A variable diameter resonator for high field proton and sodium musculoskeletal MRI

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Target Audience. Researchers working in musculoskeletal MRI, RF coil designers.

Purpose. To design a double-tuned volume coil for sodium and proton imaging of the knee at 7 Tesla with a variable diameter to optimise the sodium imaging sensitivity for different-sized patients.

Introduction. At high field (7 T and above) local volume transmit coils are widely used for head and extremity imaging, often in transmit/receive mode. When used in patient studies, the coil must be designed with a diameter sufficient for the largest patient, meaning that sub-optimal sensitivity is achieved for smaller patients. One solution is to construct a variable diameter volume resonator. While variable sized surface coils have been presented before [1] most volume coils are fixed. Here we design a double-tuned variable diameter proton/sodium volume resonator for imaging the knee or calf muscle at 7 Tesla.

Methods. All experiments were performed using a Philips Achieva whole body 7T MRI system. The variable diameter birdcage resonator was build out of 8 hollow cylindrical copper rungs (length 14 cm, inner diameter 0.3 cm, outer diameter 0.4 cm). These are arranged in a low-pass configuration and mounted in an adjustable octagonal frame which can vary the shortest distance between two neighbouring rungs from 5 to 7 cm thus enabling an overall change of diameter of the birdcage between 13 and 18.5 cm. The endrings were made of 1.3 cm wide flexible copper-on-Kapton foil. A fixed shield (27 cm diameter, 20 cm length) was used. Variable tuning capacitors are incorporated into the rungs opposite to the feed points. Two microstrip lines (1 x 2.5 x 12 cm) tuned to 298.1 MHz were mounted inside the shield for proton imaging. The sodium birdcage was capacitively impedance matched via two variable capacitors and driven in quadrature. Each proton element as well as the birdcage drive points in both large and small configurations were matched to an S_{11} value lower than -25 dB when loaded with a human knee.

Results. Figure 1A) shows the variable birdcage coil in the small diameter configuration inside the shield : the two proton microstrip lines can also be seen. Figures 1B) and 1C) show a schematic and photograph, respectively, of the mode of mechanical operation. In vivo proton and sodium images were collected from knees of three volunteers (male and female) both in the large (Figure 1D) and small (Figure 1E) diameter configurations of the coil. Imaging parameters for both configurations: proton, TE 1.9 ms, TR 21 ms, tip angle 10^o, voxelsize 1 x 1 x 2.5 mm, duration 7.5 min : sodium TE 1.5 ms, TR 100 ms, tip angle 90^o, voxel size 2.75 x 2.75 x 2.75 mm, field-of-view 220 x 220 mm, 6 signal averages, duration 10.5 min.

Discussion. This work presents a new design for birdcage coils that allows the diameter to be varied for different patients. Although the diameter changes substantially, the impedance matching of the coil changes little (~3 MHz frequency shift) between the maximum different dimensions, and this can be easily compensated by using the variable tuning capacitors on the rungs opposite the feeding ports without unduly unbalancing the coil. The impedance matching of the proton microstrips is almost unaffected when changing the sodium birdcage diameter.

Conclusion. The variable diameter birdcage coil represents a practical approach to constructing custom RF coils for high field MRI which are required for patient studies, and which are not commercially available.

References. [1] Duensing, R, Fitzsimmons J et al. Magn Reson Med 1990; 13: 378–84.

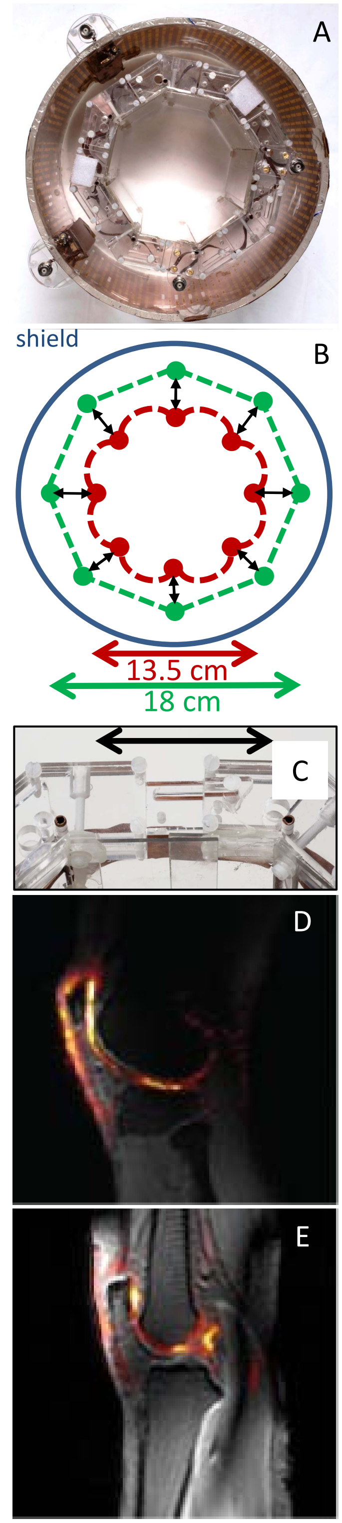

Figure 1 A) shows the variable birdcage in the small diameter configuration. B) shows the two possible configurations of the variable diameter birdcage: green is the largest possible configuration while red is the minimum open inside diameter of the coil, the shield is shown in blue. C) shows the detail of the movement mechanism: the plastic plugs can drive into one another thus allowing variable coil dimensions. D) shows an overlay of sodium and proton images of a large human knee acquired in the largest diameter configuration of the coil while E) shows data from a small human knee with the smallest diameter configuration.