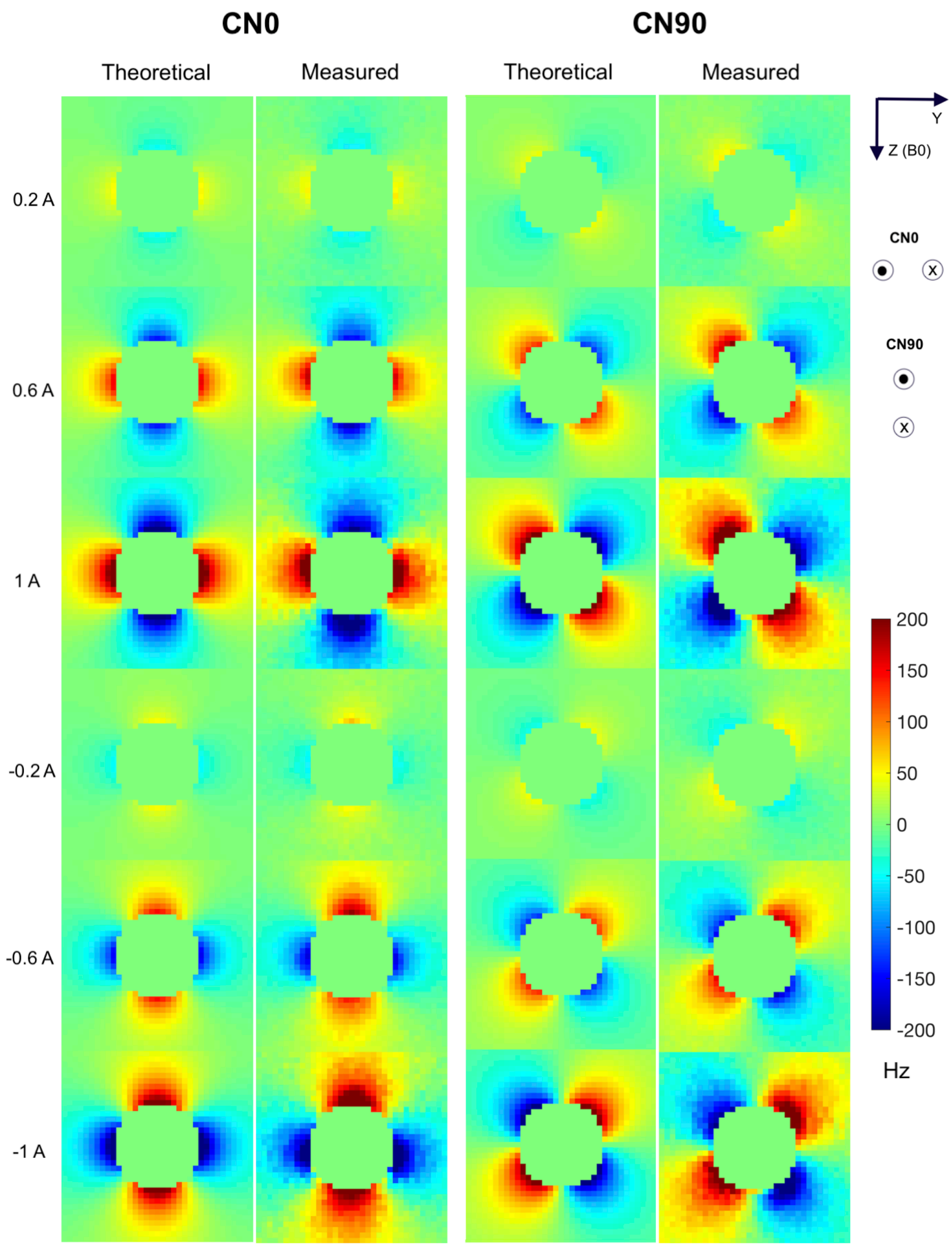
Shim Coil Validation Experiment

Methods

A validation experiment was conducted to ensure that the shim coils were producing fields that matched theoretical predictions. The metallic needle was replaced by shrink wrap tubing in order to measure the fields generated solely by the shim coils. Phantom 1 was filled with tap water and placed at the center of the scanner's YZ plane. The shim insert was placed vertically in the phantom in the (0,0,0) degree orientation. 3D gradient recalled echo (GRE) images with fieldmapping in the coronal orientation (FOV :160 x 160 x 9 mm^3, voxel: 1 x 1x 1 mm^3, 9 slices, TR/TE/ΔTE = 15/5.4/2.3 ms, FA = 9 degrees, Tacq = 44s) were acquired with the stack centered 5 cm below the surface of the water. Fieldmaps were acquired with currents ranging from -1 A to 1 A in steps of 200 mA individually for each shim coil. The ΔTE of 2.3 ms was used for currents of 0.6 A and less, while 1 ms was used for higher currents to avoid field wraps close to the insert. The baseline 0 A field was subtracted from the individual maps to yield the shim coil generated fields, which were then compared to simulated ideal maps. To assess the degree of similarity between the measured and theoretical fields, the 1- $\boldsymbol{R^2}$ value (where $\boldsymbol{R}$ is the Pearson product-moment correlation coefficient) was estimated in the central 35 mm FOV for all currents for both coils[59]. Increasing currents produced proportionately larger signal voids around the insert and therefore, morphological processing of the magnitude images was used to define masks for accurate processing of individual fieldmaps.

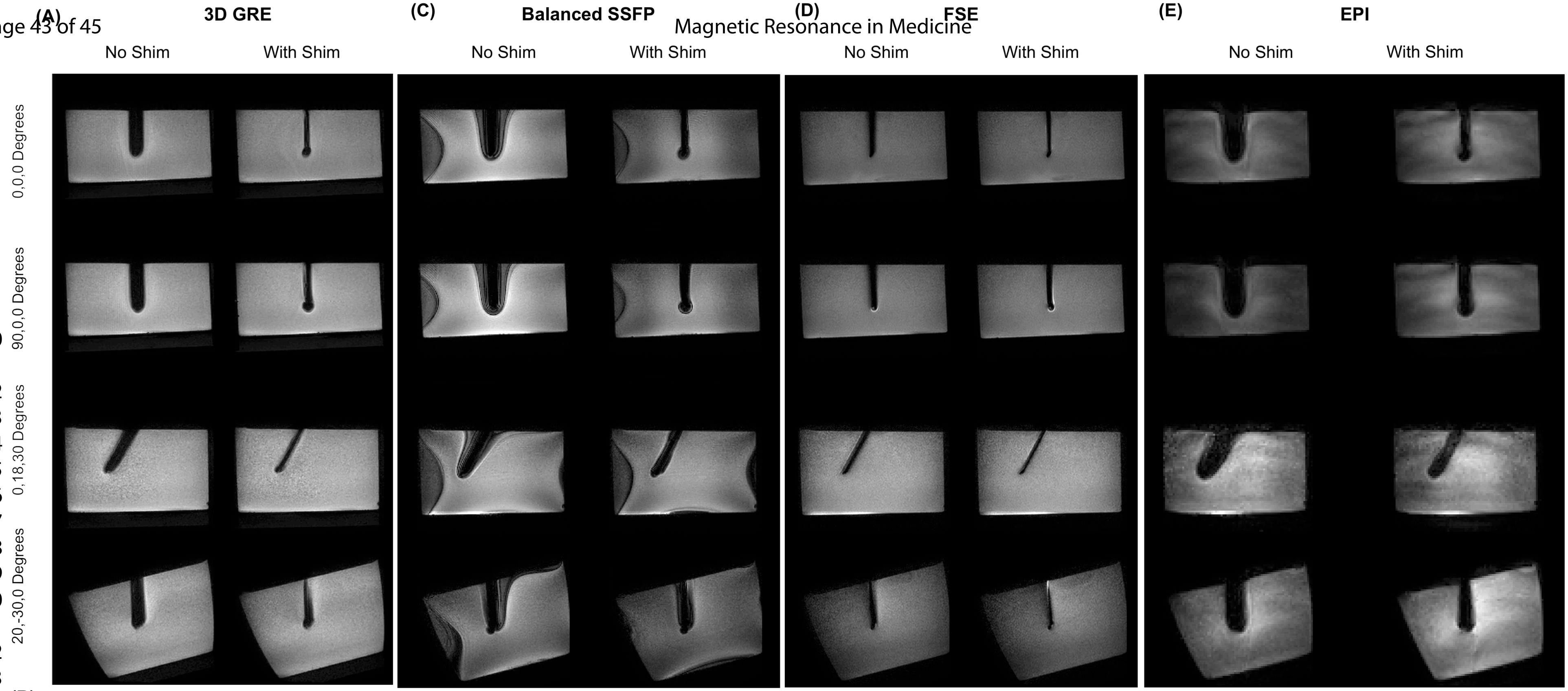
Results

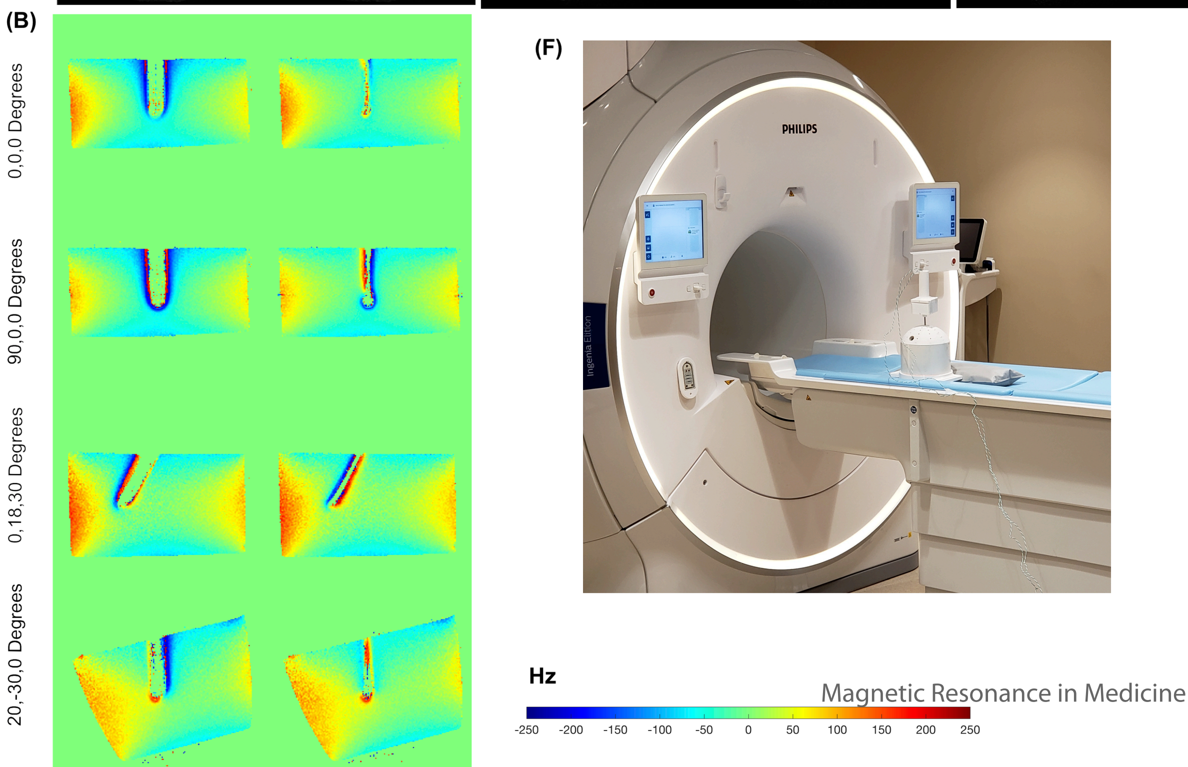
Measured fields matched theoretical fields well for both CN0 and CN90, (Results shown in Supporting Information Figure S1). The average and maximum 1 - $\boldsymbol{R^2}$ values over all the positive and negative current steps were 0.044 and 0.062 for CN0 and 0.046 and 0.082 for CN90 indicating excellent concordance. Both shim coils operated in a linear fashion within the current range tested (-1 A to 1 A). The residual errors arose mainly from noise in the measured high-resolution fieldmaps.



Supporting Information Figure S1

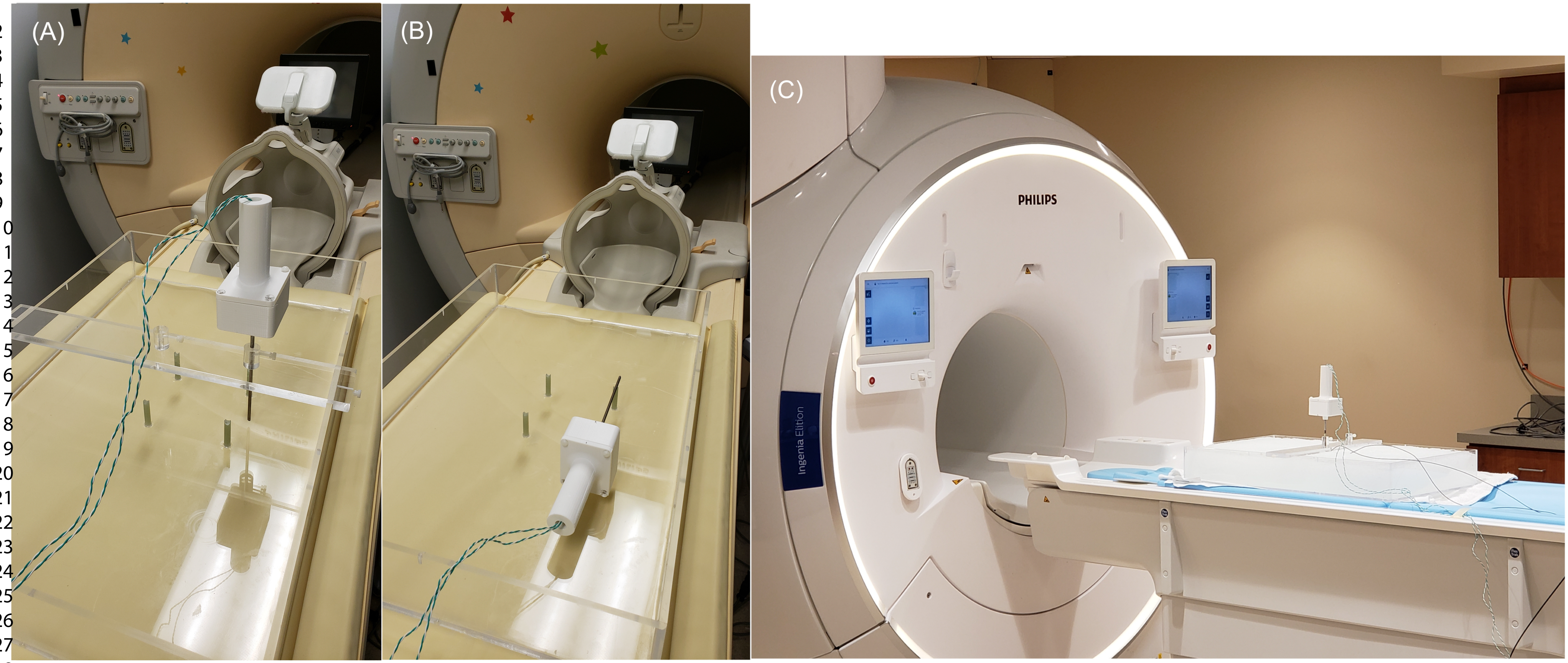
Example coronal field maps from the validation of the fabricated shim coils. Fields produced by both CN0 and CN90 match theoretical fields over the current range tested. Minor differences may be attributed to noise in the measured fieldmaps. The central mask covers the signal void produced by the shim coils.

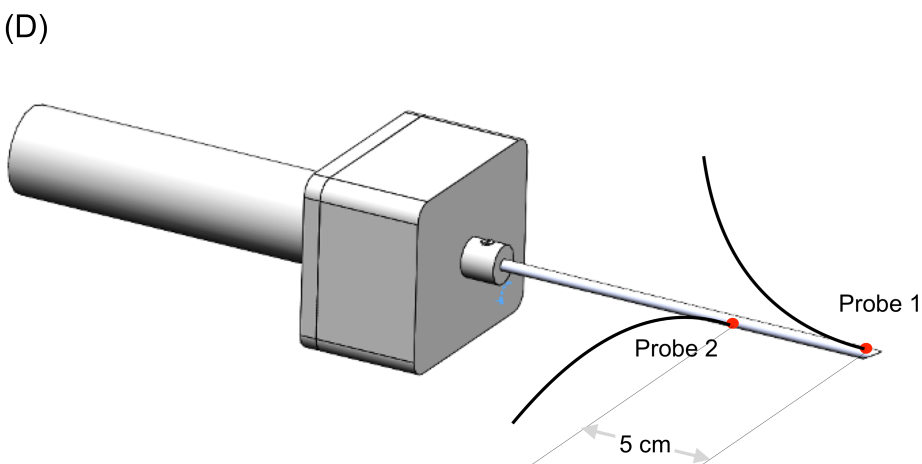




Supporting Information Figure S2

Results of needle shimming with the phantom in the 13 cm off-center position. (a-e) Shimming performance is essentially similar to when the phantom is in the center (Figure 2 in paper) (f): Image showing the phantom setup in the off-center position.





Supporting Information Figure S3

Setup for the needle heating tests. (a, b) The homebuilt ASTM 2182 standard phantom acrylic container with needle holder in a mock scanner similar to the one used in this study. Needle is shown in the two different test positions (c) The phantom setup in the scanner (d) Placement of temperature probes on the needle.

Supporting Information Table S4

Imaging parameters used in the Water Phantom Shimming (A), Porcine Tissue Shimming (B) and Heating experiments (C).

	FOV (mm)	Voxel (mm)	Slices	TR/TE/ΔTE (ms)	FA (deg)	PE Dir	PI Factor	Segment Factor	TAcq (s)
A. Needle Shimming: Water Phantom Experiment									
3D GRE	160 x 160 x 80	1 x 1 x 1	80	15/4.9/2.3	9	RL	2,1.5		140
FSE	160 x 160 x 11	1 x 1 x 1	11	2600/90	90/120	AP	2	18	47
2D bSSFP	160 x 160 x 2	1 x 1 x 2	1	6/3	90	AP	0		1
EPI	160 x 160 x 2	2 x 2 x 2	1	20/10	90	AP	2	13 (3 shots)	0.2
B. Needle Shimming: Porcine Tissue Experiment								**Repetitions**	
3D GRE	120 x 120 x 9	1 x 1 x 1	9	24/4	12	RL	2	20	530
C. Heating Tests									**Whole Body SAR (W/Kg)**
3D FSE	300 x 360 x 80	0.7 x 0.7 x 2.5	32	495/133	90/150	RL	0	25	3.2
2D bSSFP	360 x 360x 8	2 x 2 x 8	1	3.4/1.45	45	RL	0		2.7

bSSFP: Balanced Steady State Free Precession, FA: Flip Angle, PE Dir: Phase Encode Direction, TAcq: Acquisition Time, PI: Parallel Imaging (SENSE)