U-shaped Ladder TEM-Coil Structure with Truncated Sensitivity Profile in z-Direction for High Field MRI

Christoph Leussler[1], Daniel Wirtz[1], Jan Hendrik Wuelbern[1], Peter Vernickel[1], and Peter Forthmann[1]
[1] *Philips Research Europe, Hamburg, 22457, Germany*

Introduction

Conventional TEM-coils [1] come with a sensitivity profile and field-of view (FOV) that is largely extended in the *z*-direction compared with bird-cage coils (BC) [2]. There is an analog situation when comparing TEM coil arrays [3] and degenerate birdcages (DBC) [4]. The excess *z*-FOV leads to safety issues with respect to the specific absorption rate (SAR). Moreover, it reduces image quality due to additional sensitivity to noise pickup [5, 6] and back-folding. We present a novel TEM coil with modified geometry, which has the strip section of each TEM coil element extended laterally at both ends before connecting to the RF screen. We call this coil type UTEM, due to the U-shape of the individual elements. Each of these lateral extensions has been found to produce transversal B_1 field at the isocenter resulting in a steeper sensitivity profile along the *z*-axis and thus partially compensating the drawback of a traditional TEM element. Compared with a birdcage resonator, which is a floating RF structure resulting in e.g. the requirement of baluns for feeding, the defined RF ground of the TEM provides a solid reference for detuning circuits, feeding cables and pick-up coils used for RF-safety purposes.

Methods

To study the behavior of the proposed coil structure, we compare 3 different head coils, namely a DBC, a TEM-, and a UTEM-coil design. The resonators had a length of 280mm in z-direction, and eight 20mm wide strip conductor elements were mounted 20mm above the RF screen with a diameter of 350mm and a length of 375mm. Loaded to unloaded ratio of the individual elements was measured to be 3 - 5. For the UTEM, the lateral extensions form ring sections extending approximately 40° along the circumference. The individual elements were fed using serial capacitive matching. Decoupling of the experimental coil structure was realized using variable capacitors (Voltronics NMAJ15HV), which were connected between the individual elements. Each strip section was split by 4 ceramic ATC 100C capacitors. Decoupling, tuning and matching of the structure were realized using an 8 channel network analyzer (Rohde&Schwarz ZVT 8). Experiments were performed on a modified 3 T Philips Achieva MRI scanner with 8 independent Tx channels [7]. Images using single channels in Tx/Rx mode with the UTEM were acquired with a water bottle (5l, ϕ=16cm, (2g NaCl, 0.8g CuSO4)/l) serving as a load. The field pattern of the individual channels was acquired using a B_1-mapping algorithm [8]. RF shimming was applied to achieve a substantially homogeneous excitation inside the water bottle using eight elements in simultaneous parallel transmission. Finally, the same experiment was repeated with a volunteer at very low power levels.

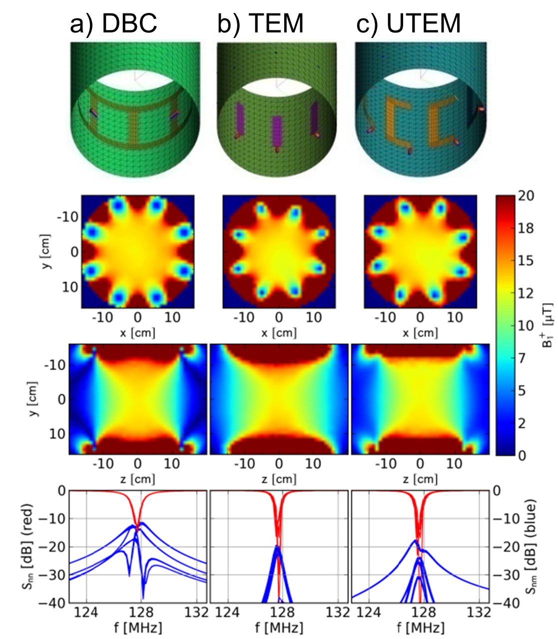

Fig. 1 Simulations: EM simulation results for head loaded coils. **a)** Degenerate birdcage (DBC) **b)** TEM array **c)** UTEM array**.** Reduced FOV coverage for the UTEM coil array is achieved compared to the conventional TEM coil array. Mutual coupling of next and non next neighbor channels is lower for UTEM compared to the degenerate birdcage DBC (S_{nn} red, S_{nm} blue).

Results

Fig. 1 shows the B_1-field simulations of a DBC, a TEM coil and the truncated UTEM structure [9]. For calculations, the models were loaded with a human head phantom (not shown). The s-matrix of the coil structures was calculated and corresponding capacitors obtained for the degenerate and matched structure. The B_1 profile of the UTEM coil shows a shorter FOV in *z*-direction compared with the TEM coil and a more homogeneous field pattern compared to the DBC and the TEM. Decoupling efficiency of the UTEM design is superior to the birdcage (-20 vs. -13dB) for next neighbour and (-23 vs. -15dB) for non-next neighbour elements. Required input RF power to achieve 13.5µT for the head loaded situation is 600 Watt for the TEM coil and 490W for the UTEM and the DBC birdcage respectively. Phantom and invivo experiments were obtained using the 8 channel UTEM coil array (Fig. 2).

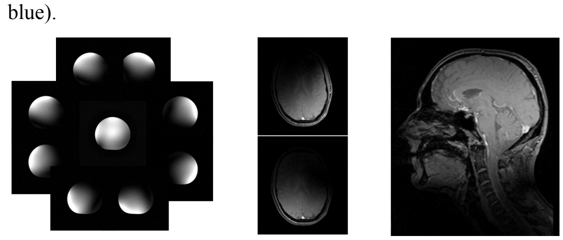

Fig. 2 Experiments: Phantom and in-vivo experiments (FFE, 4mm, TR/TE150/4,4ms) using UTEM 8 channel coil array.

Discussion

The presented approach using a TEM coil with truncated coil elements shows a reduced FOV in *z*-direction and a significantly lower RF power consumption compared with the conventional TEM coil array. The UTEM coil not only reduces noise reception from regions outside the FOV, but also reduces SAR generated in those regions during transmission while providing a more homogeneous excitation pattern. The defined RF ground provides a solid reference for detuning circuits, feeding cables and pick-up coils used for RF-safety purposes. Common mode cable currents are prevented, and mutual coupling is totally defined. This also gives a reliable reference for RF safety simulations of the subject in a loaded MR antenna system, which is especially critical for SAR estimations. The UTEM structure can be a candidate for head UHF MRI and 3T body coil applications.

References

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