

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
29 June 2006 (29.06.2006)

PCT

(10) International Publication Number
WO 2006/067664 A2

(51) International Patent Classification:
A61B 5/06 (2006.01) **A61B 19/00** (2006.01)

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(21) International Application Number:
PCT/IB2005/054171

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(22) International Filing Date:
12 December 2005 (12.12.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
04106839.6 22 December 2004 (22.12.2004) EP

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

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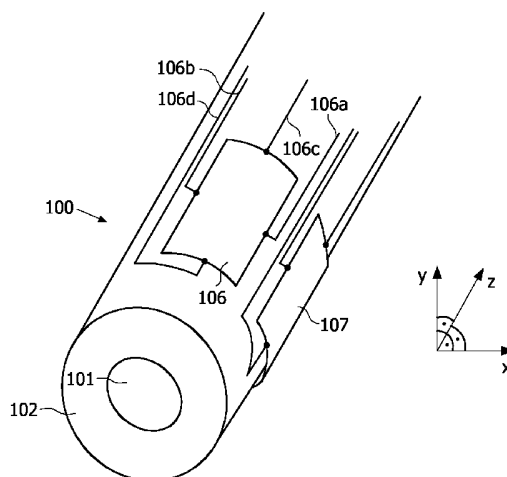
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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(54) Title: MARKER FOR POSITION DETERMINATION WITH A MAGNETIC METHOD



(57) Abstract: The invention relates to a marker whose position in an examination region can be determined by a magnetic method. This known method is used to determine the spatial distribution of magnetic particles in an examination region. A spatially inhomogeneous gradient magnetic field is generated, having at least one low field strength region in which the magnetization of the particles is in an unsaturated state, while they are in a saturated state in the rest of the region. Displacing the low field strength region by variation means inside the examination region leads to a change in the magnetization of the magnetic particles, which can be detected externally and contains information about the spatial distribution of the magnetic particles in the examination region. With the aid of the markers according to the invention it is also possible to determine the position of objects, or parts of the examination subject in the examination region, about which information cannot be determined with this method alone and which cannot therefore be represented in reconstructed images. The invention also relates to a method for localizing the marker, the use of the marker in this method and an arrangement therefor.

WO 2006/067664 A2



Published:

— without international search report and to be republished
upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Marker for position determination with a magnetic method

The invention relates to a marker whose position in an examination region can be determined by a magnetic method. The invention also relates to a method for localizing the marker, the use of the marker in this method and an arrangement therefor.

German patent application DE10151778 (referred to below as document Ax1) discloses a method for determining the spatial distribution of magnetic particles in an examination region. The spatial distribution of magnetic particles can be determined with a high temporal and spatial resolution with the aid of this method, which requires only comparatively minor equipment outlay. For example, images may then be reconstructed from this distribution. This method can be used particularly in the medical field.

Besides the magnetic particles, however, there are often also objects, or parts of the examination subject in the examination region, about which information cannot be determined with this method and which cannot therefore be represented in reconstructed images. It may nevertheless be necessary to ascertain the position of these objects and optionally show them in the images. In the medical field, for example, this is customary for invasive medical instruments such as catheters.

It is therefore an object of the invention to make it possible to find the position of these objects in the examination region.

This object is achieved as claimed in a claim 1 by a magnetizable marker whose magnetization is saturated with a magnetic field strength of at most 5 mT.

Markers are widely known from many fields of imaging. They are generally positioned on or next to objects about which it is not possible to obtain image-relevant data according to the imaging method being used. In the X-ray technique, for example, small bodies of an X-ray absorbing material (such as metal) are applied to the plastic tip of a catheter in order to make the catheter visible in the X-ray image. Alternatively, particular points on bones or other tissues are marked using markers so that these points can be found again in other X-ray exposures of the same bones or tissues, which are taken days or weeks later.

The term marker in the context of this invention is therefore intended to mean any structure with which a corresponding signal can be obtained by the method known from document Ax1. The marker must be magnetizable for this purpose, saturation of the magnetization being achieved with a field strength of at most 5 mT for the external magnetic field acting on the marker. This corresponds approximately to the order of magnitude of the saturation field strength of the magnetic particles which are used in the method of document Ax1. The signals of the marker can therefore be received and processed with the same system components. For explanation of the method and the associated apparatus structure, the entire content of document Ax1 is incorporated here by reference. It is also possible to use a marker in which saturation of the magnetization is achieved with a lower field strength of an external magnetic field, for example at 2 mT or 1 mT.

The term saturation is to be understood as follows in the context of the invention: Figs 4a and 4b of document Ax1 represent the magnetization curve of the magnetic particles described therein, a hysteresis having being omitted from the representation for simplicity. The magnetization curve is generally mirror-symmetric with respect to the x axis or a line parallel to it. The following comments refer to mirror symmetry with respect to the x axis. Starting from zero, the magnetization (y axis) rises as the magnitude of the external magnetic field (x axis) increases. The magnetization curve initially has a gradient which is more or less constant depending on the material being used. If the magnitude of the field strength of the external magnetic field is increased further, then the magnetization curve reaches a transition region within which the gradient of the magnetization curve changes, or decreases, significantly more strongly than before. If the magnitude of the field strength of the external magnetic field is increased even further, then this change of the gradient decreases significantly again and the magnetization curve once more has a more or less constant gradient, which is less than the gradient below the transition region. This gradient may even be zero. Here, a large change in the external magnetic field leads only to a minor change in the magnetization.

In the context of this invention, a magnetizable material is therefore said to be saturated when the magnitude of its magnetization lies above the transition region under the effect of an external magnetic field. The gradient of the magnetization curve above the transition region should be at least a factor of three less than below the transition region. In this case, it is not important whether the gradient of the magnetization curve changes again more strongly when the external magnetic field increases further, as is the case for example

with a material which is composed of various individual materials with different saturation field strengths.

In the example shown, the saturation is achieved with both a negative and a positive external magnetic field. The magnetization of the magnetizable material may change
5 between these two saturation states, for example by 200 mT. The greater this value is, the better the generated signals can be recorded.

In the simplest case, for example, the marker is a magnetizable solid body. Its size is determined by the accuracy of the position to be determined, naturally in conjunction with the resolution of the method. The size may also depend on how large and clearly visible
10 the marker should be in a reconstructed image. One simple geometrical shape of such a marker might be a magnetizable sphere. This is particularly suitable for marking a point independently of the "viewing direction". With the configuration as claimed in claim 2, the marker can be used to determine information not only about its position but at the same time about a direction as well. Such a marker may be fitted on a medical instrument, for example,
15 the longitudinal axis of the marker having a particular relation to the instrument. For example, a piece of soft magnetic wire may be fitted as a marker on the catheter tip, parallel to the axis of a catheter. In this way, besides the position, it is also possible to determine the orientation of the catheter tip in the examination region. An example of another embodiment is a sticking plaster, in which a small sphere or a thin threaded cross of wire or braid is
20 incorporated.

As claimed in claim 3, another form of a marker is an object which is provided with a soft magnetic layer. Such a layer may for example, be vapor deposited by known methods, or also applied or incorporated as a metal foil or foil coated with metal. Examples of such markers are a deposited cylindrical encapsulation which is placed over the tip of a
25 catheter, or a sticking plaster in which a thin deposited foil is incorporated. In general, the vapor deposited layer may have a pattern which is visible in the reconstructed image. A deposited cross or an arrow might be conceivable for the plaster, or as an alternative the cross or arrow may be covered during the deposition so as to produce a "negative" of the intended pattern. Such a soft magnetic layer may be applied at least pointwise on a nonmagnetic
30 medical instrument (for example, particular types of stainless steel are nonmagnetic).

As claimed in claim 4, an example of another embodiment is a body with a cavity in which there are magnetic particles, as described in document Ax1. The result of this, when a marker and magnetic particles are used simultaneously in the examination region, is that it is only necessary to receive and evaluate approximately similar types of

signals. Owing to the higher density of magnetic particles in the cavity, compared with the environment of the marker, the magnetic particles of the marker deliver correspondingly larger signals so that they can be seen clearly in a reconstructed image.

5 In the embodiment as claimed in claim 5, the signals generated by the marker are received directly in the vicinity of the marker. Known sensors such as coils may be used as the sensors. Compared with the signals which are received by the receiver coils disclosed in document Ax1, signals which are received by sensors arranged directly on the marker have a better signal-to-noise ratio.

10 As claimed in claim 6, the object is also achieved by a marker which has a sensor for measuring static magnetic fields. A sensor which can only record dynamic magnetic fields (for example when using a coil) is generally not very or not at all suitable for this. This will be illustrated by the following example: suppose that there is a small coil in the magnetic field represented in the Fig. 2 of document Ax1. The position of the region with a low field strength is displaced with respect to the coil by superimposing a time-varying
15 magnetic field on the gradient magnetic field. A signal is then generated in the coil, although it is caused only by the time-varying magnetic field. But since the time-varying magnetic field is substantially homogeneous as a function of position, information about where the coil is in the magnetic field is difficult or even impossible to infer from the signal generated in the coil. This would be possible, for example, if the time-variable magnetic field were not
20 homogeneous as a function of position and the position inhomogeneities were known.

A sensor as claimed in claim 6 is, for example, a Hall sensor or a giant magnetic resistant (GMR) sensor. In contrast to the previously described markers, such a marker need not have any magnetizable material since the magnetic fields acting on the examination region can be recorded directly by the sensor. In particular, the region with a
25 low magnetic field strength can be discriminated from the region with a high magnetic field strength. Since the position of these regions in the examination region is known, information about the position of the marker can be determined from the signals delivered by the sensor. A sensor generally has a working direction which is characterized in that the sensor delivers a maximum signal when there is a field line profile along this working direction. In the event
30 of a deviation from the working direction, for an equal field strength, the signal is weaker and sometimes even zero for a particular direction. In the case of a flat Hall sensor, the working direction is for example oriented perpendicularly to the surface of the sensor. In the embodiment as claimed in claim 7, the sensors can be arranged so that at least one sensor always delivers a signal.

In the embodiment as claimed in claim 8, the marker itself may be used invasively in a patient, and in particular it may remain in a patient for a prolonged time. This is necessary when, for example, a few days or weeks have to pass between the recordings of image data in order to track a healing process or the like.

5 The object is also achieved as claimed in claim 9 by a medical instrument which has a marker according to the invention, for example in analogy with the comments made above. The term medical instrument is in this case intended to mean any object which can be used by a doctor or other staff for medical purposes, for example examinations or treatments. On the one hand, these are to include objects which are applied externally on the
10 object to be examined and, for example, are placed on a patient's skin in the form of a scanning head. The term medical instrument may also refer to invasive medical instruments, such as instruments for minimal invasive operation or a catheter. They may also be probes which can be inserted into the esophagus, stomach, intestine, ear or other points of the human or animal body. This list is given by way of example and is not exhaustive.

15 The method as claimed in claim 10 is used for localizing a marker according to the invention in an examination region. Many of its steps are known from document Ax1. With the method as claimed in claim 11, it is possible on the one hand to localize the marker and, on the other hand, to determine the spatial distribution of magnetic particles. With the method as claimed in claim 12, the position of the marker can be determined first and the
20 spatial distribution can be determined subsequently in order to compile images in the environment of the marker. This is expedient when only images of the environment of the marker and not of the entire examination region are intended to be compiled. Generally, it is possible to find at least the approximate position of the marker with a low resolution. A low resolution leads to a significant reduction in the data records to the acquired and their
25 evaluation time. The position of the marker can therefore be determined relatively quickly compared with the compilation of images.

 The device as claimed in claim 13 is an arrangement known from document Ax1, which additionally has a marker according to the invention. The marker according to the invention can be used as claimed in claim 14 in this arrangement known from document
30 Ax1.

 These and other aspects of the invention are apparent from and will be elucidated with reference to the exemplary embodiments and figures described hereinafter.

In the drawings:

Fig. 1 shows the tip of a first catheter with markers

Fig. 2 shows the tip of a second catheter with markers

Fig. 3 shows a block diagram of the operation of the markers in Fig. 1

5 Fig. 4 shows a screw as a marker

Fig. 5 shows a sticking plaster as a marker

Fig. 1 represents the tip 100 of a catheter, whose axis extends in the z direction. As is known, a catheter forms a thin tube-like line through the interior of which, for example, a guide wire extends or liquids (such as contrast agents) are delivered to the catheter tip and can emerge through the opening 10.

Two known Hall sensors 106 and 107 are applied along the circumference of the tip 100. They may, for example, consist of a thin metal foil or a vapor deposited metal layer. Instead of metal, it is also possible to use a semiconductor material. Each of the Hall sensors 106 and 107 occupies about one fourth of the circumference of the catheter in the radial direction. The Hall sensors 106 and 107 are arranged mutually offset by about 90° in the radial direction. Their working directions are therefore mutually perpendicular, so that they can record magnetic fields correspondingly oriented mutually perpendicularly. The working direction of Hall sensor 106 extends in the y direction, and the working direction of Hall sensor 107 extends in the x direction. In order to record a magnetic field which extends in the z direction, a further Hall sensor (not shown) is arranged on the end side 102 of the catheter tip.

The Hall sensors may be applied either directly on the catheter tip 100 or, as an alternative, on a cylindrical encapsulation (not shown) which can be fitted over the catheter tip. With a view to an intended working direction and signal strength, the outer dimensions of the Hall sensors may also be smaller, or their mutual alignment may be different than as represented in Fig. 1.

Four electrical connections, which extend to the other end (not shown) of the catheter where they can be connected to a measuring instrument, are respectively fitted to the Hall sensors. On the Hall sensor 106, these are the connections 106a, 106b, 106c and 106d. For the sake of clarity, the connections of Hall sensor 107 are not referenced. As is known, two mutually opposite current connections, here for example 106a and 106b, are used to make a current flow through the Hall sensor 106. To this end, these current connections are connected to an adjustable current source 112 in Fig. 3. The level of the current strength is adjusted using the control unit 10. The control unit 10 corresponds to the control unit 10 in

Fig. 5 of document Ax1. In the present case, Fig. 3 is therefore to be regarded as a supplement to Fig. 5 of document Ax1. In the present case, each of the Hall sensors is connected to its own current source. As an alternative, however, all the Hall sensors may be connected to a single current source, and in particular the respective current supply terminals of the individual Hall sensors may be connected in series.

If a magnetic field acts in the working direction on the Hall sensor 106, then a voltage which can be recorded by a measuring instrument 113 in Fig. 6 is produced between the signal connections 106c and 106d. As is known, the level and polarity of the voltage depends on the one hand on the parameters of the Hall sensor, i.e. on the material of the Hall sensor and the strength of the current flowing through the Hall sensor. On the other hand, it naturally also depends on the strength and direction of the magnetic field. The measuring instrument 113 amplifies the measured voltage and converts it into digital signals, which are sent to an image processing unit 74. The image processing unit 74 likewise corresponds to the image processing unit 74 in Fig. 5 of document Ax1.

If this catheter tip is now brought into the magnetic field in Fig. 2 of document Ax1 then, owing to the known field line profile of the magnetic field, it is possible to determine the position of the catheter tip inside the magnetic field with the aid of the magnetic fields or magnetic field components recorded by the Hall sensors. This is also possible if the position of the two subregions of the magnetic field changes, since the new field line profile of the magnetic field after any positional change is likewise known. To this end the image processing unit 74, which corresponds to the image processing unit 74 in Fig. 5 of document Ax1, determines the position of the catheter tip in the magnetic field from the signals of all the Hall sensors and overlays a graphical symbol (for example a small circle or dot) at the corresponding position in the image.

In order to reduce the number of electrical wires when a plurality of Hall sensors are used, capacitors and/or inductors (not shown) for each Hall sensor may be connected in parallel with the terminals for the power supply, the capacitors and/or inductors being different for the individual Hall sensors. If the Hall sensors are supplied with an alternating current then, owing to the capacitors and/or inductors, the current respectively flowing through a Hall sensor will depend on the frequency of the alternating current. By varying the frequency, it is therefore possible to supply the Hall sensors with current successively and record their signals independently of one another. The signal terminals of all the Hall sensors may be interconnected in parallel, so that only two signal lines then need to be fed from the tip of the catheter to the measuring instrument. A similar effect is achieved if

nonlinear auxiliary resistors are used instead of capacitors or inductors, and a Hall sensor is selected not by the frequency of the current but via a corresponding readout voltage.

As an alternative to the Hall sensors, giant magnetic resistant sensors may also be arranged on the catheter. Lines may be interconnected correspondingly with these sensors as well.

Some other embodiments of the marker according to the invention are represented in Fig. 2. It represents the tip 120 of a catheter, on whose circumference an annular marker 122 is arranged. This marker consists of a thin foil of soft magnetic material or a layer of soft magnetic material, which is vapor deposited on the catheter tip 120. An alternative marker 124 is arranged on the end side of the catheter tip 120. This marker 124 consists of a flat ring of soft magnetic material, its inner and outer dimensions corresponding to those of the catheter. As an alternative, the marker 124 forms a hollow body which contains magnetic particles, as described in document Ax1. A further marker 115 is formed by a cavity located in the catheter wall, in which there are magnetic particles. It is also possible to introduce a soft magnetic sphere or a sphere filled with magnetic particles into the wall of the catheter. Another marker 123 is elongate or rod-shaped. It too can be formed by a cavity filled with magnetic particles or a magnetic wire incorporated into the wall of the catheter. If the marker 123 is oriented parallel to the axis of the catheter then, in addition to the position, this marker 123 also provides information about the direction of the catheter in the examination region.

The markers 122 and 124 arranged on the surface of the catheter 120 may additionally be coated with a biocompatible layer (not shown). Any reactions of the patient to the marker which may occur can thereby be prevented.

The magnetization characteristic of all the markers represented in Fig. 2 corresponds, for example, to those in Figs 4a and 4b of document Ax1. The saturation is achieved with a magnitude of at most 5 mT for the magnetic field strength. If the catheter 120 is used in the arrangement known from document Ax 1 and the imaging method known therefrom, then the saturation should be achieved at a similar magnetic field strength as in the case of the magnetic imaging particles used there. For the markers 124 and 115, this can be achieved straightforwardly if the hollow body contains the same magnetic particles as those used for the imaging. In all cases, the marker signals may in any event be received and evaluated by the same means as those used for the reception and evaluation of signals from the magnetic particles. In addition, the marker may be used simultaneously with magnetic

particles for imaging. Since the marker generates a higher signal than the magnetic particles surrounding it, it can be seen correspondingly better in an image.

In addition or as an alternative, in order to find one or more markers, it is possible to use a method which is known from systems with electromagnetic markers, for example from the article by Seiler et al. "A novel tracking technique for the continuous precise measurement of tumor positions in conformal radiotherapy", Phys. Med. Biol. 45 (2000) N103–N110. The system uses a method in which a priori knowledge is available about the position and the properties of the markers being used (for example by specification or by prior measurement). In the present case, for example, these properties are a special composition for each marker with respect to the frequency spectrum of the signals that occur during remagnetization.

The system then establishes positions where the markers should be in the examination region. This gives an artificial spatial distribution of the magnetizable material of the markers. Artificial signals are synthetically generated in a corresponding way to this, these being the ones recorded by the system if there actually was a marker at the established positions when changing the spatial positions of the two magnetic subregions. Actual signals from the examination region are then determined by changing the spatial positions of the two magnetic subregions, these signals coming from the markers and the magnetic particles located in the examination region. The artificially generated signals are subtracted therefrom. The spatial distribution is determined from the signals modified in this way, for example by the method of document Ax1. The artificially generated distribution of the markers is subsequently subtracted therefrom. If the markers are actually at the points which the system has established, then the positions of the markers are known to the system and the image obtained using the reconstructed distribution is perturbed only little by the markers. If the markers are not at the established positions, then other positions of the markers are established by the system and the method is carried out again.

If the signal level of the marker is not very different from the signals of the magnetic particles surrounding it, then a coil arrangement may additionally be arranged in the vicinity of all the markers represented in Fig. 2, as represented by way of example for the marker 115 by a coil 116. For the sake of clarity, the terminals and feed lines of the coil 116 are not represented. This coil 116 can be used as an additional receiver coil in order to record the signals of the marker in particular. If the marker is remagnetized, then the signals of the marker 115 will be recorded not only by the "normal" receiver coils but also by the coil 116. In this case, the coil 116 detects signals only if the subregion with a low field strength is

displaced in the vicinity of the marker 115. This can be used as additional information to determine the position of the marker in the examination region.

The coil 116 can nevertheless be used in a different way. Then, during operation, it generates a time-variable magnetic field which acts predominantly on the marker 115. To this end, as an alternative, the coil 116 may also extend radially around the catheter. The marker 115 should initially be in a subregion of the gradient magnetic field with a higher field strength. There, overall, it is exposed to a magnetic field which consists of a superposition of the gradient magnetic field and the time-variable magnetic field of the coil 116. The time-variable magnetic field of the coil 116 is in this case configured so that the total magnetic field acting on the marker 115 at any time is so great that the marker is always in a state of magnetic saturation.

If the subregion with a low magnetic field strength is then displaced to the marker 115, the marker is no longer in a state of saturation. It is constantly remagnetized by the time-variable magnetic field of the coil 116. The signals which then occur (consisting of the excitation frequency of the time-variable magnetic field of the coil 116 and harmonic overtones thereof) are recorded and evaluated, as described at length for magnetic particles in document Ax1. Since the position of the subregion with a low magnetic field strength is known, the position of the marker can be determined therefrom. If the marker is to be searched for in the examination region, then the subregion with a low magnetic field strength can be displaced by slow time-variable magnetic fields, as described in document Ax1. The marker is exactly at the position of the subregion with a low magnetic field strength when the recorded signals contain frequencies that correspond to those of the marker. The subregion with a low magnetic field strength should in this case be displaced so slowly that magnetic particles additionally contained in the examination region emit only very small signals. Similar systems are also known by the terms "fluxgate" magnetic field sensor or "Förster probe".

The subregion with a low field strength may, however, also be displaced with frequencies such as those used for normal signal generation in the magnetic particles, or for recording signals to compile images. The marker then emits signals which consist of these frequencies (and their harmonic overtones), but which are shifted by the frequency of the magnetic field of the coil 116. A frequency shift thus takes place. It is particularly straightforward to evaluate all the recorded signals when the frequency of the time-variable magnetic field of the coil 116 is different from the frequencies of the magnetic fields with which the subregion with a low field strength is displaced, and the frequencies of which the

signals of the magnetic particles are primarily composed. This is because the recorded signals then merely need to be analyzed with respect to whether they actually contain the frequencies shifted by the frequency of the time-variable magnetic field of the coil 116 or their harmonic overtones, since these signal components can only come from the marker and not from the magnetic particles. Signals for image data and signals for determining the position of the marker can then be generated and recorded simultaneously.

Figs 4 and 5 show another use of the markers according to the invention. Fig. 4 represents the cross section of a screw 201 such as may be used, for example, in the operative treatment of bone fractures. Such screws are often made of a nonmagnetic material such as titanium. In order to be able to determine their position, a first marker 202 in the screw head and a second marker 203 at the free end of the thread are incorporated into the screw 201. The spherical markers 202 and 203 consist of a soft magnetic material or a cavity filled with magnetic particles.

If the screw is to be used exclusively as a marker, in order to mark a particular position on a bone, then this screw can be made very small. As an alternative, it may then consist entirely of a soft magnetic material and, if necessary, be provided with a known biocompatible coating. Because of this coating, the screw can then remain in the bone for a longer time, so that any change of the bone or other organs or bones relative to it can be monitored by regularly checking its position.

Fig. 5 represents a sticking plaster 301, the side of the sticking plaster 301 resting on a patient's skin being visible. The sticking plaster 301 is, for example, made of fabric and centrally has a cushion region 303 with a cushion 304 which can cover a wound. Next to the cushion region 303 there are two adhesive flaps 302, with which the sticking plaster 301 can be applied to a patient in the known way. A threaded cross 305 of a metallized thread is incorporated into the cushion region 303. As an alternative to the threaded cross 305, other geometrical shapes are also conceivable. In order to avoid direct contact with a wound, the threaded cross 305 may be incorporated in a lower fabric layer of the cushion region 303, or in the cushion 304. If the sticking plaster 301 is not generally to be used for covering wounds, then the cushion region 303 may be replaced by a further adhesive region in which the threaded cross 305 is then incorporated.

CLAIMS:

1. A magnetizable marker (122, 124, 115, 123, 202, 203, 305) whose magnetization is saturated with a magnetic field strength of at most 5 mT.
2. A marker as claimed in claim 1, which consists of at least one elongate body.
3. A marker as claimed in claim 1, which consists of a layer of soft magnetic material, or is provided with one.
4. A marker as claimed in claim 1, in which there are magnetic particles.
5. A marker as claimed in one of the preceding claims, having a sensor (116) for measuring magnetic fields.
6. A marker (106, 107) having a sensor for measuring static magnetic fields.
7. A marker as claimed in claim 5 or 6, having at least two sensors with different working directions.
8. A marker as claimed in one of the preceding claims, having a biocompatible encapsulation.
9. A medical instrument (120), in particular a catheter, having a marker as claimed in one of the preceding claims.
10. A method for localizing a marker as claimed in one or more of the preceding claims in an examination region, having the steps of
 - a) introducing the marker into the examination region,

- b) generating a magnetic field with a spatial profile of the magnetic field strength such as to produce a first subregion with a low magnetic field strength and a second subregion with a higher magnetic field strength in the examination region,
- c) varying the spatial position of the two subregions in the examination region,
- 5 d) recording signals which depend on the way in which the marker is affected by this variation in the examination region,
- e) evaluating the signals in order to obtain information about the spatial position of the marker in the examination region.
- 10 11. A method as claimed in claim 10, wherein there are magnetic particles in the examination region, with the further steps of
- f) recording signals which depend on the way in which the magnetic particles are affected by this variation in the examination region,
- g) evaluating the signals in order to obtain information about the spatial
- 15 distribution of the magnetic particles in the examination region.
12. A method as claimed in claim 11, wherein the resolution when localizing the marker is less than when determining the spatial distribution of the magnetic particles.
- 20 13. A device for carrying out the method as claimed in claims 10 to 12, having
- a) a marker as claimed in one or more of claims 1 to 8,
- b) means for generating a magnetic field with a spatial profile of the magnetic field strength such as to produce a first subregion with a low magnetic field strength and a second subregion with a higher magnetic field strength in the examination region,
- 25 c) means for varying the spatial position of the two subregions in the examination region,
- d) means for recording signals which depend on the way in which the marker is affected by this variation in the examination region,
- e) means for evaluating the signals in order to obtain information about the
- 30 spatial position of the marker in the examination region.
14. Use of a marker as claimed in any one of claims 1 to 8 in an arrangement for determining the spatial distribution of magnetic particles, having

- a) means for generating a magnetic field with a spatial profile of the magnetic field strength such as to produce a first subregion with a low magnetic field strength and a second subregion with a higher magnetic field strength in the examination region,
- b) means for varying the spatial position of the two subregions in the examination region,
- c) means for recording signals which depend on the way in which the marker and/or the magnetic particles are affected by this variation in the examination region,
- d) means for evaluating the signals in order to obtain information about the spatial position of the marker and/or the magnetic particles in the examination region.

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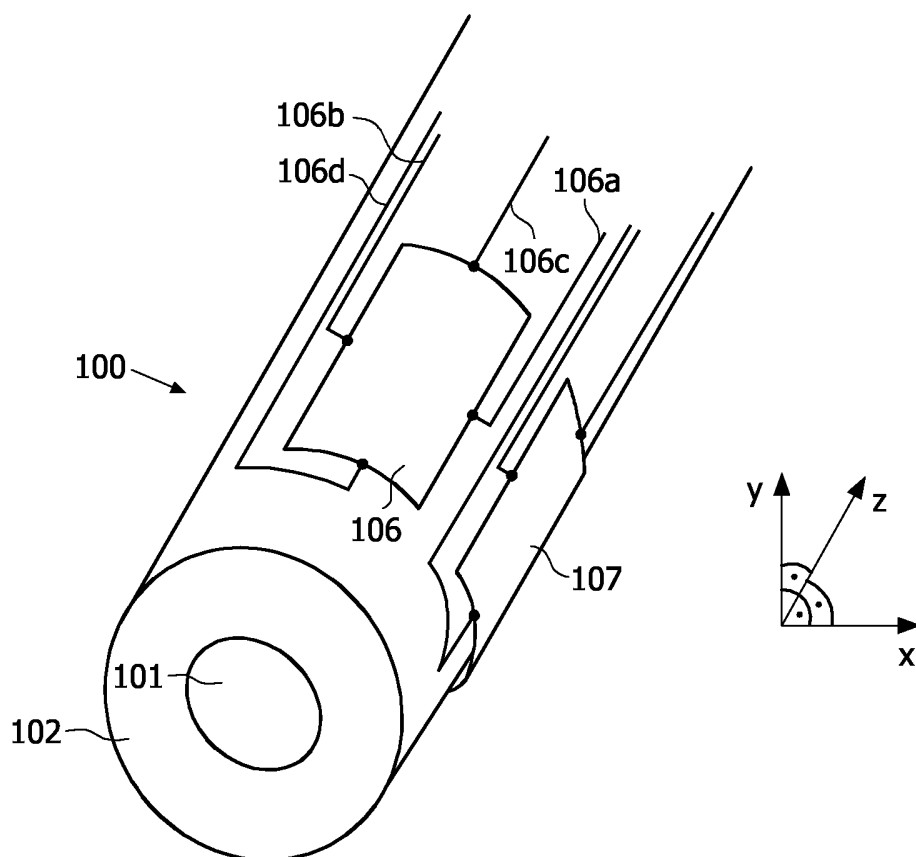


FIG. 1

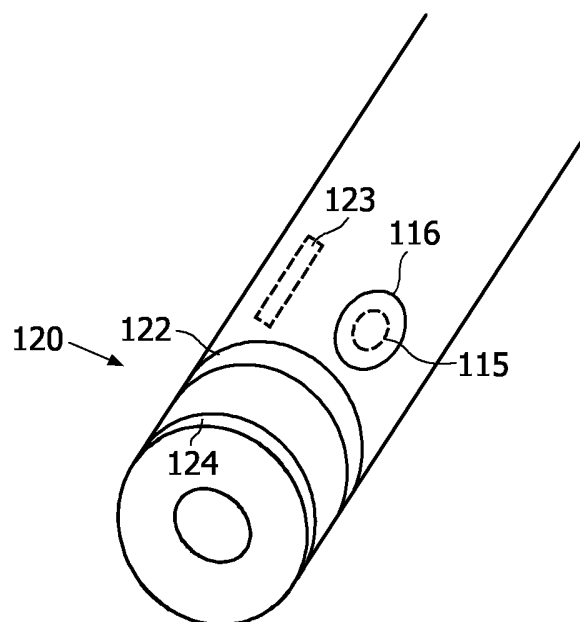


FIG. 2

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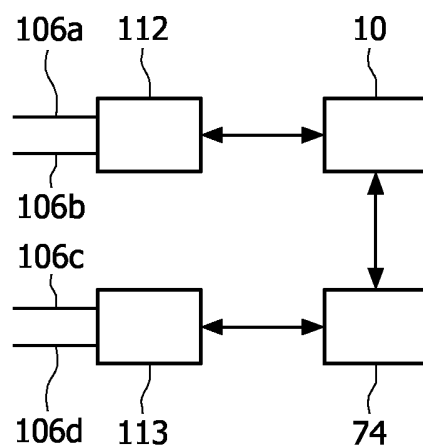


FIG. 3

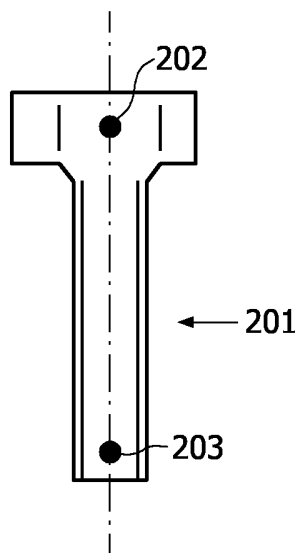


FIG. 4

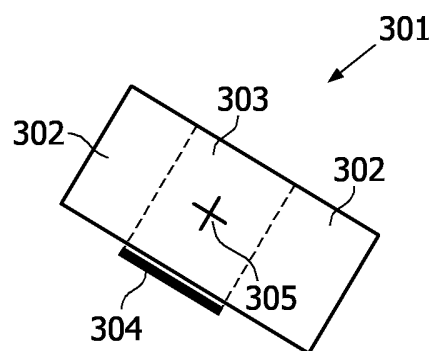


FIG. 5