

SENSE Accelerated Multiple Excitation Imaging at Ultra High Field

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Introduction

At high frequencies where magnetic field strength exceeds 3 Tesla the RF wavelength approaches the dimensions of the human head, leading to a significant B_1 phase variation across the sample. This causes destructive or constructive interference across the sample, giving highly inhomogeneous B_1 transmit and receive fields for volume probes (1). By employing multiple independent elements and exciting them sequentially using a BURST like imaging sequence (Fig. 1), we are able to separate signals due to different transmit elements within the same slice without interference (2). At the receive stage interference can then be avoided by recording the signal due to each resonant element separately. Signals can then be phase corrected before recombination. The disadvantage of this method is that there is a time penalty associated with the sequential excitation. In this work we demonstrate the use of SENSE (3) to recombine images and accelerate image readout, thus restoring the speed to near that of a single excitation readout.

Methods

The Transmission Line Matrix (TLM) method (4) was used to simulate the B_1 fields generated in a saline phantom ($\sigma=0.5S/m$, $\epsilon_r=78$). A probe consisting of four stripline elements was simulated (strips at 45, 135, 225 and 315°), each element driven by a 300MHz current source at its centre. Simulations were run to generate rotating B_1 transmit and receive field maps produced by each element. These spatial maps of amplitude and phase were then incorporated into a Bloch simulation of the sequence and used to generate simulated images. Using the four element probe, the sequence generates 16 images, one for each transmit/receive combination, each with a different sensitivity matrix S , calculated as

$$S_{\gamma,\eta,\rho} = B_{1,\gamma}^+(\mathbf{r}_\rho) \cdot B_{1,\eta}^-(\mathbf{r}_\rho)$$

Where γ and η are the transmit and receive element numbers, ρ counts the superimposed pixels and $B_{1,\gamma}^{\pm}$ are the complex transmit/receive fields at point \mathbf{r}_ρ . The sequence was tested using EPI readout at acceleration factors $R=1,2,3$ and 4.

Results

The highly inhomogeneous transmit and receive 300MHz B_1 fields for each strip element are shown in Fig. 2. Note that for a given element, the transmit and receive fields are different, as expected at short wavelength. Figure 3(a) shows the noise map for the four strip element probe. Figure 3(b-d) show the geometry factor at acceleration $R=2,3,4$. Figure 4(a) shows the root Sum-of-Squares reconstructed image combined without phase information. Figures 4(b-e) show SENSE reconstructed images at acceleration rates 1,2,3 and 4. The maximum geometry factors were found to be 1.07, 1.51 and 1.59 respectively.

Discussion

When the independent images are combined without phase information the coverage is reasonably uniform. A benefit of the inevitable B_1 field inhomogeneity is that when readout is aliased, geometry factors remain low. When applied at acceleration $R=1$, SENSE acts as an intensity correction algorithm (at the expense of non-uniform SNR), producing a very uniform image. The readout can be accelerated by a factor of 2 with virtually no loss in image quality. At higher accelerations, aliasing artefacts become visible, although it may be possible to remove these using a correction method such as UNFOLD SENSE (5). This could also be used to acquire auto-calibration data, as a body coil would not usually be available to collect sensitivity maps at very high frequencies. We have demonstrated that the SENSE algorithm has specific advantages when used with the multiple sequential excitation method.

References

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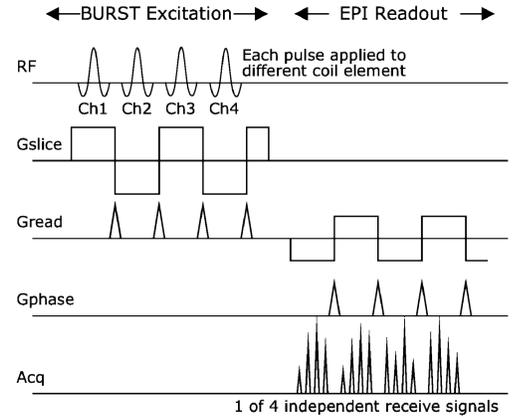


Figure 1: BURST like imaging sequence

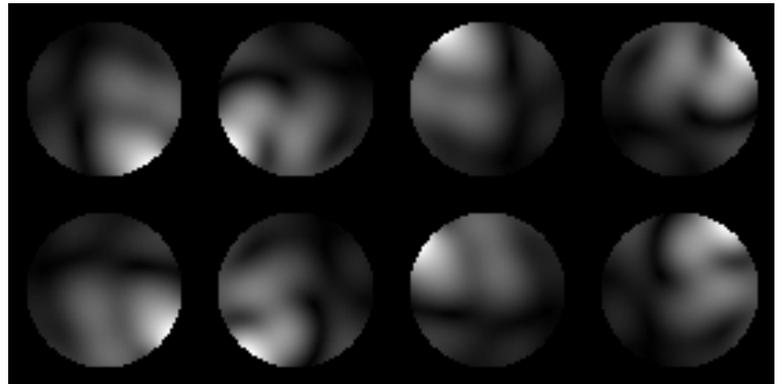


Figure 2: Simulated B_1 transmit (top) and receive (bottom) field magnitudes generated by the four probe strip elements inside a saline phantom ($\sigma=0.5S/m$, $\epsilon_r=78$) at 300MHz.

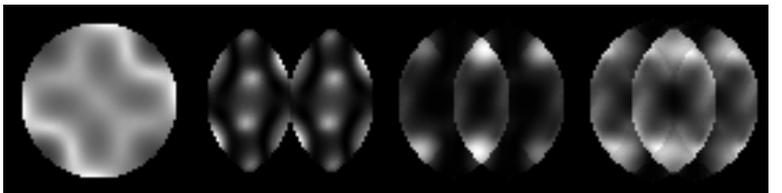


Figure 3: Noise map, and g -factor maps at $R=2,3$ and 4 (normalised to g_{max}).



Figure 4: (a) Root Sum-of-Squares and (b-e) SENSE reconstructed images at acceleration rates $R=1,2,3$ and 4.