Tranceive Phased Array with high Transmit Performance for Human Brain Application at 9.4 T

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Introduction: Despite the intrinsic advantages of ultra-high (≥7 T) field (UHF) spectroscopic imaging (SI), increased SNR and spectral resolution, few studies have been reported to date. This limitation is largely due to B_1 inhomogeneity and decrease in transmit (Tx) efficiency ($B_1/\sqrt{kW}$) (1). Tx surface loop phased arrays combined with RF shimming have been shown to improve Tx performance and homogeneity for head imaging up to 9.4 T (2,3). However, often Tx-arrays are enlarged to fit SNR-optimized receive (Rx) arrays and, therefore, cannot satisfy requirements in high B_1 and bandwidth for UHF SI. In this work we have developed a tight fit 400 MHz transceiver (Tx/Rx) head phased array to provide for efficient transmission.

Methods: The array consists of a single row with 8 (10 cm - length, 7.8cm - width) evenly spaced rectangular surface loops (Fig.1) and measures 20cm in width and 23 cm in height. It is shielded with a shield located 4 cm away. Experimental B_1 maps were obtained using the AFI sequence (5) and a head/shoulder phantom (Fig.1) constructed to match tissue properties (ε=58.6, σ=0.64 S/m) (3). Adjacent surface loops were decoupled using a resonance inductive decoupling (RID) method (4), which provided excellent decoupling (<-23 dB) between elements (Fig.2) and made it very suitable for pTx. Q_U/Q_L measured 4 to 6. All data were acquired on the Siemens Magnetom 9.4 T human imaging system. Simulations of SAR were performed using CST Studio Suite and the Virtual Family "Duke" model.

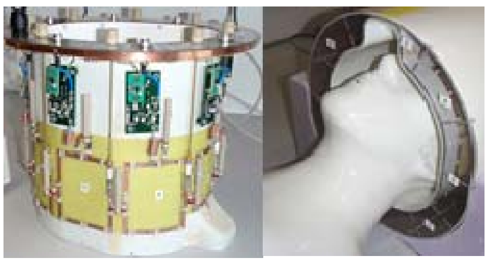

Figure 1: *Layout of the 8-channel TX/RX coil.*

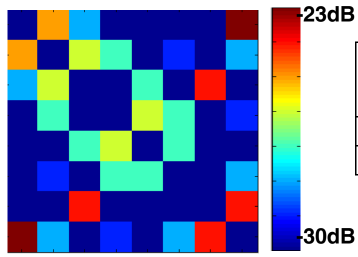

Figure 2: *S12 matrix of the coil.*

	B_1* Center	$\langle B_1\rangle_{ax}$* Ax. Slice	Homog. STD, %	$\langle B_1\rangle$* Head	SAR_{10g} W/kg, max
Exp.	19.2	12.4	23	8.4	-
Sim.	20.3	13.9	18	9.6	4.33

*B_1 values are presented in $\mu T/\sqrt{kW}$, SAR for P_{in}= 8 W measured at the coil.

Table 1: *Experimental and Simulated Data*

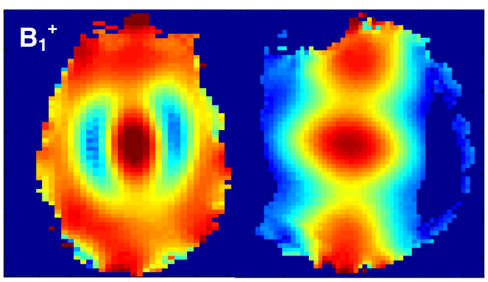

Figure 3: *Experimental CP B_1^+maps (AFI) of a head-and-shoulder tissue dielectric phantom.*

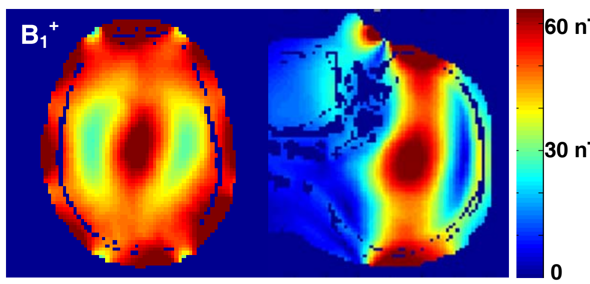

Figure 4: *Simulated CP B_1^+maps of a human voxel model (CST). Figs. 3 & 4 are scaled identically.*

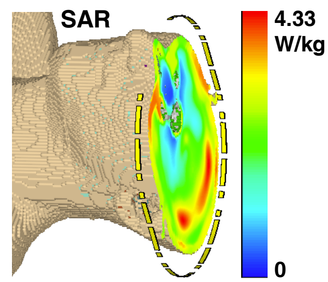

Figure 5: *SAR simulation results for CP mode.*

Results: The experimental B_1^+ maps (Fig.3) measured with the array used in the CP mode are in accordance with the simulated CP B_1^+ distribution (Fig.4). Figure 5 presents results of related SAR simulations. Table 1 summarizes all data. Tighter fit increases loading. Therefore, more energy is deposited into the sample and a high B_1^+ efficiency is achieved. As seen from Figs. 3 and 4 the relative peripheral Tx efficiency in the axial slab through the phantom's center is also improved as compared with the common CP mode UHF B_1^+ pattern produced by larger Tx coils (1-3), where peripheral B_1^+ is substantially reduced compared to that in the center. As a result, the tight fit array improves the overall axial B_1^+ distribution with elevated maximal and peripheral efficiency and improved homogeneity. B_1^+ averaged over the central axial slice, $\langle B_1\rangle_{ax}$, experimentally measured 55.6 nT/V as evaluated at the array input, which corresponds to 12.4 μT per 1 kW of RF power delivered directly to the array. Homogeneity evaluated as a standard deviation over the central axial slice measured 23%. Simulations in the head model yielded similar results (Table 1). We also evaluated the local SAR distribution with maximal SAR_{10g} measuring 4.33 W/kg when total 8 W delivered to the array input. Within the longitudinal coverage limited by the coil length the array also provided reasonably high SNR (Fig.3). However, the small number of array elements (8 elements) may limit the SNR and parallel Rx performance as compared with Rx-arrays with 30 and above elements (3). In the future we plan to develop a transceiver array with more channels for better SNR and coverage.

Conclusions: As a proof of concept we developed and constructed a tight fit 400 MHz 8-channel transceiver head phased array. The array provides high transmit efficiency and improved B_1^+ distribution and homogeneity in the axial slab through the brain center. However, to further improve SNR and longitudinal coverage along the array axis, increasing the overall number of array elements is required.

References: 1) Vaughan JT et al, Magn. Reson. Med., 46:24-30, 2001. 2) Avdievich NI et al, Appl. Magn. Reson., 41(2):483-506, 2011. 3) Shajan G et al, Magn. Reson. Med., doi: 10.1002/mrm.24726. [Epub ahead of print]. 4) Avdievich NI et al, NMR in Biomed 2013, doi: 10.1002/nbm.2989. [Epub ahead of print]. 5) Yarnykh VL, Magn. Reson. Med., 57:192-200, 2007.