CALIBRATION OF TRANSCEIVE-ARRAY RF POWER USING LANTHANIDE SHIFT AGENTS

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Introduction

The use of transceive arrays in ultra high field imaging provides the attractive ability to tailor the transmit radio-frequency field (B1+) and mitigate standing wave artifacts[1]. During the pre-scan, each parallel transmitter channel must be calibrated to determine the required power to produce a given flip angle. Problems arise when transmitting with all elements, as spatial B1+ phase interactions interfere with accurate flip angle quantification.

One method of fixing this problem relies on knowledge of the spatial phase variations. By manipulating transmitter phases, one can create regions of constructive interference and perform a sample based power calibration. However, all current methods of accurate phase mapping typically require multiple acquisitions which presuppose accurate transmitter power settings, giving rise to a chicken-or-egg scenario. One can also choose to calibrate each channel individually, the drawback being a greatly increased pre-scan time for large transmitter arrays.

In this work, we propose a simple, robust, and fast method for calibration of all transmitter channels in parallel, while avoiding the confounding effects of spatial phase interactions.

Methods

Historically, adiabatic pulses for surface coils were calibrated via the use of a small (NMR-active) tracer affixed directly at the coil center[2]. Application of a gradient orthogonal to the plane of the coil differentiates between the probe resonance and signals from the sample being scanned, allowing for accurate calibration of a RF pulse of a specified flip angle (e.g. 90 degrees) at coil center.

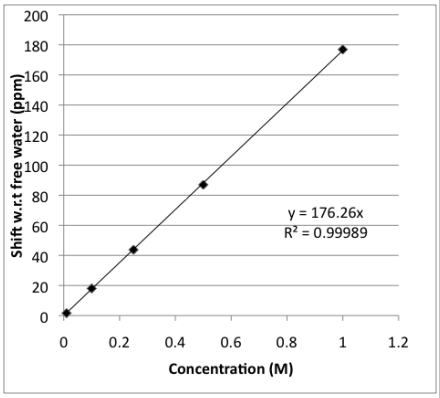

Figure 1: Experimentally determined 1H resonance shifts (w.r.t. free water), versus concentration of solute ($DyCl_3 . 6H_2O$).

We build on this notion by attaching such small tracers to the center of each of the N coils comprising the phased array (figure 2). Since (in the typical case of a cylindrical head array) one cannot create a single gradient to separate all sample and probe resonance, we instead rely on a chemical shift agent to make the tracers easily identifiable. Choosing large chemical shifts for the tracers (>50 ppm) has the added benefit of rendering them invisible in typical imaging sequences. Tracers were fabricated from NMR tubes cut to 1cm in length and filled with the shift agent and sealed..

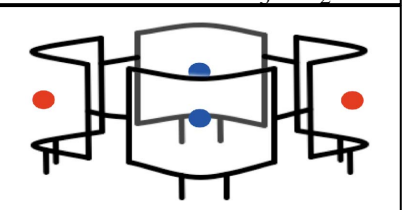

Figure 2: Example of tracer locations. Frequency shifts of tracers are alternated to limit detection by nearest-neighbours.

In order to find an appropriate shift agent for the NMR marker, aqueous solutions with varying concentrations of Dysprosium were prepared by dissolving Dysprosium Chloride Hexahydrate in de-ionized water. The resulting shift in resonance frequency with respect to free water was confirmed to vary linearly up to moderate concentrations (~1M) (figure 1), with the associated well documented increase in line broadening with shift.

During power calibration, each channel is set to transmit and receive in a narrow frequency range around the tracer offset.

Discussion

To limit 'crosstalk' between neighbouring coil elements, tracers with two separate shifts were interleaved. The current iteration of this design was tested on a 6.4cm diameter, 4 channel phased array transceive coil[3] on a Varian 9.4T 31cm small animal MR, as a proof of concept.

With the arrival of a new 7T 16 transmit-receive channel Varian/Siemens human MR scanner at our lab, work continues to implement this strategy on 8 and 16 channel transceive head coils. With the larger coil dimensions, interaction between nearest-neighbours and next-nearest neighbouring coil elements are expected to be diminished compared to the 6.4cm coil case.

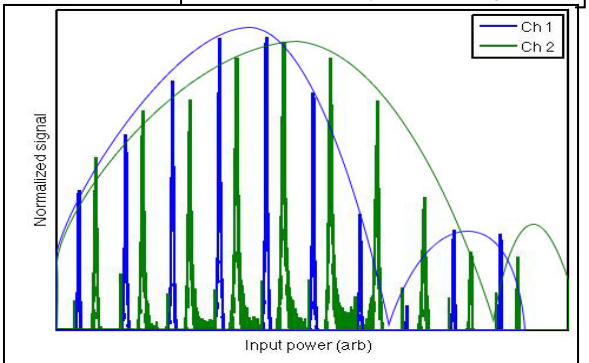

Figure 3: Power calibration curves for two elements. Tracer frequency shifts combined with narrow receive bandwidths allow for calibration in parallel. Tracers are well isolated, at ~70kHz and ~40kHz off resonance.

Conclusion

Accurate transmit power and phase calibration is an important first step for B1+ spatial mapping of high field transmit arrays. The use of integrated tracer samples allows for such calibrations.

In summary, we have prototyped a simple, fast, and robust power calibration method for parallel transmit hardware.

References:

1) Van de Moortele et al. Magn. Reson. Med. (2005) vol. 54 (6):1503-1518

2) Hendrich K, et al. Magn. Reson. Med (1991) vol. 19(2):496-501.

3) S. Oduneye, R.Menon, Proc. ISMRM #1100 (2008)

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