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.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Electromagnetic Systems, Electromagnetic Systems Group, Technical University of Denmark
Pages: 202-210
Publication date: 1 Feb 2018
Main Research Area: Technical/natural sciences

Publication information
Journal: IEEE Transactions on Biomedical Circuits and Systems
Volume: 12
Issue number: 1
Article number: 8233404
ISSN (Print): 1932-4545
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.21 SJR 0.985 SNIP 1.857
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.061 SNIP 1.587 CiteScore 3.28
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.27 SNIP 1.96 CiteScore 3.97
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.707 SNIP 2.54 CiteScore 4.83
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 1.192 SNIP 2.22 CiteScore 3.98
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.93 SNIP 1.903 CiteScore 3.34
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.546 SNIP 1.445
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.907 SNIP 1.728
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.642 SNIP 1.097
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
Authors: Sanchez-Heredia, J. D. (Intern), Avendal, J. (Ekstern), Bibic, A. (Ekstern), Lau, B. K. (Ekstern)
Pages: 1570 - 1575
Publication date: 19 Jan 2018
Main Research Area: Technical/natural sciences

Publication information
Journal: IEEE Transactions on Antennas and Propagation
Volume: 66
Issue number: 3
ISSN (Print): 0018-926X
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 3.98 SJR 1.362 SNIP 2.033
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.841 SNIP 2.526 CiteScore 3.48
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.828 SNIP 2.644 CiteScore 3.36
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.536 SNIP 2.256 CiteScore 3.65
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.471 SNIP 2.237 CiteScore 3.63
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 1.366 SNIP 2.16 CiteScore 3.42
ISI indexed (2011): ISI indexed yes
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 $[1-^{13}$C]pyruvate metabolism.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, University of California at San Francisco
Authors: Gordon, J. W. (Ekstern), Hansen, R. B. (Intern), Shin, P. J. (Ekstern), Feng, Y. (Ekstern), Vigneron, D. B. (Ekstern), Larson, P. E. Z. (Ekstern)
Pages: 92-99
Publication date: 2018
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Magnetic Resonance
Volume: 289
ISSN (Print): 1090-7807
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
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, \( \Delta \), thereby isolating \( f_p \) of the baseband signal.

General information

State: Published
Organisations: Metro-Access and Short Range Systems, Department of Electrical Engineering, Electromagnetic Systems, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance
Authors: Cimoli, B. (Intern), Johansen, T. K. (Intern), Zhurbenko, V. (Intern), Vegas Olmos, J. J. (Intern), Tafur Monroy, I. (Intern), Jensen, J. B. (Intern)
Publication date: 2018

Publication information

Journal: International Journal of Microwave and Wireless Technologies
ISSN (Print): 1759-0787
Ratings:
Web of Science (2018): Indexed yes
Web of Science (2017): Indexed Yes
Scopus rating (2016): CiteScore 0.65 SJR 0.234 SNIP 0.481
Web of Science (2016): Indexed yes
Scopus rating (2015): SJR 0.209 SNIP 0.472 CiteScore 0.53
Scopus rating (2014): SJR 0.216 SNIP 0.37 CiteScore 0.55
Web of Science (2014): Indexed yes
Scopus rating (2013): SJR 0.269 SNIP 0.692 CiteScore 0.81
ISI indexed (2013): ISI indexed yes
Scopus rating (2012): SJR 0.286 SNIP 0.579 CiteScore 0.77
ISI indexed (2012): ISI indexed no
Scopus rating (2011): SJR 0.2 SNIP 0.509 CiteScore 0.62
ISI indexed (2011): ISI indexed no
Scopus rating (2010): SJR 0.165 SNIP 0.312
Original language: English
Semiconductor Devices and IC-Technologies, TeraHertz Technology and Applications
DOIs:
10.1017/S1759078717001490
Source: FindIt
Source-ID: 2395885395
Publication: Research - peer-review › Journal article – Annual report year: 2018
A narrow line UV-induced non-persistent radical to generate highly polarized transportable glucose solid samples

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Aix Marseille Universite, University of Cambridge, Aix-Marseille University
Number of pages: 1
Publication date: 2018
Event: Abstract from 59th Experimental Nuclear Magnetic Resonance Conference, Orlando, United States.
Main Research Area: Technical/natural sciences
Electronic versions: ENC_2018_abstract_TMP.pdf

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 $^{[1-^{13}]}$Cpyruvate 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 $^{[1-^{13}]}$Cpyruvate 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 $^{[1-^{13}]}$Cpyruvate 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

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, University of Copenhagen
Pages: 6-12
Main Research Area: Technical/natural sciences
Publication information
Discovery and description of a new serogroup 7 Streptococcus pneumoniae serotype, 7D, and structural analysis of 7C and 7D

Streptococcus pneumoniae is characterised into 92 serotypes based on antigenic reactions of commercial rabbit sera to the capsular polysaccharides. During development of a bioinformatic serotyping tool (PneumoCaT), an isolate exhibited a novel codon at residue 385 of the glycosyltransferase gene wcwK encoding a distinct amino acid, which differentiates genogroup 7. Investigation by repeat serotyping and Quellung reaction revealed a novel pattern of factor sera with the isolate reacting very strongly with 7f, but also with 7e factor sera. The structure of the capsular polysaccharide was determined by NMR spectroscopy to be an approximately 5:1 combination of the structures of 7C and 7B, respectively,
and the structure of 7C was also elucidated. All data from whole genome sequencing, NMR spectroscopy, production of antisera and serotyping of the novel 7 strain shows that it is a new serotype, which will be named in the Danish nomenclature as 7D.

**General information**

State: Accepted/In press
Organisations: Department of Chemistry, Organic Chemistry, Center for Hyperpolarization in Magnetic Resonance, Technical University of Denmark, SSI Diagnostica, Public Health England
Authors: Kjeldsen, C. (Intern), Slott, S. (Ekstern), Elverdal, P. L. (Ekstern), Sheppard, C. L. (Ekstern), Kapatai, G. (Ekstern), Fry, N. K. (Ekstern), Skovsted, I. C. (Ekstern), Duus, J. Ø. (Intern)
Number of pages: 23
Publication date: 2018
Main Research Area: Technical/natural sciences

**Publication information**

Journal: Carbohydrate Research
ISSN (Print): 0008-6215
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.03 SJR 0.654 SNIP 0.801
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.59 SNIP 0.839 CiteScore 1.98
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.638 SNIP 0.856 CiteScore 2.01
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.639 SNIP 0.86 CiteScore 2.22
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.773 SNIP 1.017 CiteScore 2.2
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.76 SNIP 1.062 CiteScore 2.43
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.722 SNIP 0.868
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.883 SNIP 1.031
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.851 SNIP 0.943
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 0.751 SNIP 0.89
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 0.638 SNIP 0.906
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 0.683 SNIP 1.002
Scopus rating (2004): SJR 0.631 SNIP 0.96
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**

**State:** Published

**Organisations:** Department of Chemistry, Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Organic Chemistry

**Authors:** Kjeldsen, C. (Intern), Ardenkjær-Larsen, J. H. (Intern), Duus, J. Ø. (Intern)

**Pages:** 3030-3034

**Publication date:** 2018

**Main Research Area:** Technical/natural sciences

**Publication information**

**Journal:** Journal of the American Chemical Society

**Volume:** 140

**Issue number:** 8

**ISSN (Print):** 0002-7863

**Ratings:**

BFI (2018): BFI-level 2

Web of Science (2018): Indexed yes

BFI (2017): BFI-level 2

Web of Science (2017): Indexed Yes

BFI (2016): BFI-level 2

Scopus rating (2016): CiteScore 13.18 SJR 7.368 SNIP 2.584

Web of Science (2016): Indexed yes

BFI (2015): BFI-level 2

Scopus rating (2015): SJR 6.826 SNIP 2.632 CiteScore 12.81

Web of Science (2015): Indexed yes

BFI (2014): BFI-level 2

Scopus rating (2014): SJR 6.273 SNIP 2.578 CiteScore 11.92

Web of Science (2014): Indexed yes

BFI (2013): BFI-level 2

Scopus rating (2013): SJR 5.953 SNIP 2.455 CiteScore 11.38

ISI indexed (2013): ISI indexed yes

Web of Science (2013): Indexed yes
Discovery of Intermediates of lacZ β-Galactosidase Catalyzed Hydrolysis Using dDNP NMR
Using dissolution dynamic nuclear polarization, the sensitivity of single scan solution state 13C NMR can be improved up to 4 orders of magnitude. In this study, the enzyme lacZ β-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
State: Published
Organisations: Department of Chemistry, Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance, Organic Chemistry
Authors: Kjeldsen, C. (Intern), Ardenkjær-Larsen, J. H. (Intern), Duus, J. Ø. (Intern)
Pages: 3030-3034
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 $^1H$ signal enhancement to allow high-resolution imaging of the coronary arteries. Protons in D$_2$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
State: Accepted/In press
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in 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)
Number of pages: 5
Publication date: 2018
Main Research Area: Technical/natural sciences

Publication information
Journal: Magnetic Resonance in Medicine
ISSN (Print): 0740-3194
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.52 SJR 1.867 SNIP 1.438
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.291 SNIP 1.48 CiteScore 3.54
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.952 SNIP 1.39 CiteScore 3.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.959 SNIP 1.44 CiteScore 3.46
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.072 SNIP 1.549 CiteScore 3.61
High-performance flexible solid-state supercapacitors built from nitrogen-doped hybrid-dimensional nanocarbon materials

General information
State: Published
Organisations: Department of Chemistry, NanoChemistry, Organic Chemistry, Center for Hyperpolarization in Magnetic Resonance
Authors: Cao, X. (Intern), Duus, J. Ø. (Intern), Chi, Q. (Intern)
Number of pages: 1
Publication date: 2018
Main Research Area: Technical/natural sciences
Electronic versions:
grapheneforus2018_Cao_Xianyi_75.pdf
Source: PublicationPreSubmission
Source-ID: 147306652
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 optimising 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.

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
Publication date: 2018
Event: Abstract from 59th Experimental Nuclear Magnetic Resonance Conference, Orlando, United States.
Main Research Area: Technical/natural sciences
Electronic versions:
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 reach 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.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance
Pages: 7432-7443
Publication date: 2018
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Physical Chemistry C
Volume: 122
Issue number: 13
ISSN (Print): 1932-7447
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 4.48 SJR 1.948 SNIP 1.181
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.917 SNIP 1.268 CiteScore 4.68
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 2.027 SNIP 1.448 CiteScore 5.08
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 2.134 SNIP 1.439 CiteScore 5.14
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.514 SNIP 1.46 CiteScore 4.98
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.32 SNIP 1.457 CiteScore 4.92
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.438 SNIP 1.356
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 13C-labeled substrate mixture prepared using photo-induced nonpersistent radicals. Droplets of mixed [1-13C]pyruvic and [1-13C]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 13C-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 13C 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 13C signals from lactate, alanine, bicarbonate, and acetylcarnitine were detected following the metabolism of the injected substrate mixture. Copolarization of two different 13C-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 13C-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
Authors: Bastiaansen, J. A. M. (Ekstern), Yoshihara, H. A. I. (Ekstern), Capozzi, A. (Intern), Schwitter, J. (Ekstern), Gruetter, R. (Ekstern), Merritt, M. E. (Ekstern), Comment, A. (Ekstern)
Number of pages: 9
Publication date: 2018
Main Research Area: Technical/natural sciences

Publication information
Journal: Magnetic Resonance in Medicine
ISSN (Print): 0740-3194
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
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), 1,2 (ii) echo planar spectroscopic imaging (EPSI) sequence and (iii) phase-encoded, pulse-acquisition chemical-shift imaging (CSI)
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.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance
Pages: 674–678
Publication date: 2018
Main Research Area: Technical/natural sciences

Publication information
Journal: Analytical Chemistry
Volume: 90
Issue number: 1
ISSN (Print): 0003-2700
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 6.08
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): CiteScore 6
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): CiteScore 5.79
BFI (2013): BFI-level 2
Scopus rating (2013): CiteScore 6.01
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): CiteScore 5.8
ISI indexed (2012): ISI indexed yes
A cryogenic measurement setup for characterization microwave devices

A cryogenic measurement setup for characterization microwave devices from room to cryogenic temperatures is presented. The setup allows testing microwave devices at variable temperatures ranging from 300 to 77 K. Frequency doubler (94/188 GHz) has been cooled to 77 K and peak efficiency of 32% at an input-power level of 207 mW is achieved. For verification experimental results the millimeter-wave GaAs Schottky barrier diode model is developed for CAD simulator. The simulated peak efficiency is 37% at 77 K. The estimation of simulated and measured data of the doubler efficiency versus temperature has the same trend from 77 to 300 K which confirmed the cryogenic measurement setup applicability.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance
Authors: Rybalko, O. (Intern)
Number of pages: 5
Pages: 3123-3127
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Microwave and Optical Technology Letters
Volume: 59
Issue number: 12
ISSN (Print): 0895-2477
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 0.87 SJR 0.299 SNIP 0.568
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.337 SNIP 0.52 CiteScore 0.72
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.

General information

State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance
A narrow line UV-induced non-persistent radical in view of generating highly polarized transportable glucose solid samples

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Aix Marseille Université, University of Cambridge, Technical University of Denmark, Aix-Marseille University
Number of pages: 1
Publication date: 2017
Event: Abstract from EUROMAR 2017, Warsaw, Poland.
Main Research Area: Technical/natural sciences
Electronic versions: Euromar_2017_abstract_Capozzi_HP_glucose.pdf
Source: PublicationPreSubmission
Source-ID: 143527484
Publication: Research › Conference abstract for conference – Annual report year: 2018

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 magnetoecephalography (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 $\Delta B_z,c$ 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.

General information
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)
Number of pages: 138
Publication date: 2017

Publication Information
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 polypol 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.

General information
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
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: American Journal of Physiology - Renal Physiology
Volume: 312
Issue number: 1
ISSN (Print): 1931-857X
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): SJR 1.649 SNIP 0.968 CiteScore 3.07
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.9 SNIP 1.09 CiteScore 3.32
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.798 SNIP 1.029 CiteScore 3.27
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.049 SNIP 1.206 CiteScore 3.88
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.947 SNIP 1.317 CiteScore 3.98
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 1.916 SNIP 1.245 CiteScore 3.75
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 1.898 SNIP 1.168
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.062 SNIP 1.188
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 2.211 SNIP 1.163
Scopus rating (2007): SJR 2.331 SNIP 1.27
Web of Science (2007): Indexed yes
Scopus rating (2005): SJR 2.018 SNIP 1.175
Scopus rating (2004): SJR 2.149 SNIP 1.268
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 2.135 SNIP 1.269
Scopus rating (2002): SJR 2.363 SNIP 1.35
Scopus rating (2001): SJR 2.053 SNIP 1.322
Scopus rating (2000): SJR 1.951 SNIP 1.225
Scopus rating (1999): SJR 1.621 SNIP 1.09
Original language: English
Physiology, Urology, Diabetic nephropathy, Hyperpolarization, MRI, Renal metabolism, TEMPOL, diabetic nephropathy, renal metabolism, hyperpolarization
Electronic versions:
Anti_oxidant_treatment_attenuates_lactate_production_in_diabetic_nephropathy.pdf
DOIs:
10.1152/ajprenal.00148.2016
Source: FindIt
Source-ID: 2348822682
Publication: Research - peer-review › Journal article – Annual report year: 2017

Bloch simulation and MR fundamentals visualized

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
Publication date: 2017
Main Research Area: Technical/natural sciences
Electronic versions:
MMCE2017_visualization.pdf

Relations
Activities:
Bloch simulation and MR fundamentals visualized
Source: PublicationPreSubmission
Source-ID: 130695739
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2017
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 C magnetic resonance spectroscopic imaging.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, University of Copenhagen
Number of pages: 1
Publication date: 2017
Event: Abstract from ISMRM 25th Annual Meeting & Exhibition, Honolulu, United States.
Main Research Area: Technical/natural sciences

Day 1 of MRI and NMR education: Interactive visualization of MR basics

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
Publication date: 2017
Event: Poster session presented at ISMRM 25th Annual Meeting & Exhibition, Honolulu, United States.
Main Research Area: Technical/natural sciences

dDNP as an emerging real time analytical method for catalytic reactions

General information
State: Published
Organisations: Department of Chemistry, Organic Chemistry, Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance
Number of pages: 1
Publication date: 2017
Event: Abstract from EUROMAR 2017, Warsaw, Poland.
Main Research Area: Technical/natural sciences

Relations
Activities:
dDNP as an emergent real time analytical method for catalytic reactions
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2017
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 into 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.

General information
State: Published
Organisations: Department of Chemistry, Organic Chemistry, Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance
Authors: Meier, S. (Intern), Karlsson, M. (Intern), Jensen, P. R. (Intern)
Pages: 5571-5577
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: ACS Sustainable Chemistry & Engineering
Volume: 5
Issue number: 6
ISSN (Print): 2168-0485
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 5.92 SJR 1.523 SNIP 1.408
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 1.381 SNIP 1.338 CiteScore 5.39
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.195 SNIP 1.207 CiteScore 4.3
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
ISI indexed (2013): ISI indexed no
Original language: English
Acyclic tautomer, Epimerization, Glucose, Homogenous catalysis, Pre-steady-state, Reaction intermediate
Electronic versions:
Meier_etal_acs_sustainable_Chemistry_Engineering_.pdf. Embargo ended: 15/04/2018
DOIs:
10.1021/acssuschemeng.7b00985
Source: PublicationPreSubmission
Source-ID: 131295247
Publication: Research - peer-review › Journal article – Annual report year: 2017

DNP NMR of carbohydrate converting enzymes
Dissolution dynamic nuclear polarization (DNP) NMR can be used to increase the sensitivity of $^{13}$CNMR signal by up to four orders of magnitude. This allows for real time monitoring of reactions and observation of intermediates. The biggest drawback of the method is the loss of polarization with $T_1$ relaxation, but even with this limitation, it is possible to obtain detailed reaction parameters in less than one minute. The enzyme investigated was β-galactosidase from E. coli (E.C. 3.2.1.23). It is well described and the mechanism is generally accepted to be a double displacement with a covalently bound intermediate, however, this evidence is based on mutant of X-ray crystallography and simulations. As the natural
substrate lactose does not have any quaternary carbon with long $T_1$, the unnatural substrate o-nitrophenyl $\beta$-D-galactopyranoside was used (figure 1) as the quaternary positions have $T_1$ relaxations of ca. 15 s instead of $<2$ s. The DNP NMR monitoring of the hydrolysis of this substrate can be seen in figure 2, and another use of this substrate is for optimizing the conditions for a labelled substrate (figure 1), which would further increase the signal and allow monitoring of the carbohydrate instead of the aglycon. This is, however, not commercially available and had to be synthesized from doubly labelled galactose.

**General information**

**State:** Published  
**Organisations:** Department of Chemistry, Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance, Organic Chemistry  
**Authors:** Kjeldsen, C. (Intern), Ardenkjær-Larsen, J. H. (Intern), Duus, J. Ø. (Intern)  
**Publication date:** 2017  
**Event:** Abstract from 19th European Carbohydrate Symposium, Barcelona, Spain.  
**Main Research Area:** Technical/natural sciences  
**Electronic versions:** LIBRO_COMPLETO_EUROCARB6.pdf  
**Publication:** Research - peer-review › Conference abstract for conference – Annual report year: 2017

**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)  
**Number of pages:** 5  
**Publication date:** 2017  
**Event:** Poster session presented at ISMRM 25th Annual Meeting & Exhibition, Honolulu, United States.  
**Main Research Area:** Technical/natural sciences  
**Electronic versions:** ISMRM_bakri_2017.pdf  
**Source:** PublicationPreSubmission  
**Source-ID:** 143288712  
**Publication:** Research - peer-review › Poster – Annual report year: 2018

**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 ($<6$ months) 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

**General information**

**State:** Published  
**Organisations:** Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Rigshospitalet, Slagelse Hospital, Sheba Medical Center at Tel Hashomer, King Christian X Hospital for Rheumatic Diseases, Aarhus University Hospital, Odense University Hospital, University Hospital Herlev, Zitelab ApS, Veje Hospital, University of Southern Denmark, Hvidovre University Hospital, Copenhagen University Hospital  
**Pages:** 335-345
Encoding of inductively measured k-space trajectories in MR raw data
Encoding of Inductively Measured k-Space Trajectories in MR Raw Data

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.
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)
Number of pages: 2
Publication date: 2017
Event: Poster session presented at ISMRM 25th Annual Meeting & Exhibition, Honolulu, United States.
Main Research Area: Technical/natural sciences
Electronic versions:
Magnusson_ISMRM2017_1255.pdf
Source: PublicationPreSubmission
Source-ID: 143288980
Publication: Research - peer-review › Poster – Annual report year: 2018

Gradient distortions in EEG provide motion tracking during simultaneous EEG-fMRI
Conference abstract, selected for oral presentation by Malte Laustsen.
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.
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.
General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance
Authors: Karlsson, M. (Intern), Ardenkjær-Larsen, J. H. (Intern), Lerche, M. H. (Intern)
Number of pages: 4
Pages: 6625-6628
Publication date: 2017
Main Research Area: Technical/natural sciences

Publication information
Journal: Chemical Communications
Volume: 53
Issue number: 49
ISSN (Print): 1359-7345
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 6.06 SJR 2.506 SNIP 1.159
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 2.664 SNIP 1.314 CiteScore 6.7
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 2.701 SNIP 1.446 CiteScore 6.83
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 2.755 SNIP 1.38 CiteScore 6.73
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 3.09 SNIP 1.347 CiteScore 6.21
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.857 SNIP 1.322 CiteScore 5.96
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 2
Scopus rating (2010): SJR 2.709 SNIP 1.232
Web of Science (2010): Indexed yes
BFI (2009): BFI-level 2
Scopus rating (2009): SJR 2.588 SNIP 1.252
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 2
Scopus rating (2008): SJR 2.791 SNIP 1.236
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.851 SNIP 1.237
Web of Science (2007): Indexed yes
Scopus rating (2006): SJR 2.366 SNIP 1.183
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.129 SNIP 1.15
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.

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.
**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.

**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.
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.

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**
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Electromagnetic Systems
Number of pages: 1
Publication date: 2017
Event: Abstract from EUROMAR 2017, Warsaw, Poland.
Main Research Area: Technical/natural sciences
Electronic versions:
20170412_EUROMAR2017_ModularSSNmr.pdf
Source: PublicationPreSubmission
Source-ID: 143660235
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.

**General information**
State: Published
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)
Pages: 60-66
Publication date: 2017
Main Research Area: Technical/natural sciences

**Publication Information**
Journal: Tomography
Volume: 3
Issue number: 1
ISSN (Print): 2379-1381
Ratings:
Web of Science (2018): Indexed yes
Web of Science (2017): Indexed yes
Original language: English
RF coil, SNR, Cryogenic, 13C MRI
Electronic versions:
tomo_03_060_1_.pdf
DOIs:
10.18383/j.tom.2016.00280

**Bibliographical note**
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Source: PublicationPreSubmission
Source-ID: 130397290
Low RF-field strength cross polarization combined with photo-induced non-persistent radicals for clinically applicable dDNP

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering
Authors: Møllesøe Vinther, J. (Intern), Capozzi, A. (Intern), Albannay, M. (Intern), Ardenkjær-Larsen, J. H. (Intern)
Number of pages: 1
Publication date: 2017
Event: Poster session presented at EUROMAR 2017, Warsaw, Poland.
Main Research Area: Technical/natural sciences
Electronic versions:
poster_jmv_v2.pdf

Relations
Activities:
Low RF-field strength cross polarization combined with photo-induced non-persistent radicals for clinically applicable dDNP
Publication: Research - peer-review › Poster – Annual report year: 2017

Mary had a little Lamb: Scanner-recorded speech during MRI without gradient-induced sound

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Chinese Academy of Sciences
Authors: Pedersen, J. O. (Intern), Hanson, C. (Ekstern), Xue, R. (Ekstern), Hanson, L. G. (Intern)
Number of pages: 2
Publication date: 2017
Event: Abstract from ISMRM 25th Annual Meeting & Exhibition, Honolulu, United States.
Main Research Area: Technical/natural sciences
Electronic versions:
ISMRM17sound_1_.pdf

Relations
Activities:
Mary had a little Lamb: Scanner-recorded speech during MRI without gradient-induced sound
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2017

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 [2,3,4,6,6-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
Authors: Mishkovsky, M. (Ekstern), Anderson, B. (Ekstern), Karlsson, M. (Intern), Lerche, M. H. (Intern), Sherry, A. D. (Ekstern), Gruetter, R. (Ekstern), Kovacs, Z. (Ekstern), Comment, A. (Ekstern)
Number of pages: 8
Publication date: 2017
Main Research Area: Technical/natural sciences
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.

General information

State: Published
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)
Number of pages: 4
Publication date: 2017

Host publication information

Title of host publication: Proceedings of the International Society for Magnetic Resonance in Medicine
Main Research Area: Technical/natural sciences
Conference: ISMRM 25th Annual Meeting & Exhibition, Honolulu, United States, 22/04/2017 - 22/04/2017
Electronic versions:
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 relevance of [1-$^{13}$C]pyruvate and [1,4-$^{13}$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 13C substrates. Firstly, we investigate the effectiveness of hyperpolarized [1-$^{13}$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-$^{13}$C]pyruvate can be an alternative to FDG-PET.

In the second study, a polarization scheme for [1,4-$^{13}$C$_2$]fumarate in the SPINlab polarizer is presented. The feasibility of using [1,4-$^{13}$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-$^{13}$C$_2$]fumarate in the SPIN lab and high [1,4-$^{13}$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-$^{13}$C$_2$]fumarate and [1-$^{13}$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.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance
Authors: Eldirdiri, A. (Intern), Ardenkjær-Larsen, J. H. (Intern), Hanson, L. G. (Intern), Kjær, A. (Intern)
Number of pages: 217
Publication date: 2017

Publication information
Publisher: Technical University of Denmark (DTU)
Original language: English
Main Research Area: Technical/natural sciences
Electronic versions: my_thesis_eldirdiri.pdf

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 significative 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 typology 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.

General information
State: Published
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
Pages: 227-324
Publication date: 2017

Host publication information
Title of host publication: Small Animal Imaging: Basics and Practical Guide
Publisher: Springer
Editors: Kiessling, F., Pichler, B. J., Hauff, P.
ISBN (Print): 978-3-319-42200-8
ISBN (Electronic): 978-3-319-42202-2
Chapter: 13
Main Research Area: Technical/natural sciences
MRI, Paramagnetic probes, Molecular imaging, Hyperpolarization, CEST, MRS, MRSI, Dissolution DNP, Para-hydrogen, Metabolism, 13C
DOIs:
10.1007/978-3-319-42202-2_13
Source: FindIt
Source-ID: 2372044937
Publication: Research - peer-review › Book chapter – Annual report year: 2017

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 CSI1 acquisition for efficient encoding of multiple chemical shifts within a large FOV with high spatial resolution.

General information
State: Published
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
Publication date: 2017
Main Research Area: Technical/natural sciences
Electronic versions:
ENC20177454.2399VER.1.pdf
Source: PublicationPreSubmission
Source-ID: 130805967
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2017

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.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Sumy State University
Authors: Lysenko, A. (Ekstern), Volk, I. (Ekstern), Serozhko, A. (Ekstern), Rybalko, O. (Intern)
Pages: 163-167
Publication date: 2017

Host publication information
Title of host publication: Proceedings of 2017 IEEE Microwaves, Radar and Remote Sensing Symposium
Publisher: IEEE
ISBN (Print): 978-1-5090-5391-9
Main Research Area: Technical/natural sciences
Two-stream superheterodyne free-electron lasers, Two-stream instability, Helical electron beams
DOIs:
10.1109/MRRS.2017.8075053
Source: FindIt
Source-ID: 2392268893
Publication: Research - peer-review › Article in proceedings – Annual report year: 2017

Practical Aspects of Preamplifier Designs for 13C Imaging.

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Electromagnetic Systems, Technical University of Denmark
Authors: Johansen, D. H. (Intern), Sánchez-Heredia, J. D. (Ekstern), Zhurbenko, V. (Intern), Ardenkjær-Larsen, J. H. (Intern)
Number of pages: 5
Publication date: 2017
Event: Abstract from ISMRM 25th Annual Meeting & Exhibition, Honolulu, United States.
Main Research Area: Technical/natural sciences
Electronic versions:
Johansen_ISMRM17_LNA_final.pdf
Source: PublicationPreSubmission
Source-ID: 131964723
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2017

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

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Technical University of Denmark
Number of pages: 1
Publication date: 2017
Event: Abstract from 58th Experimental Nuclear Magnetic Resonance Conference, Pacific Grove, , United States.
Main Research Area: Technical/natural sciences
Electronic versions:
ENC_2017_abstract_Capozzi.pdf
Source: PublicationPreSubmission
Source-ID: 130573835
Probing of biochemical pathways in clonal pancreatic β–cells by quantitative dDNP of metabolite extracts

Quantifying Biochemical Activities in Living Cells with 13C dDNP NMR

Sensitivity analysis of magnetic field measurements for magnetic resonance electrical impedance tomography (MREIT)
Main Research Area: Technical/natural sciences

Publication information
Journal: Magnetic Resonance in Medicine
Volume: 79
Issue number: 2
ISSN (Print): 0740-3194

Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.52 SJR 1.867 SNIP 1.438
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.291 SNIP 1.48 CiteScore 3.54
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.952 SNIP 1.39 CiteScore 3.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.959 SNIP 1.44 CiteScore 3.46
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.072 SNIP 1.549 CiteScore 3.61
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.056 SNIP 1.476 CiteScore 3.45
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.272 SNIP 1.612
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.278 SNIP 1.564
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 2.382 SNIP 1.512
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.353 SNIP 1.549
Scopus rating (2006): SJR 2.28 SNIP 1.74
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.269 SNIP 1.834
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.121 SNIP 1.719
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 2.371 SNIP 1.575
Scopus rating (2002): SJR 2.176 SNIP 1.46
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 2.337 SNIP 1.558
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 2.037 SNIP 1.551
Scopus rating (1999): SJR 2.457 SNIP 2.147
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
Main Research Area: Technical/natural sciences

Publication information
Journal: N M R in Biomedicine
Article number: e3803
ISSN (Print): 0952-3480
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2016): CiteScore 3.18 SJR 1.42 SNIP 1.038
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.604 SNIP 1.009 CiteScore 3.23
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.602 SNIP 1.165 CiteScore 3.45
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.63 SNIP 1.311 CiteScore 3.9
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 1.594 SNIP 1.242 CiteScore 3.47
Towards new vistas in preamplifier design for MRI

High signal to noise ratio (SNR) in magnetic resonance imaging is vital for ensuring accurate diagnosis and treatment. Arrays of surface coils for receive only purposes is a well established way to increase SNR. However, due to crosstalk between the array elements, the SNR can be severely degraded. For that reason, arrays often do not exploit their full potential. By using a series decoupling network with non-conventional matching and preamplifier impedances the decoupling between elements can be increased significantly. In the presented design example, almost 6 dB additional decoupling can be achieved with no impairment of preamplifier noise figure. The decoupling changes as a function of both 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)
Pages: 1159-1162
Publication date: 2017

Host publication information
Title of host publication: Proceedings of the 47th European Microwave Conference
Publisher: IEEE
Main Research Area: Technical/natural sciences
Conference: 2017 47th European Microwave Conference (EuMC), 10/10/2017 - 10/10/2017
Decoupling, Matching networks, Noise matching, Preamplifiers, Surface coils
Electronic versions:
EuMW17.pdf
EuMW17_1_.pdf
Source: FindIt
Source-ID: 2394344137
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 pathophysiological 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.

General information
State: Published
Organisations: Department of Automation, Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Fondazione CNR/Regione Toscana G. Monasterio, Technische Universität München, Rapid Biomedical GmbH, GE Global Research, Scuola Superiore Sant'Anna, University of Pisa, Fondazione G. Monasterio
Pages: 53-61
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Journal of Medical and Biological Engineering
Volume: 36
Issue number: 1
ISSN (Print): 1609-0985
Ratings:
Web of Science (2018): Indexed yes
Web of Science (2017): Indexed Yes
Scopus rating (2016): SJR 0.277 SNIP 0.563 CiteScore 0.99
Web of Science (2016): Indexed yes
Scopus rating (2015): SJR 0.388 SNIP 0.847 CiteScore 1.21
Scopus rating (2014): SJR 0.332 SNIP 0.827 CiteScore 1.08
Scopus rating (2013): SJR 0.413 SNIP 1.136 CiteScore 1.47
Scopus rating (2012): SJR 0.393 SNIP 0.821 CiteScore 1.25
Scopus rating (2011): SJR 0.235 SNIP 0.579 CiteScore 0.78
Scopus rating (2010): SJR 0.184 SNIP 0.403
Scopus rating (2009): SJR 0.171 SNIP 0.317
Scopus rating (2008): SJR 0.16 SNIP 0.195
Scopus rating (2007): SJR 0.137 SNIP 0.23
Scopus rating (2006): SJR 0.113 SNIP 0.055
Scopus rating (2005): SJR 0.115 SNIP 0.082
Scopus rating (2004): SJR 0.116 SNIP 0.1
Scopus rating (2003): SJR 0.107 SNIP 0.072
Scopus rating (2002): SJR 0.128 SNIP 0.108
Scopus rating (2001): SJR 0.155 SNIP 0
Scopus rating (2000): SJR 0.105
Scopus rating (1999): SJR 0.1
Original language: English
DOIs: 10.1007/s40846-016-0113-4
Source: FindIt
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 solid state 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
State: Published
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)
Number of pages: 149
Publication date: 2016

Publication information
Publisher: Technical University of Denmark, Department of Electrical Engineering
Original language: English
Main Research Area: Technical/natural sciences

Relations
Projects:
A novel MR contrast agent for angiography and perfusion: Hyperpolarized water
Source: PublicationPreSubmission
Source-ID: 127840919
Publication date: 2016

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
State: Published
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)
Publication date: 2016
Main Research Area: Technical/natural sciences
Electronic versions: ISMRM2016_3639_Decoupling.pdf
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-isocaproate, 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 macromolecular 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.

General information
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, Department of Automation
Authors: Karlsson, M. (Intern), Jensen, P. R. (Intern), Ardenkjær-Larsen, J. H. (Intern), Lerche, M. H. (Intern)
Number of pages: 5
Pages: 13765–13768
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Angewandte Chemie
Volume: 128
Issue number: 43
ISSN (Print): 0044-8249
Ratings:
BFI (2018): BFI-level 1
BFI (2017): BFI-level 1
BFI (2016): BFI-level 1
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
BFI (2014): BFI-level 1
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
ISI indexed (2013): ISI indexed no
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
ISI indexed (2012): ISI indexed no
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
ISI indexed (2011): ISI indexed no
BFI (2010): BFI-level 1
BFI (2009): BFI-level 1
BFI (2008): BFI-level 1
Web of Science (2006): Indexed yes
Original language: English
Carbonsäuren, Lösungs-DNP, Hyperpolarisation, Longitudinale Relaxation, NMR-Spektroskopie
DOI:
10.1002/anie.201607535
10.1002/ange.201607535
Source: FindIt
Source-ID: 2345977526
Publication: Research - peer-review › Journal article – Annual report year: 2016
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.
Educational simulator app and web page 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].

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: 3
Publication date: 2016
Event: Poster session presented at 33rd ESMRMB Annual Scientific Meeting, Vienna, Austria.
Main Research Area: Technical/natural sciences
Electronic versions:
esmrmb2016.1b2081d.NORMAL.pdf
mozilla.pdf

Bibliographical note
Source: PublicationPreSubmission
Source-ID: 127578231
Publication: Research - peer-review › Poster – Annual report year: 2016
Efficiency Analysis of Magnetic Field Measurement for MR Electrical Impedance Tomography (MREIT)

MREIT is an emerging method to measure the ohmic tissue conductivities, with several potential biomedical applications. Its sensitivity depends on the magnitude of the applied current, which is limited to 1-2 mA in the human brain [1, 2]. This renders in-vivo applications challenging. Here, we aim to analyze and optimize the efficiency of two MREIT pulse sequences for in-vivo brain imaging.

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), Hanson, L. G. (Intern), Ehses, P. (Ekstern), Thielscher, A. (Intern), Scheffler, K. (Ekstern)
Publication date: 2016
Event: Poster session presented at 33rd ESMRMB Annual Scientific Meeting, Vienna, Austria.
Main Research Area: Technical/natural sciences

Hyperpolarised Organic Phosphates as NMR Reporters of Compartamental pH

Organic phosphate metabolites contain functional groups withpKa 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
Hyperpolarized 13C MR angiography

Magnetic resonance angiography (MRA) is a non-invasive technology that can be used for diagnosis and monitoring of cardiovascular disease; the number one cause of mortality worldwide. Hyperpolarized imaging agents provide signal enhancement of more than 10,000 times, which implies large reduction in acquisition time and improved spatial resolution. We review the role of hyperpolarized 13C agents for MR angiography and present the literature in the field. Furthermore, we present a study of the benefit of intra-arterial injection over intravenous injection of hyperpolarized agent for cerebral angiography in the rat, and compare the performance of two standard angiographic pulse sequences, the gradient echo (GRE) sequence and the balanced steady-state free precession (bSSFP). 2D coronal cerebral angiographies using intra-arterial injections were acquired with a GRE sequence with in-plane resolution of 0.27 mm and matrix size 256x128, and 2D coronal cerebral angiographies were acquired with a bSSFP sequence with in-plane resolution of 0.55 mm and matrix size 128x64. The bSSFP sequence provides higher SNR in phantoms than the GRE sequence. Similarly, intravenous injections are imaged with higher SNR with the bSSFP sequence, where the signal
destruction of the GRE sequence is avoided. However, for intra-arterial injections, the bSSFP sequence results in strong artefacts, and the GRE sequence is preferred. Hyperpolarized MRA presents many challenges and cannot currently compete with conventional contrast enhanced MRA. Further research may change this since hyperpolarization is still an immature methodology.

**General information**
- **State:** Published
- **Organisations:** Biomedical Engineering, Department of Electrical Engineering, Center for Hyperpolarization in Magnetic Resonance, University of Copenhagen
- **Authors:** Lipsø, H. K. W. (Intern), Magnusson, P. (Ekstern), Ardenkjær-Larsen, J. H. (Intern)
- **Number of pages:** 6
- **Pages:** 90-96
- **Publication date:** 2016
- **Main Research Area:** Technical/natural sciences

**Publication information**
- **Journal:** Current Pharmaceutical Design
- **Volume:** 22
- **Issue number:** 1
- **ISSN (Print):** 1381-6128
- **Ratings:**
  - BFI (2018): BFI-level 1
  - Web of Science (2018): Indexed yes
  - BFI (2017): BFI-level 2
  - Web of Science (2017): Indexed Yes
  - BFI (2016): BFI-level 2
  - Scopus rating (2016): CiteScore 2.82 SJR 1.04 SNIP 0.816
  - Web of Science (2016): Indexed yes
  - BFI (2015): BFI-level 2
  - Scopus rating (2015): SJR 1.231 SNIP 0.904 CiteScore 3.01
  - BFI (2014): BFI-level 2
  - Scopus rating (2014): SJR 1.279 SNIP 0.958 CiteScore 3.26
  - Web of Science (2014): Indexed yes
  - BFI (2013): BFI-level 2
  - Scopus rating (2013): SJR 1.278 SNIP 0.987 CiteScore 3.41
  - BFI (2012): BFI-level 2
  - Scopus rating (2012): SJR 1.263 SNIP 1.056 CiteScore 3.67
  - BFI (2011): BFI-level 2
  - Scopus rating (2011): SJR 1.382 SNIP 1.115 CiteScore 3.96
  - BFI (2010): BFI-level 2
  - Scopus rating (2010): SJR 1.628 SNIP 1.249
  - BFI (2009): BFI-level 2
  - Scopus rating (2009): SJR 1.581 SNIP 1.161
  - BFI (2008): BFI-level 2
  - Scopus rating (2008): SJR 1.61 SNIP 1.199
  - Scopus rating (2007): SJR 1.76 SNIP 1.344
  - Scopus rating (2006): SJR 1.769 SNIP 1.453
  - Scopus rating (2005): SJR 1.61 SNIP 1.254
  - Scopus rating (2004): SJR 1.379 SNIP 1.381
  - Scopus rating (2003): SJR 1.346 SNIP 1.389
  - Scopus rating (2002): SJR 1.12 SNIP 1.238
  - Scopus rating (2001): SJR 1.142 SNIP 1.026
  - Scopus rating (2000): SJR 1.155 SNIP 1.065
  - Scopus rating (1999): SJR 1.287 SNIP 1.282
- **Original language:** English
- **Magnetic resonance angiography, Hyperpolarization, 13C, HP001, DNP**
- **Electronic versions:**
  - Hyperpolarized_13C_MR_angiography.pdf
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
Journal: Tomography
Volume: 2
Issue number: 2
ISSN (Print): 2379-1381
Ratings:
Web of Science (2018): Indexed yes
Web of Science (2017): Indexed yes
Original language: English
Electronic versions:
1511.00200v2.pdf
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

Publication information
Journal: Physica Medica
Volume: 32
Issue number: Supplement 3
ISSN (Print): 1120-1797
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.03 SJR 0.679 SNIP 1.305
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 0.707 SNIP 1.231 CiteScore 1.9
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 0.859 SNIP 1.492 CiteScore 2.25
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 0.656 SNIP 0.996 CiteScore 1.67
ISI indexed (2013): ISI indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 0.417 SNIP 0.751 CiteScore 1.08
ISI indexed (2012): ISI indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 0.597 SNIP 1.168 CiteScore 1.43
ISI indexed (2011): ISI indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 0.601 SNIP 0.752
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 0.438 SNIP 0.624
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 0.257 SNIP 0.473
Scopus rating (2007): SJR 0.141 SNIP 0.184
Scopus rating (2006): SJR 0.156 SNIP 0.278
Scopus rating (2005): SJR 0.14 SNIP 0.129
Scopus rating (2004): SJR 0.259 SNIP 0.484
Scopus rating (2003): SJR 0.181 SNIP 0.341
Scopus rating (2002): SJR 0.277 SNIP 0.255
Scopus rating (2001): SJR 0.215 SNIP 0.768
Scopus rating (2000): SJR 0.241 SNIP 0.231
Scopus rating (1999): SJR 0.209 SNIP 0.232
Original language: English
Electronic versions:
ECMP2016_abstract_lars_hanson.pdf
DOIs:
10.1016/j.ejmp.2016.07.556

Bibliographical note
Source: PublicationPreSubmission
Source-ID: 127578319
Publication: Research - peer-review › Conference abstract in journal – Annual report year: 2016
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
ISSN (Print): 1090-7807
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 2.37 SJR 0.973 SNIP 0.981
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
Authors: Andersen, M. (Intern), Hanson, L. G. (Intern), Madsen, K. H. (Intern), Wezel, J. (Ekstern), Boer, V. (Ekstern), van der Velden, T. (Ekstern), van Osch, M. J. (Ekstern), Klomp, D. (Ekstern), Webb, A. G. (Ekstern), Versluis, M. J. (Ekstern)
Pages: 2020-2030
Publication date: 2016
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Magnetic Resonance in Medicine
Volume: 75
Issue number: 5
ISSN (Print): 0740-3194
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.52 SJR 1.867 SNIP 1.438
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.291 SNIP 1.48 CiteScore 3.54
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.952 SNIP 1.39 CiteScore 3.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.959 SNIP 1.44 CiteScore 3.46
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 1
Scopus rating (2012): SJR 2.072 SNIP 1.549 CiteScore 3.61
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 2
Scopus rating (2011): SJR 2.056 SNIP 1.476 CiteScore 3.45
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.272 SNIP 1.612
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.278 SNIP 1.564
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 2.382 SNIP 1.512
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.353 SNIP 1.549
Scopus rating (2006): SJR 2.28 SNIP 1.74
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.269 SNIP 1.834
Web of Science (2005): Indexed yes
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 $P(\text{\textsuperscript{13}C})$ 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, $\text{\textsuperscript{13}C}$ polarizations on sodium [1-(\textsuperscript{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 $P(\text{\textsuperscript{13}C}) = 78\%$ could even be reached for [(\textsuperscript{13}C)urea.

General information

State: Published
Organisations: Department of Automation, Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Ecole Polytechnique Federale de Lausanne (EPFL), Sorbonne Universités
Authors: Bornet, A. (Ekstern), Pinon, A. (Ekstern), Jhajharia, A. (Ekstern), Baudin, M. (Ekstern), Ji, X. (Ekstern), Emsley, L. (Ekstern), Bodenhausen, G. (Ekstern), Ardenkjær-Larsen, J. H. (Intern), Jannin, S. (Ekstern)
Number of pages: 6
Pages: 30530-30535
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Physical Chemistry Chemical Physics
Volume: 18
ISSN (Print): 1463-9076
Ratings:
BFI (2018): BFI-level 2
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 2
Web of Science (2017): Indexed yes
BFI (2016): BFI-level 2
Scopus rating (2016): CiteScore 4.06 SJR 1.678 SNIP 1.117
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 2
Scopus rating (2015): SJR 1.771 SNIP 1.244 CiteScore 4.45
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 2
Scopus rating (2014): SJR 1.772 SNIP 1.253 CiteScore 4.29
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 2
Scopus rating (2013): SJR 1.715 SNIP 1.216 CiteScore 4.05
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
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: In 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...
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 unpredicted directions, but hopefully the thoughts presented here will stimulate new ideas that can further advance the field. (C) 2016 Elsevier Inc. All rights reserved.
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: 1307656201
Publication: Research - peer-review › Poster – Annual report year: 2017

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-MRI.
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
Organisations: Department of Electrical Engineering, Department of Applied Mathematics and Computer Science, Cognitive Systems, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance
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Number of pages: 3
Pages: 4254
Publication date: 2016

**Host publication information**
Title of host publication: Proceedings of the 24th ISMRM conference
Main Research Area: Technical/natural sciences
Conference: ISMRM 24th Annual Meeting & Exhibition, Singapore, 07/05/2016 - 07/05/2016
Source: PublicationPreSubmission
Source-ID: 124384284
Publication: Research - peer-review › Conference abstract in proceedings – Annual report year: 2016

### Regional brain volumes, diffusivity, and metabolite changes after electroconvulsive therapy for severe depression

**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 (1 H- 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.

**General information**
State: Published
Organisations: Department of Electrical Engineering, Center for Magnetic Resonance, Center for Hyperpolarization in Magnetic Resonance, University of Copenhagen, Stony Brook Medicine
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Number of pages: 11
Pages: 154–164
Publication date: 2016
Main Research Area: Technical/natural sciences

**Publication information**
Journal: Acta Psychiatrica Scandinavica
Volume: 133
Issue number: 2
ISSN (Print): 0001-690X
Ratings:
- BFI (2018): BFI-level 1
- Web of Science (2018): Indexed yes
- BFI (2017): BFI-level 1
- Web of Science (2017): Indexed Yes
- BFI (2016): BFI-level 1
- Scopus rating (2016): CiteScore 3.43 SJR 2.678 SNIP 1.708
- Web of Science (2016): Indexed yes
- BFI (2015): BFI-level 1
- Scopus rating (2015): SJR 2.557 SNIP 1.951 CiteScore 3.84
- BFI (2014): BFI-level 1
- Scopus rating (2014): SJR 3.183 SNIP 2.008 CiteScore 3.9
Renal MR angiography and perfusion in the pig using hyperpolarized water

Purpose: To study hyperpolarized water as an angiography and perfusion tracer in a large animal model.

Methods: Protons dissolved in deuterium oxide (D2O) were hyperpolarized in a SPINlab dissolution dynamic nuclear polarization (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 ± 0.9% of 3.8 M protons in 15 mL of deuterium oxide was achieved with a T1 of 24 ± 1 s. This allowed injection through an arterial catheter into the renal artery and subsequently high-contrast imaging of the entire kidney parenchyma over several seconds. The dynamic images allow quantification of tissue perfusion, with mean cortical perfusion of 504 ± 123 mL/100 mL/min. Conclusion: Hyperpolarized water MR imaging was successfully demonstrated as a renal angiography and perfusion method. Quantitative perfusion maps of the kidney were obtained in agreement with literature and control experiments with gadolinium contrast.

General information
State: Published
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Number of pages: 5
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: Magnetic Resonance in Medicine
ISSN (Print): 0740-3194
Ratings:
BFI (2018): BFI-level 1
Web of Science (2018): Indexed yes
BFI (2017): BFI-level 1
Web of Science (2017): Indexed Yes
BFI (2016): BFI-level 1
Scopus rating (2016): CiteScore 3.52 SJR 1.867 SNIP 1.438
Web of Science (2016): Indexed yes
BFI (2015): BFI-level 1
Scopus rating (2015): SJR 2.291 SNIP 1.48 CiteScore 3.54
Web of Science (2015): Indexed yes
BFI (2014): BFI-level 1
Scopus rating (2014): SJR 1.952 SNIP 1.39 CiteScore 3.32
Web of Science (2014): Indexed yes
BFI (2013): BFI-level 1
Scopus rating (2013): SJR 1.959 SNIP 1.44 CiteScore 3.46
ISI indexed (2013): ISI indexed yes
Web of Science (2013): Indexed yes
BFI (2012): BFI-level 2
Scopus rating (2012): SJR 2.072 SNIP 1.549 CiteScore 3.61
ISI indexed (2012): ISI indexed yes
Web of Science (2012): Indexed yes
BFI (2011): BFI-level 1
Scopus rating (2011): SJR 2.056 SNIP 1.476 CiteScore 3.45
ISI indexed (2011): ISI indexed yes
Web of Science (2011): Indexed yes
BFI (2010): BFI-level 1
Scopus rating (2010): SJR 2.272 SNIP 1.612
BFI (2009): BFI-level 1
Scopus rating (2009): SJR 2.278 SNIP 1.564
Web of Science (2009): Indexed yes
BFI (2008): BFI-level 1
Scopus rating (2008): SJR 2.382 SNIP 1.512
Web of Science (2008): Indexed yes
Scopus rating (2007): SJR 2.353 SNIP 1.549
Scopus rating (2006): SJR 2.28 SNIP 1.74
Web of Science (2006): Indexed yes
Scopus rating (2005): SJR 2.269 SNIP 1.834
Web of Science (2005): Indexed yes
Scopus rating (2004): SJR 2.121 SNIP 1.719
Web of Science (2004): Indexed yes
Scopus rating (2003): SJR 2.371 SNIP 1.575
Scopus rating (2002): SJR 2.176 SNIP 1.46
Web of Science (2002): Indexed yes
Scopus rating (2001): SJR 2.337 SNIP 1.558
Web of Science (2001): Indexed yes
Scopus rating (2000): SJR 2.037 SNIP 1.551
Scopus rating (1999): SJR 2.457 SNIP 2.147
Original language: English
Perfusion, Magnetic resonance angiography, Hyperpolarization, DNP
Electronic versions:
H2Oangio_post_print.pdf
DOIs:
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 1H-MRI and PET but never 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
Pages: 1-13
Publication date: 2016
Main Research Area: Technical/natural sciences

Publication information
Journal: E J N M M I Physics
Volume: 3
Issue number: 1
ISSN (Print): 2197-7364
Ratings: Web of Science (2018): Indexed yes
Scopus rating (2016): SJR 0.843 SNIP 1.067 CiteScore 1.67
Web of Science (2016): Indexed yes
Scopus rating (2015): SNIP 0.284 SJR 0.408 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: Findlt
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.

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.
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

Host publication information
Title of host publication: Proceedings of 2016 41st International Conference on Infrared, Millimeter, and Terahertz waves
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.

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.
Transmission Line Resonator Segmented with Series Capacitors

Transmission line resonators are often used as coils in high field MRI. Due to the distributed nature of such resonators, coils based on them produce inhomogeneous field. This work investigates the 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
Publication date: 2016

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 the 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.

General information
State: Published
Organisations: Department of Electrical Engineering, Electromagnetic Systems, Center for Hyperpolarization in Magnetic Resonance, Center for Magnetic Resonance
Authors: Rybalko, O. (Intern), Bowen, S. (Intern), Zhurbenko, V. (Intern), Ardenkjær-Larsen, J. H. (Intern)
Pages: 1227-1230
Publication date: 2016

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.
Waveguide transition with vacuum window for multiband dynamic nuclear polarization systems

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.
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

General information
State: Published
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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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 ways to improve the DNP enhancement is to transfer microwave power from the mm-wave source to the sample more efficiently. 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 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. 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 to 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.

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), Bowen, S. (Intern), Zhurbenko, V. (Intern), Ardenkjær-Larsen, J. H. (Intern)
Number of pages: 1
Publication date: 2015
Main Research Area: Technical/natural sciences
Electronic versions:
A_282_GHz_Probe_for_Dynamic_Nuclear_Polarization.pdf
Source: PublicationPreSubmission
Source-ID: 119788945
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 limit 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
Pages: 78-84
Publication date: 2015
Main Research Area: Technical/natural sciences

Publication information
Journal: Concepts in Magnetic Resonance. Part B: Magnetic Resonance Engineering (Online)
Volume: 45B
Issue number: 2
ISSN (Print): 1552-504X
Ratings:
Web of Science (2018): Indexed yes
Web of Science (2017): Indexed Yes
Scopus rating (2016): CiteScore 0.49 SJR 0.234 SNIP 0.277
Scopus rating (2015): SJR 0.267 SNIP 0.417 CiteScore 0.78
Web of Science (2015): Indexed yes
Scopus rating (2014): SJR 0.349 SNIP 0.355 CiteScore 0.74
Scopus rating (2013): SJR 0.359 SNIP 0.46 CiteScore 0.83
ISI indexed (2013): ISI indexed no
Scopus rating (2012): SJR 0.4 SNIP 0.672 CiteScore 0.99
ISI indexed (2012): ISI indexed no
Scopus rating (2011): SJR 0.374 SNIP 0.634 CiteScore 1.09
Scopus rating (2010): SJR 0.681 SNIP 0.951
Scopus rating (2009): SJR 0.512 SNIP 0.717
Scopus rating (2008): SJR 0.492 SNIP 0.989
Scopus rating (2007): SJR 0.536 SNIP 0.781
Scopus rating (2006): SJR 0.568 SNIP 0.976
Scopus rating (2005): SJR 0.864 SNIP 1.233
Scopus rating (2004): SJR 0.428 SNIP 0.898
Scopus rating (2003): SJR 0.334 SNIP 0.834
Original language: English
Hyperpolarized 13C, Radiofrequency pulses, Transmit power, Flip angle calibration
DOIs: 10.1002/cmr.b.21282
Source: PublicationPreSubmission
Source-ID: 122160841
Publication: Research - peer-review › Journal article – Annual report year: 2016

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 Gd3+-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
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, University of Pisa, Scuola Superiore Sant'Anna, National Research Council of Italy
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.

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 of 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).

General information
State: Published
Organisations: Center for Hyperpolarization in Magnetic Resonance, Department of Electrical Engineering, Center for Magnetic Resonance, Aarhus University
Number of pages: 1
Publication date: 2015
Main Research Area: Technical/natural sciences
Electronic versions:
Abstract_DNPSymp2015.pdf

Relations
Activities:
Magnetic Resonance Angiography in the Pig using Hyperpolarized Water
Publication: Research - peer-review › Conference abstract for conference – Annual report year: 2015

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
State: Published
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
Publication date: 2015

Host publication information
Title of host publication: Proceedings. 2015 SBMO/IEEE MTT-S International Microwave and Optoelectronics Conference (IMOC)
Publisher: IEEE
ISBN (Print): 978-1-5090-0431-7
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
Electronic versions:
Modeling_of_Schottky_Barrier_Diode_Millimeter_Wave.pdf
DOIs:
10.1109/IMOC.2015.7369088
Publication: Research - peer-review › Article in proceedings – Annual report year: 2015

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.

**General information**

**State:** Published

**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

**Authors:** Giovannetti, G. (Ekstern), Hartwig, V. (Ekstern), Frijia, F. (Ekstern), Menichetti, L. (Ekstern), Positano, V. (Ekstern), Ardenkjær-Larsen, J. H. (Intern), Landini, L. (Ekstern), Lombardi, M. (Ekstern), Santarelli, M. F. (Ekstern)

**Pages:** 78–84

**Publication date:** 2015

**Main Research Area:** Technical/natural sciences

**Publication information**

**Journal:** Measurement

**Volume:** 60

**ISSN (Print):** 0263-2241

**Ratings:**

- **BFI (2018):** BFI-level 1
- **Web of Science (2018):** Indexed yes
- **BFI (2017):** BFI-level 1
- **Web of Science (2017):** Indexed Yes
- **BFI (2016):** BFI-level 1
- **Scopus rating (2016):** CiteScore 2.52 SJR 0.734 SNIP 1.63
- **Web of Science (2016):** Indexed yes
- **BFI (2015):** BFI-level 1
- **Scopus rating (2015):** SJR 0.677 SNIP 1.492 CiteScore 2.18
- **Web of Science (2015):** Indexed yes
- **BFI (2014):** BFI-level 1
- **Scopus rating (2014):** SJR 0.682 SNIP 1.686 CiteScore 1.89
- **BFI (2013):** BFI-level 1
- **Scopus rating (2013):** SJR 0.572 SNIP 1.721 CiteScore 1.8
- **ISI indexed (2013):** ISI indexed yes
- **Web of Science (2013):** Indexed yes
- **BFI (2012):** BFI-level 1
- **Scopus rating (2012):** SJR 0.532 SNIP 1.568 CiteScore 1.43
- **ISI indexed (2012):** ISI indexed yes
- **Web of Science (2012):** Indexed yes
- **BFI (2011):** BFI-level 1
- **Scopus rating (2011):** SJR 0.404 SNIP 1.387 CiteScore 1.16
- **ISI indexed (2011):** ISI indexed yes
- **Web of Science (2011):** Indexed yes
- **BFI (2010):** BFI-level 1
- **Scopus rating (2010):** SJR 0.41 SNIP 1.148
- **BFI (2009):** BFI-level 1
- **Scopus rating (2009):** SJR 0.375 SNIP 1.101
- **BFI (2008):** BFI-level 1
- **Scopus rating (2008):** SJR 0.415 SNIP 0.997
- **Web of Science (2008):** Indexed yes
- **Scopus rating (2007):** SJR 0.378 SNIP 0.752
- **Scopus rating (2006):** SJR 0.322 SNIP 1.169
- **Scopus rating (2005):** SJR 0.518 SNIP 1.195
- **Scopus rating (2004):** SJR 0.408 SNIP 0.843
- **Scopus rating (2003):** SJR 0.538 SNIP 1.091
- **Scopus rating (2002):** SJR 0.426 SNIP 1.514
- **Scopus rating (2001):** SJR 0.43 SNIP 0.61
- **Scopus rating (2000):** SJR 0.273 SNIP 0.633