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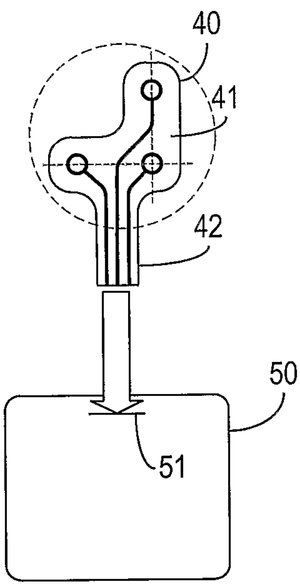
(54) Title: AN ELECTRODE AND A METHOD FOR DETERMING ELECTRICAL BIOPOTENTIALS



(57) Abstract: An electrode suitable for being attached to the skin of an animal or human being at locations normally used for attaching single-lead electrodes with a single sensor point. The electrode (40) has at least three sensors arranged to define two linearly independent directions, which allows sensing corresponding electrical potential differences in the two directions. Signals representing sensed potential differences can be transmitted wirelessly or via conductors to a processing apparatus for being transformed into electrical potentials that approximate tradüaonal potentials obtained with wired single-sensor electrodes.

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An electrode and a method for determining electrical biopotentials

Field of the invention

The invention relates to sensing of electric surface potentials by means of electrodes attached to the skin of an animal or human being. Such uses include in particular electrocardiography (ECG), electroencephalography (EEG) and electromyography (EMG).

Background

When measuring ECG, EEG and EMG a plurality of electrodes, which each have a sensor, is attached to the skin of an animal or human patient, where each electrode senses the electrical potential at a relatively small area - typically a few mm in diameter - on the skin immediately below the sensor. Usually an electrically conductive contact medium is used between the sensor and the skin. The sensed electrical potentials are transmitted through individual conductors to an apparatus, which measures, registers and/or evaluates the sensed potentials, e.g. by determining differences between electrical potentials at the electrodes and linear combinations thereof. Such systems have long been used for monitoring and diagnostic purposes.

US 4 583 549 and others disclose an ECG electrode pad comprising a flexible sheet with a plurality of ECG electrodes positioned thereon to correspond with the anatomically correct placement for precordial ECG electrodes.

US 5 724 984 discloses an electrode with a central sensor segment and several peripheral sensor segments arranged symmetrically around the central sensor segment.

US 6 577 893 discloses an integrated wireless medical diagnosis and monitoring equipment with two or more electrodes and a wireless transmitter for transmitting sensed electrode signals.

ECG signals originate from the coordinated activation and contraction of the heart muscles resulting in blood circulation through the body. The ECG signal starts at the SA node and initiates the contraction of the atrial myocardium resulting in the P wave, which travels down the centre line of the heart. The AV node and the bundle of His are activated, whereby the activation of the ventricles is initiated. First the septum (the muscle that separates the two ventricles) is activated, which results in the Q wave as the signal is travelling down the centre line of the heart. Then the free outer walls of the ventricles are activated, which results in the R and S waves. There the activation travels from the apex of the heart up the centre line, and completes the QRS complex. The T wave originates from the re-polarisation of the outer walls of the ventricles, actually travelling from the apex upright the centre line, but with inverted signal polarity, resulting in what appears to be a downward movement towards the apex. Finally, a small U wave can be found which originates from a late activation of the ventricles. The shape of the recorded ECG signal depends on the location of the electrodes and the polarity of the recording.

The ECG signal originates from measuring the difference in the biopotential between different sites on the body. There are several different standards for recording/forming the ECG signal, which will not be discussed here. In the following the 3 standard leads or limb leads (I, II, III) forming the Einthoven's triangle [10] are taken as an illustrative example. Traditionally, the electrode placements of the limb leads are on the right arm (RA), left arm (LA) and left leg (LL). In several clinical applications the limb electrodes are placed on the torso near the extremities without loss of information [5], [8].

The potential recorded between the three electrodes is defined as:

$$I = V_{RA} - V_{LA}$$

$$II = V_{RA} - V_{LL}$$

$$III = V_{LA} - V_{LL}$$

where V_{XX} is the potential recorded under electrode XX (eq. I).

Besides the primary standard limb leads the unipolar limb leads, also called augmented leads, can be calculated from the same three potential recordings as the standard and unipolar limb lead forms a vector system constructed of 6 vectors.

$$aVR = V_{RA} - (V_{LA} + V_{LL})/2$$

$$aVL = V_{LA} - (V_{RA} + V_{LL})/2$$

$$aVF = V_{LL} - (V_{RA} + V_{LA})/2$$

ECG signals are recorded as the difference between two potentials at two different sites on the body. The voltage difference is measured relative to a reference point, which is taken as a "zero potential" on the body. This means that the signal is always in relation to a single common point on the body. This reference point can be a single site/electrode placed on a site of the body that is minimally influenced by the body potential of interest, or the reference can be one or several potentials/electrodes. This dependency on a reference point(s) limits the possibilities of transmitting the signal of a single electrode over a non-reference transmission line, e.g. wirelessly. Normally this would only be possible if a relation between at least two electrodes can be made, e.g. with a pair of wires connecting two electrodes to a transmitter.

Traditionally, each sensor has its own conductor that connects the sensor to the measuring and/or evaluating apparatus. With several electrodes and a corresponding number of individual conductors there is a risk of confusing the conductors and of connecting sensors to wrong inputs of the apparatus. A patient with a set of such electrodes attached has his/her mobility restricted by the length of the conductors. In equipment powered by AC mains power supply the electrodes must be extremely well isolated from the AC mains power supply in order to ensure patient safety.

In systems for telemetric monitoring of patients a set of electrodes are attached to the patient, where each electrode is connected via a conductor to a common transmitter carried by the patient. Such systems also have conductors that restrict the freedom and the mobility of the patient.

There is a need for a disposable electrode and a system that allows wireless transmission of signals representing sensed potentials from each electrode. There is also a need for more detailed information on the electrical biopotential underneath the electrode, such as the direction of propagation of the biopotential.

Summary of the invention

The invention offers a solution to this problem. The disposal electrode of the invention is suitable for being attached to the skin of an animal or human being at locations normally used for attaching single-lead electrodes with a single sensor point. The at least three sensors or sensing points on each electrode are arranged to define two linearly independent directions, which allows sensing corresponding electrical potential differences in the two directions. Signals representing sensed potential differences can be transmitted wirelessly or via conductors to a processing apparatus for being transformed into electrical potentials that approximate traditional potentials obtained with wired single-sensor electrodes. Methods for the transformation are disclosed.

With the method of the invention the electrical potential at the location of each electrode relative to the electrical potential at a reference position is determined or estimated based on the sensed potential differences between respective pairs of sensors of the electrodes. The electrical potentials can be determined as numerical values corresponding e.g. to the traditional ECG measurements with single-lead electrodes with a single sensor point, or the electrical potentials can be determined as vector values having two coordinates that define size (a numerical value) and direction, e.g. the direction of propagation of the sensed signal.

In one dimension the body potential can be regarded as a propagating signal, which will pass under the electrodes at a given speed of propagation. Even though the action potentials originating from the heart muscle activity are placed "far" from the electrodes, the signal will propagate under the electrode due to the volume conductivity of the rest of the body.

When the two electrodes are placed close together they will both sense the same wave, and the resulting differential between the two electrodes will be small, and a gradient in the direction of the centre line can be measured, when the distance between the electrodes is known. Hereby a differentiation, in space and time, can be made of the passing body potential.

If the distance between the electrodes is large so that the entire potential wave can fit between the two electrodes, the recording would not function as a differential but as a full potential recording of under the electrode.

Using two electrodes as above works for the one-dimensional space, where the two electrodes can be placed in such a way that the centre line of the electrodes is parallel to the direction in which the potential wave is moving. If the potential wave moves in a direction different form that of the centre line, a smaller potential difference will be measured, and if the potential wave moves perpendicular to the centre line of the two electrodes, the electrodes will sense substantially the same signal, and the recorded difference between the two electrodes will be (almost) zero. Therefore the orientation of two electrodes is essential for the resulting recorded amplitude.

The invention provides an electrode with at least three sensors arranged so that lines through the centres of respective pairs of sensors define at least two linearly independent, i.e. different, directions, which preferably are perpendicular to each other. Measurements are taken using two pairs of sensors to obtain two corresponding potential differences representing vector coordinates of a two-dimensional vector corresponding to the two-dimensional gradient at any instant in time.

Brief description of the drawings

Figure 1 shows an electrode with three sensors and a button-type connection to the individual sensors,

Figure 2 shows an electrode like that in figure 1 but with four sensors,

Figure 3 shows an electrode like that in figure 4 with four sensors and a conductor strip for use as an antenna,

Figure 4 shows an electrode with three sensors and an edge connection to the individual sensors, with the edge connector connectable to a wireless transmitter,

Figure 5 shows the electrode connected to the transmitter in figure 4,

Figure 6 shows an electrode with four sensors and a conductor strip for use as an antenna, and connected to a wireless transmitter,

Figure 7 shows a system with a plurality of electrodes connected to individual wireless transmitters and a receiver receiving signals transmitted from the transmitters, and

Figure 8 illustrates the measuring principle of the invention.

Detailed description of the invention

In figure 1 is shown a first electrode 10 with a carrier sheet 11 and three sensors 12, 13, 14 on one side of the carrier sheet, which is preferably of a flexible material. The sheet 11 has an L-shaped contour. The three sensors have a size of a few mm in diameter, and they can be of any suitable type such as Ag/AgCl. The electrode has a suitable adhesive for attaching the electrode to the skin of an animal or human being, and an electrically conductive medium such as a gel at each of the sensors for creating electrical contact between the sensors and the skin. A straight line between the centres of the sensors 12 and 13 is perpendicular to a straight line between the centres of the sensors 13 and 14. The two sensors 12 and 13 can be used as one pair of sensors, and the two sensors 13 and 14 can be used as another pair of sensors, where the sensor 13 is common to both pairs. Conductors can be connected to each of the sensors in any suitable manner such as the snap type.

In figure 2 is shown a second electrode 20 of similar construction with a carrier sheet 21 and four sensors 22, 23, 24 and 25. The sheet 21 has a cruciform contour. A straight line between the centres of the sensors 22 and 24 is perpendicular to a straight line between the centres of the sensors 23 and 25. The two sensors 22 and 24 can be used as one pair of sensors, and the two sensors 23 and 25 can be used as another pair of sensors, so that none of the sensors is common to both pairs.

In figure 3 is shown a third electrode 30 of similar construction as the electrode 20 and has a carrier sheet 31 and four sensors 32, 33, 34 and 35 on the carrier sheet. The carrier sheet 31 has a circular contour. In addition the electrode 30 has an electrically conducting strip 36 applied to the sheet and a terminal 37 for connecting the strip 36 to external equipment for receiving signals from the external equipment to be wirelessly transmitted by the electrically conducting strip, which then acts as a transmitting antenna, as will be explained further below. The antenna 36 and its connector 37 are insulated such as not to come into electrical contact with the patient's skin, when the electrode is attached to a patient. The antenna can have any other suitable form than the one shown.

In figure 4 is shown an electrode 40 of similar construction to that of the electrode 10 in figure 1. The carrier sheet 41 of the electrode 40 has a tongue 42 extending from an edge of the sheet. Electrical conductor strips on the sheet extend from each of the sensors to the tongue, where at least an end portion of each conductor is exposed, so that electrical contact can be obtained to each of the sensors.

In figure 4 is also shown a wireless transmitter 50 with an opening in the form of a slit 51 for receiving the tongue 42 of the electrode 40. The transmitter 50 has contacts (not shown but known as such) for establishing electrical contact with the corresponding contacts on the tongue 42 of the electrode 40.

Figure 5 is a side view of the transmitter 50 with the tongue 42 inserted in the slit, and the electrode 40 is folded to lie close to a side face of the transmitter, where it is preferably secured by means of an adhesive. The exposed side of the electrode has an adhesive or other suitable means for detachably attaching the electrode to the skin of a patient with the sensors in electrical contact with the skin. In the shown configuration the electrode 40 and the transmitter 50 are thus suited for being attached to the skin of the patient.

In figure 6 is shown an electrode 60 of similar construction to that of the electrode 40 in figure 4. However, the sheet has a further conductor strip 61 extending along the periphery of the sheet and connected to the transmitter 50, so that the conductor strip 61 is a transmitting antenna that can receive electrical signals from the transmitter 50 to be wirelessly transmitted by the conductor strip 61 acting as an antenna.

In the embodiments in figures 4 and 6 the electrical conductor strips on the carrier including the antenna conductor strip 61 are insulated so as not to come into electrical contact with the patient's skin, when the electrodes are attached to the skin of a patient.

In figure 7 is shown a system with a plurality of electrodes connected to individual wireless transmitters 50 and a wireless receiver 70 receiving signals transmitted from the transmitters. The electrodes and transmitters can be attached to the skin of a patient at predetermined locations. The transmitters transmit signals representing the sensed potentials, and the receiver 70 receives the signals transmitted from all the transmitters.

The skilled person such as a physician or a medical assistant, who attaches e.g. traditional ECG electrodes with a single sensor to a patient, will attach the electrodes at predetermined locations identified in relation to the patient's anatomy. These locations are determined with an accuracy that allows comparison of repeated measurements performed on the same patient and of measurements taken on different patients. Repeated measurements on the same patient can e.g. be performed with short or long intervals between them and possibly also by a different staff. Measurements taken on different patients are used e.g. for statistical purposes. In order to ensure a high diagnostic value it is important that the electrodes are attached at the predetermined locations with a high accuracy every time, i.e. within prescribed limits identified in relation to the patient's anatomy and with usual skilled human accuracy.

The electrodes of the invention therefore have a size small enough so that the sensors are all within an area that can be covered by an electrode with a single sensor, which is normally used for sensing the electrical potentials on patients. The electrodes have a size that allows a plurality of the electrodes to be attached to the skin of a patient at respective locations normally used for sensing the electrical potentials, without any of the electrodes overlapping each other. In practice this means that the sensors are all within the periphery of a circle with a diameter of 70 mm or less. In figures 1, 2, 4 and 6 such a circle is indicated by a dashed circle, and the circular electrode in figure 3 is also within the periphery of such a circle.

Function of the invention

In each of the locations traditionally chosen by the operator of ECG equipment for attaching an electrode with a single sensor the operator attaches an electrode of the invention with a wireless transmitter 50 connected thereto. This is illustrated in figure 8, where one location is chosen as a reference location R. Figure 8 also shows a first location A in which the electrical potentials are to be determined with reference to the reference location R. Usually, electrodes will be attached at several further locations, in which the electrical potentials are to be determined with reference to the reference location R, but for simplicity only one such location A is shown in figure 8.

In a first embodiment of the invention the following is performed at the first location A:

an electrical potential (VA_r) is sensed in a first reference position,

an electrical potential (VA_{dirX}) is sensed in a position in a first direction from the first reference position,

a first electrical potential difference (VA_{dirX}) - (VA_r) between the electrical potential (VA_{dirX}) in the position in the first direction from the first reference position and the electrical potential (VA_r) in the first reference position is determined,

signals representing the first electrical potential difference are transmitted,

an electrical potential (VA_{dirY}) is sensed in a position in a second direction from the first reference position,

a second electrical potential difference (VA_{dirY}) - (VA_r) between the electrical potential (VA_{dirY}) in the second direction from the first reference position and the electrical potential (VA_r) in the first reference position is determined, and

signals representing the second electrical potential difference are transmitted.

At each of the further locations and at the reference location R corresponding operations are performed. The receiver receives the transmitted signals, and the electrical potential of the first location (A) relative to the reference location (R) is determined as the difference between a size of a first vector defined by the first and second electrical potential differences and a size of a reference vector defined by the third and fourth electrical potential differences.

In another embodiment of the invention the following is performed at the first location A:

an electrical potential (VA_r) is sensed in a first reference position,

an electrical potential (VA_{dirX}) is sensed in a position in the X-direction from the first reference position,

a first electrical potential difference $(VA_{dirX}) - (VA_r)$ is determined between the electrical potential (VA_{dirX}) in the X-direction from the first reference position and the electrical potential (VA_r) in the first reference position,
signals representing the first electrical potential difference are transmitted,
an electrical potential (VA_{dirY}) is sensed in a position in the Y-direction from the first reference position,
a second electrical potential difference $(VA_{dirY}) - (VA_r)$ is determined between the electrical potential (VA_{dirY}) in the Y-direction from the first reference position and the electrical potential (VA_r) in the first reference position,
signals representing the second electrical potential difference are transmitted.

At each of the further locations and at the reference location R corresponding operations are performed. The receiver receives the transmitted signals, and the electrical potential of the first location (A) relative to the reference location (R) is determined as the sum of a first difference between the first electrical potential difference and the third electrical potential difference and a second difference between the second electrical potential difference and the fourth electrical potential difference.

In the preferred embodiment wireless transmission is preferred, but wired transmission through electrical conductors is also usable.

Figure 8 illustrates the basic concept of the invention of monitoring the biopotential as a differentiating between two electrodes spaced a known distance, D_X and D_Y respectively, apart. This is done in two linearly independent directions X, Y preferably perpendicular to each other. Electrodes of the invention are attached to a first location A and at a reference location R, respectively. At the first location A the potential difference at each pair of sensors is measured as the electrical potential difference between the local reference electrode (V_r) and each of the directional electrodes (VA_{dirX} or VA_{dirY}) giving:

$$VA_x = VA_{dirX} - VA_r$$

$$VA_y = VA_{dirY} - VA_r$$

When the two linearly independent directions defined by lines through the centres of respective pairs of sensors are perpendicular to each other the length or size of the signal in two dimensions can be calculated as:

$$V_{signal} = \sqrt{VA_{dirX}^2 + VA_{dirY}^2}$$

which is proportional to the total size of the signal passing under the electrode. Not only the size of the total signal can be use in identifying the physiological function, but also the direction from where the signal originated can be determined in relation to the location of the electrode, e.g. if the signal is travelling to or away from the electrode and in which direction.

The resulting total size of the signal, e.g. the length of the sum of the two directional vectors has no information about the direction of the travelling signal. When calculating the resulting ECG leads from each of the three limb positions the result will simulate an absolute value of the traditional ECG lead (I, II, III). For the determination of the size of the signal, i.e. without determining the direction of travel of the signal, the orientation of the electrodes of the invention need not be known.

For the determination of the direction of travel of the signal, the orientation of the electrodes of the invention must be known. The electrode 40 in figure 4 is particularly suited for this and the electrode should be placed with its tongue 42 extending in a predetermined direction, e.g. up or down.

The electrodes of the invention are placed like traditional ECG electrodes in standardised locations on the skin of a patient. The electrodes record the signals in the x and y directions and transmit the two signals as a difference signal between the common reference point and the recording electrode to a monitor connected to the receiver. This results in a locally referenced signal that can be transmitted wirelessly using conventional RF technology or digital transmitting technology (e.g. Bluetooth, Zigbee, WIFI, WLAN, etc.) or other suitable wireless transmission means. This results in 2 signals for each electrode, hence 6 signals from 3 electrodes to perform a normal 3 lead ECG deviation. When the signals have been transmitted the signals can be transformed into the traditional ECG lead.

Two basic methods of transforming the sensed potential differences into traditional ECG leads (e.g. I, II, III, aVR, aVL, aVF) are contemplated:

1. Limb leads based on the length of the each derivative.

A method based on raw signal lengths:

e.g. $I = \sqrt{VA_{dirX}^2 + VA_{dirY}^2} - \sqrt{VR_{dirX}^2 + VR_{dirY}^2}$

A method based on time-integrated signal lengths:

e.g. $I = \sqrt{\left(\int VA_{dirX}\right)^2 + \left(\int VA_{dirY}\right)^2} - \sqrt{\left(\int VR_{dirX}\right)^2 + \left(\int VR_{dirY}\right)^2}$

2. Limb leads based on the directional size of the derivatives.

A method based on same orientation/direction of the electrodes:

e.g. $$I = \frac{(VA_{dirX} - VR_{dirX}) + (VA_{dirY} - VR_{dirY})}{gain}$$

A method based on integration of the electrode directional size:

e.g. $$I = \frac{\left(\int VA_{dirX} - \int VR_{dirX}\right) + \left(\int VA_{dirY} - \int VR_{dirY}\right)}{gain}$$

A method based on mean filtering of the directional size:

e.g. $$I = \frac{\left(\overset{\Delta t}{mean}(VA_{dirX}) - \overset{\Delta t}{mean}(VR_{dirX})\right) + \left(\overset{\Delta t}{mean}(VA_{dirY}) - \overset{\Delta t}{mean}(VR_{dirY})\right)}{gain}$$

Corresponding calculations can be made to obtain each of the other ECG leads II, III, aVR, aVL and aVF. Each of the calculation methods was evaluated by comparing the resulting ECG signal with the simultaneously recorded "real" ECG derivatives. The gain in the above formulas can be set to unity (1).

For comparison of the similarity of the limb leads obtained with the method of the invention to the traditional limb leads the correlations coefficients (r_{XY}) of simultaneous recordings were calculated.

Cross-correlation function:

$$R_{XY}(t_1, t_2) \overset{\Delta}{=} E\{X^*(t_1)Y(t_2)\}$$

Cross-covariance function:

$$C_{XY}(t_1,t_2)\stackrel{\Delta}{=}R_{XY}(t_1,t_2)-\mu_X^*(t_1)\mu_Y(t_2)$$

Correlation coefficient:

$$r_{XY}(t_1,t_2)\stackrel{\Delta}{=}\frac{C_{XY}(t_1,t_2)}{\sqrt{C_{XX}(t_1,t_2)C_{YY}(t_1,t_2)}}$$

The correlation coefficient can be used to evaluate the similarity between two linear dependent signals. Generally speaking the correlation coefficient will be equal to 1 when the signals are identical, and -1 when the signals are inverted relative to each other. The correlation coefficient be thus could used as a measure of similarity.

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Claims:

1. A disposable electrode for sensing electrical potentials on the skin of an animal or human being, the electrode comprising

- a carrier,
- at least three sensors carried by the carrier and arranged so that lines through centres of respective pairs of sensors define at least two linearly independent directions,
- means for detachably attaching the electrode to the skin of an animal or human being with the sensors in electrical contact with the skin,
- connections to external equipment for transmitting respective sensed electrical potentials from the sensors to the external equipment,

wherein

- the sensors are all within an area that can be covered by an electrode with a single sensor normally used for sensing the electrical potentials on animals and human beings.

2. A disposable electrode for sensing electrical potentials on the skin of an animal or human being, the electrode comprising

- a carrier,
- at least three sensors carried by the carrier and arranged so that lines through centres of respective pairs of sensors define at least two linearly independent directions,
- means for detachably attaching the electrode to the skin of an animal or human being with the sensors in electrical contact with the skin,
- connections to external equipment for transmitting sensed electrical potentials from the sensors to the external equipment,

wherein

- the electrode has a size that allows a plurality of the electrodes to be attached to the skin of a patient at respective locations normally used for sensing the electrical potentials, without any of the electrodes overlapping each other.

3. A disposable electrode for sensing electrical potentials on the skin of an animal or human being, the electrode comprising

- a carrier,
- at least three sensors carried by the carrier and arranged so that lines through centres of respective pairs of sensors define at least two linearly independent directions,
- means for detachably attaching the electrode to the skin of an animal or human being with the sensors in electrical contact with the skin,
- connections to external equipment for transmitting respective sensed electrical potentials from the sensors to the external equipment,

wherein

- the sensors are all located within the periphery of a circle with a diameter of 70 mm or less.

4. An electrode according to any one of claims 1-3 wherein the at least two linearly independent directions are perpendicular to each other.

5. An electrode according to any one of claims 1-4 further comprising an electrically conducting portion with a connection to the external equipment for receiving signals from the external equipment to be wirelessly transmitted by the electrically conducting portion.

6. An electrode according to any one of claims 1-5 having a visual indication of a predetermined orientation of the electrode.

7. A set of electrodes according to any one of claims 1-6, where the number of electrodes equals a predetermined number of locations on an animal or human body for sensing electrical potentials.

8. A system for sensing electrical potentials at predetermined locations on the skin of an animal or human being, the system comprising a set of electrodes according to claim 7 and a number of wireless transmitters equal to the number of electrodes, where each transmitter is adapted to receive sensed electrical potentials from the sensors and to transmit signals corresponding to the sensed electrical potentials.

9. A method for sensing electrical potentials at predetermined locations on the skin of an animal or human being, the method comprising

- arranging, in each of the predetermined locations, an electrode according to any one of claims 1-6,
- connecting to each of the electrodes a wireless transmitter adapted to receive sensed electrical potentials from the sensors and to transmit signals representing the sensed electrical potentials, and
- receiving from each transmitter the signals transmitted therefrom.

10. A method of determining the electrical potential of a first location (A) relative to a reference location (R) on the skin of an animal or human being, the method comprising the steps of

- attaching, to each of the first location (A) and the reference location (R) an electrode with at least three sensors arranged so that lines through centres of respective pairs of sensors define two linearly independent directions,
- sensing, with each of the sensors on each electrode, an electrical potential on the skin,
- transmitting signals representing at least two differences between pairs of potentials sensed with corresponding pairs of sensors on each electrode,
- receiving the transmitted signals, and
- determining the electrical signals at the predetermined location based on the received signals.

11. A method according to claim 10 further comprising determining parameters representing the instantaneous amplitude of a bioelectrical field in the animal or human being.

12. A method according to claim 10 further comprising determining parameters representing the instantaneous polarity of a bioelectrical field in the animal or human being.

13. A method according to claim 10 further comprising determining parameters representing the instantaneous direction of propagation of a bioelectrical field in the animal or human being.

14. A method of determining the electrical potential at a first location (A) relative to a reference location (R) on the skin of an animal or human being, the method comprising

- attaching to each of the first and reference locations an electrode with
- a carrier,
- at least three sensors carried by the carrier and arranged so that lines through centres of respective pairs of sensors define two linearly independent directions (X, Y), and where the sensors are all within an area that can be covered by an electrode with a single sensor normally used for sensing the electrical potentials at the first and reference locations,
- means for detachably attaching the electrode to the skin of an animal or human being with the sensors in electrical contact with the skin,

- at the first location (A):
  - sensing an electrical potential (VA_r) in a first reference position,
  - sensing an electrical potential (VA_{dirX}) in a position in a first direction from the first reference position,

- determining a first electrical potential difference (VA_{dirX}) - (VA_r) between the electrical potential (VA_{dirX}) in the position in the first direction from the first reference position and the electrical potential (VA_r) in the first reference position,
- transmitting signals representing the first electrical potential difference,
- sensing an electrical potential (VA_{dirY}) in a position in a second direction from the first reference position,
- determining a second electrical potential difference (VA_{dirY}) - (VA_r) between the electrical potential (VA_{dirY}) in the second direction from the first reference position and the electrical potential (VA_r) in the first reference position,
- transmitting signals representing the second electrical potential difference;

- at the reference location (R):
  - sensing an electrical potential (VR_r) in a second reference position,
  - sensing an electrical potential (VR_{dirX}) in a position in a third direction from the second reference position,
  - determining a third electrical potential difference (VR_{dirX}) - (VR_r) between the electrical potential (VR_{dirX}) in the third direction from the second reference position and the electrical potential (VR_r) in the second reference position,
  - transmitting signals representing the third electrical potential difference,
  - sensing an electrical potential (VR_{dirY}) in a position in a fourth direction from the second reference position,
  - determining a fourth electrical potential difference (VR_{dirY}) - (VR_r) between the electrical potential (VR_{dirY}) in the fourth direction from the second reference position and the electrical potential (VR_r) in the second reference position, and

- transmitting signals representing the fourth electrical potential difference,

- receiving the transmitted signals, and
- determining the electrical potential of the first location (A) relative to the reference location (R) as the difference between
  - a size of a first vector defined by the first and second electrical potential differences and
  - a size of a reference vector defined by the third and fourth electrical potential differences.

15. A method according to claim 14 wherein the signals are transmitted wirelessly.

16. A method according to claim 14 wherein the signals are transmitted via electrical conductors.

17. A method according to claim 14 wherein the size of the first vector is determined as the size of the instantaneous first and second electrical potential differences and the size of the reference vector is determined as the size of the instantaneous third and fourth electrical potential differences.

18. A method according to claim 14 wherein the size of the first vector is determined as the size of the integrated first and second electrical potential differences and the size of the reference vector is determined as the size of the integrated third and fourth electrical potential differences.

19. A method of determining the electrical potential at a first location (A) relative to a reference location (R) on the skin of an animal or human being, the method comprising

- attaching to each of the first and reference locations an electrode with

- a carrier,
- at least three sensors carried by the carrier and arranged so that lines through centres of respective pairs of sensors define two linearly independent directions (X, Y), and where the sensors are all within an area that can be covered by an electrode with a single sensor normally used for sensing the electrical potentials at the first and reference locations,
- means for detachably attaching the electrode to the skin of an animal or human being with the sensors in electrical contact with the skin,
- so that the two linearly independent directions (X, Y) defined at the first location (A) are substantially the same as the two linearly independent directions (X, Y) defined at the reference location (R);

- at the first location (A):
  - sensing an electrical potential (VA_r) in a first reference position,
  - sensing an electrical potential (VA_{dirX}) in a position in the X-direction from the first reference position,
  - determining a first electrical potential difference (VA_{dirX}) - (VA_r) between the electrical potential (VA_{dirX}) in the X-direction from the first reference position and the electrical potential (VA_r) in the first reference position,
  - transmitting signals representing the first electrical potential difference,
  - sensing an electrical potential (VA_{dirY}) in a position in the Y-direction from the first reference position,
  - determining a second electrical potential difference (VA_{dirY}) - (VA_r) between the electrical potential (VA_{dirY}) in the Y-direction from the first reference position and the electrical potential (VA_r) in the first reference position,
  - transmitting signals representing the second electrical potential difference;

- at the reference location (R):
  - sensing an electrical potential (VR_r) in a second reference position,
  - sensing an electrical potential (VR_{dirX}) in a position in the X-direction from the second reference position,
  - determining a third electrical potential difference (VR_{dirX}) - (VR_r) between the electrical potential (VR_{dirX}) in the X-direction from the second reference position and the electrical potential (VR_r) in the second reference position,
  - transmitting signals representing the third electrical potential difference,
  - sensing an electrical potential (VR_{dirY}) in a position in the Y-direction from the second reference position,
  - determining a fourth electrical potential difference (VR_{dirY}) - (VR_r) between the electrical potential (VR_{dirY}) in the Y-direction from the second reference position and the electrical potential (VR_r) in the second reference position, and
  - transmitting signals representing the fourth electrical potential difference,

- receiving the transmitted signals,
- determining the electrical potential of the first location (A) relative to the reference location (R) as the sum of
  - a first difference between the first electrical potential difference and the third electrical potential difference and
  - a second difference between the second electrical potential difference and the fourth electrical potential difference.

20. A method according to claim 19 wherein the signals are transmitted wirelessly.

21. A method according to claim 19 wherein the signals are transmitted via electrical conductors.

22. A method according to claim 19 wherein the first difference is determined as the difference between the instantaneous first and third electrical potential differences and the second is determined as the difference between the instantaneous second and fourth electrical potential differences.

23. A method according to claim 19 wherein the first difference is determined as the difference between the integrated first and third electrical potential differences and the second is determined as the difference between the integrated second and fourth electrical potential differences.

24. A method according to claim 19 wherein the first difference is determined as the difference between mean values of the first and third electrical potential differences and the second is determined as the difference between mean values of the second and fourth electrical potential differences.

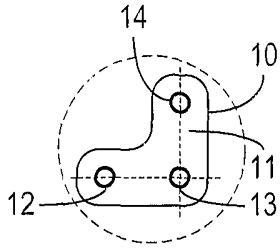

Fig. 1

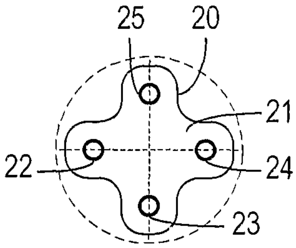

Fig. 2

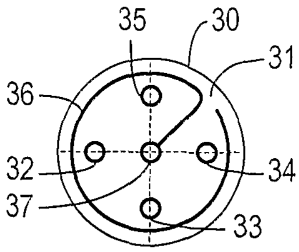

Fig. 3

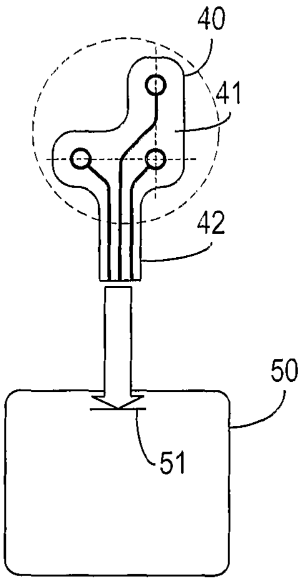

Fig. 4

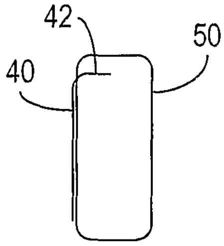

Fig. 5

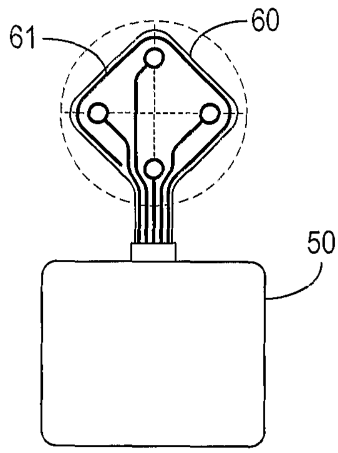

Fig. 6

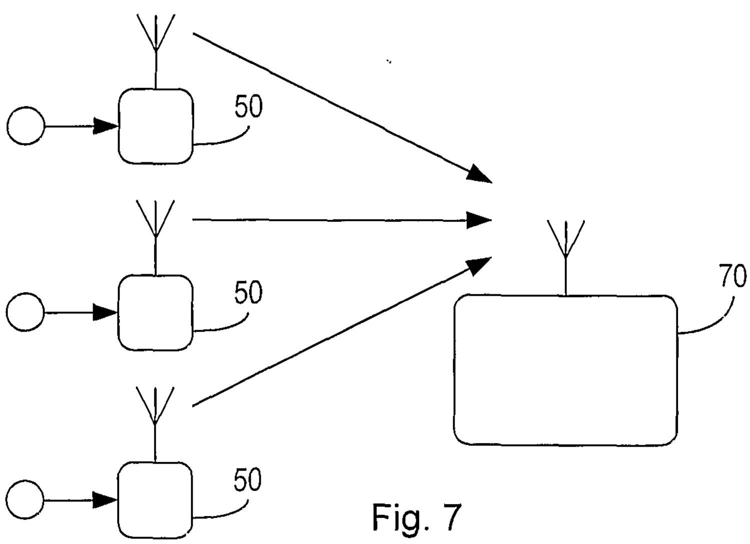

Fig. 7

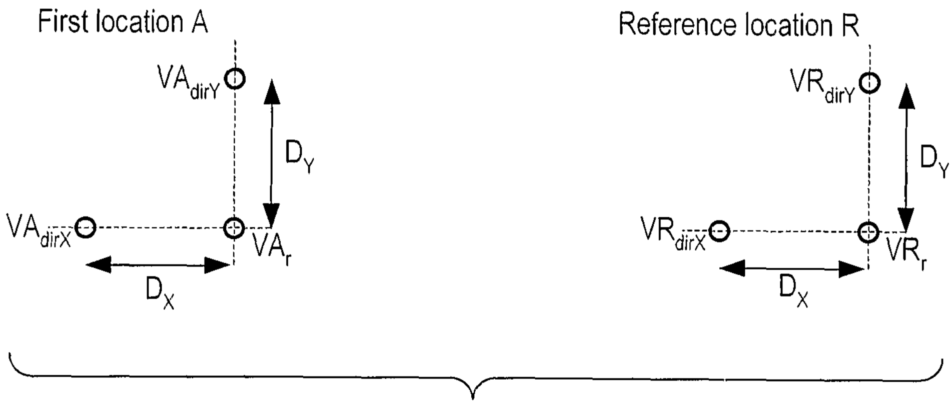
First location A
VA dirY
D Y
VA dirX
VA r
D X
Reference location R
VR dirY
D Y
VR dirX
VR r
D X

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2005/000420

A. CLASSIFICATION OF SUBJECT MATTER
A61B5/00 A61B5/0408

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2002/045836 A1 (ALKAWWAS DIMA) 18 April 2002 (2002-04-18) figures 1,2,1c,3a,4,7a-7d,8,11 paragraphs ‘0007!, ‘0008!, ‘0014!, ‘0063! - ‘0084!	1-13
X	US 6 295 466 B1 (ISHIKAWA AKIRA ET AL) 25 September 2001 (2001-09-25) claim 7; figures 1,2a,2b,7-9 column 3, line 66 - column 4, line 39 column 5, lines 30-38 column 6, line 17 - column 7, line 36 column 16, lines 31-34	1-24

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 February 2006	24/02/2006

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Kronberger, R

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 577 893 B1 (BESSON MARCUS ET AL) 10 June 2003 (2003-06-10) cited in the application column 22, line 28 - column 24, line 9; claims 31,33,50-52; figures 1,2a-2f	1-9
X	US 2002/028991 A1 (THOMPSON DAVID L) 7 March 2002 (2002-03-07) paragraphs '0021!, '0040!, '0041!, '0055!, '0057! - '0060!; figures 4,8,9	1-6
A	US 6 496 715 B1 (LEE BRIAN B ET AL) 17 December 2002 (2002-12-17) figures 9,12a,13 column 10, lines 52-63 column 13, lines 34-54 column 21, lines 1-5	1,4
A	US 5 168 874 A (SEGALOWITZ ET AL) 8 December 1992 (1992-12-08) figures 1a,3,6 column 4, line 41 - column 5, line 62 column 7, line 1 - column 8, line 4	1,5

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/DK2005/000420

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2002045836	A1	18-04-2002	NONE	
US 6295466	B1	25-09-2001	NONE	
US 6577893	B1	10-06-2003	NONE	
US 2002028991	A1	07-03-2002	NONE	
US 6496715	B1	17-12-2002	NONE	
US 5168874	A	08-12-1992	NONE	