SENSE imaging with quadrature half-volume TEM coil at 4T

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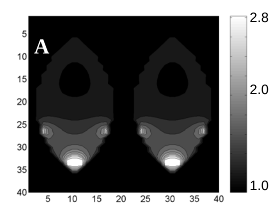
Introduction: SENSE parallel imaging (1) of the torso using arrays of multiple receive coils has been used to reduce acquisition times at low fields (1.5T). Homogeneous transmission is typically provided by a body volume coil. However at high field (>4T) it is difficult to construct an efficient body volume coil, making an alternative design highly desirable. Alternatively, an open half-volume coil can be used as an efficient transmission coil since as it provides a relatively homogeneous B_1 field while retaining high sensitivity due to a limited FOV. In principle, the same coil can also be used for reception in parallel imaging if the signals from two or more modes of the coil are digitized separately (2). The open half-volume coil also provides a more homogeneous reception profile than a surface coil array. Finally by eliminating the need for additional hardware (a separate set of receive coils) the entire design is simplified. As proof of concept, we describe the design and application of an open half-volume transmit/receive quadrature TEM coil to acquire SENSE images of the human brain at 4T (170 MHz).

Methods: An open 7-element half-volume quadrature TEM coil (20 cm id, 20 cm length, 26 cm shield diameter) was constructed using multiple tunable coaxial elements (3). The second and the third lowest modes of the coil were made degenerate and combined in quadrature to form a transmit/receive volume coil. Isolation between two modes was greater than 20 dB. During transmission the circularly polarized RF field was generated using two modes of the coil, combined in quadrature. For SENSE images the signals from each mode were acquired simultaneously but through separate receive channels.

Theory: In SENSE imaging the noise correlation and the g-factor (1) are minimized if the sensitivity profiles of the receive coils have minimal overlap. To achieve this in the half-volume coil we used the degenerate modes of the coil for multi-channel reception. In this coil the orthogonal modes are intrinsically uncorrelated, and thus noise correlation and the g-factor are minimized. The unfolding matrix and the complex sensitivity maps were obtained as described by Pruessmann et. al. (1). The g-factor in the central axial plane was calculated using the Biot-Savart Law. The noise correlation matrix was measured in the central plane using noise images (no RF pulse) obtained for each mode.

Results and Discussion: The RF power required to produce a 90° excitation in the center of the coil was 6-7 dB less than the full-volume head TEM coil (27.2 cm id, 20 cm length, 33 cm shield diameter). The averaged g-factors for FOV reduction in x- and y-directions (Figure 1) were equal to 1.18 and 1.25, respectively. Although the average g-value with FOV reduced in y-dimension was slightly worse, the reduction of FOV in this direction could still be preferable due to better peripheral g-factor distribution. SENSE images with a reduction factor R=2 were acquired from a 2L phantom and a human head. The noise correlation measured in the central axial plane of both objects was less than 5% due to intrinsic isolation of two orthogonal modes of the half-volume coil. Figure 2 shows human brain images obtained using half-volume TEM coil in the regular transmit/receive quadrature mode (2A) as well as using SENSE with 2-fold reduced FOV in x- and y-dimensions (2D and 2E). No significant difference in SNR was observed.



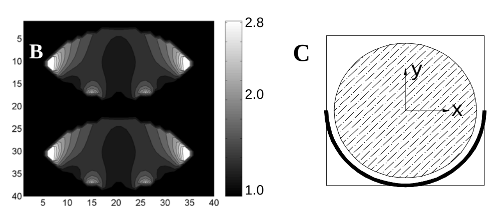


Figure 1. Simulations of g-factor with FOV reduction (R=2) in A) x- and B) y-directions with C) the coil setup.

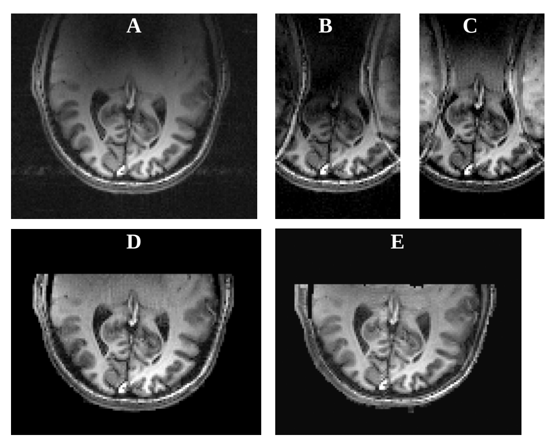


Figure 2. Axial brain images obtained using half-volume TEM in A) conventional quadrature transmit/receive mode, B and C) 2-fold reduced FOV images, and SENSE reconstructed images with reduction factor R=2 and FOV reduced in D) x- and E) y-directions.

Conclusion: We have demonstrated the feasibility of SENSE imaging using a single half-volume TEM coil at 4T. Although TEM coils can be increased in scale more easily than standard birdcage coils, for torso sized coils additional drive ports may be required (3). To increase the acceleration rate the number of degenerate modes could be increased or, alternatively, data can be acquired from multiple coupled channels (4).

References:

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