Design and Implementation of Flexible Printed Receive Coils Arrays

Joseph Russell Corea[1], Anita Flynn[1], Galen Reed[1,2], Peter Shin[2], Greig Scott[3], Ana Claudia Arias[1], and Michael Lustig[1]

[1]*Electrical Engineering and Computer Sciences, University of California, Berkeley, Berkeley, California, United States,* [2]*Radiology and Biomedical Imaging, University of California, San Francisco, San Francisco, California, United States,* [3]*Electrical Engineering, Stanford, Stanford, California, United States*

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

Introduction: Receive coils printed from solution on flexible substrates show huge potential for the manufacturing of highly conformable, lightweight receive arrays. These offer improved patient preparation, comfort, and image quality. Previous work developed a fabrication process, illustrated in Fig.1, and demonstrated feasibility of screen-printed flexible surface coils for 1.5T and 3T [1,2]. In general, as separate devices, printed coil components are inferior to conventional components. However, we argue that components used in current coil manufacturing are over-specified in a mostly body-noise dominant *(BND)* system (*i.e.,* where the main source of noise is the sample rather than the coil). Here, we present new analysis and characterization of electrical and mechanical properties of printed coil components. We also show that comparable image quality and SNR can be obtained with perceived inferior printed components without compromising the added valued of flexibility. In addition, we demonstrate a fully printed 4-channel array for 3T, which exhibits good image quality and conformability, used in several imaging scenarios.

Methods: We fabricated a series of printed capacitors composed of two different dielectric layers with dielectric constant *(k)* of 3 and 15. The thickness of the dielectric layer was varied from 25 to 75 µm and the length of the capacitors was varied from 3 to 33 mm while the width was kept constant at 5 mm. We measured the quality factor *(Q)* for all capacitors at 64 MHz and 127 MHz. Printed conductors were also created with the same footprint and thickness varying from 9 to 60 µm. These capacitors and conductors with a range of thicknesses were mechanically evaluated by repeated crease cycles and bending tests. These tests were repeated until the component failed. Arrays of receive coils were fabricated using optimized parameters from individual testing and images obtained with printed arrays were compared to that of a commercially available flexible 8-channel cardiac array.

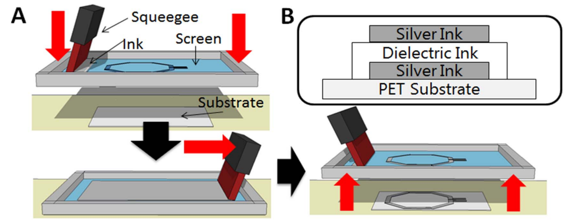

Fig (1): (A) Screen printing process used to create array (B) Cross-section of tuning capacitors.

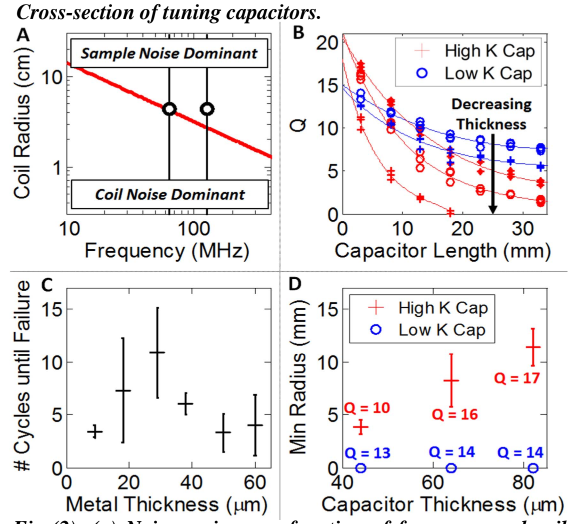

Fig (2): (a) Noise regimes as function of frequency and coil radius. Circles indicate radius of coil used at 1.5 and 3T. (B) Capacitor Q with changing thickness and length for at 127 MHz. (C) Mechanical creasing cycles for conductor. (D) Minimum bending radius for capacitors vs. overall thickness.

Results: The conductors used in our current process are more resistive than electroplated copper, and printed capacitors exhibit lower *Q* than ceramic ATC capacitors. We derived limits for *BND* from Darrasse *et al*.[3] and compared to the parameters obtained for our coil design. Figure 2(a) shows that the theoretical lower limit, in which *BND* is maintained, is 2.7 cm radius for 3T and 4.1 cm for 1.5T. We found that the capacitor design which gives highest *Q* had a thick layer of high *k* dielectric ink with the shortest length possible. The dependence of *Q* with capacitor length is shown in Fig. 2(b) for varying dielectric thickness and constant (trends at 64 and 127 MHz are similar, but only 127 MHz is shown here). Repeated crease testing, shown in Fig. 2(c), illustrates the influence of conductor thickness on mechanical stability. It was found that 30 µm thick printed conductors withstood 11 cycles while thicker printed films and copper lasted only 4 cycles. When considering the capacitor, thinner structures are more robust. Figure 2(d) shows that 40 µm structures with *Q* of 10-14 fail at a 4 mm radius of curvature whereas thicker structures, with *Q* of 13-17, fail at 12 mm. The 4-channel array was used in a 3T scanner with a T2-weighted FSE sequence with 512×512 resolution, TR/TE of 3500/114.82 ms, 90° FA, and 62.5 kHz BW to image the knee, ankle, head, and spine areas of human volunteers (Fig. 3). For the spine, the SNR obtained in the spinal column was 75 and 25 for the printed and commercial coils respectively. The printed array exhibits higher SNR because it conformed better to the patent, in addition to possessing slightly smaller elements.

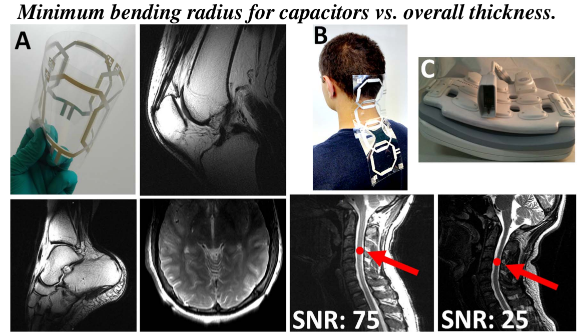

Fig (3): (a) Printed 4-channel array with different areas imaged. (b) Spine area of volunteer using printed coils and (c) traditional coil array. SNR calculated at point indicated.

Conclusions: The knowledge gained from the individual components tested allowed for the construction of a coil array that could be used on many areas of the body. Moving forward, this construction scheme enables a new generation of receive arrays to be built, giving the designer more freedom to imagine different coil geometries and applications.

[1] J. Corea et.al, ISMRM 2011 **[2]**] J. Corea et.al, ISMRM 2012 **[3]** L. Darrasse et.al Biochimie 85, 915 (2003) **[4]** T. Lee, Planar Microwave Eng. Book (2004) **[5]** P. Roemer etal. MRM. 16, 192 (1990)