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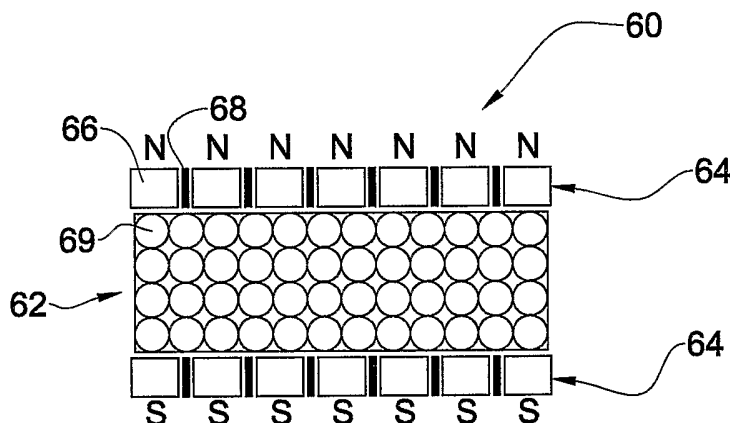
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(54) Title: A MAGNETIC RESONANCE IMAGING METHOD AND DEVICE USING A STATIC AND HOMOGENEOUS  
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(57) Abstract: Described is a system for producing an MRI image of an object portion from magnetic resonance signals produced by the object portion in response to an RF signal transmitted to the object portion when it is in a static and homogeneous magnetic field. The system includes: (i) a probe for detecting the magnetic resonance signals when in the proximity of the object portion; and (ii) a signal processing assembly adapted to receive an output signal from the probe and to process the output signal into image data sets. The probe includes a plurality of RF detectors, each having a defined location and address.

## **A Magnetic Resonance Imaging Method and Device using a Static and Homogeneous Magnetic Field**

### **ABSTRACT**

The present invention provides method, system, and detectors array, for magnetic resonance imaging (MRI) of an object portion. The imaged object portion should be in the vicinity of a probe of the system.

The MRI of the invention utilizes a homogeneous and static magnetic field, and the magnetic resonance signals originated in voxels, which together compose the imaged object portion, are detected by detectors, each of which being sensitive only to signals transmitted from its vicinity, such that magnetic resonance signal that is generated in a single voxel in the object, is detected mainly by a detector which is dedicated to detecting signals arriving from this single voxel. These magnetic resonance signals, together with codes indicative of the addresses of detectors that detected them, are processed to provide MR image of the object portion. A 1:1 mapping is thus provided between signal emitted in a given voxel to a dedicated detector.

### **FIELD OF THE INVENTION**

This invention relates to methods, systems, and detector arrays for magnetic resonance imaging ("MRI") designed for imaging an object portion.

### **BACKGROUND OF THE INVENTION**

In conventional MRI techniques, spatial resolution is achieved by superimposing a stationary magnetic field gradient on a static homogeneous magnetic field. By using a

series of excitations and signal receptions under various gradient orientations, a complete image of nuclear distribution can be obtained. Furthermore, it is a unique quality of MRI that the spatial distribution of chemical and physical characteristics of materials, such as biological tissue, can be enhanced and contrasted in many different manners by varying the excitation scheme, known as the MRI sequence, and by using an appropriate processing method.

It has been suggested to produce MR images utilizing a detector array. Examples to suggestions of this sort have been made, for example, by Kwiat et al, in Med. Phys. 18(2) pp 251-265 (1991). The article describes a method for magnetic resonance imaging, according to which an object is put under a homogeneous magnetic field, and the image is obtained by applying inverse source procedures to the data collected in an array of coil detectors surrounding the object. This approach was experimentally evaluated by Kwiat et al in Med. Eng. Phys. Vol 17 No. 4 pp.257-263 (1995). This article also describes inverse source procedures and algorithms for cancellation of mutual coupling between detectors in the array.

US Patent No. 4,825,162 describes a method for simultaneously receiving a different NMR response signal from each of a plurality of closely-spaced surface coils. A different NMR response signal is received from an associated portion of the sample to produce an image from each coil, and the images are combined on a point-by-point basis.

US Patent No. 6,600,319 describes a device and method for performing NMR measurements and imaging in a surrounding medium. The method utilizes the detection of magnetic resonance signals from within at least one region of a primary, substantially non-homogeneous, external magnetic field.

US Patent No. 6,680,610 describes an apparatus and method for decreasing image acquisition and reconstruction times in magnetic resonance imaging. Magnetic resonance data is acquired in parallel by an array of separate RF receiver coils disposed at generally

circumferentially-spaced locations relative to one another around the imaging volume defined by the body coil of a magnetic resonance imaging apparatus. The apparatus and method operate on the basis of determining an estimate of the sensitivity profile of each RF coil in the array, and thereafter, utilizing those profiles in the creation of a desired image.

### **SUMMARY OF THE INVENTION**

The present invention provides method, system, and detector array, for magnetic resonance imaging (MRI) of an object portion, also referred to as region of interest. The imaged object portion should be in the vicinity a surface defined by the detector array.

The MRI method, upon which this invention relies, utilizes a homogeneous and static magnetic field, and therefore omits the necessity of producing magnetic fields with gradient, which most prior art methods require. The magnetic resonance signals, used for the imaging originates in voxels, which together compose the region of interest. These signals are detected by detectors, each of which being sensitive mainly to signals transmitted from its vicinity, such that magnetic resonance signals which originate from a single voxel in the region of interest are detected mainly by a single corresponding detector, which in turn is dedicated to detecting signals arriving from said single voxel.

The detected signal in each RF detector is indicative of the NMR characteristics of the voxel that lies near that specific detector. Since the magnitude of the static magnetic field decreases with distance from the magnetic module producing it, it is possible to tune the excitation RF frequency to an appropriate resonance frequency that will excite only voxels in a region lying in a predetermined distance from the magnetic module that creates the magnetic field. According to the configuration of the magnets producing the magnetic field, and the nature of the RF excitation pulse (bandwidth and duration) the depth and width of the magnetically excited region will be determined. Generally, it will be a thin layer.

Signals from farther volume elements are weaker because the detected signals are inversely proportional to the cube of the distance between the source of the NMR signal and the detector. This fact requires an appropriate calibration when signals from deeper lying layers are to be collected.

The induced signal in a circular coil antenna of radius  $a$ , from a precessing magnetic dipole located at distance  $r$  perpendicular to the coil's plan and at its symmetry axis is known to be proportional to  $a^2/(a^2+r^2)^{3/2}$ . Accordingly, at the vicinity of coil detectors ( $r \sim a$ ) the signal intensity is proportional to  $1/a$ .

Therefore, microscopic coils are extremely sensitive to signals originated in their vicinity and largely insensitive to signals originated in remote voxels.

Thus, according to one aspect thereof, the present invention provides a system for producing an MRI image of an object portion from magnetic resonance signals produced thereby in response to an RF signal transmitted thereto when said object portion is in a static and homogeneous magnetic field, the system comprising:

- i. a probe for detecting said magnetic resonance signals when in the proximity of the object portion; the probe comprising a plurality of detecting units, each comprising an RF detector with a defined location and address; and
- ii. a signal processing assembly adapted to receive an output signal from said probe and to process said output signal into image data sets.

In one embodiment, the system includes a magnetic module, which forms part of the probe, and is useful for generating a static and homogeneous magnetic field in the vicinity of the probe.

The magnetic module (in this or any other embodiment) may include permanent magnets, solenoids, and the like. It may also include ferromagnetic objects (such as iron

beads) that may be utilized to improve the directionality and the intensity of the static magnetic field.

In a preferred embodiment, the system also includes an RF transmitter capable of transmitting RF signals to cause nuclear magnetic resonance in said object. This RF transmitter may also form part of the probe, for example, it may be so arranged that each of the RF detectors of the probe is also an RF emitter.

By another aspect of the invention there is provided a method for producing a magnetic resonance image of an object portion that is in a homogeneous and static magnetic field, in response to an excitation RF pulse, the method comprising

- a. introducing a probe at the proximity of said object portion, said probe comprising a plurality of RF detectors, each having a defined location and address;
- b. detecting a plurality of magnetic resonance signals produced by said object portion with said RF detectors;
- c. encoding the output of each one of said RF detectors with a code indicative of the address thereof; and
- d. processing the encoded output of said RF detectors into image data sets.

As the magnetic field utilized by the method, system, and detector array of the invention should be homogenous only in the region of interest, which is to be located in the vicinity of the probe, this magnetic field may be produced by a pair of magnets positioned in the vicinity of the probe with the north poles of both magnets heading in parallel in the same direction. Such magnet pair may be attached to the probe and capable of moving with it. Other magnet configurations are not excluded, as long as the purpose

of creating a region of homogeneous magnetic field in the desired region near the detectors is achieved.

The RF detectors of the invented system are preferably arranged in arrays of mutually decoupled detectors, as to eliminate cross-talk. The system of the invention may utilize more than one such detector array. Inter-array decoupling may be achieved electronically, by operating the various arrays sequentially.

Each of the detected signals is marked with a tag indicative of the address of the RF detector that detected it. For instance, the detected signals are simultaneously multiplexed (i.e. each being shifted by a unique frequency shift, and the frequency shifted signals being summed with a carrier signal) to create a multiplexed signal that may be amplified by a single amplifier and/or digitized by a single analog to digital (A/D) converter. The multiplexed signal may then be separated back to produce signals that represent the detected signals, each such signal being associated with a code, being indicative of the address of the detector that detected it. Becoming frequency encoded the detected signals may be summed into one and wireless transmitted for remote processing.

As A/D converters are very expensive, this arrangement allows substantial reduction of costs that may be associated with assembling or purchasing such system.

Multiplexing may be carried out using a quadratic (or other non-linear) amplifier. As such amplifiers produce noise that is not cancelled by summation, in such a case it is preferable to multiplex the signals when they are phase-shifted, such that the quadratic noise of one signal is at least partially subtracted from the noise of another.

By another of its aspects, the present invention provides a system for producing an MRI image of an object portion from magnetic resonance signals produced by voxels included in said object portion. The voxels may define the entire imaged object portion,

or may represent predetermined portions thereof. The system of the invention includes a plurality of detecting units, each with a defined location and address and each for detecting magnetic resonance signals produced by one of the voxels. Each of the detecting units includes an RF detector connected to an encoding circuit that is capable of encoding a magnetic resonance signal detected by said RF detector to produce an encoded signal, such that a plurality of encoded signals, produced by a plurality of detecting units, may be summed to produce a summed signal, which may in turn be digitized and separated to digital signals, each representing a magnetic resonance signal detected by one detecting unit and associated with a tag representative of the address of said detecting unit.

The ability to sum up signals and then separating them back again may have two advantages: it allows the use of a smaller number of A/D converters, and thus allows reduction in cost of the system, and it may be used for noise reduction.

When encoding is achieved by shifting the frequency of the detected magnetic resonance signal, by a non-linear amplifier, part of the noise is squared, and summation does not bring to SNR improvement. This may be overcome by phase shifting the signals. For instance, half the signals may be phase shifted in 180 degrees, such that summing a non-shifted signal with a shifted one brings to noise reduction.

In order to obtain a sharp image, it is preferable that the RF detectors are decoupled from each other. This may be achieved in several ways: one way is to use coils as the RF detectors, and arrange them such that adjacent coils partially overlap with each other. Such arrangement may reduce cross-talk between coils, as well known in the art. Another way is to divide the coils to groups, such that the members of each group are mutually decoupled due to the distance between them. In such a case the different groups are used for signal detection sequentially. Yet another method is to calibrate in advance

the detectors by evaluating the coupling constant between coils and using inverse source algorithm in order to retain decoupled signals.

According to one embodiment of the invention, the plurality of the RF detectors are attached to a flexible carrier that may be curved in various ways, for instance, in order to closely cover a portion of the outer surface of a human body, such as for a portion of a leg or arm. In such cases, it is preferable that the RF signal, required for producing MRI image, is transmitted from the vicinity of the RF detectors, or by the detectors themselves. In the latter case, the RF detectors function also as RF transmitters.

According to one embodiment of the invention, the system also includes a cooling unit, for cooling the electronic circuitry attached to the RF detectors as to reduce noise. Preferably, the cooling unit includes an electrically insulating and non-paramagnetic coolant agent.

Additionally, the RF detectors array for use in the system of the invention may be made replaceable, and manufactured and marketed independently of the other components of the system. Thus, the present invention also provides an array of at least 8 mutually insulated RF coils, being adapted to receiving or transmitting RF waves, each being less than 1mm in height, preferably 0.3mm or less, each having two leads, the leads of all the coils being parallel to each other, wherein each coil nearly touches its adjacent coil, touches it, or partially overlaps with it. Such an array may preferably have coils with diameter of between 20 $\mu$ m to 2mm. Coils having a diameter of between 0.2 to 3mm may be preferred for medical applications, and coils having a diameter of between 20 $\mu$ m and 200 $\mu$ m may be preferred for MRI microscopy.

Methods and systems of the invention are particularly useful for MRI imaging of object portion that is very close to the surface defined by the RF detectors. It may be applied in various applications, such as medical imaging of human body, microscopy,

geological applications, finger print identification, and various industrial applications. Thus according to one embodiment, the probe or detector array is adapted for insertion into a living body, such as a blood vessel, intestine, other hollow tubular organs, etc. For such a purpose, it may be beneficial to provide a probe or detector array with annular or cylindrical form.

### **BRIEF DESCRIPTION OF THE DRAWINGS**

In order to better understand the invention and to see how it may be used in practice, preferred embodiments will now be described by way of non-limiting examples only, in which

**Fig. 1** Fig. 1 is a schematic illustration of a system according to one embodiment of the invention, when in operation;

**Fig. 2** Fig. 2 is a schematic illustration of a system according to another embodiment of the invention, wherein a single A/D converter is used to simultaneously convert a plurality of MR signals;

**Fig. 3A** is a schematic illustration of a probe for use in a system according to one embodiment of the invention, the probe containing two groups of mutually decoupled RF detectors;

**Fig. 3B** is another schematic illustration of the probe illustrated in Fig. 3A, which shows that the detectors of the probe may be viewed as forming part of two systems, each of the kind illustrated in Fig. 2;

**Fig. 4** is a schematic illustration of a probe for use in a system according to one embodiment of the present invention, wherein adjacent RF detectors are decoupled by partial overlap.

**Fig. 5** is a schematic illustration of a probe which includes a magnetic module, for use in a system according to one embodiment of the invention;

**Fig. 6** schematically illustrates a probe with a cooling unit for use in a system in accordance with one embodiment of the present invention;

**Fig. 7A** is a schematic illustration of a cylindrical probe according to one embodiment of the invention; and

**Fig. 7B** is a schematic illustration of a probe according to another embodiment of the invention, the probe having an annular shape.

## DETAILED DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic illustration of a system **2** according to one embodiment of the invention, when in operation. The system **2** has a probe **4** and a signal processing assembly **6** connected to the probe, by wired or wireless connection **8**. The probe **4** is for detecting magnetic resonance signals when in the proximity of an object **10**, emitting such signals. The probe **4** includes a plurality of RF detectors **12**, each having a defined location and address. Each of the detectors **12** is a miniature, single loop coil. The probe **4** is positioned in a receiving distance **d** from a portion **14** of the object **10**. The receiving distance **d** may be shortened or lengthened by manipulation of the RF signal used to produce the MR response of the object **10**. Typically, the receiving distance **d** is in the range of 0.1 to 10mm, more typically 1-5mm. The location of the portion **14** may be moved by moving the probe **4**, for instance, in parallel to or perpendicularly with the

surface 10' of the object 10. When the probe 4 touches the outer surface 10' of the object 10, the portion 14 will lie most deeply inside the object.

The portion 14 may be viewed as composed of voxels 16, and each one of the detectors 12 is sensitive mainly to MR signals emitted from one of the voxels 16, which lies closest thereto. For instance, detectors 12A, 12B, and 12C are sensitive mainly to signals emitted from voxels 16A, 16B, and 16C, respectively. Accordingly, detectors 12A, 12B, and 12C are considered *corresponding* to voxels 16A, 16B, and 16C, respectively. The output of the detectors 12, each representing an MR response of its corresponding voxel, together with the addresses of the detectors, each indicative of the location of said corresponding voxel, are outputted into the signal processing assembly 6 via connection 8, and processed by the assembly 6 to produce MR image of the object portion 14. The processing assembly 6 may be located on the probe 4, away from the probe, or it may have components located on the probe and components located away therefrom.

**Fig. 2** is a schematic illustration of a system 20 according to one embodiment of the invention. The system 20 has a probe (not shown) with a plurality of detecting units 22. Shown are three such detecting units, each having an address: A, B, or C, and including an RF detector 24, an encoder 26 and a phase shifter 28. The encoder 26 is a frequency shifter. The frequency shifts applied by the frequency shifters 26 in each of the detecting units 22 are mutually different. All the detecting units 22 are outputted to a single multiplexer 30. The multiplexer 30 is outputted to an amplifier 31, and from there to a demultiplexer 32, which is an A/D converter. The output of the A/D converter 32 is inputted into a processor 36. It includes digital signals, each being associated with a code (namely, a frequency shift). Each of the digital signals corresponds to an MR signal that was detected by one of the detecting units 22, having a particular address A, B, or C, and each of the codes is indicative of this particular address. The digital signals and codes are being processed into an MR image by the processor 36.

**Fig. 3A** is a schematic illustration of a probe **40** of a system according to one embodiment of the invention. The probe **40** has two groups of RF detectors **42**. The detectors of one of the groups are shown in the figure with solid circles (and in Fig. 3B referred to as detectors of sub-system **100**), and the detectors of the other group are shown in the figure with empty circles (and in Fig. 3B referred to as detectors of sub-system **200**). The detectors in each of the groups are mutually decoupled, since the distance between each two of them is at least  $s$ , and such distance is enough to ensure decoupling. However, detectors of one group may cross-talk with detectors of the other group. Therefore, a group selector (not shown) allows activating the detectors of one of the groups while deactivating the detectors of the other group, in order to eliminate such cross-talk.

Fig. 3B is a schematic illustration of the electronics behind the probe **40** of Fig. 3A. As shown in the figure, the detectors **42** may be viewed as forming part of two sub-systems **100** and **200**, each of the kind illustrated in Fig. 2. The internal components of the sub-systems **100** and **200** are given same numeral references as those appearing in Fig. 2, raised by 100 and 200, respectively. The outputs of the demultiplexers **134** and **234** go into one processor **46**, for processing them into an MR image.

**Fig. 4** is a schematic illustration of a probe **50**, for use in a system according to one embodiment of the present invention. In the probe **50** adjacent RF detectors **52** are decoupled by partial overlap. The exact overlap required may be found empirically, and theoretical guidance for its evaluation is provided, for instance, in Kwiat et al., IEEE transactions on biomedical engineering, vol. 39 No. 5, (1992).

Such arrangement allows a larger density of detectors than the number allowed by the arrangement shown in Fig. 3A. Although dividing the detectors **52** into groups is not required for eliminating cross talk, it may still be preferable for lowering the number of detectors connected to a single multiplexer. At the circumference of the probe **50**, shown is a loop antenna **54** for transmission of excitation pulses.

**Fig. 5** is a schematic illustration of a probe **60** for use in a system according to one embodiment of the invention. The probe **60** has a coil array **62** and magnetic module **64** forming part thereof. The magnetic module **64** includes a plurality of permanent magnets **66** made of Neodymium-iron-Boron (NIB) alloy, all aligned with their north poles directing in the same direction. Spacers **68** are positioned between the magnets **66** to allow the entire probe **60** to be flexible such that it may be curved as to contact surfaces of various curvatures.

In the probe **60**, each coil **69** of the array **62** is both an RF detectors and an RF transmitter, capable of transmitting excitation pulses. The fact that the magnetic module **64**, the RF transmitters and the RF detectors are all together allows moving the probe **60** while retaining appropriate spatial relations between the magnetic field, the transmitted RF signal, and the detectors. For instance, it may be ensured that the magnetic field produced by the magnetic module **64** has a longitudinal component parallel to the coil array **62**.

**Fig. 6** schematically illustrates a probe **70** for use in a system in accordance with one embodiment of the present invention. The probe **70** includes a coil array **72** a magnetic module **74**, an electronic board **76**, a connection **78**, and a cooling unit **80**. The coil array **72** is for detecting and transmitting RF signals, similarly to the coil array of Fig. 5. The electronic board **76** includes circuits allowing encoding and multiplexing such MR signals. The connection **78** is for connecting the probe **70** to an image processing assembly (not shown), and the cooling unit **80** is for cooling the electronic board **76**.

**Figs. 7A and 7B** describe two probes **300** and **400**, each being adapted for insertion into the human body, in particular into a hollow tubular organ such as artery or intestine. Both probes **300** and **400** include a detector array **302** and **402**, respectively, and magnetic module **304** and **404**. The probe **300** has a cylindrical shape, with permanent magnets **306** at each base of the cylinder, while the probe **400** is of an annular shape, with a plurality of permanent magnets **406** at each side

of the ring. The annular shaped probe **400** may allow flow of fluid through it. In Fig. 7A the two magnets have their N pole at the same direction, (for instance, heading up), and in Fig. 7B all the north poles of all the magnets turn to the same direction, for instance, heading inside the ring.

What is claimed is:

1. A system (2) for producing an MRI image of an object portion (14) from magnetic resonance signals produced thereby in response to an RF signal transmitted thereto when said object portion is in a static and homogeneous magnetic field, the system comprising:
  - iii. a probe (4, 40, 50, 60, 70, 300, 400) for detecting said magnetic resonance signals when in the proximity of the object portion; the probe comprising a plurality of RF detectors (24, 42, 52, 69), each having a defined location and address; and
  - iv. a signal processing assembly (6) adapted to receive an output signal from said probe and to process said output signal into image data sets.
2. A system according to Claim 1, comprising a magnetic module (64, 74, 304, 404) forming part of said probe for generating a static and homogeneous magnetic field in the vicinity of the RF detectors.
3. A system according to Claim 1 wherein said probe has an RF transmitter (54) capable of transmitting RF signals to cause nuclear magnetic resonance in said object.
4. A system according to Claim 1, wherein each of said RF detectors is also an RF transmitter capable of transmitting RF signals to cause nuclear magnetic resonance in said object portion.
5. A system according to Claim 1, comprising signal encoders (26, 126, 226) for encoding the output of each of said RF detectors with a code indicative of the address of said RF detector.

6. A system according to Claim 5, comprising a multiplexer (30, 130, 230) for multiplexing the output of a plurality of encoders into a single multiplexed signal.
7. A system according to claim 6, wherein said encoders are frequency shifters.
8. A system according to Claim 7, comprising an amplifier (31, 131, 231) for amplifying said multiplexed signal.
9. A system according to Claim 7 or 8, comprising a demultiplexer for demultiplexing the amplified multiplexed signal into a plurality of components, each representing a magnetic resonance signal detected by one RF detector and associated with a code indicative of the address of said one RF detector.
10. A system according to Claim 1, wherein said probe is adapted for insertion into a living body.
11. A system according to claim 10 adapted for endoscopic purposes.
12. A system according to Claim 10, wherein said probe is adapted for insertion into a blood vessel.
13. A system according to Claim 1, wherein the probe is of an annular or cylindrical form.
14. A system according to claim 1, wherein the probe is flexible, such that it may be curved.
15. A system according to claim 1, wherein said plurality of RF detectors consisting of at least two groups, each of mutually decoupled RF detectors.
16. A system according to claim 15, comprising a group selector for activating one of said at least two groups and deactivating the at least one other group.
17. A system according to claim 2, wherein said magnetic module includes a permanent magnet.

18. A system according to claim 17, wherein said permanent magnet is made of Neodymium-iron-Boron (NIB) alloy.
19. A system according to claim 2, wherein said magnetic module includes a solenoid.
20. A system according to claim 7, wherein said frequency shifters include non-linear amplifiers.
21. A system according to claim 20, comprising phase shifters, capable of shifting the phase of each of the encoded signals, such that upon multiplexing the encoded signals, the total noise is reduced.
22. A system according to any one of the preceding claims, wherein said RF detectors define a surface, and said homogeneous and static magnetic field has a longitudinal component parallel to said surface.
23. A system according to any one of the preceding claims, further comprising a cooling unit.
24. A system according to claim 23, wherein said cooling unit comprises an electrically insulating and non-paramagnetic coolant agent.
25. A method for producing a magnetic resonance image of an object portion that is in a homogeneous and static magnetic field, in response to an excitation RF pulse, the method comprising
  - a. introducing a probe at the proximity of said object portion, said probe comprising a plurality of RF detectors, each having a defined location and address;
  - b. detecting a plurality of magnetic resonance signals produced by said object portion with said RF detectors;
  - c. encoding the output of each one of said RF detectors with a code indicative of the address thereof; and

d. processing the encoded output of said RF detectors into image data sets.

26.A method according to claim 25, wherein the processing includes multiplexing the encoded signals to produce a multiplexed signal.

27.A method according to claim 26, wherein the processing further includes demultiplexing the multiplexed signal to produce a plurality of final signals, each corresponds to a magnetic resonance signal that was detected by one RF detector, and each being associated with a code indicative of the address of said one RF detector.

28.A method according to claim 27, wherein the multiplexed signal is amplified prior to being demultiplexed.

29.A method according to claim 25, wherein said code is a frequency shift.

30.A method according to claim 28, wherein at least one of the encoded signals is phase shifted before being multiplexed, such that the multiplexed signal has higher signal to noise ratio than each of the encoded signals.

31.A method according to claim 30, wherein half of the signals are shifted by 180°.

32.A method according to Claim 25, wherein said object portion is a portion of a living body.

33.A method according to Claim 32, wherein said object portion is the interior of a tubular hollow organ.

34.A method according to Claim 33, wherein said tubular hollow organ is a blood vessel.

35.A method according to Claim 33, wherein said tubular hollow organ is an intestine.

36.A method according to claim 25, wherein said plurality of RF detectors consists of at least two groups, each of mutually decoupled RF detectors,

and each group is activated to detect RF signals when at least one other group is deactivated.

37. A method according to any one of the preceding method claims, further comprising cooling at least a portion of said probe.
38. A method according to claim 42, wherein said cooling is by an electrically insulating and non-paramagnetic coolant agent.
39. An array of at least 8 RF coils, each having the width of 2mm or less, insulated from each other, said coils being adapted to receiving and/or transmitting RF waves, each coil being less than 1mm in height, preferably 0.3mm or less, each coil having two leads, the leads of all the coils being parallel to each other, wherein the distance between each two adjacent coils is not larger than the distance in which adjacent coils nearly touch each other.
40. An array according to claim 43, wherein said distance is such that each two adjacent coils partially overlap as to be mutually decoupled.
41. An array according to claim 43 or 44, wherein each coil has width of between 20 $\mu$ m to 2mm.
42. An array according to claim 43 or 43, wherein each coil has width of between 0.3mm to 2mm.
43. An array according to claim 43 or 44, wherein each coil has a width of between 20 $\mu$ m and 200 $\mu$ m.

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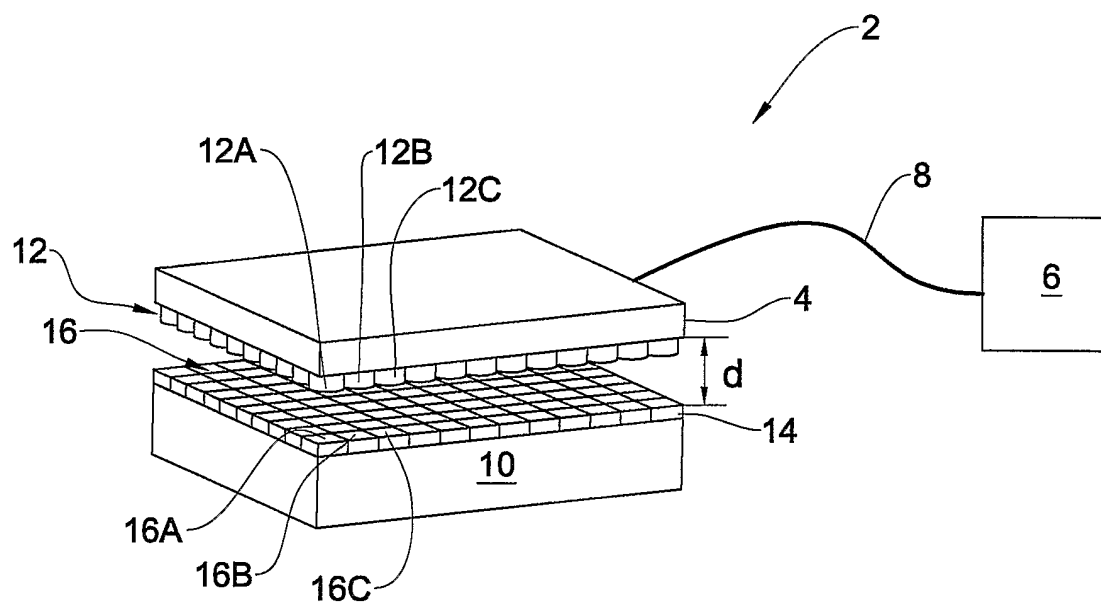


FIG. 1

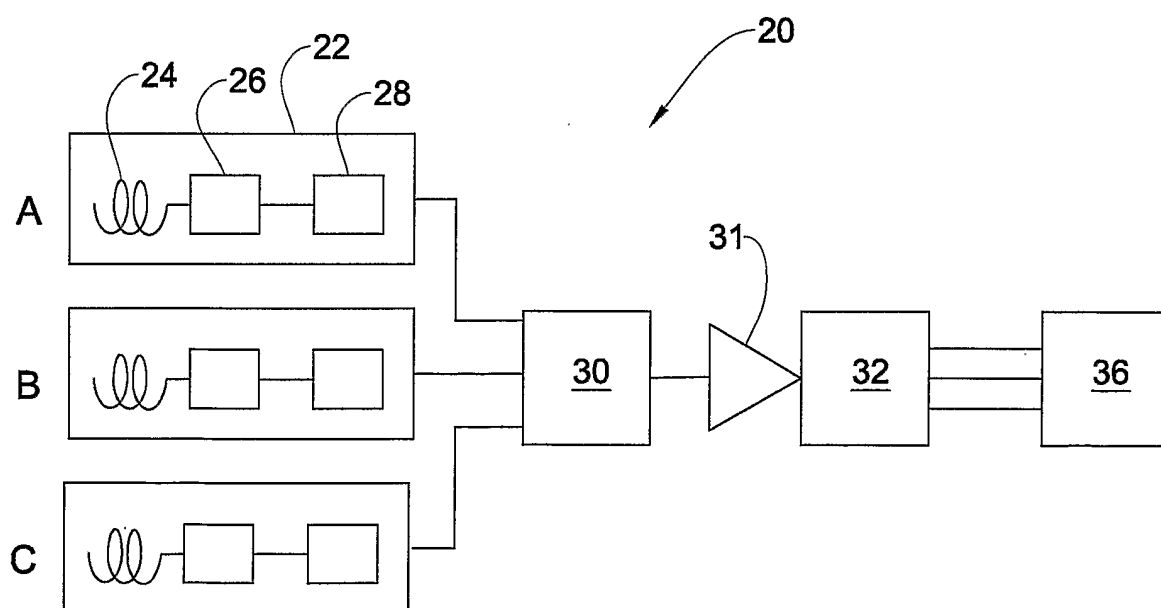


FIG. 2

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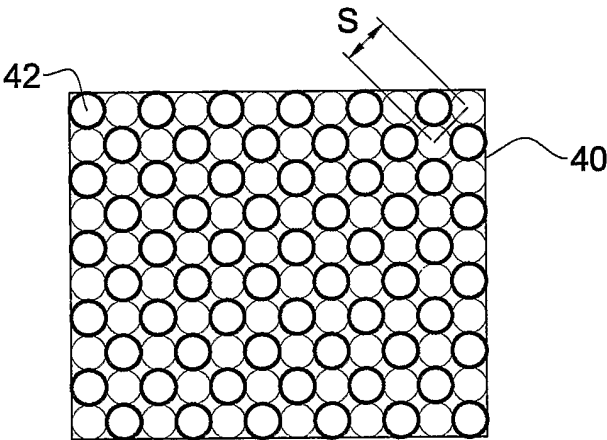


FIG. 3A

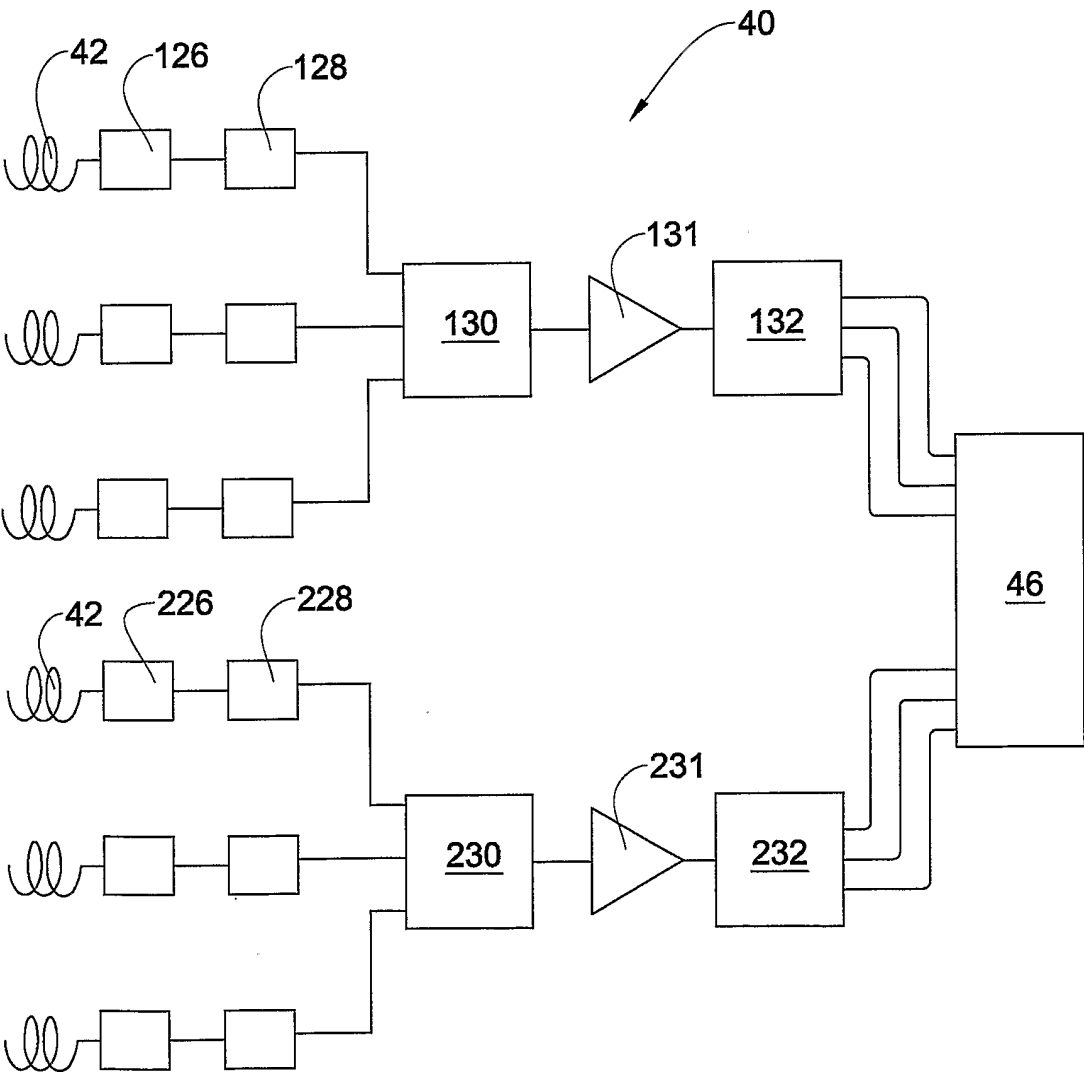


FIG. 3B

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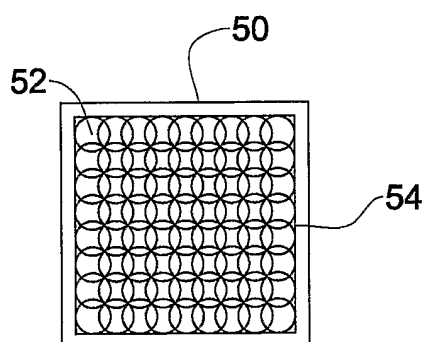


FIG. 4

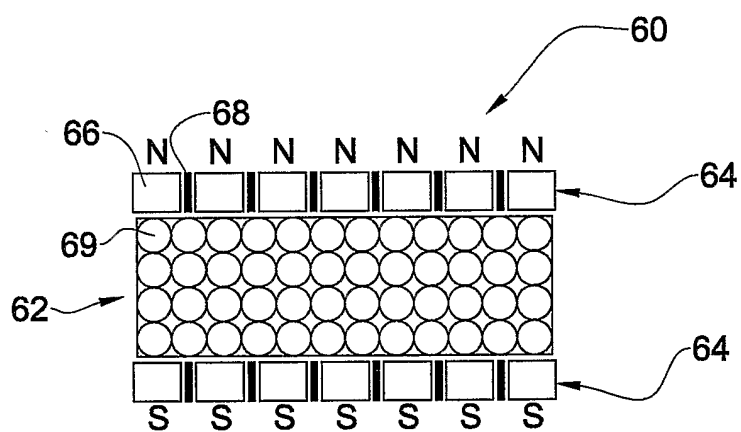


FIG. 5

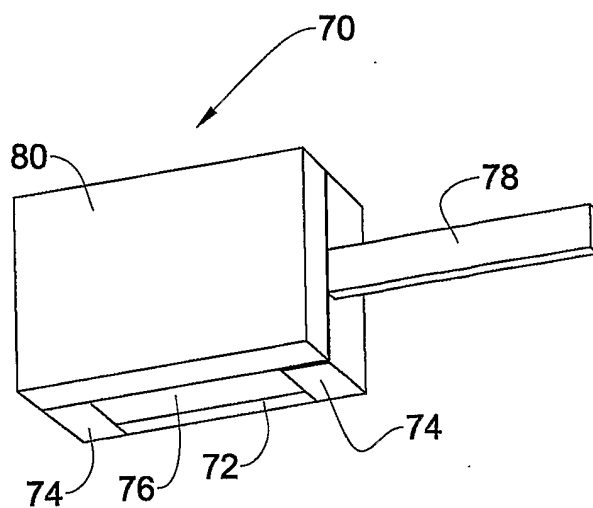


FIG. 6

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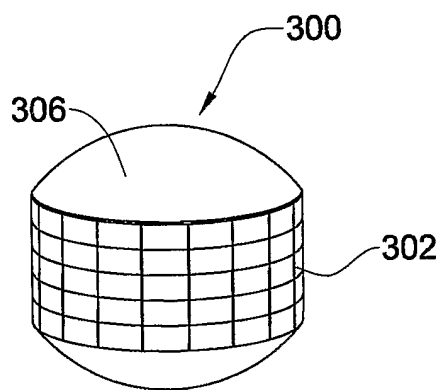


FIG. 7A

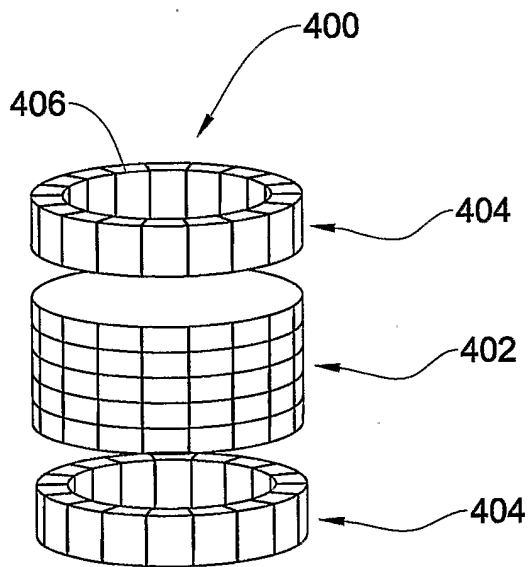


FIG. 7B