Effect of Planar Micro Coil Geometry on Magnetic Field

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Nuclear Magnetic Resonance (NMR) allows a non-destructive study of molecular structures by the measurement of their atomic nuclei magnetization. Nonetheless, NMR technique still suffers from the sensitivity weakness compared to all other spectroscopy approaches [1]. Therefore, the optimization of microcoil geometry will increase its magnetic field B_1, and will decrease the coil conductors' equivalent resistance R_s [2]. By the principle of reciprocity [3], the largest is the B1 field the largest the microcoil sensitivity is.

The sensitivity of an NMR receiver coil is expressed as the ratio of the SNR and the concentration of the measured substance [4]:

$$Sensitivity = \frac{SNR}{C_i} \quad (1)$$

where C_i is the concentration of the measured substance in mol/kg. The SNR could be described analytically by the physical parameters of the microcoil and the surrounding setting:

$$SNR \propto \omega_0 B_0 V_S \frac{B_1/i}{\sqrt{4\, K_B T_S\, R_S\, \Delta f}} \quad (3)$$

where k_B is the Boltzmann constant, T_S is the ambient temperature, and Δf is the receiver bandwidth. Two main components could be differentiated: (1) The environment components are the static magnetic field B_0, the Larmor precession frequency ω_0 proportional to B_0 and the sample volume V_s. (2) The geometrical components are B_1/i which is equivalent to the NMR signal by the principle of reciprocity, and $4\, K_B T_S\, R_S\, \Delta f$ stands for the thermal noise produced by the coil in the bandwidth of interest.
The geometrical components could be reduced to the magnetic field B_1, which is equivalent to the NMR signal by the principle of reciprocity.

The simulation and comparison of the magnetic field of different basic geometries of planar microcoil depicted in figure 1 have shown that the physical optimization is highly required in order to improve their performances and more particularly the spatial resolution, especially along the z-axis. Moreover, it will help to expand the sensitive volume of detection, which leads to an increase in signal acquisition particularly around the regions of interest (ROI) within the studied sample.

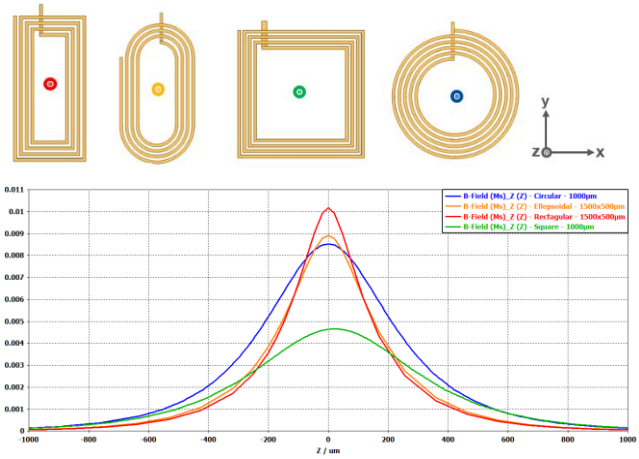

Figure 1: *Comparison of the Magnetic Field B_1 of Different Microcoil Geometries on the axis Z.*

Figure 2 depicts the high sensitivity of the ellipsoidal microcoil even though it shows half field magnitude (B_{1z} = 0.8mT) compared to its antagonists at point z = 500µm. However, its small size and surface area are very attractive for biomedical applications.

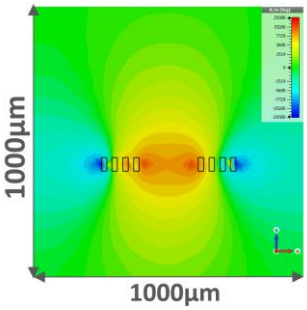

Figure 2: *Magnetic field B_1 map of the ellipsoidal coil (1000x500µm)*

The realization of compact sensing system based on microcoil will open the door to numerous medical and industrial applications such as real time measurement of cerebral metabolite.

References

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