NUMERICAL ANALYSIS OF A FOUR CHANNEL ARRAY WITH INTRINSICALLY DUAL TUNED SINGLE ELEMENT ANTENNAS PROVIDING A CONGENER RESONANT BEHAVIOR FOR COMBINED ^{23}NA/^{1}H MRI AT 7T

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Introduction: The imaging as well as the spectroscopy of X-nuclei becomes more applicable due to the higher field strength of MRI systems. For a combined imaging of the proton and the X-nuclei it is necessary to have a dual-tuned antenna or coil as presented in [1,2]. A novel single element antenna for combined ^{23}Na and ^{1}H MRI at 7T was proposed in [3] and is now taken into a four channel simulation setting which shows a congener and homogeneous field distribution at both resonance frequencies in the transversal and longitudinal cut. According to its resonance behavior the elements are named congener dual resonant antennas (CDRAs). Composite right-/left-handed (CRLH) transmission lines are forming the CDRAs and they can be terminated with an open circuit or short circuit. A comparison was done in [3] where the short circuited case provide a more homogeneous field distribution than the in the open circuited case.

Material and Methods: The simulation setting is shown in Fig. 1 where the four CDRA elements are arranged around an octagonal shaped body-emulating phantom. The antennas consist of six CRLH unit cells where each provides a 30° phase shift over its lengths. Basically the capacitances in the series path are realized by metal-insulator-metal (MIM) structures as well as the shunt capacitance. The series inductance is obtained parasitically by the line itself. A short terminated coaxial stub line is forming the shunt inductance. This type of unit cell is described in more detail for the dual-tuned case in [3] and in [4] where it was applied in a zeroth order resonant antenna (ZORA) for 7T MRI. For the numerical analysis we used the simulation platform EMPIRE XCcel that is based on the EC-FDTD method [5]. For the circular polarization the CDRAs are exited with the phase delays given in the inset of Fig. 1. The distance between each CDRA and the corresponding parallel face of the phantom is 5cm. The phantom itself have a face-to-face diameter of 22.5cm and a height of 60cm. Each CDRA is 43cm long and 9cm wide. The coaxial stub lines can be furled on the backside of the CDRAs and a thin antenna structure with a thickness of about 1cm can be realized.

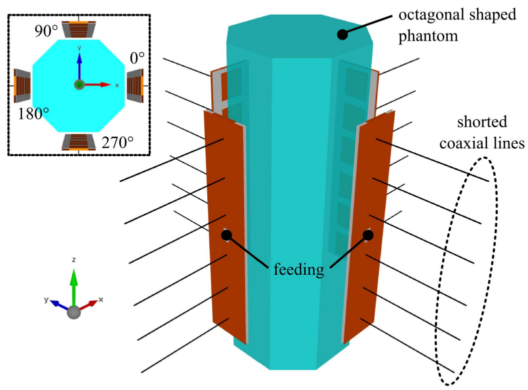

Fig. 1: Setting for the four channel simulation consisting of an octagonal shaped body-emulating phantom surrounded by four CDRA elements which are short circuited at the ends of the CRLH transmission lines. The phantom is 60cm in height and the face-to-face diameter is 22.5cm. The CDRAs are 5cm apart from the faces and fed in the center of each element at z = 0. The short circuited coaxial stub lines (in black) are forming the shunt inductances of the CRLH unit cells. The inset displays the phase delay of the excitations to create a circular polarized B_1^+-field.

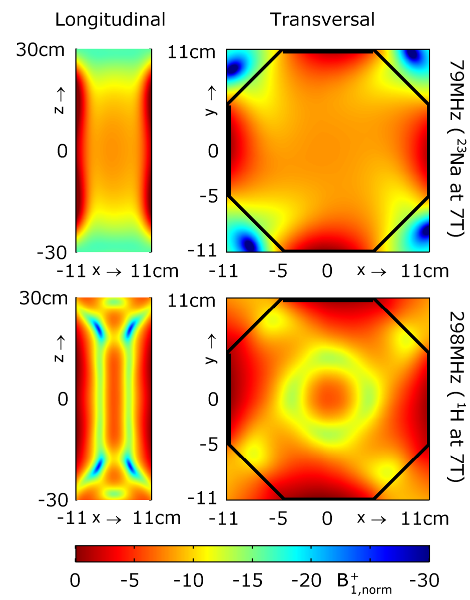

Fig. 2: Numerical results of the B_1^+-field for both resonance cases of the CDRA. The ^{23}Na (top) and ^{1}H (bottom) nuclei are both simulated for a 7T B_0-field. The magnitude of the B_1^+-field is normalized with $20*\log\{|B_1^+|/\max(|B_1^+|)\}$ and displayed on the left side in a longitudinal cut (normal to y at y = 0) and on the right side in a transversal cut (normal to z at z = 0).

Results and Discussion: The simulation results are shown in Figs. 2 and 3. The B_1^+-field shown in Fig. 2 is homogeneously distributed in the z-direction for both resonant cases of the CDRA. This result from the congener resonant behavior of the CDRA where in both resonance cases two current maxima are generated at the ends of the CDRA. This behavior of the currents is produced from the short circuits of the CRLH transmission line. Near the CDRAs the field is more linear polarized instead of circular, but this is not a problem according to the higher field amplitudes in these regions. As usual a central brightening of the B_1^+-field is visible for the ^{1}H resonance. The lower field amplitudes between the four elements especially at the ^{23}Na resonance can be avoided with a higher number of elements. Due to the Cartesian mesh for the EC-FDTD method an eight channel arrangement will be more complicated and is therefore not shown here. The B_1^+-field inhomogeneity in the longitudinal cut near the bottom and top edge of the phantom are produced by interference. The specific absorption rate (*SAR*) is shown in Fig. 3 as a local field in transversal and longitudinal cuts. It is as well as the B_1^+-field homogeneous distributed along the length of the CDRA. Due to the performance in both resonance cases of the CDRAs the four channel array is best suited for MR imaging and spectroscopy applications. The prototyping, which is the next step, is already in progress where this arrangement would be build up and first measured within our near field measurement setup [4,6].

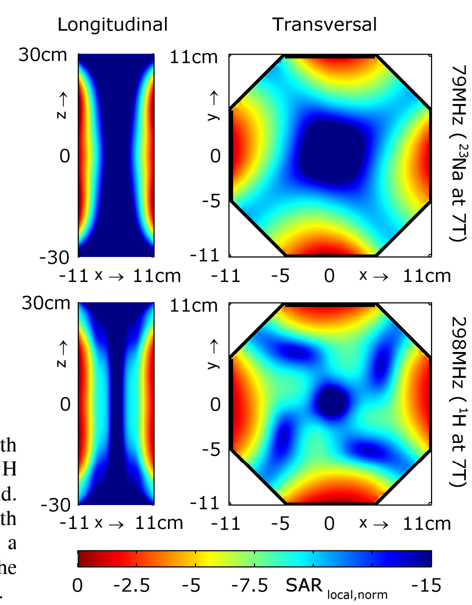

Fig. 3: Numerical results of the local *SAR* for both resonance cases of the CDRA. The ^{23}Na (top) and ^{1}H (bottom) nuclei are both simulated for a 7T B_0-field. The local *SAR* is normalized and displayed with $10*\log\{SAR_{local}/\max(SAR_{local})\}$ on the left side in a longitudinal cut (normal to y at y = 0) and on the right side in a transversal cut (normal to z at z = 0).

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