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(54) **Apparatus, method and software for tracking an object**

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Description

CROSS REFERENCES TO RELATED APPLICATIONS

[0001] This application is related to European Patent Application No. 04 253 229.1 filed on even date, entitled, "Hysteresis assessment for metal immunity," in the name of Biosens Webster, Inc., claiming priority from US Patent Application No. 10/448289 filed on 29th May, 2003 and now published as EP-A-1 510 174.

FIELD OF THE INVENTION

[0002] The present invention relates generally to non-contact tracking of objects using a magnetic field, and specifically to counteracting the effect of a moving, magnetic field-responsive article in a magnetic field.

BACKGROUND OF THE INVENTION

[0003] Non-contact electromagnetic locating and tracking systems are well known in the art, with an exceptionally broad spectrum of applications, including such diverse topics as military target sighting, computer animation, and precise medical procedures. For example, electromagnetic locating technology is widely used in the medical field during surgical, diagnostic, therapeutic and prophylactic procedures that entail insertion and movement of objects such as surgical devices, probes, and catheters within the body of the patient. The need exists for providing real-time information for accurately determining the location and orientation of objects within the patient's body, preferably without using X-ray imaging.

[0004] US-A-5,391,199 and US-A-5,443,489 describe systems wherein the coordinates of an intrabody probe are determined using one or more field sensors, such as Hall effect devices, coils, or other antennae carried on the probe. Such systems are used for generating three-dimensional location information regarding a medical probe or catheter. A sensor coil is placed in the catheter and generates signals in response to externally-applied magnetic fields. The magnetic fields are generated by a plurality of radiator coils, fixed to an external reference frame in known, mutually-spaced locations. The amplitudes of the signals generated in response to each of the radiator coil fields are detected and used to compute the location of the sensor coil. Each radiator coil is preferably driven by driver circuitry to generate a field at a known frequency, distinct from that of other radiator coils, so that the signals generated by the sensor coil may be separated by frequency into components corresponding to the different radiator coils.

[0005] WO-A-96/05768 describes a system that generates six-dimensional position and orientation information regarding the tip of a catheter. This system uses a plurality of sensor coils adjacent to a locatable site in the catheter, for example near its distal end, and a plurality of radiator coils fixed in an external reference frame. These coils generate signals in response to magnetic fields generated by the radiator coils, which signals allow for the computation of six location and orientation coordinates, so that the position and orientation of the catheter are known without the need for imaging the catheter.

[0006] US-A-6,239,724 describes a telemetry system for providing spatial positioning information from within a patient's body. The system includes an implantable telemetry unit having (a) a first transducer, for converting a power signal received from outside the body into electrical power for powering the telemetry unit; (b) a second transducer, for receiving a positioning field signal that is received from outside the body; and (c) a third transducer, for transmitting a locating signal to a site outside the body, in response to the positioning field signal.

[0007] US-A-5,425,382 describes apparatus and methods for locating a catheter in the body of a patient by sensing the static magnetic field strength gradient generated by a magnet fixed to the catheter.

[0008] US-A-5,558,091 describes a magnetic position and orientation determining system which uses uniform fields from Helmholtz coils positioned on opposite sides of a sensing volume and gradient fields generated by the same coils. By monitoring field components detected at a probe during application of these fields, the position and orientation of the probe is deduced. A representation of the probe is superposed on a separately-acquired image of the subject to show the position and orientation of the probe with respect to the subject.

Other locating devices using a position sensor attached to a catheter are described in US-A-4,173,228, US-A-5,099,845, US-A-5,325,873, US-A-5,913,820, US-A-4,905,698 and US-A-5,425,367.

[0009] Commercial electrophysiological and physical mapping systems based on detecting the position of a probe inside the body are presently available. Among them, CARTO™, developed and marketed by Biosense Webster, Inc. (Diamond Bar, California), is a system for automatic association and mapping of local electrical activity with catheter location.

[0010] Electromagnetic locating and tracking systems are susceptible to inaccuracies when a metal or other magnetically-responsive article is introduced into the vicinity of the object being tracked. Such inaccuracies occur because the magnetic fields generated in this vicinity by the location system's radiator coils are distorted. For example, the radiator coils' magnetic fields may generate eddy currents in such an article, and the eddy currents then cause parasitic magnetic fields that react with the field that gave rise to them. In a surgical environment, for example, there is a substantial amount of conductive and permeable material including basic and ancillary equipment (operating tables, carts, movable lamps, etc.) as well as invasive surgery apparatus (scalpels, catheters, scissors, etc.). The eddy currents generated in these articles and the resultant electromagnetic field distortions can lead to errors in determining the position of the object being tracked.

[0011] It is known to address the problem of the interference of static metal objects by performing an initial calibration, in which the response of the system to a probe placed at a relatively large number of points of interest is measured. This may be acceptable for addressing stationary sources of electromagnetic interference, but it is not satisfactory for solving the interference problems induced by moving magnetically-responsive objects.

[0012] US-A-6,373,240 describes an object tracking system comprising one or more sensor coils adjacent to a locatable point on an object being tracked, and one or more radiator coils, which generate alternating magnetic fields in a vicinity of the object when driven by respective alternating electrical currents. For each radiator coil, a frequency of its alternating electrical current is scanned through a plurality of values so that, at any specific time, each of the radiator coils radiates at a frequency which is different from the frequencies at which the other radiator coils are radiating.

[0013] The sensor coils generate electrical signals responsive to the magnetic fields, which signals are received by signal processing circuitry and analyzed by a computer or other processor. When a metal or other field-responsive article is in the vicinity of the object, the signals typically include position signal components responsive to the magnetic fields generated by the radiator coils at their respective instantaneous driving frequencies, and parasitic signal components responsive to parasitic magnetic fields generated because of the article. The parasitic components are typically equal in frequency to the instantaneous frequency of the driving frequency, but are shifted in phase, so that the effect at each sensor coil is to produce a combined signal having a phase and an amplitude which are shifted relative to the signal when no field-responsive article is present. The phase-shift is a function of the driving frequency, and so will vary as each driving frequency is scanned. The computer processes the combined signal to find which frequency produces a minimum phase-shift, and thus a minimum effect of the parasitic components, and this frequency is used to calculate the position of the object. Varying the driving frequency until the phase shift is a minimum is described as an effective method for reducing the effect of field-responsive articles on the signal.

[0014] US-A-6,172,499 describes a device for measuring the location and orientation in the six degrees of freedom of a receiving antenna with respect to a transmitting antenna utilizing multiple-frequency AC magnetic signals. The transmitting component consists of two or more transmitting antennae of known location and orientation relative to one another. The transmitting antennae are driven simultaneously by AC excitation, with each antenna occupying one or more unique positions in the frequency spectrum. The receiving antennae measure the transmitted AC magnetic field plus distortions caused by conductive metals. As described, a computer then extracts the distortion component and removes it from the received signals, providing the correct position and orientation output.

[0015] US-A-6,246,231 describes a method of flux containment in which the magnetic fields from transmitting elements are confined and redirected from the areas where conducting objects are commonly found.

[0016] US-A-5,767,669 describes a method for subtracting eddy current distortions produced in a magnetic tracking system. The system utilizes pulsed magnetic fields from a plurality of generators, and the presence of eddy currents is detected by measuring rates of change of currents generated in sensor coils used for tracking. The eddy currents are compensated for by adjusting the duration of the magnetic pulses.

[0017] US-A-4,945,305 and US-A-4,849,692 describe tracking systems that circumvent the problems of eddy currents by using pulsed DC magnetic fields. Sensors which are able to detect DC fields are used in the systems, and eddy currents are detected and adjusted for by utilizing the decay characteristics and the amplitudes of the eddy currents.

[0018] US-A-5,600,330 describes a non-dipole loop transmitter-based magnetic tracking system. This system is described as showing reduced sensitivity to small metallic objects in the operating volume.

[0019] EP-A-0,964,261 describes systems for compensating for eddy currents in a tracking system using alternating magnetic field generators. In a first system the eddy currents are compensated for by first calibrating the system when it is free from eddy currents, and then modifying the fields generated when the eddy currents are detected. In a second system the eddy currents are nullified by using one or more shielding coils placed near the generators.

[0020] US-A-5,831,260 describes a combined electromagnetic and optical hybrid locating system that is intended to reduce the disadvantages of each individual system operating alone.

[0021] US-A-6,122,538 describes hybrid position and orientation systems using different types of sensors including ultrasound, magnetic, tilt, gyroscopic, and accelerometer subsystems for tracking medical imaging devices.

[0022] Article surveillance systems using soft magnetic materials and low frequency detection systems have been known since the Picard patent (Ser. No. 763,861) was issued in France in 1934. Surveillance systems based on this approach generally use a marker consisting of ferromagnetic material having a high magnetic permeability. When the marker is interrogated by a magnetic field generated by the surveillance system, the marker generates harmonics of the interrogating frequency because of the non-linear hysteresis loop of the material of the marker. The surveillance system detects, filters, and analyzes these harmonics in order to determine the presence of the marker. Numerous patents describe systems based on this approach and improvements thereto, including, for example, US-A-4,622,542, US-A-4,309,697, US-A-5,008,649 and US-A-6,373,387.

[0023] US-A-4,791,412 describes an article surveillance system based upon generation and detection of phase shifted harmonic signals from encoded magnetic markers. The system is described as incorporating a signal processing technique for reducing the effects of large metal objects in the surveillance zone.

[0024] US-A-6,150,810, US-A-6,127,821, US-A-5,519,317 and US-A-5,506,506 describe apparatus for detecting the presence of ferrous objects by generating a magnetic field and detecting the response to the field from the object. A typical application of such an apparatus is detection and discrimination of objects buried in the ground. US-A-4,868,504 describes a metal detector for locating and distinguishing between different classes of metal objects. This apparatus performs its analysis by using harmonic frequency components of the response from the object.

[0025] US-A-5,028,869 describes apparatus for the nondestructive measurement of magnetic properties of a test body by detecting a tangential magnetic field and deriving harmonic components thereof. By analyzing the harmonic components, the apparatus calculates the maximum pitch of the hysteresis curve of the test body.

[0026] An article by Feiste KL et al. entitled, "Characterization of Nodular Cast Iron Properties by Harmonic Analysis of Eddy Current Signals," NDT.net, Vol. 3, No. 10 (1998), available as of May 2002 at http://www.ndt.net/article/ecndt98/nuclear/245/245.htm
describes applying harmonic analysis to nodular cast iron samples to evaluate the technique's performance in predicting metallurgical and mechanical properties of the samples.

[0027] US 6,177,792 discloses an apparatus for tracking an object, the apparatus comprising a set of multiple radiators, which are adapted to generate an energy field in a vicinity of the object, a position sensor, fixed to the object, which is adapted to generate a signal responsive to the energy field, and a control unit. The control unit is adapted to receive signals from the radiators and the position sensor, to detect mutual inductance between the multiple radiators by a harmonic detection method, and to correct the determination of the position of the object to compensate for the parasitic field components induced by the mutual inductance. An associated method of tracking is also disclosed.

[0028] US 2001/0035815 discloses an apparatus for tracking an object, the apparatus comprising a set of multiple radiators, which are adapted to generate an energy field in a vicinity of the object, an identification tag fixed to the object, which is adapted to generate a signal responsive to the energy field to act as a position sensor, and a control unit. The control unit is adapted to receive signals from the tag and thereby to identify the object by reference to a database to which the control unit has access. An associated method of tracking is also disclosed.

[0029] US 5,057,095 discloses an apparatus for tracking an object, the apparatus comprising a set of multiple radiators, which are adapted to generate an energy field in a vicinity of the object, a position sensor, fixed to the object, which is adapted to generate a signal responsive to the energy field, and a control unit. The control unit is adapted to receive the signal thereby to determine the position of the object.

[0030] There is a need for a straightforward, accurate, real-time method that addresses the problem of interference induced in electromagnetic locating and tracking systems caused by the introduction of non-stationary metallic or other magnetically-responsive articles into the measurement environment.

SUMMARY OF THE INVENTION

[0031] It is an object of some aspects of the present invention to provide apparatus and methods for improving the accuracy of electromagnetic locating and tracking systems.

[0032] It is also an object of some aspects of the present invention to provide apparatus and methods for increasing accuracy of electromagnetic location and tracking systems without concern for the presence of moving electrically- and/or magnetically-responsive materials in the space wherein measurements are being taken.

[0033] It is a further object of some aspects of the present invention to provide apparatus and methods for enabling electromagnetic location and tracking systems to function accurately in the presence of moving electrically- and/or magnetically-responsive materials in the space wherein the measurements are being taken, substantially without regard to the quantity of such materials, their conductive characteristics, velocities, orientation, direction and the length of time that such materials are within the space.

[0034] It is yet a further object of some aspects of the present invention to provide apparatus and methods for operating electromagnetic location and tracking systems without the necessity of employing means for reducing or circumventing the effects caused by eddy currents induced in moving electrically- and/or magnetically-responsive objects in the space wherein measurements are being taken.

[0035] In preferred embodiments of the present invention, apparatus for electromagnetic locating and tracking of an object, such as a probe, in a space, such as a body of a patient, comprises a plurality of electromagnetic radiators located in the vicinity of the space, a position sensor, fixed to the probe, and a control unit adapted to drive the radiators and process signals from the position sensor. To enable sensing of the position of the probe, one or more fundamental frequencies are transmitted by the radiators. When a magnetic field-responsive element, for example a surgical tool, movable lamp, cart, etc., is introduced into the vicinity of the probe, the measured position of the probe differs from its absolute position. To compensate for this interference effect on the probe, the absolute position of the probe is calculated by using a harmonic correction algorithm.

[0036] Correction is possible by use of such an algorithm because the signal received by the probe includes not only the transmitted fundamental signal but also one or more higher harmonics of the fundamental frequency, caused, for example, by phase shifting due to the non-linearity of the interfering element's hysteresis loop or caused by other factors. The pattern of these harmonics is analyzed by the control unit and compared to a previously-generated database of patterns associated with specific types of elements, in order to determine the type of element that is causing interference. The interfering effect of the element is then calculated, responsive to the type of element and the magnitude of the harmonics, and removed, such as by subtraction, from the signal received by the probe. The resulting clean signal is used as an input for calculating the absolute position of the probe.

[0037] Advantageously, in these embodiments of the present invention it is generally not necessary to employ means to reduce or circumvent the effects caused by eddy currents induced in non-stationary magnetic field-responsive elements in the space. Further advantageously, these embodiments of the present invention typically achieve the objective of accurate tracking regardless of the number of metal elements introduced to the surrounding space, their conductive characteristics, velocities, orientation, direction and the length of time that the elements are within the space.

[0038] In some preferred embodiments of the present invention, prior to apparatus being used with a patient, each element that may interfere with measurements of the position of the probe is assessed, in order to "train" the apparatus that will be used with the patient as to the interfering effect of a given element. To assess each element, the radiators generate fundamental frequencies which are measured by a receiving coil twice: first, not in the presence of the element, and second, in the presence of the element. In the presence of the element, the signal received is distorted by interference from the element. Each type of material generally has a unique hysteresis curve and therefore generates different interference and corresponding different higher harmonics. For each radiated fundamental frequency, the control unit preferably removes the clean received signal from the distorted received signal. The resulting signal, representing the effect of the element's interference on the clean signal, is generally unique for each element and therefore serves as a "fingerprint" of the element. To reduce the effect of noise and other random variations in measurement, this calculation process may be repeated with the element in different locations, and the results combined, such as by averaging, in order to generate the fingerprint. Data indicative of the fingerprint, such as a pattern of the fingerprint, is stored in association with the identity of the assessed article in a database.

[0039] Alternatively, in some preferred embodiments of the present invention, to assess each element, the radiators generate fundamental frequencies which are measured by a receiving coil twice: first, with the element at a first location, and second, with the element at a second location. The distortion of a first signal received when the element is at the first location differs from the distortion of a second signal received when the element is at the second location. For each radiated fundamental frequency, the control unit preferably calculates the difference between the first and second signals, such as by subtraction. The resulting signal, representing the effect of the element's interference on a signal that would have been received in the absence of the element, is generally unique for each element and therefore serves as a fingerprint of the element. To reduce the effect of noise and other random variations in measurement, measurements may be made when the element is in more than two locations, and the results of the calculation combined, such as by averaging, in order to generate the fingerprint. Data indicative of each fingerprint, such as a pattern of the fingerprint, is stored in association with the identity of the assessed article in a database.

[0040] In some preferred embodiments, the assessment procedure is performed in a location other than an operating room environment. For example, the assessment procedure is performed in a different location in the medical facility in which the procedure is to be performed. After assessment, the resulting assessment data and calculations are transferred to the control unit.

[0041] Alternatively or additionally, assessment is performed offsite, preferably by a third party. In this case, preferably a large number of elements and/or materials commonly used in performing medical procedures are assessed. These assessments are stored as a library in a repository, such as a database. This library is transferred to the control unit, either before or after the control unit is delivered to its user, or, alternatively, the library is transferred to a computer system or network to which the control unit has access during a procedure. It will be appreciated that onsite and offsite assessment can easily be combined, giving the user of the system the ability to add interfering elements not included in the available library or libraries.

[0042] In some preferred embodiments of the present invention, the control unit is coupled to the probe and radiators by leads. Alternatively, the probe comprises circuitry which transmits wireless signals responsive to electromagnetic radiation generated by the radiators.

[0043] It is noted that whereas some embodiments of the present invention are described with respect to assessing the element by placing the element at two different locations and maintaining the receiving coil at a generally fixed location, this is by way of illustration and not limitation. The scope of the present invention includes assessing the element by placing the element at a generally fixed location and having the receiving coil measure the field when the receiving coil is at respective first and second locations. Alternatively or additionally, both the receiving coil and the element are moved during the assessment. Each of these assessment options is an example of changing the relative positions of the receiving coil and the element.

[0044] For some applications, apparatus and methods described herein are adapted to work in conjunction with apparatus and methods described in EP-A-1,184,684 and/or in a copending US patent application filed November 22, 2002, entitled, "Dynamic metal immunity".

[0045] There is therefore provided, in accordance with an embodiment of the present invention, apparatus for tracking an object in the presence of an interfering article, as set forth in the accompanying claim 1.

[0046] There is further provided, in accordance with another embodiment of the present invention, apparatus for tracking an object as set forth in the accompanying claim 2.

[0047] There is yet further provided, in accordance with an embodiment of the present invention, a method for tracking an object in the presence an interfering article, as set forth in the accompanying claim 11.

[0048] There is also provided, in accordance with an embodiment of the present invention, a computer software product for tracking an object in the presence of an interfering article, as set forth in the accompanying claim 20.

[0049] Further, preferred, aspects are set forth in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0050] The present invention will be more fully understood from the following detailed description of preferred embodiments thereof, taken together with the drawings, in which:

Fig. 1 is a schematic, pictorial illustration of an electromagnetic locating and tracking system used during a medical procedure, in accordance with a preferred embodiment of the present invention;

Fig. 2 is a schematic, pictorial illustration of an assessment system, in accordance with a preferred embodiment of the present invention; and

Figs. 3A, 3B, and 3C are simplified frequency response graphs illustrating an example assessment of an interfering element, in accordance with a preferred embodiment of the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[0051] Fig. 1 is a schematic, pictorial illustration of an electromagnetic locating and tracking system 18 utilized to track an object, such as a probe 20, in the body of a patient 24 while providing immunity to the introduction, movement (dx), or removal of an interfering element 40, such as a ferromagnetic element, in or near a space 60 around the patient, in accordance with a preferred embodiment of the present invention. System 18 comprises a set of radiators 34, which are driven by a control unit 50 to track probe 20, preferably but not necessarily using methods and apparatus which are described in the above-cited US Patents and PCT Patent Publication to Ben-Haim and Ben-Haim et al. Thus, probe 20 comprises a position sensor (not shown), which preferably comprises field sensors, such as Hall effect devices, coils, or other antennae, for use in position determination. Alternatively or additionally, methods and apparatus known in the art are used to facilitate the tracking of probe 20. Control unit 50 comprises circuitry for processing signals received from probe 20, for detecting element 40, and for calculating the absolute position of probe 20 using a harmonic correction algorithm, as described hereinbelow.

[0052] Element 40 typically comprises an article made completely or partially of magnetically permeable material, such as ferromagnetic material. Examples of such articles include surgical tools, movable lamps, and carts. Element 40 generates parasitic fields, the phases and amplitudes of which generally depend on properties of element 40, including its dielectric constant, magnetic permeability, geometrical shape and orientation relative to probe 20. It will be appreciated that although element 40 is shown in Fig. 1 as a single element, element 40 could comprise a number of separate elements, which are often brought in and out of the area of a medical procedure.

[0053] Fig. 2 is a schematic, pictorial illustration of an assessment system 16, in accordance with a preferred embodiment of the present invention. In this preferred embodiment, prior to system 18 being used on a patient, each element 40 which may interfere with measurements of the position of probe 20 is preferably assessed by assessment system 16. To assess each element 40, the element is initially not present in space 60. One or more radiators 34 radiate a fundamental frequency for which assessment is desired. Alternatively, radiators 34 radiate a plurality of fundamental frequencies for which assessment is desired, one frequency at a time. Suitable frequencies are typically between about 200 Hz and about 12 kHz. The one or more fundamental frequencies radiated are preferably those used by radiators 34 for position sensing of probe 20 during a procedure. A receiving coil 22, fixed at any point in space 60, receives the radiated signals and conveys them to control unit 50. In a preferred embodiment of the present invention, receiving coil 22 comprises a sensor, such as a coil, Hall effect device or other antenna, dedicated to this function. In this case, the sensor in receiving coil 22 preferably is substantially identical to the sensor in probe 20. Alternatively, probe 20, temporarily fixed at any point in space 60, functions as receiving coil 22. Further alternatively, one of radiators 34, which is not being used for radiating during assessment, functions as receiving coil 22. For some applications, receiving coil 22 is oriented so that at least one of its sensors (such as a coil) is oriented to increase or maximize the strength of the signal received.

[0054] In the next step of the assessment process, element 40 is introduced into space 60, preferably near receiving coil 22. Each of the one or more fundamental frequencies radiated before the introduction of element 40 is again radiated by the same radiators 34. Receiving coil 22 receives the radiated signals and conveys them to control unit 50. In the case of a ferromagnetic element, the signal received is distorted by interference caused in part by phase shifting caused by the non-linearity of the element's hysteresis loop. This non-linearity of the hysteresis loop also induces higher harmonics of the radiated fundamental frequency. Each type of material generally has a unique hysteresis curve and therefore generates different interference and a corresponding different pattern of higher harmonics.

[0055] Reference is now made to Figs. 3A, 3B, and 3C, which show, for a single radiated fundamental frequency, a simplified example of received signals and a calculated "fingerprint," in accordance with a preferred embodiment of the present invention. Fig. 3A shows the signal received by receiving coil 22 prior to the introduction of element 40 in space 60 (the "clean received signal"), the amplitudes of which at F_0, $3F_0$, and $5F_0$ are 4.0, 0.0, and 0.0, respectively. Fig. 3B shows the signal received by receiving coil 22 after the introduction of element 40 in space 60 (the "distorted received signal"), the amplitudes of which at F_0, $3F_0$, and $5F_0$ are 4.3, 2.0, and 1.0, respectively. For each radiated fundamental frequency, control unit 40 analyzes the received signals, preferably by removing the clean received signal from the distorted received signal, such as by subtraction. The resulting signal, shown in Fig. 3C, represents the effect of electromagnetic interference of element 40 on the clean received signal. In this example, this "fingerprint" signal has amplitudes at F_0, $3F_0$, and $5F_0$ of 0.3, 2:0, and 1.0, respectively. Each type of material generally causes a unique resulting subtracted signal, which allows these signals to serve as fingerprint signals. It will be understood that the harmonic frequencies shown in Figs. 3B and 3C are illustrative only; in practice, among other differences, higher harmonics generally are present. As described hereinbelow, the ratios of the amplitudes at the different frequencies, rather than the absolute values of the amplitudes, are typically stored and used for correction during position determination.

[0056] Alternatively, in a preferred embodiments of the present invention, to assess each element, radiators 34 generate fundamental frequencies which are measured by a receiving coil 22 twice: first, with element 40 at a first location in space 60, and second, with element 40 at a second location in space 60. The distortion of a first signal received when the element is at the first location differs from the distortion of a second signal received when the element is at the second location. For each radiated fundamental frequency, control unit 50 preferably calculates the difference between the first and second signals, such as by subtraction. The resulting signal (or ratios of its amplitudes at different frequencies, as described hereinbelow), representing the effect of the interference of element 40 on a signal that would have been received in the absence of element 40, is generally unique for each element 40 and therefore serves as a fingerprint of the element. To reduce the effect of noise and other random variations in measurement, measurements may be made when the element is in more than two locations, and the results of the calculation averaged in order to generate the fingerprint.

[0057] For example, assume that the signal shown in Fig. 3B represents the first signal generated when element 40 is at the first location (as mentioned above, the amplitudes of this signal at F_0, $3F_0$, and $5F_0$ are 4.3, 2.0, and 1.0, respectively). Further assume that the amplitudes of the second signal (not shown) at F_0, $3F_0$, and $5F_0$, generated when element 40 is at the second location, are 4.6, 4.0, and 2.0, respectively. Subtracting the first signal from the second signal results in a fingerprint signal with amplitudes at F_0, $3F_0$, and $5F_0$ of 0.3, 2.0, and 1.0, respectively. Ratios of these values are stored and used for correction during a procedure, as described hereinbelow. Substantially the same ratios typically result even when measurements are made at multiple first and second locations.

[0058] The table below illustrates examples of three fingerprint signals (with arbitrary example values), in accordance with a preferred embodiment of the present invention. Element #1 represents the example element reflected in Figs. 3A, 3B, and 3C, and elements #2 and #3 represent two other example elements. Reference is made to the left portion of the table, labeled "Frequency." f_o represents the transmitted fundamental frequency, the multiples of f_o represent harmonic frequencies thereof, and the values represent relative amplitudes.

	Frequency					Ratio	
	f_o	$2f_o$	$3f_o$	$4f_o$	$5f_o$	$5f_o/3f_o$	$3f_o/f_o$
Element #1	0.2	--	2.0	--	1.0	0.5	10.0
Element #2	0.3	--	1.5	--	1.2	0.8	5.0
Element #3	0.1	--	1.0	--	0.6	0.6	10.0

[0059] Reference is now made to the right portion of the table, labeled "Ratio." In a preferred embodiment of the present invention, for each element for which assessment is performed, ratios between two or more harmonic frequencies, and between one or more harmonic frequencies and the transmitted fundamental frequency (f_o) are calculated, preferably by control unit 50 or, alternatively, by an external computer system (not shown). Each individual element assessed is uniquely characterized by its calculated ratio and/or ratios. Other possible algorithms, e.g., using combinations of two or more harmonic frequencies with the transmitted fundamental frequency and/or with each other, will be apparent to those skilled in the art having read the disclosure of the present patent application. Such other algorithms may be performed in order to produce alternative or additional values that uniquely identify different types of elements. Alternatively or additionally, assessment ratios and/or other calculated results are obtained for specific types of materials rather than specific types of elements. (Identifying the specific interfering material, without necessarily identifying the object comprising the material, is generally sufficient to perform the correction techniques described herein.) These ratios and/or results of other calculations are preferably stored in a database to which control unit 50 has access, and are used during a procedure for position compensation calculations, as described hereinbelow. ("Database," as used in the specification and in the claims, is to be understood as including substantially any suitable repository, memory device or data structure that may be used for storing this information.)

[0060] In a preferred embodiment, the assessment procedure is performed in a location other than an operating room environment. For example, the assessment procedure is performed in a different location in the medical facility in which the procedure is to be performed. In this embodiment, preferably one or more radiators substantially identical to radiators 34 are provided. After assessment, the resulting assessment data and calculations are transferred to control unit 50 using methods obvious to those skilled in the art.

[0061] Alternatively or additionally, assessment is performed offsite, preferably by a third party. In this case, preferably a large number of elements and/or materials commonly used in performing medical procedures are assessed. These assessments are stored as a library in a repository, such as a database. (It is to be understood that substantially any suitable memory device and data structure may be used for storing the library.) This library is transferred to control unit 50, either before or after control unit 50 is delivered to its user, using methods known in the art. Alternatively, the library is transferred to a computer system or network to which control unit 50 has access during a procedure. It will be appreciated that onsite and offsite assessment can easily be combined, giving the user of system 18 the ability to add elements 40 not included in the available library or libraries. Other details of implementing such a library system will be evident to those skilled in the art, having read the disclosure of the present patent application.

[0062] Reference is again made to Fig. 1. During a procedure being performed on a patient, when element 40 is introduced into the vicinity of space 60, the measured position of probe 20 differs from its actual position because of the interference generated by element 40. In a preferred embodiment of the present invention, to compensate for this interference, the harmonics induced in the signal received by probe 20 are analyzed by control unit 50. Calculations are performed on the amplitudes of the harmonics, such as the determination of ratios between the amplitudes of two or more harmonics. The results of these calculations are compared with those stored in the memory of control unit 50 in order to identify the type of previously-assessed element and/or material that element 40 is or includes, respectively. Once the element and/or material is known, the distorting effect of element 40 on the amplitude of the fundamental signal of interest received by probe 20 is calculated, for example by using the ratio of the amplitude of one or more of the harmonics to the amplitude of the fundamental signal, as calculated during the assessment and stored in a database to which control unit 50 has real-time access. The amplitude of this distorting effect is subtracted from the measured amplitude of the received fundamental signal of interest. The remaining signal, no longer distorted by the presence of element 40, is used as an input by control unit 50 for calculating the absolute position of probe 20.

[0063] Reference is again made to the right portion of the table above, labeled "Ratio," in order to provide an example of the calculation of an interference correction, using simple ratios of two harmonics, in accordance with a preferred embodiment of the present invention. For example, assume that, in the signal received by probe 20, the relative amplitude of f_o is 4.1, the relative amplitude of $3f_o$ is 1.0, and the relative amplitude of $5f_o$ is 0.5. The ratio of $5f_o$ to $3f_o$ is therefore 0.5. By comparing this ratio to the stored values reflected in the table, control unit 50 determines that, in this case, element 40 is the same type as element #1. To determine the distorting effect of element 40 on the received signal, the value of $3f_o$ (1.0) is divided by the stored ratio of $3f_o/f_o$ (10.0), resulting in 0.1. This result is subtracted from the measured amplitude of f_o (4.1), resulting in a corrected amplitude of 4.0, which is no longer distorted by the presence of element #1. This amplitude is used as an input for calculating the accurate position of probe 20.

[0064] In a preferred embodiment of the present invention, only one harmonic frequency is used to determine the identity of element 40. This is possible, for example, when one or more elements 40 being used during a procedure produce very different relative amplitudes at a certain harmonic frequency.

[0065] In a preferred embodiment of the present invention, during procedures in which multiple elements 40 are introduced into space 60 during a procedure, control unit 50 identifies each element 40 individually by performing suitable calculations. In some cases, these calculations use a number of higher harmonics, which provide additional distinguishing characteristics for elements 40, in order to aid in distinguishing multiple elements 40.

[0066] In a preferred embodiment of the present invention, when two or more elements 40 are made of the same ferromagnetic material or combination of ferromagnetic materials, there is generally no need to distinguish between these elements during a procedure. The interfering effect of such elements is combined and uniquely identifiable by the fingerprint of their material. Detection of and corrections for such elements is therefore preferably performed as a group by system 18, substantially without modification to the procedures described hereinabove.

[0067] Preferred embodiments of the present invention have been described with respect to a location system 18 wherein radiators 34 transmit electromagnetic signals and probe 20 receives these signals. It is to be understood that the scope of the present invention includes application of the techniques described herein to location systems wherein the probe transmits electromagnetic signals and radiators receive these signals.

[0068] It is to be understood that preferred embodiments of the present invention are described herein with respect to invasive medical techniques by way of example only. The scope of the present invention includes application of the techniques described herein to electromagnetic locating and tracking systems used for any purpose whatsoever.

[0069] It is to be further understood that the techniques described herein are applicable to assessment, identification and compensation for particular elements, e.g., a particular tool of known composition, as well as to assessment, identification and compensation for particular materials, e.g., a common ferromagnetic material. An "interfering article," as used in the specification and the claims, is thus to be understood as including both a particular discrete element (such as a tool) or a particular material (such as steel). Techniques described specifically with respect to element 40, element 41, or any other interfering article may be interchanged, as appropriate.

[0070] It is still further to be understood that control unit 50 may comprise a general-purpose computer, which is programmed in software to carry out the functions described herein. The software may be downloaded to the computer in electronic form, over a network, for example, or it may alternatively be supplied to the computer on tangible media, such as a CD-ROM. Further alternatively, control unit 50 may be implemented in dedicated hardware logic, or using a combination of hardware and software elements.

[0071] It will be appreciated by persons skilled in the art that the present invention is not limited to what has been particularly shown and described hereinabove. Rather, the scope of the present invention is limited by the appended claims.

Claims

1. Apparatus (18) for tracking an object (20) in the presence of an interfering article (40), comprising:

a set of one or more radiators (34), which are adapted to generate an energy field at a fundamental frequency in a vicinity (60) of the object;
a position sensor, fixed to the object (20), which is adapted to generate a signal responsive to the energy field; and **characterised by**
a control unit (50), with access to a database of one or more patterns of relative amplitudes of harmonic frequencies associated with one or more respective specific types of interfering articles, the control unit adapted to:

receive the signal,
detect the amplitude of the fundamental frequency in the signal,
detect a pattern of relative amplitudes of harmonic frequencies of the fundamental frequency present in the signal responsive to an interaction of the interfering article (40) with the energy field,
compare the pattern to the patterns of relative amplitudes of harmonic frequency stored in the database,
identify the interfering article based on the comparison,
correct the signal based on the identification of the interfering article (40) and a magnitude of one or more of the harmonic frequencies in the detected pattern, and
determine position coordinates of the object (20) based on the corrected signal.

2. Apparatus (18) for tracking an object (20), comprising:

a set of one or more radiators (34), fixed to the object (20), which radiators are adapted to generate an energy field at a fundamental frequency;
a set of one or more position sensors, located in a vicinity of the object, which are adapted to generate respective signals responsive to the energy field; and **characterised by**
a control unit (50), with access to a database of one or more patterns of relative amplitudes of harmonic frequencies associated with one or more respective specific types of interfering articles (40), the control unit adapted to:

receive the signal,
detect the amplitude of the fundamental frequency in the signal, detect a pattern of relative amplitudes of harmonic frequencies of the fundamental frequency present in the signal responsive to an interaction of an interfering article (40) with the energy field,
compare the pattern to the patterns of relative amplitudes of harmonic frequencies stored in the database,
identify the article (40) based on the comparison,
correct the signal based on the identification of the article (40) and a magnitude of one or more of the harmonic frequencies in the detected pattern, and
determine position coordinates of the object (20) based on the corrected signal.

3. Apparatus according to claim 1 or claim 2, wherein the interfering article (40) is ferromagnetic, and wherein the control unit (50) is adapted to identify the ferromagnetic interfering article.

4. Apparatus according to claim 1, 2 or 3, wherein the position sensor comprises at least one of: a Hall effect device, a coil, and an antenna.

5. Apparatus according to any one of claims 1 to 4, wherein the fundamental frequency is between 200 Hz and 12 kHz, and wherein the radiators (34) are adapted to generate the energy field at the fundamental frequency.

6. Apparatus according to any one of claims 1 to 5, wherein the control unit (50) is adapted to detect the pattern of relative amplitudes of harmonic frequencies by calculating a ratio of an amplitude of a first harmonic of the fundamental frequency present in the signal to an amplitude of a second harmonic of the fundamental frequency present in the signal, and to compare the pattern to the patterns of relative amplitude of harmonic frequencies stored in the database by comparing the calculated ratio to ratios stored in the database.

7. Apparatus according to any one of claims 1 to 6, wherein the control unit (50) is adapted to correct the signal by calculating an interfering effect of the interfering article on the signal, and by removing the interfering effect from the signal.

8. Apparatus according to claim 7, wherein the control unit (50) is adapted to remove the interfering effect by subtracting, in a frequency domain, the interfering effect from the signal.

9. Apparatus according to claim 7, wherein the control unit (50) is adapted to calculate the interfering effect by:

calculating a ratio of an amplitude of at least one of the harmonic frequencies of the fundamental frequency present in the signal to an amplitude of the fundamental frequency present in the signal, and
comparing the calculated ratio to ratios stored in the database.

10. Apparatus according to any preceding claim, wherein the object (20) is adapted to be inserted in a body of a patient (24).

11. A method for tracking an object (20) in the presence an interfering article (40), comprising:

generating an energy field at a fundamental frequency;
receiving a signal generated responsive to the energy field;
detecting the amplitude of the fundamental frequency in the signal; and **characterised by**
detecting a pattern of relative amplitudes of harmonic frequencies of the fundamental frequency present in the signal responsive to an interaction of the interfering article with the energy field;
comparing the pattern to patterns of relative amplitude of harmonic frequencies stored in a database of one or more such patterns associated with one or more respective specific types of interfering articles;
identifying the interfering article (40) based on the comparison;
correcting the signal based on the identification of the interfering article (40) and a magnitude of one or more of the harmonic frequencies in the detected pattern, and
determining position coordinates of the object (20) based on the corrected signal.

12. A method according to claim 11, wherein the interfering article (40) is ferromagnetic, and wherein identifying the interfering article comprises identifying the ferromagnetic interfering article.

13. A method according to claim 11 or claim 12, wherein the fundamental frequency is between 200 Hz and 12 kHz, and wherein receiving the energy field comprises receiving the energy field generated at the fundamental frequency.

14. A method according to any one of claims 11 to 13,
wherein detecting the pattern of relative amplitudes of harmonic frequencies comprises calculating a ratio of an amplitude of a first harmonic of the fundamental frequency present in the signal to an amplitude of a second harmonic of the fundamental frequency present in the signal, and
wherein comparing the pattern to the patterns of relative amplitudes of harmonic frequencies stored in the database comprises comparing the calculated ratio to ratios stored in the database.

15. A method according to any one of claims 11 to 14, wherein correcting the signal comprises:

calculating an interfering effect of the interfering article (40) on the signal; and
removing the interfering effects from the signal.

16. A method according to claim 15, wherein removing the interfering effect comprises subtracting, in a frequency domain, the interfering effect from the signal.

17. A method according to claim 15, wherein calculating the interfering effect comprises:

calculating a ratio of an amplitude of at least one of the harmonic frequencies of the fundamental frequency present in the signal to an amplitude of the fundamental frequency present in the signal; and
comparing the calculated ratio to ratios stored in the database.

18. A method according to any one of claims 11 to 17, wherein venerating the energy field comprises generating the energy field in a vicinity (60) of the object, and wherein receiving the signal comprises generating, at the object (20), the signal responsive to the energy field at the object.

19. A method according to any one of claims 11 to 18, wherein generating the energy field comprises generating the energy field at the object (20), and wherein receiving the signal comprises generating the signal in a vicinity (60) of the object, responsive to the energy field.

20. A computer software product for tracking an object (20) in the presence of an interfering article (40), the product comprising a computer-readable medium, in which program instructions are stored, which instructions, when read by a computer, cause the computer to:

receive a signal generated by a sensor exposed to an energy field at a fundamental frequency;
detect the amplitude of the fundamental frequency in the signal; **characterised in that** the instructions further cause the computer to
detect a pattern of relative amplitudes of harmonic frequencies of the fundamental frequency present in the signal responsive to an interaction of the interfering article (40) with the energy field;
compare the pattern to patterns of relative amplitudes of harmonic frequencies stored in a database of one or more such patterns associated with one or more respective specific types of interfering articles;
identify the interfering article (40) based on the comparison;
correct the signal based on the identification of the interfering article (40) and a magnitude of one or more of the harmonic frequencies in the detected pattern; and
determine position coordinates of the object (20) based on the corrected signal.

21. A product according to claim 20, wherein the interfering article (40) is ferromagnetic, and wherein the instructions cause the computer to identify the ferromagnetic interfering article.

22. A product according to claim 20 or claim 21, wherein the fundamental frequency is between 200 Hz and 12 kHz, and wherein the instructions cause the computer to receive the signal generated by the sensor exposed to the energy field at the fundamental frequency.

23. A product according to any one of claims 20 to 22,
wherein the instructions cause the computer to:

detect the pattern of relative amplitudes of harmonic frequencies by calculating a ratio of an amplitude of a first harmonic of the fundamental frequency present in the signal to an amplitude of a second harmonic of the fundamental frequency present in the signal, and
compare the pattern to the patterns of relative amplitudes of harmonic frequency stored in the database by comparing the calculated ratio to ratios stored in the database.

24. A product according to any one of claims 20 to 23, wherein the instructions cause the computer to correct the signal by:

calculating an interfering effect of the interfering article (40) on the signal, and
removing the interfering effect from the signal.

25. A product according to claim 24, wherein the instructions cause the computer to remove the interfering effect by subtracting, in a frequency domain, the interfering effect from the signal.

26. A product according to claim 24, wherein the instructions cause the computer to calculate the interfering effect by:

calculating a ratio of an amplitude of at least one of the harmonic frequencies of the fundamental frequency present in the signal to an amplitude of the fundamental frequency present in the signal, and
comparing the calculated ratio to ratios stored in the database.

Patentansprüche

1. Vorrichtung (18) zum Verfolgen eines Objektes (20) in der Anwesenheit eines störenden Gegenstandes (40), die aufweist:

einen Satz aus einem oder mehreren Strahlern (34), die dazu ausgelegt sind, ein Energiefeld mit einer Grundfrequenz in einer Umgebung (60) des Objektes zu erzeugen;
einen Positionssensor, der an dem Objekt (20) befestigt ist, der dazu ausgelegt ist, ein Signal ansprechend auf das Energiefeld zu erzeugen; und **gekennzeichnet durch**
eine Steuereinheit (50) mit Zugriff auf eine Datenbank aus einem oder mehreren Mustern relativer Amplituden harmonischer Frequenzen, die mit einem oder mehreren jeweiligen spezifischen Typen störender Gegenstände verknüpft sind, wobei die Steuereinheit dazu ausgelegt ist:

das Signal zu empfangen,
die Amplitude der Grundfrequenz in dem Signal zu erfassen,
ein Muster relativer Amplituden harmonischer Frequenzen der Grundfrequenz zu erfassen, das ist in dem Signal vorhanden ist, ansprechend auf eine Wechselwirkung des störenden Gegenstandes (40) mit dem Energiefeld,
das Muster mit den Mustern der relativen Amplituden harmonischen Frequenzen zu vergleichen, die in der Datenbank gespeichert sind,
den störenden Gegenstand basierend auf dem Vergleich zu identifizieren,
das Signal basierend auf der Identifikation des störenden Gegenstandes (40) und einer Größe einer oder mehrerer der harmonischen Frequenzen in dem erfassten Muster zu korrigieren, und
Positionskoordinaten des Objektes (20) basierend auf dem korrigierten Signal zu bestimmen.

2. Vorrichtung (18) zum Verfolgen eines Objektes (20), die aufweist:

einen Satz aus einem oder mehreren Strahlern (34), die an dem Objekt (20) befestigt sind, wobei die Strahler dazu ausgelegt sind, ein Energiefeld mit einer Grundfrequenz zu erzeugen;
einen Satz aus einem oder mehreren Positionssensoren, die sich in einer Umgebung des Objektes befinden, die dazu ausgelegt sind, jeweilige Signale ansprechend auf das Energiefeld zu erzeugen; und **gekennzeichnet durch**
eine Steuereinheit (50) mit Zugriff auf eine Datenbank aus einem oder mehreren Mustern relativer Amplituden harmonischer Frequenzen, die mit einem oder mehreren jeweiligen spezifischen Typen störender Gegenstände (40) verknüpft sind, wobei die Steuereinheit dazu ausgelegt ist:

das Signal zu empfangen,

die Amplitude der Grundfrequenz in dem Signal zu erfassen,
ein Muster relativer Amplituden harmonischer Frequenzen der Grundfrequenz zu erfassen, das ist in dem Signal vorhanden ist, ansprechend auf eine Wechselwirkung eines störenden Gegenstandes (40) mit dem Energiefeld,
das Muster mit den Mustern der relativen Amplituden harmonischen Frequenzen zu vergleichen, die in der Datenbank gespeichert sind,
den Gegenstand (40) basierend auf dem Vergleich zu identifizieren,
das Signal basierend auf der Identifikation des störenden Gegenstandes (40) und einer Größe einer oder mehrerer der harmonischen Frequenzen in dem erfassten Muster zu korrigieren, und
Positionskoordinaten des Objektes (20) basierend auf dem korrigierten Signal zu bestimmen.

3. Vorrichtung nach Anspruch 1 oder Anspruch 2, bei der störende Gegenstand (40) ferromagnetisch ist und bei der die Steuereinheit (50) dazu ausgelegt ist, den ferromagnetischen störenden Gegenstand zu identifizieren.

4. Vorrichtung nach Anspruch 1, 2 oder 3, bei der der Positionssensor wenigstens eine aus: einer Hall-Effekt-Einheit, einer Spule und einer Antenne aufweist.

5. Vorrichtung nach einem der Ansprüche 1 bis 4, bei der die Grundfrequenz zwischen 200 Hz und 12 kHz liegt und bei der die Strahler (34) dazu ausgelegt sind, das Energiefeld mit der Grundfrequenz zu erzeugen.

6. Vorrichtung nach einem der Ansprüche 1 bis 5, bei der die Steuereinheit (50) dazu ausgelegt ist, das Muster relativer Amplituden harmonischer Frequenzen zu erfassen, indem ein Verhältnis einer Amplitude einer ersten Harmonischen der Grundfrequenz, die in dem Signal vorhanden ist, zu einer Amplitude einer zweiten Harmonischen der Grundfrequenz, die in dem Signal vorhanden ist, berechnet wird, und das Muster mit den Mustern relativer Amplituden harmonischer Frequenzen, die in der Datenbank gespeichert sind, zu vergleichen, indem das berechnete Verhältnis mit Verhältnissen verglichen wird, die in der Datenbank gespeichert sind.

7. Vorrichtung nach einem der Ansprüche 1 bis 6, bei der die Steuereinheit (50) dazu ausgelegt ist, das Signal zu korrigieren, indem ein störender Effekt des störenden Gegenstandes auf das Signal berechnet wird und indem der störende Effekt aus dem Signal beseitigt wird.

8. Vorrichtung nach Anspruch 7, bei der die Steuereinheit (50) dazu ausgelegt ist, die störende Wirkung zu beseitigen, indem in einer Frequenzdomäne die störende Wirkung von dem Signal subtrahiert wird.

9. Vorrichtung nach Anspruch 7, bei der die Steuereinheit (50) dazu ausgelegt ist, die störende Wirkung zu berechnen, indem:

ein Verhältnis einer Amplitude wenigstens einer der harmonischen Frequenzen der Grundfrequenz, die in dem Signal vorhanden ist, zu einer Amplitude der Grundfrequenz, die in dem Signal vorhanden ist, berechnet wird, und das berechnete Verhältnis mit Verhältnissen, die in der Datenbank gespeichert sind, verglichen wird.

10. Vorrichtung nach einem der vorangehenden Ansprüche, bei der das Objekt (20) dazu ausgelegt ist, in einen Körper eines Patienten (24) eingeführt zu werden.

11. Verfahren zum Verfolgen eines Objektes (20) in der Anwesenheit eines störenden Gegenstandes (40), das aufweist:

Erzeugen eines Energiefeldes mit einer Grundfrequenz;
Empfangen eines Signals, das ansprechend auf das Energiefeld erzeugt worden ist;
Erfassen der Amplitude der Grundfrequenz in dem Signal; und **gekennzeichnet durch** das
Erfassen eines Musters relativer Amplituden harmonischer Frequenzen der Grundfrequenz, die in dem Signal vorhanden ist, ansprechend auf eine Wechselwirkung des störenden Gegenstandes mit dem Energiefeld;
Vergleichen des Musters mit Mustern relativer Amplituden von harmonischen Frequenzen, die in einer Datenbank aus einem oder mehreren solcher Muster gespeichert sind, die mit einem oder mehreren jeweiligen bestimmten Typen störender Gegenstände verknüpft sind;
Identifizieren des störenden Gegenstandes (40) basierend auf dem Vergleich;
Korrigieren des Signals basierend auf der Identifikation des störenden Gegenstandes (40) und einer Größe einer oder mehrerer der harmonischen Frequenzen in dem erfassten Muster; und
Bestimmen von Positionskoordinaten des Objektes (20) basierend auf dem korrigierten Signal.

12. Verfahren nach Anspruch 11, bei dem der störende Gegenstand (40) ferromagnetisch ist und bei dem das Identifizieren des störenden Gegenstandes das Identifizieren des ferromagnetischen störenden Gegenstandes umfasst.

13. Verfahren nach Anspruch 11 oder 12, bei dem die Grundfrequenz zwischen 200 Hz und 12 kHz liegt und bei dem das Empfangen des Energiefeldes das Empfangen des Energiefeldes, das mit der Grundfrequenz erzeugt worden ist, aufweist.

14. Verfahren nach einem der Ansprüche 11 bis 13,

bei dem das Erfassen des Musters relativer Amplituden harmonischer Frequenzen das Berechnen eines Verhältnisses einer Amplitude einer ersten Harmonischen der Grundfrequenz, die in dem Signal vorhanden ist, zu einer Amplitude einer zweiten Harmonischen der Grundfrequenz, die in dem Signal vorhanden ist, aufweist und bei dem das Vergleiches des Musters mit den Mustern relativer Amplituden harmonischer Frequenzen, die in der Datenbank gespeichert sind, das Vergleichen des berechneten Verhältnisses mit Verhältnissen, die in der Datenbank gespeichert sind, aufweist.

15. Verfahren nach einem der Ansprüche 11 bis 14, bei dem das Korrigieren des Signals umfasst:

Berechnen eines störenden Effektes des störenden Gegenstandes (40) auf das Signal; und
Beseitigen des störenden Effektes aus dem Signal.

16. Verfahren nach Anspruch 15, bei dem das Beseitigen des störenden Effektes das Subtrahieren, in einer Frequenzdomäne, des störenden Effektes von dem Signal aufweist.

17. Verfahren nach Anspruch 15, bei dem das Berechnen des störenden Effektes aufweist:

Berechnen eines Verhältnisses einer Amplitude wenigstens einer der harmonischen Frequenzen der Grundfrequenz, die in dem Signal vorhanden ist, zu einer Amplitude der Grundfrequenz, die in dem Signal vorhanden ist; und
Vergleichen des berechneten Verhältnisses mit Verhältnissen, die in der Datenbank gespeichert sindd.

18. Verfahren nach einem der Ansprüche 11 bis 17, bei dem das Erzeugen des Energiefeldes das Erzeugen des Energiefeldes in einer Umgebung (60) des Objektes umfasst und bei dem das Empfangen des Signals das Erzeugen, an dem Objekt (20), des Signals, das auf das Energiefeld an dem Objekt anspricht, umfasst.

19. Verfahren nach einem der Ansprüche 11 bis 18, bei dem das Erzeugen des Energiefeldes das Erzeugen des Energiefeldes an dem Objekt (20) umfasst und bei dem das Empfangen des Signals das Erzeugen des Signals in einer Umgebung (60) des Objektes ansprechend auf das Energiefeld umfasst.

20. Computersoftwareprodukt zum Verfolgen eines Objektes (20) in der Anwesenheit eines störenden Gegenstandes (40), wobei das Produkt ein von einem Computer lesbares Medium aufweist, in dem Programmbefehle gespeichert sind, wobei die Befehle, wenn sie von einem Computer gelesen werden, bewirken, dass der Computer:

ein Signal empfängt, das von einem Sensor erzeugt wird, welcher einem Energiefeld mit einer Grundfrequenz ausgesetzt ist;
die Amplitude der Grundfrequenz in dem Signal erfasst; **dadurch gekennzeichnet, dass** die Befehle weiter bewirken, dass der Computer
ein Musters relativer Amplituden harmonischer Frequenzen der Grundfrequenz, die in dem Signal vorhanden ist, ansprechend auf eine Wechselwirkung des störenden Gegenstandes (40) mit dem Energiefeld erfasst;
das Muster mit Mustern relativer Amplituden harmonischer Frequenzen vergleicht, die in einer Datenbank aus einem oder mehrerer solcher Muster, die mit einem oder mehreren jeweiligen bestimmten Typen störender Gegenstände verknüpft sind, gespeichert sind;
den störenden Gegenstand (40) basierend auf dem Vergleich identifiziert;
das Signal basierend auf der Identifikation des störenden Gegenstandes (40) und einer Größe einer oder mehrerer der harmonischen Frequenzen in einem erfassten Muster korrigiert; und
Positionskoordinaten des Objektes (20) basierend auf dem korrigierten Signal bestimmt.

21. Produkt nach Anspruch 20, wobei der störende Gegenstand (40) ferromagnetisch ist, und bei dem die Befehle bewirken, dass der Computer den ferromagnetischen störenden Gegenstand identifiziert.

22. Produkt nach Anspruch 20 oder 21, wobei die Grundfrequenz zwischen 200 Hz und 12 kHz liegt, und bei dem die Befehle bewirken, dass der Computer das Signal, das von dem Sensor erzeugt wird, welcher dem Energiefeld mit der Grundfrequenz ausgesetzt ist, empfängt.

23. Produkt nach einem der Ansprüche 20 bis 22,

bei dem die Befehle bewirken, dass der Computer
das Muster relativer Amplituden harmonischer Frequenzen erfasst, indem ein Verhältnis einer Amplitude einer ersten Harmonischen der Grundfrequenz, die in dem Signal vorhanden ist, zu einer Amplitude einer zweiten Harmonischen der Grundfrequenz, die in dem Signal vorhanden ist, berechnet und
das Muster mit den Mustern relativer Amplituden harmonischer Frequenzen vergleicht, die in der Datenbank gespeichert sind, indem das berechnete Verhältnis mit Verhältnissen verglichen wird, die in der Datenbank gespeichert sind.

24. Produkt nach einem der Ansprüche 20 bis 23, bei dem die Befehle bewirken, dass der Computer das Signal korrigiert, indem:

ein störender Effekt des störenden Gegenstandes (40) auf das Signal berechnet wird und
der störende Effekt aus dem Signal beseitigt wird.

25. Produkt nach Anspruch 24, bei dem die Befehle bewirken, dass der Computer den störenden Effekt beseitigt, indem, in einer Frequenzdomäne, der störende Effekt von dem Signal subtrahiert wird.

26. Produkt nach Anspruch 24, bei dem die Befehle bewirken, dass der Computer den störenden Effekt berechnet, indem:

ein Verhältnis einer Amplitude wenigstens einer der harmonischen Frequenzen der Grundfrequenz, die in dem Signal vorhanden ist, zu einer Amplitude der Grundfrequenz, die in dem Signal vorhanden ist, berechnet wird und
das berechnete Verhältnis mit Verhältnissen verglichen wird, die in der Datenbank gespeichert sind.

Revendications

1. Appareil (18) pour suivre un objet (20) en présence d'un article interférant (40) comprenant :

■ un ensemble d'un ou plusieurs radiateurs (34) qui sont adaptés pour générer un champ d'énergie à une fréquence fondamentale, à proximité (60) de l'objet ;
■ un capteur de position, fixé à l'objet (20), qui est adapté pour générer un signal sensible au champ d'énergie ; et **caractérisé par**

■ une unité de commande (50) ayant un accès à une base de données d'un ou plusieurs modèles d'amplitude relative de fréquences harmoniques associées à un ou plusieurs types respectifs d'articles interférants, l'unité de commande étant adaptée pour :
■ recevoir le signal,
■ détecter l'amplitude de la fréquence fondamentale dans le signal,
■ détecter un modèle d'amplitudes relatives de fréquences harmoniques de la fréquence fondamentale présente dans le signal, sensible à une interaction entre l'article interférant (40) et le champ d'énergie,
■ comparer le modèle aux modèles des amplitudes relatives de fréquence harmonique stockés dans la base de données,
■ identifier l'article interférant sur la base de la comparaison,
■ corriger le signal basé sur l'identification de l'article interférant (40) et d'une magnitude de fréquence harmonique stockée dans la base de données, et
■ déterminer les coordonnées de position de l'objet (20) sur la base du signal corrigé.

2. Appareil (18) pour suivre un objet (20), comprenant :

■ un ensemble d'un ou plusieurs radiateurs (34) fixés à l'objet (20), lesdits radiateurs étant adaptés pour générer

un champ d'énergie à une fréquence fondamentale ;
■ un ensemble d'un ou plusieurs capteurs de position, situés à proximité de l'objet, qui sont adaptés pour générer des signaux respectifs sensibles au champ d'énergie ; et **caractérisé par**

■ une unité de commande (50), ayant accès à une base de données d'un ou plusieurs modèles d'amplitudes relatives de fréquences harmoniques, associées à un ou plusieurs types spécifiques d'articles interférants (40), l'unité de commande étant adaptée pour :
■ recevoir le signal,
■ détecter l'amplitude de la fréquence fondamentale dans le signal,
■ détecter un modèle d'amplitudes relatives de fréquences harmoniques de la fréquence fondamentale présente dans le signal, sensible à une interaction d'un article interférant (40) avec le champ d'énergie,
■ comparer le modèle aux modèles d'amplitudes relatives de fréquences harmoniques stockées dans la base de données,
■ identifier l'article (40) sur la base de la comparaison,
■ corriger le signal sur la base de l'identification de l'article (40) et d'une magnitude d'une ou plusieurs des fréquences harmoniques dans le modèle détecté, et
■ déterminer les coordonnées de position de l'objet (20) sur la base du signal corrigé.

3. Appareil selon la revendication ou la revendication 2, dans lequel l'article interférant (40) est ferromagnétique, et dans lequel l'unité de commande (50) est adaptée pour identifier l'article interférant ferromagnétique.

4. Appareil selon les revendications 1, 2 ou 3 dans lequel le capteur de position comprend au moins un dispositif à effet Hall, une bobine et une antenne.

5. Appareil selon l'une quelconque des revendications 1 à 4, dans lequel la fréquence fondamentale est comprise entre 200 Hz et 12 kHz et dans lequel les radiateurs (34) sont adaptés pour générer le champ d'énergie à la fréquence fondamentale.

6. Appareil selon l'une quelconque des revendications 1 à 5, dans lequel l'unité de commande (50) est adaptée pour détecter le modèle d'amplitudes relatives de fréquences harmoniques, en calculant un rapport entre une amplitude d'une première harmonique de la fréquence fondamentale présente dans le signal à une amplitude d'une seconde harmonique de la fréquence fondamentale présente dans le signal, et pour comparer le modèle aux modèles d'amplitude relative de fréquences harmoniques stockées dans la base de données en comparant le rapport calculé à des rapports stockés dans la base de données.

7. Appareil selon l'une quelconque des revendications 1 à 6, dans lequel l'unité de commande (50) est adaptée pour corriger le signal, en calculant un effet interférant de l'article interférant sur le signal et en éliminant l'effet interférant du signal.

8. Appareil selon la revendication 7, dans lequel l'unité de commande (50) est adaptée pour éliminer l'effet interférant en soustrayant, dans un domaine de fréquence, l'effet interférant du signal.

9. Appareil selon la revendication 7, dans lequel l'unité de commande (50) est adaptée pour calculer l'effet interférant en :

■ calculant un rapport d'une amplitude d'au moins une des fréquences harmoniques de la fréquence fondamentale présente dans le signal, à une amplitude de la fréquence fondamentale présente dans le signal ; et
■ comparant le rapport calculé aux rapports stockés dans la base de données.

10. Appareil selon l'une quelconque des revendications précédentes, dans lequel l'objet (20) est adapté pour être inséré dans le corps d'un patient (24).

11. Procédé de suivi d'un objet (20) en présence d'un article interférant (40), comprenant :

■ la génération d'un champ énergétique à une fréquence fondamentale ;
■ la réception d'un signal généré sensible au champ énergétique ;
■ la détection de l'amplitude de la fréquence fondamentale dans le signal ; et **caractérisé par**

■ la détection d'un modèle d'amplitudes relatives de fréquences harmoniques de la fréquence fondamentale présente dans le signal sensible à une interaction de l'article interférant avec le champ énergétique ;
■ la comparaison du modèle aux modèles d'amplitude relative de fréquences harmoniques stockées dans une base de données d'un ou plusieurs de ces modèles associés à un ou plusieurs types spécifiques respectifs d'articles interférants ;
■ l'identification de l'article interférant (40) sur la base de la comparaison ;
■ la correction du signal sur la base de l'identification de l'article interférant (40) et une amplitude d'une ou plusieurs des fréquences harmoniques dans le modèle détecté ; et
■ la détermination des coordonnées de position de l'objet (20) sur la base du signal corrigé.

12. Méthode selon la revendication 11, dans lequel l'article interférant (40) est ferromagnétique et dans lequel l'identification de l'article interférant comprend l'identification de l'article interférant ferromagnétique.

13. Méthode selon les revendications 11 ou 12, dans lequel la fréquence fondamentale est comprise entre 200 Hz et 12 kHz, et dans lequel la réception du champ énergétique comprend la réception du champ énergétique généré à la fréquence fondamentale.

14. Méthode selon l'une quelconque des revendications 11 à 13,

■ dans lequel la détection du modèle d'amplitudes relatives de fréquences harmoniques comprend le calcul d'un rapport entre une amplitude d'une première harmonique de la fréquence fondamentale présente dans le signal et une amplitude de la seconde harmonique de la fréquence fondamentale présente dans le signal, et
■ dans lequel la comparaison du modèle aux modèles d'amplitudes relatives de fréquences harmoniques stockées dans la base de données comprend la comparaison du rapport calculé aux rapports stockés dans la base de données.

15. Méthode selon l'une quelconque des revendications 11 à 14, dans lequel la correction du signal comprend :

■ le calcul d'un effet interférant de l'article interférant (40) sur le signal, et
■ l'élimination de l'effet interférant du signal.

16. Méthode selon la revendication 15, dans lequel l'élimination de l'effet interférant comprend la soustraction, dans un domaine de fréquence, de l'effet interférant du signal.

17. Méthode selon la revendication 15, dans lequel le calcul de l'effet interférant comprend :

■ le calcul d'un rapport entre une amplitude d'au moins une des fréquences harmoniques de la fréquence fondamentale présente dans le signal et une amplitude de la fréquence fondamentale présente dans le signal ; et
■ la comparaison du rapport calculé aux rapports stockés dans la base de données.

18. Méthode selon l'une quelconque des revendications 11 à 17, dans lequel la génération du champ d'énergie comprend la génération du champ d'énergie à proximité (60) de l'objet, et dans lequel la réception du signal comprend la génération, au niveau de l'objet (20), du signal sensible au champ d'énergie au niveau de l'objet.

19. Méthode selon l'une quelconque des revendications 11 à 18, dans lequel la génération du champ d'énergie comprend la génération du champ d'énergie au niveau de l'objet (20) et dans lequel le signal comprend la génération du signal à proximité (60) de l'objet, sensible au champ d'énergie.

20. Produit logiciel pour suivre un objet (20) en présence d'un article interférant (40), le produit comprenant un système lisible sur ordinateur, dans lequel sont stockées les instructions de programme, lesdites instructions, quand elles sont lues par un ordinateur, provoquent :

■ la réception par l'ordinateur d'un signal généré par un capteur exposé à un champ d'énergie à une fréquence fondamentale ;
■ la détection par l'ordinateur de l'amplitude de la fréquence fondamentale dans le signal ; **caractérisé en ce que** les instructions provoquent en outré :

■ la détection par l'ordinateur d'un modèle d'amplitudes relatives de fréquences harmoniques de la fréquence fondamentale présente dans le signal, sensible à une interaction de l'article interférant (40) avec le champ d'énergie ;

■ la comparaison par l'ordinateur du modèle à des modèles d'amplitudes relatives de fréquences harmoniques stockées dans une base de données d'un ou plusieurs de ces modèles associés à un ou plusieurs types spécifiques respectifs d'articles interférants ;

■ l'identification par l'ordinateur de l'article interférant (40) sur la base de la comparaison ;

■ la correction par l'ordinateur du signal sur la base de l'identification de l'article interférant (40) et d'une amplitude d'une ou plusieurs fréquences harmoniques dans le modèle détecté ; et

■ la détermination par l'ordinateur des coordonnées de position de l'objet (20) sur la base du signal corrigé.

21. Produit selon la revendication 20, dans lequel l'article interférant (40) est ferromagnétique, et dans lequel les instructions provoquent l'identification par l'ordinateur de l'article interférant ferromagnétique.

22. Produit selon la revendication 20 ou la revendication 21, dans lequel la fréquence fondamentale est comprise entre 200 Hz et 12 kHz, et dans lequel les instructions provoquent la réception par l'ordinateur du signal généré par le capteur exposé au champ d'énergie à la fréquence fondamentale.

23. Produit selon l'une quelconque des revendications 20 à 22, dans lequel les instructions provoquent

■ la détection par l'ordinateur d'amplitudes relatives de fréquences harmoniques, en calculant un rapport entre une amplitude d'une première harmonique de la fréquence fondmentale présente dans le signal et une amplitude d'une seconde harmonique de la fréquence fondamentale présente dans le signal, et

■ la comparaison du modèle aux modèles d'amplitudes relatives de fréquence harmonique stockés dans la base de données.

24. Produit selon l'une quelconque des revendications 20 à 23, dans lequel les instructions provoquent la correction par l'ordinateur du signal en :

■ calculant un effet interférant de l'article interférant (40) sur le signal, et

■ éliminant l'effet interférant du signal.

25. Produit selon la revendication 24, dans lequel les instructions provoquent l'élimination par l'ordinateur de l'effet interférant en soustrayant, dans un domaine de fréquence, l'effet interférant du signal.

26. Produit selon la revendication 24, dans lequel les instructions provoquent le calcul par l'ordinateur de l'effet interférant en :

■ calculant un rapport entre une amplitude d'au moins une des fréquences harmoniques de la fréquence fondamentale présente dans le signal et une amplitude de la fréquence fondamentale présente dans le signal, et

■ comparant le rapport calculé aux rapports stockés dans la base de données.

FIG. 1

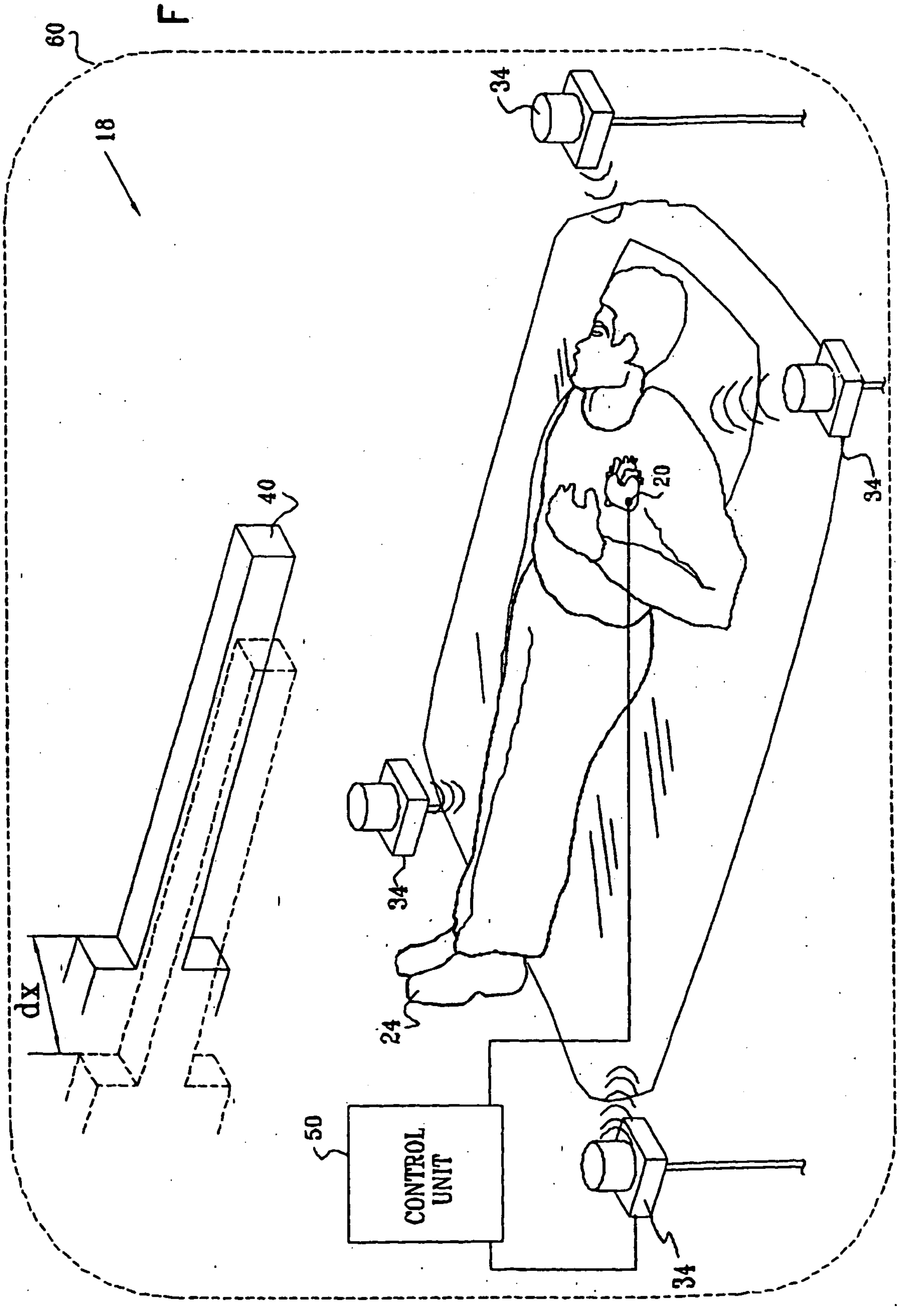
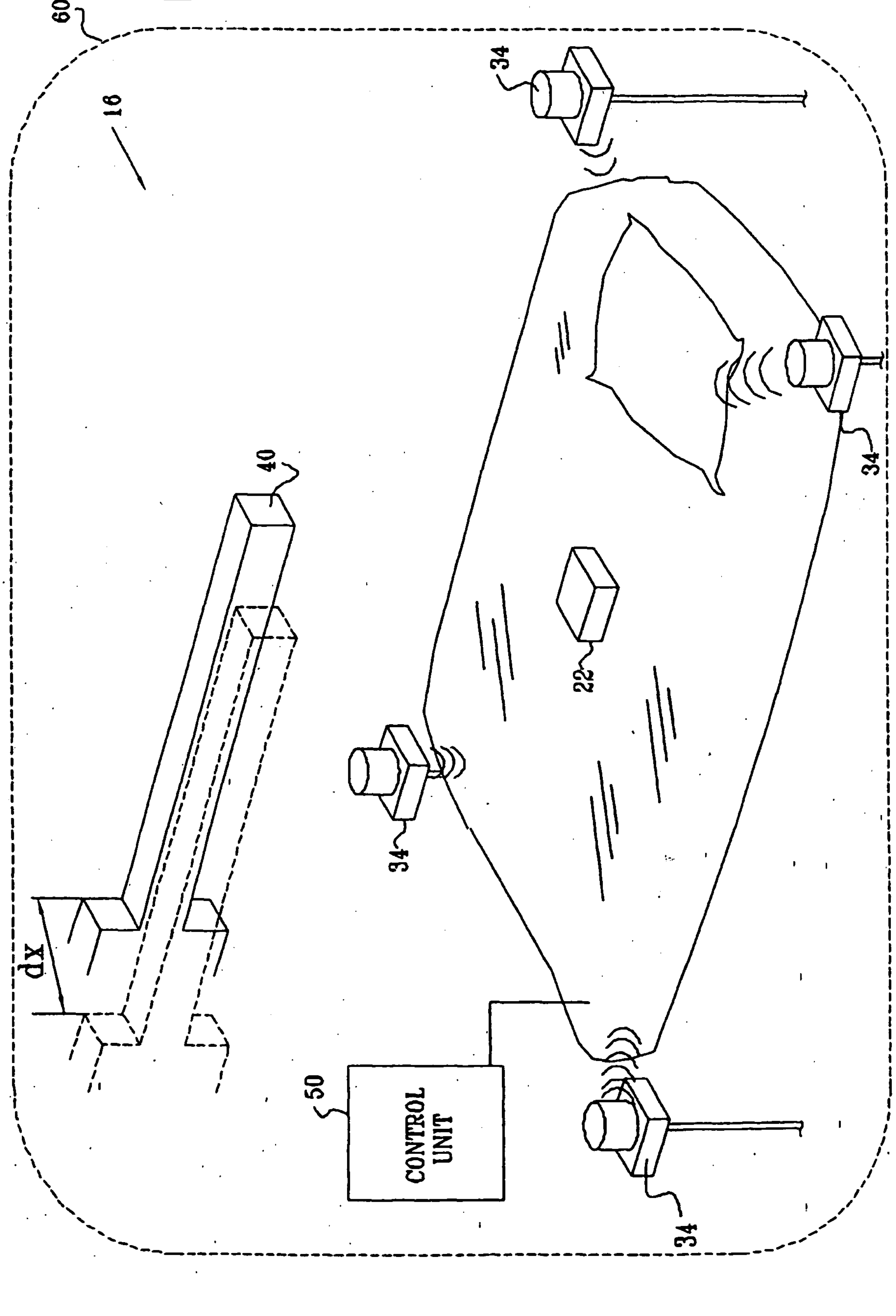


FIG. 2



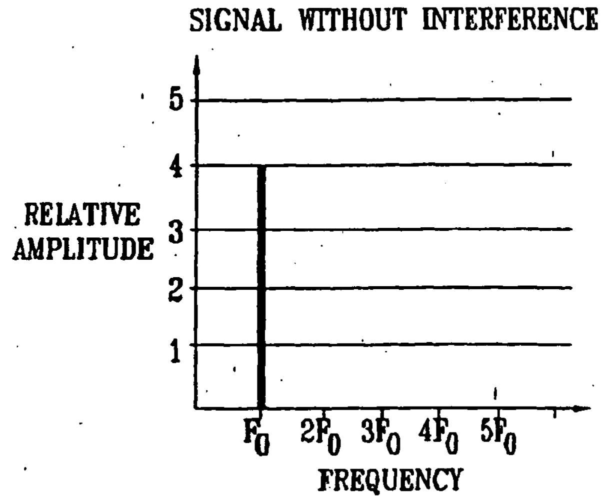


FIG. 3A

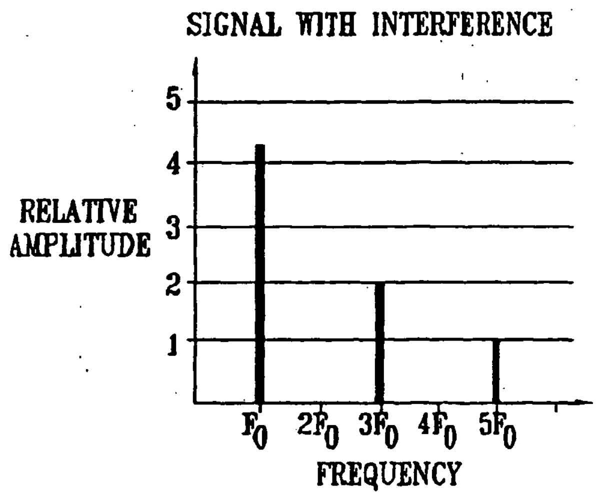


FIG. 3B

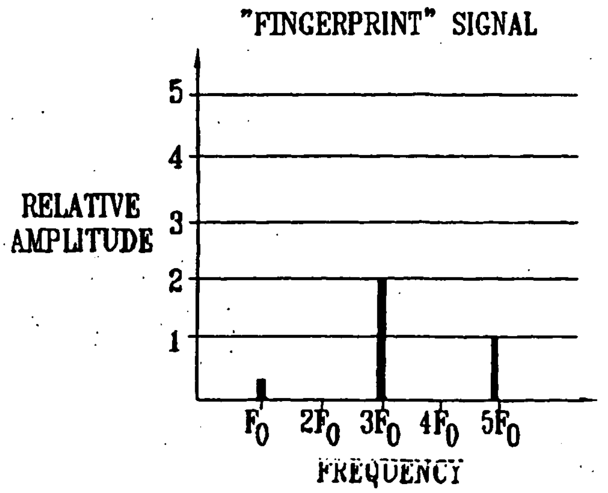


FIG. 3C

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	用于跟踪对象的装置，方法和软件		
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[标]申请(专利权)人(译)	韦伯斯特生物官能公司		
申请(专利权)人(译)	生物传感韦伯斯特，INC.		
当前申请(专利权)人(译)	生物传感韦伯斯特，INC.		
[标]发明人	GOVARI ASSAF		
发明人	GOVARI, ASSAF		
IPC分类号	A61B5/06 G01B7/004 G01V3/10 A61B5/00		
CPC分类号	A61B5/06 A61B5/062		
代理机构(译)	MERCER，CHRISTOPHER PAUL		
优先权	10/448291 2003-05-29 US		
其他公开文献	EP1481636A1		
外部链接	Espacenet		

摘要(译)

提供了用于在存在干扰物品（40）的情况下跟踪患者体内的物体的装置。一组一个或多个辐射器（34）适于在物体附近的基频处产生能量场。固定到物体的位置传感器适于产生响应能量场的信号。控制单元（50）可以访问与一个或多个相应特定类型的干扰物品相关联的一个或多个谐波频率模式的数据库。控制单元适于（a）接收信号，（b）响应于干扰物品与能量场的相互作用，检测信号中存在的基频的谐波频率模式。（c）将模式与存储在数据库中的谐波频率模式，（d）响应于比较识别干扰物品，（e）响应于干扰物品的识别和检测到的图案中的一个或多个谐波频率的大小来校正信号，（f）响应校正信号确定物体的位置坐标。

FIG. 1