Magnetic Resonance Imaging Using Standard CMOS RF Coil

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Abstract

A 45-turn 990μm wide square rectangular spiral surface coil is produced with standard CMOS fabrication process and tuned/matched to 125.3MHz, the resonance frequency for 3T MRI. Images of biological samples with isotropic spatial resolution of 78μm were acquired with the standard CMOS RF coil.

Introduction

According to the equations when the resonant frequency is lowered or coil and sample sizes go down, coil noise becomes dominant. It is obvious that downsizing the coil (smaller r) can lead to less noise as well [2]. Also designing a high sensitivity planar coil requires larger (B_1/i), the magnetic filed strength per unit current. Using narrow line width and line spacing, more number of turns can be placed within the same area, increasing the (B_1/i) [3]. With other parameters (sample size, resonance frequency, temperature, etc.) fixed, the overall signal-to-noise ratio is proportional to $(B_1/i)/\sqrt{Rc}$, Rc being the conductor resistance. (B_1/i) and resistance all increases along with number of turns hence there exists a turning point in each design that relative SNR will drop as number of turns continue to go up. There are several previous studies that used other kinds of fabrication method to exploit the effects of coil downsizing. However, they still have a line width around the size of 50μm, restricting the total coil size to be larger than 1mm and little number of turns. [4] We intend to produce a RF coil of smaller line width and size with the help of standard CMOS microfabrication technique, a mature technology widely used among microwave application devices.

Methods

The standard CMOS micro coil has a design of 990μm diameter, 45-turn, line width=spacing=5µm. This design might provide adequate SNR and penetration depth for subject size of several hundreds of microns, the average scale of biological samples such as bacteria and cells. The scale and precision of the coil can easily be met with now existing microfabrication techniques. The standard CMOS fabricated microcoil is wire bonded onto a PC board RF coil circuit. After adding non-magnetic chip and trimmer capacitors, the circuit is tuned and matched to 125.3MHz/50Ohms. The resulting S11 curve measured by the network analyzer is shown in Fig. 3, with a 3dB Q value of 53 @ 125.3MHz. C1, C2 and C3 are around 530, 240 and 300pF respectively.

Results

MR images of a biological sample were taken to test the imaging performance of the CMOS RF coil. Cross section of a *Plantago asiatica* stem, a commonly seen weed in National Taiwan University was chosen. A 2-cm segmented stem was placed right above the RF coil; both sided sealed with gel to prevent water loss during the MR scan. We used a 4-cm diameter positioning coil configuration to ensure the orthogonally of the slice selection. B1 field of the coil (Y) is set perpendicular to the main field (Z). The cross section image was taken with GEFI standard gradient echo sequence, field of view (FOV) of the image is set to 0.5cmx0.5cm, image matrix size=64x64, echo time (TE) =2.1ms, repetition time (TR) =100ms, SNR=13. The stem structure is highly discernable. The cross section of the stem has a shape of waning crescent moon with 5 evenly spaced vascular bundles filled with water to provide MR signal.

Discussion

The imaging of the first standard CMOS MRI RF coil was a success. However, the results did not fully meet the prediction of theories due to several reasons such as field homogeneity and signal loss and still remains to be corrected. Too many turns may lead to short penetration depth, causing inefficient RF excitation and reception within the designated field of view. With improved coil geometry, substrate-etched structure and thicker metal, the next version of the microcoil can provide images more practicable. The authors expect to present far better biological images taken by improved CMOS MR microcoil in the final manuscript.

References

[1] P. Glover and Sir Peter Mansfield," *Limits to Magnetic resonance microscopy*", Reports on Progress in Physics 65

[2] Peck T. L., Magin R. L. and Lauterbur P. C., "*Design and analysis of microcoils for NMR microscopy*", J. Magn.Reson. B 108

[3] A. G. Webb, "*Radiofrequency microcoils in magnetic resonance*", Progress in Nuclear Magnetic Resonance Spectroscopy 31

[4] Barjor G. et al, *NMR Spiral Surface Microcoils: Design, Fabrication, and Imaging*, Concepts in Magnetic Resonance Part B, vol. 17B(1)

[5] Wu E. et al, Preliminary study of planar RF coils for Magnetic Resonance Microscopy, IEEE EMBC, 2005

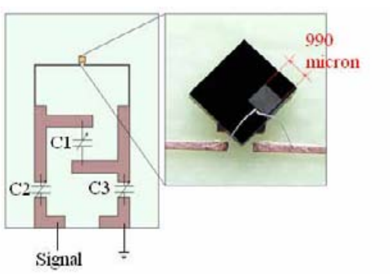

Fig.1 Standard CMOS MRI RF coil and tune/match circuit

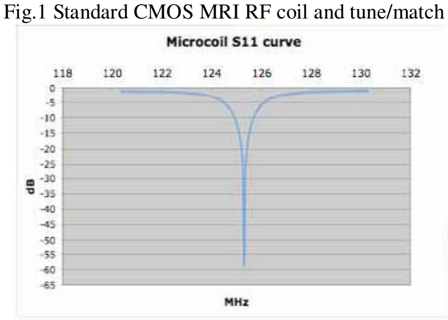

Fig.2 S11 curve of tuned/matched CMOS RF coil

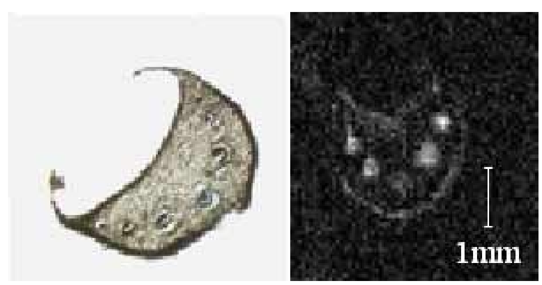

Fig.3 Acquired *Plantago asiatica* stem cross-section MR image and microscopic image