A Travelling Wave Antenna with Matched Waveguide for Head Imaging at 7 T

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Target Audience Researchers working in hardware development and ultra-high field users.

Purpose The travelling wave (TW) approach[1] to MRI involves using an antenna to propagate a TW through the bore of a 7T (or stronger) scanner. It is this wave that excites the spins which are then used to acquire the MRI image. This approach leads to an improvement in B_1^+ homogeneity as the incident wave has a uniform magnitude. However, the TW approach is relatively inefficient at delivering power to the volume of interest (VOI) due to impedance mismatches between the antenna and VOI. By using a waveguide to match the incident wave into the head, these mismatches can be reduced and a stronger B_1^+ can be generated in the VOI. Such a setup has been simulated using SEMCAD X[2, 3] and has been constructed and tested in the scanner.

Methods Simulations were performed using SEMCAD X and the virtual family[4]. The geometry is shown in Figure 1. B_1^+ and SAR maps were extracted from the simulations in order to satisfy safety criteria for *in vivo* scanning. The matched waveguide was constructed in two separate parts to facilitate ease of transportation. The screened section (corresponding to the blue simulated region) is formed from a PTFE tube, has a detachable end plate with N-type socket panel mountings to allow access to the dipole and stubs, and is screened by alternating layers of copper and dielectric tapes. The second section (corresponding to the green simulated region) is formed from hollowed out PTFE sections and has four receiver elements built around the rim of the head cavity (see Figure 2). Both halves of the waveguide were held on a base which supported their weight, kept the halves together and allowed for easy positioning on the scanner bed. The dipole was formed from 2 mm copper wire, while the stubs were formed from 2 mm copper wire with a 90° bend approximately 5 cm down the stubs length. Fine tuning and matching of the stubs could be achieved by altering the length of the stubs and the angle of the bend. The dipole and stubs were insulated from the water in the waveguide using heat shrink and small amounts of epoxy resin. The receiver elements were formed from 9 mm wide copper tape in 7 cm by 7cm square shapes. The elements were spaced 6 cm apart to minimize coupling, and were also decoupled via low-impedance pre-amplifiers. All four receivers were tuned to 298 MHz and matched to (47-51) + i (-1-+2) Ω. Scans were performed on a Philips Achieva 7T scanner. Ethical approval was obtained for *in vivo* scanning.

Results/Discussion Figure 3 shows axial images obtained using different transmission elements in the waveguide. Based upon these excitation profiles it was determined that the best homogeneity would be achieved using stub 2 with either stub 1 or stub 3. Since stubs 2 and 3 were placed at the same radius in the waveguide and therefore theoretically stimulate orthogonal modes, they were chosen for subsequent *in vivo* imaging. Figure 4 shows a typical *in vivo* image achieved using the matched waveguide. The signal produced by the water in the waveguide can cause wrapping artefacts as well as scaling problems. These can be overcome (in the short-term) by carefully selecting the image field of view and by masking the image (as shown in Figure 5). The resulting signal-to-noise ratio (295) is much better than values obtained using a patch antenna or helix (typically 30 to 40)[5], though it should be noted that these values were not obtained in an identical fashion.

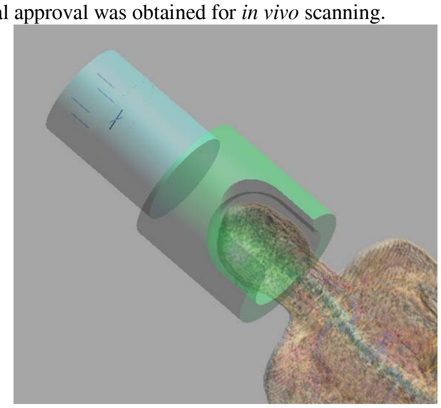

Figure 1 – simulation geometry. The blue region is screened while the green is not. Both contain water.

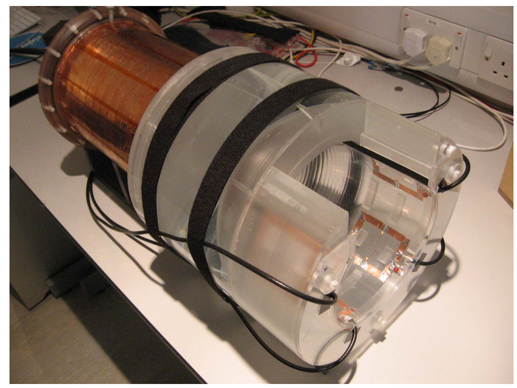

Figure 2 – The fully assembled waveguide. The four receive elements can be seen in the bottom-right of the image.

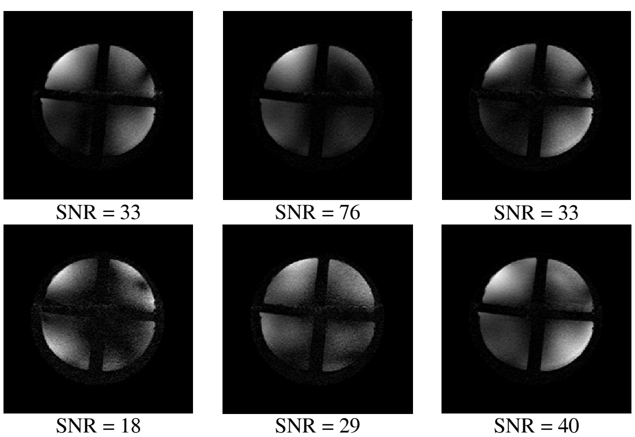

Figure 3 – Excitation profiles. Top-left: Stub 1. Top-centre: Stub 2. Top-right: Stub 3. Bottom-left: Stub 4. Bottom-centre: Dipole. Bottom-right: Stubs 2 & 3 together. All images are identical TFE protocols and have had signal from the waveguide masked out.

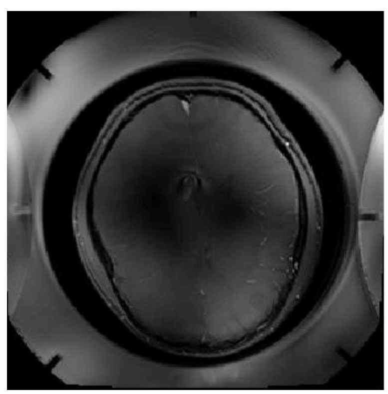

Figure 4 – Axial TFE image. Flip angle 70°. TR/TE = 3.7/1.4 ms. 1 x 1 x 6 mm. 32 averages.

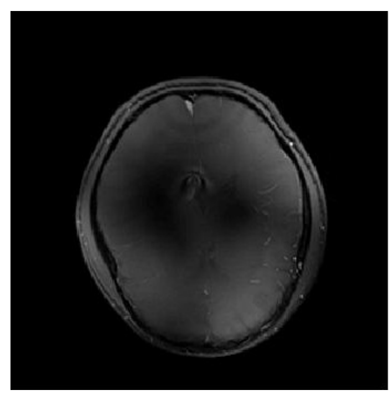

Figure 5 – The same image is in Figure 3 but with signal from the waveguide masked out. SNR = 295.

Conclusion This work has demonstrated that the matched waveguide can achieve good image quality. This could be improved further by employing the waveguide in a multi-transmit configuration, allowing B_1^+ shimming. From Figure 3 it seems reasonable to assume a combination of stubs 3 and 4 would produce homogeneous coverage, for example. Additionally, signal generated by the water in the waveguide can be easily removed by replacing the water with D_2O. This design is also compatible with the introduction of local shim coils which could be positioned in the dielectric cavity. The open front design allows for easy access with visual stimulus or breathing apparatus. **References** 1. Brunner et al., Nature 457:19, (2009). 2. SEMCAD X by SPEAG, www.speag.com. 3. Lee and Glover, Proceedings of ISMRM 2012 #2694. 4. A. Christ et al., Physics in Medicine and biology, 55 N23-N38, (2010). 5. Lee and Glover, Proceedings of ISMRM 2010 #3135.