Towards Ultimate SNR: Combination of a Multi-Element TX/RX Dipole Antenna Array with Nested and Meander Shaped RX Dipole Antenna at 7.0 Tesla

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Target audience: Basic researchers and clinical scientists interested in novel MR technology applications at ultrahigh fields (UHF) including 7.0 T.

Purpose: Dipole antenna TX/RX configurations offer improvements in signal-to-noise-ratio (SNR) and B_1^+ efficiency versus loop element or strip element configurations at ultrahigh fields [1, 2]. A TX/RX bow tie dipole antenna building block customized for 7.0 T has been introduced recently [3, 4]. To close the performance gap between coil arrays carefully examined in simulations and phantom studies and the ultimate SNR a combination of dipole antenna TX/RX arrays with common RX loop elements has been proposed [5]. To this end this work proposes the use of meander formed RX dipoles to improve the receive capability of an array consisting of TX/RX bow tie dipole antennas. For this purpose numerical field simulations are performed to characterize the transmit behavior of the array and to ensure that the array is in full compliance with RF power deposition safety guidelines. Phantom experiments were performed to measure the SNR of the proposed array.

Methods: For an easier validation of the results and to shorten the simulation time two rings of a sixteen channel dipole array were reduced to a building block consisting of 4 bow tie dipole antenna blocks in a 2x2 configuration (Figure 1a). Two experimental setups were applied. First two extra RX meander dipoles were placed between bow tie elements of the building block resulting in 4TX and 6RX channels (4RX/6RX) per building block (Figure 1b). For comparison a 4 channel TX/RX bow tie antenna building block (4TX/4RX) was used.

Numerical E- and H-field simulations were performed with CST Microwave Studio (CST GmbH, Darmstadt, Germany). The simulated E-and H-fields were evaluated in terms of B_1^+ and specific absorption rate (SAR) averaged over 10 g. For MRI measurements the receive elements consisting of a λ/2 dipole antenna and a match-tune circuit were built using copper wires and nonmagnetic trimmers (NMAF25HV1205, Voltronics, Salisbury, U.S.A). To fit the dipole antenna into the gap between bow tie elements the dipole antenna was formed into a meander shape (Figure 1c). SNR measurements were conducted with both experimental setups using a 7T whole body MR system (Magnetom, Erlangen, Germany) and a rectangular phantom (ε=75, σ=0.7 S/m). Prior to the measurements a matching of the elements better than -25 dB and a decoupling between the elements better than -10 dB were ensured. For SNR measurements a gradient echo sequence was applied (voxel size=(1.1x1.1x6) mm^3, TR= 1568 ms, TE= 1.54 ms, FA=25°) according to [6].

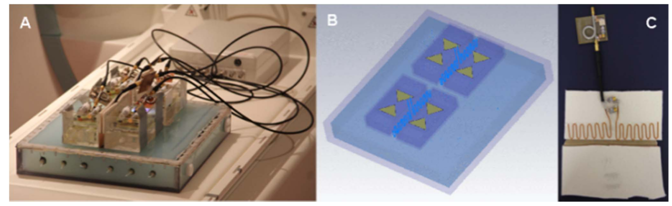

Figure 1: A) Experiment setup consisting of 4 bow tie TX/RX dipole elements, 2 extra meander RX elements and the rectangular phantom. **B)** Simulation model of the experiment setup. **C)** Receive element consisting of meander formed dipole, match-tune circuit and cable trap.

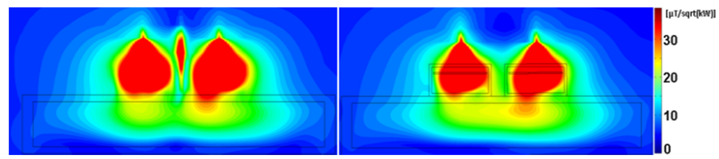

Figure 2: Simulated B_1^+-maps of 4Tx/6Rx (left) and 4Tx/4Rx configuration (right).

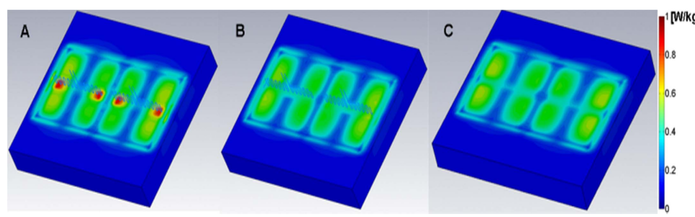

Figure 3: SAR_{10g}-simulations on the surface of the phantom. Tuned 4Tx/6Rx setup **(A)**, detuned 4Tx/6Rx setup **(B)** and 4Tx/4Rx setup **(C)**. Please note the SAR equivalence between B and C.

Results: The B_1^+ simulations showed a slight decrease in the transmit performance of the 2x2 array retrofitted with extra two meander RX elements as illustrated in Figure 2. SAR simulations demonstrated that the 4Tx/6Rx setup generated up to twice more maximum SAR on the surface of the phantom with all the receive elements being tuned. Detuning of the receive elements resulted in a SAR distribution which matched that of the 4TX/4RX configuration (Figure 3). A closer SNR examination using a ROI approach and a SNR profile across the elements demonstrated that the 4TX/6RX configuration provides larger SNR and more uniform SNR versus the 4TX/RX setup. This improvement is driven by the SNR contributions of the two extra meander RX elements (Figure 4). Averaged SNR obtained for ROI placed in the phantom revealed $SNR_{4TX/6RX}$=591±11 and $SNR_{4TX/4RX}$=535±8.

Discussion: The proposed combination of TX/RX bow tie elements and meander RX dipoles demonstrates the feasibility of using extra dipoles as receive elements for multi-channel TX/RX arrays tailored for ultrahigh field MR applications. The results indicate that despite the minor decrease in the transmit performance of the TX array the extra use of nested dipole RX elements affords an SNR increase of a TX/RX array, in particular if a cylindrical coil configuration is used . Increased SAR caused by the presence of the receive elements can be eliminated by detuning the receive elements during transmission via a detuning circuit to conform to the safety regulations. It is a recognized limitation of this work that extra meander RX elements were only placed in alignment with bow tie elements. Obviously, the receive performance of the TX/RX array can be further improved by introducing receive elements that cover the gaps in two-dimensional configurations of bow tie TX/RX configurations. Of course the combined mode proposed here can be extended to any radiative element design.

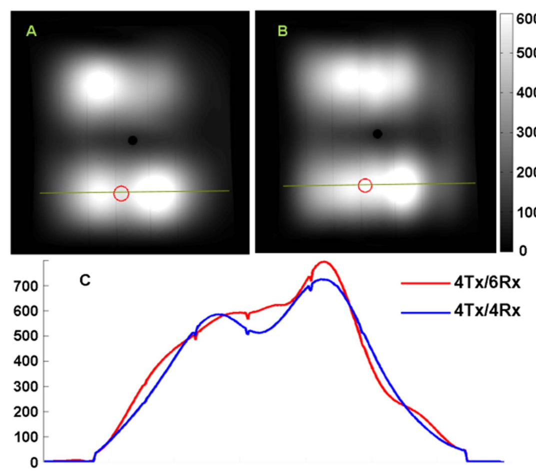

Figure 4: Measured SNR maps of the 4Tx/4Rx **(A)** and 4Tx/6Rx **(B)** setups showing the ROI´s together with the reference line used for SNR comparison. SNR derived from both setups along the reference line **(C)**.

Conclusion: The SNR performance of multi-channel TX/RX dipole arrays can be increased by incorporating the presented dipole receive elements in a TX/RX array without the need for major changes in the basic TX/RX array setup.

References: [1] Raaijmaker,A. J., MRM 2011 [2] Ipek, Ö , Phys. Med. Biol. 2012 [3] Winter, L., Proc. ISMRM 2012 [4] Özerdem, C., Proc. ISMRM 2012 [5] Wiggins, G. C., Proc. ISMRM 2012 [6] Kellman, P. MRM 2005