Prostate imaging at 7 Tesla with fractionated dipole antennas: a new type of radiative coil array element with lower SAR levels.

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Introduction Ultrahigh field body imaging requires advanced coil arrays that are designed according to new principals. Rather than generating B1 directly by currents in high-Q resonators, the array elements should setup a propagating wave into the tissue. Such an element is called a (radiative) antenna. The E- and H-fields that the antenna generates should produce a Poynting vector that is oriented towards the imaging target. One example of such an antenna is the single-side adapted dipole antenna (SiSiAD) [1]. This antenna uses a highly dielectric ceramic substrate to increase the electric distance from the dipole antenna to the tissue. In this way, the E-fields that are associated with a dipole antenna are kept outside the tissue. Although promising results have been presented, the disadvantage of this approach is that the ceramic elements are heavy and costly. In this abstract we present a new type of radiative antenna, where the legs of a dipole antenna are split into several segments. By using inductors between the segments, the voltage and current distribution over the antenna can be manipulated and the E/H ratio (wave impedance) can be decreased. In this way, the spatial dimensions of the near-field can be made smaller and/or the E-fields close by the antenna are decreased. This antenna will be called a "fractionated dipole antenna". Due to the absence of ceramics, it is lighter and cheaper than the previously developed SiSiAD antenna. In this study, the use of these new elements for prostate imaging at 7 Tesla is investigated.

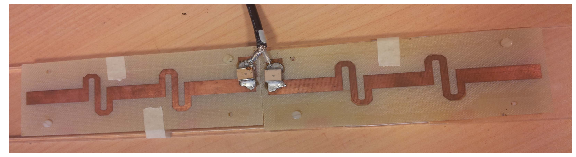

Figure 1: Fractionated dipole antenna. The legs of a 30 cm dipole antenna are split into three segments, inter-connected by inductors. Two series capacitors are used for balanced matching.

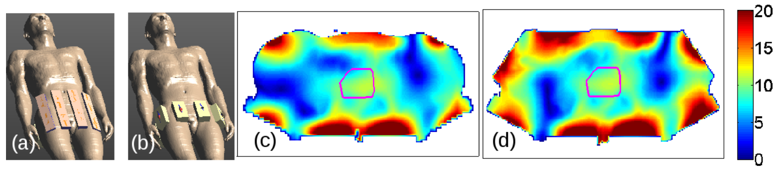

Figure 2: Simulation setup for human model 'Duke' with 4 frac. dipoles and 4 SiSiAD (a) and 8 SiSiAD (b). Prostate shimmed B_1^+ distributions (8 x 1 kW input power) for setup with frac. dipoles and SiSiAD's (c) and setup with SiSiAD only (d).

Methods Fractionated dipole antennas are built (30 cm length and 5 cm fractions) from PCB. The dipole fractions are interconnected by an inductance of 20-50 nH, which was realized by meander structures (figure 1). (The use of meanders as inductors in MRI was first demonstrated by Orzada et al [2]. Note that this design is entirely different. It has e.g. no ground plane) Four fractionated dipole antennas were built, two of which with a PMMA spacer of 10 mm (lateral placement in our setup) and two with a PMMA spacer of 20 mm (medial placement). These were used as the anterior elements in a prostate imaging experiment, combined with four SiSiAD antennas for the posterior elements. FDTD simulations (SEMCAD X, Speag, Schmid&Partner, Zurich) were performed on the Virtual Family model 'Duke' [3] to predict the expected B1 efficiency and assess the local SAR distribution for this new setup (Figure 2a). These results are compared to a simulation setup with SiSiAD elements only (figure 2b). Because SAR levels depend on B_1 shim settings, SAR performance was evaluated by calculating numerically the highest potential 10g averaged SAR in every voxel.

Results B_1^+ simulations (figure 2c and d) show that the combined array of fractionated dipole and SiSiAD antennas has the same B_1^+ efficiency as the SiSiAD antennas only (average B1+ in prostate is 9.6 uT and 10 uT respectively. In addition, figure 3 shows that the 10g averaged SAR levels under the fractionated dipole elements are at least 33% lower than under the SiSiAD antennas (10 vs 15 W/kg). The medial elements with a 20 mm spacer have even lower SAR levels than the lateral elements with a 10 mm spacer. In the volunteer measurements, 8 uT is achieved in the prostate with 8 x 1 kW input power, which is comparable to using 8 SiSiAD elements only. Imaging results are presented in figure 4. The coronal GRE image clearly shows the increased field of view in the longitudinal direction. In addition, the coupling between fractionated dipoles is much lower than for the SiSiAD elements. (S12 < -17.5 dB vs -13 dB for SiSiAD elements)

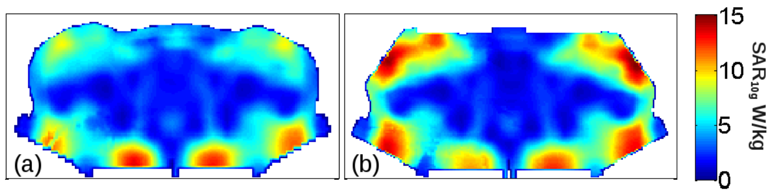

Figure 3: Maximum potential SAR (10g avg) per voxel, simulated in human model with 8 x 1 kW input power, duty cycle 1%. frac. dipoles and SiSiAD's (a) and SiSiAD only (b).

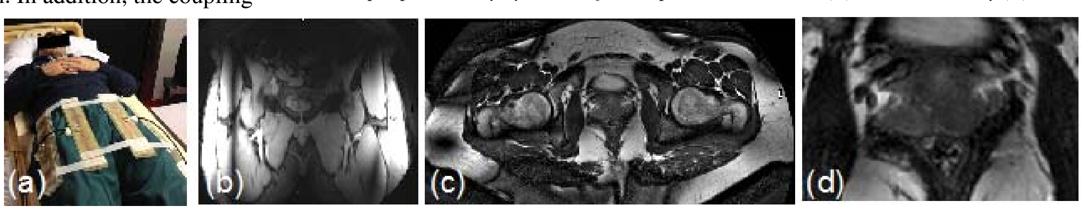

Figure 4: Imaging results with four ventral frac. dipole elements and four dorsal SiSiAD elements. a) Imaging setup b) Coronal GRE image (showing extended FOV in longitudinal direction) c) T2W TSE image TE/TR = 72/2500 ms. res: 0.5 x 0.5 x 2 mm, TSE-factor 13 d) Same image, zoom in on prostate.

Conclusion The fractionated dipole antenna as an array element is an improvement for body imaging in comparison to the single-side adapted dipole antenna. Due to the absence of ceramic, the fractionated dipole is much lighter and cheaper. It has less coupling, 33% lower local SAR levels and a larger field of fiew in the longitudinal direction. A separate receive array and/or a more comfortable foam layer could easily be fabricated within the spacing between the antenna and the subject skin. Next steps will be to fabricate four more elements for the posterior side.

[1] Raaijmakers et al. MRM 2012. [2] Orzada et al. ISMRM 2009
[3] Virtual Family, IT'IS Foundation