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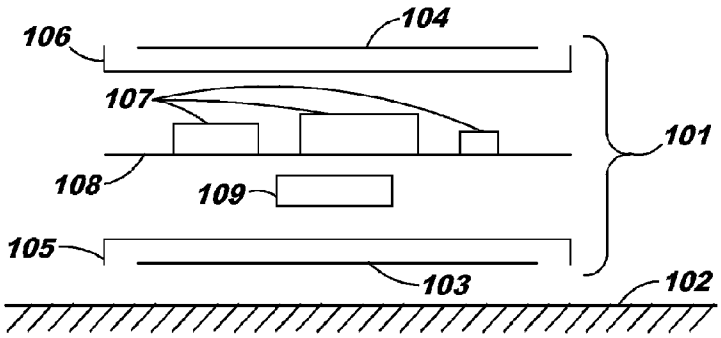

FIG. 1

(57) Abstract: A device for gathering data has first and second electrodes. The first electrode is coupled to a surface of interest, and the second electrode is coupled to "everything else" or "the air". The first electrode is shielded from the second, and from most sources of parasitic capacitance, by a shield that is driven by an active driver that drives the shield to track, and ideally to match, the instantaneous potential of the electrode. The second electrode is likewise shielded in a similar way from most sources of parasitic capacitance. These shields likewise help to limit the extent to which RFI from the device electronics couples with either of the electrodes. In this way the sensing device achieves a markedly better signal-to-noise ratio at frequency bands of interest.

WO 2011/094606 A3

2011210648 04 Sep 2014

Data Gathering System

Cross-Reference to Related Applications

This application is the Australian national phase application of International application No. PCT/US2011/023013 filed January 28, 2011, which claims the benefit of United States Provisional Patent application No. 61/300,435 filed February 1, 2010, and entitled "Two-wrist data-gathering system"; and United States Provisional Patent application No. 61/378,878 filed August 31, 2010, and entitled "Data Gathering System", the full contents of each of which is incoporated by reference herein.

Introduction

Some electromagnetic communications, e.g., EKG signals, conductance communications, RF signals, etc., are very, very difficult to detect and gather, except with inconvenient or awkward data-gathering systems. The general ambient conditions can contribute noise in whichever portion of the EM spectrum is being investigated. The source of the desired EM signal (for example a device within a live subject) may be overwhelmed or nearly overwhelmed by naturally occurring signals in the subject. The data-gathering device will likely contain a microcontroller and other electronics that will emit signals that further degrade the signal-to-noise ratio for the data gathering.

Perhaps more subtly, but also very importantly, parasitic capacitances, however small in absolute terms, can suck away electromagnetic energy at the frequency band of interest. Sources of parasitic capacitance can include relative positions of pairs of sensing electrodes, relative position of any single electrode relative to circuit boards containing ground planes, and the relative position of any single electrode relative to large metallic or conductive bodies such as batteries or power cells.

One example of a device within a live subject that may transmit a signal of interest is the ingestible event marker ("IEM") described in US patent publication 2010-0185055 entitled "Ingestible event marker systems", US patent publication 20100081894 entitled "Communication system with partial power source", US patent publication 20100022836 entitled "In-body device having a multi-directional transmitter", US patent publication 20090256702 entitled "multi-mode communication ingestible event markers and systems, and methods of using same", US patent publication number 20090135886 entitled "Transbody communication systems employing communications channels",

2011210648 04 Sep 2014

and US patent publication number 20090082645 entitled "In-body device with virtual dipole signal amplification", US patent publication number 20100312188 entitled "Body-Associated Receiver and Method ", each of which is incorporated herein by reference.

Such an IEM is necessarily extremely limited in the amount of electrical power available, and in the size of antenna available to couple the transmitter to nearby transmission media. The emitted signal is thus not much stronger than typical ambient noise sources. Heretofore the detection of such IEM signals has required the use of a patch, the patch having a form factor not unlike a large adhesive bandage, the patch applied to the abdomen of a subject so as to be nearby to the IEM when it emits its signal. The patch has potential drawbacks, among them the risk of irritation to the epidermis due to the adhesive attachment, possible interference with freedom of movement, and perhaps aesthetically displeasing appearance to some eyes.

An example of a data-gathering system that might be attempted is shown in Fig. 2. In such a system 201, the goal is to pick up a signal detectable as between (a) a surface 102 such as tissue of a subject, and (b) the "air" or general ambient region (located everywhere else in Fig. 2 besides the tissue and the detecting system). The pickup of signals is accomplished by electrode 203, which is coupled to the surface 102, and electrode 204, which is coupled to the "air". Circuit board 208 carries circuitry 207 and is connected with battery or cell ("battery") 209. The circuitry 207 is connected to the electrodes 203, 204. The hope is that a differential amplifier in the electronics 207 could take as its input each of the two electrodes 203, 204 and thereby detect signals of interest. The system 201 might be dry-coupled to tissue (as distinguished from the adhesive patch just described) and might be conveniently located elsewhere than the abdomen, for example in a bracelet or wristband, if only under such circumstances it proved to be possible to successfully detect the signals of interest.

Experience shows, however, that at frequencies of interest (perhaps tens of kilohertz), the parasitic capacitances present in such a device 201 cause a loss of a large portion of any detected signal. The parasitic capacitances may be conveniently modeled as being present between electrode 204 and the ground plane of circuit board 208, between electrode 204 and battery 209, between electrode 203 and the ground plane of circuit board 208, and between electrode 203 and battery 209. Some parasitic capacitance likely develops as well between the electrode 203 and the electrode 204.

Experience also shows that RFI (radio frequency interference) is likely to be emitted by the

2011210648 04 Sep 2014

electronics 207 and then picked up by the electrodes 203, 204. The desirably small form factor of a device 201 will obviate the use of traditional ferrite chokes and the like that might otherwise be used to try to choke off some of the coupling paths for RFI. The small form factor also juxtaposes the electrodes and the RFI sources with very little physical separation.

One approach sometimes employed to attempt to reduce RFI is to "can" the source of the RFI. In a device 201 this might be done by putting a metal shroud of a suitably selected metal or alloy around the circuitry 207. While this approach may indeed reduce RFI, it has the drawback of introducing still greater parasitic capacitances as between electrodes 203, 204.

It would be very desirable if a way could be found to detect such faint electrical signals reliably, in ways that would be more consistently acceptable to the subject than prior-art approaches. If a way could be found, it might be less irritating to the epidermis, might interfere less or not at all with freedom of movement, and might be more aesthetically pleasing to some eyes.

Summary

A device for gathering data has first and second electrodes. The first electrode is coupled to a surface of interest, and the second electrode is coupled to "everything else" or "the air". The first electrode is shielded from the second, and from most sources of parasitic capacitance, by a shield that is driven by an active driver that drives the shield to track, and ideally to match, the instantaneous potential of the electrode. The second electrode is likewise shielded in a similar way from most sources of parasitic capacitance. These shields likewise help to limit the extent to which RFI from the device electronics couples with either of the electrodes. In this way the sensing device achieves a markedly better signal-to-noise ratio at frequency bands of interest.

In one aspect, the invention provides an apparatus when used to gather data, the apparatus comprising: a first electrode, the electrode characterized as non-sticky, the electrode disposed for capacitive or electrically conductive coupling with a surface having air thereabove; a second electrode, the electrode characterized as non-sticky, the electrode disposed for capacitive or electrically conductive coupling with the air; electronic circuitry disposed physically between the first and second electrodes; the first electrode shielded by a shield located physically between the first electrode and the electronic circuitry; the second electrode shielded by a shield located between the second electrode and the electronic circuitry; the electronic circuitry comprising a first driver

receiving as an input a signal present at the first electrode, the first driver having an output coupled with the shield of the first electrode; the electronic circuitry comprising a second driver receiving as an input a signal present at the second electrode, the second driver having an output coupled with the shield of the second electrode; the electronic circuitry further comprising a differential amplifier having first and second inputs, each input connected to a respective one of the first and second electrodes; the differential amplifier having an output; the electronic circuitry further comprising means for communicating data indicative of the output of the differential amplifier to equipment external to the apparatus.

In another aspect, the invention provides a method when used in detecting signals, the method comprising the steps of: providing a first electrode, the electrode characterized as non-sticky, the electrode capacitively or electrically conductively with a surface having air thereabove; providing a second electrode, the electrode characterized as non-sticky, the electrode capacitively coupled with the air; providing electronic circuitry physically between the first electrode and the second electrode; providing a first shield physically between the first electrode and the electronic circuitry; providing a second shield physically between the second electrode and the electronic circuitry; by means of the electronic circuitry, driving the first shield to follow a signal present at the first electrode; by means of the electronic circuitry, driving the second shield to follow a signal present at the second elecrode; by means of the electronic circuitry, deriving a difference between the signal present at the first electrode and the signal present at the second electrode; and communicating data indicative of the difference to equipment external to an apparatus comprising the first electrode, the second electrode, the electronic circuitry, the first shield, and the second shield.

Description of the drawing

Figure 1 shows a sensing device according to the invention in cross-sectional view;

Figure 2 shows a possible sensing device according to the prior art in cross-sectional view; and

Figure 3 shows the sensing device of Fig. 1 in functional block diagram portrayal.

Detailed description

Turning to Fig. 1, what is shown is a sensing device 101 according to the invention in cross-sectional view. The sensing device has first and second electrodes 103 and 104. The first electrode 103 is coupled to a surface of interest 102, which might be tissue of a living subject, and the second electrode 104 is coupled to "everything else" or "the air". Although it is largely a matter of semantics, one might choose to characterize the second electrode 104 as an electrode coupling to "ground" or "space ground".

The first electrode 103 is shielded from the second electrode 104, and from most sources of parasitic capacitance, by a shield 105 that is driven by an active driver (omitted for clarity in Fig. 1) that drives the shield 105 to track, and ideally to match, the instantaneous potential of the electrode 103. The second electrode 104 is likewise shielded in a similar way from most sources of parasitic capacitance by a shield 106. These shields 105, 106 likewise help to limit the extent to which RFI from the device electronics 107 couples with either of the electrodes 103, 104. In this way the sensing device 101 achieves a markedly better signal-to-noise ratio at frequency bands of interest as compared with prior-art sensing devices.

Were it not for the shielding effects of shields 105, 106, the electrodes 103, 104 would capacitively couple parasitically with the battery 109, with ground planes in the circuit board 108, and with each other.

Figure 3 shows the sensing device 101 of Fig. 1 in functional block diagram portrayal. Electrode/shield assembly 104/106 plugs via connector 301 to the circuit board 108. Electrode/shield assembly 103/105 likewise plugs via connector 302 to the circuit board 108. The signal detected at electrode 104 is amplified in amplifier 304, which drives shield 106. The signal detected at electrode 103 is amplified in amplifier 306, which drives shield 105. The signal detected at electrode 104 is also amplified in amplifier 303, providing one of two inputs to differential amplifier 307. The resulting signal (a difference between the instantaneous potentials at the two electrodes) can then be filtered by a bandpass filter 308 and converted to a digital signal by analog-to-digital converter 309.

It will be appreciated that the amplifier 304 will need to be selected to have a frequency response sufficient to drive shield 106 at the frequency band of interest and preferably at some higher frequencies. The amplifier 304 will also need to be selected to have enough power to pump sufficient charge into and out of the shield 106 taking into account its physical size and impedance.

2011210648 04 Sep 2014

The same may be said of amplifier 306 relative to its respective shield 105.

In an exemplary aspect the frequency band of interest is 54 kilohertz plus or minus five kilohertz. Thus bandpass filter 308 is chosen to pass this band. It is thought, however, that some IEMs could be developed that emit signals at a megahertz or higher, in which case the data collection device 101 would desirably carry out its function at such frequency bands. Other devices 101 could use a frequency band at about 20 kilohertz.

It will be appreciated that amplifiers 303, 305, and 307, and filter 308, and A/D converter 309 each need to have frequency response sufficient for the frequency band of interest. It will be further appreciated that although the circuitry of Fig. 3 is depicted with discrete components such as individual op amps 303, 304, 305, 306, 307 and discrete-component active filter 308, the benefits of the invention could just as well be gained by substituting a digital signal processor of sufficient frequency response for some or most of the components portrayed in Fig. 3, without departing in any way from the invention. The amplifiers 304, 306 need to have high gain at the frequencies of interest and need to have low noise.

In the present proof-of-concept aspect, a microcontroller (omitted for clarity in Fig. 3) receives signals which are stored as data in the microcontroller (or in memory attached to the microcontroller), and the data can then be communicated external to the device 101, for example to a general-purpose computer executing appropriate software for analysis of the received signals. The circuitry 107 is powered by a small "button" cell or battery. Another approach would be to communicate the data wirelessly, for example via Bluetooth, to equipment external to the device 101. Such equipment may be a smart mobile phone running a suitable application to receive data via Bluetooth and to transmit the data further to a remote host, via GPRS or other mobile-phone data protocol.

In the present proof-of-concept aspect, the device 101 is a flat square device, 3 centimeters square. It is able to provide a wearable wristwatch form factor, only slightly larger than the button cell being used to power the device 101.

The desirable result is to pick up the signals of interest from a single distal point such as a wrist. The coupling would be by means of a non-sticky dry electrode with capacitive coupling to the body, or in some cases with electrically conductive coupling to the body. From a user's point of view this

might be an elastic belt around the waist or chest, or an elastic wristlet band, or a necklace form factor.

The electrode 103 may be gold, or platinum, or stainless steel.

The active shielding accomplished with shields 105, 106 driven by drivers 304, 306 permits the device 101 to pick up signals such as IEM signals despite being further away from the IEM than the prior-art adhesive-bandage type of patch, and despite being non-sticky. This makes the system of device and IEM more acceptable to users.

Further shielding may be disposed around the circuitry 107, connected for example to a ground plane within the circuit board 108, or connected for example to a potential defined to be between the rails defined by the battery.

It will be appreciated that devices 101 could be used in pairs, each touching a body at a different place. The two devices 101 are each coupled with "space ground" and are thus to some extent coupled to each other, through the electrodes 104. The paired devices could then collect data from the body in a somewhat "dipole" receiver arrangement.

Those skilled in the art will have no difficulty devising myriad obvious variants and improvements of the aspects set forth here, without departing in any way from the invention, all of which obvious variants and improvements are intended to be encompassed by the claims which follow.

2011210648 04 Sep 2014

CLAIMS

1. An apparatus when used to gather data, the apparatus comprising:

a first electrode, the electrode characterized as non-sticky, the electrode disposed for capacitive or electrically conductive coupling with a surface having air thereabove;

a second electrode, the electrode characterized as non-sticky, the electrode disposed for capacitive or electrically conductive coupling with the air;

electronic circuitry disposed physically between the first and second electrodes;

the first electrode shielded by a shield located physically between the first electrode and the electronic circuitry;

the second electrode shielded by a shield located between the second electrode and the electronic circuitry;

the electronic circuitry comprising a first driver receiving as an input a signal present at the first electrode, the first driver having an output coupled with the shield of the first electrode;

the electronic circuitry comprising a second driver receiving as an input a signal present at the second electrode, the second driver having an output coupled with the shield of the second electrode;

the electronic circuitry further comprising a differential amplifier having first and second inputs, each input connected to a respective one of the first and second electrodes;

the differential amplifier having an output;

the electronic circuitry further comprising means for communicating data indicative of the output of the differential amplifier to equipment external to the apparatus.

2. The apparatus of claim 1, wherein the first electrode and the second electrode are substantially planar and are parallel with each other, and wherein the electronic circuitry lies between the first and second electrodes and parallel thereto.

3. The apparatus of claim 1 or claim 2, wherein the means for communicating data indicative of the output of the differential amplifier to equipment external to the apparatus comprises a connector providing a serial data path.

4. The apparatus of any one of claims 1 to 3, wherein the means for communicating data indicative of the output of the differential amplifier to equipment external to the apparatus comprises a Bluetooth link.

2011210648 04 Sep 2014

5. The apparatus of any one of claims 1 to 4, wherein the output of the differential amplifier is bandpass filtered to a band including 54 kilohertz.

6. The apparatus of any one of claims 1 to 5 characterized as unpowered from outside of the apparatus.

7. The apparatus of any one of claims 1 to 6 further comprising a shield surrounding the electronic circuitry.

8. A method when used in detecting signals, the method comprising the steps of:

providing a first electrode, the electrode characterized as non-sticky, the electrode capacitively or electrically conductively with a surface having air thereabove;

providing a second electrode, the electrode characterized as non-sticky, the electrode capacitively coupled with the air;

providing electronic circuitry physically between the first electrode and the second electrode;

providing a first shield physically between the first electrode and the electronic circuitry;

providing a second shield physically between the second electrode and the electronic circuitry;

by means of the electronic circuitry, driving the first shield to follow a signal present at the first electrode;

by means of the electronic circuitry, driving the second shield to follow a signal present at the second electrode;

by means of the electronic circuitry, deriving a difference between the signal present at the first electrode and the signal present at the second electrode; and

communicating data indicative of the difference to equipment external to an apparatus comprising the first electrode, the second electrode, the electronic circuitry, the first shield, and the second shield.

9. The method of claim 8, wherein the communicating data indicative of the difference to equipment external to the apparatus comprises passing serial data through a connector providing a serial data path.

10. The method of claim 8 or claim 9, wherein the communicating data indicative of the difference to equipment external to the apparatus comprises passing data through a Bluetooth link.

2011210648 04 Sep 2014

11. The method of any one of claims 8 to 10, wherein the surface is skin.

12. The method of claim 11, wherein the skin is at a wrist.

13. The apparatus of any one of claims 1 to 7 or the method of any one of claims 8 to 12, substantially as described herein.

FIG. 1

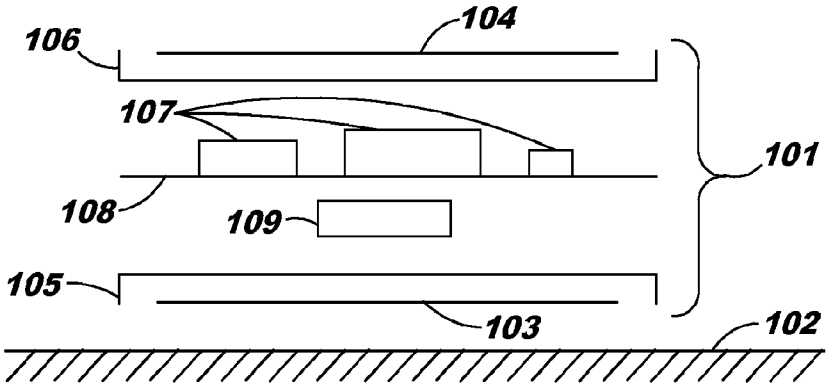

FIG. 2

Prior Art

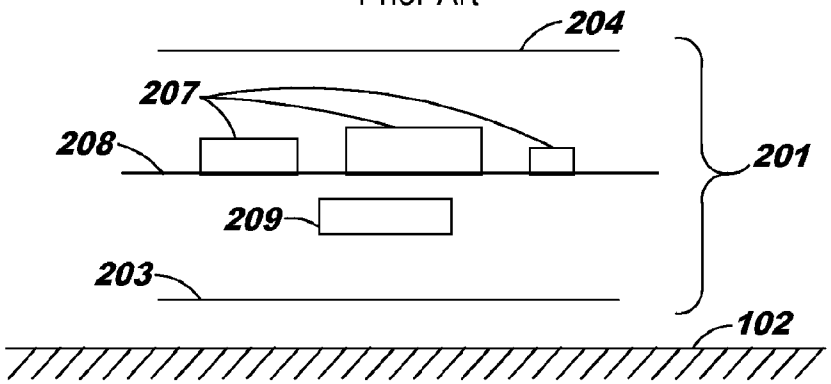
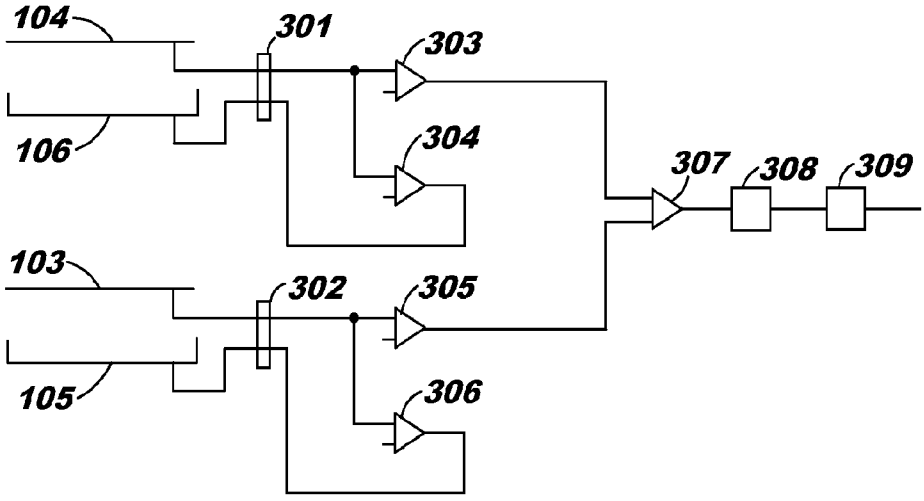
FIG. 3