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(54) MINIATURE WIRELESS APPARATUS FOR COLLECTING PHYSIOLOGICAL SIGNALS OF ANIMALS

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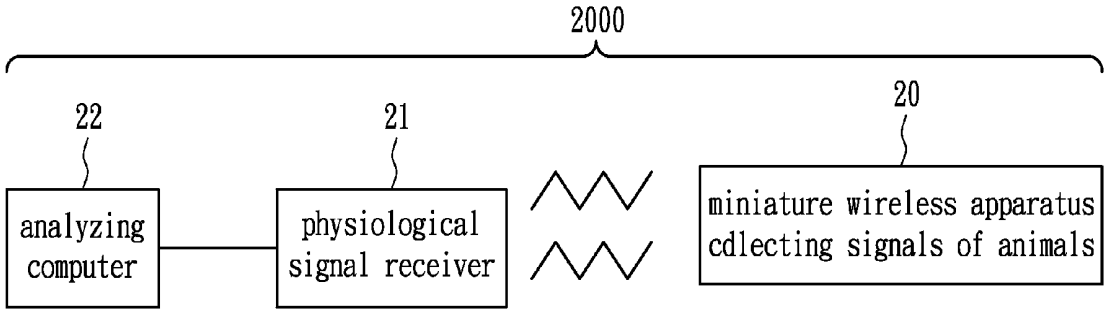
(52) **U.S. Cl.** **600/300**; 128/903; 600/544; 600/546; 600/549; 600/509

(57) **ABSTRACT**

A miniature wireless apparatus for collecting physiological signals of animals includes a connector, an amplifier module, a microcontroller, a radio module and a power supply. The connector is attached to an animal to be tested by buckling a joint of the connector to a joint of a connector on the animal to be tested, so as to collect various physiological signals. The amplifier module amplifies each of the physiological signals by an appropriate gain to generate an amplified physiological signal. The microcontroller performs analog-to-digital conversion and data compression on the amplified physiological signal to generate a digital physiological signal. The radio module modulates the digital physiological signal, and then transmits the modulated digital physiological signal to a remote receiver in a wireless transmission manner. The radio module receives remote wireless signals as well. The power supply is configured to provide power to the above circuits.



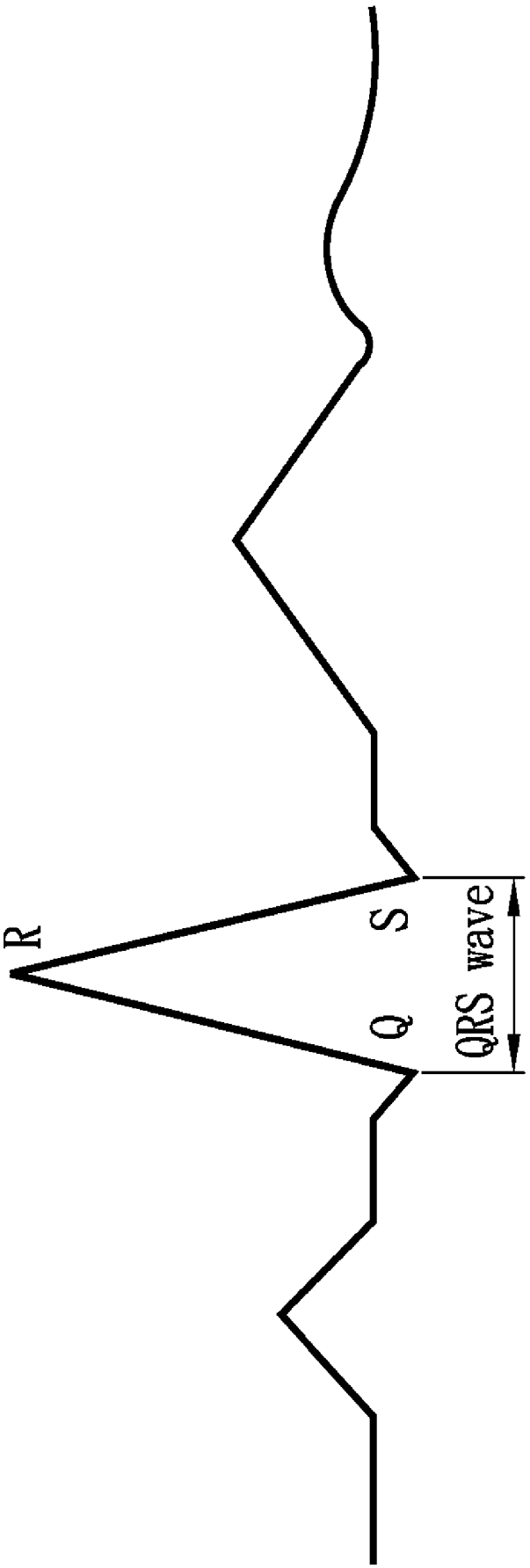


FIG. 1 (Prior Art)

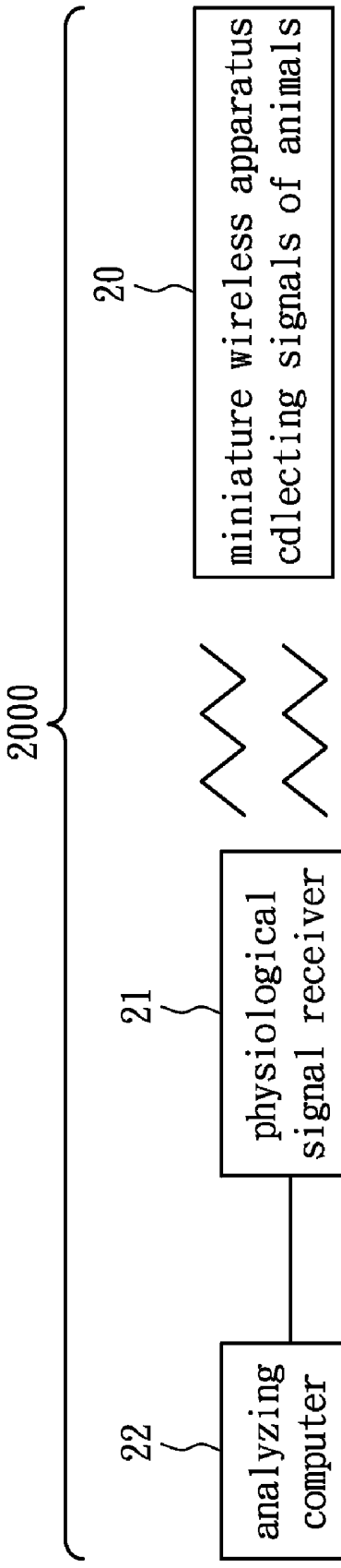

2000
20
miniature wireless apparatus cdlecting signals of animals
21
physiological signal receiver
22
analyzing computer

FIG. 2(a)

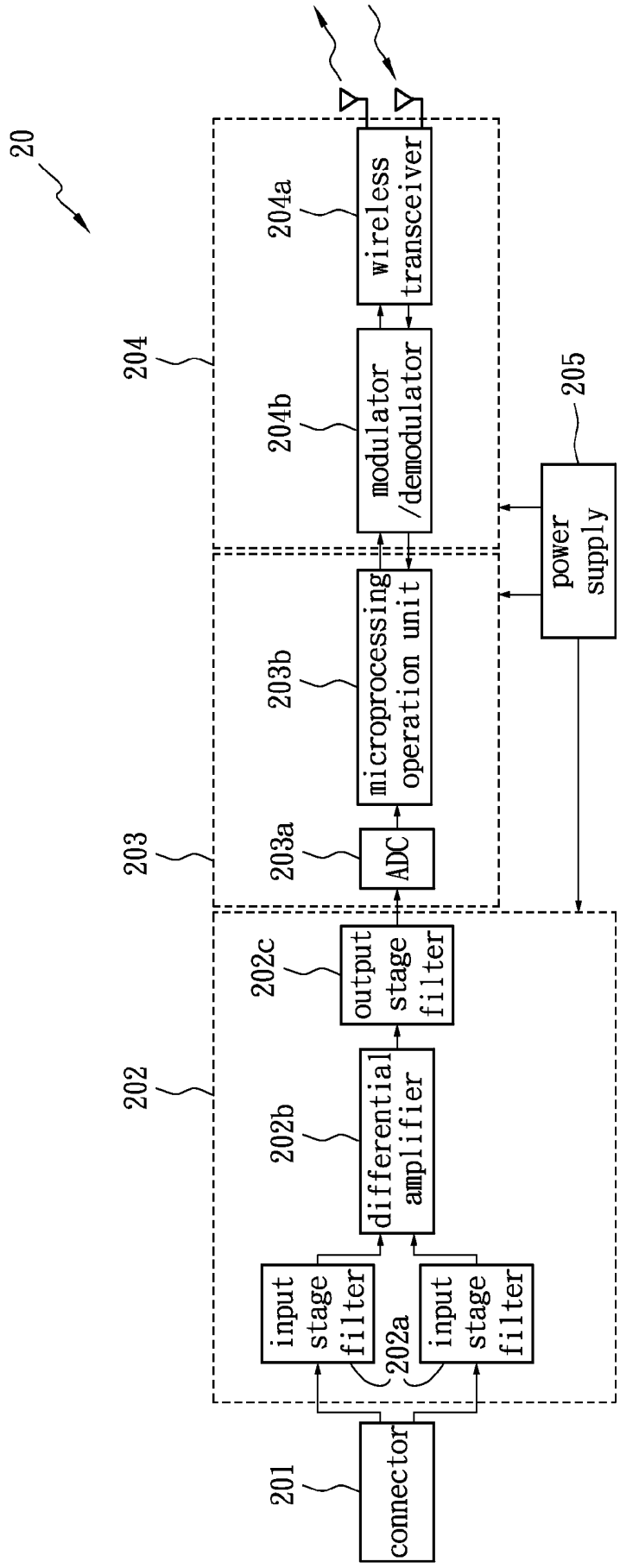

20
204
204a
wireless transceiver
204b
modulator /demodulator
205
power supply
203
203b
microprocessing operation unit
203a
ADC
202
202c
output stage filter
202b
differential amplifier
input stage filter
202a
input stage filter
201
connector

FIG. 2(b)

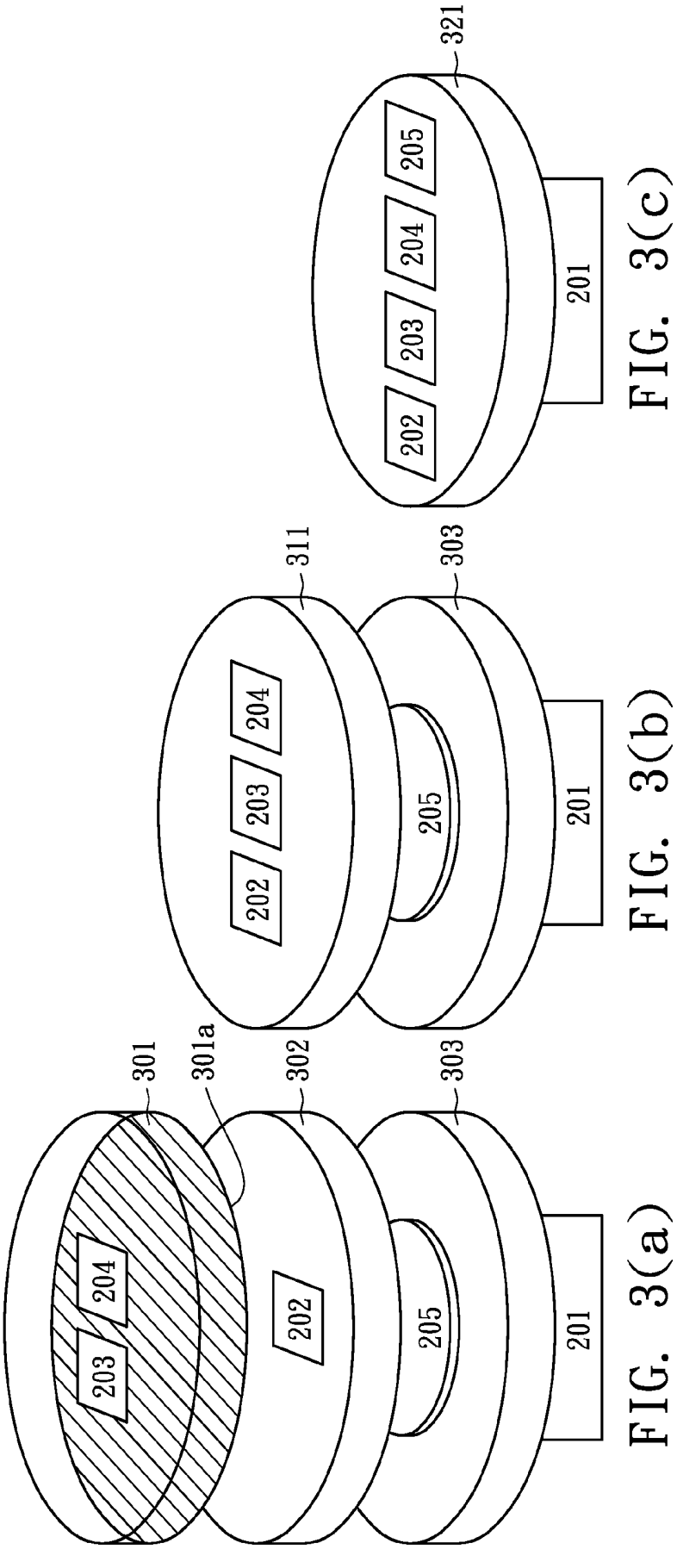


FIG. 3(a)

FIG. 3(b)

FIG. 3(c)

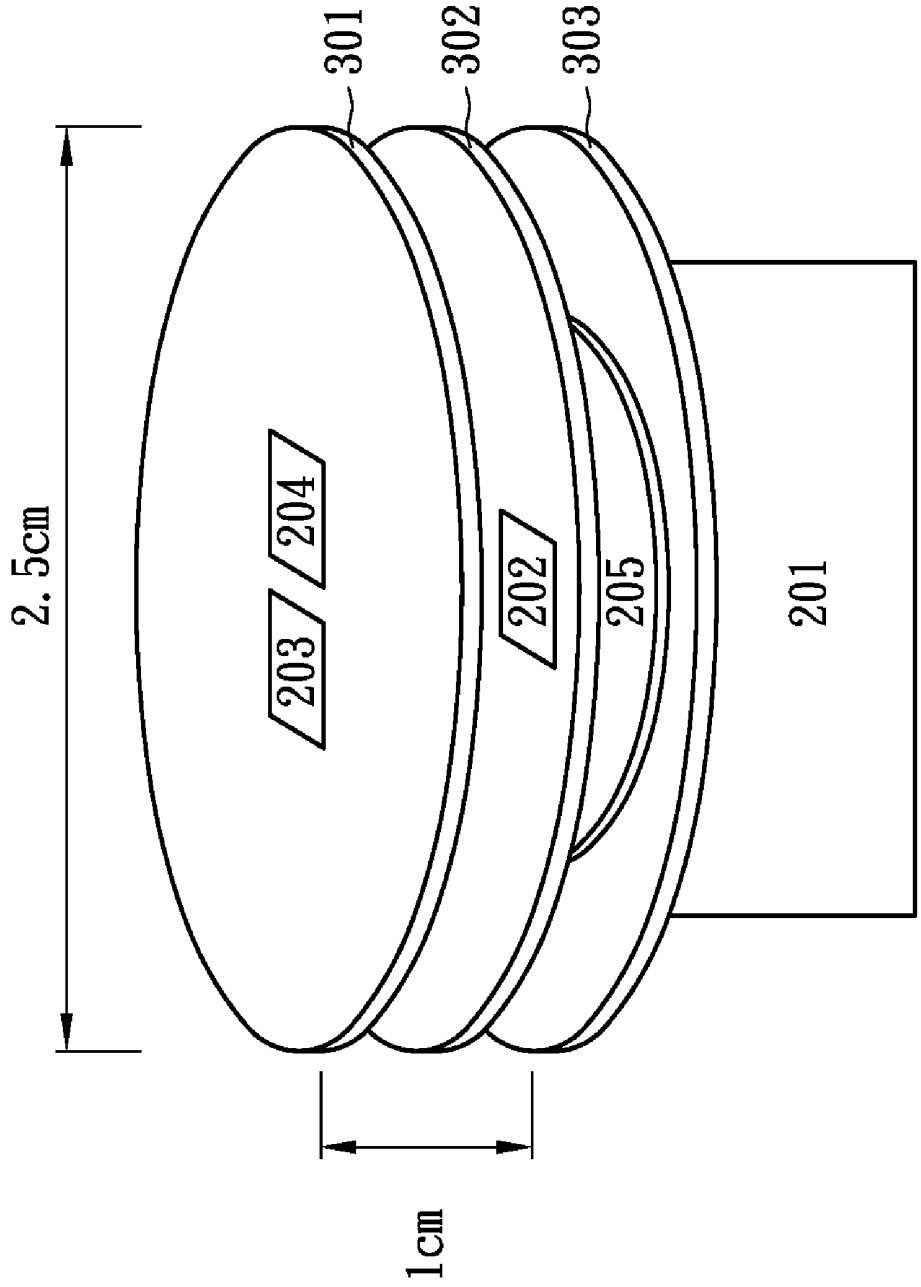


FIG. 3(d)

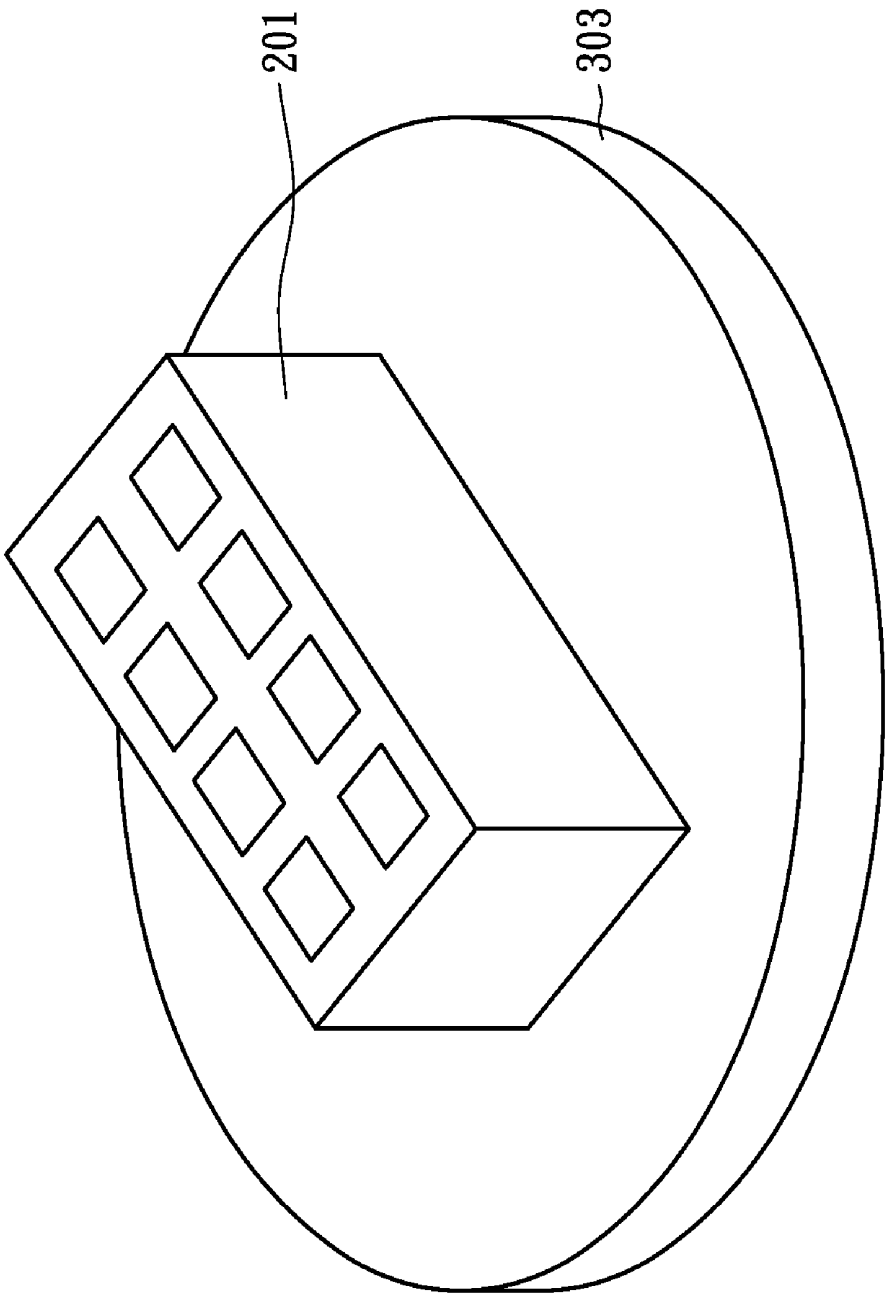


FIG. 3(e)

MINIATURE WIRELESS APPARATUS FOR COLLECTING PHYSIOLOGICAL SIGNALS OF ANIMALS

CROSS-REFERENCE TO RELATED U.S. APPLICATIONS

[0001] Not applicable.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] Not applicable.

NAMES OF PARTIES TO A JOINT RESEARCH AGREEMENT

[0003] Not applicable.

REFERENCE TO AN APPENDIX SUBMITTED ON COMPACT DISC

[0004] Not applicable.

BACKGROUND OF THE INVENTION

[0005] 1. Field of the Invention

[0006] The present invention relates to an apparatus for collecting physiological signals. More particularly, the present invention relates to a miniature wireless apparatus for collecting physiological signals of animals.

[0007] 2. Description of Related Art Including Information Disclosed Under 37 CFR 1.97 and 37 CFR 1.98.

[0008] Signals such as the electrocardiogram (ECG), electroencephalogram, respiration, and body temperature are indices of life. Indices of sleep and autonomic nervous system functions can be obtained on the basis of analysis of these signals together with electromyogram (EMG) signals. Thus, the collecting and analysis of physiological signals is helpful to the understanding of a broad range of medical information and to future medical applications. It is very important to establish the collecting and analysis mode of physiological signals of rats and mice that are commonly used in animal experiments, as the mode is an outpost of the deep understanding of normal physiological conditions and possible pathological mechanisms of human beings.

[0009] FIG. **1** is an ECG signal of the heartbeat. Generally, the peak waveband is referred to as the QRS wave, in which the point from which the waveform first turns upward is referred to as the Q point, the top point is referred to as the R point, and the bottom point is referred to as the S point. In a QRS recognition program, the QRS wave is derived from the micro physiological signals with a peak detection program, and parameters including the amplitude and the duration are measured for each QRS wave. The average value and standard deviation of the parameters are calculated to establish a standard template. Then, each QRS wave is compared with the template.

[0010] The heart rate variability (HRV) analysis is a method to analyze the physiological function of the heart on the basis of the heartbeat period sequence. The standard analysis procedure was defined by Task Force of the European Society of Cardiology and the North America Society of Pacing and Electrophysiology in 1996, and was modified by Kuo et al. in 1999. The principle is substantially as follows.

[0011] 1. First, information about the heartbeat cycle is obtained. Normally, each heartbeat is defined with the R waves in the ECG, and the time difference between an R wave and the next R wave is a heartbeat period RR.

[0012] 2. The existence of significant fluctuation, for example larger than three times the standard difference, in continuous RR sequences, indicates that heartbeat irregularities or noises may exist. If heartbeat irregularities exist, alert should be provided as the subject's condition might be life-threatening. If noises exist, the technology of measuring and analysis should be improved.

[0013] 3. If continuous RR sequences do not have large fluctuations, more detailed numerical analysis, such as the spectrum analysis (Kuo et al., 1999) and non-linear analysis (Kuo & Yang, 2002), can be performed on the RR sequences.

[0014] In past research of the interaction between sleep and cyclical rhythm, wired systems were applied to study the changes in autonomic nervous systems during the sleep of humans and rats (Yang et al., 2002-2003), and it has been confirmed that the HRV reflecting the regulation of the cardiac autonomic nerve signal has periodic changes according to the sleep stages. Furthermore, it has been found that obvious negative correlation exists between the depth of sleep and the activity of the sympathetic nerves.

[0015] The stages of sleep are mainly defined according to the electroencephalogram (EEG), EMG, and electrooculogram. If the sleep stage is easily identified, there is a better possibility of understanding the occurrence and prevention of many sleep-related diseases. The measurement of EEG alone can show the occurrence of many diseases, such as epilepsy and Alzheimer's disease. If the respiration signal can be measured at the same time, diseases related to respiration in sleep such as sleep apnea can be diagnosed. If the heart rate or HRV analysis is performed additionally, the relationship between sleep and hypertension can be understood more thoroughly. The monitoring and analysis of physiological signals in sleep will be indispensable to clinical medicine, and widespread use of the measurement of the signals will be beneficial to the prevention, monitoring and diagnosis of many diseases.

[0016] Currently, animal experiments related to physiological information performed in non-narcotic states still mainly use wired systems. To monitor various physiological functions, test animals must carry heavy wires. In addition to the fact that the animals cannot move freely, the measured physiological functions are measured under pressure, and may not represent the true physiological phenomena. Therefore, the measurement results might be inaccurate.

BRIEF SUMMARY OF THE INVENTION

[0017] The present invention discloses a miniature apparatus the size of a button for collecting physiological signals using wireless transmission, so as to facilitate the analysis on the physiological signals in various animal experiments.

[0018] The miniature wireless apparatus for collecting physiological signals of animals comprises a connector, an amplifier module, a micro controller, a radio module, and a power supply.

[0019] The miniature wireless apparatus for collecting physiological signals of animals is buckled to a connector on the animal to be tested, so as to collect a differential

physiological signal. First, noises are filtered from the differential physiological signal with an input stage filter to improve the signal to noise ratio of the signal, and then a differential amplifier differentially amplifies the differential physiological signal to generate an amplified physiological signal. Then, a signal with frequency higher than twice the analog/digital sampling frequency of the microcontroller is filtered from the amplified physiological signal with an output stage filter, so as to facilitate the analog/digital sampling of the microcontroller. The analog-to-digital conversion unit of the microcontroller performs the analog-to-digital conversion on the amplified physiological signal generated by the amplifier module with the appropriate voltage resolution and sampling rate, and then a microprocessing operation unit compresses the data to generate a digital physiological signal. The radio module receives the digital physiological signal generated by the micro controller, and a modulator/demodulator modulates the digital physiological signal into a modulated physiological signal, which is then transmitted to a remote end as a wireless physiological signal by a wireless transceiver. Meanwhile, the radio module also uses the wireless transceiver to receive the wireless signal from the remote end.

[0020] The advantages of the present invention are as follows. (1) Because of the use of wireless transmission, the motion of test animals is not limited, and the measured physiological signals are closer to the natural state than those measured by the conventional wired systems. (2) Because of the use of wireless transmission, the animals do not contact any examination instruments. Thus interference caused by the instruments (e.g., the AC power source) is avoided, and the quality of signals is more preferable than that of wired systems. (3) Because of the use of digital wireless transmission, there is less distortion in the signal transmission, which is more preferable than many analog wireless transmission systems. (4) Because of the use of digital wireless signal transmission, various (almost indefinite) transmission channels can be used, which is preferable to conventional analog wireless signal transmission. (5) The apparatus can be further miniaturized as all circuits of the amplifier module, micro controller, radio module, and power supply can be integrated in a single circuit board or even a single chip.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0021] FIG. **1** shows a graph illustration of an ECG signal of a heartbeat.

[0022] FIG. **2**(*a*) is a schematic view of a block diagram of the wireless system for collecting and analyzing physiological signals of animals according to the present invention.

[0023] FIG. **2**(*b*) is a schematic view of a block diagram of the miniature wireless apparatus for collecting physiological signals of animals according to an embodiment of the present invention.

[0024] FIGS. **3**(*a*), **3**(*b*), and **3**(*c*) are schematic views of illustrations of structures of the miniature wireless apparatus for collecting physiological signals of animals according to the present invention.

[0025] FIG. **3**(*d*) shows a schematic view of a button-type miniature structure of the miniature wireless apparatus for collecting physiological signals of animals according to an embodiment of the present invention.

[0026] FIG. **3**(*e*) shows a schematic view of a connector on the bottom surface of the miniature wireless apparatus for collecting physiological signals of animals according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0027] FIG. **2**(*a*) is a schematic view of a block diagram of the wireless system **2000** for collecting and analyzing physiological signals of animals according to the present invention. The system **2000** includes a miniature wireless apparatus **20** for collecting signals of animals, a physiological signal receiver **21**, and an analyzing computer **22**.

[0028] In accordance with an embodiment of the present invention, the miniature wireless apparatus **20** for collecting signals of animals is connected to a rat or a mouse with a connector, so as to collect physiological signals such as EEG, EMG, ECG, respiration and body temperature, and transmit the signals to the remote physiological signal receiver **21**. Then the physiological signals are transmitted to the analyzing computer **22** through a computer transmission interface of the physiological signal receiver **21**, so as to perform the analysis on the automatic sleep staging and the autonomic nervous function of the heart.

[0029] FIG. **2**(*b*) is a schematic view of a block diagram of the miniature wireless apparatus **20** for collecting physiological signals of animals according to an embodiment of the present invention. The apparatus **20** for collecting physiological signals includes a connector **201**, an amplifier module **202**, a microcontroller **203**, a radio module **204**, and a power supply **205**.

[0030] The miniature wireless apparatus for collecting physiological signals of animals **20** is buckled to a joint of a connector on the rat or mouse with a joint of the connector **201**, and electrodes are disposed below the connector on the rat or mouse. Thus, mechanical and electrical contacts can be realized at the same time, so as to collect various physiological signals, such as EEG, EMG, ECG, respiration and body temperature of the rat or mouse to be tested.

[0031] The amplifier module **202** includes a pair of input stage filters **202***a*, a differential amplifier **202***b*, and an output stage filter **202***c*. After the amplifier module **202** receives a differential physiological signal from the receiver **201**, the input stage filters **202***a* filter out the noise from the signal to increase the signal to noise ratio, and then the differential amplifier **202***b* performs a differential amplifying to generate an amplified physiological noise. The differential amplifier **202***b* attenuates the common mode noise, and meanwhile amplifies the differential physiological signal by an appropriate gain, so as to match with the voltage range of the analog-to-digital conversion of the microprocessor **203**. Then, the signal with the frequency higher than Nyquist frequency (i.e., twice the sampling frequency in the analog-to-digital conversion of the micro controller) is filtered from the amplified physiological signal by the output stage filter **202***c*, so as to facilitate the analog-digital sampling of the microcontroller **203**. In addition, the impedance of the input end of the amplifier module **202** is larger than 200 kΩ, so as to prevent electric leakage. The input stage filters **202***a* and the output stage filter **202***c* can be formed with resistive and capacitive passive elements, and the differential amplifier **202***b* can be formed with an integrated circuit operational amplifier or instrumentation amplifier.

[0032] The microcontroller **203** includes an analog-to-digital conversion unit **203***a* and a microprocessing operation unit **203***b*. The analog-to-digital conversion unit **203***a* performs the analog-to-digital conversion on the amplified physiological signal generated by the amplifier module **202** with the appropriate voltage resolution and sampling rate, and then the microprocessing operation unit **203***b* compresses the data to generate a digital physiological signal.

[0033] The radio module **204** includes a wireless transceiver **204***a* and a modulator/demodulator **204***b*. The input end of the radio module **204** connected to the microcontroller **203** forms serial or parallel digital channels, so as to receive the digital physiological signal generated by the microcontroller **203**, and the received signal is then modulated to a modulated physiological signal with the carrier of 2.4 GHz by the modulator/demodulator **204***b*. The modulated physiological signal is then transmitted to the remote physiological signal receiver **21** with the wireless transceiver **204***a* as a wireless physiological signal. Meanwhile, the wireless transceiver **204***a* also receives the wireless signal from the remote physiological signal receiver **21**. The received signal is demodulated to a digital data signal with the modulator/demodulator **204***b*, and transmitted to the microcontroller **203** via the digital channel. The wireless signal from the remote physiological signal receiver **21** includes the control signal of the apparatus **20** for collecting physiological signals and the acknowledge signal from the remote physiological signal receiver **21**. The acknowledge signal is applied in such a way that, for example, as the digital physiological signal from the microcontroller **203** with its data being compressed is flagged appropriately, and is transmitted to the radio module **204** via the digital channel to transmit and output the wireless physiological signal. By receiving the acknowledge signal transmitted by the remote transceiver, the completeness of the data output of the wireless physiological signal can be guaranteed. The radio module **204** performs the radio transmission and receiving in the 2.4 GHz Industry Science Medical (ISM) frequency band according to international standards.

[0034] The power supply **205** can be a miniature battery, a rechargeable miniature battery, or a solar power source, for providing power to all circuits in the apparatus for collecting physiological signals **20**.

[0035] FIGS. **3**(*a*), **3**(*b*), and **3**(*c*) are schematic structural views of the miniature wireless apparatus **20** for collecting physiological signals of animals according to embodiments of the present invention.

[0036] FIG. **3**(*a*) shows a multi-layer circuit board structure including circuit board layers **301**, **302**, and **303**. Each of the layers has an upper surface and a bottom surface. The microcontroller **203** and the radio module **204** are disposed on the upper surface of the circuit board layer **301**, the amplifier module **202** is disposed on the upper surface of the circuit board layer **302**, and the connector **201** is disposed on the bottom surface of the circuit board layer **303**. The radio module **204** is disposed on the top circuit board layer **301**, which is helpful to the transmission and receiving of wireless signals. As the circuits of the microcontroller **203** and the radio module **204** on the circuit board layer **301** may interfere with the signals from the amplifier module **202** on the circuit board layer **302**, a layer of isolation grounding plane **301***a* is added to the bottom surface of the circuit board layer **301**, so as to increase the signal to noise ratio of the analog circuit of the amplifier module **202** on the circuit board layer **302**. The power supply **205** can be disposed between the bottom surface of the circuit board layer **302** and the upper surface of the circuit board layer **303**, the bottom layer of the circuit board layer **302** can be in direct contact with one of the positive and negative electrodes of the power supply **205** to form a power source layer, and the upper surface of the circuit board layer **303** can be in direct contact with the other electrode of the power supply **205** to form the other power source layer. All circuits excluding the connector **201** shown in FIG. **3**(*a*) can be accommodated in a button-type miniature structure with a diameter of 2.5 cm and a height of 1 cm, as shown in FIG. **3**(*d*). The structure of the connector **201** on the bottom surface of the circuit board layer **303** is as shown in FIG. **3**(*e*).

[0037] With improvements in semiconductor technology, the elements **202**, **203**, and **204** on the circuit board layers **301** and **302** can be integrated on a single circuit board layer **311**, and the connector **201** is disposed on the bottom surface of the circuit board layer **303**, as shown in FIG. **3**(*b*). In addition, the elements **202**, **203**, **204**, and **205** on the circuit board layers **301**, **302**, and **303** can be even further integrated on a single circuit board layer **321**, as shown in FIG. **3**(*c*). Accordingly, all elements **202**, **203**, **204**, and **205** on the circuit board layer **321** can be integrated into a single chip.

[0038] The power supply **205** can be disposed between the circuit board layers **303** and **302**, as shown in FIG. **3**(*a*), or disposed between the circuit board layers **303** and **311**, as shown in FIG. **3**(*b*), which is helpful for the electrodes on the rat or mouse to be tested to isolate the interference electric waves from the circuits of the microcontroller **203** and the radio module **204**. On the other hand, the power supply **205** disposed on a lower layer is helpful to lower the center of gravity of the entire apparatus to improve the stability of the joint between the apparatus for collecting physiological signals **20** and the animal to be tested through a connector.

[0039] The above-described embodiments of the present invention are intended to be illustrative only. Numerous alternative embodiments may be devised by those skilled in the art without departing from the scope of the following claims.

1. A miniature wireless apparatus for collecting physiological signals of animals, the apparatus comprising:

a connector means in connection with an animal to be tested for collecting a differential physiological signal;

an amplifier module amplifying the physiological signal to generate an amplified physiological signal;

a microcontroller performing analog-to-digital conversion and data compression on the amplified physiological signal to generate a digital physiological signal;

a radio module modulating the digital physiological signal, transmitting the modulated digital physiological signal to a remote receiver in a wireless transmission manner, and receiving remote wireless signals; and

a power supply providing power to the amplifier module, the microcontroller and the radio module.

2. The miniature wireless apparatus of claim **1**, wherein the power supply is a miniature battery or a solar power source.

3. The miniature wireless apparatus of claim **1**, wherein the amplifier module comprises a pair of input stage filters connected to the connector, so as to filter noises to improve signal to noise ratio.

4. The miniature wireless apparatus of claim **3**, wherein the input stage filters comprise a resistor and a capacitor.

5. The miniature wireless apparatus of claim **1**, wherein the amplifier module comprises a differential amplifier for performing a differential amplification on the physiological signal to generate the amplified physiological signal, so as to match with a voltage range of the analog-to-digital conversion of the microcontroller.

6. The miniature wireless apparatus of claim **5**, wherein the differential amplifier is formed with an integrated circuit operational amplifier or an instrumentation amplifier.

7. The miniature wireless apparatus of claim **1**, wherein the amplifier module comprises an output stage filter for filtering signals with a frequency larger than twice a sampling frequency in the analog-to-digital conversion of the microcontroller, so as to facilitate the analog and digital sampling of the microcontroller.

8. The miniature wireless apparatus of claim **7**, wherein the output stage filter comprises a resistor and a capacitor.

9. The miniature wireless apparatus of claim **1**, wherein an impedance of an input end of the amplifier module is larger than 200 kΩ, so as to avoid electric leakage.

10. The miniature wireless apparatus of claim **1**, wherein the microcontroller comprises:

an analog-to-digital conversion unit connected to the amplifier module for performing analog-to-digital conversion on the amplified physiological signal with a voltage resolution and a sampling rate; and

a microprocessing operation unit connected to the analog-to-digital conversion unit for performing data compression on the digitalized amplified physiological signal to generate the digital physiological signal.

11. The miniature wireless apparatus of claim **1**, wherein the radio module comprises:

a modulator/demodulator modulating the digital physiological signal to a modulated physiological signal; and

a wireless transceiver transmitting the modulated physiological signal to the remote receiver in a manner of wireless transmission.

12. The miniature wireless apparatus of claim **1**, wherein an input end of the radio module connected to the microcontroller forms serial or parallel digital channels.

13. The miniature wireless apparatus of claim **1**, wherein the radio module performs radio transmission and receiving in a 2.4 GHz Industry Science Medical (ISM) frequency band.

14. The miniature wireless apparatus of claim **1**, wherein the remote wireless signals comprises a control signal of the wireless apparatus for collecting physiological signals and an acknowledge signal from the remote receiver.

15. The miniature wireless apparatus of claim **1**, wherein the physiological signal comprises electroencephalogram (EEG), electromyogram (EMG), electrocardiogram (ECG), respiration, and body temperature.

16. The miniature wireless apparatus of claim **15**, wherein the physiological signal is used for automatic sleep staging and cardiac autonomic nervous system function analysis.

17. The miniature wireless apparatus of claim **1**, being a multi-layer circuit board structure.

18. The miniature wireless apparatus of claim **17**, wherein the microcontroller and the radio module are disposed on a first circuit board layer, wherein the amplifier module is disposed on a second circuit board layer, wherein the connector is disposed on a third circuit board layer, and wherein the second circuit board layer is stacked between the first and the third circuit board layers.

19. The miniature wireless apparatus of claim **18**, wherein the microcontroller and the radio module are disposed on an upper surface of the first circuit board layer, wherein the amplifier module is disposed on an upper surface of the second circuit board layer, and wherein the connector is disposed on a bottom surface of the third circuit board layer.

20. The miniature wireless apparatus of claim **18**, wherein the power supply is disposed between a bottom surface of the second circuit board layer and an upper surface of the third circuit board layer.

21. The miniature wireless apparatus of claim **18**, wherein an isolation grounding plane is formed on a bottom surface of the first circuit board layer, so as to improve a signal to noise ratio of an analog circuit of the amplifier module.

22. The miniature wireless apparatus of claim **18**, wherein a bottom surface of the second circuit board layer is in direct contact with one of a positive electrode and a negative electrode of the power supply to form a power source layer, and wherein an upper surface of the third circuit board layer is in direct contact with the other electrode of the power supply to form another power source layer.

23. The miniature wireless apparatus of claim **17**, wherein the microcontroller, the radio module, and the amplifier module are disposed on a first circuit board layer, and wherein the connector is disposed on a second circuit board layer.

24. The miniature wireless apparatus of claim **23**, wherein the microcontroller, the radio module, and the amplifier module are disposed on an upper surface of the first circuit board layer, and wherein the connector is disposed on a bottom surface of the second circuit board layer.

25. The miniature wireless apparatus of claim **23**, wherein the power supply is disposed between a bottom surface of the first circuit board layer and an upper surface of the second circuit board layer.

26. The miniature wireless apparatus of claim **1**, wherein the microcontroller, the radio module, the amplifier module and the power supply are disposed on an upper surface of a circuit board layer, and wherein the connector is disposed on a bottom surface of the circuit board layer.

27. The miniature wireless apparatus of claim **1**, wherein the microcontroller, the radio module, the amplifier module and the power supply are integrated in a chip.

28. The miniature wireless apparatus of claim **2**, wherein the miniature battery is rechargeable.

* * * * *

专利名称(译)	用于收集动物生理信号的微型无线装置		
公开(公告)号	US20070244370A1	公开(公告)日	2007-10-18
申请号	US11/696820	申请日	2007-04-05
[标]申请(专利权)人(译)	KUO TERRY乙Ĵ 杨CHERYL] C H		
申请(专利权)人(译)	KUO，TERRY J. B. 杨，谢丽尔C. H. ENJOY研究公司.		
当前申请(专利权)人(译)	KUO，TERRY J. B. 杨，谢丽尔C. H. ENJOY研究公司.		
[标]发明人	KUO TERRY B J YANG CHERYL C H		
发明人	KUO, TERRY B. J. YANG, CHERYL C. H.		
IPC分类号	A61B5/00 A61B5/04		
CPC分类号	A61B5/0002 A61B5/0006 A61B5/01 A61B2503/40 A61B5/0488 A61B5/0816 A61B5/7232 A61B5/0476		
优先权	095112957 2006-04-12 TW		
外部链接	Espacenet USPTO		

摘要(译)

一种用于收集动物生理信号的微型无线装置，包括连接器，放大器模块，微控制器，无线电模块和电源。通过将连接器的接头弯曲到待测动物的连接器的接头上，将连接器连接到待测动物上，以便收集各种生理信号。放大器模块通过适当的增益放大每个生理信号以产生放大的生理信号。微控制器对放大的生理信号执行模数转换和数据压缩，以产生数字生理信号。无线电模块调制数字生理信号，然后以无线传输方式将调制的数字生理信号发送到远程接收器。无线电模块也接收远程无线信号。电源配置为向上述电路提供电力。