Slot-line antenna array for high field parallel transmit MRI

C. Leussler[1], D. Wirtz[1], and P. Vernickel[1]
[1]Philips Research Europe, Hamburg, Germany

Objective

Parallel transmission is receiving more and more attention in MRI, and multi-element transmit MRI systems become commercially available. A number of different Tx/Rx antenna types have been presented for usage in parallel transmit configurations: degenerate birdcage coils, decoupled TEM or stripline coils [1,2,3]. All of these 'traditional' coil-types have their pro's and con's. We propose a fundamentally different type of RF coil for MR applications: the slot-line array (Fig.1). Already known from microwave and radio transmission systems [4], this type of antenna provides new freedom in array design and the possibly of simplified and cheaper construction of multi-element Tx/Rx arrays.

Materials and Methods

We simulated slot antenna arrays with a Method-of-Moments tool (FEKO, EM Software & Systems-SA (Pty) Ltd, Stellenbosch, South Africa).The EM-models of the resonator arrays consist of slots impressed in a conducting cylindrical surface (∅=276 mm) and an coaxially arranged RF screen (∅=355mm) (Fig.1b). The width of each slot is 3mm. The length of each slot was adjusted such that 4 or 8 slots were distributed azimuthally along the circumference midst of the inner cylinder. Tuning and matching was achieved with a parallel capacitor C_1 and a series capacitor C_2 placed at the center of each slot [5]. Field plots were calculated and currents, voltages and capacitor values were checked for their practical feasibility.

4- and an 8-channel head-coil type Tx/Rx slot-line arrays for 3T (Fig.1a) were constructed and operated in a multi-channel transmit system [6]. The slots were tuned to 127.8 MHz using ATC100C capacitors. RF- feeding is applied centrally across each slot. RF currents travelling around the slot perimeter generate the B_1 field (Fig.2a). Matching to 50Ω was obtained using a serial variable capacitor. Resonant cable traps on each feeding line provide stable operation. Decoupling of the individual resonant slots was obtained by an additional, capacitively split decoupling ring. All lumped elements were placed inside the inner cylinder to allow access. Images using single channels in Tx/Rx-mode were acquired with a water bottle (5l, ∅=16cm, (2g NaCl, 0.8g $CuSO_4$)/l) serving as a load. When imaged at 3T with a quadrature coil setup, such a bottle already exhibits central brightening. The field pattern of the individual channels were acquired using a B_1-mapping algorithm [7]. RF shimming was applied to achieve a substantially homogeneous excitation inside the water bottle using the four or eight elements in simultaneous parallel transmission.

Results and Discussion

Simulations showed that the required B_1-magnitude can be achieved with practical components. For the model shown in Fig.1b, capacitor-values of C_1=82pF resulted for tuning each slot and C_2=8pF for matching to 50Ω. Fig.2b shows a magnitude plot of the magnetic field in the z=0 plane created by one element of the 8-channel array. Note that the plot is generated assuming ideal decoupling (all other elements off).

Fig.1a shows the corresponding coil model as realized in practice. For the 8-channel version, next neighbor decoupling was realized using a capacitively split decoupling ring while second-to-next neighbors were geometrically decoupled. Decoupling was better than -15dB in all cases, matching was better than -25dB when adjusted for the 5l phantom bottle. Tuning and decoupling could be realized in a straight forward manner. MR images were generated with a number of different slot-line arrays, 4- and 8-channel versions.

The outer images in Fig.3 show the results of imaging experiments with single channels of the 8-channel array in Tx/Rx mode. Since cable lengths in the system were not adjusted for this array, no quadrature excitation was possible. Instead, an RF-shimming tool was used for the generation of a homogeneous excitation of the phantom bottle using parallel transmission and reception (Fig.3, center).

Conclusion

We demonstrated a new type of Tx/Rx MRI-antenna based on a slot-line array. Setup, tuning and decoupling of such an array is straight forward and of significantly reduced complexity compared with conventional array designs. Parallel transmission and RF-shimming was demonstrated for an 8-channel coil. Further optimization of such an array may lead to tuning and decoupling by array design (slot width, -shape and -distribution) or mechanical tuning totally omitting lumped capacitors, and thus, significantly reducing cost. For improved homogeneity, a z-segmented array is currently under investigation. Moreover a comparison of slot-line, loop- and TEM-antennas is underway.

The authors would like to thank Dr. Kay Nehrke for support with the RF-shimming software.

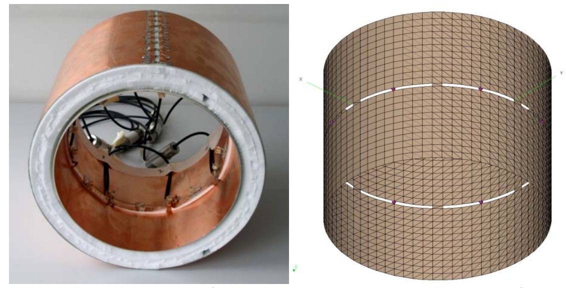

Fig.1: a) lab-model of an 8-channel slot-line array (left) and b) parametric FEKO-model with RF-screen removed (right)

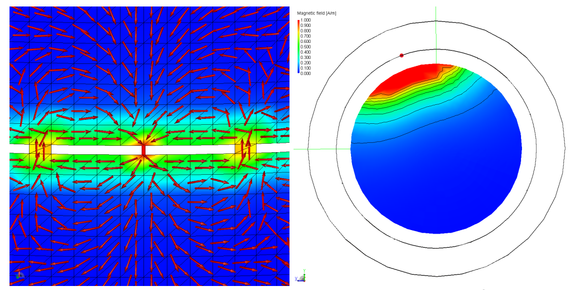

Fig.2: a) current distribution around a slot (left) and b) transversal magnetic field-distribution in the z=0 plane for single element excitation (right).

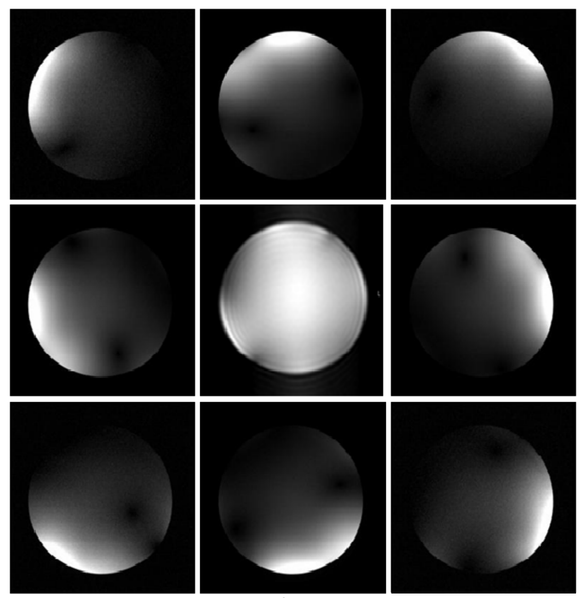

Fig.3: Transversal images of a water bottle measured with each of the 8 slots (outer pictures). For the center image an RF-shimming tool was used to generate homogeneous excitation [7].

[1] Leussler, C. et al., Proc. ISMRM 5, p.176, 1997
[2] Vernickel, P. et al., MRM, 58, p.381, 2007
[3] Adriany, G. et al., MRM, 53, p.434, 2005
[4] Booker, H. G., J. Inst. Elec. Engrs., pt 3 A, p. 620, 1946
[5] Balanis, Antenna theorie analysis and design, 3rd ed., Wiley, 2005
[6] Graesslin, I. et al., Proc. ISMRM 15, p. 1007, 2007
[7] Setsompop, K. et al., MRM, 59, p.908, 2008