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(71) Applicant *(for all designated States except DE, US)*: **KONINKLIJKE PHILIPS ELECTRONICS N.V.** [NL/NL]; Groenewoudseweg 1, NL-5621 BA Eindhoven (NL).

(71) Applicant *(for DE only)*: **PHILIPS INTELLECTUAL PROPERTY & STANDARDS GMBH** [DE/DE]; Steindamm 94, 20099 Hamburg (DE).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **VERNICKEL, Peter** [DE/DE]; C/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **GLEICH, Bernhard** [DE/DE]; C/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL). **LUEDEKE, Kai-michael** [DE/DE]; C/o Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

(74) Agents: **COHEN, Julius, S.** et al.; Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL).

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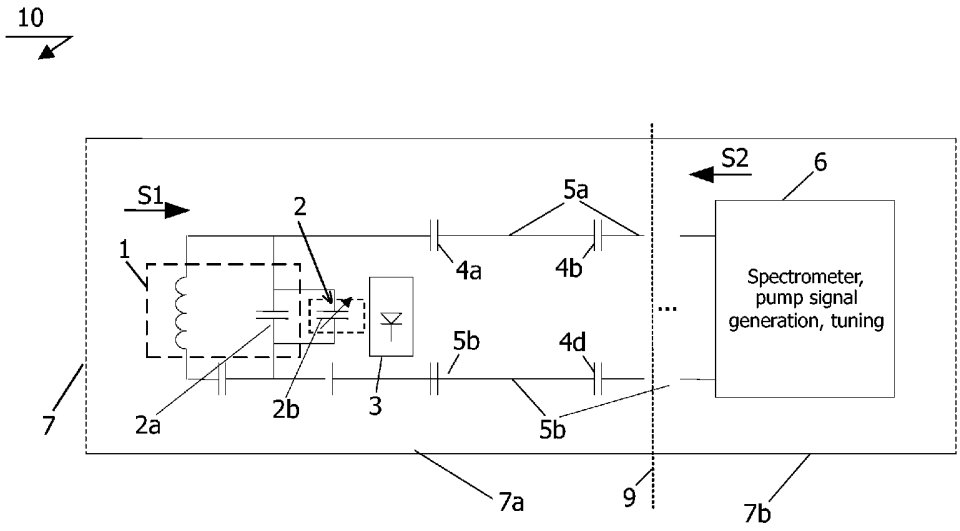
(54) Title: INTERVENTIONAL DEVICE FOR USE IN A MAGNTIC RESONANCE SYSTEM



(57) Abstract: The arrangement 10 according to the invention is suited for transmitting an informative signal Sl, generated by suitable signal generator 1 at a first electrical site 7a to a second electrical site 7b. The first electrical site 7a is electrically connected to the second electrical site 7b by means of a capacitively coupled transmission line 5a, 5b. In order to enable such capacitively coupled transmission line distributed or lumped capacitors 4a, 4b, 4c, 4d can be used. The arrangement is connectable to an accessory device 6, which may comprise a spectrometer, a further signal generator, tuning means, etc. The further signal S2 is conceived to be generated by the accessory device 6 and to be transported via the capacitively coupled transmission line 5a, 5b in a direction from the second electrical site 7b to the first electrical site 7a. The further signal S2 can be used for feeding the amplifier 2, or for carrying the signal Sl. The invention further relates to a magnetic resonance compatible device, a magnetic resonance imaging system and a method of sensing magnetic resonance energy.

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INTERVENTIONAL DEVICE FOR USE IN A MAGNETIC RESONANCE SYSTEM

The invention relates to an arrangement notably incorporated in a magnetic resonance compatible interventional device for a signal transmission between a first electrical site and a second electrical site, said arrangement comprising:

- a wiring for conducting the signal between the first electrical site and the second electrical site, said wiring comprising an input connectable to the first electrical site;
- a signal generator for generating an informative signal conceived to be transmitted via said wiring in a direction from the first electrical site to the second electrical site;
- an amplifier arranged in an electrical connection with the signal generator for providing an amplified informative signal to the input of the wiring.

The invention further relates to a magnetic resonance compatible device.

The invention still further relates to a magnetic resonance imaging system comprising a magnetic resonance imaging device for generating a magnetic resonance frequency in an imaging volume thereof and a magnetic resonance catheter conceived to be positioned in the imaging volume to pick-up a signal representative of the magnetic resonance frequency.

The invention still further relates to a method of sensing a magnetic resonance energy emanating from an imaging volume of a magnetic resonance imager, said method comprising the steps of:

- generating magnetic resonance energy by means of an excitation of a matter disposed in the imaging volume of the magnetic resonance imager using magnetic resonance excitation pulses;
- disposing a probe comprising a sensor arranged at a first electrical site for picking up an informative signal representative of said magnetic resonance energy, whereby the probe further comprises an arrangement for a signal transmission between the first electrical site and a second electrical site.

An embodiment of the arrangement as is set forth in the opening paragraph is known from US 4, 672, 972. The known arrangement is used to detect nuclear magnetic resonance spectra from an object subjected to a magnetic resonance excitation. For this purpose in the known arrangement the generator comprises a receiving coil which is arranged

to generate the informative signal by picking up a free induction decay signal generated in the object at Larmor frequency. In order to transmit the informative signal from the first electrical site, notably the measurement site, to the second electrical site, notably a data analysis site, the known arrangement comprises a wiring cable whereto a suitable amplifier is connected for amplification of the informative signal.

It is a disadvantage of the known arrangement that the electrical field generated by the radio-frequency operatable receiver coil induces radio-frequency currents in the wiring, which may be hazardously increased due to the fact that the wiring and the surrounding medium can form a resonant circuit. The thus induced currents induce not only parasitic disturbances of suitable accessory devices, but may lead to a substantial heating of the wiring and the surrounding medium, which is unacceptable, especially when such arrangement are conceived to be applied in-vivo. It is noted that in principle an imaging session comprises two phases: "transmit" and "receive". In the transmit phase all receivers are detuned and normally do not produce hazardous signal. The wiring, on the contrary, being a conductor constitutes a receiver in which hazardous currents are induced and may be amplified by a cable resonance.

It is an object of the invention to provide an arrangement which is substantially compatible to a radio-frequency environment, notably the magnetic resonance imaging environment.

To this end in the arrangement according to the invention the wiring comprises a plurality of portions connectable by elements enabling a capacitively coupled transmission line.

The technical measure of the invention is based on the insight that by sub-dividing a continuous wiring line into a plurality of portions comprising elements with capacitive electrical properties, hazardous common mode radio-frequency resonances, notably at Larmor frequency are avoided. The capacitively coupled transmission line is designed to have a substantial impedance of respective capacitive couplers for common mode. This also results in an attenuation for the informative signal, which is generated at the first electrical site. To compensate for the attenuation of the informative signal the arrangement according to the invention comprises the amplifier, preferably located in the thus formed electrical circuit nearby the first electrical site. It is noted that the capacitively coupled transmission line is known per se from WO 2004/090914 A1. The disadvantage of the known capacitively coupled transmission line is in the fact that the informative signal is substantially attenuated while passing through the known capacitively coupled transmission

line, leading to a poor signal/noise ratio of the informative signal at the second electrical site. This disadvantage is solved by the arrangement according to the invention by providing an amplifier for suitable amplification of the informative signal.

In an embodiment of the arrangement according to the invention, the arrangement further comprises a further generator for generating a further signal conceived to be transmitted via said wiring at least in a direction from the second electrical site to the first electrical site, whereby the transmission line is further arranged to have a passband for the further signal.

It is found to be advantageous to provide a further signal in the wiring, which may be conveniently used as a carrier signal for the informative signal. Thus, the informative signal is advantageously converted to another frequency with a lower attenuation in the wiring. Alternatively, the further signal may be used as a feed signal for the amplifier of the arrangement. It is preferable to select a higher frequency for the further signal than the frequency of the informative signal, because the impedance of the capacitively coupled transmission line decreases with frequency.

In a further embodiment of the arrangement according to the invention, the capacitive couplers comprise electric lumped capacitors or electric distributed capacitors. The distributed capacitors may be formed by electrical conductors aligned in mutual close vicinity and separated by a suitable dielectric material.

It is found to be advantageous to use electric distributed capacitors as they enable a design of the capacitively coupled transmission line and may be miniaturized. The latter feature is particularly important for interventional devices, like catheters, probes, implants, notably pacemakers.

In a still further embodiment of the invention the amplifier comprises a parametric amplifier.

It is found to be advantageous to use a parametric amplifier based on non-linear properties of components in the arrangement according to the invention. Examples of suitable parametric amplifiers comprise a varactor diode, or a capacitor with non-linear permittivity. An example of the arrangement using a varactor diode will be explained with reference to Figure 1. Preferably, the bias point of the diode is adjustable by supplying short RF pulses from the second electrical site. The RF pulses will be rectified by a suitable additional diode or the varactor diode itself and may be smoothed using an optional capacitor. Conveniently this feature offers an option to tune a resonant frequency of the signal generator when it is implemented as a LC-resonant circuit.

The parametric amplifier operates using a high frequency further signal because achievable amplification is directly related to the ratio between the frequency of the further signal and the frequency of the informative signal. The amplified signal is also at a high frequency because it is usually taken at a difference frequency of the further signal and the informative signal.

In a still further embodiment of the invention, whereby the further signal comprises a radio-frequency signal and the amplifier comprises a linear amplifier, the arrangement further comprises a converter arranged in an electrical connection with the linear amplifier for extracting a direct current component from the further signal for feeding the linear amplifier.

In a still further embodiment of the arrangement according to the invention, whereby a conventional linear amplifier is used. The direct current to drive the amplifier is obtained by sending radio-frequency power by means of the further signal at a convenient frequency and by converting it to direct current at the amplifier's location using a suitable converter. In this arrangement the convenient frequency is freely selectable so that the further signal does not disturb the informative signal or the accessory devices conceived to be connected to the arrangement according to the invention. Further details of this embodiment are discussed with reference to Figure 2.

In a still further embodiment of the arrangement according to the invention, whereby for the further signal comprising a radio-frequency signal, the amplifier is further arranged to comprise a device actuatable by the further signal for multiplying the informative signal.

The present embodiment is an alternative arrangement whereby extra electronic circuitry for rectifying/storing/smoothing/stabilizing the radio-frequency power of the further signal sent to direct current supply of the amplifier is omitted resulting in a simpler arrangement of electric circuitry. The amplifier is thus arranged to comprise a device, for example a transistor array, that can be directly driven by radio-frequency signals of the magnitude of usual supply voltage/currents levels. The gain of such amplifier is a function of the momentary drive level, leading to a resulting output signal being not only an amplified signal, but also a mixer or frequency translation function providing sum and difference frequencies. Preferably, a diplexer is arranged in the electrical circuit of the arrangement according to the invention, for splitting or combining these different output signal components optimally in the required way. Further details of the present embodiment are discussed with reference to Figure 3.

The magnetic resonance compatible device according to the invention is arranged to comprise the arrangement as is discussed in the foregoing.

It is found to be particularly advantageous to provide a magnetic resonance compatible device, notably a magnetic resonance compatible interventional device like a catheter or an external device, which is safe with respect to induced currents even in the environment of magnetic resonance imaging. Preferably, the envisaged devices are used for high-frequency ablation procedures, invasive temperature or pressure sensors, nuclear magnetic resonance probes used for tracking, etc. Still preferably, when the device is an interventional device which is catheter-based, the first electrical site is located at the distal end (tip) of the catheter for picking up the informative signal. In case the amplifier is designed based on a varactor diode, it is preferable that only the varactor diode is located at the distal end of the catheter, whereby other electronic components of the thus formed parametric amplifier are placed at a proximal end of the catheter. Further details of the magnetic resonance compatible device according to the invention are discussed with reference to Figure 4. Still preferably, the magnetic resonance compatible device comprises a pacemaker. It is found to be advantageous to design a pacemaker, which is safe with respect to induced currents even in environments with high intensity radio-frequency signals, notably in the environment of magnetic resonance imaging.

The magnetic resonance imaging system according to the invention comprises:
- the magnetic resonance compatible device comprising the arrangement for a signal transmission between a first electrical site and a second electrical site, said arrangement comprising:

- a wiring for conducting the signal between the first electrical site and the second electrical site comprising an input connectable to the first electrical site;

- a signal generator for generating an informative signal conceived to be transmitted via said wiring in a direction from the first electrical site to the second electrical site;

- an amplifier arranged in an electrical connection with the signal generator for providing an amplified informative signal to the input of the wiring, whereby the wiring comprises a plurality of portions connectable by elements enabling a capacitively coupled transmission line, whereby the magnetic resonance catheter is connectable to an external accessory device.

It is found to be advantageous to provide a fully integrated system for magnetic resonance imaging, whereby the magnetic resonance compatible device, notably an

interventional catheter is used for accurate tracking without inducing hazardous currents in the accessory devices or without heating the environment, notably the patient being imaged. Further aspects of the magnetic imaging system according to the invention will be discussed in more detail with reference to Figure 5.

These and other aspects of the invention will be discussed in more detail with reference to figures.

Figure 1 presents a schematic view of an embodiment of the arrangement according to the invention using a parametric amplifier.

Figure 2 presents a schematic view of an embodiment of the arrangement according to the invention with an amplifier fed by the rectified RF signal.

Figure 3 presents a schematic view of an embodiment of the arrangement according to the invention with a mixer fed by the further RF signal.

Figure 4 presents a schematic view of a first embodiment of the magnetic resonance compatible device according to the invention.

Figure 5 presents a schematic view of the magnetic resonance imaging system according to the invention.

Figure 1 presents a schematic view of an embodiment of the arrangement according to the invention using a parametric amplifier. Embodiments of suitable parametric amplifiers based on nonlinear properties of components comprise, for example, electric capacitance of the varactor diode or a capacitor with non-linear permittivity. The arrangement 10 according to the invention is suited for transmitting an informative signal S1, generated by suitable signal generator 1 at a first electrical site 7a to a second electrical site 7b. The first electrical site 7a is electrically connected to the second electrical site 7b by means of a capacitively coupled transmission line 5a, 5b. In order to enable such capacitively coupled transmission line distributed or lumped capacitors 4a, 4b, 4c, 4d can be used. The arrangement is connectable to an accessory device 6, which may comprise a spectrometer, a further signal generator, tuning means, etc. The further signal S2 is conceived to be generated by the accessory device 6 and to be transported via the capacitively coupled transmission line 5a, 5b in a direction from the second electrical site 7b to the first electrical site 7a. The further signal S2 can be used for feeding the amplifier 2, or for carrying the signal S1.

The present embodiment will describe the arrangement according to the invention based on a varactor diode 2. It is noted that the principle of the varactor diode is known per se in the art, whereby for all elements thereof standard technology may be used. The principle of the amplification by parametric amplifier can be explained as follows: the capacitance C of a capacitor is determined by the charge Q and the voltage V: C = Q/V. If the charge is kept constant and the capacity 2a is decreased, the voltage increases. This can be understood as amplification of the voltage V. The change of the capacitance 2a can be obtained by using a voltage dependent capacitor 2b. Parametric amplifiers are low noise amplifiers and their power amplification is limited to about 20 dB, which is directly related to a ratio of a frequency of the further signal S2 and the informative signal S1 and the power of the further signal S2. Additionally, the arrangement 10 may comprise a bias setting device 3. The further signal S2 is preferably selected in the order of about ten times of the frequency of the informative signal S1. Preferably, the portions of the capacitively coupled transmission line 5a, 5b are selected to be short compared with the wavelength.

Preferably, the arrangement 10 according to the invention is accommodated in a magnetic resonance compatible device, notably a catheter 7 used for MR-tracking, MR-measuring, or for conducting a therapeutic handling under MR supervision. Thus, the first electrical site 7a is located in the distal portion of the catheter (the tip), whereas the second electrical site is located at the proximal portion of the catheter 7b, which are separated by an imaginative line 9. In order to generate the informative signal S1 representative of a suitable MR measurement, the catheter 7 comprises a resonant circuit 1, comprising a receive coil and a resonance capacitor 2a. The varactor diode 2b, connected in parallel to the resonance capacitor 2a serves for necessary amplification of the informative signal S1. The bias point of the diode 2b can be adjusted with short RF pulses rectified by a suitable additional diode or the varactor diode itself and smoothed by an optional capacitor. This option advantageously enables a suitable tuning of the resonant frequency of the receive coil.

Figure 2 presents a schematic view of an embodiment of the arrangement according to the invention with an amplifier fed by the further RF signal. The arrangement 20 comprises a conventional linear amplifier 22. The informative alternating signal S1 is generated by the signal generator 21, and is amplified by the linear amplifier 22. The linear amplifier 22 is fed by the further signal S2, which is provided by a high frequency generator 28, located at or beyond the second electrical site. The further signal is fed by the capacitively coupled transmission line 25 via the rectifier 23 to the linear amplifier 22. The duplexers 24 and 26 are used to separate or to join the different RF signals as required.

Optionally an accessory device 29 is used in the arrangement 10 for carrying out a suitable data analysis.

Figure 3 presents a schematic view of an embodiment of the arrangement according to the invention with a mixer fed by the further RF signal. This particular embodiment removes the necessity for an extra electronic circuitry for rectifying/storing/smoothing/stabilizing of the RF power sent by means of the further signal to the DC supply of the linear amplifier, as discussed with reference to Figure 2. The amplifier of the present embodiment of the arrangement 30 according to the invention comprises a device, for example a transistor array, that can be directly driven by the RF signal of the magnitude of usual supply voltage/currents levels of the high frequency signal generator 38. The gain of such amplification device 32 is a function of the momentary drive level. The result of the amplification will also comprise a mixing of frequency or frequency translation function providing sum or difference frequencies between the informative signal S1 and the further signal S2. The diplexers 33 and 36 are preferably designed to split or to combine different signal components in the required way. The amplified mixed or translated informative signal S1 is preferably supplied to the spectrometer 39 for data analysis.

Figure 4 presents a schematic view of a first embodiment of the magnetic resonance compatible device according to the invention. The magnetic resonance compatible device may be implemented as an implantable pacemaker. In this case, the informative signal S1 is generated by suitable signal generation means 45 located at the first electrical site 42a, said signal S1 being representative of cardiac activity of the recipient. The informative signal is amplified by suitable amplification means (not shown) in accordance with the principles described in the foregoing. The amplified signal is transmitted to the second electrical site 42b, where it is being analyzed by suitable per se known data analysis means 41. In case when the measured cardiac activity deviates from the usual pattern of the recipient a suitable correction signal is sent to the electrodes of the pacemaker (not shown) to correct the heart rhythm. This embodiment of the pacemaker is particularly suitable for undisturbed performance in environments with high intensity of radio-frequency radiation, in particular in the environment of magnetic resonance imaging.

Figure 5 presents a schematic view of the magnetic resonance imaging system according to the invention. The magnetic resonance imaging system 51 comprises a first magnet system 52, a second magnet system 53, a power supply unit 54, an RF transmitter and modulator 56, an RF transmitter coil 55, a transmitter-receiver circuit 59, a signal amplifier and demodulation unit 70, a processing unit 72, an image processing unit 73, a monitor 74,

and a control unit 71. The first magnet system 52 serves to generate a steady magnetic field B0 in an imaging volume (not shown) of the magnetic resonance imaging system 51. The various gradient coils of the second magnet system 53 serve to generate additional magnetic fields having a gradient in the X, Y, Z directions, respectively. The Z direction of the coordinate system shown in Figure 5 corresponds by convention to the direction of the steady magnetic field in the magnet system 52. The measuring coordinate system x,y,z to be used may be chosen independently of the X, Y, Z system illustrated in Figure 5. In the context of the present application gradients are to be understood to mean temporary magnetic fields which are superposed on a steady magnetic field and cause a gradient in the steady magnetic field B0 in three respective orthogonal directions.

The gradient coils 53 are fed by the power supply unit 54. The RF transmitter coil 55 serves to generate RF magnetic fields and is connected to the RF transmitter and modulator 56. The transmitter coil 55 is connected to the signal amplifier and demodulator unit 70 via the transmitter-receiver circuit 59. The control unit 71 controls the RF transmitter and modulator 56, the power supply unit 54.

The magnetic resonance imaging system 51 according to the invention further comprises a magnetic resonance compatible device, notably an interventional catheter 60, which is conceived to be introduced in a vicinity of a target volume (not shown) of the patient P for diagnostic or therapeutic purposes. The distal portion of the catheter 60a comprises a signal generation means (not shown) for generation the informative signal, which is amplified accordingly. The amplified informative signal is transmitted via the capacitively coupled transmission line 60c to the proximal portion 60b of the catheter 60. The proximal portion 60b is connected to suitable accessory devices 70 which are arranged to carry out data analysis. Preferably, the accessory devices 70 are connected to scan controls 72 and 56 by means of wiring 77, 76, whereby the control of the transmit and receive coils of the scanner is enabled in accordance with the signal generated in the catheter 60. Preferably, the magnetic resonance imaging system 51 further comprises a storage unit 75 for storing suitable data and a display unit 74 for displaying suitable diagnostic data, like anatomic structures of the target volume and further information related to the signal of the catheter 60.

CLAIMS:

1. A magnetic resonance imaging system (50) comprising a magnetic resonance imaging device (51) for generating a magnetic resonance frequency in an imaging volume thereof and an interventional device (60) conceived to be positioned in the imaging volume to pick-up a signal representative of the magnetic resonance frequency, said interventional device being arranged, for a signal transmission between a first electrical site (7a) and a second electrical site (7b), said arrangement comprising:
- a wiring(5a) for conducting the signal between the first electrical site and the second electrical site, said wiring comprising an input connectable to the first electrical site (7b);
- a signal generator (1) for generating an informative signal (S1) conceived to be transmitted via said wiring in a direction from the first electrical site (7a) to the second electrical site (7b);
- an amplifier (2) arranged in an electrical connection with the signal generator (1) for providing an amplified informative signal to the input of the wiring (5a), whereby
the wiring comprises a plurality of portions connectable by elements (4a,4b,4c,4d) enabling a capacitively coupled transmission line (5a, 5b)
- and whereby the interventional device is connectable to an external accessory device (70).

2. An arrangement (10) according to Claim 1, whereby the arrangement further comprises a further signal generator (6) for generating a further signal (S2) conceived to be transmitted via said wiring at least in a direction from the second electrical site (7b) to the first electrical site (7a), whereby the transmission line is further arranged to have a passband for the further signal.

3. An arrangement according to Claim 1 or 2, whereby said elements (4a,4b,4c,4d) comprise electric lumped capacitors or electric distributed capacitors.

4. An arrangement according to any one of the preceding Claims, whereby the amplifier (2) comprises a parametric amplifier.

5. An arrangement (10) according to Claim 4, whereby the parametric amplifier comprises a varactor diode (2b) with an adjustable bias point, conceived to be adjusted by a current pulse (S2) propagating from the second electrical site (7b).

6. An arrangement (20) according to Claim 2 or 3, whereby the further signal (S2) comprises a radio-frequency signal and the amplifier comprises a linear amplifier (22), the arrangement further comprises a converter (23) arranged in an electrical connection with the linear amplifier for extracting a direct current component from the further signal for feeding the linear amplifier (22).

7. An arrangement (30) according to Claim 2 or Claim 3, whereby for the further signal (S2) comprising a radio-frequency signal, the amplifier is further arranged to comprise a device (32) actuatable by the further signal (S2) for multiplying the informative signal.

8. A magnetic resonance compatible device, notably an interventional device (40) comprising an arrangement (41,43,45) according to any one of the preceding Claims 1-7.

9. A magnetic resonance compatible device (60) according to Claim 8, when dependent on Claim 4 or 5, whereby said device comprises a catheter (60) with a proximal end (60b) and a distal end (60a), whereby the parametric amplifier comprises a varactor diode located in the distal end (60a) of the catheter, further components of the parametric amplifier being arranged at the proximal end (60b) of the catheter (60).

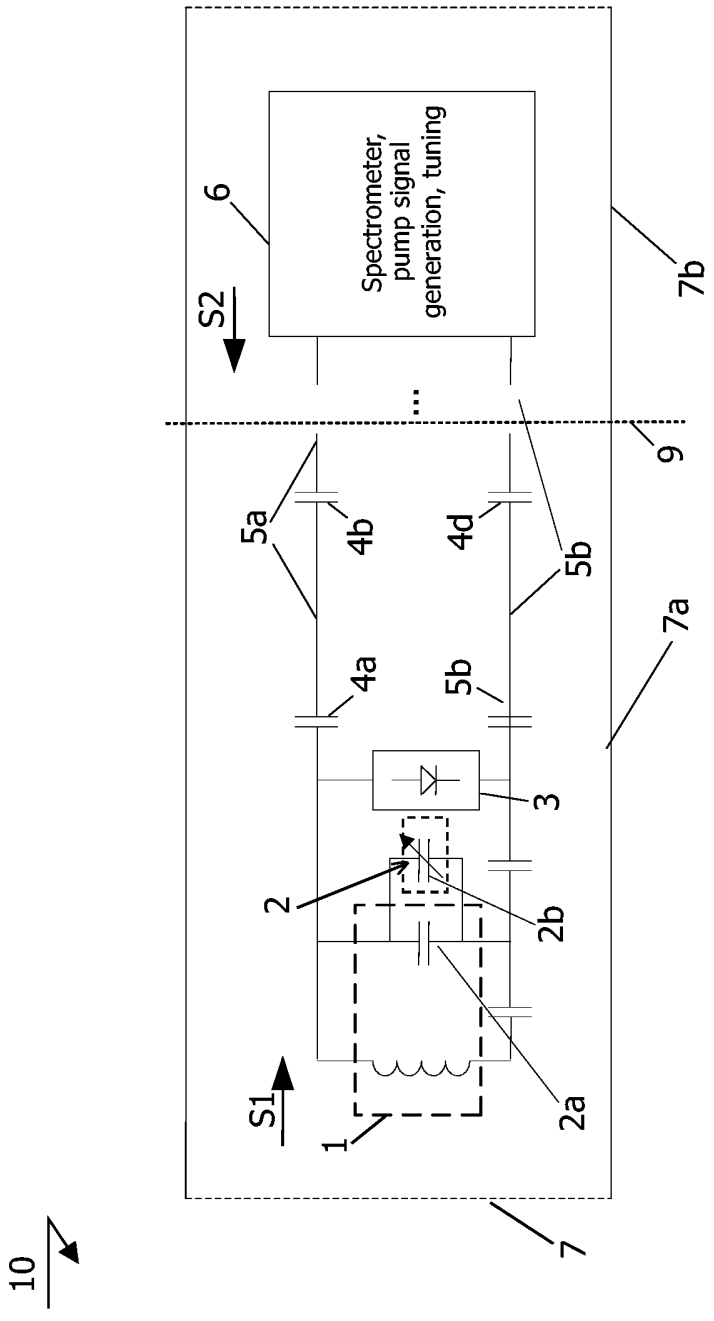
10. A magnetic resonance compatible device (40) according to Claim 8, whereby said device comprises a pacemaker.

11. An arrangement (10) for a signal transmission between a first electrical site (7a) and a second electrical site (7b), said arrangement comprising:
- a wiring (5a) for conducting the signal between the first electrical site and the second electrical site, said wiring comprising an input connectable to the first electrical site (7b);
- a signal generator (1) for generating an informative signal (S1) conceived to be transmitted via said wiring in a direction from the first electrical site (7a) to the second electrical site (7b);
- an amplifier (2) arranged in an electrical connection with the signal generator (1) for

providing an amplified informative signal to the input of the wiring (5a), whereby the wiring comprises a plurality of portions connectable by elements (4a,4b,4c,4d) enabling a capacitively coupled transmission line (5a, 5b).

12. A method of sensing a magnetic resonance energy emanating from an imaging volume of a magnetic resonance imager, said method comprising the steps of:

- generating magnetic resonance energy by means of an excitation of a matter disposed in the imaging volume of the magnetic resonance imager using magnetic resonance excitation pulses;
- disposing a magnetic resonance compatible device comprising a sensor arranged at a first electrical site for picking up an informative signal representative of said magnetic resonance energy, whereby the magnetic resonance compatible device further comprises an arrangement for a signal transmission between the first electrical site and a second electrical site, said arrangement comprising:
  - a wiring for conducting the informative signal between the first electrical site and the second electrical site, said wiring comprising an input connectable to the first electrical site;
  - an amplifier arranged in an electrical connection with the sensor for amplifying the informative signal and for providing the amplified informative signal to the input of the wiring, whereby the wiring comprises a plurality of portions connectable by elements enabling a capacitively coupled transmission line;
- attaching a signal receiver at the second electrical site for receiving the informative signal.


Spectrometer, pump signal generation, tuning
6
S2
7b
9
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S1
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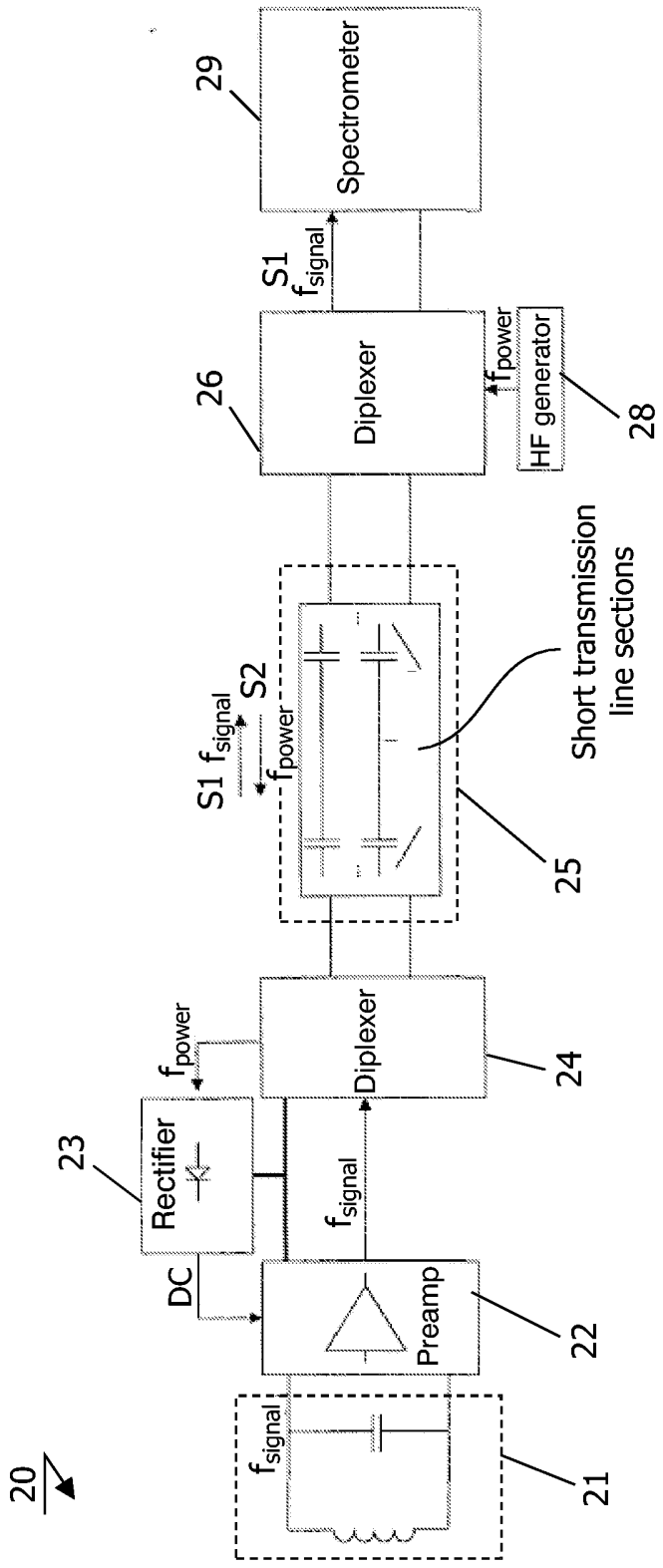
FIG.1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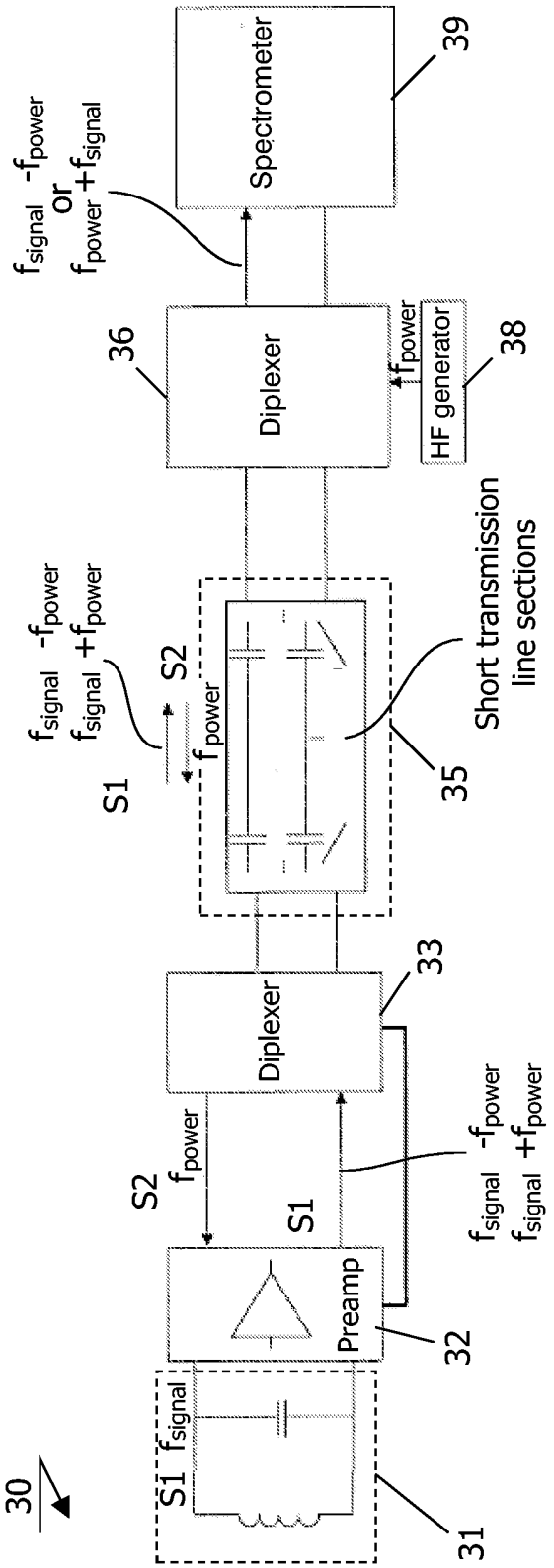
Spectrometer

FIG.2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or
f_{power} $+f_{signal}$
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Diplexer
f_{power}
HF generator
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S2
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S1
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Preamp
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FIG.3

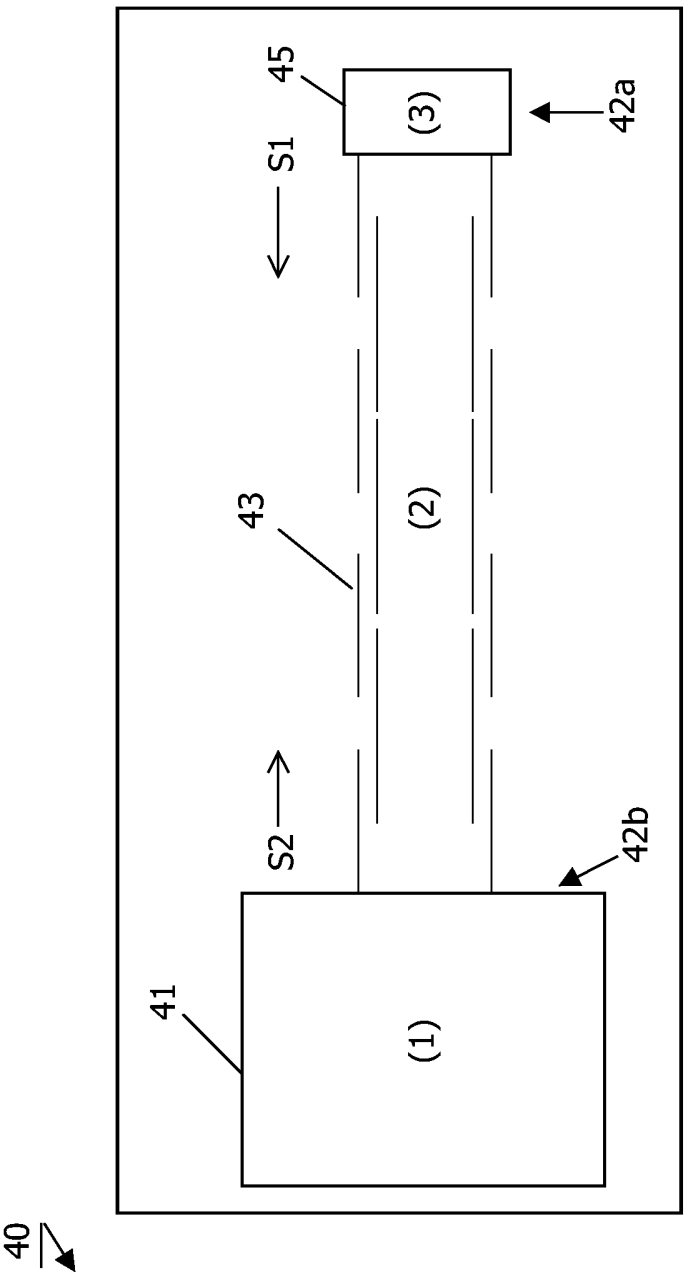
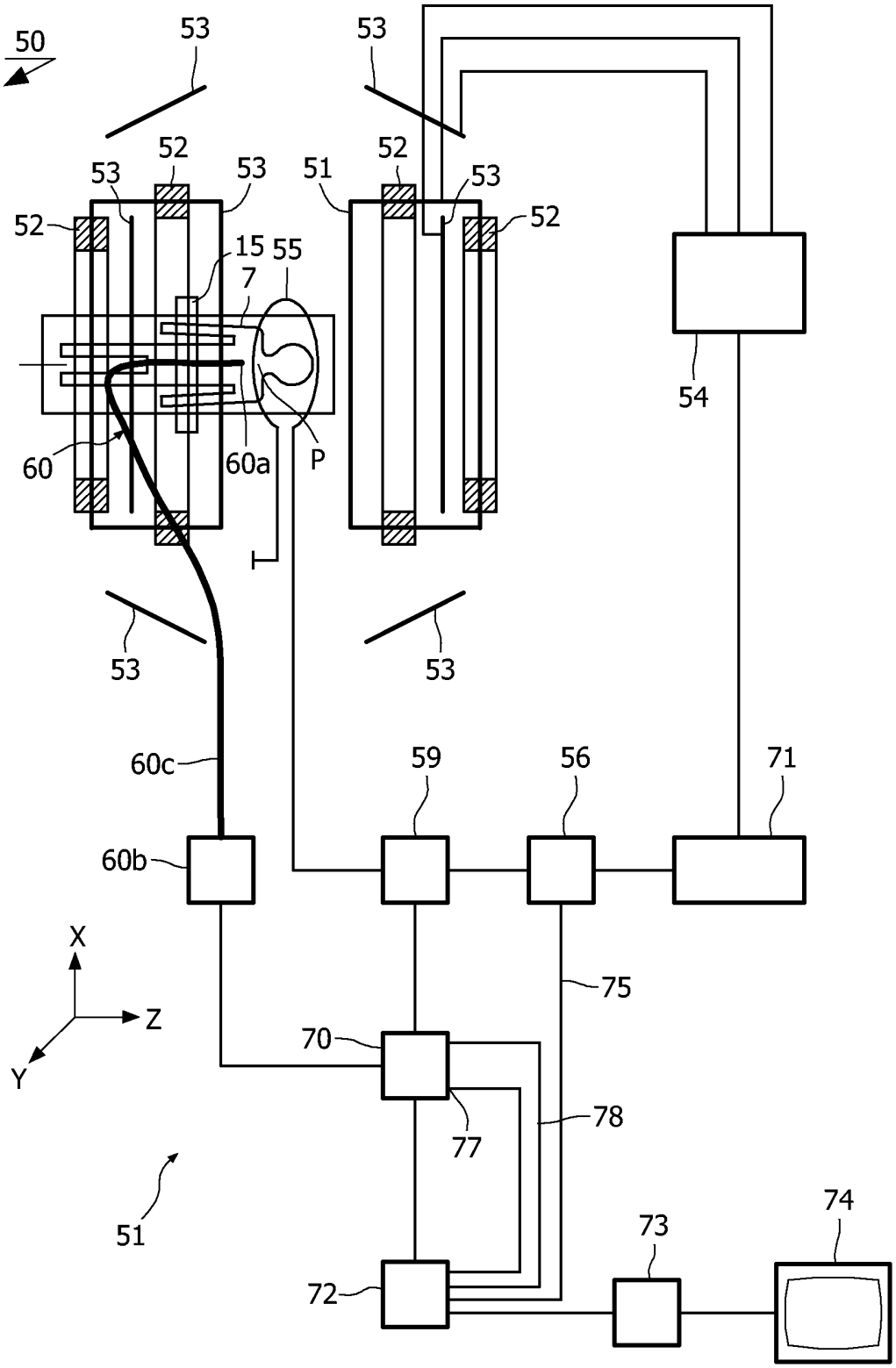


FIG.4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56
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60b
X
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Y
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74
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FIG.5

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/050975

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01R33/28 G01R33/36
ADD. A61N1/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G01R A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, INSPEC, EMBASE, WPI Data, PAJ, COMPENDEX, BIOSIS, MEDLINE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2004/056103 A1 (SEPPONEN RAIMO) 25 March 2004 (2004-03-25) paragraphs [0012], [0058]; claim 18; figures 8,9	1,2,6,8, 11,12 3-5,9,10
Y	WO 2004/090914 A (PHILIPS INTELLECTUAL PROPERTY & STANDARDS GMBH; KONINKLIJKE PHILIPS EL) 21 October 2004 (2004-10-21) cited in the application page 6, line 7 - page 9, line 14	3
Y	WO 2004/038442 A (THE GENERAL HOSPITAL CORPORATION D/B/A MASSACHUSETTS GENERAL HOSPITAL;) 6 May 2004 (2004-05-06) page 22, line 14 - page 23, line 18	4,5,9

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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"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 when the document is taken alone

"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

Date of the actual completion of the international search	Date of mailing of the international search report
28 July 2006	11/08/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Skalla, J

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2006/050975

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FERHANOGLU O. ET AL: "Investigating RF heating of pacemakers in MRI using a safety index" PROCEEDINGS OF THE INTERNATIONAL SOCIETY FOR MAGNETIC RESONANCE IN MEDICINE, TWELFTH MEETING PROCEEDINGS, 15 May 2004 (2004-05-15), page 662, XP002392281 Kyoto, Japan the whole document	10
A	US 2003/173966 A1 (SCOTT GREIG C ET AL) 18 September 2003 (2003-09-18) paragraphs [0005], [0016] - [0023]	1,4,5
A	US 6 236 205 B1 (LÜDEKE KAI-MICHAEL ET AL) 22 May 2001 (2001-05-22) column 4, line 65 - column 5, line 19; figure 3	1,4,5
A	LADD M E ET AL: "Reduction of resonant RF heating in intravascular catheters using coaxial chokes" MAGNETIC RESONANCE IN MEDICINE, ACADEMIC PRESS, DULUTH, MN, US, vol. 43, no. 4, 2000, pages 615-619, XP002260399 ISSN: 0740-3194 page 615 - page 617	1-3,9, 11,12
A	US 6 263 229 B1 (ATALAR ERGIN ET AL) 17 July 2001 (2001-07-17) column 10, line 42 - line 52	1,2,6,7, 9
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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