Superconducting 200 MHz "Phased" Array for Parallel Imaging

J. Wosik[1], K. Nesteruk[2], L-M. Xie[1], M. Kamel[1], L. Xue[1], J. A. Bankson[3]

[1]Texas Center for Superconductivity and Electrical Engineering Dept., University of Houston, Houston, Texas 77204, United States, [2]Institute of Physics Polish Academy of Sciences, Warsaw, Poland, [3]Department of Imaging Physics, The University od Texas M.D. Anderson Cancer Center, Houston, Texas, United States

Abstract.

We report on the ongoing development of a planar 200-MHz superconducting two-coil array for MRI. The array consists of patterned, multi-layered, double-sided thin films on sapphire substrates, and includes two planar 1”-diameter superconducting ($YBa_2Cu_3O_{7-x}$) coils with built-in planar capacitors for coil tuning, decoupling, and capacitive coupling/matching to the scanner. The design can be expanded into an N x M element array.

Introduction.

MRI “phased” arrays are becoming increasingly important, and current trends suggest that future MRI scanners will mainly use arrays of surface coils rather than volume and single surface coils. Image acquisition rates are now limited by physiological factors rather than hardware speed, due to recent advances in image acquisition and reconstruction methodologies [1]. Parallel imaging techniques and their variants provide faster imaging by using arrays of receiver coils, and these methods can reduce image acquisition time, in theory, by a factor equal to up to the number of elements in the array. Unfortunately, such methods have their own limitation. Namely, the signal-to-noise ratio (SNR) decreases with the square root of acceleration rates. Additionally, for given field of view, as the number of elements increases, the resulting smaller coil sizes can reduce the signal-to-noise ratio (SNR) [2]. The latter limitation can be overcome, however, and SNR dramatically improved with the use of high temperature superconductors (HTS). HTS thin films are very attractive for use as surface receiver coils because at 77 K they *exhibit an extremely low surface resistance* R_s, several orders of magnitude lower than that of copper [3]. Here we take advantage of the fact that, for a multi-element array, as the *rf* probe sizes become smaller, their resistive losses (nearly eliminated by HTS materials) largely determine overall system SNR.

Method and Results.

We have developed a novel HTS-based design of a planar multi-layered structure (superconductor/dielectric/normal metal), which, in addition to HTS resonators, also includes built-in capacitors for tuning, matching and decoupling [4] (see Fig. 1a and c). A double-sided structure was used to provide distributed capacitance for each coil resonator, in order to minimize stray electric fields that cause dielectric losses in the sample. The films were patterned into two split quasi-ring shapes (23-mm outer diameter, 17-mm inner diameter and 15-mm shorter opening dimension). This concept allows one to build-in decoupling capacitors between the coils in order to cancel mutual inductance. In Fig. 2, cancellation of the coils’ mutual inductance is demonstrated by showing that each phantom image is acquired by one coil at a time.

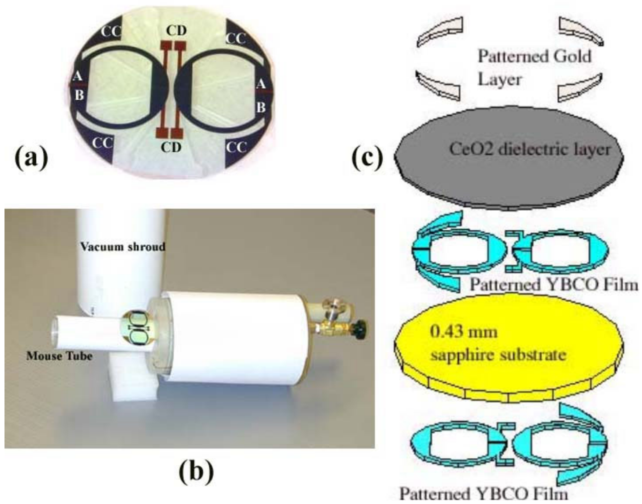

Fig. 1. (a) A picture of the upper side of an array, CC and CD denote de-coupling and coupling capacitors, respectively. A and B shows two sides of the upper quasi ring gap; (b) A picture of a part of the cryostat. The array attached to the sapphire cold-head is shown next to the mouse tube; (c) an example of the multi-layered design is shown.

The array was integrated with a custom-made G-10 liquid nitrogen cryostat (Tristan Technologies) designed for imaging of mice. The inner tube diameter is 35 mm. This cryostat allows easy positioning of the cooled coils very close to the mouse tube and can accommodate four planar substrates. The separation of the center of the array from the mouse is only 3 mm.

Conclusions.

The relatively high critical temperature of HTS materials allows for a compact cryostat design, where, for our system, the mouse-to-HTS array distance was only ~ 3 mm. The superconducting array was phantom tested at 77 K for coil decoupling, tuning, and matching.

Each coil was designed to provide a gain of at least 6 dB for this array over an identical room temperature copper array [4]. The performance of the design was *rf* tested using different loss phantoms.

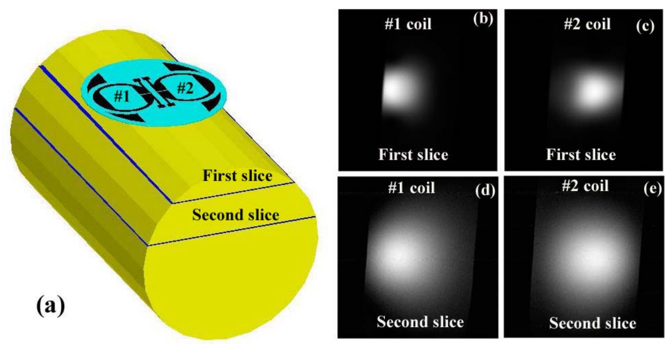

Fig. 2. (a) Configuration of the array and phantom for the coil decoupling test is shown; (b) and (c) first slice 4.7 Tesla images of the number one and number two coils, respectively; (d) and (e) second slice images of the number one and number two coils, respectively. Mutual decoupling of the both coils can be clearly seen. Note that the #1 coil was placed toward the left side of the phantom.

Phantom loaded and unloaded quality factor measurements of the room temperature, 77 K copper array, and HTS array confirmed the expected SNR gain. Further tests of the array are now under way in a 4.7 Tesla Bruker scanner.

References.

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