32 Channel Coil Array for Parallel RF Transmission

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Introduction: As part of a study that investigates a substantially distributed multi-channel parallel transmit approach, head-size 32-element transmit/receive arrays were developed. The specific goal of the coil development is to facilitate reduction of RF power dissipation in the imaged object / the coil structure, and to facilitate B1 shimming / accelerated parallel excitation for an arbitrarily oriented target slice or volume. In the following we describe the coil design and construction process, and present 3T imaging results that were obtained by driving in parallel the elements of one array with current-source RF power amplifiers.

Methods: A multi-port coil array defines individual RF field profiles that, under the control of B1 shimming coefficients or parallel RF pulses, are weighted and superimposed to create the actual RF field. The array thus plays a central role in the induction of a temporally/spatially varying B1 field that effects excitation profile control and a concomitant E field that dictates SAR. Coil geometry, the structural foundation for the current distribution that drives the RF field, has been shown to considerably impact the performance of multi-channel or multi-port operation. Fundamentally, a coil structure that supports flexible current path control is essential for most effective management of both excitation profile and RF power, hence a key factor to parallel Tx performances (1,2). In this work, alongside efforts to develop a cost effective 32-channel parallel transmit system, we designed a 3T coil array that has 32 ports, each associated with its corresponding Tx and Rx chain. Assisted by receive array design experiences as well as some guidance offered by a simulation study comparing SAR (2), we chose a geometry that has 32 properly sized individual coils populated in 8 columns on a ∅27cm cylindrical shell (Fig.1a). This geometry supports comparatively flexible control of current pattern over a surface enclosing the imaging volume. It also facilitates significant contributions from multiple element coils to any region within the volume and is therefore suited for B1 shimming / accelerated parallel excitation for an arbitrarily oriented target slice or volume.

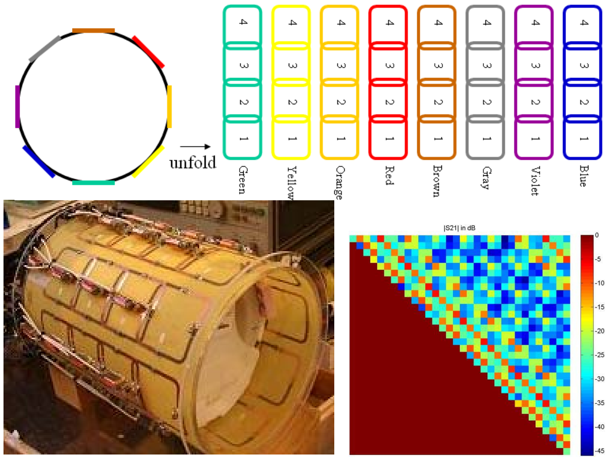

Fig. 1 32-channel parallel Tx/Rx array. The unshielded version (b) and the corresponding S21 measurements (c).

As is common with a coil array that has many elements packed into a compact space, inductive coupling among the element coils of the present array was a concern. In addition to introducing overlaps between neighboring coils in each column, we experimentally tuned the size of the gaps between adjacent columns in order to avoid excessive coupling conditions. This led to an individual coil size of 8.75cm x 8.5cm with 0.5cm trace width. One important component of our exploration of a substantially distributed RF approach is to develop practical current-source RF power amplifiers based on the low output-impedance amplifier concept (3,4), for the purpose of effecting good control of the current distribution. The decoupling effect associated with the low output-impedance RF power amplifiers is leveraged during Tx, and an analogous effect associated with the scanner's low input-impedance preamplifiers is leveraged during Rx. Sixty four shielded baluns were used to suppress effects of common-mode currents on the coaxial cables – on each cable one balun was placed at the element coil, and another, $\lambda/4$ away.

Results and discussions: Two arrays were constructed following the design. The first one is unshielded and has on each element a dynamic disable PIN diode circuitry that opens or closes the loop under a bias voltage control. This facilitates evaluations of coupling effect in imaging tests and/or the use of the scanner's body coil for receive. The 32 ports of the finished array are connected to the rest of the system through 32 T/R switches. A shielded version of the coil was also built, which assumes the same array geometry and supports both parallel Tx and parallel Rx.

Initial 3T phantom MRI experiments were conducted to evaluate the coil arrays and the amplifiers. One experiment tested Tx with eight elements of the unshielded array (eight from one of the two middle rings). A spoiled gradient echo sequence was used (TE=4.8ms, TR=34ms, 256x160 matrix and 24cm FOV). As a reference a first set of images was acquired in a setup where only one of the eight elements transmitted and all others on the array were disabled (Fig.2). A second set of images was acquired in a setup where the eight elements were connected to eight active low output-impedance RF power amplifiers and only one of the eight amplifiers had a non-zero input pulse (Fig.3a). A third set of images was acquired in the same way except that the seven other elements were connected to 50Ω terminators, mimicking a condition presented by conventional RF power amplifiers. The agreement between the first two sets of imaging results is excellent, indicating that effective decoupling and excellent coil current control were achieved. A comparison between the second and the third indicated significant improvements achieved by the use of the low output-impedance RF power amplifiers.

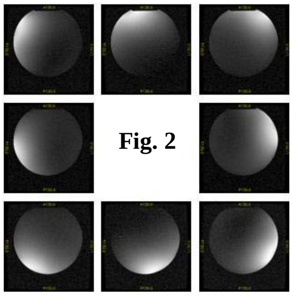

Fig. 2

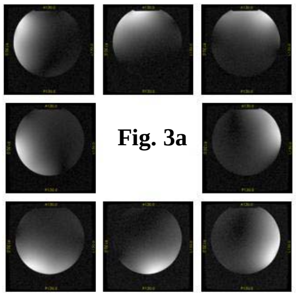

Fig. 3a

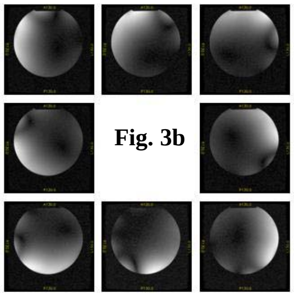

Fig. 3b

1. Y. Zhu, *14th ISMRM*, p 599, 2006. 2. R.Lattanzi, et al., *16th ISMRM*, p 614, 2008. 3. X. Chu, et al., *15th ISMRM*, p 172, 2007. 4. X. Chu, et al., *MRM* (in press).