Subject-Dependent Optimization of Parallel RF Transmission for High-Field MRI

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Introduction: For high-field MRI, parallel transmission is useful to improve the homogeneity of RF excitation, or reduce the SAR or the multidimensional- selection RF pulse width. [1] Although it is theoretically possible to achieve reasonably uniform or useful RF excitation for a set of given RF field maps by individually- driven multiple excitation RF coil elements, [2] subject-dependent RF field distribution and complexity and long acquisition time of previous RF field measurement methods make it difficult to practically use the parallel transmission optimized for each imaging subject. We found that the flip angle mapping method using composite spin-echo RF pulse [3] is rapid and accurate enough for this purpose, especially when incorporated with the echo planar imaging sequence. Optimization of driving pattern is done based on the RF field map. Simulation and experimental results show the utility of the proposed RF field mapping method applied to the subject-dependent RF field shimming and SAR reduction.

Methods: Complex RF field maps are obtained by a series of three interlaced echo-planar sequences for each transmission RF elements and a common receiver RF coil. These phase sensitive RF field maps for multiple TX elements are, then, used to optimize the RF transmission pattern. Compared with other RF field mapping methods, the proposed method is not T1 sensitive and provides an RF flip angle map with good dynamic range with reasonable SNR. The proposed mapping method can provide a 2-D field map within few seconds for each RF coil element. Relative phase difference map can also obtained by comparing the complex images with a common receiver coil. Figure 1 depicts the RF field mapping sequence, where the echo- planar imaging sequence is combined with the composite spin echo sequence. After the complex RF field maps are obtained for all the RF coil elements, driving voltages for the coil elements are optimized to achieve the best homogeneity. Although both magnitude and phase components of the driving pattern can be optimized in theory, we have optimized only magnitude components for simplicity when used for hardware implementation. The RF field mapping sequence and parallel transmission scheme have been implemented in a 3.0T MRI System (Magnum 3.0, Medinus, Korea) in Kyung-Hee University in Suwon. An 8-channel RF transmission coil and a 4-channel receiver coil are constructed (Fig.2) and used for image acquisition. The driving RF signals for multiple RF coils are generated by a single RF power amplifier and 8-way splitter with home-made attenuators with proper phase delays.

Results and Discussion: Both FDTD simulation and experiments have been performed to get an RF field map for an octagonal phantom with almost an identical result showing the utility of the field mapping method (See Fig. 3). The shape of TX coil elements is optimized by comparing the field map from various shapes of coil elements. For easy local field adjustment, 25 by 16 flat rectangular shape is selected for our parallel TX coil implementation. Figure 6 shows the field map from the transmission without optimization, (a), and that with optimization, (b), the relative nonuniformity ((Maximum – Minimum)/(Average) in %) was 48 % after optimization and 98 % before optimization, respectively.

Conclusion: A rapid RF field mapping method useful for subject-dependent parallel RF transmission is proposed. Optimized parallel transmission has been tried by using an 8-channel parallel TX RF coil. Preliminary results using a phantom shows the proposed method is useful in improving the RF field uniformity and reducing the local SAR.

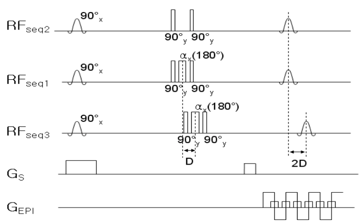

Fig. 1 Pulse sequence diagram of echo- planar RF field map imaging. The (90-0-90), (90-180-90), and shifted (90-180-90) composite spin-echo RF pulse sequences are used for B1 mapping with B0 inhomogeneity effect correction.

Fig. 2 The photograph of 8-channel TX and 4-channel RX RF coil with an octagonal phantom in it.

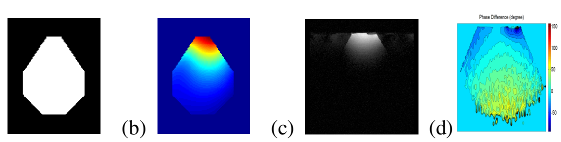

Fig. 3 B1 field map from one of the eight RF coil elements obtained by FDTD simulation (RF coil #1 at the top) (a) Phantom shape (b) B1 field map for one coil element (c) B1 field map obtained by the proposed RF flip angle mapping sequence which is similar to that obtained by simulation. (d) Phase difference map of one coil component (RF coil #1).

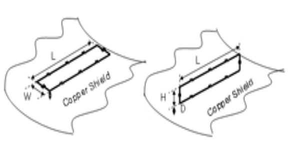

Fig. 4 Structures of two kinds of coil elements. Flat rectangular shape (left) and vertical rectangular shape (right) coils. Four different kinds of coils were used.

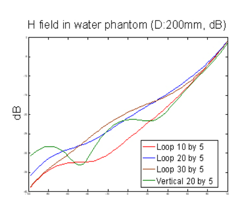

Fig. 5 Comparison of RF field maps for 4 kinds of coil shapes (flat rectangular shape (10 by 5, 20 by 5, and 30 by 5) and vertical coil (20 by 5)). The field distribution from 10x5 coil element shows the lowest values. The field from the vertical loop is strongly affected by reflection. In this simulation, the 30x5 and 20x5 elements show the better field characteristic (unit: cm).

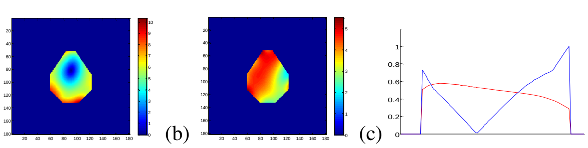

Fig. 6 Comparison of RF field map without optimization, (a), and with optimization, (b). (c) The gray levels along the dotted line (blue: non-optimized, red: optimized).

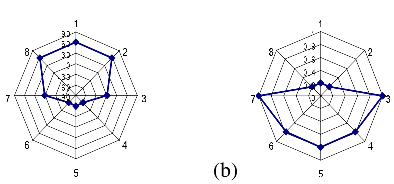

Fig. 7 Optimized driving voltages for multiple channel RF coil.
(a) Amplitude and (b) phase values are acquired by simulation.

References:

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