



### 14 LOCALIZATION ACCURACY

This procedure assesses the ability of a Magnes 2500WH/3600WH system to localize a current dipole at a known position and orientation inside a Phantom. This test measures and verifies only the location (not the orientation or magnitude) of the current dipoles.

**This procedure requires that the system be fully calibrated and have accurate real-time weight tables. Changing or swapping SAD cards necessitates a sensor recalibration and recalculation of E-tables and real-time weight tables.**

**This version of the procedure requires the use of a Fastrak system.**

#### 14.1 Acquisition Setup

- 14.1.1 Create a real-time display setup<sup>†</sup> named X1, with a display type of Continuous Waveform and a horizontal scale of 100 ms/div that consists of the following channels and vertical scales:

X1	100 m(V)
A1	5 p(T)

- 14.1.2 Create a patient scan named Phantom that collects all of the MEG channels and external channel X1 (with a gain of X1) using the following parameters:

Acquisition Mode:	Internal
High Pass Filter:	1.0 Hz
Bandwidth:	200 Hz
Sample Rate:	678 Hz
Data Type:	Raw & Average
Epoch Duration:	0.4 Seconds
Pretrigger Duration:	0.1
Number of Epochs:	50
Coils:	5 Coils
Coil Acquisition Prompt:	Don't Prompt
Transformation Calculation:	Coil Matching
Montage:	None
Data Encoding:	Delta (if shown)
Parameters → Weights:	Supine (enable analog and digital weights)
Parameters → Real-Time Display:	SenTest
Parameters → Output Trigger:	
Mean Inter-Epoch-Interval:	1500 Milliseconds
Half Range:	0
Read Internal Trigger:	<Checked>
Trigger Duration:	1.0

<sup>†</sup> To create or edit a display setup, first select the Real-Time Display... option in the Parameters menu of the Acquisition Setup window. In the window that opens, click on the Edit Display Setup... button.



## 14.2 Hardware Setup

- 14.2.1 Verify that the COH cable (9034-908) is connected from the RCC to the COH box (9034-664).
- 14.2.2 Plug the five COH coils (9034-334) to the COH head box marked LPA (1), RPA (2), NASION (3), Cz (4), and INION (5).
- 14.2.3 Affix each COH coil to its appropriate location on the Phantom (9034-179). Use the off-axis "rotated" positions for the LPA and RPA, as the dipole locations listed on the Phantom are in this "rotated" frame. Avoid routing the COH coils across the top of the Phantom or near other coils.
- 14.2.4 Connect the cable from the Phantom to any spare DB-25 connector on the MSR feedthrough panel. Connect the similar cable on the Phantom Control Box (9033-017) outside the MSR to the other side of the DB-25 connector on the MSR feedthrough panel.
- 14.2.5 Connect a BNC cable from Trigger Output #1 of the User Interface Panel to the external trigger input of a function generator (1-3135).
- 14.2.6 Connect a BNC cable from the output of the function generator to the input of the Phantom Control Box.
- 14.2.7 Connect a BNC cable from the output of the Phantom Control Box to the X1 input<sup>†</sup> of the User Interface Panel.
- 14.2.8 Set the phantom control box on a gain of X1 and energize dipole #1. Do not leave the Phantom Control Box on unnecessarily; it is battery-powered.
- 14.2.9 Set the function generator to produce a continuous sinusoidal wave with a frequency of 10 Hz and an amplitude of 1 V peak-to-peak.<sup>‡</sup> Set the symmetry (SYM) to 50%.
- 14.2.10 Select the Real-Time Display Control... option under the Utilities menu in the Acquisition Setup window. In the window that opens, click on the Display Setup button and select the X1 display. Monitor the X1 channel on the real-time display and adjust the amplitude on the function generator to obtain a signal that is about 1 Volt peak-to-peak. Switch through all 5 dipoles and verify that the signal stays the same for all 5 dipoles.
- 14.2.11 Switch the function generator to the external trigger mode.

## 14.3 Head Shape Digitization

Head Shape Digitization is necessary in order to use the Coil Matching algorithm and is linked to a specific Patient ID. This section only needs to be performed once for a measurement session. However, two measurement sessions (with different head shapes) cannot be placed under the same patient ID.

- 14.3.1 Attach the digitization headrest to the patient table. Place the phantom on this headrest. The location of the sensor is irrelevant to this section of the procedure, and should be moved as necessary to provide sufficient working room.
- 14.3.2 Select the Head Shape option under the Digitize... menu to open a Head Shape Digitizer window.

<sup>†</sup> A twinax to BNC cable must be attached to the X1 input of the User Interface Panel to make this connection.

<sup>‡</sup> If using a digital function generator (e.g., Wavetek Model 29), the true output amplitude may differ from the displayed amplitude.



- 14.3.3 In the Head Shape Digitizer window, verify that the appropriate patient has been selected. Click the `Montage...` button and select the `EEG-5coils` montage.<sup>†</sup>
- 14.3.4 Begin the head shape digitization process by clicking on the `Start` button near the bottom of the Head Shape Digitizer window. The Fastrak unit should turn on.

14.3.4.1 Index Point Entry

The program will prompt the user to digitize the location of each head fiducial point in the following order: LPA, RPA, NASION, Cz, and INION. Place the Fastrak stylus in the center of the associated COH coil. The process is controlled via the SPI switch (the switch inside the MSR that looks similar to the switch used for external trigger): click the switch once to proceed from point to point, click the switch twice to go back one point, and click the switch three times to restart the process. Once all five index points are entered, click the SPI switch once to "accept" the data.

14.3.4.2 Index Point Verification

The program will prompt the user to digitize the location of each head fiducial point again, in a manner identical to that in the previous step.

Depending on whether the verification has passed or failed, the system will respond with the Maximum Discrepancy between the two measurements or a "Verification Failure". Make sure that the Maximum Discrepancy is less than 0.2 cm before proceeding (press the `Restart Index Points` button to return to step 14.3.4.1.

14.3.4.3 Head Shape Digitization<sup>‡</sup>

Place the Fastrak stylus on the surface of the phantom. Click the SPI switch to begin the digitization. Using circular strokes, digitize as much of the phantom surface as possible without moving the phantom. Make sure that the stylus does not leave the surface of the phantom while the digitization mode is ON. Click the SPI switch once at any time during this stage to toggle the head shape digitization mode. If there is a mistake made during head shape digitization, press the `Restart Digitization` button to restart this step. Once this step is completed, either click the SPI switch twice, or press the `Stop Digitization` button.

14.3.4.4 Electrode Location Entry

The program will prompt the user to digitize the location of each EEG coil (coils 1 – 5). For the purposes of this procedure, the EEG coils are the COH coils. Digitize the COH coils as described in step 14.3.4.1 – it is critical that these COH coils be digitized in the same order. To check that each of the coils is being digitized, press the `Review Electrodes` button and verify that each coil's location is collected. If there is an error, press the `Restart Electrode Entry` button to restart this step.

Once all tasks are completed, press the `Save and Exit` button to close the Head Shape Digitizer window.

<sup>†</sup> If this montage is not an option, go to the `/home/$STAGE/config` directory and create a montage file by entering 5 lines of text in the following format: `Coil<n> 1`, where `<n> = 1, 2, 3, 4, 5`. Open a new Head Shape Digitizer window.

<sup>‡</sup> Steps are reversed in some versions of the software.



## 14.4 Data Acquisition

- 14.4.1 Place the sensor in the supine position.
- 14.4.2 Attach the patient headrest to the patient table. Rest the phantom on this headrest. Orient the Nasion on the phantom to face the MSR ceiling, similar to the orientation of a human subject. Make sure that the phantom is "centered" within the helmet and that it is pushed deep into the helmet, as a good measurement of the coil positions requires that all 5 coils attached to the surface of the phantom be close to some of the pickup coils inside the sensor. The COH coils (e.g., Cz) can be in direct contact with the outer surface of the sensor, but it should not be necessary to place the phantom that far inside the sensor.
- 14.4.3 Seal the MSR door and **perform a Quick Noise check** (see section 5). Make sure that none of the MEG channels have anomalous low frequency or white noise. These anomalies are often associated with trapped flux or poor tuning. Heat and/or retune any noisy MEG channels and repeat the measurement until the results are satisfactory.
- 14.4.4 Set the phantom control box to energize dipole #1 with a gain of X1.
- 14.4.5 Acquire data using the `Phantom` scan. The COH circuitry will energize the 5 COH coils attached to the phantom twice (once before and once after acquisition). After the acquisition is over, **print** out the results from the final Sensor Position Coil Calculation window.
- Verify that the phantom has not moved more than a few millimeters and that the COH fits are good. The first three coils should be approximately 8 cm from the origin in the head/patient frame, with the LPA in the "+y" direction, the RPA in the "-y" direction, and the NASION in the "+x" direction.
- 14.4.6 Add comments to the run that identify the dipole number and phantom orientation.

## 14.5 Data Analysis

- 14.5.1 Using the filter editor (accessed via the `Tools` menu in the Data Editor), create (unless it already exists) a bandpass filter named `bp3-30` with a low edge of 3 Hz, a high edge of 30 Hz, a sample rate of 678 Hz and a filter order of 2.
- 14.5.2 Post the real-time averaged data file and view it in the Data Editor. Using the appropriate option in the `Tools` menu, filter (in the forward and reverse directions) the data using the filter described in step 14.5.1. When filtering the data, remove the DC offset.
- 14.5.3 Post the filtered data file and view it in the Data Editor.
- 14.5.4 Using the leftmost button of the mouse, drag a time latency span across the first waveform peak (maximum or minimum). A blue line on the x-axis will mark the selected area. Save it as a selection # by clicking the rightmost button of the mouse while the mouse pointer is within the selection. Once saved, a thicker black line on the x-axis will mark the selected area.
- 14.5.5 Go to the `Tools` menu of the Data Editor and select the `Dipole Fit...` option.
- 14.5.5.1 In the Dipole Fit window, select the data file by checking the box next to the session name.



- 14.5.5.2 Click on the Channels... button to open the Channels window. Select the Center Channel Group and specify a local sphere center (X, Y, Z) of (0, 0, 0) cm. Click the Save button to record these changes before closing the Channels window.
  - 14.5.5.3 Begin the dipole fit by clicking on the appropriately labeled button in the Dipole Fit window. The Fit Results window will display the results for each latency slice selected. These results will be sent to the printer automatically.
- 14.6 Repeat the steps in sections 14.4 (do not repeat the Quick Noise check) and 14.5 for dipoles #2 – #5, rotating the phantom approximately 72° each time. Use the same session for all 5 acquisitions. Make sure the phantom is centered and pushed in deeply, and that the COH cables do not get wrapped around the phantom.



## 14.7 Test Results

- 14.7.1 For each dipole run, examine the printout from the dipole fit program (generated in step 14.5.5.3). Find the latency with the largest dipole moment magnitude  $||Q||$ .<sup>†</sup> This magnitude should be between 300 and 500 nAm when using the input signal specified in step 14.2.10. Make sure that the correlation and goodness of fit for this latency are close to 1.
- 14.7.2 Obtain an electronic or printed copy of the Localization Accuracy Report (Form 209). A sample copy of this form can be found in section 14.8. Complete the form for each dipole as follows:
- 14.7.2.1 In the "Degrees Rotated" row, enter the number of degrees (usually a multiple of 72) that the phantom was rotated when acquiring the data.
- 14.7.2.2 In the "Dipole Magnitude" row, enter the largest dipole moment magnitude  $||Q||$  in the associated printout (generated in step 14.5.5.3). Enter the X, Y, and Z coordinates corresponding to this latency in the "Measured Dipole Location" row.
- 14.7.2.3 The actual location of each dipole is marked on the base of the phantom. Enter the X, Y, and Z coordinates corresponding to this dipole in the "Actual Dipole Location" row.
- 14.7.2.4 The electronic version of the Form 209 will automatically calculate the Localization Error for each dipole. If using the printed version of Form 209, calculate and record the total error in location for each dipole using the following formula:

$$\sqrt{(\Delta X)^2 + (\Delta Y)^2 + (\Delta Z)^2}$$

where, for instance,  $\Delta X = (\text{measured X position}) - (\text{actual X position})$ .

**The localization error of each dipole must be less than 0.4 cm.**

- 14.7.2.5 From the Sensor Position Coil Calculation printout (generated in step 14.4.5), enter the X, Y, and Z coordinates in the patient/head frame for each of the 5 COH coils in the appropriate rows.
- 14.7.2.6 If using the electronic version of Form 209, print out the form.
- 14.7.2.7 Complete the remainder of Form 209 by hand (**do not fill it out electronically**) – write down the System ID, the Phantom Serial Number (located on the base of the phantom), the Phantom Control Box Serial Number (located on the back of the unit) and sign and date the form. Check the boxes labeled "Installation/PM" and "Coil Matching (HSD)", unless otherwise instructed (in rare cases where the Fastrak unit is not used for localization during installation or preventative maintenance).
- 14.7.3 Attach the following printouts to the Localization Accuracy Report, in the order specified below (separately for each dipole):
- the results of the dipole fit generated in step 14.5.5.3
  - the final Sensor Position Coil Calculation generated in step 14.4.5

**Record any deviations from localization accuracy specifications on the Summary Report form.**

<sup>†</sup> This latency should be the same for each dipole run.



14.8 LOCALIZATION ACCURACY REPORT (Form 209) SAMPLE



4-D | NEUROIMAGING

LOCALIZATION ACCURACY REPORT

System ID (e.g., WH12, WX3, EX9) \_\_\_\_\_

Head Fiducial (no HSD)

Integration

Coil Matching (HSD)

Installation/PM

Phantom Serial # \_\_\_\_\_

This phantom is not part of the system

Phantom Control Box Serial # \_\_\_\_\_

This phantom control box is not part of the system

Dipole #	1			2			3			4			5		
Degrees Rotated															
Dipole Magnitude   Q   (nAm)															
COH Locations (cm)	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
LPA															
RPA															
NASION															
Cz															
INION															
Dipole Locations (cm)	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z	X	Y	Z
Measured															
Actual															
Error: Measured - Actual															
Localization Error															

Each localization error should be less than or equal to 0.4 cm.

PERFORMED BY: \_\_\_\_\_

DATE: \_\_\_\_\_

4-D Form 209 (10/03)