A Comparison of a Patch Antenna to an End-fire Helix Antenna for use in Travelling Wave MRI

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Introduction Travelling wave (TW) MRI is a relatively new imaging technique. An antenna is used to generate a TW which then propagates through the bore. This excites all the spins in the subject, allowing large volumes to be imaged simultaneously and reducing B_1 field inhomogeneities. So far, most TW studies have used a patch antenna to create the TW, as they are simple in design and can be constructed rapidly at little cost. In this study, the performance of an end-fire helix antenna is compared to the performance of a patch antenna. Simulations are used to asses specific absorption rates (SAR) and experimental data are used to assess the signal to noise ratio (SNR) and B_1 homogeneity of both antennas.

Methods Simulations were run using XFDTD Bio Pro (Remcom Inc.). In all simulations the magnet bore was represented by a 2m long hollow conducting cylinder, with inner radius of 290mm and an outer radius of 300mm. A standard body model was loaded into the simulations with the head in the centre of the bore as needed. The antennas were placed within the bore and were driven by 1A, 50Ω, 298MHz sinusoidal currents. XFDTD was asked to calculate the local (i.e. 10g averaged) SAR within the body. An image plane was selected within the head and the B_1 field within this plane was measured. This allowed all the simulations to be scaled so that the same B_1 (10μT) was being generated in each simulation in the desired image plane. Simulations (see figure 1 for geometries) were performed to measure the maximum local SAR induced in the body by the patch antenna and end-fire helix antenna. The average SAR within the body and local SAR fields in the ZX plane were also recorded. A patch antenna was constructed using copper and Perspex. The transmission plate diameter was 367mm and the Perspex was 11mm thick. The patch antenna has two orthogonal driving ports, allowing it to be driven in quadrature and thus produce a circularly polarised TW. The patch antenna was tuned to 296MHz and had a quality factor of 14. The end-fire helix antenna was formed from 4mm diameter copper rod, bent into a helix shape (180mm pitch, 130mm diameter, with 3 turns) and supported on a hollow Perspex cylinder. A square (300mm X 300mm) copper plate provided a ground plane. The end-fire helix antenna only required a single driving port, located in the centre of the ground plate, as end-fire helix antennas generate circularly polarised fields due to their helical structure. The end-fire helix antenna was tuned to 300MHz and had a quality factor of 15. See figure 2 for images of the antennas. Scans were performed on a Phillips Achieva 7T system, using each antenna as both transmitter and receiver. Images were taken using a 20cm spherical loading phantom. Transverse slices were taken through the centre of the phantom to allow the relative SNR's of the TW antennas to be measured. B_1 maps were also taken to allow homogeneity from both TW antennas to be assessed.

Results Figure 3 shows the simulated local SAR generated by each antenna. Both antennas produce similar SAR patterns in the upper body, with the patch antenna producing slightly less SAR in the legs compared to the end-fire helix antenna. Figure 4 is a series of images taken by both antennas, with their corresponding SNR values, as well as images taken using the Phillips head volume coil (used for both transmit and receive). The patch antenna produced better SNR than the end-fire helix in all cases. See figure 5 for comparable B_1 maps from both TW antennas and from the Philips head volume coil. The patch antenna generates much better B_1 homogeneity than the end-fire helix antenna, but neither TW antenna produces a homogenous region as uniform as the head coil.

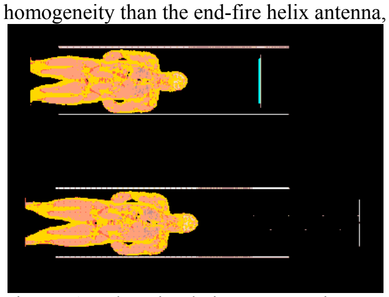

Figure 1: The simulation geometries. Top: patch antenna, bottom: end-fire helix antenna.

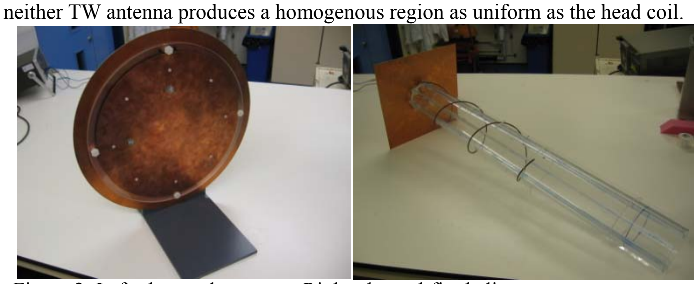

Figure 2: Left: the patch antenna. Right: the end-fire helix antenna.

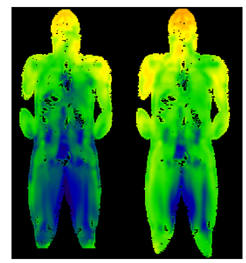

Figure 3: Local SAR fields, all with the same full scale value. Left: patch antenna, right: end-fire helix antenna.

Conclusions Although the SAR performances of each antenna were similar, the SNR and B_1 homogeneity of the patch antenna were better than those of the end-fire helix antenna. It is also much easier to construct and modify the patch antenna than the end-fire helix antenna. The patch antenna only requires its radius or the dielectric thickness to be changed in order to adjust the tuning, whereas the end-fire helix has its pitch, radius and number of turns which are all variables in its tuning. Though it may be possible to improve the performance of the end-fire helix antenna through fine tuning the design, the patch antenna can achieve better images with much less effort and therefore it is more practical to use a patch antenna rather than an end-fire helix for TW studies.

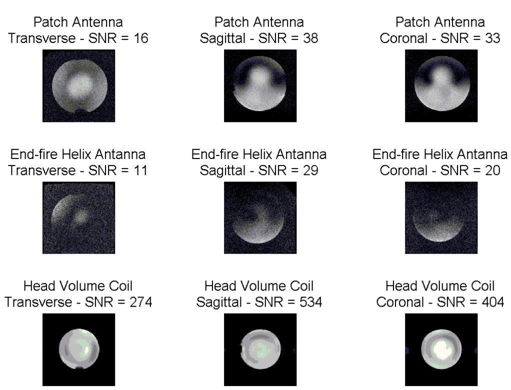

Figure 4: Scanner images and their SNR values. $B_1 = 4\mu T$, flip angle = 90°.

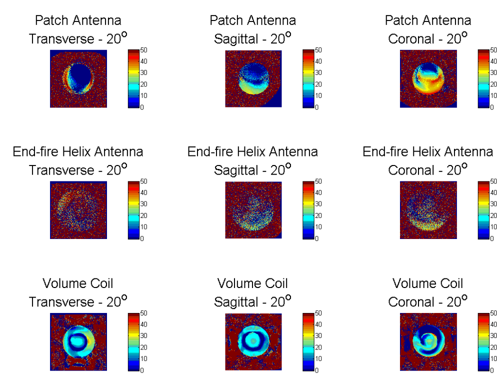

Figure 5: B_1 maps. The requested FA was 20°. FA's above 50° were removed to allow fluctuations about 20° to be seen more easily.