Transmit Coil Array for Accelerating 2D Excitation on an Eight-Channel Parallel Transmit System

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Introduction

The multiple transmit coils at the front end of a parallel transmit architecture (1,2) define the individual B1 profiles that, under the control of the parallel RF pulses, are weighted and superimposed to form the composite RF field. The coils thus play a central role in the induction of appropriate B1 spatiotemporal variations that affect excitation acceleration and the concomitant E field that dictates SAR. In this study some of the important aspects of a transmit array's construction/application were investigated. An effort to develop an improved version of a previously reported array (3) is described as a specific example.

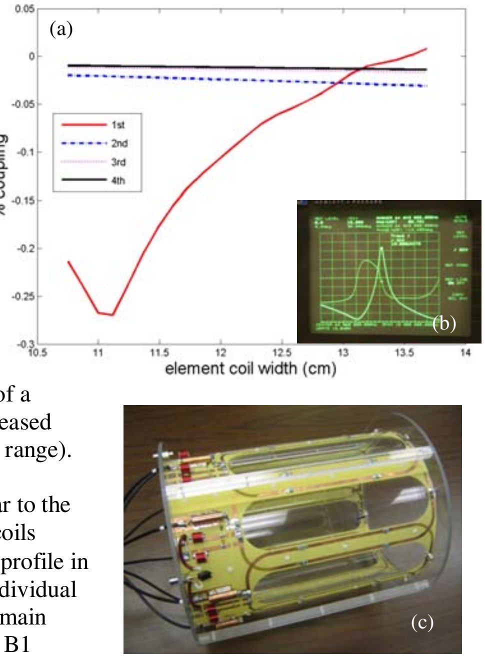

Fig. 1 Predicted coupling as a function of coil width between an element coil and its 1st-4th neighbors (a), tuning of an element in the presence of other elements (width of elements =13.4cm) (b), and the finished array (c).

Methods: A head-size transmit array consisting of eight 28x6cm^2 elements distributed azimuthally on a ∅27cm shell was originally developed to support research on an eight transmit-channel MRI system (3). The experience of constructing and using the array suggested several areas for improvement. First, the array geometry and the absence of effective low impedance-based decoupling (50Ω RF power amplifier impedance seen by the coils as opposed to the few-ohm pre-amplifier impedance seen by typical receive coils) gave rise to severe magnetic coupling that detuned the transmit coils. The coupling was beyond a level that could be handled with an appropriate B1 mapping setup (2), and was eventually managed with a cumbersome transformer-based decoupling measure. The extra components however added loss and perturbed B1 patterns along the longitudinal direction. Second, the narrow coil loops led to large B1 dynamic range over an axial FOV. For practical B1 mapping that does not rely on the use of a uniform transmit or receive sensitivity profile, this tends to prolong calibration scans (due to an increased number of RF power levels a B1 mapping procedure may need to step through for resolving the full range). Third, the T/R switch scheme does not readily support use of the elements for parallel receive.

In the present effort, a new transmit array was designed under the guidance of simulations. Similar to the original array in overall geometry, the new array is composed of eight 31cm-long rectangular loop coils azimuthally distributed on a ∅28cm shell, aiming to accelerate 2D pulses that control the flip angle profile in the x-y dimensions and take advantage of a relatively flat B1 profile longitudinally (at 1.5T). The individual coil width, which considerably impacts both the magnetic coupling and B1 dynamic range, was the main parameter to be determined. The simulation quantified, as a function of the width, vector potentials, B1 fields and E fields for each coil and further calculated an 8-by-8 coupling matrix that estimates the coupling coefficients among the coils. SAR characteristics were also investigated based on simulated parallel excitation operation.

Results and discussions: Coupling between coils and B1 dynamic range were minimized by choosing an array configuration with overlapped coils, each having a width of 13.4cm. The low coupling between coils considerably facilitated the task of constructing and tuning the array as the residual coupling was not significant enough to detune any of the coils (Fig. 1). The B1 dynamic range over the FOV was reduced by roughly a factor of two compared to the original.

The new array was configured to be transmit only, allowing the use of the scanner's body coil (or a separate array of coils) for receive. In one validation experiment, a 5cm diameter cylindrical-excitation transmit-SENSE pulse was designed for a 28cm FOV and a 90° flip angle, using spiral excitation gradients with a 14cm excitation-FOV and 1cm spatial resolution. With gradient constraints of 4 G/cm and 15 G/cm/ms, this pulse had a duration of 3.1ms, only half that of the conventional excitation pulse. A multi-power B1 mapping procedure that operates with or without the assistance of a uniform volume coil worked robustly with the new array. Fig. 3 shows one coil's B1 magnitude (a) and phase (b). Fig. 3 also shows results of the transmit-SENSE 90° excitation (d) and a single-coil excitation with the same spiral gradients (c), indicating quality creation of the main lobe and suppression of aliasing lobes.

A second new array with an identical geometry was also built. Replacing the original transmit-only T/R switch scheme was a dynamic disable PIN diode circuitry, which enables the coils' transmit functions during RF power amplifier unblank while either quickly deactivating the coils if a separate set of coil(s) is selected for receive or allowing the coils to remain activated for parallel receive. Early results suggested substantial SNR benefits derived from the array receive mode, as expected.

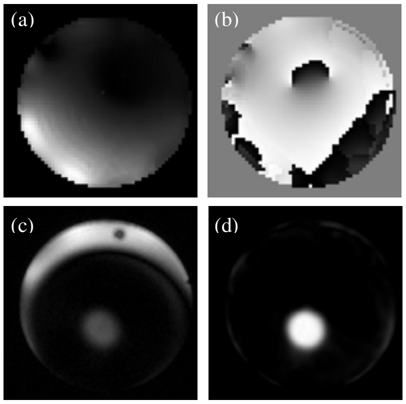

Fig. 2 Example mapped B1 magnitude (a) and phase (b); single-coil transmit result (c) and transmit-SENSE 90° excitation result (d).

In parallel excitation mode the E field in the subject varies both spatially and temporally, posing challenges to SAR investigation. Simulation study of SAR for accelerated 2D excitation of a cylindrical object was performed for both the original and the new arrays. To facilitate a comparison, the overall dimension of the original array design was slightly scaled in the simulation to match that of the new design. As expected, the power dissipated exhibited a strong dependence on transmit-SENSE acceleration factor as well as the target excitation profile, and is certainly related to the transmit array geometry. In an example case of producing a uniform excitation profile with a 6x accelerated EPI-trajectory excitation, the old array design performed better in terms of SAR. A planed further investigation of these and other results in an actual MRI setting with both the original and the new arrays is expected to provide valuable guidance for future development of transmit arrays.

1. U. Katscher, et al., *MRM* 49:144-150, 2003. 2. Y. Zhu, *MRM* 51:775-784, 2004. 3. Y. Zhu, et al., *13th ISMRM*, p 14, 2005.