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(54) SEPARATING OXIMETER SIGNAL COMPONENTS BASED ON COLOR

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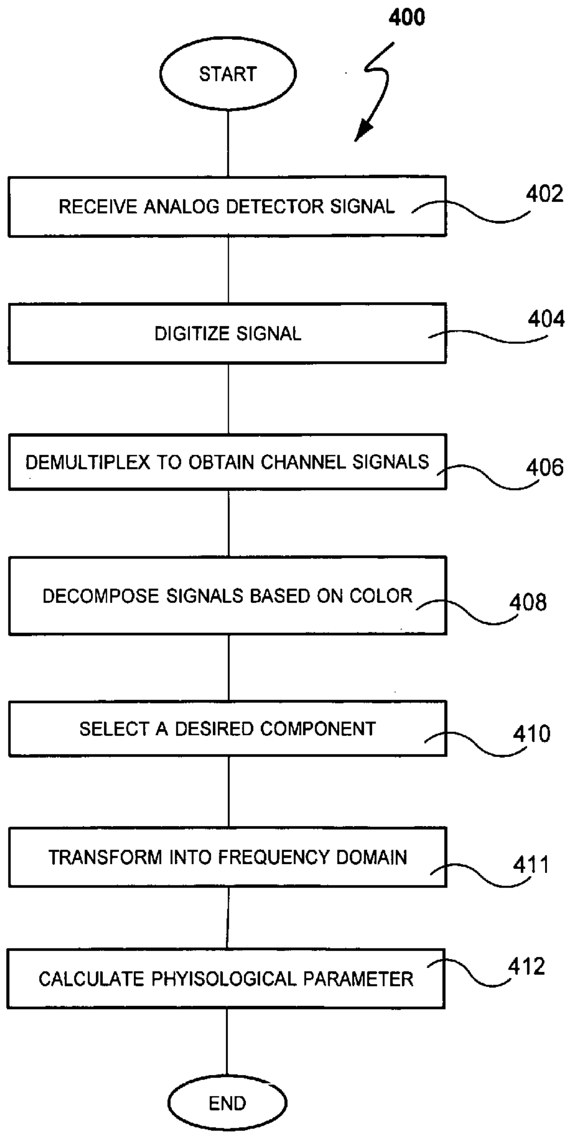
(57) **ABSTRACT**

A component of interest of an oximeter detector signal is distinguished from an interfering component based on a color difference between the components. The component of interest may be a pulsatile signal component, a baseline signal component such as a respiratory signal, or an artifact signal. The color difference between the component of interest and the interfering component is reflected in corresponding mixing ratios with respect to multiple optical channels of the pulse oximeter. The component of interest is separated from the interfering component by mathematical decomposition using the mixing ratios. In this manner, signal components can be isolated substantially free from frequency dependent filtering.



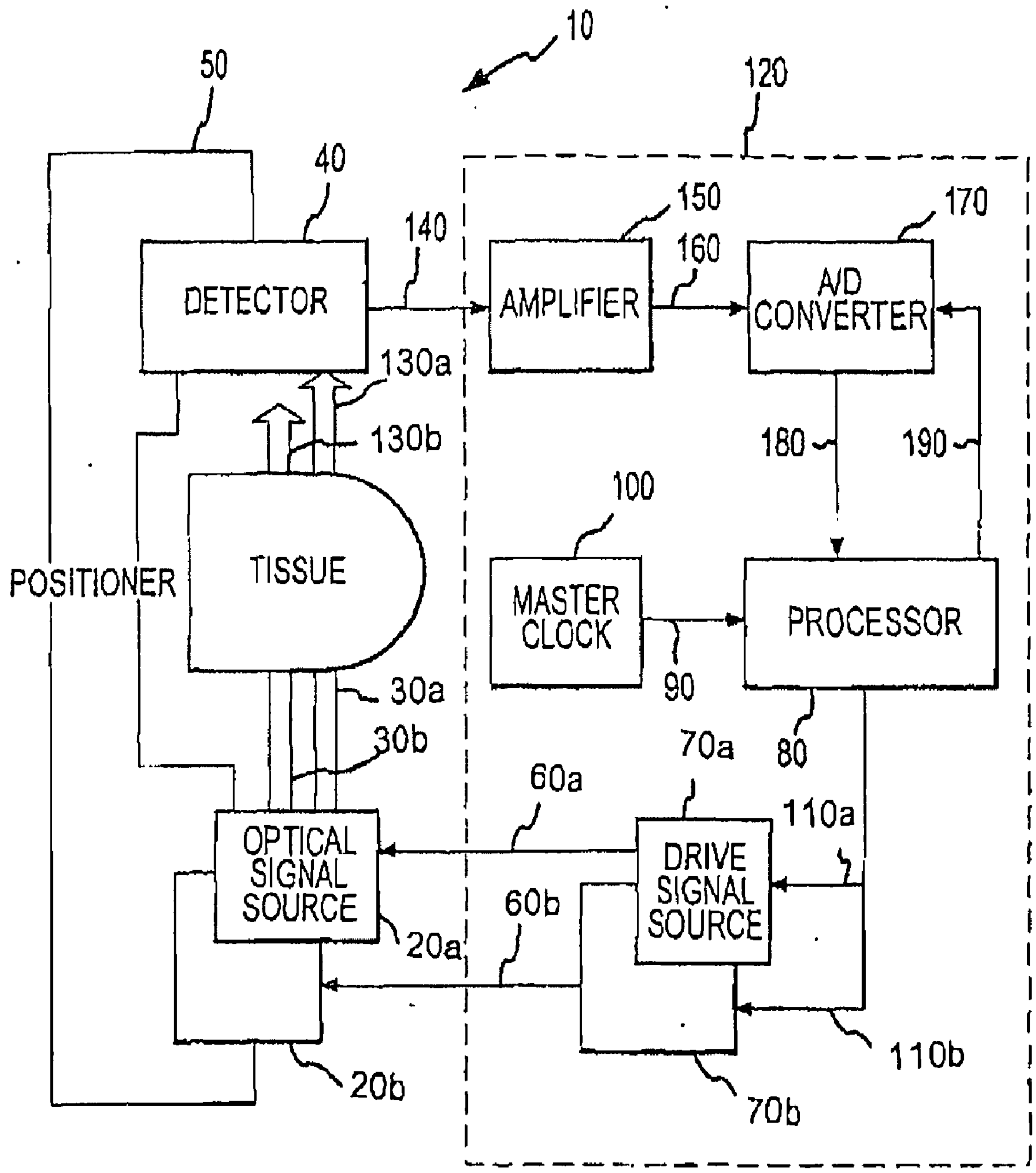

10
50
120
40
150
170
140
160
DETECTOR
AMPLIFIER
A/D CONVERTER
130a
130b
180
190
100
TISSUE
POSITIONER
MASTER CLOCK
PROCESSOR
30a
90
30b
70a
80
60a
110a
OPTICAL SIGNAL SOURCE
DRIVE SIGNAL SOURCE
60b
20a
110b
20b
70b

FIG.1

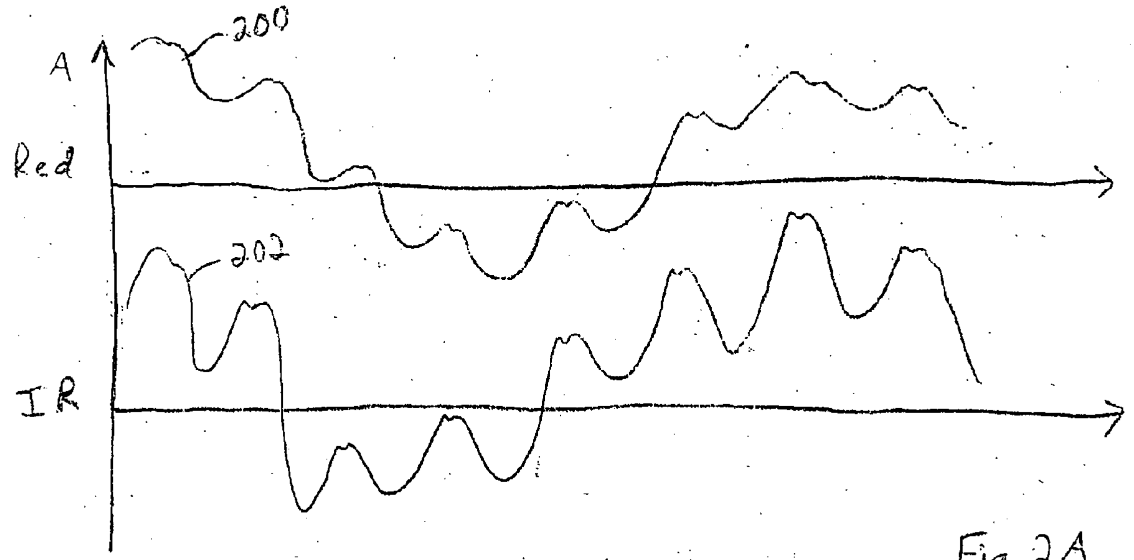


Fig. 2A

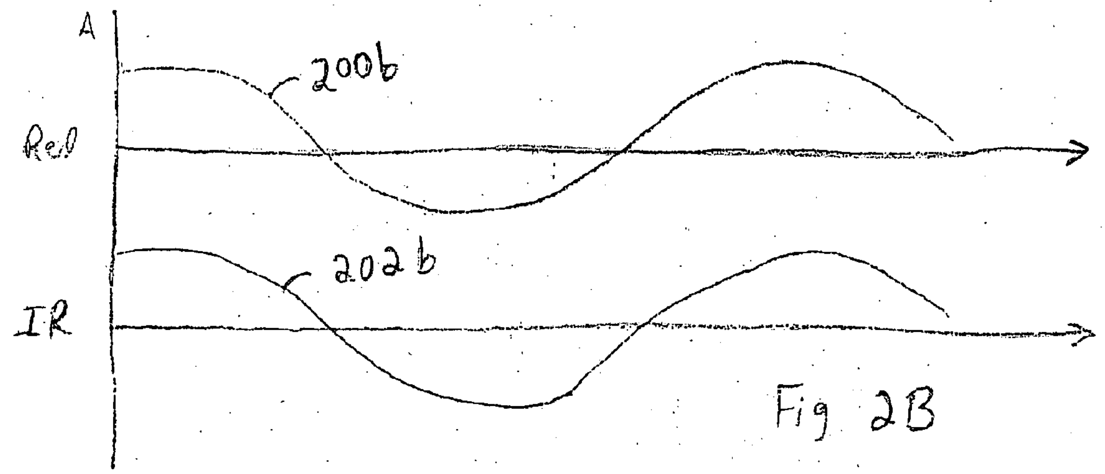


Fig 2B

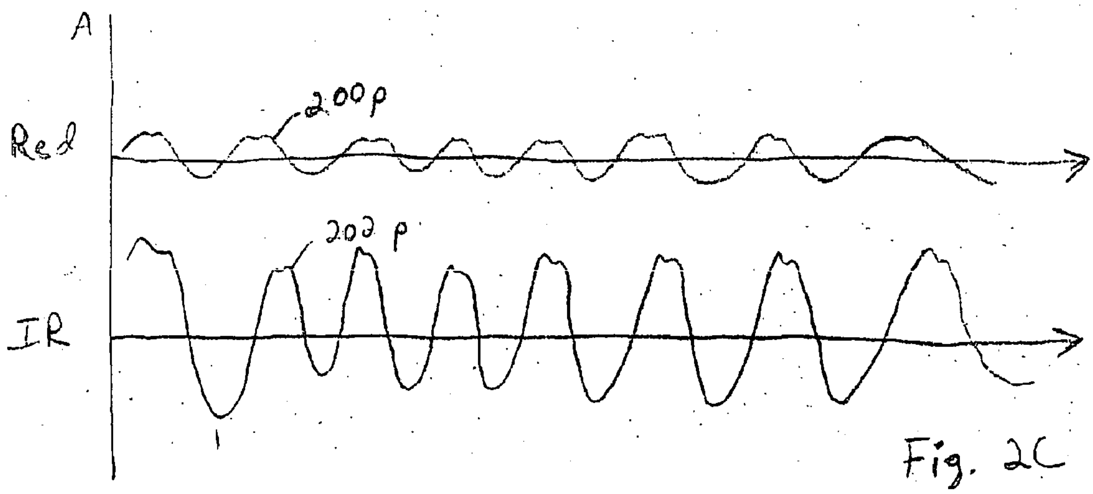


Fig. 2C

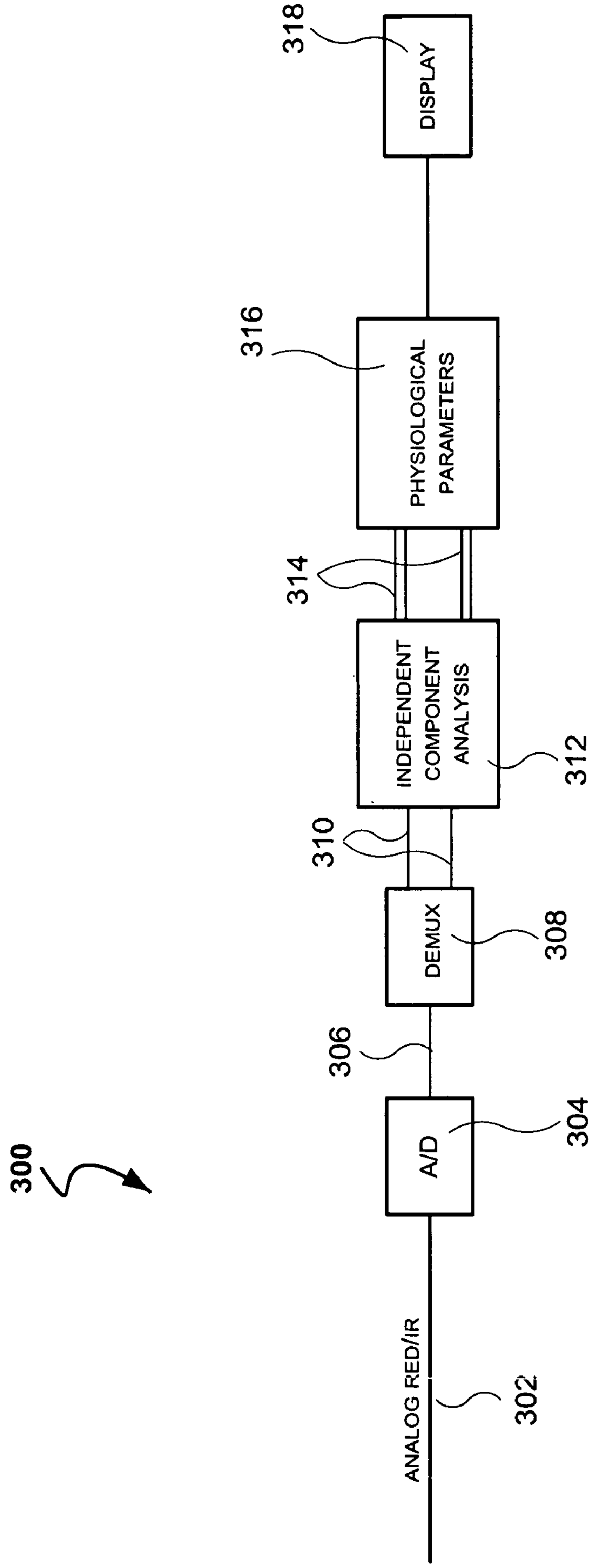

318
DISPLAY
316
PHYSIOLOGICAL
PARAMETERS
314
INDEPENDENT
COMPONENT
ANALYSIS
312
310
DEMUX
308
306
A/D
304
300
ANALOG RED/IR
302

Figure 3

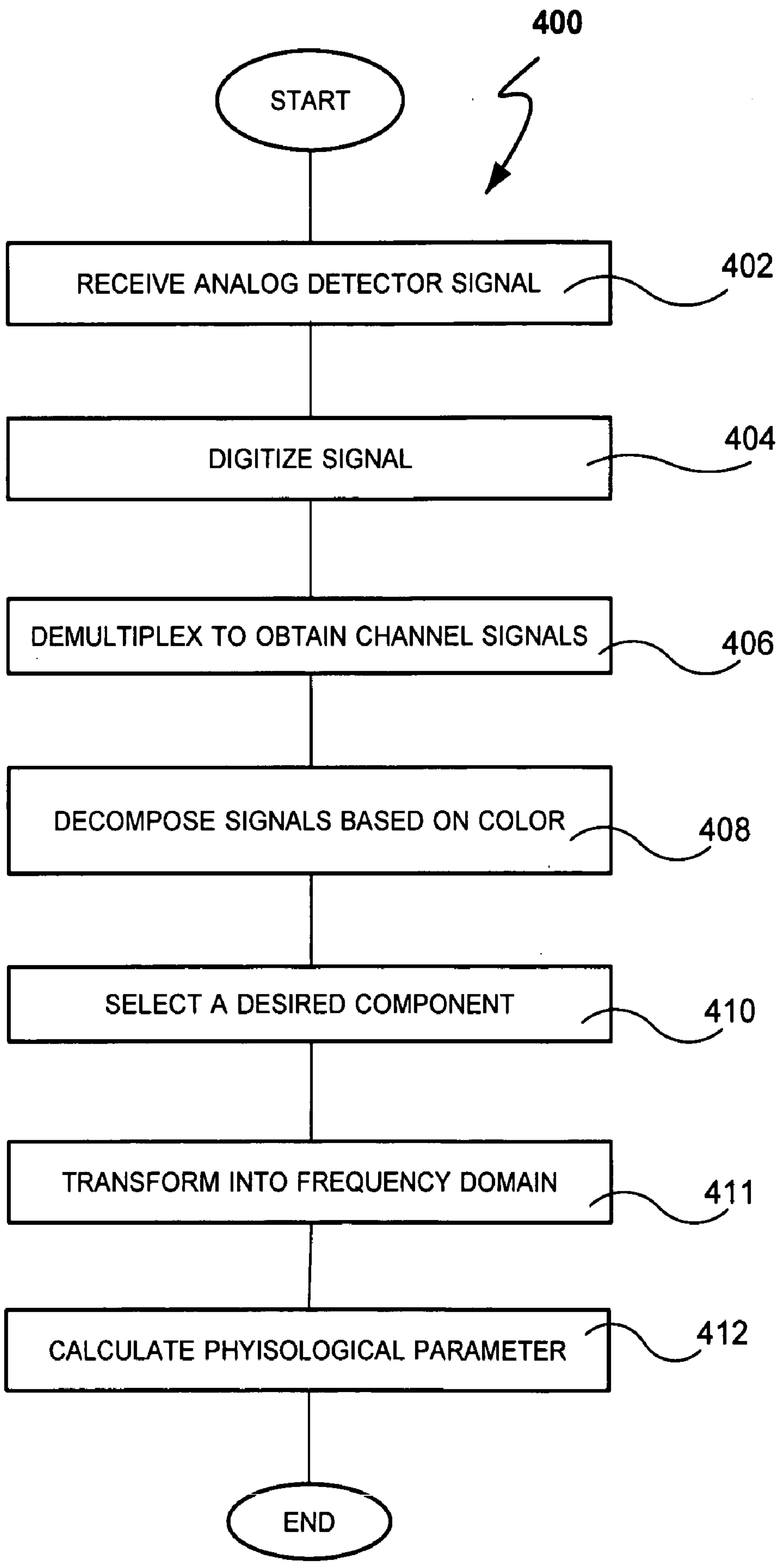

400
START
RECEIVE ANALOG DETECTOR SIGNAL
402
DIGITIZE SIGNAL
404
DEMULTIPLEX TO OBTAIN CHANNEL SIGNALS
406
DECOMPOSE SIGNALS BASED ON COLOR
408
SELECT A DESIRED COMPONENT
410
TRANSFORM INTO FREQUENCY DOMAIN
411
CALCULATE PHYISOLOGICAL PARAMETER
412
END

Figure 4

SEPARATING OXIMETER SIGNAL COMPONENTS BASED ON COLOR

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from U.S. Provisional Application Ser. No. 60/694,760 entitled "SEPARATING OXIMETER SIGNAL COMPONENTS BASED ON COLOR", filed on Jun. 28, 2005, the entirety of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates generally to pulse oximetry and, in particular, to signal processing techniques and associated structure for distinguishing a component of interest of an oximeter detector signal from an interfering component.

BACKGROUND OF THE INVENTION

[0003] Pulse oximeters are used to determine various types of physiological information for a patient, based on transmission/absorption characteristics of light transmitted through or reflected from a patient's tissue. In particular, pulse oximeters generally include a probe for attaching to a patient's appendage such as a finger, earlobe or nasal septum, or another location, particularly in the case of reflective oximeters. The probe is used to transmit pulsed optical signals of at least two wavelengths, typically red and infrared, to the patient's tissue. The transmitted signals are received by a detector that provides an analog electrical output signal representative of the received optical signals. By processing the electrical signal and analyzing signal values for one or more of the wavelengths, information can be obtained regarding blood oxygen saturation and/or other parameter values such as pulse rate, respiration rate or other blood pressure/blood volume related values.

[0004] The algorithms for determining such values are normally implemented in a digital processing unit. Accordingly, one or more analog-to-digital (A/D) converters are generally interposed between the detector and the digital processing unit. Additionally, the detector signal is generally demodulated and demultiplexed by signal processing modules. Demodulation involves separating the physiological signal of interest (generally including a more rapidly changing AC portion including a plethysmographic waveform and an optically based "DC" offset due to slowly changing absorption values associated with non-pulsatile tissue absorption) from a carrier waveform associated with the flashing optical sources. Demultiplexing involves separating the different wavelength signals associated with the different signal sources. That is, because certain parameters such as blood oxygen saturation are calculated based on differential absorption values for different transmitted optical signal wavelengths, multiple channels are typically employed in the pulse oximeter and the detected signal is generally separated, or demultiplexed, into at least two different channel signals. Typically, demodulation and demultiplexing have been implemented in analog circuitry operatively disposed between the optical signal detector and the analog-to-digital converter(s), but can be digitally implemented. As a result of such processing, one or more AC signals are obtained for analysis to yield the desired physiological information.

[0005] These AC signals may include multiple signal components including components of physiological as well as nonphysiological origin. Such physiological components may include a pulsatile component corresponding to cardiac activity, a respiration component corresponding to respiratory activity and a Mayer Wave component which, while not fully understood, appears to have a relation to the vaso motor center. The nonphysiological components may be associated with patient motion (patient induced or otherwise), electronic noise, optical noise (e.g., from ambient light) or other artifact. Generally, the nonphysiological components are not of interest in connection with obtaining the desired physiological information.

[0006] However, various physiological components may be of interest. In this regard, the pulsatile component is typically processed to yield pulse rate and oxygen saturation values as well as to display the pulsatile waveform. The respiration component can be processed to provide a breathing rate for the patient which, particularly when considered in conjunction with arterial oxygen saturation, may be of interest to a physician. The Mayer Wave also has significance for diagnostic and patient monitoring purposes. In particular, the amplitude and frequency of the Mayer Wave are seen to change in connection with hypertension, sudden cardiac death, ventricular tachycardia, coronary artery disease, myocardial infarction, heart failure, diabetes, and autonomic neuropathy and after heart transplantation. Accordingly, it may be desired to isolate or distinguish any one of various components in the AC signal under analysis.

[0007] Various types of filtering techniques have been proposed or implemented to distinguish a component of interest from other components. The pulsatile component has often been the component of interest in this regard. Some approaches have attempted to selectively pass one or more frequency bands associated with the pulsatile component. Other approaches have attempted to selectively notch or block frequency bands associated with an interfering component. In the case of distinguishing the pulsatile component from the respiratory or Mayer Wave components, high pass or low pass filters have been proposed as the pulsatile signal is generally expected to have a higher frequency than those components.

[0008] Such frequency dependent filtering techniques, however, have certain limitations. First, the expected or actual frequency ranges of these components may overlap, complicating efforts to isolate a component based on frequency dependent filtering. Even where the primary frequencies of these components are different, harmonics of one component may interfere with another component, thereby hampering certain processing techniques. For example, such harmonic interference may be problematic in identifying a pulsatile signal in cases of low perfusion. Moreover, frequency dependent filtering may result in the loss of useful information. Accordingly, alternate techniques continue to be investigated for distinguishing components of oximeter signals.

SUMMARY OF THE INVENTION

[0009] The present invention is directed to distinguishing signal components, e.g., isolating one or more signal components of interest, of a medical instrument such as a pulse oximeter, based on a mixing ratio or color analysis. Such an analysis allows the composite signal to be decomposed to yield the signal or signals of interest, preferably without requiring frequency dependent filtering. In this manner, components can be effectively distinguished even where the components may have overlapping frequencies. Moreover, potential interference associated with harmonics of a filtered frequency is substantially avoided. Loss of useful information can also be avoided or minimized, as it is unnecessary to block frequency bands.

[0010] The present inventor has recognized that signal components may have different colors that allow for distinguishing of such components. For example, in the case of pulse oximeters, it is expected that the pulsatile signal will generally be associated with arterial blood which characteristically has a bright red color. This color results in different levels of attenuation of the different channels of optical signals (typically at least including red and infrared channels) employed by the pulse oximeter. Other physiological components such as a respiratory or Mayer Wave component may be significantly associated with venous blood and tissue resulting in a different color characteristic. Thus, for example, the pulsatile component and respiratory component may be present in the red and infrared channel signals but with different mixing ratios. In this regard, certain motion artifact may be evenly mixed between red and infrared channels and other motion artifact may have different mix. Thus, in a variety of cases, different components have different color characteristics.

[0011] In accordance with the present invention, these color characteristics can be used to separate a detector signal into components. In one implementation, the detector signal is mathematically modeled as follows:

$$S_1 = s_{11} + s_{12} + \ldots + s_{1m}$$

$$S_2 = s_{21} + s_{22} + \ldots + s_{2m}$$

.

.

.

$$S_n = s_{n1} + s_{n2} + \ldots + s_{nm}$$

where

[0012] $S_{1 \ldots n}$=the signal for channels 1 . . . n; and

[0013] $s_{11 \ldots} s_{nm}$=the m signal components for the signals of channels 1 . . . n. Further, a given component as between different channels is defined by a mixing ratio for that component/channel combination. Thus, the case of an oximeter detector signal including a baseline component (such as a respiratory wave) and a pulsatile component in each of red and infrared channels, may be modeled as follows;

[0014] $S_{red}={}_{spred}+s_{bred}$

[0015] $S_{ir}=s_{pir}+s_{bir\ where}$

[0016] s_{pred}=the pulsatile component of the red channel signal S_{red};

[0017] s_{bred}=the baseline component of the channel signal;

[0018] s_{pir}=the pulsatile component of the infrared channel signal S_{ir}; and

[0019] s_{bir}=the baseline component of the infrared channel signal. the mixing ratios are given by:

$$r_p = \frac{s_{pred}}{s_{pir}}$$

$$r_b = \frac{s_{bred}}{s_{pir}}$$

where

$$r_p \neq r_b$$

It has been found that this mathematical model can be used to resolve each of the channel signals into its respective components, for example, yielding red and infrared pulsatile signals, substantially free of the baseline component, that can be used for pulserate and arterial oxygen saturation (SpO_2) calculations via conventional algorithms.

[0020] In accordance with one aspect of the present invention, a method and apparatus (collectively "utility") is provided for distinguishing a desired component of an oximeter detector signal from another component. The utility involves receiving a detector signal including first and second components, distinguishing the first component of the detector signal from the second component based on a difference in color between the components, and using the first component to determine physiological information regarding a patient. For example, the first component may be a pulsatile component, a respiratory component, a Mayer Wave component, or other physiological component. The second component may comprise another of these physiological components or a nonphysiological component. The color of the signal components may be distinguished based on differing contributions of the respective components in channels corresponding to different optical spectral compositions. In this regard, the process for distinguishing the first component from the second component may involve applying a mathematical model for resolving each of the channel signals as the sum of the signal components where color related characteristics of the signal components can be used to solve for the desired first signal component in at least one of the channels. In this manner, the desired signal component can be distinguished despite potentially overlapping frequencies of the signal components and substantially without losing useful information due to frequency dependent filtering.

[0021] In accordance with another aspect of the present invention, a utility is provided for distinguishing a pulsatile component of an oximeter signal from another physiological component such as a respiratory component, Mayer Wave component or other baseline component. The utility involves: receiving a first channel signal of a pulse oximeter; resolving the first channel signal into pulsatile and baseline components based on an analysis relating to mixing ratios, with respect to the first and second channels, of each of the pulsatile and baseline components; selecting one of the pulsatile and baseline components; and processing the selected component to obtain physiological information regarding the patient. Depending on the specific implementation, one or both of the channel signals may be resolved into the pulsatile and baseline components. For example, in the case of determining a pulse rate, the pulsatile component of a single channel signal may be sufficient. On the other hand, in the case of determining an SpO_2 value, the pulsatile component may be desired for both of the channels.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] For a more complete understanding of the present invention and further advantages, reference is now made to the following detailed description taken in conjunction with the drawings, in which:

[0023] **FIG. 1** is a block diagram illustrating a pulse oximeter in accordance with the present invention;

[0024] **FIGS. 2A-2C** illustrate a process for resolving detector signals into components in accordance with the present invention;

[0025] **FIG. 3** is a schematic diagram illustrating a system for implementing a color based filter in accordance with the present invention; and

[0026] **FIG. 4** is a flow chart illustrating a process for decomposing a detector signal into each constituent component based on a color analysis in accordance with the present invention.

DETAILED DESCRIPTION

[0027] Referring now to **FIG. 1**, there is shown a block diagram of one embodiment of a pulse oximeter **10** in which a color filter in accordance with the present invention may be implemented. The pulse oximeter **10** is configured for use in determining the pulse rate of a patient as well as one or more blood analyte levels in the patient, such as an SpO_2 level. It should be appreciated that a color filter in accordance with the present invention may be implemented in pulse oximeters that are configured differently from the pulse oximeter depicted in **FIG. 1** as well as in other environments wherein plethysmographic signals are processed in order to obtain desired information relating to patient physiological conditions from the plethysmographic signals.

[0028] The illustrated pulse oximeter **10** includes a pair of optical signal sources **20***a*, **20***b* for emitting a corresponding pair of light signals **30***a*, **30***b* centered at different predetermined center wavelengths λ_1, λ_2 through a suitable tissue site of a patient and on to a detector **40** (e.g., a photosensitive diode). It will be appreciated that the signals may be reflected from the tissue rather than transmitted through the tissue in accordance with the present invention.

[0029] The optical signal sources **20***a*, **20***b* and detector **40** may be included in a positioning device **50**, e.g., associated with a probe, to facilitate alignment of the light signals **30***a*, **30***b* with the detector **40**. For example, the positioning device **50** may be of clip-type or flexible strip configuration adapted for selective attachment to a suitable patient tissue site (e.g., a finger, an ear lobe, a foot, or the nose of the patient). The center wavelengths λ_1, λ_2 required depend upon the blood analyte level to be determined. For example, in order to determine an SpO_2 level, λ_1 may be in the red wavelength range and λ_2 may be in the infrared wavelength range. It should be appreciated that the pulse oximeter **10** may be readily implemented with more optical signal sources (e.g., four) depending, for example, upon the number of different blood analyte levels to be measured.

[0030] The optical signal sources **20***a*, **20***b* are activated by a corresponding plurality of drive signals **60***a*, **60***b* to emit the light signals **30***a*, **30***b*. The drive signals **60***a*, **60***b* are supplied to the optical signal sources **20***a*, **20***b* by a corresponding plurality of drive signal sources **70***a*, **70***b*. The drive signal sources **70***a*, **70***b* may be connected with a digital processor **80**, which is driven with a clock signal **90** from a master clock **100**. The digital processor **80** may be programmed to define modulation waveforms, or drive patterns, for each of the optical signal sources **20***a*, **20***b*. More particularly, the digital processor **80** may provide separate digital trigger signals **110***a*, **110***b* to the drive signal sources **70***a-b*, which in turn generate the drive signals **60***a*, **60***b*. In this regard, the digital trigger signals **110***a*, **110***b* may be configured to provide for multiplexing of the drive signals **60***a*, **60***b*, and in turn the light signals **30***a*, **30***b*, in accordance with a multiplexing scheme (e.g., time division, frequency division, and/or code division multiplexing).

[0031] The drive signal sources **70***a*, **70***b*, processor **80** and clock **100** may all be housed in a monitor unit **120**. While the illustrated embodiment shows the optical signal sources **20***a*, **20***b* physically interconnected with the positioning device **50** (e.g., mounted within the positioning device **50** or mounted within a connector end of a cable that is selectively connectable with the positioning device **50**), it should be appreciated that the optical signal sources **20***a*, **20***b* may also be disposed within the monitor unit **120**. In the latter case, the light signals **30***a*, **30***b* emitted from the optical signal sources **20***a*, **20***b* may be directed from the monitor unit **120** via one or more optical fibers to the positioning device **50** for transmission through the tissue site. Furthermore, the drive signal sources **70***a*, **70***b* may comprise a single drive signal generator unit that supplies each of the drive signals **60***a*, **60***b* to the optical signal sources **20***a*, **20***b*.

[0032] Transmitted light signals **130***a*, **130***b* (i.e., the portions of light signals **30***a*, **30***b* exiting the tissue) are detected by the detector **40**. The detector **40** detects the intensities of the transmitted signals **130***a*, **130***b* and outputs a current signal **140** wherein the current level is indicative of the intensities of the transmitted signals **130***a*, **130***b*. As may be appreciated, the current signal **140** output by the detector **40** comprises a multiplexed signal in the sense that it is a composite signal including information about the intensity of each of the transmitted signals **130***a*, **130***b*. Depending upon the nature of the drive signals **60***a*, **60***b*, the current signal **140** may, for example, be time division multiplexed, wavelength division multiplexed, and/or code division multiplexed.

[0033] The current signal **140** is directed to an amplifier **150**, which may be housed in the monitor unit **120** as is shown. As an alternative, the amplifier **150** may instead be included in a probe/cable unit that is selectively connectable with the monitor unit **120**. The amplifier **150** converts the current signal **140** to a voltage signal **160** wherein a voltage level is indicative of the intensities of the transmitted signals **130***a*, **130***b*. The amplifier **150** may also be configured to filter the current signal **140** from the detector **40** to reduce noise and aliasing. By way of example, the amplifier **150** may include a bandpass filter to attenuate signal components outside of a predetermined frequency range encompassing modulation frequencies of the drive signals **60***a*, **60***b*.

[0034] Since the current signal **140** output by the detector **40** is a multiplexed signal, the voltage signal **160** is also a multiplexed signal, and thus, the voltage signal **160** is demultiplexed in order to obtain signal portions corresponding with the intensities of the transmitted light signals **130***a*, **130***b*. In this regard, the digital processor **80** may be provided with demodulation software for demultiplexing the voltage signal **160**. In order for the digital processor **80** to demodulate the voltage signal **160**, it is converted from analog to digital. Conversion of the analog voltage signal **160** is accomplished with an analog-to-digital (A/D) converter **170**, which may also be included in the monitor unit **120**. The A/D converter **170** receives the analog voltage signal **160** from the amplifier **150**, samples the voltage signal **160**, and converts the samples into a series of digital words **180** (e.g., eight, sixteen or thirty-two bit words), wherein each digital word is representative of the level of the voltage signal **160** (and hence the intensities of the transmitted light signals **130***a*, **130***b*) at a particular sample instance. In this regard, the A/D converter **170** preferably provides for sampling of the voltage signal **160** at a rate sufficient to provide for accurate tracking of the shape of the various signal portions comprising the analog voltage signal **160** being converted. For example, the A/D converter **170** may provide for a sampling frequency at least twice the frequency of the highest frequency drive signal **60***a*, **60***b*, and more preferably at an even greater sampling rate in order to more accurately represent the analog voltage signal.

[0035] The series of digital words **180** is provided by the A/D converter **170** to the processor **80** to be demultiplexed. More particularly, the processor **80** may periodically send an interrupt signal **190** (e.g., once per every eight, sixteen or thirty-two clock cycles) to the A/D converter **170** that causes the A/D converter **170** to transmit one digital word **180** to the processor **80**. The demodulation software may then demultiplex the series of digital words **180** in accordance with an appropriate method (e.g., time, frequency and/or code) to obtain digital signal portions indicative of the intensities of each of the transmitted light signals **130***a*, **130***b*. In this regard, the demultiplexed digital signal portions comprise time domain plethysmographic signals corresponding to the center wavelengths λ_1, λ_2 (e.g., red and infrared) of the optical signal sources **20***a*, **20***b*. The red and infrared time domain plethysmographic signals may then be processed by the processor **80** to obtain desired patient physiological condition related information therefrom such as the patient's pulse rate and SpO_2 level.

[0036] In accordance with the present invention, the detector signal can be resolved into constituent components based on color. That is, as noted above, different components of the signal, including components of physiological origin and components of nonphysiological origins such as certain artifact, may have different colors. These different colors are associated with different mixing ratios relative to the different channels. Thus, a particular signal component may be substantially equally present in each channel, i.e., that component may be substantially white for purposes of the present analysis. By contrast, another signal component may have substantial color as reflected by a mixing ratio that is substantially different from one. Each of these components is therefore present in each of the channel signals. However, the relative contributions of the different components in the different channel signals will differ significantly. The above-noted mathematical model can be used to take advantage of these color characteristics to distinguish a particular component of interest based on color.

[0037] **FIGS. 2A-2C** illustrate an example of this process for resolving a detector signal into components based on color. In the illustrated example, a two-channel oximeter is employed including red and infrared source channels. In addition, the detector signal is assumed to be composed of a pulsatile component and a baseline component such as a respiratory wave component. It will be appreciated that an oximeter including more channels and a signal including more components may be involved in accordance with the present invention. Moreover, the color filter may be used in combination with other filters, including frequency dependent filters. For example, one or more components such as an artifact component and a physiological component (pulsatile, respiratory or Mayer Wave component), may be substantially eliminated prior to using the color filter to distinguish two remaining components.

[0038] Referring to **FIG. 2A**, an exemplary red channel signal **200** and infrared channel signal **202** are shown. For example, the signals **200** and **202** may represent the AC portions of a pulse oximeter detector signal after the signal has been digitized, demodulated (separated from the carrier signal), demultiplexed (separated into red and infrared channels), stripped of a DC offset, and otherwise processed. For purposes of the present description, it is assumed that the DC component offset has been stripped in a manner that preserved the pulsatile component as well a baseline signal as can generally be observed in **FIG. 2A**.

[0039] In accordance with the present invention, the red and infrared channel signals **200** and **202** can be resolved into the baseline and pulsatile components. The resulting components are illustrated in **FIGS. 2B and 2C**. Specifically, in **FIG. 2B**, the resulting baseline component of the red and infrared channels **200***b* and **202***b* are shown. In **FIG. 2C**, the pulsatile components **200***p* and **202***p* are shown. It will be observed in this example that the baseline signal is substantially evenly mixed as between the red and infrared channels whereas the pulsatile signal has a mixing ratio that departs significantly from unity. Indeed, the color reflected in the pulsatile signal corresponding to this mixing ratio is a fundamental property that enables SpO_2 to be determined by pulse oximeters.

[0040] The process for separating the components based on color involves use of the mathematical model as set forth above. Essentially, this is a problem of independent component analysis which has been used in other contexts, for example, to distinguish different speakers using a common microphone. In this case, pulse oximeters can provide at least two channels which allows for solving of two mixing ratios simultaneously which in turn enables separation of the channel signals **200** and **202** into the components **200***b*, **200***p*, **202***b* and **202***p*. The underlying math is well known. While this math is complex and somewhat nonlinear, it reduces in this case to solving a two by two matrix such that the implementation is not computationally intensive. That is, when the data points coming in on the red and infrared channel are multiplied by the correct values in the two by two array as determined by the mixing ratios, the signals are physically separated into their components according to the mixing ratio. The results are good in cases where there are two separate signals reflecting two separate recorded values of SpO_2, for example a pulsatile signal based on arterial blood and a respiratory signal significantly associated with venous blood and tissue or certain cases of substantially white artifact.

[0041] The associated independent components analysis module can be implemented in hardware or software. In one implementation, the module is implemented in the processor **80** of **FIG. 1**. Specifically, the processor receives the signals **200** and **202** after digitization, demodulation and demultiplexing as noted above. The signals **200** and **202** are then processed using the above-noted mathematical model to obtain the mixing ratios and populate the noted two by two matrix. The signals **200** and **202** are then processed using the matrix to separate the signals into the components **200***b*, **200***p*, **202***b* and **202***p*.

[0042] The desired components can then be used to obtain physiological information regarding the patient. For example, the pulsatile components **200***p* and **202***p* can be used to determine pulse rate and SpO_2 via conventional processes. For example, an FFT may be performed with respect to one of the signals **200***p* and **202***p* to obtain a spectrum where the fundamental frequency of the spectrum corresponds to pulse rate. In addition, the signals **200** and **202***p* may be analyzed in the time or frequency domain to calculate value correlated SpO_2. Alternatively, the value of SpO_2 may be correlated to the mixing ratios for the components **200***p* and **202***p*.

[0043] Additionally or alternatively, one or both of the components **200***b* or **202***b* may be processed to obtain physiological information. For example, in the case where the components **200***b* and **202***b* correspond to a respiratory signal, the signal may be processed to provide an output regarding the patient's breathing rate. For example, one of the signals **200***b* or **202***b* may be subjected to an FFT to provide a spectrum where the fundamental frequency of the spectrum corresponds to the patient's breathing rate. It will be appreciated that many other types of physiological information may be obtained from components such as the respiratory signal component or a Mayer Wave component.

[0044] Referring to **FIG. 3**, a schematic diagram of a system **300** implementing an independent component analysis as discussed above is shown. The system **300** includes an analog-to-digital converter **304** that receives the analog red and infrared AC signals **302** and provides a digital signal **306** indicative thereof. The signal **306** is processed by a demultiplexer **308** to provide digital channel signals **310**. These digital channel signals **310** are processed by the independent component analysis module **312** which implements the processing discussed above for separating the signals **310** into their respective components **314** based on color. One or more of the components **314** is then processed by a physiological parameter module **316** to obtain the desired physiological parameter (e.g., pulse rate, SpO_2, breathing rate, or blood pressure/volume information) which is then provided to the display **318** of the pulse oximeter.

[0045] A corresponding process may be summarized by reference to the flow chart of **FIG. 4**. The illustrated process **400** is initiated by receiving (**402**) the analog detector signal. It will be appreciated that this signal may be amplified to provide an appropriate voltage signal, bandpass filtered to remove certain types of noise and other artifact, filtered to remove a DC offset and otherwise conditioned. The signal is then digitized (**404**) to provide an appropriate signal for processing by a digital signal processing unit. The digital signal is then demultiplexed (**406**) to obtain the separate channel signals. For example, in the case of code division multiplex signals, the step of demultiplexing may involve multiplication of the digital detector signal by appropriate demultiplexing vectors to yield the individual channel signals. The channel signals are then decomposed **408** into signal components based on color as described above. A desired component or components can then be selected (**410**) to yield the desired physiological information. For example, these components may be pulsatile components, respiratory wave components or Mayer Wave components. The desired components can be transformed into frequency domain spectra and then one or more of these spectra are then used to calculate (**412**) physiological parameter information for display by the pulse oximeter.

[0046] While various embodiments of the present invention have been described in detail, it is apparent that further modifications and adaptations of the invention will occur to those skilled in the art. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present invention.

What is claimed:

1. A method for use in pulse oximetry, comprising the steps of:

receiving a first detector signal corresponding to a first optical signal channel of a pulse oximeter and a second detector signal corresponding to a second optical signal channel of said pulse oximeter;

resolving said first detector signal into first and second signal components based on an analysis related to mixing ratios, with respect to said first and second channels, of each of said first and second components; and

selecting one of said first and second components; and

processing said selected one of said first and second components to obtain physiological information regarding a patient.

2. A method as set forth in claim 1, wherein said step of resolving comprises determining a first mixing ratio of said first component with respect to said first and second channels and a second mixing ratio of said second component with respect to said first and second channels, wherein each of said first and second mixing ratios relates to a relative poser in said first and second channels of a respective one of said first and second components.

3. A method as set forth in claim 1, wherein said processing comprises determining one of a pulse rate and a respiration rate for said patient.

4. A method as set forth in claim 1, further comprising the step of resolving said second detector signal into said first and second components based on said analysis.

5. A method as set forth in claim 4, wherein said step of processing comprises using said selected one of said first and second components of each of said first and second detector signals to obtain said physiological information.

6. A method as set forth in claim 1, wherein said step of resolving comprises modeling each of said first and second detector signals as a sum of at least two components, determining mixing ratios for said at least two components with respect to at least two detector signals corresponding to at least two channels, and using said mixing ratios to resolve said first detector signal into said first and second components.

7. A method for use in pulse oximetry, comprising the steps of:

receiving a detector signal including a first component and a second component;

distinguishing said first component of said detector signal from said second component based on a difference in color between said first and second components; and

using said distinguished first component to determine physiological information regarding a patient.

8. A method as set forth in claim 7, wherein said first component is a pulsatile component ands said physiological information comprises one of pulse rate and blood oxygen saturation.

9. A method as set forth in claim 7, wherein said step of receiving comprises obtaining a digital signal corresponding to an optical signal of a pulse oximeter.

10. A method as set forth in claim 7, wherein said step of receiving further comprises receiving a second detector signal including said first and second components, wherein said first detector signal corresponds to a first channel of a pulse oximeter and said second detector signal corresponds to a second channel of said pulse oximeter.

11. A method as set forth in claim 10, wherein said separate distinguishing comprises determining a first mixing ratio of said first component with respect to said first and second channels and a second mixing ration of said second component with respect to said first and second channels.

12. A method as set forth in claim 10, wherein said step of distinguishing comprises modeling each of said first and second detector signals as a form of at least two components, determining mixing ratios for said at least two components with respect to at least two detector signals corresponding to at least two channels of said pulse oximeter, and using said mixing ratios to distinguish said first component of said detector signal from said second component.

13. A method for use in pulse oximetry, comprising the steps of:

receiving a detector signal including a first component and a second component;

mathematically decomposing said detector signal to isolate said first component from said detector signal by establishing a model of said detector signal as a combination of said first and second components and resolving said model to yield a representation of first components; and

processing said representation of said first component independent of said second component to provide physiological parameter information regarding a patient.

14. A method as set forth in claim 13, wherein said step of decomposing comprises obtaining said representation of said first component substantially free of frequency dependent filtering.

15. A method as set forth in claim 13, wherein said step of decomposing involves using a difference in color between said first and second components to isolate said first component.

16. A method as set forth in claim 15, wherein said difference in color is considered in relation to at least two optical signals of said pulse oximeter having different spectral contents.

17. A method as set forth in claim 16, wherein said step of decomposing involves determining mixing ratios with respect to measurements corresponding to said at least two optical signals.

18. A pulse oximetry apparatus, comprising:

a port for receiving first and second detector signals corresponding to first and second optical channels of said pulse oximeter, each of said first and second detector signals including first and second signal components; and

a processor for resolving said first detector signal into first and second components based on an analysis relating to mixing ratios with respect to said first and second channels of each of said first and second signal components, selecting one of said first and second components, and processing said selected one of said first and second components to obtain physiological information regarding said patient.

19. An apparatus as set forth in claim 18, wherein said processor is operative for performing said resolving by determining a first mixing ratio of said first component with respect to said first and second channels and a second mixing ratio of said second component with respect to said first and second channels, wherein each of said first and second mixing ratios relate to a relative power in said first and second channels of a respective one of said first and second components.

20. An apparatus as set forth in claim 18, wherein said processor is operative for performing said resolving by modeling each of said first and second detector signals as a sum of at least two components, determining mixing ratios for said at least two components with respect to at least two detector signals corresponding to at least two channels, and using said mixing ratios to resolve said first detector signal into said first and second components.

21. An apparatus as set forth in claim 18, wherein said processor is operative for determining one of a pulse rate and a blood oxygen saturation for said patient based on said selected one of said first and second components.

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公开(公告)日	2006-12-28
申请号	US11/251238
申请日	2005-10-14
[标]申请(专利权)人(译)	诺里斯马克
申请(专利权)人(译)	诺里斯马克
当前申请(专利权)人(译)	通用电气公司
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摘要(译)

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