B_1 Mapping and Parallel Excitation using Vector Decoupling

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Introduction: Parallel RF excitation is a novel technology that can significantly accelerate multidimensional selective excitation, improve RF homogeneity and reduce SAR. High-fidelity excitation requires accurate knowledge of the transmit array B_1 sensitivity profiles and a linear RF transmit system. We present an approach using vector decoupling [1] to facilitate measurement of the B_1 sensitivity profiles. The vector-decoupling approach also allows for a simple iterative predistortion of RF system input waveforms to achieve the desired RF currents.

Method and Results: Figure 1 shows a schematic of the four-channel parallel transmit system based on an array of vector modulators and the MEDUSA platform [2] connected to a GE Signa 1.5-T Excite scanner. An important feature of this system is the current sensor feedback capability that allows the RF coil currents to be measured during transmit. These measurements permit the derivation of a matrix operator that relates desired RF currents in the decoupled array to the voltages that one must apply to the coupled coils to achieve those currents [1]. The coupling between coils is reduced in our case by a factor of 50 from -4dB to less than -40dB as measured by the current sensors.

Figure 2 illustrates the transmit B_1 maps acquired in a 12-cm disk phantom using the magnetization-preparation based sequence of [3]. The four coils in the array are simple loops arranged azimuthally about a longitudinal cylinder with no attempt made at decoupling. The B_1 maps of the vector-decoupled array show the smooth falloff expected for a simple loop coil. In contrast, the non-decoupled array shows much higher spatial frequencies and nulls within the B_1 maps.

The B_1 mapping sequence of [3] requires an image excitation that provides signal over the entire FOV. This is easily achieved using any single coil transmit from the vector-decoupled system. If vector decoupling is not available, B_1 maps must first be estimated and a composite excitation derived that has no signal voids. This approach can be prone to error in the estimated B_1 maps. The data for Fig. 2 was acquired using a decoupled single channel as the image excitation for both decoupled and non-decoupled modes.

Figure 3 illustrates the response using decoupled and non-decoupled modes in a parallel transmit experiment. A parallel excitation was designed using the methods of [4] to produce a 20°-tip logo excitation. A 3.2-ms spiral-in trajectory was used with a resolution of 0.5 cm and FOV_{ex} of 6 cm, corresponding to a 2X acceleration. RF excitation waveforms were designed using B_1 maps from the non-decoupled and decoupled arrays. The parallel excitation profiles for the two modes are comparable.

Figure 4 illustrates the benefits of vector decoupling combined with vector iterative predistortion (VIP) [2,5]. VIP is an iterative approach for pre-distorting RF input to produce the desired RF currents. Note that the parallel transmit RF pulses will only correspond to RF currents during a parallel excitation for a decoupled array. In the vector-decoupled mode we can thus use VIP to improve RF fidelity, which helps to reduce distortion in the excitation profile as shown in Fig. 4b.

Discussion: RF current-sensor feedback was exploited to enable vector-decoupling of a transmit array. The smooth and non-zero B_1 maps of the vector-decoupled array facilitated B_1 mapping and should reduce resolution requirements. Iterative predistortion of parallel RF waveforms was determined under parallel-excitation conditions for the vector-decoupled array and resulted in improved excitation fidelity. Future work will focus on using absolute current-sensor feedback together with known RF coil geometry to aid in predicting and mapping of the B_1 sensitivity profiles.

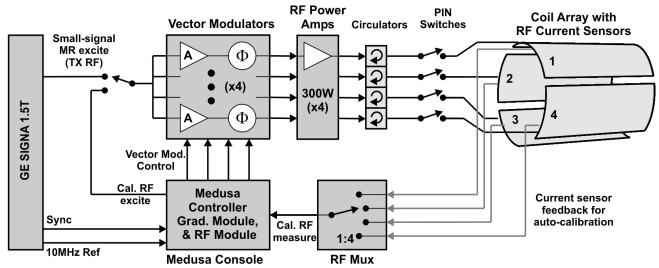

Figure 1: Schematic of 4-channel parallel transmit system showing current sensor feedback from coil array.

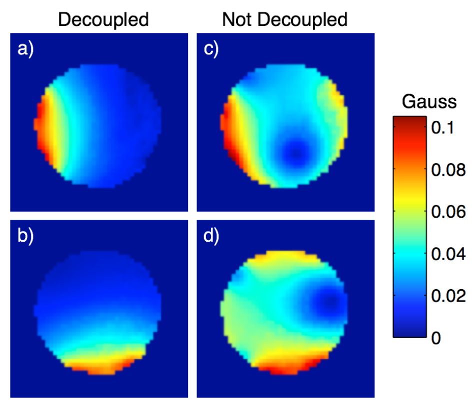

Figure 2: B_1 maps for two coils in the vector-decoupled array (a-b) and non-decoupled array (c-d). Note the higher spatial frequencies and the nulls in the B_1 maps of the non-decoupled array.

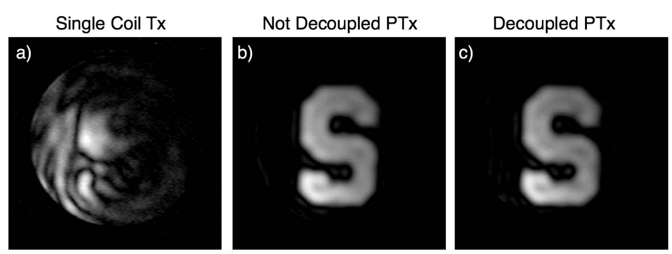

Figure 3: Parallel transmit demonstration with 2X acceleration for a 4-channel array. a) The response to a single-channel transmit of a parallel transmit pulse. b,c) The response of a parallel transmit pulse with and without vector decoupling showing similar performance.

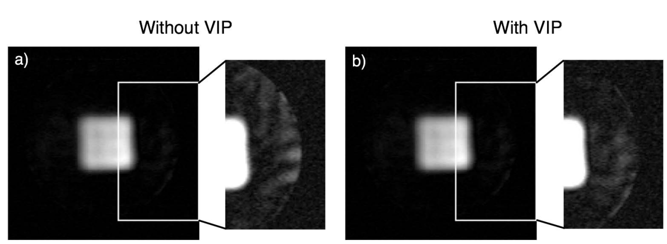

Figure 4: a) Outer volume distortion in the 2X accelerated parallel excitation is b) improved when using VIP to improve RF fidelity.

References: [1] Scott *et al.*, P. ISMRM, p. 146, 2008. [2] Stang *et al.*, P. ISMRM, p. 145, 2008. [3] Kerr *et al.*, P. ISMRM, p. 355, 2008. [4] Grissom *et al.*, MRM, 56(3):620-29, 2006. [5] Stang *et al.*, P. ISMRM, submitted, 2009.
[Acknowledgement: This work partly supported by NIH R01 EB008108, NIH R21 EB007715, NIH R01 EB005307.]