Point-Spread-Functions for RF Imaging with TRASE: Implications for Phase Gradient Coil Design and Flip Angle Calibration

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Introduction – TRASE – Imaging without B_0-Gradients

TRASE is a k-space imaging method which uses RF phase gradients instead of B_0-gradients (1). A 1D TRASE sequence consists of excitation followed by an echo train in which the RF refocusing pulses are alternately applied with fields 'A' and 'B'. These 2 fields are ideally of uniform magnitude but with positive and negative B1 phase gradients respectively. This results in k-space evolution occurring from one echo to the next, and sampling of an echo train yields a line of k-space. TRASE is a general k-space method and 2D imaging and slice selection have been demonstrated (1).

Aims of this Study

Consider 2 coils A & B with identical |B1| profiles but equal and opposite phase gradients. |B1| varies spatially because of practical design constraints, and B1phi varies linearly along the encoding axis, by design. So each location experiences a different pulse sequence. In general we might consider a set of sequences SEQ(|B1|, B1phi) with the two parameters of ranges (0 < |B1| < B1max) and (-180 < B1phi < +180). The sequences in this set will have varying levels of performance in terms of echo train generation. However it is key that reliable echo train generation is not required for this entire set of sequences, but only for the sub-set that are realized by a particular coil design. Specifically in this study we examine how the point-spread-function (PSF) for 1D TRASE imaging varies spatially for a particular simulated coil field.

Methods

We consider a matched pair of RF fields, each with both Gaussian magnitude profile along the X-axis and a linear phase gradient field in the x-direction, thus: $B_{1A,B} = \exp(x^2/2\sigma^2)\exp(\pm iG_1 x)$ with $\sigma = 100\text{mm}$ and $G_1 \equiv 1\text{deg/mm}$. We consider the on-axis response. The study was performed using full Bloch equation simulation using our simulation program (*Multibloch*). The 128-echo train sequence used for simulation is shown in the figure. We chose to study square refocusing pulses, as their use minimizes echo train duration, (although composite pulses, offering better performance could be used). PSF was investigated by forming the image of a point object as a function of the x-coordinate and flip angle at coil center. Only if flip angle is a perfect 180deg would PSF be ideal.

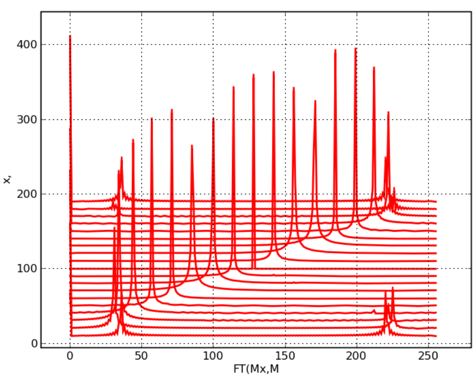
```
Flip    Phase  B1 Gradient  Length
(deg)   (deg)  (deg/mm)     (us)

90.0   -90.0   +1.0          20
======================
                            500
Flip     0.0   +1.0          20
                            499
<echo>                        1        x64
                            500
Flip   180.0   -1.0          20
                            499
<echo>                        1
======================
```

Results

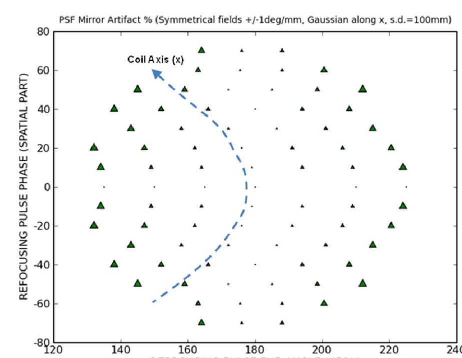
Point-spread-functions (PSF) is shown (see stacked plot) for a series of 19 locations along the simulated coil axis, at 10mm (10deg) intervals. The flip angle at the center is set to 195deg, rather than 180deg, because 195deg still offers good performance at the center, while the elevated |B1| level improves performance at the coil edges. The PSFs are good over a range -70mm ….+70mm, i.e. 140/180 = 78% of the maximum possible FOV. Poor performance at the edges can be seen with incorrect position of PSF center and also mirror artifacts. A line artifact at the extreme edge of the FOV can also be seen.

Since the principal defect that the PSFs exhibit is a mirror peak, PSF quality was summarized for a wider range of conditions by generating a scatter plot of B1 spatial phase vs. |B1|, where only points for which (mirror peak/ main peak) < 5% are shown. The size of the plot markers represents this peak ratio.



Discussion

For any real coil there is a correlation between |B1| and B1phi profiles, so only a sub-set of all potential (|B1|, B1phi) combinations occur. PSF performance is only relevant for this subset. This sequence is quite sharply divided into a main region with good PSF and a region poor PSF and mirror artifacts. Many other sequence designs are possible, but none studied so far have shown such a large high performance region as shown here (results not shown). The region shown in the scatter plot (and especially where the smaller markers are) indicates good PSF, and can be used as a set of target conditions for coil design. Off-resonance and mis-match between coil fields were not considered in this study.



Conclusions

The value of this study is in guiding phase gradient RF coil design, as information on the acceptable types of RF inhomogeneity is available. For the geometry considered here inhomogeneity causing a flip angle range from 150…195deg can be acceptable. This study also shows that sequence design, coil design and flip angle calibration are all linked. Next steps will include application of the same approach with fields from actual phase gradient coils and use in coil design.

References: 1) J.C. Sharp & S.B. King, Magn. Reson. Med. (in press); Sharp-JC ISMRM (2009); Sharp-JC et al. p.829, p.1083 ISMRM (2008); King-SB et al. ISMRM (2007); King-SB et al. ISMRM p.2628 (2006)