Geometrically Decoupled Phased Array Coils for Mouse Imaging

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Introduction: Roemer *et al* [1] introduced phased array surface coils which offer high SNR over a large field of view. Phased array volume coils, introduced by Hayes *et al* [2] have high SNR at the surface and centre of the volume. Most array coil designs typically employ a combination of geometrical and additional techniques, such as isolating preamplifiers, for element-to-element decoupling. The development of array coils for small animal MRI is of increasing interest [3-11], however isolation preamplifiers are expensive and not ubiquitous at the field strengths typically employed for small animal work (4.7T, 9.4T, etc). In addition, isolating preamps complicate the designs of coils for transmit SENSE since they do not decouple during transmit. Therefore, we have re-examined a "tried and true" method for decoupling. The work described here presents a 4 channel transmit/receive volume coil for mouse imaging that is decoupled purely geometrically, without the need for other forms of decoupling. We describe the design and construction of this coil for imaging at 4.7T. Bench measurements demonstrate good decoupling of the coil elements. Phantom images verify bench results. Preliminary design work for a modified 'open' configuration coil to facilitate the loading of animals is also presented.

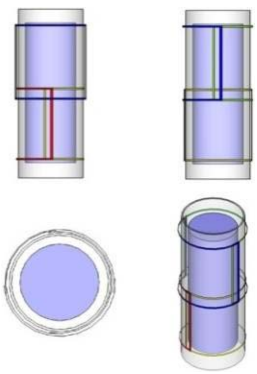

Fig 1: CAD drawing of Coil 1

Methods: The 4 element coil was constructed on the outer surface of acrylic tubing (I.D=1.5 inches, wall thickness=0.125 inches). The four elements were positioned in two sets, distinguished by their location along the length of the cylinder. One set consisted of coils located at 0° (or "top") and 180° (or "bottom"). The other set consisted of coils located at 90° (or "right") and 270° (or "left"). It was thus possible to geometrically decouple all four elements from one another by overlap, clarified by CAD diagrams in Fig. 1 and photograph in Fig. 3. Each element of both pairs has a single breakpoint with a 0-15pf tunable capacitor. The coil was constructed using strips cut from 0.125 inches wide annealed copper (thickness=0.25mm). G.E., 1.5T, HNS Rev 2 feedboards (containing the balun and the match/tune network) were modified for imaging at 4.7 T and used for transmitting/receiving signal from the coil. A cylindrical phantom (dia=35mm; length=75mm) with loading equivalent to a mouse was filled with 0.1M NaCl and 1g/L $CuSO_4$. S-parameter measurements were made on an RF network analyzer 8712ES (Agilent Technologies, Paulo Alto, CA). T/R images were acquired on a 4.7T/33cm scanner supported by a Varian Unity Inova console (spin echo, TR/TE=300/30msec, matrix=128x128, FOV=100mm, st=3mm, N_{av}=2). To examine the effectiveness of the geometric decoupling, images were acquired from each individual element with the other three coils terminated in 50ohms and then compared to images acquired from each individual element with the other three elements open-circuited. The design was then modified (one set of coils rotated and decoupling "tabs" added) to have the capability to open in order to facilitate animal loading. CAD drawings of the modified design are shown in Fig.2 and photograph in Fig 4. S-parameter bench measurements were also acquired from this coil.

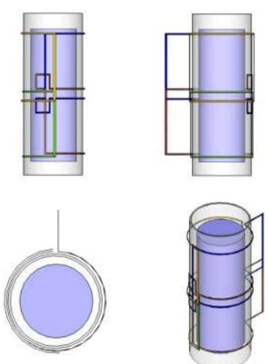

Fig.2: CAD drawing of open design, or "Coil 2"

Results: S-parameter bench measurements, (Table 1), indicate average loaded coil isolation between the elements of array coil 1 of -19.63dB. For the "open" configuration, array coil 2, the average isolation achieved was –18.06dB (data in Table 2). Image data for the case of all coils connected is shown in Fig 5. Sagittal images are shown to observe the sensitive regions of coils located at the top (0°) and bottom (180°), while coronal images show the sensitive regions for coils located at the left (90°) and right (270°). These were compared to the same images acquired from individual elements when the other elements were open circuited (Fig 6). Images obtained under these two conditions showed very slight differences, confirming the elements were well isolated and offering promise for future work based on geometric decoupling techniques alone. Since the coil had to be removed and repositioned between acquisitions in order to open circuit elements, quantification of difference in images was difficult and will be included in future work.

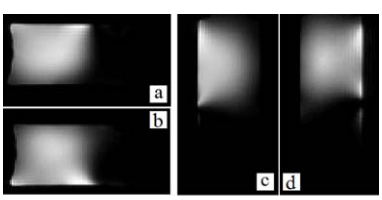

Fig.5: Images with other loops terminated to 50Ω. (a) Sagittal image; top element (b) Sagittal image; bottom element (c) Coronal image; left element (d) Coronal image; right element

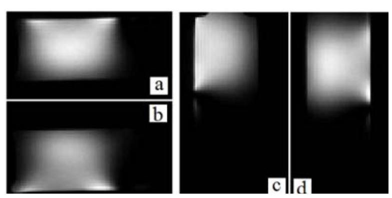

Fig.6: Images with other loops open circuited. (a)Sagittal image; top element (b)Sagittal image; bottom element (c)Coronal image; left element (d)Coronal image; right element

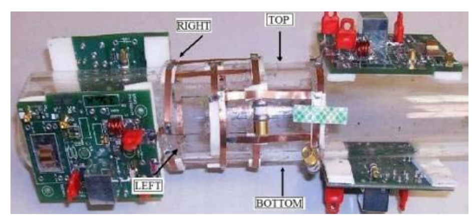

Fig 3: Coil 1

Element	1-Top	2-Bottom	3-Left	4-Right
1-Top	27.6	-16.8	-25.2	-21.2
2-Bottom		-29.7	-16.8	-18.3
3-Left			-34.4	-19.5
4-Right				-25.6

Table 1: Matrix showing coupling [dB] for Coil 1

Element	1-Top	2-Top	3-Bottom	3-Bottom
1-Top	-22.2	-19.6	-19.8	-16.8
2-Top		-21.5	-16.0	-14.3
3-Bottom			-37.0	-21.9
3-Bottom				-16.2

Table 2: Matrix showing coupling [dB] for Coil 2.

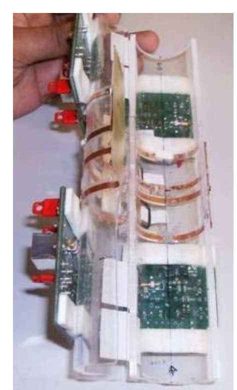

Fig 4: Modified Coil 2

Refernces: [1]Roemer et al; MRM 1990, 16(2):192–225;[2] Hayes et al; MRM 1990;18:309-319;[3] Keil et al; Proc ISMRM '08;16:1; [4] Beck et al; Review of scientific instruments 2001;Vol 72(11), 4292-4294 [5] Ullmann et al; Proc ISMRM 2004,1610 [6] Oduneye et al;Proc ISMRM2008;16:1 [7] Gareis et al; NMR Biomed. 2007;20:9; [8] Zhang et al;Proc ISMRM 2004;11:1 [9] Wargo et al;Proc ISMRM 2008; 16:1[10] Z. Wang et al.; Proc ISMRM 2008;16:1 [11] Schneider et al, MRM 2008 ;59 :636-641