RF shimming of the neck using a 2 and a 4 channel travelling wave neck array at 7T MRI

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Introduction: MRI of the human neck is important for example in imaging plaques in carotid arteries, which can fire emboli's towards the brain causing infarctions. Assessing the composition of these plaques can give a risk estimation for such clinical events, but requires high spatial resolutions. High field MRI (≥7T) of these plaques may therefore result in a better risk assessment. However, at high field tissue heating (expressed by SAR) is restraining most imaging sequences. Nonetheless, multi transmit solutions may be considered, as local SAR can be distributed, thus reducing the maximum local SAR. Likewise, antennas can be used that offer reduced local SAR. Therefore, we propose to use a leaky dielectric waveguide concept [1] which facilitates a propagating wave. The propagating wave modes are fed by radiative antenna's [2] applied with two or four channels respectively for distributing RF power deposition. Combined with RF shimming and a high density of receiver coils, the versatility of the setup was demonstrated in high resolution MRI of the spine and the carotids.

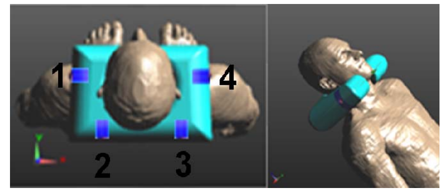

Fig 1 Overview of the neck array with four antenna positions

Materials and methods: A multi channel transmit array was used. Each transmit element consisted of a dipole antenna attached to a neck pillow filled with D_2O (fig 1) as shown in [1]. Two different configurations were used. The first configuration was 2 x 4 kW, with antenna's mounted on position 1 and 3 (see fig 1), each driven by 4 kW peak power. With these two channels phase shimming was applied to focus the RF on either the outer region of the neck (for carotid artery imaging) or on the inner region of the neck (for spine imaging). Transverse and sagittal B_1^+ maps (AFI $T_{R1/2}$ = 40/200ms, $fa_{nom} = 50^o$) [3]) were acquired on healthy volunteers for both shims. High resolution (0.4 x 0.4 x 1.5 mm^3) anatomical black-blood TSE images were acquired with both shims as well. The second configuration was 4 x 2 kW, with antenna's mounted on all four positions shown in fig 1, each driven by 2 kW peak power. Complex B_1^+ maps were acquired and phase and amplitude shimming was performed on a single slice, aimed on homogenizing the whole transversal slice of the neck. Transverse and sagital survey gradient echo scans (T_R/T_E = 50/2.5 ms) were acquired with the start shim (zero) and the optimized shim, to visualize the result of the single transverse slice based RF shimming in the longitudinal (FH) direction. B_1^+ efficiency of both coil configurations was normalized to input power and compared with each other. FDTD simulations were performed (SEMCAD X64 v14.2, Speag, Zurich, Switzerland) on the human male model from the Duke family to obtain maximum values in SAR_{10g} ($W{\cdot}kg^{-1}{\cdot}W^{-1}$).

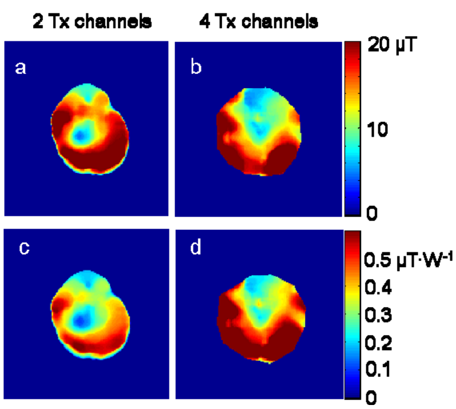

Fig 2 in-vivo transversal B1+ maps of the neck using a) 2 x 4 kW and b) 4 x 2 kW. a) and b) show similar result. Figure 2 c) and d) show the same results normalized per Watt input power at the antenna, showing a more efficient

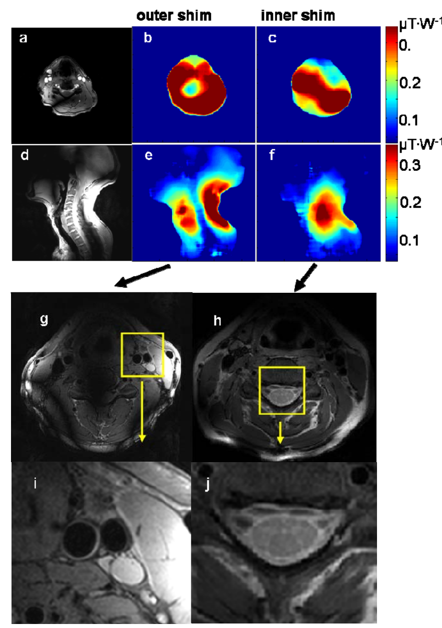

Fig 3 a-f) in-vivo B1+ maps of the 2 channel setup focused on the carotids (b, e) and on the spine (c, f) and high resolution (0.4x0.4x1.5mm3) T1W turbo spin echo's of the corresponding area's (g,h,i,j).

Results & Discussion Using two different RF shims, high resolution MRI of the carotid artery and spine can be obtained efficiently (Figure 3) even with the two channel configuration. Compared to a 4 channel configuration (Figure 2), comparable B1+ amplitude can be obtained on an absolute scale (2x4 versus 4x2 kW). However when normalized to 1W (and taken into account a 50% power loss between the amplifier and the antenna) it is clear that the 4x2 kW system is a more efficient transmit array (higher B_1^+/power, fig 2c and 2d), and thus also more SAR efficient, as none of the local SAR hotspots are overlapping. Maximum local SAR_{10g} value was simulated to be 1.95 $W{\cdot}kg^{-1}{\cdot}W^{-1}$ and located in the shoulder, for the worst case antenna (antenna 3). Even though RF shimming was performed on a single slice, uniformity in feet head direction also improved (Figure 4)

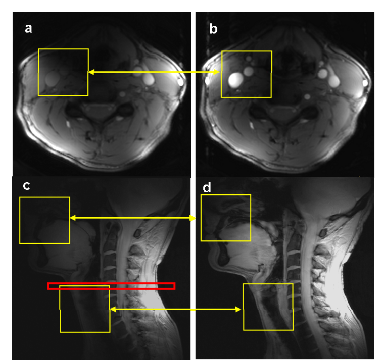

Fig 4 a) and c) show gradient echo images without RF shimming (max amplitudes, phases zero = random), where b) and d) show the same acquisitions with the optimized shimset. Also outside the slice used for shimming (red rectangle) B1+ homogeneity is improved.

Conclusion A transmit array using propagating waves through a leaky dielectric waveguide provides efficient MRI of carotids and spine at 7T. RF shimming improves the homogeneity of the B_1^+ field, while B1 increases and SAR reduces per unit input power when increasing the number of channels from 2 to 4.

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References [1] Koning et al. Proc Intl Soc Mag Reson Med 19 (2011) #327, [2] Raaijmakers et al. (2011). MRM **66**: 1488-1497, [3] Yarnykh (2007). Magn Reson Med **57**: 192-200