

USER MANUAL FOR: CMR T2 PHANTOM

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ABBREVIATIONS LIST

AP = antero-posterior
CMR = cardiovascular magnetic resonance
ECG = electrocardiogram
FOV = field of view
GE = General Electric
HF = head-foot
HDPE = high-density polypropylene
ID = phantom identity number
LCD = liquid crystal display
NiCl₂ = nickel chloride
PC = polycarbonate
PMU = physiologic monitoring unit
PVC = polyvinyl chloride
P(P)NS = predicted peripheral nerve stimulation
RL = right-left
SAR = specific absorption rate
T = tesla

INTRODUCTION

Above all, the aim is consistency each time the phantom is setup and measured. These instructions mainly attempt to keep everything the same every time: phantom orientation and position, coil setup, heart rate, factors affecting scanner calibrations such as the “shim” volume, shim methods, etc. Please try to keep this basic aim in mind. Although running the B_0 “shim” is arguably undesirable please note this is specified and should be operated in the same mode with the same receiver coils for it, and the same calculation or fitting volume used each time.

The arrangement of tubes in the phantom is not random: it avoids placing long-T₁|T₂ tubes in the corner positions where B_0 and B_1 distortions associated with the phantom are greatest. Alignment of tubes with the B_0 direction and scanning halfway along them, not towards their ends, are also important factors in avoiding measurements in regions using distorted fields.

Please do not add “loading” phantoms.

This manual suggests using an R-R interval of 900ms (heart rate 67bpm). Depending on your T₂-mapping sequence, an R-R of 800ms or 1000ms may still run repeatably reliably. Provided that the SAME R-R value is used for each session this would be acceptable if 900ms cannot easily be obtained.

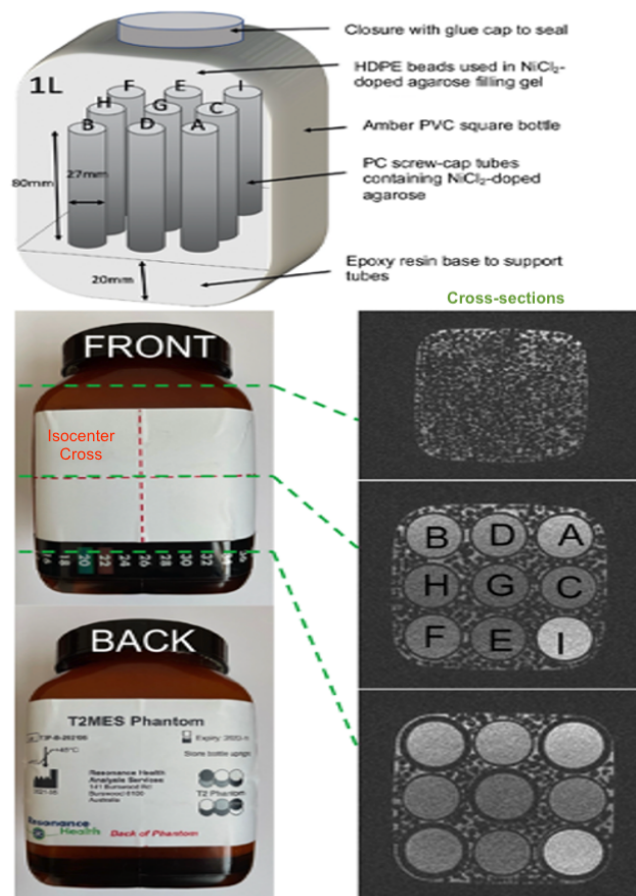
1 | PHANTOM OVERVIEW

1. The phantom consists of an amber plastic bottle sealed by a tight black cap.

△ NEVER OPEN THE CAP

2. Inside the bottle is an agar/nickel chloride (NiCl₂)/high-density plastic bead fill containing a 3 X 3 array of plastic tubes filled with the T₁/T₂ mixtures. The tubes rest on a resin layer at the base (**Figure 1**).
3. There is a label with a red isocenter cross on the front surface of the bottle to aid positioning in the scanner.
4. There is another label on the back of the bottle that contains the unique phantom identity number (ID).
5. Please use the Phantom ID for all data entry.
6. Along the top of the bottle's front surface, is a liquid crystal display (LCD) thermometer strip.

Figure 1. External and internal features of the T₂ phantom.



2 | PHANTOM CARE

1. On receiving the phantom, unpack and inspect it. If damaged, contact the manufacturer.
2. Please be gentle when moving the phantom around - do not drop or shake it.
3. Do not place heavy objects on top of or strongly against the phantom at any time (the phantom outer bottle is quite flexible).
4. In between research scans, store the phantom upright in your scanner room for temperature consistency with scanning, and in the same protected area each time.

△ **STORE THE PHANTOM VERTICALLY UPRIGHT**

3 | INSTRUCTIONS FOR PHANTOM SETUP

3.1 | TEMPERATURE

1. There is a self-adhesive LCD temperature strip with temperature range 10°C to 40°C along the upper surface of the phantom (**Figure 2**). Temperature markers appear at an interval of 2°C, but the **resolution of the strip is actually 1°C**.
2. Take note of phantom temperature **before** starting each new scan.
3. If there is a bright **GREEN** cell, this marks the exact phantom temperature (it will be an even number).
4. If there is no green cell but adjacent **BLUE** and **TAN** cells, then exact phantom temperature is the odd number **in between** (**Figure 3**).
5. Phantom temperature must be added to the <Patient Name> when **registering the new scan** on your MRI scanner (see 4.1).

Figure 2. Temperature strip



Figure 3. If **GREEN** cell = take this value.
If adjacent **TAN/BLUE** cells = take middle value.

Thermometer guide
24 Temp = 24°C

24
22 Temp = 23°C

3.2 | ORIENTATION

△ AIM TO POSITION THE PHANTOM AT ISOCENTER USING THE SAME SUPPORTING MATERIALS IN EACH SCANNING SESSION
(+/-1cm across [x] and along [z] the bed; +/-3cm for height [y])

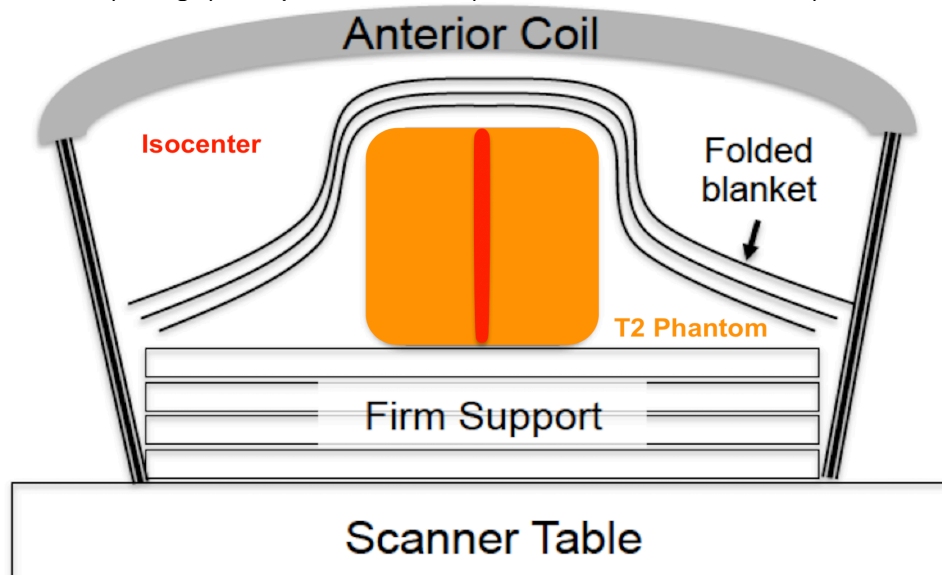
1. Set up and scan the phantom at the isocenter position and in **exactly the same** way each time for repeat scans.
2. Read your manufacturer-specific instruction in the **Appendix** for where along the table to place the phantom, i.e., in the z direction (for Siemens see A6.1.1; for Philips see A6.2.1; for GE see A6.3.1).
3. Do not place the phantom directly onto the spine or bed coil. To bring it up to isocenter you must elevate the phantom bottle above the spine or bed coil by using a firm support.
4. This height depends on your scanner model and MRI table options. (For Siemens see A6.1.1; for Philips see A6.2.1; for GE see A6.3.1). Test the height of the firm support to find one that will lift your phantom to isocenter (see **Figure 4**).

△ USE THIS SAME FIRM SUPPORT FOR ALL SUBSEQUENT SCANS.

5. The firm support must be **FIRM**. It cannot be so soft that it will deform erratically and prevent consistent phantom positioning (i.e., avoid ordinary pillows and blankets for this application).
6. Suggested materials to use as firm support include:
 - a. A stack of glued (not stapled) spine journals.
 - b. A firm supporting (foam plastic) slab that may come with your scanner equipment.
7. Once you configure the correct firm support STORE it in the scanner room with the phantom.
8. Lay the T₂ phantom onto the firm support as in **Figure 4**.

△ STORE AND ALWAYS USE THE SAME FIRM SUPPORT FOR EACH SCAN

Figure 4. Phantom (orange) setup on the table (the red line is at isocenter).



9. Consistent elevation will optimise the height of T₂ phantom's isocenter so that you obtain repeated T₂ phantom data with **CONSISTENT** tube position and orientation over time.

10. Place the firm support in the middle of the table's receiver coil relative to x-axis and between the correct table markers for where you would usually position the patient's heart.
11. The **black bottle cap** (equivalent to the 'Head') for the specified head-first registration of patient orientation must point into the bore. The isocenter cross sticker must be on the upper surface of the bottle.
12. **Before doing anything else**, move the table and shine the laser target markers onto the phantom arrangement till the laser markers are aligned with the red isocenter cross. The pair of x-lines and the pair of z-lines should overlap.
13. **Memorize phantom temperature now and before introducing bottle into the bore.**
14. Obtain a thick blanket, folded over into a generous rectangular shape and drape this over the top of the phantom. Do this after having isocentered with lights, but before applying the surface coil.
15. If possible, use the same anterior cardiac coil for all subsequent phantom experiments.
16. During the subsequent steps, note that the phantom may accidentally be shifted or twisted, and this **should be avoided**.
17. Place the anterior coil onto the blanket that is overlying the phantom with laser target marker still turned on. Adjust the position of the anterior coil manually (do not move the table nor inadvertently slide the phantom) till the isocenter cross of the coil is aligned with the laser target markers.
18. Strap the anterior coil into place to prevent it slipping off the phantom arrangement. Tighten the straps to secure the blanket around the T₂ phantom bottle.
19. While unlikely to matter, please use consistent air-flow settings for repeated scans (e.g., **set the patient fan in the scanner to medium** each session).
20. Once you configure the correct firm support, STORE it in the scanner room ready for repeated use with the phantom.

4 | PHANTOM SCANNING

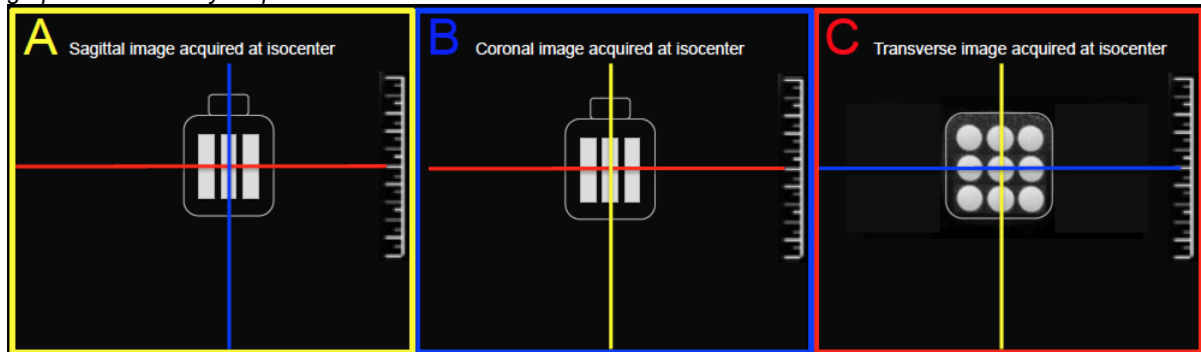
4.1 | SCAN SETUP

1. Set up the simulated electrocardiographic (ECG) signal. This user manual will prescribe an RR interval of 900ms, but if necessary, other R-R intervals could be used. **For Siemens see A6.1.2; for Philips see A6.2.2; for GE see A6.3.2.**
2. Before starting the scans make sure **all relevant coils are switched on**.
3. Start with scout or localizer imaging. For simplicity it is best if these localisers are all **acquired at isocenter with no image-plane or field of view (FOV) offsets away from isocenter**. Note that: **preset localiser protocols often contain such FOV-shifts or offsets** as typically suiting average patient morphology in the registered patient orientation. It may therefore be easier if you **TURN OFF/UNCHECK** any such FOV-shifts/offsets before running the scout.
4. Check that the physical positioning of the T₂ phantom is correct (along all three directions) as follows and that the phantom is not tilted or twisted (for system specific instructions on this see **Appendix**).
5. Isocentering the T₂ phantom along the head-foot (HF) direction (red lines in **Panels A and B in Figure 5**) should simply be governed by the laser marker. Similarly, isocentering the bottle along the supine patient right-left (RL) direction (yellow lines in **Panels B and C in Figure 5**) should again simply be governed by the laser marker.
6. Using the firm support, the T₂ phantom should be at the correct **height** such that the isocenter is halfway up the central tube, and at the level of the blue line in **Panels A and C, Figure 5**.
7. In **Panel C (Figure 5)** along the yellow line (i.e., height [y]), if the isocenter is further than **3cm** from the center of the middle tube, then **positioning is not acceptable**. Please pull

- out the table, **change the height of the firm support** and try again. Once you obtain the correct support for your scanner/phantom arrangement remember this and if possible, **store the materials used with the phantom**, so that repeated scanning is less painful!
8. In the other two directions (along the patient bed [z] and across the patient bed [x]) the center of the middle tube should be **≤1cm** from isocenter. This should be easy to achieve using the laser guidelines and isocenter cross.
 9. Please check that the phantom is not tilted or rotated in any axis beyond 10 degrees.

Figure 5. Achieving perfect isocenter position of T₂ phantom.

Note that this does not depict any particular scanning software and is for guidance in interpreting the isocenter graphics in use on your particular machine.



5 | SHIM SETTINGS AND SHIM VOLUME¹

△ BE CAREFUL TO SET THE SHIM VOLUME AS SPECIFIED IN THIS MANUAL

1. Before running any T₂ mapping sequence you must select the correct shimming method and specify a particular shim volume over the T₂ phantom. Please follow the manufacturer-specific instructions for these steps (For Siemens see A6.1.3; for Philips see A6.2.4; for GE see A6.3.4).
2. Apply the same shim volume before starting each set of experiments in a reproducible manner.
3. The shim volume should be positioned at isocenter.
4. **Remember to wait at least 10 seconds with no scanner activity whatsoever before running the first T₂ map on your phantom bottle.**
5. Now run your T₂ mapping sequence positioned transversely and positioned with FOV centered exactly at isocenter in all three directions.
6. **Remember to wait at least 10 seconds with no scanner activity whatsoever before running any further T₂ map on your phantom bottle.**

¹ N.B. 'Shim Volume' = shorthand for adjustments volume, adjust region, shim region, shim box. See manufacturer-specific Appendix for more details.

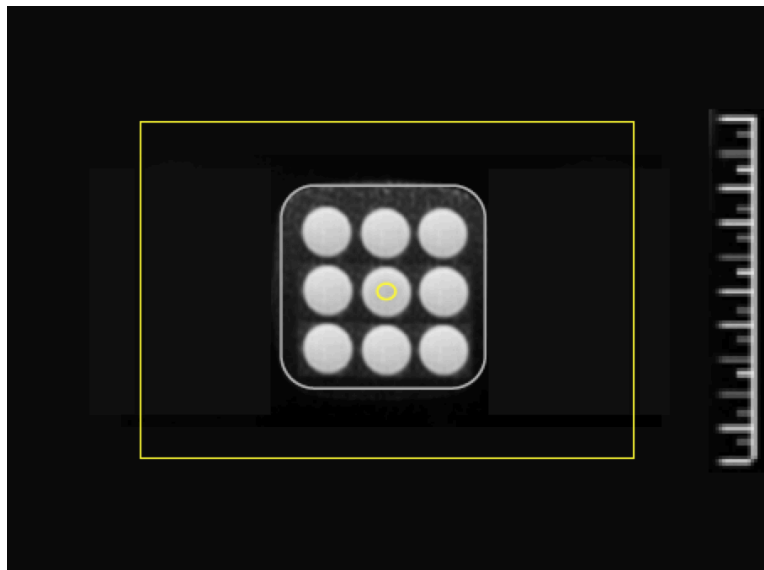
6 | APPENDIX

A6.1 | **SIEMENS**-specific instructions

A6.1.1 | Table positioning of phantom for **SIEMENS**

1. For Siemens the bottle should be positioned between **S1 and S2 marker levels** (or if using the 32-channel posterior array consistently center on that array). This is not essential, but we ask as this is easily replicated on each session in case of any unforeseen sources of variability (e.g., there is some metal in the patient table which is known to affect some sequences).
2. Our tests on a 3T Siemens Prisma with a detachable couch have suggested that a firm **support of height 10.5cm** provides the right height to achieve T2 phantom isocenter positioning along the y axis.
3. The height for your particular Siemens machine, table and couch settings **may vary** so please test firm support height to find your ideal setup (then remember it and if possible store it with phantom!).
4. If your firm support height is correct and isocentering by laser target markers was done carefully, you should expect to see transverse (axial) images similar to those in **Figure A1** when you open your T2 mapping sequence after running the scouts.
5. Aim for the middle of the T2 phantom to be within ± 1 cm of isocenter across the bed and within ± 3 cm for height (but consistent to within ± 1 cm each repeated session).

Figure A1. Confirmation of good isocentering of the T2 phantom in Siemens (same for Philips).



A6.1.2 | Setting up simulated ECG for **SIEMENS**

1. You will need the Advanced User mode (password is typically <meduser1> for Siemens).
2. Start with <Ctrl-Esc> to launch the <Windows Start> menu.
3. Chose <Run> option.
4. Type: ideacmdtool
5. <Enter>
6. Type: 1
7. <Enter> to Start PMU (physiologic monitoring unit) control.
8. Type: 1 (or '4' on >VD-level software)
9. <Enter> to start ECG simulation.

10. For <ECG period in ms [1000]:>
11. Type: **900**
12. For <RESP period in ms [3000]:>
13. <Enter>
14. For <PULSE period in ms [1000]:>
15. Type: **900**
16. For <EXT period in ms [2000]:>
17. <Enter>
18. Check that the ECG waveform parameters generated are HR=**67**bpm and RR period =900ms.
19. You may now close the black “ideacmdtool” window (you do not need to remember to turn off the simulated ECG settings by using <ideacmdtool> again after the end of your phantom scans to allow the resumption of normal clinical scans, as a new <Patient Registration> will automatically clear it).

△ FOR SIMULATED ECG PLEASE ALLOW TIME FOR SOFTWARE-“AVERAGED” HEART RATE (if your system uses it) TO SETTLE, BEFORE STARTING T₂ MAPPING

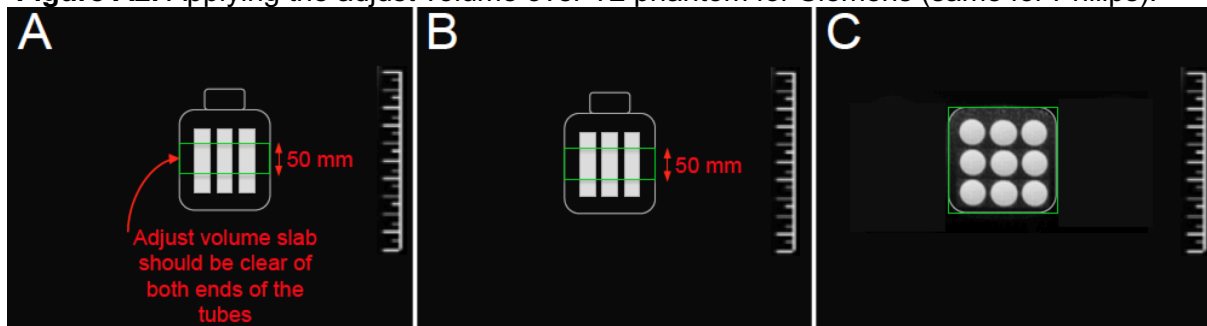
*A6.1.3 | Shim settings for **SIEMENS***

1. Navigate to <System>
2. <Adjustments>
3. Next to <B₀ Shim mode> choose the option <Cardiac>
4. If you do not have the option <Cardiac> available on your Siemens system, then choose <Standard>
5. Make sure that the option <Adjust with body coil> is **ticked**.

*A6.1.4 | Adjust volume for **SIEMENS***

1. Go to <System> and then to <Adjust Volume>.
2. Next to <! Position> select from dropdown list <Isocenter>.
3. Please apply the shim volume tightly around the phantom bottle as shown in **Figure A2**. It should be set 5cm thick in the HF direction and it should follow (+/-2cm) the size of the T₂ phantom bottle in the RL and antero-posterior (AP) directions. Adjust the size of the green volume as follows:
 - a. Set AP to **100** (mm)
 - b. Set RL to **100** (mm)
 - c. Set HF **thickness** of the shim slab to **50** (mm).
4. Prescribe the size of the volume in the 3 orthogonal planes to ensure consistent adjustments of B_0 and scanner reference frequency over the phantom each time you scan it.
5. Acquire the T₂ mapping sequence at isocenter with the T₂ phantom right in the middle of the adjust volume.

Figure A2. Applying the adjust volume over T₂ phantom for Siemens (same for Philips).



A6.2 | **PHILIPS**-specific instructions

A6.2.1 | Table positioning of phantom for **PHILIPS**

1. The T2 phantom isocenter cross should be placed at the level of the MIDDLE side marker on the Philips table (there are side markers denoting the top, middle and bottom of the elements encased in the coil base).
2. Our previous tests on a Philips Achieva suggested that 10cm was the optimal height to achieve T2 phantom bottle isocenter, **however this may vary**. To identify the correct height for your particular Philips machine, table and couch configuration please test firm support height to find your ideal setup (then remember it and if possible, store it with phantom!).
3. If your firm support height is correct and isocentering by laser target markers was done carefully, you should expect to see images like those in **Figure A1** (in previous **section A6.1.1**) when you open your T2 mapping sequence after running the scouts.

A6.2.2 | Setting up simulated ECG for **PHILIPS**

1. Right click the main window and select <Control Parameter Editor>.
2. Select <General Tab>.
3. Select <Physiology Simulation>.
4. Select <Yes>.
5. Set the number of RR intervals = 1
6. Set RR interval (in ms) = **900**
7. Click <Apply>.
8. Remember to turn off the simulated ECG settings after the end of your phantom scans to allow the resumption of normal clinical scans.

△ FOR SIMULATED ECG PLEASE ALLOW TIME FOR SOFTWARE-“AVERAGED” HEART RATE (if your system uses it) TO SETTLE, BEFORE STARTING T2MAPPING

A6.2.3 | Before running a T2 Map that involves SENSE in **PHILIPS**

1. Before setting up your mapping protocol it is your responsibility to check the control parameters of your Philips platform.
2. Ensure control parameters on Philips are set to DEFAULT VALUES.
3. Ensure no "patches" that could impact scanner behaviour unexpectedly are installed, except of course the patch to run your T2 mapping sequence if you need this.
4. Allow the scanner to perform the SENSE/CLEAR reference scans if using a T2 mapping sequence with parallel imaging.
5. If it asks about **PPNS** and **SAR** allow 1st Level.

A6.2.4 | Shim settings for **PHILIPS**

1. To set shim mode on Philips select <Contrast> tab.
2. Locate <Shim> in the column of parameters on the left.
3. Select option <Volume>. **CAUTION** - please do not use other “shim” options and if in doubt please ask for advice.
4. Next adjust the green volume slab: Please apply the shim volume tightly around the phantom bottle as shown in **Figure A2** (in previous **section A6.1.5**). It should be set 25mm thick in the HF direction and it should follow (+/-2cm) the size of the phantom bottle in the RL and AP directions.
5. Go to the tab <offc/ang>.
6. Under <Shim Size> adjust the size of the green volume as follows:

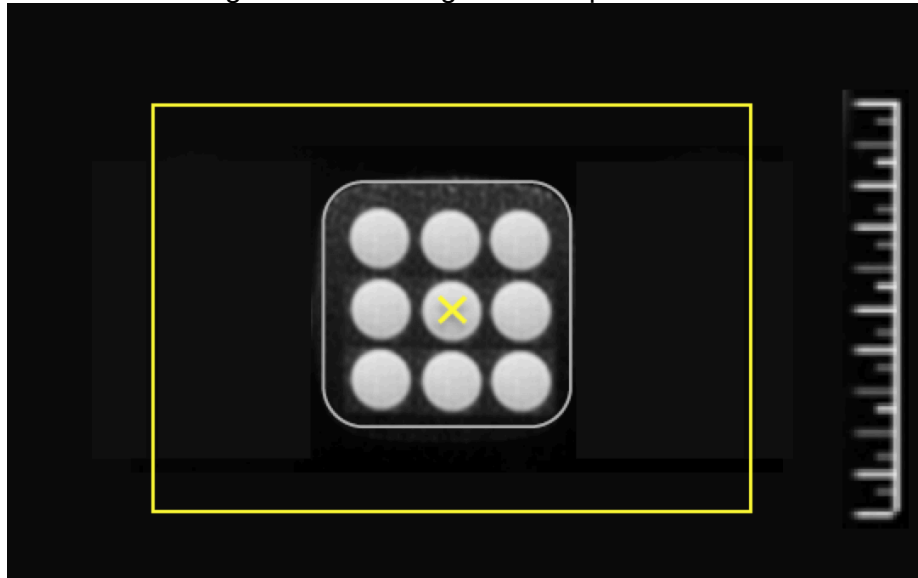
- a. Set AP to **100** (mm)
 - b. Set RL to **100** (mm)
 - c. Set HF **thickness** of the shim slab to **25** (mm).
7. Prescribe the size of the volume in the 3 orthogonal planes to ensure consistent shim and reference frequency estimation over the phantom each time you scan it.
8. Acquire the T₂ mapping sequence at isocenter with the T₂ phantom right in the middle of the adjust volume.

A6.3 | **GE-specific instructions**

A6.3.1 | *Table positioning of phantom for **GE***

1. Our previous tests on a 3T GE 750 have suggested that a firm support of height **5cm** provides the right height to achieve phantom isocenter positioning along the y axis.
2. The height for your particular GE machine, table and couch configuration **may vary** so please test firm support height to find your ideal setup (then remember it and if possible, store it with phantom!).
3. If your firm support height is correct and isocentering by laser target markers was done carefully, you should expect to see images similar to those in **Figure A3** when you open your T₂ mapping sequence after running the scouts.
4. Aim for the middle of the T₂ phantom to be within ± 1 cm of isocenter. If it's perfectly correct you will see an <X> mark in the middle tube on the GE scanning software. A ± 3 cm offset on the vertical (y) axis is acceptable but whatever height is achieved should be replicated each session to within ± 1 cm. Both horizontal directions (across [x] and along [z] the patient bed) should be easily within ± 1 cm using the laser guides and isocenter cross sticker.

Figure A3. Confirmation of good isocentering of the T₂ phantom in GE.



A6.3.2 | *Setting up simulated ECG for **GE***

1. **OUR PREFERENCE** is that you use (or purchase, if you do not already have one) a **basic 'ECG simulator' (also known as 'Chicken Heart')**. Work with CAUTION this ECG simulator may be dangerous in the magnet room.
2. Set heart rate on the device to **67bpm**.
3. Please position the ECG simulator a safe distance from the bore and follow the manufacturer's instructions.
4. The **less preferred** alternative is to use the command window to set the ECG Simulator on GE to 80bpm.
5. Go to <Tools> menu (this is the icon at the top left showing a spanner/hammer).
6. Click on the icon's arrow to reveal the drop down.
7. Select <Command Window>.
8. Type: rlogin scp
9. <Enter>
10. Login: scp

11. Password: scpsservice
12. Type: SCP_LX->EmulatePac
13. <Enter>
14. This sets a simulated ECG with rate 100bpm (this heart rate is too fast for the T₂ mapping planned. Siemens and Philips users will be using a simulated ECG of 67bpm).
15. To slow down the heart rate (imperfectly) go to back to <Tools> menu and hit the actual button.
16. Select <Open Gating Control Window>.
17. <Waveform display> (select all).
18. By setting <Trigger Lead> to <PG> heart rate will slow from 100bpm to 80bpm – it is still imperfect as the heart rate of 67bpm cannot be achieved; hence why we recommend the 'Chicken Heart'. Either way, please use the same heart rate for all sessions!
19. If you have set the simulated ECG using the command window in GE, please allow time for any software-“averaged” heart rate (if your system uses it) to settle, before starting T₂ mapping work.
20. If you have set the simulated ECG using the command window in GE, remember to disable it when done scanning to permit resumption of routine clinical scans. To disable simulated ECG: hit <Tools> icon.
21. Select <Go to Service Desktop Manager> and hit <TPS Reset> to REMOVE the simulated ECG and reset the gating.

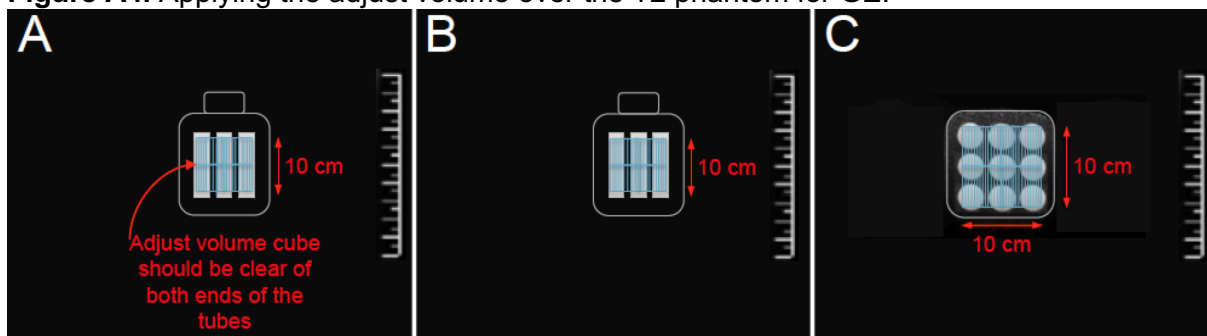
*A6.3.3 | Before running a T₂ Map that involves SENSE in **GE***

1. Select to run <**First Level Mode**> if prompted.

*A6.3.4 | Shim settings for **GE***

1. Shim volume in GE is shaped by default as an obligatory cube.
2. To adjust its size go to <Graphic Rx Toolbar> (if you do not immediately see the Toolbar, hit the <GRx> tab).
3. Click <Shim>.
4. Uncheck the <Hide Shim> option to reveal the shim cube (it will look like a green/yellow hashed cube).
5. Next to <FOV> enter <10> to set the size of the cube to 10 X 10 X 10cm.
6. Move the cube so that it covers the middle lengths of the tubes and try to avoid the edges at either end as in **Figure A4**.

Figure A4. Applying the adjust volume over the T₂ phantom for GE.



Thank you