Title:	NMR scanner with motion zeugmatography	
Patent Number:	04516075 (U.S. patents which cite this patent)	
Issue Date:	05-07-1985	
Application Date:	01-04-1983	
Application Number:	455596	
Inventor(s):	**Name**	**Location**
	Moran; Paul R.	Madison WI
Assignee(s):	**Name**	**Location**
	Wisconsin Alumni Research Foundation	Madison WI

Abstract

An NMR zeugmatographic scanner is modified to produce flow images. A motion sensitizing gradient field is applied to the gyromagnetic nuclei after transverse excitation and prior to emission measurement. The motion sensitized free induction signal which results is processed using an inverse Fourier transformation to produce a number of useful images.

Exemplary Claims

Claim 1:

In a gyromagnetic resonance instrument which performs a measurement cycle by applying a transverse excitation signal to a gyromagnetic material and to thereby impart a transverse magnetic moment thereto, and which produces a FID signal responsive to emissions by the transversely magnetized gyromagnetic material, the improvement comprising:

- means for motion sensitizing a FID signal in which a motion sensitizing magnetic field gradient F is applied to the gyromagnetic material for a period of time **2** T after its transverse excitation and prior to the production of the FID signal, and wherein the motion sensitizing magnetic field gradient F has alternating polarity with respect to the gyromagnetic material such that its integral over the time period **2** T is substantially zero; and
- detector means for receiving the FID signal and producing therefrom a signal S_1 (t) which is phase-referenced to the cosine phase of the transverse excitation signal and a signal S_2 (t) which is phase-referenced to the sine phase of the transverse excitation signal.

References to US Patents

Number	Date	Inventor
04015196	1977-03	Moore et al.
04021726	1977-05	Garroway et al.
04070611	1978-01	Ernst
04115730	1978-09	Mansfield
04254778	1981-03	Clow et al.
04284950	1981-08	Burl et al.
04297637	1981-10	Crooks
04319190	1982-03	Brown
04339716	1982-07	Young
04339718	1982-07	Bull et al.
04345207	1982-08	Bertrand et al.
04354157	1982-10	Feiner
04355282	1982-10	Young et al.

04471305	1984-09	Crooks et al.

Other References

Hilal et al., "Special Project II-Studies of Two-Dimensional Blood Flow using Nuclear Magnetic Resonance" , a 377 page proposal submitted to the Dept of Health, Education and Welfare, pp. 208-229.
J. R. Singer, "NMR diffusion and flow measurements and an introduction to spin phase graphing" , The Institute of Physics, pp. 281-291.
"Basic Concepts for Nuclear Magnetic Resonance Imaging" -Fullerton Magnetic Resonance Imaging, vol. 1, pp. 39-53, 1982.
"The NMR Blood Flowmeter-theory and history" , Battocletti et al., Med. Phys. 8(4), Jul./Aug. 1981, pp. 435-443.
"Applications de la Resonance Magnetique Nucleaire en hemodynamique(*)" , A. Constantinesco et J. Chambron, (Jan. 23, 1981), pp. 127-134.
"NMR rheotomography: Feasibility and clinical potential" -Grant et al., Med. Phys. 9(2), Mar./Apr. 1982, 188-193.

Primary Examiner:	Tokar; Michael J.
Agents:	5 Sammons; Barry E.
International Classification:	3G01R 3308
US Classification:	324-309-000 324-306-000
Field of Search:	324-300-000 324-307-000 324-309-000 324-306-000 324-312-000

Title:	NMR flow imaging using bi-phasic excitation field gradients	
Patent Number:	04654591 (U.S. patents which cite this patent)	
Issue Date:	03-31-1987	
Application Date:	07-29-1985	
Application Number:	760354	
Inventor(s):	**Name**	**Location**
	Moran; Paul R.	Winston-Salem NC
Assignee(s):	**Name**	**Location**
	Wisconsin Alumni Research Foundation	Madison WI

Abstract

An NMR zeugmatographic scanner is modified to provide flow images. A motion sensitizing, bi-phasic excitation field gradient is applied during each measurement cycle to produce transverse magnetization in paramagnetic nuclei which are moving in the direction of the gradient. The resulting free induction signal is processed using an inverse Fourier transformation to produce images of flowing paramagnetic nuclei.

Exemplary Claims

Claim 1:

In a gyromagnetic resonance instrument which performs a measurement cycle in which a FID signal produced by gyromagnetic material having a transverse magnetic moment is detected and processed to produce an indication of the amount of transverse magnetization, the improvement comprising:

- an oscillator for producing an excitation signal at the Larmor frequency of the gyromagnetic material;
- an excitation field gradient coil coupled to the oscillator and mounted in the instrument to produce a transversely directed magnetic field at the Larmor frequency which has a magnitude gradient in a preset direction; and
- control means for producing a motion sensitized FID signal by controlling the excitation signal applied to the excitation field gradient coils such that a bi-phasic excitation field gradient is applied to the gyromagnetic material.

References to US Patents

Number	Date	Inventor

04516075	1985-05	Moran
04523596	1985-06	Macovski
04528985	1985-07	Macovski
04565968	1986-01	Macovski
04595879	1986-01	Lent et al.
04602641	1986-07	Feinberg
Primary Examiner:	Tokar; Michael J.	
Agents:	5 Sammons; Barry E.	
International Classification:	4G01R 3320	
US Classification:	324-306-000 324-309-000	
Field of Search:	128-653-000 324-300-000 324-306-000 324-307-000 324-309-000 324-311-000 324-313-000 324-318-000 324-322-000	

Title:	NMR flow imaging using a composite excitation field and magnetic field gradient sequence	
Patent Number:	04697149 (U.S. patents which cite this patent)	
Issue Date:	09-29-1987	
Application Date:	11-04-1985	
Application Number:	794652	
Inventor(s):	**Name**	**Location**
	Moran; Paul R.	Winston-Salem NC
Assignee(s):	**Name**	**Location**
	Wisconsin Alumni Research Foundation	Madison WI

Abstract

An NMR zeugmatographic scanner is modified to provide motion images, During each measurement cycle the paramagnetic nuclei are subjected to a pair of transverse excitation field pulses which are separated by the application of a bi-polar magnetic field gradient which sensitizes the resulting FID signal to motion. The resulting FID signal is processed using an inverse Fourier transformation to produce images of flowing paramagnetic nuclei.

Exemplary Claims

Claim 1:

In a gyromagnetic resonance instrument which performs a measurement cycle in which a FID signal produced by gyromagnetic material which is subjected to a polarizing magnetic field and has a magnetic moment is detected and processed to produce an indication of the amount of magnetization, the improvement comprising:

- excitation means for applying an excitation field to the gyromagnetic material at the Larmor frequency of the gyromagnetic material and at a controllable strength and phase;
- magnetic field gradient means for applying a magnetic field to the gyromagnetic material which has a gradient in a controlled direction; and
- control means coupled to the excitation means and the magnetic field gradient means and being operable to perform a measurement cycle that produces a FID signal indicative of the motion of gyromagnetic material, the measurement cycle including:
- (a) applying a first excitation field pulse which tips the net magnetic moment of the gyromagnetic material away from the direction

of the polarizing magnetic field;

- (b) applying a motion sensitizing magnetic field gradient to the gyromagnetic material which has alternating polarity with respect to the net magnetic moment of the gyromagnetic material and in which the gradient is oriented to the direction in which motion is to be measured;
- (c) applying a second excitation field pulse having a strength and phase which substantially restores the magnetic moment of stationary gyromagnetic material to the direction of the polarizing magnetic field.

References to US Patents		
Number	**Date**	**Inventor**
04516075	1985-05	Moran
04516582	1985-05	Redington
04528985	1985-07	Macovski
04532473	1985-07	Wehrli
04536712	1985-08	Iwaoka et al.
04549140	1985-10	MacFall
04567893	1986-02	Charles et al.
04587488	1986-05	Young
04595879	1986-06	Lent et al.
04602641	1986-07	Feinberg
04609872	1986-09	O`Donnell
04614195	1986-09	Bottomlay et al.
04616180	1986-10	Compton

Other References

K. J. Packer, "The Study of Slow Coherent Molecular Motion by Pulsed Nuclear Magnetic Resonance" , *Molecular Physics*, 1969, vol. 17, No. 4, 355-368.
Sadek K. Hilal, Andrew Maudsley, and Frederick Kelcz, Special Project II- *Studies of Two-Dimensional Blood Flow Using Nuclear Magnetic Resonance*, pp. 208-229, privileged communication.

Primary Examiner:	Noland; Tom
Agents:	5 Quarles & Brady
International Classification:	4G01R 3320
US Classification:	324-309-000 324-306-000
Field of Search:	324-309-000 324-306-000 324-300-000 324-307-000 324-312-000 128-653-000

Title:	NMR scanner with motion zeugmatography	
Patent Number:	RE032701 (U.S. patents which cite this patent)	
Issue Date:	06-21-1988	
Application Date:	04-08-1987	
Application Number:	036103	
Inventor(s):	**Name**	**Location**

	Moran; Paul R.	Winston-Salem NC
Assignee(s):	**Name**	**Location**
	Wisconsin Alumni Research Foundation	Madison WI

Abstract

An NMR zeugmatographic scanner is modified to produce flow images. A motion sensitizing gradient field is applied to the gyromagnetic nuclei after transverse excitation and prior to emission measurement. The motion sensitized free induction signal which results is processed using an inverse Fourier transformation to produce a number of useful images.

Exemplary Claims

Claim 1:

In a gyromagnetic resonance instrument for producing an image of an extended subject which contains both stationary gyromagnetic material and moving gyromagnetic material, in +L which the instrument +L performs a measurement cycle by applying a transverse excitation signal to a gyromagnetic material and to thereby impart a transverse magnetic moment thereto, and which produces a FID signal responsive to emissions by the transversely magnetized gyromagnetic material, the improvement comprising:

- means for locating the position of the gyromagnetic material within the extended subject which is producing a FID signal;
- means for motion sensitizing a FID signal in which a motion sensitizing magnetic field gradient F is applied to the gyromagnetic material for a period of time **2** T after its transverse excitation and prior to the production of the FID signal, and wherein the motion sensitizing magnetic field gradient F has alternating polarity with respect to the gyromagnetic material such that its integral over the time period **2** T is substantially zero; and
- detector means for receiving the FID signal and producing therefrom a signal S_1 (t) which is phase-referenced to the cosine phase of the transverse excitation signal and a signal S_2 (t) which is phase-referenced to the sine phase of the transverse excitation signal.

References to US Patents

Number	Date	Inventor
04015196	1977-03	Moore et al.
04021726	1977-05	Garroway et al.
04070611	1978-01	Ernst
04115730	1978-09	Mansfield
04254778	1981-03	Clow et al.
04284950	1981-08	Burl et al.
04297637	1981-10	Crooks
04318043	1982-03	Crooks et al.
04319190	1982-03	Brown
04339716	1982-07	Young
04339718	1982-07	Bull et al.
04345207	1982-08	Bertrand et al.
04354157	1982-10	Feiner
04355282	1982-10	Young et al.
04431968	1984-02	Edelstein et al.
04443760	1984-04	Edelstein et al.
04451788	1984-05	Edelstein et al.

04471305	1984-09	Crooks et al.
04471306	1984-09	Edelstein et al.
04509015	1985-04	Ordidge et al.
04516075	1985-05	Moran
04528985	1985-07	Macovski

Other References

"The NMR Blood Flowmeter-Theory and History" , Battocletti et al., Med Phys. 8(4), Jul./Aug. 1981, pp. 435-443.
"Applications de la Resonance Magnetique Nucleaire en Hemodynamique(*)" , A. Constantiensco et J. Chambron, (Jan. 23, 1981), pp. 127-134.
"NMR Rheotomography: Feasibility and Clinical Potential" -Grant et al., Med Phys. 9(2), Mar./Apr. 1982, pp.188-193.
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Hilal et al., "Special Project II-Studies of Two-Dimensional Blood Flow Using Nuclear Magnetic Resonance" , a 377 page proposal submitted to the Dept. of Health, Education and Welfare, pp. 208-229.
J. R. Singer, "NMR Diffusion and Flow Measurements and An Introduction to Spin Phase Graphing" , The Institute of Physics, pp. 281-291.
"Basic Concepts for Nuclear Magnetic Resonance Imaging" -Fullerton Magnetic Resonance Imaging, vol. 1, pp. 39-53, 1982.
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Packer, K. J., "The Study of Slow Coherent Molecular Motion by Pulsed Nuclear Magnetic Resonance," Molecular Physics, 1969, 17(4):355-368.
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Grover, Thomas and Singer, J. R., "NMR Spin-Echo Flow Measurements," Journal of Applied Physics, Mar. 1, 1971, 43(3):938-939.
Grover, Thomas and Singer, J. R., "Recent Measurements of Flow Using Nuclear Magnetic Resonance Techniques," Modern Developments in Flow Measurements, Sep., 1971, pp. 38-46, Proc. the Harwell (Berks, England) Conference, Ed. CG Clayton (The Harwell Atomic Energy Establishment. Peter Perigrinin, Ltd., pub).
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Hahn, E. L., "Spin Echoes," Physical Review, Nov. 15, 1950, vol. 80(4):580-594.
Carr, H. Y. and Purcell, E. M., "Effects of Diffusion on Free Precession in Nuclear Magnetic Resonance Experiments," May 1, 1954, vol. 94(3):630-639.

Primary Examiner:	Tokar; Michael J.
Agents:	5 Quarles & Brady
International Classification:	4G01R 3320

US Classification:	324-309-000 324-306-000
Field of Search:	324-300-000 324-307-000 324-309-000 324-312-000 324-306-000

Title:	Radiation dosimetry by measurement of polarization and depolarization currents	
Patent Number:	04016422 (U.S. patents which cite this patent)	
Issue Date:	04-05-1977	
Application Date:	05-12-1975	
Application Number:	576272	
Inventor(s):	**Name**	**Location**
	Moran; Paul Richard	Madison WI
	Podgorsak; Ervin B.	Madison WI
	Fields; David E.	Oak Ridge TN
Assignee(s):	**Name**	**Location**
	Wisconsin Alumni Research Foundation	Madison WI

Abstract

This invention provides a method of measuring exposure to radiation, particularly x-rays, gamma rays and other forms of penetrating radiation. A dielectric body is provided and is equipped with a pair of electrodes on opposite sides thereof. In accordance with one procedure which may be called radiation induced thermally activated depolarization (RITAD), an electrostatic bias polarization is produced in the dielectric body, preferably by heating it to an elevated temperature, impressing a voltage between the electrodes to produce internal polarization in the body, and cooling the body while maintaining the voltage, so as to freeze in the bias polarization. The voltage is then removed, and the electrodes may be short circuited. The body is then exposed to the radiation to be measured. After such exposure, a current measuring circuit is established between the electrodes. The electrical currents in such circuit are observed and measured as the energy level of the body is raised, preferably by heating the body. One or more current peaks related to the radiation are observed at temperatures where no current is observed in the absence of the exposure to radiation. The magnitude of such current peaks is a measure of the total radiation dosage. Such observed current peaks are indicative of radiation induced thermally activated depolarization in the dielectric body. Many different dielectric materials may be employed, such as calcium fluoride, strontium fluoride, lithium fluoride and various ceramic materials such as magnesium oxide and beryllium oxide.

In a modified procedure, which may be called radiation induced thermally activated polarization (RITAP), the dielectric body is not given an initial bias polarization, but rather is exposed to radiation without any such initial polarization. After such exposure, the electrodes on the dielectric body are connected into a series circuit which includes a current measuring instrument and a battery or some other source of a uni-directional voltage. The electrical current in such circuit is then observed and measured as the energy level of the dielectric body is raised, preferably by heating the body. If the dielectric body has been exposed to radiation, a polarization current peak is observed at a characteristic temperature. The magnitude of the peak is a measure of the total radiation dosage. The voltage source may then be removed from the circuit so that the current measuring instrument is connected directly across the electrodes. The dielectric body is then heated to a higher temperature. At one or more characteristic temperatures, one or more depolarization current peaks are observed. The direction of the depolarization currents is opposite from the direction of the polarization current. The magnitude of the depolarization current peaks is also a measure of the total radiation dosage.

Exemplary Claims

Claim 1:

A method of measuring radiation,

- comprising the steps of providing a dielectric body made of a dielectric material selected from a group consisting of alkaline earth fluorides, other alkaline earth halides, alkali metal fluorides, other alkali metal halides, alkaline earth oxide ceramics, and alkaline earth phosphate minerals,
- exposing said dielectric body to the radiation to be measured,
- providing an electrical current measuring circuit between a pair of electrodes on opposite sides of said body,

- and producing a depolarization current in said measuring circuit by raising the energy level of said dielectric body,
- said depolarization current being a measure of the radiation exposure.

References to US Patents		
Number	**Date**	**Inventor**
03420999	1969-01	Distenfeld
03450879	1969-06	Seppi
03699337	1972-10	Hoy
03761710	1973-09	Yamashita et al.
Primary Examiner:	Willis; Davis L.	
Agents:	5 Burmeister, York, Palmatier, Hamby & Jones	
International Classification:	2G01T 116	
US Classification:	250-336-000 250-390-000 250-395-000	
Field of Search:	250-336-000 250-337-000 250-390-000 250-391-000 250-392-000 250-395-000 250-484-000 250-472-000 250-473-000	

Title:	Dielectric material for dosimeters	
Patent Number:	03935457 (U.S. patents which cite this patent)	
Issue Date:	01-27-1976	
Application Date:	08-16-1974	
Application Number:	497874	
Inventor(s):	**Name**	**Location**
	Moran; Paul R.	Madison WI
	Podgorsak; Ervin	Toronto WI CA
	Fullerton; Gary D.	Madison WI
	Fuller; Gene E.	Ridge NY
Assignee(s):	**Name**	**Location**
	Wisconsin Alumni Research Foundation	Madison WI

Abstract

A dosimeter having a dielectric material such as sapphire wherein the efficiency as measured by mean drift distance and trapping efficiency is increased by making use of a dielectric material in which the total active impurity does not exceed 50 ppm and in which any one active impurity does not exceed 10 ppm.

Exemplary Claims

CM,1. In the measurement of radiation, a dosimeter which makes use of a dielectric material in which the level of active impurities total less than **50** ppm, and in which the level of any one active impurity does not exceed **10** ppm.

References to US Patents		
Number	**Date**	**Inventor**
03450879	1969-06	Seppi

Primary Examiner:	Willis; Davis L.
Agents:	5 McDougall, Hersh & Scott
International Classification:	G01t 116
US Classification:	250-336-000 250-472-000
Field of Search:	250-336-000 250-337-000 250-472-000 250-473-000 250-483-000 250-484-000 357-290-000