Investigating Tissue-Coil Interactions of an 8-elements Transmit/Recieve Torso Phased Array Coil

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Synopsis

Parallel imaging using phased array coils has excited great interest in magnetic resonance imaging. To help the design of some novel flexible phased array coils for the human torso, we theoretically investigated the RF field of a 2T 8-element torso phased array coil loaded with an anatomically accurate model of the human torso. The RF behaviour is predicted based on a hybrid MoM/FDTD approach. The primary results are reported and simulations demonstrate the feasibility of torso imaging using phased array coils.

Methods

The combination of high frequencies and the dielectric properties of the body make it difficult to produce large volume coils with reasonable homogeneity for imaging the human torso with high field MRI systems. Phased array coils [1] are attractive in this application, particularly when operated in the transceive mode as they can provide adequate homogeneity, improved SNR, reduced RF power levels and thus reduced safety concerns [2]. A quasi-static analysis based on the Biot-Savart law does not properly allow for mutual coupling and non uniform current distributions. Here a hybrid MoM/FDTD approach based on a full-wave solution of Maxwell's equations is used. MoM is applied to evaluate the current density distribution on the coils and the FDTD method is employed to find the steady-state electromagnetic fields (EMFs) inside the torso, which are then used to calculate the B_1 field, SI, and SAR. To accurately predict the RF behaviour a voxel-based human torso model is used in the numerical simulations. Using a passive decoupling interface [3] to minimize mutual coupling between coils, an 8-element torso phased array coil, depicted in fig 1, was designed and placed around the torso centred at the position of the heart. Quadrature voltage sources are applied to each coil, and current is induced on the coils to satisfy the boundary condition of zero tangential electrical fields. Once the currents on the coils are obtained, FDTD is employed to investigate the RF fields in the presence of the inhomogeneous torso model excited by the calculated currents. Twelve PML layers [4] with a parabolic conductivity profile are located on the six open sides to effectively absorb any radiated EMF energy. A GE imaging sequence and sum of squares method [1] are used to acquire the stimulated torso images. The noise correlation matrix is not included in the simulation.

Results

Fig 2(a) shows the magnitude of transverse magnetic field component B_1 in the unloaded condition while Fig 2(b) and (c) are the transmit and receive B_1 fields in the loaded condition. Fig 3 illustrates the high local signal intensity adjacent to each coil that decreases toward the centre of the region and in Fig 4 are the simulated torso images acquired from individual coils. Using the sum of squares method the combined GE image of the human torso is depicted in Fig 5. The variation of SAR across the imaging plane is shown in Fig 6.

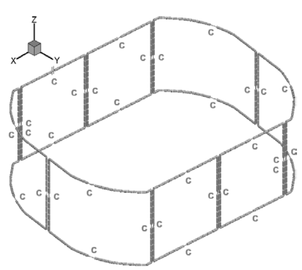

Fig 1. The 8-element torso phased array coil

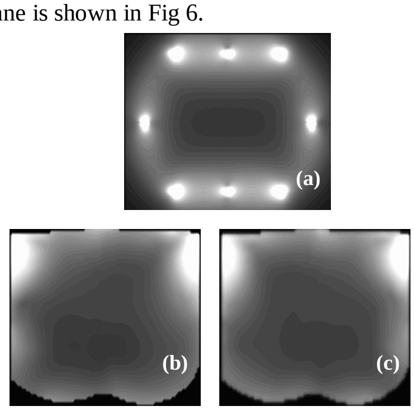

Fig 2. The simulated $|B_1|$ field

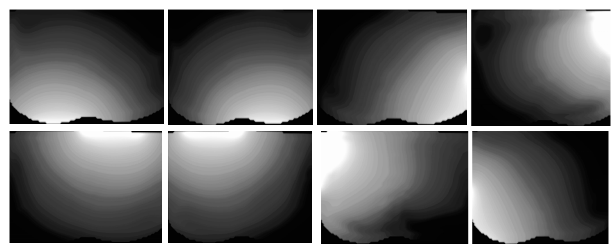

Fig 3. The signal intensity (SI) of each coil in the phased array

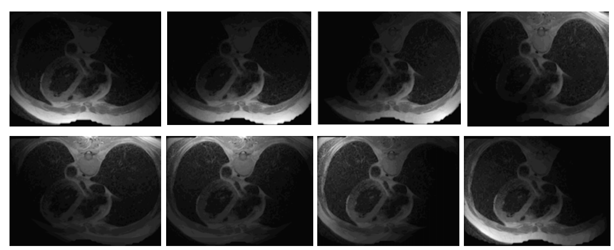

Fig 4. The simulated GE image of each coil in the phased array

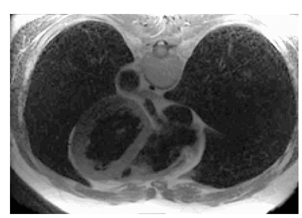

Fig 5. The combined GE image

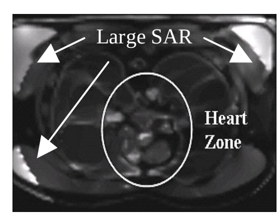

Fig 6. The SAR map

Discussion

These simulations demonstrate the possibility of simultaneously achieving a large field of view, high resolution and reduced scan times when using this type of array with parallel imaging techniques. Although some sample interaction is evident even at 2T the resulting image shows reasonable uniformity in receive only and transmit/receive modes of operation. The hybrid MoM/FDTD approach used here should prove to be even more valuable at higher fields as the increasing sample interactions can be properly taken into account. It is intended to extend this work by using a similar method to optimise coils for use at higher field strengths. Compared with a volume coil an array coil such as this has the advantage of lower global SAR however care is still required to ensure that guidelines are not exceeded in areas where the coils are close to the body.

References

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