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(54) PHYSIOLOGICAL MEASUREMENT SYSTEM WITH AUTOMATIC WAVELENGTH ADJUSTMENT

(71) Applicant: **Cercacor Laboratories, Inc.**, Irvine, CA (US)

(72) Inventors: **Walter M. Weber**, Laguna Hills, CA (US); **Ammar Al-Ali**, San Juan Capistrano, CA (US)

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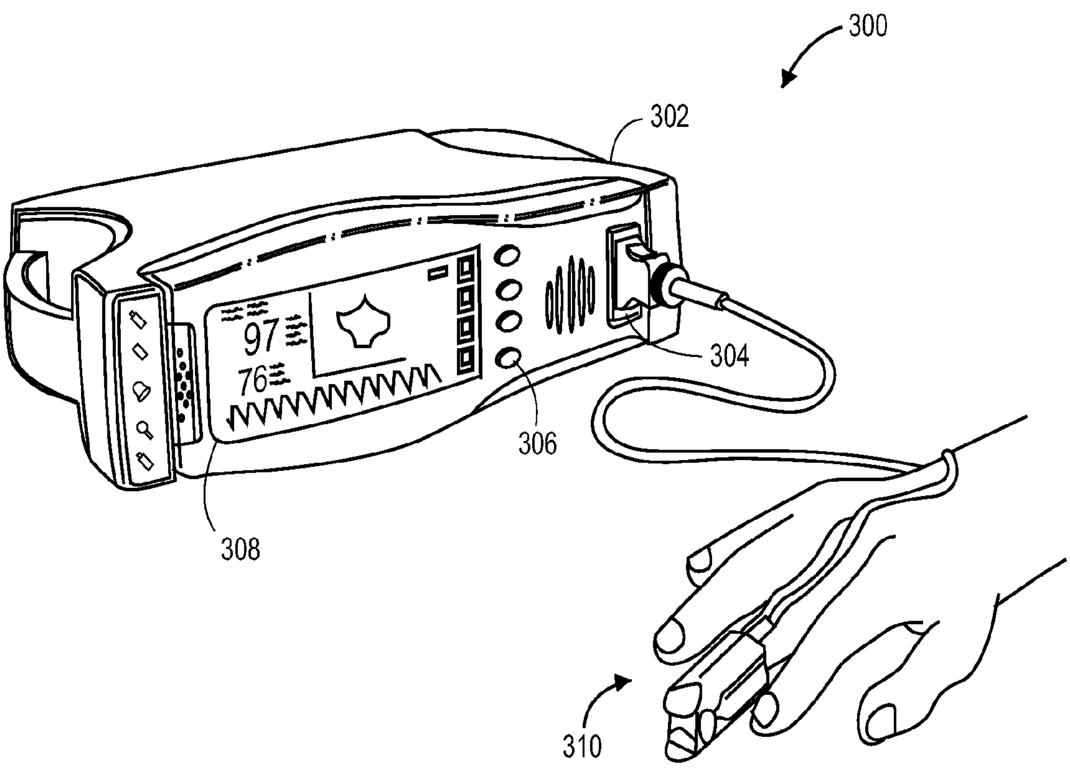
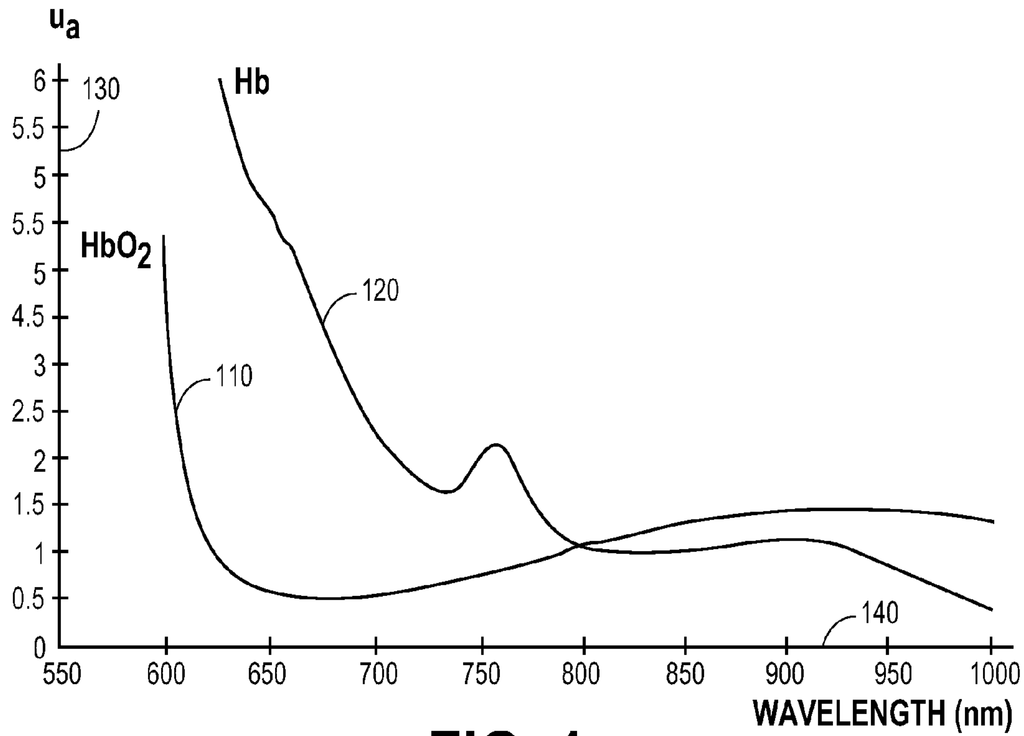
(57) **ABSTRACT**

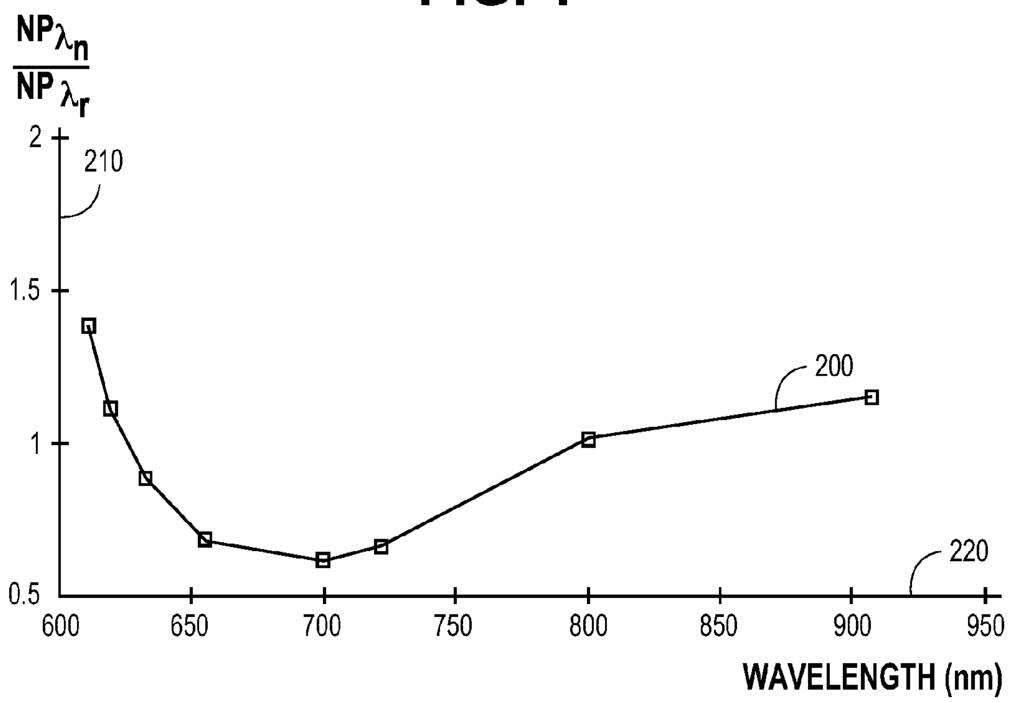
Disclosed herein is a physiological measurement system that can automatically adjust the number of wavelengths used based on the quality of a sensor signal that is reflective of an optical radiation detected at a sensor after tissue attenuation. The signal quality is examined to determine if it is sufficient to support the use of a full set of wavelengths. If it is determined to be insufficient to support the full set, a reduced number of wavelengths is used.





u_a
6
5.5
5
5.5
5
4.5
3
2.5
2
1.5
1
0.5
0
130
Hb
HbO2
120
110
140
550
600
650
700
750
800
850
900
950
1000
WAVELENGTH (nm)

FIG. 1



NPλn / NPλr
2
1.5
1
0.5
210
200
220
600
650
700
750
800
850
900
950
WAVELENGTH (nm)

FIG. 2

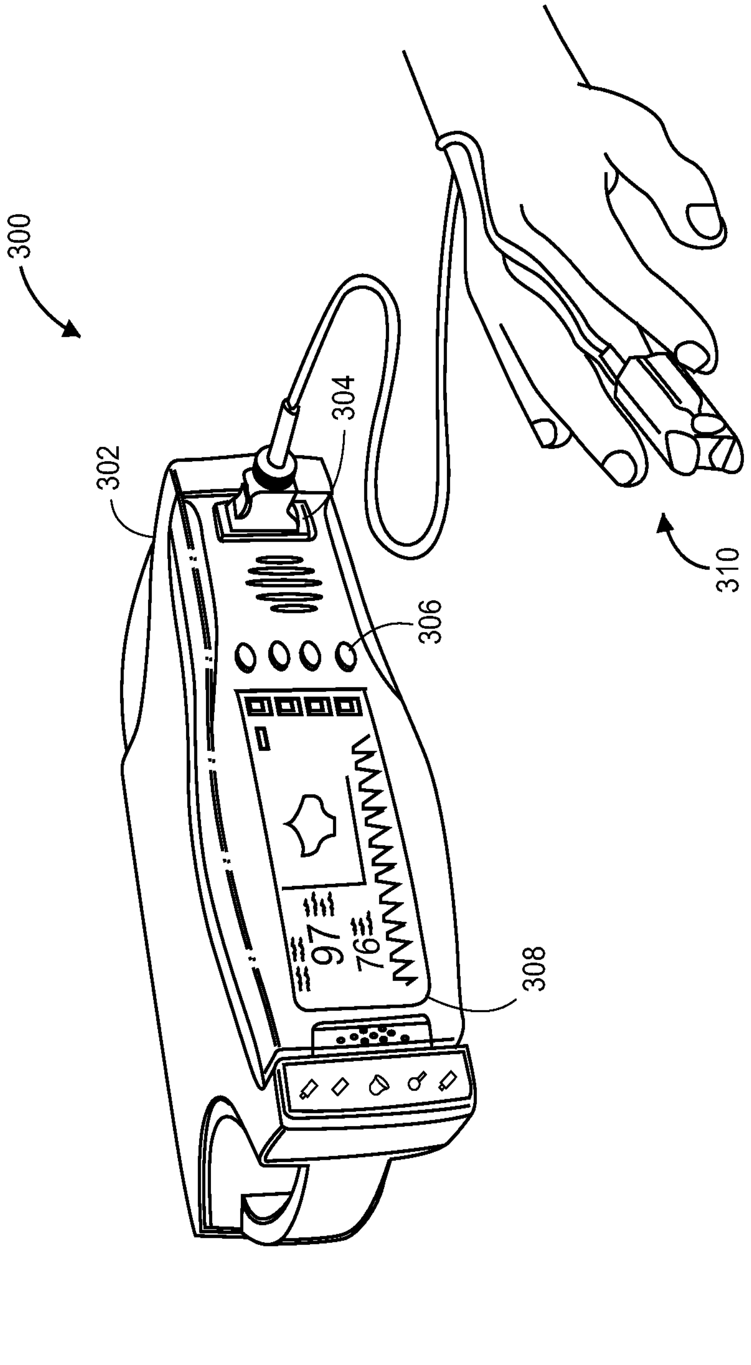


FIG. 3A

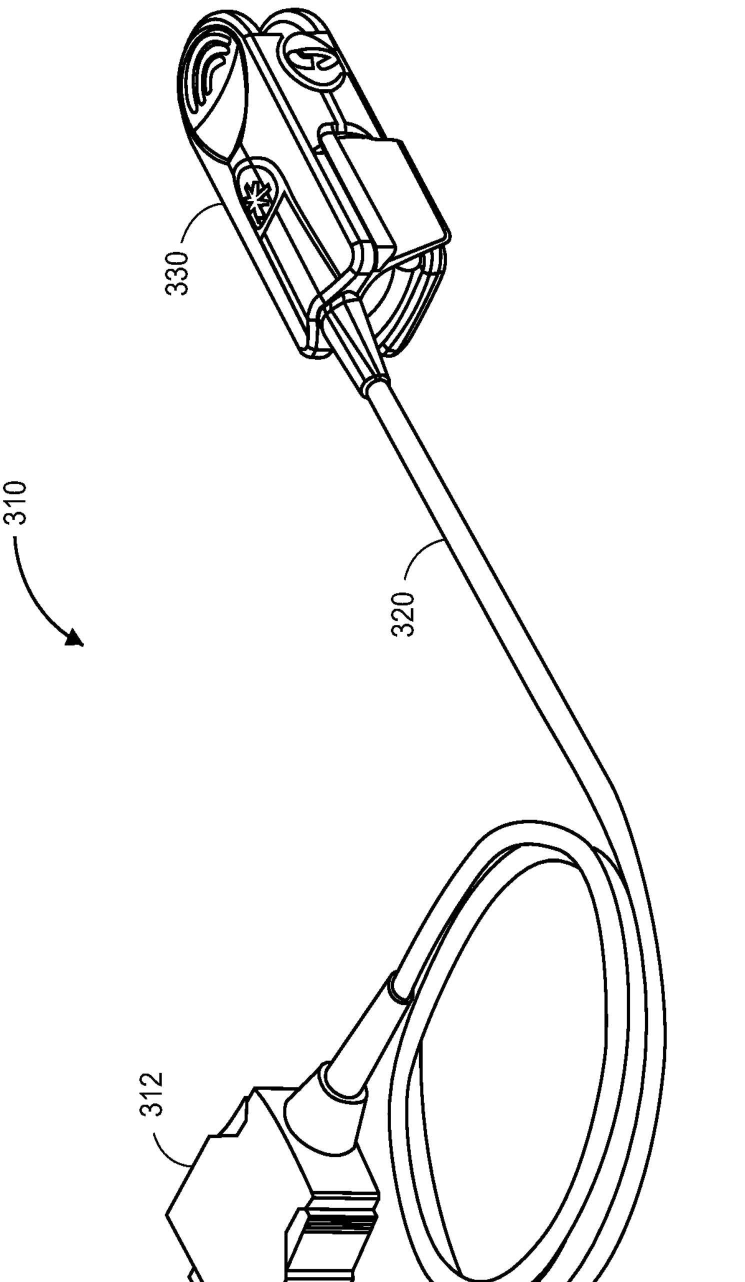


FIG. 3B

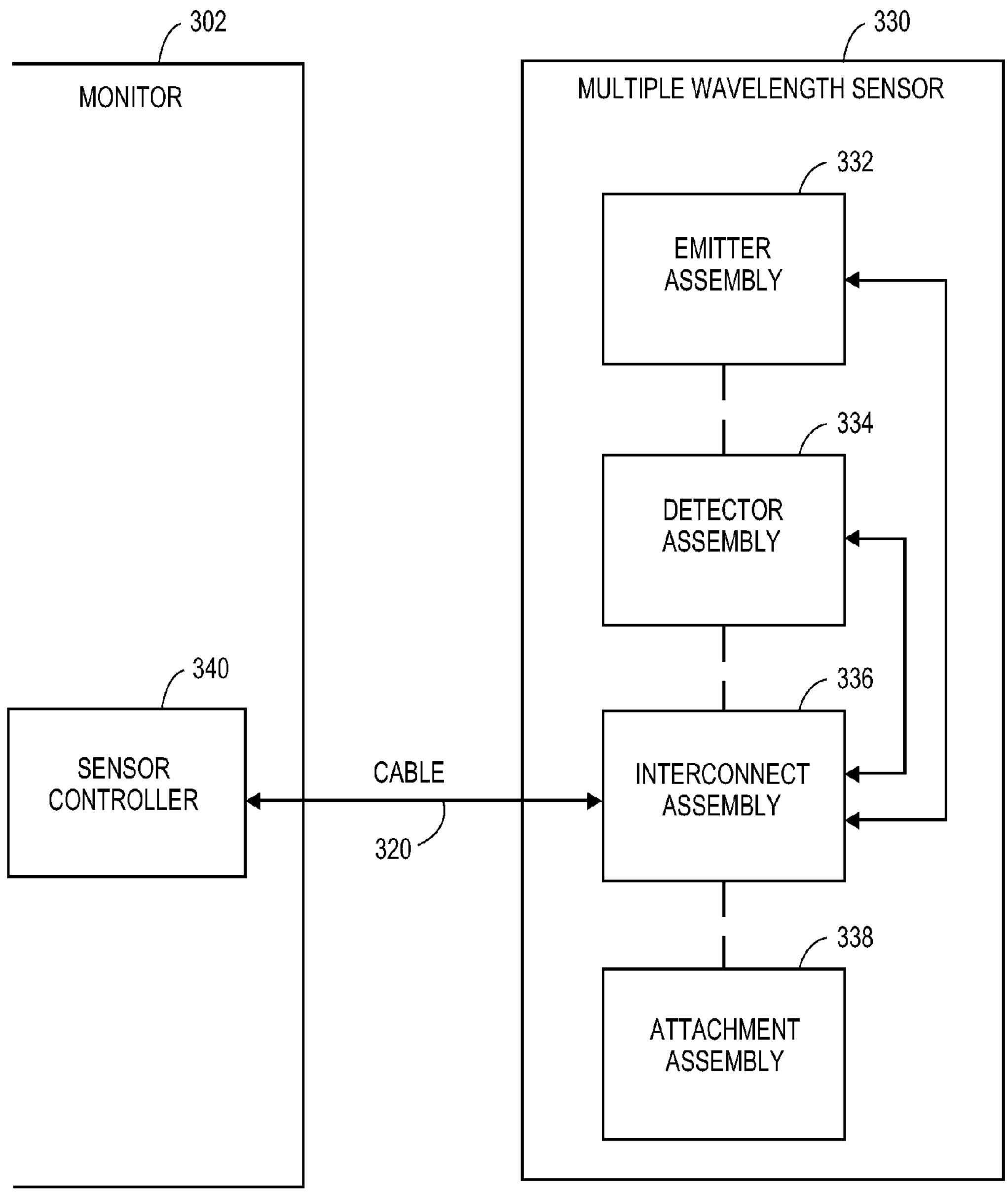

302
MONITOR
340
SENSOR CONTROLLER
CABLE
320
330
MULTIPLE WAVELENGTH SENSOR
332
EMITTER ASSEMBLY
334
DETECTOR ASSEMBLY
336
INTERCONNECT ASSEMBLY
338
ATTACHMENT ASSEMBLY

FIG. 4A

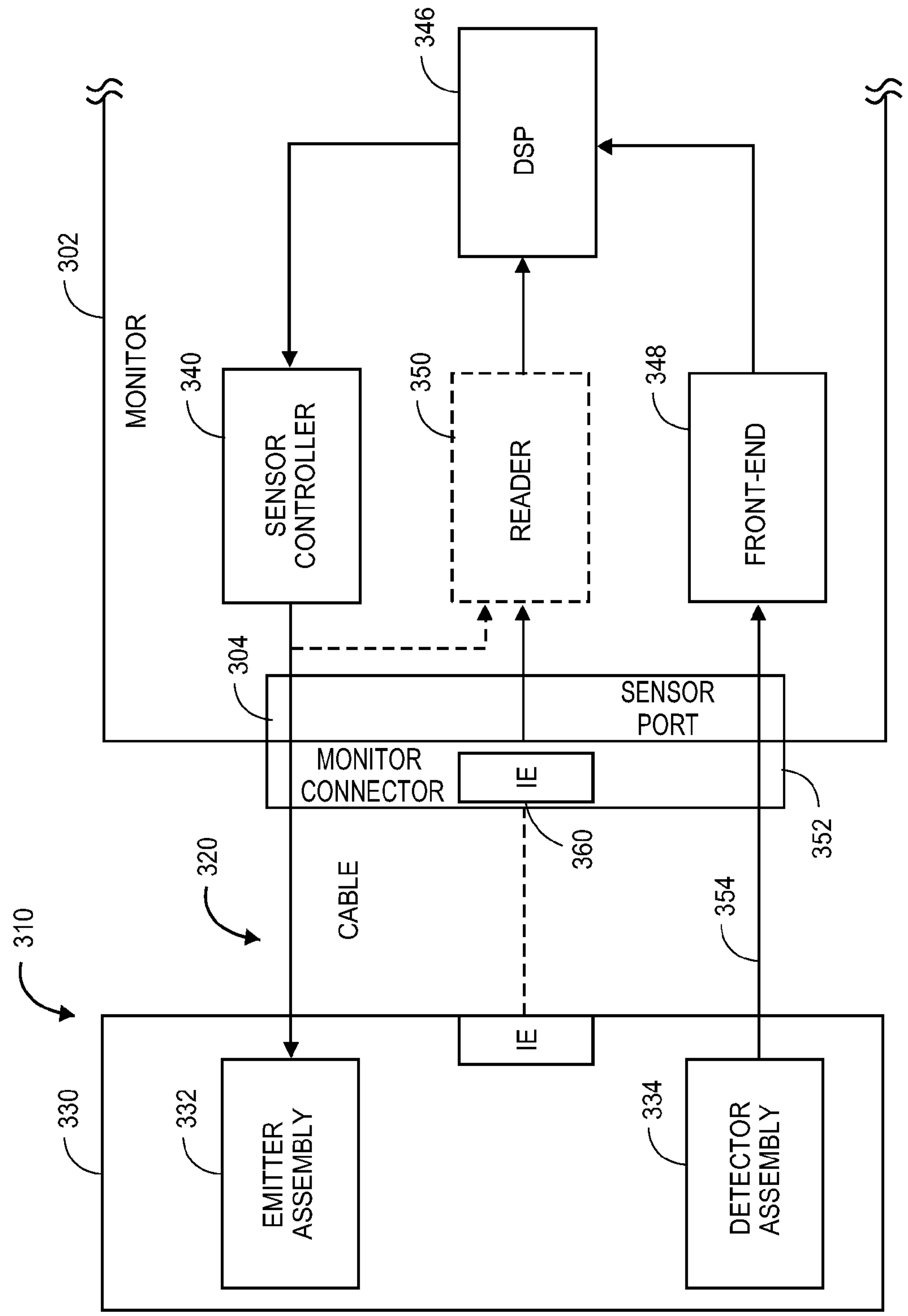

302
MONITOR
346
DSP
340
SENSOR CONTROLLER
350
READER
348
FRONT-END
304
SENSOR PORT
MONITOR CONNECTOR
IE
360
352
320
CABLE
354
310
330
332
EMITTER ASSEMBLY
IE
334
DETECTOR ASSEMBLY

FIG. 4B

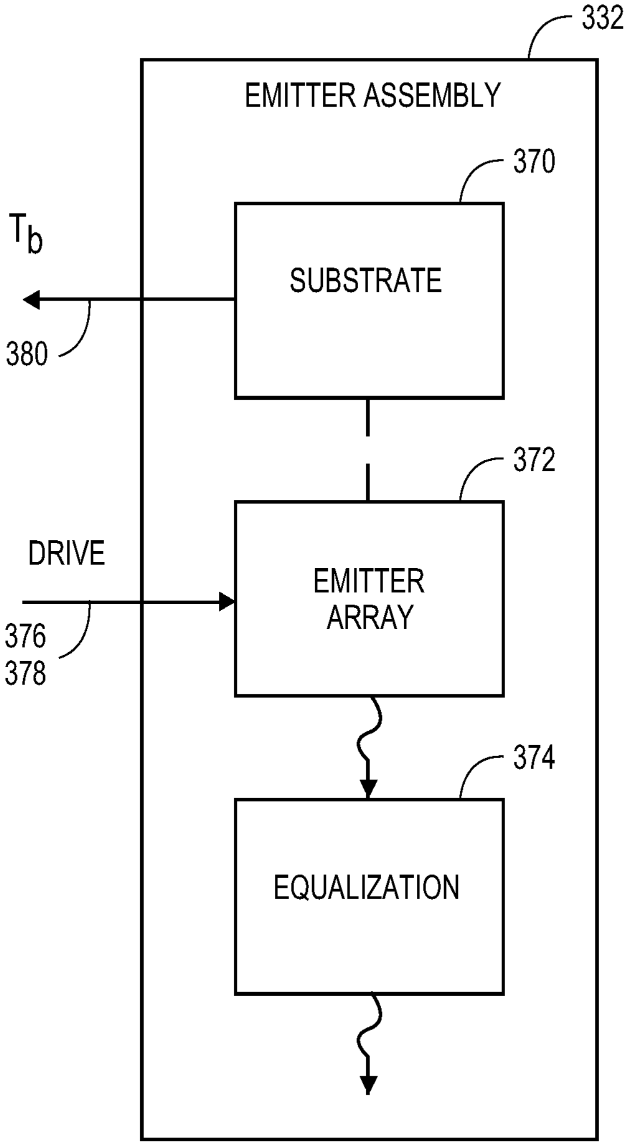
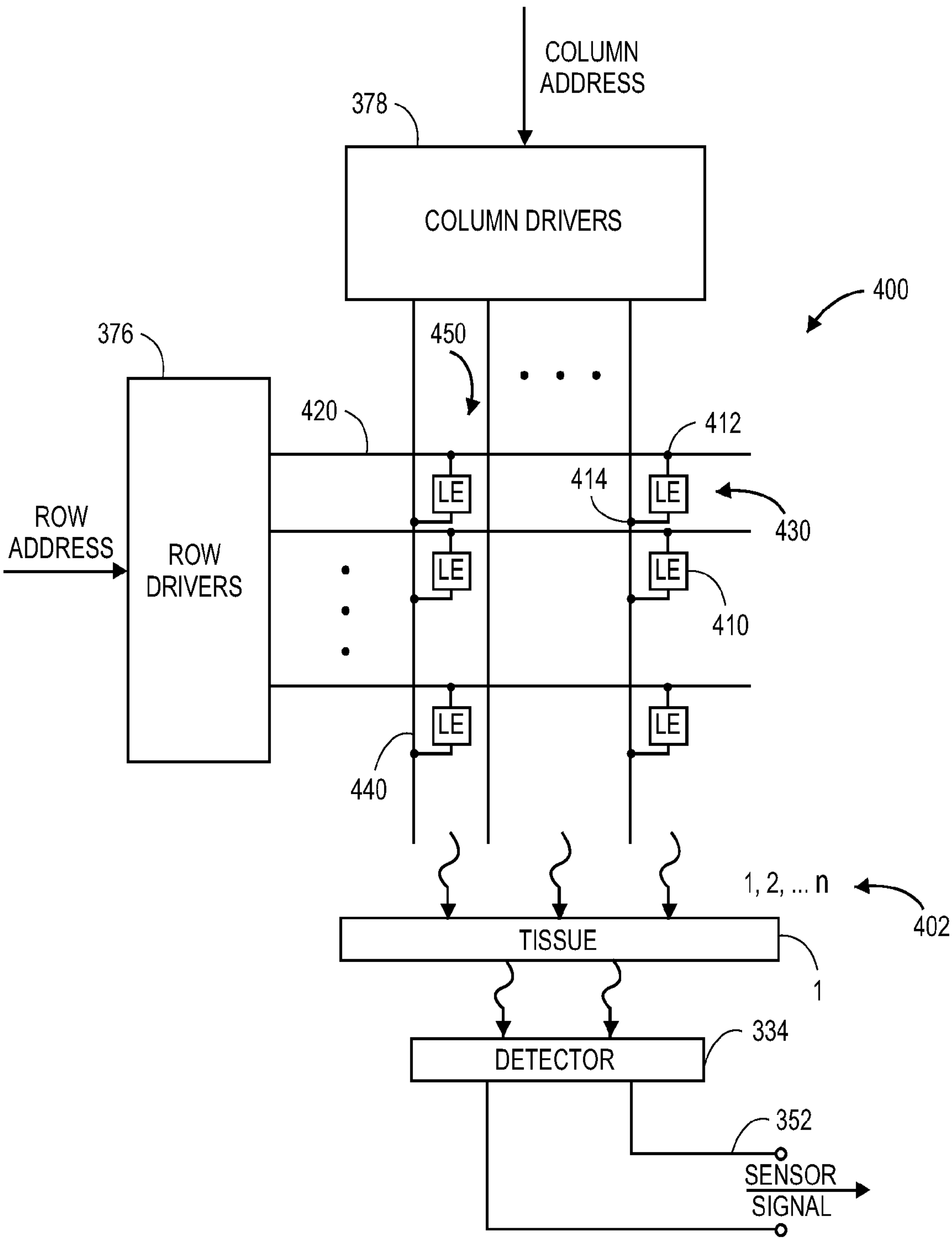

332
EMITTER ASSEMBLY
370
SUBSTRATE
Tb
380
372
DRIVE
EMITTER
ARRAY
376
378
374
EQUALIZATION

FIG. 4C



COLUMN ADDRESS
378
COLUMN DRIVERS
400
376
450
420
412
414
LE
430
ROW ADDRESS
ROW DRIVERS
410
440
1, 2, ... n
402
TISSUE
1
334
DETECTOR
352
SENSOR SIGNAL

FIG. 5A

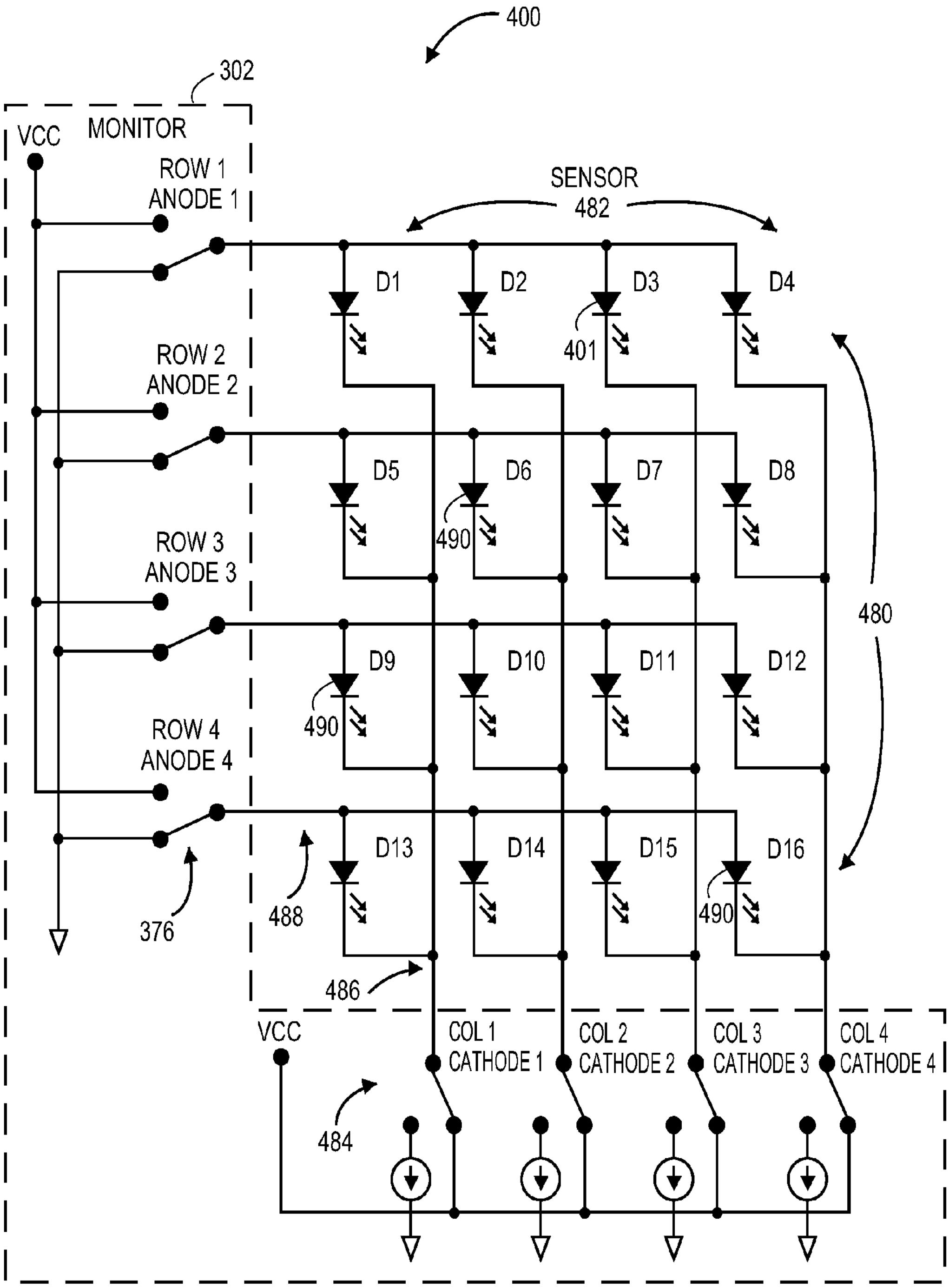

400
302
VCC
MONITOR
ROW 1
ANODE 1
SENSOR
482
D1
D2
D3
D4
401
ROW 2
ANODE 2
D5
D6
D7
D8
490
ROW 3
ANODE 3
480
D9
D10
D11
D12
490
ROW 4
ANODE 4
D13
D14
D15
D16
490
376
488
486
VCC
COL 1
CATHODE 1
COL 2
CATHODE 2
COL 3
CATHODE 3
COL 4
CATHODE 4
484

FIG. 5B

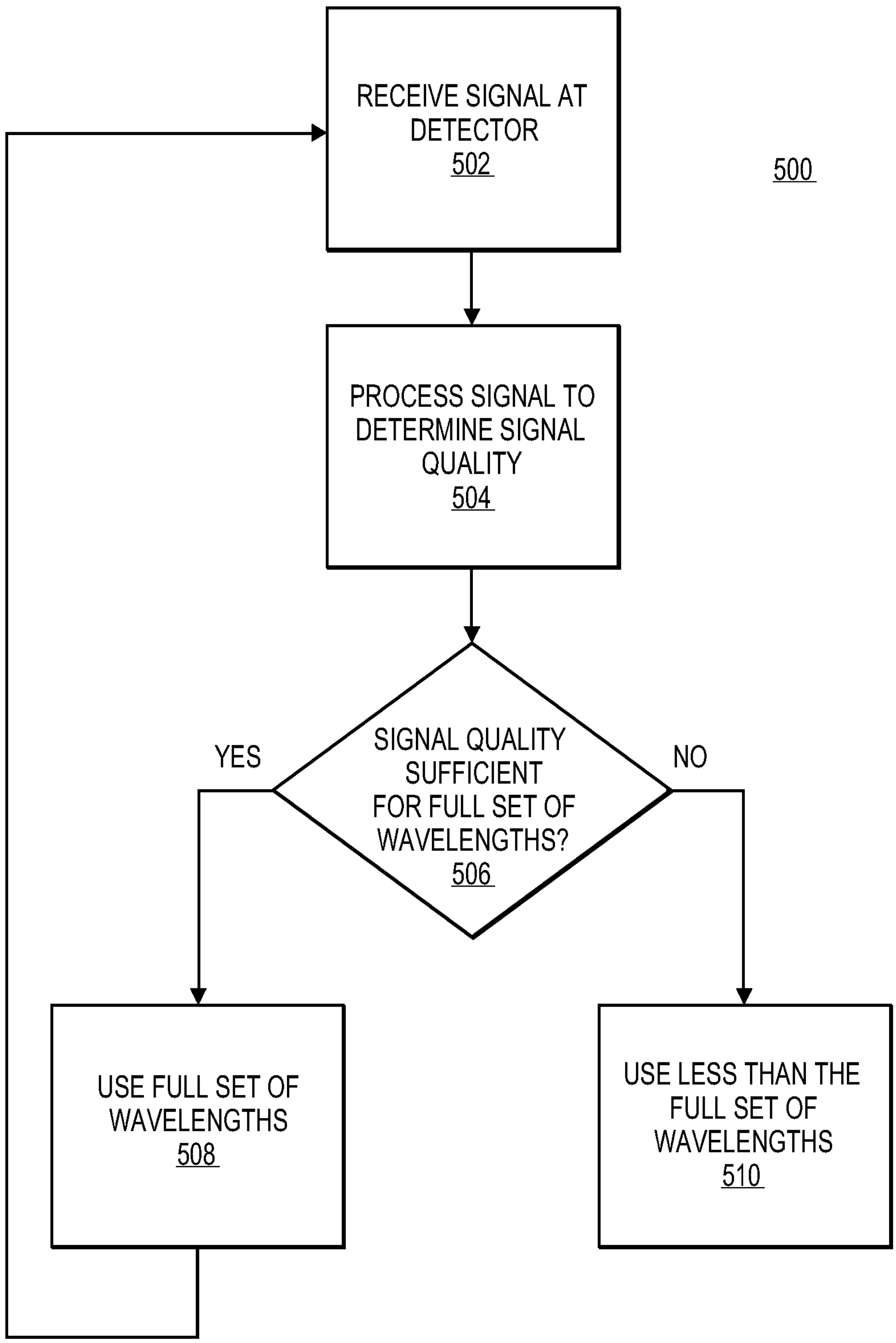

RECEIVE SIGNAL AT DETECTOR 502
500
PROCESS SIGNAL TO DETERMINE SIGNAL QUALITY 504
SIGNAL QUALITY SUFFICIENT FOR FULL SET OF WAVELENGTHS? 506
YES
NO
USE FULL SET OF WAVELENGTHS 508
USE LESS THAN THE FULL SET OF WAVELENGTHS 510

FIG. 6A

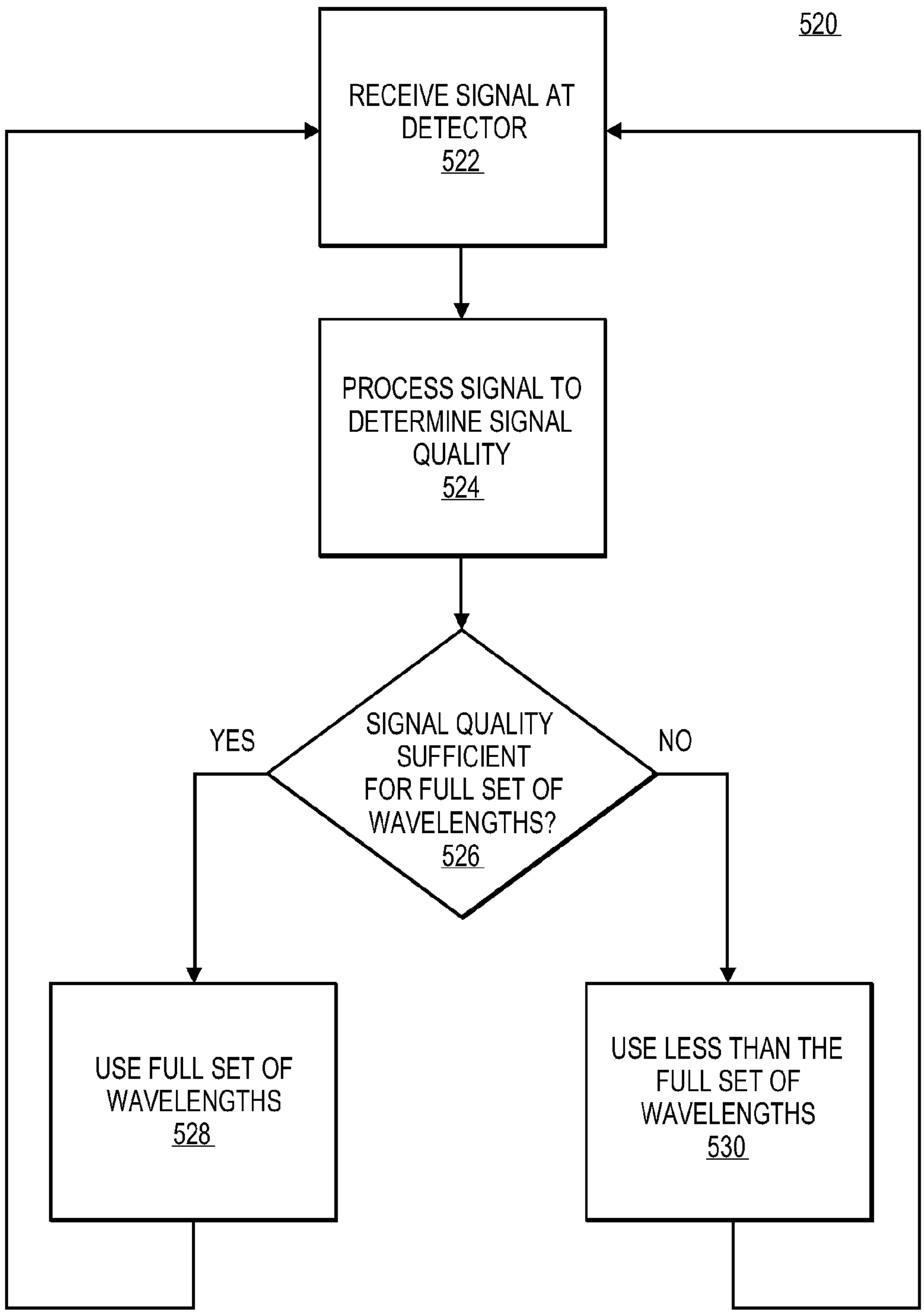

520
RECEIVE SIGNAL AT DETECTOR
522
PROCESS SIGNAL TO DETERMINE SIGNAL QUALITY
524
SIGNAL QUALITY SUFFICIENT FOR FULL SET OF WAVELENGTHS?
526
YES
NO
USE FULL SET OF WAVELENGTHS
528
USE LESS THAN THE FULL SET OF WAVELENGTHS
530

FIG. 6B

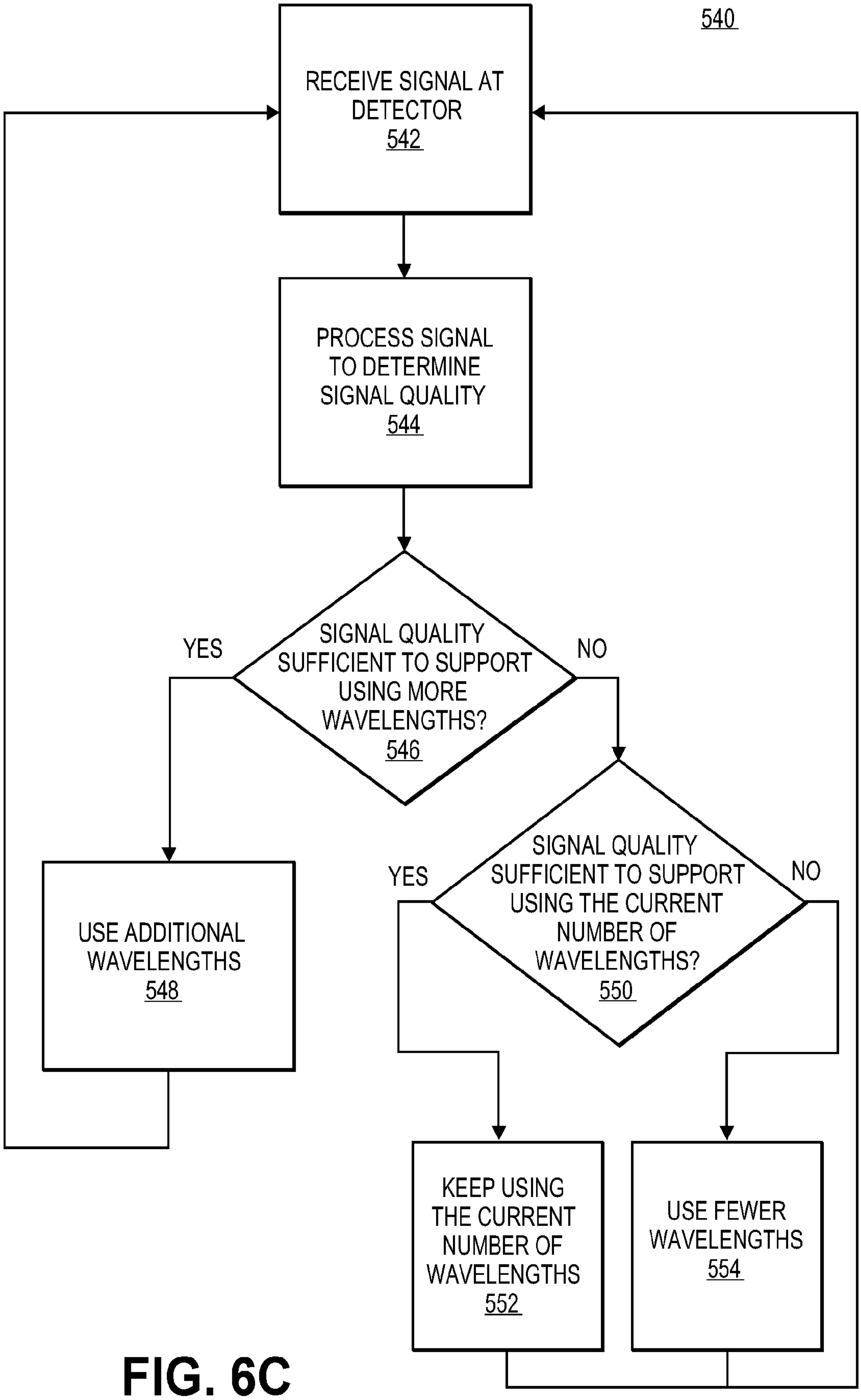

540
RECEIVE SIGNAL AT DETECTOR
542
PROCESS SIGNAL TO DETERMINE SIGNAL QUALITY
544
SIGNAL QUALITY SUFFICIENT TO SUPPORT USING MORE WAVELENGTHS?
546
YES
NO
USE ADDITIONAL WAVELENGTHS
548
SIGNAL QUALITY SUFFICIENT TO SUPPORT USING THE CURRENT NUMBER OF WAVELENGTHS?
550
YES
NO
KEEP USING THE CURRENT NUMBER OF WAVELENGTHS
552
USE FEWER WAVELENGTHS
554

FIG. 6C

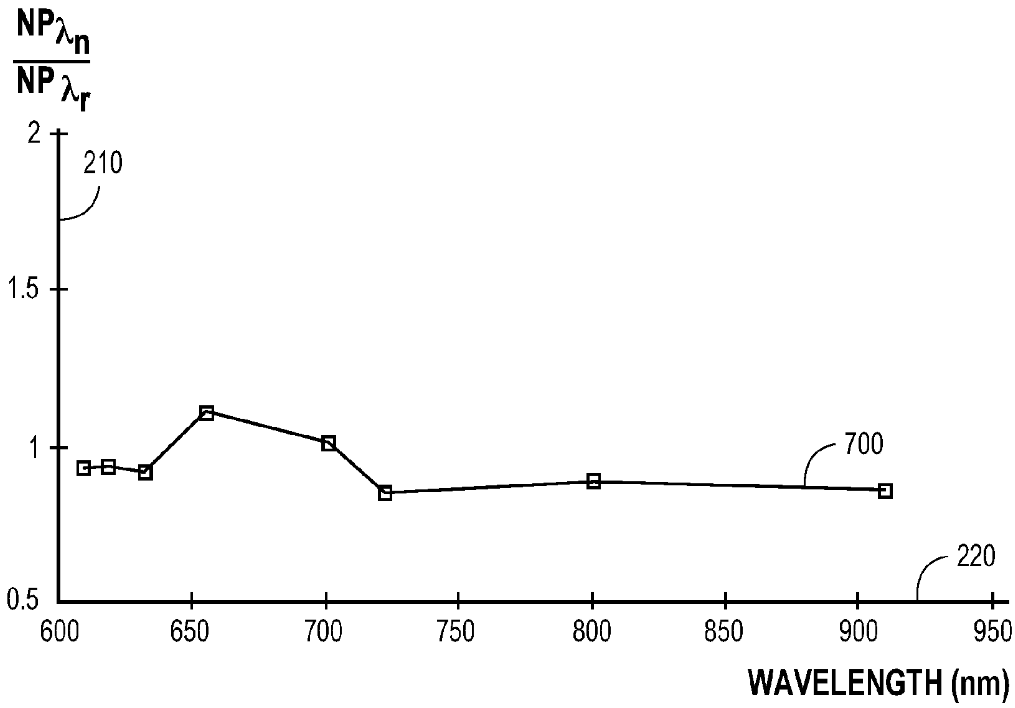

NPλn / NPλr
2
1.5
1
0.5
210
700
220
600
650
700
750
800
850
900
950
WAVELENGTH (nm)

FIG. 7A

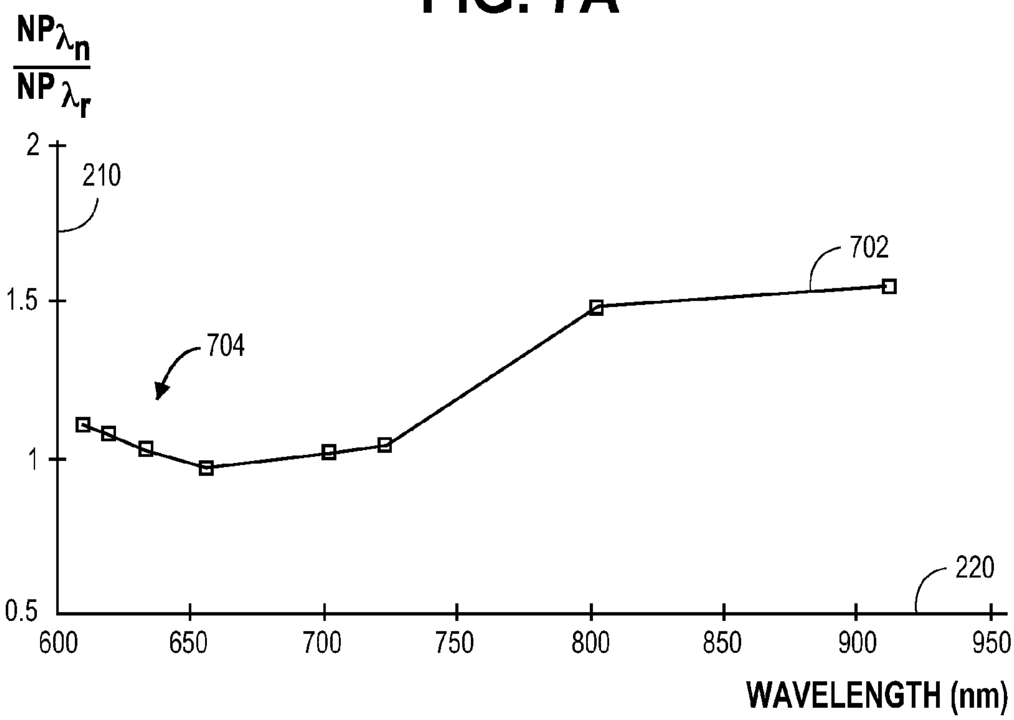

NPλn / NPλr
2
1.5
1
0.5
210
702
704
220
600
650
700
750
800
850
900
950
WAVELENGTH (nm)

FIG. 7B

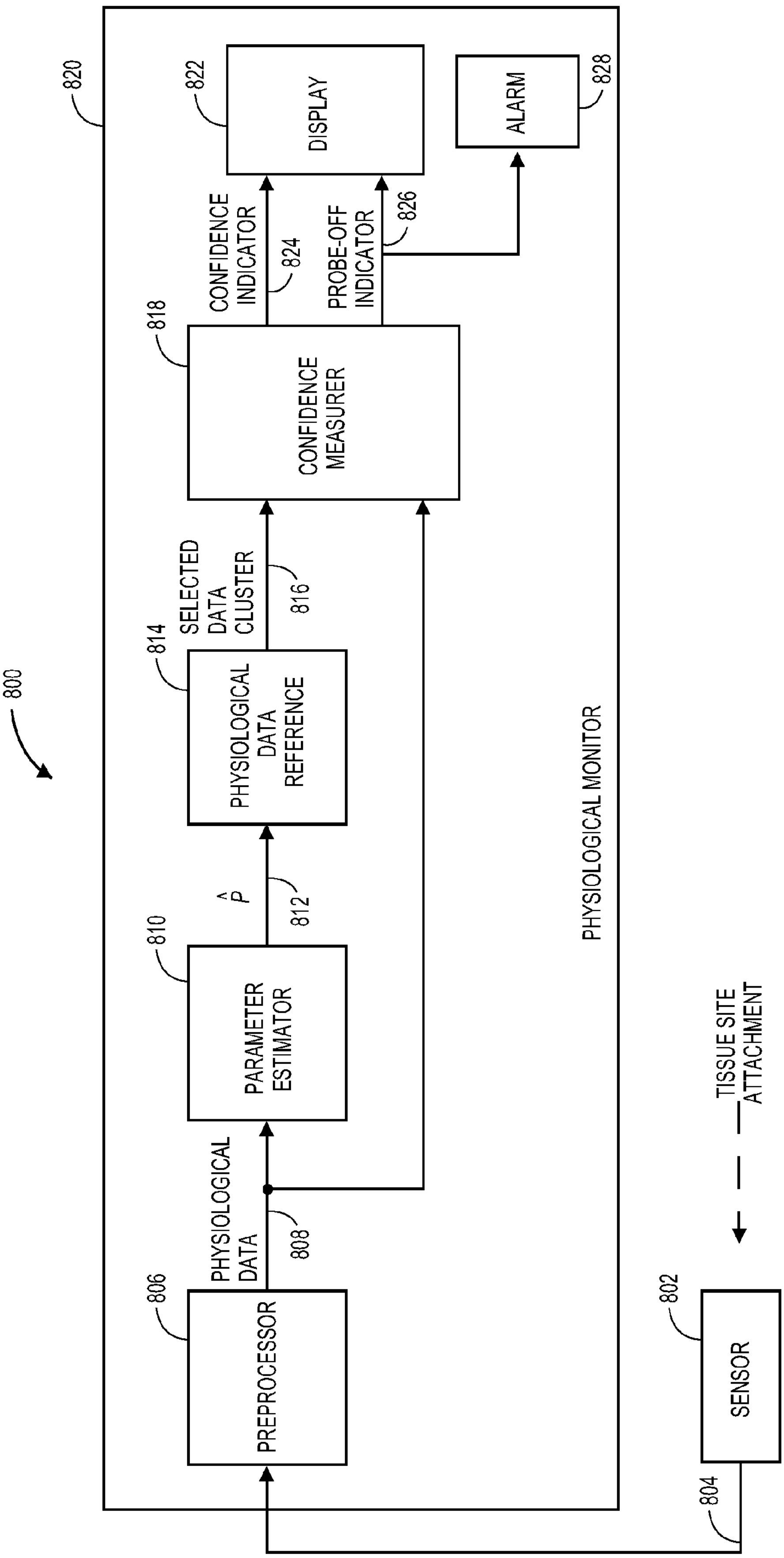
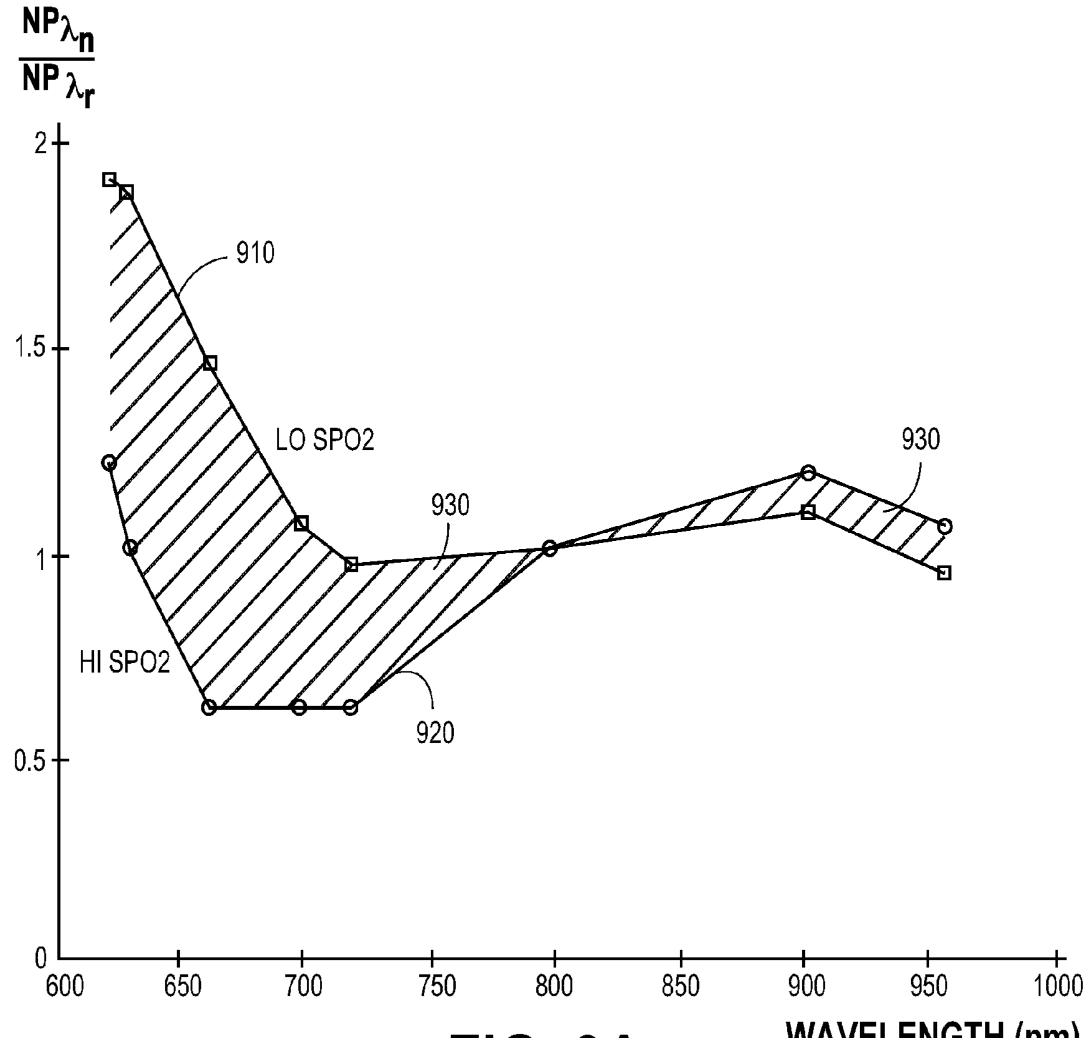
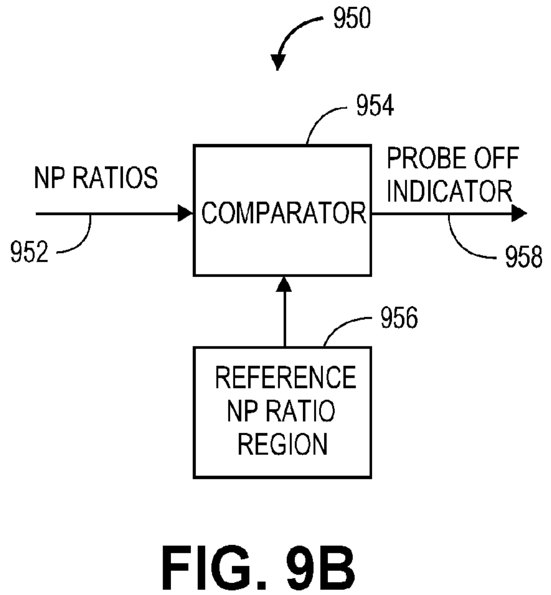

800
820
PHYSIOLOGICAL MONITOR
PREPROCESSOR
806
PHYSIOLOGICAL DATA
808
PARAMETER ESTIMATOR
810
812
PHYSIOLOGICAL DATA REFERENCE
814
SELECTED DATA CLUSTER
816
CONFIDENCE MEASURER
818
CONFIDENCE INDICATOR
824
PROBE-OFF INDICATOR
826
DISPLAY
822
ALARM
828
SENSOR
802
804
TISSUE SITE ATTACHMENT

FIG. 8



$\frac{NP\lambda_n}{NP\lambda_r}$
2
1.5
1
0.5
0
600
650
700
750
800
850
900
950
1000
910
LO SPO2
930
930
HI SPO2
920
WAVELENGTH (nm)

FIG. 9A



950
954
NP RATIOS
COMPARATOR
PROBE OFF
INDICATOR
952
958
956
REFERENCE
NP RATIO
REGION

FIG. 9B

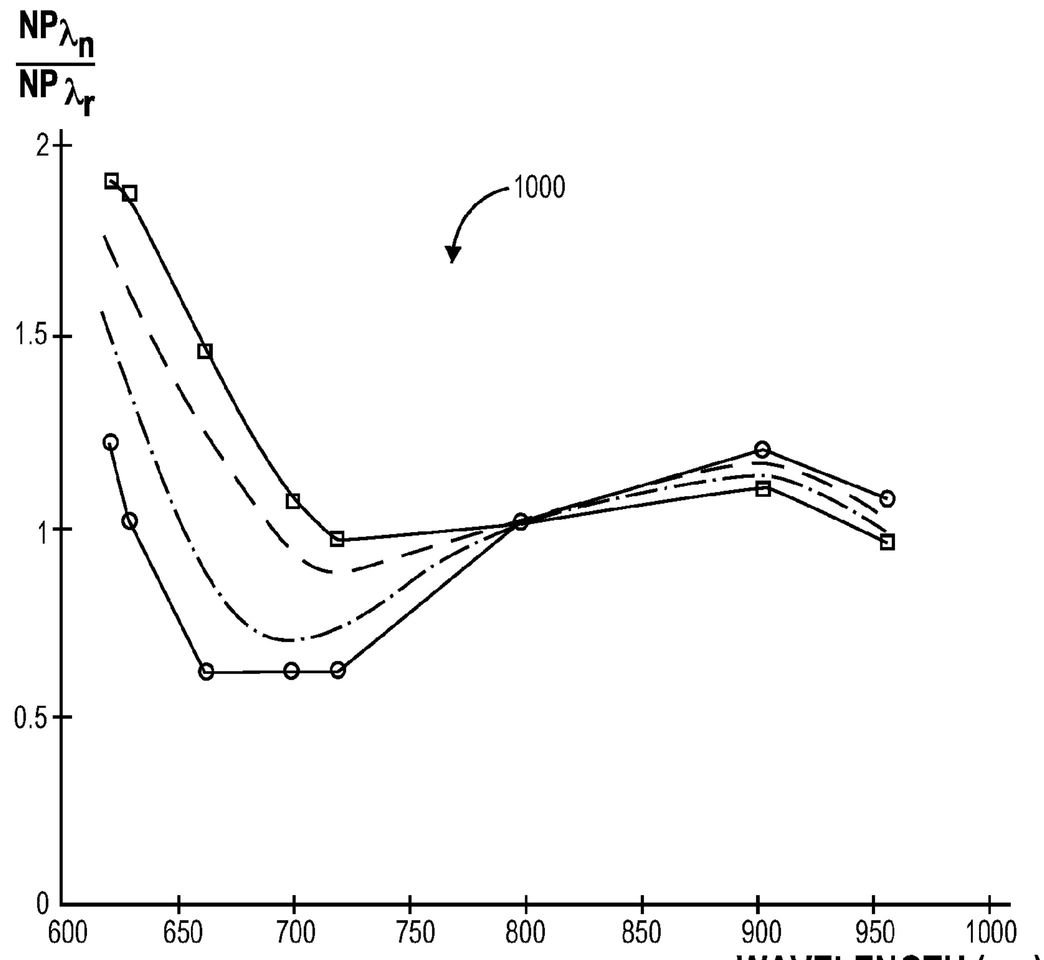


FIG. 10A

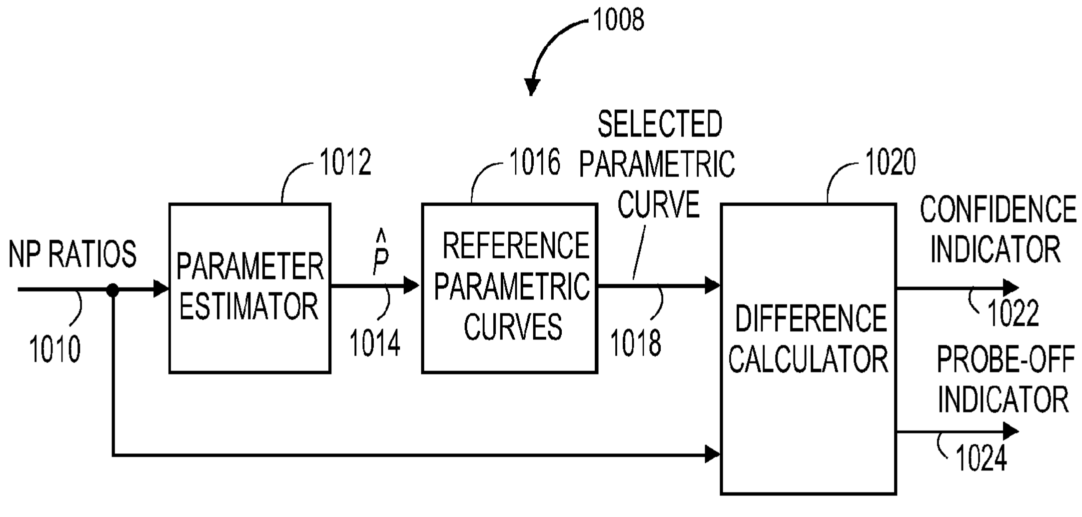


FIG. 10B

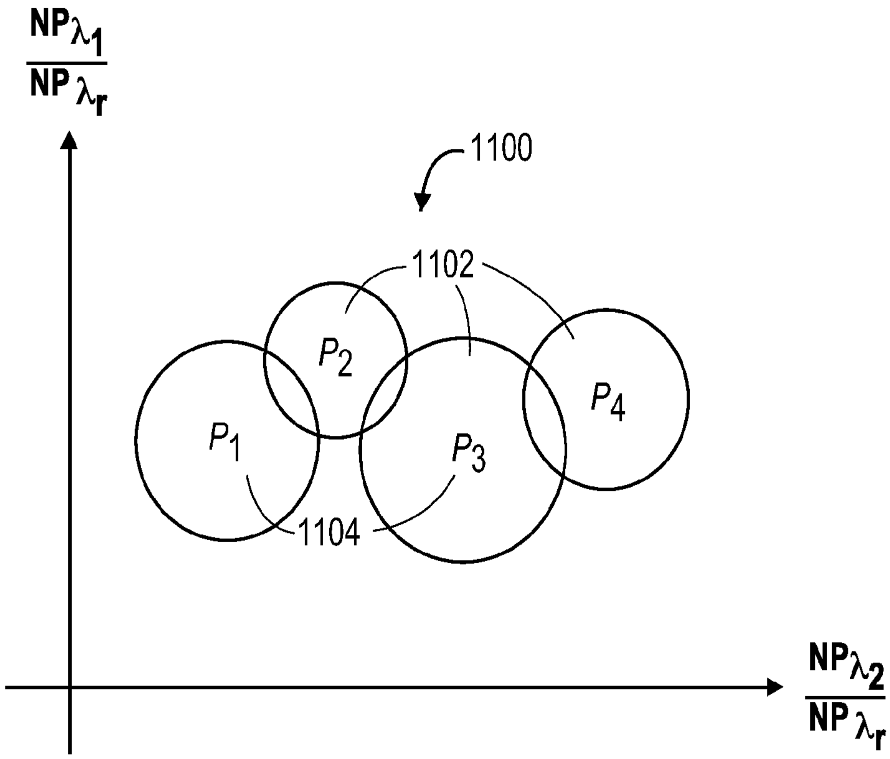


FIG. 11A

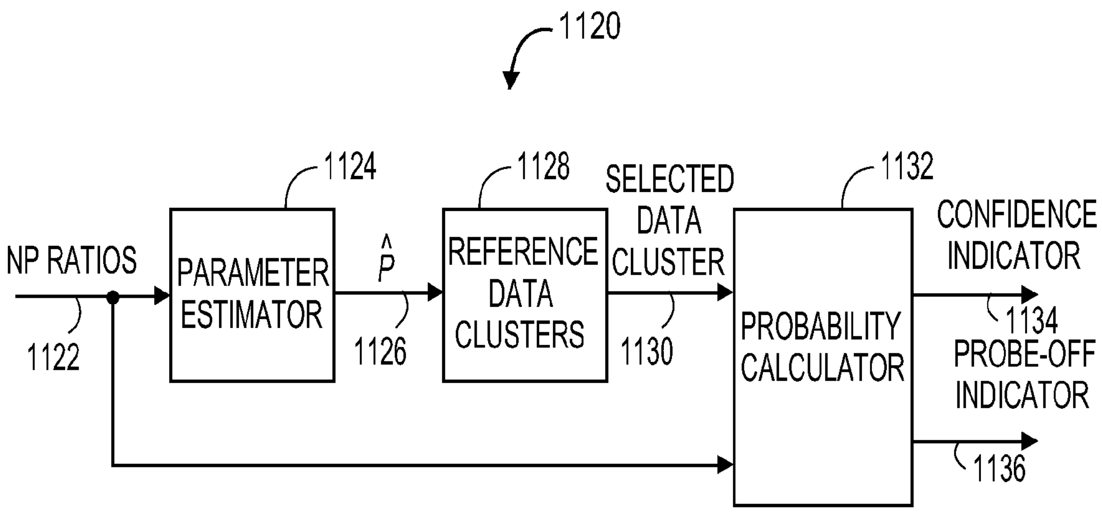


FIG. 11B

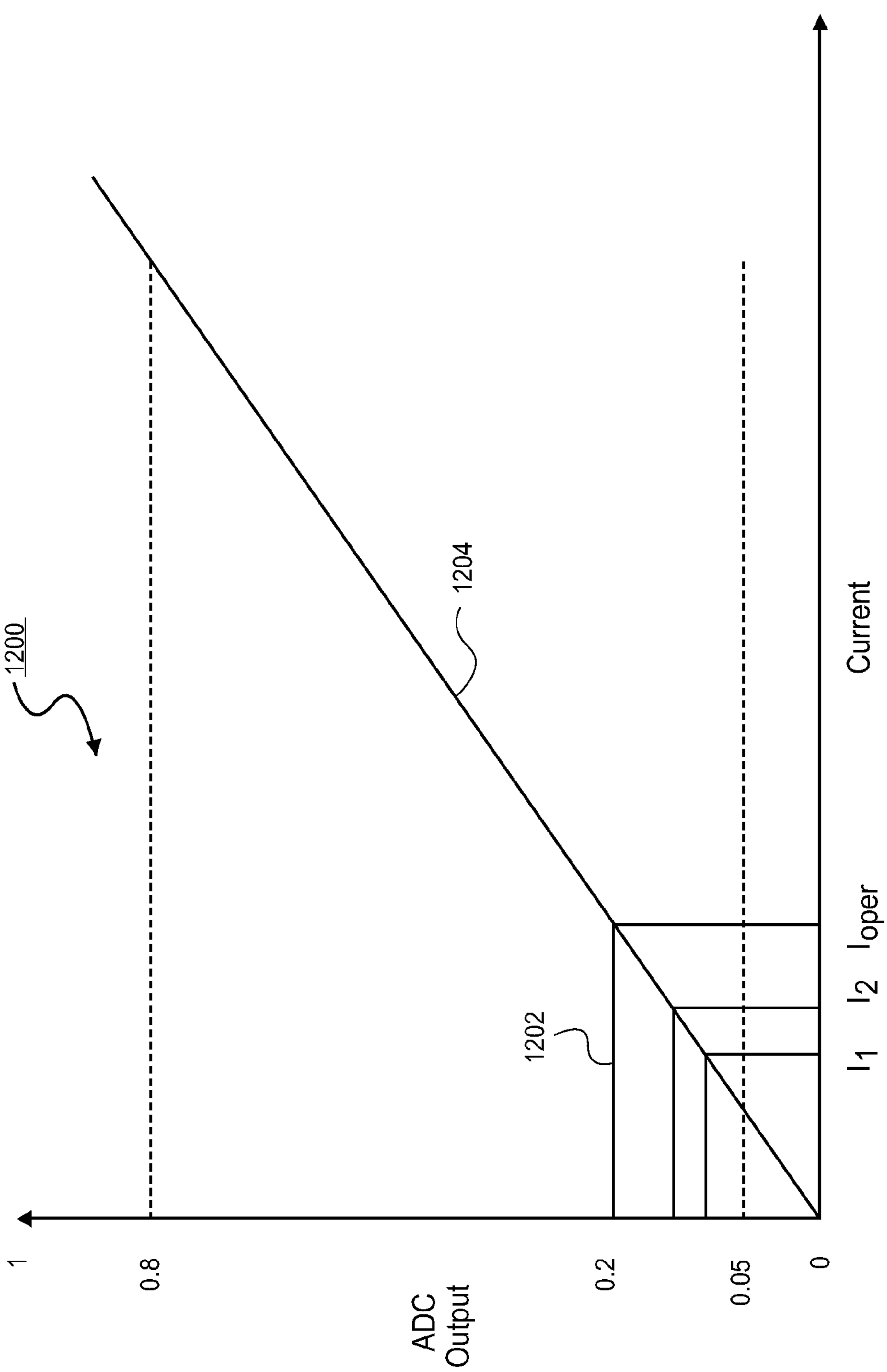


FIG. 12

PHYSIOLOGICAL MEASUREMENT SYSTEM WITH AUTOMATIC WAVELENGTH ADJUSTMENT

PRIORITY CLAIM TO RELATED PROVISIONAL APPLICATIONS

[0001] Any and all applications for which a foreign or domestic priority claim is identified in the Application Data Sheet as filed with the present application are hereby incorporated by reference under 37 CFR 1.57. The present application is a continuation of U.S. patent application Ser. No. 12/949,271, filed Nov. 18, 2010, entitled "PHYSIOLOGICAL MEASUREMENT SYSTEM WITH AUTOMATIC WAVELENGTH ADJUSTMENT," which claims priority benefit under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Ser. No. 61/264,182, filed Nov. 24, 2009, entitled "PHYSIOLOGICAL MEASUREMENT SYSTEM WITH AUTOMATIC WAVELENGTH ADJUSTMENT," and No. 61/330,253, filed Apr. 30, 2010, entitled "PHYSIOLOGICAL MEASUREMENT SYSTEM WITH AUTOMATIC WAVELENGTH ADJUSTMENT." The present application incorporates the foregoing disclosures herein by reference.

INCORPORATION BY REFERENCE OF COPENDING RELATED APPLICATIONS

[0002] The present application is related to the following copending U.S. utility applications:

	App. Sr. No.	Filing Date	Title	Atty Dock.
1	11/367,013	Mar. 1, 2006	Multiple Wavelength Sensor Emitters	MLR.002A
2	11/366,955	Mar. 1, 2006	Multiple Wavelength Sensor Equalization	MLR.003A
3	11/366,209	Mar. 1, 2006	Multiple Wavelength Sensor Substrate	MLR.004A
4	11/366,210	Mar. 1, 2006	Multiple Wavelength Sensor Interconnect	MLR.005A
5	11/366,833	Mar. 1, 2006	Multiple Wavelength Sensor Attachment	MLR.006A
6	11/366,997	Mar. 1, 2006	Multiple Wavelength Sensor Drivers	MLR.009A
7	11/367,034	Mar. 1, 2006	Physiological Parameter Confidence Measure	MLR.010A
8	11/367,036	Mar. 1, 2006	Configurable Physiological Measurement System	MLR.011A
9	11/367,033	Mar. 1, 2006	Noninvasive Multi-Parameter Patient Monitor	MLR.012A
10	11/367,014	Mar. 1, 2006	Noninvasive Multi-Parameter Patient Monitor	MLR.013A
11	11/366,208	Mar. 1, 2006	Noninvasive Multi-Parameter Patient Monitor	MLR.014A
12	12/056,179	Mar. 26, 2008	Multiple Wavelength Optical Sensor	MLR.015A
13	12/082,810	Apr. 14, 2008	Optical Sensor Assembly	MLR.015A2

[0003] The present application incorporates the foregoing disclosures herein by reference.

BACKGROUND

[0004] Spectroscopy is a common technique for measuring the concentration of organic and some inorganic constituents of a solution. The theoretical basis of this technique is the Beer-Lambert law, which states that the concentration c_i of an absorbent in solution can be determined by the intensity of light transmitted through the solution, knowing the pathlength d_λ, the intensity of the incident light $I_{0,\lambda}$, and the extinction coefficient $\varepsilon_{i,\lambda}$ at a particular wavelength λ. In generalized form, the Beer-Lambert law is expressed as:

$$I_\lambda = I_{0,\lambda} e^{-d_\lambda \cdot \mu_{a,\lambda}} \quad (1)$$

$$\mu_{a,\lambda} = \sum_{i=1}^{n} \varepsilon_{i,\lambda} \cdot c_i \quad (2)$$

[0005] where $\mu_{a,\lambda}$ is the bulk absorption coefficient and represents the probability of absorption per unit length. The minimum number of discrete wavelengths that are required to solve EQS. 1-2 are the number of significant absorbers that are present in the solution.

[0006] A practical application of this technique is pulse oximetry, which utilizes a noninvasive sensor to measure oxygen saturation (SpO_2) and pulse rate. In general, the sensor has light emitting diodes (LEDs) that transmit optical radiation of red and infrared wavelengths into a tissue site and a detector that responds to the intensity of the optical radiation after absorption (e.g., by transmission or transreflectance) by pulsatile arterial blood flowing within the tissue site. Based on this response, a processor determines measurements for SpO_2, pulse rate, and can output representative plethysmographic waveforms. Thus, "pulse oximetry" as used herein encompasses its broad ordinary meaning known to one of skill in the art, which includes at least those noninvasive procedures for measuring parameters of circulating blood through spectroscopy. Moreover, "plethysmograph" as used herein (commonly referred to as "photoplethysmograph"), encompasses its broad ordinary meaning known to one of skill in the art, which includes at least data representative of a change in the absorption of particular wavelengths of light as a function of the changes in body tissue resulting from pulsing blood. Pulse oximeters capable of reading through motion induced noise are available from

Masimo Corporation ("Masimo") of Irvine, Calif. Moreover, portable and other oximeters capable of reading through motion induced noise are disclosed in at least U.S. Pat. Nos. 6,770,028, 6,658,276, 6,157,850, 6,002,952 5,769,785, and 5,758,644, which are owned by Masimo and are incorporated by reference herein. Such reading through motion oximeters have gained rapid acceptance in a wide variety of medical applications, including surgical wards, intensive care and neonatal units, general wards, home care, physical training, and virtually all types of monitoring scenarios.

[0007] FIG. **1** illustrates HbO_2 (Oxyhemoglobin) and Hb (Hemoglobin) absorption μ_a versus wavelength. At red and near IR wavelengths below 970 nm, where water has a significant peak, Hb and HbO_2 are the only significant absorbers normally present in the blood. Thus, typically only two wavelengths are needed to resolve the concentrations of Hb and HbO_2, e.g. a red (RD) wavelength at 660 nm and an infrared (IR) wavelength at 940 nm. In particular, SpO_2 is computed based upon a red ratio Red_{AC}/Red_{DC} and an IR ratio IR_{AC}/IR_{DC}, which are the AC detector response magnitude at a particular wavelength normalized by the DC detector response at that wavelength. The normalization by the DC detector response reduces measurement sensitivity to variations in tissue thickness, emitter intensity and detector sensitivity, for example. The AC detector response is a plethysmograph, as described above. Thus, the red and IR ratios can be denoted as NP_{RD} and NP_{IR} respectively, where NP stands for "normalized plethysmograph." In pulse oximetry, oxygen saturation is calculated from the ratio NP_{RD}/NP_{IR}.

SUMMARY OF THE DISCLOSURE

[0008] Embodiments of the disclosure are directed to a physiological measurement system that can automatically adjust the number of wavelengths used based on a sensor signal that is indicative of the optical radiation detected at the sensor after tissue attenuation. In an embodiment, the physiological measurement system performs a calibration process upon power up and/or a first attachment to a tissue site. During the calibration process, the system provides test currents to the light emitting sources in the emitter assembly and examines the sensor signal to determine if the signal quality is sufficient to support the use of a full set of wavelengths. The full set of wavelengths includes eight wavelengths in an embodiment. If it is determined that the signal quality is insufficient to support the full set, a reduced number of wavelengths is used. In an embodiment, the wavelengths at 660 nm and 905 nm, the minimum two wavelengths needed to provide a SpO2 reading, are used in lieu of the full set of wavelengths. In other embodiments, other reduced numbers of wavelengths are used. In other embodiments, the physiological measurement system continually monitors signal quality and automatically adjusts the number of wavelengths used.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. **1** is a graph of oxyhemoglobin and reduced hemoglobin light absorption versus wavelength across portions of the red and IR spectrum;

[0010] FIG. **2** is a graph of NP ratios versus wavelength illustrating a tissue profile;

[0011] FIG. **3**A is a perspective view of a physiological measurement system utilizing a multiple wavelength sensor;

[0012] FIG. **3**B is a perspective view of a multiple wavelength sensor embodiment;

[0013] FIG. **4**A is a general block diagram of a multiple wavelength sensor and sensor controller;

[0014] FIG. **4**B is a general block diagram of a monitor and a sensor;

[0015] FIG. **4**C is a general block diagram of an emitter assembly;

[0016] FIG. **5**A is a general block diagram of an emitter array;

[0017] FIG. **5**B is a schematic diagram of an emitter array embodiment;

[0018] FIGS. **6**A-**6**C are flow diagrams illustrating automatic wavelength adjustment processes in accordance with various embodiments;

[0019] FIG. **7**A is a graph of NP ratios versus wavelength illustrating a probe-off profile;

[0020] FIG. **7**B is a graph of NP ratios versus wavelength illustrating a penumbra profile;

[0021] FIG. **8** is a general block diagram of a confidence measurement system;

[0022] FIG. **9**A is a graph of normalized plethysmograph (NP) ratios versus wavelength for low and high SpO_2 illustrating a NP envelope;

[0023] FIG. **9**B is a block diagram of a multiple wavelength probe off detector utilizing an NP envelope;

[0024] FIG. **10**A is a graph of NP ratios versus wavelength illustrating a family of parametric NP curves;

[0025] FIG. **10**B is a block diagram of a multiple wavelength confidence measurement system utilizing parametric NP curves;

[0026] FIG. **11**A is an NP ratio graph illustrating a family of NP data clusters;

[0027] FIG. **11**B is a block diagram of a multiple wavelength confidence measurement system utilizing NP data clusters; and

[0028] FIG. **12** is a graph showing a ratio of normalized detector signal to current provided to an LED.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029] In this application, reference is made to many blood parameters. Some references that have common shorthand designations are referenced through such shorthand designations. For example, as used herein, HbCO designates carboxyhemoglobin, HbMet designates methemoglobin, and Hbt designates total hemoglobin. Other shorthand designations such as COHb, MetHb, and tHb are also common in the art for these same constituents. These constituents are generally reported in terms of a percentage, often referred to as saturation, relative concentration or fractional saturation. Total hemoglobin is generally reported as a concentration in g/dL. The use of the particular shorthand designators presented in this application does not restrict the term to any particular manner in which the designated constituent is reported.

[0030] Embodiments of the disclosure are directed to a physiological measurement system that can automatically adjust the number of wavelengths used based on a sensor signal that is indicative of the optical radiation detected at the sensor after tissue attenuation. In various embodiments, the adjustment process utilizes various methods of NP profile comparison to derive a confidence measurement to measure the quality of the signal detected at the sensor. In other embodiments, the system provides test currents to light emitter sources in the emitter assembly and measure sensor signals in response to the light emitted to determine signal quality. If the signal quality is insufficient to support using the full set of wavelengths, the physiological measurement system can switch to using less than the full set of wavelengths.

Example Normalized Plethysmograph (NP) Tissue Profile

[0031] FIG. **2** illustrates an example of a "tissue profile" **200** for SpO2=97%. For this example, including FIGS. **7**A-**7**B, below, the sensor emits eight wavelengths (610, 620, 630, 655, 700, 720, 800 and 905 nm). The graph is a plot of NP ratios **210** versus wavelength **220**, where the NP ratios are of the form $NP_{\lambda 1}/NP_{\lambda 2}$. This is a generalization to multiple wavelengths of the ratio NP_{RD}/NP_{IR} described above in FIG. **1** for two (red and IR) wavelengths. In order to provide a common scale for these NP ratios, the ratios are calculated with respect to a reference wavelength, λr, which may be any of the available wavelengths. Thus, the plotted NP ratios are denoted $NP_{\lambda n}/NP_{\lambda r}$ over the n available wavelengths, including λr. Note that the NP ratio at the reference wavelength is $NP_{\lambda r}/NP_{\lambda r}=1$, which is 800 nm in FIG. **2**.

[0032] As shown in FIG. **2**, when a sensor is properly positioned on a tissue site, the detector only receives LED emitted light that has propagated through the tissue site after tissue scattering and absorption. Thus, a tissue profile **200** should reflect the blood constituent absorption characteristics illustrated in FIG. **1**, above. For this high oxygen saturation (97%) example, HbO_2 is the only significantly absorbing blood constituent and, indeed, the resulting tissue profile **200** is shaped like the HbO_2 absorption curve **110** (FIG. **1**).

[0033] FIG. **3**A illustrates an example physiological measurement system **300** that can output and detect wavelength profiles similar to that shown in FIG. **2**. In an embodiment, the measurement system **300** includes a monitor **302** and a multiple wavelength sensor assembly **310** with enhanced measurement capabilities as compared with conventional pulse oximetry. The physiological measurement system **300** allows the monitoring of a person, including a patient. In particular, the multiple wavelength sensor assembly **310** allows the measurement of blood constituent and related parameters in addition to oxygen saturation and pulse rate. Alternatively, the multiple wavelength sensor assembly **310** allows the measurement of oxygen saturation and pulse rate with increased accuracy or robustness as compared with conventional pulse oximetry.

[0034] In an embodiment, the sensor assembly **310** is configured to plug into a monitor sensor port **304**. Monitor keys **306** provide control over operating modes and alarms, to name a few. A display **308** provides readouts of measured parameters, such as oxygen saturation, pulse rate, HbCO and HbMet to name a few.

[0035] FIG. **3**B illustrates a multiple wavelength sensor assembly **310** having a sensor **330** adapted to attach to a tissue site, a sensor cable **320** and a monitor connector **312**. In an embodiment, the sensor **330** is incorporated into a reusable finger clip adapted to removably attach to, and transmit light through, a fingertip. The sensor cable **320** and monitor connector **312** are integral to the sensor **330**, as shown. In alternative embodiments, the sensor **330** may be configured separately from the cable **320** and connector **312**.

[0036] FIG. **4**A illustrates the sensor **330** having an emitter assembly **332**, a detector assembly **334**, an interconnect assembly **336** and an attachment assembly **338**. The emitter assembly **332** responds to drive signals received from a sensor controller **340** in the monitor **302** via the cable **320** so as to transmit optical radiation having a plurality of wavelengths into a tissue site. The detector assembly **334** provides a sensor signal to the monitor **302** via the cable **320** in response to optical radiation received after attenuation by the tissue site. The interconnect assembly **336** provides electrical communication between the cable **320** and both the emitter assembly **332** and the detector assembly **334**. The attachment assembly **338** attaches the emitter assembly **332** and detector assembly **334** to a tissue site, as described above. Additional details of the detector assembly **334**, the interconnect assembly **336** and the attachment assembly **338** are further described in the above-referenced app. Ser. No. 11/367,013, filed Mar. 1, 2006, entitled "Multiple Wavelength Sensor Emitters," which has been incorporated by reference above. The emitter assembly **332** will be described in further details below.

[0037] FIG. **4**B illustrates a monitor **302** and a corresponding sensor assembly **310**, as described generally with respect to FIGS. **3**A, **3**B and **4**A above. As discussed above, the sensor assembly **310** houses the emitter assembly **332** having emitters. In an embodiment, the emitter assembly **332** is responsive to drivers within a sensor controller **340** so as to transmit optical radiation into a tissue site. The sensor **330** also houses a detector assembly **334** that provides a sensor signal **354** responsive to the optical radiation after tissue attenuation. In an embodiment, the sensor signal **354** is filtered, amplified, sampled and digitized by a front-end **348** and input to a DSP (digital signal processor) **346**, which also commands the sensor controller **340**. The sensor cable **320** electrically communicates drive signals from the sensor controller **340** to the emitter assembly **332** and a sensor signal **354** from the detector assembly **334** to a front-end **348**. The sensor cable **320** has a monitor connector **352** that plugs into a monitor sensor port **304**.

[0038] In an embodiment, the DSP **346** processes the incoming digitalized sensor signal **354** and determines whether the signal quality requires a change to the number of wavelengths that are active in the emitter assembly. In an embodiment, the DSP **346** includes methods and components for determining signal quality as shown in FIGS. **8**A-**12**, as will be further described below.

[0039] In an embodiment, the monitor **302** also has a reader **350** capable of obtaining information from an information element (IE) **360** in the sensor assembly and transferring that information to the DSP **346**, to another processor or component within the monitor **302**, or to an external component or device that is at least temporarily in communication with the monitor **302**. In an alternative embodiment, the reader function is incorporated within the DSP **346**, utilizing one or more of DSP I/O, ADC, DAC features and corresponding processing routines, as examples. Additional details and alternate embodiments for components shown in FIG. **4**B are further described in FIGS. **41**-**46** of the above-referenced app. Ser. No. 11/367,013, filed Mar. 1, 2006, entitled "Multiple Wavelength Sensor Emitters."

[0040] In an embodiment, the monitor connector **352** houses the information element **360**, which may be a memory device or other active or passive electrical component. In a particular embodiment, the information element **360** is an EPROM, or other programmable memory, or an EEPROM, or other reprogrammable memory, or both. In an alternative embodiment, the information element **360** is housed within the sensor **330**, or an information element **360** is housed within both the monitor connector **352** and the sensor **330**. In yet another embodiment, the emitter assembly **332** has an information element **360**, which is read in response to one or more drive signals from the sensor controller **340**. In a further embodiment, a memory information element is incorporated into the emitter array **400** (FIG. **5**A) and has characterization information relating to the LEDs **490** (FIG. **5**B). In one advantageous embodiment, trend data relating to slowly varying parameters, such as perfusion index, HbCO or METHb, to name a few, are stored in an IE memory device, such as EEPROM.

Emitter Assembly

[0041] FIG. **4**C illustrates an emitter assembly **332** having an emitter array **372**, a substrate **370** and equalization **374**. The emitter array **372** has multiple light emitting sources, each activated by addressing at least one row and at least one column of an electrical grid. The light emitting sources are capable of transmitting optical radiation having multiple wavelengths. The equalization **374** accounts for differences in tissue attenuation of the optical radiation across the multiple wavelengths so as to at least reduce wavelength-dependent variations in detected intensity. The substrate **370** provides a physical mount for the emitter array and emitter-related equalization and a connection between the emitter array and the interconnection assembly. Advantageously, the substrate **370** also provides a bulk temperature measurement so as to calculate the operating wavelengths for the light emitting sources. The equalization **374** and the substrate **370** are described in further detail in above-referenced app. Ser. No. 11/367,013, filed Mar. 1, 2006, entitled "Multiple Wavelength Sensor Emitters," which has been incorporated by reference above.

Emitter Array

[0042] FIG. **5**A illustrates an emitter array **400** having multiple light emitters (LE) **410** capable of emitting light **402** having multiple wavelengths into a tissue site **1**. The emitter array **400** emits optical radiation having multiple wavelengths of predetermined nominal values, advantageously allowing multiple parameter measurements. In particular, the emitter array **400** has multiple light emitting diodes (LEDs) **410** that are physically arranged and electrically connected in an electrical grid to facilitate drive control, equalization, and minimization of optical pathlength differences at particular wavelengths. In an embodiment, an optical filter is advantageously configured to provide intensity equalization across a specific LED subset. The substrate **370** is configured to provide a bulk temperature of the emitter array **400** so as to better determine LED operating wavelengths.

[0043] As shown in FIG. **5**A, row drivers **376** and column drivers **378** are electrically connected to the light emitters **410** and activate one or more light emitters **410** by addressing at least one row **420** and at least one column **440** of an electrical grid. In an embodiment, the light emitters **410** each include a first contact **412** and a second contact **414**. The first contact **412** of a first subset **430** of light emitters is in communication with a first conductor **420** of the electrical grid. The second contact **414** of a second subset **450** of light emitters is in communication with a second conductor **440**. In an embodiment, each subset comprises at least two light emitters, and at least one of the light emitters of the first and second subsets **430**, **450** are not in common. A detector **334** is capable of detecting the emitted light **402** and outputting a sensor signal responsive to the emitted light **402** after attenuation by the tissue site **1** via monitor connector **352**. As such, the sensor signal is indicative of at least one physiological parameter corresponding to the tissue site **1**, as described above.

[0044] FIG. **5**B illustrates an emitter array **400** having LEDs **490** connected within an electrical grid of n rows and m columns totaling n+m drive lines **488**, **486**, where n and m integers greater than one. The electrical grid advantageously minimizes the number of drive lines required to activate the LEDs **490** while preserving flexibility to selectively activate individual LEDs **490** in any sequence and multiple LEDs **490** simultaneously. The electrical grid also facilitates setting LED currents so as to control intensity at each wavelength, determining operating wavelengths and monitoring total grid current so as to limit power dissipation. The emitter array **400** is also physically configured in rows **480**. This physical organization facilitates clustering LEDs **490** according to wavelength so as to minimize pathlength variations and facilitates equalization of LED intensities.

[0045] As shown in FIG. **5**B, one embodiment of an emitter array **400** comprises up to sixteen LEDs **490** configured in an electrical grid of four rows **480** and four columns **482**. Each of the four row drive lines **488** provide a common anode connection to four LEDs **490**, and each of the four column drive lines **486** provide a common cathode connection to four LEDs **490**. Thus, the sixteen LEDs **490** are advantageously driven with only eight wires, including the four anode drive lines and the four cathode drive lines as shown. This compares favorably to conventional common anode or cathode LED configurations, which require more drive lines. In a particular embodiment, the emitter array **400** is partially populated with eight LEDs having nominal wavelengths as shown in TABLE 1. Further, LEDs having wavelengths in the range of 610-630 nm are grouped together in the same row. The emitter array **400** is adapted to a physiological measurement system **300** (FIG. **3**A) for measuring H_bCO and/or METHb in addition to S_pO_2 and pulse rate.

TABLE 1

Nominal LED Wavelengths

LED	λ	Row	Col
D1	630	1	1
D2	620	1	2
D3	610	1	3
D4		1	4
D5	700	2	1
D6	730	2	2
D7	660	2	3
D8	805	2	4
D9		3	1
D10		3	2
D11		3	3
D12	905	3	4
D13		4	1

TABLE 1-continued

Nominal LED Wavelengths			
LED	λ	Row	Col
D14		4	2
D15		4	3
D16		4	4

[0046] Also shown in FIG. 5B, row drivers 376 and column drivers 484 located in the monitor 302 selectively activate the LEDs 490. In particular, row and column drivers 376, 484 function together as switches to Vcc and current sinks, respectively, to activate LEDs and as switches to ground and Vcc, respectively, to deactivate LEDs. This push-pull drive configuration advantageously prevents parasitic current flow in deactivated LEDs. In a particular embodiment, only one row drive line 488 is switched to Vcc at a time. One to four column drive lines 486, however, can be simultaneously switched to a current sink so as to simultaneously activate multiple LEDs within a particular row. LED drivers and the process of facilitating intensity equalization through the activation of two or more LEDs of the same wavelength are further described in the above-referenced app. Ser. No. 11/367,013, filed Mar. 1, 2006, entitled “Multiple Wavelength Sensor Emitters.”

[0047] Although an emitter assembly is described above with respect to an array of light emitters each configured to transmit optical radiation centered around a nominal wavelength, in another embodiment, an emitter assembly advantageously utilizes one or more tunable broadband light sources, including the use of filters to select the wavelength, so as to minimize wavelength-dependent pathlength differences from emitter to detector. In yet another emitter assembly embodiment, optical radiation from multiple emitters each configured to transmit optical radiation centered around a nominal wavelength is funneled to a tissue site point so as to minimize wavelength-dependent pathlength differences. This funneling may be accomplished with fiberoptics or mirrors, for example. In further embodiments, the LEDs 490 can be configured with alternative orientations with correspondingly different drivers among various other configurations of LEDs, drivers and interconnecting conductors.

Automatic Wavelength Adjustment Processes

[0048] FIGS. 6A-6C are flow diagrams that illustrate the automatic wavelength adjustment processes in accordance with various embodiments. FIG. 6A illustrates an automatic wavelength adjustment process 500. In an embodiment, the process 500 is executed as part of or during a calibration process that is executed when the physiological measurement system 300 is first powered up and/or when the sensor assembly 310 is attached or re-attached to a tissue site. In another embodiment, the process 500 is executed periodically when the physiological measurement system 300 is in use.

[0049] As shown, the process 500 begins in an embodiment at block 502 with the detector 334 receiving a signal after tissue attenuation as described with respect to FIG. 4A. At block 504, the received signal is processed to determine signal quality. In an embodiment, the DSP 346 is configured to process the received signal that has been digitalized by the front-end 348 to determine signal quality. At block 506, the signal quality is evaluated to determine if it is sufficient to support a full set of active wavelengths. In an embodiment, the full set of active wavelengths includes the eight wavelengths as set forth in TABLE 1 above.

[0050] If the signal quality is determined to be lower than that which is needed to support the full set of active wavelengths, at block 510 the physiological measurement system 300 will use less than the full set of active wavelengths. In an embodiment, the DSP 346 sends a signal to the sensor controller 340 (FIG. 4B) to effectuate the use of less than the full set of active wavelengths. In an embodiment, the two active wavelengths used are at 660 nm (Red) and 905 nm (IR), the minimum two needed to detect SpO2. With reference to TABLE 1 and FIG. 5B, for example, LEDs D7 and D12 would be activated at block 510 while the rest of LEDs remain inactive.

[0051] In the alternative, if the signal quality is deemed to be sufficient to support the full set of active wavelengths, then at block 508 the physiological measurement system 300 will use the full set of active wavelengths. In an embodiment, the full set of active wavelengths includes the eight shown in TABLE 1. For example, the corresponding LEDs shown in TABLE 1 would be activated at block 508. In an embodiment, the process 500 then begins again at block 502. Various methods of determining and evaluating signal quality, including criteria for determining sufficiency of a signal quality to support a full set of active wavelengths, will be further described with respect to FIGS. 8A-12.

[0052] FIG. 6B shows another process 520 for automatic wavelength adjustment in which the physiological measurement system 300 periodically determines whether the full set of wavelengths should be used. The process 520 begins in an embodiment at block 522 with the detector 334 receiving a signal after tissue attenuation as described with respect to FIG. 4A. At block 524, the received signal is processed to determine signal quality. In an embodiment, the DSP 346 is configured to process the received signal that has been digitalized by the front-end 348 to determine signal quality. At block 526, the signal quality is evaluated to determine whether it is sufficient to support a full set of active wavelengths. In an embodiment, the full set of active wavelengths includes the eight wavelengths as set forth in TABLE 1 above.

[0053] If the signal quality is deemed to be lower than that which is needed to support the full set of active wavelengths, then at block 530 the physiological measurement system 300 will use less than the full set of active wavelengths. The DSP 346 can send a change signal to the sensor controller 340 (FIG. 4B) if the physiological measurement system 300 is currently using the full set of active wavelengths. For example, the change may reduce the number of active wavelengths from the eight shown in TABLE 1 to two (e.g., 660 nm (Red) and 905 nm (IR)). However, if the physiological measurement system 300 is already using less than the full set of active wavelengths, no action is performed at block 530. In either case, the process 520 returns to block 522 where a new signal will be received and processed at the next sampling cycle.

[0054] In the alternative, if the signal quality is deemed to be sufficient to support the full set of active wavelengths, then at block 528 the physiological measurement system 300 will either continue using the full set of active wavelengths (if the full set is already used) or change to using the full set of active wavelengths (if less than the full set is being used). If a change is needed, in an embodiment the DSP 346 can send a change signal to the sensor controller **340**. The process **520** then returns to block **522**, where a new signal will be received and processed at the next sampling cycle.

[0055] FIG. **6**C shows another process **540** for automatic wavelength adjustment in which the physiological measurement system **300** periodically adjusts the number of wavelengths used depending on the detected signal quality. The process **540** begins in an embodiment at block **542** with the detector **334** receiving a signal after tissue attenuation as described with respect to FIG. **4**A. At block **544**, the received signal is processed to determine signal quality. In an embodiment, the DSP **346** is configured to process the received signal that has been digitalized by the front-end **348** to determine signal quality. At block **546**, the signal quality is evaluated to determine whether it is sufficient to support additional active wavelengths. If so, then at block **548** the physiological measurement system **300** will use additional active wavelengths (if less than the full set is being used). If a change is needed, in an embodiment the DSP **346** can send a change signal to the sensor controller **340**. The process **540** then returns to block **542**, where a new signal will be received and processed at the next sampling cycle.

[0056] If the signal quality is deemed to not be sufficient to support more active wavelengths than those that are currently being used, then at block **550** the physiological measurement system **300** will determine whether the signal qualify can at least support the current set of active wavelengths. If it is sufficient, no action is taken at block **552** and the current number of active wavelengths will continue to be used. Otherwise, the physiological measurement system **300** will use fewer wavelengths. The DSP **346** can send a change signal to the sensor controller **340** (FIG. **4**B). In any case, the process **540** returns to block **542** where a new signal will be received and processed at the next sampling cycle.

[0057] In various embodiments, portions of processes described in FIGS. **6**A-**6**C can be performed at the front-end **348**, the sensor controller **340**, the DSP **346** or any other component within physiological measurement system **300**.

Signal Quality Determination

[0058] FIGS. **7**A-**7**B illustrate profiles of two conditions that are indicative of degraded signal quality. FIGS. **8**A-**11**B describe example methods of deriving a confidence measurement that can be used to measure signal quality, and in particular, to detect degraded signal quality shown in the examples illustrated below.

[0059] FIG. **7**A illustrates an example of a probe-off profile **700**. When a sensor is completely dislodged from a patient, a so-called "probe off" condition occurs. Despite a probe off condition, an optical sensor may continue to detect an AC signal, which can be induced at the detector by other than pulsatile arterial absorption of LED emitted light. For example, small patient movements, vibrations, air flow or other perturbations may cause the pathlength between the LEDs and the detector to vary, resulting in an AC detector signal that can be mistakenly interpreted by the monitor as due to pulsatile arterial blood. Further, ambient light may reach the detector, and any modulation of the ambient light due to AC power, power fluctuations, moving objects, such as a fan, among other perturbations can be also mistaken as a pulsatile arterial signal. Probe off errors are serious because a blood constituent monitor may display normal results, such as oxygen saturation, when, in fact, the sensor is not properly attached to the patient, potentially leading to missed severe desaturation events. As shown in FIG. **7**A, a probe-off profile **700** is readily apparent as it does not have a shape related to the absorption characteristics of hemoglobin constituents.

[0060] FIG. **7**B illustrates an example of a penumbra profile **702**. When a sensor is not properly positioned or becomes partially dislodged, a penumbra condition may occur, where the detector is "shadowed" by a tissue site, such as a finger, but also receives some light directly from the emitters or indirectly reflected off the sensor housing, or both. As a result, the DC signal at the detector rises significantly, which lowers the AC/DC ratio (NP). Because red wavelengths are more significantly absorbed by Hb and HbO2, the penumbra condition is most noticeable at the red portion **704** of the $NP_{\lambda n}/NP_{\lambda r}$. This effect is readily seen in the penumbra profile **702** as compared to a normal tissue profile **200** (FIG. **2**).

[0061] Advantageously, a physiological parameter confidence measurement system, as described below, can distinguish a tissue profile **200** (FIG. **2**) from a probe-off profile **700** (FIG. **7**A) or penumbra profile **702** (FIG. **7**B), as examples. Further, a physiological parameter confidence measurement system can provide indications that the detector signal is degraded as the result of various physiological and non-physiological phenomenons.

Physiological Parameter Confidence Measurement System

[0062] FIG. **8** illustrates a physiological parameter confidence measurement system **800** having a physiological data **808** input, a confidence indicator **824** output and a probe-off indicator **826** output. In an embodiment, physiological data **808**, such as the NP ratios described above, is derived from a sensor **802** generating a sensor signal **804** responsive to multiple wavelengths of optical radiation transmitted into and attenuated by a tissue site. The confidence indicator **824** provides an observer with some measure of "goodness" for the physiological data **808**. That is, if confidence is high, it is likely the physiological data **816** is representative of a physiological condition or state. If confidence is low, the physiological data **808** may be less representative of a physiological condition or state. If the confidence is very low, a probe-off indicator **826** may be generated to alert an observer to the possibility that a sensor from which the physiological data **808** is derived is not properly positioned on a tissue site and may not be generating physiologically significant data. In an embodiment, a confidence measure may be provided as a percentage, such as 0-100%.

[0063] The confidence measure can be used to measure signal quality in the processes described above with respect to FIGS. **6**A-**6**C. For example, the confidence level threshold may be set at 80% in order for a full set of wavelengths to be used. In other embodiments, the threshold may be set by the user of the physiological measurement system **300**. In various embodiments, a confidence indicator **824** corresponding to a confidence measure may be visual (through a display **822**) or audible (through an alarm **828**) or both. The visual or audible indication may assist the user in setting the threshold.

[0064] As shown in FIG. **8**, the physiological parameter confidence measurement system **800** also has a parameter estimator **810**, a physiological data reference **814** and a confidence measurer **818**. The parameter estimator **810** derives one or more physiological parameter estimates, $\hat{P}$, **812** based upon the physiological data **810**. The parameter estimate or estimates **812** are used to select one or more data clusters **816** from the physiological data reference **814**. In an embodiment, the physiological data reference **814** is a collection of predetermined physiological data organized in data clusters. For example the physiological data reference **814** may contain clinically-derived physiological data organized according to corresponding values of a physiological parameter determined by a "gold standard" instrument. In a particular embodiment, the physiological data are NP ratios obtained for various physiological parameters, such as SpO_2, HbCO, HbMet, Hbt, fractional oxygen saturation, bilirubin or glucose to name a few, as measured with a standardized cooximeter, for example. In an embodiment, the physiological data reference **814** is a non-volatile memory or other data storage device containing predetermined physiological data. The confidence measurer **818** uses the physiological data **808** and the selected data cluster or data clusters **816** to generate the confidence indicator **824**, the probe-off indicator **826** or both.

[0065] A confidence measurement and confidence indicator, as described herein, may be combined with other signal quality and data confidence measurements and indicators, such as those described in U.S. Pat. No. 6,996,427 titled Pulse Oximetry Data Confidence Indicator and U.S. Pat. No. 6,606,511 titled Pulse Oximetry Pulse Indicator, both patents assigned to Masimo Corporation, Irvine, Calif. and incorporated by reference herein. A probe off measurement and probe off indicator as described herein may be combined with other probe off measurements and indicators, such as those described in U.S. Pat. No. 6,654,624 titled Pulse Oximeter Probe-Off Detector and U.S. Pat. No. 6,771,994 titled Pulse Oximeter Probe-Off Detection System, both patents assigned to Masimo Corporation, Irvine, Calif. and incorporated by reference herein.

[0066] FIG. **9**A illustrates NP ratio versus wavelength curves computed from a multiple wavelength sensor, such as described in the U.S. patent application titled "Multiple Wavelength Sensor," referenced above. In this example, the sensor emits eight wavelengths (620, 630, 660, 700, 730, 805, 905 and 960 nm). As with FIGS. **8**A and **8**B, the confidence measurement derived from the embodiments shown in FIGS. **9**A and **9**B can be used to adjust the number of active wavelengths that is used by the physiological measurement system **300**.

[0067] Shown in FIG. **9**A is a low oxygen saturation curve **610**, e.g. SpO_2=70% and a high oxygen saturation curve **620**, e.g. $SpO_2 \approx 100\%$. By comparison, a conventional two wavelength pulse oximetry sensor, as described above, results in a single point on a particular curve. Advantageously, the NP ratio curves **910**, **920** represent a tissue profile that can be compared to a particular sensor response to determine if a physiologically significant measurement has been made. In an embodiment, the NP ratio curves **910**, **920** delineate the boundaries of a physiologically significant NP ratio region **930**. Although described above with respect to SpO_2, such regions or boundaries can be derived for other physiological parameters such as HbCO, HbMet, Hbt, fractional oxygen saturation, bilirubin or glucose to name a few.

[0068] FIG. **9**B illustrates one embodiment of a physiological parameter confidence measurement system **950** utilizing a NP ratio region such as described with respect to FIG. **9**A, above. The confidence measurement system **950** has input NP ratios **952** measured in response to a multiple wavelength sensor, reference NP ratio region **956** that delineates physiologically significant NP ratios **930** (FIG. **9**A), and a comparator **954**. In one particular embodiment, the NP ratio region **956** is predetermined from clinically-derived data for one or more parameters of interest, such as SpO_2, HbCO, HbMet, Hbt, fractional oxygen saturation, bilirubin or glucose, to name a few. In another particular embodiment, the NP ratio region **956** is theoretically calculated. The comparator **954** compares the input NP ratios **952** with the NP ratio region **956** and generates a probe-off indicator **958** if any, or more than a predetermine number, of the input NP ratios **952** fall outside of an NP ratio region **956**.

[0069] FIG. **10**A illustrates a family of parametric NP ratio versus wavelength curves **1000** computed from a multiple wavelength sensor, such as referenced above. Each curve represents a different value of a measured parameter, such as SpO_2. For example, there may be a curve for each of SpO_2=70%, 75%, 80%, . . . 100%. Advantageously, such curves more precisely indicate physiologically significant multiple wavelength sensor measurements as compared to a bounded NP ratio region **930** (FIG. **9**A) such as described with respect to FIGS. **9**A-**9**B, above. The confidence measurement derived by the method shown in FIGS. **10**A-**10**B can be used to adjust the number of active wavelengths that is used by the physiological measurement system **300**.

[0070] FIG. **10**B illustrates another embodiment of a physiological parameter confidence measurement system **1008** utilizing parametric NP ratio curves, such as described with respect to FIG. **10**A, above. The confidence measurement system **1008** has input NP ratios **1010** measured in response to a multiple wavelength sensor, a parameter estimator **1012**, reference parametric curves **1016** and a difference calculator **1020**. The parameter estimator **1012** inputs the NP ratios **1010** so as to generate a parameter estimate **1014**, such as SpO_2, HbCO, HbMet, Hbt, fractional oxygen saturation, bilirubin or glucose, to name a few. The estimated parameter **1014** selects one or more of the reference parametric curves **1016**, which are predetermined from clinically-derived data that is stored in memory or data that is mathematically pre-calculated or calculated in real time and stored in memory. The difference calculator **1020** measures the difference between the NP ratios **1010** and the selected parametric curve **1016**. For example, a mean-squared error calculation can be made between the input NP ratios **1010** and the selected parametric curve **1018**. The resulting difference calculation is used as a confidence measure or translated into a confidence measure and a confidence indicator output **1022** is generated accordingly. Alternatively, or in addition to a confidence measure, a probe off condition can be indicated if the difference calculation is larger than a predetermined value or the confidence measure is less than a predetermined value. In another embodiment, a correlation calculator is used in place of the difference calculation. The confidence measurement derived from the embodiments shown in FIGS. **10**A-**10**B can also be used to adjust the number of active wavelengths that is used by the physiological measurement system **300**.

[0071] FIG. **11**A illustrates a family of data clusters **1100** shown in two dimensions by way of example. Each data cluster **1100** represents NP ratios clinically measured across a population for specific values **1104** of a selected parameter P, such as P_1, P_2, P_3 and P_4 as shown. Each data cluster **1100** defines a region **1102** of NP ratios measured for a particular parameter value **1104** and has a probability distribution, such as a normal distribution, over the indicated region **1102**.

[0072] For example, the clinical data can be organized as a table of known values of P, corresponding NP ratios measured over a population, and the relative number of occurrences of particular NP ratio values for each value of P. The relative number of occurrences of particular NP ratio values for a particular value of P yields an NP ratio probability distribution for that value of P. Thus, each P value **1104** in the table has a corresponding data cluster **1100** of measured NP ratios and an associated probability distribution for those NP ratios.

[0073] FIG. **11**B illustrates yet another embodiment of a physiological parameter confidence measurement system **1120** utilizing NP data clusters and corresponding probability distributions, such as described with respect to FIG. **11**A, above. The confidence measurement system **1120** has input NP ratios **1122** measured in response to a multiple wavelength sensor, a parameter estimator **1124**, reference data clusters **1128** and a probability calculator **1132**. The parameter estimator **1124** inputs the NP ratios **1122** so as to generate a parameter estimate **1126**, such as described with respect to other embodiments, above. In an embodiment, the reference data clusters **1128**, such as described with respect to FIG. **11**A, are stored in a memory device, such as an EPROM. The estimated parameter **1130** is compared with the reference data clusters **1140** so as to determine the closest region **1102** (FIG. **11**A) or closest overlapping portion of two regions **1102** (FIG. **11**A). The probability calculator **1132** computes a probability based upon the distribution above the selected region **1102** (FIG. **11**A). A confidence measure is also derived based upon the calculated probability. In a particular embodiment, the confidence measure is the calculated probability. A confidence indicator **1134** is generated in response to the confidence measure. In an embodiment, if the confidence probability or the calculated confidence measure is below a predetermined threshold, a probe-off indicator **1136** is generated. In particular embodiments, the confidence indicator **1134** or probe-off indicator **1136** or both may be alphanumeric or digital displays, optical indicators or alarms or similar audible indicators, to name a few. The confidence measurement derived from the embodiments shown in FIGS. **11**A-**11**B can also be used to adjust the number of active wavelengths that is used by the physiological measurement system **300**.

Automatic Wavelength Adjustment During Calibration

[0074] Besides utilizing the confidence measurements derived from the methods and systems shown in FIGS. **8**A-**11**B for automatic wavelength adjustment, embodiments of the physiological measurement system **300** can also automatically adjust the number of active wavelengths based on the results of a calibration process.

[0075] FIG. **12** shows a graph **1200** illustrating a signal calibration process performed by the physiological measurement system **300**. The graph plots the Analog-to-Digital Conversion (ADC) signal output (i.e. the digitalized sensor signal) against the current supplied to an LED in the emitter assembly **332**. The ADC output may be from the front-end **348** shown in FIG. **4**A, for example. As shown, the ADC signal output ranges from 0 to 1 on a normalized scale. In an embodiment, an ideal range of output is preferably between 0.05 to 0.80, with an ideal operational output at about 0.2. The ideal range of output provides a proper determination of physiological data measurements.

[0076] In an embodiment, the physiological measurement system **300** performs calibration by sending a small test current through each of the LEDs that is used in emitting optical radiation at the full set of active wavelengths (e.g. the LEDs shown in TABLE 1). The system can, for example, send a 5 milliamp current, as denoted by the symbol I_1 in graph **1200**. The detector then records the detected signal after tissue attenuation. A sample input-output is shown in line **1204**, which illustrates the ratio of measured, digitalized sensor signal to the input current provided to the LED. The calibration can then send an additional, larger test current through the LED, e.g. 10 milliamps, as denoted by the symbol I_2. Based on the level of the measured sensor signal(s) in response to the one or more test currents provided to the LED, the physiological measurement system **300** can determine whether a sensor signal output in the acceptable range can be obtained when a larger operational current is applied. For example, the physiological measurement system **300** can use the measured outputs from the test currents to extrapolate a likely sensor signal output **1202** (shown in FIG. **12** as having a normalized ADC of 0.2) based on an anticipated operational current I_{oper}. In an embodiment, the DSP **346** performs these determination calculations. In other embodiments, they are performed by other components such as the front end **348**.

[0077] In an embodiment, the calibration performs the same or similar test for each of the LEDs that is used in emitting optical radiation at the full set of active wavelengths, and determines whether the extrapolated signal output for the LED(s) for each individual wavelength is acceptable. In the example configuration shown in TABLE 1, where there is a one-to-one correspondence between LEDs and wavelengths, the calibration process would determine whether the extrapolated signal output for each LED is within the acceptable range. In an embodiment, the extrapolation takes into account that while each active LED may be driven by a different amount of operational current, an overall gain is applied to all active LEDs in the emitter array. Therefore, in an embodiment, the calibration process also attempts to determine an operational current for each active LED in order to have all sensor signals fall within the acceptable ADC range, as illustrated in the example in FIG. **12**.

[0078] In an embodiment, if one or more extrapolated signal outputs for a particular wavelength are not in the acceptable range, the physiological measurement system **300** uses a fewer number of active wavelengths, i.e., the associated LED(s), than the full set of active wavelengths. For example, in an embodiment where the full set of active wavelengths comprises eight wavelengths, if any of the eight wavelengths returns an unacceptable result in calibration, the reduction can go from eight active wavelengths to two. The two can be of the wavelengths 660 nm (red) and 905 nm (IR), the two needed for providing a SpO2 reading. In an embodiment, the LED(s) for the two active wavelengths are activated at a longer duty cycle (½ cycle/wavelength) than when the full set of active wavelengths is used (⅛ cycle/wavelength).

[0079] In other embodiments, the number of active wavelength is first reduced from eight to four, and then from four to two. In embodiments in which the physiological measurement system includes twelve active wavelengths, the number can be progressively reduced from twelve to eight to four to two, if the calibration results necessitate such a reduction. In other embodiments, the physiological measurement system **300** does not follow a pre-set reduction routine but instead attempts to maximize the number of physiological data measurements that can be obtained given the number of wavelengths that pass the calibration test. Thus, for example, instead of reducing from twelve to two when one wavelength fails the calibration test, the physiological measurement system **300** can reduce to ten, if the remaining ten can all be used to determine physiological data measurements.

Additional Embodiments

[0080] In an embodiment, the physiological measurement system **300** may return at least one physiological data measurement even when the detected signal does not support a full set of physiological data measurements. For example, if the detected signal indicates that a patient's perfusion is too low to support an Hb measurement but can otherwise support a SpO2 measurement, the physiological measurement system **300** may return the SpO2 measurement.

[0081] In an embodiment, the patient's perfusion level is used in the afore-mentioned confidence calculations. In an embodiment, the observed perfusion index is used as a factor in determining confidence. In another embodiment, the confidence level is determined based on perfusion alone. For example, an observed perfusion index that is outside of an acceptable range (e.g. below a threshold) would lead to a low confidence level.

[0082] In an embodiment, the physiological measurement system **300** provides user options for configuring the use of less than a full set of wavelengths. The options allow a user to configure the physiological measurement system **300** to specify the manner in which the number of wavelengths are reduced based on user-specified or pre-specified confidence level(s). For example, a user can configure the physiological measurement system **300** to use two wavelengths if the confidence level drops below a certain user-specified or pre-specified level. In another embodiment, a user can configure a confidence level below which a particular physiological data measurement is not returned by the physiological measurement system **300**.

[0083] A multiple wavelength sensor with automatic wavelength adjustment has been disclosed in detail in connection with various embodiments. These embodiments are disclosed by way of examples only and are not to limit the scope of the claims that follow. One of ordinary skill in art will appreciate many variations and modifications.

1-28. (canceled)

29. An optical non-invasive physiological parameter measurement system comprising:

- one or more light emitting sources configured to emit light at a plurality of wavelengths;
- a sensor configured to detect light emitted by the one or more light emitting sources after the emitted light is attenuated by body tissue, and to generate an output signal useable to measure at least one physiological parameter of the body tissue; and
- a processor configured to:
  - cause the one or more light emitting sources to emit light at the plurality of wavelengths;
  - determine a physiological parameter estimate from a first output signal received from the sensor based on detected light emitted at the plurality of wavelengths;
  - determine a confidence measurement value based on the physiological parameter estimate and a physiological data reference;
  - cause the one or more light emitting sources to emit light at less than the plurality of wavelengths by deactivating at least one of the plurality of wavelength emissions when the confidence measurement value is less than a threshold value; and
  - determine a physiological parameter measurement based on a second output signal received from the sensor based on detected light emitted at less than all of the plurality of wavelengths.

30. The system of claim **29**, wherein the processor is further configured to:

- determine a second physiological parameter estimate from the second output signal received from the sensor based on detected light emitted at the less than all of the plurality of wavelengths;
- determine a second confidence measurement value based on the second physiological parameter estimate and a second physiological data reference; and
- activate at least one of deactivated wavelength emissions when the confidence measurement value is greater than the threshold value.

31. The system of claim **29**, wherein the physiological data reference comprises a normalized plethysmograph ratio region bounded by a high normalized plethysmograph ratio curve and a low normalized plethysmograph ratio curve.

32. The system of claim **31**, wherein the high normalized plethysmograph ratio curve is a high oxygen saturation (SpO_2) curve and the low normalized plethysmograph ratio curve is a low oxygen saturation (SpO_2) curve.

33. The system of claim **29**, wherein the physiological data reference comprises a reference parametric curve that is predetermined from clinically-derived data.

34. The system of claim **29**, wherein the physiological data reference comprises a data cluster defining a region of normalized plethysmograph values.

35. The system of claim **29**, wherein the less than the plurality of wavelengths comprises two wavelengths.

36. The system of claim **35**, wherein one of the two wavelengths is in the red range and the other of the two wavelengths is in the infrared range.

37. The system of claim **29**, wherein the plurality of wavelengths comprises at least eight wavelengths.

38. The system of claim **29**, wherein the physiological parameter measurement comprises a SpO_2, HbCO, HbMet, Hbt, factional oxygen saturation, bilirubin, or glucose measurement.

39. A method for automatically adjusting a number of a plurality of wavelengths used in a physiological measurement system, the method comprising:

- emitting light at a plurality of wavelengths with one or more light emitting sources;
- detecting, with a sensor, light emitted by one or more light emitting sources after attenuation by body tissue, the sensor generating a first output signal;
- determining a physiological parameter estimate from the first output signal received from the sensor based on the detected light emitted at the plurality of wavelengths;

determining a confidence measurement value based on the physiological parameter estimate and a physiological data reference;

deactivating at least one of the plurality of wavelength emissions when the confidence measurement value is less than a threshold value to cause the plurality of light emitting sources to emit light at less than the plurality of wavelengths by; and

determining a physiological parameter measurement based on a second output signal received from the sensor based on the detected light emitted at the less than all of the plurality of wavelengths.

40. The method of claim **39**, further comprising:

determining a second physiological parameter estimate from the second output signal received from the sensor based on detected light emitted at the less than all of the plurality of wavelengths;

determining a second confidence measurement value based on the second physiological parameter estimate and a second physiological data reference;

activating at least one of deactivated wavelength emissions when the confidence measurement value is greater than the threshold value.

41. The method of claim **39**, wherein the physiological data reference comprises a normalized plethysmograph ratio region bounded by a high normalized plethysmograph ratio curve and a low normalized plethysmograph ratio curve.

42. The method of claim **41**, wherein the high normalized plethysmograph ratio curve is a high oxygen saturation (SpO_2) curve and the low normalized plethysmograph ratio curve is a low oxygen saturation (SpO_2) curve.

43. The method of claim **39**, wherein the physiological data reference comprises a reference parametric curve that is predetermined from clinically-derived data.

44. The method of claim **39**, wherein the physiological data reference comprises a data cluster defining a region of normalized plethysmograph values.

45. The method of claim **39**, wherein the less than the plurality of wavelengths comprises two wavelengths.

46. The method of claim **45**, wherein one of the two wavelengths is in the red range and the other of the two wavelengths is in the infrared range.

47. The method of claim **39**, wherein the plurality of wavelengths comprises at least eight wavelengths.

48. The method of claim **39**, wherein the physiological parameter measurement comprises a SpO_2, HbCO, HbMet, Hbt, factional oxygen saturation, bilirubin, or glucose measurement.

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摘要(译)

本文公开了一种生理测量系统，其能够基于传感器信号的质量自动调节所使用的波长的数量，该传感器信号的质量反映了在组织衰减之后在传感器处检测到的光学辐射。检查信号质量以确定是否足以支持使用全套波长。如果确定不足以支持全套，则使用减少数量的波长。