The Accuracy of Transmitter Gain Optimization at 7T

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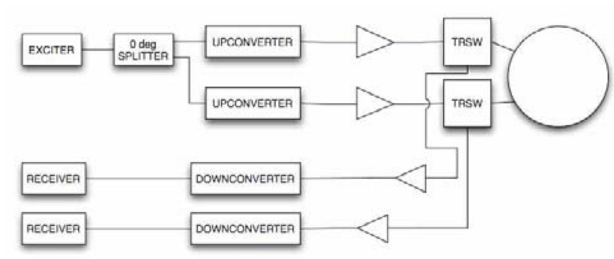
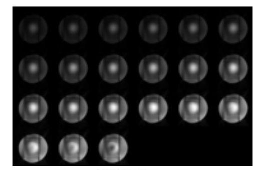


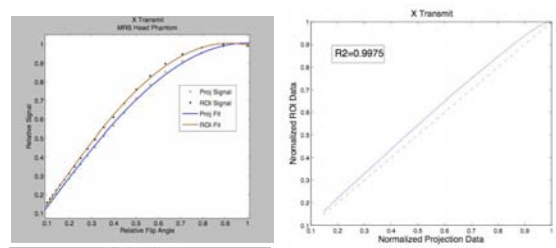
INTRODUCTION

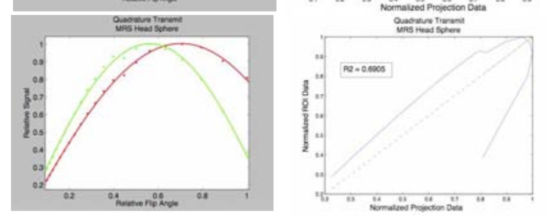
As indicated by finite difference time domain calculations [1], the inhomogeneous B_1 field distribution in lossy dielectrics complicates the optimization of transmitter gain, and so the actual flip angles for a given pulse sequence for imaging and spectroscopy applications at 7T. Two common methods of optimizing transmitter gain -- stepping the transmitter gain (TG) while observing a single projection through the object, and measuring the ratio of spin echoes and stimulated echoes for a projection through the object -- both rely on projections which significantly underestimate the actual flip angles within the object, due to signal cancellation between regions with high signal and low signal which result from the intrinsic B1 variation within the object. As shown below, however, for the TG stepping method, the spatial projection error is not significant at 7T provided the flip angle never exceeds 90 degrees.

METHODS AND MATERIALS



All imaging was performed on a GE Signa 7T Human Research MR System with prototype RF coils developed by GE. The transmitter configuration is as shown in Figure 1. Gradient refocused echo planar imaging at various transmitter gain settings was performed on a head phantom containing doped water which was designed to match the conductivity of the brain at 63 MHz. Offline reconstruction using a separate reference phase correction was performed in Matlab. For the projection measurement, the maximum of the sum over rows of each image was taken; for the region of interest (ROI) measurement, a ROI was placed on one of the images and the mean within that ROI was measured for each image in the series. The resulting data vectors were fit to a sinusoid to determine the equivalent B_1.





RESULTS AND DISCUSSION

As discussed by Hoult [2] and others, the signal in the image should be proportional to $\frac{B_{1,r} \cdot B_{1,t}}{\left|B_{1,t}\right|} \sin\left(\gamma \left|B_{1,t}\right| \alpha\right)$ where $B_{1,r}$ is the receive component of the B_1 field at unit current of the coil (the counter-rotating component for this quadrature coil) and $B_{1,t}$ is the (co-rotating) transmit component. $B_{1,r}$ is independent of the transmitter gain. The effect of the receive field, which of course does not change with TG, is eliminated by normalizing all the images in the series to a maximum of unity.

Figure 2 above right shows the reconstructed images of a single slice at different transmitter gains. A single column wide phase correction artifact can be seen; the ROIs were chosen to avoid this artifact. Figure 3 shows the projection and ROI data when only the X coil was used as a transmitter; the datasets are shown with a fit to a single sinusoid, and the correlation (r^2=0.9975) is shown at right. Figure 4 shows the corresponding fits for the quadrature case; clearly the differences between the projection and ROI measurements are significant.

The fit data are summarized in the table at the bottom right, showing the maximum flip angle at full transmitter gain measured by the projection and ROI methods for X transmit only, Y transmit only, and in quadrature. For the two linear cases, the errors are quite small, because the maximum flip angle remains below 90 degrees throughout the slice. In quadrature, the stronger transmit field allows higher flip angles, and the error becomes quite significant. Had more power been available in the linear cases, similar behavior would have been seen. These effects are expected to be more pronounced in a phantom than an actual head.

Transmit	Projection	ROI	Delta
X	90.09 deg	98.01 deg	-8.1%
Y	85.05 deg	89.60 deg	-5.1%
Quad	127.89 deg	160.20 deg	-20.2%

REFERENCE:

[1] Collins, CM and Smith, MB MRM 45: 684-91, 2001

[2] Hoult, DI Conc Magn Res 12 (4): 173-87, 2000.