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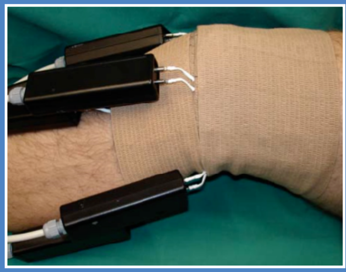
WearableMRI

WEARABLE MRI DETECTOR AND SENSOR ARRAYS



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What it's about…

Advancing magnetic resonance imaging (MRI) by introducing elastic, lightweight signal detectors that patients can wear like a piece of clothing.

Context and project goals

This project aims to advance the technology of magnetic resonance imaging (MRI), which is one of the most widely used imaging modalities in medical diagnostics and research. The variety of anatomical and functional features, processes, and diseases that can be visualised with MRI is steadily increasing. However, the technique also faces fundamental limitations with respect to its sensitivity, speed, and fidelity of the dynamic magnetic fields involved. One effective way of addressing the sensitivity and speed limitations is parallel data acquisition with RF detector arrays. However, current rigid detector setups exploit this potential only partly and are limited in terms of ergonomics. Mechanical rigidity compromises sensitivity because is prevents adjustment to individual sizes and shapes of target anatomies. It also prevent changes in posture, such as the flexion of joints, and impairs patient comfort. Fixed detector electronics incur suboptimal performance as effective loads vary from patient to patient, taking a further toll on effective sensitivity.

The main goal of this project is to address these issues jointly by developing wearable, adaptive detector arrays with miniaturized on-detector receivers. In this concept, mechanical adaptiveness will be achieved by stretchable and elastic detector loops that automatically conform to the individual anatomy and posture. Arrays of elastic detector loops will be complemented by adaptive electronics that sense effective port impedances and automatically adjust variable matching networks for optimal sensitivity yield. On-detector reception will be accomplished with an integrated circuit and optical conversion for safe, digital signal transmission.

To address the limited fidelity of magnetic field evolutions during MRI scans, the recent concept of concurrent magnetic field sensing with NMR field probes will be expanded. Field sensing introduces tolerance to field imperfections and perturbations by enabling data correction upon image reconstruction as well as feedback control during scans. NMR field probes yield RF signals of the same nature as the primary MRI signals. Therefore, the second goal of this proposal is to integrate the chip receiver to be developed into NMR field probes to enable modular, scalable arrays of high-accuracy field sensors. Such sensor arrays will be assembled both in rigid form, to enhance the basic field monitoring applications, and in wearable configurations. The latter will offer the additional functionalities of bulk motion tracking during MRI scans and the observation of subtle field fluctuations related to physiological processes inside the body.

How it differentiates from similar projects in the field

Advancing MRI detection is the aim of numerous research and development efforts in academia and the healthcare industry around the world.

What renders this project unique in this field is the radical step from rigid, cage-like detectors to wearable assemblies that conform to the patient. To master this transition, the project faces unique challenges of mechanical and electronic adaptiveness along with those of miniaturization.

Quick summary of the project status and key results

The first year of this project had been dedicated to system design considerations and the definition of interface specifications, concept studies for the flexible detector frontend and the optical link, design of the integrated receiver, and the definition of a PCB-based evaluation platform.

Efforts during the second year have largely been directed at actual implementation. The most eminent step recently completed is the fabrication and deployment of the integrated receiver, which, at a size of just a few mm, performs MR signal digitization and decimation for subsequent optical transmission. The chip has been successfully tested and its specifications have been verified.

Meanwhile the remainder of in-magnet electronics and the evaluation platform have equally been advanced to the point of enabling full operation in a basic system configuration. Using this configuration, a first MRI experiment has recently been successfully performed, yielding the project's first actual MR image.

Success stories

One highlight of the first year was the first successful signal acquisition with the PCB-based platform for in-magnet digitization and optical signal transmission. Jonas Reber, doctoral student in the project, gave a highly attended presentation of these results at the Annual Meeting of the International Society for Magnetic Resonance in Medicine, the premier peer-reviewed conference in MRI technology.

A second highlight has been the invitation by ETH Zurich president Ralph Eichler to present our MRI activities to the ETH council upon its annual consultations with the ETH board. The entire council spent a full hour in the MRI labs and received our presentation of the WearableMRI project very positively.

The undisputed highlights of the second year have been the successful realization of the integrated receiver and obtaining the first actual MR image with the WearableMRI system. Given the complexity of the system and its components the team was elated by these "first-time-right" successes.

Main publications

Reber J, Marjanovic J,Brunner DO, Schmid T, Moser U, Dietrich BE, Barmet C, Pruessmann KP, In-Bore Broadband Array Receivers with Optical Transmission, Proceedings of ISMRM 2014, #619.

Marjanovic J, Reber J, Brunner DO, Weiger M, Dietrich BE, Schmid T, Moser U, Barmet C, Pruessmann KP, Dead Time Reduction with a Variable Rate Broadband Receiver – Applications to Zero Echo Time Imaging, Proceedings of ISMRM 2014, #927.

Sporrer B., Bettini L., Vogt C., Mehmann A., Reber J., Marjanovic J., Burger T., Brunner D., Tröster G., Prüssmann K. and Huang Q., Integrated CMOS Receiver for Wearable Coil Arrays in MRI Applications, Proceeding of DATE 2015 Conference, #1152, Grenoble, March 2015."

"Make yourself comfortable. Detector clothes boost the utility and ergonomics of MRI"