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(54) **Title:** CATHETER RADIO FREQUENCY ADAPTER FOR WIRELESS COMMUNICATION

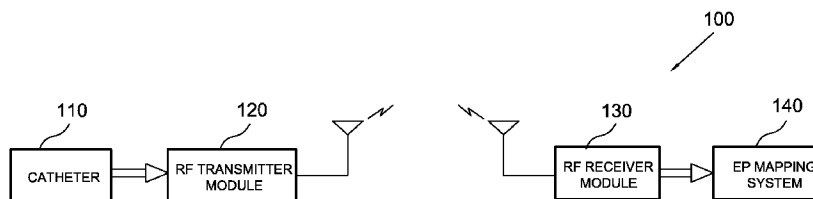


FIG. 1

(57) **Abstract:** A catheter system for wireless communication with an electrophysiological (EP) mapping system. The catheter system comprises a catheter, a catheter adapter, and a radio frequency receiver module. The catheter includes a plurality of mapping electrodes including a tip electrode disposed on a distal portion of the elongated body, the mapping electrodes detecting electrocardiograph (ECG) signals; and a reference electrode being disposed on the elongated body at a distance from the plurality of mapping electrodes such that the reference electrode substantially does not detect electrocardiograph signals. The catheter includes a handle. The catheter adapter is attached to the handle. The catheter adapter includes an RF transmitter module for receiving, processing, and transmitting the detected ECG signals. The reference electrode provides a reference signal to the radio frequency (RF) transmitter module. The RF receiver module receives the transmitted ECG signals. The RF receiver module is coupled to the EP mapping system.

WO 2010/011846 A1

CATHETER RADIO FREQUENCY ADAPTER FOR  
WIRELESS COMMUNICATION

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application Serial Number 61/135,837, filed on July 23, 2008, entitled “Catheter radio frequency adapter”, which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] This invention relates generally to electrophysiological (EP) mapping systems and catheter devices, and more specifically to a radio frequency (RF) adapter for providing wireless communication between a catheter and an electrophysiological mapping system.

[0003] Catheters are flexible, tubular devices that are widely used by physicians performing medical procedures to gain access into interior regions of the body. For diagnostic purposes, a catheter is usually connected by a cable to an EP mapping system. The catheter includes a plurality of electrodes on its distal area. The catheter electrodes detect signals from the tissue surrounding the distal area of the catheter and send the detected signals to the EP mapping system. The EP mapping system uses the detected signals to generate a map of the tissue surrounding the catheter distal region.

[0004] Currently, a catheter cannot communicate wirelessly with an EP mapping system.

## BRIEF SUMMARY OF THE INVENTION

[0005] One embodiment of the present invention is a catheter system for wireless communication with an electrophysiological (EP) mapping system. The catheter system comprises a catheter, a catheter adapter, and a radio frequency receiver module. The catheter includes an elongated body having a distal end, and a proximal end, a plurality of mapping electrodes including a tip electrode being disposed on a distal portion of the elongated body, the plurality of mapping electrodes detecting electrocardiograph (ECG) signals; and a reference electrode being disposed on the elongated body at a distance from the plurality of mapping electrodes such that the reference electrode substantially does not detect electrocardiograph (ECG) signals. The catheter includes a handle. The catheter adapter is attached to the handle. The catheter adapter includes an RF transmitter module for receiving, processing, and transmitting the detected ECG signals. The reference electrode provides a reference signal to the radio frequency (RF) transmitter module. The RF receiver module receives the transmitted ECG signals. The RF receiver module is coupled to the EP mapping system.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Figure 1 is a block diagram illustrating the system 100 of the present invention.

[0007] Figure 2 is a block diagram of one embodiment of the RF transmitter module 120 of the present invention.

[0008] Figure 3 is a block diagram of one embodiment of the RF receiver module 130 of the present invention.

[0009] Figure 4 is a block diagram illustrating the self-creating reference scheme of the present invention.

[0010] Figure 5 shows an external view of an embodiment of the catheter 110.

[0011] Figure 6 shows an embodiment 600 of the system of the present invention, where a single receiver unit 602 including several individual RF receiver modules communicates with several distinct transmitter units.

## DETAILED DESCRIPTION OF THE INVENTION

[0012] The catheter RF adapter of the present invention allows a diagnostic catheter to communicate wirelessly with an EP mapping system. Without a cable attaching the diagnostic catheter to an EP mapping system, a physician will be able to manipulate and control the catheter with greater ease.

[0013] The catheter RF adapter of the present invention comprises an RF transmitter module and a RF receiver module. The RF transmitter module is adapted to be securely attached to the handle of the catheter. The RF receiver module is coupled to the front end of the EP mapping system.

[0014] Figure 1 is a block diagram illustrating the system 100 of the present invention. System 100 comprises a catheter 110, an RF transmitter module 120, an RF receiver module 130, and an EP mapping system 140.

[0015] The catheter 110 comprises a distal region. The catheter distal region includes bands of electrodes positioned spaced apart in different longitudinal sections of the distal region. The tip of the catheter may also include an electrode. The catheter tip electrode and the catheter bands of electrodes send electrocardiograph (ECG) signals to the RF transmitter module 120. The tip electrode and the number of bands of electrodes determine the number of signals being outputted to the RF transmitter module 120, which in turn determine the number of RF channels used for wireless transmission. In one embodiment of the invention, the catheter 110 outputs 20 signals to the RF transmitter module 120 which processes the 20 signals and transmits the processed signals in 20 corresponding RF channels. The catheter 110 also includes a reference band electrode located at a large distance from the last band of electrode that senses an ECG signal, i.e., the furthest band electrode from the catheter distal end.

[0016] Figure 2 is a block diagram of one embodiment of the RF transmitter module 120 of the present invention. In this embodiment, the RF transmitter module 120 comprises a multiplexer 210, an amplifier 230, an analog-to-digital (A/D) converter 240, a microcontroller 250, and an RF transmitter 260. The

RF transmitter module 120 is securely attached to the handle of the catheter 110. The RF transmitter module 120 further comprises a buffer 270 to drive a DC voltage to each of the input signals to the multiplexer 210 and to the reference electrode of the catheter 110. Due to the buffer 270, the input signals to the multiplexer 210 and the signal from the reference electrode have each practically the same DC voltage component.

[0017] The multiplexer 210 receives, at its 20 inputs, 20 ECG analog signals in parallel from the catheter 110, and outputs a single ECG analog signal.

[0018] The amplifier 230 receives at its inputs the single ECG analog signal and the signal from the reference electrode. The amplifier 230 amplifies the difference between the ECG analog signal and the signal from the reference electrode to a level suitable for wireless transmission and outputs the amplified analog signal to the A/D converter 240.

[0019] The A/D converter 240 converts the amplified analog signal to a digital signal and outputs the digital signal to the microcontroller 250.

[0020] The microcontroller 250 codes the digital signal into a format suitable for wireless transmission. In one embodiment, an error correcting code is also employed in coding the digital signal. The microcontroller 250 outputs the coded digital signal to the RF transmitter 260. The microcontroller 250 also outputs a multiplexer control interface signal 252 to control the operation of the multiplexer 210.

[0021] The RF transmitter 260 receives the coded digital signal and transmits it over the air medium as an RF signal in a corresponding RF channel.

[0022] Figure 3 is a block diagram of one embodiment of the RF receiver module 130 of the present invention. In this embodiment, the RF receiver module 130 comprises an RF receiver 310, a microcontroller 320, a multi-channel digital-to-analog (D/A) converter 330. The RF receiver module 130 also includes a set of indicators 328 to indicate status and any errors.

[0023] The RF receiver 310 receives the RF signal over the air medium from the corresponding RF channel and outputs the digital signal to the microcontroller 320.

[0024] The microcontroller 320 decodes the digital signal and outputs the decoded digital signal to the multi-channel D/A converter 330.

[0025] The multi-channel D/A converter 330 converts the digital signal into an analog signal. The multi-channel D/A converter 330 also demultiplexes the analog signal into 20 analog signals which are then outputted to the EP mapping system.

[0026] In order to measure the ECG signals, a reference signal is needed. In an existing catheter system where a catheter is connected to an EP system by a cable, a signal measured from a body surface of a patient via a patch connected directly to the EP system by a cable is used as a reference signal. In the present invention, where the communication to the EP system is wireless, a novel self-creating reference scheme is employed to provide a reference signal.

[0027] Figure 4 is a block diagram illustrating the self-creating reference scheme of the present invention. Buffer 270, which comprises an operational amplifier configured as a voltage follower, drive a DC voltage  $V_{\text{bias}}$  to each of the electrodes of the catheter, including a reference electrode which is located on the catheter at a distance far from the last of the other electrodes. The distance is sufficiently large so that, when the distal portion of the catheter is placed inside the heart, the reference electrode is located outside and away from the heart. In one embodiment, the distance is 24 centimeters. In one embodiment,  $V_{\text{bias}}$  is about 1.5 Volts. Since the tissue impedance is about 100 Ohms to 120 Ohms, a 10 kilo-Ohms resistor is used for isolation for each of the ECG signals from the 20 electrodes.

[0028] Due to the buffer 270 driving the DC voltage  $V_{\text{bias}}$  out to the reference electrode, the signal from the reference electrode is practically equal to the DC voltage  $V_{\text{bias}}$ , and serves as a virtual reference.

[0029] The multiplexer 210 receives, at its 20 inputs, 20 ECG analog signals in parallel from the catheter 110, and outputs a single ECG analog signal.

[0030] The amplifier 230 comprises a differential amplifier. The differential amplifier receives the single ECG analog signal at its positive input and the signal from the reference electrode at its negative input. The amplifier 230 amplifies the difference between the 2 signals and outputs an amplified ECG analog signal that substantially does not have a DC component.

[0031] Figure 5 shows an external view of an embodiment of the catheter 110. In this embodiment, the catheter 110 has a tip electrode 502 and 3 band electrodes 504 for detecting ECG signals. The catheter 110 further includes the reference band 510 for providing a reference signal to the amplifier 230. The reference band is located at a distance  $L$  from the last band electrode 504, that is, the furthest band electrode from the distal end of the catheter 110. In one embodiment,  $L$  is equal to 24 cm.

[0032] Figure 6 shows an embodiment 600 of the system of the present invention, where a single receiver unit 602 including several individual RF receiver modules communicates with several distinct transmitter units. The single receiver unit 602 can identify the source of a received signal based on the specific RF channel frequency, data address packet, an unique identification of a transmitter unit. Software configuration is used to pair the transmitter catheter and the receiver unit. The transceivers can operate at frequencies between 2.400GHz to 2.525GHz.

[0033] While the invention has been described in terms of several embodiments, those of ordinary skill in the art will recognize that the invention is not limited to the embodiments described, but can be practiced with modification and alteration within the spirit and scope of the appended claims. The description is thus to be regarded as illustrative instead of limiting.

## CLAIMS

What is claimed is:

1. A catheter system for wireless communication with an electrophysiological (EP) mapping system, the catheter system comprising:
  - a catheter comprising:
    - an elongated body having a distal end, and a proximal end;
    - a plurality of mapping electrodes including a tip electrode being disposed on a distal portion of the elongated body, the plurality of mapping electrodes detecting electrocardiograph (ECG) signals; and
    - a reference electrode being disposed on the elongated body at a distance from the plurality of mapping electrodes such that the reference electrode substantially does not detect electrocardiograph (ECG) signals; and
    - a handle;
  - a catheter adapter attached to the handle, the catheter adapter including a radio frequency (RF) transmitter module for receiving, processing, and transmitting the detected ECG signals;
- wherein the reference electrode provides a reference signal to the radio frequency (RF) transmitter module; and
- an RF receiver module for receiving the transmitted ECG signals, the RF receiver module being coupled to the EP mapping system.

received by the International Bureau on 23 November 2009 (23.11.09)

What is claimed is:

1. A catheter system for wireless communication with an electrophysiological (EP) mapping system, the catheter system comprising:

a catheter comprising:

an elongated body having a distal end, and a proximal end;

a plurality of mapping electrodes including a tip electrode being disposed on a distal portion of the elongated body, the plurality of mapping electrodes detecting electrocardiograph (ECG) signals; and

a reference electrode being disposed on the elongated body at a distance from the plurality of mapping electrodes such that the reference electrode substantially does not detect electrocardiograph (ECG) signals; and

a handle; and

a catheter adapter attached to the handle, the catheter adapter including a radio frequency (RF) transmitter module for receiving, processing, and transmitting the detected ECG signals;

wherein the reference electrode provides a reference signal to the radio frequency (RF) transmitter module.

2. The catheter system of claim 1 further comprising:

a RF receiver module for receiving the transmitted ECG signals, the RF receiver module being coupled to the EP mapping system.

3. The catheter system of claim 1 wherein the reference electrode is disposed on the elongated body at a distance of approximately 24 centimeters from a last mapping electrode of the plurality of mapping electrodes, the last mapping electrode being the furthest mapping electrode from the distal end of the elongated body.

4. The catheter system of claim 1 wherein the RF transmitter module comprises a multiplexer having a plurality of inputs, each of the inputs receiving a mapping electrode

signal from a corresponding mapping electrode of the plurality of mapping electrodes, the multiplexer outputting an analog signal.

5. The catheter system of claim 4 wherein the RF transmitter module further comprises a buffer to drive a direct-current voltage to the reference electrode and to each of the mapping electrode signals.

6. The catheter system of claim 5 wherein the reference signal provided by the reference electrode is substantially equal to the direct-current voltage.

7. The catheter system of claim 5 wherein the RF transmitter module further comprises a plurality of resistors of high impedance to isolate the mapping electrode signals from the buffer.

8. The catheter system of claim 4 wherein the RF transmitter module further comprises an amplifier, the amplifier receiving the analog signal from the multiplexer and the reference signal and outputting an amplified analog signal that substantially does not have a direct-current component.

9. The catheter system of claim 8 wherein the RF transmitter module further comprises an analog-to-digital converter, a microcontroller, and an RF transmitter.

10. The catheter system of claim 1 wherein the RF transmitter module operates at frequencies between 2.400 GHz to 2.525 GHz.

11. The catheter system of claim 2 wherein the RF receiver module is one of a plurality of RF receiver modules included in a receiver unit, the plurality of RF receiver modules communicating with a plurality of corresponding RF transmitter modules:

12. The catheter system of claim 11 wherein the receiver unit can identify a source of a received signal based on at least one of a specific RF channel frequency, a data address packet, and a unique identification of a RF transmitter module of the plurality of RF transmitter modules.

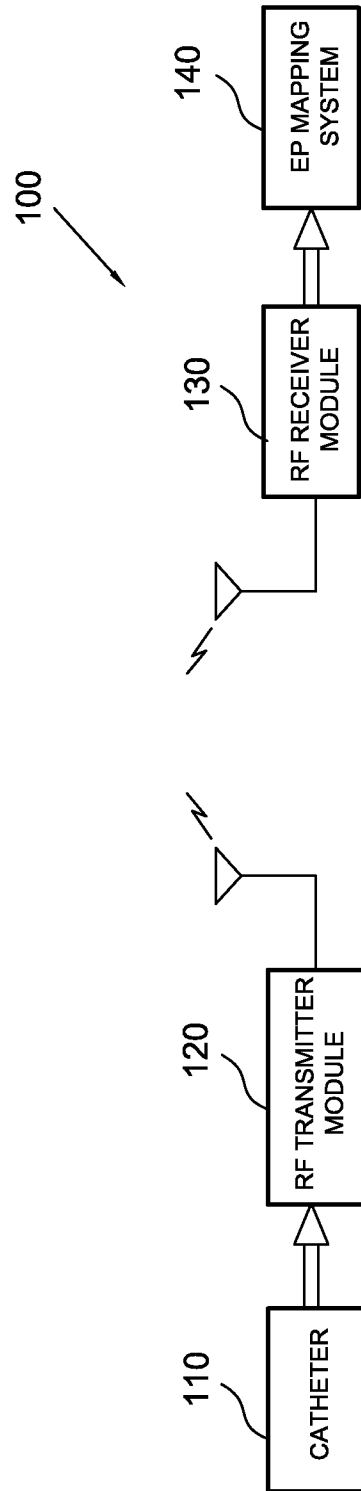


FIG. 1

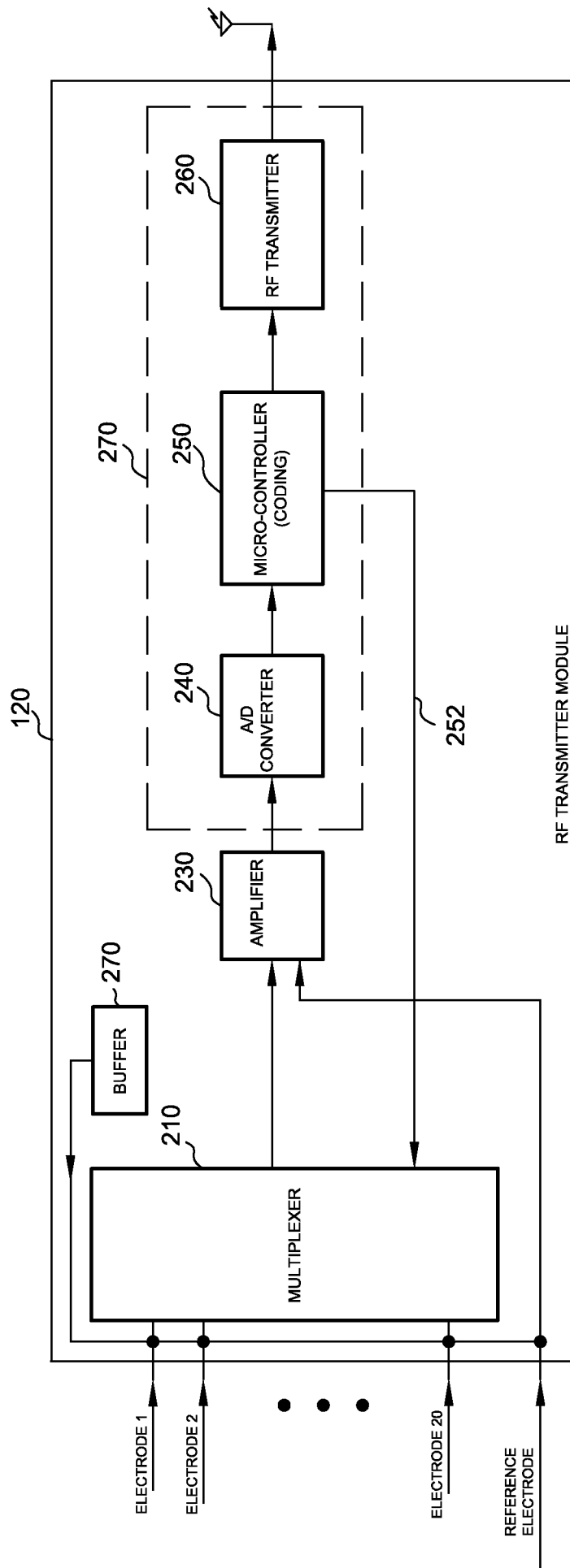


FIG. 2

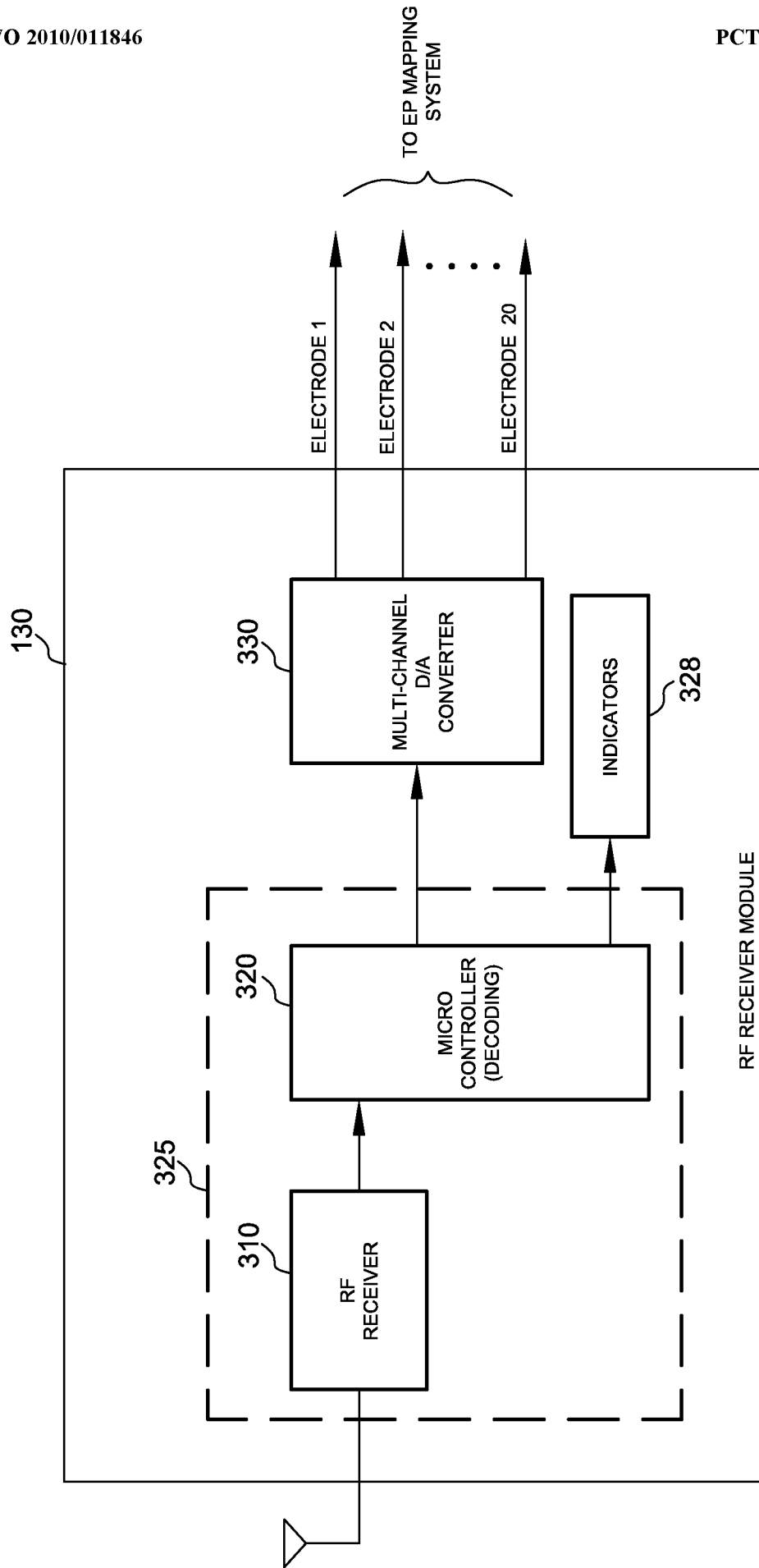


FIG. 3

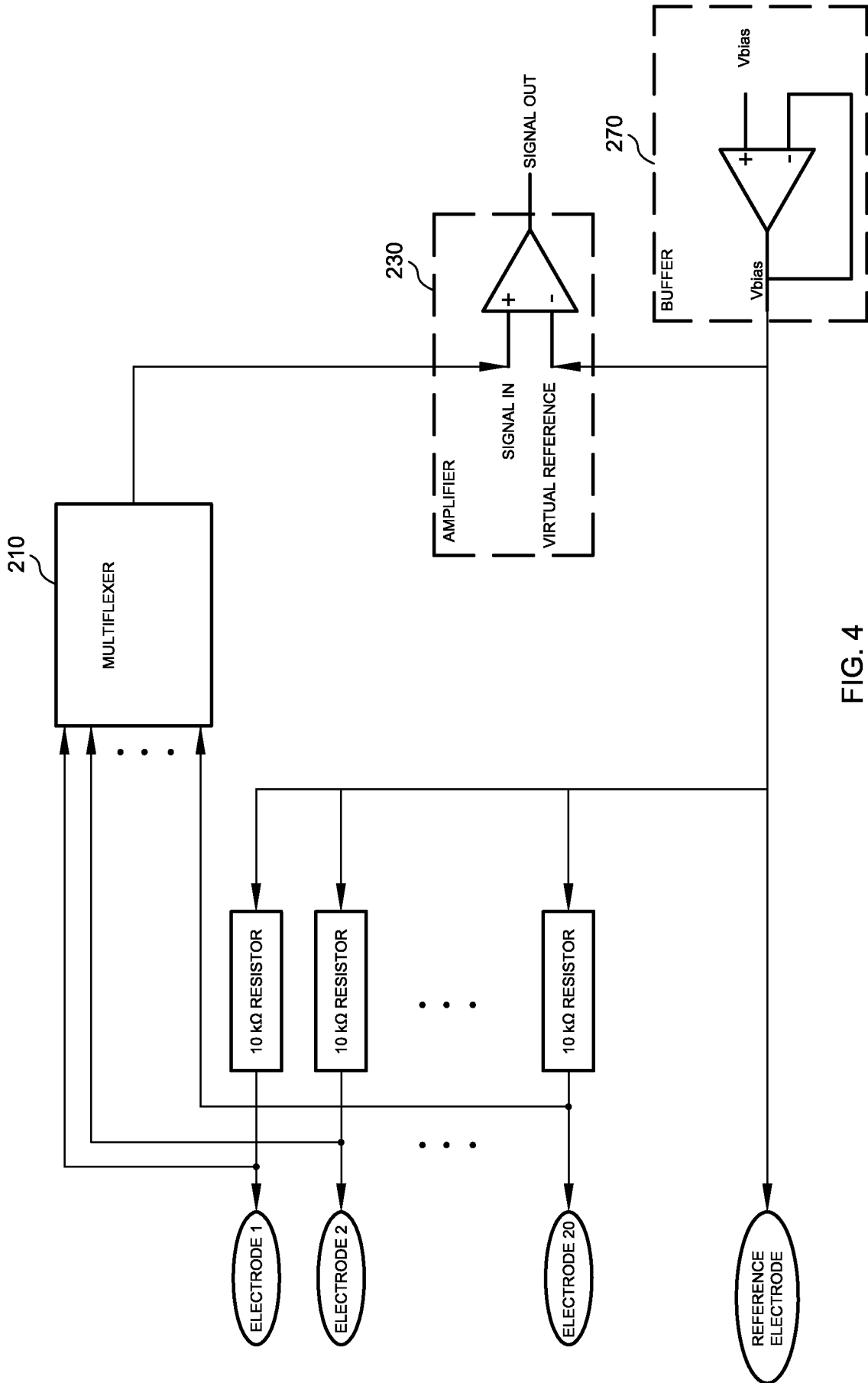


FIG. 4

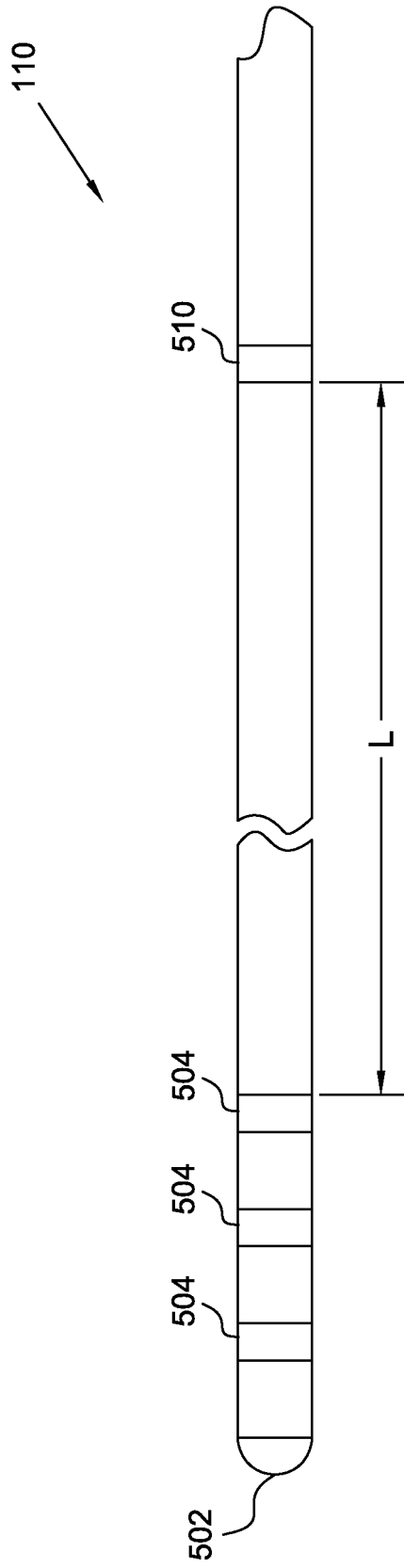


FIG. 5

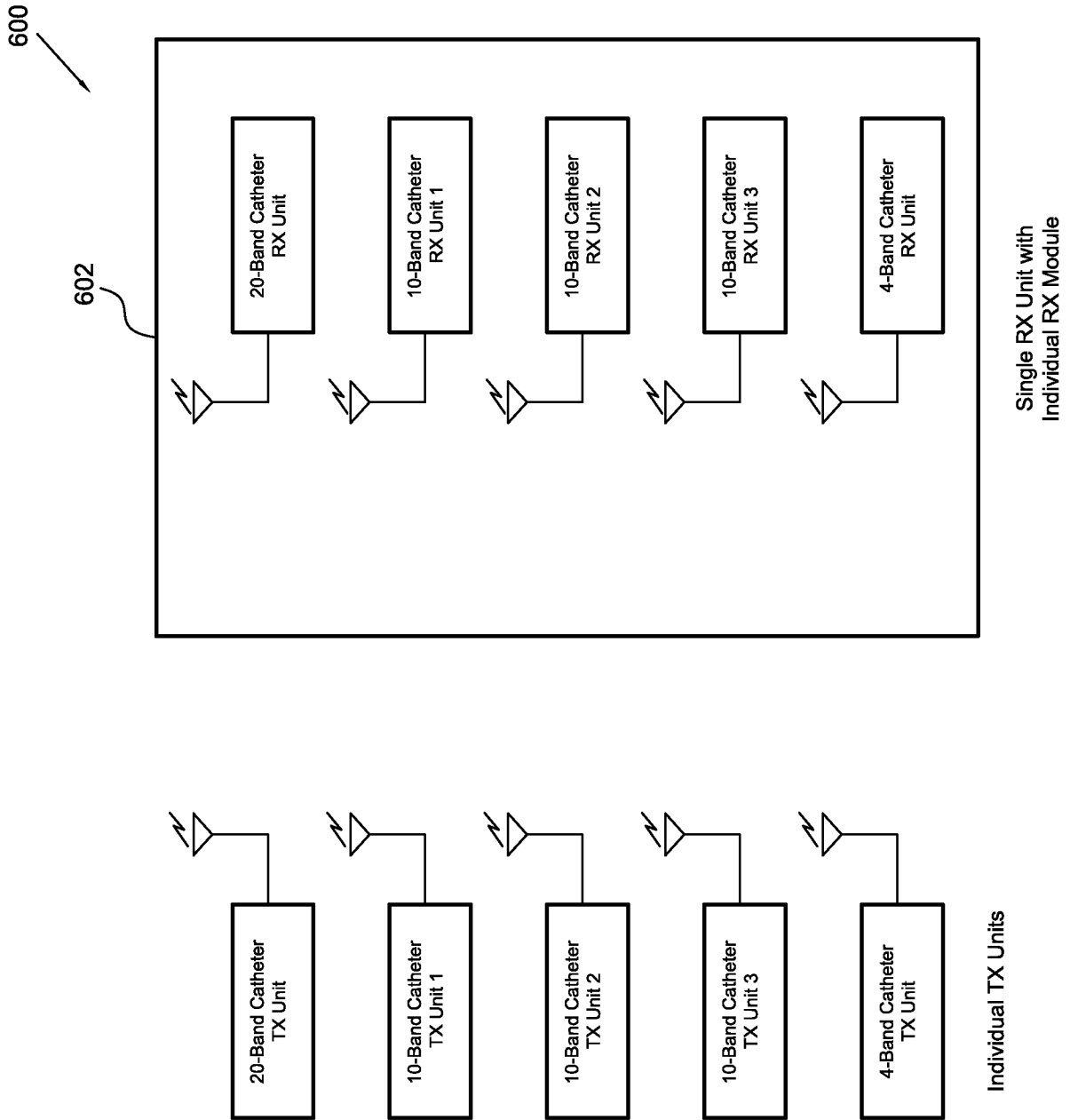


FIG. 6

**INTERNATIONAL SEARCH REPORT**

International application No  
PCT/US2009/051560

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> INV. A61B5/00      A61B5/042      A61M25/00				
According to International Patent Classification (IPC) or to both national classification and IPC				
<b>B. FIELDS SEARCHED</b>				
Minimum documentation searched (classification system followed by classification symbols) A61B A61M				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practical, search terms used) EPO-Internal				
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
Y	US 2008/033290 A1 (SAADAT VAHID [US] ET AL) 7 February 2008 (2008-02-07) figures 8B-9C, 12 paragraphs [0002], [0061], [0063], [0076]	1		
Y	WO 2007/146409 A (ACQUISTA ANGELO JOSEPH [US]) 21 December 2007 (2007-12-21) abstract paragraphs [0013], [0029] - [0031], [0038], [0041], [0042], [0064] figure 9B	1		
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<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C.	<input checked="" type="checkbox"/> See patent family annex.			
* Special categories of cited documents :				
<table style="width:100%; border:none;"> <tr> <td style="width:50%; border:none;">                     *A* document defining the general state of the art which is not considered to be of particular relevance                      *E* earlier document but published on or after the international filing date                      *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)                      *O* document referring to an oral disclosure, use, exhibition or other means                      *P* document published prior to the international filing date but later than the priority date claimed                 </td> <td style="width:50%; border:none;">                     *T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention                      *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone                      *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.                      *&amp;* document member of the same patent family                 </td> </tr> </table>			*A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. *&* document member of the same patent family
*A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document but published on or after the international filing date *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. *&* document member of the same patent family			
Date of the actual completion of the international search  <p align="center">27 August 2009</p>		Date of mailing of the international search report  <p align="center">10/09/2009</p>		
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer  <p align="center">Vanderperren, Yves</p>		

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/US2009/051560

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>DESILETS T ET AL: "Wireless Esophageal Catheter Dedicated to Respiratory Diseases Diagnostic"</p> <p>2006 IEEE INTERNATIONAL SYMPOSIUM ON CIRCUITS AND SYSTEMS 21-24 MAY 2006 ISLAND OF KOS, GREECE, IEEE - PISCATAWAY, NJ, USA, 21 May 2006 (2006-05-21), pages 2581-2584, XP010938929 ISBN: 978-0-7803-9389-9 figure 1 page 2581 - page 2583</p> <p>-----</p>	1
A	<p>DE 10 2005 035795 A1 (RHEINISCH WESTFAELISCH TECH HO [DE]) 9 November 2006 (2006-11-09) abstract paragraphs [0011], [0021]</p> <p>-----</p>	1
A	<p>WO 2008/075295 A (KONINKL PHILIPS ELECTRONICS NV [NL]; PHILIPS CORP [US]; DEKKER RONALD) 26 June 2008 (2008-06-26) abstract figure 1 page 1, line 1 - line 3 page 1, line 23 - line 28 page 2, line 17 - line 31</p> <p>-----</p>	1
A	<p>DE 10 2005 003171 A1 (BIOTRONIK CRM PATENT AG [CH]) 3 August 2006 (2006-08-03) figure 1 paragraphs [0005], [0020], [0025] - [0027]</p> <p>-----</p>	1
A	<p>US 2008/108904 A1 (HEIL RONALD W [US]) 8 May 2008 (2008-05-08) figure 1 paragraph [0023] - paragraph [0025]</p> <p>-----</p>	1

# INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/US2009/051560
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Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2008033290	A1	07-02-2008	NONE	
WO 2007146409	A	21-12-2007	EP 2073886 A2 US 2007293774 A1	01-07-2009 20-12-2007
DE 102005035795	A1	09-11-2006	EP 1876948 A1 WO 2006117154 A1 JP 2008539835 T US 2009088609 A1	16-01-2008 09-11-2006 20-11-2008 02-04-2009
WO 2008075295	A	26-06-2008	NONE	
DE 102005003171	A1	03-08-2006	NONE	
US 2008108904	A1	08-05-2008	WO 2008057720 A1	15-05-2008

专利名称(译)	用于无线通信的导管射频适配器		
公开(公告)号	<a href="#">EP2303102A1</a>	公开(公告)日	2011-04-06
申请号	EP2009790773	申请日	2009-07-23
申请(专利权)人(译)	ST.犹达医疗用品, INC.		
当前申请(专利权)人(译)	ST.犹达医疗用品, INC.		
[标]发明人	VU WILLIAM MINH NGUYEN THO HOANG		
发明人	VU, WILLIAM, MINH NGUYEN, THO, HOANG		
IPC分类号	A61B5/00 A61B5/042 A61M25/00		
CPC分类号	A61B5/0422 A61B5/0006 A61B5/0031		
优先权	61/135837 2008-07-23 US		
外部链接	<a href="#">Espacenet</a>		

#### 摘要(译)

一种用于与电生理 ( EP ) 映射系统进行无线通信的导管系统。导管系统包括导管, 导管适配器和射频接收器模块。导管包括多个映射电极, 包括设置在细长体的远端部分上的尖端电极, 映射电极检测心电图 ( ECG ) 信号; 参考电极设置在细长体上, 与多个映射电极相距一定距离, 使得参考电极基本上不检测心电图信号。导管包括手柄。导管适配器连接到手柄。导管适配器包括RF发射器模块, 用于接收, 处理和发送检测到的ECG信号。参考电极向射频 ( RF ) 发射器模块提供参考信号。RF接收器模块接收发送的ECG信号。RF接收器模块耦合到EP映射系统。