First results experimental thin rectal probe for high field MRI
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Introduction
In 7 Tesla MRI the Larmor frequency is close to 300 MHz. At this frequency the penetration depth in muscle tissue is only 56 mm. For good SNR and high B1+ efficiency it is therefore desirable to insert antennas into the body, close to the object to be imaged. Fortunately at 300 MHz, the wavelength in muscle tissue is only 120 mm. This implies that short electrical dipoles and monopoles can act as efficient antennas. This kind of antennas can be constructed with a much smaller diameter than conventional loop antennas, which allows insertion in a narrow and/or vulnerable lumen, like a cancer affected rectum.

Methods
The outer isolation and outer shield of a coaxial cable (RG223) was removed over a length of 300 mm, on the last 60 mm the inner shield was also removed, leaving the insulator and central conductor. This coaxial assembly was inserted in a Rüsch #18 ballooncatheter, resulting in an antenna with an outer diameter of 6 mm. The antenna was tuned and matched with a CLC π-network. An agar block of 160*160*60 mm with 2 g/l NaCl was used as phantom, the antenna was inserted centrally (figure 1). Using the coaxial assembly as transmit and receive antenna, a TSE scan (TR/TE 7000/120 ms) of the agar block was obtained on a Philips 7 Tesla MRI scanner. This setup was modelled in Semcad X14.4. Using the variable gridding facility of this program the coaxial assembly could be rendered with a resolution of 0.075 mm (figure 2), while maintaining an acceptable total number of voxels (193*166*170) and computation time (14 h). A thermal test was performed in a phantom with a fiberoptic thermometer attached to the antenna. Finally the antenna was rectally inserted in a healthy, male volunteer. 3D MRI was obtained with the antenna in vivo using gradient echo sequences.

Results
Figure 3 shows the central slice of the simulated B1+ map, normalised to an input power of 1 W. At this power, a B1+ of 2 uT was obtained at a distance of 20 mm from the antenna. The B1+ pattern corresponds to the black-white zones in the TSE image, reflecting full excitation versus inversion of the magnetisation caused by the varying B1+ (figure 4), confirming the validity of the simulation. With 25 W input power a B1+ of 10 uT can be obtained, sufficient for a flip angle of 90° (figure 4). Figure 5 shows the temperature rise in the phantom with 15W RF-CW applied to the antenna. Figures 6 and 7 show transverse and sagittal images obtained in the volunteer, reflecting a relatively large field of view.

Conclusion
A thin coaxial antenna is suitable for minimally invasive imaging of the rectum. With a peak power of 25 W a B1+ of 10 uT can be achieved at a distance of 20 mm. The average power should be kept below 10 W to avoid SAR problems. Even though the transmit field was very non-uniform, in vivo images demonstrate the ability of the antenna to obtain detailed anatomic information in the rectal area.

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References