# An advantageous combination of travelling wave and local receive for spine MR imaging at 7T: local SAR reduction and SENSE reconstruction

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**Introduction:** Spine is an elongated superficial structure containing a lot of fine details. Therefore, ultra high field spine MR imaging will be beneficial due to the SNR gain from a higher magnetic field strength. Furthermore, the mostly superficial location of the spine would make sufficient RF penetration realizable which is often a problematic issue at high fields. Recently developed high field RF techniques for body imaging mostly involve the use of dedicated transcieve coil array. However, positioning a transmission coil close to the human tissue causes inevitably local high SAR deposition in the tissue in close proximity to the coil and $B_1^+$ performance is restricted by RF safety considerations [1]. Moreover, by combining transmit and receive in one coil, design compromises are inevitable. In addition to a local transmit concept, the novel technique of travelling wave RF excitation has been proposed for spine imaging [2]. This technique uses a patch antenna placed in the beginning of the bore of an MR scanner to transmit and receive RF signal. The distant location of the antenna from the body together with the patient conductive shielding prevents the exposure of human tissue to high peak electric fields (high local SAR values). A downside of travelling wave is the reduced receive sensitivity due to attenuation of the $B_1^-$ fields and the fact that the antenna sees a large volume leading to higher sample noise. These considerations have led us to explore a concept consisting of travelling wave for RF excitation combined with local receive by a dedicated spine array coil. In our work we demonstrate the feasibility of such concept for lumbar spine imaging at 7T.

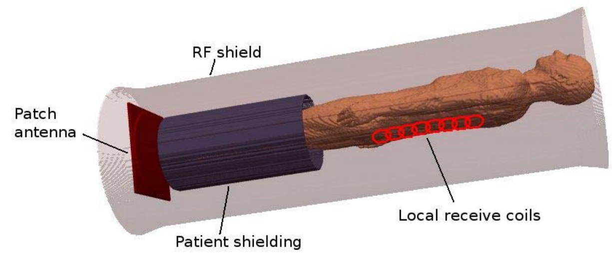


*Figure 1. The volunteer is placed in the bore with his covered feet in front of the patch antenna. The legs are covered with the conductive shielding to prevent power losses in the legs. Eight overlapping receive coils are placed at his back.*

**Methods and Materials:** To compare RF safety and $B_1^+$ field distribution of the travelling wave and one local transmit coil for spine imaging FDTD simulations were performed using a male adult model from the Virtual Family [3]. For an in-vivo experiment the patch antenna was placed in front of the feet of a male healthy volunteer in the bore of a 7T whole body MR scanner (Philips Medical Systems). To prevent power dissipation in legs they were covered with a thin conductive shield. For local receive a home-designed array of eight overlapping loop coils was placed on the back of the volunteer (Figure 1). The receive coils were detuned with PIN diodes during transmission. Fast field echo images were obtained (FFE 3D, TR/TE 22/3.3 ms, ACQ voxel 1/1/3 mm$^3$). To have an optimal combination of all the receive channels images were reconstructed with SENSE factor of 1. For this purpose all the receive sensitivities were mapped using the travelling wave in Tx/Rx as a homogeneous reference.

**Results and Discussion:** Figure 2 illustrates the computed sagittal $B_1^+$ and SAR distributions in the human torso with the travelling wave and local coil excitation. The travelling wave has relatively homogeneous RF coverage of the human torso comparing with the rapid decay of $B_1^+$ field with the distance of the local transmitting coil. Also SAR values are distributed more homogeneously using travelling wave excitation and it prevents high local SAR values at the back of the patient. In-vivo GRE images of lumbar spine are present in figure 3. Images show a large field of view of the travelling wave excitation. A significant improvement of the image quality can be achieved by using SENSE reconstruction which is possible with a travelling wave reference scan.

**Conclusions:** We have shown that spine imaging at ultra high fields with the combination of the travelling wave and local receive coils has three benefits: 1) low local SAR values, 2) high receive sensitivity due to local receive and 3) available reference scan for optimal signal reconstruction (SENSE).

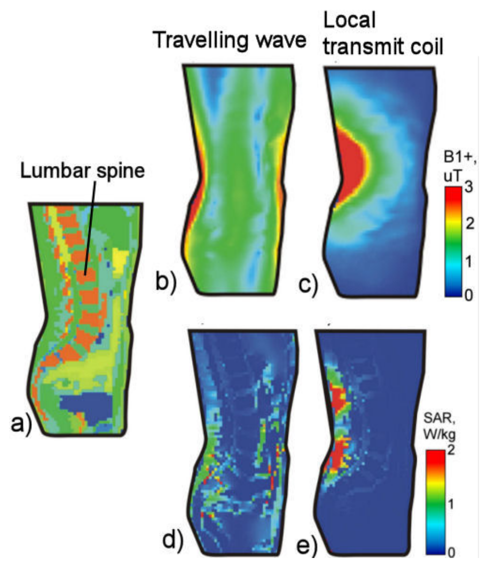


*Figure 2. a) Simulated anatomy, FDTD simulated $B_1^+$ distributions with b) travelling wave excitation and c) local transmit coil for the same amount of power delivered to the antennas ports, computed SAR distributions in the human torso with d) travelling wave excitation and e) local transmit coil. Local peak SAR (FA 20° in the lumbar spine region, pulse length 1 ms, duty cycle 0.05) averaged over 1 cm$^3$: d) 4.5 W/kg and e) 11 W/kg.*

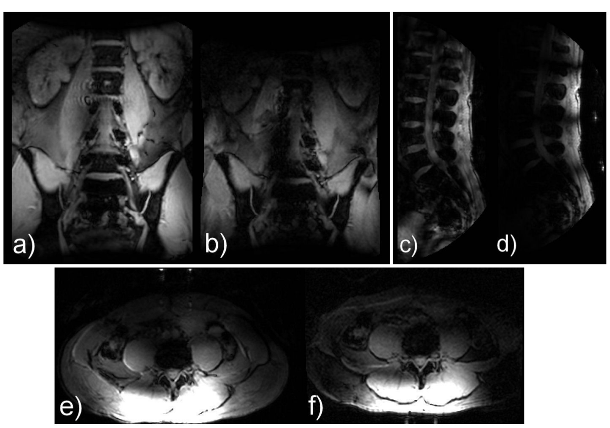


*Figure 3. GRE in-vivo images of the abdomen obtained with the travelling wave excitation and local receive coils. Images a),c),e) were post-processed with the SENSE reconstruction and b),d),f) without the reconstruction.*

**References:** [1] O. Kraff et al., “An Eight-Channel Phased Array RF Coil for Spine MR Imaging at 7 T”, Investigative Radiology, Vol. 44, #11, 734-740**;** [2] A. Andreychenko et al., “Effective delivery of the traveling wave to distant locations in the body at 7T”, 17th ISMRM, 2009; [3] A. Christ et al., "The Virtual Family – Development of anatomical CAD models of two adults and two children for dosimetric simulations”, in preparation.