A dipole antenna for pelvis imaging at 7T

Sedig S Farhat[1], Daniel J Lee[1], Carolyn Costigan[1], Penny A Gowland[1], and Paul M Glover[1]
[1]*University of Nottingham, Nottingham, Nottinghamshire, United Kingdom*

Background: There are many examples of surface coils that have been designed for field strengths in the range of 1.5T to 3T. However, there are few that have been designed for use at 7T which can provide high SNR and high quality images. Up until now the majority of RF coils have been designed as near field antennas. These coils produce a large magnetic field in the near field region [1]. But there is a major problem; as frequency increases the wavelength becomes shorter than the dimensions of a sample volume. This makes it difficult to generate a uniform radio frequency over a sample volume of interest. The aim of this work was to design and build a transmit/receive dipole antenna for imaging the human pelvis.

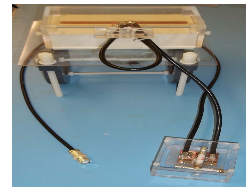

Figure 1: The dipole antenna.

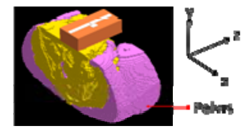

Figure 2: The dipole antenna, modelled in XFDTD

Methods: To obtain high quality images, a computational electromagnetic method XFDTD (REMCOM) was used to design and evaluate the coil. The dipole (modelled in XFDTD, see Figure 2) consisted of a dielectric ceramic (15cm x 7.3cm x 4cm, ε_r = 37), with a copper dipole mounted on top [2]. Each arm of the dipole was a quarter wavelength (6.8 cm) long so that the maximum current distributions were at the centre and nodes were at both ends. The dipole was tuned and matched to 50 ohm at 298 MHz by employing a half-wave balun and a tuning and matching circuit. The pelvis images for used for generating tissue maps were obtained from a healthy female volunteer on the Philips 3T MRI scanner using the body coil. Segmenting of the pelvis tissues was performed using ITK-SNAP software. MATLAB code was written to convert the segmentation data into the required XFDTD file format. The healthy pelvis tissue can be divided into five types; fat, muscle, uterus, bladder, and bone as shown in Figure 2. The pelvis mesh file was loaded in XFDTD and then the dielectric properties of tissues were computed at 298 MHz. On the 7T a Turbo Spin Echo sequence was used to obtain images from a healthy volunteer in the proliferative phase of her cycle with following parameters: FOV= 180x180x37 mm, voxel size 0.7x0.8x3 mm, TE/TR=520/80 ms, which used a nominal refocusing flip angle which varied from 110 to 170^o.

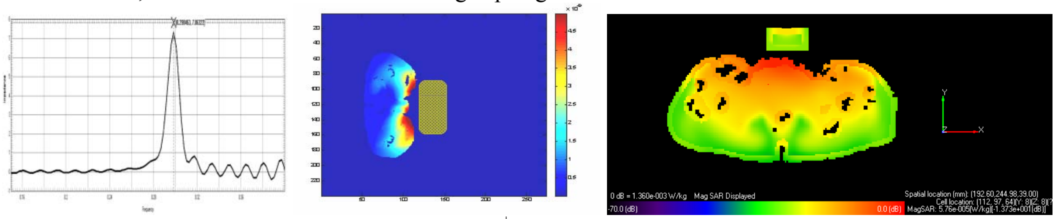

Figure 3: (Left) Impedance vs. frequency. (Centre) B_1^+ map for the dipole antenna. (Right) The SAR distribution.

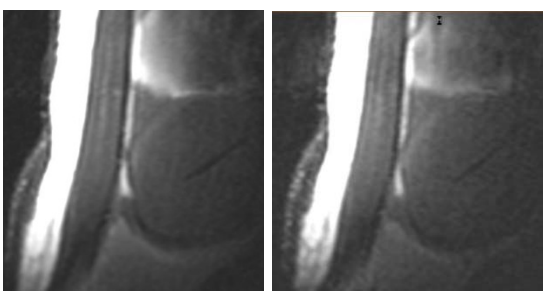

Figure 4 Sagittal pelvic images taken using the dipole antenna, (left) at 160 degrees and (right) for a 135 degree nominal refocusing pulse

Results: Figure 3 shows the results of the simulation for the SAR distribution in the human pelvis. The maximum 10g average SAR/$(B_1^+)^2$ ratio were computed in XFDTD and found to be 0.645 W Kg^{-1} μT^{-2}. It can be noted that the dipole antenna provides us with very good image quality and contrast at sub-millimetre resolution as shown in figure 4. It can be seen that the dipole covers both near field and far field regions where the energy is flowing away from the dipole and the electromagnetic energy propagates into the pelvis. The structure of the subject shows skin, fat, muscles and myometrium and endometrium of uterus. The sequence is surprisingly robust to the variation in B1 across the field of view, but further work is required to improve the refocusing pulse and improve image contrast.

Conclusions: The dipole antenna shows the desired improvement in SNR and homogeneous coverage as shown in figure 4. Coverage goes much further into the pelvis than is shown in the image, indicating that the dipole antenna is better suited for imaging structures deeper into the body than loop or strip transmitting elements.

References: [1] Roemer P. B., W. A. Edelstein, C. E. Hayes, S. P. Souza. *The NMR Phased Array*. Magnetic Resonance in Medicine, Vols. 16, 192-225, 1990. [2] A. Raaijmakers, High field imaging at low SAR: Tx/Rx prostate coil array using radiative elements for efficient antenna –patient power transfer. ISMRM 2010 proceedings.