Traveling Wave Imaging of the Human Head at 7 Tesla: Assessment of SNR, Homogeneity and B1+ Efficiency

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Introduction: The traveling wave concept for 7T MR imaging was first demonstrated by Brunner et al [1]. In the most common RF transmit coil designs, a quadrature RF field is created within a cylindrical volume in the near-field regime. In contrast, the traveling wave approach creates a traveling wave mode down the entire bore of the scanner. This has the potential to provide more uniform excitation and whole body imaging, though reflections at dielectric boundaries such as between air and tissue typically create non-uniform excitations in large volumes even with the traveling wave system. We have constructed a traveling wave system based on a patch antenna and have assessed its performance for human head imaging, including homogeneity, B_1^+ efficiency and calibrated SNR comparisons to a CP head coil.

Methods: A circular patch antenna was used for excitation and reception. The patch antenna consists of a square slab of 32mm thick acrylic (www.mcmaster.com) 400mm on a side. The back side is covered with self adhesive copper foil (3M St. Paul MN) to form a ground plane, and a 348mm diameter circular patch of copper foil is applied to the front side. 0 and 90 degree feed points are created 75mm from the center of the patch by drilling holes through the substrate and attaching the shield of an RG58 coax to the ground plane and the central conductor of the coax to the circular patch. RF power is split equally with a Wilkinson divider and phase between the two driving ports is controlled through cable length. One T/R switch and preamp assembly is used in each line (Stark Contrast, Erlangen Germany), and the signal from each port is recorded separately and the reconstructed images are combined as the sum of squares. The patch antenna was compared to a CP head coil (Invivo Corp, Gainesville FL) with 270mm diameter and 150mm length. Power deposition for the patch antenna was measured using a large rectangular gelatin phantom with physiological saline concentration (350 x 230 x 90mm dimensions) with a fluoroptic probe (Luxtron, Santa Clara CA) and an infrared thermometer (Fluke, Everett WA). Simulations were performed in XFDTD (Remcom, State College PA) to determine SAR distribution and radiative losses. Human images were acquired with a 2D GRE (TR/TE/Flip = 100/5/20, Slice=3mm, BW=300, 256x256, FoV 500mm and 280mm). B_1+ was mapped in a coronal plane passing through the brightest part of the image for both the patch antenna and CP head coil by taking a series of 2D GRE images at a number of different RF pulse amplitudes (TR/TE = 1000/5, Slice=3mm, 64x64, FoV=200mm, BW=180). Based on the B1+ measure, SNR maps were obtained by taking a 2D GRE with RF pulse magnitude set to provide equal excitation at the brightest central region of the head for each coil (TR/TE/Flip = 200/4.07/50deg, 128x128, FoV 220x220mm, BW=300) and an additional scan with no RF excitation to provide noise statistics. All images were obtained on a Siemens 7 Tesla scanner (Siemens Healthcare, Erlangen, Germany).

Results: S11 for each port was -18dB unloaded and -21db loaded. S12 isolation was <-22dB in either case. Based on the temperature measurements and SAR simulations coil file parameters were chosen to limit power deposition in the subject to safe levels. It was not possible to obtain a scanner transmitter reference calibration, so the reference value was set to 425volts. It appeared that close to 800 volts would be required for normal scanner transmit calibration. Sagittal GRE images with the patch antenna and CP head coil are shown in Figure 1. The homogeneity of the signal in the head was subject dependent, but always showed the highest intensity in the brain stem, whereas the brightest region in the CP head coil images is typically more superior in the region of the Thalamus. Significant levels are signal are also picked up from the shoulders and torso with the patch antenna. With the brightest region more inferior in the patch antenna images, very homogeneous axial images were obtained throughout the whole brain (Figure 2). Image homogeneity, measured as the SD/Mean for the whole brain, was .17 for the patch antenna and .24 for the CP head coil in an axial slice just above the corpus callosum. The peak B_1^+ value in the head for the patch antenna was approximately ½ that for the CP head coil. SNR maps using excitations calibrated from the B_1^+ measures are shown in Figure 3, and profiles through the axial maps are shown in Figure 4. The SNR provided by the patch antenna averages about 1/3 that of the CP head coil, a result which is not surprising since the patch antenna is exciting a large portion of the body and hence is more analogous to a body coil than an head coil.

Conclusions: The signal distribution in head images obtained with the patch antenna traveling wave system show a fundamentally different distribution than typical CP head coils. While the patch antenna does not provide uniformity overall, in axial slices it can provide a more uniform image than the CP head coil. This uniformity is however subject dependent, but can be modified through the application of dielectric pads to the head. The low SNR of the receive images suggests that the primary potential application of the traveling wave concept would be for excitation, with local surface coils used for receive. It is hoped that further technical development can improve the transmit efficiency of the method. While the traveling wave approach does not automatically provide uniform excitation, it exhibits significantly different excitation patterns compared to existing transmit coils and provides an exciting new opportunity for manipulating B_1^+ at high field.

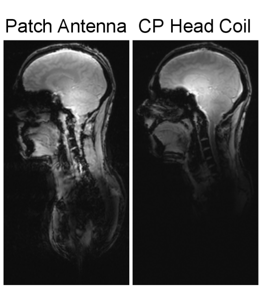

Fig. 1 Sagittal GRE images

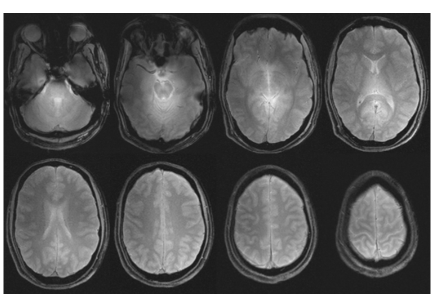

Fig. 2. Axial GRE images obtained with the patch antenna in T/R mode showing remarkable homogeneity

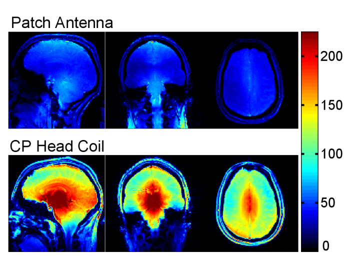

Fig. 3. SNR for the patch antenna and CP head coil

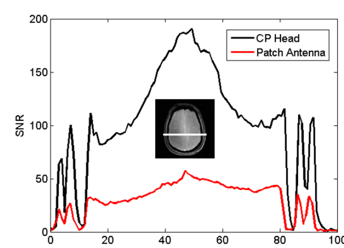

Fig. 4. SNR profiles through an axial slice for the patch antenna and CP head coil

[1] Brunner et al "Travelling wave MR on a whole-body system", 16th ISMRM, Toronto 2008 p434