Improved Excitation Homogeneity at High Frequencies with RF Pulses of Time Varying Spatial Characteristics

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Introduction: Conventional volume coils of all types produce non-uniform B1 fields inside the human body at high frequencies (1,2,3,4). However, the spin excitation produced by two closely spaced RF pulses can be additive if applied over short time spans. Consequently, with separate pulses of different spatial characteristics, the net spin excitation will arise from the scalar sum of the field magnitudes compared with the vector sum if the fields were applied simultaneously. Hence, two separate transmit pulses can provide a net spin excitation profile which would be unachievable by a pulse of single spatial distribution. This method, in principle, can be used to improve the homogeneity of spin excitation at high frequencies.

Methods: A commercially available FDTD software package and a 5mm human head and body biomesh (XFDTD, Remcom, Inc, PA USA) were used to simulate the time varying magnetic and electric fields from each individual element of an eight element shielded end-capped transmission line volume coil of 36cm OD, 28cm ID and 20cm length. From the time series data the appropriate right and left handed circularly polarized fields were obtained for unit current on each element. Using these individually computed element fields, the B1 field of any desired drive pattern could be obtained by the linear combination of the individual element fields.

To evaluate the possibility of using dual transmit pulses two methods were investigated: 1) a first pulse using the homogeneous (primary) mode of the volume coil followed by a second pulse using the secondary (e.g. gradient) mode of the volume coil, 2) two transmit pulses where the current amplitudes and phases of all coil elements were optimized for each pulse to provide a net maximally uniform excitation. For the first method, Brent's optimization algorithm (5) was used to find the relative amplitudes of each pulse that minimized the standard deviation of the combined circularly polarized transmit field over a single axial slice. For the second method, simulated annealing was used for optimization of the multiple current amplitude and phase variables over the same metric (5).

In all cases, the spin excitation was taken to be the scalar sum of the of the individual field magnitudes of the two pulses: spin relaxation effects were ignored for the purposes of the computations.

Results and Discussion: Figure 1A shows the relative spin excitation over one midbrain slice with uniform quadrature excitation at 300 MHz. Fig 1B shows the results obtained using primary mode excitation followed by secondary mode excitation at 300MHz. Figure 1C shows the results obtained using two pulses each optimized for overall maximally homogeneous excitation. Figure 2A-C show the corresponding line plots through the center portion of these slices. The net resultant spin excitation had a standard deviation of 21% for the primary mode, 8.5% for the primary followed by the secondary mode (2.5X improvement), and 4.5% for excitation with two optimized field patterns (4.5X homogeneity improvement).

Conclusion: This work shows the feasibility of substantially improving spin excitation homogeneity at high frequencies by the use of a transmit field of time varying spatial characteristics which consists of two separate pulses with different field distributions. Even by exciting the primary followed by secondary modes of a volume coil, a greater than two fold reduction in spin inhomogeneity can be achieved. With the use of two spatially optimized pulses, transmit homogeneity at 7T can potentially be improved to levels better than those found at 3T with standard single pulse methods.

References:
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Figure 1: Computed Spin Excitation Maps, single axial slice at 300MHz
A. Primary volume coil mode **B.Primary followed by secondary mode** **C. Two optimized pulses**

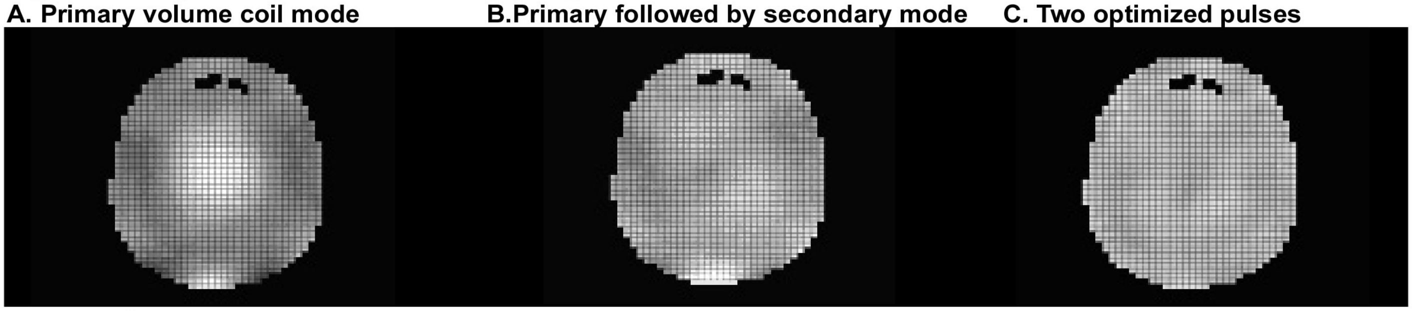

Figure 2: Corresponding line plots through horizontal center line