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D E C I S I O N
of 28 November 2003

Case Number: T 0247/00 - 3.4.1

Application Number: 96926688.1

Publication Number: 0813685

IPC: G01R 33/20

Language of the proceedings: EN

Title of invention:
System and method for contraband detection using nuclear quadrupole resonance

Applicant:
Quantum Magnetics, Inc.

Opponent:
-

Headword:
-

Relevant legal provisions:
EPC Art. 56

Keyword:
"Inventive step (yes) - after amendment"

Decisions cited:
-

Catchword:
-

Case Number: T 0247/00 - 3.4.1

D E C I S I O N
**of the Technical Board of Appeal 3.4.1
of 28 November 2003**

Appellant: Quantum Magnetics, Inc.
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Decision under appeal: **Decision of the Examining Division of the European Patent Office posted 21 October 1999 refusing European application No. 96926688.1 pursuant to Article 97(1) EPC.**

Composition of the Board:

Chairman: G. Davies
Members: M. G. L. Rognoni
G. Assi

Summary of Facts and Submissions

I. The appellant (applicant) lodged an appeal, received on 17 December 1999, against the decision of the examining division, dispatched on 21 October 1999, refusing the European patent application No. 96926688.1 (publication number 0 813 685). The fee for the appeal was paid 17 December 1999. The statement setting out the grounds of appeal was received on 18 February 2000.

II. In the contested decision, the examining division held that the subject-matters of claims 1 and 17 according to the main request and to the first and second auxiliary requests lacked an inventive step within the meaning of Article 56 EPC, having regard to the following documents:

D1: US-A-5 206 592

D2: Electronics and Communications in Japan, Part 1, Vol. 77, 1994, pages 37 to 45

D3: Rev. Sci. Instrum. 53 (1982) pages 984 to 988

D4: US-A-5 208 537

D5: WO 94/12891

D6: Advances in Analysis and Detection of Explosives, J. Yinon (ed.) 1993, Kluwer Academic Publishers, M.L. Buess *et al.*:"Explosives Detection by ^{14}N pure NQR^{+}", pages 361 to 368

D7a: US-A-5 024 229

D7b: J. Magn. Res. 68 (1986) pages 319 to 322

D8: J. Magn. Res. 47 (1982) pages 515 to 521

III. Oral proceedings were held on 9 October 2003.

IV. The appellant requests that the decision under appeal be set aside and a patent be granted on the basis of the following documents:

- Claims 1 and 10 faxed on 7 November 2003 and claims 2 to 9, 11 and 12 filed in the oral proceedings on 9 October 2003;

- Pages 5 to 7 of the description filed in the oral proceedings, with pages 1 to 4 and 8 to 23 of the description as originally filed;

- Figures 1 to 7 as originally filed.

V. The wording of claim 1 reads as follows:

"A system for detecting a target substance within a class of explosives and narcotics containing quadrupolar nuclei in a specimen employing the phenomenon of nuclear quadrupole resonance (NQR), the system including:

- *a sequence controller (21) having means for providing timing and programming pulses to said system;*

- *a radio frequency (RF) subsystem (22) comprising:*
  - *a variable frequency RF source (23) to provide pulsed RF excitation at a frequency generally corresponding to a predetermined characteristic nuclear quadrupolar resonant frequency of the specimen, wherein nuclear quadrupolar resonant frequency is the frequency of nuclear precession*

due to quadrupolar interaction with molecular electric field gradients;

– *a detection head subsystem (33) comprising:*

– *an RF coil to transmit the RF excitation and functioning as the pickup coil for the NQR signals from the specimen and providing an NQR output signal, wherein said RF coil, and is a single turn RF coil made of a single sheet (34) of highly conductive material shaped and configured to define a cavity (52, 65) of predetermined volume therein and to receive the specimen within the cavity defined by said RF coil, said RF coil being formed on an insulator frame (51) with a linear gap (101) between confronting edges of said RF coil sheet, and wherein the RF signal from said RF source is transmitted within said cavity and is uniformly applied to the specimen within said RF coil cavity;*

– *a multiplicity of static tuning capacitors (102) connected between said RF coil confronting edges, said static tuning capacitors being configured and spaced to provide a uniform RF flux field within said RF coil cavity when excited by RF pulses; and*

– *an electrically conductive RF shield (37) surrounding, spaced from and electrically isolated from said RF coil, said RF shield being shaped and configured to provide electromagnetic interference and radiofrequency interference (EMI/RFI) shielding from external noise and to* *prevent RF magnetic flux from escaping from said RF coil cavity and RF shield configuration, said RF shield configuration being longer than said RF coil, thereby extending beyond both said first end and said second end of said coil, wherein said cavity has a first end and a second end and is rectangular in shape, with its shorter sides having a first dimension, wherein the spacing between said RF coil and said RF shield is about one-half of said first dimension, and wherein said RF shield extends past at least the open end of said RF coil by a distance that is substantially equal to one-half of said first dimension, said RF shield being an electrically integral part of said RF coil to improve the Q and the efficiency of said RF coil and contributing to the uniformity of flux field applied to the specimen within said RF coil, said RF coil and said RF shield forming a scanner;*

– *at least one cavity extension element (66, 71) coupled to said scanner and comprising waveguide below cut-off, said extension element having an opening therethrough which is the same cross-sectional size as said cavity;*

– *automatic means for tuning said RF coil to about the desired characteristic nuclear quadrupolar resonant frequency for the specimen under test and comprising:*
  – *a series of fixed value capacitors (93) switched by controllable switch means (94); and*

- *control means (91) for controlling the switching sequence of said capacitors to establish maximum power transfer efficiency of said RF coil;*

- *a signal capture and data processing subsystem (41) having a digital signal processor (44) and comprising:*
  - *means for receiving the NQR output signal from said RF coil, and*
  - *means for processing the NQR output signal from said RF coil;*

- *memory means which store characteristics of NQR signals from at least one target substance in the class explosives and narcotic compounds;*

- *means for comparing characteristics of the processed NQR output signal with the characteristics in memory and emitting a final output signal;*

- *a display device (46) receiving the final output signal from said signal capture and processing subsystem and having means to selectively indicate:*
  - *the presence of the target substance,*
  - *the absence of the target substance, and*
  - *an intermediate result when conditions of the received signal from the specimen indicate that further testing is necessary; and*

- *means to identify and differentiate acoustic ringing signals from NQR signals, wherein said identifying and differentiating means comprises:*

- *said sequence controller and said RF source, in combination with said detection head subsystem to apply excitation RF pulses to said RF coil which are separate and distinct from the RF excitation pulses at the quadrupolar resonant frequency, whereby the system is operated at a frequency outside the range of the NQR sample frequency, or*
- *means to determine the nature of the signal response based on the principle of acoustic ringing that the ringing signal decays with time and, within a limited time period, between respective RF pulses, the NQR signal increases with time."*

Claims 2 to 9 are dependent on claim 1.

The wording of claim 10 reads as follows:

"A method for detecting a target substance within a class of explosives and narcotics containing quadrupolar nuclei in a specimen using a system according to claim 1, said method comprising the steps of:

- *providing precisely programmed timing pulses to the detection system;*
- *providing excitation RF pulses of a predetermined frequency to the RF coil;*
- *detecting by the RF coil the NQR signals emitted by target substances within the specimen;*
- *entering known characteristics of NQR signals of target substances in memory in a data signal processor (44) in the detection system;*

- *inserting the specimen within the cavity formed in the RF coil; then*
- *automatically tuning the RF coil to maximum power transfer efficiency for RF signals transmitted within the RF coil cavity;*
- *transmitting the RF pulses into the cavity formed by the RF coil and creating a uniform flux field within the RF coil to which the specimen is subjected;*
- *identifying acoustic ringing signals and differentiating said ringing signals from NQR signals, wherein said identifying and differentiating step comprises the steps of:*
  - *applying an RF signal to the RF coil which is separate and distinct from the NQR excitation signal, and*
  - *determining if a ringing signal is present by operating the system at a frequency outside the range of the NQR sample frequency or by determining the nature of the signal response based on the principle of acoustic ringing that the ringing signal decays with time and, within a limited time period, between respective RF pulses, the NQR signal increases with time;*
- *processing the NQR signals and comparing them to signal characteristics in memory to determine whether the detected NQR signals indicate the presence of a target substance; and*
- *indicating whether conditions of the received signal indicate that further examination is necessary, or selectively indicating whether the target substance is present in the specimen or*

whether the target substance is absent from the specimen."

Claims 11 and 12 are dependent on claim 10.

VI. The appellant essentially argued that the present application addressed the problem of producing a system for detecting explosives and narcotics by means of NQR which was commercially viable and that a solution based on the combination of features recited in claim 1 was not suggested by any of the cited documents.

Reasons for the Decision

1. The appeal is admissible.

2.1 Claim 1 differs from the corresponding claim according to the second auxiliary request refused by the examining division essentially in that it further specifies the following features:

(a) the automatic means for tuning the RF coil comprises:

- *"a series of fixed valued capacitors (93) switched by controllable switch means (94); and*
- *control means (91) for controlling the switching sequence of said capacitors to establish maximum power transfer efficiency of said RF coil;"*

the detection head subsystem (33) comprises:

- an RF coil, *"said RF coil being formed on an insulator frame (51) with a linear gap (101) between confronting edges of said RF coil sheet;*

– *a multiplicity of static tuning capacitors (102) connected between said RF coil confronting edges, said static tuning capacitors being configured and spaced to provide a uniform RF flux field within said RF coil cavity when excited by RF pulses;"*

(b) wherein said cavity is *"rectangular in shape, with its shorter sides having a first dimension, wherein the spacing between said RF coil and said RF shield is about one-half of said first dimension, and wherein said RF shield extends past at least the open end of said RF coil by a distance that is substantially equal to one-half of said first dimension"*;

(c) *"- .... whereby the system is operated at a frequency outside the range of the NQR sample frequency, or*

- means to determine the nature of the signal response based on the principle of acoustic ringing that the ringing signal decays with time and, within a limited time period, between respective RF pulses, the NQR signal increases with time."

2.2 Features (a) are based on claims 12 and 17 of the originally filed application, while features (b) find support in claims 4 to 6 as originally filed. Features (c) correspond to lines 20 to 24 and 27 to 30 on page 21 of the original application.

2.3 Claim 10 differs from the method claim 17 of the second auxiliary request considered by the examining division essentially in that:

- it relates to a method "*using a system according to claim 1*" ;
- the step of identifying acoustic ringing is specified as disclosed in lines 20 to 24 and 27 to 30 on page 21 of the application as originally filed.

2.4 Hence, the Board is satisfied that all the documents filed by the appellant do not include subject-matter extending beyond the content of the application as originally filed (Article 123(2) EPC).

3.1 D1 relates to a system for detecting a target substance by nuclear quadrupole resonance comprising a meanderline surface coil for irradiating the specimen with a train of radiofrequency pulses and for detecting a signal in response to said radiation (see Fig. 2(a)). The preference given to this particular kind of surface coil is due to the fact that "*the meanderline surface coil localizes the sensitive inspection region to a well-defined region adjacent to the coil so that a specimen can be scanned without the use of substantial RF power. As a result of the electrical and magnetic fields of the meanderline surface coil falling off rapidly over distance, a person can be scanned by this system without depositing significant RF power into the body*" (cf D1 column 2, lines 15 to 23).

Though D1 (see column 5, lines 20 to 24) teaches that "when inspecting reasonably small packages of approximately 30 cm linear dimensions where power deposition is not a great concern, a cylindrical or rectangular solenoidal coil may be appropriate", it does not specify whether the specimen to be examined should be located within the coil.

3.2 D6 reports on a project to construct and evaluate a full size, nuclear quadrupolar resonance detector of explosives, in particular RDX-based explosives, with a view to providing "*realistic design criteria for an NQR prototype fieldable at an airport*" (see "*Introduction*", first four lines). This document points out that a "*very intriguing type of surface coil*" for a people scanner is the meanderline, since the RF field intensity falls off very rapidly away from the coil's surface, so as to provide a scanner with sufficient sensitivity to see an explosive on the human body, while limiting the deposition of significant RF power into the body (see page 362, last paragraph).

For the purpose of scanning airline baggage, however, D6 suggests using a large radiofrequency (RF) coil inside a screened cage (cf. Fig. 1 and page 363, first paragraph). This arrangement allows the detection of the NQR signal from an explosive anywhere within the "*NQR RF coil volume*" (page 365: *"Summary"*). In fact, a fairly large "*active volume of 300 liters*" can be interrogated in a short time ("*6 seconds*") (cf "*Abstract*"). In this respect, the Board has no doubt that the "*coil volume*" relates to the volume defined by the three-dimensional solenoid and not the volume of the external field generated by the coil and delimited by the cage, as maintained by the appellant.

As D6 relates to a baggage screening system and shows or necessarily implies several features recited in claim 1 of the present application, it represents an appropriate starting point for assessing the patentability of the present invention.

4.1 Starting from D6, a problem addressed by the present application can be defined as providing "*a commercially practical system employing the known properties of the substances and the known principles of NQR to detect and identify contraband products which may be hidden inside airline baggage or concealed in a variety of packaging*" (cf page 7, lines 16 to 19 of the application as originally filed).

4.2 According to the appellant, the combination of a single-turn RF coil and of an electrically conductive RF shield surrounding the coil, as specified in claim 1, constituted an essential feature which would distinguish the present invention from the prior art.

5.1 Documents D7a, D7b and D8 relate to loop-gap resonators for NMR applications. In the course of the appeal, the appellant reiterated the view already expressed in the examination proceedings that all documents relating to NMR should be disregarded as irrelevant. The Board, however, concurs with the examining division that NQR and NMR are closely related technical fields, in particular, as far as the basic principles of spin excitation and of detection of resonance response signals are concerned. This view is corroborated by several statements in the prior art which link NQR to NMR (cf D1, column 1, lines 37 to 42; D5 page 2, lines

25 to 30 and page 7, line 28 to page 8, line 5; D6, page 362, second full paragraph).

5.2 D7b is concerned with NMR spectroscopy and points out that the major difficulty encountered with large-volume applications in this field (page 319, first and second paragraphs) is that the conventional coil design becomes difficult to apply because, as the inductor's size increases to accommodate large samples, the capacitance required to tune it becomes impractically small. However, resonance may be easily achieved with a loop-gap resonator (Figure 1), which offers the following advantages:

-- it is easy to construct and tune;
-- its very high Q guarantees efficient detection and RF delivery to the sample;
-- the RF field is very uniform.

In one specific embodiment shown in D6, a variable capacitor and several chip capacitors are placed along the gap of a single-turn coil to provide resonance at 34 MHz and a tuning range of 5 MHz (page 321, second paragraph).

5.3 D7a acknowledges that single-turn solenoids having a cylindrical conductor with a slit along its length have been proposed for use as resonators in magnetic resonance spectroscopy (column 1, lines 41 to 65). The resonator is constructed around a dielectric form within which the mass under test is placed. A conductive foil of metal is wrapped around the form and constitutes a cylinder with a gap running along its length. Capacitors which may be fixed or variable are placed along the gap , whereby their distribution and values provide a means for tuning the uniformity or homogeneity of the RF field created within the device.

5.4 D8 provides a further example of loop-gap resonators for ESR spectroscopy between 1 and 10 GHz.

5.5 Though the system of D6 (cf page 361, Abstract; page 363 third paragraph; and page 364, last paragraph) is designed for RDX-based explosives and thus works at a much lower resonant frequency (3.4 MHz or 5.2 MHz), the Board considers, in accordance with the decision of the examining division, that, in view of the known advantages of a loop-gap resonator in NMR applications (see *eg* D7b), it would have been obvious to a skilled person to select such a resonator for the system disclosed in D6. In fact, no technical prejudice against this choice can be identified.

6.1 However, an essential requirement that distinguishes the system known from D6 and the claimed invention is that the latter is a commercially viable system and, as such, supposed to handle different pieces of luggage at a relatively high speed. This requires, *inter alia,* an open-ended detection head which should meet the following specifications:

- it should be easily tuned and quickly retuned to the proper resonant frequency once the piece of luggage has entered the scanner volume;
- the RF field within the coil volume should be uniform and not be affected by external fields.

6.2 The Board accepts the appellant's submission that the combination of features (a) and (b) specified above (see item 2.1) achieves the above effects and thus gives an essential contribution to solving the problem addressed in the present application.

7.1 As to features (a), the cited prior art comprises two documents, D3 and D4, which are concerned with automatically tuning NQR or NMR systems.

7.2 D3 relates to a high-power radio frequency irradiation system with automatic tuning which is considered to be useful "*in a nuclear quadrupole double resonance spectrometer, and in other resonance experiments involving frequency sweeps*" (see Abstract).

According to D3, it is known to employ in a NQR system an automatically tuned LC circuit in which a solenoidal coil is in resonance with a bank of capacitors that may be switched into or out of the circuit. Coarse tuning is accomplished by switching capacitors according to a look-up table. Fine tuning is achieved by adjusting a variable air capacitor for minimum phase shift (page 984, left-hand column, last paragraph and right-hand column, first paragraph). The embodiment shown in D3 (Fig. 3) comprises a coil which is connected to a binary capacitor array via a transmission line. Impedance matching and tuning is accomplished by switching in and out the capacitors until maximum current through the coil is achieved (see D3 "*Experimental*" and first paragraph of *"Operation"*).

7.3 D4 deals with the problem of matching a transmission/reception antenna in a nuclear magnetic resonance imaging apparatus to the impedance of a high-frequency system which feeds the antenna. This problem arises while the body to be imaged changes the antenna impedance. A "transformation network" comprising capacitors connected in series and in parallel is used to change the impedance of the transmission/reception coil (cf D4, column 3, lines 21 to 42).

7.4 Though autotuning systems were generally known before the priority date of the present application, none of the prior art documents teaches to use a loop gap generator with the capacitor arrangement specified in claim 1, whereby a first set of fixed capacitors located in the gap ensures field homogeneity, whereas a second set of switched capacitors is responsible for retuning the cavity to the proper frequency.

8.1 As to feature (b), D2 relates to a magnetic resonance imaging system (MRI), *ie* to a system which irradiates high frequency pulses from an antenna into a specimen (for instance the human body) under a static magnetic field. For such a system, it is imperative that the antenna should possess uniform and high sensitivity. Hence, this document is, in particular, concerned with the optimisation of an antenna located inside "*a conducting cylindrical RF shield*" (see "SUMMARY"). Since the antenna characteristics do not depend only on the antenna's structure, but are also greatly affected by the cylindrical RF shield built outside it, it is necessary to analyse the effect of the shield length on the antenna as well as that of different shield shapes (page 37, right-hand column, second and third paragraph). An example of an antenna combined with a shield is given in Figure 5 which shows a multiple element resonator inside a conducting shield in the shape of a cylinder.

8.2 In summary, D2 points out the following:

- an appropriate shield increases the sensitivity of the system (page 41, left-hand column, last paragraph to page 42, right-hand column, first paragraph);

- a cylindrical shield behaves like a waveguide with a certain cut-off frequency which depends on the shield diameter; if the resonant frequency is below the cut-off frequency, it cannot propagate inside the shield and thus the radiation loss of the antenna is reduced (page 42, right-hand column, last paragraph).

8.3 None of the cited documents, however, teaches to relate the shorter side of a rectangular cavity to the spacing between the cavity and the shield, and to the extension of the shield beyond the lateral opening of the coil. The Board has no reason to doubt that such dimensional relationships can provide a particularly advantageous balance between noise isolation, loading of the coil and minimization of the total system volume (cf application as filed, page 18 , lines 12 to 14).

9. D5, which was cited in the contested decision in connection with acoustic ringing, does not show any features relating to the tuning of a resonant cavity or to the relative dimensions of a coil and a shield.

10.1 For these above reasons, the Board finds that it was not obvious to a person skilled in the art starting from D6 to arrive at a system falling within the terms of claim 1. Hence, the subject-matter of this claim involves an inventive step within the meaning of Article 56 EPC.

10.2 Claim 10 relates to a method for detecting a target substance using a system according to claim 1 and, thus, also involves an inventive step within the meaning of Article 56 EPC.

10.3 Claims 2 to 9 and 11 and 12 are dependent on claims 1 and 10, respectively. Consequently, their subject-matters comply with the requirement of Article 56 EPC.

11. In summary, the Board finds that the appellant's request meets the requirements of the EPC, and that a patent can be granted on the basis thereof.

Order

For these reasons it is decided that:

1. The decision under appeal is set aside.

2. The case is remitted to the department of the first instance with the order to grant a patent on the basis of the appellant's request, according to the following documents:

- Claims 1 and 10 faxed on 7 November 2003 and claims 2 to 9, 11 and 12 filed in the oral proceedings on 9 October 2003;
- Pages 5 to 7 of the description filed in the oral proceedings with pages 1 to 4 and 8 to 23 of the description as originally filed;
- Figures 1 to 7 as originally filed.

The Registrar:	The Chairman:
R. Schumacher	G. Davies