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Silveira et al.

(54) **SENSOR CONFIGURATIONS FOR ANATOMICAL VARIATIONS**

(71) Applicant: **COVIDIEN LP**, MANSFIELD, MA (US)

(72) Inventors: **Paulo E.X. Silveira**, Boulder, CO (US); **Sarah Hayman**, Boulder, CO (US); **Jill Klomhaus Anderson**, Longmont, CO (US); **Paul S. Addison**, Edinburgh (GB); **James N. Watson**, Dunfermline (GB)

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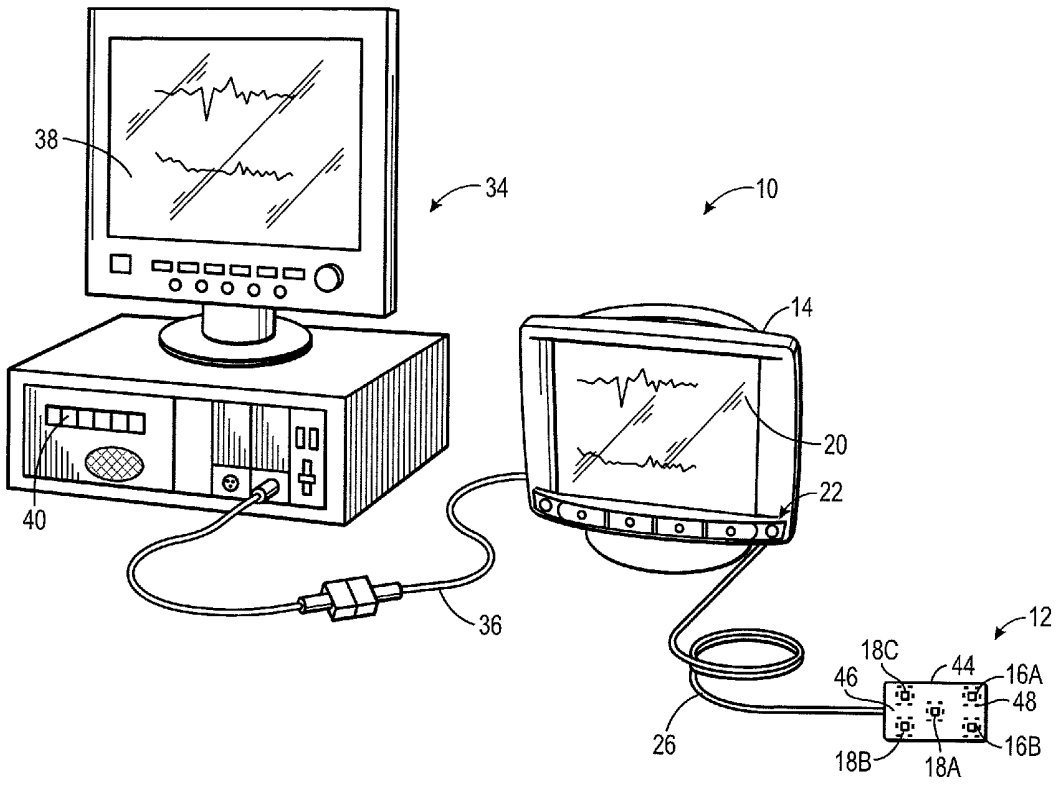
(57) **ABSTRACT**

A medical sensor includes a first set of optical components configured to obtain a first set of signals for determining a first regional oxygen saturation measurement. The first set of optical components includes a first emitter, a first detector separated from the first emitter by a first distance along a first axis, and a second detector separated from the first emitter by a second distance along the first axis, wherein the second distance is greater than the first distance. The sensor also includes a second set of optical components configured to obtain a second set of signals for determining a second regional oxygen saturation measurement. The second set of optical components includes a second emitter and a third detector separated from the second emitter by a third distance along a second axis, different from the first axis.



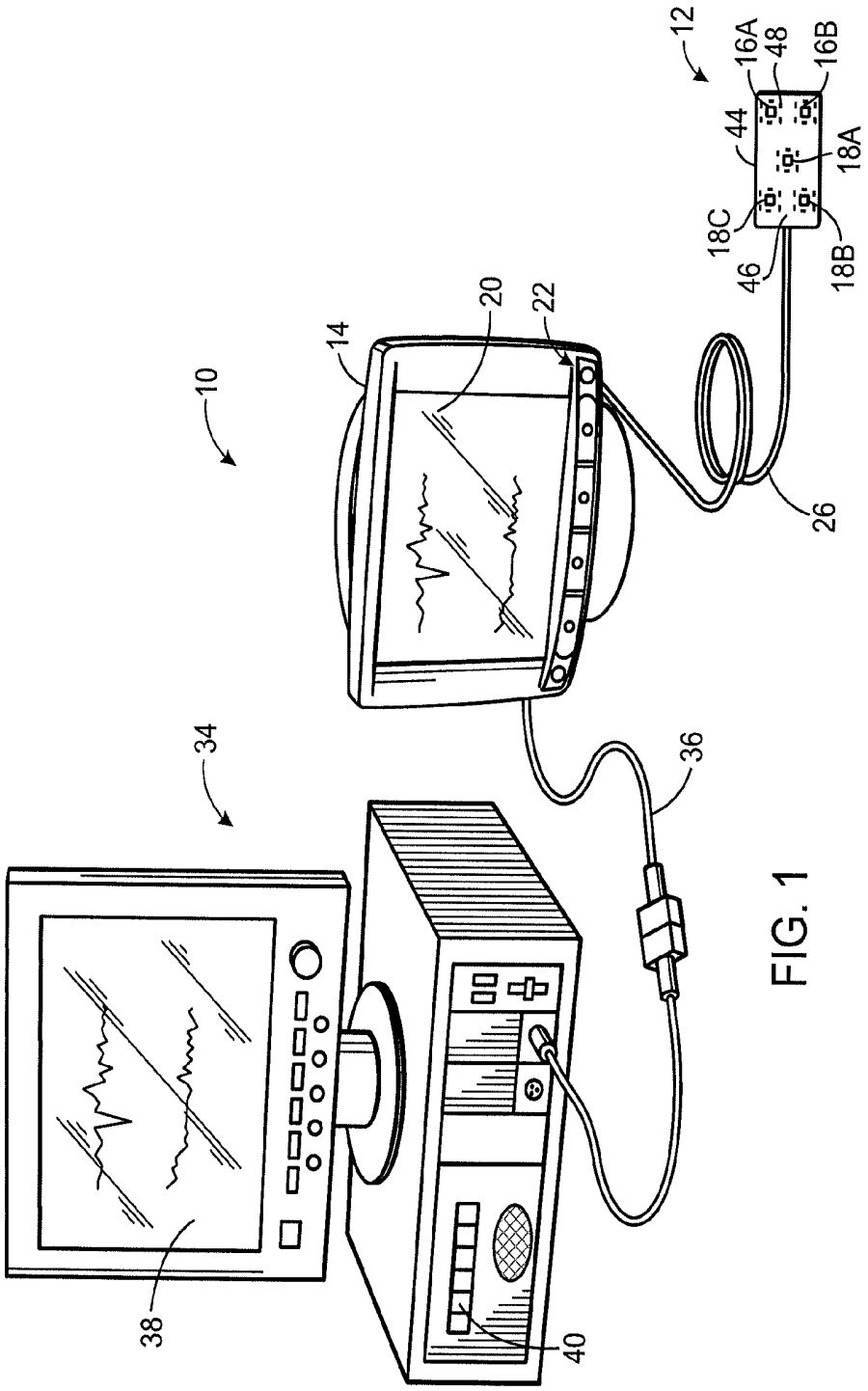


FIG. 1

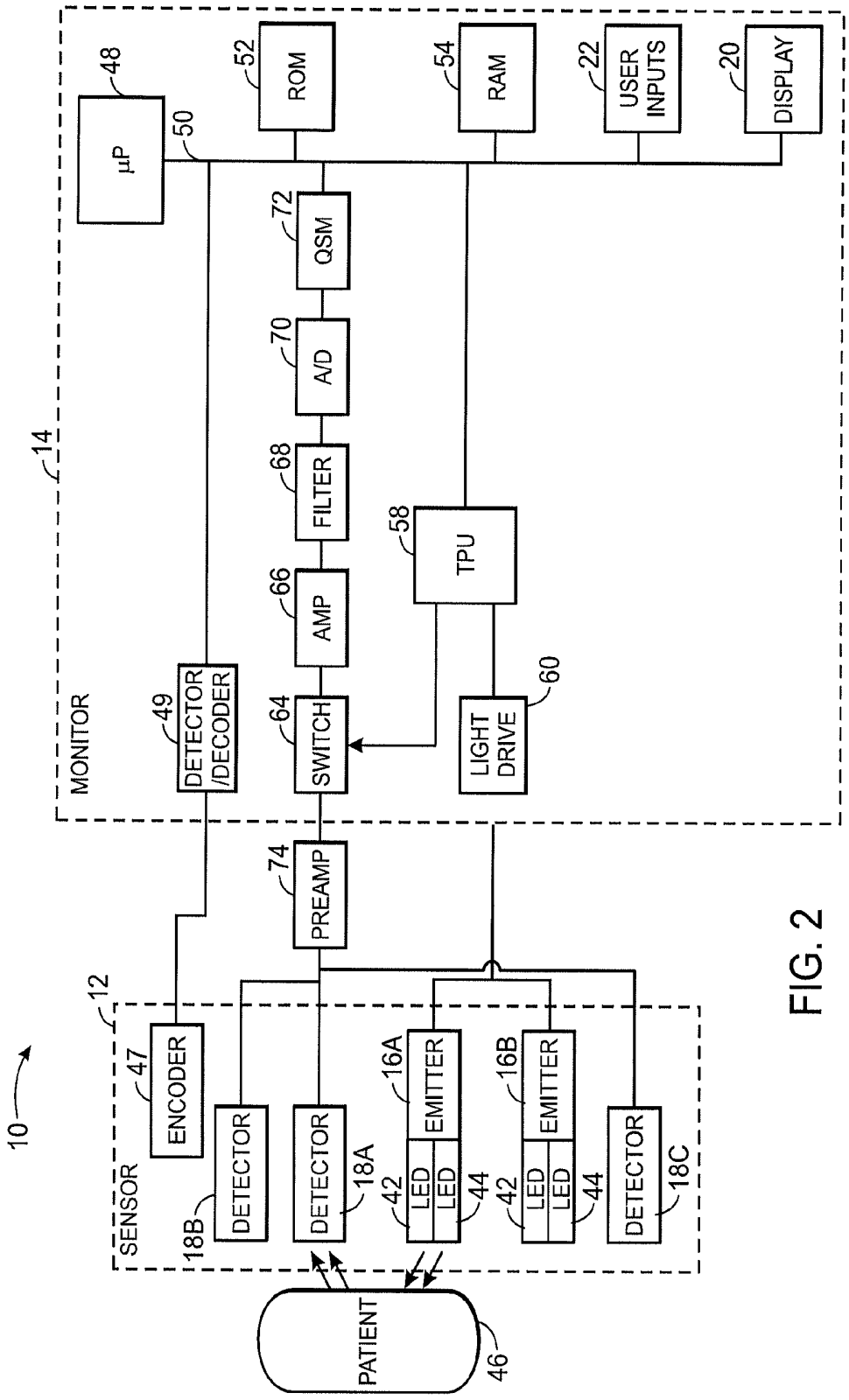

10
MONITOR
14
µP
48
50
ROM
52
RAM
54
USER INPUTS
22
DISPLAY
20
QSM
72
A/D
70
FILTER
68
AMP
66
TPU
58
DETECTOR /DECODER
49
SWITCH
64
LIGHT DRIVE
60
PREAMP
74
SENSOR
12
ENCODER
47
DETECTOR
18B
DETECTOR
18A
16A
EMITTER
LED
LED
42
44
16B
EMITTER
LED
LED
42
44
DETECTOR
18C
PATIENT
46

FIG. 2

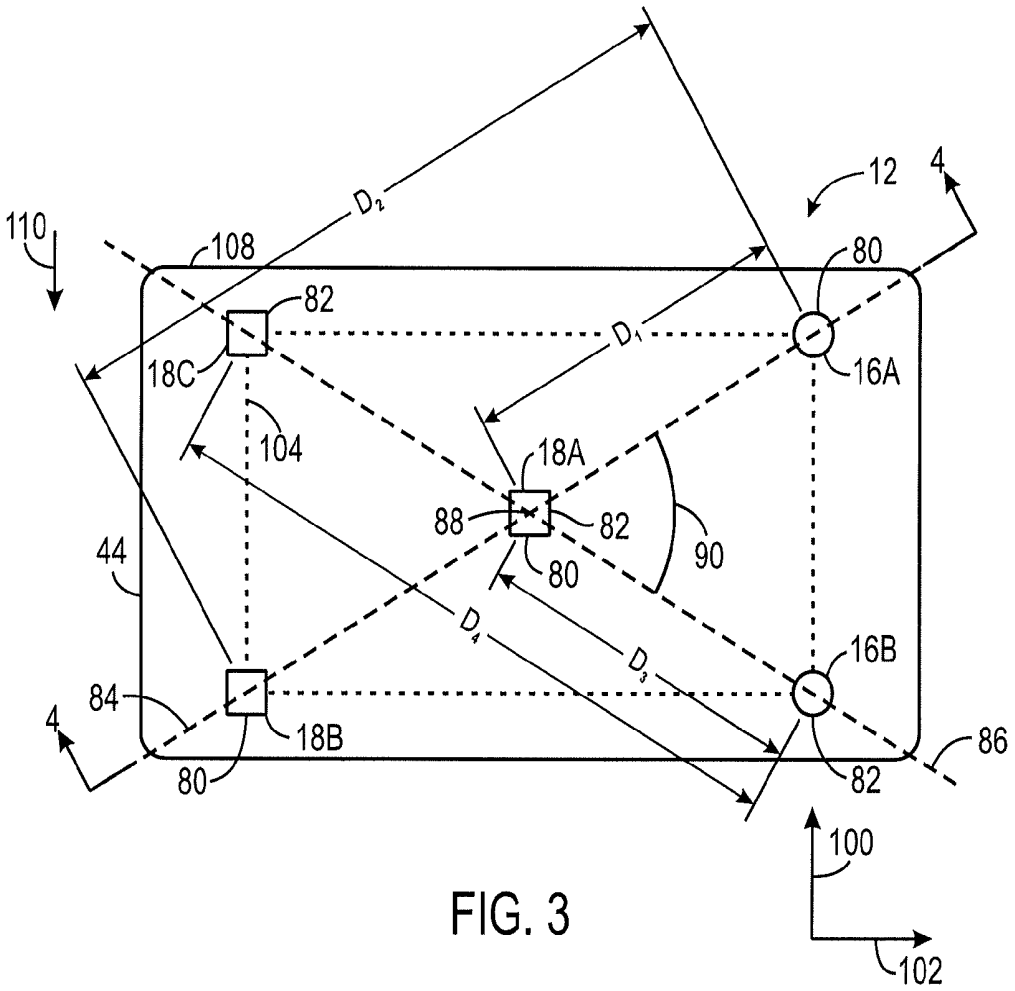

110
108
D_2
12
4
80
82
D_1
16A
18C
104
18A
88
82
90
80
44
D_4
D_3
16B
84
18B
4
80
82
86
100
102

FIG. 3

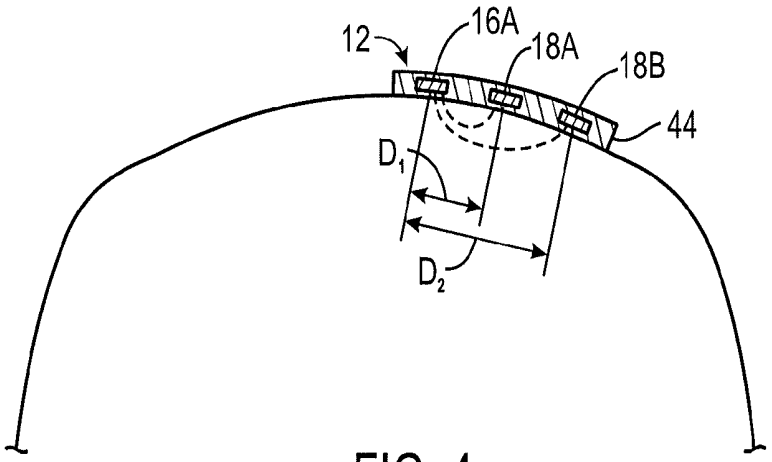

12
16A
18A
18B
44
D_1
D_2

FIG. 4

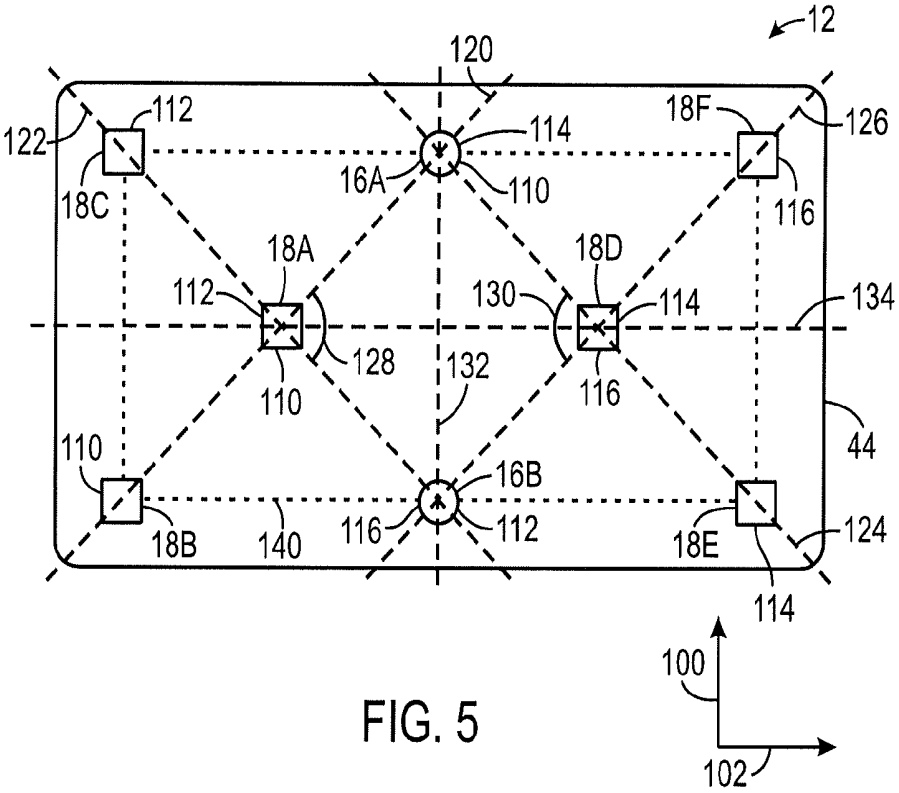

12
120
112
122
114
18F
126
18C
16A
110
116
18A
18D
112
130
114
134
128
132
110
116
110
44
16B
18B
140
116
112
18E
124
114
100
102

FIG. 5

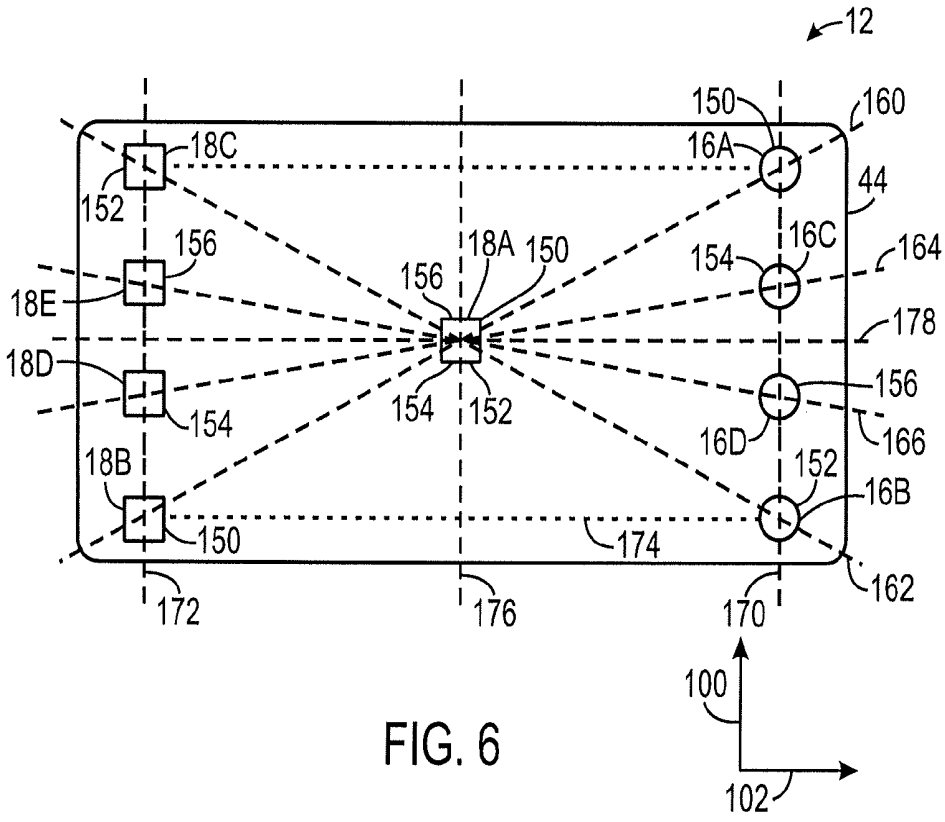

12
150
160
18C
16A
152
44
156
18A
150
16C
154
164
18E
156
178
18D
154
154
152
156
16D
166
18B
152
16B
150
174
172
176
170
162
100
102

FIG. 6

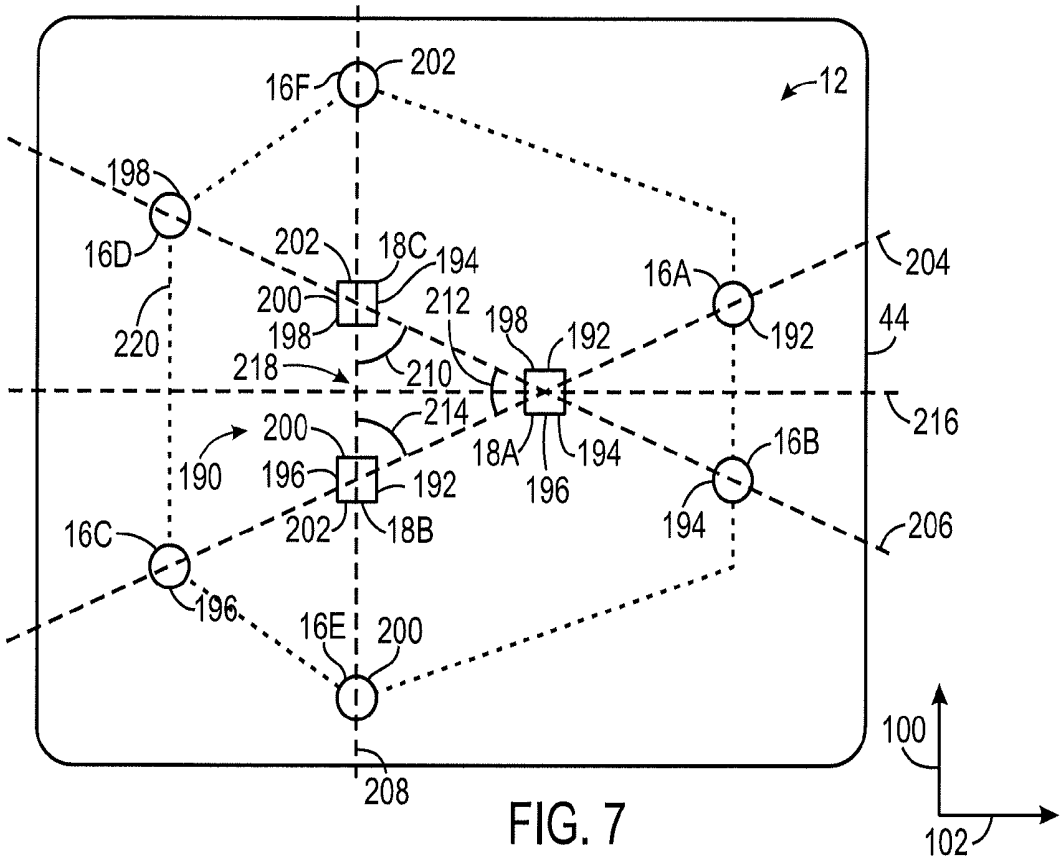

16F
202
12
198
16D
202
18C
194
204
200
212
16A
220
198
198
192
44
192
218
210
216
214
200
18A
194
16B
190
196
192
196
202
18B
194
206
16C
196
16E
200
100
208
102

FIG. 7

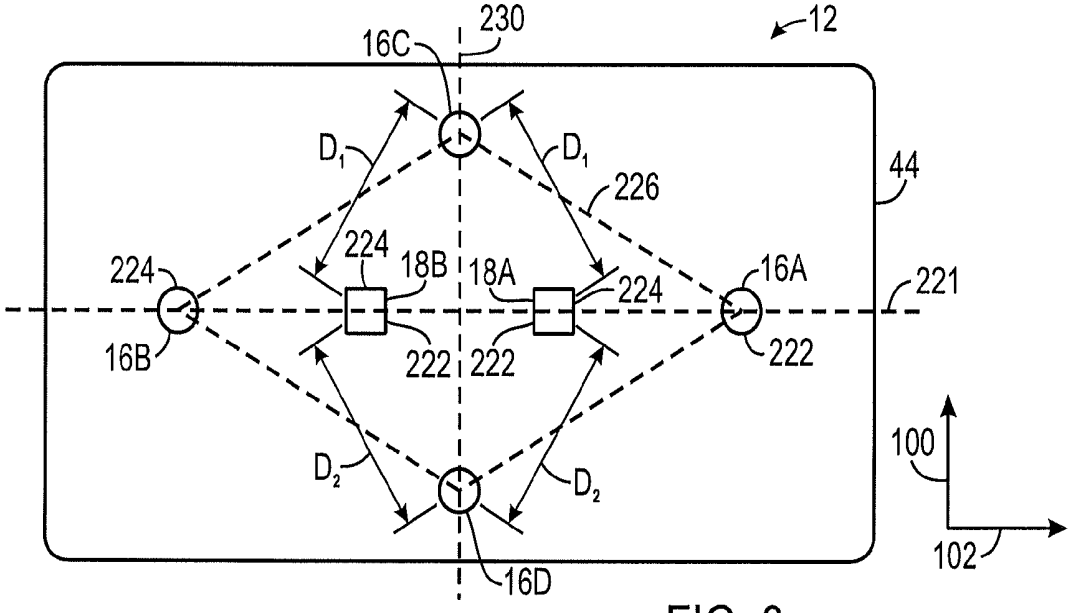

230
16C
12
D1
D1
44
226
224
18B
18A
224
16A
221
224
16B
222
222
222
100
D2
D2
102
16D

FIG. 8

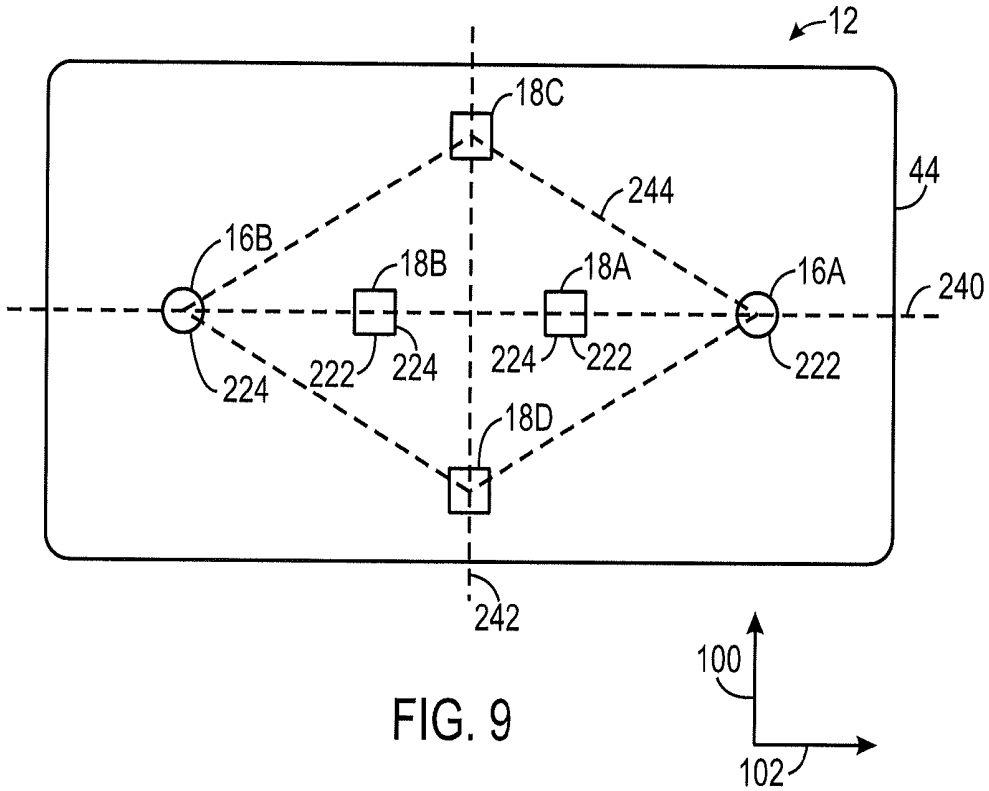

12
18C
44
244
16B
18B
18A
16A
240
224
222
224
224
222
222
18D
242
100
102

FIG. 9

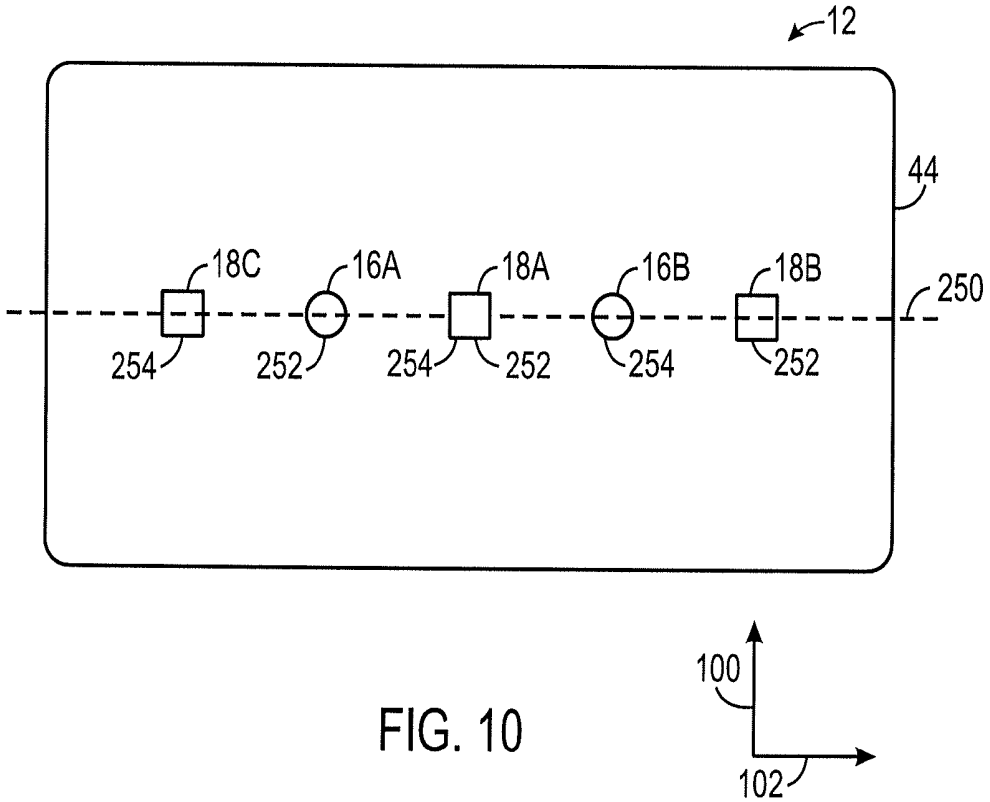

12
44
18C
16A
18A
16B
18B
250
254
252
254
252
254
252
100
102

FIG. 10

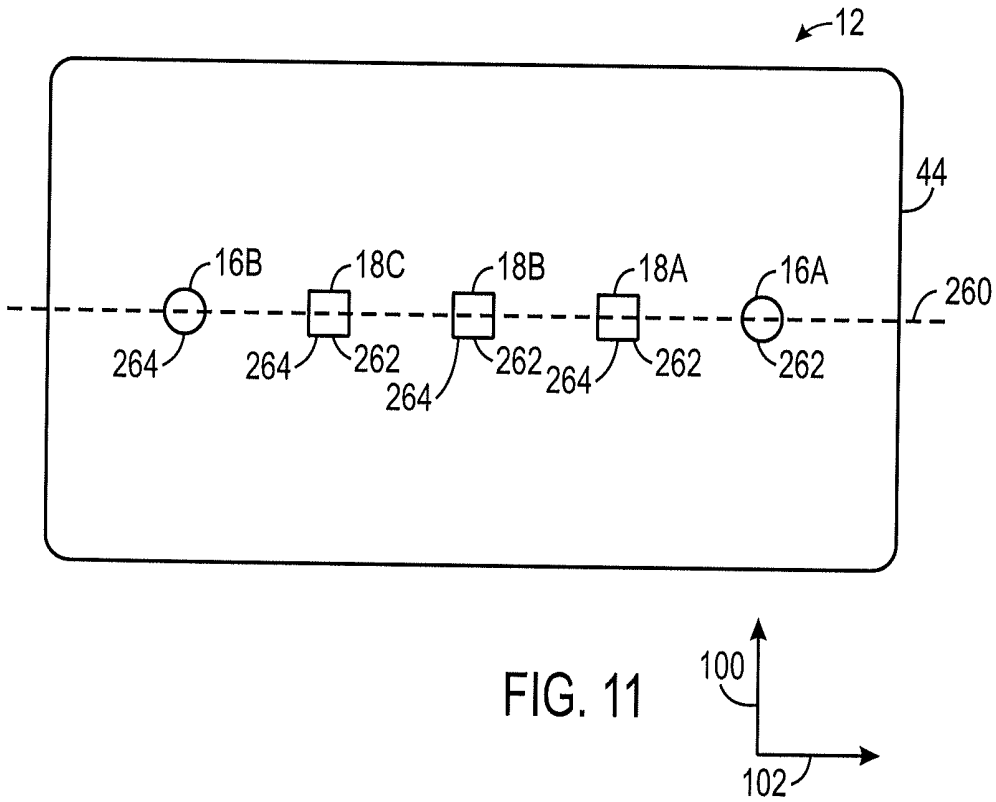

12
44
16B
18C
18B
18A
16A
260
264
262
264
262
264
262
264
262

FIG. 11

100
102

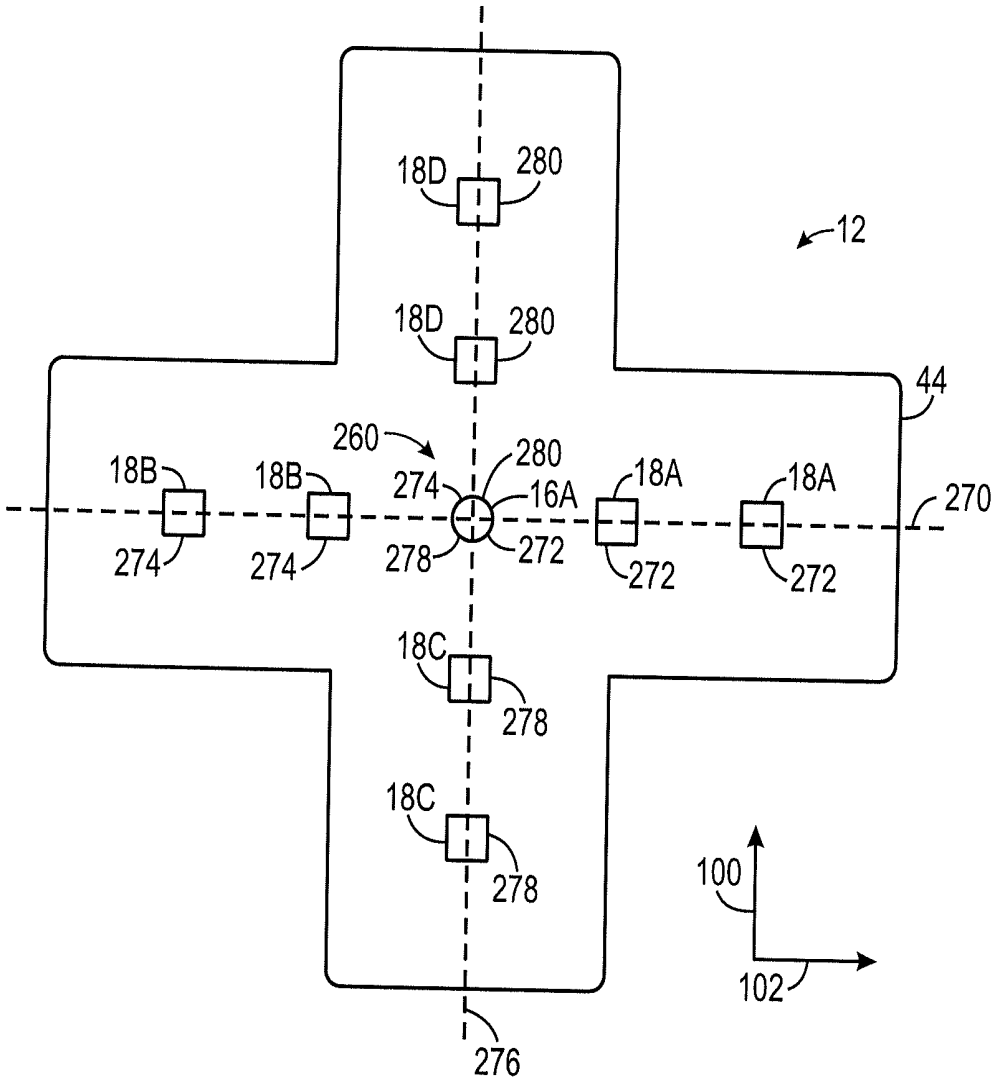

18D
280
12
18D
280
44
260
280
18B
18B
274
16A
18A
18A
270
274
274
278
272
272
272
18C
278
18C
278
100
102
276

FIG. 12

SENSOR CONFIGURATIONS FOR ANATOMICAL VARIATIONS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 61/940,671, filed Feb. 17, 2014, entitled "Sensor Configurations for Anatomical Variations," which is incorporated by reference herein in its entirety.

BACKGROUND

[0002] The present disclosure relates generally to medical devices and, more particularly, to medical sensors and systems for determining physiological parameters, such as plethysmographically-determined parameters.

[0003] This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present disclosure, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

[0004] A wide variety of devices have been developed for non-invasively monitoring physiological characteristics of patients. For example, an oximetry sensor system may non-invasively measure and monitor various blood flow characteristics of a patient, such as a blood oxygen saturation of hemoglobin in arterial blood, a volume of individual blood pulsations supplying the tissue, and/or the rate of blood pulsations corresponding to each heart beat of a patient. During operation, the oximeter sensor emits light and photoelectrically senses the absorption and/or scattering of the light after passage through the perfused tissue. A photoplethysmographic waveform, which corresponds to the cyclic attenuation of optical energy through the patient's tissue, may be generated from the detected light. Additionally, one or more physiological characteristics may be calculated based upon the amount of light absorbed or scattered. More specifically, the light passed through the tissue may be selected to be of one or more wavelengths that may be absorbed or scattered by the blood in an amount correlative to the amount of the blood constituent present in the blood. The amount of light absorbed and/or scattered may then be used to estimate the amount of blood constituent in the tissue using various algorithms.

[0005] For example, a regional saturation sensor may be applied to the patient's head or other body location to monitor the patient. Such sensors generally include one or more emitters that emit the light and one or more detectors that detect the light. The light detected may be used to calculate one or more of the above physiological characteristics based upon the absorption or scattering of light. The one or more emitters and the one or more detectors may be coupled to an oximeter sensor that couples to an oximeter monitor. Attaining accurate and reliable data may be difficult with typical oximeter sensor configurations, which only monitor a relatively small area of the patient's tissue, for example. Additionally, attaining accurate and reliable data may be difficult with typical oximeter sensor configurations due to lack of redundancy and/or symmetry in measurements, and/or due to the limited availability of light penetration depths and tissue monitoring volume provided by such typical sensor configurations.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Advantages of the disclosed techniques may become apparent upon reading the following detailed description and upon reference to the drawings in which:

[0007] FIG. **1** is a front perspective view of an embodiment of a monitoring system configured to be used with a sensor for regional saturation;

[0008] FIG. **2** is a block diagram of the monitoring system of FIG. **1**;

[0009] FIG. **3** is a bottom view of an embodiment of a sensor configured to be used in conjunction with the monitoring system of FIG. **1** to obtain two regional saturation measurements using two emitters and three detectors;

[0010] FIG. **4** is a side view of the sensor of FIG. **3** applied to a patient, in accordance with an embodiment;

[0011] FIG. **5** is a bottom view of an embodiment of a sensor configured to obtain four regional saturation measurements using two emitters and six detectors;

[0012] FIG. **6** is a bottom view of an embodiment of a sensor configured to obtain four regional saturation measurements using four emitters and five detectors;

[0013] FIG. **7** is a bottom view of an embodiment of a sensor configured to obtain six regional saturation measurements using six emitters and three detectors;

[0014] FIG. **8** is a bottom view of an embodiment of a sensor configured to obtain two regional saturation measurements using two emitters and two detectors and having additional emitters configured to monitor tissue uniformity;

[0015] FIG. **9** is a bottom view of an embodiment of a sensor configured to obtain two regional saturation measurements using two emitters configured to emit alternating wavelengths of light and two detectors and having additional emitters configured to monitor tissue uniformity; and

[0016] FIG. **10** is a bottom view of an embodiment of a sensor configured to obtain two regional saturation measurements using emitters and detectors arranged linearly in an alternating pattern;

[0017] FIG. **11** is a bottom view of an embodiment of a sensor configured to obtain two regional saturation measurements using two sensing units, each sensing unit having three detectors; and

[0018] FIG. **12** is a bottom view of an embodiment of a sensor configured to obtain four regional saturation measurements using one emitter and four sets of detectors arranged about the emitter.

DETAILED DESCRIPTION OF SPECIFIC EMBODIMENTS

[0019] One or more specific embodiments of the present techniques will be described below. In an effort to provide a concise description of these embodiments, not all features of an actual implementation are described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but would nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

[0020] When introducing elements of various embodiments of the present disclosure, the articles "a," "an," and "the" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to "one embodiment" or "an embodiment" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

[0021] The present embodiments relate generally to sensor designs or configurations for non-invasive patient monitoring using near-infrared spectroscopy. Such sensors may include optical elements configured for regional oxygen saturation monitoring or photoplethysmography. For example, the sensors disclosed herein may include one or more emitters and one or more detectors for determining the blood oxygen saturation in a particular region of a patient's body, such as a cerebral or somatic region. Further, the sensors disclosed herein may include features to facilitate sensing across multiple tissue levels. In particular embodiments, the disclosed sensors may provide certain advantages over traditional sensors. For example, the sensors described herein may provide symmetry and/or redundancy, for more accurate and/or reliable and/or robust regional oxygen saturation measurements. Additionally, the sensors described herein may be configured to monitor a relatively large two-dimensional area and a relatively large volume of tissue as compared to traditional regional saturation sensors, for example, resulting in increased robustness to variations in sensor placement. Thus, the regional saturation measurements obtained may be less sensitive to non-uniformities in the tissue or local changes in the tissue, and may therefore provide more accurate, reliable, and robust regional saturation measurements for the region or organ of interest. Additionally, although the present embodiments are discussed in the context of regional oxygen saturation, it should be understood that other types of sensors or patient monitoring systems (e.g., those used for measuring arterial oxygen saturation, water fraction, hematocrit, or bispectral index) may benefit from the configurations and/or techniques disclosed herein.

[0022] With the foregoing in mind, FIG. **1** depicts an embodiment of a patient monitoring system **10** that may be used in conjunction with a medical sensor **12**. In certain embodiments, the features of the sensor **12** as provided herein may be incorporated into sensors for use at a wide variety of tissue locations, such as a head, back, a stomach, a heel, an arm, a leg, an ear, or any other appropriate measurement site. In addition, although the embodiment of the patient monitoring system **10** illustrated in FIG. **1** relates to photoplethysmography or regional oximetry, the system **10** may be configured to obtain a variety of medical measurements with any suitable medical sensor. For example, the system **10** may, additionally be configured to determine blood pressure, respiration rate, patient electroencephalography (e.g., a bispectral index), or any other desired physiological parameter.

[0023] As noted, the system **10** includes the sensor **12** that is communicatively coupled to a patient monitor **14**. Although only one sensor **12** is shown coupled to the monitor **14** in FIG. **1**, in other embodiments, two, three, four, or more sensors **12** may be coupled to the monitor **14**. The sensor **12** may include one or more emitters **16** and one or more detectors **18**. In the particular embodiment illustrated, the sensor **12** includes two emitters **16**A, **16**B and three detectors **18**A, **18**B, **18**C. Each of the emitters **16** and the detectors **18** of the sensor **12** are coupled to the monitor **14** via a cable **26** coupled to the monitor **14**. The cable **26** may interface directly with the sensor **12** and may include a plurality of conductors (e.g., wires).

[0024] The monitor **14** includes a monitor display **20** configured to display information regarding the physiological parameters monitored by the sensor **12**, information about the system **10**, and/or alarm indications, for example. The monitor **14** may include various input components **22**, such as knobs, switches, keys and keypads, buttons, etc., to facilitate operation and configuration of the monitor **14**. As discussed in more detail below, the monitor **14** also includes a processor that may be used to execute code, such as code for implementing any of the various monitoring functionalities enabled by the sensor **12**. For example, the monitor **14** may be configured to process signals generated by the detectors **18** to estimate the amount of oxygenated hemoglobin in a monitored region of the patient.

[0025] In some embodiments, the monitor **14** may be coupled to a multi-parameter patient monitor **34** via a cable **36** connected to a sensor input port. In addition to the monitor **14**, or alternatively, the multi-parameter patient monitor **34** may be configured to calculate physiological parameters and to provide a central display **38** for the visualization of information from the monitor **14** and from other medical monitoring devices or systems. The multi-parameter monitor **34** includes a processor that may be configured to execute code. The multi-parameter monitor **34** may also include various input components **40**, such as knobs, switches, keys and keypads, buttons, etc., to provide for operation and configuration of the multi-parameter monitor **34**. In addition, the monitor **14** and/or the multi-parameter monitor **34** may be connected to a network to enable the sharing of information with servers or other workstations.

[0026] In certain embodiments, the sensor **12** may be a wireless sensor **12**. Accordingly, the sensor **12** may establish a wireless communication with the patient monitor **14** and/or the multi-parameter patient monitor **34** using any suitable wireless standard. The patient monitor **14** may establish a wireless communication with the multi-parameter patient monitor **34**. By way of example, the wireless module may be capable of communicating using one or more of the ZigBee standard, WirelessHART standard, Bluetooth standard, IEEE 802.11x standards, or MiWi standard. In certain embodiments, a pre-amplifier (see FIG. **2**) may be provided between the sensor **12** and the monitor **14** to convert analog signals into digital signals, computer parameters, and/or communicate the same robustly to the monitor **14**, for example.

[0027] The sensor **12**, illustrated as operatively connected to the monitor **14**, may include a sensor body **44** (e.g., a substrate) that houses and/or supports the one or more emitters **16** for emitting light at certain wavelengths into a tissue of a patient and the one or more detectors **18** for detecting the light after it is reflected and/or absorbed by the blood and/or tissue of the patient. The sensor body **44** may be formed from any suitable material, including rigid or conformable materials, such as fabric, paper, rubber or elastomeric compositions (including acrylic elastomers, polyimide, silicones, silicone rubber, celluloid, PDMS elastomer, polyurethane, polypropylene, acrylics, nitrile, PVC films, acetates, or latex).

[0028] A patient-contacting surface **46** of the sensor **12** may be an adhesive layer, in some embodiments. Thus, the patient-contacting surface **46** may include any adhesive mate-

rial suitable for integration into medical devices (e.g., a hypoallergenic adhesive material). In some embodiments, the adhesive material may be substantially transparent with respect to the wavelengths of light used for the oximetry measurements performed by the sensor **12**. In other embodiments where the patient-contacting adhesive layer **46** is not transparent with respect to the wavelengths of light used for the oximetry measurements, the patient-contacting adhesive layer **46** may include optical windows **48** (e.g., openings), illustrated as dashed lines, corresponding to the respective positions of the one or more emitters **16** and the one or more detectors **18**. By way of example, the patient-contacting surface **46** may include an acrylic adhesive, a silicon-based adhesive, or a hydrocolloid adhesive. Generally, hydrocolloid adhesives may provide enhanced comfort for the patient and avoid damage to the patient's skin when the sensor **12** is removed or repositioned. A release liner may also be provided to prevent the inadvertent attachment of the patient-contacting surface **46** to a surface before the intended use of the sensor **12**. The release liner may include any liner having a release material suitable for use with the patient-contacting surface **46**, such as a coated release paper or a release plastic film. Example release materials include polyolefins (e.g., polypropylene, high- and low-density polyethylene), polyesters (e.g., biaxially-oriented polyethylene terephthalate), polyvinyl alcohol, polystyrene, or the like.

[0029] As provided herein, the sensor **12** may be configured to perform regional oximetry. In regional oximetry, by comparing the relative intensities of light received at two or more detectors **18**, it is possible to estimate the blood oxygen saturation of hemoglobin in a region of a body. Whereas pulse oximetry measures blood oxygen based on changes in the volume of blood due to pulsing tissue (e.g., arteries), regional oximetry typically examines blood oxygen saturation within the venous, arterial, and capillary systems within a region of a patient. For example, a regional oximeter system **10** may include the sensor **12** configured to be placed on a patient's forehead and may be used to calculate the oxygen saturation of a patient's blood within the venous, arterial, and capillary systems of a region underlying the patient's forehead (e.g. in the cerebral cortex). As illustrated in FIG. **1**, the sensor **12** may include two emitters **16**A, **16**B (e.g., a first emitter and a second emitter) and three detectors **18**: one detector **18**A (e.g., a first detector) that is relatively "close" to the emitters **16**A, **16**B and two detectors **18**B, **18**C (e.g., a second detector and a third detector) that are relatively "far" from the two emitters **16**A, **16**B. Light intensity of one or more wavelengths may be received at the "close" and the "far" detectors **18**A, **18**B, **18**C. Thus, the close detector **18**A may receive a first portion of light and the far detectors **18**B, **18**C may receive a second portion of light. Each of the detectors **18** may generate signals indicative of their respective portions of light, and the resulting signals may be compared to arrive at a regional saturation value that pertains to additional tissue through which the light received at the "far" detector **18**B, **18**C passed (tissue in addition to the tissue through which the light received by the close detector **18**A passed, e.g., the brain tissue) when it was transmitted through a region of a patient (e.g., a patient's cranium).

[0030] In certain embodiments, light emitted by the first emitter **16**A may be received at the first detector **18**A and the second detector **18**B, and the signals generated based on the light received by the first detector **18**A and the second detector **18**B may be utilized to generate a first oxygen saturation value. Additionally or alternatively, light emitted by the second emitter **16**B may be received at the first detector **18**A and the third detector **18**C, and the signals generated based on the light received by the first detector **18**A and the third detector **18**C may be compared to generate a second oxygen saturation value. For example, the first and the second regional oxygen saturation values may be determined via the following equations:

$$R=\ln([I_1(\lambda_1)]/[I_1(\lambda_2)/I_2(\lambda_2)]) \quad (1)$$

and

$$rSO_2=S=R(AMb(r_2-r_1)[c])^{-1}-(B/A) \quad (2)$$

[0031] In the above equations, I_1, I_2, r_1, and r_2 are the signal intensities and distances between the near detector **18**A and the far detectors **18**B, **18**C, respectively. λ_1 and λ_2 refer to the two wavelengths of light emitted by each of the emitters **16**A, **16**B, and A and B are constants related to the extinction coefficients of oxygenated and reduced hemoglobin. In certain embodiments, the second wavelength (λ_2) may be an isobestic point (e.g., 804 nm). As discussed in more detail below, in some embodiments, the wavelengths of light emitted by one emitter (e.g., emitter **16**A) may be different and/or alternate with the wavelengths of light emitted by another emitter (e.g., emitter **16**B). [c] is the combined concentration of all hemoglobin, additionally factored by the concentration of blood in the tissue. Mb is an empirically determined constant related to the mean path length of light through the subdermal tissue. The foregoing is merely illustrative and any suitable equations and/or processing techniques may be used to calculate regional oximetry values, in accordance with the present embodiments. Additionally, surface data from the skin and skull may be subtracted out to produce a regional oxygen saturation (rSO_2) value for deeper tissues. Other methods to calculate regional blood oxygen saturation, such as those provided in U.S. Pat. Nos. 5,139,025 and 5,217,013 or U.S. Patent Publication No. 2011/0112387, filed Nov. 12, 2009, the disclosures of which are incorporated by reference in their entirety herein for all purposes, may be employed.

[0032] Turning to FIG. **2**, a block diagram of an embodiment of the medical system **10** of FIG. **1** is illustrated. The sensor **12** may include optical components in the form of one or more emitters **16** and one or more detectors **18**. As shown, the sensor **12** includes two emitters **16**A, **16**B and three detectors **18**A, **18**B, **18**C. The one or more emitters **16** and the one or more detectors **18** may be arranged in a reflectance or transmission-type configuration with respect to one another. However, in embodiments in which the sensor **12** is configured for use on a patient's forehead, the one or more emitters **16** and the one or more detectors **18** may be in a reflectance configuration.

[0033] The one or more emitters **16** may be a light emitting diode, superluminescent light emitting diode, a laser diode, or a vertical cavity surface emitting laser (VCSEL). The one or more emitters **16** and the one or more detectors **18** may include optical fiber sensing elements. The one or more emitters **16** may include a broadband or "white light" source, in which case the one or more detectors **18** could include any of a variety of elements for selecting specific wavelengths, such as reflective or refractive elements or interferometers. Alternatively, the sensor **12** may sense light detected from the tissue is at a different wavelength from the light emitted into the tissue. Such sensors may be adapted to sense fluores-

cence, phosphorescence, Raman scattering, Rayleigh scattering and multi-photon events, or photoacoustic effects.

[0034] In one embodiment, the one or more emitters **16** may be configured for use in a regional saturation technique. To that end, each of the one or more emitters **16** may include two light emitting diodes (LEDs) **42** and **44** (e.g., a first LED and a second LED) that are configured to emit at least two wavelengths of light, e.g., red or near infrared light. In one embodiment, the LEDs **42** and **44** emit light in the range of 600 nm to about 1000 nm. In a particular embodiment, the first LED **42** is configured to emit light at about 730 nm and the second LED **44** is configured to emit light at about 810 nm. In some embodiments, as discussed in more detail below, one or more emitters **16** may be configured to provide wavelengths of light different from other emitters **16** of the sensor **12**. For example, the LEDs **42** and **44** of the first emitter **16**A may provide two wavelengths of light (e.g., about 724 nm and 812 nm, respectively), and the LEDs **42** and **44** of the second emitter **16**B may provide two wavelengths of light (e.g., about 770 nm and 850 nm, respectively) different from the two wavelengths of light provided by the first emitter **16**A. It should be understood that, as used herein, the term "light" may refer to one or more of ultrasound, radio, microwave, millimeter wave, infrared, visible, ultraviolet, gamma ray or X-ray electromagnetic radiation, and may also include any wavelength within the radio, microwave, infrared, visible, ultraviolet, or X-ray spectra, and that any suitable wavelength of light may be appropriate for use with the present disclosure.

[0035] In any suitable configuration of the sensor **12**, the one or more detectors **18** may each be an array of detector elements configured to detect light at various intensities and wavelengths. In one embodiment, light enters the one or more detectors **18** after passing through the tissue of the patient **46**. In another embodiment, light emitted from the one or more emitters **16** may be scattered by multiple elements in the patent's tissue to be reflected back and enter the one or more detectors **18**. The one or more detectors **18** may convert the received light at a given intensity, which may be directly related to the absorbance and/or scattering of light in the tissue of the patient **46**, into an electrical signal. That is, when more light at a certain wavelength is absorbed, less light of that wavelength is typically received from the tissue by the one or more detectors **18**, and when more light at a certain wavelength is scattered and reflected back, more light of that wavelength is typically received from the tissue by the one or more detectors **18**. After converting the received light to an electrical signal, the one or more detectors **18** may send the signal to the monitor **14**, where physiological characteristics may be calculated based at least in part on the absorption and/or scattering of light by the tissue of the patient **46**.

[0036] In certain embodiments, the medical sensor **12** may also include an encoder **47** that may provide signals indicative of the wavelength of one or more light sources of the one or more emitters **16**, which may allow for selection of appropriate calibration coefficients for calculating a physical parameter such as blood oxygen saturation. The encoder **47** may, for instance, include a coded resistor, an electrically erasable programmable read only memory (EEPROM), or other coding device (such as a capacitor, inductor, programmable read only memory (PROM), RFID, parallel resident currents, or a colorimetric indicator) that may provide a signal to a microprocessor **48** related to the characteristics of the medical sensor **12** to enable the microprocessor **48** to determine the appropriate calibration characteristics of the medical sensor **12**. The encoder **47** may also include information related to the number of emitters **16**, the number of detectors **18**, and/or the configuration of and/or spacing between the emitters **16** and detectors **18**, for example. Further, the encoder **47** may include encryption coding that prevents a disposable part of the medical sensor **12** from being recognized by a microprocessor **48** unable to decode the encryption. For example, a detector/decoder **49** may translate information from the encoder **47** before it can be properly handled by the processor **48**. In some embodiments, the encoder **47** and/or the detector/decoder **49** may not be present.

[0037] Signals from the one or more detectors **18** and/or the encoder **47** may be transmitted to the monitor **14**. The monitor **14** may include one or more processors **48** coupled to an internal bus **50**. Also connected to the bus **50** may be a ROM memory **52**, a RAM memory **54**, and the display **20**. A time processing unit (TPU) **58** may provide timing control signals to light drive circuitry **60**, which controls when each of the one or more emitters **16** are activated, and if multiple light sources are used, the multiplexed timing for the different light sources. It is envisioned that the emitters **16** may be controlled via time division multiplexing of the light sources. Thus, in some embodiments, the light from each of the one or more emitters **16** may be emitted in staggered, or alternating, manner TPU **58** may also control the gating-in of signals from the one or more detectors **18** through a switching circuit **64**. These signals are sampled at the proper time, depending at least in part upon which of the multiple light sources is activated, if multiple light sources are used. In certain embodiments, multiple emitters **16** may emit different wavelengths of light simultaneously, and the signals received by the one or more detectors **18** may be separated (e.g., filtered) based on wavelength or a modulation frequency, for example, to enable determination of one or more regional saturation measurements using the appropriate signals. The received signal(s) from the one or more detectors **18** may be passed through an amplifier **66**, a low pass filter **68**, and an analog-to-digital converter **70** for amplifying, filtering, and digitizing the electrical signals from the ear sensor **12**. The digital data may then be stored in a queued serial module (QSM) **72**, for later downloading to RAM **54** as QSM **72** fills up. In an embodiment, there may be multiple parallel paths for separate amplifiers, filters, and A/D converters for multiple light wavelengths or spectra received.

[0038] In an embodiment, based at least in part upon the received signals corresponding to the light received by the detector **18**, the processor **48** may calculate the oxygen saturation using various algorithms, such as the algorithms set forth above with respect to FIG. **1**. These algorithms may use coefficients, which may be empirically determined For example, algorithms relating to the distance between the one or more emitters **16** and the one or more detectors **18** may be stored in the encoder **47**, the ROM memory **52**, or any suitable location, and accessed and operated according to processor **48** instructions.

[0039] Furthermore, one or more functions of the monitor **14** may be implemented by a pre-amplifier **74**. In some embodiments, the pre-amplifier **74** may be configured to carry out all of the functions of the monitor **14**, except for providing the display **20** and the user inputs **22**. In certain embodiments, one or more functions of the monitor **14** may be implemented directly in the sensor **12**. For example, in some embodiments, the sensor **12** may include one or more

processing components capable of calculating the physiological characteristics from the signals obtained from the patient **46**. In accordance with the present techniques, the sensor **12** may be configured to provide desired contact between the patient **46** and the detector **18**, and/or the emitter **16**. The sensor **12** may have varying levels of processing power, and may output data in various stages to the monitor **14**, either wirelessly or via the cable **26**. For example, in some embodiments, the data output to the monitor **14** may be analog signals, such as detected light signals (e.g., oximetry signals or regional saturation signals), or processed data.

[0040] In some embodiments, the sensor **12** may include one or more emitters **16** and/or one or more detectors **18** configured to provide multiple regional saturation measurements. Such configurations may be utilized to monitor regional saturation across a large surface area of the patient's tissue and/or to provide useful comparative measurements and/or redundancy, for example. FIG. **3** is an embodiment of the sensor **12** that includes multiple optical elements (e.g., one or more emitters **16** and one or more detectors **18**) arranged on the sensor body **44** to facilitate patient monitoring. As shown, the sensor **12** includes two emitters **16**A, **16**B and three detectors **18**A, **18**B, **18**C arranged in the configuration shown in FIG. **1**. In the illustrated embodiment, the first emitter **16**A is configured to be used with the first detector **18**A and the second detector **18**B to obtain a first regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the second detector **18**B form a first set of detectors, and the first emitter **16**A and the first set of detectors (i.e., the first detector **18**A and the second detector **18**B) form a first sensing unit **80** (e.g., a set of optical components or a regional saturation sensing unit) for obtaining the first regional saturation measurement. As depicted, the sensor **12** also includes the second emitter **16**B configured to be used with the first detector **18**A and the third detector **18**C to obtain a second regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the third detector **18**C form a second set of detectors, and the second emitter **16**B and the second set of detectors (i.e., the first detector **18**A and the third detector **18**C) form a second sensing unit **82** for obtaining the second regional oxygen saturation measurement. Although only two sensing units **80**, **82** are depicted in FIG. **3**, it should understood that any suitable number of sensing units may be provided to obtain any desired number of regional oxygen saturation values.

[0041] In the depicted configuration, the emitter **16**A of the first sensing unit **80** is a first distance D_1 from the first detector **18**A and a second distance D_2 from the second detector **18**B. As shown, the distance D_1 is less than D_2. In addition, the second emitter **16**B of the second sensing unit **82** is positioned a third distance D_3 from the first detector **18**A and a fourth distance D_4 from the second detector **18**C. As shown, the distance D_3 is less than D_4. As discussed in more detail below, the optical components of the sensing units **80**, **82** may be arranged symmetrically, and thus, in certain embodiments, the distance D_1 may be equal to D_3 and/or the distance D_2 may be equal to D_4. Such a configuration (e.g., symmetrical and/or equal distances as noted above) may provide redundant measurements, and the redundancy can be used to increase the accuracy and/or robustness of the measurement. The accuracy can be increased, for example, by averaging the measurements from each of the sensing units **80**, **82**, for example. The robustness can be increased, for example, by rejecting the measurement that presents the highest amount of noise (e.g., estimated by the standard deviation of the signal), or by rejecting that measurement which deviates the most from the median value of combined measurements, as discussed in more detail below.

[0042] With reference to FIG. **4**, which shows a side-cross sectional view of the sensor **12** of FIG. **3** taken along line **4-4**, the emitter-detector spacing at the first distance D_1 represents a shallower optical path and the emitter-detector spacing at the second distance D_2, greater than the first distance D_1, represents a deeper optical path for tissue penetration (e.g., cranial penetration). In certain embodiments, distance D_1 is about 75% of the distance D_2. In a particular embodiment, distance D_1 is about 30 mm and distance D_2 is about 40 mm. In other embodiments, D_1 may be approximately 1-3 centimeters (cm) and D_2 may be approximately 3-4 cm. Each sensing unit of the sensor **12**, for example the first and second sensing units **80**, **82** of FIG. **3**, may have similar emitter-detector spacing. For example, the third distance D_3 in FIG. **3** represents a shallower optical path and the emitter-detector spacing at the fourth distance D_4, greater than the third distance D_3, represents a deeper optical path for tissue penetration. In certain embodiments, distance D_3 is about 75% of the distance D_4. In a particular embodiment, distance D_3 is about 30 mm and distance D_4 is about 40 mm. In other embodiments, D_3 may be approximately 1-3 centimeters (cm) and D_4 may be approximately 3-4 cm.

[0043] Turning again to FIG. **3**, the first and the second sensing units **80**, **82** may be arranged in a generally X-shaped configuration such that a first axis **84** of the first sensing unit **80** intersects a second axis **86** of the second sensing unit **82**. Where the first and the second sensing units **80**, **82** both include the first detector **18**A (e.g., light from the first emitter **16**A and light from the second emitter **16**B is detected at the first detector **18**A and is utilized to determine the first and the second regional oxygen saturation measurements), a point of intersection **88** of the first axis **84** and the second axis **86** is located at the first detector **18**A, as shown. In some such embodiments, the first axis **84** and the second axis **86** are positioned at an angle **90** relative to one another. The angle **90** may be any suitable angle. For example, the angle may be between about 10-90 degrees, 20-80 degrees, 30-70 degrees, 40-60 degrees, or between about 45-55 degrees.

[0044] As shown in FIG. **3**, the one or more emitters **16** and the one or more detectors **18** may be arranged to provide (e.g., form) a two-dimensional monitoring area **104** (e.g., a two-dimensional area of contact between the sensing units and a surface of the patient's skin when applied to the patient). In the embodiment of FIG. **3**, the two-dimensional monitoring area **104** is defined by the first emitter **16**A, the second emitter **16**B, the second detector **18**B, and the third detector **18**C. In the illustrated embodiment, the angle **90** and/or the distances d between the one or more emitters **16** and the one or more detectors **18** may affect the size and geometry (e.g., shape) of the two-dimensional monitoring area **104**. For example, the first and second sensing units **80**, **82**, and thus, the two-dimensional monitoring area **104** may extend about 0.5-6 cm along a vertical axis **100** of the sensor **12** and/or about 3-8 cm along a horizontal axis **102** of the sensor **12**. The two-dimensional monitoring area **104** may have any suitable size. In certain embodiments, the two-dimensional monitoring area **104** may be approximately 6, 7, or 8 cm^2. In some embodiments, the two-dimensional monitoring area **104** may be greater than approximately 5, 10, 15, 20, or 25 cm^2. In some

embodiments, the two-dimensional monitoring area **104** may be about 5-20, 6-15, or 7-10 cm^2. A larger two-dimensional monitoring area **104** may result in a larger volume of tissue being monitored, which results in decreased sensitivity to variations in sensor placement. For example, in medical settings, sensors **12** are often applied to the patient at a first (e.g., original) location, removed from the patient, and subsequently replaced on the patient close to or in the same general region of the original location (e.g., the forehead, the abdomen, or the like). Sensors **12** configured to monitor a larger volume of tissue may result in a larger fraction of the volume of tissue that is monitored before replacement being monitored after replacement, resulting in decreased variation in signals before and after replacement of the sensor **12**. Moreover, sensors **12** configured to monitor a larger volume of tissue may result in decreased sensitivity to localized physiological variations. This decreased sensitivity is desirable since clinicians may be interested in monitoring a whole organ (e.g., the brain) rather than a small fraction of the organ.

[0045] Further, the first detector **18**A may be smaller in size than the second and/or third detector **18**B, **18**C in order to equalize the differences in light intensity received/detected due to the distance of the detector from corresponding emitters **16**A, **16**B. Thus, the size of the detector **18**A, **18**B, **18**C may be a function of the distance of the detector **18**A, **18**B, **18**C from the corresponding emitter **16**A, **16**B. The size and/or the distance of the detectors **18**A, **18**B, **18**C from the corresponding emitter **16**A, **16**B may be a function of a desired mean path length of light traversing through human tissue. As noted above, although two emitters **16**A, **16**B and three detectors **18**A, **18**B, **18**C are depicted in FIG. **3**, any suitable number of detectors **18** or emitters **16** may be utilized. Further, although the two sensing units **80**, **82** each include two detectors **18**, it should be understood that three or more detectors **18** may be provided in the set of detectors **18** for one or more of the sensing units **80**, **82**. Additionally, although two sensing units **80**, **82** for obtaining two regional saturation measurements are depicted, any suitable number of sensing units may be provided.

[0046] With reference to FIG. **3**, the monitor **14** may be configured to receive signals from each of the detectors **18** of each sensing unit **80**, **82** and to process the signals to determine the first and second regional oxygen saturation measurements. In certain embodiments, the monitor **14** may be configured to analyze the signals received and/or to analyze the first and second regional oxygen saturation measurements (e.g., quantitative values) to make various determinations. For example, the monitor **14** may compare the signals and/or the measurements. The monitor **14** may determine an average of the measurements. The monitor **14** may determine a median of the measurements, which may facilitate exclusion of outliers, for example. The monitor **14** may omit one or more measurements that exceed a predetermined threshold or are greater than a certain number of standard deviations away from the predetermined threshold or the average, which may facilitate exclusion of outliers, for example. The monitor **14** may determine a signal-to-noise ratio (SNR) of each of the signals, arbitrate based on the SNR, calculate a weighted average based on the SNR (e.g., weights are determined based on the SNR and the weighted measurements are averaged), and/or omit one or more of the signals having an SNR below a predetermined SNR threshold. In some embodiments, the monitor **14** may determine a quality metric (e.g., a confidence metric) based on variations (e.g., differences or degree of correlation) between the signals and/or the measurements. In certain embodiments, the monitor **14** may determine and/or provide the quality metric of each signal, each measurement, or of the average or the mean calculated by the monitor **14**, for example. In some embodiments, the monitor **14** may evaluate which signal(s) or measurement(s) should be used to determine the patient's regional oxygen saturation based on the emitter-detector spacing, the signal-to-noise ratio, and/or the quality metric.

[0047] In certain embodiments, the monitor **14** may be configured to compare the signals and/or the measurements to identify and/or to evaluate variations in the patient's tissue. In particular, the monitor **14** may evaluate variations in the patient's tissue underlying the sensor **12** and/or the two-dimensional monitoring area **104**, for example. It is generally desirable to place regional oxygen saturation sensors over a uniform and/or structurally consistent tissue bed to generate accurate, reliable, and/or repeatable regional oxygen saturation measurements. Anatomical differences in tissue, fluid layers, and/or bone structures underlying the sensor **12** and/or the two-dimensional monitoring area **104** may affect a path traveled by the emitted light and, thus, the regional oxygen saturation measurements. Accordingly, it may be desirable for the sensor **12** to compare the signals generated by each detector and/or the regional saturation measurements determined based on the signals to evaluate the tissue bed and/or to determine whether the sensor **12** should be repositioned. For example, if the regional oxygen saturation measurements obtained by the different sensing units (e.g., the first and the second sensing units **80**, **82**) vary by more than a predetermined variation threshold (e.g., by more than 1%, 3%, 5%, 10% or more), the monitor **14** may determine that the sensor **12** is not positioned over a suitably uniform tissue bed. In such circumstances, the monitor **14** may provide an indication that the sensor **12** should be repositioned. The indication provided by the monitor **14** may take any suitable form, including an audible alarm or a visual alarm or message on the display **20** of the monitor **14**. As discussed in more detail below, in embodiments where the sensor **12** includes more than two sensing units for obtaining more than two regional saturation measurements, the monitor **14** may be configured to provide an indication of which portion of the sensor **12** should be repositioned. For example, if all signals or measurements are within the predetermined variation threshold except for one sensing unit having one or more detectors **18** located near a top edge **108** (e.g., a first edge) of the sensor **12**, the monitor **14** may be configured to indicate that the sensor **12** should be moved lower (e.g., in a first direction), as shown by arrow **110**, on the patient's tissue.

[0048] In some embodiments, the first and the second regional oxygen saturation measurements may be separately displayed on the monitor display **20** as a numeric or other such quantified value, constituting an approximately instantaneous real-time value, and/or as a point in a graphical plot, representing a succession of such values taken over time. In certain embodiments, a single calculated regional oxygen saturation value may be displayed on the monitor display **20**, and the single calculated value may be based on any of the above processing techniques and thus may be an average, a median, or the like. In some embodiments, an indication of the quality metric may be provided on the monitor display **20**, such as via a numerical value or other suitable indicator. In some embodiments, the monitor display **20** may be configured to provide an indication of which of the sensing units

were utilized to determine the displayed regional oxygen saturation value. For example, the monitor display **20** may indicate that only the first sensing unit **80** was used, that only the second sensing unit **82** was used, or that an average of the first and the second regional saturation measurements obtained by both sensing units **80**, **82** was calculated and displayed. In some embodiments, the monitor display **20** may provide an indication related to a reason that certain signals or measurements are not provided, such as due to a variance between the measurements being above the predetermined variance threshold, for example.

[0049] Although described with respect to the embodiment of FIG. **3**, it should be understood that such processing techniques may be adapted for use with any of the embodiments of the sensor **12** disclosed herein. For example, where the sensor **12** includes more than two sensing units for obtaining regional saturation measurements, the monitor **14** may be configured to combine all of the measurements (e.g., average or median), omit certain measurements based on SNR, or the like. Additionally, the monitor display **20** may be adapted to provide the appropriate information for the particular sensor configuration, including in any of the manners discussed above with respect to FIG. **3**.

[0050] With the foregoing in mind, additional embodiments of the sensor **12** are provided in FIGS. **5-10**. FIG. **5** illustrates an embodiment of the sensor **12** having four sensing units **110**, **112**, **114**, **116** for obtaining four regional saturation measurements. As shown, the sensor **12** includes two emitters **16**A, **16**B and six detectors **18**A, **18**B, **18**C, **18**D, **18**E, **18**F. As disclosed above with respect to FIG. **3**, the first emitter **16**A is configured to be used with the first detector **18**A and the second detector **18**B to obtain a first regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the second detector **18**B form a first set of detectors, and the first emitter **16**A and the first set of detectors (i.e., the first detector **18**A and the second detector **18**B) form a first sensing unit **110** for obtaining the first regional saturation measurement. As depicted, the sensor **12** also includes the second emitter **16**B configured to be used with the first detector **18**A and the third detector **18**C to obtain a second regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the third detector **18**C form a second set of detectors, and the second emitter **16**B and the second pair of detectors (i.e., the first detector **18**A and the third detector **18**C) form a second sensing unit **112** for obtaining the second regional oxygen saturation measurement.

[0051] As shown, the sensor **12** of FIG. **5** includes two additional sensing units **114**, **116**. Thus, the first emitter **16**A is configured to be used with the fourth detector **18**D and the fifth detector **18**E to obtain a first regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the fourth detector **18**D and the fifth detector **18**E form a third set of detectors, and the first emitter **16**A and the third pair of detectors (i.e., the fourth detector **18**D and the fifth detector **18**E) form a third sensing unit **114** for obtaining the third regional saturation measurement. As depicted, the sensor **12** also includes the second emitter **16**B configured to be used with the fourth detector **18**D and the sixth detector **18**F to obtain a fourth regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the fourth detector **18**D and the sixth detector **18**F form a fourth set of detectors, and the second emitter **16**B and the fourth pair of detectors (i.e., the fourth detector **18**D and the sixth detector **18**F) form a fourth sensing unit **116** for obtaining the fourth regional oxygen saturation measurement.

[0052] In the illustrated embodiment, the first and third sensing units **110**, **114** include the first emitter **16**A, and the second and the fourth sensing units **112**, **116** include the second emitter **16**B. Additionally, the first and second sensing units **110**, **112** include the first detector **18**A, and the third and fourth sensing units **114**, **116** include the fourth detector **18**D. The emitter **16** and corresponding detectors **18** of each sensing unit **110**, **112**, **114**, **116** may be positioned along a respective axis of the sensing unit **110**, **112**, **114**, **116**, in some embodiments. For example, the first emitter **16**A and the first pair of detectors **18**A, **18**B may be positioned along a first axis **120**. The second emitter **16**B and the second pair of detectors **18**A, **18**C may be positioned along a second axis **122**. The first emitter **16**A and the third pair of detectors **18**D, **18**E may be positioned along a third axis **124**. The second emitter **16**B and the fourth pair of detectors **18**D, **18**F may be positioned along a fourth axis **126**.

[0053] The distance d between the emitter **16** and corresponding detectors **18** of each sensing unit **110**, **112**, **114**, **116** may be any suitable distance, including those discussed above with respect to FIG. **3**. Similarly, a first angle **128** between the first axis **120** and the second axis **122** and/or a second angle **130** between the third axis **124** and the fourth axis **126** may be any suitable angle, including those discussed above with respect to FIG. **3**. In certain embodiments, the first angle **128** and the second angle **130** may be equal, although in other embodiments the first angle **128** and the second angle **130** may differ to facilitate monitoring various different tissues and to facilitate application of the sensor **12** to various different tissue sites. As shown, the emitters **16** and the detectors **18** are arranged symmetrically (e.g., a mirror-image) about a vertical axis of symmetry **132** and/or a horizontal axis of symmetry **134**, which may also be vertical and horizontal center lines of the sensor **12**. The emitters **16** are positioned along the vertical axis of symmetry **132** and/or the first and the fourth detectors **18**A, **18**D are positioned along the horizontal axis of symmetry **134**.

[0054] The one or more emitters **16** and the one or more detectors **18** of the sensor **12** of FIG. **5** may be arranged to provide (e.g., form) a two-dimensional monitoring area **140**. In the embodiment shown in FIG. **5**, the two-dimensional monitoring area **140** is defined by the second detector **18**B, the third detector **18**C, the fifth detector **18**E, and the sixth detector **18**F, although the first emitter **16**A and/or the second emitter **16**B may be positioned to define the two-dimensional monitoring area **104** in certain embodiments. The angles **128**, **130** and/or the distances d between the one or more emitters **16** and the one or more detectors **18** may affect the size and geometry (e.g., shape) of the two-dimensional monitoring area **140**. For example, some or all of the sensing units **110**, **112**, **114**, **116**, and thus the two-dimensional monitoring area **140**, may extend about 0.5-6 cm along the vertical axis **100** of the sensor **12** and/or about 3-8 cm along the horizontal axis **102** of the sensor **12**. As discussed above with respect to FIG. **3**, the two-dimensional monitoring area **140** may have any suitable size. In certain embodiments, the two-dimensional monitoring area **140** may be approximately 6, 7, or 8 cm^2. In some embodiments, the two-dimensional monitoring area **140** may be greater than approximately 5, 10, 15, 20, or 25 cm^2. In some embodiments, the two-dimensional monitoring area **104** may be about 5-20, 6-15, or 7-10 cm^2.

[0055] The signals received from the detectors **18** of the sensor **12** of FIG. **5** and/or the regional oxygen saturation measurements determined based on the received signals, may be processed and/or displayed in a similar manner as disclosed above with respect to FIG. **3**. For example, the four regional saturation measurements determined based on the signals received from the four sensing units **110**, **112**, **114**, **116** may be compared, averaged, and/or displayed. The monitor **14** may be configured to evaluate uniformity of the tissue underlying the sensor **12** based on a variance between the signals and/or measurements, for example. In some embodiments, the monitor **14** may be configured to determine whether the sensor **12** should be repositioned based on the variance, as set forth above. As compared with the sensor **12** of FIG. **3**, the configuration of the sensor **12** in FIG. **5** may generally monitor a larger area (e.g., may have a larger two-dimensional monitoring area **140**) and/or may provide more signals and measurements that can be utilized in the above-described processing steps, for example.

[0056] FIG. **6** illustrates an embodiment of the sensor **12** having four sets of optical components for obtaining four regional saturation measurements. As shown, the sensor **12** includes four emitters **16**A, **16**B, **16**C, **16**D and five detectors **18**A, **18**B, **18**C, **18**D, **18**E arranged into four sensing units **150**, **152**, **154**, **156**. As in FIG. **3**, the first emitter **16**A is configured to be used with the first detector **18**A and the second detector **18**B to obtain a first regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the second detector **18**B form a first set of detectors, and the first emitter **16**A and the first set of detectors (i.e., the first detector **18**A and the second detector **18**B) form a first sensing unit **150** for obtaining the first regional saturation measurement. As depicted, the sensor **12** also includes the second emitter **16**B configured to be used with the first detector **18**A and the third detector **18**C to obtain a second regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the third detector **18**C form a second set of detectors, and the second emitter **16**B and the second set of detectors (i.e., the first detector **18**A and the third detector **18**C) form a second sensing unit **152** for obtaining the second regional oxygen saturation measurement.

[0057] As shown, the sensor **12** of FIG. **6** includes two additional sensing units **154**, **156**. The third emitter **16**C is configured to be used with the first detector **18**A and the fourth detector **18**D to obtain a first regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the fourth detector **18**D form a third set of detectors, and the third emitter **16**C and the third set of detectors (i.e., the first detector **18**A and the fourth detector **18**D) form a third sensing unit **154** for obtaining the third regional saturation measurement. As depicted, the sensor **12** also includes the fourth emitter **16**D configured to be used with the first detector **18**A and the fifth detector **18**E to obtain a fourth regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the fifth detector **18**E form a fourth set of detectors, and the fourth emitter **16**D and the fourth set of detectors (i.e., the first detector **18**A and the fifth detector **18**E) form a fourth sensing unit **156** for obtaining the fourth regional oxygen saturation measurement.

[0058] In the illustrated embodiment, the first sensing unit **150** is positioned along a first axis **160**, the second sensing unit **152** is positioned along a second axis **162**, the third sensing unit **154** is positioned along a third axis **164**, and the fourth sensing unit **156** is positioned along the fourth axis **166**. Each of the sensing units **150**, **152**, **154**, **156** includes the first detector **18**A, and the axes **160**, **162**, **164**, **166** intersect at the first detector **18**A. As shown, the emitters **16**A, **16**B, **16**C, **16**D are arranged linearly along line **170** and at least some of the detectors **18**B, **18**C, **18**D, **18**E are arranged linearly along line **172**. In certain embodiments, all of the detectors **18** positioned relatively far from the corresponding emitter **16** of respective sensing units may be arranged linearly, such as along line **172**, as shown in FIG. **6**. As shown, a two-dimensional monitoring area **174** is defined by the emitters **16**A, **16**B, **16**C, **16**D and the detectors **18**B, **18**C, **18**D, **18**E, that are positioned far from the corresponding emitter **16**.

[0059] The distance between adjacent emitters **16** along line **170** may be uniform or may vary, and similarly, the distance between adjacent detectors **18** along line **172** may be uniform or may vary. Additionally, the distance between the emitter **16** and the corresponding detectors **18** of each sensing unit **150**, **152**, **154**, **156** may be uniform across sensing units or may vary. As shown, the far detectors **18**B, **18**C, **18**D, **18**E are positioned on a first side of a vertical axis **176** of the sensor **12**, which may be a vertical center axis of the sensor **12**. In some such embodiments, the emitters **16**A, **16**B, **16**C, **16**D are positioned on a second side of the vertical axis **170** of the sensor **12**. In certain embodiments, the emitters **16** and the detectors **18** may be arranged symmetrically about a horizontal axis **178** of the sensor **12**, which may be a horizontal center axis of the sensor **12**. The first detector **18**A may be located in any suitable position between the emitters **16** and the far detectors **18**B, **18**C, **18**D, **18**E.

[0060] The signals received from the detectors **18** of the sensor **12** of FIG. **6** and/or the regional oxygen saturation measurements determined based on the received signals, may be processed and/or displayed in a similar manner as disclosed above with respect to FIG. **3**. For example, the four regional saturation measurements determined based on the signals received from the four sensing units **150**, **152**, **154**, **156** may be compared, averaged, and/or displayed. The monitor **14** may be configured to evaluate uniformity of the tissue underlying the sensor **12** based on a variance between the signals and/or measurements, for example. In some embodiments, the monitor **14** may be configured to determine whether the sensor **12** should be repositioned based on the variance, as set forth above. As compared with the sensor **12** of FIG. **3**, the configuration of the sensor **12** in FIG. **5** may generally monitor a larger area (e.g., may have a larger two-dimensional monitoring area **140**) and/or may provide more signals and measurements that can be utilized in the above-described processing steps, for example.

[0061] FIG. **7** illustrates an embodiment of the sensor **12** having six sensing units for obtaining six regional saturation measurements. As shown, the sensor **12** includes six emitters **16**A, **16**B, **16**C, **16**D, **16**E, **16**F and three detectors **18**A, **18**B, **18**C. The emitters **16** are generally arranged about the detectors **18**, which are positioned on an interior portion **190** of the sensor **12** relative to the emitters **16**. Positioning the detectors **18** in the interior portion **190** may facilitate light shielding or blocking of ambient light from the detectors **18**, for example. As disclosed above with respect to FIG. **3**, the first emitter **16**A is configured to be used with the first detector **18**A and the second detector **18**B to obtain a first regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the second detector

18B form a first set of detectors, and the first emitter 16A and the first set of detectors (i.e., the first detector 18A and the second detector 18B) form a first sensing unit 192 for obtaining the first regional saturation measurement. As depicted, the sensor 12 also includes the second emitter 16B configured to be used with the first detector 18A and the third detector 18C to obtain a second regional oxygen saturation measurement when the sensor 12 is applied to the patient. Thus, the first detector 18A and the third detector 18C form a second set of detectors, and the second emitter 16B and the second set of detectors (i.e., the first detector 18A and the third detector 18C) form a second sensing unit 194 for obtaining the second regional oxygen saturation measurement.

[0062] As shown, the sensor 12 of FIG. 7 includes additional sensing units 196, 198, 200, 202. The third emitter 16C is configured to be used with the first detector 18A and the second detector 18B to obtain a third regional oxygen saturation measurement when the sensor 12 is applied to the patient. Thus, like the first emitter 16A, the third emitter 16C is also configured to be used with the first set of detectors (e.g., the first detector 18A and the second detector 18B) to obtain a regional saturation measurement. However, the third emitter 16C is positioned proximate to the second detector 18B and distal from the first detector 18A, while the first emitter 16A is positioned proximate to the first detector 18A and distal from the second detector 18B. The third emitter 16C and the first pair of detectors form a third sensing unit 196 for obtaining the third regional saturation measurement.

[0063] As depicted, the sensor 12 also includes the fourth emitter 16D configured to be used with the third detector 18C and the first detector 18A to obtain a fourth regional oxygen saturation measurement when the sensor 12 is applied to the patient. Thus, like the second emitter 16B, the fourth emitter 16D is also configured to be used with the second set of detectors (e.g., the first detector 18A and the third detector 18C) to obtain a regional saturation measurement. However, the fourth emitter 16D is positioned proximate to the third detector 18C and distal from the first detector 18A, while the second emitter 16B is positioned proximate to the first detector 18A and distal from the third detector 18C. The fourth emitter 16D and the second set of detectors form a fourth sensing unit 198 for obtaining the fourth regional saturation measurement.

[0064] In certain embodiments, a fifth emitter 16E may be provided and may be configured to be used with the second detector 18B and the third detector 18C to obtain a fifth regional oxygen saturation measurement when the sensor 12 is applied to the patient. Thus, the second detector 18B and the third detector 18C form a third set of detectors, and the fifth emitter 16E and the third set of detectors (i.e., the second detector 18B and the third detector 18C) form a fifth sensing unit 200 for obtaining the fifth regional oxygen saturation measurement. A sixth emitter 16F may be provided and may be configured to be used with the second detector 18B and the third detector 18C to obtain a sixth regional saturation measurement when the sensor 12 is applied to the patient. Thus, like the fifth emitter 16E, the sixth emitter 16F is also configured to be used with the third set of detectors (e.g., the second detector 18B and the third detector 18C) to obtain a regional saturation measurement. However, the sixth emitter 16F is positioned proximate to the third detector 18C and distal from the second detector 18B, while the fifth emitter 16E is positioned proximate to the second detector 18B and distal from the third detector 18C. The sixth emitter 16F and the third set of detectors form a sixth sensing unit 202 for obtaining the sixth regional saturation measurement. As shown, in certain embodiments, the first and/or third sensing units 192, 196 may be positioned along a first axis 204, the second and/or fourth sensing units 194, 198 may be positioned along a second axis 206, and/or the fifth and/or sixth sensing units 200, 202 may be positioned along a third axis 208.

[0065] In the illustrated embodiment having three detectors 18A, 18B, 18C, the detectors 18A, 18B, 18C, and/or the axes 204, 206, 208 may be arranged in a generally triangular orientation. Angles 210, 212, 214 defined by the axes 204, 206, 208 extending between the detectors 18A, 18B, 18C may be any suitable angle, such as approximately 10-170 degrees, 15-110 degrees, 20-90 degrees, 25-80 degrees, 30-70 degrees, or 35-60 degrees, for example. Additionally, some or all of the angles 210, 212, 214 may be equal to one another or may vary. In certain embodiments, the emitters 16 and the detectors 18 may be symmetrically arranged about an axis of symmetry 216, which may also be a horizontal axis, a vertical axis, a center horizontal axis, or a center vertical axis of the sensor, depending on the arrangement of the emitters 16 and detectors 18 relative to the sensor body 44, for example. As shown, the axis of symmetry 216 may extend through the first detector 18A and/or may intersect the axis 208 at a midpoint 218 centered between the second detector 18B and the third detector 18C and/or centered between the fifth emitter 16E and the sixth emitter 16F, as shown. In the embodiment of FIG. 7, one or more of the emitters 16 positioned about the detectors 18 may define a two-dimensional monitoring area 220.

[0066] It should be understood that the emitters 16 and the detectors 18 of FIG. 7 may be arranged in any of a variety of configurations. For example, the detectors 18A, 18B, 18C may be equidistant from one another and may form an equilateral triangle (e.g., angles 210, 212, 214 may be equal to one another) having a center point (not shown) at a center of the equilateral triangle. In such cases, the emitters 16A, 16B, 16C, 16D, 16E, 16F may be arranged about the detectors 18A, 18B, 18C and may be equidistant from the center point, and thus, the sensor 12 may have a tri-fold symmetry about the center point positioned within the equilateral triangle formed by the detectors 18A, 18B, 18C. Such a configuration may be particularly useful for determining a proper location for the sensor 12. As noted above, by way of example, differences in signal quality between the six sensing units 192, 194, 196, 198, 200, 202 may be used to indicate to the user a direction in which to move the sensor 12 to increase the symmetry of signals obtained via the six sensing units 192, 194, 196, 198, 200, 202, and thus, better monitor a particular organ (e.g., a kidney).

[0067] The signals received from the detectors 18 of the sensor 12 of FIG. 7 and/or the regional oxygen saturation measurements determined based on the received signals, may be processed and/or displayed in a similar manner as disclosed above with respect to FIG. 3. For example, the six regional saturation measurements determined based on the signals received from the six sensing units 192, 194, 196, 198, 200, 202 may be compared, averaged, and/or displayed. The monitor 14 may be configured to evaluate uniformity of the tissue underlying the sensor 12 based on a variance between the signals and/or measurements, for example. In some embodiments, the monitor 14 may be configured to determine whether the sensor 12 should be repositioned based on the variance, as set forth above. As compared with the sensor 12

of FIG. **3**, the configuration of the sensor **12** in FIG. **7** may generally monitor a larger area (e.g., may have a larger two-dimensional monitoring area **220**) and/or may provide more signals and measurements that can be utilized in the above-described processing steps, for example.

[0068] FIG. **8** illustrates an embodiment of the sensor **12** having two sensing units for obtaining two regional saturation measurements. As shown, the sensor **12** includes a first emitter **16**A, a second emitter **16**B, a first detector **18**A, and a second detector **18**B, each positioned linearly along a first axis **221**. In the depicted embodiment, the first emitter **16**A is configured to be used with the first detector **18**A and the second detector **18**B to obtain a first regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the second detector **18**B form a first set of detectors, and the first emitter **16**A and the first set of detectors (i.e., the first detector **18**A and the second detector **18**B) form a first sensing unit **222** for obtaining the first regional saturation measurement. As depicted, the sensor **12** also includes the second emitter **16**B that is also configured to be used with the first detector **18**A and the second detector **18**B to obtain a second regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, like the first emitter **16**A, the second emitter **16**B is also configured to be used with the first set of detectors (e.g., the first detector **18**A and the second detector **18**B) to obtain a regional saturation measurement. However, the second emitter **16**B is positioned proximate to the second detector **18**B and distal from the first detector **18**A, while the first emitter **16**A is positioned proximate to the first detector **18**A and distal from the second detector **18**B. The second emitter **16**B and the first set of detectors form a second sensing unit **224** for obtaining the second regional saturation measurement.

[0069] In certain embodiments, the sensor **12** may include one or more additional emitters **16** that may be used to obtain additional data, such as information related to the uniformity of the tissue bed underlying the sensor **12** and/or a two-dimensional monitoring area **226**. The one or more additional emitters **16** may emit one or more wavelengths of light, and in some embodiments, may emit only a single wavelength that enables identification of tissue or structural properties. By way of example, a third emitter **16**C and/or a fourth emitter **16**D may be provided in the sensor **12** of FIG. **8**. The one or more additional emitters **16** may be positioned in any suitable location, although as shown the third emitter **16**C is positioned on one side of the axis **221**, and the fourth emitter **16**D is positioned on another side of the first axis **221**. Additionally, in the illustrated embodiment, the third emitter **16**C is positioned a first distance D_1 relative to each of the detectors **18**A, **18**B, while the fourth emitter **16**D is positioned a second distance D_2 relative to each of the detectors **18**A, **18**B. In some embodiments, some or all of the emitters **16** for detecting tissue uniformity may be equal distances from each of the detectors (e.g., the first distance D_1 may be equal to the second distance D_2). As shown, the third emitter **16**C and the fourth emitter **16**D are positioned along a second axis **230**.

[0070] The light emitted by the third emitter **16**C may be received at the first detector **18**A and/or the second detector **18**B. The signals generated by the detectors **18**A, **18**B may not be utilized for regional saturation measurements as the light received at each of the detectors **18**A, **18**B from the third emitter **16**C traveled the same first distance D_1 and thus through the same tissue depth. However, the light received at each detector **18** may be utilized to determine tissue uniformity. For example, because the light emitted by the third detector **16**A travels the first distance D_1 to reach the first and second detectors **18**A, **18**B, variations in the detected light at each detector **18**A, **18**B may indicate non-uniformity of the tissue between the third emitter **16**C and the detectors **18**A, **18**B. Where D_1 is equal to D_2, variations in the detected light emitted by each emitter **16**A, **16**B and detected at each detector **18**A, **18**B may indicate non-uniformity of the tissue between the emitters **16**A, **16**B and the detectors **18**A, **18**B about the first axis **221**, for example.

[0071] The signals received from the detectors **18** of the sensor **12** of FIG. **8** and/or the regional oxygen saturation measurements determined based on the received signals, may be processed and/or displayed in a similar manner as disclosed above with respect to FIG. **3**. For example, the two regional saturation measurements determined based on the signals received from the two sensing units **222**, **224** may be compared, averaged, and/or displayed. The monitor **14** may be configured to evaluate uniformity of the tissue underlying the sensor **12** based on a variance between the signals and/or measurements, for example. As discussed above, additional emitters **16** may be used to determine additional information related to uniformity of the tissue. In some embodiments, the monitor **14** may be configured to determine whether the sensor **12** should be repositioned based on the variance, as set forth above. As compared with the sensor **12** of FIG. **3**, the configuration of the sensor **12** in FIG. **8** provides a relatively compact, linear sensor that may be desirable for certain tissue sites, while still obtaining multiple regional saturation measurements and/or monitoring tissue uniformity, for example.

[0072] FIG. **9** illustrates an embodiment of the sensor **12** having two sensing units for obtaining two regional saturation measurements. As shown, the sensor **12** includes a first emitter **16**A, a second emitter **16**B, a first detector **18**A, and a second detector **18**B positioned linearly along the first axis **240** in a similar configuration as discussed above with respect to FIG. **8**. Additionally, a third detector **18**C and/or a fourth detector **18**D may be provided, such as along a second axis **242**, as shown. The third detector **18**C and/or the fourth detector **18**D may be configured to receive light from one or both of the emitters **16**A, **16**B, and the signals generated by the detectors **18**C, **18**D based on the light received may be utilized to calculate regional saturation measurements and/or to evaluate the uniformity of the tissue underlying the sensor **12**, as discussed above.

[0073] In certain embodiments, the first emitter **16**A and the second emitter **16**B may be configured to emit alternating wavelengths of light. For example, the first emitter **16**A may emit a first wavelength λ_1 and a third wavelength λ_3, while the second emitter **16**B may emit a second wavelength λ_2 and the fourth wavelength λ_4. In some embodiments, the first wavelength λ_1 is less than the second wavelength λ_2, which is less than the third wavelength λ_3, which is less than the fourth wavelength λ_4. For example, the first emitter **16**A may emit the first wavelength λ_1 of about 724 nm and the third wavelength λ_3 of about 812 nm, while the second emitter **16**B may emit the second wavelength λ_2 of about 770 nm and the fourth wavelength λ_4 of about 850 nm, although any suitable wavelengths may be emitted by the emitters **16**A, **16**B. Multiple pairs of different wavelengths may be suitable for obtaining various physiological parameters and for determining regional oxygen saturation. Thus, using a first pair of suitable wavelengths, the first wavelength λ_1 and the third wavelength λ_3, to calculate a first regional oxygen saturation measure-

ment using the first sensing unit **222** and using a second, different pair of suitable wavelengths, the second wavelength λ_2 and the fourth wavelength λ_4, to calculate a second regional saturation measurement using the second sensing unit **224** may provide redundancy and robustness in monitoring, along with reduced part count and associated costs as compared to the system having each emitter **16** configured to emit all of the wavelengths (e.g., the first wavelength λ_1, the second wavelength λ_2, the third wavelength λ_3, and the fourth wavelength λ_4). Although emitting different wavelengths of light from the respective emitters **16** of different sensing units to calculate regional oxygen saturation are discussed herein in the context of the sensor **12** of FIG. **9**, it should be understood that any of the embodiments of the sensor **12** disclosed herein may utilize different (e.g., alternating) wavelengths.

[0074] The signals received from the detectors **18** of the sensor **12** of FIG. **9** and/or the regional oxygen saturation measurements determined based on the received signals, may be processed and/or displayed in a similar manner as disclosed above with respect to FIG. **3**. For example, the two regional saturation measurements determined based on the signals received from the two sensing units **222**, **224** may be compared, averaged, and/or displayed. The monitor **14** may be configured to evaluate uniformity of the tissue underlying the sensor **12** based on a variance between the signals and/or measurements, for example. In some embodiments, the monitor **14** may be configured to determine whether the sensor **12** should be repositioned based on the variance, as set forth above. As compared with the sensor **12** of FIG. **3**, the configuration of the sensor **12** in FIG. **9** provides a relatively compact, linear sensor that may be desirable for certain tissue sites, while still obtaining multiple regional saturation measurements and/or monitoring tissue uniformity, for example. Where additional detectors **18**C, **18**D are provided, regional saturation measurements may be based on light received at the additional detectors **18**C, **18**D, and thus, the regional saturation measurements may be based on a relatively larger tissue area (e.g., a two-dimensional monitoring area **244**). Furthermore, in any of the embodiments disclosed herein, given the reciprocal nature of light and most electromagnetic waves travelling through tissue, positions of emitters **16** and detectors **18** in a given sensing unit may be exchanged with each other without affecting functionality. That is, one emitter **16** may be moved to a location of one detector **18** and vice-versa. In certain applications, it may be preferred to keep detectors **18** closer to the center of the sensor **12** since then the detectors **18** are better shielded from ambient light.

[0075] FIG. **10** illustrates a sensor **12** having two sensing units configured to obtain two regional saturation measurements. As shown, the emitters **16** and the detectors **18** are arranged linearly along an axis **250** in an alternating pattern, such that each emitter **16** is positioned between and/or is adjacent to two detectors **18**. In such a configuration, the light emitted by the first emitter **16**A and detected by the second detector **18**B travels through the patient's tissue and under the second emitter **16**B. Additionally, the light emitted by the second emitter **16**B and detected by the third detector **18**C travels through the patient's tissue and under the first emitter **16**A.

[0076] In the depicted embodiment, the first emitter **16**A is configured to be used with the first detector **18**A and the second detector **18**B to obtain a first regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the second detector **18**B form a first set of detectors, and the first emitter **16**A and the first set of detectors (i.e., the first detector **18**A and the second detector **18**B) form a first sensing unit **252** for obtaining the first regional saturation measurement. As depicted, the sensor **12** also includes the second emitter **16**B that is also configured to be used with the first detector **18**A and a third detector **18**C to obtain a second regional oxygen saturation measurement when the sensor **12** is applied to the patient. Thus, the first detector **18**A and the third detector **18**C form a second set of detectors, and the second emitter **16**B and the second set of detectors (e.g., the first detector **18**A and the third detector **18**C) form a second sensing unit **254** for obtaining the second regional saturation measurement.

[0077] The signals received from the detectors **18** of the sensor **12** of FIG. **10** and/or the regional oxygen saturation measurements determined based on the received signals, may be processed and/or displayed in a similar manner as disclosed above with respect to FIG. **3**. For example, the two regional saturation measurements determined based on the signals received from the two sensing units **252**, **254** may be compared, averaged, and/or displayed. The monitor **14** may be configured to evaluate uniformity of the tissue underlying the sensor **12** based on a variance between the signals and/or measurements, for example. As discussed above, additional emitters **16** may be used to determine additional information related to uniformity of the tissue. In some embodiments, the monitor **14** may be configured to determine whether the sensor **12** should be repositioned based on the variance, as set forth above. As compared with the sensor **12** of FIG. **3**, the configuration of the sensor **12** in FIG. **10** provides a relatively compact, linear sensor that may be desirable for certain tissue sites, while still obtaining multiple regional saturation measurements and/or monitoring tissue uniformity, for example.

[0078] FIG. **11** illustrates a sensor **12** having at least one sensing unit, each sensing unit including one emitter **16** and three or more detectors **18** configured to receive light from the emitter **16** to generate a regional saturation measurement. As shown, a first emitter **16**A, a first detector **18**A, a second detector **18**B, and a third detector **18**C are arranged linearly along an axis **260** and may form a first sensing unit **262** configured to obtain a first regional saturation measurement. The light emitted by the first emitter **16**A is detected at each of the three detectors **18**A, **18**B, **18**C, and the signals generated by each of the three detectors **18**A, **18**B, **18**C may be utilized by the monitor **14** to determine the first regional saturation measurement. In certain embodiments, additional emitters **16** and/or detectors **18** may be provided, such as along the axis **260**. For example, as shown, a second emitter **16**B is provided along the axis **260**. The second emitter **16**B and the three detectors **18**A, **18**B, **18**C may form a second sensing unit **264** configured to obtain a second regional saturation measurement. Thus, light emitted by the second emitter **16**B may be detected at each of the three detectors, **18**A, **18**B, **18**C, and the signals generated by each of the three detectors **18**A, **18**B, **18**C may be utilized by the monitor **14** to generate the second regional saturation measurement. As noted above, any of the embodiments disclosed herein may be adapted to include sensing units having three or more detectors **18**.

[0079] The signals received from the detectors **18** of the sensor **12** of FIG. **11** and/or the regional oxygen saturation measurements determined based on the received signals, may be processed and/or displayed in a similar manner as disclosed above with respect to FIG. **3**. For example, the two

regional saturation measurements determined based on the signals received from the two sensing units **262**, **264** may be compared, averaged, and/or displayed. The monitor **14** may be configured to evaluate uniformity of the tissue underlying the sensor **12** based on a variance between the signals and/or measurements, for example. As discussed above, additional emitters **16** may be used to determine additional information related to uniformity of the tissue. In some embodiments, the monitor **14** may be configured to determine whether the sensor **12** should be repositioned based on the variance, as set forth above. As compared with the sensor **12** of FIG. **3**, the configuration of the sensor **12** in FIG. **11** provides a relatively compact, linear sensor that may be desirable for certain tissue sites, while still obtaining multiple regional saturation measurements and/or monitoring tissue uniformity, for example.

[0080] FIG. **12** illustrates a sensor **12** having four sensing units. As shown, the sensor **12** includes one emitter **16** and four sets of detectors **18**A, **18**B, **18**C, **18**D (e.g., each set includes multiple detectors **18**) positioned about the emitter **16**. The emitter **16** is positioned in a central portion **260** of the sensor **12**, and each set of detectors **18**A, **18**B, **18**C, **18**D may extend radially-outwardly from the emitter **16**, such as in a cross or X configuration, for example. As shown, the emitter **16** and a first set of detectors **18**A may be positioned along a first axis **270** and may form a first sensing unit **272** for obtaining a first regional saturation measurement. The emitter **16** and a second set of detectors **18**B may be positioned along the first axis **270** and may form a second sensing unit **274** for obtaining a first regional saturation measurement. As shown, the first set of detectors **18**A may be positioned on one side of a second axis **276**, while the second set of detectors **18**B may be positioned on another side of the second axis **276**. The emitter **16** and a third set of detectors **18**C may be positioned along the second axis **276** and may form a third sensing unit **278** for obtaining a third regional saturation measurement. The emitter **16** and a fourth set of detectors **18**D may be positioned along the second axis **276** and may form a fourth sensing unit **280** for obtaining a fourth regional saturation measurement. As shown, the third set of detectors **18**C may be positioned on one side of a first axis **270**, while the fourth set of detectors **18**D may be positioned on another side of the first axis **270**.

[0081] The signals received from the detectors **18** of the sensor **12** of FIG. **12** and/or the regional oxygen saturation measurements determined based on the received signals, may be processed and/or displayed in a similar manner as disclosed above with respect to FIG. **3**. For example, the four regional saturation measurements determined based on the signals received from the four sensing units **272**, **274**, **278**, **280** may be compared, averaged, and/or displayed. The monitor **14** may be configured to evaluate uniformity of the tissue underlying the sensor **12** based on a variance between the signals and/or measurements, for example. As discussed above, additional emitters **16** may be used to determine additional information related to uniformity of the tissue. In some embodiments, the monitor **14** may be configured to determine whether the sensor **12** should be repositioned based on the variance, as set forth above. As compared with the sensor **12** of FIG. **3**, the configuration of the sensor **12** in FIG. **12** may be desirable for certain monitoring sites and/or may provide more signals and measurements that can be utilized in the above-described processing steps, for example.

[0082] While the disclosure may be susceptible to various modifications and alternative forms, specific embodiments have been shown by way of example in the drawings and have been described in detail herein. However, it should be understood that the embodiments provided herein are not intended to be limited to the particular forms disclosed. Rather, the various embodiments may cover all modifications, equivalents, and alternatives falling within the spirit and scope of the disclosure as defined by the following appended claims.

What is claimed is:

1. A medical sensor, comprising:

a substrate;

a first set of optical components configured to obtain a first set of signals for determining a first regional oxygen saturation measurement, comprising:

a first emitter disposed on the substrate;

a first detector disposed on the substrate, the first detector being separated from the first emitter by a first distance along a first axis; and

a second detector disposed on the substrate, the second detector being separated from the first emitter by a second distance along the first axis, wherein the second distance is greater than the first distance; and

a second set of optical components configured to obtain a second set of signals for determining a second regional oxygen saturation measurement, comprising:

a second emitter disposed on the substrate; and

a third detector disposed on the substrate, the third detector being separated from the second emitter by a third distance along a second axis different from the first axis.

2. The medical sensor of claim **1**, wherein the second set of optical components comprises the first detector.

3. The medical sensor of claim **2**, wherein the first detector is separated from the second emitter by a fourth distance along the second axis, wherein the fourth distance is approximately equal to the first distance and is less than the third distance.

4. The medical sensor of claim **3**, wherein a two-dimensional monitoring area on a patient defined by the first emitter, the second emitter, the second detector, and the third detector when the medical sensor is disposed on the patient is at least 5 cm^2.

5. The medical sensor of claim **1**, wherein the first distance is between about 10 mm and 20 mm and the second and the third distances are between about 30 mm and 40 mm.

6. The medical sensor of claim **1**, comprising:

a third set of optical components configured to obtain a third regional oxygen saturation measurement, comprising:

the first emitter;

a fourth detector and a fifth detector separated from the first emitter along a third axis;

a fourth set of optical components configured to obtain a fourth regional oxygen saturation measurement, comprising:

the second emitter; and

the fourth detector and a sixth detector separated from the second emitter along a fourth axis.

7. The medical sensor of claim **6**, wherein a two-dimensional monitoring area on a patient defined by the second detector, the third detector, the fifth detector, and the sixth detector when the medical sensor is disposed on the patient is at least 5 cm^2.

8. The medical sensor of claim **1**, comprising a third set of optical components configured to obtain a third regional oxygen saturation measurement, comprising:

the second detector;

the third detector; and

a third emitter disposed on the substrate and separated from the second detector and the third detector along a third axis different from the first and second axes.

9. The medical sensor of claim **8**, comprising a fourth set of optical components configured to obtain a fourth regional saturation measurement, comprising:

the second detector;

the third detector; and

a fourth emitter disposed on the substrate and separated from the second detector and the third detector and the third emitter along the third axis.

10. The medical sensor of claim **1**, comprising an axis of symmetry extending through the first detector, wherein the first and second sets of optical components are arranged symmetrically about the axis of symmetry.

11. The medical sensor of claim **1**, wherein the first emitter is configured to emit wavelengths of light different than wavelengths of light emitted by the second emitter.

12. A medical monitoring system, comprising:

a medical sensor, comprising:

a substrate;

a first set of optical components disposed on the substrate and configured to obtain a first set of signals for determining a first regional oxygen saturation measurement comprising:

a first emitter spaced apart from a first detector and a second detector along a first axis;

a second set of optical components disposed on the substrate and configured to obtain a second set of signals for determining a second regional oxygen saturation measurement, comprising:

a second emitter disposed spaced apart from the first detector and a third detector along a second axis different from the first axis; and

a medical monitor configured to:

receive the first and second sets of signals; and

determine a first regional oxygen saturation measurement based on the first set of signals and a second regional oxygen saturation measurement based on the second set of signals.

13. The medical monitoring system of claim **12**, wherein the medical monitor is configured to provide a notification to reposition the medical sensor on a patient if the first and second sets of signals differ by more than a predetermined threshold amount.

14. The medical monitoring system of claim **12**, wherein the medical sensor comprises an axis of symmetry extending between the first detector, wherein the first and second sets of optical components are arranged symmetrically about the axis of symmetry.

15. The medical monitoring system of claim **11**, wherein the first emitter is configured to emit wavelengths of light different than wavelengths of light emitted by the second emitter.

16. The medical monitoring system of claim **11**, wherein the first and second emitters are aligned along a first vertical axis of the medical sensor and wherein the second and third detectors are aligned along a second vertical axis of the medical sensor parallel to the first vertical axis.

17. The medical monitoring system of claim **16**, comprising a third emitter aligned with the first and second emitters along the first vertical axis and a fourth detector aligned with the second and third detectors along the second vertical axis, wherein the third emitter, first detector, and fourth detector form a third set of optical components configured to obtain a third set of signals for determining a third regional oxygen saturation measurement.

18. The medical monitoring system of claim **17**, wherein the medical monitor is configured to determine the first, second, and third regional oxygen saturation measurements using the first, second, and third sets of optical components, respectively, to determine a mean of the measurements, and to exclude one or more measurements that vary by more than a predetermined difference from the mean.

19. A medical monitoring system, comprising:

a medical sensor, comprising:

a first set of optical components configured to obtain a first set of signals for determining a first regional oxygen saturation measurement comprising:

a first emitter configured to emit a first wavelength and a third wavelength of light; and

a second set of optical components comprising configured to obtain a second set of signals for determining a second regional oxygen saturation measurement comprising:

a second emitter configured to emit a second wavelength and a fourth wavelength of light, wherein the first wavelength is less than the second wavelength, which is less than the third wavelength, which is less than the fourth wavelength; and

a medical monitor configured to:

receive the first and the second sets of signals; and

determine a first regional oxygen saturation measurement based on the first set of signals and a second regional oxygen saturation measurement based on the second set of signals.

20. The medical sensor of claim **19**, wherein the medical sensor comprises two or more detectors spaced apart from the first emitter and the second emitter linearly along an axis of the medical sensor.

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[标]发明人	SILVEIRA PAULO E X HAYMAN SARAH ANDERSON JILL KLOMHAUS ADDISON PAUL S WATSON JAMES N		
发明人	SILVEIRA, PAULO E.X. HAYMAN, SARAH ANDERSON, JILL KLOMHAUS ADDISON, PAUL S. WATSON, JAMES N.		
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摘要(译)

医疗传感器包括第一组光学组件，其被配置为获得用于确定第一区域氧饱和度测量值的第一组信号。第一组光学组件包括第一发射器，第一探测器，第一探测器沿第一轴与第一发射器隔开第一距离，第二探测器沿第一轴与第一发射器隔开第二距离，其中第二距离大于第一个距离。传感器还包括第二组光学组件，其被配置为获得用于确定第二区域氧饱和度测量的第二组信号。第二组光学组件包括第二发射器和第三检测器，第二发射器与第二发射器沿第二轴分开第三距离，第二轴不同于第一轴。