Reducing Side Lobes and SAR in Parallel Transmission Using Variable Density Spirals

Y. Liu[1] and J. Ji[1]

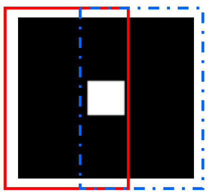
[1]Electrical and Computer Engineering, Texas A&M University, College Station, Texas, United States

INTRODUCTION

Transmit-SENSE using multiple excitation channels has emerged as an effective approach to shorten RF pulse duration. Uniform spiral and EPI are currently the k-space trajectories of the choice in the literature [1,2,3]. Variable-density spirals have been previously used to provide improved excitation profiles in spatial selective excitation [4]. In this work, numerical simulations were used to study Transmit-SENSE with variable-density spiral k-space trajectories. The results demonstrate that variable density spirals provide reduced side lobes and lower SAR than uniform density spirals, for both non-accelerated and accelerated excitations.

METHOD

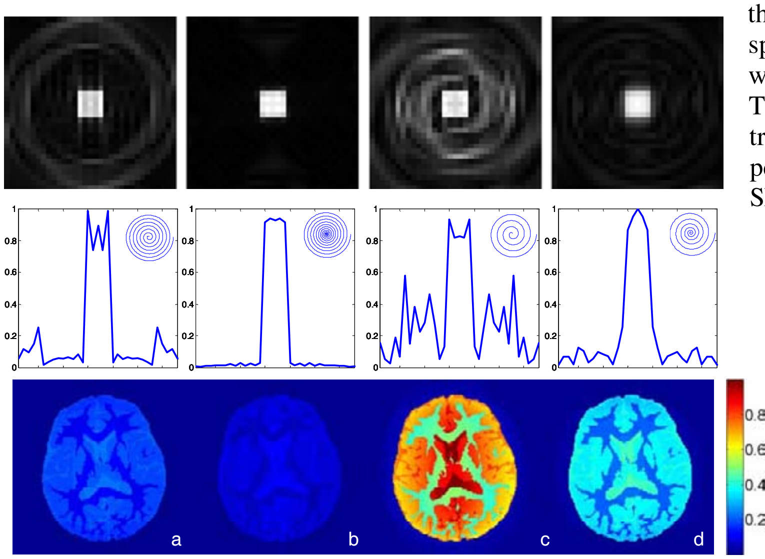
The sensitivity of a two-channel transmit array coil were simulated based on the Biot-Savart law. Each coil element is planar rectangle with a size of 19.2 x 19.2 cm. The two coils were placed 13 cm apart (Fig. 1 on the left). The desirable excitation profile was set to be a 4 x 4 cm square at the center of a brain image phantom, placed in parallel to the coil plane with a vertical distance of 4 cm. The image acquisition field-of-view (FOV) was 32 x 32 cm. The variable-density spirals were designed using an empirical approximation



defined as $k(\tau) = k_{max}\, \tau^{\alpha} \exp(i2\pi N\tau)$ where k_{max} is the maximal k-space radius covered, $\tau(t)$ is the temporal parameterization of the trajectory, and α is a parameter to control the density of the spirals (α = 1: uniform spirals; α = 2, central k-space twice as dense as the outer k-space). The maximum gradient of 1G/cm and maximum slew rate of 2G/cm were used to constrain $\tau(t)$ [5]. The revolutions of spiral N was determined by a 12 x 12 cm filed-of-excitation (FOX) according to $N = [1-(1-\Delta x/FOX)^{(1/\alpha)}]^{-1}$, where Δx is the desired resolution. For accelerated scan, the revolutions (therefore pulse duration) are reduced by an acceleration factor denoted as R. The multi-channel RF pulses were computed using an image-domain design method proposed in [3]. The simulated coil sensitivity and computed pulses were input to a Bloch simulator to generate and visualize the excitation profiles on a 32x32 rectilinear grid within the FOV. The side lobes are quantified by Sidelobe Level (SLL) defined as SLL = 20log10(|largest sidelobe value/central profile value|). The SAR was computed using time-averaged SAR = $\sigma E^2/(2\rho T)$, assuming the conductivity map σ (fat 0.03, white matter 0.35, gray matter 0.6, CSF 0.7, in S/m), and proton density map ρ (fat 1.06, white matter 1.03, grey matter 1.03, CSF 1.06, in kg/m^3). E is the total electrical field produced by all the coils [6]. Excitations with (R=2) and without accelerations (R=1) were simulated and the SLL and SAR were compared.

SIMULATION RESULTS AND DISCUSSION

Figure 2 (top row) shows a set of representative excitation profiles generated. The middle row shows the 1-D profiles of the line in the middle of the FOV. Note the significantly reduced side lobes in the second and the fourth column where variable-density spiral were used. The SAR distribution shown in the bottom row indicates that variable density spiral also reduced the RF power absorption rate as compared with the conventional spirals. These advantages were obtained with slightly longer pulse duration (see Table). In addition, there is a small resolution loss associated with variable density spirals. This trajectory is complementary to transmit-SENSE which can reduce pulse time but may lead to increase SAR. Therefore variable-density spirals provide a new and improved tradeoff that can be used to improve the sidelobes and SNR performance of multi-dimensional excitations using transmit-SENSE.



	R=1 α=1	R=1 α=2	R=2 α=1	R=2 α=2
SLL (dB)	-9.89	-22.9	-3.89	-15.2
T (ms)	7.08	9.76	4.05	5.23
Relative SAR	0.25	0.13	1	0.5

Fig 2: Excitation profiles, profile along center location, corresponding kspace trajectory and maximum SAR within FOX (a) uniform density N = 8; (b) varible density, R = 2; (c) variable density, R = 1; (d) variable density, R = 2.

REFERENCES

[1] Katscher U., et. al., Magn Reson Med 2003;49:144-150. [2] Zhu Y., et al., Magn Reson Med 2004;51:775-784. [3] Grissom W., et.al, Magn Reson Med 2006; 56:620-629. [4] Schroder C, et.al., J Magn Reson 2003; 18:136-141. [5] Kim DH, et. al., Magn Reson Med 2003; 50:214-219. [6] Katscher U., et. al., MAGMA 2005;18:81-88.