Coil tuning with piezoelectric actuators using the MRI signal as the optimization parameter

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TARGET AUDIENCE: Coil engineers and Ultra-high field MR community

PURPOSE: To determine the effectiveness of using MRI signal as a metric for tuning a transverse electromagnetic (TEM) coil[1]. Optimal peak transmit power is the end goal for a tuned and matched coil, particularly with limited RF power such as at ultra-high field. The effect of tune vs. match on MRI signal is explored for the four elements of a transmit and receive (T/R) array and compared to the S_{11} (reflected/forward) power ratio.

METHODS: A four channel 7T cardiac T/R TEM coil was fitted with piezoelectric actuators (PI, Auburn, MA) for electronic adjustment of the tune and match capacitors (for details see abstract by G. Keith). The coil consisted of four parallel TEM elements 5 cm apart and 15 cm long[1], designed for cardiac imaging at 7T (Siemens, Erlangen Germany). We investigated three metrics, the magnitude of an FID received on the element of interest, and two different reconstructions of a turbo flash (TFL) acquisition, either the sum of squares (SOS) image received on a completely separate array of four receive elements or the sum of image magnitude received from the same element as transmit. The experiment started by tuning and matching all coil elements using S_{11} and then initiating a grid sampling pattern for a single element. One measurement was acquired for 30 by 32 different tune by match positions with a 2.6 s pause between measurements. For each of these measurement locations an S_{11} power ratio was also calculated using an AD8302 gain detector (Analog devices, Norwood, MA) connected to directional couplers at the RF amplifier and corrected for return cable losses. For the TFL measurements the TR:TE was 3.4:1.4 ms, matrix size was 64 x 48, FOV 350 x 263 mm^2, slice thickness 20 mm and 6/8 phase partial Fourier. Transmit voltage was adjusted to give no more than a maximum flip angle of 5° at any point in space. In a phantom, made to resemble human loading and doped with gadobutrol at 0.04 mmol/l, the process was repeated for each of the four array elements. A reduced tune / match parameter space was acquired for one element in two volunteers.

RESULTS: The figure shows the S_{11} measured over this parameter space, it is plotted as a percent of power delivered, $100*(1 - 10^{S11/10})$, and as the reflected/forward ratio in dB (on the right). We found that the TFL sum image magnitude received from the transmitting element was most sensitive and most closely resembled the S_{11}. The FID response did not align with S_{11} maps, and the sum of squares combined images had a less well defined and noisy peak. The sum image magnitude received from the transmitting element over the parameter space is shown in the figure; all numbers are reported relative to the maximum found at any location. In all four coil elements the MRI maximum fell within an S_{11} of -10 dB or less. The region corresponding to S_{11} = -15 dB is outlined in the S_{11} map and superimposed on the equivalent TFL map. The figure lastly shows the parameter space for the sum image magnitude received from the transmitting element for a volunteer. The volunteer image intensities have more variation than the phantom scans giving a broader maximum region in both.

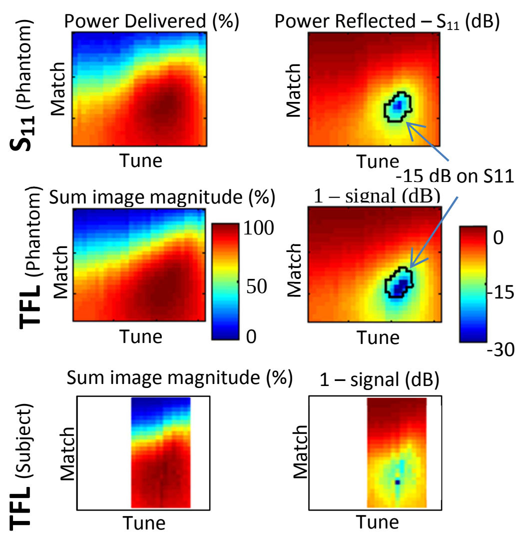

Figure: Effect of tune and match in 30 x 32 grid on S11 compared to MRI signal in a turbo flash (TFL) image. TFL signal is the sum of image magnitude received on the transmitting element.

DISCUSSION: MRI is an attractive metric to use in coil tuning as it ensures optimal coil performance. This setup would lend its self to automated MRI driven coil tuning. In phantom experiments the MRI signal shows a broader peak than S_{11}, demonstrating that it is less sensitive at the optimum. The volunteer scan further shows a greater level of noise and a broader maximum region. When using MRI as a metric you ensure an optimal solution for tune, match and coil de-coupling, analogue to assessing both the reflected power and power coupled to other channels. Limitations of using MRI as a metric is that there is no absolute reference to determine an acceptable tune and match state, image acquisition is fairly slow, and the sample must be in the scanner.

CONCLUSION: We have demonstrated that MRI signal in a T/R TEM coil is a viable metric for automated coil tuning, although less sensitive around the optimum than S_{11}.

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REFERENCE: 1: Snyder C, DelaBarre L, Van De Moortele P-F et al. Stripline/TEM Transceiver Array for 7T Body Imaging. Proc. Intl. Soc. Mag. Reson. Med 2007, pp 164.