A Concentrically Shielded Transceive Array Coil Optimized for B1+ Inhomogeneity Correction at 7T

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Introduction: A multiple channel transceive array offers the possibility for flexible mitigation of the transmit inhomogeneity at high fields through either B_1^+ shimming or by the use of spatially tailored RF excitation pulses accelerated to useful durations using parallel transmit (pTx). Accelerating the transmit RF pulses requires a distinct spatial sensitivity profile. One of the major problem in the design of transmit array coil at high fields is the coil coupling and the radiation losses which increases as the square of the coil size and to the fourth power of the frequency. The conventional decoupling either by overlapping or by a shared capacitor requires the array coil to be large. In this sense, the size of the array coil depends on the decoupling method used. By placing an in-plane concentric shield around the coil, as proposed by Lanz et al. (1), the return flux from the loop is concentrated between the coil conductor and the ground loop, thereby reducing the flux threading the adjacent elements in an array. This decoupling method provides extra freedom in Tx array design since it does not impose a restriction on the size of the transmit elements. We utilize this degree of freedom to develop a loop coil array with a loop size intermediate between that needed for an overlapped or capacitively decoupled loop array and a narrow loop array where the loops are far enough apart to have minimal coupling. We validate this principle in an optimized 8 channel concentrically shielded loop array coil at 7T and evaluated its performance for B_1 shimming.

Methods: The coil was tested on a prototype 7T scanner (Siemens Healthcare, Erlangen, Germany) equipped with 8 transmit channels and 32 receive channels. Eight rectangular loop T/R elements were tuned to the Larmor frequency with 16 distributed capacitors and placed on the outer surface of a 280mm dia acrylic tube (Fig 1). The loop coil elements were 14 cm long and 4.5 cm wide. Each coil is surrounded by a thin copper ring shield, in the coil plane, concentric with the outside of the coil. The copper ring was 1mm wide and the distance between the copper ring shield to the center of the 5mm wide coil trace was 6mm. The copper ring shield is connected to the ground of the coil. The coil was matched to 50 ohm with a simple series match circuit followed by a 50 ohm 180º lattice balun to stop the common mode currents. Each transmit channel contained a T/R switch and preamplifier to allow the array to operate as a receive coil as well as a transmit coil. The transmit B_1^+ field was mapped by measuring low flip angle image received through a uniform birdcage mode synthesized from the 8 receive channels and measuring and dividing out this reception profile (B_1^-). Parallel excitation RF pulses were designed based on the image domain approach (2).

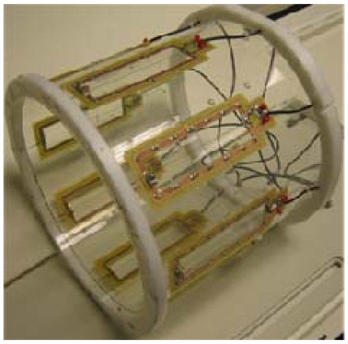

Figure 1: The Constructed 8-channel concentric shielded transceiver coil.

Results: The average S12 coupling between the neighbors was better -15 dB and the S12 between the next nearest neighbors was better than -25 dB. The average S11 was better than -20 dB. Fig 2 shows the magnitude and phase of the excitation profile of the 8 coils. Figure 3 shows the comparison between the RF shimming obtained with the constructed concentric shielded coil and the RF shimming obtained with the 8 alternate elements of a 16 channel capacitively decoupled stripline array coil (3). The normalized standard deviation (NSD = SD/Mean) was used as a metric to measure the B_1^+ homogeneity. The comparison was done on the same spherical saline phantom having inhomogeneity similar to that of a human head at 7T. The RF shimming in the concentric shielded coil has a lower standard deviation (18.3%) compared to the RF shimming obtained with the stripline array coil (23.5%). The concentrically shielded loop coil gives a good compromise between the B1 homogeneity and the usability of the coil. Figure 4 shows a 2D spatially tailored excitation obtained by accelerating the spiral gradient trajectory four times.

Conclusion: The wider circumferential B_1 field coverage of the concentric shielded loop compared to the stripline element and the steeper fall off of the B_1 field compared to the conventional loop has the potential to improve the compensation of the dielectric center brightening effect common in head imaging at high fields. An 8 channel concentrically shielded array coil was built and validated for parallel excitation at 7T. Initial results shows that the geometry of the concentrically shielded array coil could be optimized to improve the B_1^+ homogeneity, providing a good compromise between the conventional loops and the stripline elements.

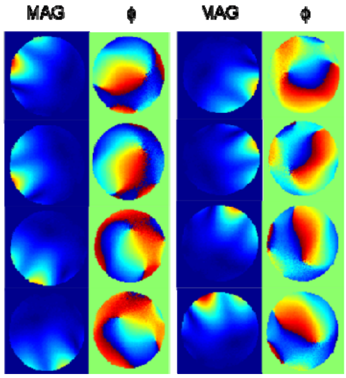

Figure 2 : The magnitude and Phase of the excitation profile.

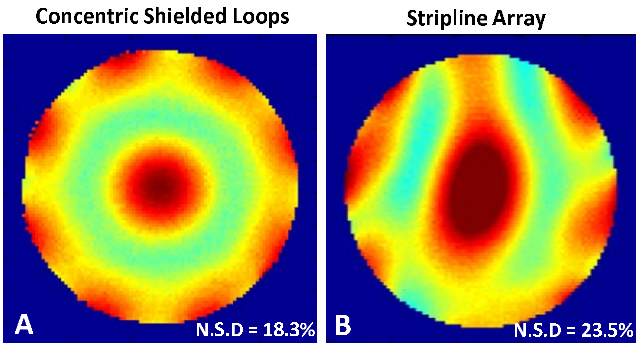

Figure 3 : RF shimming obtained with the A) concentric shielded loop coil (NSD = 18.3%) and the 3) stripline array coil (NSD = 23.5%).

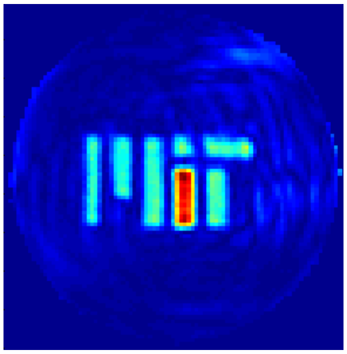

Figure 4: A 4x accelerated 2D excitation pattern

Refrences: 1) Lanz et al. ISMRM 2006, Seattle Pg 217. 2) Setsompop et al. MRM 2006, 56(5), 1163-1171 3) Alagappan et al. ISMRM 2008, Toronto, Pg 144.