Surface Coil for EPR irradiation to reduce SAR in Fixed-Field PEDRI

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Abstract

Proton Electron Double Resonance Imaging (PEDRI) is a **combination** of proton nuclear magnetic resonance (**NMR**) imaging and electron paramagnetic resonance (**EPR**). It is used to image biological samples that contain paramagnetic molecules. The technique involves irradiating the paramagnetic sample at its electron spin resonance and this is followed by NMR signal acquisition by RF excitation at the NMR frequency. In most cases the biological sample is placed inside a dual resonator assembly which consists of a whole body EPR resonator surrounding a whole body NMR resonator. However in applications where it is required to image specialized organs (heart, kidney) a surface coil can be used for EPR irradiation. This will help to reduce the power deposited in the sample due to the high frequency EPR irradiation pulse. We demonstrate the use of a surface resonator for EPR irradiation and a "whole body" solenoid coil for NMR signal acquisition. The aim is to employ local rather than whole body EPR irradiation when the region of interest is close to the surface of the sample. The experiment is performed at 20.1mT and the EPR and NMR irradiation frequency are 567MHz and 856 kHz respectively.

Introduction

PEDRI or DNP imaging is based on the **Overhauser effect**. It is a useful technique to study the distribution of paramagnetic molecules in-vivo. In PEDRI, the sample is irradiated at the electron resonance frequency of the paramagnetic molecule before NMR signal acquisition. In regions of the sample containing the excited paramagnetic molecules there is transfer of polarization from the electron spin to the proton spin and this results in NMR signal enhancement also known as the Overhauser enhancement. In effect the regions containing the paramagnetic molecules light up on an NMR image. Since the EPR irradiation frequency is about 660 times the NMR frequency at any given field, PEDRI is usually performed at low field (<100mT). Whole body resonators namely a solenoidal coil for NMR and an Alderman Grant for EPR are commonly used. Even at a field strength of about 0.01T the EPR frequency is about 238MHz, and a significant portion of the applied RF power contributes to sample heating.

Materials and methods

The objective here is to demonstrate the use of a surface coil for EPR irradiation in biological samples when the region of interest is close to the surface of the sample. An EPR surface coil with loop diameter 20mm based on the design proposed by Hirata has been constructed and is shown in fig1. The static magnetic field B_0 used for the experiment is 20.1mT, the corresponding NMR and EPR resonant frequency are 856 kHz and 567 MHz respectively. Images of an anesthetized mouse collected soon after an intraperitoneal injection of 0.5ml of 200Mm 3CP. The EPR irradiation pulse was set at a power level of 3W. An image was also collected without EPR irradiation which served as the control image. The same experiment was performed with a "whole body" coil based on the Alderman Grant design for EPR and a solenoid coil for NMR irradiation for the sake of comparison. The same EPR power levels were used in each case.

Results and Discussion

The Overhauser enhancement E in the enhanced regions of the sample containing the paramagnetic molecules is calculated in each case and is shown in table 1. It is the ratio of the NMR signals in a region of interest with and without EPR irradiation. The signal to noise ratio (SNR) in each of the images is also calculated. It can be seen that for a given EPR power level (3W in this case) the enhancement E produced in the Overhauser enhanced region and the SNR of the image is greater in case of a surface coil setup. The reason for this being decrease in the non resonant power deposited in the sample and a stronger B_1 field ($\mu T/W^{1/2}$) produced in case of a surface coil when compared to the Alderman Grant resonator for the same EPR power level. The higher SNR in case of the surface coil setup maybe partially due to higher Overhauser enhancement and the slice orientation chosen in case of the surface coil (coronal Vs sagittal slice in case of the whole body coil setup).

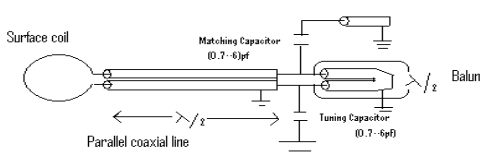

Fig1. Schematic of EPR surface resonator

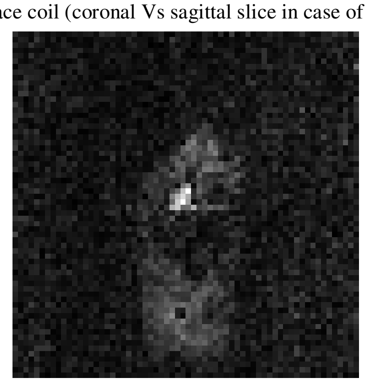

Fig2. Whole body coil setup

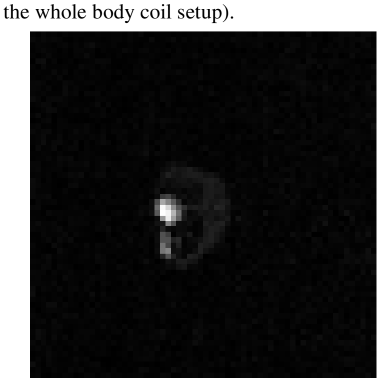

Fig.3 Surface coil setup

Coil Assembly	Overhauser Enhancement	SNR
Whole body coil for EPR, NMR	12	22
Surface coil –EPR, Whole body coil for NMR	18	31

Conclusion

To conclude, the project demonstrates the use of a surface resonator for PEDRI experiments concerning specific organs in biological samples. The Overhauser enhancement depends on the strength of the B_1 component of the EPR irradiation [3]. The increase in Overhauser enhancement can be attributed to the reduction in non resonant power deposition and stronger B_1 field that induces a greater electron spin polarization and therefore results in a larger NMR signal. In this study the organ of interest is the mouse heart, which extends to a depth of about 10mm from the surface of the sample and a surface coil is well suited for the application. As the volume of the sample that is exposed to EPR irradiation is small sample overheating is not a problem and the setup can be used even at high EPR frequencies (1GHz).

References

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