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mTMS käämilaite yhdellä paluulinjalla

mTMS lindningsanordning med enkel returlinje

mTMS coil device with single return line

(57) Tiivistelmä - Sammandrag - Abstract

Saadaan monikanavaisen transkraniaalisen magneettistimulaation (mTMS) kelalaite (10), jossa on yksi sähkövirran paluujohto (26). Mainitussa mTMS-kelalaitteessa (10) on ainakin kaksi kelakäämiä (20) kotelossa (14), jolloin ainakin kahdella kelakäämillä (20) on yksi, yhteinen sähkövirran paluujohto (26). Vähentämällä sähkövirran paluujohtojen määrää kaapelointia (12) mTMS-kelalaitteeseen (10) päin ja tästä mTMS-kelalaitteesta (10) pois voidaan vähentää, jolloin järjestelmää saadaan kevennetyksi ja sen hallinta ja käyttö helpottuu.

Provided herein is a multichannel Transcranial Magnetic Stimulation (mTMS) coil device (10) having a single power return line (26). An mTMS coil device (10) having at least two coil windings (20) in a casing (14), wherein at least two coil windings (20) have a single, shared power return line (26) is disclosed. By reducing the number of return lines, the cabling (12) to and from the mTMS coil device (10) can be reduced making the system lighter and easier to maneuver and use.

mTMS COIL DEVICE WITH SINGLE RETURN LINE

FIELD OF INVENTION

The present invention relates to multichannel Transcranial Magnetic Stimulation coil
5 devices (mTMS). In particular to mTMS coil device having a single return line.

BACKGROUND OF INVENTION

Typical TMS coil devices have a single, standard figure 8 coil within a casing. The
circuitry within or connected to the TMS coil device is able to adjust primarily the
10 amplitude and frequency of stimulation pulses. In order to change the position, direction
and/or orientation of a stimulation pulse requires the TMS coil device to be physically
moved to the proper position.

Currently, TMS coil devices are typically hand held by an operator. Several tools exist to
help the operator place the TMS coil device in the correct location and keep it there.
15 However, several problems persist. One major problem is that the most important
parameter for accurate stimulation is the relationship between the TMS coil device and a
patient's head. Even if the TMS coil device is kept still and in a good position, if the
patient moves their head then the stimulation will no longer be accurate, even without the
TMS coil device moving. As it is difficult to keep a patient's head perfectly still the
20 problem of accurate stimulation will always persist if the relationship between the TMS
coil device and patient's head remains the key factor for accuracy.

Other problems persist as finding both the proper location and orientation of a TMS coil
device in order to provide a desired stimulation can be difficult, awkward and time
consuming. Therefore, there exists a need for a way to rely less on the actual position of
25 and orientation of the TMS coil device in relation to a patient's head for accurate
stimulation.

Additionally, when multiple coil windings are used in a single casing the number of input
and return lines to and from the casing grows and can become unwieldy, making use of the
coil device challenging.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a multichannel Transcranial Magnetic Stimulation (mTMS) coil device.

It is an aspect of certain embodiments of the present invention to provide an mTMS coil device having at least two coil windings in a casing, wherein at least two coil windings have a single, shared power return line.

By reducing the number of return lines, the cabling to and from the mTMS coil device can be reduced making the system lighter and easier to maneuver and use.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows an mTMS coil device.

Fig. 2 shows a standard figure 8 coil winding.

Fig. 3 shows an efficient figure 8 coil winding example.

Fig. 4 shows two separate figure 8 coil windings and the predetermined direction of their intended induced electric fields.

Fig. 5 shows the coil windings of figure 4 in an overlapping configuration oriented with an angle between them of 90 degrees.

Fig. 6 shows the coil windings of figure 4 in an overlapping configuration oriented with an angle between them of 120 degrees.

Figs. 7a-7g show example combinations of unstacked coil windings.

Fig. 8 shows an example of a pair of overlapped figure 8 coils in a single casing.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

Figure 1 shows an example of a multichannel Transcranial Magnetic stimulation (mTMS) coil device 10. The mTMS coil device 10 has a casing 14. The casing 14 has an input cable opening 16 for input/return cabling 12. The mTMS coil device 10 may or may not include

the actual input/return cabling 12. Additionally, there may be more than one opening 16 and/or more than one input/return cabling 12.

Within the casing 14 of the mTMS coil device 10 are at least two coil windings. An example of a standard Transcranial Magnetic Stimulation (TMS) coil winding is presented
 5 in figure 2. Both the solid and dotted lines represent wires which together form the standard coil winding 20. The wires 21 wrapped in a coil which are represented with solid lines have current passing through them in a direction opposite to that of the direction of the wires 22 wrapped in a coil which are represented with a dotted line. By opposite, it is meant either clockwise or counterclockwise direction of current flow. The same
 10 convention of solid and dotted lines is continued through the application unless otherwise noted.

The standard coil winding 20 has an input line 24 and a return line 26. The input line 24 is for introducing a current to the coil winding 20. The return line 26 is for returning current, e.g. to a power storage medium, e.g. a capacitor or capacitor bank. . In some
 15 implementations, the return line 26 may be used for returning current to a dissipation medium, e.g., a power resistor or transistor. In other implementations, some portion of the current may be returned to a capacitor bank while the rest of it is passed to a dissipation element. The input line 24 is typically, but not always, connected to a crossing wire 23. Similarly, the return line 26 is typically connected to a crossing wire 25. Crossing wires
 20 will be discussed in more detail below.

Additionally presented herein is an efficient coil winding 30, as shown for example in figure 3. The efficient coil winding 30 has generally the same construction as discussed with regards to the standard coil winding 20 above. The efficient coil winding has first
 25 wires 31 with current traveling through them in a first direction and second wires 32 with current traveling through them in a second direction, opposite to the first direction. The wires 31 and 32 forming the coils are connected to input 34 and return lines 36 respectively, typically by crossing wires 33 and 35 respectively. The design of the coil wires 31 and 32 lead to increased efficiencies over the standard coil winding 20. Additionally, the crossing wire design can lead to increased efficiencies, together with or
 30 in place of the coil wires design. These advantages will be discussed in more detail below. While the majority of figures show an efficient coil winding design as discussed with respect to figure 3, the present invention can be applied to any coil winding design.

Figures 4 and 5 show a simple example of the present invention. Figure 4 shows a first coil winding 40 and a second coil winding 42. The first and second coil windings are both shown with respective power input lines and returns. The direction of the electric field induced by the magnetic field to be generated by coil winding 40 is shown as 41. Similarly, the direction of the electric field induced by the magnetic field to be generated by coil winding 42 is shown as 43. In figure 4, the first and second coil windings are oriented 90 degrees to each other. Similarly, the directions of the electric fields to be generated are perpendicular to each other.

The direction 41 of the electric field induced by the magnetic field to be generated by coil winding 40 is an example of typical current technology in TMS coil devices where the direction of the current traveling through the coil cannot be freely chosen during operation. In other words, the current waveform in a typical system has the same polarity from one pulse to another, although the current waveform amplitude can be changed. However, in an example where the circuitry of the TMS device allows the direction of the current in a coil to be reversed then the direction of the resulting electric field could also extend up to 180 degrees from that currently shown. Additionally, these are some of the most basic, figure 8 coil winding examples with a straight forward generated magnetic field and induced electric field. Other coil winding designs produce different types and orientations of induced electric fields, some of which will be described below.

Each of the coil windings discussed herein is for generating a magnetic field and an induced electric field when a current is passed through them. Additionally, while numerous examples of coil geometries are discussed herein, within the mTMS coil device, the geometry of each coil will remain essentially the same, though some deformation may occur during use. Thus, each coil winding is for generating an electric field in at least one predetermined direction and orientation when a current is passed through the coil. As stated above, a coil winding may be for generating more than one electric field with a unique predetermined direction and/or orientation. For example as discussed above, wherein when a current is reversed in a coil the resultant electric field will differ, in a predetermined way, from the original electric field.

Figure 5 shows the first coil winding 40 partially overlapping the second coil winding 42. The combination 50 of the two coil windings 40 and 42, in the orientation with respect to each other as shown in figure 4, results in the range of electric field generations as shown

by 51, depending on the relative amplitudes of the currents in coil windings 40 and 42. Additionally, the return lines of each of the coil windings 40 and 42 are shown as 46a and 46b respectively.

By partially overlapping the two coil windings 40 and 42 it is possible to generate two
5 individual electric fields, one from each coil winding, which then create a desired resultant electric field. By separately controlling each of the coil windings it is possible to have a virtually continuous range of resultant electric fields between the predetermined directions and orientations of each of the involved coil windings. With the example of coil windings 40 and 42, without the possibility of reversing the current direction through the coils
10 windings, the resultant range 51 is 90 degrees, when the coils are arranged with 90 degrees between them.

A similar example is shown in figure 6 with a different combination 60 of coil windings 40 and 42. In combination 60, coil winding 42 is rotated 120 degrees from coil winding 40 which results in a range of resultant electric fields of 120 degrees, as represented by 61.

15 As shown in both figures 5 and 6, each of the coil windings has essentially the same geometry, e.g. efficient figure 8 geometry, but are in different orientations. However, coil windings with different geometries can be used, as will be discussed with regards to at least figures 7 below.

As shown in the examples of figures 5 and 6, each of the coils has an axis of symmetry and
20 a center point. Coil windings typically have some axis of symmetry, as shown for example in figures 7a-f. Additionally, all coil windings will have some center point, which could be a center of mass or a geometric center.

According to certain examples of the present invention, at least two, or each, of the coil windings will have an axis of symmetry and a center point. The overlapping combination
25 of coils can be overlapped in numerous manners. One manner is that the center points of the coil windings are overlapping and then there is an angle between their respective axis's of symmetry. Another manner is with the center points of the coil windings offset from each other, e.g. wherein the center points are not overlapping.

Taking figure 5 as an example, when current is only passed through coil 40, the resultant
30 electric field will be in direction 41. Similarly, when current is only passed through coil 42 the resultant electric field will be in direction 43. However, if current is passed through

both coils simultaneously, the resultant electric field will be the sum of both individual electric fields and can be anything between directions 41 and 43. In an example where the current in each coil winding could be reversed during operation, then the resultant electric field could be generated anywhere within a 360 degree range.

- 5 While the coil windings can be the same geometry and same features, they may also be different, as shown in figures 7a-g. Though not necessarily, the coil windings will be discussed herein as a primary coil winding and secondary coil windings. However, any of the coil windings could be equal to or subservient to others in operation regardless of their description herein.
- 10 As an example, a first coil winding 71 is a primary coil winding and is for generating a first, primary induced electric field. As a figure 8 coil is the standard coil in TMS coil devices, it is used herein as the first coil winding. However, any of the other coil windings could be considered the first coil winding. One or more additional, secondary, coil windings can then then be overlapped with the first and create secondary electric fields.
- 15 The predetermined direction and/or orientation of the electric field to be generated by a secondary coil winding would thus typically be different from that of the first coil winding. Furthermore, secondary coil windings can be considered as for generating an electric field which is for altering some property of the first, primary electric field. For example, one or more secondary coil windings can be for altering, together or separately, the direction,
- 20 position and/or orientation of the electric field of the first coil winding. Similarly, while the coils are physically overlapping they are typically overlapping in at least a predetermined direction of a electric field to be generated by at least one of the coil windings.

- 25 However, as discussed in more detail below, examples of the present invention can include one or more identical coil windings fully overlapped with each other, though not shown in the figures. One potential use for this would be to control the pulses separately, either at different times and/or simultaneously, for different advantages.

The different types of coils which are overlapped, and the manner in which they are overlapped, determine the types of controls the combination has over the resultant electric field.

- 30 In figures 7a-g, the current is flowing counter-clockwise in the dashed wires and clockwise in black solid wires. These wires were computed for curved surfaces, and are projected into plane using azimuthal equidistant projection. The exact coil-winding shape

can depend on a selected curvature, target depth, maximum coil size, and various other variables. This dependency is visible in the slightly varied shapes for the first order derivatives in different sets. Here, this variation is due to the numerical algorithms used to generate the coils. Note that also the number of turns in the coils may be changed to produce coils with desired properties.

Figures 4-6 show what we call here 0th order derivative coil windings 40 and 42. Combining these coil windings, as discussed, allows for the rotation of electric field.

Figure 7a shows a 0th order derivative coil winding 71 and a 1st order derivative coil winding 72. Combining these coil windings allows for vertical adjustments of a target position of a resultant electric field.

Figure 7b shows a 0th order derivative coil winding 71 and a different 1st order derivative coil winding 73. Combining these coil windings allows for horizontal adjustments of a target position of a resultant electric field.

Figure 7c shows two 0th order derivative coil windings 71 and 75, in different orientations sandwiching a 1st order derivative coil winding 74. Combining these three coil windings allows for vertical adjustments of a target position and orientation correction of a resultant electric field.

Figure 7d shows two 0th order derivative coil windings 71 and 75, in different orientations with a 1st order derivative coil winding 73. Combining these three coil windings allows for horizontal adjustment of a target position with orientation correction of the resultant electric field.

Figure 7e shows two 0th order derivative coil windings 71 and 75, in different orientations sandwiching a 1st order derivative coil winding 72 and also with a 1st order derivative coil winding 73. Combining these four coil windings allows for horizontal and vertical adjustment of a target position along with orientation correction of the resultant electric field.

Figure 7f shows two 0th order derivative coil windings 75 and 71, in different orientations with three 1st order derivative coil windings, 76 and two 73's in different orientations. Combining these five coil windings allows for horizontal and vertical adjustment of a target position along with arbitrary orientations of the resultant electric field within the

range of possible orientations depending on whether the current circuitry is able to reverse current waveform polarities or not.

Figure 7g shows an example of a 12-coil orthogonal layer coverage coil array. The coil array can have large, thin overlapping coils. As can be seen from the figures, the individual coils do not all have an axis of symmetry, yet all have a center.

In all of the examples so far, the ideal method of overlapping of the coil windings is to arrange their center points so that they are substantially overlapping. Figure 8 is an example of the combined coils 82 housed within the casing 81a of an mTMS coil device 80. The combined coils 82, similar to those shown in figure 5, each have an input line 84 and 85 and return lines 87 and 86. In the present example, the return lines 87 and 86 of the two cables are connected, via a connector 88, to a single return line 89. The single return line and input lines are housed in the cabling 81b of the mTMS coil device 80 of the present example. The single return will be described in more detail below.

As seen in the example of figure 8, the first and second coil windings only partially overlap within the casing 81a. Essentially, the coil windings are stacked with one coil winding on top of the other coil winding. Typically the coil windings will be electrically separated from each other. Portions of the coil windings though may be electrically connected, for example via the connector 88 connecting the return lines 87 and 86 of each of the coil windings of the combination 82.

In most cases, the position and orientation of secondary coils will be fixed with respect to the position and orientation of the first coil winding. For example, when used in navigated TMS stimulation, it is important to know the position and orientation of all of the coil windings in a coil device during stimulation in order to know the exact electric field being generated. However, the position and/or orientation of one or more of the coil can be adjusted with respect to another coil winding or several windings during operation. In such examples, it is important that either the position and orientation of each coil is known or is derivable. Being able to adjust the physical relationship between two or more coils during operation adds an additional degree of control to the overall control of the resultant electric field. Some examples of this as such will be described below.

Additionally, though it has been described that the combination of multiple coils generally involves aligning and overlapping the center points of the multiple coils, the center points

may also be offset. When overlapping the center points, any center point can be chosen, e.g. center of symmetry or center of gravity.

In a combination with more than 2 coil windings, not all coil windings need overlap with all other coil windings. While all coil windings may overlap, one coil may overlap two
5 separate coils which do not overlap each other. Additionally, further non-overlapping coils can be housed in the casing of the mTMS coil device which do not overlap any of the other coils.

While primary and secondary coils and electric fields have been described, in typical implementations one coil is not significantly stronger than other coils. In these typical
10 implementations all of the coils are nearly equally important, though they may be simply referred to as primary or secondary.

Coil combinations are typically a combination, or an approximate combination, of low order spatial derivatives of a focal TMS-coil induced 2D/3D vector electric field at some point. For 2D, this can be, for example, any combination of the coil windings shown in
15 figures 7a-g or similar such 2D designs. The combination can be a linear combination, e.g. the sum and difference pairs of the component coil windings. The combination can also be a non-linear combination, e.g. one half coil from one coil winding and another half coil from another coil winding. The combination can also be constructed from coil windings that are not derived as spatial derivatives of basic coil forms.

20 The coil windings of a combination may be orthogonal with respect to one or more of the other coil windings. However, non-orthogonal combinations of the coils are also possible. Orthogonality can result in zero mutual inductance. Additionally, orthogonality can result in the lead fields of the coil winding as being orthogonal in the space of the induced current patterns.

25 The efficiency of the coil windings can be effected by the shape of the wires of the coil winding as well as the wire dimensions. In addition to TMS, there are other uses for coil combinations. For uses such as magnetoencephalography (MEG), a thin wire, e.g. having a diameter on the order of 0.1 mm or less, can be ideal. For uses such as TMS, the wire diameter should be sufficient to accommodate high currents. However, thick wires may
30 require larger currents, due to increased distance to a desired target and decreased number

of loops. Therefore, the diameter of the coil winding can be selected based on the intended use of the coil device.

Additionally, the dimensions of the wire of the coil winding may be varied along the path of the coil winding. Thus, for example, thinner crossing wires, or even flattened wire, can be used in certain sections. Thus, a thinner coil and/or more stackable coil winding can be created.

The cross-sectional area of the coil windings can be varied, e.g. having smaller wire in certain parts. Furthermore, a non-circular filament can be used, e.g. where the crossing wire is twisted by 90 degrees. Such use allows for more coil loops while keeping the crossing thickness smaller than a circular filament.

As discussed herein, a wire means any material which has a non-zero conductance. Additionally, a wire can be used to form conducting paths isolated from the surroundings. The material can be high or low Tc superconducting or normal conducting material.

The mTMS coil devices described herein can be used for stimulating a target location on or within the brain of a subject. Stimulation electronics may include IGBT transistors, MOSFETs, thyristors or other suitable components. The polarity of the stimulation current waveform may be fixed or it may be controllable. If controllable it may be controllable with relays or transistors, for example. An example of a circuit design allowing polarity switching is described in Figure 9 of US Provisional application 61/830,181 filed June 3, 2010 which is incorporated herein in its' entirety.

The number of channels in the stimulating electronics may be equal to or less than the number of coils in the mTMS device. Each coil may have its own electronics and capacitor(s). If there are less electronics channels than coils, the electronics may be connected to those coils which are needed for delivering a given stimulus at a given time. The connections to desired coils can be changed either manually or electronically, e.g. with switches.

The electronics may include a controller which controls the overall flow of current to the combination of coils in the mTMS coil device. One controller can be present for separately controlling the current in each of the coil windings power input line. Additionally, at least one controller can control the current in at least two coil windings power input lines.

Additionally, according to certain embodiments of the present invention, there is a method of controlling an mTMS coil in accordance with any of the embodiments and examples disclosed herein.

5 An mTMS coil can be controlled by controlling a first current through a power line of a first coil winding to generate a first electric field. As discussed above, for the purposes of the discussion, the first electric field can be considered a primary electric field.

10 Additionally, the position, direction and/or orientation of the primary electric field can be modified by separately controlling at least one second current through at least one second power line to generate at least one secondary magnetic field inducing at least one secondary electric field.

The position, direction and/or orientation of the primary electric field can also be modified by adjusting the position and/or orientation of the second coil winding with respect to the first coil winding.

15 The present methods can include the control of multiple coil windings, as show for example in figures 7a-g.

Furthermore, the method can include the step of generating at least two magnetic pulses, with different target points and/or orientations. This can be done with the mTMS coil device in the same location and/or orientation. For example, with an mTMS coil device 80 of figure 8, by controlling the current in both figure 8 coils it is possible to fire multiple 20 pulses from the same position and orientation of the casing but with the induced electric field from the resultant magnetic field being in different directions as discussed with respect to figure 5.

25 Additionally, the multiple, two or more, magnetic pulses can come within a short period of time, e.g. 200 microseconds to 2 seconds. The coil windings can be controlled such that at least two of the coil windings produce a magnetic field at the same time. Additionally, the coil windings can be controlled such that the at least two coil windings produce a magnetic field at the same frequency. Thus, the at least two coil windings will affect each other's induced electric fields on each pulse. By controlling the currents differently for different pulses, the induced electric fields can rapidly change without the need for physically 30 moving the mTMS coil device.

Additionally, the at least two coil windings can be controlled such that the at least two coil windings produce a magnetic field at different frequencies. For example, one can produce pulses at a 10 Hz while another coil winding produces pulses at 5 Hz. Therefore, some pulses may be overlapping while others are not. Furthermore, at least two coil windings
5 can be controlled such that their pulses never, or rarely overlap. Such an example could be used for increasing the rate of pulses by staggering two fully or partially overlapped coils.

Further variations are possible. For example, some coil(s) of a combination may be controlled in a biphasic manner while other(s) in the combination are controlled in a monophasic manner. Some coil(s) could produce slow pulses compared to another coil(s)
10 producing faster pulses. Two pulses can be generated which essentially oscillate, have different frequencies, resonant frequencies or differ in another manner.

The method can further include the step of determining a location and/or orientation of the mTMS coil device. Furthermore, the method can include the step of determining a desired location and orientation of a target for an induced electric field and/or generated magnetic
15 field. These can be a typical step of navigated TMS. Then, by separately controlling the generation of magnetic fields from multiple coil winding it is possible to generate a desired magnetic field and/or induced electric field, with a desired orientation at the target site.

A method can also include the steps of selecting a new target location and/or orientation for a magnetic/electric field to be generated, and separately controlling the generation of
20 magnetic fields from the first and second coil windings of the mTMS coil device to generate a desired magnetic/electric field for the new target without adjusting the location or orientation of the mTMS coil device.

Without the use of an mTMS coil device in accordance with the present invention, someone using a TMS device needs to align both the physical position and physical
25 orientation of a TMS coil device to produce a desired stimulus. If the user moves during stimulation, has trouble stabilizing the TMS coil device in one position or otherwise has difficulty using the device then providing accurate and desired stimulation with a human operator can be quite challenging. Using the present device and method, depending on the coil winding combination, the user need only generally align the mTMS coil device near a
30 desired location and the system can compensate for any improper alignment through control of the different coil windings.

The methods described here may also be carried out by a computer program product stored on a transitory or non-transitory computer readable medium.

Further embodiments also include a processor and/or computer. Examples of computers are, e.g. a traditional computer one or more of its variants, e.g., a mobile phone, a tablet,
5 or a customized device. A computer program product and/or control electronics for controlling the stimulation target and parameters may also be included.

A stimulus target can be considered to be, e.g., a single stimulus location with a given stimulus orientation and width, a single stimulus location with a set of different stimuli (e.g., stimuli with different directions, strengths, durations, or widths), or it may
10 consist of or comprise several spatially distinct locations which are stimulated. Different targets can be stimulated simultaneously, or with desired delays. Some of the targets can be stimulated simultaneously while some are stimulated separately. The stimulation sequence can be specified by the user or it may be computed algorithmically. Repetitive TMS is also included as an option within this framework.

15 When a target is to be stimulated, the computer program product may compute the coil windings currents and/or their waveforms needed for delivering the desired stimulus to the target. The computational procedure may be based on e.g., a spherical head model, boundary element method, or finite element method. This computation can be done essentially online before a given stimulus or the computation can be based on using a
20 lookup table and using precomputed parameter values (with possible correction terms, e.g., if the current amplitudes/ waveforms needs to be scaled), this can be considered as offline computation.

The multi coil winding arrangement allows for changing the stimulus target (or the stimulus orientation) without moving (or rotating) the coil(s). The stimulation target(s) can
25 be specified by the user using a computer program product, computer program parameter or by moving the coil to a desired position. This can allow changing the stimulation region / changing the stimulus orientation, if the mTMS coil has a limited range of targets that it can stimulate, e.g., if it can stimulate only to a certain direction.

The computer program product may include an anatomical image, such as, e.g. MRI,
30 CT image, a photograph, or a CAD model, of a subject's head/brain, on which a user may mark a desired stimulus target. Therefore the computer program product can know which

targets the user wants to be stimulated. The computer program product may also keep track of the targets that have been stimulated.

Electronic targeting may take into account the coil or head movement. This may be based on measuring the respective position of the head and the coil. Thus, when the coil
 5 and head move with respect to each other, the computer program product adjusts the stimulus parameters accordingly, so that the desired stimulus e.g., a given electric field strength, is delivered to the target. This kind of adjustment can be performed also when the coil is adjusted to fit the subject's head, e.g., by deforming coils or positioning coil modules. If an mTMS coil, or one of a set of mTMS coils, has only partial coverage of a
 10 target region, the computer program product may assist the user for positioning the coil sufficiently close to the target so that a desired stimulus can be delivered to the target.

As mentioned above, the stimulus sequence may be based on a user-specified pattern or it may be designed algorithmically, for example using feedback from the system, e.g., measured electroencephalography (EEG) data or electric signals from the
 15 muscles. The mTMS device may be used together with EEG or other physiological measurement modality which can give feedback to the stimulation system. The feedback may be automatic (such as EEG data) or it may be given by an operator. The feedback may also be based on, e.g., the subjects/patients performance in a given task, e.g., object naming. The feedback data can be used to adjust/choose the parameters for the next
 20 stimulus (or some of the stimuli which occur later in time).

Furthermore, as mentioned above, a plurality of coil windings may share a single return line. For example, an mTMS coil device may comprise at least two coil windings in a casing. Each coil winding can have a power input line. The power input line of each coil winding may be separate or it may be shared among two or more coil windings.
 25 Furthermore, the at least two coil windings have a single, shared power return line.

In an mTMS coil device with several coil windings, some may have their own return lines and some may share a common return line. Figure 8 shows an example of an mTMS coil device having a two coil combination 82 and sharing a single power return cable 89.

Each of the coil windings can have a separate power return line, for example return lines
 30 87 and 86 in figure 8 and wherein the multichannel TMS coil device further comprises at

least one connector 88 connecting the separate power return lines 86 and 87 to a shared power return line 89.

Furthermore, as can be seen in figure 8, the power return lines 86 and 87 can be oriented near to and/or overlapping each other. The path of the power return lines can be arranged
5 separately within the casing and/or their desired location can be designed into the coil windings themselves.

Described herein is a multichannel Transcranial Magnetic Stimulation (mTMS) coil device comprising; at least two coil windings in a casing, wherein each coil winding has a power input line, and wherein at least two coil windings have a single, shared power return line.
10 The mTMS coil device may also have all coil windings share the same shared power return. The mTMS coil device may also have a single power return. The mTMS coil device may also be such that each of the coil windings has a separate power return line, and wherein the multichannel TMS coil device further comprises at least one connector connecting the separate power return lines to the shared power return line. The mTMS coil
15 device may also have the power return lines of at least two of the coil windings are oriented near to or overlapping each other. The mTMS coil device may also further comprise a casing which contains the at least two coil windings. The mTMS coil device may also have the casing including one power input cable per coil winding and at least one less power return cable than power input cables. The mTMS coil device may also have the
20 power input cables of at least two of the coil windings separated from each other. The mTMS coil device may also have the coil windings stacked on top of each other. The mTMS coil device may also have at least two of the coil windings with substantially different geometries.

It is to be understood that the embodiments of the invention disclosed are not limited to
25 the particular structures, process steps, or materials disclosed herein, but are extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

Reference throughout this specification to “one embodiment” or “an embodiment” means
30 that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, appearances of the phrases “in one embodiment” or “in an embodiment” in various places

throughout this specification are not necessarily all referring to the same embodiment.

As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and
5 unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary. In addition, various embodiments and example of the present invention may be referred to herein along with alternatives for the various components thereof. It is understood that such embodiments, examples, and
10 alternatives are not to be construed as de facto equivalents of one another, but are to be considered as separate and autonomous representations of the present invention.

Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided, such as examples of lengths, widths, shapes, etc., to provide a
15 thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that the invention can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of the invention.

20 While the forgoing examples are illustrative of the principles of the present invention in one or more particular applications, it will be apparent to those of ordinary skill in the art that numerous modifications in form, usage and details of implementation can be made without the exercise of inventive faculty, and without departing from the principles and concepts of the invention. Accordingly, it is not intended that the invention be limited,
25 except as by the claims set forth below.

CLAIMS

1. A multichannel Transcranial Magnetic Stimulation (mTMS) coil device comprising;
 - at least two coil windings in a casing,
 - 5 - wherein each coil winding has a power input line, and
 - wherein at least two coil windings have a single, shared power return line.
2. An mTMS coil device according to claim 1, wherein all coil windings share the same shared power return.
3. An mTMS coil device according to any of the preceding claims, wherein the
 10 mTMS coil device has a single power return.
4. An mTMS coil device according to any of the preceding claims, wherein each of the coil windings has a separate power return line, and wherein the mTMS coil device further comprises at least one connector connecting the separate power return lines to the shared power return line.
- 15 5. An mTMS coil device according to claim 4, wherein the power return lines of at least two of the coil windings are oriented near to or overlapping each other.
6. An mTMS coil device according to any of the preceding claims, further comprising a casing which contains the at least two coil windings.
7. An mTMS coil device according to claim 6, wherein the casing includes one power
 20 input cable per coil winding and at least one less power return cable than power input cables.
8. An mTMS coil device according to any of the preceding claims, wherein the power input cables of at least two of the coil windings are separated from each other.
9. An mTMS coil device according to any of the preceding claims, wherein the coil
 25 windings are stacked on top of each other.
10. An mTMS coil device according to any of the preceding claims, wherein at least two of the coil windings have substantially different geometries.

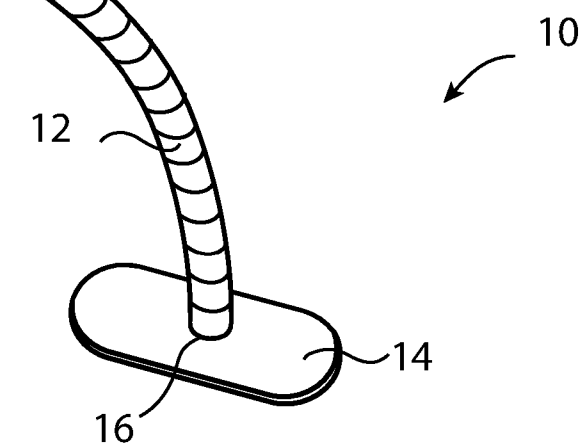


Fig. 1

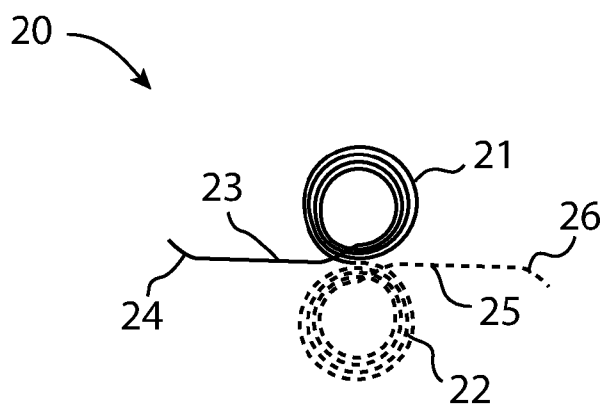


Fig. 2

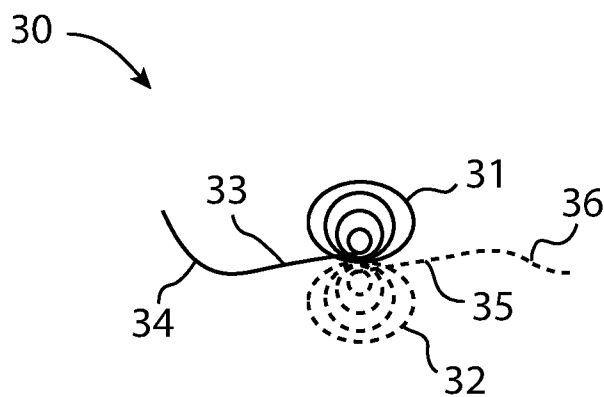


Fig. 3

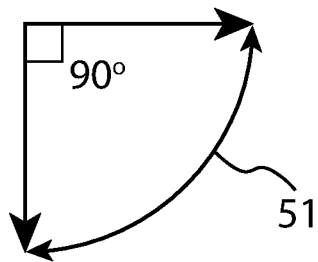
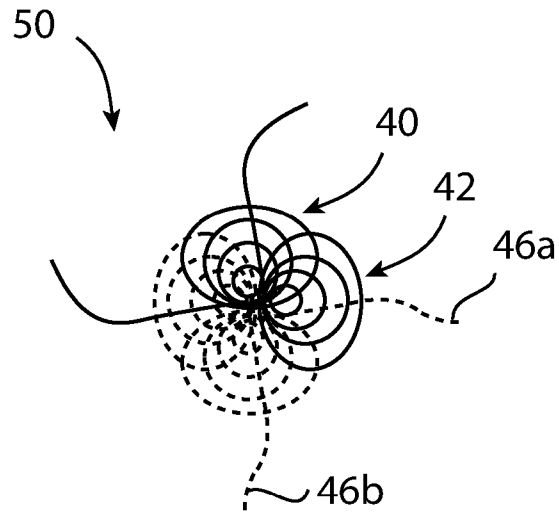
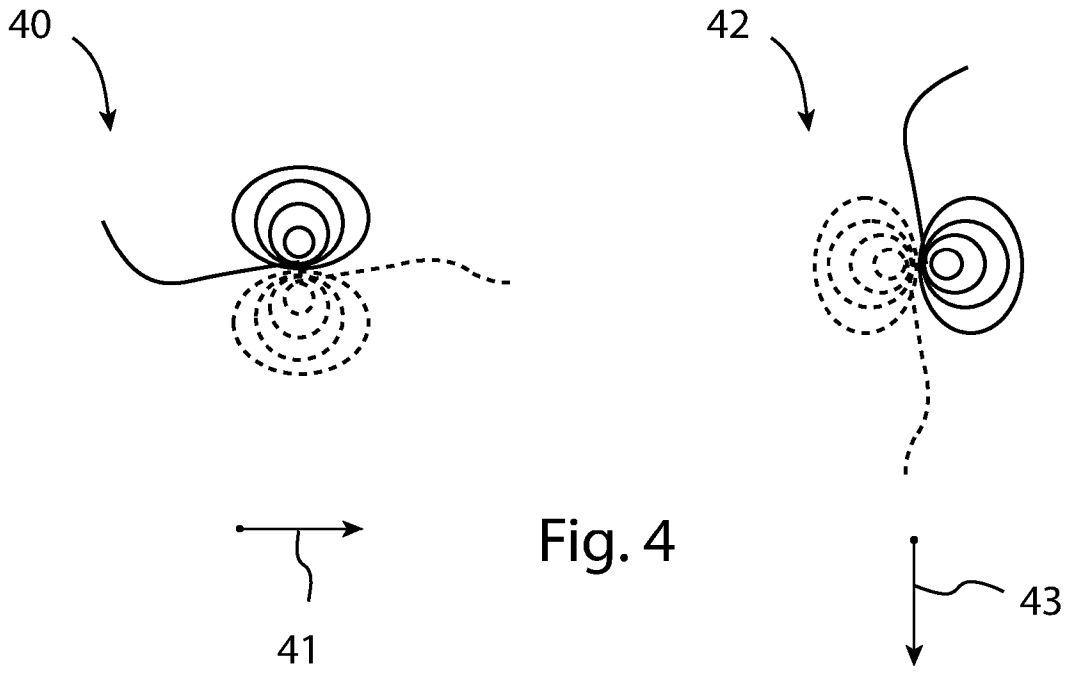


Fig. 5

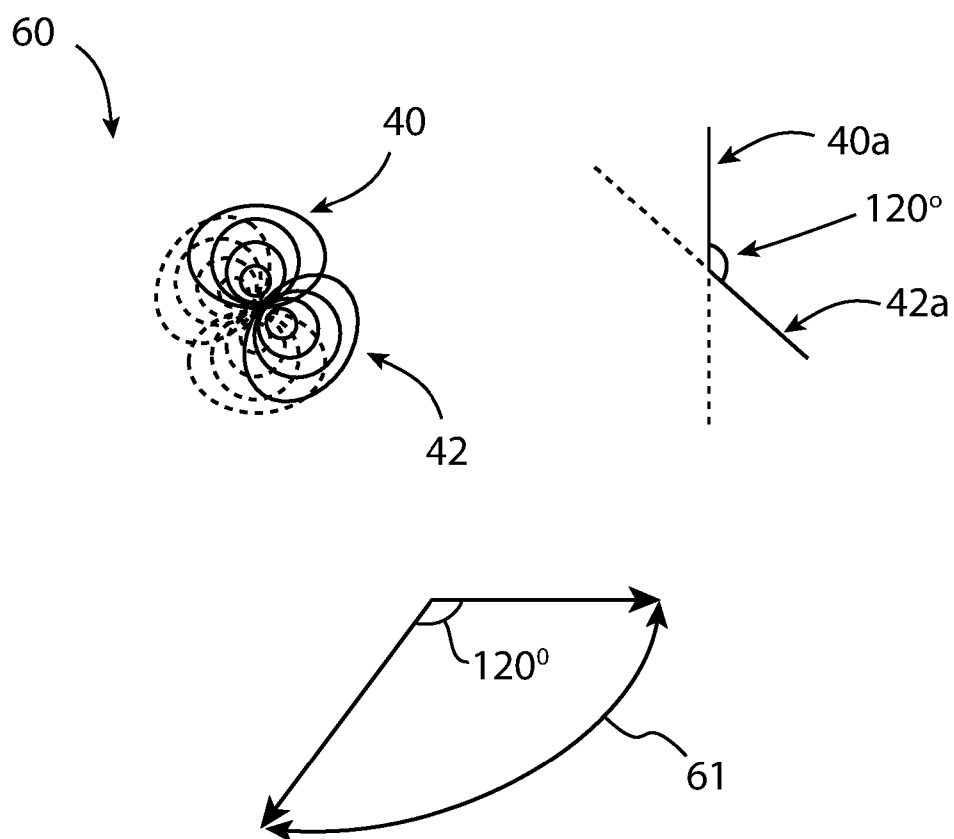
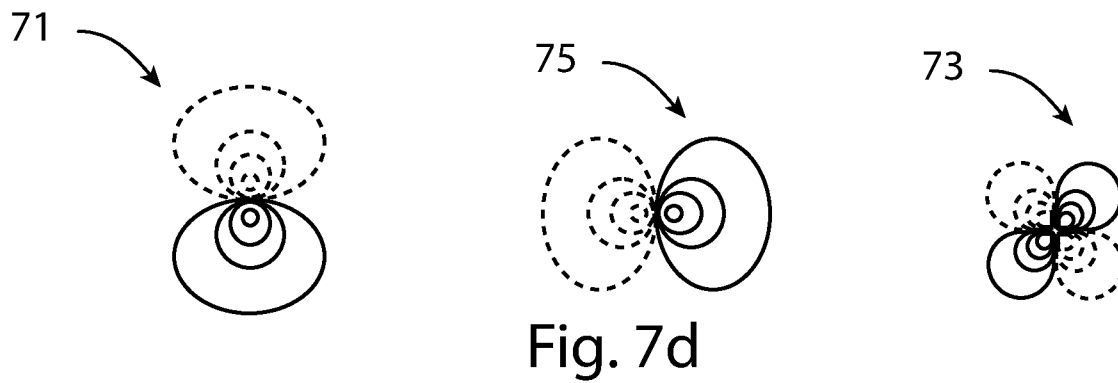
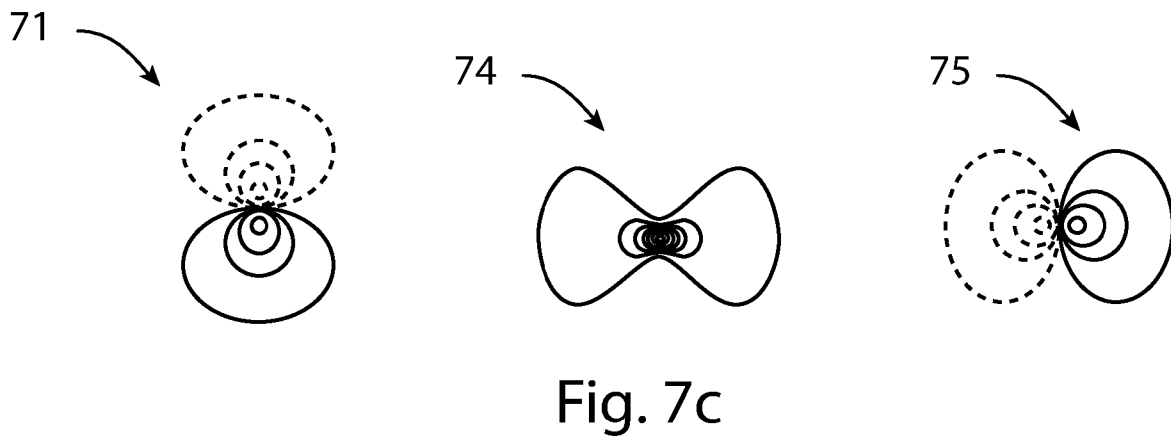
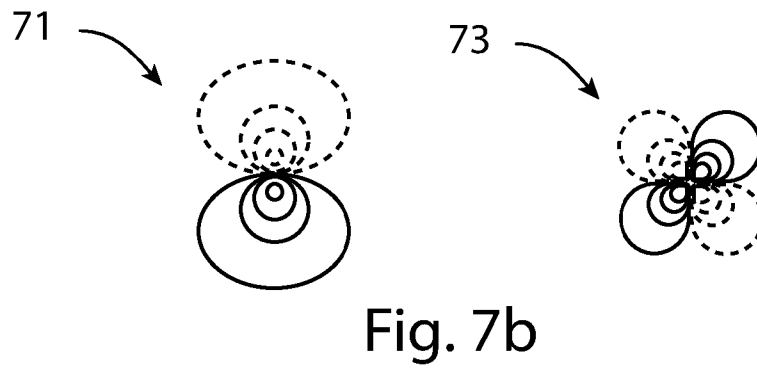
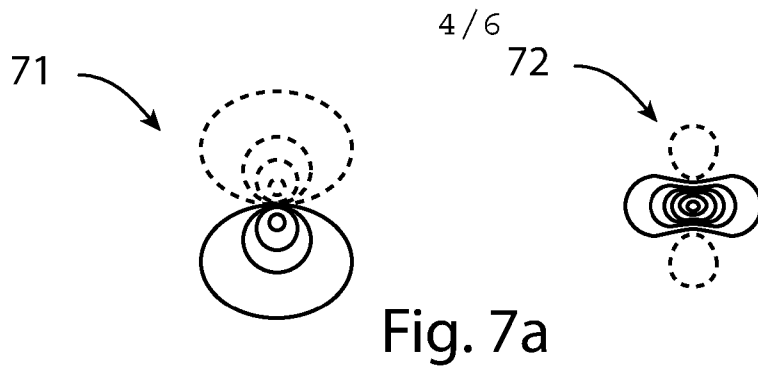


Fig. 6



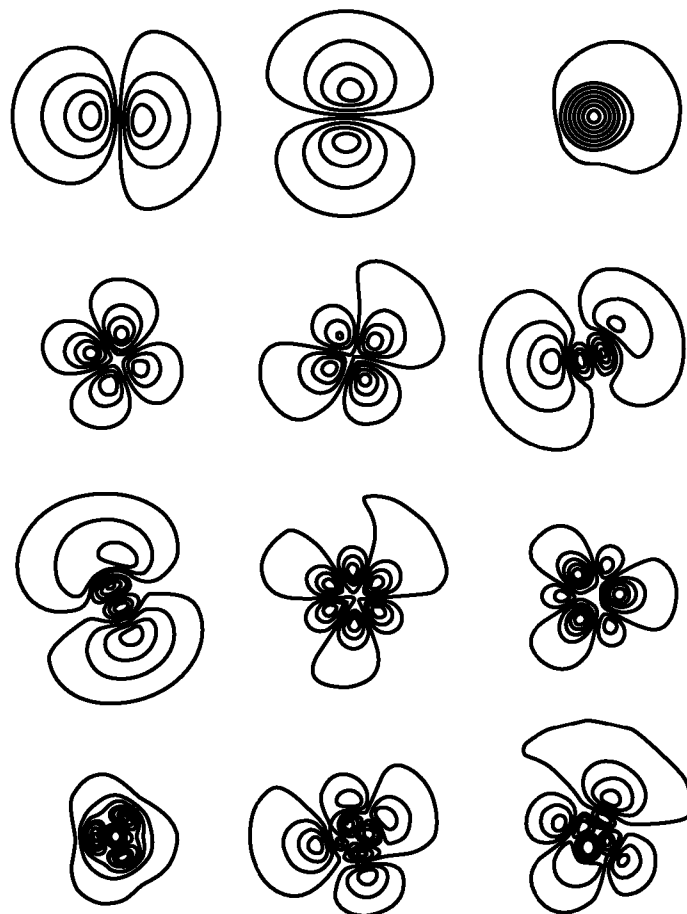
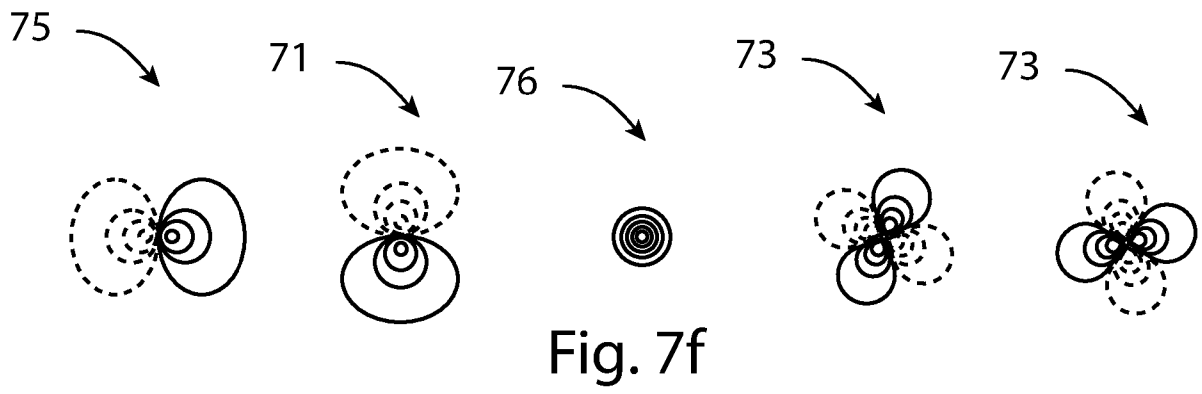
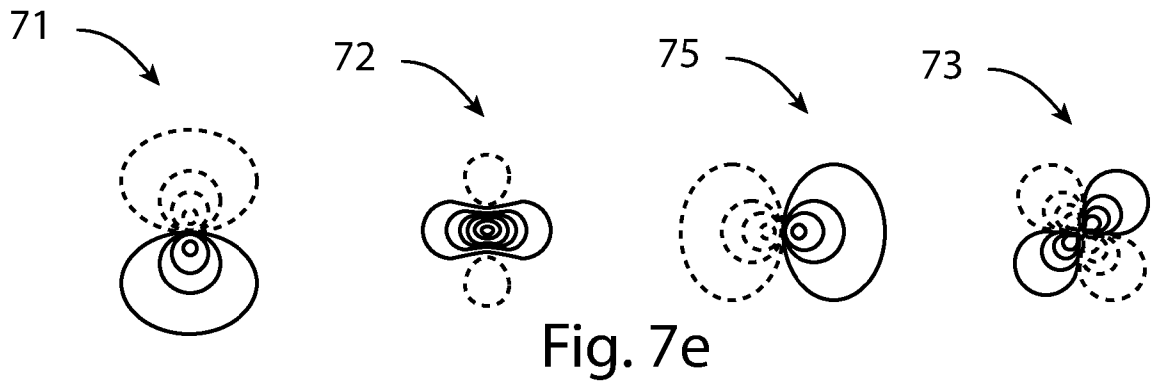


Fig. 7g

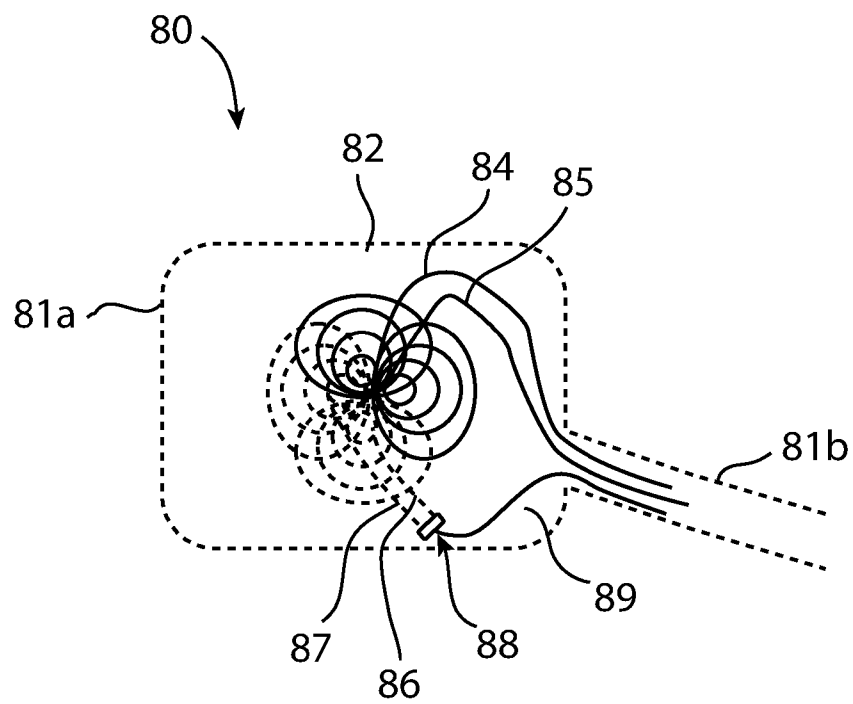


Fig. 8

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SEARCH REPORT

PATENT APPLICATION No.		CLASSIFICATION	
20145510		IPC A61N 1/40 (2006.01) H01F 5/04 (2006.01)	CPC A61N 1/40 H01F 5/04
PATENT CLASSES SEARCHED (classification systems and classes)			
IPC: A61N, H01F			
DATABASES CONSULTED DURING THE SEARCH			
EPO-Internal, WPI, COMPDX, EMBASE, INSPEC, TDB, NPL, XP3GPP, XPAIP, XPESP, XPESP2, XPETSI, XPI3E, XPIEE, XPIETF, XPIOP, XPOAC, XPRD, XPTK			

DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*)	Bibliographic data on the document and relevant passages	Relevant to claims
X	JP 2012125546 A (UNIV OSAKA) 05 July 2012 (05.07.2012) figures and abstract [online] EPOQUENET EPODOC & WPI	1 - 10
X	US 2005154426 A1 (BOVEJA BIRINDER R [US] et al.) 14 July 2005 (14.07.2005) abstract, claims, and figures	1 - 10
X	US 2008058581 A1 (AHO MATTI [FI]) 06 March 2008 (06.03.2008) abstract, claims, and figures	1 - 10
X	US 4994015 A (CADWELL JOHN A [US]) 19 February 1991 (19.02.1991) abstract, claims, and figures	1 - 10
Continued on the next sheet ☐		

*) X Document indicating that the invention is not novel or does not involve an inventive step with respect to the state of the art.
Y Document indicating that the invention does not involve an inventive step with respect to the state of the art if combined with one or more other documents in the same category.
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Further information given in the annex ☐

Date 28.01.2015	Patent Examiner Lauri Rostila Telephone (09) 6939 5691
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