Developments in static and pulsed magnetic field systems for detection of magnetic resonance in non-uniform magnetic fields

The evolution of wearable diagnostic devices and more importantly, increasing consumer awareness, have demanded advancements in sensing mechanisms, sensor data analysis and data processing. Magnetics technologies such as current sensing, actuation, switching, navigation and data recording have all evolved technologically with the demand of lower operational power and long-term system stability. However, none of these advancements, have incorporated operations in low magnetic fields since these fields are non-uniform, vary spatially and provide low data resolution. In this work, the possibility of magnetic field detections in low non-uniform magnetic fields is explored. Magnetic fields produced by neodymium iron boron permanent magnets were studied, simulated and tested with portable pulsed field generation systems to detect magnetic resonance signals in non-uniform DC magnetic fields. Advances in detection capabilities in non-uniform fields will allow new application areas to develop, potentially revolutionizing medical diagnostics.

Initially, we analyze different aspects of the sensor and detection system in detail. We first study magnetic fields produced by different permanent magnet geometries. The spatial magnetic field variations in the magnet's exterior are simulated using finite element methods. In particular, regions of localized field uniformity are identified for ring magnet geometries. Various modifications to ring magnets such as magnet dimensions, inclusion of magnetic inserts, placement of multiple magnets and orientations are simulated to identify the best geometry with maximum magnetic flux density in locally uniform regions.

We next consider the generation of pulsed magnetic fields using portable electronic circuits. These pulsed fields are used alongside the static fields in magnetic resonance measurements. We discuss design considerations for creating portable pulsed magnetic field circuits, delivering up to 10A at operational frequencies ranging from 2 to 5 MHz, via design of two prototype circuits. Both these circuits rely on application of pulsed sinusoids to switching devices connected to inductors.

A combination of the static and pulsed magnetic fields constitute the magnetic resonance sensing and detection system that is used to study ferromagnetic and paramagnetic materials. We record responses from ferromagnetic materials placed in non-uniform magnetic fields with applications in oil-well industry and paramagnetic materials within organic media. These measurements validated operations of such portable sensor systems, thereby ushering in possibilities for future portable magnetic resonance measurements in low and non-uniform magnetic fields.