United States Patent

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[15] **3,639,907**

[45] **Feb. 1, 1972**

[54] INTERROGATED TELEMETRY ALARM SYSTEM FOR PHYSIOLOGICAL MONITORING

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[22] Filed: **Sept. 2, 1969**

[21] Appl. No.: **854,582**

[52] **U.S. Cl.**.....**340/150,** 346/33 ME, 128/2.1 A

[51] **Int. Cl.**.....**H04q 9/00**

[58] **Field of Search**.....340/150, 311, 183; 346/33 ME; 128/2.1 A, 2.05 R

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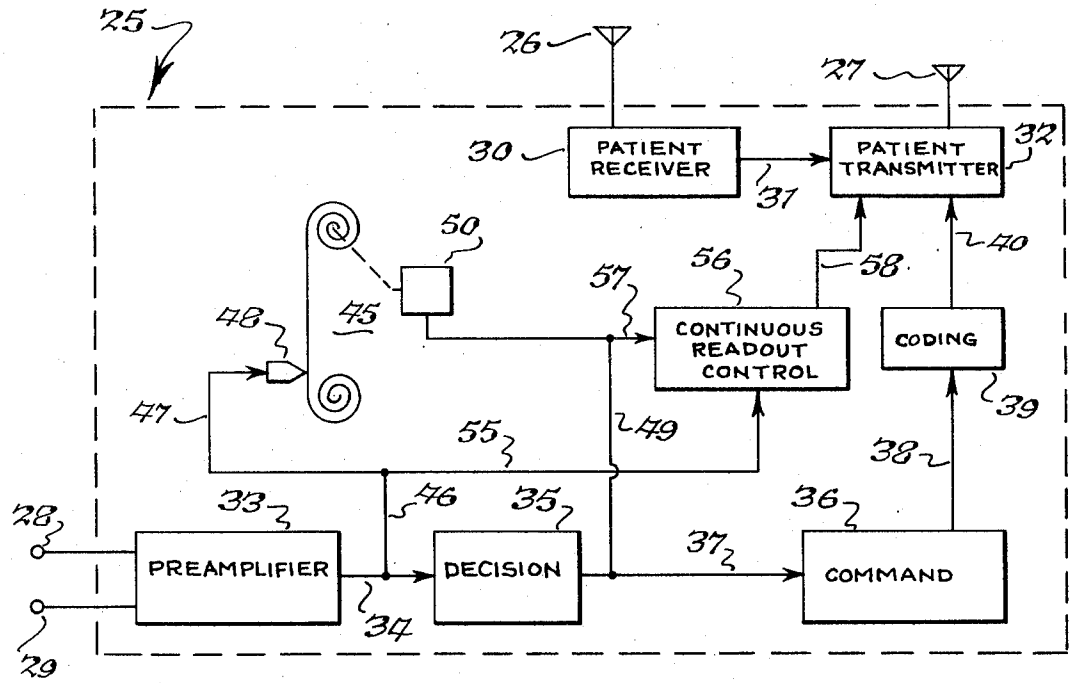
[57] **ABSTRACT**

Apparatus for monitoring from a single station a physiological condition of each of a plurality of remotely located patients. A radio transmitter at the station generates sequentially a plurality of tone signals, one for each patient and each of a different frequency, on a common carrier. A radio receiver with each patient has a band pass corresponding to a particular one of the tone signals. Each receiver when addressed activates a radio transmitter with the patient for transmitting to a single receiver at the station a coded signal indicative of the physiological state of the patient, derived from signal generating means operatively connected to the patient. The signals received at the station are sequentially routed, decoded, and applied to suitable indicators.

4 Claims, 2 Drawing Figures



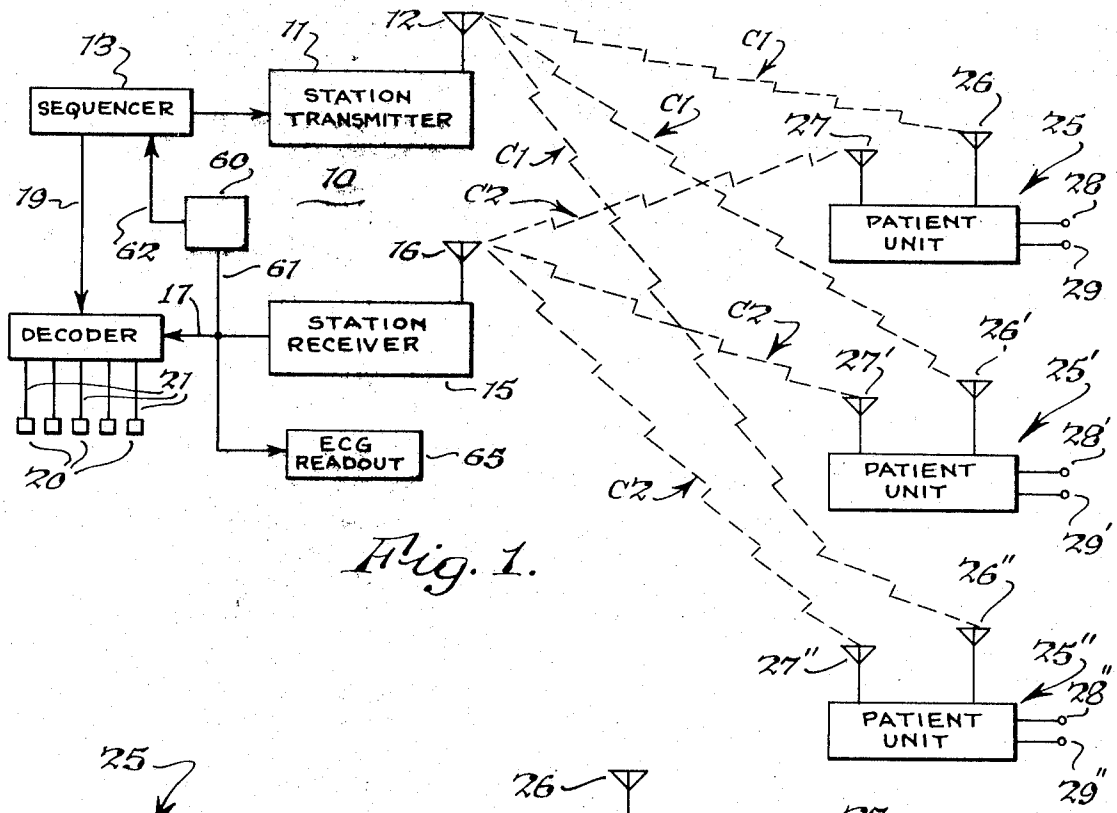


Fig. 1.

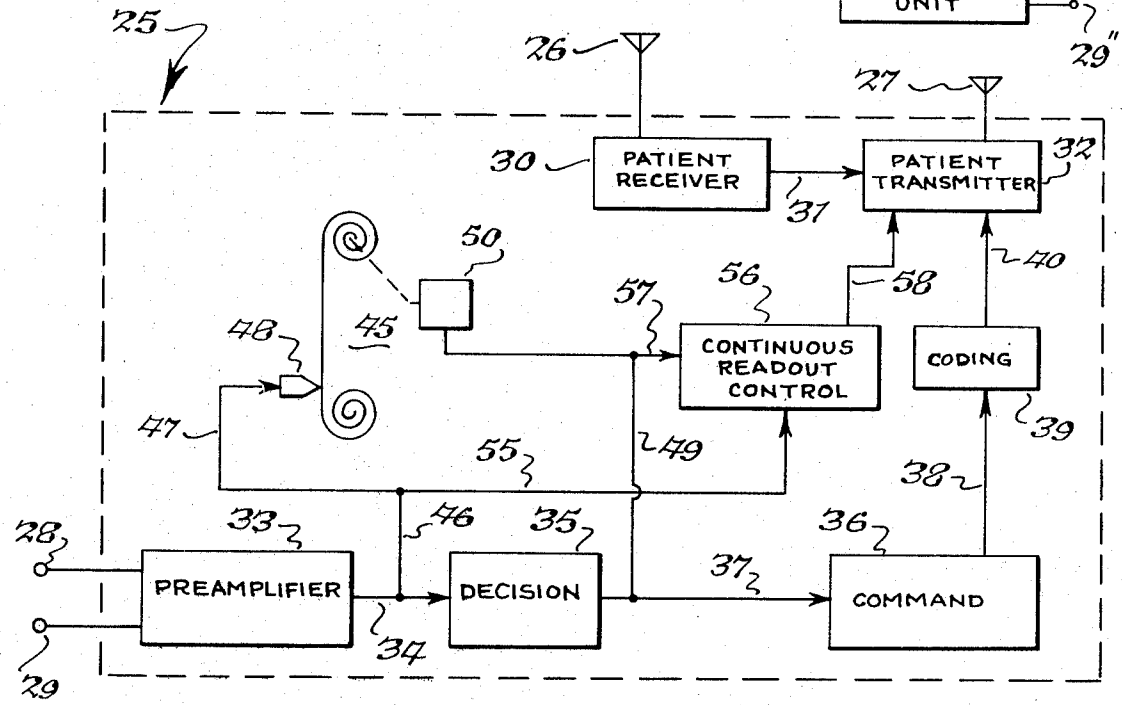


Fig. 2.

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INTERROGATED TELEMETRY ALARM SYSTEM FOR PHYSIOLOGICAL MONITORING

BACKGROUND OF THE INVENTION

The present invention relates to the telemetry art and, more particularly, to a system for monitoring the physiological condition of each of a large number of patients by the telemetry.

Physiological monitoring of a large number of patients by automatic means is becoming increasingly necessary as shortages of hospital personnel increase and as hospital activities expand and become more highly specialized. Upon leaving intensive care units, patients are in hospital areas which often are relatively less rigidly observed, and in such areas automatic physiological monitoring can reduce the mortality rate from cardiac arrest and fibrillation. As hospital care progresses from its present state, additional intensive care units, each of a more specialized nature, are envisioned and will augment the need for automatic physiological monitoring.

Automatic physiological monitoring by telemetry has been proposed and is particularly advantageous because of the ability to continuously monitor an ambulatory patient. Heretofore, the number of patients that could be accommodated economically by telemetry was limited to about 10 patients due to equipment and frequency spectrum limitations. For example, there must be interference-free reception from one patient about 200 feet from a receiving antenna and delivering only 2 or 3 microvolts of signal to the receiver, and yet another patient on an adjacent telemetry channel and positioned only about 10 feet from the same antenna must not contribute any crosstalk. Otherwise, an alarm might be received from the wrong patient. In addition, the channel separations must be unequal so as to avoid unwanted modulation products from mixed transmitter signals, from mixed receiver local oscillators and from various I.F. signals traveling through the system.

SUMMARY OF THE INVENTION

It is, therefore, an object of this invention to provide apparatus for continuously monitoring the physiological condition of each of a large number of patients, such as about 100, by telemetry.

It is a further object of this invention to provide such apparatus which is readily usable with ambulatory patients.

It is an additional object of this invention to provide such apparatus which provides a rapid indication of the type of patient disorder giving rise to an alarm, deferred access to stored physiological data, and continuous readout of data from a patient in alarm.

It is a further object of the present invention to provide such apparatus which can monitor a large number of patients at a relatively fast rate, for example the total number of patients every 10 or 20 seconds.

The present invention provides physiological monitoring apparatus including a radio receiver with each patient and connected in controlling relation to a corresponding radio transmitter with each patient, each receiver having a different frequency passband. The receivers are addressed sequentially by a radio transmitter at a monitoring station which generates sequentially a corresponding plurality of coded tones on a common carrier. Each receiver, when addressed, activates the transmitter which is controls which, in turn, transmits a coded signal indicative of the patient's physiological condition to a single radio receiver at the monitoring station whereupon the signal is routed and decoded.

The foregoing and additional advantages and characterizing features of the present invention will become clearly apparent upon a reading of the ensuing detail description of an illustrative embodiment together with the included drawing depicting the same.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

FIG. 1 is a schematic block diagram of physiological monitoring apparatus in accordance with the present invention; and

FIG. 2 is a schematic block diagram showing in more detail a portion of the apparatus of FIG. 1.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENT

In a preferred arrangement of physiological monitoring apparatus constructed in accordance with the present invention, the equipment designated generally at **10** on the left hand side of FIG. 1 is stationary, being in a fixed location relative to the patients being monitored. For convenience hereafter, the components in this portion of the apparatus will be designated with the term, station. The nurses's station on a hospital floor or the central monitoring station in an intensive care unit are examples of where station apparatus **10** can be located.

Station apparatus **10** comprises a radio transmitter **11** having a radiating antenna **12** which transmitter functions, briefly, to generate a radiofrequency signal consisting of a plurality of coded tones on a common carrier. There would be generated, more specifically, a different tone or a combination of different tones for each patient, and the tones would be transmitted sequentially. A sequencing means **13** suitable for this purpose is operatively connected through a line **14** to transmitter **11**. Station apparatus **10** further comprises a radio receiver **15** having a receiving antenna **16** which receiver functions, briefly, to receive radiofrequency signals on a different channel relative to that of transmitter **11**. More specifically, receiver **15** responds to signals received from patients being monitored which signals indicate the physiological condition of each patient. Receiver **15** is operatively connected through a line **17** to a decoding circuit **18** which also is operatively connected to sequencing means **13** through a line **19**. The purpose of this arrangement is to route properly a received and decoded signal to a particular one of a plurality of indicators **20**, one for each patient, which are connected to the output of decoder **18** through lines designated **21**. Indicators **20** preferably are lamps or other visual devices which tell the observer immediately when a particular patient is experiencing a physiological disorder, as will be described in more detail hereafter.

The physiological monitoring apparatus of the present invention also includes components, designated **25**, **25'**, **25''**, etc., in FIG. 1, there being one component or unit for each patient, and the different units for different patients being distinguished in FIG. 1 by the use of primed designations. Each unit **25** preferably is of a size and construction readily adapted to be carried by an ambulatory patient and for this reason will be referred to as being patient-carried. Each patient-carried unit includes, briefly, a radio receiver, the antenna of which is designated **26** in FIG. 1, adapted to respond to a particular one of the coded tones generated by transmitter **11** at station **10**. Each unit **25** further includes a radio transmitter connected in controlled relation to the receiver and which functions, when activated, to transmit from an antenna **27**, radiofrequency signals indicative of that patients's physiological condition. These signals are received by receiver **15** at station **10**. Each unit **25** further includes input terminals **28, 29** for receiving electrical signals indicative of the patient's physiological condition. For example, when the apparatus of the present invention is used to monitor the cardiac behavior of each of a number of patients, input terminals **28, 29** are connected directly to the patient, being placed in or on his chest in a conventional manner, and the voltages thereon indicative of cardiac behavior are amplified and processed by additional circuitry in component **25** as will be described hereafter. Alternatively, terminals **28, 29** may be connected to the output of an appropriate transducer operatively connected to the patient.

FIG. 2 shows in more detail a preferred form of each patient-carried unit 25 especially suitable for monitoring cardiac behavior. A radio receiver 30 is operatively connected to antenna 26 and has a particular frequency passband which permits reception of a particular one of the coded tones from station transmitter 11. Receiver 30 is connected through a line 31 in controlling relation to a radio transmitter 32 which, in turn, is operatively connected to antenna 27. By virtue of this arrangement, receiver 30 when addressed by one of the coded tones from station transmitter 11 activates transmitter 32 which, in turn, radiates from antenna 27 a coded signal indicative of that patient's physiological condition, in this particular example a signal coded in terms of cardiac behavior.

Transmitter 32 is provided with information concerning the patient's cardiac behavior by the following arrangement. Input terminals 28, 29 are connected to the input of a preamplifier 33 which is designed to have an amplification factor of about 1,000 when the apparatus is employed in cardiac monitoring. In this particular situation the signals on terminals 28, 29 indicative of the patient's heartbeat will have an amplitude of only about 2–3 microvolts. The amplified signals appearing at the output of preamplifier 33 are applied through a line 34 to the input of a decision circuit 35, the purpose of which is to determine whether the signals are indicative of normal or abnormal physiological behavior. For example, in monitoring of cardiac activity, the repetition rate of signals applied to circuit 35 is the information parameter. Circuit 35, which can include standard frequency responsive and logic networks, in this particular example makes a comparative determination as to whether the rate is normal, indicating that the cardiac condition of the patient is satisfactory, too fast indicating tachycardia/fibrillation, or too slow indicating bradycardia/arrest. The frequency parameter on the input signal to circuit 35 can be converted therein to an amplitude or pulse width parameter on the output thereof. For example, circuit 35 can be constructed to provide no output when the rate is normal but to provide an output or alarm signal when either of the above-mentioned disorders is detected, the particular one being determined by output signal amplitude, duration or even polarity.

There is also included a command circuit 36, the input of which is connected through a line 37 to the output of decision circuit 35. The output of command circuit 36 is applied through a line 38 to a coding means 39, operatively connected to transmitter 32 through a line 40. The purpose of command circuit 36 is to transform the signals received from decision circuit 35, indicative of the patient's condition, into corresponding signals which are suitable to command operation of coding means 39 to generate a coded signal corresponding to the particular condition of the patient. Coding means 39 can have several known forms, depending upon the manner in which the output signal of transmitter 32 is to be modulated in terms of information concerning the physiological condition of the patient. The signal from transmitter 32 can, for example, be a coded tone in a one of three code indicating patient satisfactory, bradycardial/arrest alarm or tachycardia/arrest alarm. A fourth state might be added to the code indicating no signal from the transmitter so that the particular patient's equipment can be repaired or replaced. Instead of coded tones, other types of modulation, for example pulse width, might be employed.

It is apparent, therefore, that command circuit 36 can have several known forms depending upon the nature of coding means 39 and the type of signals required to operate it. In certain applications it also may be possible to incorporate the function of command circuit 36 into either or both of decision circuit 35 and coding means 39.

The patient-carried apparatus 25 also includes a tape-loop recorder, designated generally at 45, for providing deferred access to stored physiological data, for example about 10 minutes of recorded ECG activity. The output of preamplifier 33 accordingly is connected by lines 46 and 47 to a recording head 48 of tape recorder 45. Tape recorder 45 would be placed in operation at the patient's location whenever it is desired that recording begin. Preferably, alarm activation would stop the tape so as to store the previous ten minutes of data preceding the event and to this end the output of decision circuit 35 is connected by a line 49 to a controlled tape drive means 50.

The physiological monitoring apparatus of the present invention operates in the following manner. It is, in effect, an interrogation system, and is somewhat similar to the IFF system (Identification, Friend or Foe) used in military aircraft. The patient-carried radio transmitters, such as transmitter 32, all operate at the same frequency but transmit only when interrogated. In monitoring of cardiac behavior, the response modulation can be one of four audio tones, one for "no alarm," the second for "bradycardia/arrest alarm," the third for "tachycardia/fibrillation alarm," and the fourth for "no signal alarm."

Station transmitter 11 together with the patient-carried receivers, one of which is receiver 30, constitute an interrogator. Transmitter 11 operates on a frequency different from that on which patient-carried transmitters 32 operate so that the overall system uses only two radiofrequency channels. The coded tones provided by transmitter 11, one for each patient, are generated sequentially under control of sequencer 13 which in one form can be a two-gang stepping switch. One gang provides sequencing of code generation by transmitter 11, represented schematically by line 14, and the other gang controls routing of signals from receiver 15 through decoder 18 to the particular one of the patient indicator 20. Since only a tone is elicited from each patient transmitter 32 in response to interrogation, i.e., the corresponding patient receiver 30 being addressed by the particular coded tone from transmitter 11, the patient scanning rate is very fast, sampling 100 patients every 10 or 20 seconds.

The interrogator portion of the apparatus of the present invention can comprise one of several interrogation systems commercially available, modified so as to be coded with respect to the patients being monitored. One is an induction coupled, low frequency variety wherein station antenna 12 would comprise a wire surrounding the patients being monitored and antennae 26, 26', etc., each with a particular patient, would be induction-coupled to the wire in a manner similar to the coupling between transformer secondary and primary coils. A second variety is of the radiofrequency type, operating in the range of about 27 to about 54 megacycles, and including vibrating needs in the receivers for decoding.

Decoder 18 at the monitoring station 10 would include standard radio receiver detector circuitry, the exact nature depending upon the type of modulation employed in the patient transmitters 32. It is contemplated that the speed of operation of sequencer 13 in relation to the time needed for a radio signal to travel from station 10 and for a response signal to return is such that one response signal will be properly routed to a patient indicator 20 before sequencer 13 advances to the next step for generation of the next coded tone in transmitter 11. The output of decoder 18, routed to the particular line 21, could be one of three voltage levels depending upon the nature of the alarm received. Each indicator 20 could include three lamps differentiated by color or by indicia according to the nature of the alarm, and there would be included also suitable voltage level responsive circuitry for energizing the lamps.

The alarm signals generated by patient transmitters 32 rather than being coded tones could be microsecond duration pulses. In this case, three radio receivers instead of a single-station receiver 15, could be employed to locate the particular patient by vector resolution techniques. Such techniques are well known, for example Loran, and in this particular situation three receivers measure the time difference in arrival of a signal from a single transmitter (patient transmitter 32) rather than three transmitters sending signals to a single receiver which is the usual case.

The apparatus of the present invention advantageously provides continuous monitoring of a large number, for example about **100**, ambulatory patients. Monitoring is done at an extremely fast rate, such as the total number of patients every 10 or 20 seconds. Moreover, the patient-carried transmitters **32** operate only upon interrogation, in a time-sharing mode, thereby reducing battery drain and permitting less frequent battery replacement. All patient transmitters are identical units and only the coding elements in the patient receivers **30** are different so transmitter construction and tuning is advantageously quite simple.

The apparatus of the present invention can include an additional arrangement whereby in response to the occurrence of an alarm, a continuous readout of the patient's ECG signal automatically is transmitted to the station. To this end line **46**, on which the ECG signal is available from the output of preamplifier **33**, is connected by a line **55** to the input of a component designated **56** in FIG. **2** for controlling the operation of transmitter **32** in this continuous readout mode. Component **56** is to operate only in response to the occurrence of an alarm signal provided by decision circuit **35**, and for this reason component **56** is connected in controlled relation through a line **57** and line **49** to the output of decision circuit **35**. Circuit **56** is connected by a line **58** to transmitter **32** whereby the carrier thereof is modulated with the patient's ECG signal. Circuit **56** in addition would be constructed to provide an additional tone which when transmitted to station **10** would stop sequencing of transmitter **11** and hold it on the particular channel where the alarm had been received. To this end a frequency-responsive circuit, designated **60** in FIG. **1**, is connected to the output of receiver **15** by a line **61** and adapted to respond to this particular tone. Circuit **60**, in turn, is connected to sequencing means **13** by a line **62** to command stopping thereof.

The receiver **15** at station **10** then would receive continuous ECG data from the patient and would ignore all other patients on the system until that particular patient's transmitter had been cleared whereupon the system would again start sequencing through the total number of patients. Readout and possibly also storage of the particular patient's continuous ECG signal is performed by conventional equipment, designated **65**, connected to the output of receiver **15**.

It is therefore apparent that the present invention accomplishes its intended objects. While a single specific embodiment thereof has been described in detail, this is done for the purpose of illustration without thought of limitation.

I claim:

1. Apparatus for monitoring from a single station a physiological condition of each of a plurality of remotely located patients comprising:

a. a radio receiver with each patient and each receiver having a different frequency passband;

b. a radio transmitter with each patient and connected in controlled relation to said receiver;

c. a signal producing means adapted to be operatively connected to each patient for providing electrical signals having a parameter which varies in accordance with changes in a physiological characteristic of the particular patient;

d. decision circuit means with each patient and having an input coupled to the output of said signal producing means, said decision circuit means comparing the variations in said parameter with a predetermined normal value and providing an output alarm signal in response to abnormal variations in said parameter;

e. coding means with each patient coupled to said decision circuit means and to said transmitter whereby the radiofrequency signal generated by each transmitter is coded in terms of the alarm state of the physiological characteristic of the particular patient;

f. a radio transmitter at said station for generating sequentially a plurality of signals, the number being equal to the total number of patients being monitored and the frequency of each one corresponding to a particular passband of one of said receivers whereby said transmitter with each patient is periodically interrogated;

g. a radio receiver at said station for receiving signals from said transmitter with each patient;

h. decoding means connected to the output of said station receiver and operative sequentially in synchronism with said station transmitter for decoding the physiological state signal from each patient; and

i. a plurality of indicating means, one for each patient, operatively connected to said decoding means.

2. Apparatus as defined in claim **1** wherein each signal producing means comprises:

a. an input terminal adapted to be operatively connected to the particular patient for sensing electrical signals indicative of cardiac behavior; and

b. an amplifier having an input connected to said terminal and an output; and

c. decision circuit means having an input connected to the output of said amplifier, and wherein said decision circuit provides

output alarm signals in response to an abnormal rate of signals applied to the input thereof.

3. Apparatus as defined in claim **2** further including magnetic tape recording means, the recording element of which is connected to the output of said amplifier and the drive means of which is connected in controlled relation to the output of said decision circuit for stopping said tape recording means in response to an alarm signal.

4. Apparatus as defined in claim **2** further including means connected in controlled relation to the output of said decision circuit for coupling the output of said amplifier directly to said patient transmitter in response to an alarm signal.

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