6 channel radiative transmit array with a 16 channel surface receiver array for improved carotid vessel wall imaging at 7T

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Introduction: MRI of the carotid artery and plaque composition is important for assessing the associated risk of stroke. Imaging these plaques at 7T may result in higher resolution and in improved risk assessment, compared to lower field strengths. Although 7T MRI offers a higher intrinsic SNR, it remains a challenge to utilize this full potential due to high RF power deposition and non uniformity in B1. The potential of 7T MRI for the carotid arteries was already shown by ref [1] using local transceiver coils. However, both transmitting and receiving with the same (transceive) coil is a compromise between sensitivity and SAR-restriction. Closely positioned coils (like surface coils) have high sensitivity but deploy a high local SAR, more distant coils are less SAR restricted at the cost of local sensitivity. *Aim: to design a transmit array with a uniform B1+ distribution and low RF power deposition, together with a dedicated surface coil receive array for optimal sensitivity at the carotid arteries*. Here we propose the use of an array of radiative antennas for providing SAR optimized B1+, while an array of small surface elements are used for optimized detection. This setup was compared with a 2 channel SNR optimized surface coil transceiver both in phantoms as well as in healthy volunteers.

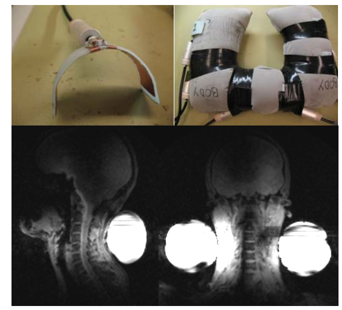
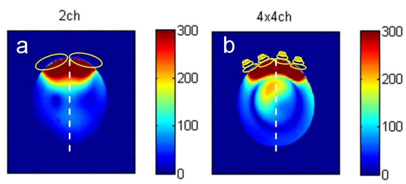


Fig 1: upper left: a single C-shaped dipole antenna. Upper right: 6 dipole antenna's attached neck pillow filled with water as a substrate. Below: fast scout scan to demonstrate positioning.

Methods: *Transmit:* Radiative antennas were used for transmit, similar to the antenna's proposed in ref [1].
An array was designed consisting of six separate single-side adapted dipole antennas attached to a neck pillow filled with water (Fig 1) and was driven by six 1kW amplifiers. The permittivity of water allows for short antennas, while waves propagate with minimal reflections through the tissue. RF phase shimming was applied to optimize the B1+ at the carotids.



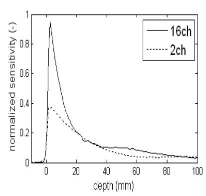


Fig 2: Above: the SNRmaps of the 2channel transceiver coil (a) and the 16channel receive-only coil (b) in phantom. Left: B1+ corrected sensitivity graph shows that at 30mm the 16ch coil has equal SNR as the optimal dimensioned 2ch coil.

Receive: A small element receiver coil matrix was designed and constructed. It consists of 4 arrays of 4 surface coils that can be placed individually against the neck. The matrix is flexible, making it possible to place each element closely to the neck and load all coil-elements properly. Decoupling was realized by partial overlapping in B_0-direction and by distance in the transverse direction. Each individual coil is elliptical shaped with a dimension of 10 by 20mm. As the elements were strongly coupled to the tissue, no additional preamplifier decoupling circuitry was included. All elements are detunable and can be used in combination with high power transmit fields. The array was interfaced via a 16-channel receive only box of the 7T scanner (Philips, Cleveland, USA). *Phantom experiments*: Receive properties of the 16-channel receive array were compared with a closely positioned 2x2 channel bilateral transceiver array (Machnet B.V., Eelde, The Netherlands) with optimal dimensions for receiving at ±30mm depth (depth of carotid artery). A cylindrical phantom with diameter 135mm was used and for transmit the standard Philips 7T birdcage headcoil was used. Gradient echo images were acquired and corrected for B1+ to acquire sensitivity maps. *In-vivo experiments*: turbo spin echo images (TSE, T_R/T_E = 3000/43ms, turbofactor 7, res 0.5 x 0.5 x 1.0 mm^3, TA = 4:06min) were acquired with the transceivers as well as the 6ch Tx/ 16ch Rx combination. With the new coil configuration high resolution MRI was performed (TSE, T_R/T_E = 1500/43ms, turbofactor 7, 0.3 x 0.3 x 1.0 mm^2, TA = 3:58min).

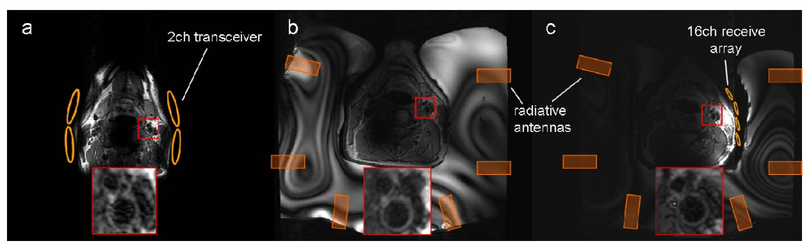


Fig 3: 2D TSE images: *a)* 2x2 channel transceive surface coil, *b)* 6 channel radiative antenna array, used as transceiver coil and *c)* 6 channel transmit array used in combination with the 16 channel receive array. The carotid arteries are pointed out by the red square.

Results/Discussion: The new radiative neck array was able to deliver 20μT at the carotids using only phase-image based RF phase shimming. This enabled the acquisition of turbo spin echo images. Also, a smaller gradient in B1+ compared to the local transceiver coil makes this transmit array less sensitive to small errors in RF power optimization. The highest electric fields are deposed in the pillow instead of in the body. To illustrate this (Fig 3b and 3c), water was used as a substrate rather than for instance deuterium (which excludes high signals close to the antennas). The low SAR properties of this transmit array enable improvements in the MR sequences, since many are now SAR-restricted. Figure 3 shows the images acquired with the different setups. Figure 2 shows the receive patterns of the different setups. It shows that at the average depth of the carotid artery (+/- 30 mm) the 16channel array has similar SNR as the optimal sized transceiver coil, showing that possible additional noise by added electronics is not dominant. This means that the arrays are a good alternative for the optimally sized coils with an extra advantage of accelerated imaging using SENSE.

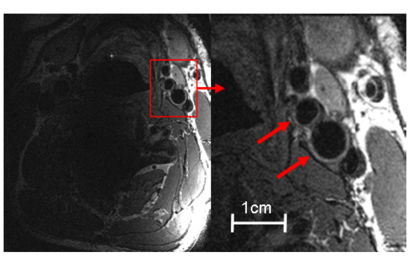


Fig 4: High resolution 2D TSE images with an in-plane resolution of 0.3 x 0.3 mm. Acquisition time 3:58min, slice thickness 1mm. Arrows indicate carotid arteries. Acquired with setup as shown in Figure 3c.

Conclusion: A 6 channel radiative transmit array was designed and constructed with low RF power deposition and relative uniform B1+. Combined with a dedicated 16 channel small element receive coil a TSE sequence could be implemented to show that 7T can be used for clinical high spatial resolution imaging to asses carotid vessel wall integrity.

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[1] Kraff et al. Proceedings 17th ISMRM, 2009 # 3007
[2] Raaijmakers et al, Proceedings 18th ISMRM 2010 #6791