(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) International Publication Date
12 March 2009 (12.03.2009)

PCT

(10) International Publication Number
WO 2009/031092 A1

(51) International Patent Classification:
G01R 33/385 (2006.01)

(21) International Application Number:
PCT/IB2008/053534

(22) International Filing Date:
1 September 2008 (01.09.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
07115877.8 7 September 2007 (07.09.2007) EP

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

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **LIMPENS, Patrick, W., P.** [NL/NL]; c/o High Tech Campus, Building 44, NL-5656 AE Eindhoven (NL). **ROOZEN, Nicolaas, B.** [NL/NL]; c/o High Tech Campus, Building 44, NL-5656 AE Eindhoven (NL).

(74) Agents: SCHOUTEN, Marcus, M. et al.; High Tech Campus, Building 44, NL-5656 AE Eindhoven (NL).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declaration under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:
— *with international search report*

(54) Title: MAGNETIC RESONANCE EXAMINATION SYSTEM WITH REDUCED ACOUSTIC NOISE

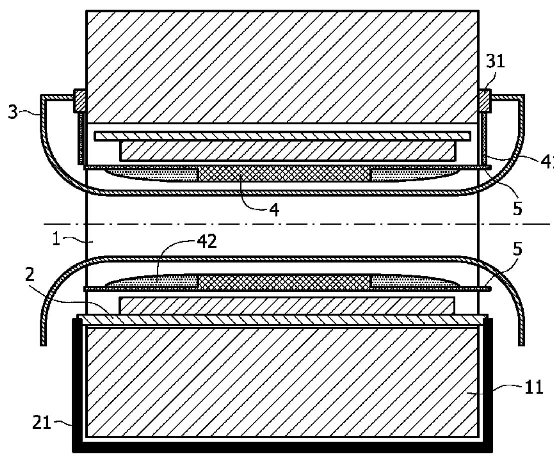

FIG. 1

(57) Abstract: A magnetic resonance examination system comprises an examination zone (1), a gradient coil (2) to generate a gradient magnetic field in the examination zone and a cover (3) positioned between the gradient coil and the examination zone. An RF antenna (4) mounted on an antenna-carrier (5) and positioned between the cover and the gradient coil. The combination of the cover and the antenna-carrier form a double wall with a gap between them. The cover and the antenna-carrier are together located between the gradient coil and the examination zone and effectively counteract the propagation of acoustic noise from the vibrating gradient coil to the examination zone and to the outside of the magnetic resonance examination system.

WO 2009/031092 A1

Magnetic resonance examination system with reduced acoustic noise

FIELD OF THE INVENTION

The invention pertains to a magnetic resonance examination system that comprises a gradient coil. In the magnetic resonance examination system a main static spatially uniform magnetic field is applied. When the gradient coil is activated, a gradient magnetic field is applied across the examination zone and superposed o the main static magnetic field. The gradient magnetic field provides spatial (phase and read) encoding of the magnetic resonance signals that are generated from an object to be examined. When the electrical current through the gradient coil is changed, vibrations of the electrical conductors of the gradient coil occur due to the Lorentz forces to the electrical conductors. In practice, gradient switching causes vibrations of the electrical conductors in the audible frequency range. If no steps are taken, these vibrations generate acoustic noise in the examination zone and also beyond the magnetic resonance examination system. The acoustic noise is found annoying and uncomfortable for a patient to be examined and for the staff operating the magnetic resonance examination system.

BACKGROUND OF THE INVENTION

A magnetic resonance examination system with a gradient coil is known from the Japanese patent application **JP2005/095479**.

This known magnetic resonance examination system comprises a sound insulation that covers the gradient coil. The sound insulation reduces the propagation of acoustic noise from the vibrating electrical conductors of the gradient coil into the examination zone.

SUMMARY OF THE INVENTION

An object of the invention is to provide a magnetic resonance examination system in which acoustic noise generated by the gradient coil is more effectively reduced.

This object is achieved by the magnetic resonance examination system of the invention comprising

- a gradient coil to generate a gradient magnetic field in the examination zone

- a cover positioned between the gradient coil and the examination zone
- an RF antenna mounted on an antenna-carrier and positioned between the cover and the gradient coil.

The combination of the cover and the antenna-carrier form a double wall with a gap between them. The cover and the antenna-carrier are together located between the gradient coil and the examination zone and effectively counteract the propagation of acoustic noise from the vibrating gradient coil to the examination zone and to the outside of the magnetic resonance examination system. The invention is based on the insight that a double wall or a double panel that comprises two walls or panels that are separated by a gap is more effective as acoustic insulation than the sum of the acoustic insulation provided by each of the walls or panels individually. The invention is further based on the recognition that the antenna-carrier itself forms a panel as well as the cover between the antenna-carrier and the examination zone. The antenna-carrier for example has the form of a cylindrical carrier tube or coil former.

The examination zone is generally the region in which good quality magnetic resonance images can be produced of an object, notably a patient to be examined. The examination zone is generally within the region where the magnetic resonance examination system has main magnetic field of appropriate spatial homogeneity and in which the gradient coil produces a gradient magnetic field of appropriate spatial linear field strength. When further steps are taken to correct for artefacts due to main field inhomogeneity and/or gradient non-linearity then the examination zone can be extended.

The cover is positioned between the examination zone and the gradient coil and hides the gradient coil, the RF antenna and other parts of the magnetic resonance examination system from view from the examination zone. The cover also may be shaped to provide an attractive design of the magnetic resonance examination system. Further functions of the cover include for example protection of equipment behind the covers (e.g. RF coil) from body fluids. The cover also provides improved patient safety by shielding from electric conducting hazardous parts (prevent electrical shocks); shielding from hot parts (prevent burns) and creating a suitable distance between patient and RF antenna to have the patient in a low enough EM field (prevent burn form to high local SAR (Specific Absorption Rate).

The cover and the antenna-carrier forming together a double panel acoustic noise insulation do not affect the other functions of the cover and/or the antenna-carrier.

The double panel formed by the cover and the antenna-carrier reduces effectively the acoustic noise level in the examination zone and outside of the magnetic resonance examination system caused by the vibrations of the gradient coil. Also propagation of acoustic noise to other components of the magnetic resonance examination system, such as a cryostat, is reduced. Hence, the acoustic noise level outside of the magnetic resonance examination system is reduced and also He boil-off due to deposition of acoustic energy in the cryostat is avoided. In particular, experiments have shown that a reduction of 18dB/octave is achieved. The reduction of the acoustic noise level improves comfort for the patient to be examined as well as for the staff operating the magnetic resonance examination system. Because patient comfort is improved, the patient to be examined is generally less anxious and acquisition of magnetic resonance signals and image quality is improved.

The gradient coil is preferably mounted on its own proper frame that is separate from the main structure of the magnetic resonance examination system. A gradient coil mounted in its own proper frame is per se known from the international application **WO 2006/054187-A1**

These and other aspects of the invention will be further elaborated with reference to the embodiments defined in the dependent Claims.

According to a further aspect of the invention, the cover is mounted to the main structure of the magnetic resonance examination system by a so-called structural decoupling. This structural decoupling includes a coupling member that achieves mechanical support between the components that are mechanically coupled, while the acoustic impedance of the coupling member is far less than the acoustic impedance of the components that are coupled. This structural decoupling reduces the propagation of acoustic vibrations into the main structure, e.g. including the cryostat, of the magnetic resonance examination system. The coupling member acts as a spring and damper in a mass-spring-damper system. The components that are supported by the coupling member act as a mass in the mass-spring-damper system. Below the first resonance frequency of this mass-spring-damper system, the coupling member acts as a mechanical support for the components. For above the first resonance frequency, in the audible frequency range (50 Hz – 20 kHz), it mechanically decouples the components. Attenuations of more than 10 dB can be achieved in the latter range.

According to another aspect of the invention, the antenna-carrier is mounted to the main structure of the magnetic resonance examination system by a so-called structural decoupling. This structural decoupling of the antenna-carrier to the main structure reduces the propagation of acoustic vibrations into the main structure, e.g. including the cryostat, of the magnetic resonance examination system. Acoustic noise in the examination space is reduced by a decoupling structure between either the gradient coil or the magnet's outer vessel or between the outer vessel and the antenna carrier.

Resilient, e.g. rubber, grommets are suitable as the coupling member to mount the cover and the antenna-carrier to the main structure at low acoustic impedance.

According to a further aspect of the invention a soft foam member is disposed between the antenna-carrier and the cover. The cover is suspended from the antenna-carrier by means of the soft foam member. The soft foam member further reduces transmission of acoustic vibrations from the gradient coil to the main structure and into the examination zone. In particular, the soft foam member avoids that acoustic resonances occur in the gap between the antenna-carrier and the cover and this transmission of acoustic vibrations is reduced.

Further reduction of transmission of acoustic vibrations is achieved by absorber material between the antenna-carrier and the cover.

These and other aspects of the invention will be elucidated with reference to the embodiments described hereinafter and with reference to the accompanying drawing wherein

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 schematically shows an example of a magnetic resonance examination system in which the invention is applied;

Figure 2 schematically shows a detail of an embodiment of the magnetic resonance examination system of the invention and

Figure 3 shows experimental results of the acoustic noise reduction achieved with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 schematically shows an example of a magnetic resonance examination system in which the invention is applied. The magnetic resonance examination system has a main structure 11 which for example includes main field superconducting coils and a cryostat to cool liquid Helium that is used to cool the main coils below their critical temperature to render them superconducting. The gradient coils 2 are mounted on a separate frame 21 that is separate from the main structure. The RF antenna 4, e.g. in the form of a quadrature body coil (QBC), is mounted on the antenna-carrier 5. The antenna carrier usually is a resin coil former. The covers 3 hide the gradient coils and the QBC from view from the examination zone. As is apparent form Figure 1, the cover 3 and the antenna-carrier 5 form a double wall that is located between the gradient coil 2 and the examination zone 1. This structure effectively reduces acoustic noise in the examination zone and in the neighborhood of the magnetic resonance examination system generated by switching of the gradient coil.

The cover 3 is mounted on the main structure 11, in particular on the cryostat by the structural decoupling 31. The antenna carrier (coil former) is connected to the cover at the structural decoupling 31 by way of a soft foam member 41. Further reduction of acoustic noise propagation into the examination zone is achieved by the absorber material 42 between the coil former 5 and the cover 3.

Figure 2 schematically shows a detail of an embodiment of the magnetic resonance examination system of the invention. In particular Figure 2 shows a detail of the structural decoupling 31 which connects the antenna-carrier 5 to the cryostat 11. The coil former 5 is connected to the cryostat by way of a compliant grommet 32. The grommet is compliant in that the first resonance of the mass-spring system is well below 50 Hz (which is the lower limit of the audible frequency range). The cover or antenna carrier is the mass in the system, the grommet is the spring in this system. Also the cover 3 is mounted to the cryostat by means of a compliant grommet 32. Further, Figure 2 shows the cover is suspended from the coil former 5 by a soft foam member 43 which counteracts the propagation of acoustic noise into the examination zone 1. The soft foam member renders the construction of the covers and the antenna carrier more stiff, at the expense of some propagation of acoustic noise into the examination zone. Alternatively, the soft foam member 43 can be dispensed with when selecting a material for the covers that in inherently more self supporting and thus forms a more stiff cover.

Figure 3 shows experimental results of the acoustic noise reduction achieved with the invention. For the frequency range from 10 Hz to 3kHz the acoustic isolation is shown for the magnetic resonance examination system of the invention having a double wall structure and a comparable known magnetic resonance examination system. Improved acoustic isolation is achieved 0.3kHz to 3kHz and notably good results are achieved in the ranges 0.5-0.9kHz and around 1.1kHz and around 2kHz, where the acoustic insulation is about 13dB or 5dB improved, respectively as compared to a single insulation layer.

CLAIMS:

1. A magnetic resonance examination system comprising

- an examination zone (1)
- a gradient coil (2) to generate a gradient magnetic field in the examination zone
- a cover (3) positioned between the gradient coil and the examination zone
- an RF antenna (4) mounted on an antenna-carrier (5) and positioned between the cover and the gradient coil.

2. A magnetic resonance examination system as claimed in Claim 1, the magnetic resonance examination system having a main structure, wherein the cover is mounted to the main structure by a structural decoupling.

3. A magnetic resonance examination system as claimed in Claim 2, wherein the antenna carrier is mounted to the main structure by a structural decoupling.

4. A magnetic resonance examination system as claimed in Claim 2 or 3, wherein the structural decoupling is formed by a resilient grommet.

5. A magnetic resonance examination system as claimed in Claim 1,wherein the cover is suspended from the antenna-carrier, in particular by a soft foam member.

6. A magnetic resonance examination system as claimed in Claim 1, wherein an absorber material is disposed between the antenna-carrier and the covers.

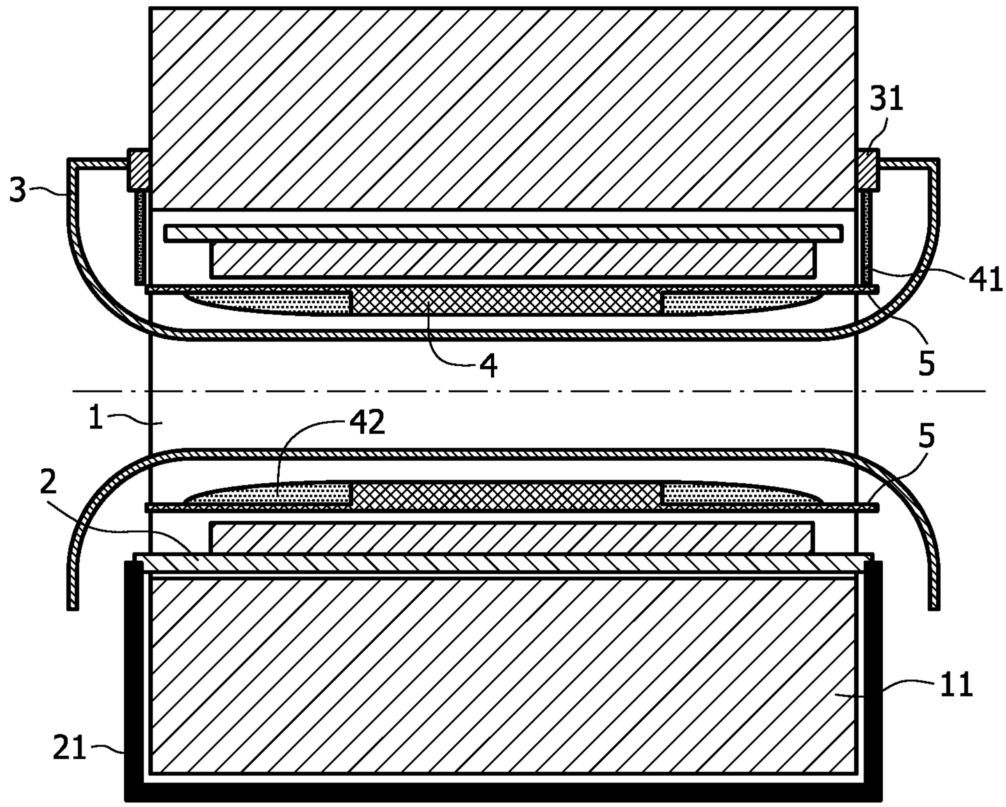

FIG. 1

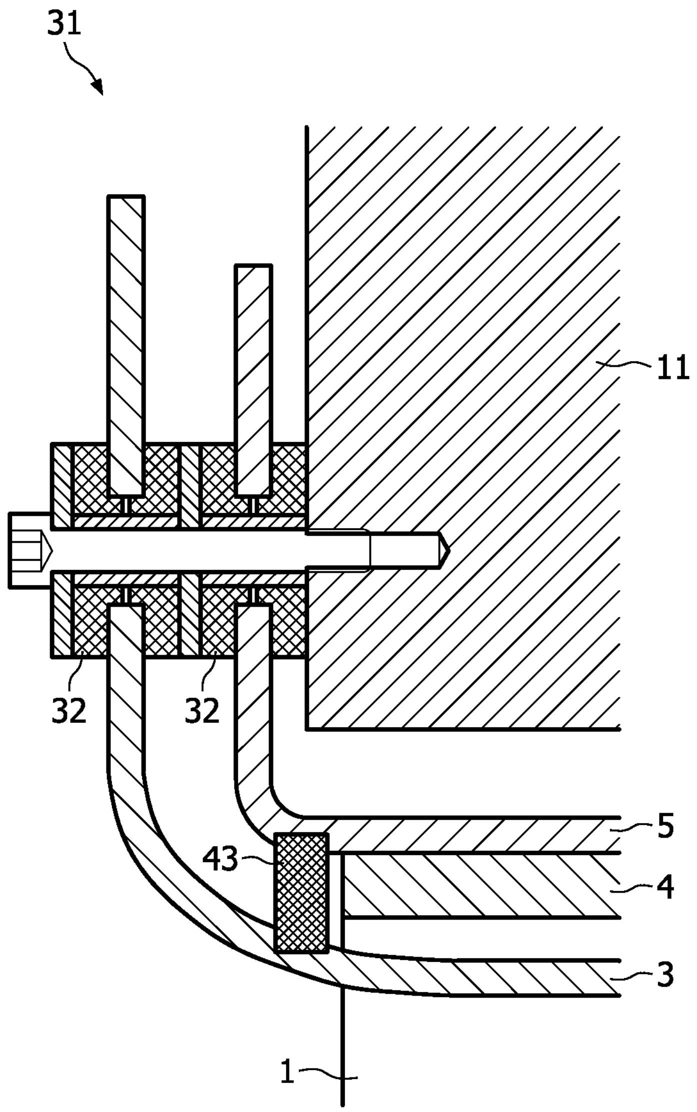

FIG. 2

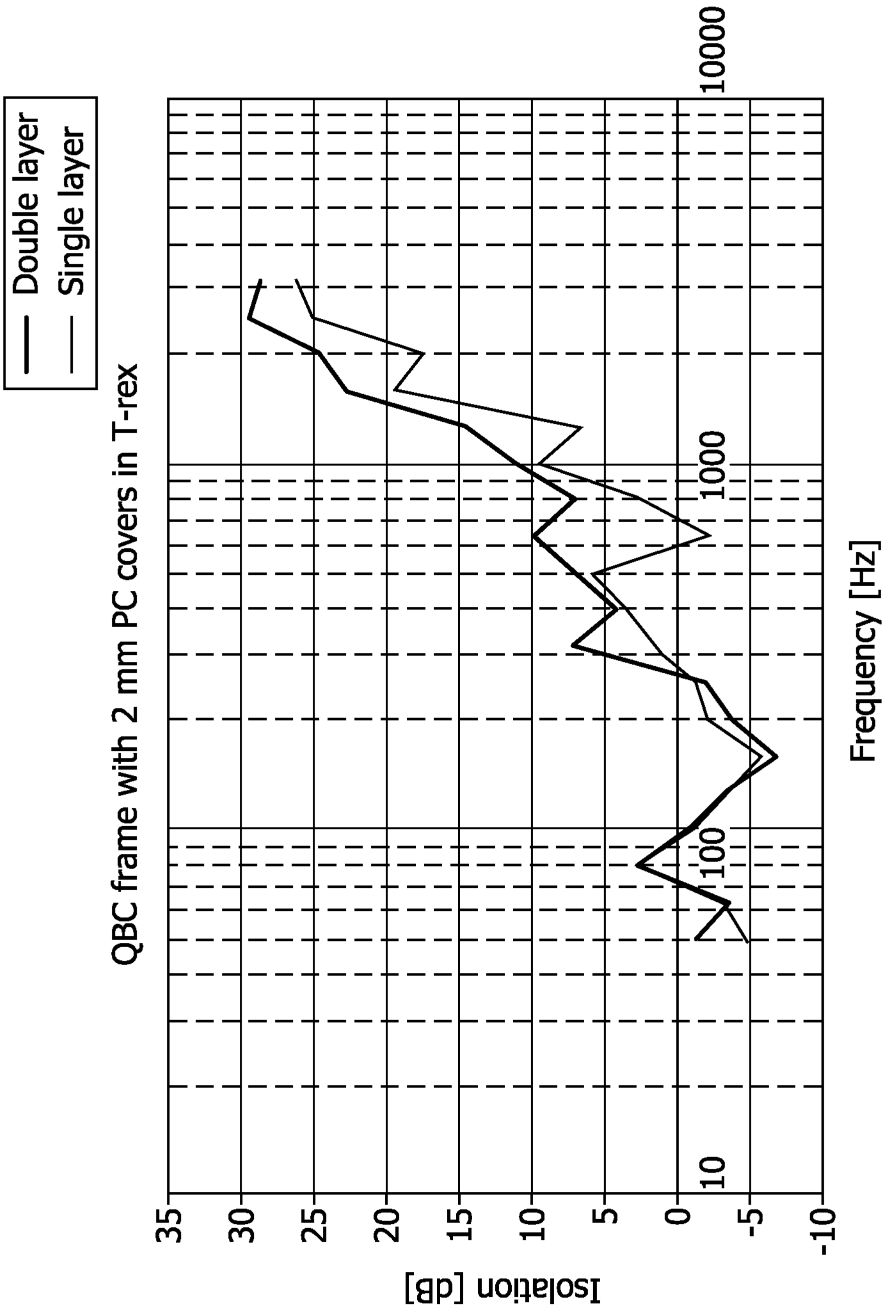
QBC frame with 2 mm PC covers in T-rex
Double layer
Single layer
Isolation [dB]
35
30
25
20
15
10
5
0
-5
-10
10
100
1000
10000
Frequency [Hz]

FIG. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2008/053534

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01R33/385

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

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, COMPENDEX

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 1 193 507 A (GEN ELECTRIC [US]) 3 April 2002 (2002-04-03) paragraphs [0017], [0019], [0021] - [0025], [0028], [0036] - [0038]; figures 1-4	1-3,6
X	JP 2001 299719 A (HITACHI MEDICAL CORP) 30 October 2001 (2001-10-30) the whole document	1-4
X	JP 2005 095479 A (HITACHI MEDICAL CORP) 14 April 2005 (2005-04-14) cited in the application figures 1,4-6	1,3,5

-/--

[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

"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 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
21 October 2008	30/10/2008

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, Fax: (+31-70) 340-3016	Lersch, Wilhelm

Form PCT/ISA/210 (second sheet) (April 2005)

International application No
PCT/IB2008/053534

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	EP 1 077 382 A (GEN ELECTRIC [US]) 21 February 2001 (2001-02-21) paragraphs [0003] - [0005], [0015] - [0022]; figures 2,5	1,2 6
Y	US 6 414 489 B1 (DEAN DAVID E [US] ET AL) 2 July 2002 (2002-07-02) column 2, line 46 - column 4, line 42; figures 1-5	6
A	DE 10 2004 042100 A1 (SIEMENS AG [DE]) 5 January 2006 (2006-01-05) paragraphs [0003], [0016] - [0022]; figures 1,2	2-4
A	JP 2001 258864 A (TOSHIBA MEDICAL SYS CO LTD; TOKYO SHIBAURA ELECTRIC CO) 25 September 2001 (2001-09-25) figures 4-7	2,3
A	KATSUNUMA A ET AL: "Quiet MRI with novel acoustic noise reduction" MAGNETIC RESONANCE MATERIALS IN PHYSICS, BIOLOGY AND MEDICINE, CHAPMAN AND HALL, LONDON, GB, vol. 13, no. 3, 1 January 2002 (2002-01-01), pages 139-144, XP002246720 ISSN: 1352-8661 the whole document	3

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2008/053534

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 1193507 A	03-04-2002	CN 1344928 A	17-04-2002
		DE 60130854 T2	17-07-2008
		JP 4049565 B2	20-02-2008
		JP 2002219112 A	06-08-2002
		KR 20020026835 A	12-04-2002
		US 6437568 B1	20-08-2002
JP 2001299719 A	30-10-2001	NONE	
JP 2005095479 A	14-04-2005	NONE	
EP 1077382 A	21-02-2001	DE 60032976 T2	08-11-2007
		JP 2001178703 A	03-07-2001
		US 6252404 B1	26-06-2001
US 6414489 B1	02-07-2002	NONE	
DE 102004042100 A1	05-01-2006	NONE	
JP 2001258864 A	25-09-2001	JP 3367932 B2	20-01-2003