Current Controlled Transmit/Receive Elements in Parallel Excitation and Parallel Imaging

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Introduction and Motivation

State-of-the-art MRI typically relies on a power driven body coil and a receive-coil array for parallel imaging (PI). However, at 3T and above parallel excitation (PEX) techniques utilizing multi element transmit coil arrays are much better suited to handle B_1-homogeneity issues. In power driven transmit arrays, electromagnetic coupling between the coil elements poses a major challenge. Mutual couplings distort the excitation profiles of the single elements and aggravates SAR control during parallel transmission, since the reflected powers depend on the amplitudes and phases of individual channels. In a recent work [1] we demonstrated that coupling issues may be circumvented by applying simple MOSFET based current sources to drive the transmit array. By controlling the current in each element parasitic currents induced in neighboring elements are suppressed. Furthermore, we introduced a circuit scheme which allows to switch each coil element between transmit and receive mode while avoiding detrimental effects of ferromagnetic parts and DC currents. In this work we demonstrate the feasibility of PEX and PI methods when using a current controlled transmit and receive (^{2}CONTAR) array in vivo.

Materials and Methods

The transmit/receive array used for PI and PEX experiments consists of four ^{2}CONTAR elements based on current sheet antennas (CSA [2]) arranged around a head sized phantom as shown in Fig.1. Decoupling during transmission is achieved by applying current sources based on power MOSFETs. To avoid B_0 distortions arising from ferromagnetic impurities of the MOSFETs and from the DC currents within the circuit the coil elements are driven via λ/2-transmission lines. During reception, decoupling is achieved by switching each coil element to a low input impedance preamplifier via an additional λ/4-transmission line. A pin diode circuit is used to switch between transmit and receive mode [1]. PEX and PI experiments were carried out on a Bruker 3T whole body scanner equipped with four independent transmit and receive RF channels. In receive mode we determined the g-factor using a SENSE type PI technique. The performance of the array in PEX mode was demonstrated by applying accelerated 2D spatially selective excitation pulses [3].

Results

Mutual couplings of ^{2}CONTAR elements are typically below 22 dB during transmission and 25dB during reception. The maximum $B_1^{(+)}$ field of 2µT is limited by the maximum RF current delivered by the MOSFET source (about 5A). The results of an in-vivo PI (SENSE) experiment are shown in Fig. 2 indicating reasonable PI performance. Homogeneous excitation was achieved by driving the 4 elements in circularly polarized mode (driven with mutual phase of 0°,90°,180°,270°). Results of a 2D pattern specific excitation (Transmit SENSE) experiment are shown in Fig.3.

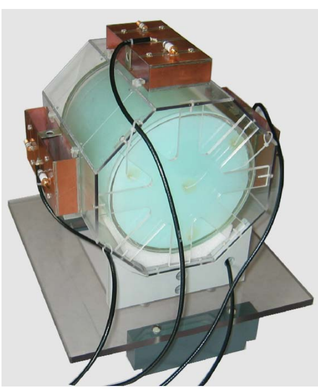

Fig.1: 4-channel ^{2}CONTAR array and gel phantom (i.d. 20 cm)

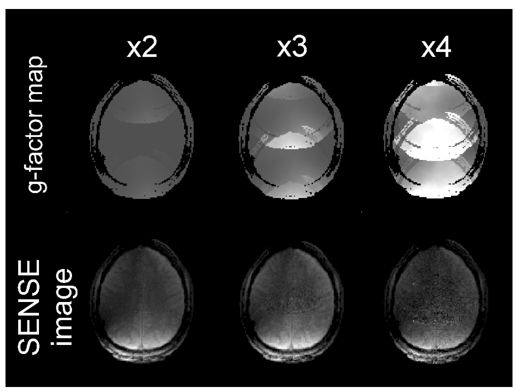

Fig.2: PI with ^{2}CONTAR array in vivo (axial slice in human head) with acceleration factors 2, 3, and 4. Maximum g-factors are 1.3, 3.2, and 8.1, respectively.

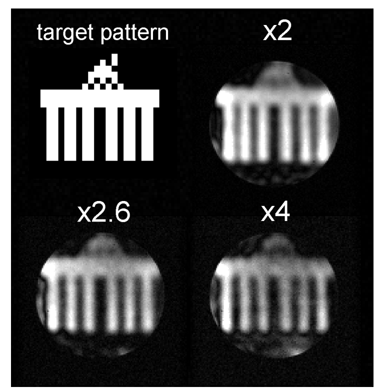

Fig.3: 2D spatially selective PEX experiments in the gel phantom using the ^{2}CONTAR array and varying acceleration factors.

Conclusions

We have shown experimentally that the presented current controlled transmit and receive MR coil array, employing a novel RF circuit, allows to solve the problem of inherently coupled coil elements by combining two different active decoupling strategies: current control during transmission and preamplifier decoupling during reception. This development promises major benefits for the realization and optimization of novel MRI methods. By spatial separation of current source and coil element, using an appropriate RF transmission line, the coil current can be controlled without compromising the B_0 homogeneity, which is of major importance in PEX as well as in EPI experiments. In addition, decoupling of the coil elements allows simpler SAR control since parasitic excitation of neighboring elements is avoided. A further benefit of current controlled transmit arrays as compared to conventional power driven coils is the independence from the loading and hence the spatial arrangement of the elements. This opens the possibility to design flexible arrays which can easily be adopted to different geometries or applications. Finally, current controlled decoupling avoids time consuming iterative decoupling routines thereby drastically facilitating impedance matching in MR, which may be a major point in the clinical applicability of novel PEX methods.

References

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