Operational inkjet-printed metal-on-kapton MRI receiver coil

D. Mager[1], U. Loeffelman[1], A. Peter[1], L. Del Tin[1], E. Fischer[2], P. J. Smith[1], J. Hennig[2], and J. G. Korvink[1]

[1]Dept. of Microsystems Engineering – IMTEK, University of Freiburg, Freiburg, Germany, [2]Dept. of Diagnostic Radiology, Medical Physics, University Hospital Freiburg, Freiburg, Germany

Introduction

We present for the **first time** the results of a self-resonant MR receiver coil, manufactured on a **flexible Kapton foil**, with the metal lines pattern by **inkjet printing**. The conductive tracks of the coil were produced using a colloidal silver ink. The supporting capacitors in the inductive loop have also been produced by inkjet printing. An MRI image sequence was taken using a Bruker BioSpec scanner at 9.4 T. The results of the measurement were **comparable** to a standard receiver coil. Inkjet printing can therefore be considered as a feasible approach in the rapid and **low cost** production of receiver coils.

Preliminary steps and supporting components

In a commercial PCB technique, copper is selectively removed from a completely covered substrate. Inkjet printing works the other way round, in that it is an additive technique. The conductive material is deposited only where it is desired. The proof of principle of inkjet printing RF components was done by Redinger et al, who produced components for RF-ID Tags/circuits at 13.5 MHz [1].

In order to achieve the goal, an inkjet printable version of all the electrical components of the receiver circuit had to be found and analysed [2]. A receiver circuit is a resonance circuit. The resonant circuit is based on the resistance R [Ω], the inductance L [H] and capacitance C [F] of the loop. Test series for each component have been inkjet printed and characterised. The components showed a fairly **linear scaling** behaviour with regard to size (L and C) and to layer thickness (R) [3].

Printing the circuit and the measurement

The targeted scanner has 9.4 T field, the coil needed therefore to be optimized for 400 MHz. The coil was 25 mm by 25 mm, and the track width was 1mm Fig. 1. As the coil had a circumference of ~100 mm, two capacitors were inserted into the coil, homogenising the field distribution and reducing wave effects. These two capacitors were implemented, by inkjet printing the tracks of the coil piecewise on **both sides** of the substrate (Fig. 2) using a Dimatix Material Printer (DMP 2800, FujiFilm Dimatix). The substrate had a thickness of 50 µm. By printing the parts of the track on opposing surfaces of the thin substrates, they formed two capacitors that uses Kapton/Polyimide as the dielectric (ε_r=3.6), see Fig. 1. The silver ink (SunTronic U5603, SunJet, Bath , UK) needed to be dried and the silver particles to be sintered together, again the Kapton (200HN 50 µm, Krempel Group) proved to be ideal because it can sustain the temperature of 300°C which was used to thoroughly cure the silver track. The values of the capacitors can easily be calculated since they result from **pure geometrical** properties; they scale with the overlapping area of the tracks (4 mm² = 2.6 pF) [2]. The Kapton foil with the coil-capacitor arrangement is connected to a small circuit which matches the setup to the 50 Ω wave resistance and allows retuning around 400MHz Fig. 4. The tuning capacitors can be set between 5 – 13 pF and the matching capacitor between 2 – 8 pF. The tuning was done using a network analyser (Agilent 5071C). The Bode diagram of the tuned and matched circuit is shown in Fig. 3. The circuit was connected to a Bruker BioSpec 94/21 Magnet at 9.4T (Bruker BioSpin GmbH Germany). Gradient echo images of a silicone oil phantom were taken. Fig. 5 shows the resultant images, the coil showed behaviour comparable to commercial coils.

Conclusions and outlook

Inkjet printing was used for the first time to produce and test an MRI receiver coil. The advantage of this fabrication process is that it allows the **direct creation** of coils. The process produces the structures rapidly and has a geometrical accuracy which is better than **100 µm**. It can, therefore, speed up the iterative process of finding **optimized** coil shapes. Also inkjet printing is not limited to planar substrates, since it can be easily adapted to produce **non-planar structures**.

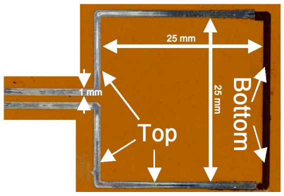

Fig. 1: Image of a printed coil on a Kapton foil

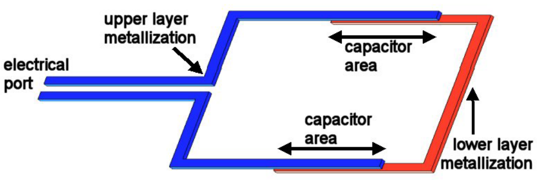

Fig. 2: Schematic of the coil arrangement without Kapton

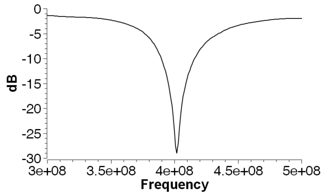

Fig. 3: Bode diagram of the tuned circuit

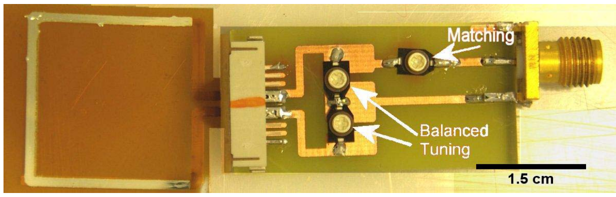

Fig. 4: Coil attached to the tuning and matching circuit

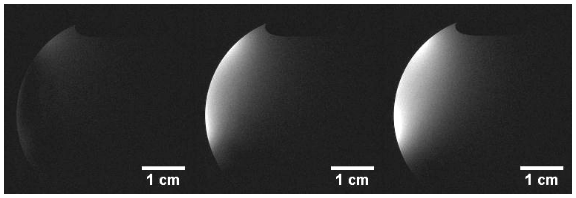

Fig. 5: MRI Gradient Echo Image of a silicone phantom made using the inkjet printed coil

References

[1]Redinger et al: *An Ink-Jet-Deposited Passive Component Process for RFID,* IEEE transactions on electrical devices, 51, p.1978-1983, 2004 [2]Smith et al: *Can Inkjet Printing make MRI coils,* ISMRM 2008 [3]Mager et al: *Inkjet Printing of structures for MRI coils,* Proc. Digital Fabrication 2008, p.891-894
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