Computerised Tuning of an 8-channel Cardiac TEM Array at 7T: an Integrated System Using Piezoelectric Actuators and Power Monitors

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Target Audience: Ultra-high field, Cardiac, Coil designers.

Purpose: Ultra-high field (UHF) MR imaging has been shown to have significant potential for cardiac imaging[1], but uniform RF excitation can be difficult to achieve in the human torso. This problem can be addressed by the use of B_1 shimming and parallel transmit[2] techniques in conjunction with multiple RF transmit coils. However, using such an array at higher values of B_0 requires each of the coils to be tuned separately to the relevant Larmor frequency and matched to the impedance of the system which, for an array with say 8 channels, is somewhat time consuming. This work describes a fully automated tuning solution, which we have developed and evaluated on phantoms and in vivo.

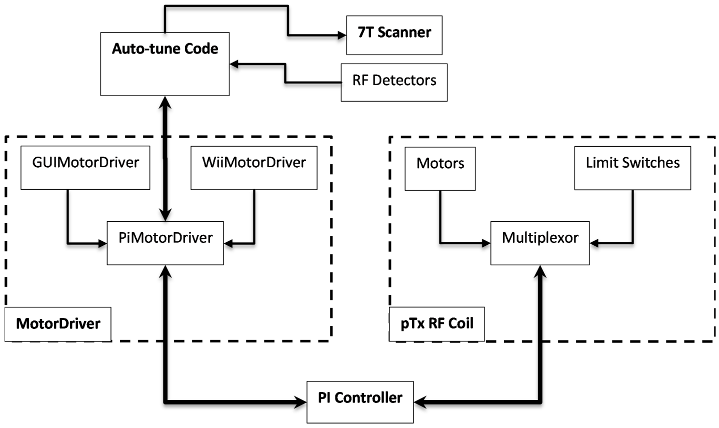

Figure 1: Data flow diagram of the whole auto-tune system, including the classes of the MotorDriver and the additional components of the RF array.

Methods: The auto-tune method was implemented on the posterior part of an 8-channel transmission line (TEM) cardiac array for use on a 7T whole-body scanner (Siemens Healthcare, Erlangen, Germany). Both halves of the array consist of 4 stripline TEM transceivers (Figure 3) each with a dedicated pair of capacitors for tuning and matching. Manual tuning and matching was performed by the manipulation of threaded tuning rods, a lengthy process which, for an 8-channel array, can take around 30-40 minutes for each subject. Eight piezoelectric stepping actuators (PI motors, Physik Instrumente, MA, Figure 3) replaced the tuning rods[3]. These motors were controlled by custom designed MATLAB MotorDriver software interfaced to a controller (E-861 NEXACT, Physik Instrumente, Germany). The performance of the motors was evaluated on the bench and at 7T. Four RF phase and gain detectors (AD8302, Analogue devices) received signals from the RF amplifier DICO ports to measure the ratio between the forward and reflected power (S_{11}). The scanner was then configured to send out RF pulses to each coil element and the auto-tune algorithm synchronised the movement of the motors.

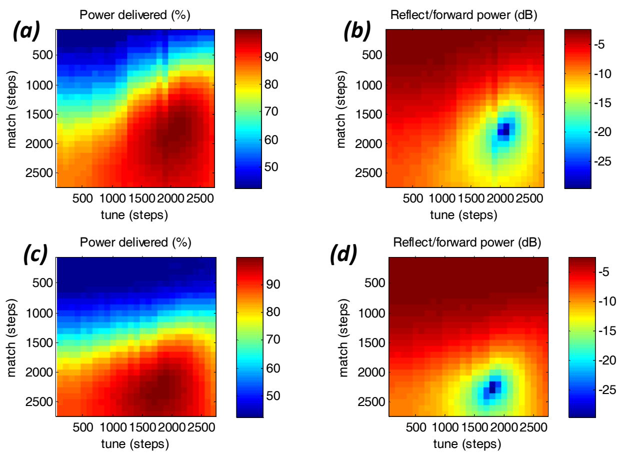

Figure 2: Tune/match profiles for a single element of the coil array showing (a) the percentage of power that reaches the coil which is delivered to the phantom, and (b) the S_{11} profile of the element in dBs. Axes are in units of PI motor steps. (c) and (d) show the same profiles for a volunteer

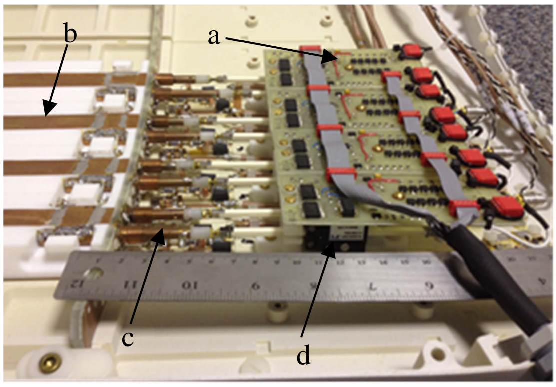

Figure 3: Photograph of the inside of the posterior part of the RF array, showing (a) custom designed multiplexor boards with optical limit detection, (b) the four coil elements, (c) the tune/match capacitor rods, and (d) the piezoelectric actuators.

Results & Discussion: The piezo motors are powerful and robust and were found to operate correctly in the 7T magnet. The only difference at high field was in the limit switch voltage thresholds. Figure 2 shows the tune/match profiles for channel 8 of the coil array for both a large saline phantom and a human volunteer. These were obtained by recording the reflected/forward power ratio across all of 2-D tune/match space. The profiles shown in Figure 2(a) and (b) show clear peaks in the power that is delivered to the phantom. There is a substantial region around the point of maximum S_{11} (2100, 1800, -29.65dB) where the power ratio is less than -15dB ('acceptable tune'). For the volunteer Figure 2(c) and (d) the results were similar, although there is a significant shift in the maximum point of S_{11} (1800, 2300, -29.62dB). Auto-tuning using this approach has proved to be robust on 4 subjects requiring approximately 3 minutes per subject (for details see abstract by CT Rodgers).

Conclusion: Auto-tuning at 7T is practical on clinical MRI systems. The setup presented proved to be more reliable and robust than a previous iteration[3]. This approach can be used to quickly maximise the available B_1^+ and so improves the viability of clinical CMR at 7 Tesla where imaging speed and maximum B_1^+ are priorities.

References

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2. Katscher U, Börnert P, Leussler C, et al. *Magn. Reson. Med.* 2003; 49:144-150.
3. Snyder CJ, Rodgers CT, DelaBarre L, et al. *Proceedings of the 19th Annual meeting of ISMRM.* 2011;7255.