PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 : A61B 5/05	A1	(11) International Publication Number: WO 86/ 01093
		(43) International Publication Date: 27 February 1986 (27.02.86)

(21) International Application Number: PCT/US85/01543

(22) International Filing Date: 13 August 1985 (13.08.85)

(31) Priority Application Number: 640,670

(32) Priority Date: 13 August 1984 (13.08.84)

(33) Priority Country: US

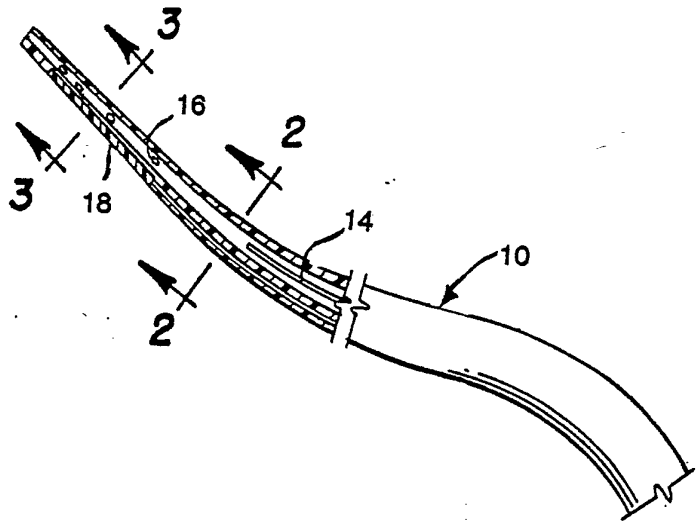
(71)(72) Applicant and Inventor: BERKE, Howard, Roy [US/US]; 22055 McClellen Road, Cupertino, CA 95014 (US).

(74) Agents: WATT, Phillip, H. et al.; Fitch, Even, Tabin & Flannery, Room 900, 135 South LaSalle Street, Chicago, IL 60603 (US).

(81) Designated States: AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent).

Published
With international search report.

(54) Title: SOLID STATE NMR PROBE



(57) Abstract

An *in vivo* NMR probe (30, 50) is disposed at the distal end of a catheter or endoscope (10) for obtaining NMR spectra from within a patient. The probe (30) is constructed from a passive integrated circuit including a receiving coil (32) and a parametric amplifier (34) for frequency up-converting the received frequency of the NMR emissions. One or more coaxial cables (22) disposed in a lumen (20) of the catheter (10) connect the integrated circuit probe (30) to an external NMR processor. The external processor may also excite the coil to radiate a localized perturbation field prior to obtaining NMR emission data of an area of interest. Alternatively, the probe (50) may be constructed from an active circuit (54) which enables the coil (52A-H) to be tuned to an NMR emission frequency of interest. A closed loop refrigeration circuit utilizing lumens (24) in the catheter or Peltier junction devices on the integrated circuit provide for temperature stability of the active devices.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	**GA**	Gabon	**MR**	Mauritania
AU	Australia	**GB**	United Kingdom	**MW**	Malawi
BB	Barbados	**HU**	Hungary	**NL**	Netherlands
BE	Belgium	**IT**	Italy	**NO**	Norway
BG	Bulgaria	**JP**	Japan	**RO**	Romania
BR	Brazil	**KP**	Democratic People's Republic of Korea	**SD**	Sudan
CF	Central African Republic			**SE**	Sweden
CG	Congo	**KR**	Republic of Korea	**SN**	Senegal
CH	Switzerland	**LI**	Liechtenstein	**SU**	Soviet Union
CM	Cameroon	**LK**	Sri Lanka	**TD**	Chad
DE	Germany, Federal Republic of	**LU**	Luxembourg	**TG**	Togo
DK	Denmark	**MC**	Monaco	**US**	United States of America
FI	Finland	**MG**	Madagascar		
FR	France	**ML**	Mali		

SOLID STATE NMR PROBE

The present invention is directed to a probe for detecting NMR spectra and more particularly to such a probe which is insertable into a polarized sample to be imaged to detect NMR spectra from localized areas within said sample.

In known NMR, a sample to be magnetically imaged is placed within a relatively high magnetic field to polarize the spin axis of its molecules. The sample is then subjected to a perturbation magnetic field to upset the polarization of the spin axis. An RF receiver scans the surface of the sample to detect the electromagnetic spectra from the perturbed spin axes. Since the spin axis for various molecules will react differently, the sample can be imaged from the RF spectra emitted from the spin axes. The RF receiver includes a coil to detect the NMR spectra and to develop an electrical signal as a function thereof.

However, in many applications it is desirable to detect electromagnetic RF emissions from with the sample. However, the depth of the region imaged is approximately the width of the coil of the RF receiver of the probe.

An important use for such a probe is in medical NMR imaging for diagnosis. In medical applications, a patient is inserted into an NMR scanner. The scanner is relatively large since it is an electromagnetic coil which usually completely surrounds the patient. The prior art NMR receiver is scanned over the skin surface of the patient to obtain an NMR image.

However, in medical applications, it is highly advantageous to detect the spectra corresponding phosphorous emissions from within the body. For example, in tumor growth, phosphorous emissions are significantly higher if the tumor is active as compared

to those phosphorous emissions when the tumor is malignant. However, since prior art NMR receivers cannot "see" into the body, tumors existing on organs deep within the body are not easily scanned. Also, the RF field to introduce a perturbation field to the magnetic polarization, must be relatively high to perturb the magnetic spin axis of the phosphorous molecules within the body of the patient.

A prior art probe for in vivo measurement is known for measurement of NMR spectra from a canine heart. The probe is disposed at the end of a catheter and includes a two turn solenoid which is passed through a superficial cutdown in an external jugular vein. The coil is positioned in the apex of the right ventricle by fluoroscopic monitoring. NMR spectra were collected by usual means. A disadvantage and limitation of such an in vivo probe is that because of the size of the solenoid, the probe must be surgically implanted by passing the catheter through the surgical incision. Another disadvantage and limitation of the prior art in vivo probe is that the solenoid is subject to body temperature and is not easily cooled. Cooling of the solenoid below body temperature is desirable to minimize thermo-resistive variations in the impedance of the solenoid.

Another application for a probe which can "see" within a sample is on quality assurance automated equipment for the chemical and pharmaceutical industries. An automated processing line could pass magnetically polarized samples of a chemical solution under the probe. The probe can then be inserted into the solution for detecting the electromagnetic spectra of the polarized spin axis. Thus, the molecular composition of the solution could then be determined and a decision made on whether said solution is within quality control specifications.

Summary of the Invention

It is therefore an object of the present invention to overcome one or more of the disadvantages and limitations enumerated above.

It is a primary object of the present invention to provide an NMR probe which is intrusively insertable into a sample for obtaining local NMR spectra.

It is an important object of the present invention to provide a probe at a distal end of the catheter which does not require a surgical incision to pass the NMR probe therethrough.

It is a further object of the present invention which minimizes the size of the probe by integrated circuit techniques.

Yet another object of the present invention is to provide cooling of the probe to eliminate thermoresistive disturbances of the RF coil when inserted in a body.

Yet another object of the present invention is to provide an NMR probe which relies on passive circuit elements for temperature stability.

According to the present invention, an NMR probe for detecting NMR spectra emitted from within a sample includes an integrated circuit carried at a distal end of the probe. The integrated circuit includes a coil for converting the detected NMR spectra into an electrical signal. The size of the coil is selected in accordance with the frequency of the spectra desired to be scanned. The integrated circuit also includes means for frequency up-converting the electrical signal developed by the coil. By frequency up-converting the signal, the effective temperature of the coil is lowered thereby minimizing the requirement for cooling of the coil. However, in one aspect of the present invention, additional cooling of the coil may

be provided by conventional refrigeration means or by integrated Peltier junction devices.

The probe also includes means for conducting the up-converted signal to an external processing means of a typical NMR system. The external processor includes means for impedance matching the coil to the impedance of the sample to maximize power transfer.

In one aspect of the present invention, the frequency up-converter includes a passive parametric amplifier which has an integrated circuit capacitor. The capacitor sinusoidally varies at a selected second frequency higher than the detected first frequency. The up-converted signal has a frequency which is the sum of the first and second frequencies. The integrated capacitor may be formed from the reverse bias PN junction of an integrated circuit diode. The processor means would include means for developing a further electrical signal for reverse biasing the diode and modulating the depletion region width of the reverse bias PN junction. The conducting means conducts the further electrical signal to the diode.

In another aspect of the present invention, where localized spectra are desired to be imaged, such as phosphorous emissions, the integrated circuit coil may also be operated as a transmitter of the pertabation electromagnetic field. The conducting means may conduct a signal from the external processor to the coil for developing the excitation pertabation field.

These and other objects, advantages and features of the present invention will become more apparent from the following description when read in conjunction with the accompanying drawings and the appended claims.

Brief Description of the Drawings

FIGURE 1 is a diagrammatic illustration,

partially in cross section of a typical catheter useful in practicing the present invention;

FIGURE 2 is a cross sectional view of the catheter taken along line 2-2 of FIGURE 1;

FIGURE 3 is a cross sectional view of the catheter taken along line 3-3 of FIGURE 1;

FIGURE 4 is a schematic diagram of an integrated circuit probe for use with the catheter shown in FIGURE 1; and

FIGURE 5 is an alternate embodiment of the integrated circuit probe according to the present invention.

Description of the Preferred Embodiment

Referring now to FIGURES 1-3, there is shown a catheter/endoscope 10. Catheter/endoscope 10 includes a lumen 12 for obtaining a biological sampling or making an infusion into an artery. For example, an angiographic catheter will obtain a sample of blood within lumen 12. The diameter of catheter/endoscope 10 ranges typically from a minimum of 2 millimeters for an angiographic catheter to a centimeter or more for an endoscope insertable through external body orifices. A typical angiographic catheter also includes a guide wire 14, shown partially in FIGURE 1, which is received by lumen 12 and normally extends out the tip of the angiographic catheter to provide a guide or track for catheter 10 when it is necessary to guide catheter 10 through relatively sharp ends, for example, in an artery. Catheter 10 may also include a plurality of side holes 16 at its distal end for better receiving a fluid sample.

Catheter/endoscope 10 has an outside diameter adequate to allow for the non-traumatic, minimally invasive, percutaneous or intraorificial introduction and passage of the device. Material selected will be non-thrombogenic and non-toxic substances that are

selected for their magnetic susceptability to be rapidly visualized during scanning of the NMR spectra.

An NMR probe is embedded with a probe head region 18 disposed at the distal end of catheter/endoscope 10. Probe head region 18 is preferably fabricated from the same material as catheter/endoscope 10. Catheter/endoscope 10 includes at least one further lumen 20 through which one or more coaxial conductors 22 are disposed. Coaxial conductors 22 provide means for conducting electrical signals from the probe head, hereinbelow described, to an external processor of the NMR scanner (not shown). Coaxial conductor 22 to meet the requirements of the relatively small size of lumen 22 is fabricated from an extruded gold filament which is insulated with an appropriate dielectric with a shielded metallization surrounding the dielectric. Coaxial conductors of the requisite size for practicing the present invention are commercially available. Catheter/endoscope 10 may also include further lumens 24 for carrying additional coaxial cables, similar to coaxial cable 22, or be used for conducting additional fluids, as hereinbelow described.

Referring now to FIGURE 4, there is schematically shown one embodiment of an integrated circuit NMR probe 30 of the present invention. Integrated circuit 30 includes an integrated circuit coil 32 for converting the detected NMR spectra into an electrical signal having a frequency F_S. Coil 32 is coupled to a parametric amplifier 34 for frequency up-converting the electrical signal applied thereto. Parametric amplifier 34 includes a capacitor 36 having a time variable capacitance. When the capacitance of capacitor 36 sinusoidally varies at a second selected frequency F_p, parametric amplifier develops an output signal along the line 38 having the frequency of the

algebraic sum of F_s and F_p. Line 38 is conventionally bonded to a center conductor of coaxial cable 22 by conventional bonding means to integrated circuits. A line 40 is bonded to the shielding conductor of coaxial cable 22. A line 42 is bonded to the center conductor of a further coaxial cable (not shown) which provides a signal for sinusoidally varying the capacitance of capacitor 36.

In one embodiment of the present invention, capacitor 36 is an integrated circuit diode operated in reverse by its condition. The signal applied to line 42 has a DC component for reverse biasing the integrated circuit diode and an AC component for modulating the depletion zone width of the reverse bias PN junction. By modulating the depletion width, the inherent capacitance of a reverse bias PN junction is sinusoidally varied.

Coil 32, and lines 38, 40 and 42 are formed from depositing a metallization layer on oxide grown on integrated circuit 30 and selectively etching to form a continuous conductive path. Note that coil 32 requires a further oxidation and second metallization to provide a conductive path from the center of the coil to parametric amplifier 34 when coil 32 contains more than one loop. The number of loops of coil 32 is determined by the frequency of the NMR spectra desired to be measured. The width of coil 32 is approximately equal to the depth of the sample from which the NMR spectra may be determined.

In some applications, it is desirable to also operate coil 32 as a transmitting antenna for a pertubation field. A further conductor 44 may also disposed on integrated circuit 30 and operatively coupled through parametric amplifier to coil 32. A further coaxial cable, similar to cable 22, may provide an RF signal developed by external processing means of

the NMR scanner to apply an RF signal to coil 32. In response to such RF signal, coil 32 radiates an electromagnetic field to provide a localized pertubation to the resonance bin axis of the desired spectra.

Parametric amplifier 34 is well known in the art. Known semiconductor parametric amplifiers are described in Semiconductor-Diode Parametric Amplifiers, Blackwell and Kotzebue, Prentiss Hall, 1961. Another function of parametric amplifier 34 is to provide impedance matching between the impedance of coils 32 and the impedance of coaxial conductor 22 to maximize power transmissions of the signal. Also, by frequency of converting the electrical signal is frequency F_S the effective temperature of coil 32 as seen by external processing means is lowered by a factor commensurate with frequency F_P. Thus, coil 32 may not be additionally cooled when inserted into a body to reduce thermal noise of thermal resistive changes of coil 32. However, additional cooling means may be provided with integrated circuit 30 as hereinbelow described.

Referring now to FIGURE 5, there is shown an alternate integrated circuit probe 50 which includes active components. Integrated circuit 50 includes a plurality of integrated circuit coils 52A-H, fabricated as hereinabove described. An active gate array 54 is programmed to selected one of coils 52A-H. For example, if coil 52A is selected, a one-turn coil is provided. Similarly, if coil 52H is selected an 8-turn coil is selected. A number of turns of the coil selected may thus be programmed remotely from the external processor. An appropriate binary control signal is developed by the external processor and applied to appropriate coaxial conductors through catheter/endoscope 10 to control lines 56_{0-2}.

Control lines 56_{0-2} are conventional metallization paths on integrated circuit 50. Gate array 54 may include common base bipolar transistors to selectively couple one of outputs A-H to an output line 58 which carries the electrical signal developed by coil 52 in response to the NMR spectra and having a frequency F_S. A further metallization lead 60 is bonded to the external conductor of coaxial cable 22 as hereinabove described. Gate array 54 may also include preamplifier means and filter means for filtering the electrical signal as frequency F_S.

When the NMR probe is instructed from integrated circuit 50, the active components thereon need to be cooled to obtain temperature stability. Since in a preferred embodiment of the present invention, if the actual components will be subject to the internal body temperature. Thus, without cooling, thermal noise may obscure the detected NMR spectra. Accordingly, lumens 24 carry a cooling fluid to probe tip region 18 for maintaining a constant temperature below body temperature thereof. For example, cooling means may include a well known closed loop refrigeration circuit. The condenser, compressor and expansion valve of such a cooling circuit are disposed external of catheter/endoscope 10. Lumens 24 provide means for conducting the cooling fluid and also provide the evaporator function of a closed loop cooling system.

In another embodiment of the present invention, cooling means may be integrated on integrated circuit 50 in the form of Peltier junction devices. Such Peltier junction devices comprise reverse bias diodes who have thermal characteristics across the PN junction similar to that of dissimilarities across metallic thermocouples. By regulating the reverse bias voltage across the Peltier

junction, temperature stability of the active component of gate array 54 and of coil 52 may be maintained.

Of course, the present invention need not be restricted to medical applications as hereinabove described. The apparatus of the present invention is useful whenever an integrated circuit NMR probe has utility for obtaining NMR spectra within a sample. It should there be obvious that numerous uses and modifications to the present invention can be made by those skilled in the art without departing from the inventive concepts disclosed herein which are defined by the scope of the appended claims.

WHAT IS CLAIMED IS:

1. In an NMR system having means for magnetically polarizing a sample to be imaged and means for processing detected NMR spectra of said sample, an NMR probe for detecting NMR spectra emitted from within said sample comprising: an integrated circuit carried at a distal end of said probe for insertion into said sample, said integrated circuit including a coil for converting the detected NMR spectra into an electrical signal having a selected first frequency and means for frequency up-converting said electrical signal; and means for conducting said up-converted signal to said processing means.

2. An NMR probe as set forth in Claim 1 wherein said frequency up converter means includes: a passive parametric amplifier having an integrated circuit capacitor, said capacitor having a capacitance which sinusoidally varies at a selected second frequency higher than said first frequency, said up-converted signal having a frequency which is the sum of said first and said second frequencies.

3. An NMR probe as set forth in Claim 2 wherein said capacitor includes: an integrated circuit diode having a p-n junction, said processor means including means for developing a further electrical signal for reverse biasing said diode and for modulating the depletion region width of said reverse bias p-n junction, said conducting means being further for conducting said further electrical signal to said diode.

4. An NMR probe as set forth in Claim 3 wherein said conducting means includes one or more coaxial cables disposed within said probe.

5. An NMR probe as set forth in Claim 1 wherein said probe is fabricated from NMR visible

material.

6. An NMR probe as set forth in Claim 1 wherein the number of turns of said coil is selected for receiving selected frequency NMR spectra of a component of said sample.

7. An NMR probe as set forth in Claim 1 wherein said coil includes metalization disposed on a surface of said integrated circuit and selectively etched to form said coil.

8. An NMR probe as set forth in Claim 1 wherein said probe further includes:

means for cooling said integrated circuit to a substantially constant temperature below the temperature of said sample.

9. An NMR probe as set forth in Claim 8 wherein said cooling means includes:

a plurality of Peltier junction devices integrated into said integrated circuit, said processing means including means for developing a further electrical signal for driving said Peltier junction devices, said conducting means be further for conducting said further signal to said devices.

10. An NMR probe as set forth in Claim 9 wherein said Peltier junction devices are disposed proximate to said coil for reducing thermo-resistive variation in the impedance said coil.

11. An NMR probe as set forth in Claim 8 wherein said cooling means includes:

a closed loop refrigeration circuit having an evaporator in thermal conduction with said integrated circuit, and a condenser, compressor and expansion valve disposed external to said probe and being operatively coupled to said evaporator.

12. An NMR probe as set forth in Claim 1 wherein said processing means includes means for developing a further electrical signal at a selected

second frequency, said conducting means further including means for conducting said further signal to said coil, said coil radiating an electromagnetic field in response to said signal for selectively modulating the magnetic polarization of said sample within the region of said integrated circuit.

13. In an NMR system having means for magnetically polarizing a sample to be imaged and means for processing detected NMR spectra of said sample, an NMR probe for detecting NMR spectra within said sample comprising: an integrated circuit carried at a distal end of said probe for insertion into said sample, said integrated circuit including a plurality of coils, each of said coils being for converting NMR spectra into an electrical signal, and means for enabling a selected one of said coils to detect NMR spectra at a selected frequency at which said selected one of said coils resonates; and means for conducting said electrical signal to said processing means.

14. An NMR probe as set forth in Claim 13 wherein said coupling means includes: a programmable gate array having a plurality of control inputs and plurality of outputs, each of said outputs being coupled to an associated one of said coils, said processing means including means for developing a plurality of binary programming signals for programming said gate array, said conducting means being further for conducting said programming signals to said control inputs of said gate array.

15. An NMR probe as set forth in Claim 14 wherein said conducting means includes one or more coaxial cables disposed within said probe.

16. An NMR probe as set forth in Claim 13 wherein said probe is fabricated from NMR visible material.

17. An NMR probe as set forth in Claim 13 wherein said probe further includes:

means for cooling said integrated circuit to a substantially constant temperature below the temperature of said sample.

18. An NMR probe as set forth in Claim 17 wherein said cooling means includes:

Peltier junction devices integrated into said integrated circuit, said processing means including means for developing a further electrical signal for driving said Peltier junction devices, said conducting means being further for conducting said signal to said devices.

19. An NMR probe as set forth in Claim 17 wherein said cooling means includes:

a closed loop refrigeration circuit having an evaporator in thermal conduction with said integrated circuit, and a condenser, compressor and expansion valve external to said probe and being operatively coupled to said evaporator.

20. In an NMR system having an NMR scanner for receiving a living organism and for magnetically polarizing said organism, and means for processing detected NMR spectra from said organism, a catheter/endoscope comprising: a plurality of lumens disposed longitudinally within said catheter/endoscope; an integrated circuit carried at a distal end of said catheter/endoscope for receiving NMR emissions at an area of interest within said organism, said integrated circuit including a coil for converting the detected NMR emissions into an electrical signal having a selected first frequency and means for frequency up-converting said electrical signal; and an electrical conductor for conducting said up-converted signal to said processing means, said electrical conductor being disposed within one of said lumens.

21. A catheter/endoscope as set forth in Claim 20 wherein said frequency of converter means includes: a passive parametric amplifier having an integrated circuit capacitor, said capacitor having a capacitance which sinusoidally varies at a selected second frequency higher than said first frequency, said up converted signal having a frequency which is the sum of said first and said second frequencies.

22. A catheter/endoscope as set forth in Claim 21 wherein said capacitor includes: an integrated circuit diode having a p-n junction, said processor means including means for developing a further electrical signal for reverse biasing said diode and for modulating the depletion region width of said reverse bias p-n junction, said conducting means being further for conducting said further electrical signal to said diode.

23. A catheter/endoscope as set forth in Claim 22 wherein said conducting means includes one or more coaxial cables, each of said cables being disposed within an associated one of said lumens.

24. A catheter/endoscope as set forth in Claim 20 wherein said probe is fabricated from NMR visible material.

25. A catheter/endoscope as set forth in Claim 20 wherein the number of turns of said coil is selected for receiving selected NMR emissions of a component of said sample.

26. A catheter/endoscope as set forth in Claim 20 wherein said coil includes metalization disposed on a surface of said integrated circuit and selectively etched to form a coil.

27. A catheter/endoscope as set forth in Claim 20 wherein said probe further includes: means for cooling said integrated circuit to a substantially constant temperature below the temperature of said

organism.

28. A catheter/endoscope as set forth in Claim 27 wherein said cooling means includes: a plurality of Peltier junction devices integrated into said integrated circuit, said processing means including means for developing a further electrical signal for driving said Peltier junction devices, said conducting means be further for conducting said further signal to said devices.

29. A catheter/endoscope as set forth in Claim 28 wherein said Peltier junction devices are disposed proximate to said coil for reducing thermo-resistive emissions of said coil.

30. A catheter/endoscope as set forth in Claim 27 wherein said cooling means includes: a closed loop refrigeration circuit having an evaporator and thermal conduction with said integrated circuit, and a condenser, compressor and expansion valve disposed external to said probe and being operatively coupled to said evaporator.

31. A catheter/endoscope as set forth in Claim 20 wherein said processing means includes means for developing a further electrical signal at a selected third frequency, said conducting means further including means for conducting said further signal to said coil, said coil radiating an electromagnetic field in response to said signal for selectively modulating the magnetic polarization of said sample within the region of said integrated circuit.

32. A system for in vivo sensing of RF energy emanating from a body exposed to a NMR scanner comprising:

means for receiving RF energy emanating from said body, said receiving means being dimensioned for insertion into said body; and

means for inserting said receiving means into

said body and for localizing said receiving means at an area of interest within said body.

33. A system in accordance with Claim 32 wherein said inserting means includes an endoscopic tube insertable through an orifice of said body into an organ of said body, said receiving means being disposed at a distal end of said tube.

34. A system as set forth in Claim 32 wherein said inserting means includes an angiographic catheter insertable into a vessel of said body, said receiving means being disposed at a distal end of said catheter.

35. A system as set forth in Claim 32 wherein said system further includes: means for cooling said receiving means to a preselected temperature when said receiver is placed in said body.

36. A system as set forth in Claim 35 wherein: said cooling means includes means for pumping the cooling fluid from a source of said cooling fluid external of said body through said receiving means when inserted into said body; and said inserting means includes means for communicating said cooling fluid from said source to said receiving means.

37. A system as set forth in Claim 36 wherein said inserting means includes an endoscopic tube being insertable through an orifice of said body into an organ of said body and having fluid channels communicating said source with said receiving means, said receiving means being disposed at a distal end of said tube.

38. A system as set forth in Claim 36 wherein said inserting means includes an angiographic catheter being insertable into a vessel of said body and having fluid channels communicating said source with said receiving means, said receiving means being disposed at a distal end of said catheter.

39. A method for in vivo sensing RF energy emanating from an area of interest within a body exposed to an NMR scanner comprising: providing an RF receiver dimensioned to be received within said body for sensing said RF energy; and placing said receiver at said area of interest.

40. A method as set forth in Claim 39 wherein said placing step includes: attaching said receiver to a distal end of an endoscopic tube; and inserting said tube into an orifice of said body communicating with an organ of said body to position said receiver at said area of interest.

41. A method in accordance with Claim 40 wherein said method further includes: pumping a cooling fluid from a source of cooling fluid external of said body to said receiver placed in said body through selected lumens in said tube to maintain said receiver at a preselected temperature.

42. A method as set forth in Claim 39 wherein said placing step includes: attaching said receiver to a distal end of an angiographic catheter; and inserting said catheter into a vessel of said body to position said receiver at said area of interest.

44. A method as set forth in Claim 39 wherein said method further includes: cooling said receiver to maintain a selected temperature when said receiver is placed in said body.

43. A method in accordance with Claim 42 wherein said method further includes: pumping a cooling fluid from a source of cooling fluid external of said body to said receiver placed in said body through selected lumens in said catheter to maintain said receiver at a preselected temperature.

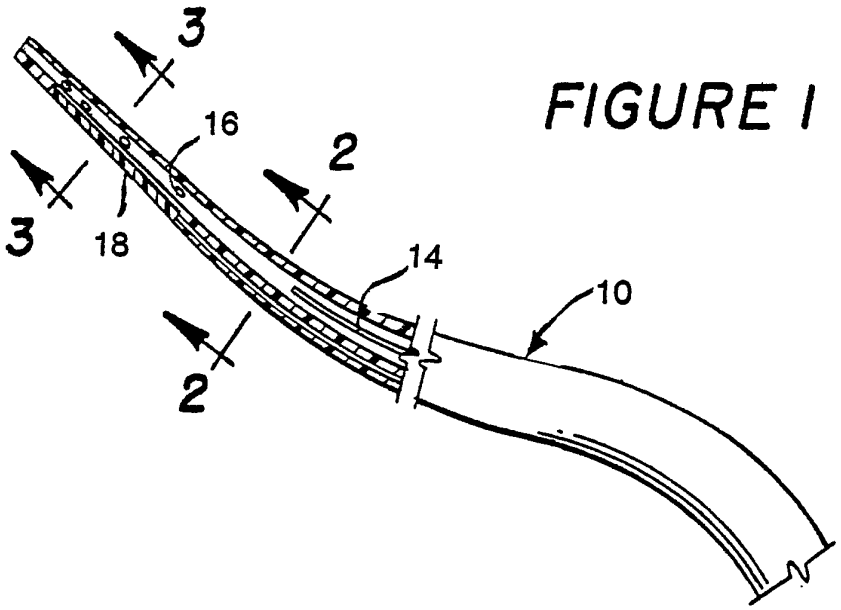


FIGURE 1

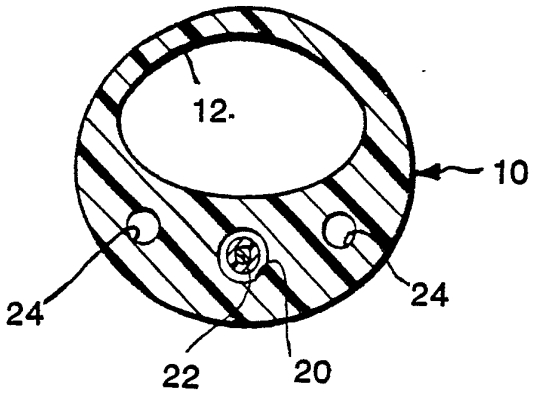


FIGURE 2

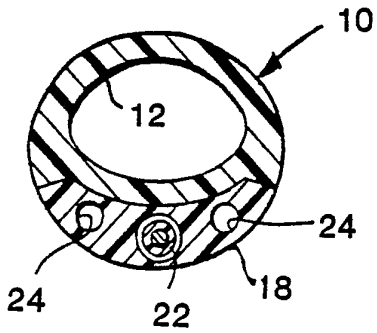


FIGURE 3

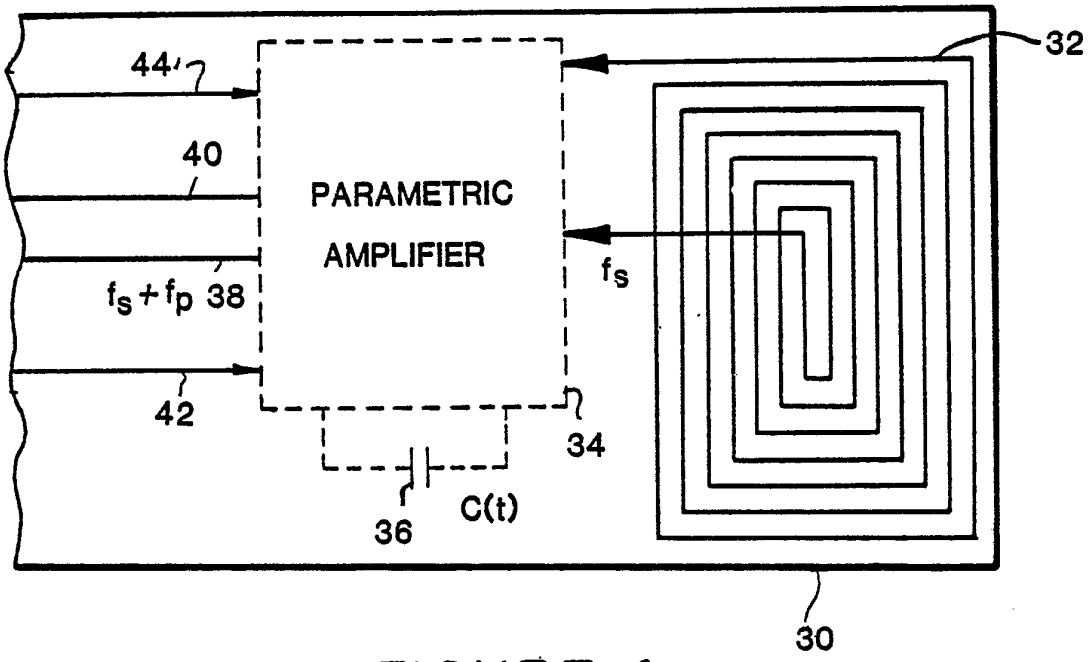


FIGURE 4

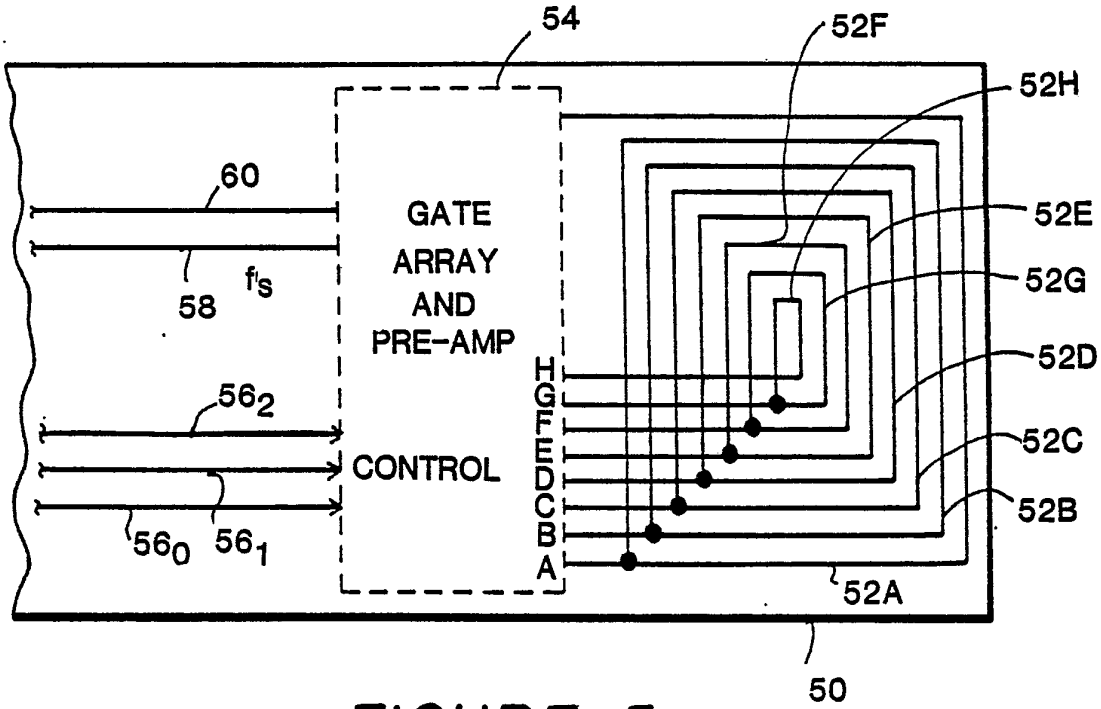


FIGURE 5

INTERNATIONAL SEARCH REPORT

International Application No PCT/US85/01543

I. CLASSIFICATION OF SUBJECT MATTER (If several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

INT CL 4 A61B 5/05
CL 128/653

II. FIELDS SEARCHED

Minimum Documentation Searched [4]	
Classification System	Classification Symbols
U.S.	128/653,658,303.1,748 324/318,322 336/57,62,150

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [5]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category [6]	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US, A, 3,391,690 09 July 1968 ARMAO	8-11,17-19, 17-30,35,36, 41,43,44
Y	US, A, 4,385,636 31 May 1983 COSMAN	32,35,36,39, 44
Y	US, A, 2,961,657 22 November 1960 HODGES et al	13-16
Y	US, A, 2,719,920 04 October 1955 Ellis	13-16
Y	US, A, 3,942,519 09 March 1976 SHOCK	8-11,17-19, 27-30,35,36, 41,43,44
Y	US, A, 3,971,383 27 July 1976 VAN GERVEN	8-11,17-19, 27-30,35,36, 41,43,44
Y	US, A, 4,445,892 01 May 1984 HUSSEIN et al	37-38
A	NL, A, 7,900,245 15 July 1980 PHILLIPS	13-16
A,P	US, A, 4,488,135 11 December 1984 SCHWARTZ	8-11,17-19, 27-30,35,36, 41,43,44
A,P	US, A, 4,467,305 21 August 1984 ANDO	8-11,17-19 27-30,35,36, 41,43,44

Cont. on next sheet

[6] Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
07 October 1985	17 OCT 1985
International Searching Authority [1]	**Signature of Authorized Officer [20]**
ISA/US	R. SMith

Form PCT/ISA/210 (second sheet) (October 1981)

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No [18]
Y	US, A, 3,448,739 10 June 1969 STARK et al	34,38,42
Y	US, A, 4,279,252 21 July 1981 MARTIN	34,38,42
A	US, A, 3,365,686 23 January 1968 PETERSEN	13-16
X	The society of Magnetic Resonance in Medicine, second annual meeting 16-19 August 1983 (San Francisco, CA USA) KANTOR et al, "A Catheter NMR Probe for in vivo NMR Measurements of Internal Organs" page 192	1-44