:



3.12 SVD panel

### 3.8.1 Singular Values Slider

This is used for selection of the number of singular values. The selected number is shown in the right text box. The number can also be selected graphically on the SVD display (3.9).

### 3.8.2 Fraction of Correction

This edit box receives a numerical input as the fraction of correction. The number should be between 0 and 1.

### 3.8.3 Apply Pushbutton

The callback routine of this pushbutton is *corgui*('ApplyCorrection'), which executes following steps:

- 1) Saving current corrector pattern data
- 2) Writing calculated corrector values to EPICS Process Variables (PV) to perform orbit correction
- 3) Waiting 1 second for BPM processing
- 4) Refreshing orbit GUI

### 3.8.4 Remove Pushbutton

The callback routine of this pushbutton, *corgui*('RemoveCorrection'), restores the corrector to the prior corrector pattern. It executes following steps:

- 1) Writing saved data to EPICS PV to restore previous corrector pattern
- 2) Refreshing orbit GUI

### 3.8.5 Refresh Fit Pushbutton

The callback routine of this pushbutton is *orbgui*('RefreshOrbGUI'), which executes the refreshing orbit GUI process.

### 3.8.6 Enable Timed Correction Checkbox

The call back routine of this checkbox is *corgui*('TimedCorrect'), which executes the orbit correction steps 1) to 4) described in 3.8.3 every 7 seconds as long as the beam current is larger than a set value, and other criteria are satisfied. Can select either or both horizontal and vertical planes.

### 3.9 SVD DISPLAY

A graphic of the SVD display is given in Figure 3.13.

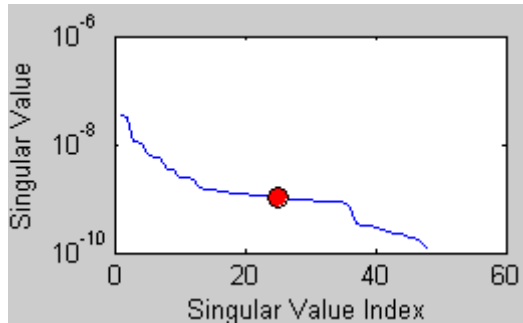


Figure 3.13 SVD display

The SVD display shows a blue, solid dynamic line for singular value plot. The red dot can be dragged with mouse cursor to slide on the blue line to select desired singular value number. The selected number is shown in the SVD display (3.8.1).

### 3.10 MENUS

The CLSORB GUI provides with a set of Windows style menus to facilitate user operation.

#### 3.10.1 File Menu

The File menu contains options for file operations, which includes:

- **New figure:** create new figure
- **Open:** open a existing file
- **Close:** exit the CLSORB GUI
- **Save:** save file
- **Save as:** save file to designated file
- **Print**

#### 3.10.2 Plot Menu

The Plot menu has two options:

- **BPM Plot Scale:** bring up a dialog box for BPM plot control. A graphic is given below:

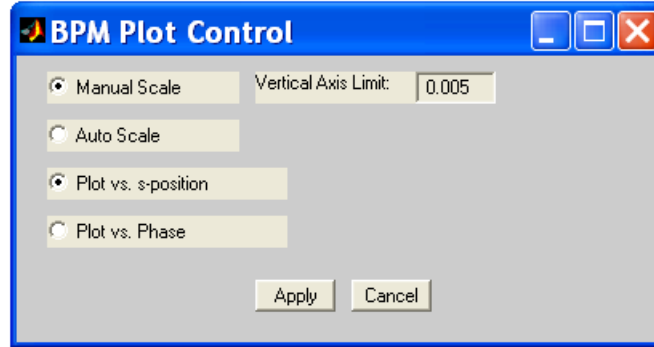


Figure 3.14 BPM plot control

- **Corrector Plot Scale:** bring up a dialog box for corrector plot control. A graphic is given below:

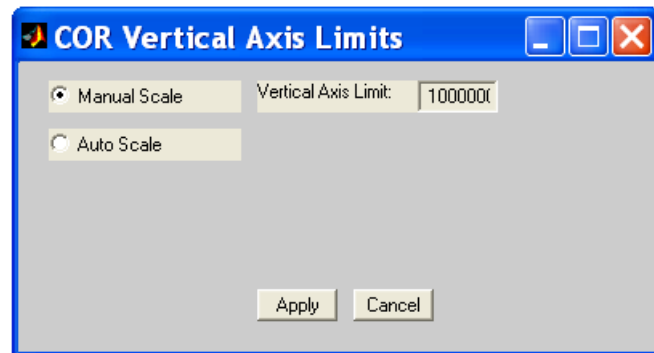


Figure 3.15 Corrector vertical axis limits

### 3.10.3 BPMs Menu

The BPMs menu contains following options:

- **Select All BPMs:** selected BPM icon color is set green
- **Select No BPM:** unselected BPM icon color is set yellow
- **Remove BPM Drag Changes:** remove offsets
- **Show BPM State:** display BPM settings on the MatLab command window
- **Archive X/Y-Orbit:** archive present orbit as orbit reference
- **Load X/Y-Reference Orbit:** read archived orbit as reference
- **Load Zero X/Y-Reference:** load zeros into reference orbit
  - i.e.,  $reference = gain \times (ref - offset) = 0$
- **Archive Golden X/Y-Orbit:** archive present orbit as golden reference orbit
- **Load Golden X/Y-Orbit:** read archived golden orbit as reference
- **Select X-BPM Weights:** brings up the following screen for horizontal BPM weights selection

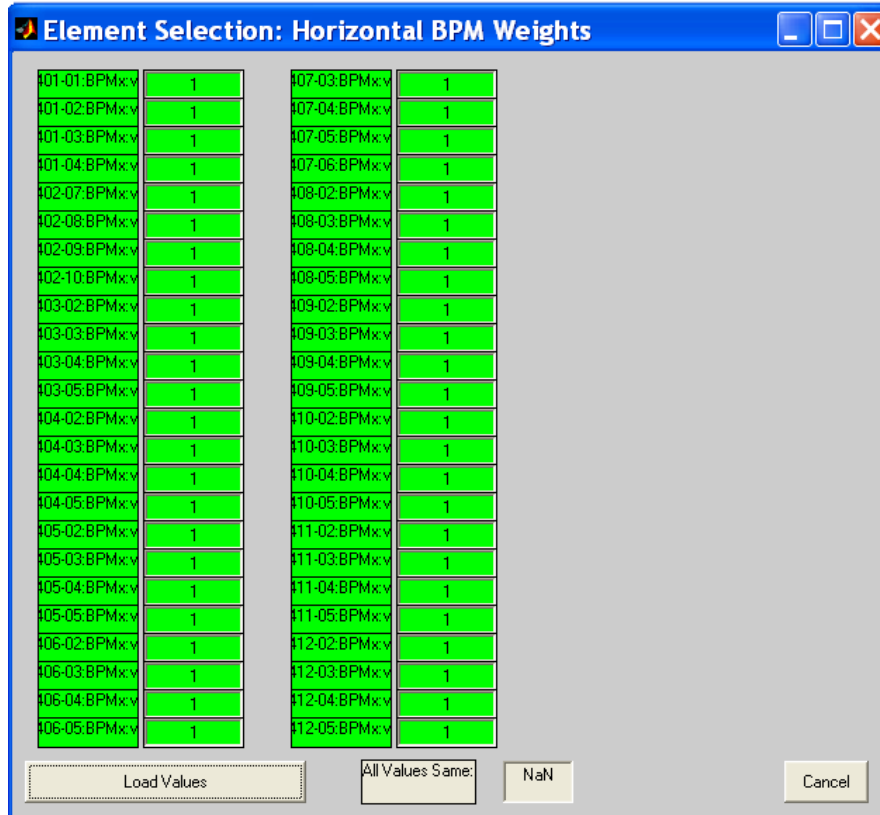


Figure 3.16 Horizontal BPM weights selection

- **Select Y\_BPM Weights:** brings up a screen for vertical BPM weights selection. The screen layout is identical with that in Figure 3.16.
- **Help with BPM Functions**

### 3.10.4 Correctors Menu

The corrector menu contains following options:

- **Update Correctors:** acquire corrector readbacks, plot, and re-calculate fit
- **Select All Correctors:** select all available correctors, selected icons turn green
- **Select No Correctors:** unselect all available correctors, unselected icons turn yellow
- **Select X-Corrector Weights:** bring up a screen for horizontal corrector weight selection. A graphic of the horizontal corrector weight selection screen is given in the following Figure 3.17

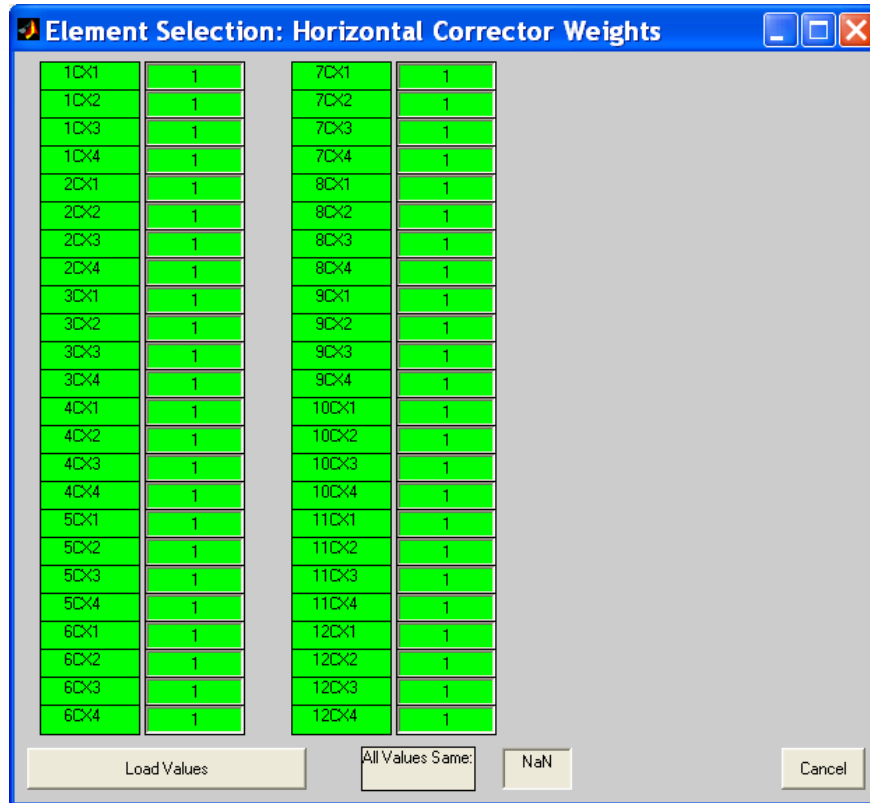


Figure 3.17 Horizontal corrector weight selection

- **Select Y-Corrector Weights:** brings up a screen for vertical corrector weights selection. The screen layout is identical with that in Figure 3.17.
- **Show Corrector State:** display corrector settings on the MatLab command window
- **Help with Corrector Functions**

### 3.10.5 Beamlines Menu

The Beamline menu contains following options:

- **Select Beam Lines**
- **Select Y-Photon BPM Weights**
- **Update Photon Beamline Data**

### 3.10.6 Simulator Menu

The Simulator menu contains following options for simulation settings:

- **New Quad Alignment:** apply quadrupole offsets
- **Make New Reference Orbit:** produce and load a random orbit for reference
- **Corrector strengths to zero:** set corrector strengths to zero
- **Quad alignment to zero:** set quadrupole offsets to zero
- **Update Optics:** recompute linear optics

- **Fit Tunes to 14.15/5.23:** set tune back to nominal values

### 3.10.7 R-Matrix Menu

The R-Matrix menu contains following options:

- **Read Response Matrix:** prompt the user to select a configuration file to load a saved response matrix
- **Write Response Matrix:** prompt the user to specify a file name and path to save the response matrix
- **Show Eigenvectors**
- **Show Response:** display columns of response matrix
- **Select X-Corrector Strength (BPM):** bring up a screen for the selection of corrector currents for horizontal response to BPMs. A graphic of the screen is given below:

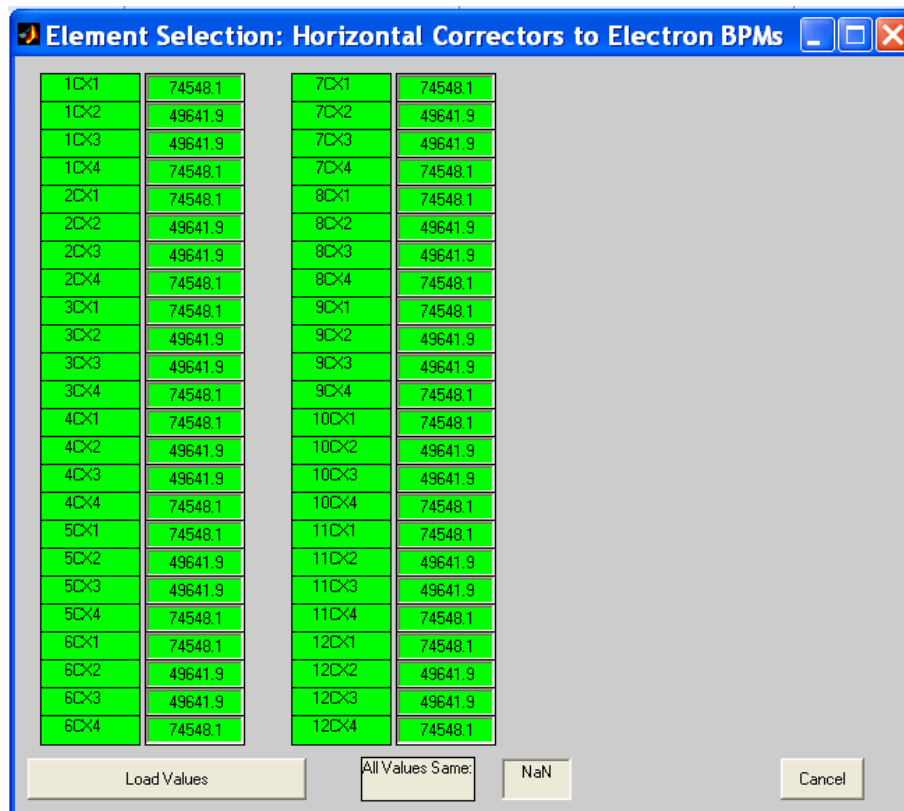


Figure 3.18 Horizontal corrector strengths selection

- **Measure Horizontal to BPMs:** measuring horizontal response matrix to BPMs
- **Select Y-Corrector Strengths (BPM):** bring up a screen for the selection of corrector currents for vertical response to BPMs. The layout of the screen is identical to that in Figure 3.18.
- **Select Y-Corrector Strengths (Beamlines):** bring up a screen for the selection of corrector currents for vertical response to beamlines. The layout of the screen is identical to that in Figure 3.18.
- **Measure Vertical to BPMs:** measure vertical response matrix to BPMD

- **Measure Vertical to Beamlines:** measure vertical response matrix to beamlines

## REFERENCE

[1] Hao Zhang, "Current Accelerator Operations Use of Matlab - System Overview 2004, 7.2.61.5"

[2] Matlab, the Math Works, Natick, MA

[3] J. Corbett, et al, "Interactive Orbit Control in MatLab", Proceeding of Particle Accelerator Conference, Chicago 2001