Simulation and Construction of a Modified Turnstile Dipole Tx Antenna for Whole Body 7T MRI with an Extended Gradient Coil RF-shield of 1.58 m Length

T. Herrmann[1], J. Mallow[1], J. Stadler[2], O. Speck[3], M. Kladeck[3], and J. Bernarding[1]

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

Introduction:

MRI at ultra high field (UHF) requires different Tx-coils for excitation of different body parts since the construction of one large body coil similar to those at lower fields is difficult. Moreover, at 7T B1 is inhomogeneous as the RF-wave length within the object is smaller than the object extensions. A new method, the travelling wave concept **[1]**, offers the potential to overcome some of these restrictions: In RF-coils the usable B1-field is restricted to dimensions and geometry of the RF-coil itself, except the RF-coil is considered as RF-resonator which can go beyond this restriction **[4]**, contrary to this in the travelling wave concept the usable B1-field is restricted to the dimensions of the waveguide (RF-shield) only. While standard transmit coils at 7T excite rather small volumes, the MR travelling wave concept allows exciting large volumes depending on the length of the RF-shield. For an antenna with a frequency of 297MHz the approximate wavelength is about 1m. Thus the RF-shield of the gradient coil (**Fig. 1)** with a diameter of 64cm can be used as a waveguide. As our system has an extended gradient RF-shield with a length of 1.58m the travelling wave concept has the potential to work as a whole body coil. This study evaluates the use as an efficient body coil replacement in the future.

Methods:

All measurements were performed on a 7T Siemens whole body scanner (Siemens, Erlangen, Germany). When 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 in the RF-shield of the 7T Siemens whole body scanner in compare to the 7T Phillips Achieva whole body scanner **[1]** is an advantage. Thus, the wave propagates through the whole RF-shield without damping. The cut-off frequency decreases if the relative permittivity inside the bore increases. A modified mid-fed turnstile dipole antenna (**Fig. 2**) was designed and constructed by using field simulation software **[3]**. The antenna has a length of 47cm according to the velocity factor and produces a circularly polarized B1-field to achieve high excitation efficiency. The complete MRI scanner-system was simulated after designing a CAD model to analyze the behaviour of the transmitted field under different conditions e.g. different positions of the antenna. The simulations were evaluated by performing several experiments, where the antenna was used for transmitting and receiving. In additional experiments, the antenna was only used to transmit RF-power while a 12-ch. phased array Rx coil **[2]** and a surface Rx coil were used for signal reception. To increase the directional characteristics of the turnstile dipole antenna, an RF-reflector was placed behind the antenna to excite a 180° flip angle with lower transmit voltage. Sequence Parameters: (**Fig. 3**) GRE sequence TR: 2000ms, TE: 4.52ms, matrix: 256x256, slice thickness: 1mm, slice distance: 1mm, FoV: 90x90mm; (**Fig 4**) GRE sequence TR: 2180ms, TE: 4.52ms, matrix: 256x256, slice thickness: 1mm, slice distance: 1mm, FoV: 90x90mm.

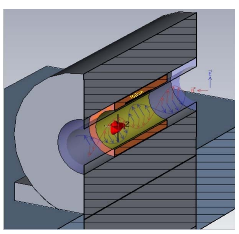

Fig. 1 CAD simulation model of the MRI System with turnstile dipole Tx antenna

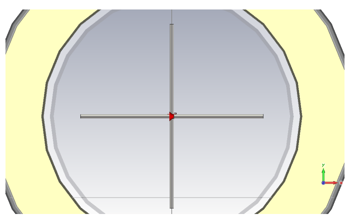

Fig. 2 Enlarged CAD Model of the turnstile dipole Tx antenna

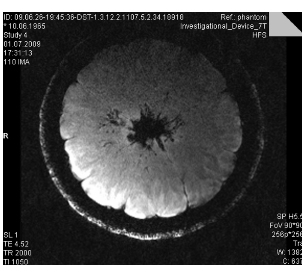

Fig. 3 MRI of an orange acquired with Dual Helmholtz Coil (Tx) and 12-ch. phased array coil (Rx)

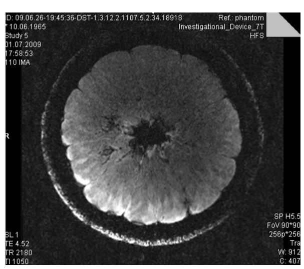

Fig. 4 MRI of an orange acquired with antenna (Tx) and 12-ch. phased array coil (Rx)

Results and conclusion:

The field simulation software allowed optimizing the directivity of the turnstile dipole antenna inside the MRI system. **(Fig. 4)** shows that the excitation by the modified turnstile dipole is more homogeneous than by the Dual Helmholtz CP Coil (Tx) **(Fig. 3)**. The 12-ch. phased array RF-coil (Rx) results in residual inhomogeneities. Of course the turnstile dipole antenna can be used for signal reception, but the signal-to-noise (SNR) is rather low since B1-filling factor for the turnstile dipole antenna is insufficient for small objects like a orange **(Fig. 4)**. Using the turnstile dipole antenna as Tx and a phased array RF-coil for Rx the highest SNR can be achieved under Travelling Wave conditions because the B1-filling factor for phased array RF-coil is much better. The application of an RF-reflector placed behind the antenna lowered the required transmission voltage by approx. 40%. Different positions of the antenna were tested. Best results were achieved by positioning the antenna at the entrance of the RF-shield of the gradient coil (**Fig. 1**). Using an extra-long RF-shield as a wave guide, the travelling wave excitation opens the potential to act as an efficient body coil under UHF conditions. However the remaining problems of exposing sensitive body parts, such as the human head by increased SAR needs to be solved.

Supported by Saxony-Anhalt (Germany) Grant

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 2009. http://www.cst.com
[4] Vaughan, J.T. et al: Whole-body imaging at 7T: Preliminary results. Magn. Reson. Med. 61, 244–248(2008);