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(54) **ECG SYSTEM WITH MULTI MODE ELECTRODE UNITS**

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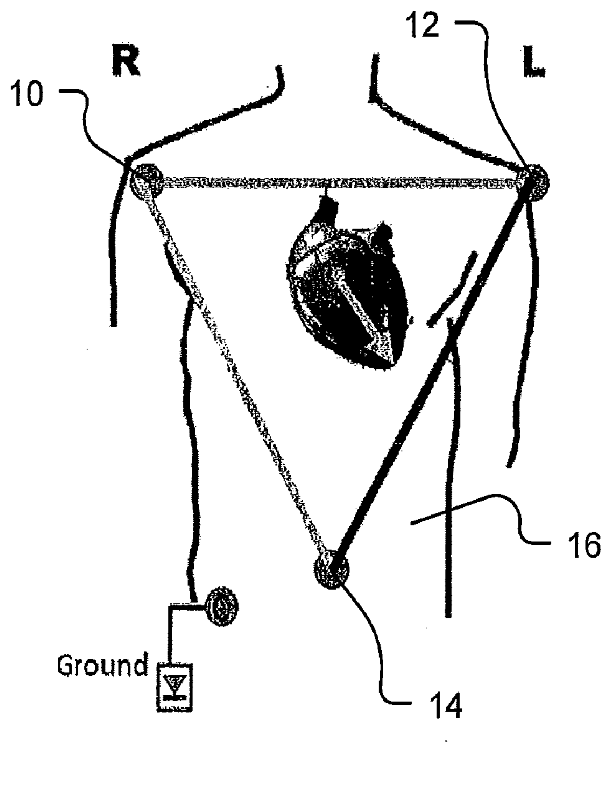
(57) **ABSTRACT**

Systems and apparatus for monitoring heart muscle activity of an individual include a first electrode unit, for receiving a first signal indicative of electrical, activity at a first location on a body of the individual and a second electrode unit for receiving a second, signal indicative of electrical activity at a second location on the body of the individual. Each of the first and second electrode units is configurable to operate in a field-sensing mode wherein the electrode unit is placed on or it! proximity to the individual's skin, and a current-sensing mode wherein the electrode unit is coupled to a resistive sensor sensing element placed directly on the individual's skin. The field-sensing mode can be either non-contact field-sensing mode.



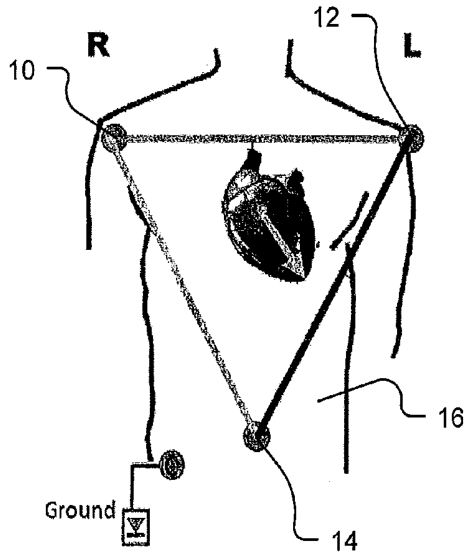


FIGURE 1

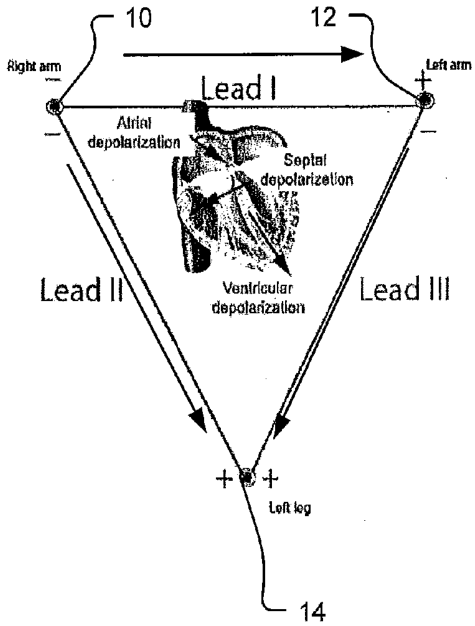


FIGURE 2

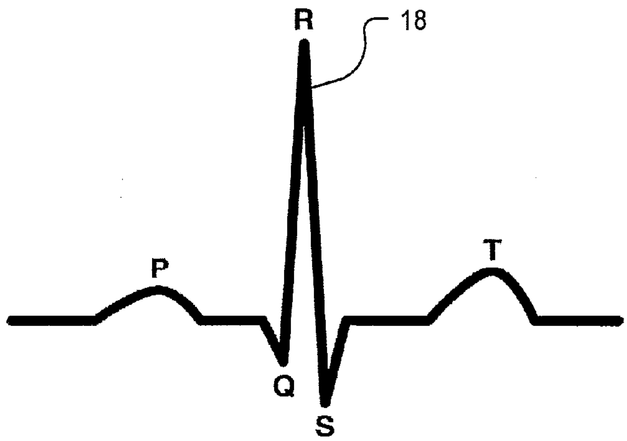


FIGURE 3

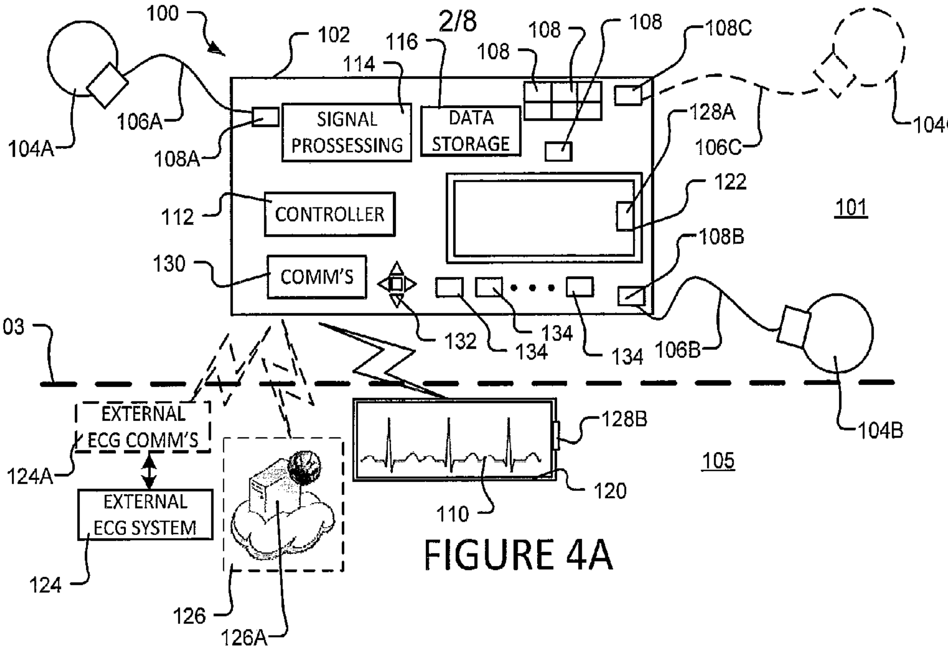


FIGURE 4A

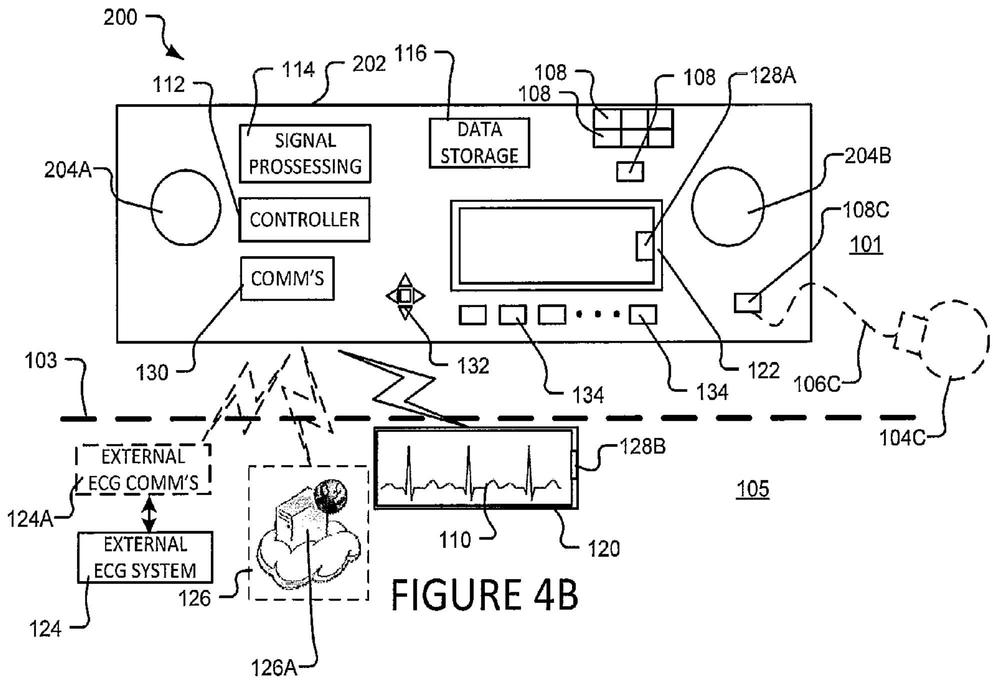
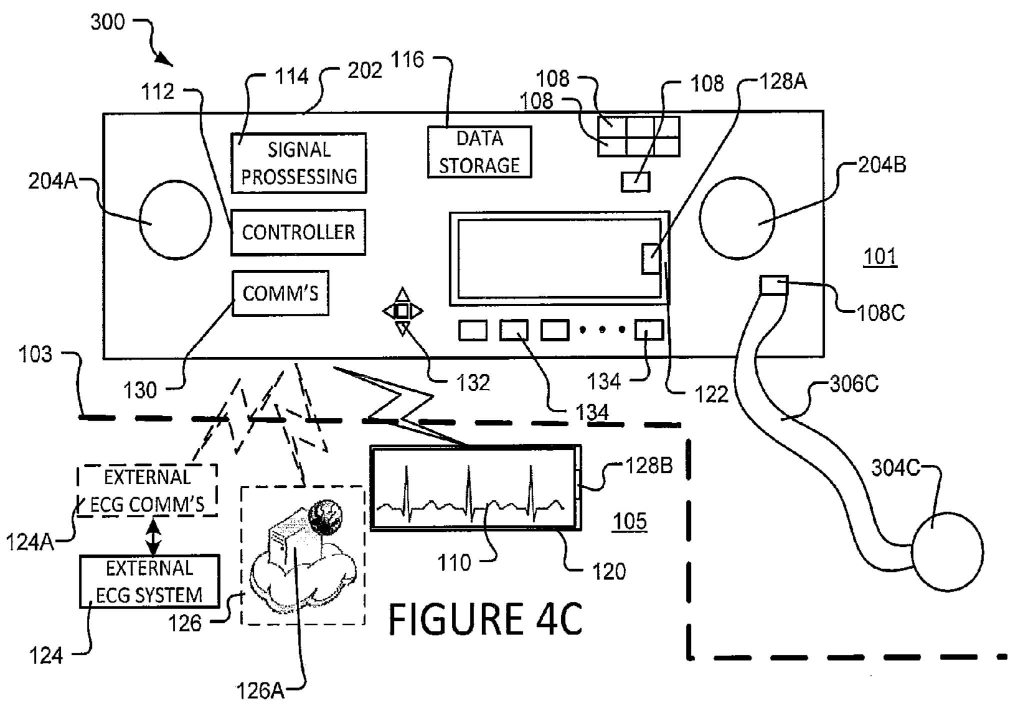


FIGURE 4B


300
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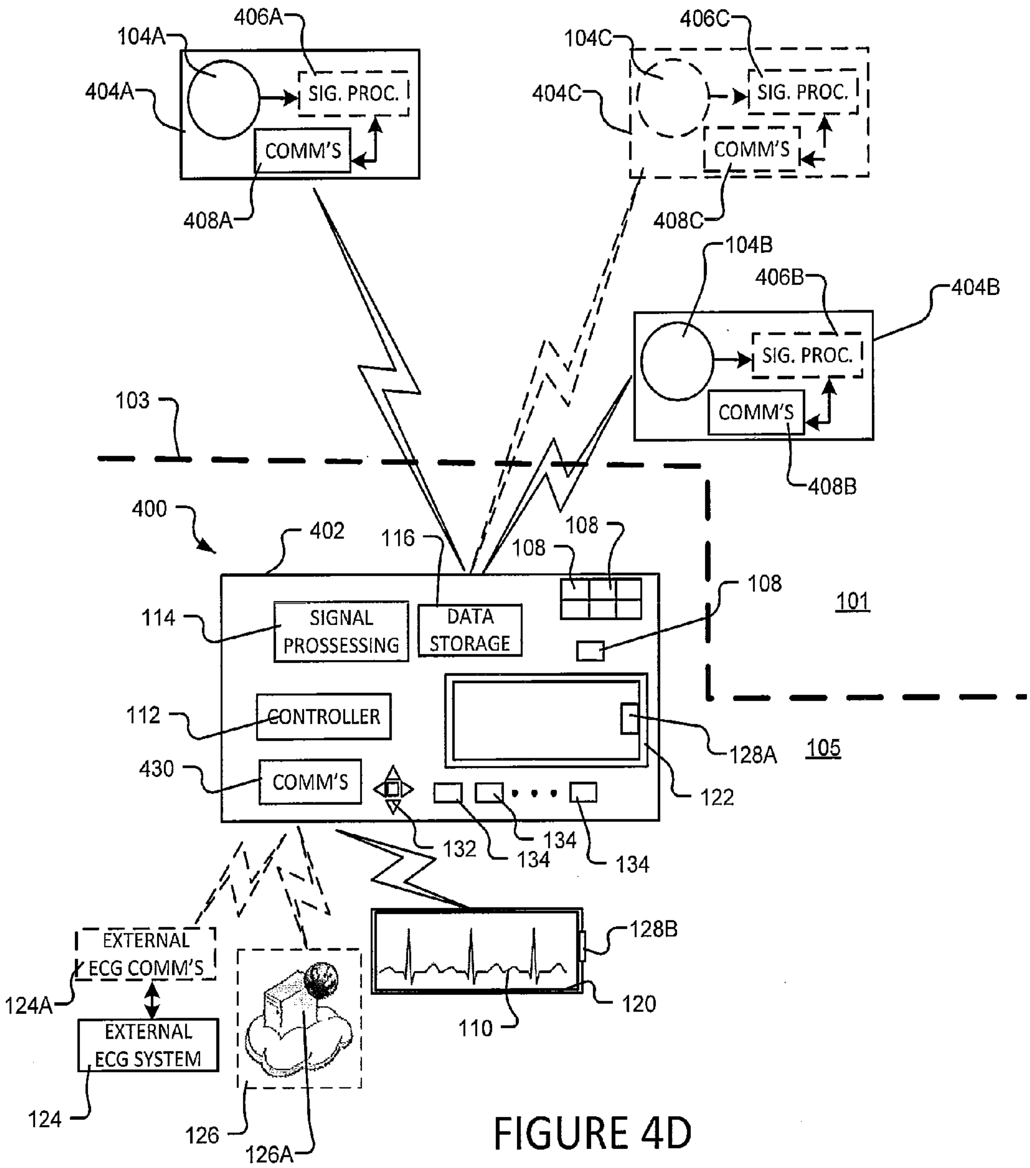
114
202
116
108
108
108
128A
SIGNAL PROSSESSING
DATA STORAGE
204A
204B
CONTROLLER
101
COMM'S
108C
103
130
132
134
122
134
306C
128B
304C
EXTERNAL ECG COMM'S
105
124A
EXTERNAL ECG SYSTEM
110
120
126
124
126A

FIGURE 4C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406A
SIG. PROC.
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COMM'S
408A
104C
406C
SIG. PROC.
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104B
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404B
SIG. PROC.
COMM'S
408B
103
400
402
116
108
108
114
SIGNAL PROSSESSING
DATA STORAGE
108
101
112
CONTROLLER
128A
105
430
COMM'S
122
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128B
EXTERNAL ECG COMM'S
124A
EXTERNAL ECG SYSTEM
120
110
124
126
126A

FIGURE 4D

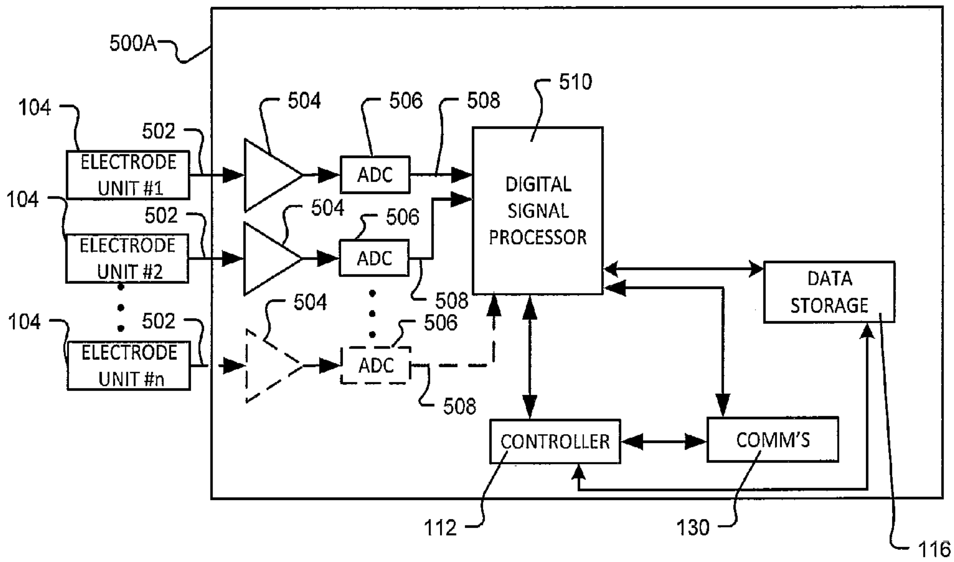


FIGURE 5A

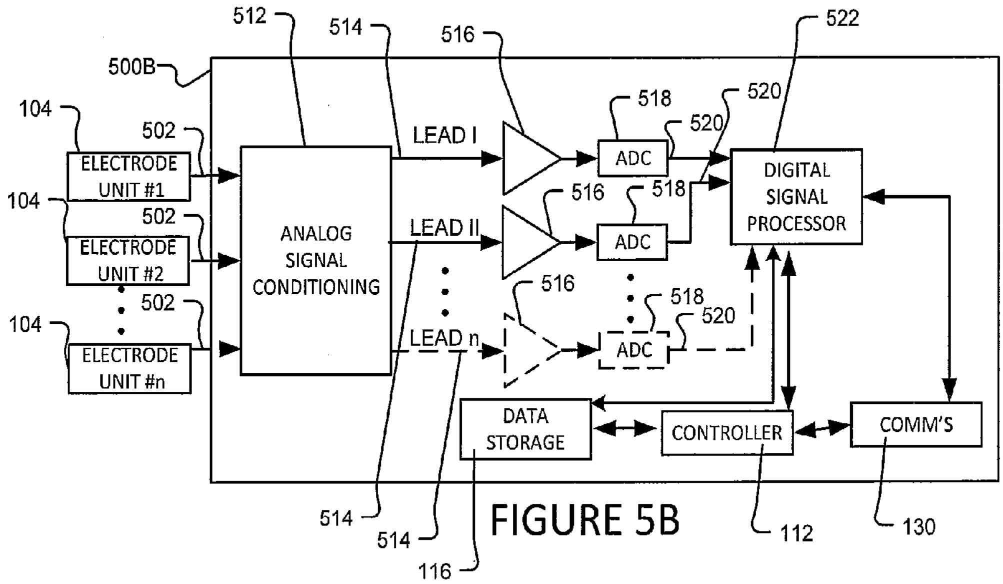
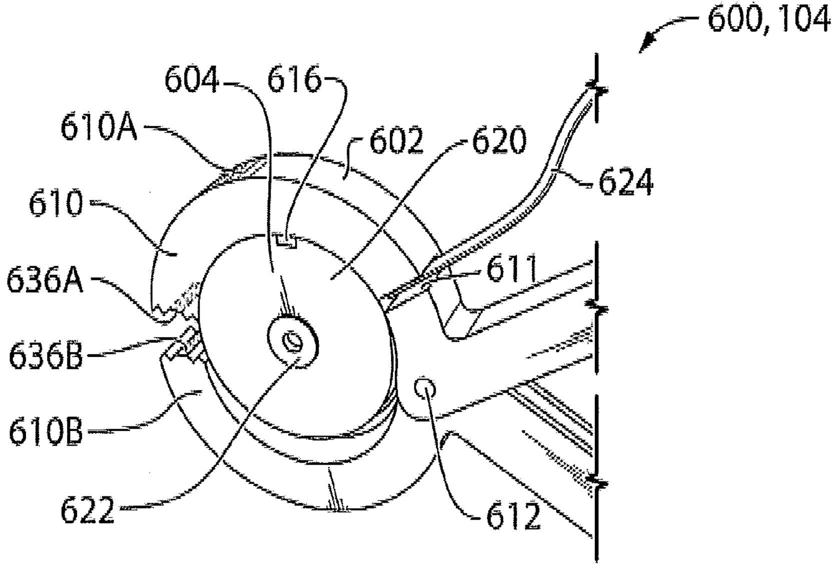


FIGURE 5B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636A
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FIG.6A

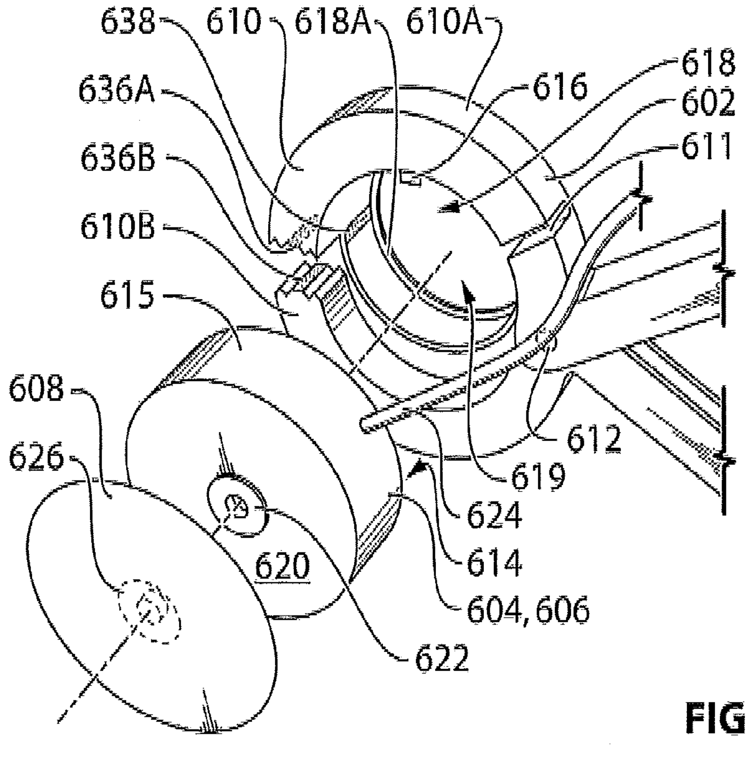
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FIG.6B

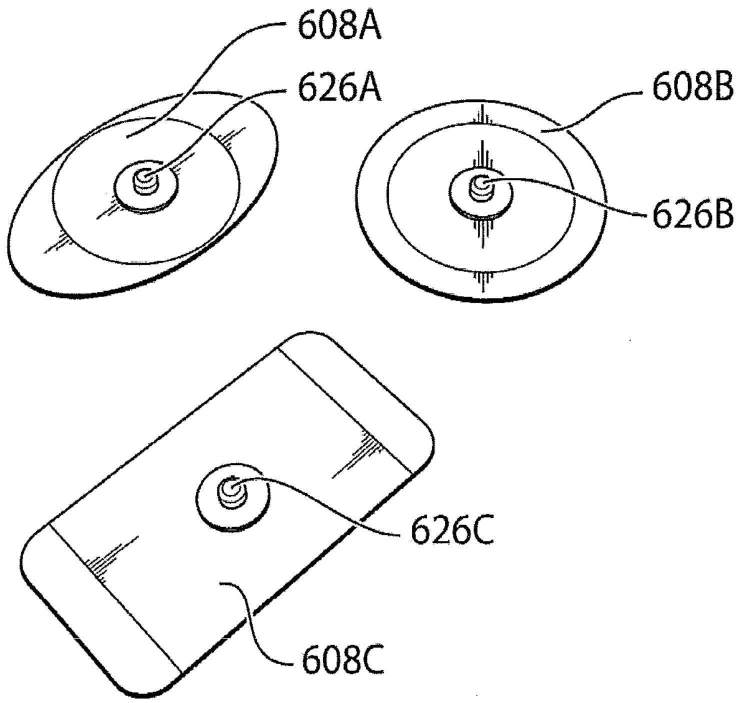

FIG. 7A

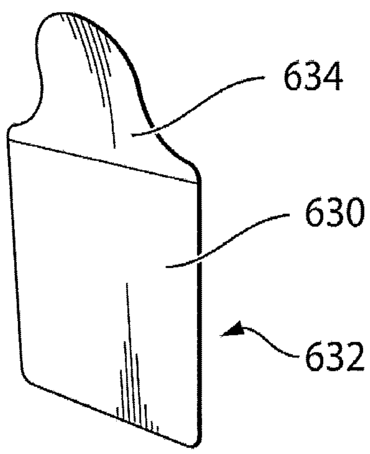

FIG. 7B

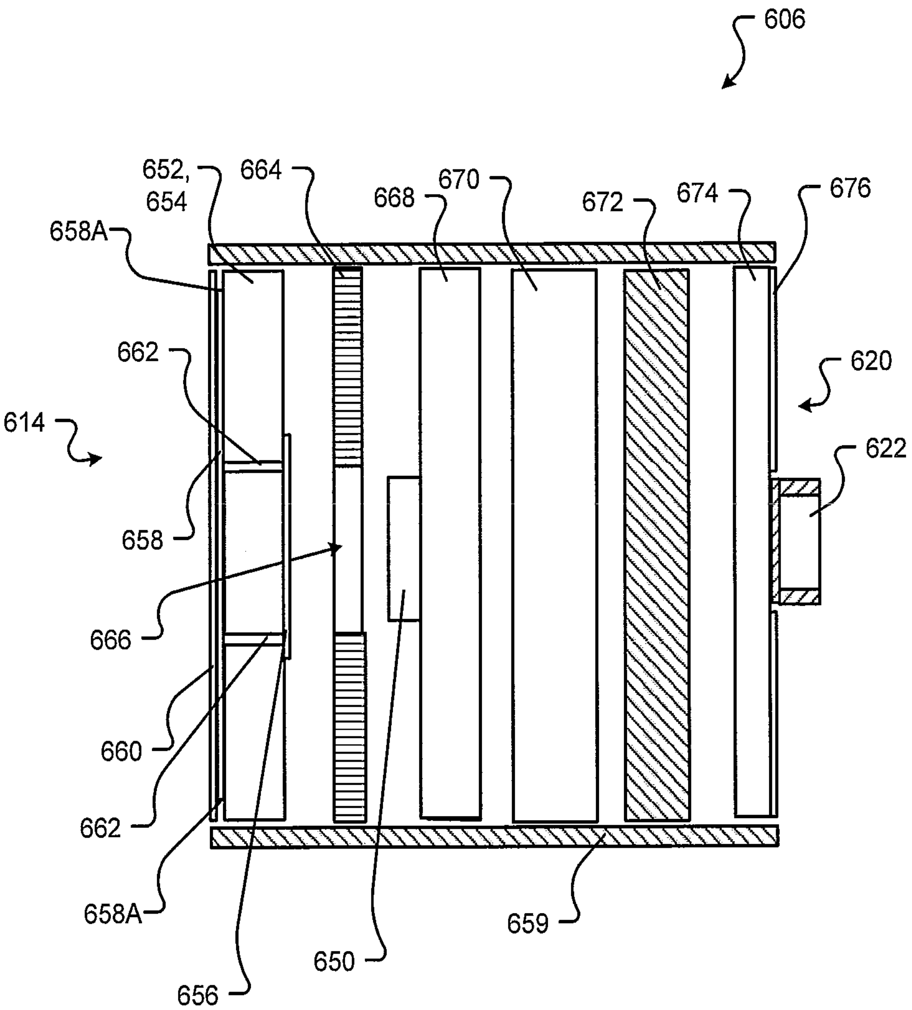
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FIG. 8

ECG SYSTEM WITH MULTI MODE ELECTRODE UNITS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority from U.S. provisional application No. 61/596,543 filed Feb. 8, 2012 entitled REMOTE MONITORING ECG SYSTEM. This application claims the benefit under 35 U.S.C. §119 of U.S. provisional application No. 61/596,543 filed Feb. 8, 2012 entitled REMOTE MONITORING ECG SYSTEM which is hereby incorporated herein by reference.

TECHNICAL FIELD

[0002] The technology described herein relates to electrocardiography (ECG) systems which detect electrical activity at locations on a patient's body.

BACKGROUND

[0003] A conventional ECG system typically consists of between 3 and 10 electrodes placed on areas of a patient's body to detect electrical activity. The electrodes are connected to an ECG monitor by a commensurate number of wires/cables. A conventional ECG electrode typically comprises a resistive sensor element which is placed directly against the patient's skin. A number of electrodes are placed against the patient's skin to detect the electrical characteristics of the heart (e.g. the current through or voltage across the resistive sensor element) at desired vantage points on the patient's body. The detected signals are relayed through the wires to the ECG monitor, which is typically located on a lab table or the like, away from the patient's body. A signal processing unit within the ECG monitor processes the signals to generate an ECG waveform which can be displayed on a display of the ECG monitor.

[0004] FIGS. **1** and **2** show three electrodes **10**, **12**, **14** arranged in the so-called Einthoven's triangle on a patient's body **16**. As is known in the art, electrodes **10**, **12** and **14** may be respectively referred to as the Right Arm (RA), Left Arm (LA) and Left Leg (LL) electrodes because of the locations that they are commonly placed on body **16**. To generate an ECG signal, various potential differences are determined between the signals from electrodes **10**, **12**, **14**. These potential differences are referred to as "leads". Leads have polarity and associated directionality. The common leads associated with the Einthoven's triangle shown in FIGS. **1** and **2** include: lead I (where the signal from RA electrode **10** is subtracted from the signal from LA electrode **12**); lead II (where the signal from RA electrode **10** is subtracted from the signal from LL electrode **14**); and lead III (where the signal from LA electrode **12** is subtracted from the signal from LL electrode **14**). In addition to the leads shown in FIG. **2**, other common leads associated with the Einthoven's triangle configuration include: the AVR lead (where one half of the sum of the signals from LA and LL electrodes **12**, **14** is subtracted from the signal for RA electrode **10**); the AVL lead (where one half of the sum of the signals from RA and LL electrodes **10**, **14** is subtracted from the signal for LA electrode **12**); and the AVF lead (where one half of the sum of the signals from RA and LA electrodes **10**, **12** is subtracted from the signal for LL electrode **14**). As is known in the art, the AVR lead is oriented generally orthogonally to lead III, the AVL lead is oriented generally orthogonally to lead II and the AVF lead is oriented generally orthogonally to lead I. The signals from each of these leads can be used to produce an ECG waveform **18** as shown in FIG. **3**. Additional sensors can be added to provide different leads which may be used to obtain different views of the heart activity. For example, as is well known in the art, sensors for precordial leads V1, V2, V3, V4, V5, V6 may be added and such precordial leads may be determined to obtain the so-called **12** lead ECG.

[0005] Some issues with traditional ECG technology make it an impediment for use, particularly in emergency response situations. The multiple electrodes and their corresponding wires may require extensive time to set up which may be critical in emergency circumstances. Having to maneuver around and detangle a large number of wires can be a nuisance. Multiple electrodes and wires can make it difficult to move a patient or administer medical aid to a patient. Signal noise from movement of the wires and wire tension can also degrade the quality of the ECG reading. Multiple wires can be particularly problematic during cardiac monitoring, where the ECG wires are attached to a patient for a long time. These issues with traditional ECG technology are exacerbated where there is a significant distance between the patient and the ECG monitor (i.e. where the electrode wires are long).

[0006] In addition to the problems with wires, current ECG systems use contact electrodes with resistive sensor elements. Such contact electrodes must be placed in direct contact with the patient's skin to obtain accurate signals. Typically, these contact electrodes are stuck to the patient's skin using an adhesive. The use of contact electrodes can be problematic in some circumstances. By way of non-limiting example, it may be undesirable or difficult to remove the patient's clothing in certain situations—e.g. where the patient may have privacy concerns, where the patient is suspected of having a spinal cord injury and/or the like. As another example, the patient may have a condition which makes it undesirable or difficult to apply current-sensing electrodes to the skin—e.g. the patient is suffering from burns to their skin, the patient has body hair which must be removed prior to using the contact electrodes, the patient is allergic to the adhesive and/or the like.

[0007] There is a general desire for improved ECG systems. By way of non-limiting example, there is a general desire for an ECG system that can provide greater flexibility for use by medical professionals in a variety of different circumstances, such as might be the case for emergency response technicians (EMTs). There is a general desire for ECG systems that may be more convenient and/or simple to use than existing ECG systems.

[0008] The foregoing examples of the related art and limitations related thereto are intended to be illustrative and not exclusive. Other limitations of the related art will become apparent to those of skill in the art upon a reading of the specification and a study of the drawings.

SUMMARY

[0009] One aspect of the invention provides a system for monitoring heart muscle activity of an individual comprising: a first electrode unit for generating a first signal indicative of electrical activity of the heart muscle at a first location on a body of the individual; and a second electrode unit for generating a second signal indicative of electrical activity of the heart muscle at a second location on the body of the individual. Each of the first and second electrode units is configurable to operate in: a field-sensing mode wherein the elec-

trode unit is configured to generate its corresponding signal based on a detected electric field at a location on or in proximity to the individual's skin; and a current-sensing mode wherein the electrode unit is configured to generate its corresponding signal based on current flow through a resistive sensor element placed directly on the individual's skin.

[0010] Another aspect of the invention provides an electrode unit for use in an ECG system comprising: a capacitive sensor element for detecting electric field; a spring-biased clamp for attachment of the electrode unit to an individual's clothing when operating in a non-contact field-sensing mode; and an attachment means for physical and electrical attachment of the electrode unit to a resistive sensor element when operating in a resistive mode.

[0011] Another aspect of the invention provides a system for monitoring heart muscle activity of an individual comprising: a first electrode unit for generating a first signal indicative of electrical activity of the heart muscle at a first location on a body of the individual, the first electrode unit comprising a first capacitive sensing element for detecting electric field; a second electrode unit for generating a second signal indicative of electrical activity of the heart muscle at a second location on the body of the individual, the second electrode unit comprising a second capacitive sensing element for detecting electric field; and a plurality of inputs, each input adapted to receive a corresponding signal from a current-sensing electrode unit indicative of electrical activity at a corresponding location on the body of the individual.

[0012] Another aspect of the invention provides a system for monitoring heart muscle activity of an individual comprising: a first input for receiving a first signal indicative of electrical activity of the heart muscle at a first location on a body of the individual; a second input for receiving a second signal indicative of electrical activity of the heart muscle at a second location on the body of the individual; wherein each of the inputs is adapted to receive a signal from a field-sensing electrode unit or from a current-sensing electrode unit and the system is configured to differentiate between signals received from field-sensing electrode units and signals received from current-sensing electrode units and to generate one or more ECG waveforms based on the received signals.

[0013] Another aspect of the invention provides a system for monitoring heart muscle activity of an individual comprising: a first field-sensing electrode unit for generating a first signal indicative of electrical activity of the heart muscle at a first location on a body of the individual, the first field-sensing electrode unit configured to generate the first signal based on a detected electric field at a location on or in proximity to the individual's skin; and a second current-sensing electrode unit for generating a second signal indicative of electrical activity of the heart muscle at a second location on the body of the individual, the second current-sensing electrode unit configured to generate the second signal based on current flow through a resistive sensor element placed directly on the individual's skin; wherein the system is configured to combine the first signal and the second signal to generate an ECG waveform.

[0014] Another aspect of the invention provides a method for generating a ECG waveform related to heart muscle activity of an individual, the method comprising: providing a plurality of electrode units, each electrode unit configured to generate a corresponding signal indicative of electrical activity of the heart muscle at a corresponding location on a body of the individual; operating at least one first one of the plurality of electrode units in a field-sensing mode, wherein the at least one first one of the electrode units is configured to generate its corresponding signal based on a detected electric field at a location on or in proximity to the individual's skin; operating at least one other one of the plurality of electrode units in a current-sensing mode, wherein the at least one other one of the plurality of electrode units is configured to generate its corresponding signal based on current flow through a resistive sensor element placed directly on the individual's skin; and using the signals generated by the at least one first one of the plurality of electrode units and generated by the at least one other one of the plurality of electrode units to generate one or more ECG waveforms.

[0015] In addition to the exemplary aspects and embodiments described above, further aspects and embodiments will become apparent by reference to the drawings and by study of the following detailed descriptions.

BRIEF DESCRIPTION OF DRAWINGS

[0016] Exemplary embodiments are illustrated in referenced figures of the drawings. It is intended that the embodiments and figures disclosed herein are to be considered illustrative rather than restrictive.

[0017] FIG. **1** is a schematic illustration of the electrodes of a conventional ECG system arranged on the patient's body in an Einthoven's triangle configuration.

[0018] FIG. **2** is a schematic illustration of the electrodes of a conventional ECG system arranged in an Einthoven's triangle configuration and a number of the corresponding leads.

[0019] FIG. **3** is a typical ECG waveform of the type that might be displayed on an ECG system.

[0020] FIG. **4**A schematically illustrates an ECG system architecture according to a particular embodiment. FIG. **4**B schematically illustrates an ECG system architecture according to another particular embodiment. FIG. **4**C schematically illustrates an ECG system architecture according to another particular embodiment. FIG. **4**D schematically illustrates an ECG system architecture according to another particular embodiment.

[0021] FIG. **5**A is a block diagram showing one implementation of a signal processing system for processing data from the electrode units of the FIGS. **4**A-**4**D ECG systems according to a particular embodiment. FIG. **5**B is a block diagram showing one implementation of a signal processing system for processing data from the electrode units of the FIGS. **4**A-**4**D ECG systems according to another particular embodiment.

[0022] FIGS. **6**A and **6**B are respectively assembled and exploded isometric views of a multi-mode electrode unit according to a particular embodiment.

[0023] FIGS. **7**A and **7**B illustrate different resistive sensor elements that may be used with the FIGS. **6**A, **6**B electrode unit.

[0024] FIG. **8** is an exploded cross-sectional view of a capacitive sensor element that may be used with the FIG. **6**A, **6**B electrode unit according to a particular embodiment.

DESCRIPTION

[0025] Throughout the following description, specific details are set forth in order to provide a more thorough understanding to persons skilled in the art. However, well known elements may not have been shown or described in detail to avoid unnecessarily obscuring the disclosure.

Accordingly, the description and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

[0026] FIG. **4**A schematically illustrates an ECG system **100** according to a particular embodiment. ECG system **100** comprises a base unit **102** and two or more electrode units **104**A, **104**B, **104**C (collectively and individually, electrode units **104**). Electrode units **104** may be located relative to a patient's body **101** (as discussed in more detail below) to generate signals indicative of electrical activity of the patient's heart at their corresponding locations. In the schematic illustration of FIG. **4**A, locations **101** on the patient's body are shown as being above the thick dashed line **103** and locations **105** away from the patient's body are shown as being below the thick dashed line **103**. In currently preferred embodiments, electrode units **104** are multi-function electrode units of the type described below, although this is not necessary. In the illustrated embodiment of FIG. **4**A, ECG system **100** is shown as having three electrode units **104**A, **104**B, **104**C which may be used in an Einthoven's triangle configuration. In some embodiments, third electrode unit **104**C is not necessary and system **100** may use as few as two electrode units **104**. In some embodiments, system **100** may be provided with more than three electrode units **104** (as discussed in more detail below) to provide additional leads and corresponding additional views of heart muscle electrical activity.

[0027] In the FIG. **4**A embodiment, electrode units **104** are removably connected to base unit **102** by corresponding cables **106**A, **106**B, **106**C (collectively and individually, cables **106**) which may be removably connected to base unit **102** using suitable electrical, signal transmission connectors **108**A, **108**B, **108**C (collectively and individually, connectors **108**). Connectors **108** may comprise, for example: slidable locking electric connectors, spring-biased electric connectors, magnetic connectors and/or the like. Base unit **102** is preferably constructed to be sufficiently small and lightweight that it can comfortably rest on a patient's body **101** without discomfort and without impacting the patient's ECG waveform. By way of non-limiting example, base unit **102** could be rested on a patient's chest, strapped or clipped (using suitable straps (not shown) or clips (not shown)) to the patient's clothing, arm or leg, and/or the like. With base unit **102** being so proximate to the patient, cables **106** may be correspondingly short. In some embodiments, cables **106** are less than 50 cm in length. In some embodiments, cables **106** are less than 30 cm in length.

[0028] In the illustrated embodiment, ECG waveforms **110** generated by ECG system **100** are displayed on a display **120**. In some embodiments, display **120** may be integral with base unit **102**. However, in the illustrated embodiment, display **120** is removably attached to base unit **102** at cradle **122**, so that display **120** can be separated from base unit **120** to a location **105** away from the patient's body to permit easy reading by medical professionals without requiring the medical professionals to lean over top of or otherwise crowd the patient's body **101**. In the illustrated embodiment, ECG waveforms **110** are wirelessly communicated to display **120** when display **120** is detached from base unit **102**. When display **120** is located in cradle **122**, ECG waveforms **110** may be provided directly (via a suitable complementary connectors **128**A, **128**B) to display **120**—i.e. without wireless communication.

[0029] Base unit **102** may comprise suitably configured hardware and/or software components for processing signals from electrode units **104** and for generating corresponding ECG waveform(s) **110** for display on display **120**. In the illustrated embodiment, such components include: a controller **112**, signal processing hardware **114**, data storage **116**, communications hardware **130** and user interface components **132**. For simplicity, only a number of components germane to the present invention are described in detail here. It will be appreciated by those skilled in the art that base unit **102** may comprise other electronic components suitable for operation as described herein. These components may be configured to provide particular functionality using suitably coded software (not explicitly shown). Controller **112** may interact with and control the other functional components of ECG system **100**. By way of non-limiting example, controller **112** may comprise any suitable controller, such as, for example, a suitably configured computer, microprocessor, microcontroller, field-programmable gate array (FPGA), other type of programmable logic device, pluralities of the foregoing, combinations of the foregoing, and/or the like. Controller **112** may have access to software which may be stored in computer-readable memory (not shown) accessible to controller **112** and/or in computer-readable memory that is integral to controller **112**. Controller **112** may be configured to read and execute such software instructions and, when executed by controller **112**, such software may cause controller **112** to implement one or more of the methods described herein.

[0030] Signal processing hardware **114** may comprise any suitable analog or digital signal conditioning and/or signal processing components for generating ECG waveforms **110** from the signals obtained from electrode units **104**. By way of non-limiting example, signal processing hardware **114** may comprise amplifiers, buffers, filters, analog to digital converters, suitably configured digital signal processors and/or the like. Data storage **116** may comprise any suitable memory (e.g. solid state memory) that may be used to store digital ECG data. In some embodiments, data storage **116** may be integrated into other components (e.g. controller **112** or signal processing hardware **114**). In some embodiments, data storage **116** is not necessary.

[0031] Communications hardware **130** may comprise suitable hardware (e.g. WAN interfaces, LAN interfaces) for wireless communication according to one or more wireless digital communications protocols. Non-limiting examples of such protocols, include: a suitable Bluetooth communication protocol; wireless USB protocol; 802.11 wireless protocol; Zigbee protocol and/or the like. In some embodiments, display **120** may not be detachable from base unit **102** in which case display **120** may be connected via suitable electrical contacts. In some embodiments, display **120** may be removable from cradle **122**, but attached to base unit **102** with a signal communication cable or the like. In such embodiments, some or all of communications hardware **130** may not be required. In some embodiments, communications hardware **130** may facilitate communication of ECG data (e.g. data stored in data storage **116**, real time ECG waveforms **110** and/or the like) from base unit **102** to an external ECG system **124**. In some embodiments, where external ECG system **124** is not capable of wireless communications or of wireless digital communications, ECG system **100** may comprise a suitable external ECG system communications component **124**A which may be used to communicate with communications hardware **130** and to convert any received data/signals from communications hardware into a format capable of being interpreted by external ECG system **124**. External ECG system communications component **124**A may comprise hardware similar to any of the hardware described herein for base unit **102**.

[0032] In some embodiments, communications hardware **130** may facilitate communication of ECG data (e.g. data stored in data storage **116**, real time ECG waveforms **110** and/or the like) from base unit **102** to another device **126**A (e.g. a computer or the like) via a network **126** or via a direct communication link (not shown) for further processing and/or display. By way of non-limiting example, network **126** may comprise: a local area network (LAN), such as a hospital network, a work place network or the like; or a wide area network (WAN), such as the Internet, a cellular network or the like). In some embodiments, communications hardware **130** may additionally or alternatively facilitate wired communication with external ECG system **124** or with another device **126**A (e.g. a computer or the like) via a network **126**.

[0033] Display **120** together with user interface inputs **130** may be used (by controller **112**) to implement a text-based or graphical user interface (UI). User interface inputs **130** may comprise any suitable pointing device, buttons, touch screen and/or the like through which a medical professional can interact with and control ECG system **100**. By way of non-limiting example, a medical professional could control such a user interface to: freeze ECG waveform **110** on display **120**; view historical waveforms **110** or pulses; switch between the waveforms **110** of different leads; toggle between views of single ECG waveforms **110** or multiple ECG waveforms **110**; zoom in on ECG waveform **110** on display **120**; measure characteristics (e.g. amplitude and/or frequency) of ECG waveform **110**; communicate with other devices (e.g. external ECG system **124** and/or another device via network **126**); print to suitably configured printer device; toggle a "grph-paper" background on display **120**; identify abnormal ECG rhythms; display measurements associated with other diagnostic equipment (explained in more detail below) which may be connected to ECG system **100** (e.g. blood pressure, blood sugar, pulse oximetry (SpO_2), body temperature and/or the like); display alarms or alerts associated with abnormalities measured by such other diagnostic equipment; provide temporal information (e.g. clocks or stopwatches), alarms and/or alerts; and/or the like.

[0034] Base unit **102** may comprise a number of additional connectors **108** for optional connection to additional electrode units **104** (not shown). For example, in the illustrated embodiment, base unit comprises seven additional connectors **108** for connection to seven additional electrode units **104**. With a total of ten electrode units **104**, ECG system can be configured to provide the so-called "12 lead" ECG functionality.

[0035] Base unit **102** may also comprise suitable connections **134** for connecting to other medical equipment (not shown). Such connections **134** may be used to accept data from such equipment (e.g. from medical diagnostic equipment). By way of non-limiting example, such medical diagnostic equipment may comprise a blood pressure cuff, a glucometer, a pulse oximetry (SpO_2) monitor, and end-tidal carbon dioxide ($ETCO_2$) monitor, a thermometer and/or the like. Connections **134** may also be used for other medical equipment. In some embodiments, connections **134** may be used to connect to a pair of defibrillator pads or paddles which may be used to deliver defibrillation shock(s) (e.g. pacing defibrillation, cardio version defibrillation and/or automatic external defibrillation) to a patient. While not expressly shown, base unit **102** may comprise a separate rechargeable battery which may be used to deliver such defibrillation shock (s).

[0036] FIG. **4**B schematically illustrates an ECG system **200** according to a particular embodiment. ECG system **200** is similar in many respects to ECG system **100** described above and the same reference numerals are used to refer to features of ECG system **200** that are similar to features of ECG system **100**. Like ECG system **100**, ECG system **200** comprises a base unit **202** and two or more electrode units **204**A, **204**B (collectively and individually, electrode units **204**). ECG system **200** differs from ECG system **100** principally in that electrode units **204** are integral with base unit **202**. Other than being located within base unit **202**, electrode units **204** may be substantially similar to electrode units **104** described herein.

[0037] In the illustrated embodiment, ECG system is shown as having a third electrode unit **104**C which attaches to base unit **202** via cable **106**C and connector **108**C to facilitate operation of ECG system **200** in an Einthoven's triangle configuration. Third electrode unit **104**C may be substantially similar to electrode units **104** described herein. In some embodiments, third electrode unit **104**C is not necessary and system **100** may use as few as two electrode units **204**. In some embodiments, a third electrode unit **204** may be provided as an integral part of base unit **202** (i.e. similar to electrode units **204** of the FIG. 4B embodiment). Like ECG system **100**, ECG system **200** comprises connectors **108** for accepting additional electrode units **104** to provide additional leads and corresponding additional views of heart muscle electrical activity.

[0038] In some embodiments, electrode units **204** may be detachable from base unit **202**—e.g. to sense electrical activity of the heart at different locations away from base unit **202**. For example, electrode units **204** may be provided in suitable sockets (not expressly shown), so that they can function to sense heart activity within their corresponding sockets. But electrodes **204** may be removed from their sockets, so that they can be connected to base unit **202** by suitable cables and connectors (similar to cables **106** and connectors **108** described above for electrode units **104**). In this manner, electrode units **204** may also be able to sense electrical activity at locations away from base unit **202**.

[0039] In other respects, ECG system **200** may be substantially similar to ECG system **100** described herein.

[0040] FIG. **4**C schematically illustrates an ECG system **300** according to a particular embodiment. ECG system **300** is similar in many respects to ECG systems **100**, **200** described above and the same reference numerals are used to refer to features of ECG system **300** that are similar to features of ECG systems **100**, **200**. Like ECG system **200**, ECG system **300** comprises a base unit **202** and two or more electrode units **204** that are integral with base unit **202**. ECG system **300** differs from ECG systems **100**, **200** described herein in that ECG system comprises a third electrode unit **304**C which is connected to base unit **202** via connector **108**C and extension arm **306**C. Third electrode unit **304**C may be substantially similar to electrode units **104** described herein and may permit ECG system **300** to operate in an Einthoven's triangle configuration. However, in ECG system **300** of the FIG. **4**C embodiment, extension arm **306**C is fabricated from flexible, semi-rigid (e.g. limited elasticity) material that may be deformed by the ECG operator and, once deformed, may retain its shape so that electrode unit **304**C remains in a desired location relative to the patient's body **101** until extension arm **306C** is intentionally reshaped or repositioned by the ECG operator. Suitable materials for extension arm **306C** may include, for example, memory plastic and/or the like. In some embodiments, extension arm **306C** may comprise a casing having the flexible, semi-rigid (e.g. limited elasticity) properties which may in turn house a cable (e.g. similar to cable **106** described herein). It will be appreciated that in some embodiments, any electrode units **104** described as being connected to their respective base units may be connected via flexible, semi-rigid (e.g. inelastic) extension arms similar to extension arm **306C**.

[0041] In other respects, ECG system **300** may be substantially similar to ECG systems **100**, **200** described herein.

[0042] FIG. **4D** schematically illustrates an ECG system **400** according to a particular embodiment. ECG system **400** is similar in many respects to ECG systems **100**, **200**, **300** described above and the same reference numerals are used to refer to features of ECG system **400** that are similar to features of ECG systems **100**, **200**, **300**. ECG system **400** comprises a base unit **402** and two or more electrode assemblies **404A**, **404B**, **404C** (collectively and individually, electrode assemblies **404**). Each electrode assembly **404A**, **404B**, **440C** may comprise a corresponding electrode unit **104A**, **104B**, **104C** which may be similar to electrode units **104** described herein. However, each electrode assembly **404A**, **404B**, **404C** may comprise corresponding signal processing components **406A**, **406B**, **406C** (collectively and individually, signal processing components) and communications components **408A**, **408B**, **408C** (collectively and individually, communications components **408**). Signal processing components **406** may comprise any suitable analog or digital signal components for conditioning and/or processing the signals obtained from electrode units **104**. By way of non-limiting example, signal processing components **408** may comprise amplifiers, buffers, filters, analog to digital converters, suitably configured digital signal processors and/or the like. Communications components **408** may comprise any suitable hardware for analog or digital wireless communication of signals obtained from electrode units **104** (and processed by signal processing components **406**) back to base unit **402**. In this manner, base unit **402** may be positioned at a location **105** away from the patient's body **101**. In some embodiments, electrode assemblies **404** may be electrically connected to one another (e.g. to provide a common ground or reference potential). In some embodiments, electrode assemblies **404** may share some of signal processing components **406** and/or communications components **408**.

[0043] Electrode assemblies **404** may be located relative to a patient's body **101** (as discussed in more detail below) to generate signals indicative of electrical activity of the patient's heart at their corresponding locations and may wirelessly communicate these signals back to base unit **402** at a location **105** away from the patient's body **101**. In the illustrated embodiment of FIG. **4D**, ECG system **400** is shown as having three electrode assemblies **404A**, **404B**, **404C** which may be used in an Einthoven's triangle configuration. In some embodiments, third electrode assembly **404C** is not necessary and system **400** may use as few as two electrode assemblies **404**. In some embodiments, system **400** may be provided with more than three electrode assemblies **404** to provide additional leads and corresponding additional views of heart muscle electrical activity. In some embodiments, electrode assemblies **404** may comprise suitably configured controllers (not shown) which may control signal processing components **406** and/or communications components **408**.

[0044] Communications hardware **430** (and associated software) of ECG system **400** may differ from that of ECG systems **100**, **200**, **300** in that communications components **430** of ECG system **400** may be additionally configured to communicate wirelessly with electrode assemblies **404**. In other respects, ECG system **400** may be substantially similar to ECG systems **100**, **200**, **300** described herein.

[0045] FIG. **5A** is a block diagram showing one implementation of a signal processing system **500A** for processing data from electrode units **104** according to a particular embodiment. Signal processing system **500A** may provide some of signal processing hardware **114** used with any of the ECG systems (e.g. ECG systems **100**, **200**, **300**, **400**) described herein. In some implementations, various portions of signal processing system **500A** (e.g. amplifiers **504**, ADCs **506** and or the like) could be implemented as parts of electrode units **104** (as opposed to being implemented as parts of base units **102**, **202**, **302**, **402**). In general, it will be appreciated that the components shown in the FIG. **5A** schematic illustration are functional components which could be implemented by various forms of suitably configured hardware.

[0046] Signal processing system **500A** receives analog data from electrode units **104**. Each electrode unit **104** generates a corresponding analog signal **502** which is amplified by a corresponding amplifier **504** and digitized by a corresponding analog-to-digital converter (ADC) **506** before being provided (as a digital signal **508**) to digital signal processor (DSP) **510**. In some embodiments, DSP **510** may include integral ADC converters **506**. DSP **510** may be configured to generate leads from digital signals **508** and to generate corresponding ECG data (e.g. ECG waveform **110**). Digital signal processor **510** may additionally be configured to filter the various digital signals **508** (and/or combinations of such signals). For example, DSP **510** may be configured to filter various signals (or combinations of signals) to remove or mitigate the effects of breathing and/or other sources of artifacts. DSP **510** may addition or alternatively function to apply active noise cancellation algorithms, based on inverted ambient noise data. DSP **510** may additionally or alternatively scale signals **508** received from electrode units **104** operating in different modes (explained in more detail below). DSP **510** may additionally or alternatively provide synchronization functionality by introducing time delays to one or more of signals **508**. Such time delays may be determined based on temporal correlation functions as between signals **508** and/or based on feature (e.g. edges, peaks and/or the like) detection within signals **508**. DSP **510** also combines the various signals **508** to generate leads and corresponding ECG waveforms.

[0047] As is known in the art of digital signal processing, DSP **510** may be configured to process signals using functionality such as sample and hold functions, data acquisition functions, multi stage filtering and bandwidth limiting, filtering based for example on a rolling window, averaging functions, peak detection, temporal alignment of signals provided by different electrode units **104**, positive and negative edge detection, time duration of PQRST portion of the ECG signal and relationship between them. Digital signal processor **510** may be controlled by controller **112**. In some embodiments, however, DSP **510** and controller **112** may be implemented by the same hardware. In the FIG. **5A** embodiment, DSP **510** has access to data storage **116**. In some embodiments, all or part of data storage **116** may be integral to DSP **510**. DSP **510** may output ECG data to data storage **116** and/or to display **120** (via communications components **130**) and may provide the background functionality for such outputs. As discussed above, in some embodiments when display **120** is located in cradle **122** or when display is integral with base unit **102**, ECG data may be provided directly to display **120** without involving communications hardware **130**.

[0048] FIG. **5**B is a block diagram showing one implementation of a signal processing system **500**B for processing data from electrode units **104** according to another particular embodiment. Signal processing system **500**B may provide some of signal processing hardware **114** used with any of the ECG systems (e.g. ECG systems **100**, **200**, **300**, **400**) described herein. Signal processing system **500**B receives analog data from electrode units **104**. Each electrode unit **104** generates a corresponding analog signal **502** which is received at analog signal conditioning block **512**. Analog signal conditioning block **512** comprises various amplifiers (e.g. summing amplifiers and/or differential amplifiers and/or inverting amplifiers) which combine analog signals **502** in various ways known in the art to generate leads **514**. Each lead **514** is then amplified by a corresponding amplifier **516** and digitized by a corresponding analog-to-digital converter (ADC) **518** before being provided (as a digital lead signal **520**) to digital signal processor (DSP) **522**. Digital signal processor **522** may then be configured to use digital lead signals **520** to generate corresponding ECG data (e.g. ECG waveform **110**). Other than for receiving leads (as opposed to signals from electrode units **104**), DSP **522** may comprise and provide functionality similar to that described above for DSP **510**.

[0049] A description of electrode units is now provided. For the sake of brevity, the description of electrode units refers to electrode units **104**, it being understood that electrode units **204**, **304** may have similar features. In some embodiments, one or more of electrode units **104** comprise resistive sensor elements for sensing the current through or voltage across the resistive sensor element. Electrode units **104** which comprise resistive sensor elements may be referred to herein as current-sensing electrode units (without loss of generality that the voltage across resistive sensor elements could be detected). Current sensing electrode units **104** operate by placing the resistive sensor element in direct contact with a patient's skin. In some embodiments, one or more of electrode units **104** comprise capacitive sensor elements which detect the presence of electric field. Electrode units **104** which comprise capacitive sensor elements may be referred to herein as field-sensing electrode units. Unlike resistive sensor elements, the capacitive sensor elements of field-sensing electrode units **104** do not require direct contact with the skin and may function by being placed close to the patient's body (e.g. overtop of clothes).

[0050] ECG systems **100**, **200**, **300**, **400** described may use either (or both) of current-sensing electrode units **104** and field-sensing electrode units **104**. Each of connectors **108** may be capable of accepting either current-sensing electrode units **104** or field-sensing electrode units **104**. In particular embodiments, a combination of current-sensing electrode units **104** and field-sensing electrode units **104** may be used in any of ECG systems **100**, **200**, **300**, **400** to monitor the heart muscle electrical activity of the patient. The choice of which particular electrode unit **104** may depend on the preferences of the system's operator, the electrode units that are currently available, and the circumstances (e.g. whether it is difficult to remove the patient's clothing, or whether the patient already has exposed skin at the desired vantage points).

[0051] In particular embodiments, one or more of electrode units **104** that is used in systems **100**, **200**, **300**, **400** may comprise a multi-mode electrode unit **104** which can be configured to operate in one of a plurality of different modes. Such multi-mode electrode units **104** may operate as current-sensing electrode units by providing a resistive sensor element placed in direct contact with a patient's skin (i.e. under the patient's clothing (or at least with no intervening clothing between the sensor and the patient's skin)). Such multi-mode electrode units **104** may also operate as field-sensing electrode units which involve placing a capacitive sensor element in direct contact with a patient's skin (i.e. under the patient's clothing (or at least with no intervening clothing between the sensor and the patient's skin)). When such field-sensing electrode units are placed in direct contact with a patient's skin (i.e. under the patient's clothing (or at least with no intervening clothing between the sensor and the patient's skin)), such electrode units may be referred to herein as operating in "contact" mode. Such multi-mode electrode units **104** may also operate as field-sensing electrode units which involve placing a capacitive sensor element on top of the patient's clothing and not directly against the skin. When the patient's clothing is located between the electrode unit and the patient's skin, the electrode unit may be referred to herein as operating in "non-contact" mode. Since current-sensing electrode units typically require direct contact with the skin (i.e. no intervening clothing) to detect a signal, it is not necessary to describe current-sensing electrode units as operating in contact mode or non-contact mode, it being understood that when a current-sensing electrode unit **104** is operative, it operates in contact mode.

[0052] FIGS. **6**A and **6**B show a multi-mode electrode unit **600**, which may be used for electrode unit **104** of any of ECG systems **100**, **200**, **300**, **400**. Multi-mode electrode unit **600** may be configured for operation in field-sensing contact mode, field-sensing non-contact mode and/or current-sensing mode. Any one or more of electrode units **104**, **204**, **304** may comprise an electrode unit **600** of the type shown in FIGS. **6**A and **6**B. Electrode unit **600** comprises a clamp portion **602** and a sensor portion **604** which is removably attached to clamp portion **602**. As discussed in more detail below, sensor portion **604** comprises a capacitive sensor element **606** which permits electrode unit **600** to operate in a field-sensing contact mode (where sensor portion **604** is in direct contact with the patient's skin) or a field-sensing non-contact mode (where sensor portion **604** is located outside of the patient's clothing or otherwise is not in contact with the patient's skin). Further, at least one of clamp portion **602** and sensor portion **604** comprise a mechanism for electrical connection with a resistive sensor element **608** (FIG. **6**B) which permits electrode unit **600** to operate in a current-sensing mode. Because electrode unit **600** can be placed either on skin or atop clothing and because electrode unit **600** can operate as a current-sensing electrode unit or a field-sensing electrode unit, electrode unit **600** is versatile and can be used in a range of different situations. For example, in some situations it may be desirable or more convenient to leave the clothing on the patient and to place the electrode unit **600** on top of the patient's clothing. In other situations the patient's skin may be exposed at desired vantage points—for example, the patient's torso may be exposed to allow the performance of a procedure (such as, by way of non-limiting example, defibrillation, CPR, insertion of a chest tube and/or the like) which requires direct contact with or exposure of the sking and so in those cases it may be convenient to place electrode unit **600** directly against the skin.

[0053] When electrode unit **600** operates in a field-sensing, non-contact mode, electrode unit **600** is placed over the patient's clothing. As seen in FIGS. **6**A and **6**B, electrode unit **600** comprises a clamp **610**. In the illustrated embodiment of FIGS. **6**A and **6**B, clamp **610** comprises a pair of arms **610**A, **610**B which are pivotally connected to one another at pivot joint **612** and which are biased toward each other (e.g. by a suitably connected spring, a suitable deformable element and/or the like (not shown)) so that clamp **610** is biased toward a closed configuration. Arms **610**A, **610**B can be used to grip a part of the patient's clothing to attach the electrode unit **600** to the patient's clothing at the desired vantage point while the electrode unit **600** is being operated in field-sensing, non-contact mode. More particularly, when electrode unit **600** is operated in field-sensing, non-contact mode, a portion of the patient's clothing may be grasped between arms **601**A, **601**B of clamp **610** and proximate surface **614** of sensor portion **604** may be positioned directly atop the patient's clothing. This permits capacitive sensor element **606** to sense the electric field associated with the patient's heart-muscle activity and to provide a corresponding signal on one or more conductors of cable **624** which may be conveyed back to the base unit of the ECG system. Cable **624** may comprise one of cables **106** described above (see FIG. **4**A, for example).

[0054] In some embodiments, sensor portion **604** is removably attached to clamp portion **602**, so that sensor portion **604** may optionally be detached from clamp portion **602** (FIG. **6**B) for use of sensor portion **604** in field-sensing, contact mode. More particularly, as can be seen by comparing FIGS. **6**A and **6**B, sensor portion **604** may be attached to clamp portion **602** (e.g. retained in cavity **618** in the particular case of the illustrated embodiment) to provide a unitary electrode unit **600** and sensor portion **604** may also be detached from clamp portion **602** to provide sensor portion **604** separately. When sensor portion **604** is separated from clamp portion **602**, the proximate surface **614** of sensor portion **604** may be placed into contact with a patient's skin to permit capacitive sensor element **606** to sense the electric field associated with the patient's heart-muscle activity in a contact mode and to provide a corresponding signal on one or more of the conductors of cable **624** which is conveyed back to the base unit of the ECG system.

[0055] It is not necessary that sensor portion **604** be removed from clamp portion **602** for operation of electrode unit **600** in field-sensing, contact mode. In some embodiments, electrode unit **600** (including clamp portion **602** and sensor portion **604**) may be located such that proximate surface **614** of sensor portion **604** is adjacent the patient's skin. For example, as shown in FIG. **6**B, cavity **618** (in which sensor portion **604** is retained) comprises a rim **618**A around its peripheral edge, but rim **618**A defines an opening **619** which permits proximate surface **614** of sensor portion **604** to directly contact a patient's skin. With this configuration, capacitive sensor element **606** is able to sense the electric field associated with the patient's heart-muscle electrical activity in a field-sensing, contact mode (and to provide a corresponding signal to the ECG base unit on cable **624**) even when sensor portion **604** is attached to clamp portion **602**.

[0056] Sensor portion **604** and/or clamp portion **602** may comprise a locking mechanism **616** for keeping sensor portion **604** attached to clamp portion **602**. In the FIG. **6**A, **6**B embodiment, sensor portion **604** is received in cavity **618** of clamp portion **602** and a spring-biased locking mechanism **616** extends (radially inwardly in the case of the illustrated embodiment) over an edge of distal surface **620** of sensor portion **604**. When spring-biased locking mechanism **616** extends over the edge of distal surface **620** of sensor portion, locking mechanism **618** holds sensor portion **604** in cavity **618** (e.g. against rim **618**A) and thereby locks sensor portion **604** into attachment with clamp portion **602**. To detach sensor portion **604** from clamp portion **602**, an operator may slide locking mechanism **616** against the spring bias (radially outwardly in the case of the illustrated embodiment) to remove sensor portion **604** from cavity **618**. Some embodiments may comprise a plurality of spring-biased locking mechanisms **616**. In some embodiments, sensor portion **604** may be locked to clamp portion **602** using different additional or alternative locking mechanisms. In the illustrated embodiment, when sensor portion **602** is located in cavity **618**, cable **624** which is attached to sensor portion **604** runs through a channel **611** formed in a sidewall of cavity **618** of clamp portion **602**. In other embodiments, cable **624** may run through different features when sensor portion **604** is attached to clamp portion **602**.

[0057] In some embodiments, when electrode unit **600** is being used in field-sensing, contact mode, electrode unit **600** (or sensor portion **604** of electrode unit **600**) may be adhered to the skin of the patient using adhesive tape, adhesive stickers, a suctioning mechanism or other means. For example, a double-sided adhesive sticker or tape can be placed between the patient's skin and electrode unit **600** (or sensor portion **604** of electrode unit **600**) to adhesively connect electrode unit **600** (or sensor portion **604** of electrode unit **600**) to the patient's skin. Similarly, adhesive tape can be applied over top of electrode unit **600** to tape electrode unit **600** in contact with a patient's skin and to permit electrode unit **600** to be used in field-sensing contact mode. In some embodiments, electrode unit **600** (or sensor portion **604** of electrode unit **600**) may comprise a suction cup or suction hole (not shown) fluidly coupled to a suctioning bulb (not shown). The bulb may be squeezed prior to placement of the suction cup/hole on the patient's skin. Once the suction cup/hole is placed on the skin, the bulb is released to create a suctioning connection between the suction cup/hole and the skin, thereby holding electrode unit **600** (or sensor portion **604** of electrode unit **600**) against the patient's skin. In some embodiment, a piece of tape may be applied to the patient's skin with an end portion of the tape extending away from the patient's skin. The end portion of the tape may then be adhered to a side surface **615** of sensor portion **604** or the end portion of the tape may be gripped between arms **610**A, **610**B of clamp **610** to help hold electrode unit **600** (or sensor portion **604** of electrode unit **600**) against the patient's skin to thereby facilitate operation in field-sensing contact mode.

[0058] In addition to operating in field-sensing non-contact mode and field-sensing contact mode as discussed above, electrode unit **600** also operates in current-sensing mode. More particularly, at least one of clamp portion **602** and sensor portion **604** comprise a mechanism for electrical connection with a resistive sensor element **608** (FIG. **6**B) which permits electrode unit **600** to operate in a current-sensing mode. In the illustrated embodiment, sensor portion **604** of electrode unit **600** comprises a snap-mechanism **622** for connection to a complementary snap-mechanism **626** on resistive sensor element **608**. In the illustrated embodiment, snap-mechanism **622** is located on distal surface **620** of sensor portion **604**. In other embodiments, snap mechanism **622** may be located on other surface(s) of sensor portion **604** and/or clamp portion **602**. Snap mechanism **622** is in electrical contact with one or more conductors in cable **624** so that a signal may be conveyed back to the base unit of the ECG system via cable **624**. The cable **624** conductor that is in electrical contact with snap mechanism **622** may be (but need not be) the same cable **624** conductor that is in electrical contact with the capacitive sensor element **606**.

[0059] FIG. **7**A shows a variety of resistive sensor elements **608**A, **608**B, **608**C (collectively and individually, resistive sensor elements **608**) of different shapes and sizes, each with a corresponding snap-mechanism **626**A, **626**B, **626**C (collectively and individually, snap-mechanisms **626**). In the current North American industry standard, snap-mechanisms **626** of resistive sensor elements are male snap-mechanisms **626**. Accordingly, snap-mechanism **622** of electrode unit **600** may comprise a female snap-mechanism sized and shaped to mate with male snap-mechanisms **626** of resistive sensor elements **608**. Snap-mechanisms **622**, **626** are complimentary to one another, so that when they are engaged, there is a small amount of deformation of one or both of snap-mechanisms **622**, **626** such that restorative forces associated with that deformation tend to lock snap-mechanisms **622**, **626** to one another.

[0060] In use, a resistive sensor element **608** is connected to electrode unit **600** via a connection of snap-mechanisms **622**, **626** and then the side of resistive sensor element **608** opposite snap-mechanism **626** is adhered to the skin of the patient for operative in current-sensing contact mode. Typically, resistive sensor elements **608** comprise an adhesive "peel and stick" type backing which may be used for this purpose. The heart muscle electrical activity signal detected by resistive sensor element **608** is conveyed via the contact between snap-mechanism **622**, **626** to cable **624** and to the base unit of the ECG system. When operating in current-sensing mode, sensor portion **604** of electrode unit **600** may be removed from clamp portion **602** of electrode unit **600** is the same manner discussed above. This is not necessary, however, and electrode unit **600** may operate in current-sensing mode with sensor portion **604** connected to clamp portion **602**.

[0061] Resistive sensor elements **608** having snap-mechanisms **626** are common, but are not the only type of resistive sensor element. FIG. **7**B depicts another type of resistive sensor element **630** which comprises an active surface **632** which may be adhered to the patient's skin (e.g. with a peel and stick type adhesive or a suitable external adhesive). Resistive sensor element **603** also comprises a tab **634**, such that when active surface **632** is adhered to the patient's skin, tab **634** may be bent (or may otherwise extend) away from the patient's body. Multimode electrode unit **600** may also function in a current-sensing contact mode with resistive sensor elements **630**. More particularly, tab **634** of resistive sensor element may be clamped between the arms **610**A, **610**B of clamp **610**. One or both of the engagement surfaces of clamp **610** may be provided with electrical contacts **636**A, **636**B (collectively and individually, clamp contacts **636**). Clamp contacts **636** may be electrically connected to transmit a current-sensing contact signal through electrode unit **600** and a conductor of cable **624** back to the base unit of the ECG system.

[0062] In the case of the illustrated embodiment, clamp contacts **636** are in electrical contact with electrical contact **638** (e.g. via a suitable wire or other conductor within one or both arms **610**A, **610**B of clamp **610**. Electrical contact **638** may comprise any suitable electrical contact pin, plate, socket, shoe and/or the like. In the illustrated embodiment, electrical contact **638** is located on a wall of cavity **618**. Sensor portion **604** may be provided with a complementary electrical contact (not shown in the illustrated view) which is in electrical contact with one of the conductors of cable **624**. The electrical contact in sensor portion **604** may be complementary to electrical contact **638** and may comprise any suitable electrical contact pin, plate, socket, shoe and/or the like. In some embodiments, one or both of contact **638** and the contact in sensor portion **604** may be spring-loaded. When sensor portion **604** is connected to clamp portion **602** (e.g. sensor portion **604** is located in cavity **618** as shown in FIG. **6**A of the illustrated embodiment), the electrical contact shoe of sensor portion **604** makes electrical contact with electrical contact shoe **638** of clamp portion **602**, thus completing an electrical contact from clamp contacts **636**, through electrical contact shoe **638** of clamp portion **602** and the electrical contact shoe of sensor portion **604** to a conductor of cable **624** and back to the base unit of the ECG system. In this manner, electrode unit **600** may work in current-sensing contact mode with resistive sensor element **630** and may convey heart activity signals back to the base unit of the ECG system.

[0063] In electrode unit **600** of the FIG. **6**A, **6**B embodiment, clamp **610** serves two functions. As described above, clamp **610** can be used to attach to a current-sensing element **630** so that electrode unit **600** can be operated in a current-sensing mode. Alternately, clamp **610** can be used to attach electrode unit **600** to clothing when the electrode unit **600** is being operated in a field-sensing non-contact mode. In other embodiments a separate clamping structure may be provided for each of these functions.

[0064] In the illustrated embodiment of FIGS. **6**A and **6**B, sensor portion **604** is connected to clamp portion **602** at a location between arms **610**A, **610**B of clamp portion **602**. This is not necessary. In some embodiments, sensor portion **604** may be connected to other locations on clamp portion **602**. By way of non-limiting example, sensor portion **604** may be connected to an outside of one of arms **610**A, **610**B of clamp portion **602** or within one of arms **610**A, **610**B of clamp portion **602**—i.e. such that sensor portion **604** is not located between arms **610**A, **610**B. In the illustrated embodiment, sensor element **602** is generally round in cross-section. In other embodiments, sensor element **602** may have a keyed-shape (i.e. a protrusion from one its sidewall **615** and a corresponding groove in the sidewall of cavity **618** or vice versa) or some other cross-sectional shape. This may help to ensure alignment between electrical contact shoe **638** and the complementary electrical contact shoe on sensor portion **604**.

[0065] In the description of FIGS. **6**A and **6**B above, signals from resistive sensor elements **608**, **630** and from capacitive sensor elements **606** are conveyed back to the base unit of the ECG system via cable **624**. Cable **624** may comprise one of cables **106** described above. Cable **624** may be connected to the base unit using a corresponding connector **108** (see FIG. **4**A, for example). Connectors **108** may comprise multi-conductor (e.g. multi-pin) connectors. Such conductors/pins may comprise, without limitation: a ground pin; one or more current-sensing signal pins (e.g. one pin connected to snap-mechanism **622**, one pin connected clamp contacts **636** or one pin connected to both snap-mechanism **622** and clamp contacts **636**); and one or more field-sensing signal pins (e.g. connected to field-sensing element **606**). In some embodiments, signals from both field-sensing element **606**, snap mechanism **622** and clamp contacts **636** may be connected to the same pin of connectors **108**. Cable **624** and connectors **108** may comprise additional pins for conveying additional information from electrode unit **600**. For example, cable **624** may comprise conductors and connectors **108** may comprise pins for signals from proximity sensor(s) which may assist with determining the operational mode electrode unit **600**, as explained below. As discussed above in FIG. **4**D, electrode unit **600** may be provided as part of an electrode assembly **404** where signals are wirelessly conveyed from electrode assemblies **404** to the base unit of the ECG system. In such embodiments, cable **624** may be considered to be a suitable electrical contact to signal processing components **406** of electrode assembly **404**—see FIG. **4**D.

[0066] Where electrode units **104** of ECG systems **100**, **200**, **300**, **400** are provided by multi-mode electrode units **600**, an ECG system **100**, **200**, **300**, **400** may be operated with its electrode units **600** operating in different modes. By way of non-limiting example, electrode units **104**A, **104**B may operate in any desired combination or permutation of: field-sensing non-contact mode (i.e. over clothing), field-sensing contact mode (i.e. directly against the patient's skin) and current-sensing mode. Similarly, each of electrode unit **104**C and any additional electrode units connected to connectors **108** may operate in any desired one of: field-sensing non-contact mode, field-sensing contact mode and current-sensing mode.

[0067] The operation of electrode units **104** in different operational modes within a particular ECG system **100**, **200**, **300**, **400** may yield corresponding electrical signals **502** (see FIGS. **5**A, **5**B) having different amplitudes. For example, an electrode unit **104** operating in current-sensing mode typically provides a signal **502** which is several orders of magnitude larger than an electrode unit **104** operating in field-sensing mode. Similarly, an electrode unit **104** operating in a field-sensing contact mode may yield a slightly stronger (e.g. 10%-50% stronger) signal **502** than an electrode unit **104** operating in field-sensing non-contact mode. Signals **502** having different amplitudes can be scaled or the like (e.g. by signal processing hardware **114**) to normalize the signals prior to determining ECG leads (or other combined or differential signals). Suitable scaling factors can be pre-determined parameters, user-configurable parameters, system-configurable parameters or determined on an ad hoc basis. In one non-limiting example, digital signal processor **510** (FIG. **5**A) may be configured to determine the amplitude (e.g. the maximum and minimum level) of each signal from each electrode unit **104** and to use this information to scale the signals from the various electrodes to normalize the signals to have at least approximately the same amplitude. In another non-limiting example, an amplifier or automatic gain control circuit (AGC) in analog signal conditioning circuitry **512** (FIG. **5**B) may scale signals from electrode units operating in different modes by suitable pre-determined factor(s) in effort to normalize the signals from electrode units operating in different modes. In some embodiments, scaling may be non-linear.

[0068] In some circumstances, it may be desirable to determine the operational modes of electrode units **104** so that appropriate adjustments can be made to their corresponding signals before generating ECG leads (or other combined or differential signals). For example, where one electrode unit **104** is being operated in a field-sensing mode and another electrode unit **104** is being operated in a current-sensing mode, it may be desirable to scale the signals to have the same order of magnitude.

[0069] As discussed above with reference to FIGS. **6**A and **6**B, in some embodiments, signals from different operational modes of electrode unit **600** can be conveyed on different conductors of cable **624** and conveyed to the base unit of an ECG system through a different pin of connector **108**. In this manner, the ECG system may be able to tell the operational mode of each of its electrode units **104**. In some embodiments, an operator may additionally or alternatively provide information to the ECG system (e.g. via user inputs **132**) to allow the ECG system to determine which electrode unit **104** is operating in which operational mode. In some embodiments, the strength of the signal from each electrode unit **104** may additionally or alternatively be used by the ECG system to determine the operational mode of each electrode unit **104**. For example, a signal having an amplitude above a certain threshold may be indicative of a current-sending mode of operation.

[0070] In some embodiments, one or more additional sensors (not expressly shown) can additionally or alternatively be incorporated into electrode units **104** to assist with determining the mode of operation. For example, one or more first proximity sensors can be located in electrode unit **104** to detect a presence of a resistive sensor element (e.g. a resistive sensor element **608** connected to snap-mechanism **622** or a resistive sensor element **630** clamped between arms **610**A, **610**B of clamp **610**). If the one or more first proximity sensors detect a resistive sensor element, then ECG system may conclude that electrode unit **104** is operating in current-sensing mode. One or more second proximity sensors can be located in electrode unit **104** to detect the proximity of the patient's skin. If the one or more second proximity sensors detect that the patient's skin is within a certain threshold distance and the one or more first proximity sensors do not detect a resistive sensor element, then ECG system may conclude that electrode unit **104** is operating in field-sensing contact mode. On the other hand, if the one or more second proximity sensors detect that the patient's skin is outside of the threshold distance and the one or more first proximity sensors do not detect the resistive sensor element, then it may be assumed that the electrode unit **104** is operating in a field-sensing non-contact mode. In some embodiments, the one or more second proximity sensors may be configured to detect the presence of a clamp portion of the electrode unit (explained in more detail below) and may conclude that electrode unit **104** is operating in a field-sensing non-contact mode when the clamp portion is sufficiently proximate or a field-sensing contact mode when the clamp portion is sufficiently far away.

[0071] It will be appreciated that the use of proximity sensors represent just one sensor-based technique for determining the operational mode of an electrode unit **104**. Sensors other than proximity sensors may additionally or alternatively be used to help with the determination of the operations mode of an electrode unit **104**. For example, suitable electrical contact sensors (e.g. micro-switches) and/or the like could be used to detect the presence of resistive sensor elements and/or clothing. For example, suitable proximity sensor, micro-switches, electrical contact sensors or the like could be used to detect whether or not clamp **610** is closed and could thereby be used to determine if a resistive sensor element or clothing was being held in clamp **610**.

[0072] As discussed above, electrode unit **600** comprises a capacitive sensor element **606** which enables electrode unit **600** to operate in a field-sensing mode. FIG. **8** is an exploded cross-sectional view of a capacitive sensor element **606** that may be used with the FIG. **6**A, **6**B electrode unit **600** according to a particular embodiment. Capacitive sensor element **606** comprises proximate and distal surfaces **614**, **620** corresponding to proximate and distal surfaces **614**, **620** shown in FIG. **6**B. The main sensor of capacitive sensor element **606** comprises an electrodynamic sensor **650** which is sensitive to local electric field. A non-limiting example of a suitable electrodynamic sensor **650** is described, for example, in U.S. Pat. No. 7,885,700. Another non-limiting example of a suitable electrodynamic sensor **650** is the sensor No. PS25205B marketed by Plessey Semiconductors Ltd. of the UK.

[0073] Capacitive sensor element **606** of the FIG. **8** embodiment comprises a number of components and layers:

[0074] An antenna component **652** which serves as an antenna to increase electromagnetic signal sensitivity of electrodynamic sensor **650** and to improve the signal resolution of electrodynamic sensor **650**. Antenna component **652** of the illustrated embodiment comprises a PCB core **654**. On an inner side of PCB core **654**, antenna component **652** comprise a layer of metallization (e.g. solder plated conductor) **656** which is in direct electrical contact with electrodymamic sensor **650** (described below). On an outer side of PCB core **654**, antenna component **652** comprises a layer of metallization (e.g. solder plated conductor) **658**, which is in turn coated with a thin non-conductive protective (e.g. solder mask) layer **660**. Inner and outer metallization layers **656**, **658** are electrically connected to one another by conductive vias **662** provided at suitable locations. Outer metallization layer **658** may be transversely recessed (e.g. by 1-5 mm) at its transverse edges **568**A to insulate outer metallization layer **658** from sensor housing **659**. Metallization layer **658** (and, possibly metallization layer **656**) may serve as the radiating element of an antenna which is in electrical contact with the sensing surface of electrodynamic sensor **650**. Metallization layer **658** and, possibly metallization layer **656** (i.e. the radiating element of antenna component **652**) may have a surface area that is greater than a surface area of the sensing surface of electrodynamic sensor **650**. In some embodiments, an outer peripheral rim of antenna component **652** could be provided with a stepped profile (e.g. an outer peripheral rim having less thickness in the left-to-right dimension of FIG. **8**) to accommodate the thickness of rim **618**A (see FIG. **6**B).

[0075] A sensor-positioning layer **664** may be used on an inside of antenna layer **652** and may provide a cut-out **666** as shown to ensure the proper placement and/or orientation of electrodynamic sensor **650**. Sensor-positioning layer **664** may comprise a suitable non-conductive PCB material or a single-layer PCB substrate with etched out copper layer.

[0076] A sensor-holding layer **668** which holds electrodynamic sensor **650**. Sensor-holding layer **668** may comprise a sensor-holding PCB. Sensor-holding layer **668** may provide suitable solderable contacts to solder electrodynamic sensor **650** and suitable electrical connections to main PCB layer **672** described below. In some embodiments, sensor-holding layer **668** and main PCB layer **672** may comprise complementary (e.g. male and female) electrical contacts and/or connector components (not shown) that mate when sensor element **606** is assembled.

[0077] An insulator layer **670**, which provides compressive force and facilitates proper electrical contact between the inner metallization layer **656** of antenna layer **652** and electrodynamic sensor **650**. Insulation layer **670** may comprise Ethafoam™ material, for example. Insulator layer **670** may comprise a cut-out section (not shown) which permits electrical connections between sensor-holding layer **668** and main PCB layer **672** (as discussed above).

[0078] A main PCB layer **672** which houses the electronic circuitry (e.g. amplifiers, other signal conditioning components and/or the like) for operation of capacitive sensing element **606**. Main PCB layer may provide electrical contact to cable **624** described with reference to FIGS. **6**A and **6**B above.

[0079] A distal component **674** serving as distal surface **620**. Distal component **674** may comprise a metalized layer **676** which may provide electrical noise shielding. In the illustrated embodiment, metallization layer **676** is provided on the outside of distal component **674**.

[0080] A snap-mechanism **622** for connecting to complementary snap mechanism **626** of resistive sensor elements **608**. In the illustrated embodiment, snap-mechanism **622** comprises a female snap mechanism. In other embodiments, however, snap-mechanism **622** could comprise a male snap mechanism. As discussed above, snap-mechanism **622** may be electrically connected to a conductor in cable **624**. Snap-mechanism **622** may be electrically insulated from metallization layer **676** by suitable etching of metallization layer **676** or some other suitable insulating technique.

[0081] ECG systems (e.g. systems **100**, **200**, **300**, **400**) according to particular embodiments may include mechanisms for reducing the effects of ambient electrical noise. More particular, ECG systems according to particular embodiments may comprise one or both of a grounding strap (not shown) or a right leg electrode (not shown). Such a grounding strap or right leg electrode may be used in addition to the grounding techniques implemented in electrode units **104** and/or in addition to filtering techniques provided by signal processing components described above to reduce the ambient electrical noise's impact on received electrical heart activity signals. Some sources of ambient noise (e.g. power line hum that could be either 60 Hz or 50 Hz) may be too strong to be effectively filtered by using the signal processing circuitry of the ECG systems. Accordingly, in some embodiments, one or both of a grounding strap or a right leg electrode may be used to increase the signal-to-noise ratio for subsequent signal processing.

[0082] A grounding strap may be provided to link the negative side of the power source (e.g. battery (not shown)) of base unit **102** to the patient's skin while limiting the current flow for patient safety. Such a grounding strap may be similar to the grounding straps used in electronics laboratories and/or electronic fabrication facilities and may be worn so as to touch the patient's skin to be effective for ambient electrical noise rejection (e.g. common mode rejection of the amplifiers associated with electrode units **104**).

[0083] A Right Leg Drive (RLD) electrode may be implemented to inject the "inverted" polarity noise of same amplitude as an ambient electrical noise onto the patient's skin in order to compensate for the common mode noise. The RLD circuitry may comprise an inverting amplifier, a filter and a safety limiting resistor to prevent exceeding the safety limit of the noise signal injected onto the skin. This RLD electrode may or may not touch the skin in order to inject inverted ambient noise into the system. The DSP may use the inverted ambient noise signal from the RLD electrode to at least partially cancel ambient noise and to thereby increase the signal-to-noise ratio. A RLD electrode may be provided with similar physical characteristics as electrode unit **600** described above and may comprise a clamp portion similar to clamp portion **602** for attaching to a patient's clothing or the like.

[0084] In some embodiments, ECG systems **100**, **200**, **300**, **400** (FIGS. **4**A-**4**D) are portable and lightweight systems that are convenient to use and transport. For example, they may be compact enough to be carried by hand so that they are easy to transport to a patient's current location, which may be in the patient's home or in some other location. In some embodiments, ECG systems **100**, **200**, **300**, **400** may be designed to be small enough to fit within a carrying bag or pocket.

[0085] While a number of exemplary aspects and embodiments have been discussed above, those of skill in the art will recognize certain modifications, permutations, additions and sub-combinations thereof. For example:

[0086] In the illustrated embodiment of FIGS. **6**A and **6**B, cable **624** is shown as being permanently attached to sensor portion **604**. This is not necessary. In some embodiments, cable **624** may be attached to clamp portion **602** and the outputs of sensor portion **604** (e.g. sensed signals) may be connected to cable **624** by suitable electrical contact(s) between clamp portions **602** and sensor portion **604**. In some embodiments, connections to resistive sensor elements (e.g. snap mechanism **622** and/or clamp contacts **636**) can be routed through clamp portion **602** without the need for sensor portion **602**.

[0087] In some embodiments, clamp portion **602** of electrode unit **600** may be fabricated from bacteria resistant material (e.g. suitable plastic and/or the like).

[0088] In some embodiments, ECG systems **100**, **200**, **300**, **400** may be configured to provide a heart-shaped graphic on display **120** and to interpret the ECG data to cause the heart-shaped graphic to simulate actual heart-muscle activity as detected in the ECG data.

[0089] In some embodiments, multi-mode electrode units **600** (or any variations of multi-mode electrodes **600** described herein) may be connected to prior art ECG systems—e.g. in the place of conventional electrode units. When connected in this manner, suitable adapters may be used to provide output signals from electrode units **600** in a format useable by the prior art ECG system.

[0090] In some embodiments, cables (e.g. cables **106**, cables **624**) associated with the various electrode units described herein may be retractable and may be housed, for example, in the base unit or in the housing of the electrode unit.

[0091] In some embodiments, an electrode unit comprising a capacitive sensor element **606** (see FIGS. **6**A, **6**B) could be incorporated into a blood pressure cuff and attached to the body of a patient via the blood pressure cuff to sense heart muscle electrical activity in a field-sensing contact or field-sensing non-contact mode.

[0092] It is therefore intended that the scope of the following appended claims and claims hereafter introduced should not be limited by the embodiments set forth in the examples, but should be given the broadest interpretation consistent with the description as a whole.

What is claimed is:

1. A system for monitoring heart muscle activity of an individual comprising:

a first electrode unit for generating a first signal indicative of electrical activity of the heart muscle at a first location on a body of the individual; and

a second electrode unit for generating a second signal indicative of electrical activity of the heart muscle at a second location on the body of the individual;

wherein each of the first and second electrode units is configurable to operate in:

a field-sensing mode wherein the electrode unit is configured to generate its corresponding signal based on a detected electric field at a location on or in proximity to the individual's skin; and,

a current-sensing mode wherein the electrode unit is configured to generate its corresponding signal based on current flow through a resistive sensor element placed directly on the individual's skin.

2. A system according to claim **1** wherein each of the electrode units is configurable to operate in:

a non-contact field-sensing mode wherein the individual's clothing is located between the electrode unit and the individual's skin; and

a contact field-sensing mode wherein the individual's clothing is not located between the electrode unit and the individual's skin.

3. A system according to claim **1** wherein:

the first electrode unit is configured to operate in the field-sensing mode to thereby generate the first signal based on the detected electric field at the location on or in proximity to the individual's skin;

the second electrode unit is configured to operate in the current-sensing mode to thereby generate the second signal based on current flow through the resistive sensor element placed directly on the individual's skin; and

wherein the system is configured to combine the first signal and the second signal to generate an ECG waveform.

4. A system according to claim **3** wherein the first sensor is configured to operate in a non-contact field-sensing mode wherein the individual's clothing is located between the electrode unit and the individual's skin.

5. A system according to claim **3** wherein the first sensor is configured to operate in a contact field-sensing mode wherein the individual's clothing is not located between the electrode unit and the individual's skin.

6. A system according to any one of claims **2** to **5** wherein each of the electrode units comprises a capacitive sensor element.

7. A system according to claim **6** wherein the capacitive sensor element of each of the electrode units comprises:

an electrodynamic sensor which is sensitive to electromagnetic waves;

an antenna comprising an electrically conductive radiating element for receiving electromagnetic waves, the radiating element in electrical contact with a sensing surface of the electrodynamic sensor and having a surface area which is larger than a surface area of the sensing surface of the electrodynamic sensor, the antenna located relatively more proximate than the electrodynamic sensor to the individual's skin during operation of the electrode unit in field-sensing mode.

8. A system according to claim **7** wherein the capacitive sensor element of each of the electrode units comprises an electrically non-conductive layer disposed on the radiating element, wherein the non-conductive layer is on an outside face of the electrode unit which is located relatively more proximate than the radiating element to the individual's skin during operation of the electrode unit in the field-sensing mode.

9. A system according to any one of claims **6** to **8** wherein at least one of the electrode units comprises a clamp.

10. A system according to claim **9** wherein the clamp is provided in a clamp portion of the electrode unit, the capacitive sensor element is provided in a sensor portion of the electrode unit and the clamp portion and sensor portion are attachable to, and detachable from, one another.

11. A system according to any one of claims **9** to **10** wherein the clamp comprises a pair of clamp teeth for clamping objects therebetween and the clamp is shaped to clamp the individual's clothing between the clamp teeth and to thereby of the at least one electrode unit to the individual's clothing when operating in the non-contact field-sensing mode.

12. A system according to any one of claims **9** to **11** wherein the clamp comprises a pair of clamp teeth for clamping objects therebetween and one or more electrically conducting clamp contacts located in one or both of the teeth for clamping an electrically conductive tab on the resistive sensor element between the clamp teeth and corresponding electrical attachment of the resistive sensor element to the one or more clamp contacts.

13. A system according to any one of claims **1** to **12** wherein at least one of electrode units comprises a first connector component for receiving a second complementary connector component of the resistive sensor element for removably electrically connecting the resistive sensor element to the electrode unit by connecting the first and second connector components.

14. A system according to claim **13** wherein the first and second connector components are shaped such that connecting the first and second connector components causes deformation of at least one of the first and second connector components and corresponding restorative forces which tend to maintain the connection between the first and second connector components.

15. A system according to claim **7** wherein the capacitive sensor element of each electrode unit comprises a first connector component for receiving a second complementary connector component of the resistive sensor element for removably electrically connecting the resistive sensor element to the electrode unit by connecting the first and second connector components, the first connector component located on a side of the electrodynamic sensor opposite that of the antenna.

16. A system according to any one of claims **2** to **15** wherein at least one of the electrode units comprises a first proximity sensor configured to detect a presence of the resistive sensor element.

17. A system according to claim **16** wherein the at least one of the electrode units comprises a second proximity sensor configured to detect proximity of the individual's skin and to thereby permit determination of whether the electrode unit is operating in the non-contact field-sensing mode or the contact field-sensing mode.

18. A system according to any one of claims **2** to **17** wherein the first electrode unit is operating in the non-contact field-sensing mode simultaneously with the second electrode unit operating in the contact field-sensing mode and wherein the system is configured to combine the first signal and the second signal to generate an ECG waveform.

19. A system according to any one of claims **1** to **18** wherein the first electrode unit is operating in the field-sensing mode simultaneously with the second electrode unit operating in the current-sensing mode and wherein the system is configured to combine the first signal and the second signal to generate an ECG waveform.

20. A system according to any one of claims **1** to **19** comprising a base unit connected to the electrode units to receive the first and second signals, the base unit comprising a digital signal processor configured to generate one or more ECG waveforms based on a combination of the first and second signals.

21. A system according to claim **20** wherein at least one of the electrode units is integral with the base unit.

22. A system according to claim **20** wherein at least one of the electrode units is removably connected to the base unit by a corresponding cable.

23. A system according to claim **20** wherein at least one of the electrode units is wirelessly connected to the base unit.

24. A system according to any one of claims **20** to **23** wherein the base unit is configured to display the one or more ECG waveforms on a display.

25. A system according to claim **24** wherein the display is removably connected to the base unit and the base unit and the display are configured for wireless communication of the one or more ECG waveforms from the base unit to the display when the display is removed from the base unit.

26. A system according to any one of claims **20** to **25** comprising a grounding strap electrically connected to a power supply of the base unit, wherein, in operation, the grounding strap is placed directly on the individual's skin.

27. A system according to any one of claims **20** to **26** wherein the digital signal processor is configured to process the first and second signals and to differentiate between portions of the signals attributable to heart muscle activity and portions of the signals attributable to one or more of the individual's breathing and the individual's body motion.

28. A system according to any one of claims **20** to **27** wherein the digital signal processor is configured to scale at least one of the first and second signals to accommodate for differences in the strength of the signals due to operation of the first and second electrode units in different modes.

29. A system according to claim **28** wherein the digital signal processor is configured to automatically scale at least one of the first and second signals by automatic adjustment of amplifier gain of one or more amplifiers.

30. A system according to any one of claims **1** to **29** comprising a right leg drive electrode configured to generate an inverted ambient noise signal and wherein the system is configured to use the inverted ambient noise signal to at least partially cancel ambient noise from the first and second signals.

31. An electrode unit for use in an ECG system comprising:
a capacitive sensor element for detecting electric field;
a spring-biased clamp for attachment of the electrode unit to an individual's clothing when operating in a non-contact field-sensing mode; and
an attachment means for physical and electrical attachment of the electrode unit to a resistive sensor element when operating in a resistive mode.

32. An electrode unit according to claim **31** wherein the capacitive sensor element comprises:
an electrodynamic sensor sensitive to electromagnetic waves;
an antenna comprising an electrically conductive radiating element for receiving electromagnetic waves, the radiating element in electrical contact with a sensing surface of the electrodynamic sensor and having a surface area which is larger than a surface area of the sensing surface of the electrodynamic sensor, the antenna located relatively more proximate than the electrodynamic sensor to the individual's skin during operation of the electrode unit in field-sensing mode.

33. An electrode unit according to claim **32** wherein the capacitive sensor element comprises an electrically non-conductive layer disposed on the radiating element, wherein the non-conductive layer is on an outside face of the electrode unit which is located relatively more proximate than the radiating element to the individual's skin during operation of the electrode unit in the field-sensing mode.

34. An electrode unit according to any one of claims **31** to **33** wherein the attachment means comprises a first connector component for receiving a second complementary connector component of the resistive sensor element for physical and electrical attachment of the electrode unit to the resistive sensor element by connecting the first and second connector components.

35. An electrode unit according to claim **34** wherein the first and second connector components are shaped such that connecting the first and second connector components causes deformation of at least one of the first and second connector components and corresponding restorative forces which tend to maintain the connection between the first and second connector components.

36. An electrode unit according to claim **32** wherein the attachment means comprises a first connector component for receiving a second complementary connector component of the resistive sensor element for physical and electrical attachment of the electrode unit to the resistive sensor element by connecting the first and second connector components and wherein the first connector component is located on a side of the electrodynamic sensor opposite that of the antenna

37. An electrode unit according to any one of claims **31** to **36** wherein the attachment means comprises the clamp, the clamp comprising a pair of clamp teeth configured to hold a portion of a resistive sensor element therebetween.

38. An electrode unit according to claim **37** wherein the clamp comprises one or more electrically conducting clamp contacts located in one or both of the teeth for providing electrical contact to the resistive sensor element.

39. An electrode unit according to any one of claims **31** to **38** comprising a first proximity sensor configured to detect a presence of the resistive sensor element.

40. An electrode unit according to claim **39** comprising a second proximity sensor configured to detect proximity of the individual's skin.

41. A system for monitoring heart muscle activity of an individual comprising:
a first electrode unit for generating a first signal indicative of electrical activity of the heart muscle at a first location on a body of the individual, the first electrode unit comprising a first capacitive sensing element for detecting electric field;
a second electrode unit for generating a second signal indicative of electrical activity of the heart muscle at a second location on the body of the individual, the second electrode unit comprising a second capacitive sensing element for detecting electric field; and
a plurality of inputs, each input adapted to receive a corresponding signal from a current-sensing electrode unit indicative of electrical activity at a corresponding location on the body of the individual.

42. A system according to claim **41** comprising:
a base unit configured to receive any available signals generated by the first and second electrode units and received at the plurality of inputs and to generate one or more ECG waveforms based on the available signals; and
a display removably connected to the base unit;
the base unit and the display configured for wireless communication of the one or more ECG waveforms from the base unit to the display when the display is removed from the base unit.

43. A system according to claim **42** wherein the first and second electrode units are integrally housed in the base unit.

44. A system according to any one of claims **42** and **44** wherein the plurality of inputs are provided on the base unit.

45. A system for monitoring heart muscle activity of an individual comprising:
a first input for receiving a first signal indicative of electrical activity of the heart muscle at a first location on a body of the individual;
a second input for receiving a second signal indicative of electrical activity of the heart muscle at a second location on the body of the individual;
wherein each of the inputs is adapted to receive a signal from a field-sensing electrode unit or from a current-sensing electrode unit and the system is configured to differentiate between signals received from field-sensing electrode units and signals received from current-sensing electrode units and to generate one or more ECG waveforms based on the received signals.

46. A system according to claim **45** comprising:
a base unit which houses the first and second inputs; and
a display removably connected to the base unit;
the base unit and the display configured for wireless communication of the one or more ECG waveforms from the base unit to the display when the display is removed from the base unit.

47. A system according to any one of claims **45** to **46** comprising: a first field-sensing electrode unit connectable to the first input; and a second field-sensing electrode unit connectable to the second input.

48. A system according to any one of claims **45** to **46** comprising: a first field-sensing electrode unit connectable to the first input; and a second current-sensing electrode unit connectable to the second input.

49. A system according to any one of claims **47** to **48** wherein the first electrode unit is connectable to the first input by way of a first flexible arm.

50. A system according to claim **49** wherein the first flexible arm comprises memory plastic.

51. A system according to claim **47** wherein each one of the first and second field-sensing electrode units comprises a capacitive sensor element, the capacitive sensor element comprising:

an electrodynamic sensor sensitive to electromagnetic waves;

an antenna comprising an electrically conductive radiating element for receiving electromagnetic waves, the radiating element in electrical contact with a sensing surface of the electrodynamic sensor and having a surface area which is larger than a surface area of the sensing surface of the electrodynamic sensor, the antenna located relatively more proximate than the electrodynamic sensor to the individual's skin during operation of the field-sensing electrode unit.

52. A system according to claim **51** wherein the capacitive sensor element of each of the first and second field-sensing electrode units comprises an electrically non-conductive layer disposed on the radiating element, wherein the non-conductive layer is on an outside face of the field-sensing electrode unit which is located relatively more proximate than the radiating element to the individual's skin during operation of the field-sensing electrode unit.

53. A system according to any one of claims **46** to **52** comprising one or more additional inputs, wherein each one of the one or more additional inputs is adapted to receive a corresponding additional signal from a field-sensing electrode unit or a current-sensing electrode unit, the corresponding additional signal indicative of electrical activity of the heart muscle at a corresponding location on the body of the individual.

54. A system according to any one of claims **46** to **53** wherein the base unit comprise one or more of: a clip for connecting the base unit to the individual's clothing, arm or leg; and a strap for connecting the base unit to the individual's clothing arm or leg.

55. A system according to claim **47** wherein the base unit comprises one or more clips for removably attaching the first and second field-sensing electrode units to the base unit.

56. A system according to claim **47** wherein the first field-sensing electrode unit is housed in the base unit at a first position and the second field-sensing electrode unit is housed in the base unit at a second position spaced apart from the first position by a distance at least half of a length of the base unit.

57. A system according to any one of claims **46** to **56** comprising a grounding strap electrically connected to a power supply of the base unit, wherein, in operation, the grounding strap is placed directly on the individual's skin.

58. A system according to any one of claims **46** to **56** wherein the base unit comprises a digital signal processor configured to generate the one or more ECG waveforms based on one or more combinations of the received signals.

59. A system according to claim **58** wherein the digital signal processor is configured to process the received signals and to differentiate between portions of the signals attributable to heart muscle activity and portions of the signals attributable to one or more of the individual's breathing and the individual's body motion.

60. A system according to any one of claims **58** to **59** wherein the digital signal processor is configured to scale at least one of the received signals to accommodate for differences in the strength of signals received from field-sensing electrode units and signals received from current-sensing electrode units.

61. A system according to claim **60** wherein the digital signal processor is configured to automatically scale at least one of the received signals by automatic adjustment of amplifier gain of one or more amplifiers.

62. A system according to any one of claims **45** to **61** comprising a right leg drive electrode configured to generate an inverted ambient noise signal and wherein the system is configured to use the inverted ambient noise signal to at least partially cancel ambient noise from the first and second signals.

63. A system for monitoring heart muscle activity of an individual comprising:

a first field-sensing electrode unit for generating a first signal indicative of electrical activity of the heart muscle at a first location on a body of the individual, the first field-sensing electrode unit configured to generate the first signal based on a detected electric field at a location on or in proximity to the individual's skin; and

a second current-sensing electrode unit for generating a second signal indicative of electrical activity of the heart muscle at a second location on the body of the individual, the second current-sensing electrode unit configured to generate the second signal based on current flow through a resistive sensor element placed directly on the individual's skin;

wherein the system is configured to combine the first signal and the second signal to generate an ECG waveform.

64. A system according to claim **63** comprising any of the features, combinations of features or sub-combinations of features of claims **1** to **62**.

65. A method for generating an ECG waveform related to heart muscle activity of an individual, the method comprising:

providing a plurality of electrode units, each electrode unit configured to generate a corresponding signal indicative of electrical activity of the heart muscle at a corresponding location on a body of the individual;

operating at least one first one of the plurality of electrode units in a field-sensing mode, wherein the at least one first one of the electrode units is configured to generate its corresponding signal based on a detected electric field at a location on or in proximity to the individual's skin;

operating at least one other one of the plurality of electrode units in a current-sensing mode, wherein the at least one other one of the plurality of electrode units is configured to generate its corresponding signal based on current flow through a resistive sensor element placed directly on the individual's skin; and

using the signals generated by the at least one first one of the plurality of electrode units and generated by the at least one other one of the plurality of electrode units to generate one or more ECG waveforms.

66. A method according to claim **65** comprising one or more features or method steps based on any of the features, combinations of features or sub-combinations of features of claims **1-64**.

67. Apparatus, systems and methods comprising any features, combinations of features or sub-combinations of features of any of the preceding claims.

68. Apparatus, systems and methods comprising any features, combinations of features or sub-combinations of features described herein.

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patsnap

专利名称(译)	具有多模电极单元的ECG系统
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摘要(译)

用于监测个体的心肌活动的系统和装置包括：第一电极单元，用于接收指示个体身体上的第一位置处的电活动的第一信号;以及第二电极单元，用于接收指示第二电极的第二信号。个人身体第二个位置的电活动。第一和第二电极单元中的每一个可配置成以场感测模式操作，其中电极单元放置在其上或者它上面！接近个人的皮肤，以及电流感测模式，其中电极单元耦合到直接放置在个人皮肤上的电阻传感器感测元件。场感测模式可以是非接触场感测模式。