

Construction of a 2-Channel Transmit/Receive Neck Array for Carotid Artery Vessel Wall Imaging at 7 Tesla

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Target Audience: In this study, a 2-channel neck coil was constructed for high-resolution carotid artery vessel wall imaging. The coil was used as a transceiver in a parallel transmit mode and its safety for use with human subjects was thoroughly assessed. Thus, this study is of particular interest to ultra high field MRI scientists working on RF coil design, parallel transmission (pTx) and coil safety.

Purpose: Atherosclerotic plaques in the bifurcation of the carotid artery vessels can pose a significant stroke risk from stenosis, thrombosis and emboli, or plaque rupture. However, the possibility of the latter depends on the structure of the plaque and its stability. So far, the assessment of such depositions, and the evaluation of the risk they pose, is not satisfactory with 3T black blood imaging [1]. It is expected that the SNR increase at 7 Tesla, together with an appropriate and patient-safe RF coil, will result in higher resolution images that would help in assessing better the composition of atherosclerotic plaques in vessel walls.

In this study, a 2-channel custom built neck transceiver was designed and constructed, with the aim of investigating the benefits of the higher field strength using a novel black blood imaging sequence using DANTE preparation pulses [2] and implemented on a Siemens 7T scanner. However, in pTx mode the safety of the subject may be compromised through excessive RF heating and thus RF safety needs to be assessed in advance.

Methods: A 2-channel neck array was constructed using ellipsoid loops placed at each side of the neck, held together with a flexible cradle. For each coil, a pair of accessible variable capacitors was used for fine tuning and matching and the channels were tuned/matched at 297.2MHz and ≤ -20 dB [Fig 1]. The coil was connected to the scanner via a custom T/R switch [Fig 2].

Electromagnetic simulation software was used for safety simulation and SAR estimation with two human phantoms using Semcad X (SPEAG, Zurich) [3] [Fig 3]. The E-fields for 1 Watt transmission per channel were calculated for each element and were then processed with MATLAB for estimation of worst case local SAR. The transmission power limit per channel was set to be the worst case scenario, which is the maximum SAR resulting from the sum of the E field magnitudes of the two elements. The SAR is calculated over 10g mass cubes, averaged according to the IEEE/IEC 62704-1 standard [4].

For the evaluation and validation of the simulations a meat phantom was used. The temperature was measured using fibre optic probes under the estimated hot spot, and a temperature-sensitive liquid crystal sheet (Edmund Optics, Barrington, NJ) was placed over the surface of the sample for the visualisation of the heating distribution and was compared with the simulated distribution. A healthy male subject was used to assess the coil's viability for carotid artery imaging using a protocol consisting of B1 mapping to estimate the flip angle map and to calculate the reference voltages, followed by DANTE-prepared black blood imaging of the vessel wall. The DANTE preparation module parameters were: 150 pulses, flip angle 15° (at the location of the carotid arteries), inter-pulse spacing 1.5ms, gradient strength 20mT/m for G_x, G_y and G_z.

Results & Discussion: The worst-case heating scenario, as defined in the Methods section, generated a maximum local SAR of 7.3W/kg for 1 Watt per channel input [Fig 3-A,B]. Thus, for 1st level mode (20W/kg max [4]), the power limit is 2.78 Watt per channel. The heating profile was similar to simulated and temperature increase measurement was within $\pm 10\%$ margin from simulation [Fig 3, C-F].

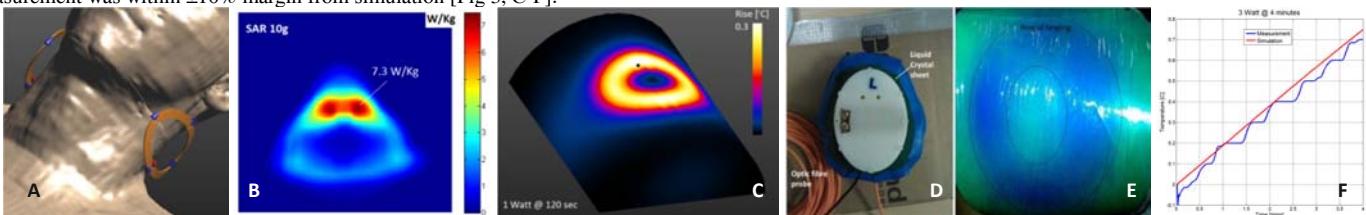


Fig 3: Imaging setup in Semcad X with virtual family phantom [3] (A), transverse slice of worst case scenario 10g SAR (B). Heat profile simulation of beef phantom (C), experimental setup with liquid crystal sheet, temperature probe and the matching heating profile Simulation (D,E), simulation (red) vs measurement (blue) for a 4 minute beef phantom scan for 3 Watt CW (F).

Imaging with a pork phantom produced a resolution of 0.4mm isotropic [Fig 4, A] and images of a male healthy subject [Fig 4, B-C] gave a resolution of 0.6mm isotropic for the FLASH sequence with DANTE preparation pulses and sufficiently suppressed blood signal [Fig 4, D-E].

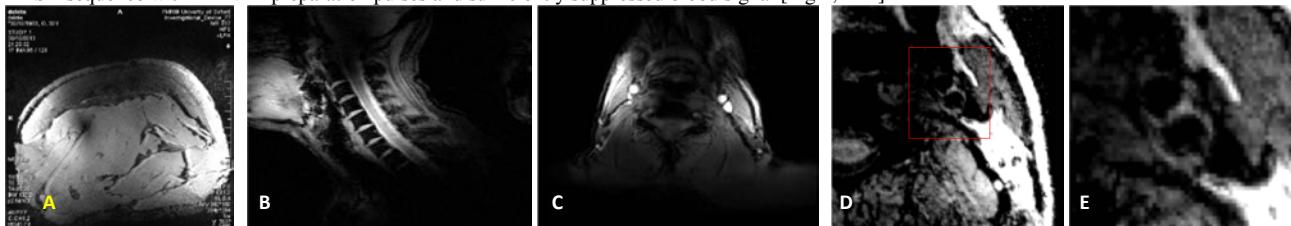


Fig 4: Imaging of a pork phantom with the 2-channel coil, 0.4mm isotropic (A), sagittal and transverse slices of FLASH localiser (B-C), left carotid imaging of FLASH sequence with DANTE preparation pulses (D) and zoom image to the carotid bifurcation 0.6mm isotropic with sufficient blood suppression (E).

Conclusion & Future Work: A 2-channel coil was designed to target the carotid arteries operating under pTx mode and a black blood imaging sequence was implemented for blood signal suppression and vessel wall imaging. The initial results from the subject and phantom imaging show adequate penetration of the B1 field as well as power efficiency of the coil within the safety limits. A 0.4mm isotropic resolution was achieved in the meat phantom and a 0.6mm resolution in human imaging with successful blood signal suppression on one side. Further coil and sequence optimisation is required for efficient artefact reduction, black blood suppression, and maximisation of the resolution. A separate receive array which will be placed close to the neck in order to improve the SNR is under construction.

References: [1] Den Hartog AG et al. Curr. Cardiol. Rev. 7:28–34, 2011, [2] Li L et al, Mag Res Med, 68:1423-1438, 2012 [3] Christ A et al, Phys. Med. Biol. 55:N23-N38, 2010 [4] IEC, Medical Electrical Equipment, 60601-2-33, 2010



Fig 1: Right channel of the coil without lid (left), both channels with protective lid (right)

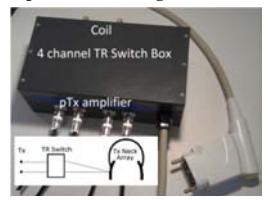


Fig 2: A custom built 4-channel T/R interface box used for connecting to the coil