Diagonal-Arranged Quadrature Coil Arrays for 3D SENSE Imaging

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Synopsis: A key requirement for the design of a parallel imaging [1,2] array is that the local complex sensitivity profiles of the coil elements need to be distinctive enough from each other. In this paper, we present an 8-element quardrature array coil [3] with each of its eight elements being diagonally arranged to optimize the distinctiveness of the complex sensitivity generated by the coil elements. The diagonal-arranged quadrature (DAQD) coil provides 3D SENSE imaging capability not only for an 8-channel MRI system but also for a 4-channel MRI system if the eight elements are properly combined into four output channels.

Introduction: Recent studies [4,5] have shown that both the amplitude and phase of the complex sensitivity of RF coils can provide useful information for facilitating SENSE imaging. So far, to our knowledge, RF coil with 3D SENSE capability are design for MRI scanners equipped with eight or higher number of receivers [6,7,8]. Although 8-channel MRI systems are getting their popularity, most of the MRI systems in use are still 4-channel versions. Therefore, it is highly desirable to design 3D SENSE coils that can be used on both 8-channel and 4-channel MRI systems. Here we demonstrate that a longer and diagonally arranged coil can perform the similar function for SENSE imaging as two smaller coils distributing in the same diagonal direction. This concept has been implemented in an 8-element diagonal-arranged quadrature torso coil that can be used as either an 8-channel or a 4-channel 3D SENSE coil.

Methods and Materials: The 8-element DAQD coil (shown in Fig. 1) consists of an anterior and a posterior section with a rectangular shape of 33x42 cm^2. Each of the two sections is formed by four coils, as illustrated in Fig.2 for the anterior section, two loop coils (L1, L2) and two saddle coils (S1, S2). Each of the eight coils is arranged along a diagonal direction of the rectangle, as shown in Fig. 3. For example, the upper and lower portions of L1 locate, respectively, at the upper-left and lower-right corners of the rectangle. This novel design allows the sensitivity of a coil to distribute along a diagonal direction and to be distinctive from that of the other coil arranged along another diagonal of the rectangle. Therefore, for SENSE imaging S1 and S2 or L1 and L2 are equivalent to four individual loop coils locating at the four corners of the rectangle. The quadrature design for the DAQD coil not only provides phase information of the coils for SENSE imaging but also improves the intrinsic SNR of the coil. The mutual inductance between L1 and L2 is minimized by overlapping the two coils at their middle sections, illustrated as the shaded area in Fig. 3. Only a small overlap is needed for isolating S1 from S2 because the semi-quadrature nature between the two coils. The ratio of the physical length to width of the saddle coils is properly adjusted to minimize the lost of the $\mathbf{B_1}$ sensitivity in the z-direction (i.e., in the $\mathbf{B_0}$ direction). The eight coils can be used directly as eight individual channels for 3D SENSE imaging on an 8-channel MRI scanner. However, by combining each loop-saddle pair, for example, L1 and S1, through a 90^o combiner (Fig. 2), we can turn the eight elements into four output channels. This allows 3D SENSE imaging to be performed on a 4-channel MRI scanner as well.

Results and Discussions: Figures 4 and 5 show the simulated g-factor map, with a reduction factor of 2, for the 8-channel and 4-channel DAQD coils, respectively, for the three phase encoding (PE) directions. Although the g-factor values for the 4-channel DAQD coil are somewhat higher than those for the 8-channle DAQD coil, they are still low enough inside the region of interest to ensure SENSE imaging in all the three directions. Fig. 6 shows the full and ASSET (R=2) volunteer images obtained using an 8-channel DAQD torso coil on a GE Signa 1.5T 8-channel MRI scanner.

Fig. 1 The DAQD 3D SENSE coil.

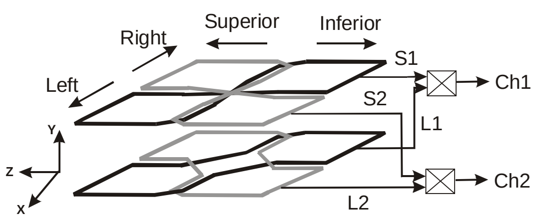


Fig. 2. Schematic for the anterior four coil elements.

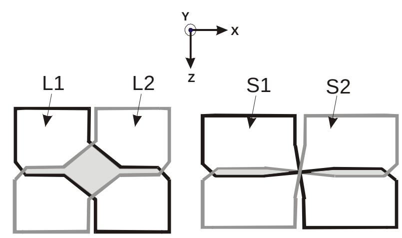
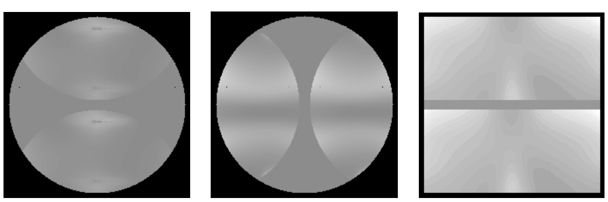
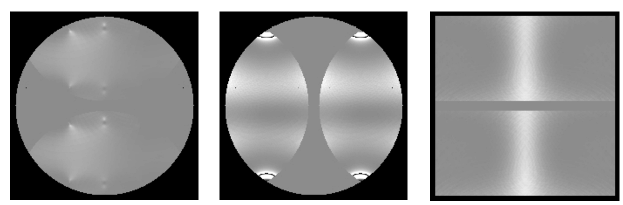


Fig. 3. Top view the two loop coils (left) and the two saddle coils (right).



G_{max}=1.26, G_{avg}=1.04 PE: A/P, Slice: Axial; G_{max}=1.43, G_{avg}=1.11 PE: L/R, Slice: Axial; G_{max}=1.21, G_{avg}=1.08 PE: S/I, Slice: Coronal

Fig. 4. G-factor map (R=2) for the 8-channel DAQD coil.



G_{max}=1.45, G_{avg}=1.06 PE: A/P, Slice: Axial; G_{max}>3.0, G_{avg}=1.19 PE: L/R, Slice: Axial; G_{max}=1.62, G_{avg}=1.1 PE: S/I, Slice: Coronal

Fig. 5. G-factor map (R=2) for the 4-channel DAQD coil.

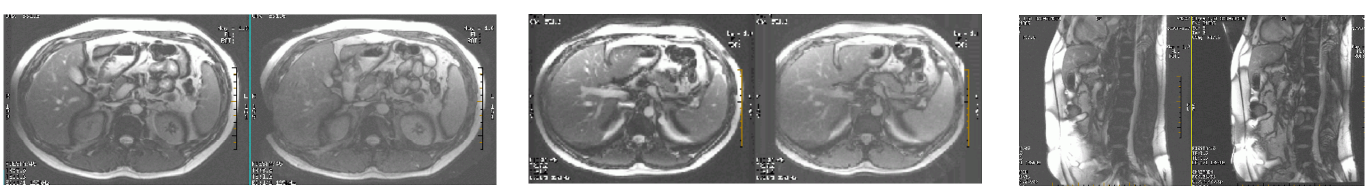


Fig.6 Full (left image in each panel) and ASSET with R=2 (right image in each panel) images for phase encoding in the A/P direction (left panel), L/R direction (middle panel) and SI direction (right panel).

Conclusions: The diagonal arrangement for each of the eight coils of the DAQD coil array optimizes the distinctiveness of the complex sensitivity profiles of the coils and facilitates SENSE imaging in all the three dimensions. Combining each quadrature loop-saddle pair of the DAQD coil array, we turn the eight coils into four output channels and achieve 3D SENSE imaging on a 4-channel MRI scanner.

References: 1) Pruessman, K.P., et. al., MRM, 42, p952-962, 1999. 2) Solickson, D.K., et. al., MRM, 38, p591-603, 1997. 3) US patent pending. 4) Hajnal, J.V., et. al., Proc. 8th ISMRM, p1719, 2000. 5) Weiger, M., et. al., MRM, 45, p495-504, 2001. 6) Okamoto, K., et. al., Proc. 10th ISMRM, p859, 2002. 7) Klinge, J.H.A., et. al., Proc. 10th ISMRM, p904, 2002. 8) Dumoulin, C.L., et. al., Proc. 11th ISMRM, p431, 2003.