A Fully Integrated Automatic Tune and Match System for an 8-Channel Transmit/Receive Cardiac TEM Array at 7T: Initial Results in a Phantom and Volunteers

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

Purpose: Multiple transmit/receive coil arrays utilising the Transverse Electromagnetic (TEM) design are an attractive approach to body imaging at 7T due to the TEM's good B_1^+ performance at Ultra-High Field strength (UHF)[1]. However, this design must be tuned to the relevant Larmor frequency and matched to the impedance of the system for every subject that is scanned. In a system where the tune/match is manipulated manually the process is time-consuming (an average of 30 mins for 8-channels) and tedious. This work expands on a previously presented system for auto-tuning a cardiac TEM array at 7T[2], extending the system from a proof-of-principle to the full 8-channel array and presents results on a phantom and on a group of human subjects.

Methods: Manual tuning rods were replaced with a novel type of piezoelectric actuator (N310 NEXACT, Physik Instrumente, Germany) controlled from a MATLAB GUI environment (The Mathworks Inc., Natick, USA) via a single dedicated controller unit (E-861 NEXACT, Physik Instrumente, Germany). The actuators directly controlled the position of sixteen variable tune/match rod capacitors. Eight RF phase and gain detectors (AD8302, Analog Devices) were connected to the directional coupler (DICO) ports of the 8 RF amplifiers on the Siemens 7T (parallel transmit) pTx scanner to allow for automated sensing of the tune state by the measurement of forward and reflected power. An optimisation algorithm was employed to allow the system to achieve the optimal tune solution[3]. This is considered to be the minimum achievable value for S_{nn} (the ratio of forward to reflected power on coil *n*) for each channel where, by convention, the maximum acceptable value of S_{nn} was -15dB, corresponding to 3% reflected power[4]. The performance of the system was first evaluated on a 20 litre saline drum phantom. A robust and rigorous algorithm was designed to push the actuators to a variety of starting points from close to the point of tune, to the extremes of the actuator/capacitor range and then call the optimisation algorithm to see how it coped from all positions. A total of eight volunteers were used over 10 sessions to evaluate the performance and viability of the system in vivo. Three iterations were performed on each of the volunteers per session, with the starting point for the first iteration being a known point midway in the range of travel of each tune/match capacitor. The starting point for the second and third iterations was the final position from the preceding run.

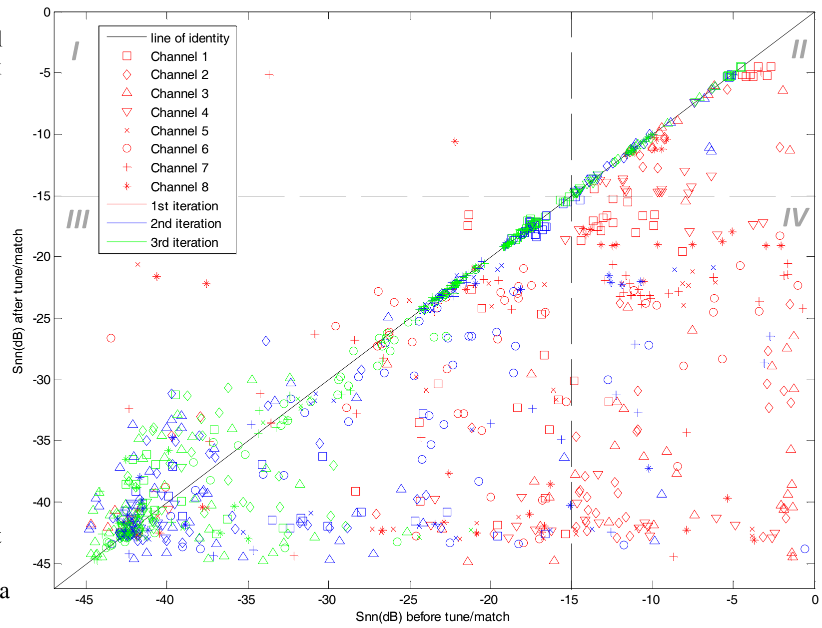

Figure 1: The value of S_{nn} before the algorithm was run is plotted against that recorded after the tuning process. Points shown in red are data for the first iteration of the experiment, while the blue and green points are data for the second and third iterations respectively.

Results & Discussion: Figure 1 shows the results of the evaluation of performance on the phantom. The system was able to meet the -15dB criterion in 85.7% of cases, even in the extreme scenarios provided by the algorithm. The concentration of points on or below the line of identity shows the positive effect of the tuning algorithm on the S-matrix. Figure 2 shows the results of the volunteer tests. Of the eight S_{nn} values gathered in each run (one for each element) only the worst is plotted, against the total time taken to tune/match the whole array. The reduction in time from an average of 310 seconds for the first iteration, to 103 seconds for the third iteration shows that, by choosing a suitable starting point, the duration of the tuning process can be kept to a minimum.

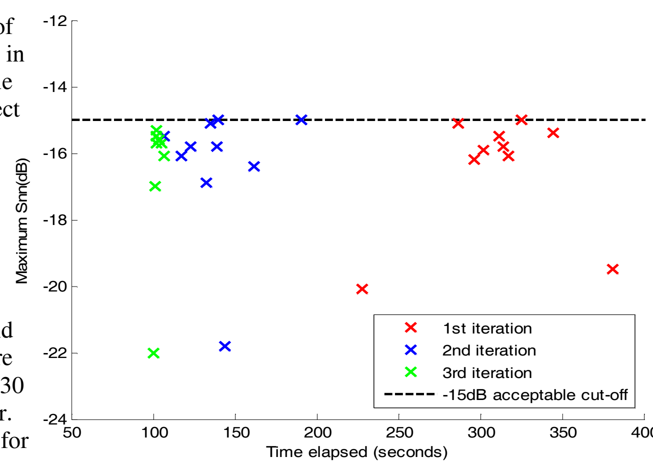

Figure 2: Duration of auto-tune process vs. worst result over eight channels for each run. Iterations are colour-coded as in Figure 1.

Conclusion: The auto-tuning system described has proved to be a robust and reliable approach to the problem of tuning TEM coil elements. Perhaps more importantly it has reduced the time taken for this process from an average of 30 minutes to a maximum of 6 minutes and potentially significantly faster. Furthermore, this system has now entered into routine pre-scan use in our lab for both volunteers and clinical studies.

References

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Acknowledgments

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