

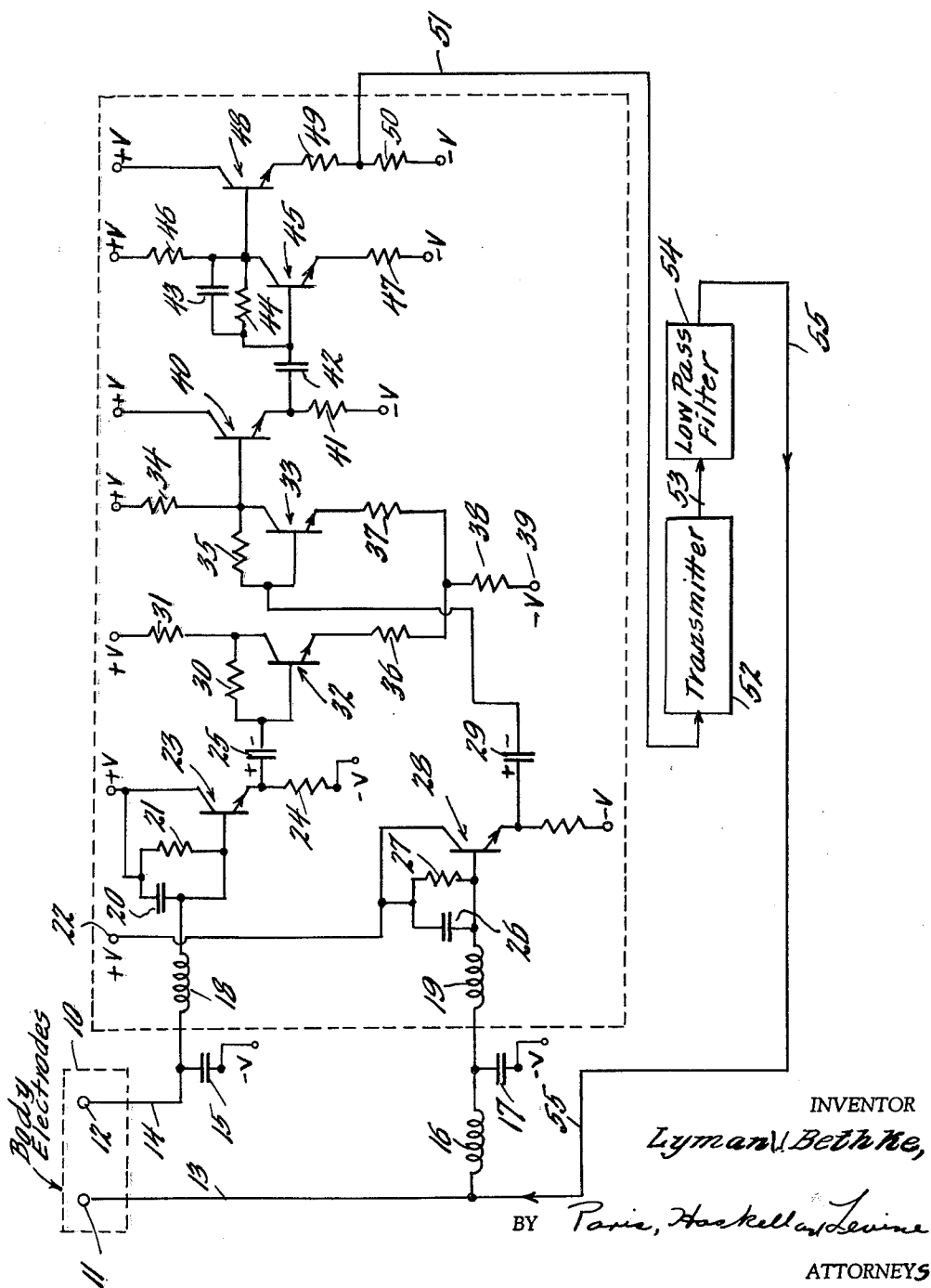
July 20, 1965

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3,195,534

RADIO ELECTROCARDIOGRAPH APPARATUS

Filed June 8, 1961



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3,195,534

RADIO ELECTROCARDIOGRAPH APPARATUS
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Filed June 8, 1961, Ser. No. 115,711

6 Claims. (Cl. 128—2.06)

This invention generally relates to diagnostic electro medical apparatus and is particularly concerned with improvements in portable electronic radio electrocardiograph apparatus adapted to be carried by the patient and to transmit electrocardiograph data to a remote receiving location by means of radiant radio waves.

It is accordingly a principal object of the invention to provide a radiocardiograph system comprised of high gain miniaturized electronic circuitry of small size, lightweight and minimized complexity that is adapted to be carried by the patient.

A further object is to provide such electromedical apparatus that responds to low voltage level electrical signals obtained from electrodes attached to the body and converts the body generated voltage signals into a form suitable for modulating a radio electrocardiograph transmitter also carried by the patient.

Still another object is to provide a portable battery powered apparatus of this type that is relatively insensitive to variations in temperature and in the potential of the battery and provides a stable base line transmitted electrocardiograph signal adapted to be conveyed by radio waves to a remote location.

A still further object is to provide such a system that substantially rejects other extraneous electrical signals and reproduces low voltage level cardiac produced signals for radio transmission to a remote detector.

Still another object is to provide such a miniature apparatus adapted to be worn by the patient and consequently subjected to heating by the body yet being relatively insensitive thereto and to other external conditions such as noise, vibration and the like.

Other objects and many additional advantages will be more readily understood by those skilled in the art after a detailed consideration of the following specification taken with the single accompanying drawing illustrating in electrical schematic form one preferred embodiment of the invention.

Referring now to the drawing for a detailed consideration of one preferred radio electrocardiograph system embodying the invention, there are shown the various component circuits of a complete detecting and transmitting means that is adapted to be carried by the patient within a miniature housing (not shown) that occupies a space no larger than a small package of cigarettes. The apparatus may be easily carried by the patient in a shirt pocket or easily strapped or applied to the body without being observable, thereby minimizing any embarrassment or discomfort to the user.

As shown, the system generally includes a pair of small sensors or electrodes 11 and 12, illustrated within dotted enclosure 10, adapted to be attached closely together to the body of the patient in the preferred regions near the heart for best measuring the electrical signals produced by the cardiac muscles. Since the system is adapted to provide a dynamic measurement of the patient's heart while the patient is performing a variety of body exercises and normal routine activities, these electrodes 11 and 12 must necessarily be constructed in such manner as to provide a continuous low resistance electrical contact over long period of time and despite various body movements bringing about changes in the curvature of the body. Additionally, it is desired that the electrodes be very small in size, easily attached to the body and unobjection-

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able to the patient. Accordingly, it is preferred to employ small self adhering electrodes as disclosed in co-pending application Serial No. 116,586, filed June 12, 1961, assigned to the same assignee, now Patent No. 3,085,577 although as will be appreciated, the present invention is not limited to the use of such electrodes.

For connecting the electrodes 11 and 12 to the apparatus, there is provided electrical conductors 13 and 14, each of which is preferably a thin insulated wire to provide flexibility for permitting unrestrained movement of the patient, and being innocuous and not readily noticeable in appearance. The lead 14 is connected to one input of a stabilized and compensated differential amplifier through a low pass filter comprising shunt capacitor 15 and series inductor 18 and the lead 13 is connected to a second input of the amplifier through a low pass filter comprising a pair of series connected inductors 16 and 19 and a shunting capacitor 17.

The electrical signals produced by the body and adapted to be detected by the electrocardiograph are very low voltage level signals in the order of 1 or 2 millivolts and occurring at frequencies to be detected in the range of from one tenth (.1) cycle to about 120 cycles each second. Consequently, one function of the filters in each line of conductors 13 and 14 is to prevent the transmission of any extraneous signal or noise occurring at higher frequency from being introduced into the detecting and transmitting apparatus.

The differential amplifier circuit, schematically shown in detail within the dotted enclosure, functions to amplify the low voltage level signals being obtained from the electrodes by a ratio in the range of 200 to 300 to 1 and, in addition, further combines this pair of signals in such manner as to reject or eliminate any spurious electrical body signal that is produced and transmitted by the electrodes thereby effectively separating and eliminating the spurious or undesired signals from the desired cardiac signals. As will be discussed in greater detail hereafter, this circuit is also provided with stabilizing and compensating means whereby variations in the temperature of the components or in the voltage supplied by the portable battery 22 energizing the circuits will not appreciably vary the characteristics of the electrical body signals being amplified and transmitted by the system.

The amplified and filtered intelligence signal produced by the differential amplifier circuit is then directed over line 51 to a miniature radio frequency transmitter 52 where this intelligence signal is employed to modulate the carrier frequency of the transmitter 52 and produce a variable frequency radio signal over line 53 leading to a low pass filter 54. The low pass filter 54, operating in the radio frequency range, removes all of the undesired higher harmonics and other high frequency noise and spurious electrical signals and conveys the desired output radio signal over line 55. This radio signal over line 55 is adapted to be propagated outwardly into space to a remotely located radio receiver, placed in a hospital, in a doctor's office or in another remote monitoring station. At this remote station the propagated radio beam is received and detected and the electrocardiograph signal is displayed and recorded as is desired thereby to indicate the condition of the patient being observed.

As will be appreciated by those skilled in the medical diagnostic arts, the fact that the present invention is miniature in size, may be worn by the patient, and is wireless or not connected by wires to any stationary recording apparatus, permits dynamic electrocardiogram measurements to be taken of the patient while he is performing his normal body exercises and activities at locations remote from the doctor's office. With conventionally wired electrocardiogram apparatus on the other hand, the patient is restrained in his activities while the

measurements are being made by the electrical wires interconnecting the sensors or electrodes attached to the patient and the stationary recording apparatus located in the doctor's office or hospital. For this reason, in conventional electrocardiogram testing, the patient is required to simulate various activities during the test by an artificial program of body exercises and the test results obtained are accordingly not always representative of the actual stresses to which the patient may be subjected under normal everyday conditions.

According to further features of the invention, it is intended that the system may be installed on the patient and put into use by persons having the necessary training in cardiology to interpret and properly use the test information obtained while at the same time not requiring that such doctors or medical technicians be required to acquire any detailed expertise in the fields of transmitters or electronics. For this reason it is desired to eliminate, so far as possible, the number of electrical connections and adjustments and to provide the complete detecting and transmitting equipment in the form of a small self-contained package having a minimum number of external electrical wires and adjustment means.

To this end, according to the invention, it is preferred that the transmitter not be provided with a separate external radiating antenna but instead that the antenna be combined with the external lead-in wire 13 leading from the electrode 11 to the input filter and amplifier.

Returning to the drawing for a detailed understanding of this feature, the radio frequency output signal taken from the low pass filter 54 is initially directed over output line 55. Output line 55 is, in turn, fed back and connected to the input terminal receiving the electrode lead line 13 whereby the output radio frequency signal is connected to energize the external lead line 13 serving as a radiating antenna to propagate the radio beam. Since the incoming cardiograph signal being taken from the body through electrode sensor 11 and passed over line 13 is at a much lower frequency, in the order of cycles, and the radio beam output signal over line 13 is at much higher frequencies, usually in the kilocycle bands, the input filter, comprising coils 16 and 19 and capacitor 17, discriminates between the input and output signals and prevents the radio beam output signal from entering the amplifier while enabling the signal from the electrode 11 to do so. Thus, the external flexible connector 13 serves the combined function of connecting the body electrode 11 to the apparatus while also serving the additional function of providing radiating antenna for the radio transmitter 52 and filter means 54.

As a result of this dual function provided by electrical line 13, all of the amplifier transmitter 52, filter 54, lead 55, and battery may be contained within a single miniature housing having only two external leads or wires 13 and 14 for connection to the electrodes 11 and 12.

Due to the fact that the external electrical leads 13 and 14 are generally positioned closely together, the output radio signal on lead 13 may also be produced in lead 14 by electrical induction. However, the low pass input filter for line 14, including capacitor 15 and inductor 18, prevents this induced signal from entering the amplifier in the same manner as the low pass filter in series with line 13.

Considering now in greater detail the structure and function of the preferred amplifier circuit, each of the two signals from the electrodes 11 and 12 is introduced into a different input or channel of the amplifier. The signal from electrode 11, after passing through the low pass filter is directed to the base electrode of transistor 28 and the signal from electrode 12, after passing through its separate filter, is directed to transistor 23.

The transistors 23 and 28 are each connected in an identical emitter follower type stage configuration which circuits are characterized as providing a high input im-

pedance to the electrodes 11 and 12 and a relatively low output impedance to succeeding stages in the amplifier. In this manner, the electrodes 11 and 12 are impedance matched to the amplifier for efficiently energizing the amplifier circuit yet variations in the impedances in the amplifier or electrodes will not adversely affect the transmission of signals therethrough.

Tracing through this circuit stage, the collector electrode of transistor 23 is directly connected to be energized by the positive battery potential at 22 and the emitter electrode thereof is connected to the negative terminal of the battery 22 through a series resistor 24. The base electrode is biased by being connected to the positive battery potential at 22 through a resistor 21, and a bypass capacitor 20 is provided in parallel with resistor 21 to stabilize the transistor 23 against high frequency oscillation by by-passing high frequency signals therethrough. It is also to be noted that the capacitor 20 functions as part of the input filter to by-pass any high frequency signals from reaching the base electrode. The output signal from the stage is taken from the emitter electrode and directed through a high capacity miniature titanium electrolytic coupling capacitor 25, thereby enabling only alternating current signals to pass through to the next succeeding stage. This later connection prevents drift or change in the potential of the battery source 22 from affecting the signal being conveyed to the next stage in the amplifier.

In the second input channel of the amplifier, the transistor 28 is connected identically with transistor 23, having an oscillation preventing and filtering capacitor 26, a biasing resistor 27, an emitter resistor, and a large capacity miniature titanium coupling capacitor 29 for passing only the alternating current signal to the succeeding stage.

The two signals taken from the transistors 23 and 28 are then directed to a common mode rejection stage comprised of transistors 32 and 33, with the signal from transistor 23 being coupled through capacitor 25 to the base electrode of transistor 32 and the signal from transistor 28 being coupled through capacitor 29 to the base electrode of transistor 33.

In this stage, the emitter elements of both transistors 32 and 33 are connected in common to the negative terminal of battery 22 through a mutual feedback resistor 38 whereby as the current through one of these transistors tends to increase, feedback across resistor 38 is in a direction to decrease current through the other and if the current through one tends to decrease, the current through the other is accordingly increased. Additionally, by means of this mutual feedback connection, if the current through both transistors tends to increase or decrease in unison, the potential produced at the collector electrode of either transistor remains substantially constant. For this reason, this circuit connection is termed as a common mode rejection circuit due to the fact that it will pass only signals that do not appear in common to both transistors but will not pass signals that commonly energize both transistors 32 and 33.

Continuing this analysis, it will be recalled that the base electrode of transistor 32 is energized according to the signal sensed by electrode 12 and therefore the current through transistor 32 is controlled thereby and likewise the current through transistor 33 is controlled by the signal from electrode 11. Consequently, if both electrodes detect the same signal, the common mode rejection stage will reject this signal and will pass only signals that do not appear in common to both electrodes. Since the electrodes 11 and 12 are spaced at different locations from the heart, the electrical signals detected by these electrodes and originating from the heart will differ from one another and such signals will be passed by the common mode rejection stage. Conversely, however, whenever the spaced electrodes 11 and 12 detect the same signal, such signal must originate from some other source and it is accordingly desired that this signal not be transmitted but

rather rejected as being spurious to the desired measurement.

The single output signal from the common mode rejection circuit is taken from the collector element of transistor 33 and thence directly coupled to the base electrode of a succeeding transistor 40 being connected in an emitter follower configuration as an impedance matching stage to couple the common mode rejection signal to the succeeding stages. The direct current connection is made in this instance to eliminate the need for an additional large capacity coupling capacitor, such as capacitors 25 and 29 discussed above.

To stabilize the common mode rejection transistors 32 and 33 against change in the potential of the battery 22 and against change in temperature of the transistors 32 and 33 as may be occasioned by the body heat of the patient carrying the apparatus, each of transistors 32 and 33 is provided with a direct current feedback resistor 30 and 35, respectively, each interconnecting the collector and base electrodes thereof. These resistors 30 and 35 each function in combination with their associated resistors 31 and 34, respectively, in the collector circuits of the transistors 32 and 33 to stabilize these transistors against drifting due to battery potential changes or temperature changes thereby to prevent any undesired variation in the cardiac or intelligence signal due to such drift.

The common mode rejection circuit also provides a gain or amplification of approximately 10 to 1 thereby to enhance the low level body signals sensed by the electrodes.

In the further succeeding stage, comprising transistor 45, the selected intelligence signal is amplified by an additional gain of about 20 to 30 to raise its voltage level sufficiently to modulate the radio transmitter 52, and it is then passed through an impedance matching stage or buffer stage, comprising transistor 43 that serves to couple this amplified signal to the transmitter 52.

The amplifier stage of transistor 45 is alternating current coupled to the preceding buffer stage of transistor 40, by means of a large capacity but miniature-sized capacitor 42, but is directly coupled to its succeeding buffer stage of transistor 43.

The amplifying stage (transistor 45) is also provided with a direct current feedback resistor 44 interconnecting its collector and base electrodes and cooperating with a collector resistor 46 to stabilize against variations in the battery potential or changes in temperature affecting the current flow through the transistor 45. A capacitor 43 is provided in shunt with resistor 44 to further stabilize against oscillation of the transistors in the same manner as in the first stage described above.

The output signal from the preferred amplifier-common rejection circuit is then directed over line 51 to modulate the radio transmitter 52 whereupon a frequency modulated radio beam is propagated to a remote location as desired.

Thus, the amplifier circuit as described enhances the body signal obtained from the electrodes 11 and 12 sufficiently to modulate a radio beam transmitter thereby to produce a frequency modulated radio beam for transmission to a remote location. The amplifier also responds to the signals detected by a pair of transducers or electrodes 11 and 12 to reject spurious signals and potentials produced by the body and select those representing the cardiograph information desired. The amplifier also provides compensation against variations in the potential of the portable battery 22 and against changes in temperature of the transistors, occasioned by external heating sources such as the body heat produced by the patient wearing the portable apparatus.

The radio transmitter 52 is also adapted to be miniaturized in size and battery powered by the same battery 22. It is preferably packaged within the small modular housing as the amplifier and consequently subjected to the same heating by the body of the patient. For this reason,

the transmitter is preferably also compensated against changes in battery potential and temperature and one preferred embodiment thereof is disclosed in copending application Serial Number 118,605, filed June 21, 1961, and assigned to the same assignee, although as will be appreciated by those skilled in the art, other transmitter configurations may be employed.

Although but one preferred embodiment of the invention has been illustrated and described, it is believed evident that many variations may be made without departing from the spirit and scope of the invention. Accordingly, this invention should be considered as being limited only according to the following claims hereto.

I claim:

1. A medical diagnostic radio system comprising transducers for attachment to a living organism and transducing physiological signals, amplifier means for amplifying said electrical signals obtained from the transducers, a radio transmitter modulated by said amplified signals to propagate radio signals corresponding to said physiological signals obtained from the body to a remote location, said system being miniaturized and contained within a small housing adapted to be carried by the living organism, a powering battery for providing energization of said amplifier means and transmitter, said amplifier means comprising a differential transistor amplifier stage energized by said physiological signals from said transducers to produce a single-ended output signal, and including a pair of transistors interconnected in common mode feedback relationship, each transistor being energized in response to a different transducer, a single-ended transistor amplifier stage being energized in response to one of said common mode transistors, and impedance decoupling transistor stages for coupling said transducers to said common mode transistors and for coupling said single-ended transistor amplifier stage to one of the common mode transistors.

2. In the system of claim 1, said impedance decoupling stages comprising a transistor being direct current coupled to the previous stage and alternating current coupled to a succeeding stage.

3. A radio electrocardiograph system adapted to be intimately carried by a living organism comprising transducers for attachment to the organism and producing physiological signals, a signal amplifier for amplifying said physiological signals, a radio frequency signal transmitter being modulated by said amplified signals and producing a radio frequency signal at its output corresponding to said physiological signals, electrical conductors interconnecting the transducers with the signal amplifier, means interconnecting said output of the transmitter in feedback to said electrical conductors, whereby said electrical conductors also serve as a transmitting antenna for said radio physiological signals and filter means associated with the amplifier for decoupling the transmitter in feedback to said amplifier while coupling the transducers thereto.

4. In the system of claim 3, means for compensating said amplifier against spurious variations caused by heat transfer between the organism and the amplifier and variation in the potential of the battery.

5. A body-carried electrocardiograph system for transmitting radio waves corresponding to variations in the heart organ of the body comprising: electrodes for attachment to the body for transducing low frequency, low voltage level physiological signals, an amplifier for amplifying said physiological signals, a radio frequency transmitter adapted to be modulated by said amplifier for producing a high frequency radio wave output modulated by said physiological signals, flexible electrical conductors, low frequency pass filter means interconnecting the body electrodes to said amplifier, and means connecting the output of said transmitter to energize said electrical conductors in advance of said filter means, whereby said flexible conductors for coupling the physio-

logical signals from the electrodes also constitute a radiating antenna for said radio wave, and said low frequency pass filter means prevent said radio waves from entering said amplifier.

6. An electrocardiograph system comprising: a portable battery powered radio transmitter adapted to be carried by the patient and propagating radio waves at its output, electrodes adapted to be attached to the patient for transducing body signals to modulate said transmitter, input means including a flexible conductor and an amplifier for coupling and amplifying said body signals from said electrodes to said transmitter, said amplifying means containing stabilizing means to prevent variations in the potential of the energizing battery and variations in the temperature of the system occasioned by the heat generated by the patient's body from spuriously varying the signals being coupled to said transmitter means, low frequency pass filter means in said input means, and means for connecting the output of said transmitter means to said flexible conductor at a position in advance of said filter means and amplifier means thereby to provide a radiating antenna for said transmitter means whereby said flexible conductor receives both said body signals and said radio waves at the output of said transmitter,

and said low frequency pass filter prevents said radio waves from passing to said amplifier.

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