A continuous capacitance loop detector for high sensitivity 7T MRI

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Introduction

Development of high magnetic field strength imaging systems at 7 Tesla pose several challenges to existing coil designs routinely used at lower fields such as element coupling, tuning, matching and cable interactions. Since coil size determines imaging depth sensitivity, this imposes a size constraint along with a fixed inductance of the coil. The inductance, in turn, determines the capacitance values needed to resonate the coil. However, capacitance values can become comparable to stray capacitance at high frequencies for a given coil size [1]. In this study we built a high sensitivity flexible continuous capacitance coil (CCC) detector array for operation at 300 Mhz without the need of commercial capacitors to tune it. We applied this receive-only 8-channel CCC array in phantom and volunteer studies. To assess coil performance, we computed SNR values and compared these results to those of a commercially available coil and by acquiring high resolution, 200 micron in plane, brain images at 7T.

Methods

The continuous capacitance coil array was developed and tested for use in a research 7T human scanner (GE Healthcare, Waukesha, WI USA). Each coil element was built from flexible, 0.64 mm thick, dual layer high frequency circuit board material with a dielectric relative permittivity of 10.2 (Rogers Corporation, Chandler, AZ, USA). Using a circuit board milling machine (T-tech, Norcross, GA, USA) each coil element was identically milled to 8.5 cm average diameter and trace width of 5 mm. On the top copper laminate, four equally distributed gaps, 1.5 mm in width were milled and an extra one 15 degrees away from an existing gap used for tapping. On the bottom surface, eight 1.5 mm gaps equally distributed around the loop were milled but shifted from the top ones by 22.5 degrees. Thus, thirteen continuous capacitors were created around the loop. A coaxial cable (RG-223) along with a seamlessly built semi-rigid ground cable trap tuned to 300Mhz (to block common mode currents) was cut to be low impedance to allow for preamp decoupling. This cable assembly was then connected to a simple 1:1 balun, which included a pin-diode for detuning, at the tapping gap of the coil. The continuous distributed capacitance coil thus created by design tuned to a frequency of 298.15 Mhz. A total of eight coil elements were reproducibly constructed in this manner without the need for further tuning. A rigid coil-housing frame was built to contour the oval shape of the head. Inside this frame a 1 mm thick high density polyethylene sheet was added with an overlapping gap left at the forehead portion of the oval for adjusting to different size heads. To minimize nearest neighbor coupling, the eight coil elements were laid, one by one, on top of the sheet while making transmission measurements using a 4 port E5070B network analyzer (Agilent Technologies, CA, USA) while adjusting coil overlap. To compare coil performance, the same transmitter and receiver preamps were used from a commercially available detunable head coil with 8ch receive (Nova Medical, Wilmington, MA, USA). SNR profiles were generated from proton density gradient echo images acquired from human volunteers using both coils. Informed consent was obtained from the volunteers. High-resolution image acquisition parameters were: GRE, TE=12, TR=250, Matrix=1024x768, FOV=20cm, NEX=2, 10 slices, Time= 6:30min.

Results

Bench top coil measurements of unloaded to loaded Q ratio was 10, indicating strong sample noise dominance. At frequency (300Mhz), insertion loss, while loaded, was measured to be –40 dB or better for all elements. Due to the continuous capacitance of the coil, minimal or no frequency shift was observed while coil loading. While loaded, a broad S11 trace was observed accompanied by a good matching as shown in Figure 1. Unloaded isolation for nearest neighbors was measured to be –25 dB while for next to nearest neighbor was –15dB. Figure 2 shows the SNR profile across the middle of axial head images for both the CCC (top) and the commercial coil (bottom). The CCC was upto five times more sensitive near the edges and 50-to-60% more sensitive in the middle of the head than the commercial receive coil. Finally Figure 3 depicts high resolution, intensity corrected, axial and sagittal images 200 µm in-plane resolution, 2mm thick with zoomed image details.

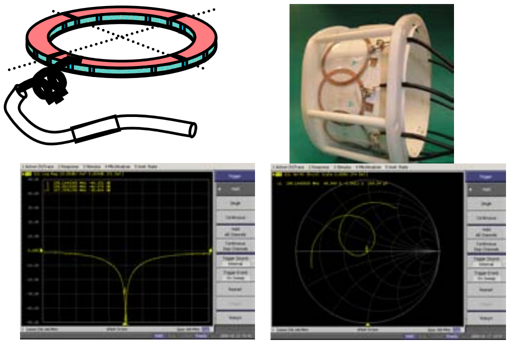

Figure 1 Clockwise from top, CCC element, coil array, tuning and matching measurements.

Conclusions

In this work we have described a new 7T CCC design which provides more than 2-fold increase in SNR in the brain cortex for high resolution MRI. This design has many advantages with respect to conventional coils. The coil is easy to build reproducibly. It allows for the construction of relatively large diameter coils. It performs well under heavy human tissue loading and with the elements very close to the brain for maximal SNR. The absence of soldered capacitors around the trace minimizes failures and allows for flexible adjustment around the head.

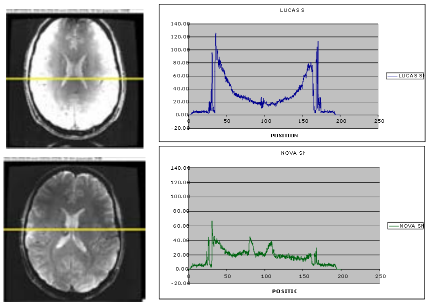

Figure 2 SNR profiles along horizontal pixel position, top CC coil, bottom commercial coil.

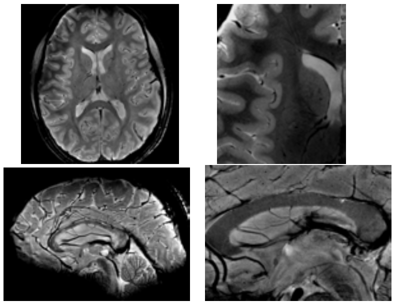

Figure 3 CCC high resolution images axial and sagittal orientation with detailed zoom.

Reference: 1. L.L Wald et al. Appl Magn. Reson. 28, 1-XXX (2005).

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