(19) DANMARK

(10) DK/EP 2635178 T3

Patent- og Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.: ***A 61 B 5/0507 (2021.01)*** *H 01 Q 17/00 (2006.01)*

(45) Oversættelsen bekendtgjort den: **2021-11-15**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2021-08-11**

(86) Europæisk ansøgning nr.: **11796831.3**

(86) Europæisk indleveringsdag: **2011-11-03**

(87) Den europæiske ansøgnings publiceringsdag: **2013-09-11**

(86) International ansøgning nr.: **IL2011050003**

(87) Internationalt publikationsnr.: **WO2012059929**

(30) Prioritet: **2010-11-03 US 409565 P**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

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(56) Fremdragne publikationer:
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WO-A2-2009/031149
WO-A2-2011/141915
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US-A- 4 344 440
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DESCRIPTION

FIELD AND BACKGROUND OF THE INVENTION

[0001] The present invention, in some embodiments thereof, relates to an electromagnetic EM probe and, more particularly, but not exclusively, to an EM probe for transmission and/or reception of electromagnetic radiation and a method of generating the EM probe.

[0002] EM radiation, such as RF and MW radiation, is potentially useful means of monitoring and diagnosing body tissues. The dielectric properties of the tissues may be a basis of detecting various pathologies and physiological trends.

[0003] Examples for using RF and MW radiation for monitoring and diagnosing body tissues is found, inter alia, in International patent application pub. No WO 2010/100649, International patent application pub. No WO 2009/031150, and/or International patent application pub. No 2009/031149.

[0004] The design and fabrication of such EM probes present various challenges.

[0005] During the last years, various EM probes have been developed. For example United States Patent 6,233,479 describes a Microwave Hematoma Detector which is a non-invasive device designed to detect and localize blood pooling and clots near the outer surface of the body. While being geared towards finding subdural and epidural hematomas, the device can be used to detect blood pooling anywhere near the surface of the body. Modified versions of the device can also detect pneumothorax, organ hemorrhage, atherosclerotic plaque in the carotid arteries, evaluate perfusion (blood flow) at or near the body surface, body tissue damage at or near the surface (especially for burn assessment) and be used in a number of NDE applications. The device is based on low power pulsed microwave technology combined with a specialized antenna, signal processing/recognition algorithms and a disposable cap worn by the patient which will facilitate accurate mapping of the brain and proper function of the instrument. The invention may be used for rapid, non-invasive detection of subdural or epidural hematoma in human or animal patients, detection of hemorrhage within approximately 5 cm of the outer surface anywhere on a patient's body.

[0006] Another example is described in U.S. Patent No. 7,184,824 which describes an EM probe for examining tissue in order to differentiate it from other tissue according to the dielectric properties of the examined tissue are provided. The EM probe includes an inner conductor, having a plurality of sharp, thin, conductive spikes, at a proximal end with respect to a tissue for examination, the plurality of sharp, thin, conductive spikes being operative to enhance the electrical fringe fields, where interaction with the tissue for examination occurs.

[0007] Another example is described in U.S. Patent No. 7,591,792 which describes: a tissue

sensors house for one or more sensor elements. Each element has a housing mounted substrate and a superstrate with a planar antenna between. A transitional periphery (TP) of a superstrate outer surface interconnects a base to a plateau. At least some of the TP has a generally smooth transition. Plural elements are spaced by the housing. Alternately, the superstrate TP is flat, the housing extends to the outer superstrate surface and a shield surrounds the element. The housing is flush with or recessed below the superstrate and defines a TP between the housing and superstrate. A method converts a reference signal to complex form; plots it in a complex plane as a reference point (RP); converts a measurement signal to complex form; plots it in the complex plane as a measurement point (MP); determine a complex distance between the MP and the RP; and compares complex distance to a threshold.

[0008] Another example is described in WO 00/64343 which describes: a microwave hemorrhagic stroke detector includes a low power pulsed microwave transmitter with a broad-band antenna for producing a directional beam of microwaves, an index of refraction matching cap placed over the patients head, and an array of broad-band microwave receivers with collection antennae. The system of microwave transmitter and receivers are scanned around, and can also be positioned up and down the axis of the patients head. The microwave hemorrhagic stroke detector is a completely non-invasive device designed to detect and localize blood pooling and clots or to measure blood flow within the head or body. The device is based on low power pulsed microwave technology combined with specialized antennas and tomographic methods. The system can be used for rapid, non-invasive detection of blood pooling such as occurs with hemorrhagic stroke in human or animal patients as well as for the detection of hemorrhage within a patient's body.

[0009] Another example is described in WO 2006/085052 which describes methods and apparatus for reducing signal artifacts resulting from reflections from the surface of the object. In one method, a similar paths algorithm is used to create a calibration signal to reduce signal artefacts. In another method, an equivalent location algorithm is used to create calibration data to reduce signal artefacts, in another method, blocking screens are positioned in contact with, or closely adjacent to, the surface. In another method, an anti-reflective layer is employed. The methods may be employed singly or jointly in a breast tumour imaging device.

[0010] Another example is described in U.S. Patent No. US 2007/123770 which describes: a sensor device for detecting a change in the level of fluid within tissue of a body includes: a housing having a plurality of bridge segments, the bridge segments connecting at intersections and being arranged to circumscribe an opening defined by the housing; and a plurality of antenna elements at least partially seated within the housing at intersections of the bridge segments. Each of the plurality of antenna elements includes a generally planar antenna mounted to a substrate material at a base of the planar antenna. An outer surface of the planar antenna faces away from the substrate. Each of the plurality of antenna elements further includes an electrical shield surrounding the substrate. A sensor for detecting a change in the level of fluid within tissue of a body including a first antenna pair includes a first transmitting antenna and a first receiving antenna. The first transmitting antenna is spaced

from and connected to the first receiving antenna by a first bridging segment. The sensor further includes at least a second antenna pair including a second transmitting antenna and a second receiving antenna. The second transmitting antenna is spaced from and connected to the second receiving antenna by a second bridging segment. The first antenna pair and the second antenna pair are placed in spaced connection by a first spacing segment and a second spacing segment so that an open area is defined by the first antenna pair, the second antenna pair, the first spacing segment and the second spacing segment.

[0011] Another example is described in U.S. Patent No. 2007/208404 which describes: a lighting system that includes a leadframe, and a light active sheet material laminated on the leadframe and electrically connected to the leadframe. The light active sheet material includes a transparent electrically conductive top substrate, a pattern of one or more light emitting diode (LED) chip(s) sandwiched between the leadframe and the top substrate, and a non-conductive transparent adhesive material disposed between the leadframe, the LED chip(s), and the top substrate. The LED chip(s) is (are) preformed before being patterned in the light active sheet material as an unpackaged discrete semiconductor device having an anode p-j unction side and a cathode n-junction side. Either of the anode and the cathode side is in electrical communication with the top substrate and the other of the anode and the cathode side is in electrical communication with the leadframe.

[0012] Document US 2007/123770 discloses a sensor device for detecting a change in the level of fluid within tissue of a body, said device comprising plurality of antenna elements in a housing comprising electromagnetic energy absorbing material.

SUMMARY OF THE INVENTION

[0013] According to the present invention there is provided an electromagnetic (EM) probe for monitoring at least one biological tissue, as defined in claim 1. Preferred embodiments are defined in claims 2-12.

[0014] According to the present invention there is provided a method of producing an electromagnetic (EM) probe for monitoring at least one biological tissue according to claim 13.

[0015] According to some embodiments of the present invention there is provided a method of monitoring at least one biological tissue according to claim 14.

[0016] Unless otherwise defined, all technical and/or scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the invention pertains. Although methods and materials similar or equivalent to those described herein can be used in the practice or testing of embodiments of the invention, exemplary methods and/or materials are described below. In addition, the materials, methods, and examples are illustrative only and are not intended to be necessarily limiting.

[0017] Implementation of the method and/or system of embodiments of the invention can involve performing or completing selected tasks manually, automatically, or a combination thereof. Moreover, according to actual instrumentation and equipment of embodiments of the method and/or system of the invention, several selected tasks could be implemented by hardware, by software or by firmware or by a combination thereof using an operating system.

[0018] For example, hardware for performing selected tasks according to embodiments of the invention could be implemented as a chip or a circuit. As software, selected tasks according to embodiments of the invention could be implemented as a plurality of software instructions being executed by a computer using any suitable operating system. In an exemplary embodiment of the invention, one or more tasks according to exemplary embodiments of method and/or system as described herein are performed by a data processor, such as a computing platform for executing a plurality of instructions. Optionally, the data processor includes a volatile memory for storing instructions and/or data and/or a non-volatile storage, for example, a magnetic hard-disk and/or removable media, for storing instructions and/or data. Optionally, a network connection is provided as well. A display and/or a user input device such as a keyboard or mouse are optionally provided as well.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] Some embodiments of the invention are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of embodiments of the invention. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the invention may be practiced.

[0020] In the drawings:

FIG. 1 is a schematic sectional illustration of an electromagnetic (EM) radiation EM probe for monitoring at least one biological tissue not forming part of the present invention;

FIG. 2 is a schematic sectional illustration of an EM probe for monitoring at least one biological tissue having a circumferential flange, according to some embodiments of the present invention;

FIG. 3A is a schematic sectional illustration of an EM probe for monitoring at least one biological tissue having a circumferential flange, according to some embodiments of the present invention;

FIG. 3B is a schematic sectional illustration of an EM probe for monitoring at least one biological tissue having a circumferential flange, according to some embodiments of the present invention;

FIG. 4 is a schematic sectional illustration of an EM probe for monitoring at least one biological tissue having a zigzagged circumferential flange, according to some embodiments of the present invention;

FIG. 5 is a schematic sectional illustration of an EM probe for monitoring at least one biological tissue having a cup shaped cavity with inner walls covered by one or more layers of absorbing materials, according to some embodiments of the present invention;

FIG. 6 is a schematic sectional illustration of an EM probe for monitoring at least one biological tissue having a dome shaped cavity, according to some embodiments of the present invention;

FIGs. 7A and 7B are schematic illustrations of an EM probe having an EM element placed outside of the interior volume of a cup shaped cavity, according to some embodiments of the present invention;

FIG. 8 is a schematic sectional illustration of a wearable device having an EM probe for monitoring at least one biological tissue, according to some embodiments not forming part of the present invention;

FIG. 9 is a sectional schematic illustration of a system for monitoring a biological tissue(s) by an analysis of passing through signals, according to some embodiments not forming part of the present invention;

FIG. 10A and FIG. 10B which are a sectional schematic illustration and a three dimensional illustration of a printed circuit board (PCB) EM probe having a fabricated cup shaped cavity, according to some embodiments not forming part of the present invention;

FIGs. 11A, 11B and 11C are images of surface current density in an EM probe without a layer of absorbing material, in an EM probe with a layer of absorbing material, and in an EM probe with a layer of absorbing material covering the bottom side only of a circumferential flange, according to some embodiments of the present invention;

FIGs. 12A and 12B and 12C are images of H-field distribution in an EM probe without a layer of absorbing material, in an EM probe with a layer of absorbing material, and in an EM probe with a layer of absorbing material covering the bottom side only of a circumferential flange, according to some embodiments of the present invention; and

FIGs. 13A and 13B and 13C are images of E-field distribution in an EM probe without a layer of absorbing material, in an EM probe with a layer of absorbing material, and in an EM probe with a layer of absorbing material covering the bottom side only of a circumferential flange, according to some embodiments of the present invention.

DESCRIPTION OF EMBODIMENTS OF THE INVENTION

[0021] The present invention, in some embodiments thereof, relates to an electromagnetic EM probe and, more particularly, but not exclusively, to an EM probe for transmission and/or reception of electromagnetic radiation and a method of generating the EM probe.

[0022] According to some embodiments of the present invention, there is provided an electromagnetic (EM) probe for monitoring dielectric properties in one or more biological tissues using a cup shaped cavity which is coated with one or more layers of absorbent material and has a circumferential flange. The cup shaped cavity houses an element for radiating and/or capturing EM radiation and has a single opening for the passage of the EM radiation. In such a manner, the cup shaped cavity forms a closed interference reduced volume when the opening is placed on top of or above a skin area of a monitored user. Such an EM probe is less sensitive to changes in the skin in an area outside the circumference of the EM probe, for example more than 2cm, or more than 4cm, and/or to changes which are introduced when the EM probe is being touched and/or changes which are related to the mechanical interfacing and/or coupling of the EM probe to the skin.

[0023] The circumferential flange is set to reduce the sensitivity to noise from the proximity of the EM probe, for example from external EM transmission sources, such as, for example, cellular phones, thus improving the signal to noise ratio (SNR) and therefore on the quality of reception. Moreover, the circumferential flange and the absorbing layers prevent from at least some of the EM transmissions to make their way to the external surface of the EM probe. In such a manner, the amount of escaped signals which add noise to the external environment may be reduced. It may reduce currents escaping or penetrating the EM probe to/from the external side of the EM probe or exposed body surfaces. Such currents may be conducted on the skin, or external conductive parts of the EM probe, like its cavity and/or conducting elements, such as cables. Such currents may, for example, be induced by currents related to a transmitting EM probe, or its connected cables, onto the conductive parts, or proximate skin area, of a receiving EM probe, via conduction or induction, resulting in parasitic crosstalk between them. The circumferential flange may be placed on the edge of the opening or attached to the external walls of the cup shape cavity few millimeters above the opening. The circumferential flange may be a bendable flange and/or a flexible flange which is adjusted to be closely attached to the skin surface of a monitored user. Optionally the flange is also set to assist in prevention of entry of fluid and/or water and/or perspiration into the area under the EM probe. Optionally, the flange is set to enable an airtight interface of the EM probe to the skin area, enabling attachment by air pressure differences of the EM probe, and/or increasing the effectiveness of the isolation functionality of the flange by improving the mechanical coupling of the flange to the skin area. For example by use of another layer, for example a sub millimeter layer of silicon material, covering the bottom side of the flange. The circumferential flange may be zigzagged, jagged, and/or curved to extend the path of signals passing therethrough. The absorbing material may cover external walls of the cup shaped cavity, the circumferential flange or any portion thereof, and/or a portion of the internal walls of the cup shaped cavity. A layer of absorbing material may be placed on the lower side of the circumferential flange so as to be in contact with the monitored skin area.

[0024] According to some embodiments not forming part of the present invention, the EM probe is a printed circuit board (PCB) EM probe fabricated in known fabrication techniques.

[0025] Before explaining at least one embodiment of the invention in detail, it is to be understood that the invention is not necessarily limited in its application to the details of construction and the arrangement of the components and/or methods set forth in the following description and/or illustrated in the drawings and/or the Examples. The invention is capable of other embodiments or of being practiced or carried out in various ways.

[0026] Reference is now made to FIG. 1, which is a schematic sectional illustration of an electromagnetic (EM) radiation EM probe 100 for monitoring at least one biological tissue, according to some embodiments not forming part of the present invention. The EM probe 100 includes a cup shaped cavity 103 having an opening 110 and an interior volume 102. As FIG. 1 depicts a section illustration, the depicted broken line represents the diameter of the opening 110. The outer surface of the cup shaped cavity 103, namely the external sides of the cup shaped cavity 103 which do not face the interior volume 102 are covered with one or more layers 104 of a material for absorbing EM radiation. The one or more layers 104 are set to absorb electric fields and/or magnetic fields.

[0027] For example regarding the complex permittivity of the absorbing material at a frequency of about 1 Ghz, ε' is between 2 and 60 typically around 30 and ε" is between 1 and 30 typically 5 and regarding the complex permeability of the absorbing material, μ' is between 1 and 30 typically 20 and μ" is between 2 and 30 typically 6 to 15. The cup shaped cavity 103, which may be referred to as a cavity is made of a conductive material. The absorbing material may be any material that dissipates EM energy, for example Eccosorb® MCS, GDS and BSR. Optionally, the thickness of the one or more layers 104 is between about 0.1 millimeters (mm) and about 10 cm.

[0028] Optionally, the height of the cup shaped cavity 103 is between about 0.5 millimeters (mm) and about 10cm. Optionally, the width of the opening 110 of the cup shaped cavity 103 is between about 0.5 millimeters (mm) and about 20 centimeters. Optionally, the opening width is set according to the transmitted and/or received frequency and/or the size or configuration of the EM element(s).

[0029] Optionally, the cup shaped cavity 103 comprises a plurality of chambers wherein in each chamber contains a different EM element, such as the EM element 101. The plurality of EM elements can also be used inside a single non-divided or partly chambered cavity.

[0030] The one or more layers 104 are applied, for example laminated, on the cup shaped cavity 103 and/or molded as cup sized and shaped to engulf the cup shaped cavity 103 without blocking the opening 110. The cup shaped cavity 103 is optionally shaped to have a cubical outline, a cylindrical outline, a dome outline, a pyramid outline, or a conical outline, each having an open base set for being in direct or indirect (for example, via intermediate substance) contact with a skin tissue of a monitored, diagnosed EM probed, and/or monitored user.

Optionally, the cup shaped cavity 103 is made of a conductive material, such as metal. Optionally and respectively the one or more layers 104 has a respective outline.

[0031] Optionally, the one or more layers 104 are extended to increase the surface area of absorbing material which is found above the space between the skin area above a monitored intrabody target area and the EM probe 100.

[0032] The EM probe 100 further includes one or more emitting and/or receiving elements 101 which are placed in the interior volume 102. Optionally, the EM radiation is radio frequency (RF) radiation and/or microwave (MW) radiation for example from a few 100MHz's up to a few GHz. The emitting and/or receiving elements 101 are connected, by conducting element(s) 301, such as cables, for example coaxial cables, and/or waveguides, for example metal tubes used to carry microwave and/or RF energy with little loss of power, to external means for generating and/or analyzing EM signals, as further described below. The conducting element(s) 301 may be connected to the emitting and/or receiving elements 101 via an aperture in the lateral walls of the cup shaped cavity 103 and/or an aperture in the top wall of the cup shaped cavity 103, for example as shown in FIG. 2. As used herein, an emitting and/or receiving element means a transducer, an antenna, for example a bowtie antenna, an ultra-wide band (UWB) antenna, a micro strip antenna, a slot fed antenna, a dipole antenna, a patch antenna, and a spiral element antenna, a feedhorn and/or a tip of a waveguide which delivers and/or collects EM radiation . For example, in FIG. 1, an antenna is connected via a coaxial cable 301 to an external means for generating and/or analyzing EM signals (not shown).

[0033] Optionally, the interior volume 102 remains empty and therefore filled with air when being used. Optionally, the interior volume 102 is filled with a dielectric substance having a relatively high dielectric coefficient, for example about 10, such as Rogers R3010. Optionally, the dielectric substance has a dielectric coefficient which relatively matches the dielectric coefficient of body tissues or any matching material in-between. In such a manner, dielectric discontinuity is reduced and the efficiency of the transmission of the emitting element 101 and the sensitivity of the EM receiving element 101 is increased. Optionally, a layer of dielectric material, elastic, shape preserving or other, or a composition of different materials, such as a gel with or without dielectric increasing agents, for example metal oxides or fluids, and is applied between the EM probe and the skin area 201. Optionally separating the layer of dielectric material and the skin is a layer of a biocompatible material.

[0034] Reference is now made to FIG. 2, which is a schematic sectional illustration of an EM probe 100 for monitoring at least one biological tissue, according to some embodiments of the present invention. The EM probe 100 is similar to the one depicted in FIG. 1, however it further includes a circumferential flange 105 that is attached to the cup shaped cavity 103, in proximity to the opening 110, for example few millimeters above the opening edge, as shown in FIG. 2 or on the same plane of the opening edge, as depicted in FIG. 3.

[0035] The circumferential flange 105 is placed around the opening 110, optionally so as to be parallel to a skin area 201 in proximity to a monitored, EM probed, and/or diagnosed tissue(s)

of a monitored user in proximity to the skin area 201 about implanted antenna. The circumferential flange 105 is made of a conductive material, such as metal. The circumferential flange 105, which is optionally a non-circular or circular metal ring, surrounds the opening and is electrically coupled, for example galvanically connected, to the cup shaped cavity 103. Optionally, the circumferential flange 105 is an integral part of the cup shaped cavity 103. For example the circumferential flange 105 is a portion of the cup shaped cavity 103 that is bended to be substantially in parallel or in parallel to the skin area of a monitored, EM probed, and/or diagnosed tissue(s) of a monitored user.

[0036] It should be noted that the EM probe 100 may be part of an intrabody implant, such as a subdermal implant. In such an embodiment, the EM probe 100 is sized and shaped to be placed between the tissues. In such an embodiment, the opening 110 may directly face a fat layer or a muscle layer. In such embodiments, the aforementioned structure of the EM probe 100 reduces currents that may develop on the tissue surface.

[0037] Optionally, the circumferential flange 105 is placed so that in use, the lower part thereof is in touch with or in a close proximity to the skin area 201, for example as shown at FIG. 3, or for instance via a cloth (.i.e. a shirt, pants). Optionally, at least a portion of the circumferential flange 105 is covered by one or more layers of absorbing materials 106 which are in touch with or in a close proximity to the skin area 201. Generally and especially in the case where the EM probe is on top of a cloth, a construction similar to FIG. 3B can be used (at least the area marked with 95 is filled with air only). In this case, pressure is applied to the EM probe 100, for example by use of a chest strap, pushing it towards the body. The pressure applied on the depicted construction concentrates on the circumferential flange 105 and serves to improve mechanical coupling of the circumferential flange 105 to the skin area or, in the case of clothing reduce the gap, created by the layer of clothing.

[0038] The portion is the edge of the circumferential flange 105, namely the area which is extended away from the cup shaped cavity 103. Optionally, the circumferential flange 105 is placed so that in use, the lower part of the one or more layers of absorbing materials 106 is in touch with or in a close proximity to the skin area 201. In the embodiment depicted in FIG. 2, the inner wire of the connected cable 301 is used for carrying signals intended to and/or received from the emitting and/or receiving elements 101, for brevity referred to herein as an EM element 101. Optionally, the EM element 101 is driven by a coaxial cable 301 whose inner wire and shield are connected to the EM element 101. Optionally, only the inner conductor is connected to the EM element 101. Optionally, the shield is connected and/or coupled to the cup shaped cavity 103.

[0039] The circumferential flange 105 conducts EM radiation originating from the cup shaped cavity 103 and/or from the interior volume 102 and/or from the skin area 201, facilitating its absorption in the layers of absorbing materials 106. Optionally, the circumferential flange 105 is continuous and annular. Optionally, the circumferential flange 105 comprises a plurality of separate elements which form a non continuous and annular structure around the opening 110. Optionally, the circumferential flange 105 is continuous and planar.

[0040] The circumferential flange 105 increases isolation of the interior volume 102 from interference signals from areas and/or layers that are in the periphery of the EM probe and are superficial, for example the skin layer or fat layer, rather than from internal body tissues and/or organs that are of interest and are substantially in a region that is in front of the opening 110. The circumferential flange 105 effectually guides interference signals, such as close proximity parasitic EM radiation and/or currents traveling on the skin area 201, along the absorbing material 106 so as to dissipate them. In such a manner interfering effects may be reduced or eliminated. The interference signals are the radiation and/or currents which may be from the EM element 101, or from an area external to the EM probe, and travel along the body surface, for example on the skin 201 and/or via proximate subdermal tissues, such as fat and/or organs in close proximity to circumferential flange 105. The isolation of the interior volume 102 from interference signals may reduce the noise caused by parasitic signals originated from the EM transmission of the EM element 101 and/or from external interference signals which are not intercepted from the body of the monitored user. The isolation of the interior volume 102 also reduces the sensitivity to environment changes, such as hand movements or skin changes in proximity to the EM probe 100. In such a manner, for example, the effects of reflection signals originating from hand or other movements in the proximity of the EM probe and/or skin contour changes may be reduced.

[0041] Optionally, the distance between the peripheral outer edge of the circumferential flange 105 and the peripheral inner edge thereof is between 0.1 centimeters (cm) and 5cm and/or a few wavelengths, for example 0.3cm. Optionally, the circumferential flange 105 is placed, at least partly, inside the interior volume 102.

[0042] Optionally, the circumferential flange 105 is substantially rigid. The larger the surface area of the circumferential flange 105, the higher is the isolation from interference signals. Since the isolation functionality of the circumferential flange 105 and the one or more layers of absorbing materials 106 are more effective when attached to the skin, optionally, at least some of the circumferential flange 105 and the absorbing material 106 which covers it are flexible so as to increase the surface area which is attached to the skin. Optionally, the circumferential flange 105 is substantially flexible, for example made of fiber based structures, flexible polymers, and/or a mesh having shape memory characteristics. This circumferential flange 105 may be bended in order to curve according to the surface of the skin area 201. Optionally, part of the circumferential flange 105 is rigid and part of flange 105 is flexible. In this case the flexible and rigid parts may be coupled or galvanically connected, and each part is coated with the absorbing material 106 separately or jointly. Optionally, the rigid portion is closer to the EM element 101 than the flexible portion, so the nearest volume to the EM element 101 is fixated and possibly pressed against the skin to decrease possible geometrical changes, for example of the skin and fat in proximity to the EM element. Optionally, the circumferential flange is jagged, zigzagged, curved, and/or bended along a plane parallel to the opening 110, for example shown in numeral 401 of FIG. 4. In such a manner, the path signals are passing along the circumferential flange 105 is longer so that their absorption is increased.

[0043] Some elements of the EM probe 100 are attached to the body of the monitored user, for example using adhesives, while others are disconnected therefrom.

[0044] According to some embodiments of the present invention, the circumferential flange 105 is set to enable an airtight interface between the EM probe 100 and the skin area, enabling attachment by air pressure differences. For example, a sub millimeter layer of silicon material is placed to cover the bottom side of the circumferential flange 105 and to form the airtight interface when attached to a skin area. The airtight interface may also increase the effectiveness of the isolation functionality of the circumferential flange 105 by improving the mechanical coupling of the circumferential flange 105 to the skin area. Optionally, a pressure regulator is attached to the cup shaped cavity 103 so as to control the air pressure in the inner volume of the cup shaped cavity 103. In such a manner, the air pressure differences may be controlled by the user and/or a clinician attaching the EM probe 100. In such an embodiment, the EM probe 100 is constructed to form an air gap above the opening 110. By reducing the air pressure in the gap, the attachment of the EM probe 100 to the skin area is formed. For example the gap created between the horizontal plane of the opening 110 and a plane thereabove in the cup shaped cavity 103. The lower pressure can be created by the pressure regulator, for example one or more one way valves connected to one or more pumps such as rubber balls. Another option is a mechanical lever that deforms the cup shaped cavity 103 after the attachment thereof to the skin area, substantially pulling back the dielectric material away from the skin creating a low pressure air gap.

[0045] According to some embodiments of the present invention, the circumferential flange 105 is a detachable element, set to be attached to a skin area above the monitored intrabody volume of the patient. In such an embodiment, the circumferential flange 105 may remain attached to the skin for durations of time in between different monitoring and/or diagnosis sessions, assisting in placement of the EM probe in following sessions. In addition, the ability to detach the cup shaped cavity 103 and optionally the EM element 101 which is mounted therein, allows, for example, cleaning the skin area between the sessions, replacing the cup shaped cavity 103 and/or the EM element 101 and/or repairing elements of the EM probe 100 without having to reposition or attach the circumferential flange 105.

[0046] Reference is now made to the isolation of the cable 301. In use, the edge of cable 301, which connects to the EM element 101, is typically close to the skin, parasitic EM radiation radiating from the skin area 201 and/or escaping from the cup shaped cavity 103 and/or originating from other sources may induce parasitic currents on the cable 301 that introduce noise. Optionally, a layer of an absorbing material 302, such as the aforementioned absorbing material, coats the cable 301 in proximity to the external surface of the cup shaped cavity 103. Optionally, the coating is along a portion of the cable 301, starting from the area in close proximity to the cup shaped cavity 103. This coating prevents from parasitic EM radiations which travel along the skin area 201 or passing through the air in proximity to the EM probe 100 from substantially affecting currents conducted by the cable 301 and/or substantially interfering with reception of the signals. This coating also prevents currents conducted on the cable from substantially radiating back into the same or other EM probes and/or their cables.

This leakage might interfere with the operation of receiving signals from the monitored area in the body.

[0047] In some cases, a network of EM probes, each as shown at 100, is used for receiving and/or capturing signals from the monitored area in the body. In such an embodiment, the sensitivity of this network is greatly determined by the effect of crosstalk interference between the EM probes. Such crosstalk interference includes a reception of an EM signal that is transmitted from the network EM probes and does not propagate through an intended path. This EM signal might propagate on the skin, through air, or through cables or electronics connecting the EM probes, rather than through internal body tissues and/or organs. The crosstalk interference might interfere with the operation of the network and may also increase sensitivity to artifacts that are a result of body movements and changes in the surrounding. The aforementioned isolation isolates the EM probes from one another. Cables connecting the different EM probes might carry some of the signals on their outer shield and therefore should also be protected by the absorbing material as described herein. Moreover, the cables may operate as antennas transferring radiation and inducing currents on proximate cables. Currents induced on the cable of a receiving EM probe by radiation from a cable of a transmitting EM probe may penetrate into the internal volume of the receiving EM probe and therefore introduce noise. The crosstalk signal may be affected by movement of the cable or any respective movements between the cables increasing the overall noise in the system.

[0048] According to some embodiments not forming part of the present invention, some of the inner walls of the cup shaped cavity 103 are covered by one or more layers of absorbing materials, such as the aforementioned absorbing materials, for example as depicted by numeral 111 in FIG. 5. Optionally, the lateral walls of the cup shaped cavity 103 are covered with the aforementioned absorbing materials. Optionally, the lateral walls of the cup shaped cavity 103 and the circumferential flange 105 are covered with the aforementioned absorbing materials so that none of them touches the skin of the patient. Optionally, all the inner walls of the cup shaped cavity 103 are covered with the aforementioned absorbing materials. Optionally only the portions of the inner walls which are closer to the opening 110 are covered with the layers of absorbing materials 111. For example, FIG. 6 depicts a cup shaped cavity which is shaped as a dome. The circumferential flange 105 is encircled and marked with numeral 105. Optionally, only the inner wall of the cup shaped cavity 103 which faces the opening 110 remains uncovered by layers of absorbing material, for example as shown at FIG. 5.

[0049] It should be noted that layers 104, 106, 111 and 302 employ an absorbing material in proximity to conducting parts such as the cup shaped cavity 103, the circumferential flange 105 and/or the connected cable 301 so that parasitic EM signals and radiation traveling along these parts may be dissipated. In such a manner, interference signals, which propagate in close proximity to the EM element 101, are absorbed in one or more of the layers 104, 106, 111 and 302. The interference signals may be signals originated from the EM element 101, signals entering the interior volume 102 from the skin area 201, and/or straying signals which do not arrive from an intended path, i.e. parasitic signals.

[0050] According to some embodiments not forming part of the present invention, the EM element 101 is connected, via the cable 301, to a receiver and/or a transmitter which may be located in a different housing, for example in a mobile or a stationary unit, or within an element that is integrated with the EM probe, externally to the cup shaped cavity 103. Optionally one or more attachment elements, as defined below, are used for attaching the EM probe 100 to the monitored user so that the opening 110 faces the skin area 201, for example as shown in FIGs. 1-4.

[0051] Reference is now also made to FIGs. 7A and 7B, which are schematic illustrations of an EM probe 150 having an EM element generating EM radiation, which is placed outside of the interior volume of the cup shaped cavity 103, according to some embodiments of the present invention. In such an embodiment, a conducting element, such as a waveguide, is used for conducting EM radiation, such as RF and/or MW waves which are generated outside of the cup shaped cavity 103 and conducted into the interior volume thereof. At least the lower portion of the circumferential flange around the opening is covered with an absorbing material 155, as described above. Optionally, also the external lower part of the cup shaped cavity 103 is covered with the absorbing material 155.

[0052] Reference is now made to FIG. 8, which is a sectional schematic illustration of a wearable device 500 for monitoring a biological tissue(s), according to some embodiments not forming part of the present invention. The wearable device 500 include a housing 499 which contains one or more of the EM probe 100 and one or more additional components for monitoring a monitored user, optionally ambulatory, and optionally for detecting one or more physiological patterns according to a dielectric property, for example as described in International patent application pub. No WO 2010/100649, International patent application pub. No WO 2009/031150, and/or International patent application pub. No 2009/031149. The dielectric property is calculated based on the reading of the EM radiation captured by the EM element. Optionally, a transmitter 502 is used to generate a signal that is transmitted to the EM element 101 for transmission. Optionally, a receiver 503 is used to receive a signal that is received by the EM element 101. Optionally, the processing unit 504 is a microprocessor or any other computing unit used to analyze the outputs of the receiver 503 and/or to control the transmitter 502. The processing is optionally performed as described in International patent application pub. No WO 2010/100649, International patent application pub. No WO 2009/031150, and/or International patent application pub. No 2009/031149. Optionally, the wearable device 500 includes one or more attachment elements 505, such as straps, coatings of adhesive. When straps are used, the wearable device 500 may be placed above a cloth (i.e. shirt, pants). Adhesive elements, and buckle components, for attaching the wearable monitoring apparatus 500 to the body of a monitored user with the opening 110 facing a skin area (not shown). In another embodiment not forming part of the present invention, such attachment elements 505 may be used for connecting only the EM probe 100 to the skin area. It should be noted that the components described in FIG. 8 may be part of a stationary system in which only the EM probe 100 is attached to the body of the monitored user.

[0053] Reference is now made to FIG. 9, which is a sectional schematic illustration of a system 500 for monitoring a biological tissue(s) by an analysis of passing through signals 903, according to some embodiments not forming part of the present invention. Components 502-504 are as depicted in FIG. 8, however in these embodiments at least two EM probes 901, 902 are used. One EM probe 901 is used for transmitting EM radiation toward a body organ or a number of body tissues and another EM probe 902 is used for receiving the passing through EM radiation 903. Optionally, the transmitting EM probe 901 is also set to receive reflections of the EM radiation from the body part. Optionally, the EM probe 902 is also set to transmit EM radiation toward the body part. Each one of the EM radiation EM probes 901, 902 may be defined as any of the aforementioned embodiments. In such an embodiment the intended path can be, for example, the path passing from EM probe 902 to EM probe 901. The isolation properties as described in the aforementioned may serve to minimize interference to the reception of EM radiation from this path.

[0054] Reference is now made to FIG. 10A, which is a sectional schematic illustration of a printed circuit board (PCB) EM probe 600 having a fabricated cup shaped cavity 601 and to FIG. 10B which is a three dimensional schematic illustration of this PCB EM probe 600, according to some embodiments not forming part of the present invention. The PCB EM probe 600 is created by a number of layers. As shown at 602, a layer of absorbent material, such as Eccosorb® MCS, is placed above a layer of conductive material 603, such as a metal layer. A stratified layer 620 below the conductive material 603 is constructed. The stratified layer 620 includes lateral walls 604, which are formed around a dielectric substance 608 having a relatively high dielectric coefficient, for example about 10, such as Rogers R3010, for example as described above. A conducting element 606, such as a wire, is placed in the dielectric substance 608, optionally in parallel to the layer of conductive material 603, and is extended outside the PCB EM probe through the lateral walls with no electrical connection to them. Another electrical connection (not shown) is possibly made and extended to the outside of the PCB EM probe, in a similar manner to the EM element 615 or to the fabricated cup shaped cavity. This allows connecting an EM element 615, such as an antenna thereto. In such a manner, an internal volume is formed contained within the reflecting walls 604 and the layer of conductive material 603.

[0055] According to some embodiment not forming part of the present invention the PCB EM probe 600 may be created by fabricating and bonding 4 layers, using fabrication techniques. For example, each layer is fabricated from a "blank PCB" made of a bonded metal, for example copper, and a substrate such as Rogers R3010. The metal on the "blank PCBs" are etched away and the layers are then bonded together. The layers in such an embodiment can be comprised of the following layers:

1. 1) a first layer the top of the formed cup shaped cavity and underneath it a substrate,
2. 2) a second layer an additional substrate and underneath an etched antenna and one or more conducting wires feeding it,
3. 3) a third layer - an additional substrate and underneath it an etched peripheral circumferential flange, and

4. 4) a fourth layer - a bare substrate layer with no metal.

[0056] These 4 layers are bonded together where the first layer is the topmost layer and fourth layer is the bottom layer. Optionally, the lateral wall(s) 604 are made by drilling dense via holes and filling them with a conductive material. Such dense via holes, optionally with metal connecting among them in each horizontal layer, may function as a metal plate for wavelengths greater than the distance between each pair of dense via holes. When such via holes are drilled in said substrate some dielectric material may remain effectively outside the cup shaped cavity due to fabrication limitations, for example 612 as in FIG. 10A. Optionally, the four layers are sized and shaped as in FIG. 10B. Optionally, a shaped absorbing material is bonded on the top of the created PCB EM probe and on the bottom side of the flange. Electronic circuitry like amplifiers, transformers, filters, receivers and transmitters, data collector and/or communication modules may be constructed between each pair of layers. For example, additional layers can be added on top of the cup and use the conductive upper part of the cap as a ground plane. This electronic circuitry can then be put inside an additional cavity. Various embodiments and aspects of the present invention as delineated hereinabove and as claimed in the claims section below find experimental support in the following examples.

EXAMPLES

[0057] Reference is now made to the following examples, which together with the above descriptions, illustrate some embodiments of the invention in a non limiting fashion.

[0058] Reference is now made to FIGs. 11A, 11B and 11C, which are images of respectively, surface current density in an EM probe without a layer of absorbing material and a surface current density in an EM probe with a layer of absorbing material covering both sides of a circumferential flange as well as covering a cup shaped cavity, and a current density in an EM probe with a layer of absorbing material covering the bottom side only of a circumferential flange, according to some embodiments of the present invention. Reference is also made to FIGs. 12A, 12B and 12C, which are images of, respectively, H-field distribution in an EM probe without a layer of absorbing material and a H-field distribution in an EM probe with a layer of absorbing material covering both sides of a circumferential flange as well as covering a cup shaped cavity, and an H-field distribution in an EM probe with a layer of absorbing material covering the bottom side only of a circumferential flange, according to some embodiments of the present invention. Reference is also made to FIGs. 13A, 13B and 13C, which are images of, respectively, E-field distribution in an EM probe without a layer of absorbing material, E-field distribution in an EM probe with a layer of absorbing material covering both sides of a circumferential flange as well as covering a cup shaped cavity, and an E-field distribution in an EM probe with a layer of absorbing material covering the bottom side only of a circumferential flange, according to some embodiments of the present invention. Figures 11-13 depict a simulation of an EM probe having an antenna mounted in an inner volume of a cup shape

cavity. The antenna radiates RF radiation in a frequency belonging to band of about 0.4Ghz or 0.9Ghz or 2.4Ghz or 5.6Ghz or belonging to a UWB band, for example in 3-6Ghz band, or another frequency or band in the UHF band. The sizes of the cup shape cavity is optionally of a square shape of dimension about 2,4,5,7,10,13,17 or 20 centimeters and the antenna is sized to spanning 20, 30, 50, 80, 90, or 95% of the width of the cavity. As depicted by these figures, the layer of absorbing material isolates the radiated area and limits it to the inner volume of the EM probe.

REFERENCES CITED IN THE DESCRIPTION

Cited references

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

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- WO2009031150A **[0003]** **[0052]** **[0052]**
- WO2009031149A **[0003]** **[0052]** **[0052]**
- US6233479B **[0005]**
- US7184824B **[0006]**
- US7591792B **[0007]**
- WO0064343A **[0008]**
- WO2006085052A **[0009]**
- US2007123770A **[0010]** **[0012]**
- US2007208404A **[0011]**

ELEKTROMAGNETISKE SONDER, FREMGANGSMÅDER TIL FREMSTILLING DERAF OG FREMGANGSMÅDER, DER ANVENDER SÅDANNE ELEKTROMAGNETISKE SONDER

PATENTKRAV:

1. Elektromagnetisk (EM) sonde til overvågning af mindst ét biologisk væv, der omfatter:

et kopformet hulrum (103) med en åbning (110) og et indre volumen (102),

en periferisk flange (105), der strækker sig væk fra det kopformede hulrum i samme plan som en kant af åbningen eller få millimeter over planet af åbningens kant for at reducere en følsomhed over for støj fra nærhed af EM-sonden,

mindst ét lag af et materiale (106) til at absorbere elektromagnetisk stråling, der påføres over mindst én af en del af den periferiske flange og en del af det kopformede hulrums ydre overflade, og

mindst ét elektromagnetisk (EM) strålingselement (101), der er indrettet til at udføre

mindst én af udsendelse og indfangning af elektromagnetisk (EM) stråling via det indre volumen,

kendetegnet ved, at den periferiske flange og det kopformede hulrum er elektrisk koblet og fremstillet af et ledende materiale,

ved, at den periferiske flange er indstillet til at blive fastgjort til den overvågede bruger på en måde, så en bundflade af den periferiske flange og åbningen vender mod et hudområde på den overvågede bruger,

og ved, at det mindst ene lag dækker mindst kanten af den periferiske flanges bundflade.

2. EM-sonde ifølge krav 1, hvor mindst en del af den periferiske flange er indstillet til at blive aftageligt forbundet til det kopformede hulrum.

3. EM-sonde ifølge krav 2, hvor den periferiske flange er indstillet til at blive fastgjort til en overvåget bruger for at muliggøre aftagelig forbindelse af det kopformede hulrum dertil på en måde, så åbningen vender mod et hudområde på den overvågede bruger.

4. EM-sonde ifølge krav 1, hvor den periferiske flange og det kopformede hulrum er støbt som en enkelt enhed.

5. EM-sonde ifølge krav 1, hvor den periferiske flange er mindst delvis fleksibel.

6. EM-sonde ifølge krav 1, hvor den periferiske flange zigzagger langs et plan, der er parallelt med åbningen.

7. EM-sonde ifølge krav 1, hvor afstanden mellem en perifer yderkant af den periferiske flange og en perifer inderkant af den periferiske flange af den periferiske flange er mindst 0,3 centimeter.

8. EM-sonde ifølge krav 1, hvor det kopformede hulrum har en strukturform, der er valgt fra en gruppe bestående af: en kasse, en terning, en kuppel, en kegle og en pyramide.

9. EM-sonde ifølge krav 1, hvor den periferiske flange er en ikke-cirkelformet periferisk flange.

10. EM-sonde ifølge krav 1, hvor den periferiske flange er mindst delvist indeholdt i det kopformede hulrum.

11. EM-sonde ifølge krav 1, hvor den periferiske flange er konfigureret til at danne en lufttæt grænseflade med et hudområde på en patient, hvilken lufttætte grænseflade er indstillet til at fastgøre EM-sonden til et hudområde på en patient via lufttryksforskelle.

12. EM-sonde ifølge krav 1, hvor EM-sonden er en intrabody-sonde.

13. Fremgangsmåde til fremstilling af en elektromagnetisk (EM) sonde til overvågning af mindst ét biologisk væv, der omfatter:

tilvejebringelse af et kopformet hulrum (103) med en åbning (110) og et indre volumen (102),

dannelse af en periferisk flange (105) i det væsentlige omkring det kopformede hulrum og strækkende sig væk fra det kopformede hulrum i samme plan som en kant af åbningen eller få millimeter over planet af åbningens kant,

påføring af mindst ét lag (106) af et materiale til at absorbere elektromagnetisk stråling over mindst en del af den periferiske flange,

anbringelse af et emitterende element (101), der er konfigureret til mindst én af udsendelse og indfangning af elektromagnetisk (EM) stråling, og

elektrisk forbindelse af det emitterende element til mindst én af en elektromagnetisk (EM) modtager og en elektromagnetisk (EM) sender,

kendetegnet ved, at den periferiske flange og det kopformede hulrum er elektrisk koblet og fremstillet af et ledende materiale,

ved, at den periferiske flange er indstillet til at blive fastgjort til den overvågede bruger på en måde, så en bundflade af den periferiske flange og åbningen vender mod et hudområde på den overvågede bruger,

og ved, at det mindst ene lag dækker mindst kanten af den periferiske flanges bundflade.

14. Fremgangsmåde til overvågning af mindst ét biologisk væv ved anvendelse af en sonde (100) ifølge krav 1,

hvilken fremgangsmåde omfatter anvendelse af sonden til at overvåge dielektriske egenskaber i et eller flere biologiske væv hos en overvåget bruger, idet sonden fastgøres til en overvåget bruger på en måde, så åbningen (110) vender mod et hudområde på den overvågede bruger.

DRAWINGS

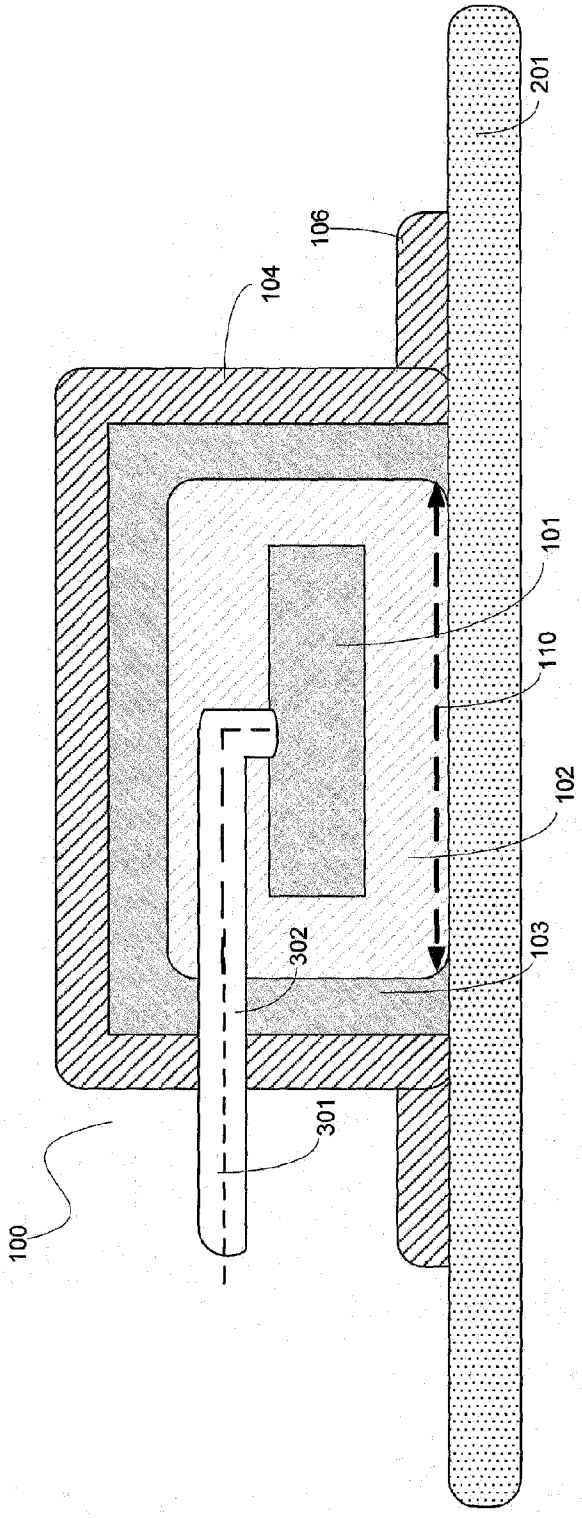


FIG. 1

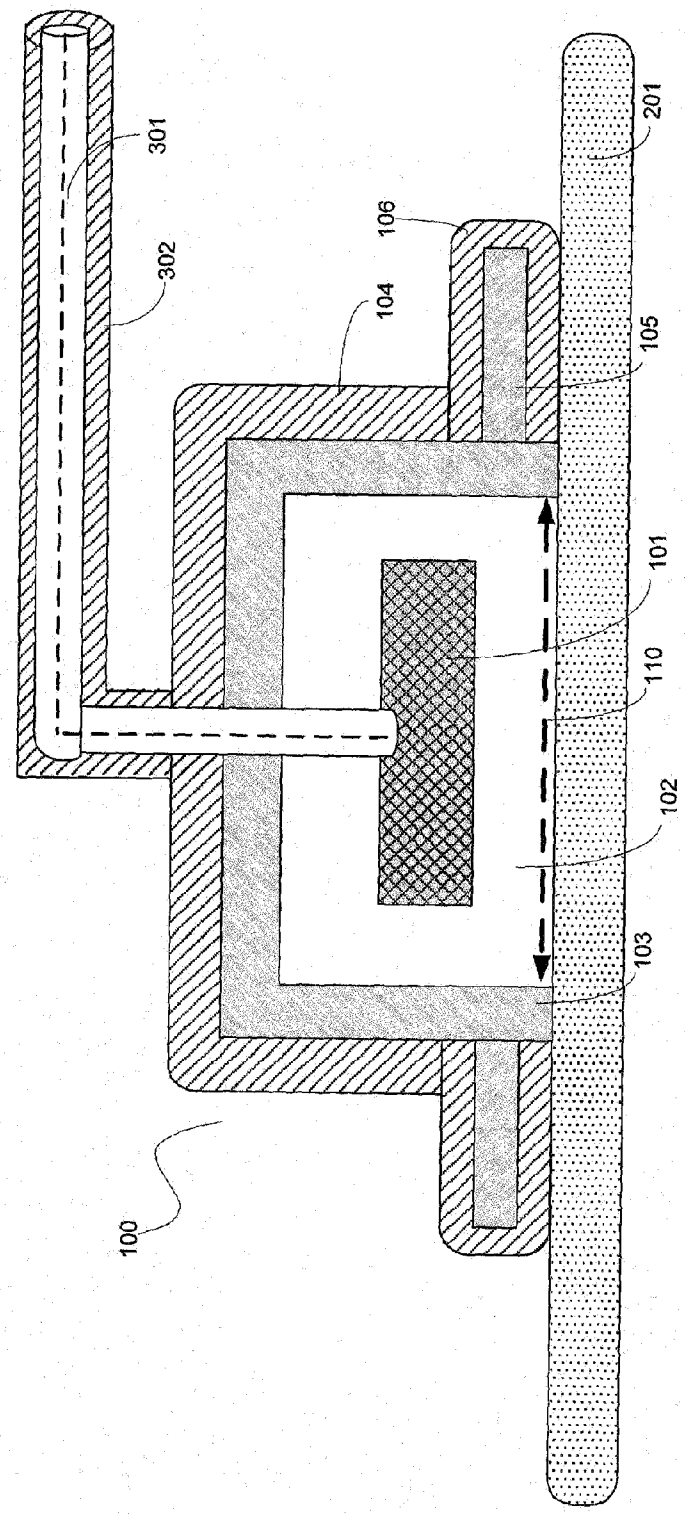


FIG. 2

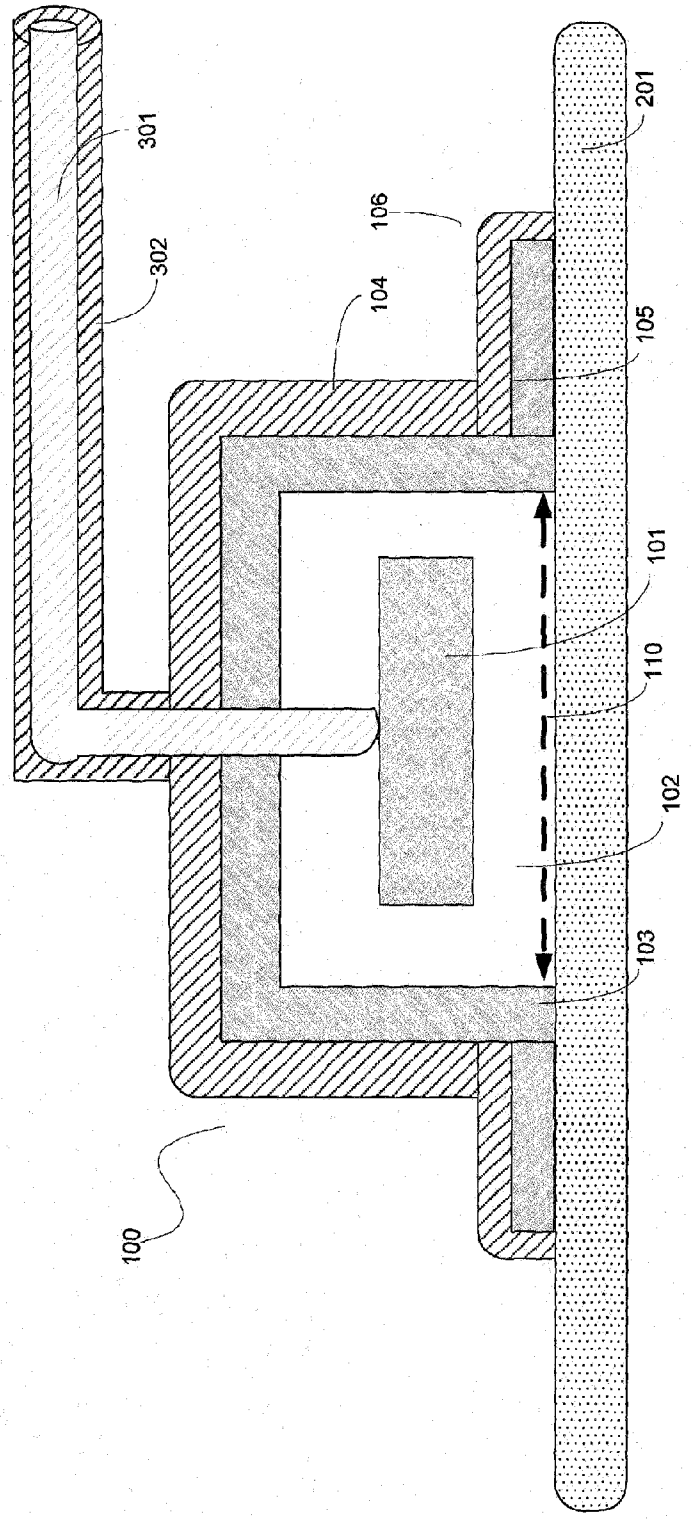


FIG. 3A

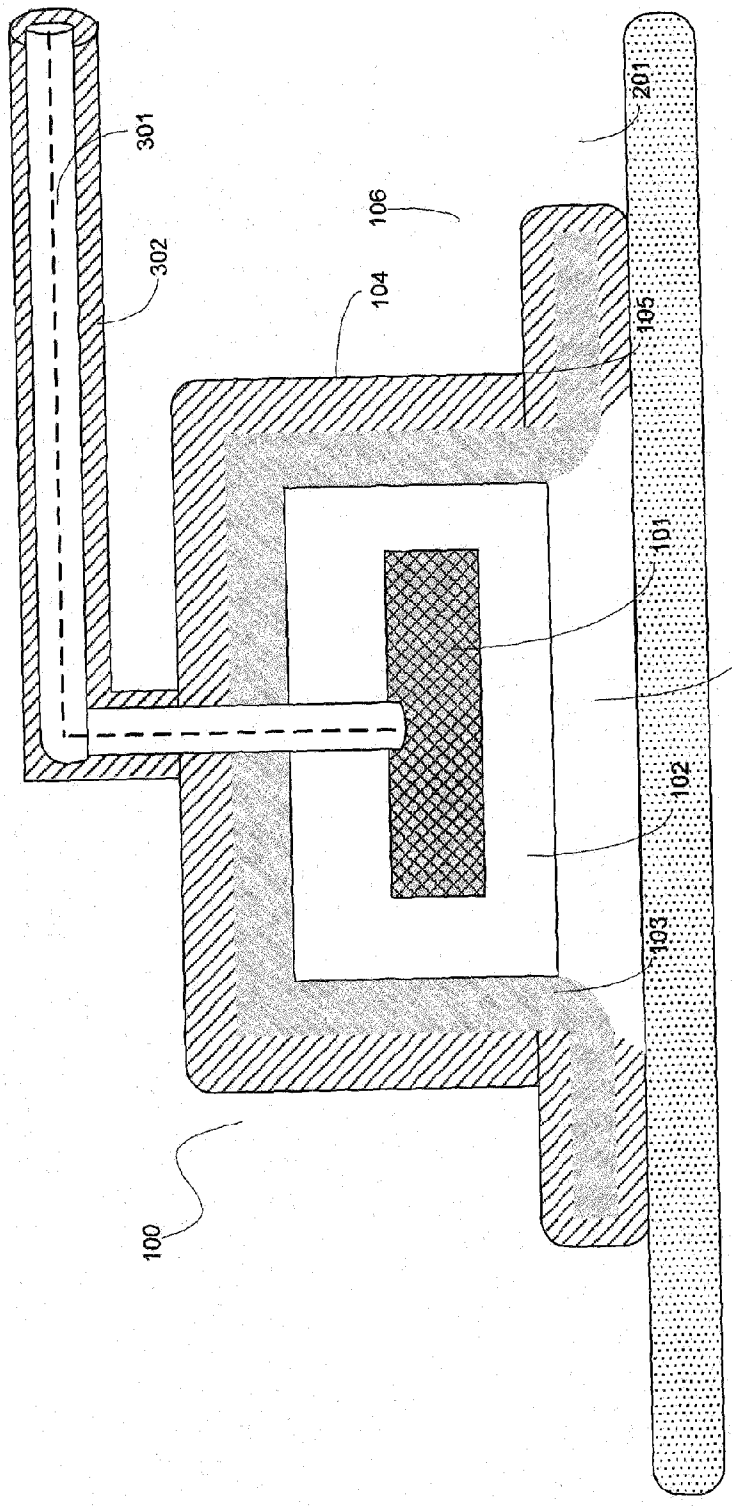


FIG. 3B

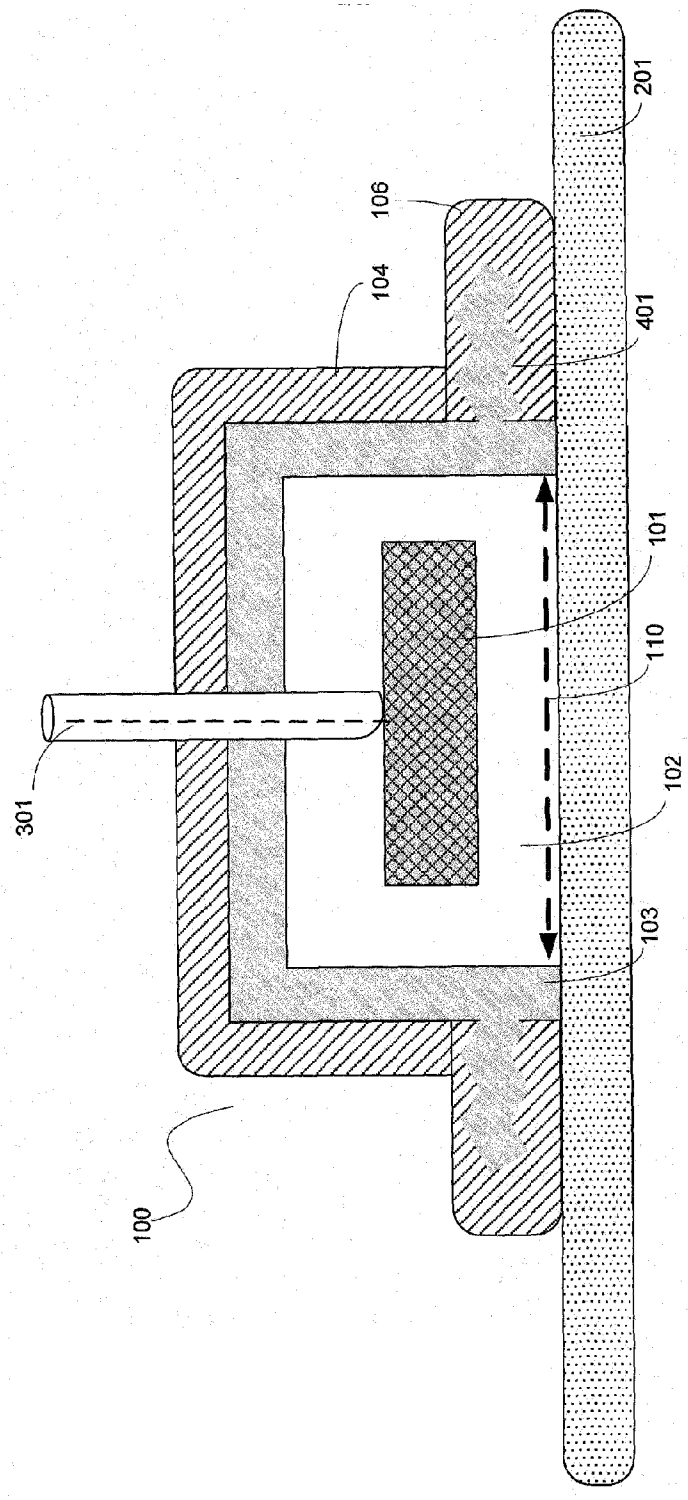


FIG. 4

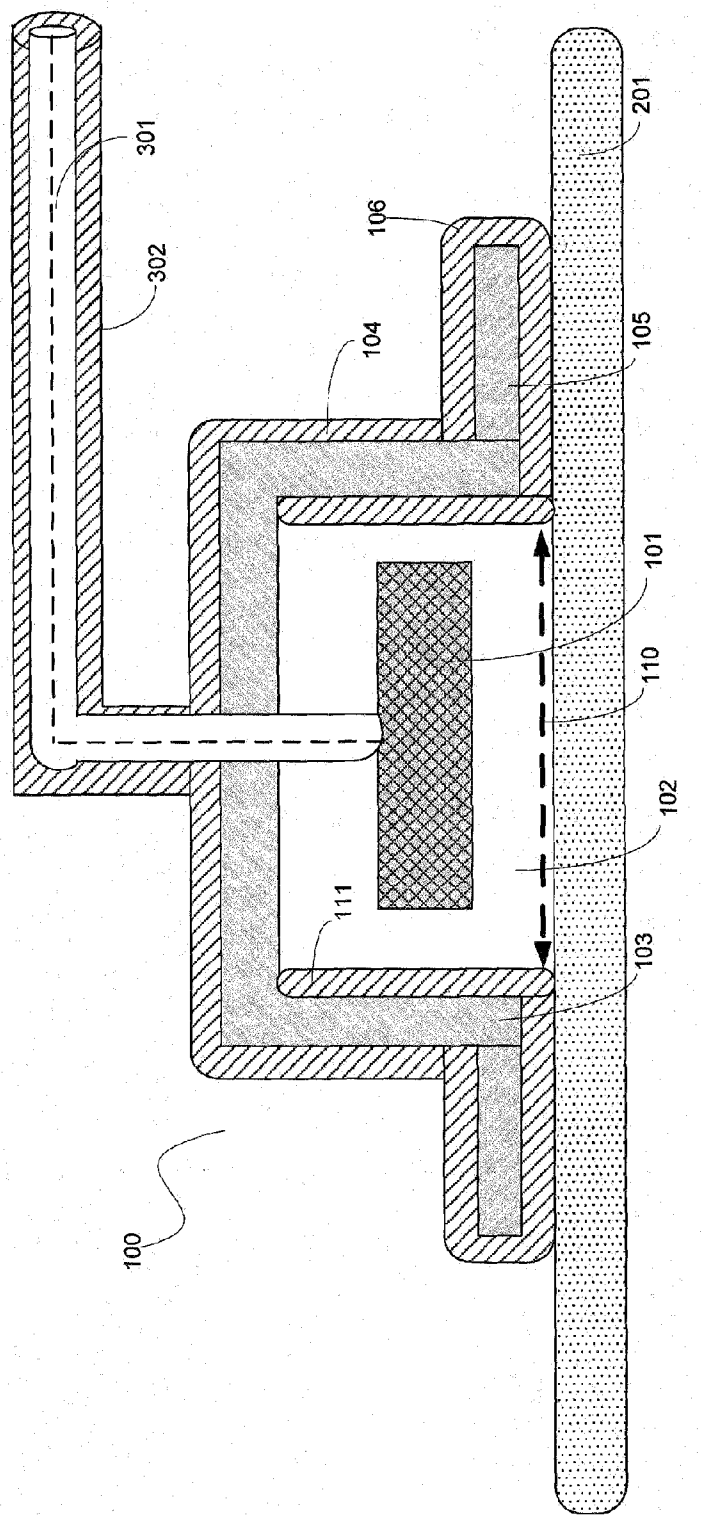


FIG. 5

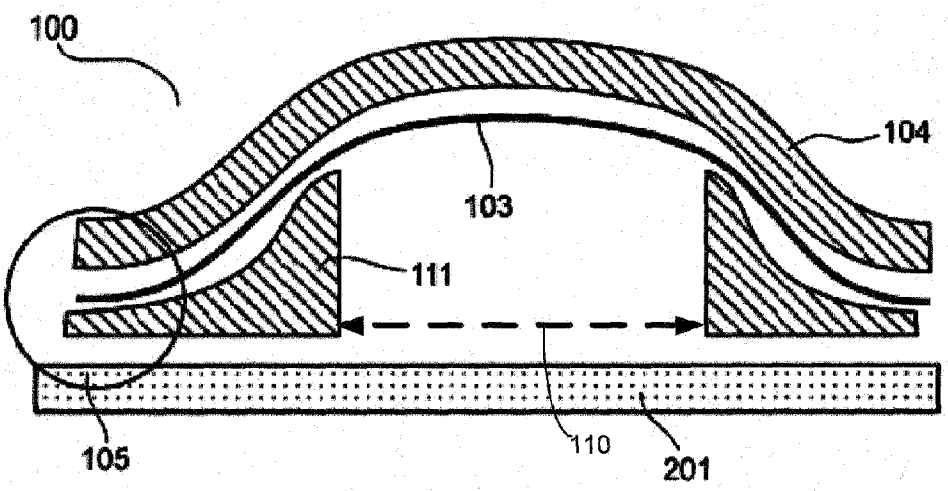


FIG. 6

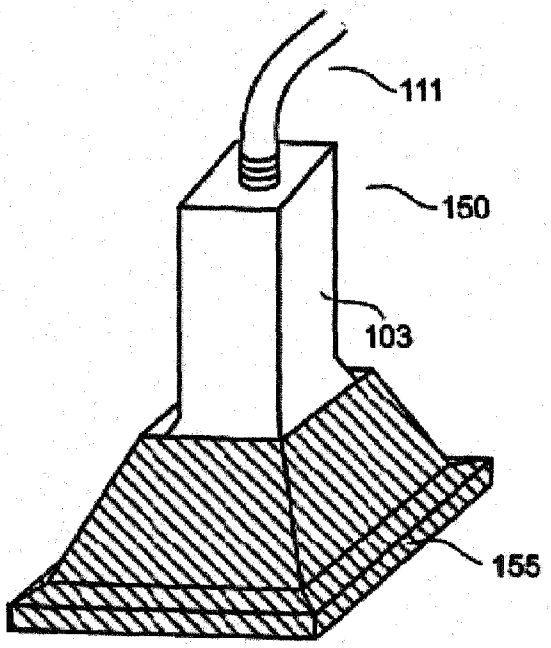


FIG. 7A

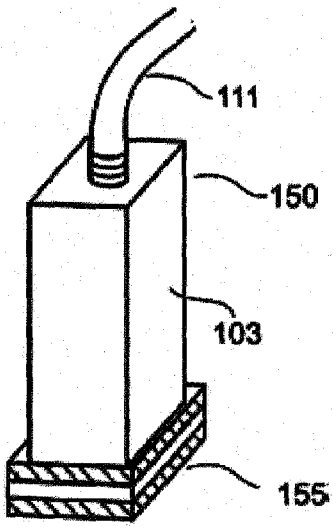


FIG. 7B

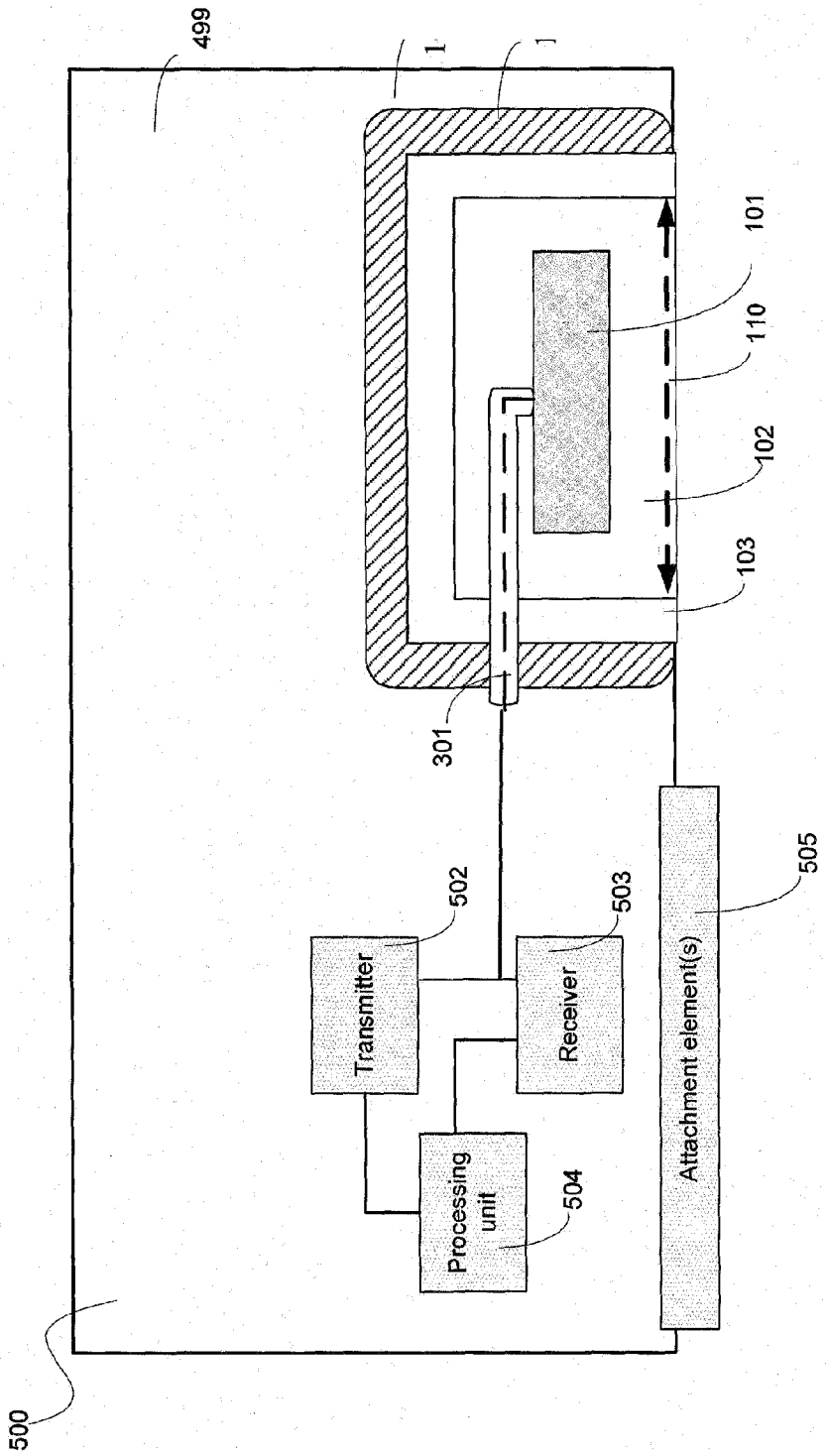

499
1
1
101
110
102
103
301
502
503
505
Transmitter
Receiver
Attachment element(s)
Processing unit
504
500

FIG. 8

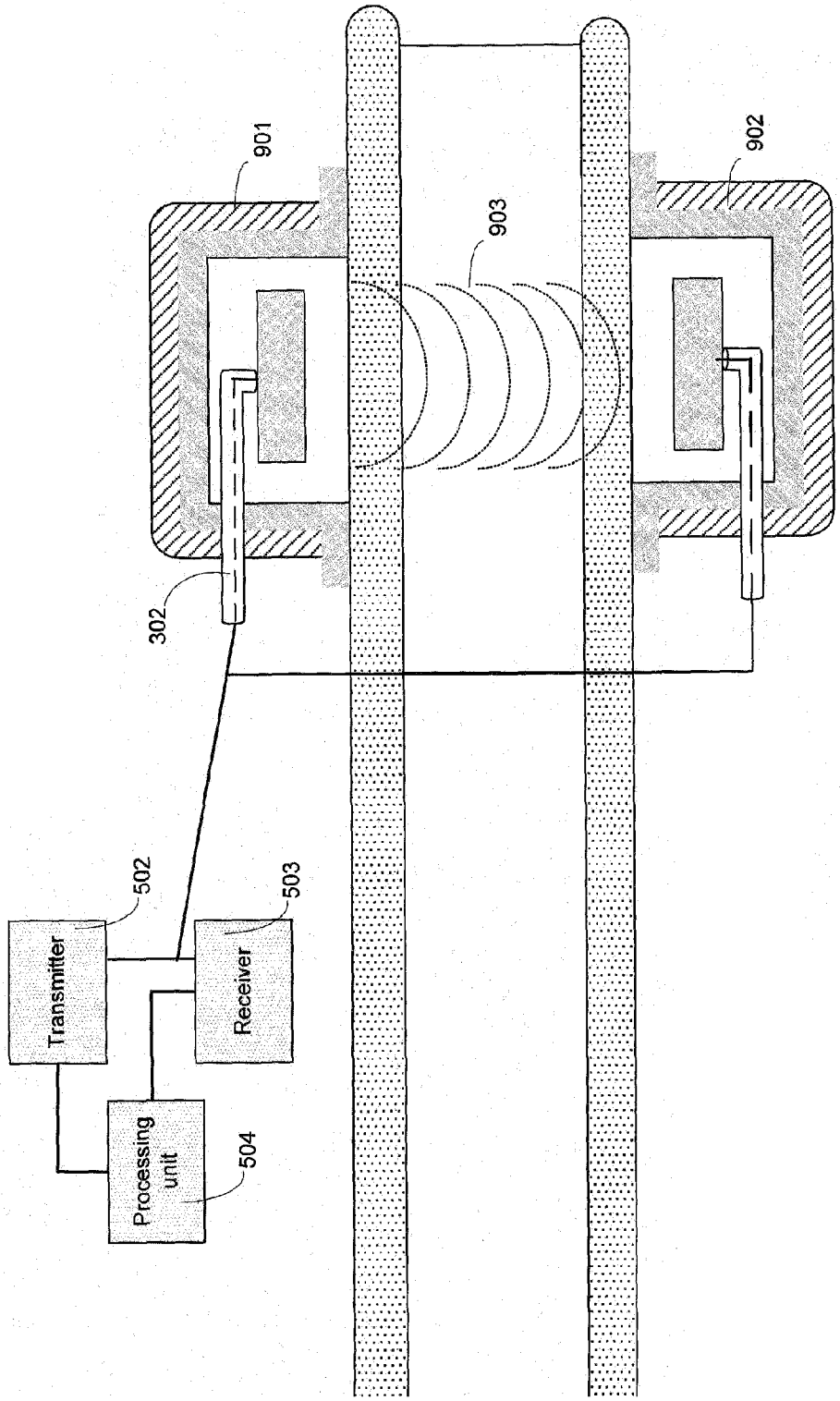

901
902
903
302
502
503
504
Transmitter
Receiver
Processing unit

FIG. 9

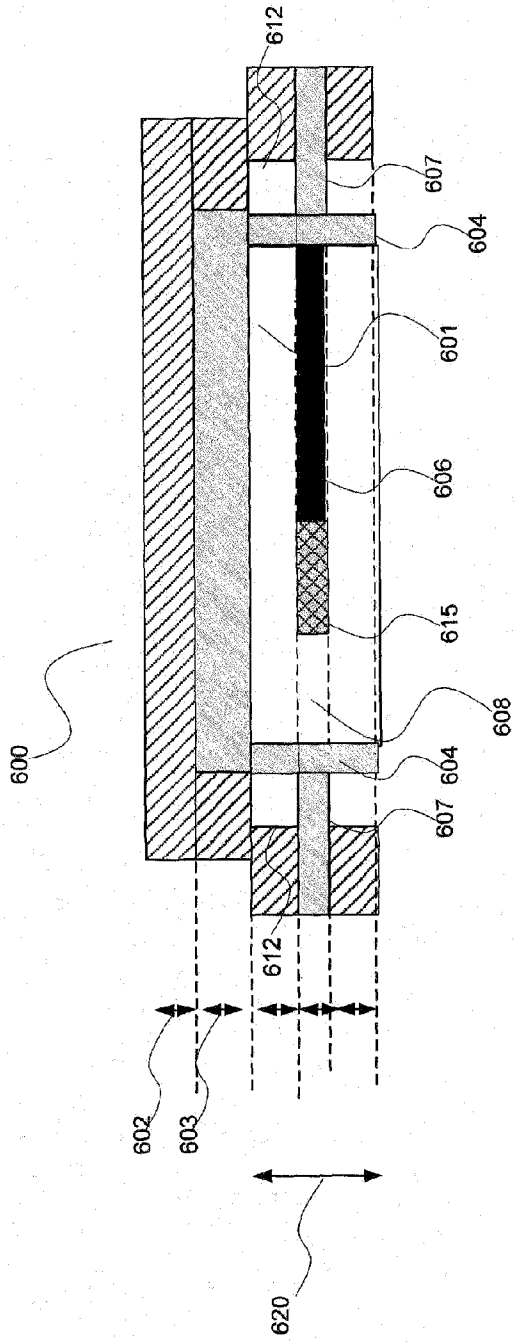


FIG. 10A

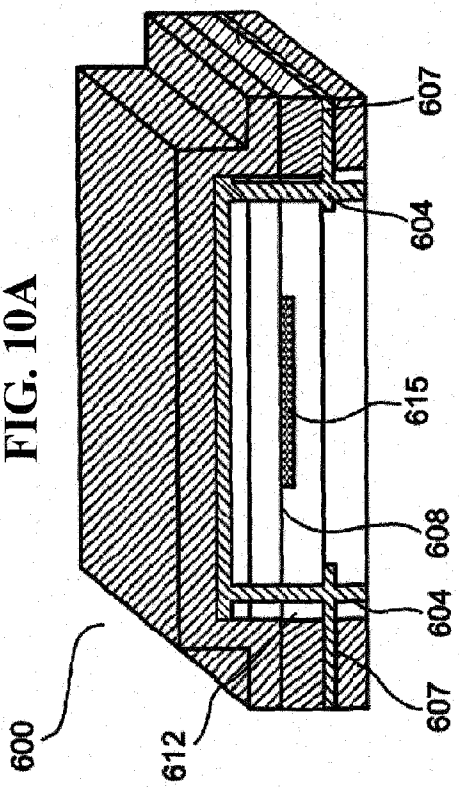


FIG. 10B

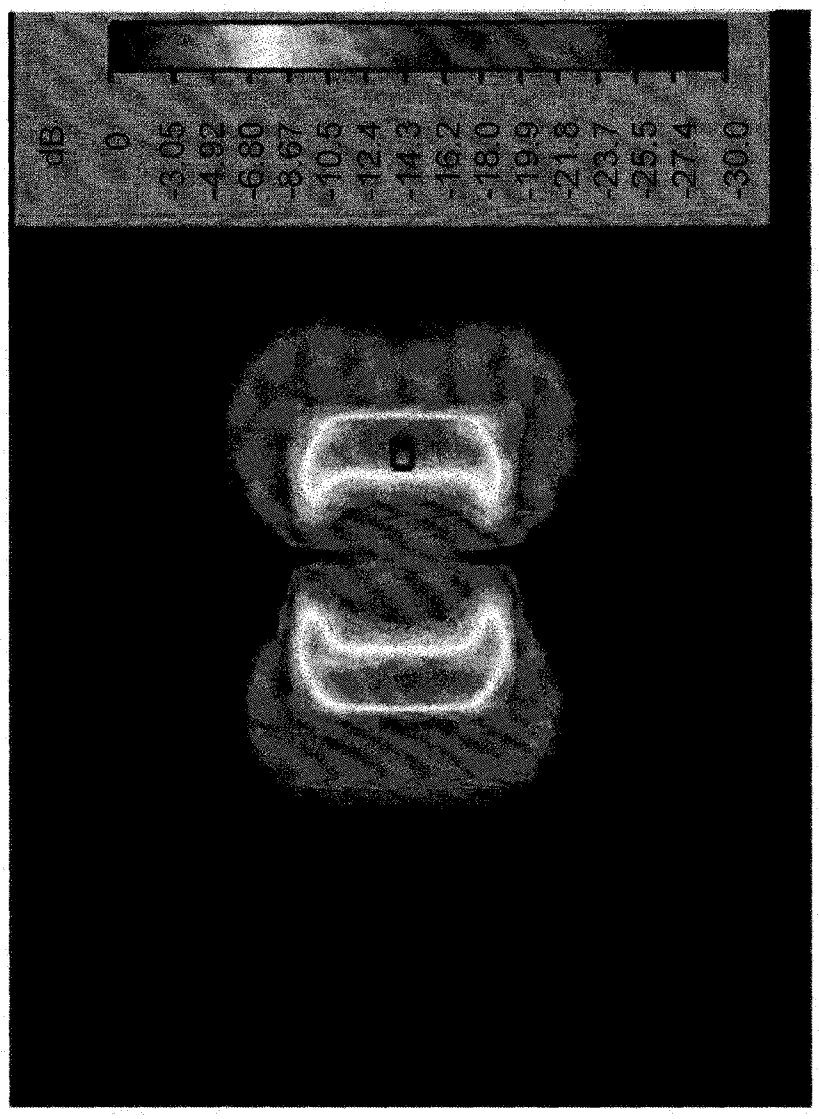


FIG. 11A

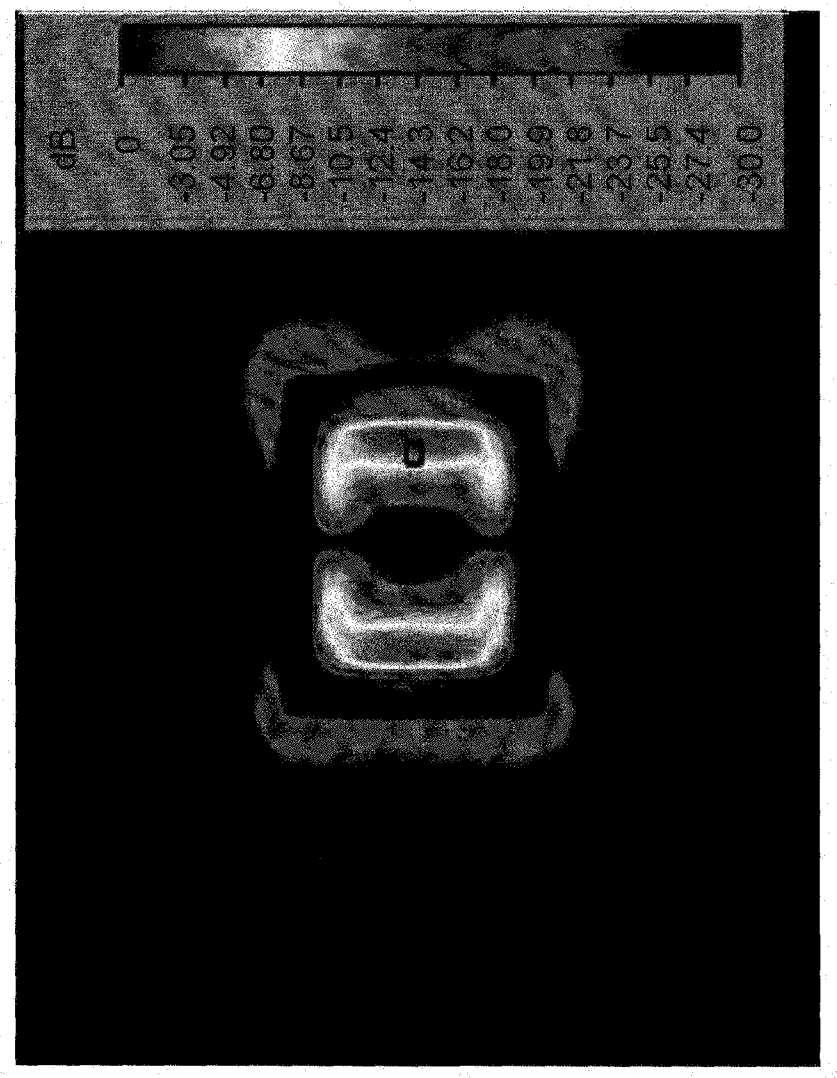

dB
0
-3.05
-4.92
-6.80
-8.67
-10.54
-12.43
-14.30
-16.17
-18.06
-19.93
-21.80
-23.67
-25.54
-27.41
-30.0

FIG. 11B

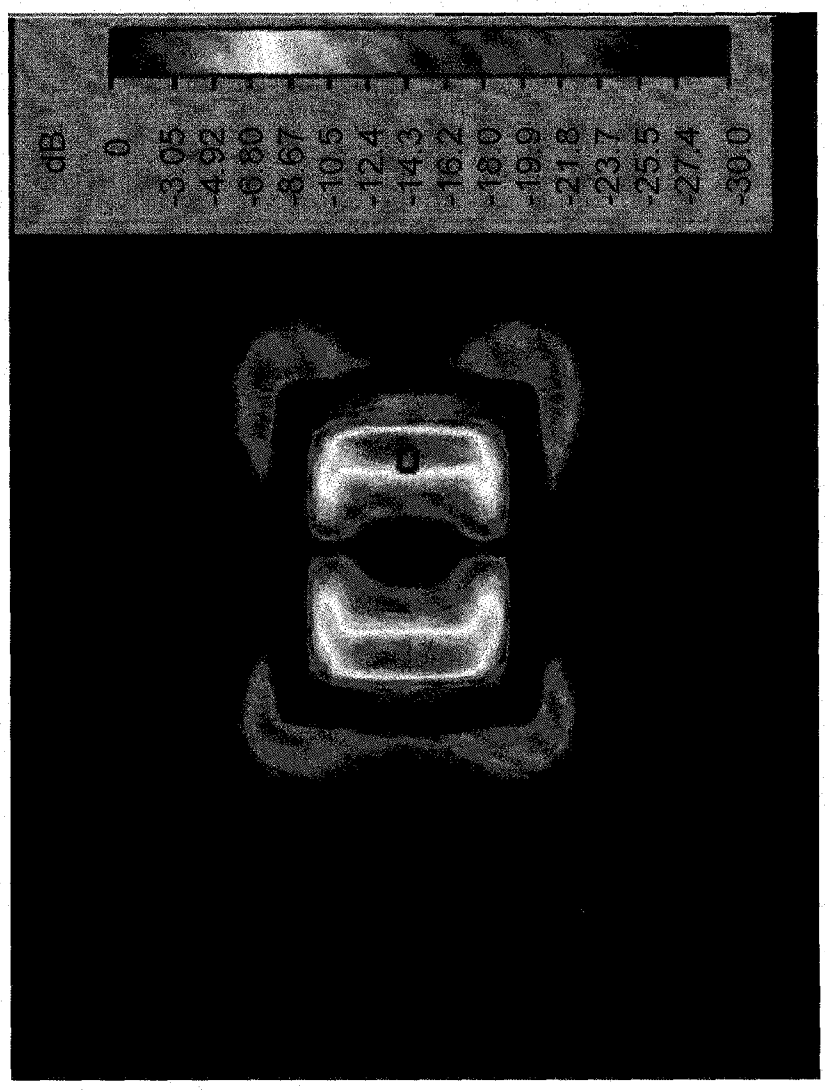


FIG. 11C

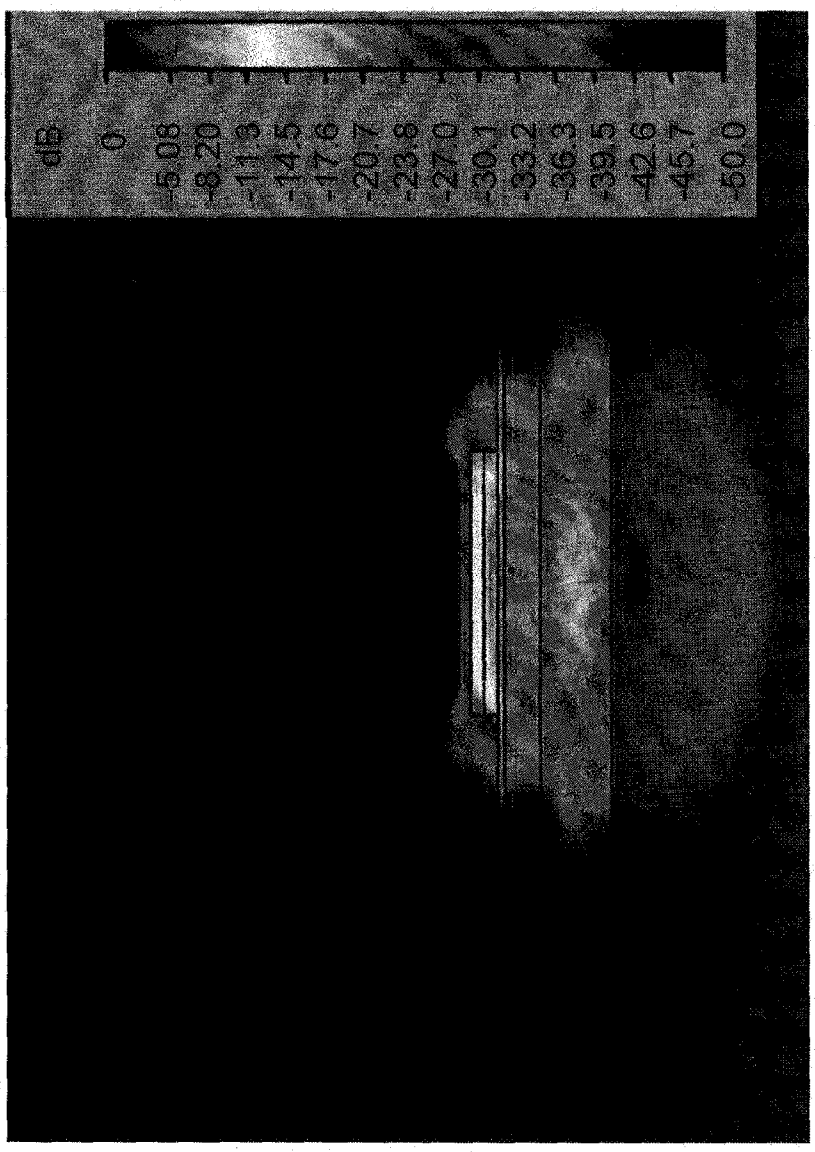


FIG. 12A

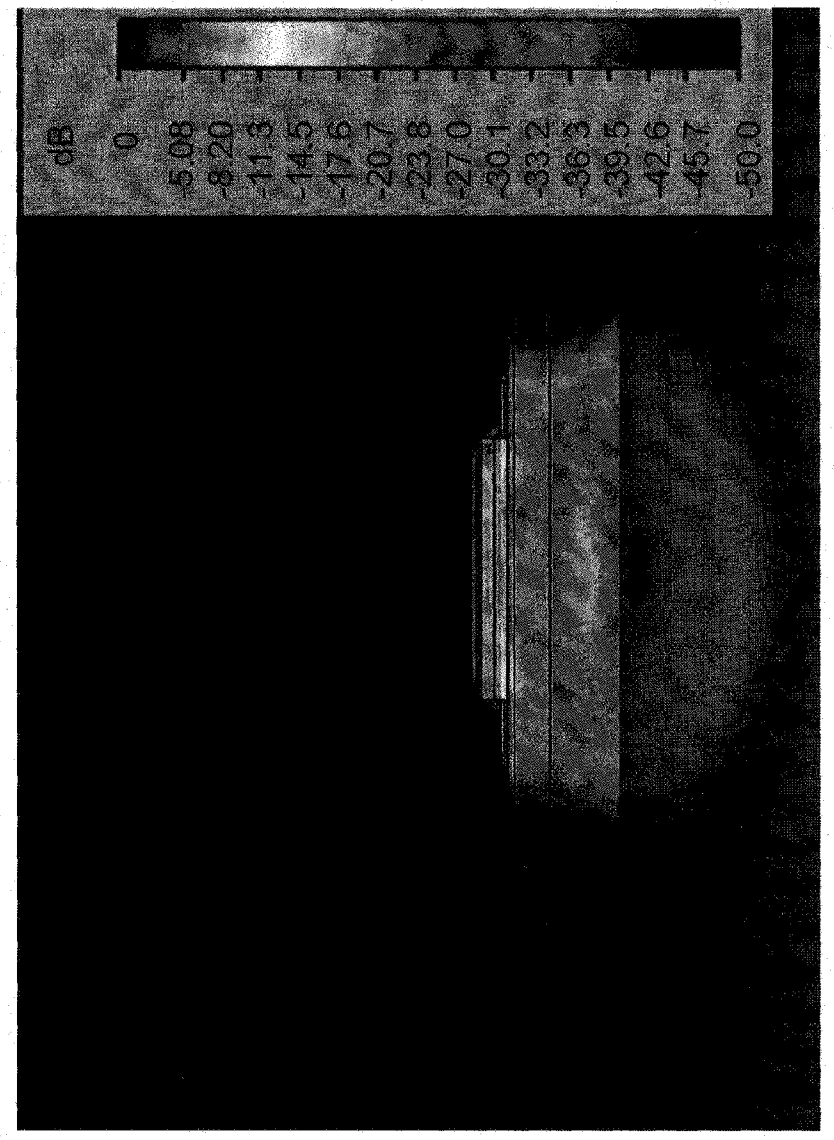


FIG. 12B

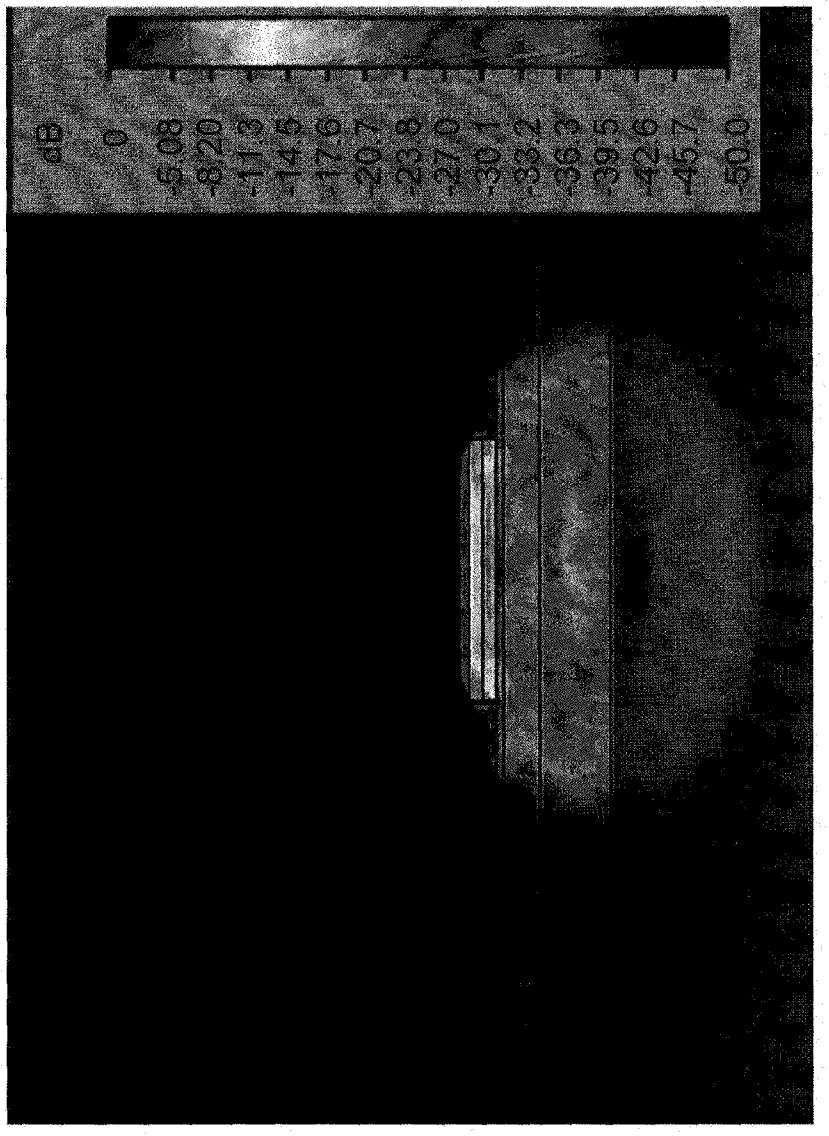


FIG. 12C

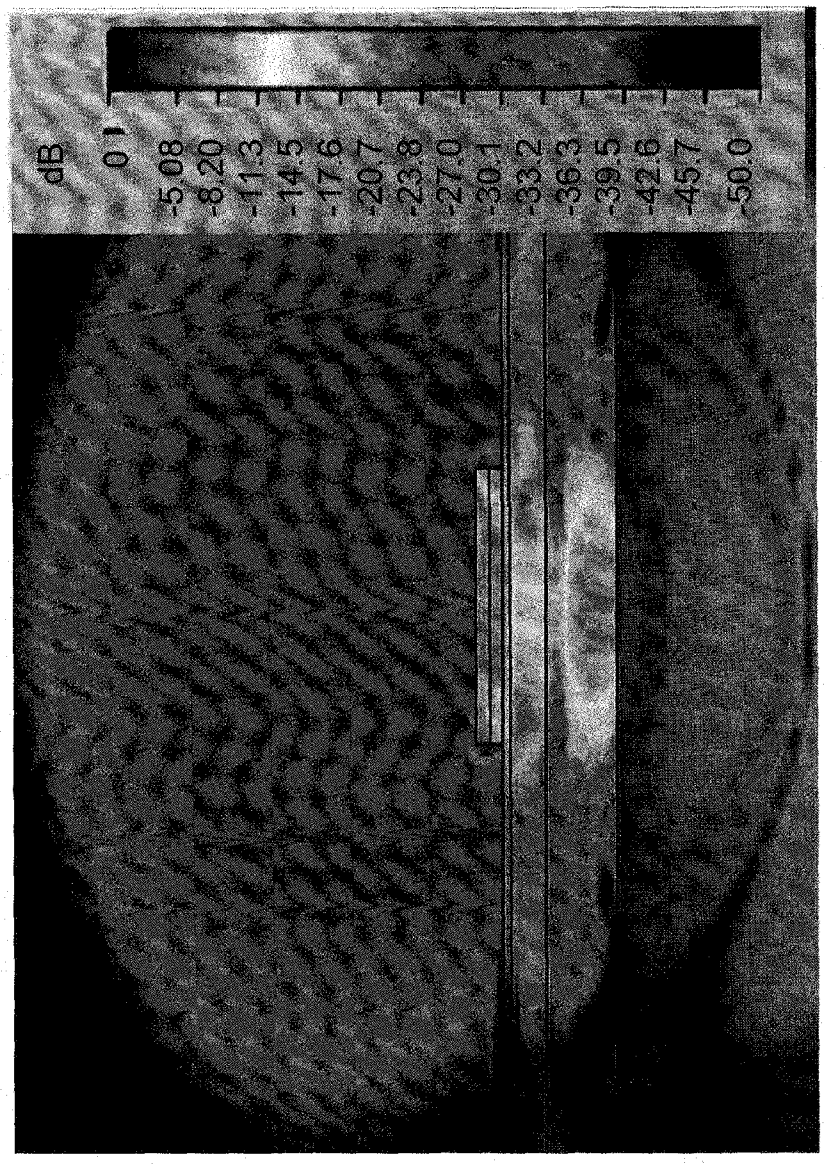


FIG. 13A

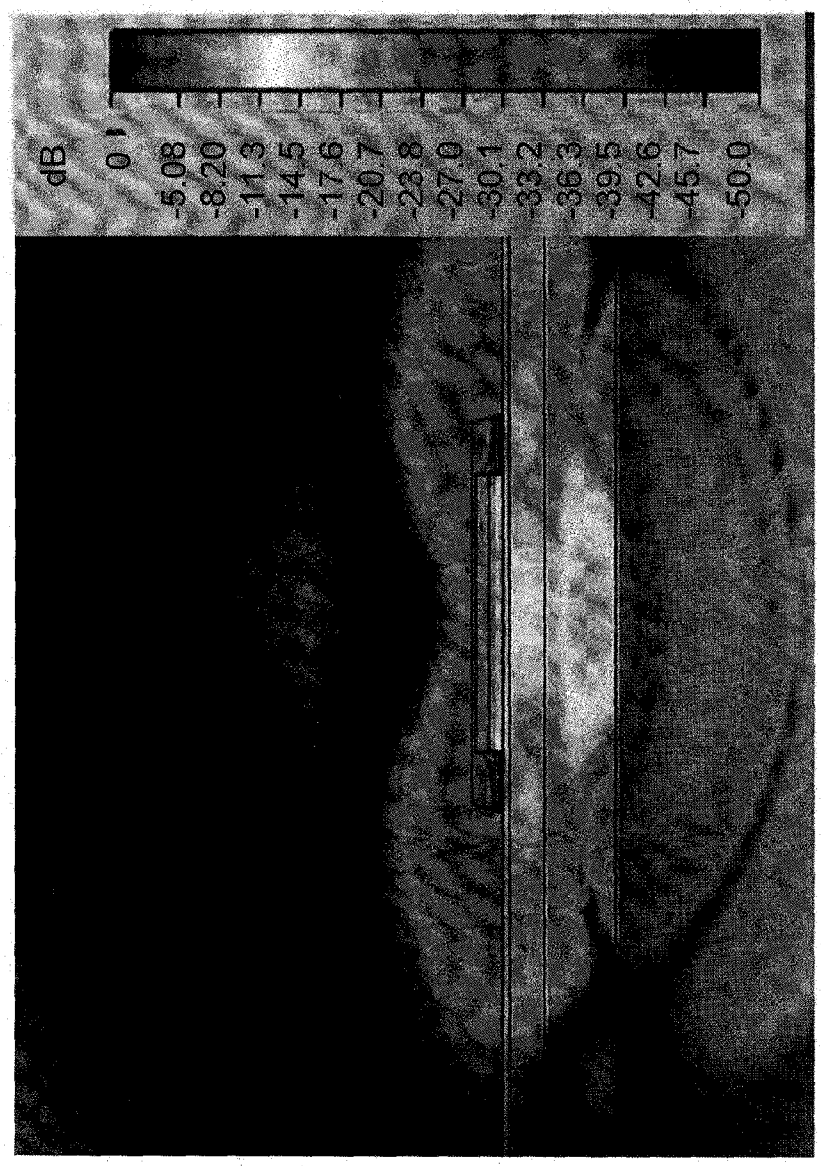


FIG. 13B

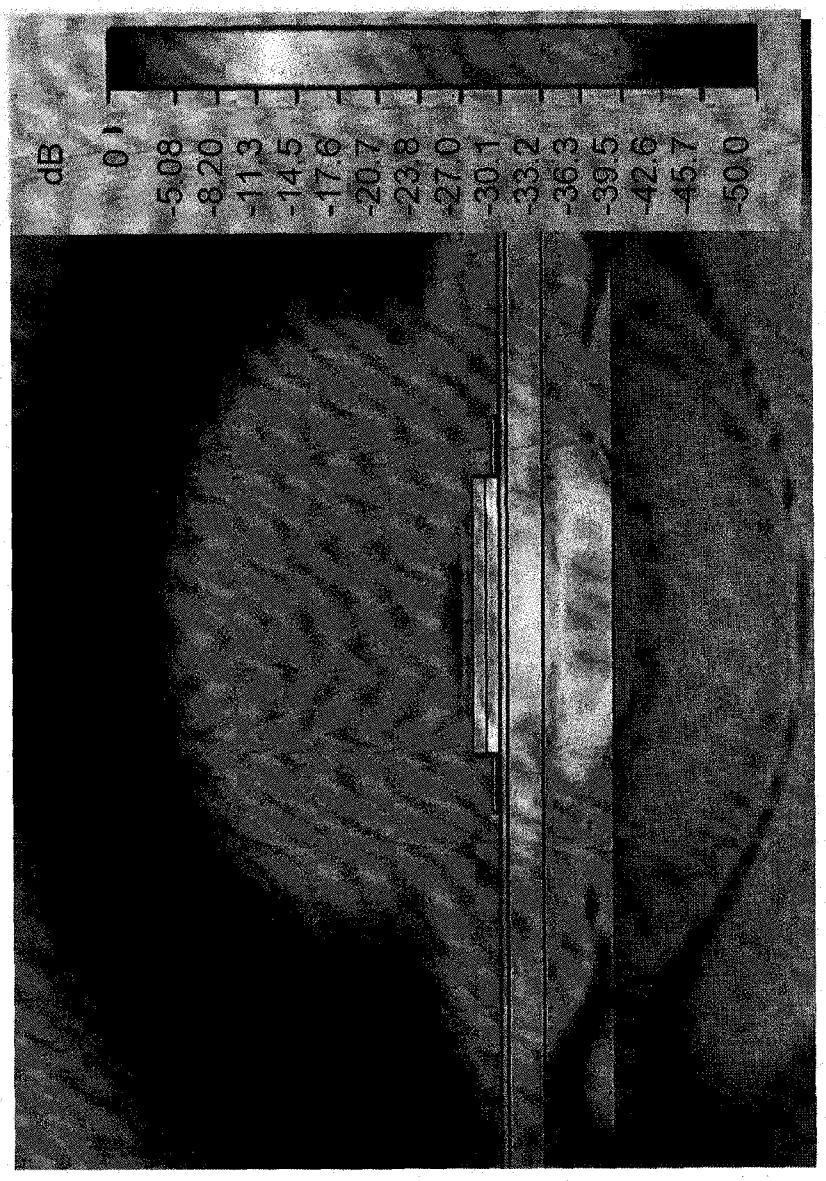


FIG. 13C