A method for calibrating multi-channel RF systems

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Introduction

Parallel Transmit (pTx) MRI is a fast developing area of research. A rate-limiting step in the development of the technology is the availability of suitable hardware, particularly in whole body MRI systems. There have already been several low cost multi-channel hardware configurations proposed, including those utilising vector modulators [1,2] and on-coil amplifiers [3]. These and more conventional systems are likely to exhibit non-linearities and differential characteristics between channels, suggesting that a rapid system level calibration approach would be useful. This abstract describes a method to calibrate the channels of multi-transmit systems, including generation of look-up table style corrections. The method was tested on a vector-modulator (VM) pTx system.

Methods

The calibration procedure directly utilizes NMR signal. This allows the entirety of the RF transmit chain to be characterized, so that the imperfections of all of its constituent parts are accounted for. Low flip angle non-selective RF pulses are repeatedly transmitted through a single channel of the RF chain. The amplitude and phase of each pulse is modulated so that measurements are made across the entirety of the operating range of the transmit hardware. A small doped phantom is placed in the centre of the transmission coil, the short-T1 allowing a short TR to be used. An FID is collected after each pulse, whose relative amplitude and phase directly relates to the modulation applied by the transmit hardware. This is repeated for each transmit channel. The Larmour frequency is calculated for each FID throughout the calibration and any drifts are corrected for. The transfer function between the measured signal and the modulation parameters is then calculated and is used to control the hardware in future experiments.

The proposed method was tested on a Philips 3T Achieva scanner. The pTx hardware calibrated was an eight channel vector-modulator system [2], inserted into the RF transmission chain between the low-level spectrometer output and the RF amplifier. The single channel scanner output (FA = 5°)was passed through an eight-way splitter (Mini-Circuits ZCSC-8-1+), the outputs of which were then modulated using an Analog Devices ADL5390 VM. The modulation each VM applies is controlled by two voltages between 0-1V, updated each TR (TR = 1.5s) using MatLab operating synchronously with the sequence. Multiple averages (N = 5) were taken for each calibration point. The eight channels were calibrated serially, placing a single VM in line with the scanner amplifier in turn, with transmission and reception using a T-R head coil.

A thin-plate spline transformation [4] was used to model the transfer function between the frequency drift-corrected calibration data and the specified control voltages. The calibration was tested by comparing demanded and measured signals.

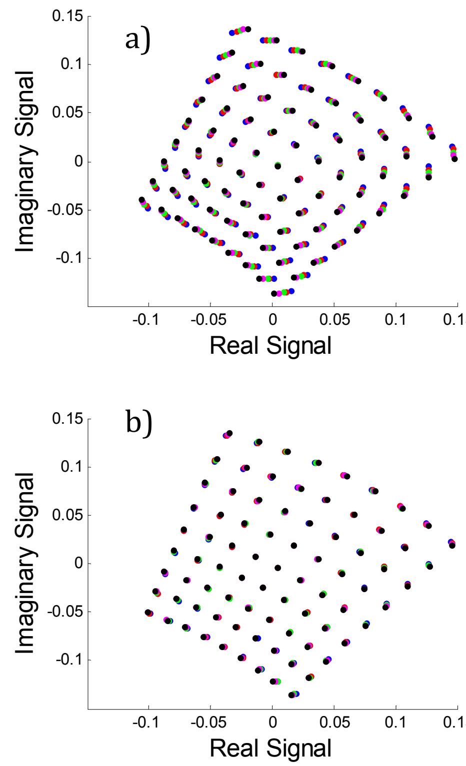

Figure 1 – a) Raw calibration data, and b) data after frequency correction. Different coloured points indicate different signal averages.

Results: For all figures, different colored points indicate sequential averages. Figure 1a shows the raw calibration data for a typical single channel. The response displays substantial non-linearity and there is a progressive phase evolution throughout the duration of the calibration. This is consistent with a frequency drift between repeats of the measurement cycle. Figure 1b shows the result of accounting for the phase drift by using the frequency estimation from each FID. Figure 2 shows the result of repeating the experiment using calibrated drive values determined from the calibration data in figure 1b. The result is a regular grid of received signal values, confirming that the previous calibration step has been effective (average error relative to average demanded signal amplitude = 1.7%).

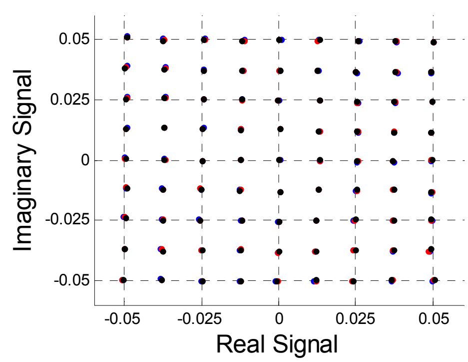

Figure 2 – Results of calibration procedure verification. Different colours indicate different signal averages.

Discussion and Conclusions: A simple system level method has been presented that allows precise calibration of multi-channel RF systems. Use of a small phantom avoids the need for gradient based spatial localization and collection of the time evolving FID allows for system frequency drift to be accommodated without compromising the calibration accuracy.

References: [1] Stang, P. et. al. Proc. ISMRM 07:169, [2] Padormo, F. et. al. ISMRM PPI Workshop 09, [3] Gudino, N. et. al. Proc ISMRM 2009:397, [4] Bookstein, F. L. IEEE Trans. PMAI 1989:11(6) p. 567