United States Patent	12383182
Kind Code	B2
Date of Patent	August 12, 2025
Inventor(s)	Chahine; Tony et al.

Multi-sensor resistive textile ECG system

Abstract

An ECG sensor system comprising: a substrate having a first side and a second side, the substrate of a non-conducting material; a plurality of textile-based sensors positioned on the first side, each of the plurality of textile-based sensors spaced apart from one another on the first side, the second side covering one side of the each of the plurality of textile-based sensors as an insulating covering, the each of the plurality of textile-based sensors including conductive fibres interlaced with one another; and a conductive trace connected to the each of the plurality of textile-based sensors, each of the conductive traces for connecting the plurality of textile-based sensors to an electronic controller for sending and receiving electronic signals from a selected pair of the plurality of textile-based sensors.

Inventors:	**Chahine; Tony (Toronto, CA), Alizadeh-Meghrazi; Milad (Toronto, CA)**
Applicant:	**MYANT INC.** (Toronto, CA)
Family ID:	**1000008750234**
Assignee:	**Myant Inc. (Toronto, CA)**
Appl. No.:	**17/292666**
Filed (or PCT Filed):	**November 12, 2018**
PCT No.:	**PCT/IB2018/058877**
PCT Pub. No.:	**WO2020/099906**
PCT Pub. Date:	May 22, 2020

Prior Publication Data

Document Identifier	**Publication Date**
US 20220007986 A1	Jan. 13, 2022

Publication Classification

Int. Cl.: **A61B5/304** (20210101); **A61B5/00** (20060101); **A61B5/27** (20210101); **A61B5/282** (20210101); **D03D1/00** (20060101); **D03D15/00** (20210101); **D03D15/283** (20210101); **D03D15/533** (20210101); **D04B1/14** (20060101); **D04B1/22** (20060101)

U.S. Cl.:

CPC **A61B5/304** (20210101); **A61B5/27** (20210101); **A61B5/282** (20210101); **A61B5/6804** (20130101); **D03D1/0088** (20130101); **D03D15/00** (20130101); **D03D15/283** (20210101); **D03D15/533** (20210101); **D04B1/14** (20130101); **D04B1/22** (20130101); A61B2562/164 (20130101)

Field of Classification Search

USPC: None

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2010/0041975	12/2009	Chen et al.	N/A	N/A
2011/0288605	12/2010	Kaib et al.	N/A	N/A
2013/0131460	12/2012	Yuen	N/A	N/A
2016/0287128	12/2015	Jain	N/A	A61B 5/282
2017/0056644	12/2016	Chahine et al.	N/A	N/A
2017/0079348	12/2016	Chahine et al.	N/A	N/A
2017/0265763	12/2016	Gazzoni et al.	N/A	N/A
2018/0168508	12/2017	Biel et al.	N/A	N/A
2018/0344171	12/2017	Straka et al.	N/A	N/A
2019/0223739	12/2018	Rapin et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
107205678	12/2016	CN	N/A
3634215	12/2019	EP	N/A
2013528070	12/2012	JP	N/A
2016044933	12/2015	WO	N/A
2017045062	12/2016	WO	N/A
2018161152	12/2017	WO	N/A

OTHER PUBLICATIONS

European Patent Office, Extended European Search Report for European Patent Application No. 18940268.8, dated Jun. 15, 2022. cited by applicant

PCT, Written Opinion and International Search Report of International Application No. PCT/IB2018/058877, mailing date Jul. 26, 2019. cited by applicant

Japanese Patent Office, Office Action dated Sep. 27, 2022 for Japanese Patent Application No. 2021-525249. cited by applicant

Japanese Patent Office, Notice of Allowance dated Mar. 28, 2023 for Japanese Patent Application

No. 2021-525249. cited by applicant
Chinese Patent Office, Office Action dated Nov. 20, 2023 for Chinese Patent Application No. 201880099803.3. cited by applicant
Stahl, Ted, "What Embroiderers Should Know About Thermo-FLOCK", URL: https://www.tedstahl.com/what-embroiderers-should-know-about-thermo-flock/, Apr. 18, 2018. cited by applicant
Communication pursuant to Article 94(3) EPC issued in connection with European Patent Application No. 18 940 268.8 on Nov. 14, 2023. cited by applicant

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Primary Examiner: Tejani; Ankit D

Attorney, Agent or Firm: Norton Rose Fulbright Canada LLP

Background/Summary

FIELD
(1) The present disclosure relates to ECG sensors for smart textiles.
BACKGROUND
(2) The existing wearables in the market for measuring ECG signals (specifically for health applications) are limited to record from fixed locations. Any noise (or artifact) can attenuate the recorded signal. As well, these wearables cannot be used for research purposes as they are limited to specific locations on the body. Further, the existing ECG data acquisition tools (non-wearables) which have been widely used for medical applications can record high quality ECG signals from different locations on the body. These data acquisition tools use gel-electrodes to record ECG signals. Thus, they suffer from (a) need for clinician to supervise the recording from patients, (b) need for skin preparation and (c) need for stable position to connect electrode wires to the patients (they cannot be used for continuous recording of ECG signals on the daily basis).
(3) While current non-fibre gel electrodes are useful in collecting ECG signals, woven or knit ECG sensors suffer from the disadvantage of intermittent or sub optimal contact with the wear's skin. Thus, a textile-based sensor cannot measure ECG signals with a desired resolution as they are limited to a particular location of the body, such that appropriate measurement resolution is hampered by inherent lack of firm skin contact during measurement. Thus, collection of necessary ECG features for heart-related diagnosis may not achievable by a woven, knit, electrode.
(4) Therefore, as observed, current gel electrodes can be used to provide better signal quality with lower impedance as compared to textile-based electrodes. However gel electrodes also suffer from potential skin allergy (if uses for a long time), must firmly and at all times attach to the body (e.g. using adhesives), requires complex wiring, and requires skin preparation by clinical professionals in advance (as well as during) of signal collection.
SUMMARY
(5) It is an object of the present invention to provide system of textile-based electrodes and sensors applicable to ECG measurement to obviate or mitigate at least one of the above presented disadvantages.
(6) Multi sensor textile-based ECG platform (e.g. band) measures ECG signals with desired resolution from different locations of the patient's body to facilitate appropriate measurement when firm skin contact is not possible for all the electrodes simultaneously. Furthermore, this platform provides additional chances to collect necessary ECG features for heart-related diagnosis which are not achievable by a single electrode.
(7) Advantages of using multiple textile electrodes for ECG measurement can include: provides

reasonably good signal quality; biocompatible (no skin allergy); higher impedance than traditional gel electrodes; touches body; little skin preparation; can work wirelessly; can be incorporated into textiles, making the possibility of being used as a wearable and therefore reusable.
(8) A first aspect provided is an ECG sensor system comprising: a substrate having a first side and a second side, the substrate of a non-conducting material; a plurality of textile-based sensors positioned on the first side, each of the plurality of textile-based sensors spaced apart from one another on the first side, the second side covering one side of the each of the plurality of textile-based sensors as an insulating covering, the each of the plurality of textile-based sensors including conductive fibres interlaced with one another; and a conductive trace connected to the each of the plurality of textile-based sensors, each of the conductive traces for connecting the plurality of textile-based sensors to an electronic controller for sending and receiving electronic signals from a selected pair of the plurality of textile-based sensors.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) The foregoing and other aspects will now be described by way of example only with reference to the attached drawings, in which:
(2) FIG. **1** is system view of textile examples for wearing or otherwise positioning adjacent to a body of a wearer;
(3) FIGS. **2**, **2***a* are an exemplary view of a textile computing platform of the garment of FIG. **1** incorporated into an article of clothing including a variety of sensors/actuators and conductive pathways;
(4) FIG. **3***a* shows a side view of an embodiment of an ECG sensor system of the textile computing platform shown in FIG. **2**;
(5) FIG. **3***b* shows a different side view of the ECG sensor system of the textile computing platform shown in FIG. **2**;
(6) FIG. **4***a* shows a top view of a sensor of the system of FIG. **3***b;*
(7) FIG. **4***b* shows an alternative embodiment of the sensor of FIG. **3***b;*
(8) FIG. **5** is an example component view of a controller of the system of FIG. **1**;
(9) FIG. **6** is an embodiment of interlacing for the fibres of the textile of FIG. **1**;
(10) FIG. **7** is a further embodiment of interlacing for the fibres of the textile of FIG. **1**;
(11) FIG. **8** is an example ECG trace representing the signals of the system of FIG. **1**; and
(12) FIG. **9** is an example component view of a computer device of the system of FIG. **1**;
DETAILED DESCRIPTION
(13) Referring to FIG. **1**, shown is a body **8** of a wearer for wearing one or more textile based computing platforms **9** positioned about one or more regions (e.g. knee, ankle, elbow, wrist, hip, shoulder, neck, etc.) of the body **8**. For sake of simplicity, textile based computing platforms **9** can also be referred to as textile computing platforms **9**. For example, the textile computing platforms **9** can also be referred to as a wrist sleeve **9**, a knee sleeve **9**, a shoulder sleeve **9**, an ankle sleeve **9**, a hip sleeve **9**, a neck sleeve **9**, a chest sleeve, etc. It is also recognised that the sleeve can be referred to as a band. It is also recognized that the textile computing platform **9** can be incorporated as part of a larger garment **11** (e.g. a pair of briefs **11** as shown in ghosted view for demonstration purposes only). It is recognized that the garment **11** could also be a shirt, pants, body suit, as desired. As such, a fabric/textile body **13** of the garment **11** can be used to position the textile computing platform **9** for selected areas of the body **8**. In other words, the textile computing platform **9** contains a number of textile computing components, e.g. sensors/actuators **18**, electronic circuits **17**, controller **14**—see FIG. **2**, which are all incorporated into or otherwise mounted on a fabric/textile body **13** of the garment **11**. It is also recognised that the textile computing platform **9**

can be incorporated into a textile **11** (e.g. a fabric sheet, a covering, or other fabric structure) that is not worn by the body **8**, rather is positioned adjacent to the body **8**. Examples of the textile **1** can include bedsheets, seat coverings (e.g. car seat), etc. In terms of uses for the textile computing platform **9**, it is envisioned that one or more textile computing platforms **9** can be distributed (e.g. worn) about the body **8** of the user. Whether embodied as a single or multiple textile computing platforms **9**, it is envisioned that the textile computing platform(s) **9** provide for multiple sensors/electrodes **18** for positioning about the body strategically in order to measure ECG signals, for example, which need appropriate contact with the skin of the body **8**. As further described below, a multi-sensor **18** system **19** is provided such that a controller **14** can determine which of the sensors/electrodes **18***a,b,c,d* of the multi-sensor system **19** are out of contact with the skin and thus are discarded as signal generators **6***a*/receivers **6***b* for the generation/collection of ECG signals **6***a*,**6***b* of desired resolution while utilizing the collection (e.g. system **19**) the textile-based sensors/electrodes **18***a,b,c,d*—see FIG. **2**.
(14) Referring again to FIGS. **1** and **2**, the textile computing platform **9** can be integrated with the textile/fabric body **13** (e.g. a plurality of fibres/threads/yarn interlaced as woven and/or knitted, as desired). The textile computing platform **9** has the controller **14** for sending/receiving signals to one or more sensors/actuators **18** distributed about the body **13**. The shape of the sensors/actuators **18** can be elongate (e.g. as a strip extending in a preferred direction) or can extend as a patch in a plurality of directions (e.g. extend side to side and end to end). The signals are transmitted between the sensors/actuators **18** and the controller **14** via one or more electronic circuits **17** connecting the controller **14** to each of the sensors/actuators **18**. It is also recognized that the electronic circuits **17** can also be between individual pairs of the sensors/actuators **18**, as desired. As further described below, the sensors/actuators **18** can be textile based, i.e. incorporated via interlaced (e.g. knitting, weaving) as integral to the material structural integrity of the fabric layer of the body **13** (formed as a plurality of interlaced threads of electrically conductive and optionally non-conductive properties). Further, the electronic circuits **17** (e.g. electrically conductive threads) can also be incorporated/interlaced (e.g. knitting, weaving, etc.) into/with the adjacent fabric layer of the body **13** (also comprising a plurality of interlaced threads/fibres). The controller **14**, further described below, can include a network interface (e.g. wireless or wired) for communicating with a computing device **23** (e.g. smart phone, tablet, laptop, desktop, etc.) via a network **25**.
(15) It is recognised that the conductive fibres **24***a* of the textile-based sensors **18** can be interlaced with the non-conductive fibres **24***b* in the body of the base fabric layer **13** (recogniszing that the non-conductive fibres **24***b* insulate electrically the individual sensors **18** (e.g. sensors **18***a,b,c,d* of the system **19**) from undesirably communicating with one another via the body of the base fabric layer **13**. It is desired that the individual sensors **18** communicate **7** with one another via the body **8** of the wearer, as further described below. Referring to FIG. **2***a*, shown is the electrical signal communication **7** between various sensors **18***a,b,c* via an electrically conductive pathway of the body **8** of the wearer.
(16) As shown in FIGS. **3***a,b*, the fabric layer of the body **13** has a first side **10** and a second side **12**, such that the sides **10**, **12** are opposed to one another (e.g. front and back) with respect to the body **8** of the wearer. For example, the base fabric layer **13** of the “front” or top side **10** has base fibres **24***b* protecting the sensors/actuators **18** from undesirable contact (e.g. moisture/grounding/etc.) with the environment external to the wearer. In terms of the back side **12**, the sensors/electrodes **18** are exposed from the base fabric layer **13** (acting as a substrate—see FIG. **4**) so as to provide for direct contact with the skin of the wearer, while at the same time the base fabric layer **13** insulates the sensors/electrodes from one another via intra spacing **20** between the sensors **18** within a group while also having a inter spacing **22** between respective groups. For example, referring to FIGS. **3***a,b*, generator group **24** contains a set of actuator sensors **18***a,b,c,d* and receiver group **26** contains a set of receiver sensors **18***e,f,g,h,i,j,k*. It is recognised that the intra spacing **20** between sensors **18** within a group can be less than the inter spacing **22** between groups

(or sets **24**,**26**) of the sensors **18**. It is recognised that the intra spacing **20** between sensors **18** within a group can be greater than the inter spacing **22** between groups (or sets **24**,**26**) of the sensors **18**. It is recognised that the intra spacing **20** between sensors **18** within a group can be equal to the inter spacing **22** between groups (or sets **24**,**26**) of the sensors **18**. In any event, the groups/sets **24**,**26** of sensors **18** can used to designate function of the sensors **18**, for example as discussed having an actuator group **24** and a receiver group **26**. It is recognised that the actuator group **24** can have more individual sensors **18** that contained within the receiver group **26**. It is recognised that the actuator group **24** can less individual sensors **18** that contained within the receiver group **26**. It is recognised that the actuator group **24** can an equal number of individual sensors **18** as contained within the receiver group **26**.

(17) In view of the above, as further described below, the controller **14** can utilize one of the sensors **18** from the actuator group **24** and one or more from the receiver group **26** from which to generate the signal **6***a* and thus collect the signal **6***b* via the conductive body pathway **7**. The collected signal(s) **6***b* can be examined for appropriate signal quality by the controller **14**, recognizing that signals of deemed undesirable quality (e.g. signal amplitude below a set amplitude minimum, signal detail such as below a set number of desired signal characteristics/features present such as peaks, intervals and other ECG indicators—see FIG. **8**) would be discarded by the controller **14** and alternative sensors **18** would be selected to use in generating and collecting the signals **6***a*,*b*. For example, referring to FIGS. **3***a*,*b* the controller **14** can select and generate a signal **6***a* from sensor **18***a* (from the actuator group **24**) and then collect and receive the signal(s) **6***b* from one or more of the sensors **18***e*,*f*,*g*,*h*,*i*,*j*,*k* from the collector group **26**. Upon examination of the collected signal(s) **6***b*, the controller would analyze the signal(s) **6***b* to determine if they are of acceptable signal quality. If so then the controller **14** could continue to use actuator sensor **18***a* to generate the signal **6***a* and the receiver sensor(s) **18***e*,*f*,*g*,*h*,*i*,*j*,*k* to collect the signal(s) **6***b*. On the other hand, if none of the collected signal(s) **6***b* was/were deemed of unacceptable quality, then the controller could decide to select another generator sensor (e.g. sensor **18***b*) to use as the signal **6***a* generator. In this manner, the controller **14** can utilize the system of multi-sensors **19** in order to choose pairings of the sensors **18**, e.g. an actuator sensor **18***a* with a receiver sensor **18***f*, that result in an acceptable collected signal **6***b* of deemed ECG quality. It is recognised that as discussed above, any of the sensors **18** of the system **19** can change their degree of direct contact with the skin of the wearer during the measurement of the signals **6***a*,*b*, for example due to movement of the wearer.

(18) This real time change potential in direct contact between any of the sensors **18** of the system **19** and the skin requires the controller **14** to analyze the collected signals **6***b* over time and thus decide if a change in sensors **18** being used in the sensor pairing for ECG signal **6***a*,*b* collection is needed, in view of determined signal quality. As such, it is recognised that over time, a deemed acceptable sensor **18** pairing (e.g. a selected actuator sensor **18** of the generation group **24** with a selected receiver sensor **18** of the receiver group **26**) can be dynamically changed during the ongoing signal generation and collection. It is assumed that deemed signal(s) **6***b* of poor or unacceptable quality can be due to direct skin contact of any sensor **18** being below a set contact standard or contact limit/threshold. For example, the set contact standard or contact limit/threshold can be defined using parameters such as but not limited to; 1) a specified percentage of surface area of the sensor **18** is in direct contact with the skin, 2) a specified force or pressure between the surface of the sensor **18** and the skin, 3) a specified level of moisture between the surface of the sensor **18** and the skin, and/or 4) a specified location of the sensor **18** with respect to an identified/desired location on the skin of the wearer. As such, it is recognised that the desired location and/or direct contact parameters of the sensors **18** can change over time (e.g. in real time) and thus the controller **14** can sense these changes in direct contact of the sensors **18** in view of the determined signal **6***b* quality. It is recognised that the degree of direct contact of the sensor **18** with the skin can be proportional with the conductivity between the sensor **18** and the skin and thus can

be representative of the degree of quality (e.g. amplitude, presence of key signal features/characteristics, etc.) present in the collected signal(s) **6***b*. For example, in the extreme case of where the generator sensor **18***a* and/or the receiver sensor **18***f* are/is not in contact with the skin, the controller **14** would recognize the absence of any collected signal **6***b* in response to the generated signal **6***a* and thus would choose to deselect the currently utilized generator sensor **18***a* and/or the receiver sensor **18***f* and try again with a different sensor **18** pairing (e.g. retry with sensor **18***b* and **18***f*, retry with senor **18***a* and **18***e*, retry with and/or sensor **18***b* and **18***g*, etc.). Alternatively, for example, in the other extreme case of where the generator sensor **18***a* and/or the receiver sensor **18***f* are/is in acceptable contact with the skin, the controller **14** would recognize the collected signal **6***b* in response to the generated signal **6***a* as of acceptable quality and thus would choose to continue using the currently utilized generator sensor **18***a* and/or the receiver sensor **18***f* rather than try again with a different sensor **18** pairing (e.g. retry with sensor **18***b* and **18***f*, retry with senor **18***a* and **18***e*, retry with and/or sensor **18***b* and **18***g*, etc.). Alternatively, for example, in the intermediate case of where the generator sensor **18***a* and/or the receiver sensor **18***f* are/is in intermittent or otherwise borderline acceptable contact with the skin, the controller **14** would recognize the collected signal **6***b* in response to the generated signal **6***a* as of a borderline/acceptable/or unacceptable quality and thus would act accordingly (e.g. choose to continue using the currently utilized generator sensor **18***a* and/or the receiver sensor **18***f* or try again with a different sensor **18** pairing (e.g. retry with sensor **18***b* and **18***f*, retry with senor **18***a* and **18***e*, retry with and/or sensor **18***b* and **18***g*, etc.).

(19) It is also recognised that the controller **14** could try different sensor **18** pairings in order to select the best received signal **6***b* for use as the reported signal **6***b* for that time period. In other words, the controller **14** could alternate the selected sensor **18** pairings using a selection frequency greater than the signal reporting frequency (i.e. the controller **14** tries 10 pairings in sequence and the picks the best signal **6***b* to report as representative for the 10 pairings). Accordingly, it is recognized that the controller **14** is continually monitoring the collected signal **6***b* quality and selecting/deselecting the sensor **18** pairings. Further, it is recognised that the sensor **18** parings can be a one to one (**18***a* to **18***e*), a many to one (**18***a*,*b* to **18***e*), or a one to many (**18***a* to **18***e*,*f*) relationship as desired as applicable to the way in which the controller **14** is utilizing the system **19** to generate and collect the signals **6***a*,*b* deemed pertinent to the task at hand, e.g. collection of quality ECG signals.

(20) In terms of the sensors **18** themselves, the materials of the fibres **24***a* can be conductive yarns that are knitted into the sensor **18**. The shapes of the sensor can be circular or rectangular, for example having a contact conductive surface **40** and a backside insulated surface **42** (see FIGS. **3***a*,*b*) but the shapes don't matter as much since specific shapes can be selected/used for each application. This arrangement of the sensors **18** with the groupings **24**,**26** can covers the whole area around the heart horizontally (due to the sensor **18** size, number of sensors **18**, distribution of the sensors **18** on the base fabric layer **13** and associated individual leads (e.g. conductive signal pathways/circuits **17** connecting the sensors **18** to the controller **14**). It is recognised that the spacing **20** can be selected as a matter of density and resolution of the signals **6***b* that one wishes to capture via the controller **14**. As further discussed below, the mechanism used by the controller **14** underlying all ECG signals **6***a*,*b* is based on calculating the potential between a pair of electrodes **18** as conducted via the body conductive pathway **7**. Grouping electrodes in the two different groups **24**,**26** (e.g. two sides) can also help recording ECG signals **6***b* from different respective relative distances.

(21) Referring again to FIGS. **2***a*,**3***a*,*b*, preferably the side **10** and the side **12** of the fabric layer of the body **13** are situated in the same plane (e.g. a flat or curved fabric surface of thickness T—uniform or varied) in a composition of the textile computing platform **9** of the garment **11** (see FIG. **2**). It is recognised that the sensors/actuators **18** of the textile based computing platform **9** can be formed as integral components of the interlacing of the fibres making up the body **13**—see FIGS.

4*a*, **6**, **7**. The fabric of the body **13** can be comprised of interlaced resilient fibres **24***b* (e.g. stretchable natural and/or synthetic material and/or a combination of stretchable and non-stretchable materials, recognizing that at least some of the fibres comprising the sensors/actuators **18** are electrically conductive, i.e. metallic). It is also recognised that the fibres **24***a* making up the sensors **18** can be separate from the interlacing of the fibres **24***b* making up of the fabric body layer **13**—see FIG. **4***b*, such that the fibres **24***a* of the sensor **18** are independently woven/knit from the fibres **24***b* and thus the already formed sensor **18** is applied to the already formed base fabric layer **13** as an applique or individual patch. In this example, the fibres **24***a* of the sensor **18** are non-integral with respect to the fibres **24***b* of the base fabric layer **13**.

(22) In view of the above, the multi sensor **18** textile-based ECG system **19** (e.g. in the form of a band) can be used to measure ECG signals **6***b* with appropriate resolution from different locations of the body **8** (based on the positioning of the sensors **18** within the garment/textile **11** as well as the positioning of the garment/textile **11** itself with respect to the body **8**) to facilitate correct measurement when firm (i.e. deemed appropriate by the controller **14** via analysis of signal **6***b* quality) skin contact is not possible for all the electrodes **18** simultaneously. Furthermore, this system **19** can provide additional chances to collect desired ECG features for heart-related diagnosis which are not achievable by a single electrode. Accordingly, as shown, one embodiment of the textile computing platform **9** is as an ECG belt comprising multiple textile electrodes **18** with embedded electronics (e.g. controller **14**) that provides continuous recording of ECG signals **6***b* from different locations on the body **8**. The ECG belt **9** can not only provide a wearable that can be comfortably used on the daily basis by the wearer but can also record desired quality ECG signals **6***b* as deemed by the controller **14**. The recorded signal **6***b* can be either saved on the SD card (electronics—e.g. memory **211**—see FIG. **8**) or shared through cloud web-service via communication between the controller **14** and a networked computer device **23** via the network **25**—see FIG. **2**. The textile computing platform **9** design, for example, can comprises 11 textile electrodes **18**, (e.g. evenly) distributed via spacings **20**, to provide a full spectrum ECG recording (see FIG. **8**).

(23) Further, it is advantageous as the textile computing platform **9** (e.g. belt) can be utilized for continuous recording of quality ECG signals **6***b* from multiple locations on the body **8**, with being repositionable and/or reuseable. Therefore, this textile computing platform **9** can have huge implications for detection and diagnosis of heart-related disorders, e.g., cardiovascular disease, heart failure, postpericardiotomy syndrome, etc.

(24) Features of the textile computing platform **9** can be features such as but not limited to: 1) the multi-sensor ECG band **9** provides capturing notable signal features of the heart signal **6***b*—see FIG. **8**′ 2) main advantages of our multi-sensor **18** strategy of the system **19** can be to increase the reliability of measuring system, by replacing/deselecting the lost/low quality signal/sensor **18** (weakness) with the another available/redundant sensor **18** and/or to increase the likelihood of extracting the main features of the heart signal **6***b*, ECG band **9** comprises for example 11 electrodes **18**, distributed evenly (distance: 0.5 cm), connected to the corresponding electronics module **207** of the controller **14**, textile electrodes **18** can be made of highly conductive silver yarns, surface resistivity is 30±15 Ohm (shape: e.g. circle with radius of 1.9 cm), and/or the textile electrodes **18** can be knitted/woven with different interlacing structures.

(25) In view of the above, the system **19** disclosed herein can be implemented by a person and can include the garment **11** (e.g. suit or a belt/band) comprising a plurality of sensors **18** (e.g. textile-based ECG sensors) attached or otherwise embedded to/into fabric layer **13** of the garment **11** for measuring ECG activity (e.g. signals **6***b*) of the wearer. Generated/collected signals **6***a*,*b* of the sensors **18** can be sent/received via wires or cords (e.g. conductive pathway **17**) to an electronic device (e.g. PCB) **14** attached via the electrical connectors **6** such as but not limited to snap type connectors (to fabric of the garment body layer **13** for transmitting (e.g. via a wireless network module **202**—see FIG. **5**) the information as sensor data to a computing device **200**—see FIG. **9**

(e.g. mobile device). The computing device **200** and/or the controller **14** can include a processor **208** for running an application **201** (e.g. ECG application) capable of interpreting the sensor **18** data.

(26) For example, the application **201** can process the sensor **18** data to derive ECG recordings **50** (see FIG. **8**) having various ECG features **52** collected over time **54**. Capacitance and/or resistance (e.g. potential) can be measured across the body conductive pathway **7** between sensors **18** by the controller **14**. For example, changes/absolute measurement(s) in resistance and/or capacitance (i.e. potential) can be measured using a bridge circuit (e.g. a Wheatstone bridge or Wien bridge) contained or otherwise sensed by the controller device **14**, a type of electrical circuit in which two circuit branches are "bridged" by a third branch connected between the first two branches at some intermediate point along them. A source of power (e.g. a battery) of the controller device **14** can be connected to the bridge circuit along with a measuring device (e.g. a voltmeter, ammeter, or galvanometer) of the controller device **14** to detect the potential signals **6***b* in the conductive pathway **7** between selected sensors **18**.

(27) The electronic device **14** (e.g. controller **14**) can be any device capable of being incorporated into a garment/textile **11** for receiving signals from one or more sensors **18** and transmitting the received signals (e.g. via a wireless transmitter) to the computing device **200**. Non-limiting examples of an electronic device **14** according to the embodiments are a printed circuit board, RF module, transceiver module, and system-on-a-chip module. In one embodiment, the electronic device **14** can be an eight-channel printed circuit board having a Bluetooth low-energy wireless transmitter for transmitting the information received from a sensor **18** to the computing device **200**. A power source of the controller **14**, for example, can be attached via the connector(s) **6** to the garment body layer **13** for providing power to one or more sensors **18** and an electronic device **14** attached to the garment **11**. In one embodiment, the power source can be a battery included within the electronic device **14**. The power source can be actuated for example by an on-off switch connected to the power source and accessible to the wearer of the garment **11**.

(28) Application **201**

(29) The system can include an application **201** running on a computing device **200** and/or the controller **14** (e.g. smartphone or tablet) that can receive a transmission from the electronic device **14** of the garment **11** including sensor data **6***b* representative of information received by the electronic device **14** from one or more sensors **18** (e.g. ECG sensors) of the garment **11** and optionally orientation data generated by the electronic device **14**. The data **6***b* (e.g. sensor data and/or orientation data in digital format) received by the computing device **200** from the electronic device **14** can be stored by the computing device **200** in memory **211** accessible by a processor **208** of the computing device **200** capable of running the application **201**. Similarly, the controller **14** can have memory **211** accessible by a processor **208** of the computing device **200** capable of running the application **201**.

(30) The application **201** can be programmed to instruct the processor **208** to parse and/or interpret the sensor data **6***b* received from the sensors **18** of the garment **11**, as well as to actuate various sensors **18** to generate signals **6***a*. For example, where a garment includes a plurality of sensors **18**, the application **201** can parse the sensor data **6***b* into separate pools of data where each pool contains data collected by a different sensor **18** involving of one or more body **8** locations underlying the sensor(s) **18** on/in the layer **13** adjacent to the one or more body portions. The processor **208** can interpret the data from each pool to determine the pattern of activity collected by a single sensor **18** throughout the duration. For example, the application **201** can determine whether or not a particular sensor **18** was active (i.e. transmitted a signal **6***b*) during the ECG recording period and when during the recording the sensor **16** was active (e.g. in firm contact with the skin). If the processor **208** determines that a particular sensor **18** was active (i.e. transmitted a signal **6***b* to the electronic device **14**) at a particular time during the recording period, then the processor **208** can further determine the magnitude of the signal **6***b* generated by the sensor **18** at that time as well

as whether it contains the necessary ECG features **52** (e.g peaks, intervals, etc.) within that recording period **54**.

(31) The application **201** can be executed as a set of instructions by a processor **208** of the computing device **200** and/or controller **14**. Each of the modes (e.g. interaction mode; calibration mode) of the application **201** can also include a set of instructions for execution by the processor **208**, and the processor **208** can communicate with each of the modes and/or components (e.g. **207**) of the modes to execute the instructions. For example, in the "real-time" interaction mode the processor **208** can communicate with the electronics **207** of the to emit/receive signals **6***a,b*. Therefore, it will be understood that the application **201** includes executable instructions capable of generating/receiving sensor data **6***a,b* (and optionally orientation data) from selected sensors **18**, to deselect or otherwise select alternative sensors **18** of the system **19** in the event certain sensor pairings are deemed of questionable or unacceptable quality, select multiple pairings of sensors **18** and decide what pairing provided the best/most desired signal **6***b* based on processing the received data to identify features **52** of the ECG recording **50** that are acceptable as compared to ECG feature models **56** stored in memory **211**, and displaying the results of the processing to a user interface **204** of the computing device **14**,**200** for display to a user of the computing device **14**,**200**.

(32) In view of the above, it is recognised that the application **201** can be configured as a general activity (e.g. ECG) based application **201** that is for monitoring the ECG signals **6***b* of the specified body portions associated with the sensor(s) **18** in/on the garment fabric layer **13** adjacent to the body portion(s).

(33) Referring to FIG. **9**, the computing device can be device **200**. In some embodiments, the electronic device can be device **200**. When electronic device is device **200**, at least some of the sensor signal processing (and optionally the orientation data processing) can be done using the electronic device of the garment **11** before sending the processed information (e.g. as sensor data). The device **200** can configured to communicate over a communications network (e.g. Bluetooth, wireless network, etc.) with the connection interface **202** and thus via the controller **14**. The application **201** can receive data entry by the user (e.g. via the user interface **204**) and/or by another application running on the data processing system **206** for accessing the sensor data (e.g. processed or otherwise). The device **200** can be a land-based network-enabled personal computer. However, the invention is not limited for use with personal computers. For instance, the device **200** can comprise a wireless communications device, such as a wireless-enabled personal data assistant, a tablet, or mobile telephone if the communications network is configured to facilitate wireless data communication. In addition, the invention is not limited to only facilitating transmission of sensor data (and optionally orientation data) between the electronic device and computing device (e.g. device **200**), and can be used to transmit raw data, processed sensor data, and/or any other multimedia data in addition or substitution of the sensor data, as desired. The device **200** can comprise a network interface **202**, a user interface **204**, and a data processing system **206** in communication with the network interface **202** and the user interface **204**. Typically, the network interface **202** comprises an Ethernet network circuit card, however the network interface **202** may also comprise an RF antenna for wireless communication over the communications network. Preferably, the user interface **204** comprises a data entry device (such as keyboard **209**, microphone or writing tablet), and a display device **210** (such as a CRT or LCD display). The user interface **204** can include one or more user input devices such as but not limited to a QWERTY keyboard (e.g. keyboard **209**, a keypad, a stylus, a mouse, a microphone and the user output device such as an LCD screen display and/or a speaker. If the screen is touch sensitive, then the display can also be used as the user input device as controlled by the data processing system **206**. The device **200** can include a network interface **202**, such as a network interface card or a modem, coupled via connection to a data processing system **206**. The network interface **202** is connectable during operation of the device **200** to the network (e.g. an Intranet and/or an extranet such as the Internet), which enables the device **200** to communicate with each other as appropriate. The network can

support the communication of the network messages for the various transmitted data (e.g. sensor data) there between. The data processing system **206** can include a processor **208**, and a non-volatile memory storage device (DISC) **211** (such as a magnetic disc memory or electronic memory) and a read/write memory (RAM) **211** both in communication with the processor **208**. The DISC includes data which, when loaded into the memory **211**, comprise processor instructions for the processor **208** which define memory objects for allowing the device **200** to communicate over the communications network. Operation of the device **200** is facilitated by the data processing system **206**. The memory **212** is used to store data for access by the respective user and/or operating system/executable instructions of the device **2002**. The processor **208** facilitates performance of the device **200** configured for the intended task through operation of the network interface **202**, the user interface **204** and other application programs/hardware of the device **200** by executing task related instructions. These task related instructions can be provided by an operating system, and/or software applications located in the memory **212**, and/or by operability that is configured into the electronic/digital circuitry of the processor(s) **208** designed to perform the specific task(s). Further, it is recognized that the data processing system **206** can include the computer readable storage medium **211** coupled to the processor **208** for providing instructions to the processor **208** and/or to load/update the instructions. The computer readable medium **211** can include hardware and/or software such as, by way of example only, magnetic disks, magnetic tape, optically readable medium such as CD/DVD ROMS, and memory cards. In each case, the computer readable medium **211** may take the form of a small disk, floppy diskette, cassette, hard disk drive, solid-state memory card, or RAM provided in the memory **211**. It should be noted that the above listed example computer readable mediums **211** can be used either alone or in combination. Further, it is recognized that the device **200** can include the executable applications comprising code or machine readable instructions for implementing predetermined functions/operations including those of an operating system. The processor **208** as used herein is a configured device and/or set of machine-readable instructions for performing operations as described by example above. As used herein, the processor **208** may comprise any one or combination of, hardware, firmware, and/or software. The processor **208** acts upon information by manipulating, analyzing, modifying, converting or transmitting information for use by an executable procedure or an information device, and/or by routing the information with respect to an output device. The processor **208** may use or comprise the capabilities of a controller or microprocessor, for example.

(34) Accordingly, any of the functionality of the executable instructions (e.g. through modules associated with selected tasks) may be implemented in hardware, software or a combination of both. Accordingly, the use of a processor **208** as a device and/or as a set of machine-readable instructions is hereafter referred to generically as a processor/module for sake of simplicity. The memory **211** is used to store data locally as well as to facilitate access to remote data stored on other devices connected to the network. The data can be stored in a table, which can be generically referred to as a physical/logical representation of a data structure for providing a specialized format for organizing and storing the data. General data structure types can include types such as but not limited to an array, a file, a record, a table, a tree, and so on. In general, any data structure is designed to organize data to suit a specific purpose so that the data can be accessed and worked with in appropriate ways. In the context of the present environment, the data structure may be selected or otherwise designed to store data for the purpose of working on the data with various algorithms executed by components of the executable instructions, depending upon the application thereof for the respective device **200**. It is recognized that the terminology of a table/database is interchangeable with that of a data structure with reference to the components of the environment.

(35) Referring to FIG. **5**, the computing device can be the controller **14**. When electronic device is controller **14**, at least some of the sensor signal processing (and optionally the orientation data processing) can be done using the electronic device of the garment **11** before sending the processed

information (e.g. as sensor data). The controller **14** can configured to communicate over a communications network (e.g. Bluetooth, wireless network, etc.) with the connection interface **202** and thus via the computing device **200**. The application **201** can receive data entry by the user (e.g. via the user interface **204**) and/or by another application running on the data processing system **206** for accessing the sensor data (e.g. processed or otherwise). The controller **14** can be a land-based network-enabled personal computer. However, the invention is not limited for use with personal computers. For instance, the controller **14** can comprise a wireless communications device, such as a wireless-enabled personal data assistant. In addition, the invention is not limited to only facilitating transmission of sensor data (and optionally orientation data) between the electronic device and computing device (e.g. device **200**), and can be used to transmit raw data, processed sensor data, and/or any other multimedia data in addition or substitution of the sensor data, as desired. The controller **14** can comprise a network interface **202**, a user interface **204**, and a data processing system **206** in communication with the network interface **202** and the user interface **204**. Typically, the network interface **202** comprises an Ethernet network circuit card, however the network interface **202** may also comprise an RF antenna for wireless communication over the communications network. Preferably, the user interface **204**, optional for the controller **14**, comprises a data entry device (such as keyboard **209**, microphone or writing tablet), and a display device **210** (such as a CRT or LCD display). The user interface **204** can include one or more user input devices and the user output device such as an LCD screen display and/or a speaker. If the screen is touch sensitive, then the display can also be used as the user input device as controlled by the data processing system **206**. The device **200** can include a network interface **202**, such as a network interface card or a modem, coupled via connection to a data processing system **206**. The network interface **202** is connectable during operation of the controller **14** to the network (e.g. an Intranet and/or an extranet such as the Internet), which enables the controller **14** to communicate with each other as appropriate. The network can support the communication of the network messages for the various transmitted data (e.g. sensor data) there between. The data processing system **206** can include a processor **208**, and a non-volatile memory storage device (DISC) **211** (such as a magnetic disc memory or electronic memory) and a read/write memory (RAM) **211** both in communication with the processor **208**. The DISC includes data which, when loaded into the memory **211**, comprise processor instructions for the processor **208** which define memory objects for allowing the controller **14** to communicate over the communications network **25**, as well as to interact with the sensors **18** of the textile computing platform **9**. Operation of the controller **14** is facilitated by the data processing system **206**. The memory **211** is used to store data for access by the respective user and/or operating system/executable instructions of the controller **14**. The processor **208** facilitates performance of the controller **14** configured for the intended task through operation of the network interface **202**, the user interface **204** and other application programs/hardware of the controller **14** by executing task related instructions. These task related instructions can be provided by an operating system, and/or software applications located in the memory **211**, and/or by operability that is configured into the electronic/digital circuitry of the processor(s) **208** designed to perform the specific task(s). Further, it is recognized that the data processing system **206** can include the computer readable storage medium **211** coupled to the processor **208** for providing instructions to the processor **208** and/or to load/update the instructions. The computer readable medium **211** can include hardware and/or software such as, by way of example only, magnetic disks, magnetic tape, optically readable medium such as CD/DVD ROMS, and memory cards. In each case, the computer readable medium **211** may take the form of a small disk, floppy diskette, cassette, hard disk drive, solid-state memory card, or RAM provided in the memory **211**. It should be noted that the above listed example computer readable mediums **211** can be used either alone or in combination. Further, it is recognized that the controller **14** can include the executable applications comprising code or machine readable instructions for implementing predetermined functions/operations including those of an operating system. The processor **208** as used herein is a configured device and/or set of machine-readable instructions for performing operations as described by example above. As used herein, the processor **208** may comprise any one or combination of, hardware, firmware, and/or software. The processor **208** acts upon information by manipulating, analyzing, modifying, converting or transmitting information for use by an executable procedure or an information device, and/or by routing the information with respect to an output device. The processor **208** may use or comprise the capabilities of a controller or microprocessor, for example. Accordingly, any of the functionality of the executable instructions (e.g. through modules associated with selected tasks) may be implemented in hardware, software or a combination of both. Accordingly, the use of a processor **208** as a device and/or as a set of machine-readable instructions is hereafter referred to generically as a processor/module for sake of simplicity. The memory **211** is used to store data locally as well as to facilitate access to remote data stored on other devices connected to the network. The data can be stored in a table, which can be generically referred to as a physical/logical representation of a data structure for providing a specialized format for organizing and storing the data. General data structure types can include types such as but not limited to an array, a file, a record, a table, a tree, and so on. In general, any data structure is designed to organize data to suit a specific purpose so that the data can be accessed and worked with in appropriate ways. In the context of the present environment, the data structure may be selected or otherwise designed to store data for the purpose of working on the data with various algorithms executed by components of the executable instructions, depending upon the application thereof for the respective controller **14**. It is recognized that the terminology of a table/database is interchangeable with that of a data structure with reference to the components of the environment.

(36) Electrocardiography (ECG or EKG) can be defined as the process of recording the electrical activity of the heart over a period of time using electrodes **18** placed over the skin of the body **8**. These electrodes **18** can be used by the controller **14** detect the tiny electrical changes on the skin that arise from the heart muscle's electrophysiologic pattern of depolarizing and repolarizing during each heartbeat. It is very commonly performed to detect any cardiac problems. In a conventional 12-lead ECG, ten gel electrodes (i.e. non-textile based) are fixedly placed on the patient's limbs and on the surface of the chest. The overall magnitude of the heart's electrical potential is then measured from twelve different angles (“leads”) and is recorded over a period of time (usually ten seconds). In this way, the overall magnitude and direction of the heart's electrical depolarization is captured at each moment throughout the cardiac cycle, in reliance on the fixed in contact and position of the gel electrodes, as facilitated by a clinician administering the ECG testing. The graph of voltage versus time produced by this noninvasive medical procedure is an electrocardiogram. In the conventional process, using gel electrodes, is such that the clinician can always rely upon each of the gel electrodes to respond (i.e. transmit when transmitting and receive when receiving) reliably. Therefore, in conventional gel based electrode procedures, deselection or otherwise selection of which sensors **18** to use as the best recorded signal **6***a* is not done, as it is unnecessary. Due to the guaranteed contact between the skin and the gel electrode. For instance, if the gel electrode stops working, the ECG test is stopped, the gel electrode reattached firmly, and the ECG testing continues. At no time during the traditional ECG test, using gel electrodes, does the clinician decide which of sensor pairings should be relied upon to provide the desired ECG signal. Therefore, the current system **19** can be different in that the degree skin contact of the textile-based sensors **18** can vary (e.g. from contact to no contact, from no contact to contact, and/or vary in contact quality) during the ECG testing period **54** (see FIG. **8**).

(37) Referring again to FIG. **8**, in general there can be three main components **52** to an ECG signals **6***b*: the P wave, which represents the depolarization of the atria; the QRS complex, which represents the depolarization of the ventricles; and the T wave, which represents the repolarization of the ventricles. It can also be further broken down into the following components/features **52**: O is the origin or datum point preceding the cycle, P is the atrial systole contraction pulse, Q is a

downward deflection immediately preceding the ventricular contraction, R is the peak of the ventricular contraction, S is the downward deflection immediately after the ventricular contraction, T is the recovery of the ventricles, and U is the successor of the T wave but it is small and not always observed. Therefore, during each heartbeat, a healthy heart has an orderly progression of depolarization that starts with pacemaker cells in the sinoatrial node, spreads throughout the atrium, passes through the atrioventricular node down into the bundle of His and into the Purkinje fibers, spreading down and to the left throughout the ventricles. This orderly pattern of depolarization gives rise to the characteristic ECG tracing represented by the signals **6***b*. To the trained clinician, an ECG signal **6***b* conveys a large amount of information about the structure of the heart and the function of its electrical conduction system. Among other things, an ECG signal **6***b* can be used to measure the rate and rhythm of heartbeats, the size and position of the heart chambers, the presence of any damage to the heart's muscle cells or conduction system, the effects of heart drugs, and the function of implanted pacemakers. It is further recognised that the controller **14** via the electronics **207** provides for the fundamental component to an ECG as the instrumentation amplifier, which is responsible for taking the voltage difference between leads **17** of the sensors **18** and amplifying the signal **6***b*. ECG voltages as signals **6***b* measured across the body **8** can be on the order of hundreds of microvolts up to 1 millivolt (the small square on a standard ECG is 100 microvolts). This low voltage preferably relies upon a considered “low” noise circuit and instrumentation amplifiers of the electronics **207**. The controller **14** can use analog-to-digital converters in the electronics **207** to convert the signal **6***b* to a digital signal that can then be manipulated with digital electronics. This can provide for digital recording of ECGs and use on computers.

(38) The electronics **207** and/or the associated application **201** can include a rhythm analysis algorithm that produces a computerized interpretation of the ECG. The results from these algorithms can be considered “preliminary” until verified and/or modified by someone trained in interpreting ECGs. Included in this analysis can be the computation of common parameters **52** that include PR interval, QT interval, corrected QT (QTc) interval, PR axis, QRS axis, and more. Further, in ECG measurement, the electrodes/sensors **18** are the actual textile-based conductive pads attached to the body surface. Any pair of electrodes **18** can measure the electrical potential difference between the two corresponding locations of attachment via the body conductive pathway **7**. Such a pair can be defined as forming a lead. However, “leads” can also be formed between a physical electrode and a virtual electrode, known as the Wilson's central terminal, whose potential is defined as the average potential measured by three limb electrodes that are attached to the right arm, the left arm, and the left foot, respectively.

(39) Referring to FIG. **6**, shown is an exemplary knitted configuration for the sensors **18** of a network of electrically conductive fibres **3505** in, for example, a segment of an electrically conductive circuit **17** and/or sensor/actuator **18** (see FIG. **1**). In this embodiment, an electric signal (e.g. current) is transmitted to conductive fibre **3502** from a power source (not shown) through a first connector **3505**, as controlled by a controller **3508** (e.g. controller **14**). The electric signal is transmitted along the electric pathway along conductive fibre **3502** past non-conductive fibre **3501** at junction point **3510**. The electric signal is not propagated into non-conductive fibre **3501** at junction point **3510** because non-conductive fibre **3501** cannot conduct electricity. Junction point **3510** can refer to any point where adjacent conductive fibres and non-conductive fibres are contacting each other (e.g. touching). In the embodiment shown in FIG. **10**, non-conductive fibre **3501** and conductive fibre **3502** are shown as being interlaced by being knitted together. Knitting is only one exemplary embodiment of interlacing adjacent conductive and non-conductive fibres. It should be noted that non-conductive fibres forming non-conductive network **3506** can be interlaced (e.g. by knitting, etc.). Non-conductive network **3506** can comprise non-conductive fibres (e.g. **3501**) and conductive fibres (e.g. **3514**) where the conductive fibre **3514** is electrically connected to conductive fibres transmitting the electric signal (e.g. **3502**). For example, the interlacing method of the fibres in FIG. **6** can be referred to as weft knitting.

(40) In the embodiment shown in FIG. **6**, the electric signal continues to be transmitted from junction point **3510** along conductive fibre **3502** until it reaches connection point **3511**. Here, the electric signal propagates laterally (e.g. transverse) from conductive fibre **3502** into conductive fibre **3509** because conductive fibre **3509** can conduct electricity. Connection point **3511** can refer to any point where adjacent conductive fibres (e.g. **3502** and **3509**) are contacting each other (e.g. touching). In the embodiment shown in FIG. **6**, conductive fibre **3502** and conductive fibre **3509** are shown as being interlaced by being knitted together. Again, knitting is only one exemplary embodiment of interlacing adjacent conductive fibres. The electric signal continues to be transmitted from connection point **3511** along the electric pathway to connector **3504**. At least one fibre of network **3505** is attached to connector **3504** to transmit the electric signal from the electric pathway (e.g. network **3505**) to connector **3504**. Connector **3504** is connected to a power source (not shown) to complete the electric circuit.
(41) FIG. **7** shows an exemplary woven configuration of a network of electrically conductive fibres **3555**. In this embodiment, an electric signal (e.g. current) is transmitted to conductive fibre **3552** from a power source (not shown) through a first connector **3555**, as controlled by a controller **3558** (e.g. controller **14**). The electric signal is transmitted along the electric pathway along conductive fibre **3552** past non-conductive fibre **3551** at junction point **3560**. The electric signal is not propagated into non-conductive fibre **3551** at junction point **3560** because non-conductive fibre **3551** cannot conduct electricity. Junction point **3560** can refer to any point where adjacent conductive fibres and non-conductive fibres are contacting each other (e.g. touching). In the embodiment shown in FIG. **20**, non-conductive fibre **3551** and conductive fibre **3502** are shown as being interlaced by being woven together. Weaving is only one exemplary embodiment of interlacing adjacent conductive and non-conductive fibres. It should be noted that non-conductive fibres forming non-conductive network **3556** are also interlaced (e.g. by weaving, etc.). Non-conductive network **3556** can comprise non-conductive fibres (e.g. **3551** and **3564**) and can also comprise conductive fibres that are not electrically connected to conductive fibres transmitting the electric signal. The electric signal continues to be transmitted from junction point **3560** along conductive fibre **3502** until it reaches connection point **3561**. Here, the electric signal propagates laterally (e.g. transverse) from conductive fibre **3552** into conductive fibre **3559** because conductive fibre **3559** can conduct electricity. Connection point **3561** can refer to any point where adjacent conductive fibres (e.g. **3552** and **3559**) are contacting each other (e.g. touching). In the embodiment shown in FIG. **7**, conductive fibre **3552** and conductive fibre **3559** are shown as being interlaced by being woven together. The electric signal continues to be transmitted from connection point **3561** along the electric pathway through a plurality of connection points **3561** to connector **3554**. At least one conductive fibre of network **3555** is attached to connector **3554** to transmit the electric signal from the electric pathway (e.g. network **3555**) to connector **3554**. Connector **3554** is connected to a power source (not shown) to complete the electric circuit. Again, weaving is only one exemplary embodiment of interlacing adjacent conductive fibres, such as fibres **24***a*,*b* as shown in demonstrating the interlacing technique of weaving the sensor **18** containing the fibres **24***a* as connected to the body **13** fibres **24***b* via connecting fibres **24***c*.
(42) It is recognised that in general, a knit fabric is made up of one or more fibres formed into a series of loops that create rows and columns of vertically and horizontally interconnected stitches. A vertical column of stitches is called a wale, and a horizontal row of stitches is called a course.
(43) In view of FIGS. **4***a*,**4***b* and **6**,**7**, the interlacing of the fibres **24***a*, **24***b*, **24***c* (optional) making the sensor **18** in combination with the fabric layer of the body **13** can be provided using knitting as the interlacing method via warp knitting (describing the direction in which the fabric is produced), also referred to as flat knitting, which is a family of knitting methods in which the fibres **24***a*, **24***b*, **24***c* zigzag along the length of the fabric (the combination of the wall structure **28** with the body **13**), i.e. following adjacent columns, or wales, of knitting, rather than a single row (also referred to as weft knitting). A warp knit is made with multiple parallel fibres that are simultaneously looped

vertically (at the same time) to form the fabric. A warp knit is typically produced on a flat-bed knitting machine, which delivers flat yardage. For example, a “Flat” or Vee Bed knitting machine can consists of 2 flat needle beds arranged in an upside-down “V” formation. These needle beds can be up to 2.5 metres wide. A carriage, also known as a Cambox or Head, moves backwards and forwards across these needle beds, working the needles to selectively, knit, tuck or transfer stitches. The flat knitting machine can provide for complex stitch designs, shaped knitting and precise width adjustment. Again as the name infers, flat bed are horizontal needle beds where the yarn is moved across the vee shaped needle bed within feeders.

(44) For comparison, knitting across the width of the fabric is called weft knitting (also referred to as circular knitting), for example see FIG. **6**. Contrary to warp knitting, weft knitting (describing the direction in which the fabric is produced) is such fabric made with a single yarn that's looped to create horizontal rows, or courses, with each row built on the previous row. A weft knits is typically performed on a circular knitting machine, which produces a tube of fabric. For example, circular, as the name infers, is knitting in the round. Here the yarn fed directly [up to 32 separate yarns] into the needle bed that spins around in one direction and creates a tube on fabric through the centre. Simultaneous construction of the desired sensor **18**, in combination with the fabric layer of the body **13**, cannot be performed as desired using circular knitting techniques. Accordingly, for interlacing done as knitting, warp knitting is needed to simultaneous construct the desired sensor **18** in combination with the fabric layer of the body **13**

(45) Further, interlacing of the fibres **24***a*, **24***b*, **24***c* (optional) making up the sensor **18** in combination with the fabric layer of the body **13** can be provided using weaving as the interlacing method, which is composed of a series of warp (lengthwise) fibres interlaced with a series of weft (crosswise) fibres. As such, in a woven fabric, the terms warp and weft refer to the direction of the two sets of fibres making up the fabric. As discussed, the sensors **18** can be integral with the interlacing of the fabric body layer **13**. Alternatively, as discussed, the sensors **18** can be non-integral with the interlacing of the fabric body layer **13**.

Claims

1. An ECG sensor system comprising: a substrate having a first side and a second side being opposed to the first side, the substrate of a non-conducting material; a plurality of textile-based sensors positioned on the first side of the substrate, each of the plurality of textile-based sensors spaced apart from one another on the first side of the substrate, the second side of the substrate opposing the first side and covering one side of each of the plurality of textile-based sensors as an insulating covering, the insulating covering including non-conductive fibres, and wherein each of the plurality of textile-based sensors includes conductive fibres interlaced with one another; and a conductive trace connected to the each of the plurality of textile-based sensors, each of the conductive traces for connecting the plurality of textile-based sensors to controller device for sending and receiving electronic signals from a selected pair of the plurality of textile-based sensors to measure an ECG of a wearer, wherein said plurality of textile-based sensors includes at least one textile-based ECG generator electrode for transmitting a controller-generated signal generated by the controller device through skin of a user, and least one textile-based ECG receiver electrode spaced apart from the textile-based ECG generator electrode, said at least one ECG receiver electrode configured to sense the controller-generated signal through said skin of said user, wherein said controller device is configured to: generate said controller-generated signal; transmit said controller-generated signal through said at least one textile-based ECG generator electrode; sense said controller-generated signal from said at least one textile-based ECG generator electrode via said at least one textile-based ECG receiver electrode; based on said sensing said controller-generated signal, generated by said controller device, and transmitted by said at least one textile-based ECG receiver electrode, determine that said at least one textile-based ECG generator

electrode and/or said at least one textile-based ECG receiver electrode is causing said controller-generated signal that is transmitted through the at least one of the textile-based ECG generator electrode to be of unacceptable signal quality; de-select said at least one textile-based ECG generator electrode and/or said at least one textile based ECG receiver electrode, and select another textile-based ECG generator electrode and/or ECG receiver electrode; and repeat said generating of the controller-generated signal and said sensing of said controller-generated signal using the another textile-based ECG generator electrode and/or ECG receiver electrode.

2. The ECG sensor system of claim 1, wherein the non-conducting material is a non-interlaced material such as plastic.

3. The ECG sensor system of claim 1, wherein the non-conducting material includes non-conductive fibres as an interlaced material selected from the group consisting of: a woven material and a knit material.

4. The ECG sensor system of claim 1, wherein the substrate is in the form of a band and the plurality of textile-based sensors are distributed along the band.

5. The ECG sensor system of claim 1, wherein the plurality of textile-based sensors are divided into a generator group and a receiver group, such that a group spacing between a generator sensor of the generator group and a receiver sensor of the receiver group is larger than spacing between the sensors within the generator group and spacing between the sensors within the receiver group, the generator sensor being adjacent to the receiver sensor.

6. The ECG sensor system of claim 3, wherein the conductive fibres and the non-conductive fibres are interlaced with one another to form an integral interlaced structure.

7. The ECG sensor system of claim 3, wherein the conductive fibres and the non-conductive fibres are connected to one another forming a non-integral structure, such as an applique.

8. The ECG sensor system of claim 6, wherein respective conducting surfaces of the plurality of textile-based sensors is raised from a surrounding insulating surface of the first side.

9. The ECG sensor system of claim 1 further comprising the controller device configured via stored instructions for execution by a computer processor for deselecting at least one of the sensors from the selected pair and selecting a replacement sensor from the plurality of textile-based sensors, a basis for said deselecting based on analysis of a quality of the electronic signals.

10. The ECG sensor system of claim 1 further comprising the controller device configured via stored instructions for execution by a computer processor for alternating different pairings from the plurality of textile-based sensors as the select pair and choosing a determined optimum signal from the electronic signals received from the alternating different pairings.

11. The ECG sensor system of claim 7, wherein respective conducting surfaces of the plurality of textile-based sensors is raised from a surrounding insulating surface of the first side.