

## MULTILAYER MICRO COIL PHASED ARRAY FOR MRI

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**Abstract:** A planar phased-array of microcoils for applications in magnetic resonance imaging (MRI) of 2D samples at the microscale is presented for the first time. The previously reported [1] wirebonding technology has been adapted to fabricate phased-arrays with a sensitive area of up to (18.3mm<sup>2</sup>) for 7 microcoils. The phased array of microcoils has been characterized for MRI purposes yielding an **in plane resolution of 80x80μm<sup>2</sup>** with an **SNR of 34** in an acquisition time of 2:30min.

**Introduction:** Scaling down the MR receiver-coil increases the SNR, thus the achievable image resolution. However, the field of view (FOV) is therefore drastically limited. By arranging microcoils in a phased-array configuration, one combines the advantages of high SNR and large FOV. Phased-arrays have been introduced at the macroscale by Roemer et al. [2] and have since then been widely used in MRI. To our knowledge this work is the first report of a planar phased-array for MRI at the microscale.

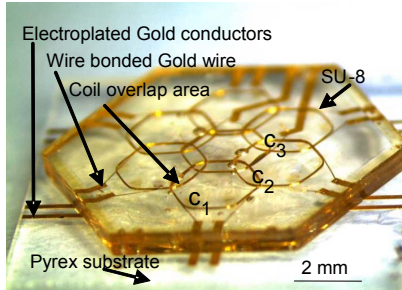


Fig. 1: The planar phased-array consists of 7 coils arranged in 3 height levels. They are embedded in SU-8 made of gold wirebonded coils.

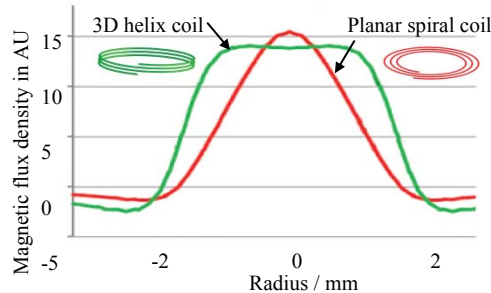


Fig. 2: Comparison of simulated magnetic flux density generated by a planar spiral coil and a 3D helix coil over their aperture of 2mm at a distance of 400μm from the coils surface.

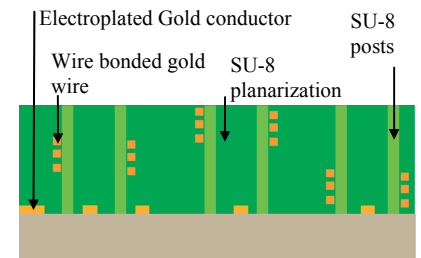


Fig. 3: Device cross-section  
1) Electroplating of gold 2) Structuring of SU-8 pillars & frame 3) Wire bonding of coils 4) SU-8 planarization

**Fabrication of phased array and proof of decoupling:** PCB technology is commonly used for the fabrication of planar phased array micro coils. In this paper we propose an innovative approach by using 3D wirebonded microcoils, similar to those reported in [1]. The advantage of our approach is shown in Figure 2: the magnetic flux of a 3D microcoil is uniform in a significantly larger area than the magnetic flux of a planar microcoil of similar dimension.

In order to fabricate the planar phased-array, the technology reported in [1] has been taken one step forward in order to: (i) allow for overlapping of microcoils on **three different layers** by optimizing the winding procedure, (ii) provide a planar sensitive area by embedding the entire array in SU-8 epoxy, thus further reducing the field inhomogeneity due to magnetic susceptibility mismatch and (iii) reduce signal loss due to electric resistance by electroplating the conductors. The process flow is described in Figure 3 and a photo of the device is given in Figure 1. A phased-array is mounted on a printed circuit board (PCB), entailing the required electrical circuitry, for matching, tuning and actively decoupling transmitting and receiving coils. The impedance of a coil is determined (2.5Ω; 46nH) with an impedance analyzer (Agilent E4991A), matching the simulation results. The individual characteristics and coupling between overlapping and non-overlapping coils (Figure 4), while tuning and matching the system to 400MHz and 50Ω, show that they are **decoupled (s<sub>i,j</sub> > -20dB)**. The system is connected to preamplifiers and tested in a Bruker 9.4T MRI scanner. MRI images were taken with two coils as shown in Figure 5. An SNR of 34 was obtained in a short measurement of 2:30min with a resolution of 80x80μm<sup>2</sup>. The images acquired with only one coil (SNR 30), while the other is still resonant, proves the decoupling, since no signal is obtained from the inactive coil's area.

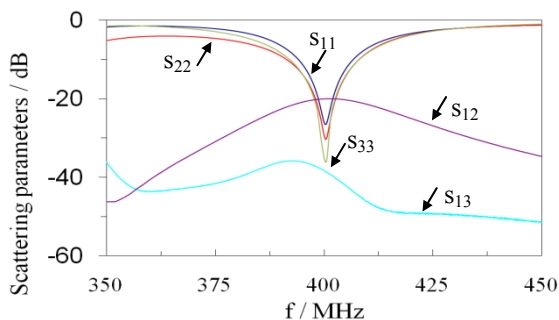


Fig. 4: Measured values of the input port voltage reflection coefficient (s<sub>11</sub>) and voltage gain (s<sub>12</sub>)

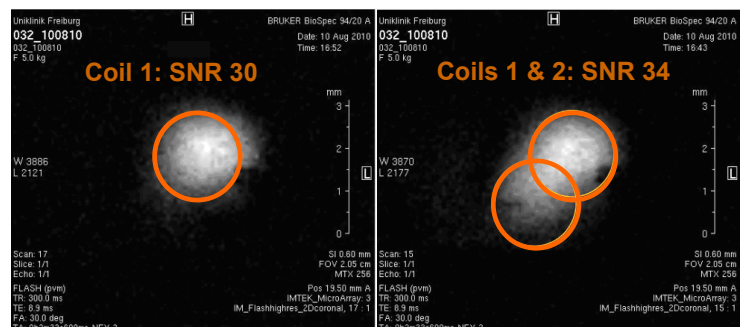


Fig. 5: MRI results of individual and combined coils. The results prove the inductive decoupling. Sample H<sub>2</sub>O with CuSO<sub>4</sub>, scan time 2:30 min, in-plane matrix size 80x80μm<sup>2</sup>, slice thickness 180μm, FOV 2x2cm<sup>2</sup>

**The results demonstrate the capabilities of the innovative approach i.e. high SNR combined with high resolution and fast image generation with large FOV, opening new perspectives for analyzing thin tissue slices or parallel imaging of multiple micro objects.**

### References:

- [1] V. Badilita et al., On-chip three dimensional microcoils for MRI at the microscale, *LOC* (2010)
- [2] P. B. Roemer et al., The NMR phased array. *Magn. Reson. Med.* 16, 192–225 (1990)