A large volume HEM dielectric resonator for musculoskeletal applications at ultra high field

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Target Audience. MRI coil designers, researchers working in high field musculoskeletal magnetic resonance.

Purpose. To design an efficient dielectric resonator for imaging the human knee at high fields (7 Tesla and above).

Introduction. Although most resonators for MRI are made from multiple conductive elements with appropriate lumped elements for tuning to the correct frequency, there is increasing interest in the use of high permittivity cavity, waveguide and dielectric resonators [1-4], which are particularly suited for high field applications. Rather than approximating the desired current distribution by a series of conductive elements, cavity or dielectric resonators have a continuous current distribution and therefore need no lumped elements for tuning.

Methods. Electromagnetic simulations were performed in CST Microwave Studio using the eigenmode solver. Based on the simulation results an annular resonator was constructed from polymethylmethacrylate with an outer diameter of 255 mm, inner diameter of 154 mm and height 89 mm. Two impedance matching segmented loops were placed at 90 degrees to one another to couple into the degenerate $HEM_{11\delta}$ modes. Images of the human knee were acquired using a three-dimensional gradient echo sequence: field-of-view 200 x 150 x 150 mm, TR/TE 10/2.9 ms, in-plane resolution 0.75 x 0.75 mm, slice thickness 2 mm, 20 degree tip angle. All experiments were performed on a whole body 7 Tesla scanner: informed consent was obtained from all volunteers, and the protocols were approved by the institutional review board.

Results. Figure 1 shows the results from the electromagnetic simulation, showing that the degenerate $HEM_{11\delta}$ modes produce quadrature magnetic fields that are perpendicular to the long axis of the annulus, as desired. A photograph shows the realization of the coil. Also displayed are a series of T1-weighted images of the knee showing excellent signal homogeneity across the entire knee, with clear visualization of, for example, the articular cartilage.

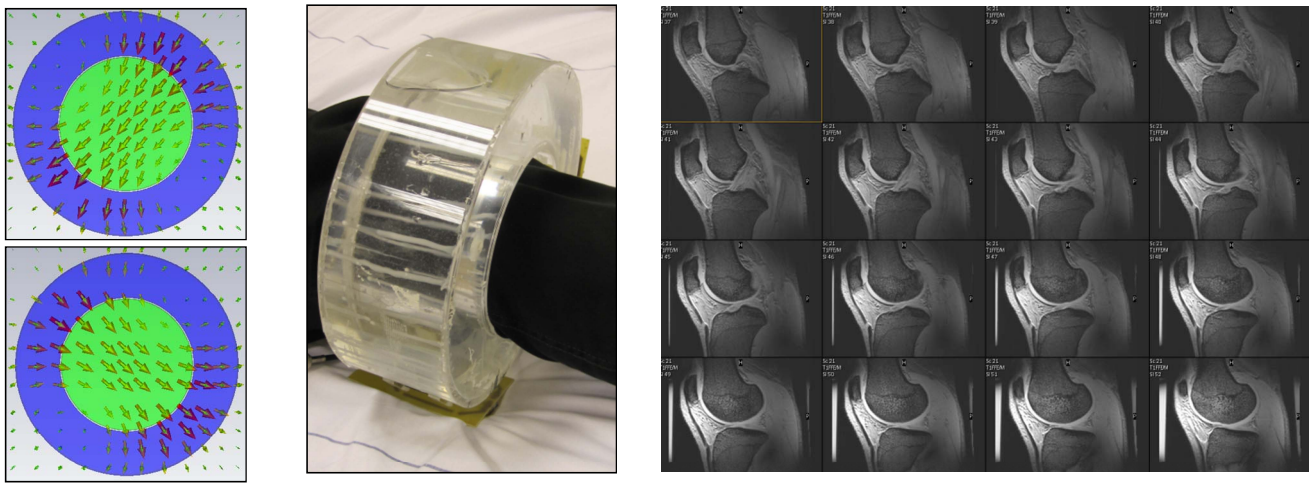

Figure 1. (left) Simulated magnetic field components corresponding to the two frequency degenerate $HEM_{11\delta}$ modes resonant at 298.1 MHz. Blue represents the outer annulus filled with water and the green is a homogenous tissue phantom assigned dielectric properties of tissue. (centre) Photograph of the assembled dielectric resonator placed around a volunteers knee. The two coupling networks can be seen underneath the resonator. (right) A subseries of adjacent slices from a three-dimensional T1-weighted imaging sequence.

Discussion and Conclusion. Dielectric resonators are a particularly attractive design for high field since the resonance frequencies of useful modes are similar to the relevant Larmor frequencies for practical dimensions. This works shows that short length-to-diameter coils with high efficiency can produce high quality images of the human knee with a very simple design.

References. [1] Brunner DO et al. 2009;457(7232):994-998. [2] Alt S et al. Magnetic Resonance in Medicine 2012;67(4):1173-1182. [3] Andreychenko A et al. Magn Reson Med doi: 10.1002/mrm.245122012. [4] Aussenhofer SA, Webb AG. Magn. Reson. Med. 68:1325-1331 (2012).