An Extensible Transmit Array System using Vector Modulation and Measurement

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INTRODUCTION:

Transmit arrays offer important enhancements to MRI including improved RF fidelity, selectivity, and pulse acceleration. However, significant challenges remain in the hardware implementation of Tx array systems, and their integration with existing scanners. We demonstrate a 4-channel modular expandable vector-modulated transmit array system that can be easily adapted to most scanners. Furthermore, our system incorporates coil current sensors and RF instrumentation to permit automated measurement and feed-forward compensation for coil coupling and other non-ideal RF effects.

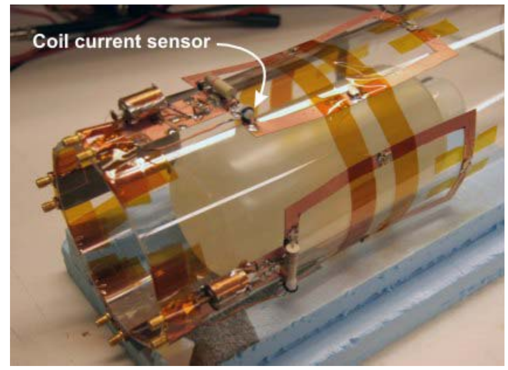

Figure 1: Our 4-channel RF coil array with current sensors.

METHODS:

Our transmit array system is based on vector modulation of the small-signal RF output from a typical scanner [1]. We use one modulator per transmit channel in our array. Each unit produces a unique output signal by applying independent amplitude weights and phase shifts to the common small-signal RF input. The outputs of the modulators are passed to a bank of 300W RF power amplifiers, through PIN-diode switches, and then to the transmit coil array. Control of the modulators, RF amps, and transmit switches is handled by a Medusa Gradient Module and Controller. Medusa synchronizes with a host scanner and can update the amplitude/phase on each transmit channel at rates up to 375 KSPS, allowing for complex RF pulse shaping. To facilitate various system calibrations, we equipped our transmit array with coil-current loop sensors. A Medusa RF Module and a 4:1 multiplexer provide the RF instrumentation to excite and measure coil response. Using this measurement system along with vector modulation, we can characterize and pre-compensate for coil coupling during parallel transmit, as well as examine effects like amplifier non-linearity and uneven coil loading [2]. Both the transmit array and measurement features of our system can be controlled via Matlab, allowing pulse sequences to be designed and loaded from a single working environment.

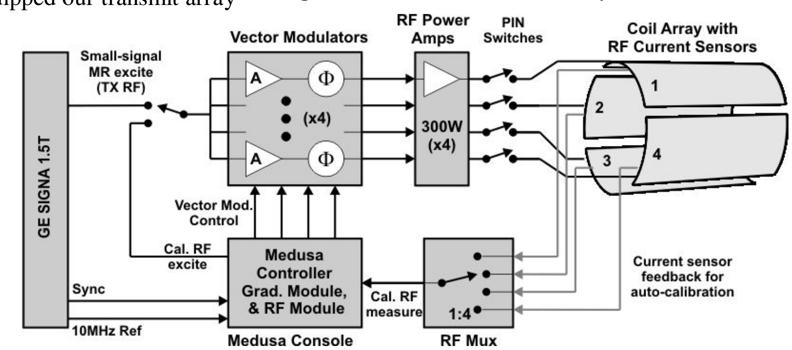

Figure 2: Our 4-channel transmit array system employs vector-modulators for independent coil control. The Medusa Console performs both modulator waveform control as well as RF coil current measurement for calibration.

RESULTS:

We tested our system with both static and dynamically-shimmed RF pulses. In all cases, a hard-pulse is transmitted from the host SIGNA scanner and is then shaped by our vector modulators. Small-tip excitations were used to approximate a B1 field map. Figure 3 shows the pattern from a standard slice-selective pulse before and after coil-decoupling compensation and static B1-shimming. In this case, the same pulse is played on all coils in the array, but with individual amplitude and phase adjustment. We see a successful flat-field excitation. In Figure 4, we employed fully-dynamic shimmed excitation based on a 'spokes' method [3] where each coil was excited with a unique waveform.

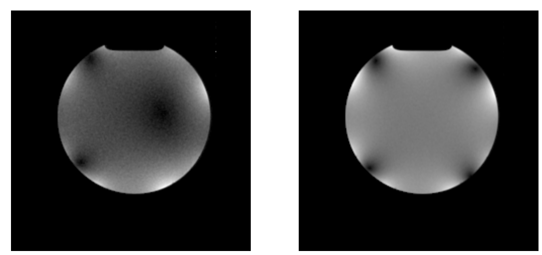

Figure 3: Field pattern showing coil-coupling **(left),** and after decoupling and static-vector B1-shimming **(right)**.

DISCUSSION & CONCLUSIONS:

We have successfully demonstrated our transmit array approach with static and dynamic B1-shimming. Our measurement system together with vector modulation successfully performed coil decoupling. While coil decoupling is not strictly necessary for transmit arrays, it yields more predictable nearly-ideal field patterns easing pulse sequence design. Additional forms of system calibration can performed such as RF amplifier linearity and phase correction. Our transmit array architecture has the benefit of being easily scaled to large numbers of transmit channels since only a single RF output is required from the scanner.

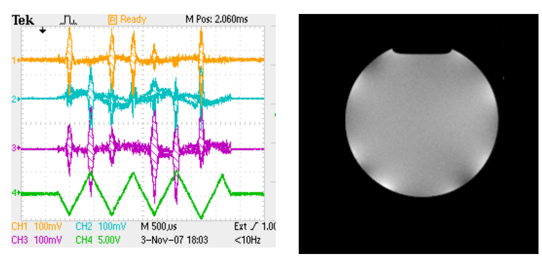

Figure 4: Time-varying 'spokes' B1-shim excite waveforms + gradient **(left)**, Result for 'spokes' excitation **(right)**.

REFERENCES:

[1] P. Stang et al., Proc 15th ISMRM, p169, 2007.
[2] G. Scott et al., Proc 15th ISMRM, p168, 2007.
[3] Setsompop et al., MRM, 56: 1163-71, 2006.
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