Feasibility numerical study of the travelling wave MRI at 3T

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Introduction. The travelling wave magnetic resonance imaging (twMRI) approach has been proved successful at 3T [1] and 7T [2] for large magnet bores. However, there is still some controversy regarding the feasibility of the twMRI being able to generate images a lower frequency than 300 MHz. To study this, we chose the parallel-plate waveguide (PPWG) because it is able to propagate any frequency for the principal mode, and its cut-off frequency is zero. Then, the PPWG Poynting vector fields with a human phantom and the magnetic fields for the principal mode were numerically computed at 3T.

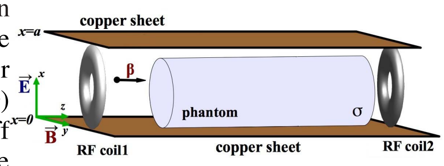

Figure 1. PPWV simulation setup of B1.

Material and Methods. The PPWG allows us to easily compute the transverse electromagnetic (TEM) mode due to its simple design. To investigate how the energy flow in the waveguide, Poynting vector fields were computed for two cases: a) PPWG and one RF coil and, b) only one RF coil and no waveguide, see Fig. 2. The RF coil was used in the transmission mode only for both simulations. Also, the principal mode, TM_0 with propagation along the *z*-direction as in [3] was computed for both the empty and cylindrical phantom-filled PPWG cases. The cylindrical phantom was 30 cm in diameter and 40 cm long with σ =73.16. Magnetic field simulations were also calculated for a pair of circular coils and the PPWG: one coil was used for transmission and the other one for reception. The RF coils are shown in Fig. 1: the left coil was used for transmission of the RF signal and the right one was used for reception only. These computations included a simulated human phantom, built using the COMSOL graphical interface. It was assumed that the relative permittivities for the bone and muscle were 15 and 65 respectively. The finite element method was used to numerically compute all electromagnetic parameters, using COMSOL MULTIPHYSICS (COMSOL, Burlington, MA, USA) at 128 MHz (3T for protons). The PPWG was 100cm long and 50cm wide, and $\mu=4\pi \times 10^{-7}$ H/m, $\varepsilon_0 = 1\text{x}10^{-9} /36\pi$ F/m.

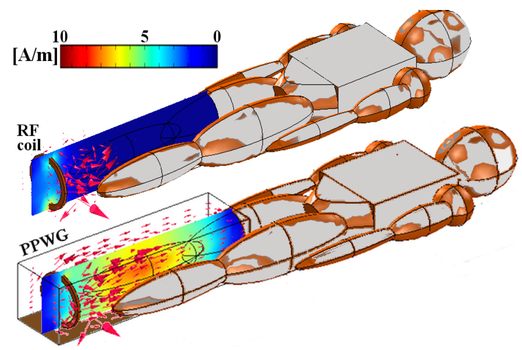

Fig. 2. Poynting vector simulations: top) RF coil only and b) RF coil plus PPWV.

Results and Discussion. The numerical simulations of Poynting vector fields for both cases are shown in Fig. 2. These numerical simulations showed that the energy flow in the direction parallel to the waveguide plates and inside the waveguide. A larger field-of-view can be covered in comparison with the simulation using only the RF coil. These numerical results indicate that the RF signal can propagate inside a waveguide filled with a phantom mimicking a human leg and, showing that the RF field is able to reach a greater volume. The PPWG magnetic field simulations of the principal mode were also computed and shown in Fig. 3. As expected, the magnetic field patterns of both cases are clearly different. The PPWG with the phantom inside generates a pretty similar pattern as reported by other groups at different resonant frequencies [4-5], while the empty PPWG has an expected standing wave pattern. These numerical results together with the experimental evidence reported in [3] reveal that twMRI is possible at 3 Tesla. The interaction of the RF energy and the phantom requires a much deeper analysis to reveal the physics involved in these phenomena.

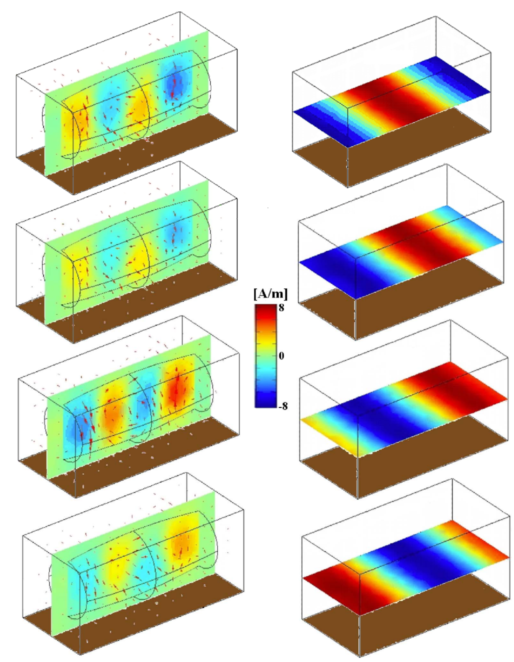

Fig. 3. PPWV B1 of TEM with phantom (left) and no phantom (right).

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References. 1. Vazquez F, et.al. ISMRM-ESMRMB, 6484, 2010. 2. Brunner DO, et.al. Nature 457, 994, 2009. 3. Vazquez F, et.al. ISMRM, 1908, 2011. 4. D. Brenner, et.al. ISMRM, 1907, 2011. 5. B. Zhang, et.al. Magn Reson Med. 67, 1183, 2012.