Intrinsically decoupled Current CONtrolled Transmit And Receive (^{2}CONTAR) coil elements for arbitrarily arranged transceive coil arrays.

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Introduction

Parallel imaging (PI) and Parallel Excitation (PEX) methods in MR require decoupled coil elements as part of the whole coil array for signal reception as well as for spin excitation. Transmit coil arrays are usually driven by voltage sources with fixed source impedance (50 Ω). Due to mutual inductance this inherently leads to a coupling of the individual coil elements within the array resulting in RF field distortions during transmission and inappropriate sensitivity profiles during reception. Furthermore, the need for iterative tuning and matching routines as well as dedicated decoupling networks complicates the use of transmit array systems. While going to higher RF frequencies these problems will worsen and can be avoided by the design of alternative RF coil schemes only [1,2]. In this contribution we present a novel Current CONtrolled Transmit And Receive coil element (^{2}CONTAR-coil) for a parallel driven **transmit/receive** array. It combines the current source decoupling introduced in [1] for transmission with a transmit/receive switch to apply the well established preamplifier decoupling for reception. Avoiding complicated feedback circuits [2] a coil array is implemented which guarantees full control over the RF fields within the object.

Materials and Methods

Decoupling during transmission as well as during reception is achieved by combining two complimentary strategies: during transmission the coil current is controlled by a specially designed current source, while during reception the coil element is switched to a preamplifier with an effective high input impedance (Fig.1). The RF coil (1) consists of a series resonance circuit which is tuned to the MR frequency. To avoid B_0 field distortions caused by magnetic impurities and DC currents within the circuits the RF current source (3) is placed sufficiently far away from RF coil employing a n*λ/2 transmission line (2). The core of the RF current source consists of a (slightly magnetic) MOSFET. The transistor's operating point is controlled by two DC voltages, V_{DD} (drain voltage) und V_{GG} (gate voltage), to achieve a current source like behavior. During operation V_{GG} is overlaid by the input RF signal. Altogether, this leads to an effective decoupling of the individual coil elements by control of the antenna currents. Switching between transmission and reception mode is achieved in the following way. During transmission the RF current source (3) controls the current of the coil, while the preamplifier is disconnected from the network by diode A. Switching off V_{DD} the current source is disconnected from the network by diode B. Hence, during reception the MR signal voltages induced in the RF coil (1) are passed through a series resonance circuit comprising of L and C and a n*λ/2 transmission line to the high impedance preamplifier (4). When using a low impedance preamplifier a n*λ/4 transmission line is to be used.

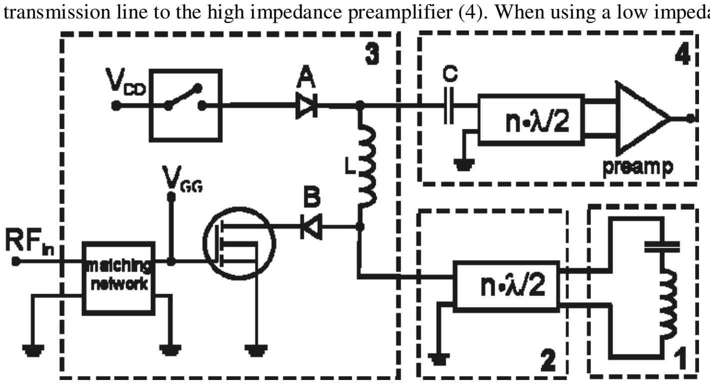

Fig. 1: Scheme of a single ^{2}CONTAR-coil circuit. The subunits of the circuit defined by dashed lines are the MR coil (1), the n*λ/2 transmission line (2), the RF current source (3) and the signal preamplifier with high input impedance (4). A and B indicate diodes for switching between transmit and receive mode.

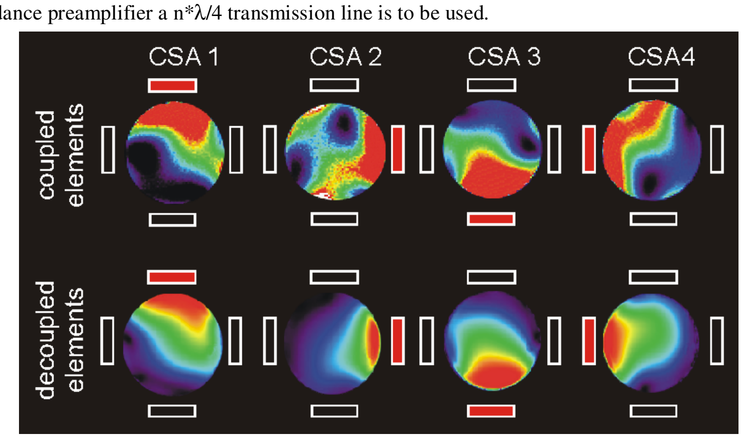

Fig. 2: $B_1^{(+)}$ profiles obtained in a head sized gel phantom by using one of the four CSAs (column 1 to 4) of the 4-channel T/R coil array, using a conventional power amplifier (top), using ^{2}CONTAR circuits (bottom).

Results

Employing the RF scheme described above and a Current Sheet Antenna (CSA) as MR coil element [3] we built a novel MR transmit/receive array, which consists of four CSAs allowing for multi channel measurements of the human head or head sized phantoms. To specify the performance of the array driven by current sources as compared to conventional voltage sources, we performed MR measurements in a head sized gel phantom and determined the decoupling between the coil elements. To this end we mapped $B_1^{(+)}$ in a central axial slice (Fig. 2), carried out on a Bruker Medspec 30/100 System operating at 3T (125MHz). In both cases the CSA elements were tuned to 125 MHz. Matching to 50 Ω was performed for the voltage driven array only. From Fig. 2 it is clearly seen, that conventional feeding results in heavily distorted $B_1^{(+)}$ maps whereas the ^{2}CONTAR coil elements behave like single elements. For the latter we found an improvement in decoupling by 17 dB. From the $B_1^{(+)}$ maps it becomes apparent that improved decoupling results in improved homogeneity and localization of the excitation profiles.

Conclusion

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 switching to preamplifier decoupling during reception. This development will yield in the following major benefits relevant for the realization and optimization of novel MRI methods. By spatial separation of current source and the coil element using an appropriate RF transmission line the coil current may be controlled without distortions of the B0 magnetic field homogeneity, which is a major concern in transmit SENSE experiments as well as in echo planar imaging. In addition, decoupling of the coil elements allows applying higher RF fields in the sample avoiding parasitic excitation of neighboring elements. A further benefit of current controlled MR transmission as compared to voltage controlled techniques is it's independence from spatial coil arrangement. This opens the possibilities to design dedicated coil geometries tailored for special MR 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 parallel excitation methods.

References

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