CAPACITIVELY TUNABLE PATCH ANTENNA FOR HUMAN HEAD IMAGING AT 9.4 TESLA

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Introduction: The generation of a homogeneous, circularly polarized B_1^+ field across the human head is a remarkable challenge at the field strength of 9.4 Tesla due to the small RF wavelength in tissue. The most promising way to overcome this problem is the use of coil arrays since they offer the possibility to tailor the excitation field by altering the current amplitude, phase and RF waveform on each element independently. However, besides the high hardware demands and the need for B_1 calibration pre-scans, we experience that at 400 MHz it is necessary to tune and match each coil element prior to the actual scan because of the strong coupling of the coil to the head of the subject.

A microstrip patch antenna, recently used for "traveling wave" excitation [1,2], promises to be an easy-to-build RF setup that produces a fairly homogeneous B_1^+ field over a large field of view *per se* [3], i.e. without the need for time consuming calibrations, but with the drawback that more RF power is needed in comparison to conventional coils. In order to improve efficiency and sensitivity, and especially for the use in waveguides that are too narrow to support the TE_{11} mode, the antenna must be brought in close proximity to the subject. This requires a mechanism to easily tune and match the coil to different loads. Here we present a capacitively tunable patch antenna for human head imaging at 9.4 Tesla as well as a simulation-based evaluation of the antenna's efficiency and SAR depending on the distance to the subject and relative to a tight-fitting 16-channel transceiver array.

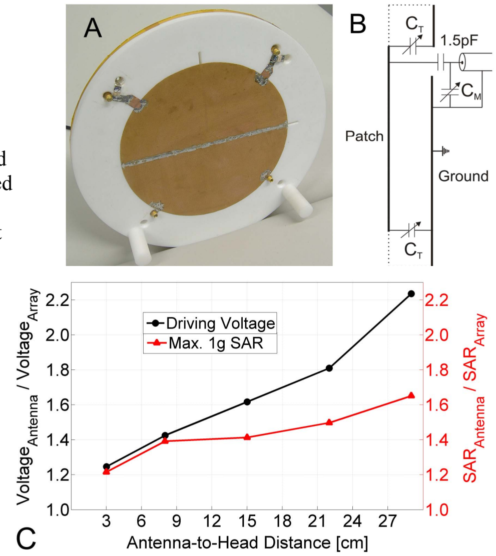

Figure 1: Antenna (A) and the tuning/matching circuit (B) of one channel. Fig.1C shows the driving voltage (black) necessary to scale the B1+ field to a reference value when the antenna is placed at various distances to the head as well as the resulting SAR (red).

Materials and Methods: Experiments were performed on a 9.4 Tesla magnet (Siemens/Magnex) equipped with a head-only gradient with an RF shield with an inner diameter of 40cm. The cutoff frequency of this waveguide is approximately 439MHz. To support a traveling wave at 400MHz the inner diameter of the RF shield must be at least 44cm. The patch antenna (Fig.1A) consists of a Teflon disc (r=320mm, h=20mm) which acts as the dielectric substrate, a copper patch (r=105mm) on the front side and a copper ground plane at the back. Instead of a continuous surface, a netted structure was etched on the patch as well as the ground since this reduced eddy currents significantly. Holes were drilled into the substrate in order to connect the two coaxial cables to the antenna and to include the tuning and matching network (Fig.1B). The use of two tuning capacitors C_T per port is reasonable since their balance defines the distribution of the current on the patch and therefore the quality of decoupling. The feed points had an angular offset of 90° and a phase delay of the same angle was introduced between the ports to obtain a circularly polarized B_1^+ field. Finally, the antenna was placed at a distance of about 15cm from the top of the volunteer's head whose shoulders were covered with an RF shielding fabric in order to suppress spurious signal from the body. In reception mode, the signal was sampled on the two channels separately and combined in a RSS manner. The simulations were performed with XFDTD (Remcom, PA).

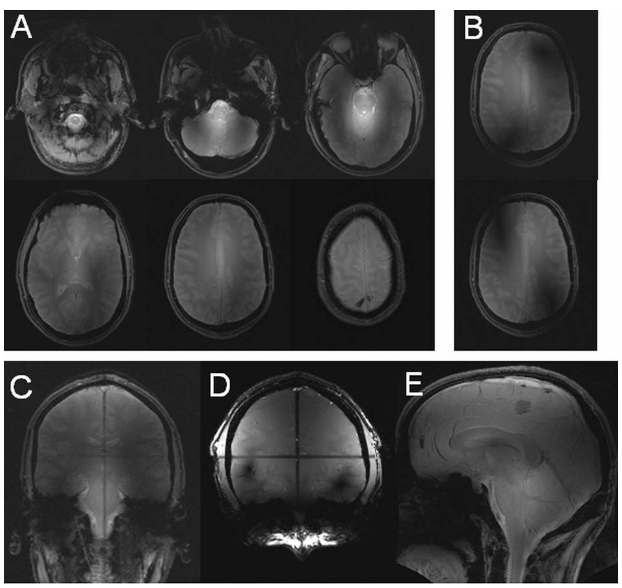

Figure 2: Axial (A, NEX=4), coronal (C) and sagittal (E, NEX=8) FLASH images obtained with the antenna, Fig.2B shows images received with the two channels separately. D is a coronal FLASH image obtained with an elliptical 16-channel T/R microstrip array.

Results: The antenna together with a human body model was simulated inside the waveguide and compared to a detailed model of a 16-channel T/R array. All simulations were scaled so that the same B_1^+ field in the center of the brain was obtained. The results are shown in Fig.1C: The black curve shows the necessary driving voltage relative to the array while the red curve shows the maximum 1g averaged SAR for various head-antenna distances. The results suggest that in this specific situation, efficiency can be considerably improved by reducing the head-antenna distance although the performance of the array is not reached. SAR was found to drop slightly when the coil is placed closer to the head but was higher than for the array at all distances.

In experiment, a shift in the input impedance could be observed when antenna and subject were moved into the RF shield of the gradient which must be compensated when tuning is performed with the patient table outside the bore. Fig. 2A, B, C and E show first FLASH images (TR/TE = 40/4.12ms, 256x256) obtained with the patch antenna. Although central brightening and a shading in the periphery can be observed in lower axial slices, there are no signal voids due to a weak local B_1^+ field which we typically observe in the left-right direction of the lower brain in images obtained with T/R arrays (Fig.2D) in the quadrature mode.

Discussion: A far field or "traveling wave" excitation with a patch antenna is not efficient when the Larmor frequency is near or below the cutoff frequency of the empty waveguide, as it is the case with our magnet/RF shield combination. The tunable patch antenna presented here can be brought in close proximity to the subject, thereby acting almost as a surface coil which is efficient, quickly tuned and matched and which produces a fairly homogeneous B_1^+ field in the human head *per se*, even at 400MHz. Since the signal reception doubtlessly contributes a considerable proportion of the remaining signal inhomogeneity (see Fig.2B), the tunable patch antenna combined with a dedicated receive array could be a promising setup for human head imaging at very high fields.

References: [1] Brunner et al. ISMRM, 2008, p.434. [2] Zhang et al. ISMRM 2009, p. 4746. [3] G. Wiggins et al. ISMRM 2009, p.2942.