Travelling-Wave Excitation for Primate MRI at 7T Whole Body MRI-System

Johannes Mallow[1], Tim Herrmann[2], Judith Mylius[3], Joerg Stadler[3], and Johannes Bernarding[1]

[1]*Department of Biometry and Medical Informatics, OvG University Magdeburg, Magdeburg, Germany,* [2]*Department of Biometry and Medical Informatics, OvG University Magdeburg, Magdeburg, Saxony-Anhalt, Germany,* [3]*Leibniz-Institute for Neurobiology, Magdeburg, Germany*

INTRODUCTION

Primate MRI at ultra high field (UHF) requires individual Tx-coils for excitation of different body parts since the construction of one large body-coil, is difficult [4]. If Primate functional MRI is the focus, volume Tx-coil limits the freedom for stimulation because the necessary fixation unit does not fit into commercial volume coils. The traveling-wave concept [1], offers the potential to overcome some of these restrictions: In volume RF-coils the usable B_1^+ -field is restricted to dimensions and geometry of the RF-coil itself, except the RF-coil is considered as a RF-resonator which can also overcome this restriction. Contrary to this, in the traveling-wave concept the usable B_1^+ -field is restricted to the dimensions of the waveguide (RF-shield) only. While standard transmit coils at 7T excite rather small volumes, the MR traveling-wave concept allows the excitation of larger volumes only depending on the length of the RF-shield. For an antenna with a frequency of 297.2 MHz the approximate wavelength is about 1m. Thus the RF-shield of the gradient coil (**Fig. 1A**) with a diameter of 64cm can be used as a waveguide. As our MRI-system has an extended gradient RF-shield with a length of 147.1cm the traveling-wave concept has the potential to work as a whole body coil.

MATERIALS AND METHODS

All measurements were performed on a 7T Siemens whole body scanner with SC72a gradient coil system (Siemens, Erlangen, Germany). If enclosing only air, the RF-shield has a cut-off frequency of 275 MHz for the propagating TE11 (H11) mode, which is below the proton Larmor frequency at 7T. The bigger diameter of the RF-shield of the 7T Siemens whole body scanner in comparison to other 7T systems [1] is an advantage. Thus, the wave propagates through the whole RF-shield without damping but a reflection of approx. 20% caused by the end of the RF-shield if no match is provided. The cut-off frequency decreases if the relative permittivity inside the bore increases. A patch antenna (**Fig. 4A**) was designed and constructed (**Fig. 4B**) by using field simulation software [3]. The antenna has a total diameter of 44 cm and a patch diameter of 24 cm. This 2 port patch antenna generates a circular polarized B_1^+-field to achieve high excitation efficiency. The complete MRI-system was simulated after designing a CAD model to analyze the behavior of the transmitted field under different conditions e.g. different positions of the antenna (**Fig. 1C**). The simulations were evaluated by performing several experiments, in which the antenna was used for transmit and receive. For a better evaluation of the performance of this approach, the antenna was also only used to transmit RF-power while a 12-ch. phased array [2] Rx-coil and a 3-ch. phased array primate coil (**Fig. 2A**) we used for signal reception. To increase the directional characteristics of the patch antenna, additional tuning and matching capacitors were mounted to excite a 180° flip angle with lower transmit voltage to increase the RF-Energy efficiency inside the RF-shield. The designed 3-ch. phased array primate coil offers more space for auditory stimulation options in the primate fMRI.

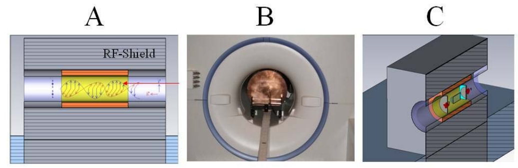

Fig 1: **A)** Scheme of propagating waves inside RF-shield **B)** patch antenna for RF excitation on backside **C)** simulation model of the 7T MRI system [3]

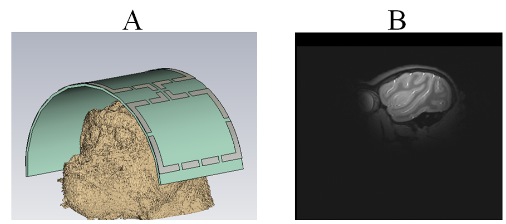

Fig 2: **A)** Designed simulation model of the 3-ch. phased array coil (Rx) with biological Macaque model **B)** MRI of a male Macaque acquired with patch antenna (Tx) and 3-ch. phased array coil. Sequence Parameters: TSE TR: 6000ms, TE: 240ms, matrix:256x256, FoV:140x140mm, slice thickness: 0.5mm, slice distance: 1mm, α=120° Ref. Amplitude = 310V (180°)

RESULTS

The field simulation software allowed optimizing the directivity of the designed patch antenna (**Fig. 4A**) inside the MRI system. (**Fig. 3B**) shows that the excitation by the designed patch antenna can achieve the same homogeneity as the Dual Helmholtz CP coil (Tx) shown in **Fig. 3B**. The designed patch antenna can still be used for signal reception, but the signal-to-noise (SNR) is rather low since B_1^+-filling factor for the patch antenna is insufficient for small objects like a grapefruit (**Fig. 3B**). With this designed patch antenna as Tx and the 3-ch. phased array primate coil for Rx the highest SNR can achieved under travelling-wave conditions because the B_1^+-filling factor for a phased array coil is much better. The results of the 3-ch. phased array primate coil with Macaque as a subject show very high SNR in cover region of this coil (**Fig. 2B**). The anatomical MRI measurement was performed with the following sequence parameters: Turbo Spin Echo TR: 6000ms, TE: 240ms, matrix:256x256, FoV:140x140mm, slice thickness: 0.5mm, slice distance: 1mm, α=120° Ref. Amplitude = 310V (180°). Using an extra-long RF-shield as a wave guide, to avoid coupling between the antenna and the subject, the travelling-wave excitation opens the potential to act as an efficient body-coil under UHF conditions.

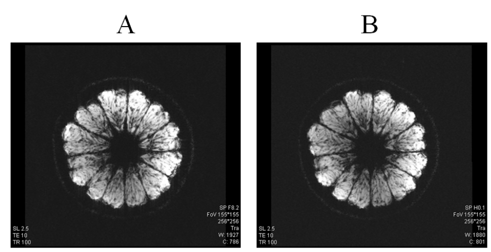

Fig 3: **A)** MRI of an grapefruit acquired with Dual Helmholtz CP coil (Tx) and 12-ch. phased array coil (Rx) **B)** MRI of an grapefruit acquired with patch antenna (Tx) and 12-ch. phased array coil Sequence Parameters: GRE with TR: 100ms, TE: 10ms, matrix: 256x256, slice thickness: 2.5mm, slice distance: 1mm, FoV: 155x155mm

CONCLUSION

To apply the travelling-wave concept to act as an efficient body-coil some limitations need to be solved. The limited RF-power at standard 7T whole body MRI-Systems is 8 kW peak power in comparison to 25 kW peak power which are required for an internal 3T body-coil. 7T Radio Frequency Power Amplifier (RFPA) are much more expensive instead of 3T RFPA . In the present state the travelling-wave concept is capable to work as a body-coil at 7T for primates and opens the possibility to use only phased array coil for receive which increases the freedom for the stimulation in primate fMRI widely.

REFERENCES

[1] Brunner, D.O., Pruessmann, K. et al., 2009, Nature, vol. 457, p. 994-998 [2] Roemer, P.B., Edelstein, W.A.,Hayes, C.E., Souza, S.P.& Mueller, O.M. The NMR phased array. Magn. Reson. Med. 16, 192–225(1990) [3] CST: Field Simulation Software: CST MICROWAVE STUDIO 2010. http://www.cst.com [4] Vaughan JT, Adriany G, Snyder CJ, Tian J, Thiel T, et al. (2004) Efficient high-frequency body coil for high-field MRI. Magn Reson Med 52: 851-859. [5] Alt S., Mueller M. et al.: Targeted travelling wave MRI using a coaxial waveguide. ISMRM 2010;

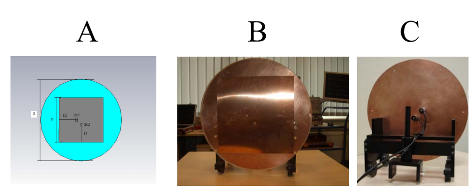

Fig 4: Designed patch antenna **A)** Simulation model [3] **B)** front side of the constructed prototype **C)** back side of the constructed patch antenna

ACKNOWLEDGEMENTS

This work was supported by a grant of Saxony-Anhalt (Germany) (PJ-Nr. 507 support code: 3802208) and the Federal Ministry of Education and Research (Germany)