A modular approach to large arrays using stacked segments

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Phased-array radiofrequency (RF) coils are often utilized for improving the signal-to-noise ratio (SNR) and are indispensable for parallel imaging. For achieving high acceleration factors, there is currently substantial interest in novel array designs with as many segments as possible. However, coupling between coil elements may lead to undesired effects, such as peak splitting and suboptimal SNR. A strategy for maximizing the number of segments and reducing coupling problems is to use pairs of orthogonal coils in combination with proper consideration of both magnitude and phase of the complex coil sensitivity (1). In this study, we propose a stacked combination of loop coils and microstrip transmission-line elements (MTL), which are intrinsically orthogonal, to obtain a large number of coil segments.

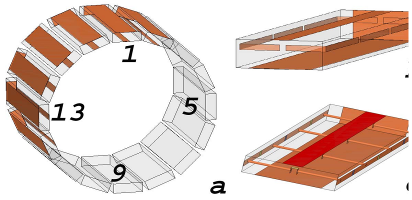

Fig. 1. Array coil design.

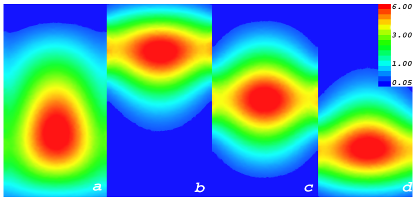

Fig. 2. B_1 field computed for MTLs (a), loops on top (b), middle loops (c), bottom loops (d)

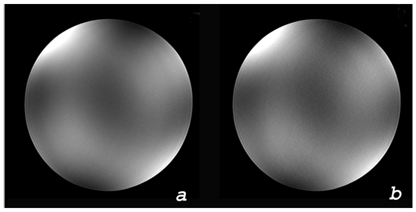

Fig. 3. Spin-echo (SE) images without (a) and with GRAPPA (b, R=2).

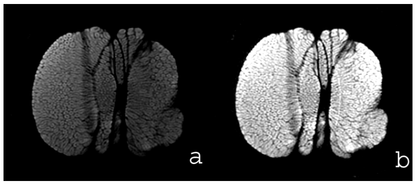

Fig. 4. SE images of a pomelo with 4 MTLs (a), with all 8 segements (b).

Methods. The general coil design (Fig.1) is based on up to 16 stacks arranged on the extent of a cylinder (25-cm diameter). Each stack contains one MTL and at least one loop coil. Each MTL element consists of a 12µm-thick Cu strip (length 30 cm; width 2 cm) on a polypropylene plate (30cm × 5cm × 2cm; $\varepsilon_r \approx 2.2$) and is terminated with capacitors. In a first prototype, each MTL element is supplemented by one loop (5cm × 20cm; Fig. 1b) made of 12-µm thick, 5-mm wide Cu foil and arranged perpendicularly to the MTL. Fig. 1c shows an alternative stack design (used in numerical simulations) consisting of one MTL element and three capacitively decoupled loops. This 3-loop structure is formed by adding 1-mm wide Cu wires leading through the polypropylene plate. Each array segment (i.e., MTLs and loops) is separately tuned by a shunt capacitor and matched by two series capacitors to 50 Ω. To suppress common-mode currents on the semi-rigid cable between coil and preamplifier, the cable was bent to a 7-mm diameter, six-turn helix. The outer shield of the semi-rigid cable was tuned to 123.2 MHz by a shunt capacitor. Preamplifier decoupling was employed for all channels. During transmission (performed using the body coil), all segments are actively decoupled by PIN diodes. For reception, it is possible to select a subset of segments controlled by the scanner software. In this case, segments which are not selected for reception are actively detuned by PIN diodes.

Results. Numerical calculations of the RF field distribution as well as investigations of tuning and matching and decoupling of the coil segments were performed using HFSS 11 and Designer V3.5 (Ansoft, Pittsburgh, PA), assuming a cylindrical phantom (diameter 16 cm; length 36 cm; permittivity 63.4; conductivity 0.46 S/m) that was also used in imaging experiments as a load. Fig. 2 shows numerical results for a set of 16 stacks, each consisting of one MTL element and one 3-loop structure. A quadrature transmission field was assumed in these calculations by proper assignment of the phases of the driving sources for MTLs / loops (φ_1=0°/–90°, φ_2=–22.5°/–112.5°,…). Results indicate a potential of achieving sensitivity variation in direction of B_0. Measurements with a network analyzer yielded decoupling between different segments of > 20dB for both stack types (MTL / single-loop, MTL / 3-loop), consistent with the scattering parameters obtained from the simulations. Imaging experiments with a prototype receive-only array consisting of four stacks (MTL / single-loop coil, i.e., a total of 8 segments) in positions 3, 7, 11, and 15 as indicated in Fig. 1 were performed on a 3T-Magnetom Trio (Siemens, Erlangen, Germany). Fig. 3 compares scans without and with parallel imaging demonstrating artifact-free images and excellent SNR with an acceleration factor, R=2. Residual aliasing artifacts were visible for $R \geq 3$. Fig. Comparison of images obtained with all segments (4 MTLs + 4 single-loops) to those recorded with detuned loop coils (4 MTL segements only) showed an SNR gain by a factor of 1.4 (Fig. 4) indicating similar effectiveness of all segments.

Conclusion. Array coils with a large number of segments and excellent decoupling between segements can be designed from stacks of MTLs plus one or more loop-structures consisting of one or more loops. Simulations indicate a potential for parallel imaging with acceleration in z-direction.

Reference. 1. JV Hajnal, Proc. Intl. Soc. Magn. Reson. Med. 2000; 8: 1719.