

Improved 2D RF Shimming with a local Detunable 8-Element Transmit/Receive Coil Array using DREAM and SENSE at 3T

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Introduction

To date whole body transmit-receive volume coils are used for MRI imaging. While these coils [1,2] do have an excellent homogeneity in human body applications at 1.5 T, the B_{1+} homogeneity at higher field strengths (3 T and beyond) must be corrected to achieve acceptable image quality. Furthermore, whole body excitation can result in intolerably high local and global SAR or increased scan time. Standalone local transmit coil arrays have been introduced for imaging parts of the human body with reasonable B_{1+} homogeneity and acceptable SAR at 7T [3,4]. Similar arrays have been applied also at 3T and provide a proper means to further reduce SAR, particularly in combination with SAR determination based on exact B_{1+} maps [5]. However, mapping a high number of individual transmit channels comes with the burden of increased total scan time, because separate B_{1+} mapping scan is required for each channel. Modern mapping techniques like DREAM [6] allow for a substantial reduction of scan time during B_{1+} mapping to tolerable level. In this abstract, we demonstrate the combination of DREAM and SENSE [7] for B_{1+} -shimming using an 8-channel local TX/RX array for the human torso at 3T [8,9]. We present a detunable local transmit coil array, which can be operated in two modes. In a first mode, the coil acts as a receive-only coil array in combination with the conventional transmit body coil. In the 2nd mode, the coil is used as local TX/RX array with the mentioned advantages. While the required SENSE reference information is generated in the first mode, this information is used to accelerate the acquisition of the B_{1+} maps based on the DREAM technique in the second mode. Using both modes sequentially, we obtain all information required for exact B_{1+} mapping and fast RF shimming. The significant RF power reduction and reduced SAR compared with large volume body coils render such surface coil array very promising for clinical applications, for instance in cardiac and prostate MRI.

Method

The coil: Anterior and posterior part of the array consist of 4 individual octagonal coil element, with an inner diameter of 130mm. Each element is split four times and is resonating using ATC 100E and Voltronics tuning capacitors (NMAJ20-4). The decoupling of adjacent coil elements is achieved by overlap. Diagonal elements are decoupled using high-Q inductive transformers. Common mode currents are suppressed using cable traps directly downstream from the matching circuit providing stable tuning and decoupling of the individual elements. The coils were matched for an intended distance of 20 mm between phantom and coil. Overlap distance and components such as transformers and capacitors were determined using the EM simulation tool FEKO [10]. Local transmit receive switches with integrated low noise preamplifiers (NF<0.5dB, low insertion loss) are located at a distance of about 1m from the coil. For the 2nd mode of operation, decoupling of the local TX/RX coils from the body coil is achieved using series PIN diodes MA4P7446F (Macom).

The sequence: Experiments were performed on a modified 3 T Philips Achieva MRI scanner with 8 independent TX channels [11]. In the 2nd mode, the 8-channel body coil [12] is driven in quadrature mimicking the operation of a standard birdcage coil. T/R switching and detuning of the local TX/RX coil is provided by the MR system. RF shimming was performed as follows: In a first step, the array is used in RX mode in combination with the body coil, and the required SENSE reference information is generated. In the second step, the B_{1+} maps of the individual array elements are acquired using DREAM, further accelerated by SENSE (transverse orientation, field-of-view (FOV) = 450×270 mm², scan matrix= 128×40, SENSE factor= 2, phase-encoding direction: AP, slices = 10, slice thickness = 10 mm, slice gap = 20 mm, STEAM flip angle $\alpha=60^\circ$, imaging flip angle $\beta=10^\circ$, TR= 3.3 ms, TE = 1.2 / 1.9 ms, total scan duration for 8 Tx channels = 11s). In the last step, the B_{1+} maps are used for B_{1+} shimming using proper phases and magnitudes to achieve a homogeneous excitation in the intended imaging slice.

Results

Decoupling of the unloaded coil elements is -25 dB and -15 dB for the loaded case (torso shaped water phantom (350*350*190mm), filled with 9,6l H₂O, 14,4kg C₆H₁₂O₆, 0,96kg NaCl). Fig. 2 shows shimmed DREAM B_{1+} maps of the water phantom. For each orientation, a different shim set was applied. Fig. 3 shows a coronal 2D B_{1+} shimmed phantom image obtained in the 2nd mode with the local transmit-receive coil array (left) and a system body coil image (right) for comparison.

Discussion

The presented approach using a local detunable 8-element transmit coil array with two selective mode, shows the feasibility of reduced FOV MRI with significantly lower RF power consumption compared with the large system body coil. The improved efficiency of the local transmit coil may help to overcome SAR constraints and shortening of RF pulses, TE and TR. This concept is very flexible, because the local transmit coil array can be used for local transmission, but also in combination with the body coil as a receive only coil array.

References

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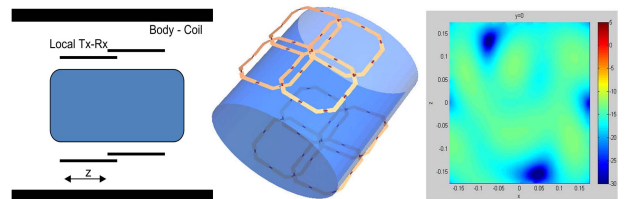


Fig. 1: Eight-element local transmit-receive coil array placed on an elliptical water phantom. Anterior and posterior coil array do have the same layout. The phantom (350×350×190mm³) is filled with 9,6kg H₂O, 14,4kg C₆H₁₂O₆, 0,96kg NaCl). Experimental set up used (left and center). Calculated B_{1+} (shimmed) for local Tx-Rx array (right).

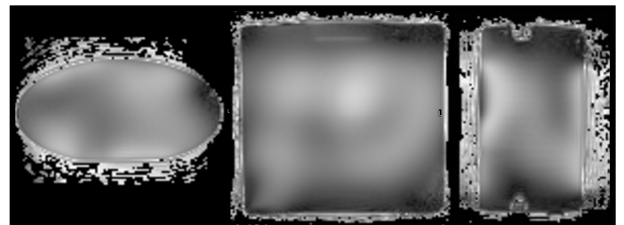


Fig. 2: Shimmed B_1 maps of elliptical water phantom acquired using DREAM. A different shim set was applied for each orientation.

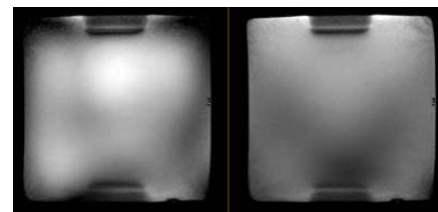


Fig.3: Coronal 2D B_1 shimmed phantom image using local transmit-receive coil array (left) and system body coil (right).