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N. A. ROTH

3,199,508

CODING OF PHYSIOLOGICAL SIGNALS

Filed April 25, 1962

2 Sheets-Sheet 1

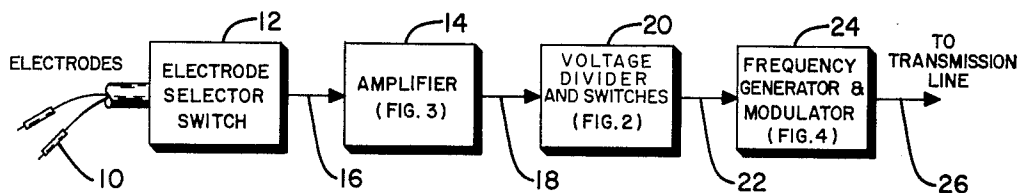


Fig. 1

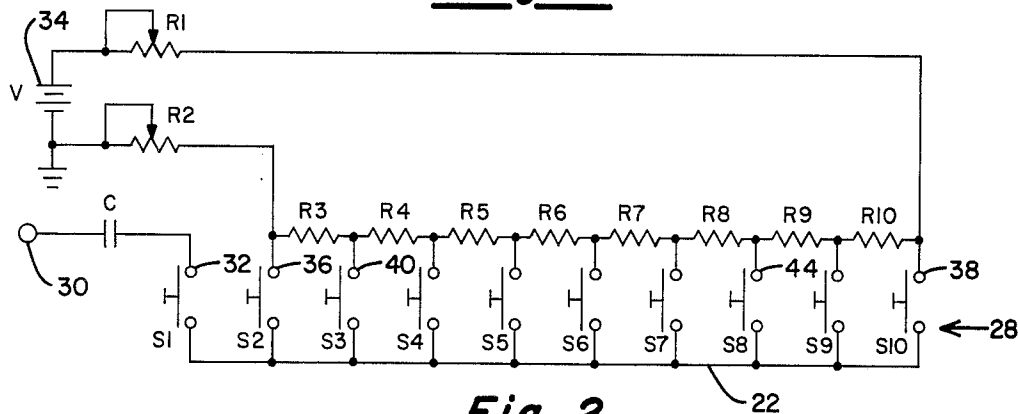


Fig. 2

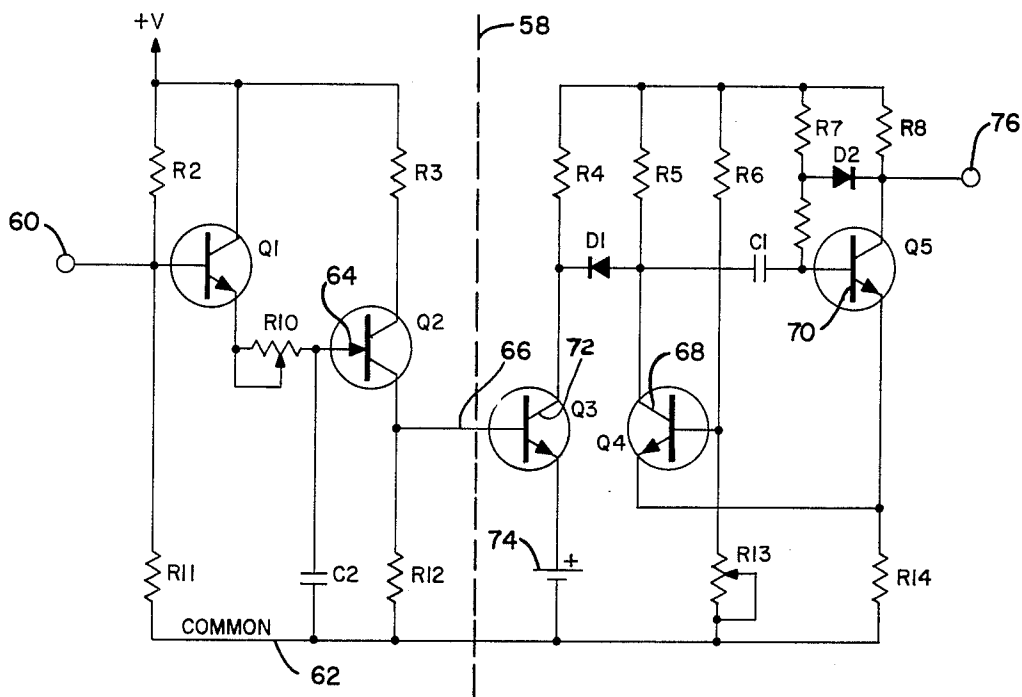


Fig. 4

INVENTOR
NORMAN A. ROTH

BY

Marvin Jacobson
ATTORNEY

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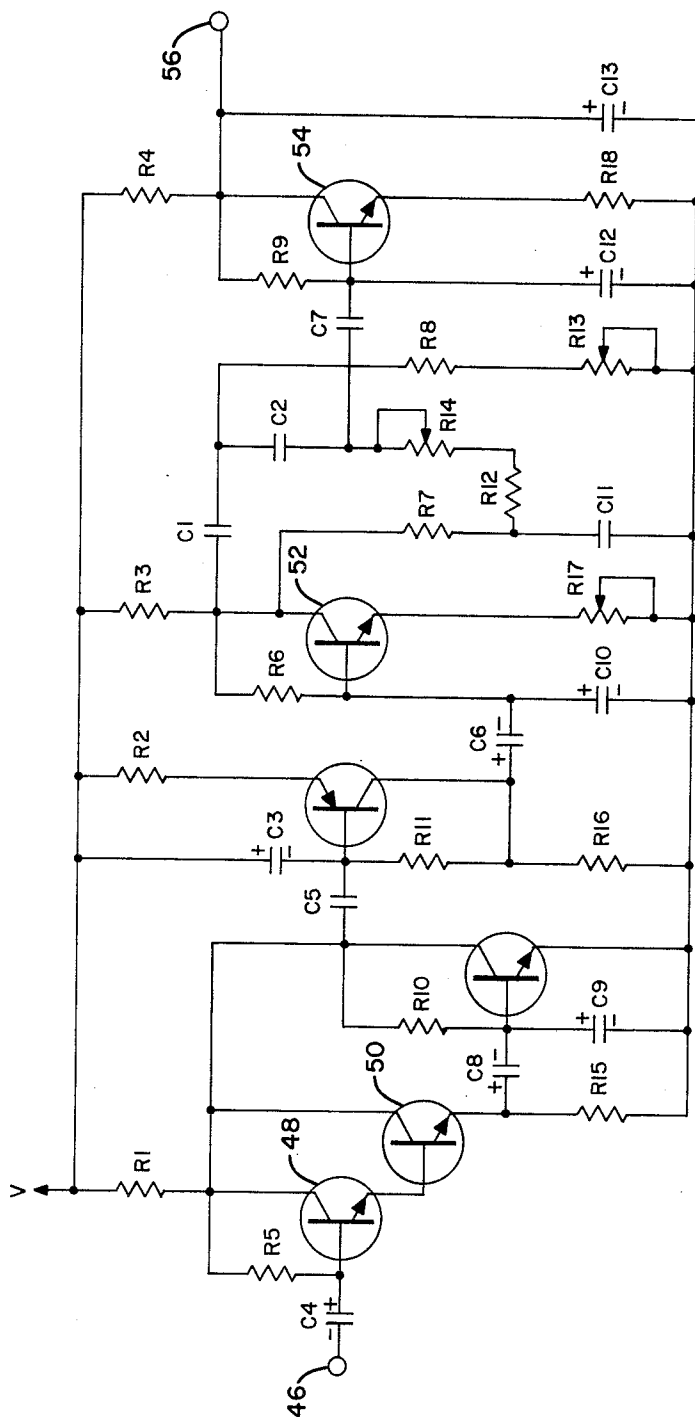


Fig. 3

INVENTOR
NORMAN A. ROTH
BY *Marvin Jacobson*
ATTORNEY

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CODING OF PHYSIOLOGICAL SIGNALS

Norman A. Roth, St. Paul, Minn., assignor to W/R Medical Electronics Co., St. Paul, Minn., a corporation of Minnesota

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9 Claims. (Cl. 128--2.06)

This invention is limited to the field of electronic-medical instrumentation and more particularly to electronic apparatus for use with medical instrumentation which senses physiological diagnostic waveforms emanating from a human body, such as an electrocardiogram (ECG), an electroencephalogram (EEG) and the like.

A recent trend in the medical profession is toward a system of centralized processing of physiological data, such as ECG and EEG waveforms, for analysis and diagnosis. In this type of system, the readings taken by a physician or trained nurse at the doctor's office, clinic or hospital are transmitted to a remote central location. The location is staffed by highly skilled specialists and is equipped with electronic devices for ensuring rapid and accurate diagnosis. A system of this type provides an efficient, high-grade service to a large segment of the medical field.

There are various ways of implementing this type of system. Among the systems in operation today is one in which amplified reproductions of the ECG or EEG waves, as they are detected on the patient, are transmitted in real-time, for example via telephone lines, from a hospital or doctor's office to the remote central processing location. At the central location the waveforms are visually displayed to be viewed by a medical specialist who makes his diagnosis and transmits his opinion back to the calling hospital or doctor.

Another system contemplates the use of electronic data processing devices such as digital and analog computers to perform the diagnosis. As in the previously mentioned system, the waveforms are transmitted in real-time mode to the central data processing area where they are inputted to the electronic equipment. In general, the signal waveforms are inserted into a computer via peripheral equipment such as a magnetic tape.

In both of the above systems it is often possible that an immediate diagnosis is not required so that the ECG or EEG readings can be stored in a magnetic tape which is later delivered to the central location for processing. Additionally, it is usually necessary to retain the readings in a storage device such as a magnetic tape in order to maintain the medical history of the patient for possible future use in diagnosis. It is a general object of this invention to provide apparatus for use in a centralized medical data processing system.

It is a more specific object of this invention to provide apparatus for use in transmitting identified physiological diagnostic wave signals, such as ECG and EEG signals, from their source to a remote central processing location.

A further object of this invention is to provide apparatus for use in a system for magnetically recording signal representations of physiological diagnostic waves such as ECG, EEG and the like.

Still a further object of this invention is to provide apparatus for furnishing selective identification coding along with the transmitted or recorded physiological diagnostic wave signals.

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Yet another object of this invention is to provide the immediately preceding object wherein the coding apparatus is relatively simple to operate and maintain.

Still another object of this invention is to provide semi-automatic identification of recorded physiological signals.

In the embodiment of this invention described herein, the physiologic waveforms detected by electrodes coupled to the body are transmitted to an amplifier having high fidelity characteristics. The amplifier output is coupled via a coding section into a combined carrier-wave frequency generator and modulator circuit, the output of which is coupled to a telephone line for transmission to a remote location. The coding section includes means for selectively switching the modulator input to the amplifier output or one of a plurality of respectively different D.-C. voltage levels. In this manner codes identifying the patient, the doctor, the calling source, etc., are transmitted along with the physiological signals for record-keeping purposes and for associating these signals to the respective patients.

These and other objects and features will become apparent in the course of the following detailed description, in which:

FIG. 1 is a block diagram of an embodiment of this invention;

FIG. 2 is a preferred embodiment of the selectively alterable coding circuit which constitutes another aspect of this invention for use in the apparatus of FIG. 1;

FIG. 3 is an electrical schematic of an illustrative amplifier for use in the FIG. 1 embodiment;

FIG. 4 is an electrical schematic of an illustrative frequency generator and modulator circuit for use in FIG. 1.

In the block diagram of FIG. 1, ECG electrodes, shown generally as 10, are coupled in the well-known manner to the various parts of the body, usually the legs, arms and chest. The low-level, low-frequency diagnostic waves, usually in the order of less than one millivolt and ranging from about one to fifty cycles per second, are coupled through an electrode selector switch 12, which is well-known in the art, to the input of amplifier 14 via line 16. The amplifier has characteristics of high gain with a very accurate reproduction of the input signal to retain the critical portions of the diagnostic waves while providing sufficient power to drive a utilization device such as a strip recorder, magnetic tape, or a frequency modulating circuit, as will subsequently be described. The amplifier output signal is coupled via output line 18 to the input of coding section 20.

As will be subsequently described in greater detail in reference to FIG. 2, the coding section 20 preferably comprises an output signal line 22, a D.-C. voltage divider network and a plurality of manually operable switches. The switches are connected in such a manner as to provide the means for selectively setting the signal line 22 to the amplifier output or to one of a plurality of different D.-C. voltage levels from the voltage divider.

The frequency generator and modulator circuit (FC-M) 24 includes a circuit for producing a carrier wave signal and a circuit for modulating the carrier in accordance with the signal appearing at the input thereto via signal line 22. In a preferred embodiment, the carrier is frequency-modulated although it is within contemplation of the instant invention to use amplitude modulation. The A.-C. signal representations of the physiological waveforms outputted by the amplifier 18 and the D.-C. voltage levels

provided by the coding section 20 can be considered to be electrical analog signals. The modulation of the carrier wave effectively digitizes these signals with respect to a reference level so that the relative magnitudes of the D.-C. and A.-C. signals can be represented. This will become more apparent from the subsequent more detailed description of the FG-M.

The modulated output of the FG-M 24 is coupled to a transmission line via line 26. The transmission line is preferably a telephone line connecting the calling testing location, such as a doctor's office or a hospital, to the remote central processing location. It is contemplated that the teachings of this invention are readily adaptable for other transmission systems such as wireless radio communication.

Referring now to FIG. 2 there is shown a preferred embodiment of the coding section 20 of FIG. 1. The coding section, in combination with the other sections of the apparatus of FIG. 1, provides an important contribution to the utility of the instant invention since it provides the means for supplying identification information in conjunction with the physiological data so that the latter can be specifically related to an individual patient, time of day, the treating physician and other important criteria. Also, the identification information allows recording and maintaining of medical history.

The output signal line 22 is connected in common to one terminal of ten manually operable switches, shown in their open position, respectively labelled S1-S10. Since these terminals are electrically connected together they are labelled collectively as 28. A signal input terminal 30 receives the output of amplifier 14 and is coupled to the other terminal, 32, of switch S1 through capacitor C. The capacitor provides D.-C. isolation between the amplifier output and the signal line 22 when S1 is closed while presenting negligible impedance to the A.-C. signal output from the amplifier. Connected across a D.-C. voltage source V, which may be in the range of about 20 volts and as symbolically shown by battery 34, is a voltage divider network comprising variable resistors R1 and R2 and fixed resistors R3-R10 in seriatim. At the junction of every two resistors in the voltage divider the other terminal of each of the switches S2-S10 is connected. All of the switches S1-S10 have a number designation, respectively 0-9, and all are mechanically linked together, by means not shown, so that only one is operable at one time. In other words, if one of the switches is in the closed position, manual closing of any of the other switches will cause the previously closed switch to open. In general, the voltage divider resistors are selected and adjusted so that as each of the switches, respectively S2-S10, is successively closed the D.-C. potential in line 22 increases in equal increments. Additionally, it is within contemplation of the instant invention that the voltage divider network can be designed to place signal line 22 at the same D.-C. potential when switch S5 is closed as it is when switch S1 is closed.

The operation of the coding section of FIG. 2 in the combination of FIG. 1 can best be described by an illustrative example. As will be subsequently described in greater detail, the modulator portion of circuit 24 will effect a transmission line output signal of a different frequency for each respectively different D.-C. potential applied to its input via signal line 22. In the overall system each subscribing doctor or hospital is given a code designation. Assume, in this example, the calling physician has a five digit code of 19247. After initial contact with the central processing location has been established but prior to the transmission of the ECG readings, the doctor manually closes switches labeled S2, S10, S3, S5 and S8 in that order. The D.-C. potentials at terminals 36, 38, 40, 42, and 47 of said switches are successively applied to signal line 22 to cause, through the modulator circuit, correspondingly different frequency signals on the output transmission line 26. At the receiving central proc-

essing location these signals are recognized as identifying the physician. In a similar manner, each patient can be assigned different codes which are also transmitted for identification. Similarly, the ECG readings can be identified in respect to each of the particular electrodes. After all of identification data has been transmitted switch S1 is closed to apply the amplifier output to the signal line 22 for transmission to the remote location through the FG-M circuit.

FIG. 3 is an illustrative electrical schematic of a relatively high-gain, high-fidelity amplifier for use in the embodiment of this invention. The input terminal 46 is connected to signal line 22. The first two stages include a pair of NPN transistors, 48 and 50, connected in the emitter follower configuration to provide a high input impedance to the low-level A.-C. input signal. The remaining four stages are designed to provide the desired amplification without introducing distortion. Intermediate transistor 52 and the output transistor 54 there is a reject circuit which is designed to filter out the undesirable effects caused by power line frequencies. Because of the relatively low signal levels and the importance of faithfully reproducing the input signal at an amplified scale, it is essential that interfering noise be filtered. Since power line frequencies are so close to the range of signal frequencies they are generally the most troublesome. The amplifier output is connected to line 18 via output terminal 56. Typical orders of magnitude are a 750 millivolt output signal produced in response to a one millivolt input signal.

Referring now to FIG. 4, in general the portion of the circuit to the left of broken line 58 can be considered as the modulator circuitry while the remaining portion can be considered as a frequency generator. For descriptive purposes the circuits are treated in a combined manner since the signal output frequency developed by the frequency generator is dependent on the signal inputted thereto from the modulator circuit.

Input terminal 60 is connected to the signal line 22 from the coding section 20. D.-C. voltage source +V provides power for the circuit and the D.-C. as well as A.-C. signal common line is labeled as such at 62. The base element of NPN transistor Q1, which is connected in the emitter follower circuit configuration to present a high input impedance, is connected to the input terminal 60. Resistor R10 and capacitor C2 form a series RC integrator circuit with a capacitor being charged by the emitter current of transistor Q1. Unijunction transistor Q2 has its control electrode 64 connected to the junction of resistor R10 and capacitor C2 and its emitter-collector circuit, including resistors R3 and R12 in series, is connected across the D.-C. voltage source +V. The emitter current of transistor Q1 flowing through resistor R10 charges capacitor C2 toward the potential applied to the base of transistor Q1. When the charge across C2 reaches the "firing" potential of the unijunction transistor Q2, it conducts heavily and a short RC time constant discharge path is provided through resistor R12. When the charge across C2 falls below the "threshold" potential of Q2, the latter cuts off and C2 again starts charging. In this manner, a sawtooth waveform signal is developed across C2 and is applied to the control electrode 64. Since R10 is in the order of one-hundred times the value of R12, the rise time of the leading edge of the sawtooth wave is considerably greater than the fall time of the trailing edge. The frequency of the sawtooth wave varies in accordance with the magnitude of the potential at input terminal 60. When the unijunction transistor Q2 conducts, the signal appearing across R12 is coupled to the base of trigger transistor Q3 via line 66 to provide the modulating signal input to the frequency generator.

The frequency generator is essentially a one-shot triggered multivibrator comprising a pair of NPN transistors, Q4 and Q5, having a common emitter resistor, R14. The collector 68 of transistor Q4 is coupled to the base 70 of

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transistor Q5 through capacitor C1. The triggering input pulse is applied to capacitor C1 through diode D1 which is connected to collector 72 of transistor Q3. Battery 74, in the emitter circuit of Q3, is polarized to back bias the emitter-base junction of NPN transistor Q3.

When the multivibrator transistor Q5 is conducting its collector and the output terminal 76 connected thereto are at a relatively low potential level. A pulse signal from the modulator circuit applied to the base of the triggering transistor Q3 causes it to conduct to apply a negative pulse to base 70 of transistor Q5 from the collector of Q3 through diode D1 and capacitor C1. This causes Q5 to cut off, driving the output terminal 76 to a positive potential level. Feedback to transistor Q4 through the common emitter resistor R14 causes Q4 to conduct which further aids in keeping Q5 cut off. When capacitor C1 becomes fully charged, base 70 of Q5 rises to a level sufficient to cause Q5 to conduct. This in turn causes Q4 to cut off so that the multivibrator circuit is returned to its initial stable condition and the output terminal returns to a relatively low potential level. Subsequent input pulse signals via line 66 result in repeated operations as described above. Since the repetition rate of the output signal at terminal 76 is determined by the frequency of the pulse signals on line 66 and the latter, in turn, varies with the potential of the input signal at input terminal 60, it can be seen that the transmission line signal, which is obtained from terminal 76, is modulated in accordance with the data input at terminal 60. As previously described the latter is selectively either coded identification data in the form of D.-C. potentials or amplified physiological signals from the amplifier, the selection being made in the coding section.

Although in general the coding section is utilized in the combination described for providing identification of medical data transmitted to a remote location, the instant invention contemplates other utility. For example, in the event the diagnostic waveforms are recorded directly onto a strip recorder so that the FG-M circuit is not required, the output of the coding section on signal line 22 is connected directly to the strip recorder. This alleviates the burden normally encountered in identifying the strip chart records since the manually operable selective switching of the coding section semi-automatically identifies each record so that hand entries are not required. It is further within contemplation of the instant invention that a recording device, such as a magnetic tape, can be coupled directly to the output terminal 76 to record the diagnostic signals along with the identifying signals.

Although the foregoing detailed description was in reference to identification and transmission of ECG signals, it is within the scope of the instant invention to include other physiological signals, ECG signals being only illustrative and not limited.

It is understood that suitable modifications may be made in the structure as disclosed provided such modifications come within the spirit and scope of the appended claims. Having now, therefore fully illustrated and described my invention, what I claim to be new and desire to protect by Letters Patent is:

1. In combination: a plurality of electrical probes each adapted for sensing physiological signals of a different nature; an amplifier having its input coupled to said probes for producing output signals which are amplified substantial reproductions of said sensed physiological signals; a D.-C. voltage divider network for providing a plurality of D.-C. electrical reference coding signals; a signal output line for transmitting electrical signals to a utilization device; and means for selectively switching said signal output line to the output of said amplifier or respectively different ones of said voltage divider coding signals whereby each of the respective physiological signals appearing on said signal output line is suitably identified by associated D.-C. electrical coding signals on said output line.

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2. In combination: a plurality of electrical probes adapted for sensing physiological signals; an amplifier coupled to said probes for producing output signals which are amplified substantial reproductions of said sensed signals; a signal output line; a D.-C. voltage divider network for providing a plurality of respectively different D.-C. potentials; a first manually operable switch coupling said amplifier to said signal output line for transferring the amplifier output signal to said output line when in the electrically closed condition; and a plurality of other manually operable switches connected between said voltage divider and said output line for transferring said respectively different potentials thereto when in the electrically closed condition whereby each of the physiological signals outputted by said amplifier to said output line is associated with identifying D.-C. signals appearing on said output line.

3. The combination of claim 2 wherein only one of said switches can be closed at any one time.

4. In combination: a plurality of electrical probes adapted for coupling to an animal body for sensing physiological signals emanating therefrom; an amplifying circuit having an input and an output, said amplifier outputting amplified substantial reproductions of its input; means for selectively coupling each of said probes to the amplifier input; a frequency generator for producing a carrier wave signal; a modulating circuit coupled to said frequency generator for modulating said carrier wave in response to and in accordance with signals received at its input; a D.-C. voltage divider network for providing a plurality of respectively different D.-C. potentials; and switching means for selectively applying said amplifier output signals and said D.-C. potentials to the input of said modulating circuit whereby each of the modulating physiological signals on the carrier wave is identified by corresponding D.-C. potentials which modulate the carrier wave.

5. The combination of claim 4 wherein said switching means comprises a plurality of manually operable switches.

6. The combination of claim 5 characterized by only one of said switches being operable at any one time.

7. The combination of claim 6 wherein one of said switches is connected between the amplifier output and said modulating circuit input and the others of said switches are each connected between the respectively different potential points on the voltage divider network and the modulating circuit input.

8. In combination: a plurality of electrical probes adapted for coupling to an animal body for detecting physiological diagnostic waves emanating therefrom; an amplifying circuit having an input and an output, said amplifier outputting substantial reproductions of its input signals; means for selectively connecting each of said probes to the amplifier input; a frequency generator for producing a carrier signal wave; a modulating circuit coupled to said frequency generator for modulating said carrier wave in response to and in accordance with signals applied to its input; a signal line connected to the input of the modulating circuit; a first manually operable switch for coupling the amplifier output signal to said signal line when in the electrically closed condition; a D.-C. voltage divider network for providing a plurality of respectively different D.-C. potentials; and a plurality of additional manually operable switches each connected between a respectively different potential point in said network and said signal line for selectively setting the modulating circuit input to a corresponding one of said D.-C. potentials when in the electrically closed condition for modulating the carrier signal with corresponding identification signals for each of the modulating amplifier output signals.

9. The combination of claim 8 characterized by only one of said switches being operatively in the electrically closed condition at any one time.

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