

# High Order Shimming for fMRI

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## Introduction

Shimming is a process whereby the magnetic field is made more uniform. Historically it involved the insertion of small tabs of metal into the pole pieces of the electromagnet (which engendered the name) while measuring the field in many places with a Gaussmeter. I'm old enough to have actually done this many times (electricity **had** been invented then, but several of my colleagues were still working on "fire").

Shimming is important in fMRI because rapid scanning (EPI or Spiral) is much more sensitive to off-resonance than conventional imaging. Even if the magnet is well shimmed during servicing, the insertion of a human in the magnet destroys the homogeneity (on the ppm level). The AutoShim function on Signa performs a linear shim, i.e. corrects for linear gradients in the field, by adjusting DC currents in the gradient coils. In addition, the spiral reconstruction program performs a linear shim correction on a slice-by-slice basis. However, the shape of heads and bodies guarantees that residual higher order heterogeneities remain. It is desirable to correct for them as much as possible to avoid blurring and signal loss.

Dong-Hyun Kim, a student of Dan Spielman's, Elfar Adalsteinsson, and Dan in our lab have developed an automated package to perform higher order shimming. It acquires scans using a spiral sequence, calculates the field map and shim correction needed, and downloads the resistive shim power supply, gradients and spectrometer center frequency. The shim terms thus optimized are zero (Z0), first (X, Y, Z1), all the second order components (XY, X<sup>2</sup>-Y<sup>2</sup>, ZX, ZY, Z2), and Z3. I call it DK-Shim in honor of Dong-Hyun.

## DK-Shim

The shim should be done after anatomic scanning, and before functional scans are acquired. Thereafter, "AutoShim" on the Signa should NOT be done, unless you want to destroy the shim you just optimized.

1. Copy protocol from Head, protocol #(2. Shim). Specify the coil being used (e.g. helmethead or head). Do not alter any other parameters except starting and ending slice locations in the S/I direction. For the latter, you will have to insert numbers offset by the center of the slice volume specified by your anatomic scans in the S/I direction. The intent is that the table should not move (more than a mm or so) when prescribing this scan.

A script called 'shimcalc' is available to do the prescription calculation.

Example. The prescription for your anatomic scan ended with:

	S/I	R/L	A/P
Start:	S69.6	does not matter	
End:	S10.2	does not matter	

>shimcalc

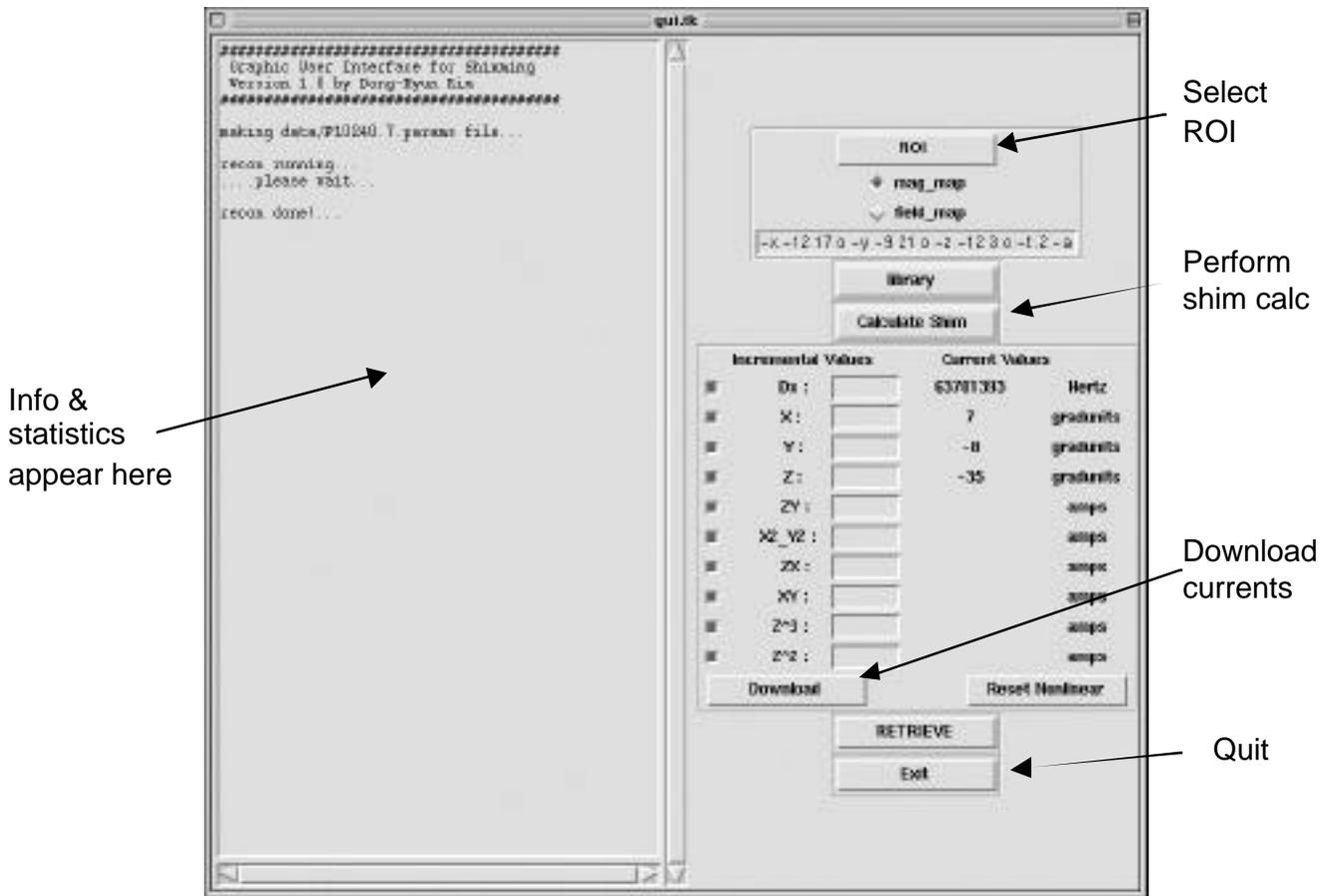
```
Enter your anatomic S/I values (start, stop): s69.6 s10.2
Here are the shim S/I start/end locations:      S155.7/I76.8
Do not alter any other prescription values
Be sure the number of slices scanned is 32
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You should enter S155.7 and I76.7 into the start and end locations for the shim prescription, overwriting the values of S116.2/I116.3.

2. Once you've saved the changes to this series, run it before your first functional scan. (You will not need to run it again unless you change slice prescriptions and move the table more than a few cm.)

- To run it:

Hit Scan. After 4 sec of scanning, a Graphic User Interface (GUI) window will appear with a number of options on the RHS, as shown below.

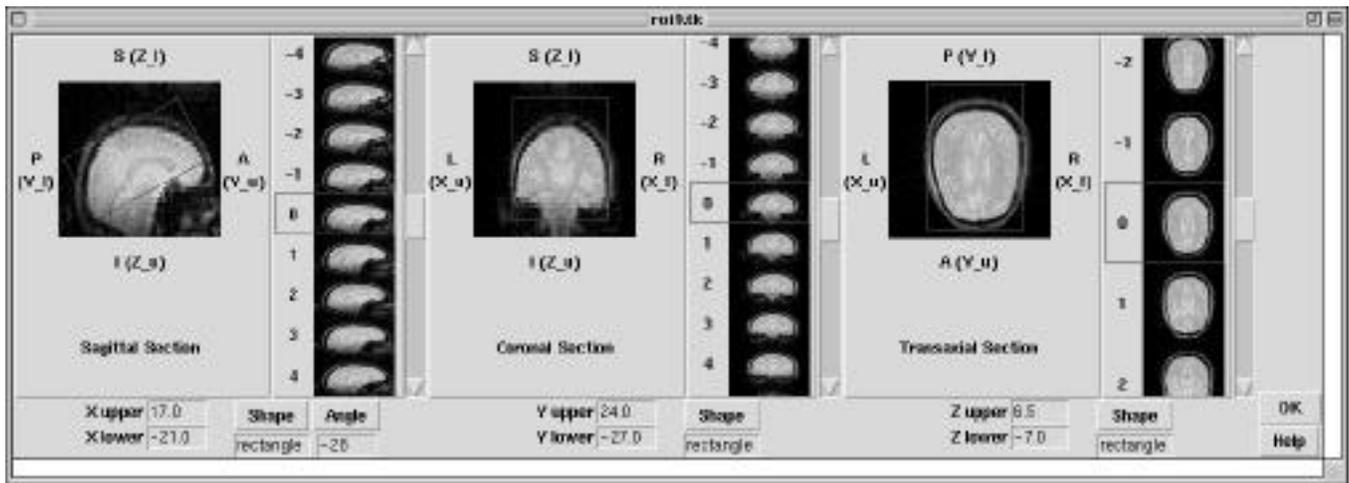


3. Wait for Recons to finish as denoted on LHS (a few seconds).

4. Hit 'ROI'. A window as shown below will appear, with low resolution slices in 3 scan planes. Each has a red outline ROI on it. Your job is to modify the ROI for each of the 3 planes so that it properly outlines the brain area that you most care about (which could be the whole brain). Under the option Shape you can pick oval or rectangle – double click on one to change it; the change takes place when you next click on the ROI. Left click+drag on one side of the ROI to change the shape of the outline, else click in the center to move it. As you change the ROI in one plane, concomitant changes will appear in other planes. It is not necessary to be very precise to outline the brain. When you are satisfied with the 3D ROI, hit 'OK'. This GUI will disappear.

5. Hit 'Shim'. In the window on the left, calculated statistics will appear. Examine Current Field Map Statistics and Predicted Field Map Statistics, given in RMS and peak-to-peak Hz. The estimate should result in smaller numbers (better homogeneity).

6. Hit 'Download'. This will result in transfer of the new shim values to the shim power supply. When it finishes doing so (several seconds of commands on the LHS of the screen), hit 'Exit'. The GUI will disappear.



7. Now verify the shim by doing another scan:

Hit Scan

In the Shim GUI, hit 'Shim'

Check that the new Current shim values are nicer.

Hit 'Download'

Hit 'Exit'

8. If the new Predicted values in the step above are considerably different than the Current values, GO\_TO step 7. Else, stop this. The chances are you'll do about as well as possible with this one iteration.