A symmetrically fed microstrip coil array for 7T

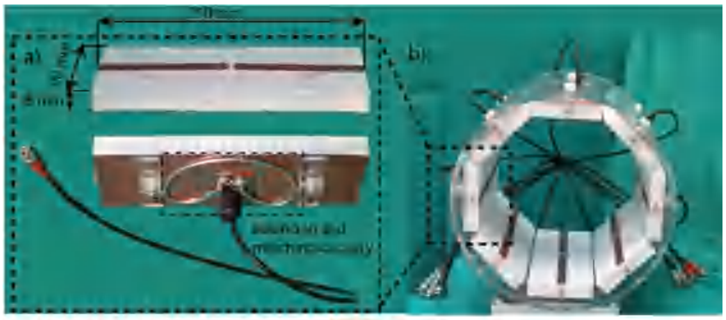
D. O. Brunner[1], N. De Zanche[1], J. Froehlich[2], D. Baumann[2], and K. P. Pruessmann[1]

[1]Institute for Biomedical Engineering, University and ETH Zurich, Zurich, Switzerland, [2]Laboratory for Electromagnetic Fields and Microwave Electronics, ETH Zurich, Zurich, Switzerland

Introduction

Transmit/receive microstrip arrays have been demonstrated to provide low mutual coupling and are therefore often used for ultra-high-field MRI [1]. However, several design issues remain, including limits to the length of single strip elements, high SAR, and sensitivity to cable positions due to exposure of cable grounds to stray electric fields. In this work we describe an 8-channel microstrip head array for 7T (298 MHz) that addresses these problems by several design changes. The main novelties implemented in this coil are a new feeding and cabling concept at the center of the microstrip line and the use of very low dielectric substrate materials between the elements and backplane.

Materials and Methods



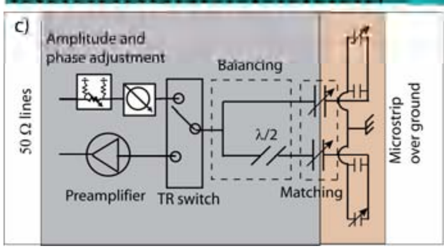


Figure 1: a) Single element from top and bottom view showing the microstrip and the balancing and matching circuitry b) mounted head coil array c) schematic of the feeding, balancing and matching concept

To provide maximum evanescent magnetic fields from the microstrip and lowest possible loss inside the elements, each element uses a sandwich construction consisting of 14 mm thick polymethacrylimide closed cell foam ($\varepsilon \sim 1.05$, linear loss $\tan(\delta)<0.0002$) between two 2 mm thick PTFE (Teflon) sheets ($\varepsilon \sim 2.1$, $\tan(\delta)<0.0002$) . The elements show mechanical stability comparable to that of bulk PTFE formers with a lower dielectric constant, lower cost and easier machining. The strip consists of a 15 mm wide copper tape glued to one side of a sandwich of total dimensions 250×90 mm^2, with a copper shield on the opposite side. In order to feed the strip line at the center, the cable signal is transformed from unbalanced to balanced by a $\lambda/2$ 50 Ω line mounted on the shield of each element. The feed lines are then matched by two trimmer capacitors to the impedance of the microstrip. In order to reduce radiation and increase stability the matching circuitry is mounted on dedicated circuit boards on the back of the coil. The resonance frequency of the elements can be adjusted by two trimmer capacitors at the end of each element opposite the feed (see Fig.1). The individual elements are mounted inside an acrylic former with an inner radius of 240 mm and a outer radius of 300 mm.

MR measurements were carried out on a Philips Achieva 7T whole- body system, using a standard FFE sequence, with each element connected through a T/R switch to a low-noise preamplifier mounted within the magnet bore. The feeding of the individual elements was provided by a Butler matrix with additional phase shifters and attenuators allowing an individual adjustment of the transmit power. Bench assessment was performed using standard S parameter measurements on a network analyzer. FDTD simulations were set up in CST Microwave Studio® by tuning and matching each element in the simulation. In the simulations the coil was loaded by a 150 mm diameter saline water sphere. All simulation where normalized to 1 W forward power providing independence of the matching situation for comparability. For comparison, a conventional strip line element was built with the same geometry but fed at one of the ends as done conventionally.

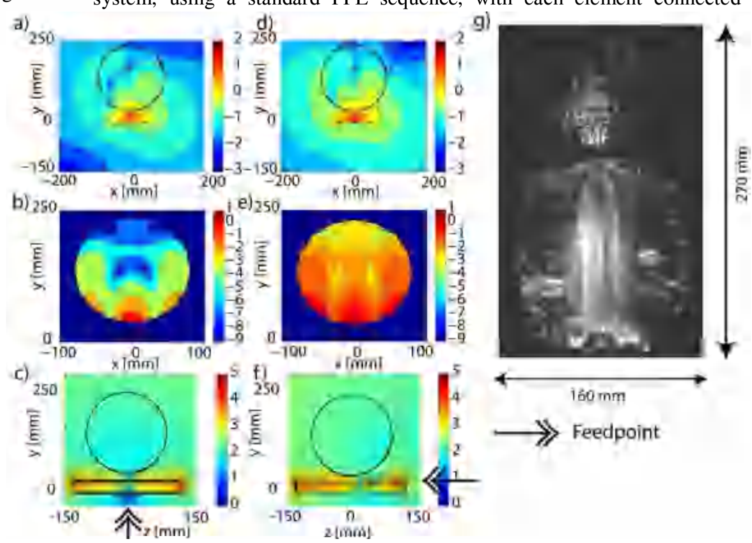


Figure 2: a) – c) Simulation results for a symmetrically fed element of the central transversal B_1^+ field [A/m], corresponding SAR distribution [W/kg] and absolute value of the electric field [V/m] for the central longitudinal slice, c)-f) corresponding plots to a) – c) for the side fed elements, e) straight forward gradient echo image of a pineapple

Results and Discussion

Coupling between all coil pairs was below -15 dB. In comparison to the asymmetric feed the tuning and matching was seen to be much more stable. This can be explained by considering the electrical field distribution at the connection point of the cable (see Fig 2c, 2d). Due to the symmetry of the proposed design, the electric fields assume a minimum at the feeding point, thus minimizing currents on the cable shields in contrast to the conventional design. This improves drastically the stability of the grounding of the entire array with respect to cable repositioning. The simulations also show an improved B_1^+ to SAR (i.e., electric field) ratio compared to the side-fed element. This can be explained by the low impedance (~1 Ω) at the central feed point, resulting in a low voltage at the central gap and thus low electric fields beneath it. The added efficiency found in the simulations is supported by the very low matching capacitance that was needed (~ 1 pF, showing that the impedance of the coil is low) and the ratio of unloaded to loaded Q that was roughly 2 for the symmetric vs. 3 for the asymmetric element. This shows that the electric fields penetrating the sample were weaker than in the asymmetric case. The longitudinal extent of the coil is demonstrated by imaging a sagittal slice of a pineapple (see Fig. 2 g). The field of view of the image has a longitudinal dimension of 270 mm and good coverage is demonstrated along the full extent of the coil. This suggests that the array will be suitable for whole-brain imaging down to the cervical spine. Advanced safety measures will need to be taken prior to in-vivo validation.

[1] G. Adriany et al. Proc. Intl. Soc. MRM 14 (2006), [2] T.J. Vaughan et al. MRM 46 (2001), [3] G. Bogdanov et al. MRM 47 (2002)