Cryogenic Preamplifiers for Magnetic Resonance Imaging

Pursuing the ultimate limit of detection in magnetic resonance imaging (MRI) requires cryogenics to decrease the thermal noise of the electronic circuits. As cryogenic coils for MRI are slowly emerging cryogenic preamplifiers are required to fully exploit their potential. A cryogenic preamplifier operated at 77 K is designed and implemented for C imaging at 3 T (32.13 MHz), using off-the-shelves components. The design is based on a high electron mobility transistor (ATF54143) in a common source configuration. Required auxiliary circuitry for optimal cryogenic preamplifier performance is also presented consisting of a voltage regulator (noise free supply voltage and optimal power consumption), switch, and trigger (for active detuning during transmission to protect the preamplifier). A gain of 18 dB with a noise temperature of 13.7 K is achieved. Performing imaging experiments in a 3 T scanner showed an 8% increased signal-to-noise ratio from 365 to 399 when lowering the temperature of the preamplifier from 296 to 77 K while keeping the coil at room temperature. This paper thus enables the merger of cryogenic coils and preamplifiers in the hopes of reaching the ultimate limit of detection for MRI.
Radiative MRI Coil Design Using Parasitic Scatterers: MRI Yagi

Conventionally, radiofrequency (RF) coils used for magnetic resonance imaging (MRI) are electrically small and designed for nearfield operation. Therefore, existing antenna design techniques are mostly irrelevant for RF coils. However, the use of higher frequencies in ultrahigh field (UHF) MRI allows for antenna design techniques to be adapted to RF coil designs. This study proposes the use of parasitic scatterers to improve the performance of an existing 7T MRI coil called the single-sided adapted dipole (SSAD) antenna. The results reveal that scatterers arranged in a Yagi fashion can be applied to reduce local specific absorption rate (SAR) maxima of a reference SSAD by 40% with only a 6% decrease in the propagated B1+ field at the tissue depth of 15 cm. The higher directivity of the proposed design also decreasing the coupling with additional elements, making this antenna suitable for use in high density arrays. These findings show the potential of parasitic scatterers as an effective method to improve the performance of existing radiative MRI coils.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance, Center for Magnetic Resonance, Lund University, Lite-On Mobile AB
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Pages: 1570 - 1575
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3D Hyperpolarized C-13 EPI with Calibrationless Parallel Imaging

With the translation of metabolic MRI with hyperpolarized $^{13}$C agents into the clinic, imaging approaches will require large volumetric FOVs to support clinical applications. Parallel imaging techniques will be crucial to increasing volumetric scan coverage while minimizing RF requirements and temporal resolution. Calibrationless parallel imaging approaches are well-suited for this application because they eliminate the need to acquire coil profile maps or auto-calibration data. In this work, we explored the utility of a calibrationless parallel imaging method (SAKE) and corresponding sampling strategies to accelerate and undersample hyperpolarized $^{13}$C data using 3D blipped EPI acquisitions and multichannel receive coils, and demonstrated its application in a human study of [1-13C]pyruvate metabolism.

General information
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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, University of California at San Francisco
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Web of Science (2016): Indexed yes
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Scopus rating (2015): SJR 1.111 SNIP 1.07 CiteScore 2.88
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.113 SNIP 1.013 CiteScore 2.26
Web of Science (2014): Indexed yes
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Scopus rating (2012): SJR 1.117 SNIP 1.046 CiteScore 2.28
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BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.097 SNIP 1.137 CiteScore 2.55
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
3-Fold SNR Enhancement of Small Animal 13C MRI using a Cryogenically Cooled (88 K) RF Coil

SNR in hyperpolarized 13C MRI is often limited by the low sensitivity of the receive RF chain at the low Larmor frequency of 13C. In this study we present an RF transparent (non-metallic) cryostat designed for small animal imaging, which allows a coil temperature of 88 K, with a coil-to-sample distance below 3 mm. Performance of the cryostat equipped with a 30 x 40 mm2 13C surface coil (3 T, 32 MHz) was tested and 3-fold SNR gain over room temperature coil was achieved.

General information
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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Electromagnetic Systems, University of Houston, Institut für Luft- und Kältetechnik Gemeinnützige Gesellschaft mbH
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Accurate Noise Figure Measurements for Highly Mismatched Preamplifiers
A method reducing the uncertainty of noise figure measurements of highly mismatched preamplifiers is presented. In many cases when measuring the noise figure of preamplifiers for MRI receive arrays the uncertainty is approximately ±0.4 dB. Since the noise figure of the preamplifier is also in this range, a more accurate method is needed. Here we show an increase of 59 % in noise figure accuracy by adding an attenuator between the noise source and preamplifier.

General information
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A comprehensive study of cryogenic cooled millimeter-wave frequency multipliers based on GaAs Schottky-barrier varactors

The benefit of cryogenic cooling on the performance of millimeter-wave GaAs Schottky-barrier varactor-based frequency multipliers has been studied. For this purpose, a dedicated compact model of a GaAs Schottky-barrier varactor using a triple-anode diode stack has been developed for use with a commercial RF and microwave CAD tool. The model implements critical physical phenomena such as thermionic-field emission current transport at cryogenic temperatures, temperature dependent mobility, reverse breakdown, self-heating, and high-field velocity saturation effects. A parallel conduction model is employed in order to include the effect of barrier inhomogeneities which is known to cause deviation from the expected I--V characteristics at cryogenic temperatures. The developed model is shown to accurately fit the I--V -T dataset from 25 to 295 K measured on the varactor diode stack. Harmonic balance simulations using the model are used to predict the efficiency of a millimeter-wave balanced doubler from room to cryogenic temperatures. The estimation is verified experimentally using a 188 GHz balanced doubler cooled down to 77 K. The model has been further verified down to 14 K using a 78 GHz balanced doubler.
A device and method for generating a polybinary signal

The present disclosure relates to a method for generating an L-level polybinary signal, comprising the steps of: providing a baseband signal with a spectrum defined by a predefined frequency period, f_p; filtering the baseband signal using a low-pass filter having a pre-defined cut-off frequency, f_c, and a pre-defined polynomial order, n, whereby the L-polybinary signal is generated; filtering the L-polybinary signal before or after it is generated, with at least one band-stop filter having a pre-defined center frequency, f_c, and a pre-defined bandwidth, Δ, thereby isolating f_p of the baseband signal.

Age-dependent effects of brain stimulation on network centrality

Functional magnetic resonance imaging (fMRI) studies have suggested that advanced age may mediate the effects of transcranial direct current stimulation (tDCS) on brain function. However, studies directly comparing neural tDCS effects between young and older adults are scarce and limited to task-related imaging paradigms. Resting-state (rs-) fMRI, that is independent of age-related differences in performance, is well suited to investigate age associated differential neural tDCS effects. Three “online” tDCS conditions (anodal, cathodal, sham) were compared in a cross-over, within-subject design, in 30 young and 30 older adults. Active stimulation targeted the left sensorimotor network (active electrode over left sensorimotor cortex with right supraorbital reference electrode). A graph-based rs-fMRI data analysis approach (eigenvector centrality mapping) and complementary seed-based analyses characterized neural tDCS effects. An interaction between anodal tDCS and age group was observed. Specifically, centrality in bilateral paracentral and posterior regions (precuneus, superior parietal cortex) was increased in young, but decreased in older adults. Seed-based analyses revealed that these opposing patterns of tDCS-induced centrality modulation were explained from differential effects of tDCS on functional coupling of the stimulated left paracentral lobule. Cathodal tDCS did not show significant effects. Our study provides first evidence for differential tDCS effects on neural network organization in young and older adults. Anodal stimulation mainly affected coupling of sensorimotor with ventromedial prefrontal areas in young and decoupling with posteromedial areas in older adults.
Aging, Eigenvector centrality mapping, Graph analysis, Resting-state functional connectivity, Transcranial direct current stimulation

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Analysis of dDNP NMR metabolic data from cancer cells

With the rise of the field of systems biology, metabolomic data have been integrated with the data for other -omic sciences, and these gigantic collections of correlated data have with the ever improving computing power, been data mined to locate biomarkers and motifs.[1] In this project the metabolic fingerprint of four prostate cancer cell lines, with different levels of aggression were analyzed. Metabolic data were obtained by incubating the cells with 13C6-d7 isotope labeled glucose, then quenching the metabolism, removing the cell debris and hyperpolarizing the metabolite extracts with dissolution Dynamic Nuclear Polarization (dDNP).

By integrating the peaks of the resulting NMR spectra, a collection of metabolic data was obtained without the need for identification of specific compounds. On this data, data mining was applied, with the aim to identify biomarkers of cancer and to classify the aggressiveness of the cancer. The illustrations below show examples of obtained NMR spectra for the different cell types (on the left) and Principal Components-Discriminant Function Analysis (PCDFA) results from the four prostate cancer cell types and a breast cancer cell line, in red, (on the right). The PC-DFA is clearly able to separate the cell types, with the most aggressive clustering together (blue and green). As dDNP MNR have been shown to be quantitative and reproducible,[2] it could be an important tool in the future for cancer diagnostics.

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A narrow line UV-induced non-persistent radical to generate highly polarized transportable glucose solid samples

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An Automatically Generated Texture-based Atlas of the Lungs

Many pulmonary diseases can be characterized by visual abnormalities on lung CT scans. Some diseases manifest similar defects but require completely different treatments, as is the case for Pulmonary Hypertension (PH) and Pulmonary Embolism (PE): both present hypo- and hyper-perfused regions but with different distribution across the lung and require different treatment protocols. Finding these distributions by visual inspection is not trivial even for trained radiologists who currently use invasive catheterism to diagnose PH. A Computer-Aided Diagnosis (CAD) tool that could facilitate the non-invasive diagnosis of these diseases can benefit both the radiologists and the patients. Most of the visual differences in the parenchyma can be characterized using texture descriptors. Current CAD systems often use texture information but the texture is either computed in a patch-based fashion, or based on an anatomical division of the lung. The difficulty of
Finding these divisions in abnormal lungs calls for new tools for obtaining new meaningful divisions of the lungs. In this paper, we present a method for unsupervised segmentation of lung CT scans into subregions that are similar in terms of texture and spatial proximity. To this extent, we combine a previously validated Riesz-wavelet texture descriptor with a well-known superpixel segmentation approach that we extend to 3D. We demonstrate the feasibility and accuracy of our approach on a simulated texture dataset and show preliminary results for CT scans of the lung comparing subjects suffering either from PH or PE. The resulting texture-based atlas of individual lungs can potentially help physicians in diagnosis or be used for studying common texture distributions related to other diseases.

General information
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An MR-Compatible Haptic Interface With Seven Degrees of Freedom
Functional magnetic resonance imaging (fMRI) is a powerful tool for neuroscience. It allows the visualization of active areas in the human brain. Combining this method with haptic interfaces allows one to conduct human motor control studies with an opportunity for standardized experimental conditions. However, only a small number of specialized MR-compatible haptic interfaces exist that were mostly built around specific research questions. The devices are designed for pure translational, rotational, or grasping movements. In this work, we present a novel MR-compatible haptic interface with seven degrees of freedom (DoF), which allows for both translations and rotations in three DoF each, as well as a two-finger precision grasp. The presented haptic interface is the first one with these capabilities and is designed as a universal tool for human motor control studies involving fMRI. It allows for the switching of the paradigm to reprogramming rather than redesigning when moving on to a new research question. We introduce its kinematics and control, along with results of MR compatibility tests and a preliminary fMRI study, showing the applicability of the device.

General information
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Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Technical University of Munich, Max-Planck-Institute for Biological Cybernetics, Institute for Innovation and Change Methodologies, University of Tubingen, Volkswagen AG, Free University of Bozen-Bolzano
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Automatic skull segmentation from MR images for realistic volume conductor models of the head: Assessment of the state-of-the-art

Anatomically realistic volume conductor models of the human head are important for accurate forward modeling of the electric field during transcranial brain stimulation (TBS), electro- (EEG) and magnetoencephalography (MEG). In particular, the skull compartment exerts a strong influence on the field distribution due to its low conductivity, suggesting the need to represent its geometry accurately. However, automatic skull reconstruction from structural magnetic resonance (MR) images is difficult, as compact bone has a very low signal in magnetic resonance imaging (MRI). Here, we evaluate three methods for skull segmentation, namely FSL BET2, the unified segmentation routine of SPM12 with extended spatial tissue priors, and the skullfinder tool of BrainSuite. To our knowledge, this study is the first to rigorously assess the accuracy of these state-of-the-art tools by comparison with CT-based skull segmentations on a group of ten subjects. We demonstrate several key factors that improve the segmentation quality, including the use of multi-contrast MRI data, the optimization of the MR sequences and the adaptation of the parameters of the segmentation methods. We conclude that FSL and SPM12 achieve better skull segmentations than BrainSuite. The former methods obtain reasonable results for the upper part of the skull when a combination of T1- and T2-weighted images is used as input. The SPM12-based results can be improved slightly further by means of simple morphological operations to fix local defects. In contrast
to FSL BET2, the SPM12-based segmentation with extended spatial tissue priors and the BrainSuite-based segmentation provide coarse reconstructions of the vertebrae, enabling the construction of volume conductor models that include the neck. We exemplarily demonstrate that the extended models enable a more accurate estimation of the electric field distribution during transcranial direct current stimulation (tDCS) for montages that involve extraencephalic electrodes. The methods provided by FSL and SPM12 are integrated into pipelines for the automatic generation of realistic head models based on tetrahedral meshes, which are distributed as part of the open-source software package SimNIBS for field calculations for transcranial brain stimulation.

General information
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Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 4.323 SNIP 2.03 CiteScore 6.9
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Web of Science (2008): Indexed yes
Combined Hyperpolarized $^{13}$C-pyruvate MRS and $^{18}$F-FDG PET (HyperPET) Estimates of Glycolysis in Canine Cancer Patients

$^{13}$C Magnetic Resonance Spectroscopy (MRS) using hyperpolarized $^{13}$C-labeled pyruvate as a substrate offers a measure of pyruvate-lactate interconversion and is thereby a marker of the elevated aerobic glycolysis (Warburg effect) generally exhibited by cancer cells. Here, we aim to compare hyperpolarized $[1^{13}$C]pyruvate MRS with simultaneous $^{18}$F-2-fluoro-2-deoxy-D-glucose (FDG) PET in a cross-sectional study of canine cancer patients. Methods: Canine cancer patients underwent integrated PET/MRI using a clinical whole-body system. Hyperpolarized $[1^{13}$C]pyruvate was obtained using dissolution-DNP. $^{18}$F-FDG PET, dynamic $^{13}$C MRS, $^{13}$C MRS Imaging (MRSI) and anatomical $^{1}$H MRI was acquired from 17 patients. Apparent pyruvate-to-lactate rate constants were estimated from dynamic $^{13}$C MRS. $^{18}$F-FDG Standard Uptake Values and maximum $[1^{13}$C]lactate-to-total-$^{13}$C ratios were obtained from tumor regions of interest. Following inspection of data, patients were grouped according to main cancer type and linear regression between measures of lactate generation and $^{18}$FFDG uptake were tested within groups. Between groups, the same measures were tested for group differences. Results: The main cancer types of the 17 patients were sarcoma (n = 11), carcinoma (n = 5) and mastocytoma (n = 1). Significant correlations between pyruvate-to-lactate rate constants and $^{18}$FFDG uptake were found for sarcoma patients, whereas no significant correlations appeared for carcinoma patients. The sarcoma patients showed a non-significant trend towards lower $^{18}$FFDG uptake and higher lactate generation than carcinoma patients. However, the ratio of lactate generation to $^{18}$FFDG uptake was found to be significantly higher in sarcoma as compared to carcinoma. The results were found both when lactate generation was estimated as an apparent pyruvate-to-lactate rate constant from dynamic $^{13}$C MRS and as an $[1^{13}$C]lactate-to-total-$^{13}$C ratio from $^{13}$C MRSI. Conclusions: A comparison of hyperpolarized $[1^{13}$C]pyruvate MRS with simultaneous $^{18}$F-FDG PET indicate that lactate generation and $^{18}$FFDG uptake in cancers can be related and that their relation depend on cancer type. This finding could be important for the interpretation and eventual clinical implementation of hyperpolarized $^{13}$C. In addition, the differences between the two modalities may allow for better metabolic phenotyping performing hybrid imaging in the form of hyperPET
Comparison of two alternative sequences for human in-vivo brain MR Current Density Imaging (MRCDI)

MRCDI is a novel technique, utilizing dierent phase-sensitive MR methods for non-invasive measurements of weak currents in the human body, which is important in several neuroscience applications. Here, we compare the in-vivo performance of two dierent MR methods, multi-echo spin echo (MESE) and steady-state free precession free induction decay (SSFP-FID), with single- vs. multi-gradient-echo readouts. We demonstrate that multi-gradient-echo readouts improve both methods. We validate the linear dependence of the measured current-induced magnetic eld on the injected current strength for both methods, and propose the more ecient...
SSFP-FID method as being well suited for highly sensitive single-slice human in-vivo MRCDI.

**Contributed review: camera-limits for wide-field magnetic resonance imaging with a nitrogen-vacancy spin sensor**

Sensitive, real-time optical magnetometry with nitrogen-vacancy centers in diamond relies on accurate imaging of small ($<10^{-2}$), fractional fluorescence changes across the diamond sample. We discuss the limitations on magnetic field sensitivity resulting from the limited number of photoelectrons that a camera can record in a given time. Several types of camera sensors are analyzed, and the smallest measurable magnetic field change is estimated for each type. We show that most common sensors are of a limited use in such applications, while certain highly specific cameras allow achieving nanotesla-level sensitivity in 1 s of a combined exposure. Finally, we demonstrate the results obtained with a lock-in camera that paves the way for real-time, wide-field magnetometry at the nanotesla level and with a micrometer resolution.
Discovery of Intermediates of lacZ beta-Galactosidase Catalyzed Hydrolysis Using dDNP NMR

Using dissolution dynamic nuclear polarization, the sensitivity of single scan solution state C-13 NMR can be improved up to 4 orders of magnitude. In this study, the enzyme lacZ beta-galactosidase from Escherichia coli was subjected to hyperpolarized substrate, and previously unknown reaction intermediates were observed, including a 1,1-linked disaccharide. The enzyme is known for making 1,6-transglycosylation, producing products like allolactose, that are also substrates. To analyze the kinetics, a simple kinetic model was developed and used to determine relative transglycosylation and hydrolysis rates of each of the intermediates, and the novel transglycosylation intermediates were determined as better substrates than the 1,6-linked one, explaining their transient nature. These findings suggest that hydrolysis and transglycosylation might be more complex than previously described.

General information
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Organisations: Department of Chemistry, Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Organic Chemistry
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  Scopus rating (2015): SJR 6.775 SNIP 2.63 CiteScore 12.81
  Web of Science (2015): Indexed yes
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  Scopus rating (2014): SJR 6.294 SNIP 2.587 CiteScore 11.92
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  Scopus rating (2013): SJR 5.993 SNIP 2.466 CiteScore 11.38
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  Web of Science (2007): Indexed yes
  Scopus rating (2006): SJR 4.662 SNIP 2.252
  Web of Science (2006): Indexed yes
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  Scopus rating (2003): SJR 3.421 SNIP 2.236
  Web of Science (2003): Indexed yes
  Scopus rating (2002): SJR 3.223 SNIP 2.345
Dynamic coronary MR angiography in a pig model with hyperpolarized water
To investigate dynamic coronary MR angiography using hyperpolarized water as a positive contrast agent. Hyperpolarization can increase the signal by several orders of magnitude, and has recently been translated to human cardiac application. The aim was to achieve large 1 H signal enhancement to allow high-resolution imaging of the coronary arteries. Protons in D2 O were hyperpolarized by dissolution dynamic nuclear polarization. A total of 18 mL of hyperpolarized water was injected into the coronary arteries of healthy pigs (N=9; 3 injections in 3 animals). The MRI images were acquired with a gradient-echo sequence in an oblique slab covering the main left coronary arteries with 0.55 mm in-plane resolution. The acquisition time was 870 ms per frame. A more than 200-fold signal enhancement compared with thermally polarized water at 3 T was obtained. Coronary angiographic images with a signal-to-noise ratio from the left main stem of 269 ± 169 and coronary sharpness from the proximal left anterior descending coronary artery of 0.31 ± 0.086 mm-1 were obtained. Dynamic images were acquired over a 10 s time window. Hyperpolarized water MR angiography of the coronary arteries in a large animal model with high signal-to-noise ratio and high spatial and temporal resolution was obtained. Magn Reson Med, 2018. © 2018 International Society for Magnetic Resonance in Medicine.

General information
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Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Aarhus University
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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.77 SJR 1.89 SNIP 1.411
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.52 SJR 1.945 SNIP 1.451
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.329 SNIP 1.481 CiteScore 3.54
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.015 SNIP 1.382 CiteScore 3.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.039 SNIP 1.433 CiteScore 3.46
Effects of transcranial direct current stimulation for treating depression: A modeling study

Background: Transcranial direct current stimulation (tDCS) above the left dorsolateral prefrontal cortex (IDLPFC) has been widely used to improve symptoms of major depressive disorder (MDD). However, the effects of different stimulation protocols in the entire frontal lobe have not been investigated in a large sample including patient data.

Methods: We used 38 head models created from structural magnetic resonance imaging data of 19 healthy adults and 19 MDD patients and applied computational modeling to simulate the spatial distribution of tDCS-induced electric fields (EFs) in 20 frontal regions. We evaluated effects of seven bipolar and two multi-electrode 4×1 tDCS protocols.

Results: For bipolar montages, EFs were of comparable strength in the IDLPFC and in the medial prefrontal cortex (MPFC). Depending on stimulation parameters, EF cortical maps varied to a considerable degree, but were found to be similar in controls and patients. 4×1 montages produced more localized, albeit weaker effects.

Limitations: White matter anisotropy was not modeled. The relationship between EF strength and clinical response to tDCS could not be evaluated.

Conclusions: In addition to IDLPFC stimulation, excitability changes in the MPFC should also be considered as a potential mechanism underlying clinical efficacy of bipolar montages. MDD-associated anatomical variations are not likely to substantially influence current flow. Individual modeling of tDCS protocols can substantially improve cortical targeting. We make recommendations for future research to explicitly test the contribution of IDLPFC vs. MPFC stimulation to therapeutic outcomes of tDCS in this disorder.
Fast CSF MRI for brain segmentation; Cross-validation by comparison with 3D T₁-based brain segmentation methods

ObjectiveIn previous work we have developed a fast sequence that focuses on cerebrospinal fluid (CSF) based on the long T-2 of CSF. By processing the data obtained with this CSF MRI sequence, brain parenchymal volume (BPV) and intracranial volume (ICV) can be automatically obtained. The aim of this study was to assess the precision of the BPV and ICV measurements of the CSF MRI sequence and to validate the CSF MRI sequence by comparison with 3D T-1-based brain segmentation methods.

Materials and methodsTen healthy volunteers (2 females; median age 28 years) were scanned (3T MRI) twice with repositioning in between. The scan protocol consisted of a low resolution (LR) CSF sequence (0:57min), a high resolution (HR) CSF sequence (3:21min) and a 3D T-1-weighted sequence (6:47min). Data of the HR 3D-T-1-weighted images were downsampled to obtain LR T-1-weighted images (reconstructed imaging time: 1:59 min). Data of the CSF MRI sequences was automatically segmented using in-house software. The 3D-T-1-weighted images were segmented using FSL (5.0), SPM12 and FreeSurfer (5.3.0).

ResultsThe mean absolute differences for BPV and ICV between the first and second scan for CSF LR (BPV/ICV: 12 +/- 9/7 +/- 4cc) and CSF HR (5 +/- 5/4 +/- 2cc) were comparable to FSL HR (9 +/- 11/19 +/- 23cc), FSL LR (7 +/- 4,6 +/- 5cc), FreeSurfer HR (5 +/- 3/14 +/- 8cc), FreeSurfer LR (9 +/- 8,12 +/- 10cc), and SPM HR (5 +/- 3/4 +/- 7cc), and SPM LR (5 +/- 4,5 +/- 3cc). The correlation between the measured volumes of the CSF sequences and that measured by FSL, FreeSurfer and SPM HR and LR was very good (all Pearson's correlation coefficients >0.83, R-2 .67-.97). The results from the downsampled data and the high-resolution data were similar.

ConclusionBoth CSF MRI sequences have a precision comparable to, and a very good correlation with established 3D T-1-based automated segmentations methods for the segmentation of BPV and ICV. However, the short imaging time of the fast CSF MRI sequence is superior to the 3D T-1 sequence on which segmentation with established methods is performed.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, University Medical Centre Utrecht, National Institutes of Health
Authors: van der Kleij, L. A. (Ekstern), de Bresser, J. (Ekstern), Hendrikse, J. (Ekstern), Siero, J. C. W. (Ekstern), Petersen, E. T. (Intern), de Vis, J. B. (Ekstern)
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Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.11 SJR 1.236 SNIP 1.101
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.427 SNIP 1.136 CiteScore 3.32
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.559 SNIP 1.148 CiteScore 3.54
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.772 SNIP 1.153 CiteScore 3.94
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.982 SNIP 1.156 CiteScore 4.15
ISI indexed (2012): ISI indexed yes
Feasibility and resolution limits of opto-magnetic imaging of neural network activity in brain slices using color centers in diamond

We suggest a novel approach for wide-field imaging of the neural network dynamics of brain slices that uses highly sensitivity magnetometry based on nitrogen-vacancy (NV) centers in diamond. Invitro recordings in brain slices is a proven method for the characterization of electrical neural activity and has strongly contributed to our understanding of the mechanisms that govern neural information processing. However, this traditional approach only acquires signals from a few positions, which severely limits its ability to characterize the dynamics of the underlying neural networks. We suggest to extend its scope using NV magnetometry-based imaging of the neural magnetic fields across the slice. Employing comprehensive computational simulations and theoretical analyses, we determine the spatiotemporal characteristics of the neural fields and the required key performance parameters of an NV magnetometry-based imaging setup. We investigate how the technical parameters determine the achievable spatial resolution for an optimal 2D reconstruction of neural currents from the measured field distributions. Finally, we compare the imaging of neural slice activity with that of a single planar pyramidal cell. Our results suggest that imaging of slice activity will be possible with the upcoming generation of NV magnetic field sensors, while single-shot imaging of planar cell activity remains challenging.
Human In-vivo Brain MR Current Density Imaging (MRCDI) based on Steady-state Free Precession Free Induction Decay (SSFP-FID)

MRCDI is a novel technique for non-invasive measurement of weak currents in the human head, which is important in several neuroscience applications. Here, we present reliable in-vivo MRCDI measurements in the human brain based on SSFP-FID, yielding an unprecedented accuracy. We demonstrate the destructive influences of stray magnetic fields caused by the current passing through feeding cables, and propose a correction method. Also, we show inter-individual differences in MRCDI measurements for two different current profiles, and compare the measurements with simulations based on individualized head models. The simulations of the current-induced magnetic fields show good agreement with in-vivo brain measurements.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Copenhagen University Hospital, University of Tubingen
Authors: Göksu, C. (Intern), Hanson, L. G. (Intern), Siebner, H. (Ekstern), Ehses, P. (Ekstern), Scheffler, K. (Ekstern), Thielscher, A. (Intern)
Number of pages: 3
Publication date: 2018
Main Research Area: Technical/natural sciences
Electronic versions: ISMRM18_0542_Cihan_HumanMRCDI.pdf

Ideal Coil Decoupling in Receive Arrays using Negative Resistance Preamplifiers
This work presents the method of achieving ideal decoupling between elements in a receive coil array. Generally, preamplifier decoupling is limited by nonidealities of the implemented components. It is shown analytically and numerically, that for the ideal (lossless) matching circuits the input resistance of the preamplifier should be zero, while for the realistic lossy case a small negative resistance can be used to achieve ideal decoupling. Here we use a negative input
resistance preamplifier (NIRP) to compensate for the loss of the circuit. The analysis is verified experimentally showing a decoupling of -62 dB when a NIRP with an input resistance of -0.023 $\Omega$ is used.

**General information**

State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Electromagnetic Systems
Authors: Johansen, D. H. (Intern), Sánchez-Heredia, J. D. (Intern), Zhurbenko, V. (Intern), Ardenkjær-Larsen, J. H. (Intern)
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Main Research Area: Technical/natural sciences
Electronic versions:
ISMRM18_1711_Decoupling.pdf
Source: PublicationPreSubmission
Source-ID: 151671534
Publication: Research - peer-review › Paper – Annual report year: 2018

**Increased variability of watershed areas in patients with high-grade carotid stenosis**

Purpose: Watershed areas (WSAs) of the brain are most susceptible to acute hypoperfusion due to their peripheral location between vascular territories. Additionally, chronic WSA-related vascular processes underlie cognitive decline especially in patients with cerebral hemodynamic compromise. Despite of high relevance for both clinical diagnostics and research, individual in vivo WSA definition is fairly limited to date. Thus, this study proposes a standardized segmentation approach to delineate individual WSAs by use of time-to-peak (TTP) maps and investigates spatial variability of individual WSAs.

Methods: We defined individual watershed masks based on relative TTP increases in 30 healthy elderly persons and 28 patients with unilateral, high-grade carotid stenosis, being at risk for watershed-related hemodynamic impairment. Determined WSA location was confirmed by an arterial transit time atlas and individual super-selective arterial spin labeling. We compared spatial variability of WSA probability maps between groups and assessed TTP differences between hemispheres in individual and group-average watershed locations.

Results: Patients showed significantly higher spatial variability of WSAs than healthy controls. Perfusion on the side of the stenosis was delayed within individual watershed masks as compared to a watershed template derived from controls, being independent from the grade of the stenosis and collateralization status of the circle of Willis. Conclusion: Results demonstrate feasibility of individual WSA delineation by TTP maps in healthy elderly and carotid stenosis patients. Data indicate necessity of individual segmentation approaches especially in patients with hemodynamic compromise to detect critical regions of impaired hemodynamics.

**General information**

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Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Technical University of Munich, Philips Research, Technische Universität München
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Scopus rating (2017): SNIP 1.505 SJR 1.661 CiteScore 3.34
Web of Science (2017): Indexed Yes
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BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.761 SNIP 1.655 CiteScore 3.04
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.92 SNIP 1.794 CiteScore 3.19

For hyperpolarized 13C MRI acquisitions aimed at metabolic rate constant estimation, the Bloch-Siegert shift enables encoding of the transmit field (B1+-field) amplitude within a single hyperpolarized substrate injection. This ability is needed since most clinical hyperpolarized MRI studies use inhomogeneous transmit coils, and because kinetic modeling based on incorrect flip angles can lead to incorrect rate constant estimations. This study demonstrates the feasibility of integrated B1+ mapping for large volume thermal and hyperpolarized phantoms in a clinical setup using a clamshell transmit coil and a 16-channel receive array, and a 3D stack-of-spirals sequence. Phase-sensitive coil-combination was achieved using ESPiRiT.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, University of California at San Francisco
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Number of pages: 3
Publication date: 2018
Main Research Area: Technical/natural sciences
Electronic versions:
ISMRM18_3698_RieB1.pdf
Source: PublicationPreSubmission
Source-ID: 149080401
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2018
Kinetic Analysis of Hexose Conversion to Methyl Lactate by Sn Beta: Effects of Substrate Masking and of Water

Simple sugars bear promise as substrates for the formation of fuels and chemicals using heterogeneous catalysts in alcoholic solvents. Sn-Beta is a particularly well suited catalyst for the cleavage, isomerization and dehydration of sugars into more valuable chemicals. In order to understand these processes and save resources and time by optimizing them, kinetic and mechanistic analyses are helpful. Herein, we study substrate entry into the Sn-Beta catalysed methyl lactate process using abundant hexose substrates. NMR spectroscopy is applied to show that the formation of methyl lactate occurs in two kinetic regimes for fructose, glucose and sucrose. The majority of methyl lactate is not formed from the substrate directly, but from methyl fructosides in a slow regime. At 160 °C, more than 40% of substrate carbon are masked (i.e. reversibly protected in situ) as methyl fructosides within few minutes when using hydrothermally synthesised Sn-Beta, while more than 60% methyl fructosides can be produced within few minutes using post synthetically synthesised Sn-Beta. A significant fraction of substrate thus is masked by rapid methyl fructoside formation prior to subsequent slow release of fructose. This release is the rate limiting step in the Sn-Beta catalysed methyl lactate process, but can be accelerated by the addition of small amounts of water at the expense of maximum methyl lactate yield.

General information
State: Published
Organisations: Department of Chemistry, Centre for Catalysis and Sustainable Chemistry, Organic Chemistry, Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Haldor Topsoe AS
Authors: Tosi, I. (Intern), Riisager, A. (Intern), Taarning, E. (Ekstern), Jensen, P. R. (Intern), Meier, S. (Intern)
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Main Research Area: Technical/natural sciences

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Journal: Catalysis Science & Technology
Volume: 18
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ISSN (Print): 2044-4753
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 5.47 SJR 1.797 SNIP 1.149
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 5.64 SJR 1.811 SNIP 1.287
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.804 SNIP 1.314 CiteScore 5.46
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.885 SNIP 1.47 CiteScore 5.44
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.744 SNIP 1.296 CiteScore 4.89
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Scopus rating (2012): SJR 1.595 SNIP 1.036 CiteScore 3.7
ISI indexed (2012): ISI indexed no
ISI indexed (2011): ISI indexed no
Original language: English
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Publication: Research - peer-review › Journal article – Annual report year: 2018
Liquid-State Polarization of 30% through Photo-Induced Non-Persistent Radicals on $^{13}$C Pyruvic Acid

**General information**

State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance
Number of pages: 1
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Main Research Area: Technical/natural sciences

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Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2018

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**Liquid-State $^{13}$C Polarization of 30% through Photoinduced Nonpersistent Radicals**

Hyperpolarization via dissolutiondynamic nuclear polarization (dDNP) is crucial to significantly increasing the magnetic resonance imaging (MRI) sensitivity, opening up in vivo real-time MRI using $^{13}$C-labeled substrates. The range of applications, however, is limited by the relatively fast decay of the nuclear spin polarization together with the constraint of having to polarize the spins near the MRI magnet. As recently demonstrated, the employment of UV-induced nonpersistent radicals represents an elegant solution to tackling these drawbacks. Nevertheless, since its introduction, the spread of the technique has been prevented by the relatively low achievable polarization, slow buildup time, and time-consuming sample preparation. In the present work, thanks to a thorough investigation of the radical generation step, we provide a robust protocol to enhance the efficiency and performance of the UV-radical technique. Under optimal conditions, it was possible to produce up to 60 mM radical in less than 5 min, and it reached maximum DNP enhancement with a buildup time constant of approximately 25 min at 6.7 T and 1 K, resulting in 30% $^{13}$C liquid-state polarization.

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Ratings:
- BFI (2018): BFI-level 1
- Web of Science (2018): Indexed yes
- BFI (2017): BFI-level 1
- Scopus rating (2017): CiteScore 4.58 SJR 2.135 SNIP 1.147
- Web of Science (2017): Indexed yes
- BFI (2016): BFI-level 1
- Scopus rating (2016): CiteScore 4.48 SJR 1.964 SNIP 1.195
- Web of Science (2016): Indexed yes
- BFI (2015): BFI-level 1
- Scopus rating (2015): SJR 1.886 SNIP 1.26 CiteScore 4.68
- Web of Science (2015): Indexed yes
- BFI (2014): BFI-level 1
- Scopus rating (2014): SJR 2.032 SNIP 1.447 CiteScore 5.08
- Web of Science (2014): Indexed yes
- BFI (2013): BFI-level 1
- Scopus rating (2013): SJR 2.143 SNIP 1.445 CiteScore 5.14
- ISI indexed (2013): ISI indexed yes
Molecular imaging of tumor photoimmunotherapy: Evidence of photosensitized tumor necrosis and hemodynamic changes

Near-infrared photoimmunotherapy (NIR PIT) employs the photoabsorbing dye IR700 conjugated to antibodies specific for cell surface epidermal growth factor receptor (EGFR). NIR PIT has shown highly selective cytotoxicity in vitro and in vivo. Cell necrosis is thought to be the main mode of cytotoxicity based mainly on in vitro studies. To better understand the acute effects of NIR PIT, molecular imaging studies were performed to assess its cellular and vascular effects. In addition to in vitro studies for cytotoxicity of NIR PIT, the in vivo tumoricidal effects and hemodynamic changes induced by NIR PIT were evaluated by C-13 MRI using hyperpolarized [1,4-C-13(2)] fumarate, R-2* mapping from T-2*-weighted MRI, and photoacoustic imaging. In vitro studies confirmed that NIR PIT resulted in rapid cell death via membrane damage, with evidence for rapid cell expansion followed by membrane rupture. Following NIR PIT, metabolic MRI using hyperpolarized fumarate showed the production of malate in EGFR-expressing A431 tumor xenografts, providing direct evidence for photosensitized tumor necrosis induced by NIR PIT. R2* mapping studies showed temporal changes in oxygenation, with an accompanying increase of deoxyhemoglobin at the start of light exposure followed by a sustained decrease after cessation of light exposure. This result suggests a rapid decrease of blood flow in EGFR-expressing A431 tumor xenografts, which is supported by the results of the photoacoustic imaging experiments. Our findings suggest NIR PIT mediates necrosis and hemodynamic changes in tumors by photosensitized oxidation pathways and that these imaging modalities, once translated, may be useful in monitoring clinical treatment response.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, National Cancer Institute, National Institute of Neurological Disease and Stroke
Authors: Kishimoto, S. (Ekstern), Oshima, N. (Ekstern), Yamamoto, K. (Ekstern), Munasinghe, J. (Ekstern), Ardenkjær-Larsen, J. H. (Intern), Mitchell, J. B. (Ekstern), Choyke, P. L. (Ekstern), Krishna, M. C. (Ekstern)
Pages: 1-10
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Main Research Area: Technical/natural sciences
Multichannel Hyperpolarized 13C MRI in a Patient with Liver Metastases using Multi-slice EPI and an Alternating Projection Method for Denoising

Hyperpolarized 13C-pyruvate for monitoring metabolism of liver metastases in vivo is being investigated for clinical trials of new therapeutics. This study applied advances in multichannel receive arrays and sequence design for human 13C liver imaging and investigated a new denoising method. The method is based on an alternating projection method to enforce structuredness and low-rankness, and is applied with automatic threshold estimation. In vivo data demonstrate improved quality of kinetic modeling after denoising. However, simulations revealed certain unresolved pitfalls.

General information
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Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, University of California at Berkeley, University of California at San Francisco
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Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2018

Multi-dimensional microstructural imaging offers novel in vivo insights into brain pathology: an application to multiple sclerosis

Magnetic resonance imaging is today the most versatile imaging method for characterization of multiple sclerosis (MS) in vivo, but clinical examinations lack sensitivity to capture changes in the tissue microstructure. Using a multi-dimensional microstructural imaging approach, we demonstrate how it is possible to obtain more specific and broader microstructural insights about the underlying pathology of MS. For this we use a comprehensive battery of conventional and novel diffusion weighted imaging and quantitative MRI sequences each capable of explaining different and complementary microstructural properties. This allows us to explore the underlying pathology of MS, which is normally only accessible with histology.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Copenhagen University Hospital, Lund University
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Number of pages: 3
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Main Research Area: Technical/natural sciences
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On the importance of precise electrode placement for targeted transcranial electric stimulation

Transcranial electric stimulation (TES) is an increasingly popular method for non-invasive modulation of brain activity and a potential treatment for neuropsychiatric disorders. However, there are concerns about the reliability of its application because of variability in TES-induced intracranial electric fields across individuals. While realistic computational models offer can help to alleviate these concerns, their direct empirical validation is sparse, and their practical implications are not always clear. In this study, we combine direct intracranial measurements of electric fields generated by TES in surgical epilepsy patients with computational modeling. First, we directly validate the computational models and identify key parameters needed for accurate model predictions. Second, we derive practical guidelines for a reliable application of TES in terms of the precision of electrode placement needed to achieve a desired electric field distribution. Based on our results, we recommend electrode placement accuracy to be<1cm for a reliable application of TES across sessions.
Precision temperature sensing in the presence of magnetic field noise and vice-versa using nitrogen-vacancy centers in diamond

We demonstrate a technique for precision sensing of temperature or the magnetic field by simultaneously driving two hyperfine transitions involving distinct electronic states of the nitrogen-vacancy center in diamond. Frequency modulation of both driving fields is used with either the same or opposite phase, resulting in the immunity to fluctuations in either the magnetic field or the temperature, respectively. In this way, a sensitivity of 1.4 nT Hz^{-1/2} or 430 μK Hz^{-1/2} is demonstrated. The presented technique only requires a single frequency demodulator and enables the use of phase-sensitive camera imaging sensors. A simple extension of the method utilizing two demodulators allows for simultaneous, independent, and high-bandwidth monitoring of both the magnetic field and temperature.
Probing cardiac metabolism by hyperpolarized 13C MR using an exclusively endogenous substrate mixture and photo-induced nonpersistent radicals

To probe the cardiac metabolism of carbohydrates and short chain fatty acids simultaneously in vivo following the injection of a hyperpolarized 13 C-labeled substrate mixture prepared using photo-induced nonpersistent radicals. Droplets of mixed [1-13 C]pyruvic and [1-13 C]butyric acids were frozen into glassy beads in liquid nitrogen. Ethanol addition was investigated as a means to increase the polarization level. The beads were irradiated with ultraviolet light and the radical concentration was measured by ESR spectroscopy. Following dynamic nuclear polarization in a 7T polarizer, the beads were dissolved, and the radical-free hyperpolarized solution was rapidly transferred into an injection pump located inside a 9.4T scanner. The hyperpolarized solution was injected in healthy rats to measure cardiac metabolism in vivo. Ultraviolet irradiation created nonpersistent radicals in a mixture containing 13 C-labeled pyruvic and butyric acids, and enabled the hyperpolarization of both substrates by dynamic nuclear polarization. Ethanol addition increased the radical concentration from 16 to 26 mM. Liquid-state 13 C polarization was 3% inside the pump at the time of injection, and increased to 5% by addition of ethanol to the substrate mixture prior to ultraviolet irradiation. In the rat heart, the in vivo 13 C signals from
lactate, alanine, bicarbonate, and acetylcarnitine were detected following the metabolism of the injected substrate mixture. Copolarization of two different 13 C-labeled substrates and the detection of their myocardial metabolism in vivo was achieved without using persistent radicals. The absence of radicals in the solution containing the hyperpolarized 13 C-substrates may simplify the translation to clinical use, as no radical filtration is required prior to injection.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Lausanne University Hospital, Ecole Polytechnique Federale de Lausanne (EPFL), University of Florida, University of Lausanne
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Number of pages: 9
Publication date: 2018
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BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): CiteScore 3.77 SJR 1.89 SNIP 1.411
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.52 SJR 1.945 SNIP 1.451
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.329 SNIP 1.481 CiteScore 3.54
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.015 SNIP 1.382 CiteScore 3.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.039 SNIP 1.433 CiteScore 3.46
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.158 SNIP 1.553 CiteScore 3.61
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.16 SNIP 1.461 CiteScore 3.45
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.356 SNIP 1.606
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.331 SNIP 1.553
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 2.468 SNIP 1.5
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.397 SNIP 1.536
Scopus rating (2006): SJR 2.319 SNIP 1.756
Web of Science (2006): Indexed yes
Signal to noise comparison of metabolic imaging methods on a clinical 3T MRI

MRI with hyperpolarized tracers has enabled new diagnostic applications, e.g. metabolic imaging in cancer research. However, the acquisition of the transient, hyperpolarized signal with spatial and frequency resolution requires dedicated imaging methods. Here, we compare three promising candidates for 2D MR spectroscopic imaging (MRSI): (i) multi-echo balanced steady-state free precession (me-bSSFP), (ii) echo planar spectroscopic imaging (EPSI) sequence and (iii) phase-encoded, pulse-acquisition chemical-shift imaging (CSI).

Skull segmentation from MR scans using a higher-order shape model based on convolutional restricted Boltzmann machines

Transcranial brain stimulation (TBS) techniques such as transcranial magnetic stimulation (TMS), transcranial direct current stimulation (tDCS) and others have seen a strong increase as tools in therapy and research within the last 20 years. In order to precisely target the stimulation, it is important to accurately model the individual head anatomy of a subject. Of particular importance is accurate reconstruction of the skull, as it has the strongest impact on the current pathways due to its low conductivity. Thus providing automated tools, which can reliably reconstruct the anatomy of the human head from magnetic resonance (MR) scans would be highly valuable for the application of transcranial stimulation methods. These head models can also be used to inform source localization methods such as EEG and MEG. Automated segmentation of the skull from MR images is, however, challenging as the skull emits very little signal in MR. In order to avoid topological defects, such as holes in the segmentations, a strong model of the skull shape is needed. In this paper we propose a new shape model for skull segmentation based on the so-called convolutional restricted Boltzmann machines (cRBMs). Compared to traditionally used lower-order shape models, such as pair-wise Markov random fields (MRFs), the cRBMs model local shapes in larger spatial neighborhoods while still allowing for efficient inference. We compare the skull segmentation accuracy of our approach to two previously published methods and show significant improvement.
Slice-wise motion tracking during simultaneous EEG-fMRI
Slice-wise motion tracking during combined electroencephalography (EEG) and echo planar imaging (EPI) is developed. Using gradient-induced noise on the EEG for tracking, no interleaved navigator modules or additional hardware is needed. The motion parameters are determined after a calibration and training scan. The method is explored in a phantom and in vivo.

Stable isotope-resolved analysis with quantitative dissolution dynamic nuclear polarization
Metabolite profiles and their isotopomer distributions can be studied non-invasively in complex mixtures with NMR. The advent of dissolution Dynamic Nuclear Polarization (dDNP) and isotope enrichment add sensitivity and resolution to such metabolic studies. Metabolic pathways and networks can be mapped and quantified if protocols that control and exploit the ex situ signal enhancement are created. We present a sample preparation method, including cell incubation, extraction and signal enhancement, to facilitate reproducible and quantitative dDNP (qdDNP) NMR-based isotope tracer analysis. We further illustrate how qdDNP was applied to gain systematic and novel metabolic phenotypic insights into aggressive cancer cells.
Ultra-low power transmitter for encoding non-MR signals in Magnetic Resonance (MR) recordings

Advancing Magnetic Resonance Imaging (MRI) technology requires integration of the MRI scanners with sensors and systems for monitoring various non-MRI signals. In this paper, we present design and integration of a low power AM radio transmitter into a 3T MRI scanner, which can be used for efficient collection of data from non-MRI sensors. The transmitter consumes only 1.3mW while transmitting 2.7µW at 120MHz with high frequency stability. The presented design is useful in low power applications requiring high frequency stability and is intended for wireless transmission of non-MR signal.
Ultra-Wideband Coplanar Waveguide to Asymmetric Coplanar Stripline Transition from DC to 165 GHz

This paper presents an ultra-wideband coplanar waveguide (CPW)-to-asymmetric coplanar stripline (ACPS) transition based on aluminum nitride (AlN) substrate. The concepts of designing CPW, ACPS, and CPW-to-ACPS transition are explained. In order to suppress parasitic modes, vias going through AlN substrate are added along the ground traces. The signal trace is tapered out and chamfered to reduce the reflection caused by the termination of ground trace. The CPW-to-ACPS transition is designed, fabricated, and measured in a back-to-back configuration. The fabricated CPW-to-ACPS transition can provide a bandwidth of 165 GHz with an associated insertion loss of 3 dB.
Volume of the human hippocampus and clinical response following electroconvulsive therapy

Background: Hippocampal enlargements are commonly reported following electroconvulsive therapy (ECT). To clarify mechanisms, we examined if ECT induced hippocampal volume change relates to dose (number of ECT sessions and electrode placement) and acts as a biomarker of clinical outcome. Methods: Longitudinal neuroimaging and clinical data from ten independent sites participating in the Global ECT-MRI Research Collaboration were obtained for mega analysis. Hippocampal volumes were extracted from structural MR images, acquired before and after patients (n=281) experiencing a major depressive episode completed an ECT treatment series using right unilateral (RUL) and bilateral (BL) stimulation. Untreated non-depressed controls (n=95) were scanned twice. Results: The linear component of hippocampal volume change was 0.28%, 0.08 SE, per ECT session, p<0.001. Volume change varied by electrode placement in the left (BL: 3.3 ± 2.2%, d=1.5; RUL: 1.6 ± 2.1%, d=0.8; p=0.0001), but not the right hippocampus (BL: 3.0 ± 1.7%, d=1.8; RUL: 2.7 ± 2.0%, d=1.4; p=0.36). Volume change for electrode placement per ECT session varied similarly by hemisphere. Individuals with greater treatment-related volume increases had poorer outcomes (MADRS change -1.0, 0.35 SE, per 1% volume increase, p=0.005), although effects were not significant after controlling for ECT number (slope: -0.69, 0.38 SE, p=0.069). Conclusions: The number of ECT sessions and electrode placement impacts the extent and laterality of hippocampal enlargement, but volume change is not positively associated with clinical outcome. Results suggest the high efficacy of ECT is not explained by hippocampal enlargement, which alone, might not serve as a viable biomarker for treatment outcome.

General information
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Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, University of Bergen, University of California, University of New Mexico, Cleveland Clinic, Feinstein Institute for Medical Research, University of Munster, Donders Institute for Brain, Cognition and Behavior, Psychiatric Center Copenhagen, Rigshospitalet, Copenhagen University Hospital, KU Leuven, VU University Medical Centre, Donders Institute for Brain, Cognition and Behavior
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How to target inter-regional phase synchronization with dual-site Transcranial Alternating Current Stimulation

Large-scale synchronization of neural oscillations is a key mechanism for functional information exchange among brain areas. Dual-site Transcranial Alternating Current Stimulation (ds-TACS) has been recently introduced as non-invasive technique to manipulate the temporal phase relationship of local oscillations in two connected cortical areas. While the frequency of ds-TACS is matched, the phase of stimulation is either identical (in-phase stimulation) or opposite (anti-phase stimulation) in the two cortical target areas. In-phase stimulation is thought to synchronize the endogenous oscillations and hereby improve behavioral performance. Conversely, anti-phase stimulation is thought to desynchronize neural oscillations in the two areas, which is expected to decrease performance. Critically, in- and anti-phase ds-TACS should only differ with respect to temporal phase, while all other stimulation parameters such as focality and stimulation intensity should be matched to enable an unambiguous interpretation of the behavioral effects. Using electric field simulations based on a realistic head geometry, we tested how well this goal has been met in studies, which have employed ds-TACS up to now. Separating the induced electrical fields in their spatial and temporal components, we investigated how the chosen electrode montages determined the spatial field distribution and the generation of phase variations in the injected electric fields. Considering the basic physical mechanisms, we derived recommendations for an optimized stimulation montage. The latter allows for a principled design of in- and anti-phase ds-TACS conditions with matched spatial distributions of the electric field. This knowledge will help cognitive neuroscientists to design optimal ds-TACS configurations, which are suited to probe unambiguously the causal contribution of phase coupling to specific cognitive processes in the human brain.
A microwave window for K band electromagnetic systems
This article proposes a solution for microwave window at K band. Properties of the window such as performance (transparency) at microwave frequencies, dimensions, and mounting place are discussed. The dimensions of the window were optimized in a full-wave simulator. To verify the design and simulation results the prototype of the window is realized by implementing into transition section and tested experimentally. The microwave window provides low return loss |S11| below −30 dB, low insertion loss |S21| below −0.5 dB and can be used for electromagnetic systems where vacuum sealing is required. © 2017 Wiley Periodicals, Inc.
A narrow line UV-induced non-persistent radical in view of generating highly polarized transportable glucose solid samples

General information
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A Novel Magnetic Resonance Imaging (MRI) Approach for Measuring Weak Electric Currents Inside the Human Brain
Knowing the electrical conductivity and current density distribution inside the human brain will be useful in various biomedical applications, i.e. for improving the efficiency of non-invasive brain stimulation (NIBS) techniques, the accuracy of electroencephalography (EEG) and magnetoencephalography (MEG) source localization, or localization of pathological tissues. For example, the accuracy of electric field simulations for NIBS techniques is currently reduced by assigning inaccurate ohmic conductivity values taken from literature to different brain tissues. Therefore, the knowledge of individual ohmic conductivity values may open up the possibility of creating more realistic and accurate head models, which may ameliorate the simulations and practical use of NIBS techniques. Magnetic resonance current density imaging (MRCDI) and magnetic resonance electrical impedance tomography (MREIT) are two emerging methods for calculating the current flow and for reconstructing the ohmic conductivity distribution inside the human brain. Both methods use measurements of the magnetic field $\Delta Bz,c$ that are induced by weak currents applied via surface electrodes. The sensitivity of the
measurements directly affects the accuracy of the current flow estimations and the quality of the reconstructed conductivity images. It increases with increasing strength of the injected currents that are limited to 1-2 mA for in-vivo human brain applications. Therefore, sensitivity improvements of the underlying MRI methods are crucial for implementing MRCDI and MREIT in neuroscience and clinical applications. In this thesis, systematic sensitivity and efficiency analyses of two different MRI pulse sequences, multi-echo spin echo (MESE) and steady-state free precession free induction decay (SSFP-FID), are performed in order to optimize these sequences for in-vivo application in the human brain. The simulations are validated by comprehensive phantom experiments. Secondly, the optimized sequences are tested for in-vivo human brain applications, and adapted to increase their robustness to physiological noise. The current-induced magnetic field \( \Delta B_z,c \) inside the brain is measured in different individuals, revealing inter-individual \( \Delta B_z,c \) differences due to anatomical variability. Finally, volume conductor models of the individuals are created and used to simulate the current-induced \( \Delta B_z,c \) images and the current flow distributions. Comparison of the \( \Delta B_z,c \) and current flow simulations and measurements demonstrates a good correspondence. In summary, the results presented in this thesis pave the way for employing the optimized MRI sequences in future studies to improve the efficiency of NIBS techniques.

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- **State**: Published
- **Organisations**: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance
- **Authors**: Göksu, C. (Intern), Thielscher, A. (Intern), Hanson, L. G. (Intern)
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**Antioxidant treatment attenuates lactate production in diabetic nephropathy**
The early progression of diabetic nephropathy is notoriously difficult to detect and quantify before the occurrence of substantial histological damage. Recently, hyperpolarized [1-13C]pyruvate has demonstrated increased lactate production in the kidney early after the onset of diabetes, implying increased lactate dehydrogenase activity as a consequence of increased nicotinamide adenine dinucleotide substrate availability due to upregulation of the polyl pathway, i.e., pseudohypoxia. In this study, we investigated the role of oxidative stress in mediating these metabolic alterations using state-of-the-art hyperpolarized magnetic resonance (MR) imaging. Ten-week-old female Wistar rats were randomly divided into three groups: healthy controls, untreated diabetic (streptozotocin treatment to induce insulinopenic diabetes), and diabetic, receiving chronic antioxidant treatment with TEMPOL (4-hydroxy-2,2,6,6-tetramethylpiperidin-1-oxyl) via the drinking water. Examinations were performed 2, 3, and 4 wk after the induction of diabetes by using a 3T Clinical MR system equipped with a dual tuned13C/1H-volume rat coil. The rats received intravenous hyperpolarized [1-13C]pyruvate and were imaged using a slice-selective13C-IDEAL spiral sequence. Untreated diabetic rats showed increased renal lactate production compared with that shown by the controls. However, chronic TEMPOL treatment significantly attenuated diabetes-induced lactate production. No significant effects of diabetes or TEMPOL were observed on [13C]alanine levels, indicating an intact glucose-alanine cycle, or [13C]bicarbonate, indicating normal flux through the Krebs cycle. In conclusion, this study demonstrates that diabetes-induced pseudohypoxia, as indicated by an increased lactate-to-pyruvate ratio, is significantly attenuated by antioxidant treatment. This demonstrates a pivotal role of oxidative stress in renal metabolic alterations occurring in early diabetes.

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- **State**: Published
- **Organisations**: Department of Automation, Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Aarhus University, Danish Diabetes Academy Membership, Uppsala University
- **Pages**: F192-F199
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- **Main Research Area**: Technical/natural sciences
An X-band Schottky diode mixer in SiGe technology with tunable Marchand balun
In this paper, we propose a double balanced mixer with a tunable Marchand balun. The circuit is designed in a SiGe BiCMOS process using Schottky diodes. The tunability of the Marchand balun is used to enhance critical parameters for double balanced mixers. The local oscillator-IF isolation can be changed from –51 to –60.5 dB by tuning. Similarly, the IIP2 can be improved from 41.3 to 48.7 dBm at 11 GHz, while the input referred 1-dB compression point is kept constant at 8 dBm. The tuning have no influence on conversion loss, which remains at 8.8 dB at a LO power level of 11 dBm at the center frequency of 11 GHz. The mixer has a 3 dB bandwidth from 8 to 13 GHz, covering the entire X-band. The full mixer has a size of 2050 μm × 1000 μm.

General information
State: Published
Organisations: Department of Electrical Engineering, Electromagnetic Systems, Department of Electromagnetic Systems, Center for Magnetic Resonance, Weibel Scientific A/S
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Bloch simulation and MR fundamentals visualized
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Centre-surround organization of fast sensorimotor integration in human motor hand area

Using the short-latency afferent inhibition (SAI) paradigm, transcranial magnetic stimulation (TMS) of the primary motor hand area (M1HAND) can probe how sensory input from limbs modulates corticomotor output in humans. Here we applied a novel TMS mapping approach to chart the spatial representation of SAI in human hand-knob. We hypothesized SAI is somatotopically expressed in M1HAND depending on both the site of peripheral electrical nerve stimulation and the cortical spot targeted by TMS within M1HAND. The left index or little finger was stimulated 23 ms before focal single-pulse TMS of the right M1HAND. Using frameless stereotaxy, we applied biphasic-TMS pulses at seven stimulation positions above right M1HAND and recorded the motor evoked potentials (MEPs) from relaxed left first-dorsal-interosseous (FDI) and abductor-digitii-minimi (ADM) muscles. Homotopic stimulation of the finger close to the muscle targeted by TMS revealed a somatotopic expression of afferent inhibition matching the somatotopic representation of unconditioned MEPs (homotopic SAI). Conversely, heterotopic stimulation of a finger distant to the muscle targeted by TMS induced short-latency afferent facilitation (SAF) of MEPs in M1HAND. Like homotopic SAI, heterotopic SAF was somatotopically expressed in M1HAND. Together, the results provide first-time evidence that fast sensorimotor integration involves centre-inhibition and surround-facilitation in human M1HAND.
Characterization and flip angle calibration of 13C surface coils for hyperpolarization studies

The aim of the present work is to address the challenge of optimal flip angle calibration of 13C surface coils in hyperpolarization studies. To this end, we characterize the spatial profile of the flip angle and demonstrate that it allows for a simple calibration improving the signal-to-noise ratio for hyperpolarized 13C magnetic resonance spectroscopic imaging.

Cortical mapping, Short-latency afferent inhibition, Somatotopy, Surround facilitation, Transcranial magnetic stimulation
Comparing TMS perturbations to occipital and parietal cortices in concurrent TMS-fMRI studies-Methodological considerations

Neglect and hemianopia are two neuropsychological syndromes that are associated with reduced awareness for visual signals in patients' contralesional hemifield. They offer the unique possibility to dissociate the contributions of retinogeniculate and retino-colliculo circuitries in visual perception. Yet, insights from patient fMRI studies are limited by heterogeneity in lesion location and extent, long-term functional reorganization and behavioural compensation after stroke. Transcranial magnetic stimulation (TMS) has therefore been proposed as a complementary method to investigate the effect of transient perturbations on functional brain organization. This concurrent TMS-fMRI study applied TMS perturbation to occipital and parietal cortices with the aim to 'mimick' neglect and hemianopia. Based on the challenges and interpretational limitations of our own study we aim to provide tutorial guidance on how future studies should compare TMS to primary sensory and association areas that are governed by distinct computational principles, neural dynamics and functional architecture.

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Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
This paper presents two types of coplanar transitions based on aluminum nitride (AlN) substrate for interposer designs of terabit transceivers. The designs of coupled coplanar waveguide (CCPW), coupled line, coplanar waveguide (CPW), and coplanar stripline (CPS) based on AlN substrate are explained. The effects of absorber layer and wire bonding bridges are described. Two types of coplanar transitions are designed and simulated in back-to-back configuration with wire bonding bridges. When driven by differential signal pair, the proposed CCPW-to-coupled line transition in back-to-back configuration with wire bonding bridges achieves a simulated return loss of 11 dB and insertion loss of 2 dB up to 110 GHz. As for single-ended signals, a CPW-to-CPS transition in back-to-back configuration with wire bonding bridges has been designed, fabricated, and measured. The fabricated CPW-to-CPS transition can provide a −3 dB transmission bandwidth up to 80 GHz with associated return loss better than 12 dB.
Day 1 of MRI and NMR education: Interactive visualization of MR basics

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Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance
Authors: Hanson, L. G. (Intern)
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Detecting Elusive Intermediates in Carbohydrate Conversion: A Dynamic Ensemble of Acyclic Glucose-Catalyst Complexes

The role of acyclic carbohydrates in pathways towards value-added chemicals has remained poorly characterized due to the low population of acyclic forms, and due to their instability under reaction conditions. We conduct steady-state and pre-steady state measurements by direct reaction progress monitoring with sensitivity-optimized NMR spectroscopy in the molybdate-catalyzed epimerization of glucose to mannose. We detect an exchanging pool of at least five acyclic glucose-catalyst complexes under near-optimum reaction conditions. In the presence of catalyst, the acyclic glucose population increases within few seconds prior to reaching a steady state. Exchange between the acyclic intermediates increases at conditions that favor epimerization. Species accounting for less than 0.05% of total glucose can be monitored with sub-second time resolution to allow kinetic analysis of intermediate formation and catalytic conversion. Epimerization occurs 2-3 orders of magnitude-fold faster than the binding of acyclic glucose to the catalyst at near-optimum reaction conditions. The current study brings insight in to the nature of acyclic intermediate-catalyst complexes of very low population and into experimental strategies for characterizing very minor intermediates in carbohydrate conversion to value-added compounds.

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Web of Science (2016): Indexed yes
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Scopus rating (2015): SJR 1.389 SNIP 1.353 CiteScore 5.39
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Echo Planar Spectroscopic Imaging of Hyperpolarized 13C in a Clinical System with Reduced Chemical Shift Artifacts

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, University of New Mexico, Copenhagen University Hospital
Authors: Eldirdiri, A. (Intern), Posse, S. (Ekstern), Hanson, L. G. (Intern), Hansen, R. B. (Intern), Hansen, A. E. (Ekstern), Ardenkjær-Larsen, J. H. (Intern)
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Effect of a treat-to-target strategy based on methotrexate and intra-articular betamethasone with or without additional cyclosporin on MRI-assessed synovitis, osteitis, tenosynovitis, bone erosion, and joint space narrowing in early rheumatoid arthritis: results from a 2-year randomized double-blind placebo-controlled trial (CIMESTRA)

Objectives: To investigate whether a treat-to-target strategy based on methotrexate (MTX) and intra-articular (IA) betamethasone suppresses magnetic resonance imaging (MRI)-determined measures of disease activity and reduces joint destruction in early rheumatoid arthritis (eRA) patients, and to investigate whether concomitant cyclosporin A (CyA) provides an additional effect.Method: In the 2-year randomized, double-blind, treat-to-target trial CIMESTRA, 160 patients with eRA (<6months) were randomized to MTX, intra-articular betamethasone and CyA, or placebo CyA. A total of 129 patients participated in the MRI substudy, and had contrast-enhanced MR images of the non-dominant hand at months 0, 6, 12, and 24. MR images were evaluated for osteitis, synovitis, tenosynovitis, bone erosion, and joint space narrowing (JSN), using validated scoring methods.Results: Significant reductions were seen at 6months in all inflammatory parameters [synovitis, mean change -1.6 (p
Encoding of inductively measured k-space trajectories in MR raw data

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Encoding of Inductively Measured k-Space Trajectories in MR Raw Data

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Forming of space charge wave with broad frequency spectrum in helical relativistic two-stream electron beams: Paper

We elaborate a quadratic nonlinear theory of plural interactions of growing space charge wave (SCW) harmonics during the development of the two-stream instability in helical relativistic electron beams. It is found that in helical two-stream electron beams the growth rate of the two-stream instability increases with the beam entrance angle. An SCW with the broad frequency spectrum, in which higher harmonics have higher amplitudes, forms when the frequency of the first SCW harmonic is much less than the critical frequency of the two-stream instability. For helical electron beams the spectrum expands with the increase of the beam entrance angle. Moreover, we obtain that utilizing helical electron beams in multiharmonic two-stream superheterodyne free-electron lasers leads to the improvement of their amplification characteristics, the frequency spectrum broadening in multiharmonic signal generation mode, and the reduction of the overall system dimensions.

Renal ischemia/reperfusion injury (IRI) is a leading cause of acute kidney injury (AKI), and at present, there is a lack of reliable biomarkers that can diagnose AKI and measure early progression because the commonly used methods cannot evaluate single-kidney IRI. Hyperpolarized [1,4-C-13(2)] fumarate conversion to [1,4-C-13(2)] malate by fumarase has been proposed as a measure of necrosis in rat tumor models and in chemically induced AKI rats. Here we show that the degradation of cell membranes in connection with necrosis leads to elevated fumarase activity in plasma and urine and secondly that hyperpolarized [1,4-C-13(2)] malate production 24 h after reperfusion correlates with renal necrosis in a 40-min unilateral ischemic rat model. Fumarase activity screening on bio-fluids can detect injury severity, in bilateral as well as unilateral AKI models, differentiating moderate and severe AKI as well as short- and long-term AKI. Furthermore after verification of renal injury by bio-fluid analysis the precise injury location can be monitored by in vivo measurements of the fumarase activity non-invasively by hyperpolarized [1,4-C-13] fumarate MR imaging. The combined in vitro and in vivo biomarker of AKI responds to the essential requirements for a new reliable biomarker of AKI.

General information
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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Technical University of Denmark, Aarhus University, GE Healthcare, GE Healthcare, Brondby, Denmark

Authors: Nielsen, P. M. (Ekstern), Eldirdiri, A. (Intern), Bertelsen, L. B. (Ekstern), Jorgensen, H. S. (Ekstern), Ardenkjær-Larsen, J. H. (Intern), Laustsen, C. (Ekstern)
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Main Research Area: Technical/natural sciences

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**GABA-edited echo-planar spectroscopic imaging (EPSI) with MEGA-sLASER at 7T**

**General information**
- **State:** Published
- **Organisations:** Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Copenhagen University Hospital
- **Authors:** Magnusson, P. O. (Ekstern), Boer, V. O. (Ekstern), Marsman, A. (Ekstern), Lundell, H. (Ekstern), Hanson, L. G. (Intern), Petersen, E. T. (Intern)
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**Gradient distortions in EEG provide motion tracking during simultaneous EEG-fMRI**

Conference abstract, selected for oral presentation by Malte Laustsen.

**General information**
- **State:** Published
Human in-vivo brain magnetic resonance current density imaging (MRCDI)

Magnetic resonance current density imaging (MRCDI) and MR electrical impedance tomography (MREIT) are two emerging modalities, which combine weak time-varying currents injected via surface electrodes with magnetic resonance imaging (MRI) to acquire information about the current flow and ohmic conductivity distribution at high spatial resolution. The injected current flow creates a magnetic field in the head, and the component of the induced magnetic field $\Delta B_z,c$ parallel to the main scanner field causes small shifts in the precession frequency of the magnetization. The measured MRI signal is modulated by these shifts, allowing to determine $\Delta B_z,c$ for the reconstruction of the current flow and ohmic conductivity. Here, we demonstrate reliable $\Delta B_z,c$ measurements in-vivo in the human brain based on multi-echo spin echo (MESE) and steady-state free precession free induction decay (SSFP-FID) sequences. In a series of experiments, we optimize their robustness for in-vivo measurements while maintaining a good sensitivity to the current-induced fields. We validate both methods by assessing the linearity of the measured $\Delta B_z,c$ with respect to the current strength. For the more efficient SSFP-FID measurements, we demonstrate a strong influence of magnetic stray fields on the $\Delta B_z,c$ images, caused by non-ideal paths of the electrode cables, and validate a correction method. Finally, we perform measurements with two different current injection profiles in five subjects. We demonstrate reliable recordings of $\Delta B_z,c$ fields as weak as 1nT, caused by currents of 1mA strength. Comparison of the $\Delta B_z,c$ measurements with simulated $\Delta B_z,c$ images based on FEM calculations and individualized head models reveals significant linear correlations in all subjects, but only for the stray field-corrected data. As final step, we reconstruct current density distributions from the measured and simulated $\Delta B_z,c$ data. Reconstructions from non-corrected $\Delta B_z,c$ measurements systematically overestimate the current densities. Comparing the current densities reconstructed from corrected $\Delta B_z,c$ measurements and from simulated $\Delta B_z,c$ images reveals an average coefficient of determination $R^2$ of 71%. In addition, it shows that the simulations underestimated the current strength on average by 24%. Our results open up the possibility of using MRI to systematically validate and optimize numerical field simulations that play an important role in several neuroscience applications, such as transcranial brain stimulation, and electro- and magnetoencephalography.

General information

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Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Copenhagen University Hospital, Max-Planck-Institute for Biological Cybernetics
Authors: Göksu, C. (Intern), Hanson, L. G. (Intern), Siebner, H. R. (Ekstern), Ehses, P. (Ekstern), Scheffler, K. (Ekstern), Thielischer, A. (Intern)
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Human In-vivo MR Current Density Imaging (MRCDI) Based on Optimized Multi-echo Spin Echo (MESE)

General information
State: Published
Hyperpolarized $^{133}$Cs is a sensitive probe for real-time monitoring of biophysical environments

$^{133}$Cs NMR is a valuable tool for non-invasive analysis of biological systems, where chemical shift and relaxation properties report on changes in the physical environment. Hyperpolarization can increase the liquid-state $^{133}$Cs NMR signal by several orders of magnitude and allow real-time monitoring of physical changes in cell based systems.
Hyperpolarized Water Perfusion in the Porcine Brain – a Pilot Study
Dynamic Contrast-Enhanced MR (DCE-MR) perfusion assessment with gadolinium contrast agents is currently the most widely used cerebral perfusion MR method. Hyperpolarized water has recently been shown to succeed 13C probes as angiography probe. In this study, we demonstrate the feasibility of hyperpolarized water for visualizing the brain vasculature of a large animal in a clinically relevant setting. In detail, reference perfusion values were obtained and large to small arteries could be identified.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Aarhus University
Authors: Søvsø Szocska Hansen, E. (Ekstern), Lipsø, H. K. W. (Intern), Tougaard, R. S. (Ekstern), Laustsen, C. (Ekstern), Ardenkjær-Larsen, J. H. (Intern)
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Hyperpolarized xenon by d-DNP using the clinical GE SpinLab polarizer system
Hyperpolarized (HP) 129Xe have been demonstrated as a useful probe for magnetic resonance (MR) lung imaging and show promise for in vivo perfusion imaging and brown adipose tissue characterization. Reports of large polarization...
enhancements for 129Xe using dynamic nuclear polarization (DNP) have raised expectations that DNP can be an alternative to the standard spin exchange optical pumping (SEOP) method. We show that it is possible to produce HP 129Xe gas using the clinical GE SpinLab polarizer, thus extending the practical use of the system beyond the primary purpose of hyperpolarizing liquid biomolecules.

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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Aarhus University
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**Imaging regional metabolic changes in the ischemic rat heart in vivo using hyperpolarized(1-13C)Pyruvate**
We evaluated the use of hyperpolarized 13C magnetic resonance imaging (MRI) in an open-chest rat model of myocardial infarction to image regional changes in myocardial metabolism. In total, 10 rats were examined before and after 30 minutes of occlusion of the left anterior descending coronary artery using hyperpolarized [1-13C]pyruvate. Cardiac metabolic images of [1-13C]pyruvate and its metabolites [1-13C]lactate, [1-13C]alanine, and [13C]bicarbonate were obtained before and after ischemia. Significant reduction in the [1-13C]alanine and [1-13C]lactate signals were observed in the ischemic region post ischemia. The severity of the ischemic insult was verified by increased blood levels of troponin I and by using late contrast-enhanced MRI that showed enhanced signal in the ischemic region. This study shows that hyperpolarized MRI can be used to image regional metabolic changes in the in vivo rat heart in an open-chest model of ischemia reperfusion. Hyperpolarized MRI enables new possibilities for evaluating changes in cardiac metabolism noninvasively and in real time, which potentially could be used for research to evaluate new treatments and metabolic interventions for myocardial ischemia and to apply knowledge to future application of the technique in humans.

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**Bibliographical note**
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Source: FindIt
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Impact of tumor position, conductivity distribution and tissue homogeneity on the distribution of tumor treating fields in a human brain: A computer modeling study

Background
Tumor treating fields (TTFields) are increasingly used in the treatment of glioblastoma. TTFields inhibit cancer growth through induction of alternating electrical fields. To optimize TTFields efficacy, it is necessary to understand the factors determining the strength and distribution of TTFields. In this study, we provide simple guiding principles for clinicians to assess the distribution and the local efficacy of TTFields in various clinical scenarios.

Methods
We calculated the TTFields distribution using finite element methods applied to a realistic head model. Dielectric property estimates were taken from the literature. Twentyfour tumors were virtually introduced at locations systematically varied relative to the applied field. In addition, we investigated the impact of central tumor necrosis on the induced field.

Results
Local field "hot spots" occurred at the sulcal fundi and in deep tumors embedded in white matter. The field strength was not higher for tumors close to the active electrode. Left/right field directions were generally superior to anterior/posterior directions. Central necrosis focally enhanced the field near tumor boundaries perpendicular to the applied field and introduced significant field non-uniformity within the tumor.

Conclusions
The TTFields distribution is largely determined by local conductivity differences. The well conducting tumor tissue creates a preferred pathway for current flow, which increases the field intensity in the tumor boundaries and surrounding regions perpendicular to the applied field. The cerebrospinal fluid plays a significant role in shaping the current pathways and funnels currents through the ventricles and sulci towards deeper regions, which thereby experience higher fields. Clinicians may apply these principles to better understand how TTFields will affect individual patients and possibly predict where local recurrence may occur. Accurate predictions should, however, be based on patient specific models. Future work is needed to assess the robustness of the presented results towards variations in conductivity.
Improved Decoupling for 13C coil Arrays Using Non-Conventional Matching and Preamplifier Impedance

In this study, we describe a method to obtain improved preamplifier decoupling for receive-only coils. The method relies on the better decoupling obtained when coils are matched to an impedance higher than 50Ω. Preamplifiers with inductive imaginary impedance and low real impedance, increase the effectiveness of the decoupling. A 2-channel 13C array of 50 mm loop coils show an increase of Q-factor of the coils from 247 to 365. The measured SNR, using two small phantoms, demonstrated a similar improvement.

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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Electromagnetic Systems, Aarhus University
Authors: Sanchez, J. D. (Intern), Johansen, D. H. (Intern), Hansen, R. B. (Intern), Hansen, E. S. (Ekstern), Laustsen, C. (Ekstern), Zhurbenko, V. (Intern), Ardenkjær-Larsen, J. H. (Intern)
Number of pages: 3
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Event: Abstract from ISMRM 25th Annual Meeting & Exhibition, Honolulu, United States.
Main Research Area: Technical/natural sciences
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Improved reconstruction for IDEAL spiral CSI

In this study we demonstrate how reconstruction for IDEAL spiral CSI (spectroscopic imaging scheme developed for hyperpolarized dynamic metabolic MR imaging) can be improved by using regularization with a sparsity constraint. By exploiting sparsity of the spectral domain, IDEAL spiral CSI can achieve chemical shift encoding by acquisition of only few time-shifted echoes. The minimum number of echoes required to avoid noise amplification can be decreased by means of regularization enforcing spectral sparsity, hereby reducing scan time. Improvements achieved by using regularized reconstruction are demonstrated for in vivo data from a hyperpolarized cardiac study of a pig.

General information
Large-signal modeling of multi-finger InP DHBT devices at millimeter-wave frequencies

A large-signal modeling approach has been developed for multi-finger devices fabricated in an Indium Phosphide (InP) Double Heterojunction Bipolar Transistor (DHBT) process. The approach utilizes unit-finger device models embedded in a multi-port parasitic network. The unit-finger model is based on an improved UCSD HBT model formulation avoiding an erroneous RciCbci transit-time contribution from the intrinsic collector region as found in other III-V based HBT models. The mutual heating between fingers is modeled by a thermal coupling network with parameters extracted from electro-thermal simulations. The multi-finger modeling approach is verified against measurements on an 84 GHz power amplifier utilizing four finger InP DHBTs in a stacked configuration.

Low conversion loss 94 GHz and 188 GHz doublers in InP DHBT technology

An Indium Phosphide (InP) Double Heterojunction Bipolar Transistor (DHBT) process has been utilized to design two doublers to cover the 94 GHz and 188 GHz bands. The 94 GHz doubler employs 4-finger DHBTs and provides conversion loss of 2 dB. A maximum output power of nearly 3 dBm is measured while the doubler is not entirely saturated. The DC power consumption is 132 mW. The 188 GHz doubler utilizes a 1-finger DHBT. Conversion loss of 2 dB and a maximum output power of −1 dBm are achieved at 188 GHz with on-wafer measurements. The DC power consumption is 24 mW under saturated conditions. Both doublers operate over a broad bandwidth. The total circuit area of each chip is 1.41 mm2.
Low cost, compact, two-channel NMR spectrometer for CP-DNP

General information
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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Electromagnetic Systems
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Publication: Research › Conference abstract for conference – Annual report year: 2018

Low-Noise Active Decoupling Circuit and its Application to 13C Cryogenic RF Coils at 3T

We analyze the loss contributions in a small, 50-mm-diameter receive-only coil for carbon-13 (13C) magnetic resonance imaging at 3 T for 3 different circuits, which, including active decoupling, are compared in terms of their Q-factors and signal-to-noise ratio (SNR). The results show that a circuit using unsegmented tuning and split matching capacitors can provide 20% SNR enhancement at room temperature compared with that using more traditional designs. The performance of the proposed circuit was also measured when cryogenically cooled to 105 K, and an additional 1.6-fold SNR enhancement was achieved on a phantom. The enhanced circuit performance is based on the low capacitance needed to match to 50 when coil losses are low, which significantly reduces the proportion of the current flowing through the matching network and therefore minimizes this loss contribution. This effect makes this circuit particularly suitable for receive-only cryogenic coils and/or small coils for low-gamma nuclei.

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Organisations: Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance, Center for Magnetic Resonance, Electromagnetic Systems, Aarhus University
Authors: Sanchez, J. D. (Intern), Søvsø Szocska Hansen, E. (Ekstern), Laustsen, C. (Ekstern), Zhurbenko, V. (Intern), Ardenkjær-Larsen, J. H. (Intern)
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Main Research Area: Technical/natural sciences

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Measuring glucose cerebral metabolism in the healthy mouse using hyperpolarized C-13 magnetic resonance

The mammalian brain relies primarily on glucose as a fuel to meet its high metabolic demand. Among the various techniques used to study cerebral metabolism, C-13 magnetic resonance spectroscopy (MRS) allows following the fate of C-13-enriched substrates through metabolic pathways. We herein demonstrate that it is possible to measure cerebral glucose metabolism in vivo with sub-second time resolution using hyperpolarized C-13 MRS. In particular, the dynamic C-13-labeling of pyruvate and lactate formed from C-13-glucose was observed in real time. An ad-hoc synthesis to produce [2,3,4,6-H-2(5), 3,4-C-13(2)]-D-glucose was developed to improve the 13C signal-to-noise ratio as compared to experiments performed following [U-H-2(7), U-C-13]-D-glucose injections. The main advantage of only labeling C3 and C4 positions is the absence of C-13-C-13 coupling in all downstream metabolic products after glucose is split into 3-carbon intermediates by aldolase. This unique method allows direct detection of glycolysis in vivo in the healthy brain in a noninvasive manner.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Ecole Polytechnique Federale de Lausanne (EPFL), University of Texas Southwestern Medical Center
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BFI (2018): BFI-level 1
Microstrip Resonator for High Field MRI with Capacitor-Segmented Strip and Ground Plane

High field MRI coils are often based on transmission line resonators. Due to relatively short wavelength of RF fields, such coils produce uneven field patterns. Here we show, that it is possible to manipulate magnetic field patterns of microstrip resonators in both planes (sagittal and transverse) segmenting stripe and ground plane of the resonator with series capacitors. The design equations for capacitors providing symmetric current distribution are derived. The performance of two types of segmented resonators are investigated experimentally. To authors’ knowledge, a microstrip resonator, where both, strip and ground plane are capacitor-segmented, is shown here for the first time.

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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Electromagnetic Systems, Copenhagen University Hospital
Authors: Zhurbenko, V. (Intern), Boer, V. (Ekstern), Petersen, E. T. (Intern)
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Publication: Research - peer-review » Article in proceedings – Annual report year: 2017
Monitoring Cancer Response to Treatment with Hyperpolarized $^{13}$C MRS

Monitoring the cancer response to treatment, non-invasively, by medical imaging is a key element in the management of cancer. For patients undergoing treatment, it is crucial to determine responders from non-responders in order to guide treatment decisions. Currently, PET is the most widely used technique for imaging tumor function by measuring the uptake of the glucose analogue FDG. FDG-PET can visualize changes in metabolic activity and indicate if a patient will respond to a particular therapy, sometimes within hours of the first treatment. However, PET is not effective in all tumor types, and the patient is exposed to ionizing radiation. The introduction of hyperpolarized $^{13}$C MRS has opened completely new possibilities to study the biochemical changes in disease processes. Numerous $^{13}$C-labeled compounds were proposed to interrogate various aspects of cancer cell metabolism. The aim of this study is to investigate the relevancy of $[1-^{13}\text{C}]$pyruvate and $[1,4-^{13}\text{C}_2]$fumarate in monitoring the changes in cellular metabolism and necrosis that may occur as a result of cancer therapy. This project also aims to improve existing $^{13}$C MRSI methods to efficiently utilize the signal from hyperpolarized $^{13}$C substrates. Firstly, we investigate the effectiveness of hyperpolarized $[1-^{13}\text{C}]$pyruvate in detecting the treatment response in two types of NSCLC xenografted in mice, in comparison with FDG- and FLT-PET. We show here a significant reduction in tumor lactate levels, obtained by MRS, in HCC-827 tumors, as well as lower FLT- and FDG-PET uptake with erlotinib treatment. These findings were validated ex vivo, where LDH activity level and Ki-67 IHC staining was significantly lower in treated HCC-827 tumors. Furthermore, the reduction in LDH activity levels correlated with the lactate levels found using $^{13}$C MRS. These findings indicate the hyperpolarized $[1,^{13}\text{C}]$pyruvate can be an alternative to FDG-PET.

In the second study, a polarization scheme for $[1,4-^{13}\text{C}_2]$fumarate in the SPINlab polarizer is presented. The feasibility of using $[1,4-^{13}\text{C}_2]$fumarate as marker for monitoring induced necrosis is demonstrated in vivo in two rat models; ischemia/reperfusion induced necrosis in kidneys and turpentine induced necrosis in muscle. High polarization was achieved for $[1,4-^{13}\text{C}_2]$fumarate in the SPIN lab and high $[1,4-^{13}\text{C}_2]$malate signal was observed from the necrotic tissue in both models. The elevated malate signal observed in the ischemia/reperfusion induced injury in kidney showed high correlation with well-known blood and urine bio-markers used to characterize acute kidney injuries. Moreover, simultaneous assessment of metabolism and necrosis was achieved using dual polarization of $[1,4-^{13}\text{C}_2]$fumarate and $[1-^{13}\text{C}]$pyruvate. Finally, a symmetric echo planar spectroscopic imaging sequence for hyperpolarized $^{13}$C spectroscopic acquisition in clinical scanners is presented with a reconstruction algorithm that separately reconstruct the data from odd and even echoes in order to reduce artifacts from gradient imbalances. The reconstruction algorithm employs re-gridding in the spatio-temporal frequency space to compensate for the chemical shift displacements. The sequence is compared with conventional phase-encoded chemical shift imaging on a clinical PET/MRI system in phantoms and a large animal model. The SNR per unit time of EPSI for $^{13}$C at thermal equilibrium was comparable to CSI. The reconstruction pipeline improved the localization compared to direct FFT, which resulted in spatial blurring. The encoding speed of EPSI allowed dynamic imaging of tumor metabolism with high spatial and temporal resolutions and reduced blurring due to T1 decay.

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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance
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Relations
Projects:
Monitoring Cancer Response to Treatment with Hyperpolarized $^{13}$C MRS
Publication: Research › Ph.D. thesis – Annual report year: 2017

MRI
This chapter discusses principles of nuclear magnetic resonance (NMR) and MRI followed by a survey on the major classes of MRI contrast agents (CA), their modes of action, and some of the most significant applications. The two more established classes of MRI-CA are represented by paramagnetic metal complexes (i.e., Gd(III) and Mn(II)) and iron oxide particles, acting on $T_1$ and $T_2^*$ of the water protons signals, respectively. Along the years many efforts have been devoted to endow these relaxation enhancement agents with improved sensitivity, targeting, and responsive properties that have markedly broadened the range of applications in respect to the clinically used systems. CEST agents represent innovative frequency-encoding probes that yield negative contrast in the MR images upon transfer of saturated magnetization from the agent to the "bulk" water signal. Interesting developments have been attained that markedly increase the number and topology of systems with CEST properties. Currently much attention is also devoted to hyperpolarized molecules that display a sensitivity enhancement sufficient for their direct exploitation for the formation of the MR image. A real breakthrough is provided by the use of molecules (such as pyruvate) that report about the cellular metabolism, thanks to
the maintenance of the hyperpolarization in the derived species.

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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, ETH Zurich, University of Torino, University of Freiburg, Lausanne University Hospital, Ecole Polytechnique Federale de Lausanne (EPFL), Technical University of Munich, Bruker Biospin GmbH
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Chapter: 13
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Non-Cartesian Parallel Imaging Reconstruction of Undersampled IDEAL Spiral 13C CSI Data
The short-lived nature of hyperpolarization places high demands on signal acquisition. To acquire large FOVs with high spatial resolution, and to fully capture substrate uptake and metabolic conversion, fast data acquisition is crucial. Parallel imaging uses multi-channel coils to achieve reduced scan times based on spatial information inherent to each coil element. In this work, we explored the combination of non-cartesian parallel imaging reconstruction and spatially undersampled IDEAL spiral CSI acquisition for efficient encoding of multiple chemical shifts within a large FOV with high spatial resolution.

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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance
Authors: Hansen, R. B. (Intern), Hanson, L. G. (Intern), Ardenkjær-Larsen, J. H. (Intern)
Number of pages: 1
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On-chip patch antenna on InP substrate for short-range wireless communication at 140 GHz
This paper presents the design of an on-chip patch antenna on indium phosphide (InP) substrate for short-range wireless communication at 140 GHz. The antenna shows a simulated gain of 5.3 dBi with 23% bandwidth at 140 GHz and it can be used for either direct chip-to-chip communication or chip-level integration and packaging. In the transmission frequency band from 130 GHz to 150 GHz the estimated in-band gain variation is 0.5 dBi which guarantees gain uniformity. The antenna with optimized dimension is implemented for a transition between elevated coplanar waveguide (ECPW) and rectangular waveguide. The chip-to-waveguide transition in back-to-back configuration exhibits a simulated return loss of 10 dB and insertion loss of 3 dB from 128 GHz to 153 GHz. For higher directivity, a horn antenna is used together with the chip-to-waveguide transition forming an extended packaging structure that is suitable for the transceiver (Tx and Rx) chips. The simulated gain of the extended packaging structure is 11.9 dBi with 23% bandwidth at 140 GHz and the in-band gain variation is 2 dBi.
Plural three-wave resonances of space charge wave harmonics in transit section of klystron-type two-stream FEL with helical electron beam

We have carried out the research of plural three-wave resonances of space charge wave (SCW) harmonics in the transit section of the klystron type two-stream superheterodyne free-electron laser (TSFEL) with helical electron beam in cubic non-linear approximation. We have found out that two-stream instability critical frequency increases with increasing of two-stream electron beam input angle in the focusing longitudinal magnetic field. Due to this fact, the frequency domain in which plural three-wave parametric resonances of SCW harmonics take place increases. The two-stream instability growth rate also increases in helical electron beams with increasing of the beam input angle. Therefore, the saturation lengths in TSFELs with helical electron beams are shorter compared to TSFELs utilizing straight electron beams. We have shown that SCWs with broad frequency spectrum form in two-velocity helical relativistic electron beam due to plural three-wave parametric resonances. We have demonstrated that klystron-type TSFEL with helical electron beam can be used as a source of powerful multiharmonic electromagnetic waves in millimeter-infrared wavelength ranges.
Preparation of Radical-Free Hyperpolarized Water using Photo-induced non-persistent Radicals on a “SpinLab-like” dissolution-DNP Polarizer

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Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2017

Renal MR angiography and perfusion in the pig using hyperpolarized water
Purpose: To study hyperpolarized water as an angiographyand perfusion tracer in a large animal model.Methods: Protons dissolved in deuterium oxide (D2O) werehyperpolarized in a SPINlab dissolution dynamic nuclear polarizat-(dDNP) polarizer and subsequently investigated in vivo in a pig model at 3 Tesla (T). Approximately 15 mL of hyperpolarized water was injected in the renal artery by hand over 4–5 s.Results: A liquid state polarization of 5.3 6 0.9% of 3.8 M pro-tons in 15 mL of deuterium oxide was achieved with a T1of24 6 1 s. This allowed injection through an arterial catheter into the renal artery and subsequently high-contrast imaging ofthe entire kidney parenchyma over several seconds. The dynamic images allow quantification of tissue perfusion, with amean cortical perfusion of 504 6 123 mL/100 mL/min.Conclusion: Hyperpolarized water MR imaging was success-fully demonstrated as a renal angiography and perfusion meth-od. Quantitative perfusion maps of the kidney were obtained in agreement with literature and control experiments with gad-o-linium contrast.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Aarhus University
Authors: Lipsø, H. K. W. (Intern), Hansen, E. S. S. (Ekstern), Tougaard, R. S. (Ekstern), Laustsen, C. (Ekstern), Ardenkjær-Larsen, J. H. (Intern)
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.329 SNIP 1.481 CiteScore 3.54
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BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.015 SNIP 1.382 CiteScore 3.32
Web of Science (2014): Indexed yes
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Scopus rating (2013): SJR 2.039 SNIP 1.433 CiteScore 3.46
ISI indexed (2013): ISI indexed yes
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Scopus rating (2012): SJR 2.158 SNIP 1.553 CiteScore 3.61
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.16 SNIP 1.461 CiteScore 3.45
ISI indexed (2011): ISI indexed yes
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BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.356 SNIP 1.606
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Web of Science (2009): Indexed yes
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Scopus rating (2008): SJR 2.468 SNIP 1.5
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.397 SNIP 1.536
Scopus rating (2006): SJR 2.319 SNIP 1.756
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.298 SNIP 1.833
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.154 SNIP 1.741
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Scopus rating (2003): SJR 2.383 SNIP 1.599
Scopus rating (2002): SJR 2.328 SNIP 1.451
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 2.301 SNIP 1.506
Web of Science (2001): Indexed yes
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Scopus rating (1999): SJR 2.457 SNIP 2.123
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Electronic versions:
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Sensitivity analysis of magnetic field measurements for magnetic resonance electrical impedance tomography (MREIT)

Purpose: Clinical use of magnetic resonance electrical impedance tomography (MREIT) still requires significant sensitivity improvements. Here, the measurement of the current-induced magnetic field (DBz,c) is improved using systematic efficiency analyses and optimization of multi-echo spin echo (MESE) and steady-state free precession free induction decay (SSFP-FID) sequences. Theory and Methods: Considering T1, T2, and T 2 relaxation in the signal-to-noise ratios (SNRs) of the MR magnitude images, the efficiency of MESE and SSFP-FID MREIT experiments, and its dependence on the sequence parameters, are analytically analyzed and simulated. The theoretical results are experimentally validated in a saline-filled homogeneous spherical phantom with relaxation parameters similar to brain tissue. Measurement of DBz,c is also performed in a cylindrical phantom with saline and chicken meat. Results: The efficiency simulations and experimental results are in good agreement. When using optimal parameters, DBz,c can be reliably measured in the phantom even at injected current strengths of 1 mA or lower for both sequence types. The importance of using proper crusher gradient selection on the phase evolution in a MESE experiment is also demonstrated. Conclusion: The efficiencies observed with the optimized sequence parameters will likely render in-vivo human brain MREIT feasible.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, University of Tubingen
Authors: Göksu, C. (Intern), Scheffler, K. (Ekstern), Ehses, P. (Ekstern), Hanson, L. G. (Intern), Thielscher, A. (Intern)
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Web of Science (2017): Indexed Yes
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Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.329 SNIP 1.481 CiteScore 3.54
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.015 SNIP 1.382 CiteScore 3.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.039 SNIP 1.433 CiteScore 3.46
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.158 SNIP 1.553 CiteScore 3.61
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.16 SNIP 1.461 CiteScore 3.45
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.356 SNIP 1.606
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.331 SNIP 1.553
Simultaneous imaging of hyperpolarized [1,4-13 C2 fumarate, [1-13 C]pyruvate and 18 F-FDG in a rat model of necrosis in a clinical PET/MR scanner

A co-polarization scheme for [1,4-13 C2 fumarate and [1-13 C]pyruvate is presented to simultaneously assess necrosis and metabolism in rats with hyperpolarized 13 C magnetic resonance (MR). The co-polarization was performed in a SPINlab polarizer. In addition, the feasibility of simultaneous positron emission tomography (PET) and MR of small animals with a clinical PET/MR scanner is demonstrated. The hyperpolarized metabolic MR and PET was demonstrated in a rat model of necrosis. The polarization and T1 of the co-polarized [1,4-13 C2 fumarate and [1-13 C]pyruvate substrates were measured in vitro and compared with those obtained when the substrates were polarized individually. A polarization of 36 ± 4% for fumarate and 37 ± 6% for pyruvate was obtained. We found no significant difference in the polarization and T1 values between the dual and single substrate polarization. Rats weighing about 400 g were injected intramuscularly in one of the hind legs with 200 μL of turpentine to induce necrosis. Two hours later, 13 C metabolic maps were obtained with a chemical shift imaging sequence (16 × 16) with a resolution of 3.1 × 5.0 × 25.0 mm3 . The 13 C spectroscopic images were acquired in 12 s, followed by an 8-min 18 F-2-fluoro-2-deoxy-d-glucose (18 F-FDG) PET acquisition with a resolution of 3.5 mm. [1,4-13 C2 ]Malate was observed from the tissue injected with turpentine indicating necrosis. Normal [1-13 C]pyruvate metabolism and 18 F-FDG uptake were observed from the same tissue. The proposed co-polarization scheme provides a means to utilize multiple imaging agents simultaneously, and thus to probe various metabolic pathways in a single examination. Moreover, it demonstrates the feasibility of small animal research on a clinical PET/MR scanner for combined PET and hyperpolarized metabolic MR.

General information

State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, University of Copenhagen
Authors: Eldirdiri, A. (Intern), Clemmensen, A. (Ekstern), Bowen, S. (Intern), Kjær, A. (Ekstern), Ardenkjær-Larsen, J. H. (Intern)
Number of pages: 9
Publication date: 2017
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Article number: e3803
The impact of large structural brain changes in chronic stroke patients on the electric field caused by transcranial brain stimulation

Transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (TDCS) are two types of non-invasive transcranial brain stimulation (TBS). They are useful tools for stroke research and may be potential adjunct therapies for functional recovery. However, stroke often causes large cerebral lesions, which are commonly accompanied by a secondary enlargement of the ventricles and atrophy. These structural alterations substantially change the conductivity...
distribution inside the head, which may have potentially important consequences for both brain stimulation methods. We therefore aimed to characterize the impact of these changes on the spatial distribution of the electric field generated by both TBS methods. In addition to confirming the safety of TBS in the presence of large stroke-related structural changes, our aim was to clarify whether targeted stimulation is still possible. Realistic head models containing large cortical and subcortical stroke lesions in the right parietal cortex were created using MR images of two patients. For TMS, the electric field of a double coil was simulated using the finite-element method. Systematic variations of the coil position relative to the lesion were tested. For TDCS, the finite-element method was used to simulate a standard approach with two electrode pads, and the position of one electrode was systematically varied. For both TMS and TDCS, the lesion caused electric field "hot spots" in the cortex. However, these maxima were not substantially stronger than those seen in a healthy control. The electric field pattern induced by TMS was not substantially changed by the lesions. However, the average field strength generated by TDCS was substantially decreased. This effect occurred for both head models and even when both electrodes were distant to the lesion, caused by increased current shunting through the lesion and enlarged ventricles. Judging from the similar peak field strengths compared to the healthy control, both TBS methods are safe in patients with large brain lesions (in practice, however, additional factors such as potentially lowered thresholds for seizure-induction have to be considered). Focused stimulation by TMS seems to be possible, but standard tDCS protocols appear to be less efficient than they are in healthy subjects, strongly suggesting that tDCS studies in this population might benefit from individualized treatment planning based on realistic field calculations.
coil and preamplifier performance. Thus, the fundamental trade-off between noise and decoupling is discussed. This work embarks on the path towards new vistas in design of preamplifiers for surface coil arrays for magnetic resonance imaging.

**General information**
- State: Published
- Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Electromagnetic Systems, Center for Hyperpolarization in Magnetic Resonance
- Authors: Johansen, D. H. (Intern), Sanchez, J. D. (Intern), Zhurbenko, V. (Intern), Ardenkjær-Larsen, J. H. (Intern)
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**Transcranial magnetic stimulation of right inferior parietal cortex causally influences prefrontal activation for visual detection**

For effective interactions with the environment, the brain needs to form perceptual decisions based on noisy sensory evidence. Accumulating evidence suggests that perceptual decisions are formed by widespread interactions amongst sensory areas representing the noisy sensory evidence and fronto-parietal areas integrating the evidence into a decision variable that is compared to a decisional threshold. This concurrent transcranial magnetic stimulation (TMS)-fMRI study applied 10 Hz bursts of four TMS (or Sham) pulses to the intraparietal sulcus (IPS) to investigate the causal influence of IPS on the neural systems involved in perceptual decision-making. Participants had to detect visual signals at threshold intensity that were presented in their left lower visual field on 50% of the trials. Critically, we adjusted the signal strength such that participants failed to detect the visual stimulus on approximately 30% of the trials allowing us to categorise trials into hits, misses and correct rejections (CR). Our results show that IPS-relative to Sham-TMS attenuated activation increases for misses relative to CR in the left middle and superior frontal gyri. Critically, while IPS-TMS did not significantly affect participants' performance accuracy, it affected how observers adjusted their response times after making an error. We therefore suggest that activation increases in superior frontal gyri for misses relative to correct responses may not be critical for signal detection performance, but rather reflect post-decisional processing such as metacognitive monitoring of choice accuracy or decisional confidence.

**General information**
- State: Published
- Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Max-Planck-Institute for Biological Cybernetics
- Authors: Leitao, J. (Ekstern), Thielscher, A. (Intern), Lee, H. (Ekstern), Tuennerhoff, J. (Ekstern), Noppeney, U. (Ekstern)
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16-Channel surface coil for 13C-hyperpolarized spectroscopic imaging of cardiac metabolism in pig heart

Magnetic resonance spectroscopy (MRS) of hyperpolarized 13C pyruvate and its metabolites in large animal models is a powerful tool for assessing cardiac metabolism in patho-physiological conditions. In 13C studies, a high signal-to-noise ratio (SNR) is crucial to overcome the intrinsic data quality limitation due to the low molar concentration of certain metabolites as well as the low flux of conversion. Since 13C-MRS is essentially a semi-quantitative technique, the SNR of the spectra acquired in different myocardial segments should be homogeneous. MRS coil design plays an important role in achieving both targets. In this study, a 16-channel receive surface coil was designed for 13C hyperpolarized studies of the pig heart with a clinical 3-T scanner. The coil performance was characterized by phantom experiments and compared with that of a birdcage coil used in transmit/receive mode. Segmental signal distribution in the left ventricle (LV) was assessed by experiments on six healthy mini pigs. The proposed coil showed a significant increase in SNR for the LV wall close to the coil surface with respect to that for the birdcage but also significant segmental inhomogeneity. Hence, the use of the 16-channel coil is recommended for studies of septal and anterior LV walls.
A novel MR contrast agent for angiography and perfusion: Hyperpolarized water

Magnetic Resonance Imaging (MRI) is an important tool in medical imaging, and is widely used for its high spatial and temporal resolution, and low safety concerns. However, the technique has its limitations due to the inherent low sensitivity, making it inferior to Computed Tomography (CT) in terms of spatial and temporal sensitivity and to nuclear medicine methods in terms of molecular imaging sensitivity. By hyperpolarization, the available signal can be enhanced by several orders of magnitude, and potentially close some of these gaps. In this thesis work, the purpose is to demonstrate that water, hyperpolarized by dissolution Dynamic Nuclear Polarization (d-DNP), can be applied as an MRI contrast agent for angiography and perfusion. The first part of the project focuses on development of a protocol for production of large samples of hyperpolarized protons in D2O. The samples are polarized and dissolved in a fluid path compatible with the installed base of commercial polarizers developed for clinical research. The solidstate DNP is optimized at 6.7 T and 1.2 K by microwave frequency modulation. A solid-state polarization of 70% is obtained. The dissolution procedure is optimized by introduction of a fluorinated solvent to accelerate the transition from solid to liquid state, and efficient radical extraction is obtained with a two-phase system of water and heptane. A final liquid state polarization of 13% in samples of 16 mL is obtained, suitable for large animal experiments. In second part of the project, hyperpolarized water is applied for angiographic imaging and perfusion measurements in a pig model. Renal angiography of 0.55 mm in-plane isotropic resolution is demonstrated and perfusion measurements provides values comparable to conventional Gd-T1-DCE analysis. Finally, it is demonstrated that the method can be applied to acquire dynamic coronary MR angiography with temporal resolution of less than 1 s, apparent Signal-to-Noise Ratio of 269±169 and coronary sharpness of 0.31±0.086 mm-1, which is superior to coronary MRA available in today’s clinical practice.

General information

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Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance
Authors: Lipsø, H. K. W. (Intern), Ardenkjær-Larsen, J. H. (Intern), Hanson, L. G. (Intern)
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Relations
Challenges in Polybinary Modulation for Bandwidth Limited Optical Links

Optical links using traditional modulation formats are reaching a plateau in terms of capacity, mainly due to bandwidth limitations in the devices employed at the transmitter and receivers. Advanced modulation formats, which boost the spectral efficiency, provide a smooth migration path towards effectively increase the available capacity. Advanced modulation formats however require digitalization of the signals and digital signal processing blocks to both generate and recover the data. There is therefore a trade-off in terms of efficiency gain vs complexity. Polybinary modulation, a generalized form of partial response modulation, employs simple codification and filtering at the transmitter to drastically increase the spectral efficiency. At the receiver side, polybinary modulation requires low complexity direct detection and very little digital signal processing. This paper provides an overview of the current research status of the key building blocks in polybinary systems. The results clearly show how polybinary modulation effectively reduces the bandwidth requirements on optical links while providing high spectral efficiency.
neuroimaging or electrophysiology.

**General information**

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Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, University of Tubingen, University of Copenhagen, Christian Albrechts University
Authors: Bergmann, T. O. (Ekstern), Karabanov, A. (Ekstern), Hartwigsen, G. (Ekstern), Thielscher, A. (Intern), Siebner, H. R. (Ekstern)
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Scopus rating (2016): CiteScore 6.31 SJR 3.967 SNIP 1.759
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 4.583 SNIP 1.852 CiteScore 6.71
Web of Science (2015): Indexed yes
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Scopus rating (2014): SJR 4.323 SNIP 2.03 CiteScore 6.9
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
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Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
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Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 3.728 SNIP 1.818 CiteScore 6.31
ISI indexed (2011): ISI indexed yes
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BFI (2010): BFI-level 2
Scopus rating (2010): SJR 3.654 SNIP 1.869
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 3.954 SNIP 1.899
Web of Science (2009): Indexed yes
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Scopus rating (2008): SJR 4.196 SNIP 1.771
Web of Science (2008): Indexed yes
Web of Science (2007): Indexed yes
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Decoupling Scheme for a Cryogenic Rx-Only RF Coil for 13C Imaging at 3T
In this study we evaluate the different active decoupling schemes that can be used to drive an Rx-only coil, in order to determine the optimal design for 13C MRI at 3T. Three different circuit schemes are studied: two known ones (with regular series and parallel tuning respectively), and a novel one which we found to be optimal for this case. The circuits have been cooled to 77K to reduce coil noise. Preliminary tests with the preamplifier cooled to 77K for reduction of noise figure, are also reported.

General information
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Organisations: Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance, Center for Magnetic Resonance, Electromagnetic Systems, Aarhus University
Authors: Sanchez, J. D. (Intern), Søvsø Szocska Hansen, E. (Ekstern), Laustsen, C. (Ekstern), Zhurbenko, V. (Intern), Ardenkjær-Larsen, J. H. (Intern)
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Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2016

Difference between Extra- and Intracellular T1 Values of Carboxylic Acids Affects the Quantitative Analysis of Cellular Kinetics by Hyperpolarized NMR
Incomplete knowledge of the longitudinal relaxation time constant (T1) leads to incorrect assumptions in quantitative kinetic models of cellular systems, studied by hyper-polarized real-time NMR. Using an assay that measures the intracellular signal of small carboxylic acids in living cells, the intracellular T1 of the carboxylic acid moiety of acetate, keto-isocaprate, pyruvate, and butyrate was determined. The intracellular T1 is shown to be up to four-fold shorter than the extracellular T1. Such a large difference in T1 values between the inside and the outside of the cell has significant influence on the quantification of intracellular metabolic activity. It is expected that the significantly shorter T1 value of the carboxylic moieties inside cells is a result of macro-molecular crowding. An artificial cytosol has been prepared and applied to predict the T1 of other carboxylic acids. We demonstrate the value of this prediction tool.

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Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Department of Automation
Dissolution Dynamic Nuclear Polarization capability study with fluid path

Signal enhancement by hyperpolarization is a way of overcoming the low sensitivity in magnetic resonance; MRI in particular. One of the most well-known methods, dissolution Dynamic Nuclear Polarization, has been used clinically in cancer patients. One way of ensuring a low bioburden of the hyperpolarized product is by use of a closed fluid path that constitutes a barrier to contamination. The fluid path can be filled with the pharmaceuticals, i.e. imaging agent and solvents, in a clean room, and then stored or immediately used at the polarizer. In this study, we present a method of filling the fluid path that allows it to be reused. The filling method has been investigated in terms of reproducibility at two extrema, high dose for patient use and low dose for rodent studies, using [1-13C]pyruvate as example. We demonstrate that the filling method allows high reproducibility of six quality control parameters with standard deviations 3–10 times smaller than the acceptance criteria intervals in clinical studies.
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BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): SNIP 0.963 SJR 1.182 CiteScore 2.57
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.37 SJR 1.016 SNIP 0.983
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.111 SNIP 1.07 CiteScore 2.88
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.113 SNIP 1.013 CiteScore 2.26
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.103 SNIP 0.937 CiteScore 2.41
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.117 SNIP 1.046 CiteScore 2.28
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.097 SNIP 1.137 CiteScore 2.55
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 1.363 SNIP 1.066
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 1.632 SNIP 1.123
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 1.52 SNIP 1.08
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 1.375 SNIP 1.083
Scopus rating (2006): SJR 1.436 SNIP 1.062
Scopus rating (2005): SJR 1.337 SNIP 1.122
Scopus rating (2004): SJR 1.305 SNIP 1.362
Scopus rating (2003): SJR 1.252 SNIP 1.195
Web of Science (2003): Indexed yes
Scopus rating (2002): SJR 1.096 SNIP 0.928
Scopus rating (2001): SJR 1.398 SNIP 0.782
Scopus rating (2000): SJR 0.759 SNIP 1.031
Web of Science (2000): Indexed yes
Scopus rating (1999): SJR 1.134 SNIP 1.039
Original language: English
Biophysics, Biochemistry, Nuclear and High Energy Physics, Condensed Matter Physics, Dissolution-DNP, Dynamic Nuclear Polarization, Hyperpolarization, Polarizer, Dissolution, Filling, Magnetic resonance, Optical instruments, Spin polarization, Acceptance criteria, Dissolution DNP, Dissolution dynamics, Dynamic nuclear polarization, High reproducibility, Standard deviation, Polarization
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Educational simulator app and webpage for exploring Nuclear and Compass Magnetic Resonance

A graphical app and browser-based simulator, CompassMR, was developed for initial Magnetic Resonance (MR) education. It is available at http://drcmr.dk/CompassMR/ and executes directly in most browsers with no further need for software. Easy access and a simple user interface invite student experimentation that improves understanding of basic MR phenomena. The simulator is used to introduce and explore electromagnetism, magnetic dipoles, static and radiofrequency fields, Compass MR, the free induction decay (FID), relaxation, the Fourier transform (FFT), the resonance condition, spin, precession, the Larmor equation, Nuclear MR, resonant excitation (linear and quadrature), and off-resonance effects.

Methods and implementation:
The simulator is a complete HTML5/JavaScript[1,2] rewrite of the JavaCompass[3] so it now executes in modern browsers with no additional software needed. Spin dynamics and enhanced responsiveness was added. Android App conversion was accomplished using Adobe PhoneGap[4]. The basis for the graphical spin simulation is the semi-classical Bloch vector equation[5] for a proton in combined stationary and oscillating magnetic fields, B0 and B1. For providing intuitive insight, the corresponding classical equation of motion for a compass needle in similar fields is used to simulate Compass Magnetic Resonance (CMR) that is similar to NMR except for needle vibration substituting nuclear precession. The nuclear Bloch vector moves like the magnetic moment of a classical rotating charge distribution [6] as shown in the simulator. Spin is a consequence of Quantum Mechanics (QM) and not all aspects of spin and nuclei are represented in this naive picture. Beyond spin, the consequences of QM for proton MR are largely not observable, however, and the QM Bloch vector moves as shown in the simulator. Hence, it demonstrates nuclear dynamics more accurately than typical QM-inspired "cone" pictorial representations aimed at giving better representations of MR than classical mechanics, while often doing the opposite. This justification of the classical perspective is discussed in detail in [7].
Enhancing predicted efficacy of tumor treating fields therapy of glioblastoma using targeted surgical craniectomy: A computer modeling study

Objective: The present work proposes a new clinical approach to TTFields therapy of glioblastoma. The approach combines targeted surgical skull removal (craniectomy) with TTFields therapy to enhance the induced electrical field in the underlying tumor tissue. Using computer simulations, we explore the potential of the intervention to improve the clinical efficacy of TTFields therapy of brain cancer.

Methods: We used finite element analysis to calculate the electrical field distribution in realistic head models based on MRI data from two patients: One with left cortical/subcortical glioblastoma and one with deeply seated right thalamic anaplastic astrocytoma. Field strength was assessed in the tumor regions before and after virtual removal of bone areas of varying shape and size (10 to 100 mm) immediately above the tumor. Field strength was evaluated before and after tumor resection to assess realistic clinical scenarios. Results: For the superficial tumor, removal of a standard craniotomy bone flap increased the electrical field strength by 60-70% in the tumor. The percentage of tissue in expected growth arrest or regression was increased from negligible values to 30-50%. The observed effects were highly focal and targeted at the regions of pathology underlying the craniectomy. No significant changes were observed in surrounding healthy tissues. Median field strengths in tumor tissue increased with increasing craniectomy diameter up to 50-70 mm. Multiple smaller burr holes were more efficient than single craniectomies of equivalent area. Craniectomy caused no significant field enhancement in the deeply seated tumor, but rather a focal enhancement in the brain tissue underlying the skull defect.

Conclusions: Our results provide theoretical evidence that small and clinically feasible craniectomies may provide significant enhancement of TTFields intensity in cerebral hemispheric tumors without severely compromising brain protection or causing unacceptable heating in healthy tissues. A clinical trial is being planned to validate safety and efficacy.
Evaluation of a Modified High-Definition Electrode Montage for Transcranial Alternating Current Stimulation (tACS) of Pre-Central Areas

Objective: To evaluate a modified electrode montage with respect to its effect on tACS-dependent modulation of corticospinal excitability and discomfort caused by neurosensory side effects accompanying stimulation. Methods: In a double-blind cross-over design, the classical electrode montage for primary motor cortex (M1) stimulation (two patch electrodes over M1 and contralateral supraorbital area) was compared with an M1 centre-ring montage. Corticospinal excitability was evaluated before, during, immediately after and 15 minutes after tACS (10 min., 20 Hz vs. 30 s low-frequency transcranial random noise stimulation). Results: Corticospinal excitability increased significantly during and immediately after tACS with the centre-ring montage. This was not the case with the classical montage or tRNS stimulation. Level of discomfort was rated on average lower with the centre-ring montage. Conclusions: In comparison to the classic montage, the M1 centre-ring montage enables a more focal stimulation of the target area and, at the same time, significantly reduces neurosensory side effects, essential for placebo-controlled study designs.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, KU Leuven, Copenhagen University Hospital
Authors: Heise, K. F. (Ekstern), Kortzorg, N. (Ekstern), Saturnino, G. B. (Ekstern), Fujiyama, H. (Ekstern), Cuypers, K. (Ekstern), Thielscher, A. (Intern), Swinnen, S. P. (Ekstern)
Number of pages: 5
Pages: 700–704
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Brain Stimulation
Volume: 9
High-field dissolution dynamic nuclear polarization of [1-13C]pyruvic acid

[1-13C]pyruvate is the most widely used hyperpolarized metabolic magnetic resonance imaging agent. Using a custom-built 7.0 T polarizer operating at 1.0 K and trityl radical-doped [1-13C]pyruvic acid, unextrapolated solution-state 13C polarization greater than 60% was measured after dissolution and rapid transfer to a spectrometer magnet, demonstrating the signal enhancement attainable using optimized hardware. Slower rates of polarization under these conditions can be largely overcome with higher radical concentrations.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Swiss Federal Institute of Technology, Lausanne University Hospital
Authors: Yoshihara, H. A. I. (Ekstern), Can, E. (Ekstern), Karlsson, M. (Intern), Lerche, M. H. (Intern), Schwitter, J. (Ekstern), Comment, A. (Ekstern)
Pages: 12409-12413
Publication date: 2016
Main Research Area: Technical/natural sciences
HP Xenon by d-DNP using the clinical GE SPINlab polarizer system

**General information**

State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Aarhus University, Aarhus University Hospital
Authors: Mariager, C. (Ekstern), Ringgaard, S. (Ekstern), Ardenkjær-Larsen, J. H. (Intern), Laustsen, C. (Ekstern)
Number of pages: 1
Publication date: 2016
Event: Abstract from EUROMAR 2016, Aarhus, Denmark.
Main Research Area: Technical/natural sciences
Electronic versions: HP_Xenon.pdf

Hyperpolarised Organic Phosphates as NMR Reporters of Compartmental pH

Organic phosphate metabolites contain functional groups with pKa values near the physiologic pH range, yielding pH-dependent $^{13}$C chemical shift changes of adjacent quaternary carbon sites. When formed in defined cellular compartments from exogenously hyperpolarised $^{13}$C substrates, metabolites thus can yield localised pH values and correlations of organelle pH and catalytic activity.

**General information**

State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Department of Chemistry, Organic Chemistry
Authors: Jensen, P. R. (Intern), Meier, S. (Intern)
Number of pages: 4
Pages: 2288-2291
Publication date: 2016
Main Research Area: Technical/natural sciences
Imaging Renal Urea Handling in Rats at Millimeter Resolution using Hyperpolarized Magnetic Resonance Relaxometry

In vivo spin spin relaxation time (T2) heterogeneity of hyperpolarized [(13)C,(15)N2]urea in the rat kidney was investigated. Selective quenching of the vascular hyperpolarized (13)C signal with a macromolecular relaxation agent revealed that a long-T2 component of the [(13)C,(15)N2]urea signal originated from the renal extravascular space, thus allowing the vascular and renal filtrate contrast agent pools of the [(13)C,(15)N2]urea to be distinguished via multi-exponential analysis. The T2 response to induced diuresis and antidiuresis was performed with two imaging agents: hyperpolarized [(13)C,(15)N2]urea and a control agent hyperpolarized bis-1,1-(hydroxymethyl)-1-(13)C-cyclopropane-(2)H8. Large T2 increases in the inner-medullar and papilla were observed with the former agent and not the latter during antidiuresis. Therefore, [(13)C,(15)N2]urea relaxometry is sensitive to two steps of the renal urea handling process: glomerular filtration and the inner-medullary urea transporter (UT)-A1 and UT-A3 mediated urea concentrating process.
Simple motion correction and subspace denoising algorithms are presented to aid in the multi exponential data analysis. Furthermore, a T2-edited, ultra long echo time sequence was developed for sub-2 mm(3) resolution 3D encoding of urea by exploiting relaxation differences in the vascular and filtrate pools.

**General information**

State: Published
Organisations: Department of Automation, Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, University of California
Pages: 125-135
Publication date: 2016
Main Research Area: Technical/natural sciences

**Publication information**

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Volume: 2
Issue number: 2
ISSN (Print): 2379-1381
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DOIs: 10.18383/j.tom.2016.00127
Source: FindIt
Source-ID: 2348543484
Publication: Research - peer-review › Journal article – Annual report year: 2016

**Interactive web site and app for early magnetic resonance education**

Teaching and understanding basic Magnetic Resonance (MR) is a challenge. This is clear from the educational literature that often repeats misinterpretations of quantum mechanics reminiscent of its earliest formulations (see www.drcmr.dk/MR that also links to the developed software). Modern quantum formulations of MR are much closer to classical descriptions than to typical quantum inspired myths frequent in literature. This opens for intuitive educational computer simulation using modern web technologies offering excellent interactive possibilities for experimentation.

**General information**

State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance
Authors: Hanson, L. G. (Intern)
Number of pages: 1
Pages: 258
Publication date: 2016
Conference: 1st European Congress of Medical Physics, Athens, Greece, 01/09/2016 - 01/09/2016
Main Research Area: Technical/natural sciences

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Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): SNIP 1.115 SJR 0.792 CiteScore 2.09
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Investigating tumor perfusion by hyperpolarized (13) C MRI with comparison to conventional gadolinium contrast-enhanced MRI and pathology in orthotopic human GBM xenografts: Correlation of 13C Perfusion Imaging and Gd-Enhanced Contrast MRI

Dissolution dynamic nuclear polarization (DNP) enables the acquisition of (13) C magnetic resonance data with a high sensitivity. Recently, metabolically inactive hyperpolarized (13) C-labeled compounds have shown to be potentially useful for perfusion imaging. The purpose of this study was to validate hyperpolarized perfusion imaging methods by comparing with conventional gadolinium (Gd)-based perfusion MRI techniques and pathology. Dynamic (13) C data using metabolically inactive hyperpolarized bis-1,1-(hydroxymethyl)-[1-(13) C]cyclopropane-d8 (HMCP) were obtained from an orthotopic human glioblastoma (GBM) model for the characterization of tumor perfusion and compared with standard Gd-based dynamic susceptibility contrast (DSC) MRI data and immunohistochemical analysis from resected brains. Distinct HMCP perfusion characteristics were observed within the GBM tumors compared with contralateral normal brain tissue. The perfusion parameters obtained from the hyperpolarized HMCP data in tumor were strongly correlated with normalized peak height measured from the DSC images. The results from immunohistochemical analysis supported these findings by showing a high level of vascular staining for tumor that exhibited high levels of hyperpolarized HMCP signal. The results
from this study have demonstrated that hyperpolarized HMCP data can be used as an indicator of tumor perfusion in an orthotopic xenograft model for GBM. Magn Reson Med, 2016. © 2016 Wiley Periodicals, Inc.
Large dose hyperpolarized water with dissolution-DNP at high magnetic field

We demonstrate a method for the preparation of hyperpolarized water by dissolution Dynamic Nuclear Polarization at high magnetic field. Protons were polarized at 6.7T and 1.1K to >70% with frequency modulated microwave irradiation at 188GHz. 97.2±0.7% of the radical was extracted from the sample in the dissolution in a two-phase system. 16±1mL of 5.0M (1)H in D2O with a polarization of 13.0±0.9% in the liquid state was obtained, corresponding to an enhancement factor of 4000±300 compared to the thermal equilibrium at 9.4T and 293K. A longitudinal relaxation time constant of 16±1s was measured. The sample was polarized and dissolved in a fluid path compatible with clinical polarizers. The volume of hyperpolarized water produced by this method enables angiography and perfusion measurements in large animals, as well as NMR experiments for studies of e.g. proton exchange and polarization transfer to other nuclei.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance
Authors: Lipsø, H. K. W. (Intern), Bowen, S. (Intern), Rybalko, O. (Intern), Ardenkjær-Larsen, J. H. (Intern)
Pages: 65-72
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Magnetic Resonance
Volume: 274
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BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Scopus rating (2017): SNIP 0.963 SJR 1.182 CiteScore 2.57
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.37 SJR 1.016 SNIP 0.983
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.111 SNIP 1.07 CiteScore 2.88
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.113 SNIP 1.013 CiteScore 2.26
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.103 SNIP 0.937 CiteScore 2.41
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
Measuring Motion-Induced B0-Fluctuations in the Brain Using Field Probes

Purpose: Fluctuations of the background magnetic field (B0) due to body and breathing motion can lead to significant artifacts in brain imaging at ultrahigh field. Corrections based on real-time sensing using external field probes show great potential. This study evaluates different aspects of field interpolation from these probes into the brain which is implicit in such methods. Measurements and simulations were performed to quantify how well B0-fluctuations in the brain due to body and breathing motion are reflected in external field probe measurements. Methods: Field probe measurements were compared with scanner acquired B0-maps from experiments with breathing and shoulder movements. A realistic simulation of B0-fluctuations caused by breathing was performed, and used for testing different sets of field probe positions. Results: The B0-fluctuations were well reflected in the field probe measurements in the shoulder experiments, while the breathing experiments showed only moderate correspondence. The simulations showed the importance of the probe positions, and that performing full 3rd order corrections based on 16 field probes is not recommended. Conclusion: Methods for quantitative assessment of the field interpolation problem were developed and demonstrated. Field corrections based on external field measurements show great potential, although potential pitfalls were identified.

General information
State: Published
Organisations: Center for Magnetic Resonance, Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance, Department of Applied Mathematics and Computer Science, Cognitive Systems, Leiden University Medical Center, Leiden University, University Medical Centre Utrecht
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Pages: 2020-2030
Publication date: 2016
Main Research Area: Technical/natural sciences
Microwave-gated dynamic nuclear polarization

Dissolution dynamic nuclear polarization (D-DNP) has become a method of choice to enhance signals in nuclear magnetic resonance (NMR). Recently, we have proposed to combine cross-polarization (CP) with D-DNP to provide high polarization $P((13)C)$ in short build-up times. In this paper, we show that switching microwave irradiation off for a few hundreds of milliseconds prior to CP can significantly boost the efficiency. By implementing microwave gating, $(13)C$ polarizations on sodium $[1-(13)C]$acetate as high as 64% could be achieved with a polarization build-up time constant as short as 160 s. A polarization of $P((13)C) = 78\%$ could even be reached for $[(13)C]$urea.
Muscle growth is reduced in 15-month-old children with cerebral palsy

Aim
Lack of muscle growth relative to bone growth may be responsible for development of contractures in children with cerebral palsy (CP). Here, we used ultrasonography to compare growth of the medial gastrocnemius muscle in children with and without CP.

Method
Twenty-six children with spastic CP (15 males, 11 females; mean age 35mo, range 8-65mo) and 101 typically developing children (47 males, 54 females; mean age 29mo, range 1-69mo) were included. Functional abilities of children with CP equalled levels I to III in the Gross Motor Function Classification System. Medial gastrocnemius muscle volume was constructed from serial, transverse, two-dimensional ultrasonography images.

Results
Typically developing children, medial gastrocnemius volume increased linearly with age. Among children with CP, medial gastrocnemius volume increased less with age and deviated significantly from typically developing children at 15 months of age (p < 0.05).

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, University of Copenhagen, Helene Elsass Center, University of Queensland
Authors: Herskind, A. (Ekstern), Ritterband-Rosenbaum, A. (Ekstern), Willerslev-Olsen, M. (Ekstern), Lorentzen, J. (Ekstern), Hanson, L. G. (Intern), Lichtwark, G. (Ekstern), Nielsen, J. B. (Ekstern)
Pages: 485-491
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Developmental Medicine and Child Neurology
Volume: 58
On the present and future of dissolution-DNP

Dissolution-DNP is a method to create solutions of molecules with nuclear spin polarization close to unity. The many orders of magnitude signal enhancement have enabled many new applications, in particular in vivo MR metabolic imaging. The method relies on solid state dynamic nuclear polarization at low temperature followed by a dissolution to produce the room temperature solution of highly polarized spins. This work describes the present and future of dissolution-DNP in the mind of the author. The article describes some of the current trends in the field as well as outlines some of the areas where new ideas will make an impact. Most certainly, the future will take unpredictable directions, but hopefully the thoughts presented here will stimulate new ideas that can further advance the field. (C) 2016 Elsevier Inc. All rights reserved.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance
Oxygen metabolic competition in the lactic acidotic diabetic kidney: A point of no return?

Diabetic nephropathy is directly related to renal hypoxia, with an increased mitochondrial uncoupling and increased energy demand to maintain normal renal function. Lowering the oxygen content in inspired air has shown to worsen the prognostic outcome of diabetic patients independent of glycemic control. We therefore tested the hypothesis that acutely altered renal oxygen availability alters metabolic pathways related to cellular energy production.
Probing treatment response of glutaminolytic prostate cancer cells to natural drugs with hyperpolarized [5-13C]glutamine

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Bracco Imaging
Authors: Jensen, P. R. (Intern), Canape, C. (Ekstern), Catanzaro, G. (Ekstern), Karlsson, M. (Intern), Lerche, M. H. (Intern)
Number of pages: 1
Publication date: 2016
Main Research Area: Technical/natural sciences
Electronic versions:
WMIC_poster.pdf
Source: PublicationPreSubmission
Source-ID: 130760201
Publication: Research - peer-review › Conference abstract in journal – Annual report year: 2016

Prospective motion correction for MRI using EEG-equipment
A new prospective motion correction technique is presented that is based on signals from gradient switching, in an EEG-cap with interconnected electrodes the subject wears during scanning. The method has no line-of-sight limitations as optical methods, requires no interleaved navigator modules or additional hardware for sites already doing EEG-fMRI. Instead a training scan is performed were signals recorded with the EEG-system are correlated with motion parameters estimated by image realignment. Initial results from application of the method in a phantom are promising.

General information
State: Published
Reaching with the sixth sense: Vestibular contributions to voluntary motor control in the human right parietal cortex

The vestibular system constitutes the silent sixth sense: It automatically triggers a variety of vital reflexes to maintain postural and visual stability. Beyond their role in reflexive behavior, vestibular afferents contribute to several perceptual and cognitive functions and also support voluntary control of movements by complementing the other senses to accomplish the movement goal. Investigations into the neural correlates of vestibular contribution to voluntary action in humans are challenging and have progressed far less than research on corresponding visual and proprioceptive involvement. Here, we demonstrate for the first time with event-related TMS that the posterior part of the right medial intraparietal sulcus processes vestibular signals during a goal-directed reaching task with the dominant right hand. This finding suggests a qualitative difference between the processing of vestibular vs. visual and proprioceptive signals for controlling voluntary movements, which are pre-dominantly processed in the left posterior parietal cortex. Furthermore, this study reveals a neural pathway for vestibular input that might be distinct from the processing for reflexive or cognitive functions, and opens a window into their investigation in humans. (C) 2015 The Authors. Published by Elsevier Inc.
This paper presents rectangular waveguide-to-coplanar waveguide (CPW) transitions at U-band (40–60 GHz) using E-plane probe and wire bonding. The designs of CPWs based on quartz substrate with and without aluminum cover are explained. The single and double layer rectangular waveguide-to-CPW transitions using E-plane probe and wire bonding are designed. The proposed rectangular waveguide-to-CPW transition using wire bonding can provide 10 GHz bandwidth at U-band and does not require extra CPWs or connections between CPWs and chips. A single layer rectangular waveguide-to-CPW transition using E-plane probe with aluminum package has been fabricated and measured to validate the proposed transitions. To the authors’ best knowledge, this is the first time that a wire bonding is used as a probe for rectangular waveguide-to-CPW transition at U-band.
Objective: To investigate the role of hippocampal plasticity in the antidepressant effect of electroconvulsive therapy (ECT).

Method: We used magnetic resonance (MR) imaging including diffusion tensor imaging (DTI) and proton MR spectroscopy (1H-MRS) to investigate hippocampal volume, diffusivity, and metabolite changes in 19 patients receiving ECT for severe depression. Other regions of interest included the amygdala, dorsolateral prefrontal cortex (DLPFC), orbitofrontal cortex, and hypothalamus. Patients received a 3T MR scan before ECT (TP1), 1 week (TP2), and 4 weeks (TP3) after ECT.

Results: Hippocampal and amygdala volume increased significantly at TP2 and continued to be increased at TP3. DLPFC exhibited a transient volume reduction at TP2. DTI revealed a reduced anisotropy and diffusivity of the hippocampus at TP2. We found no significant post-ECT changes in brain metabolite concentrations, and we were unable to identify a spectral signature at 1.30 ppm previously suggested to reflect neurogenesis induced by ECT. None of the brain imaging measures correlated to the clinical response. Conclusion: Our findings show that ECT causes a remodeling of brain structures involved in affective regulation, but due to their lack of correlation with the antidepressant effect, this remodeling does not appear to be directly underlying the antidepressant action of ECT.
Renal Ischemia/Reperfusion necrosis monitoring with hyperpolarized fumarate

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Aarhus University
Authors: Nielsen, P. M. (Forskerdatabase), Eldirdiri, A. (Intern), Bertelsen, L. B. (Ekstern), Qi, H. (Ekstern), Stødkilde-Jørgensen, H. (Ekstern), Laustsen, C. (Ekstern)
Publication date: 2016

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Main Research Area: Technical/natural sciences
Conference: ISMRM 2016 Annual Meeting & Exhibition, Singapore, Singapore, 07/05/2016 - 07/05/2016
Source: FindIt
Source-ID: 2303775748
Publication: Research - peer-review › Article in proceedings – Annual report year: 2016
Simultaneous PET/MRI with 13C magnetic resonance spectroscopic imaging (hyperPET): phantom-based evaluation of PET quantification

Background: Integrated PET/MRI with hyperpolarized 13C magnetic resonance spectroscopic imaging (13C-MRSI) offers simultaneous, dual-modality metabolic imaging. A prerequisite for the use of simultaneous imaging is the absence of interference between the two modalities. This has been documented for a clinical whole-body system using simultaneous 1 H-MRI and PET but not for 13C-MRSI and PET. Here, the feasibility of simultaneous PET and 13C-MRSI as well as hyperpolarized 13C-MRSI in an integrated whole-body PET/MRI hybrid scanner is evaluated using phantom experiments.

Methods: Combined PET and 13C-MRSI phantoms including a NEMA [18F]-FDG phantom, 13C-acetate and 13C-urea sources, and hyperpolarized 13C-pyruvate were imaged repeatedly with PET and/or 13C-MRSI. Measurements evaluated for interference effects included PET activity values in the largest sphere and a background region; total number of PET trues; and 13C-MRSI signal-to-noise ratio (SNR) for urea and acetate phantoms. Differences between measurement conditions were evaluated using t tests. Results: PET and 13C-MRSI data acquisition could be performed simultaneously without any discernible artifacts. The average difference in PET activity between acquisitions with and without simultaneous 13C-MRSI was 0.83 (largest sphere) and −0.76 % (background). The average difference in net trues was –0.01 %. The average difference in 13C-MRSI SNR between acquisitions with and without simultaneous PET ranged from –2.28 to 1.21 % for all phantoms and measurement conditions. No differences were significant. The system was capable of 13C-MRSI of hyperpolarized 13C-pyruvate. Conclusions: Simultaneous PET and 13C-MRSI in an integrated whole-body PET/MRI hybrid scanner is feasible. Phantom experiments showed that possible interference effects introduced by acquiring data from the two modalities simultaneously are small and non-significant. Further experiments can now investigate the benefits of simultaneous PET and hyperpolarized 13C-MRI in vivo studies.

General information

State: Published
Organisations: Department of Automation, Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, University of Copenhagen, CEA Saclay
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Scopus rating (2016): SJR 0.902 SNIP 1.062 CiteScore 1.67
Web of Science (2016): Indexed yes
Scopus rating (2015): SNIP 0.278 SJR 0.414 CiteScore 0.61
Original language: English
Medicine & Public Health, Nuclear Medicine, Imaging / Radiology, Applied and Technical Physics, Computational Mathematics and Numerical Analysis, Engineering, general, SC11, PET/MRI, 13C magnetic resonance spectroscopic imaging, Hyperpolarization, Quantification, Interference
Electronic versions: filestore_8_.pdf
DOIs: 10.1186/s40658-016-0143-6

Bibliographical note

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Source-ID: 2303722380
Publication: Research - peer-review » Journal article – Annual report year: 2016
Single-Shot-RARE for rapid 3D hyperpolarized metabolic ex vivo tissue imaging: RF-pulse design for semi-dense spectra
MRS of hyperpolarized (HP) 13C-enriched compounds is a promising method for in vivo cancer diagnosis. Sentinel lymph node ex vivo tissue sample histology used in clinical routine for breast cancer metastasis diagnosis requires time consuming sample analysis. 3D-HP-MRSI can potentially speed up the diagnosis given a sensitive marker that can be efficiently imaged in tissue after homogenous injection. The entire sample can be confined within the imaged volume giving the possibility of complete spatial non-selectivity of the radio frequency (RF) pulses in the RF pulse design with no chemical shift localization errors. Since only a few product signals are of interest for this application, a combination of under-sampled temporal encoding, frequency selective excitation and the Single-Shot-RARE sequence offers favourable SNR characteristics. Small peak separations are challenging, however, since they require narrow excitation transition-bands. We have designed a 3D-MRSI pulse sequence for hyperpolarized ex vivo sample imaging for semi-dense compound spectra (few components, relatively small separations), ultimately aimed to be used for metastasis detection in excised lymph nodes.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Department of Applied Mathematics and Computer Science, Image Analysis & Computer Graphics, Copenhagen University Hospital
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Publication date: 2016
Event: Poster session presented at 33rd ESMRMB Annual Scientific Meeting, Vienna, Austria.
Main Research Area: Technical/natural sciences
Electronic versions: esmrb2016.0ef049b.NORMAL.pdf
Single_Shot_RARE_for_rapid_3D_hyperpolarized_metabolic_ex_vivo_tissue_imaging_RF_pulse_design_for_semi_dense_spectra_ESMRMB_Annual_Scientific_Meeting_2016.pdf

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Source: PublicationPreSubmission
Source-ID: 127578292
Publication: Research - peer-review › Poster – Annual report year: 2016

Spatiotemporal structure of intracranial electric fields induced by transcranial electric stimulation in humans and nonhuman primates
Transcranial electric stimulation (TES) is an emerging technique, developed to non-invasively modulate brain function. However, the spatiotemporal distribution of the intracranial electric fields induced by TES remains poorly understood. In particular, it is unclear how much current actually reaches the brain, and how it distributes across the brain. Lack of this basic information precludes a firm mechanistic understanding of TES effects. In this study we directly measure the spatial and temporal characteristics of the electric field generated by TES using stereotactic EEG (s-EEG) electrode arrays implanted in cebus monkeys and surgical epilepsy patients. We found a small frequency dependent decrease (10%) in magnitudes of TES induced potentials and negligible phase shifts over space. Electric field strengths were strongest in superficial brain regions with maximum values of about 0.5 mV/mm. Our results provide crucial information of the underlying biophysics in TES applications in humans and the optimization and design of TES stimulation protocols. In addition, our findings have broad implications concerning electric field propagation in non-invasive recording techniques such as EEG/MEG.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Nathan S. Kline Institute for Psychiatric Research, Feinstein Institute for Medical Research
Authors: Opitz, A. (Ekstern), Falchier, A. (Ekstern), Yan, C. (Ekstern), Yeagle, E. M. (Ekstern), Linn, G. S. (Ekstern), Megevand, P. (Ekstern), Thielscher, A. (Intern), Ross, D. A. (Ekstern), Milham, M. P. (Ekstern), Mehta, A. D. (Ekstern), Schroeder, C. E. (Ekstern)
Number of pages: 11
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Scientific Reports
Volume: 6
Spectroscopic approaches to resolving ambiguities of hyper-polarized NMR signals from different reaction cascades

The influx of exogenous substrates into cellular reaction cascades on the seconds time scale is directly observable by NMR spectroscopy when using nuclear spin polarization enhancement. Conventional NMR assignment spectra for the identification of reaction intermediates are not applicable in these experiments due to the non-equilibrium nature of the nuclear spin polarization enhancement. We show that ambiguities in the intracellular identification of transient reaction intermediates can be resolved by experimental schemes using site-specific isotope labelling, optimised referencing and response to external perturbations.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Department of Chemistry, Organic Chemistry
Authors: Jensen, P. R. (Intern), Meier, S. (Intern)
Number of pages: 4
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Main Research Area: Technical/natural sciences

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Ratings:
TE01 mode converter for highly overmoded circular waveguide at 188 GHz

A design of a G-band TE01 mode converter is presented in this work. It consists of a TE01 mode launcher followed by a tapered waveguide section. Full-wave simulated reflection coefficient of stainless steel converter is better than −15 dB and transmission coefficient is better than −1.5 dB in a frequency range from 173 GHz to 193 GHz. The design is useful in applications employing highly overmoded circular waveguides.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance, Center for Magnetic Resonance, Electromagnetic Systems
Authors: Rybalko, O. (Intern), Zhurbenko, V. (Intern), Ardenkjær-Larsen, J. H. (Intern)
Number of pages: 2
Pages: 1-2
Publication date: 2016
The BOLD cerebrovascular reactivity response to progressive hypercapnia in young and elderly.

Blood Oxygenation Level Dependent (BOLD) imaging in combination with vasoactive stimuli can be used to probe cerebrovascular reactivity (CVR). Characterizing the healthy, age-related changes in the BOLD-CVR response can provide a reference point from which to distinguish abnormal CVR from the otherwise normal effects of ageing. Using a computer controlled gas delivery system, we examine differences in BOLD-CVR response to progressive hypercapnia between 16 young (28 ± 3 years, 9 female) and 30 elderly subjects (66 ± 4 years, 13 female). Furthermore, we incorporate baseline T2* information to broaden our interpretation of the BOLD-CVR response. Significant age-related differences were observed. Grey matter CVR at 7 mm Hg above resting PetCO2 was lower amongst elderly (0.19 ± 0.06%ΔBOLD/mm Hg) as compared to young subjects (0.26 ± 0.07%ΔBOLD/mm Hg). White matter CVR at 7 mm Hg above baseline PetCO2 showed no significant difference between young (0.04 ± 0.02%ΔBOLD/mm Hg) and elderly subjects (0.05 ± 0.03%ΔBOLD/mm Hg). We saw no significant differences in the BOLD signal response to progressive hypercapnia between male and female subjects in either grey or white matter. The observed differences in the healthy BOLD-CVR response could be explained by age-related changes in vascular mechanical properties.
Towards Motion-Insensitive Magnetic Resonance Imaging Using Dynamic Field Measurements.

Magnetic resonance imaging (MRI) of the brain is frequently used for both clinical diagnosis and brain research. This is due to the great versatility of the technique and the excellent ability to distinguish different types of soft tissue. The image quality is, however, heavily degraded when the subject being scanned moves, which in many cases is impossible to avoid. Subject motion during scanning is therefore one of the big challenges for the method. Techniques to correct for image quality degradation due to subject motion are under rapid development. A promising approach is to monitor the head motion during scanning and update the MRI scanner in real-time such that the imaging volume follows the head motion (prospective motion correction). In this thesis, prospective motion correction is presented where head motion is determined from signals measured with an electroencephalography (EEG) cap with inter-connected electrodes that the subject wears during scanning. The signals measured with the EEG system are induced voltages due to temporal changes of the gradient fields. The signals contain information about the head position because these magnetic field changes are spatially depending, and because the induced voltages also depend on the orientation of the wire-loops relative to the direction of field changes. Some of the advantages with the developed technique are that it can be used in closed head coils where camera based tracking is facing problems, and that it does not require additional hardware for the many hospitals and research institutions that already have an EEG-system for use in an MRI environment. In the thesis, the technique is
considered in detail and proof of concept is demonstrated with phantom experiments. The experiments show that the newly developed technique has potential, but further optimization is required to improve accuracy and precision, and to improve the practical usability.

During MR examinations, a radio frequency (RF) field is transmitted into the subject to tip the magnetization of the hydrogen nuclei in the body away from equilibrium, and measurable signal is emitted. Changes in the transmitted RF field due to subject motion has up to now largely been left undescribed in the literature. This effect of subject motion is considered in the second study of the thesis, which focuses on single voxel spectroscopy where the effects are believed to have significant impact. A linear model is proposed to estimate tip angle changes during the scan from motion parameters, e.g. obtained from an external tracking system. The technique requires a previously performed calibration scan where the tip angle changes are measured for different head positions. A method for measuring actual tip angle changes was therefore implemented and pilot experiments were performed in a phantom and a healthy volunteer. The simple model seems promising based on these preliminary results. In MRI of the brain, not only head motion, but also motion of other parts of the body can lead to image degradation. This is because tissue is magnetized by the very strong, static background field (B0) such that the tissue contributes slightly to the background field.

Motion of the body is thus felt in the brain as small fluctuations in the background field, and e.g. breathing motion can lead to substantial image quality degradation for certain brain imaging sequences through this effect. It has previously been shown that magnetic field sensors (field probes) can be applied to stabilize the B0 field during scanning. However, the field probes are placed around the head, while it is the B0-fluctuations inside the head that are of interest. This interpolation problem is the subject of the last study in the thesis. Experiments were performed with healthy volunteers to test how field estimates in the brain based on outside field probe measurements compare to field measurements performed in the brain, in cases with breathing and shoulder motion. Simulations were performed to elucidate where the field probes should be placed in order to optimize the correspondence.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Department of Applied Mathematics and Computer Science, Cognitive Systems
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Number of pages: 108
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Publisher: Technical University of Denmark, Department of Electrical Engineering
Original language: English
Main Research Area: Technical/natural sciences
Publication: Research › Ph.D. thesis – Annual report year: 2016

Transcranial brain stimulation: closing the loop between brain and stimulation
PURPOSE OF REVIEW: To discuss recent strategies for boosting the efficacy of noninvasive transcranial brain stimulation to improve human brain function. RECENT FINDINGS: Recent research exposed substantial intra- and inter-individual variability in response to plasticity-inducing transcranial brain stimulation. Trait-related and state-related determinants contribute to this variability, challenging the standard approach to apply stimulation in a rigid, one-size-fits-all fashion. Several strategies have been identified to reduce variability and maximize the plasticity-inducing effects of noninvasive transcranial brain stimulation. Priming interventions or paired associative stimulation can be used to 'standardize' the brain-state and hereby, homogenize the group response to stimulation. Neuroanatomical and neurochemical profiling based on magnetic resonance imaging and spectroscopy can capture trait-related and state-related variability. Fluctuations in brain-states can be traced online with functional brain imaging and inform the timing or other settings of transcranial brain stimulation. State-informed open-loop stimulation is aligned to the expression of a predefined brain state, according to prespecified rules. In contrast, adaptive closed-loop stimulation dynamically adjusts stimulation settings based on the occurrence of stimulation-induced state changes. SUMMARY: Approaches that take into account trait-related and state-related determinants of stimulation-induced plasticity bear considerable potential to establish noninvasive transcranial brain stimulation as interventional therapeutic tool.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Copenhagen University Hospital
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Number of pages: 8
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Main Research Area: Technical/natural sciences

Publication information
Journal: Current Opinion in Neurology
Volume: 29
Issue number: 4
Transmission Line Resonator Segmented with Series Capacitors

Transmission line resonators are often used as coils in high field MRI. Due to distributed nature of such resonators, coils based on them produce inhomogeneous field. This work investigates application of series capacitors to improve field homogeneity along the resonator. The equations for optimal values of evenly distributed capacitors are presented. The performances of the segmented resonator and a regular transmission line resonator are compared.

General information

State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Electromagnetic Systems, University of Copenhagen
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Number of pages: 4
Tunable 13C/1H dual channel matching circuit for dynamic nuclear polarization system with cross-polarization

In this paper we report initial results of design and practical implementation of tuning and matching circuit to estimate a performance of Dynamic Nuclear Polarization (DNP) at a magnetic field of 6.7 T. It is shown that developed circuit for signal observation is compact, easy to make and provides low return loss (typically better than ~45 dB) at a tuning range ±3 MHz for both resonant frequencies. In addition, transmission parameters measured between 13C and 1H channels are less than ~17 dB and ~50 dB for 71.8 MHz and 285.5 MHz, respectively showing a good isolation between the two channels. Measurement results with a tuning and matching circuit prototype are presented including obtained spectra (13C and 1H) and estimation of the signal-to-noise ratio.

Ultrashort electromagnetic clusters formation by two-stream superheterodyne free electron lasers

A cubic nonlinear self-consistent theory of multiharmonic two-stream superheterodyne free electron lasers (TSFEL) of a klystron type, intended to form powerful ultrashort clusters of an electromagnetic field is constructed. Plural three-wave parametric resonant interactions of wave harmonics have been taken into account. An amplitude, phase and spectral analyses of the processes occurring in such devices have been carried out. The conditions necessary for the forming of the ultrashort clusters of an electromagnetic field have been found out. The possibility of the ultrashort electromagnetic cluster formation in the multiharmonic TSFEL-type systems has been demonstrated.
A low loss waveguide transition section and oversized microwave vacuum window covering several frequency bands (94 GHz, 140 GHz, 188 GHz) is presented. The transition is compact and was optimized for multiband Dynamic Nuclear Polarization (DNP) systems in a full-wave simulator. The window is more broadband than commercially available windows, which are usually optimized for single band operation. It is demonstrated that high-density polyethylene with urethane adhesive can be used as a low loss microwave vacuum window in multiband DNP systems. The overall assembly performance and dimensions are found using full-wave simulations. The practical aspects of the window implementation in the waveguide are discussed. To verify the design and simulation results, the window is tested experimentally at the three frequencies of interest.

General information
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Organisations: Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance, Center for Magnetic Resonance, Electromagnetic Systems
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Number of pages: 5
Publication date: 2016
Main Research Area: Technical/natural sciences
Where does TMS Stimulate the Motor Cortex? Combining Electrophysiological Measurements and Realistic Field Estimates to Reveal the Affected Cortex Position

Much of our knowledge on the physiological mechanisms of transcranial magnetic stimulation (TMS) stems from studies which targeted the human motor cortex. However, it is still unclear which part of the motor cortex is predominantly affected by TMS. Considering that the motor cortex consists of functionally and histologically distinct subareas, this also renders the hypotheses on the physiological TMS effects uncertain. We use the finite element method (FEM) and magnetic resonance image-based individual head models to get realistic estimates of the electric field induced by TMS. The field changes in different subparts of the motor cortex are compared with electrophysiological threshold changes of 2 hand muscles when systematically varying the coil orientation in measurements. We demonstrate that TMS stimulates the region around the gyral crown and that the maximal electric field strength in this region is significantly related to the electrophysiological response. Our study is one of the most extensive comparisons between FEM-based field calculations and physiological TMS effects so far, being based on data for 2 hand muscles in 9 subjects. The results help to improve our understanding of the basic mechanisms of TMS. They also pave the way for a systematic exploration of realistic field estimates for dosage control in TMS.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Max-Planck-Institute for Biological Cybernetics
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Number of pages: 12
Hyperpolarized 2-oxoglutarate as metabolic agent in MR

Hyperpolarized 1-13C-2-oxoglutarate as contrast agent in 13C Magnetic Resonance diagnostic technique (13C-MRI) for use in the diagnosis of cancer. In particular, upon administration of said 1-13C-2-oxoglutarate, signals of 1-13C-glutamate are detected. More in particular, different MR signals from 13C nuclei are detected and compared, said comparison being useful to determine a difference between tumor and non-tumor tissues, to determine the aggressiveness of a tumor or the efficacy of an anti-tumor therapy.

General information
State: Published
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Publication date: 2 Sep 2015

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3D metabolic ex vivo sample imaging of hyperpolarized compounds using a 3D single-shot RARE (3D SS-RARE) sequence, combining spectral RF selectivity with under-sampled spectral encoding at signal read-out

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Organisations: Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance, Center for Magnetic Resonance, Copenhagen University Hospital, Albeda Research ApS
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Main Research Area: Technical/natural sciences
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DNPsymposium2015_p105.pdf
Source: PublicationPreSubmission
Source-ID: 119536386
Publication: Research › Conference abstract in proceedings – Annual report year: 2015

A 282 GHz Probe for Dynamic Nuclear Polarization
Introduction In DNP, microwave irradiation of a sample facilitates the transfer of spin polarization from electrons to nuclei. One of the way to improve the DNP enhancement is to transfer microwave power from the mm-wave source to the sample more effectively. Several methods and techniques to efficiently transport microwave energy from the microwave source to the sample have been developed. For example, a corrugated waveguide allows to deliver mm-wave energy from external source to the probe with minimum losses. The conventional approach at high frequencies is to irradiate the sample directly from the waveguide, while at low frequencies the cavity of the probe is used as a microwave resonator. It is important to optimize the arrangement of microwave, RF and sample handling components. In this paper a solution for the double channel microwave probe for operation at 10.1 T (13C frequency is 108 MHz, 1H frequency is 430 MHz, electron frequency is 282 GHz) is developed. The construction of the probe is detailed. Probe configuration The analysis of the probe structure is performed using a full-wave electromagnetic simulator (CSTMicrowave Studio 2014). Structurally, the
probe consists of two sections: microwave can with RF coil; the rest of the probe consists of a waveguide, sample tube and coaxial transmission line. The probe is designed to study cylindrical samples with diameter - 9 mm, and height – 2-20 mm. An RF coil which is housed in cylindrical Macor coil form (dielectric with ε=5.64 and tangent δ is 0.0025) surrounds the sample. The RF coil has a saddle form and was made out of two current loops run on opposite sides of a cylinder (in parallel). Material of the coil is copper wire with diameter equal to 0.7 mm. Coil dimensions are: diameter - 13 mm; height - 22.0 mm. The self resonant frequency of the coil is 976 MHz. A magnetic field distribution at 108 MHz and 430 MHz was calculated for the RF coil, the results revealed a good homogeneity and intensity along x,y,z axes. Figure 1 shows the general view of the probe and cross section through the microwave container with field distribution. Operating frequency is 282 GHz to drive DNP. On the top of the model is mounted a corrugated, circular waveguide. To avoid losses and to maintain the constraint that the RF coil surrounding the sample should not be close to metal parts. An additional advantage of using the corrugated waveguide is that the losses and power dissipation in free space are negligible. In our construction of the probe we have optimized relevant parameters of the probe. Conclusion We have demonstrated the feasibility of the probe design for DNP applications at 10.1 T from the microwave and RF point of view. The performance simulations of the microwave cavity have demonstrated that the electromagnetic field is effectively concentrated at the sample location.

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Organisations: Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance, Center for Magnetic Resonance, Electromagnetic Systems
Authors: Rybalko, O. (Intern), Bowen, S. (Intern), Zhurbenko, V. (Intern), Ardenkjær-Larsen, J. H. (Intern)
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Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2015

A fast and simple method for calibrating the flip angle in hyperpolarized 13C MRS experiments
Hyperpolarized 13C Magnetic resonance represents a promising modality for in vivo studies of intermediary metabolism of bio-molecules and new biomarkers. Although it represents a powerful tool for metabolites spatial localization and for the assessment of their kinetics in vivo, a number of technological problems still limits this technology and needs innovative solutions. In particular, the optimization of the signal-to-noise ratio during the acquisitions requires the use of pulse sequences with accurate flip angle calibration, which is performed by adjusting the transmit power in the prescan step. This is even more critical in the case of hyperpolarized studies, because the fast decay of the hyperpolarized signal requires precise determination of the flip angle for the acquisition. This work describes a fast and efficient procedure for transmit power calibration of magnetic resonance acquisitions employing selective pulses, starting from the calibration of acquisitions performed with non-selective (hard) pulses. The proposed procedure employs a simple theoretical analysis of radiofrequency pulses by assuming a linear response and can be performed directly during in vivo studies. Experimental MR data validate the theoretical calculation by providing good agreement.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Fondazione CNR/Regione Toscana G. Monasterio, National Research Council of Italy
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Main Research Area: Technical/natural sciences

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The intrinsic physicochemical properties of the sample formulation are the key factors for efficient hyperpolarization through dissolution dynamic nuclear polarization (dissolution-DNP). We provide a comprehensive characterization of the DNP process for Na-$[1-13C]$acetate selected as a model for non-self-glassing agents: the solid-state polarization dynamics of different formulations and the effect of the paramagnetic agent (trityl radical) on the pattern of polarization and the relaxation profile were extensively analyzed. We quantified the effects of the glassing agent and Gd$^{3+}$-chelate on DNP performance. The results reported here describe the constraints of the acetate formulation useful for future studies in this field with non-self-glassing enriched molecules.

General information
State: Published
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Pages: 1885–1893
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Web of Science (2018): Indexed yes
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Scopus rating (2017): CiteScore 2.75
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.64
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
In Vivo Phenotyping of Tumor Metabolism in a Canine Cancer Patient with Simultaneous (18)F-FDG-PET and Hyperpolarized (13)C-Pyruvate Magnetic Resonance Spectroscopic Imaging (hyperPET): Mismatch Demonstrates that FDG may not Always Reflect the Warburg Effect

In this communication the mismatch between simultaneous (18)F-FDG-PET and a (13)C-lactate imaging (hyperPET) in a biopsy verified squamous cell carcinoma in the right tonsil of a canine cancer patient is shown. The results demonstrate that (18)F-FDG-PET may not always reflect the Warburg effect in all tumors.

General information
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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, University of Copenhagen
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Main Research Area: Technical/natural sciences

Publication information
Journal: Diagnostics
Volume: 5
Magnetic Resonance Angiography in the Pig using Hyperpolarized Water

Introduction Magnetic Resonance Angiography (MRA) is an important tool in diagnostics of medical conditions such as emboli, stenosis and aneurysms. Sub-millimetre resolution can be obtained with proton imaging, and further optimization can be obtained with Gd-based blood pool agents. However, the acquisition time is several minutes, and conventional MRA methods thus fail to image within a single respiration or heartbeat and therefore suffers from motion artefacts. We demonstrate that hyperpolarized (HP) water can be used as an imaging agent to provide subsecond angiographies in pigs. Previous work on hyperpolarization for imaging agents in large animals has mainly been focused on 13C, but small volumes of hyperpolarized water with lower polarization has been demonstrated. Injection of hyperpolarized protons allows for the use of MRI coils and pulse sequences already existing in the clinic. Secondly, the magnetization achievable with hyperpolarized water is superior to other nuclei. Methods A 1 mL sample of 50% water and 50% glycerol with 30 mM TEMPO is polarized in a Spinlab (GE Healthcare) at 5 T, 0.9 K, 139.9 GHz for an hour. The sample is rapidly dissolved in 16 mL deoxygenized dissolution medium (DM) consisting of 1 mM EDTA, 50 mM sodium L-ascorbate, 1.9 mM NaH2PO4 and 8 mM Na2HPO4 dissolved in D2O. The DM is filled in the syringe with 7.6 g nonaflourobutyl methyl ether, which will accelerate the dissolution process and extract radical from the polar phase, and hence extend the T1. 10 mL deoxygenized heptane is added to the receiver to further extract the radical. The polarization is quantified in two ways: 1) the signal integral (FID amplitude) is compared to a thermally polarized, pure water reference sample (110 M) and 2) the line width due to radiation damping is compared to the radiation broadening of a thermally polarized, pure water sample. The two methods agree. Proton concentration is quantified by NMR measurement of the dissolved sample added a reference molecule. The images are acquired on a 3 T MRI system (GE healthcare) with a 4 channel array surface coil with a gradient echo sequence with 5 ° flip angle, slice thickness of 40 mm, TR = 3.4 ms, TE = 0.9840 ms, 256x256 matrix, FOV = (140 mm)². The acquisition time is 870 ms. 15 mL HP substance is injected over 5 s, initiated 15 s after dissolution through a catheter in the right renal artery of a 40 kg pig. Results The protons are polarized by dissolution DNP to an enhancement of more than 2000 times at 9.4 T, corresponding to a polarization of 13% at time of injection. T₁ of ~20 s is achieved in vitro for a 1H concentration of 4.5 M. A zoom of a renal MRA is shown in Figure 1. The image maps minor branches of the renal arteries, and the perfusion can be traced over time (time series not shown).

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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Aarhus University
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Magnetic Resonance Angiography in the Pig using Hyperpolarized Water
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Modeling of Schottky Barrier Diode Millimeter-Wave Multipliers at Cryogenic Temperatures
We report on the evaluation of Schottky barrier diode GaAs multipliers at cryogenic temperatures. A GaAs Schottky barrier diode model is developed for theoretical estimation of doubler performance. The model is used to predict efficiency of doublers from room to cryogenic temperatures. The theoretical estimation is verified experimentally using a 78 GHz doubler cooled down to 14 K. The observed efficiency improvement due to cooling is approximately 4 % per 100 degrees.

General information
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Organisations: Department of Electrical Engineering, Electromagnetic Systems, Center for Hyperpolarization in Magnetic Resonance, Center for Magnetic Resonance, Virginia Diodes Inc.
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Number of pages: 4
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Main Research Area: Technical/natural sciences
Conference: 2015 SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference (IMOC), Porto de Galinhas, Brazil, 03/11/2015 - 03/11/2015
Cryogenic temperature, Frequency multiplier, GaAs diodes, Millimeter wave, Varactor
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Simulation and comparison of coils for Hyperpolarized 13C MRS cardiac metabolism studies in pigs
Hyperpolarized 13C Magnetic Resonance represents a promising modality for in vivo spectroscopy since it provides a unique opportunity for the non-invasive assessment of regional cardiac metabolism. Although it represents a powerful tool for the study of the heart physiology in pig models, by permitting metabolic activity mapping, a number of technological problems still limit this technology and need innovative solutions such as the design of suitable radiofrequency (RF) coils, capable to provide a large sensitivity region. This work describes the simulation and the comparison of different 13C coil configurations, constituted by various arrangement of circular, butterfly and birdcage coils designed for hyperpolarized studies of pig heart with a clinical 3T scanner. The coils characterization is performed by developing a Signal-to-Noise Ratio (SNR) model, previously validated with experimental results, for coils performance evaluation in terms of coil resistance, sampleinduced resistance and magnetic field pattern. In particular, coil resistances were calculated from Ohm's law, while magnetic field patterns and sample induced resistances were calculated using a numerical Finite-Difference Time-Domain (FDTD) algorithm. Theoretical SNR-vs-depth profiles were calculated for each coil configuration. We believe the paper could be interesting for graduate students and researchers in the field of magnetic resonance coil design and development, especially for 13C studies.

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Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, National Research Council of Italy, Fondazione CNR/Regione Toscana G. Monasterio
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Transcranial Magnetic Stimulation: An Automated Procedure to Obtain Coil-specific Models for Field Calculations

Background: Field calculations for transcranial magnetic stimulation (TMS) are increasingly implemented online in neuronavigation systems and in more realistic offline approaches based on finite-element methods. They are often based on simplified and/or non-validated models of the magnetic vector potential of the TMS coils.

Objective: To develop an approach to reconstruct the magnetic vector potential based on automated measurements.

Methods: We implemented a setup that simultaneously measures the three components of the magnetic field with high...
spatial resolution. This is complemented by a novel approach to determine the magnetic vector potential via volume integration of the measured field.

Results: The integration approach reproduces the vector potential with very good accuracy. The vector potential distribution of a standard figure-of-eight shaped coil determined with our setup corresponds well with that calculated using a model reconstructed from X-ray images.

Conclusion: The setup can supply validated models for existing and newly appearing TMS coils.

General information
State: Published
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Scopus rating (2017): SNIP 1.533 SJR 2.753 CiteScore 4.46
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 4.4 SJR 2.523 SNIP 1.385
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.454 SNIP 1.38 CiteScore 4.28
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.006 SNIP 1.256 CiteScore 3.88
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BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.116 SNIP 1.604 CiteScore 4.62
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.72 SNIP 1.054 CiteScore 3.58
ISI indexed (2012): ISI indexed yes
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Scopus rating (2011): SJR 2.619 SNIP 1.791 CiteScore 4.73
ISI indexed (2011): ISI indexed yes
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10.1016/j.brs.2015.07.035
Source: FindIt
Source-ID: 2279865150
TMS field modelling-status and next steps

In the recent years, an increasing number of studies used geometrically accurate head models and finite element (FEM) or finite difference methods (FDM) to estimate the electric field induced by non-invasive neurostimulation techniques such as transcranial magnetic stimulation (TMS) or transcranial weak current stimulation (tCS; e.g., Datta et al., 2010; Thielscher et al., 2011). A general outcome was that the field estimates based on these more realistic models differ substantially from the results obtained with simpler head models. This suggests that the former models are indeed needed to realistically capture the field distribution in the brain. However, it is unclear how accurate even these more advanced models are and, in particular, to which extent they allow predicting the physiological outcome of stimulation. An experimental validation of the novel methods for field calculation is thus necessary. Focusing on motor cortex stimulation by TMS, our goal is to explore to which extent the field estimates based on advanced models correlate with the physiological stimulation effects. For example, we aim at testing whether interindividual differences in the field estimates are also reflected in differences in the MEP responses. This would indicate that the field calculations accurately capture the impact of individual macroanatomical features of the head and brain on the induced field distribution, in turn strongly supporting their plausibility. Our approach is based on the SimNIBS software pipeline (www.simnibs.de) that allows for the automatic creation of accurate head models from structural and diffusion-weighted magnetic resonance images (MRI) (Windhoff et al., 2011). This enables us to perform field calculations for multiple subjects, as required in neuroscientific studies. We substantially improved the software in order to improve its usability in a group analysis. At the moment, we are performing field calculations and are acquiring motor mapping data in a group of subjects for a systematic comparison of both data sets. I will give an overview on the status of the SimNIBS project. I will start by summarizing the key findings on how the individual brain anatomy shapes the electric field induced by TMS (Thielscher et al., 2011; Opitz, 2011). The putative link between the modeling results and basic physiological TMS effects is highlighted. I will then introduce the novel features of SimNIBS that include the import of coil positions from neuronavigation systems, improved support for diffusion-weighted MRI and transformation of the estimated fields into MNI space for group analysis. Preliminary results on the comparison between field estimates and motor mapping data will be presented. To summarize, field estimates based on accurate head models have already proven highly useful for a better understanding of the biophysics of non-invasive brain stimulation. The improved software tools now allow for systematic tests of the links between the estimated fields and the physiological effects in multi-subject studies. This will give the knowledge needed, e.g., for a more accurate spatial targeting of specific brain areas by TMS.
Online control in reaching and grasping: Functional specificity of neuronal correlates

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance
Authors: Cornelsen, S. (Ekstern), Thielscher, A. (Intern), Himmelbach, M. (Ekstern)
Publication date: 2012
Conference: Annual Meeting of the Neuroscience Society, New Orleans, United States, 13/10/2012 - 13/10/2012
Main Research Area: Technical/natural sciences

Publication information
Journal: Society for Neuroscience Abstract Viewer and Itinerary Planner
Volume: 42
Original language: English
grasping perturbed movement, reaching perturbed movement, unperturbed movement, Primates Mammalia Vertebrata Chordata Animalia (Animals, Chordates, Humans, Mammals, Primates, Vertebrates) - Hominidae [86215] human common
, 00520, General biology - Symposia, transactions and proceedings, 12002, Physiology - General, 20504, Nervous system
- Physiology and biochemistry, Neural Coordination, anterior intraparietal sulcus nervous system, dorsal premotor cortex
nervous system, dorsolateral circuit nervous system, dorsomedial circuit nervous system, medial intraparietal sulcus
nervous system, superior parieto-occipital sulcus nervous system, BOLD fMRI imaging and microscopy techniques,
diagnostic techniques, online control grasping task laboratory techniques, online control reaching task laboratory
techniques, whole-brain functional MRI imaging and microscopy techniques, diagnostic techniques, Movement and
Support, Nervous System
Hyperpolarized $^{13}$C magnetic resonance imaging — principles and applications.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance
Authors: Ardenkjær-Larsen, J. H. (Intern), Golman, K. (Ekstern), Brindle, K. M. (Ekstern)
Number of pages: 14
Publication date: 2010

Host publication information
Title of host publication: Molecular Imaging: Principles and Practice
Editors: Weissleder, R., Ross, B. D., Rehemtulla, A., Gambhir, S. S.
ISBN (Print): 978-1-607-95005-9
Chapter: 25
Main Research Area: Technical/natural sciences
Publication: Research › Book chapter – Annual report year: 2010

Method and apparatus for measuring weak magnetic fields.
When measuring weak magnetic fields, a container containing a medium, such as a solution containing a stable radical, is placed in a polarising magnetic field, which is essentially at right angles to the field to be measured. The polarising field is interrupted rapidly, the interruption being preceded by the impression of a high-frequency electromagnetic signal. The frequency of the signal corresponds to the resonance frequency of the free electron spin. The frequency and amplitude of the precessing nuclei, which are a function of the strength of the measured field, are recorded by a pick-up coil.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance
Authors: Ardenkjær-Larsen, J. H. (Intern)
Publication date: 29 Jun 1995

Publication information
IPC: G01R 33/28 A N
Patent number: WO9517684
Date: 29/06/1995
Priority date: 22/12/1993
Priority number: DK19930001431
Original language: English
Electronic versions:
Main Research Area: Technical/natural sciences
Source: espacenet
Source-ID: WO9517684
Publication: Research › Patent – Annual report year: 1995

Activities:

Dynamic switching of W-band signals for active and reconfigurable delivery - Ph.D. defense
Period: 14 May 2018
Vitaliy Zhurbenko (External examiner)
Department of Electrical Engineering
Center for Magnetic Resonance
Electromagnetic Systems
Center for Hyperpolarization in Magnetic Resonance

Description
Chairman of Evaluation Board
Degree of recognition: International
Links:
http://www.fotonik.dtu.dk/kalender/2018/05/phd-defence-by-juan-sebastian-rodriguez-paez?id=83e2d8b8-065a-4bb8-910c-dab8bb1b21b (Announcement)
Activity: Examinations and supervision › Internal examination

ISMRM study group on Detection and Correction of Motion in MRI and MRS (External organisation)
Period: 2017 → 2018
Lars G. Hanson (Chairman)
Department of Electrical Engineering
Center for Magnetic Resonance
Center for Hyperpolarization in Magnetic Resonance

Description
Chairman, ISMRM study group on Detection and Correction of Motion in MRI and MRS
Degree of recognition: International

Related external organisation
ISMRM study group on Detection and Correction of Motion in MRI and MRS
Activity: Membership › Membership of research networks or expert groups

Scientific Committee of the European Congress of Medical Physics 2018 (External organisation)
Period: 2017 → 2018
Lars G. Hanson (Member)
Department of Electrical Engineering
Center for Magnetic Resonance
Center for Hyperpolarization in Magnetic Resonance
Degree of recognition: International

Related external organisation
Scientific Committee of the European Congress of Medical Physics 2018
Activity: Membership › Membership of research networks or expert groups

Principles and Applications of Dissolution Dynamic Nuclear Polarization
Period: 13 Nov 2017 → 17 Nov 2017
Vitaliy Zhurbenko (Participant)
Department of Electrical Engineering
Center for Magnetic Resonance
Center for Hyperpolarization in Magnetic Resonance

Description
PhD level training school
Degree of recognition: International
Links:
http://www.conferencemanager.dk/dDNP-training-school/

Related event
Principles and Applications of Dissolution Dynamic Nuclear Polarization
13/11/2017 → 17/11/2017
Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.
Quantifying Biochemical Activities in Living Cells with $^{13}$C dDNP NMR
Period: 24 Jul 2017
Mathilde Hauge Lerche (Invited speaker)
Magnus Karlsson (Other)
Jan Henrik Ardenkjær-Larsen (Other)
Pernille Rose Jensen (Other)
Andrea Capozzi (Other)
Center for Hyperpolarization in Magnetic Resonance
Department of Electrical Engineering
Center for Magnetic Resonance
Degree of recognition: International
Documents:
ismar2017_Mathilde_Hauge_Lerche

Related event
International Society of Magnetic Resonance
23/08/2017 → 28/08/2017
Quebec City, Canada
Activity: Talks and presentations › Conference presentations

A narrow line UV-induced non-persistent radical in view of generating highly polarized transportable glucose solid samples
Period: 2 Jul 2017 → 6 Jul 2017
Andrea Capozzi (Guest lecturer)
Alessandro Coi (Panel member)
S Patel (Panel member)
Olivier Ouari (Panel member)
Magnus Karlsson (Guest lecturer)
Mathilde Hauge Lerche (Guest lecturer)
Arnaud Comment (Panel member)
Jan Henrik Ardenkjær-Larsen (Panel member)
Center for Hyperpolarization in Magnetic Resonance
Department of Electrical Engineering
Center for Magnetic Resonance
Degree of recognition: International
Documents:
Euromar-2017_abstract-Capozzi_HP-glucose

Related event
EUROMAR 2017
02/07/2017 → 06/07/2017
Warsaw, Poland
Activity: Talks and presentations › Conference presentations

Low RF-field strength cross polarization combined with photo-induced non-persistent radicals for clinically applicable dDNP
Period: 2 Jul 2017 → 6 Jul 2017
Joachim Møllesøe Vinther (Speaker)
Andrea Capozzi (Speaker)
Mohammed Albannay (Speaker)
Jan Henrik Ardenkjær-Larsen (Speaker)
Center for Hyperpolarization in Magnetic Resonance
Department of Electrical Engineering
**Poster Presentation**

**Period:** 2 Jul 2017 → 6 Jul 2017

Ronja Maja Malinowski (Speaker)

Center for Hyperpolarization in Magnetic Resonance
Department of Electrical Engineering

**Preparation of Radical-Free Hyperpolarized Water using Photo-induced non-persistent Radicals on a "SpinLab-like" dissolution-DNP Polarize**

**Period:** 2 Jul 2017 → 6 Jul 2017

Andrea Capozzi (Speaker)
Alessandro Coi (Panel member)
Magnus Karlsson (Panel member)
Mathilde Hauge Lerche (Guest lecturer)
Jan Henrik Ardenkjær-Larsen (Guest lecturer)

Center for Hyperpolarization in Magnetic Resonance
Department of Electrical Engineering

**Jarek Wosik**
Start date: 2 Jun 2017
Vitaliy Zhurbenko (Host)

Department of Electrical Engineering
Center for Magnetic Resonance
Electromagnetic Systems
Center for Hyperpolarization in Magnetic Resonance

**Description**
Seminar on advanced coil building technologies
Degree of recognition: International
Activity: Hosting a guest lecturer

**Mary had a little Lamb: Scanner-recorded speech during MRI without gradient-induced sound**
Period: 26 Apr 2017
Jan Ole Pedersen (Speaker)
Department of Electrical Engineering
Center for Magnetic Resonance
Degree of recognition: International
Documents:
ISMRM17sound(1)

**Related event**
ISMRM 25th Annual Meeting & Exhibition
22/04/2017 → 27/04/2017
Honolulu, United States
Activity: Talks and presentations › Conference presentations

**Encoding of Inductively Measured k-Space Trajectories in MR Raw Data**
Period: 25 Apr 2017
Jan Ole Pedersen (Speaker)
Department of Electrical Engineering
Center for Magnetic Resonance
Degree of recognition: International
Documents:
abstract_001

**Related event**
ISMRM 25th Annual Meeting & Exhibition
22/04/2017 → 27/04/2017
Honolulu, United States
Activity: Talks and presentations › Conference presentations

**ISMRM 25th Annual Meeting & Exhibition**
Period: 22 Apr 2017 → 27 Apr 2017
Jan Ole Pedersen (Speaker)
Department of Electrical Engineering
Center for Magnetic Resonance
Degree of recognition: International

**Related event**
ISMRM 25th Annual Meeting & Exhibition
22/04/2017 → 27/04/2017
Honolulu, United States
Activity: Talks and presentations › Conference presentations
Wavelet Coding for Radio-Over-Fiber, PhD Defence
Period: 14 Mar 2017
Vitaliy Zhurbenko (External examiner)
Department of Electrical Engineering
Center for Magnetic Resonance
Electromagnetic Systems
Center for Hyperpolarization in Magnetic Resonance

Description
Master of the Ceremony
Degree of recognition: Local
Links:
http://www.fotonik.dtu.dk/kalender/2017/03/phd-defence-by-lucas-cavalcante?id=e93c494b-8fc3-4cd1-b5c0-dfffa98382ba
(Announcement)
Activity: Examinations and supervision › Internal examination

Bloch simulation and MR fundamentals visualized
Period: 11 Mar 2017
Lars G. Hanson (Speaker)
Center for Hyperpolarization in Magnetic Resonance
Department of Electrical Engineering
Center for Magnetic Resonance

Description
Invited talk
Degree of recognition: International
Documents:
MMCE2017_visualization
Links:
http://drcmr.dk/MR (Related content)

Related event
Magnetic Moments in Central Europe 2017
08/03/2017 → 12/03/2017
Budapest, Hungary
Activity: Talks and presentations › Conference presentations

National Science Centre (NCN) (External organisation)
Period: 2016
Vitaliy Zhurbenko (Member)
Center for Hyperpolarization in Magnetic Resonance
Department of Electrical Engineering
Center for Magnetic Resonance
Electromagnetic Systems

Description
Poland
Degree of recognition: International

Related external organisation
National Science Centre (NCN)
Activity: Membership › Membership in review committee
Vice-Chair, ISMRM study group on Detection & Correction of Motion in MRI & MRS (External organisation)
Period: 2016 → 2017
Lars G. Hanson (Participant)
Copenhagen Center for Health Technology
Center for Hyperpolarization in Magnetic Resonance
Department of Electrical Engineering
Center for Magnetic Resonance

Description
Research Network of the International Society for Magnetic Resonance in Medicine
Degree of recognition: International

Related external organisation

Vice-Chair, ISMRM study group on Detection & Correction of Motion in MRI & MRS
Activity: Membership › Membership of research networks or expert groups

CST Workshop Series 2016
Period: 14 Nov 2016
Vitaliy Zhurbenko (Organizer)
Center for Hyperpolarization in Magnetic Resonance
Department of Electrical Engineering
Center for Magnetic Resonance
Electromagnetic Systems

Description
Local coordination of the workshop.
Computer simulation activities at EMS, DTU

Related event

CST Workshop Series 2016
14/11/2016 → 14/11/2016
Kgs. Lyngby, Denmark
Activity: Attending an event › Participating in or organising workshops, courses, seminars etc.

Risks related to static magnetic fields
Period: 1 Sep 2016
Lars G. Hanson (Invited speaker)
Copenhagen Center for Health Technology
Center for Hyperpolarization in Magnetic Resonance
Department of Electrical Engineering
Center for Magnetic Resonance

Description
Invited oral presentation
Links:
http://dx.doi.org/10.1016/j.ejmp.2016.07.272

Related event

1st European Congress of Medical Physics
01/09/2016 → 04/09/2016
Athens, Greece
Member of the ESMRMB Nomination and Awards Committee (External organisation)
Lars G. Hanson (Participant)
Copenhagen Center for Health Technology
Center for Hyperpolarization in Magnetic Resonance
Department of Electrical Engineering
Center for Magnetic Resonance
Degree of recognition: International

Related external organisation

Member of the ESMRMB Nomination and Awards Committee
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

Prizes:

Best Trainee Presentation
Rie Beck Hansen (Recipient)
Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance

Details
Awarded date: 18 Jun 2018
Prize: Prizes, scholarships, distinctions

EliteForsk-rejsestipendium
Rie Beck Hansen (Recipient)
Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance

Details
Awarded date: 23 Feb 2017
Degree of recognition: National
Granting Organisations: Uddannelses- og Forskningsministeriet
event: EliteForsk-konferencen
Prize: Prizes, scholarships, distinctions