A 16 channel T/R Open-Faced Head Array for Humans at 9.4T.

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Introduction:
At 9.4 Tesla the ^{1}H frequency related wavelength in the human dielectric tissue is smaller than the head dimensions. This leads to severe field inhomogeneities due to RF interference patterns [1-3] and represents significant challenges for conventional 'homogeneous' volume coil building methodology. Additional difficulties arise due to the increased RF power demands and spatial constraints on RF coil arrangements within a head gradient coil. However by using technology that allows the control of individual transmit coil element excitation in phase, amplitude and pulse shape it has been shown that some of these effects can be mitigated and brain imaging has been demonstrated to be feasible in research applications at 9.4T and above [4-6]. Here we explore the feasibility of addressing some of these issues through a open faced 16 channel transceiver array.

Methods:
The array elements were built as individual λ/2 transmisson line resonators using 12 mm teflon dielectric, 12 mm wide copper strip conductor and a 42 mm wide RF groundplane. The eight resonance elements in the lower former and the two upper elements at the seam between the formers are 13 cm in length. The remaining six elements of the upper array were reduced in length, resulting in four 10 cm and two 7.5 cm elements to cover the frontal cortex. Finite Difference Time Domain(FDTD) modeling utilizing the visual human digital atlas of an adult male head (Remcom, PA) was used to numerically predict RF (B_1) field magnitude and SAR in order to evaluate the effect of the shorter elements of the upper holder on the available B_1. The simulations were performed with individually tuned resonance elements and 22.5deg phase increments between neighboring elements. Healthy volunteers were studied after giving informed consent according to the procedures approved by the Institutional Review Board. MR experiments were performed using a 65cm horizontal bore magnet (Magnex Scientific/Varian). A Varian DirectDrive (Varian Inc, Palo Alto,CA) console was used in conjuction with up to sixteen 500W RF Amplifiers (CPC, NY). Forwarded and reflected power were monitored for the individual transmit channels to ensure patient safety. The B_1^+ shim capability of the array was evaluated utilizing a previously published algorithm [7-9].

Results:
Decoupling capacitors at the RF feedpoint reduce next neighbor coupling to average values of 20±5dB [10]. These decoupling values and the required capacitive decoupling patch between upper and lower holder part were determined in benchmeasurements with a human load. The so found pre-adjustments did not have to be altered between volunteers in the scanner. Tune /Match capacitor settings however were adjusted for individual volunteers to increase transmit efficiency and SNR. With RF phase shimming the achievable local γB_1 for a 3x3x3cm^3 ROI in the occipital lobe was 1.5 kHz. Simulation results indicate that the tailored coil elements sufficiently cover the whole cortex while reducing local SAR in the facial region. The shorter elements of the upper coil however do cause a decrease in achievable B1 in the frontal cortex observed in simulation and experiment. RF shim routines were found to be essential to determine the optimal set of transmit phases.

Discussion and Conclusions:
Initial results indicate that simply by adjusting the phase in individual RF coil elements the B_1^+ field can be manipulated significantly to achieve order of magnitude improved B_1^+ for a targeted region of interest. Significant gains in SNR, transmit efficiency and decrease in global SAR were realized. Our RF front-end allows additionally the utilization of amplitude and pulse shape modification to further improve the ability to modify the transmit homogeneity. Future studies will explore this in greater detail.
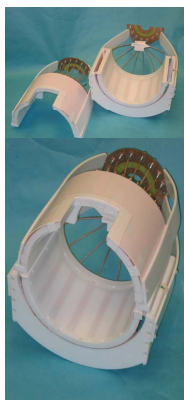

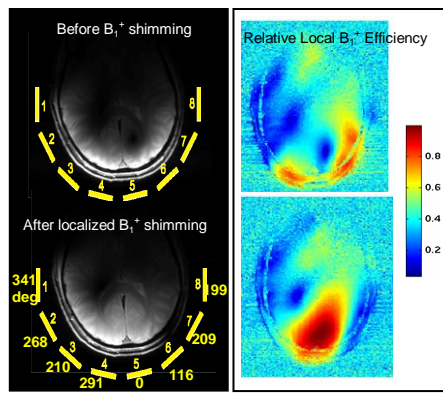**Fig. 1** Shows the upper and lower coil former and the combined coil (20 x24cm^2)

Fig. 2 A: Example of a local B1 Phase shim solution for the lower coil array **B**: Shows the resulting relative gain in B_1^+ efficiency.
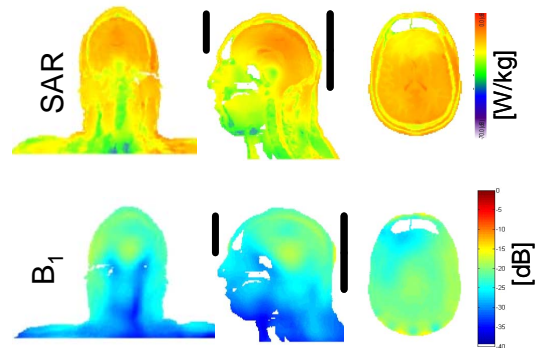
Fig. 3 FDTD simulations of SAR (upper row) and B1 (lower row) to evaluate the effect of the shortened transmit elements. The coil position is indicated in the sagittal view.

References:
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