Screen Printed Flexible 2-Channel Receive Coil Array

Joseph R Corea[1], Ana Claudia Arias[1], Anita Flynn[1], Greig Scott[2], Peter Shin[3], and Michael Lustig[1]
[1]*EECS, UC Berkeley, Berkeley, California, United States,* [2]*EE, Stanford University, Stanford, California, United States,* [3]*EE, UC San Francisco, San Fransisco, California, United States*

Target Audience: RF coil designers, hardware engineers, and array designers.

Introduction We present a fully screen-printed 2-channel receiver array for 3T systems. Our approach takes advantage of recent breakthroughs in printing electronic components and conductive traces from solution, rather than using conventional copper traces and discrete ceramic capacitors. The arrays are printed on thin plastic film substrate using integrated flexible components. These flexible devices allow coils to conform better to anatomy, potentially giving a higher signal-to-noise ratio (SNR) for a larger group of patients. We have previously presented preliminary screen printed single surface coils for 1.5T [1]. Here we report a detailed analysis of the printed components and process used to fabricate the coils. In addition we demonstrate here a major step towards clinical usability: a fully printed array and the first phantom and in-vivo imaging results.

Methods and Results: I. ***Processing-*** We fabricate integrated components on a polyester substrate by printing materials layer by layer from solution using screen-printing. The fabrication details are shown in Fig. 1. For the purpose of this work we designed screens to use an 8.9cm diameter octagonal coil [3]. The dielectric layer used in the printed capacitors is composed of a blend of barium titanate ($BaTiO_3$) and a UV curable polymer (CreativeMaterials (CM) 116-20). The amount of $BaTiO_3$ in the blend can be varied to change capacitance. Figure 1 shows results of several fabrications with varying blend ratios yielding capacitances of 1 pF to 400 pF. For our coil 21pF and 40 pF capacitors were required for tuning to 3T. In addition to blend composition, the area of the top electrode is optimized to fine-tune the coils to 127.72 MHz. The conducting loops and capacitor electrodes are printed from a silver micro-flake ink (CM 118-09). After annealing at 125 °C for 20 minutes sheet resistance of 8×10^{-2} Ω/□ were obtained for the conducting layers. The array designed for the 3 T was fabricated with 1 matching capacitor and 3 tuning capacitors, with a dielectric blend of 1:19 ($BaTiO_3$:polymer).

II. Testing- To measure the performance of the printed components, several additional single coils were fabricated using a mixture of printed and discrete ceramic capacitors. Images of doped saline phantoms with varying radii were acquired to determine coil performance with bending and capacitor type (printed capacitor, discrete ceramic capacitor, and mixtures of the two) using a 3T GE scanner (3D GRE, 1min, 5mm slice, 12.04/2.8 ms, 140×140 mm FOV, 25° flip angle, 62.5 BW). The types of capacitors had only a subtle effect on the quality factor and SNR of the image as shown in Fig. 2.

A 2-channel array was fabricated by overlapping single coil elements to form a linear array (Fig 3). The 8.9 cm diameter coils were printed on each side of the substrate to ensure DC isolation. The geometric null point in S11 traces was determined by creating two separate surface coils and overlapping them until the effect of one coil on the other could not be seen at (11.7 mm overlap). The quality factor for the array was determined, by S11 measurements to be 130 when loaded with a saline phantom. An array with the same shape was made with etched copper on a Kapton substrate with ceramic capacitors and had the same loaded quality factor, indicating similar losses for both types. Further flexible array functionality is shown in Fig. 3, as it is used to image (T2-weighted FSE) the knee of a human volunteer while flexed. For imaging, non-printed Q-spoiling circuitry was attached to the coils.

Conclusions and outlook The coil array designed show a resonant frequency of 127.7 MHz with input impedance matched to 50 ohms. Coils have shown similar performance to ones created using etched copper and several in vivo images have been taken. Using the manufacturing technique described a linear array of any practical length could be made simply by repeating the single coil design alternating from front to back of the substrate, allowing for major progression towards clinical use.

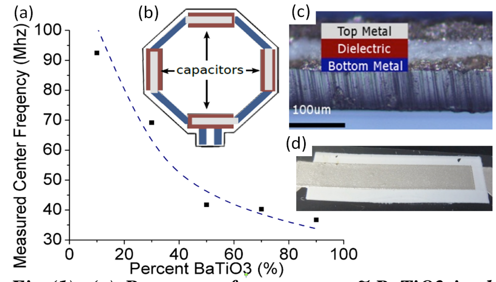

Fig (1): (a) Resonance frequency vs. %BaTiO3 in the capacitors' dielectric. (b) Coil is printed starting with bottom silver conductor (Blue) followed by a dielectric (Red). Capacitors are sized using top layer of silver (Grey). (c) Microscope image of cross section and (d) Top down photo of printed capacitor

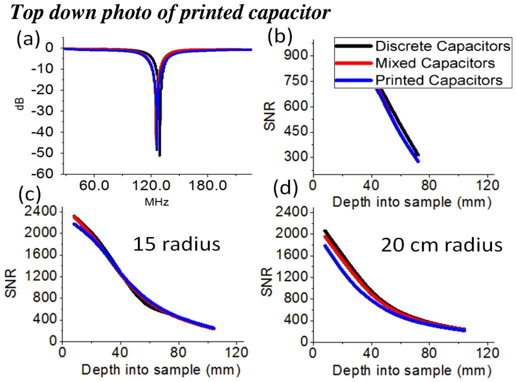

Fig (2): (a) S11 measurements from single coils with different capacitor types. (b, c, d) SNR from images using coils with different capacitor types on cylindrical phantoms with varying radii.

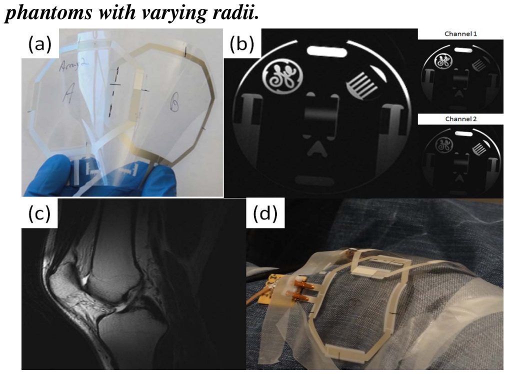

Fig (3): (a) A 2 channel array was created by screen printing and used to image several phantoms. (b) Resulting images from each channel and composite. (c) In vivo images of volunteer's knee using printed array (d) Array on volunteer's knee

[1] S.M. Wright et al. Theory and application of array coils in MR spectroscopy. NMR Biomed, 10(8):394–410, Dec 1997.**[2]** J. Corea et. al, ISMRM 2011 **[3]** S. S. Vasanawala Proc. Intl. Soc. Mag. Reson. Med. 19 (2011) **[4]** D. Mager et. al, IEEE TMI 2010; 29(2):pp 482-7