March 19, 1963 R. J. HANAK 3,082,405

ELECTRICAL SYSTEMS

Filed Oct. 15, 1958 3 Sheets-Sheet 1

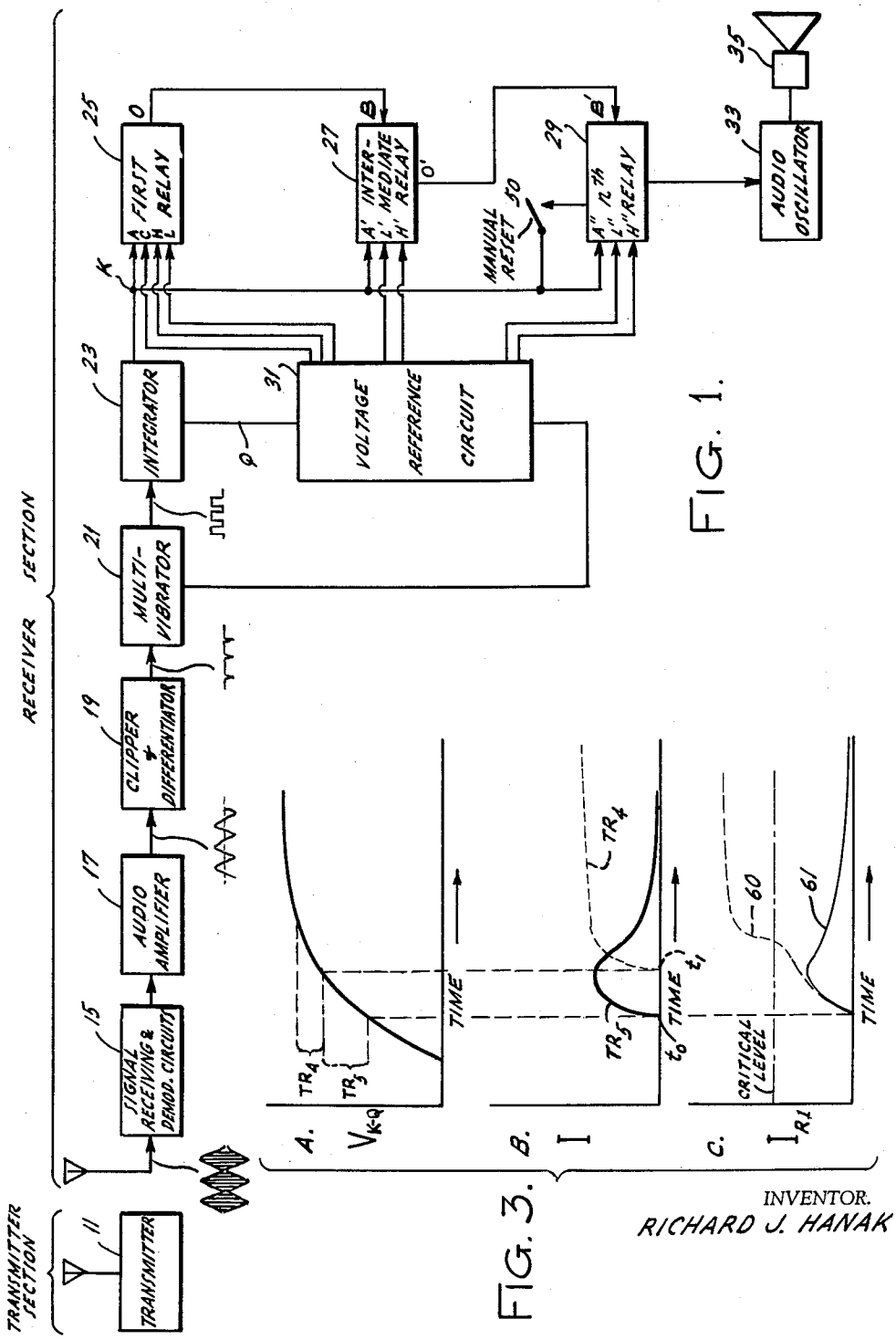


FIG. 1.

FIG. 3.

INVENTOR.
RICHARD J. HANAK

March 19, 1963 R. J. HANAK 3,082,405

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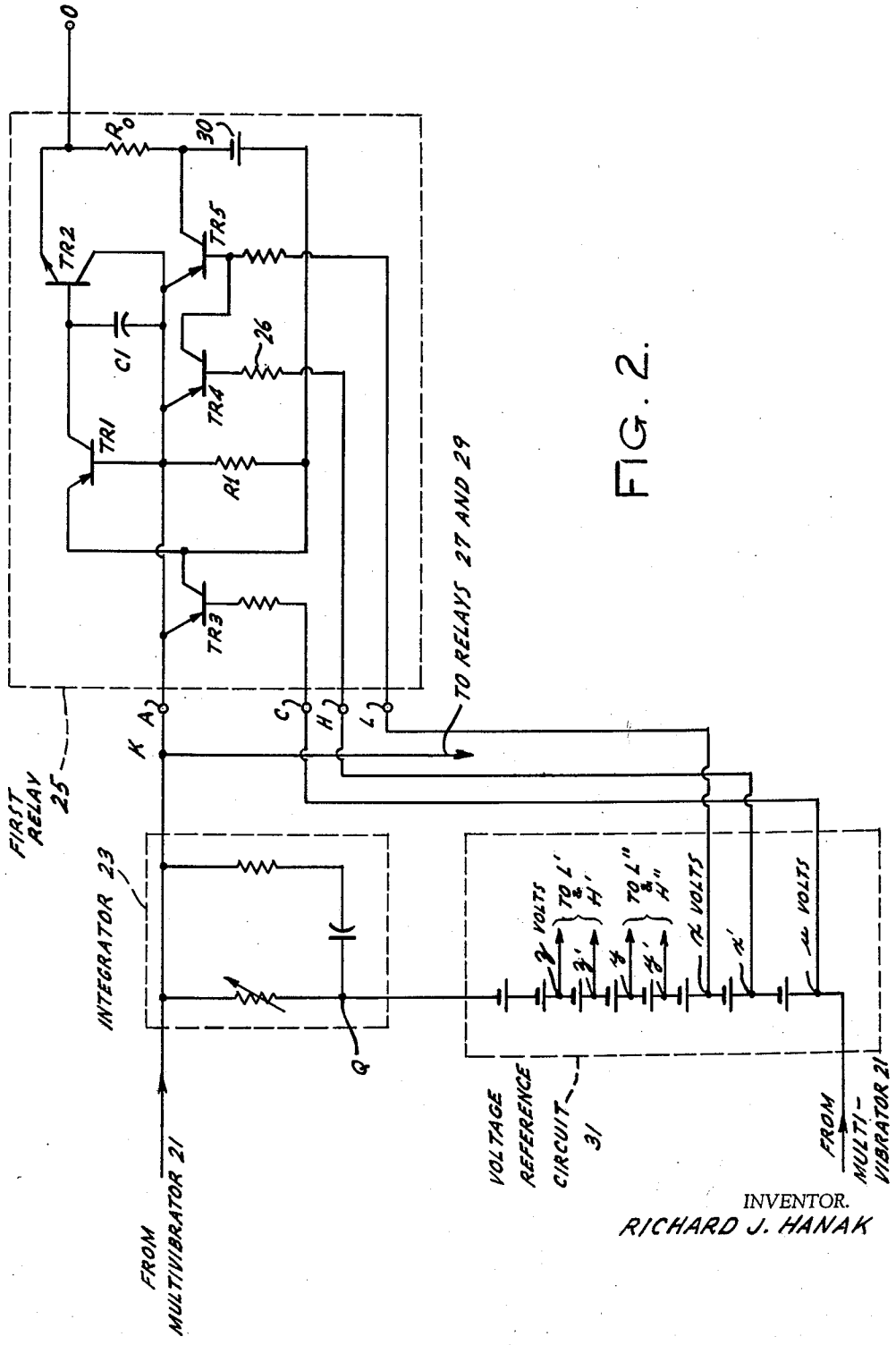


FIG. 2.

INVENTOR.
RICHARD J. HANAK

March 19, 1963 R. J. HANAK 3,082,405

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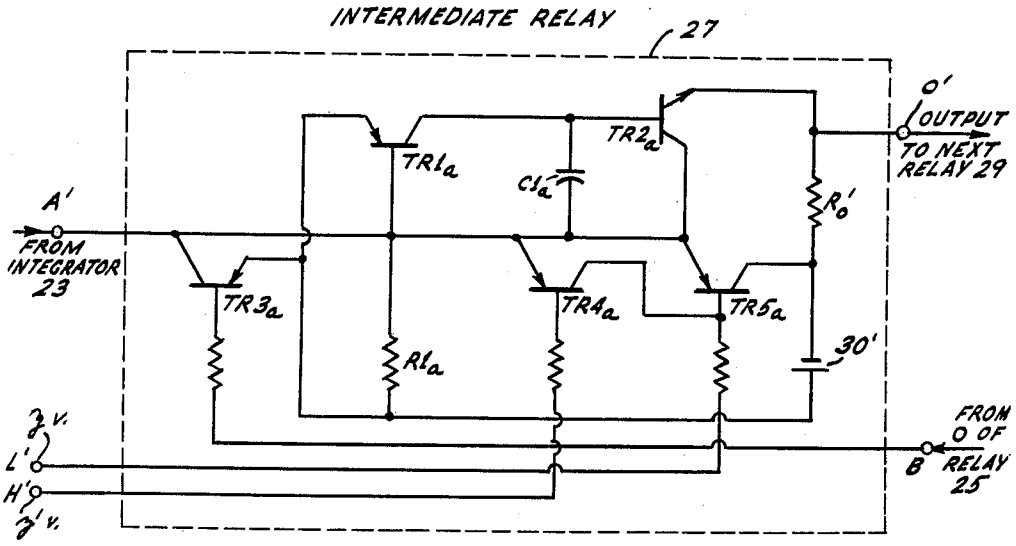
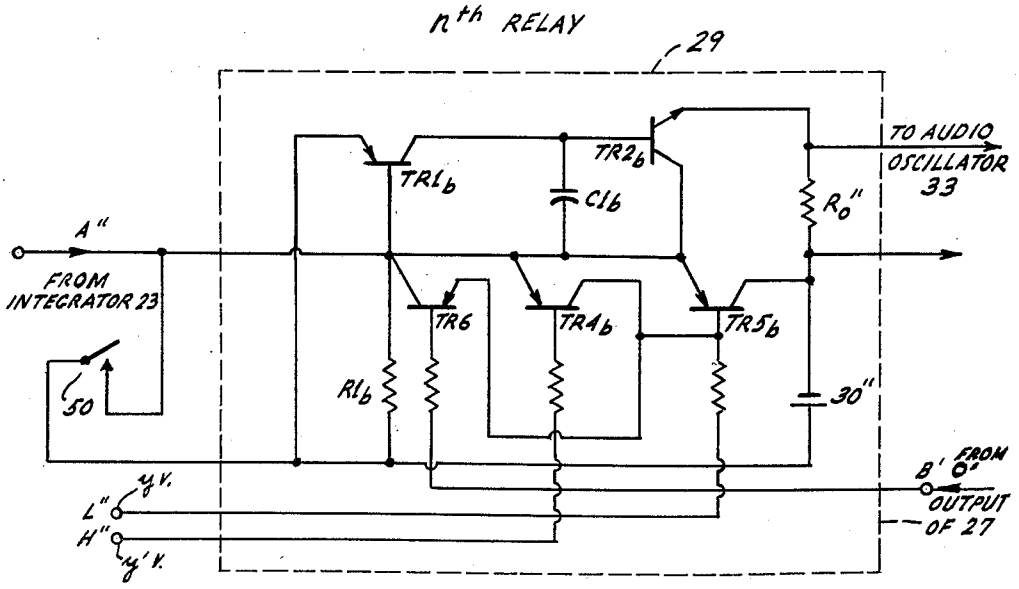


FIG. 4.



INVENTOR.
RICHARD J. HANAK

FIG. 5.

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ELECTRICAL SYSTEMS

Richard J. Hanak, 671 S. Highland Ave., Merion Station, Pa.

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10 Claims. (Cl. 340—171)

This invention relates to electrical systems and in particular to systems for actuating selected ones of a plurality of receivers to the exclusion of all other receivers.

In recent years there has been an increased demand for so-called paging systems, e.g., systems by which a central station can communicate with selected individuals carrying portable receivers. The central station transmits certain signals which are received by the receivers and utilized to alert selected ones of the carriers of the receivers. Paging systems may be of two general types, i.e., ones in which *all* receivers respond to the transmitted signal, or ones in which only *selected* receivers respond to the transmitted paging signals. It is with the latter type of system, the selective paging system, that this invention is concerned.

Selective paging systems may be categorized by their operative principles; a few of the many types of selective paging systems will now be mentioned in order to clarify the advantages of the present invention. One type consists of a transmitter which sends out electrical signals modulated at predetermined frequencies which are received by a number of receivers. Each receiver has a mechanically resonant reed which is tuned to a different modulation frequency. When the transmitted modulation signal has a frequency to which a particular reed is resonant, the receiver containing said reed emits an audible signal which informs the carrier that he is to call the central station to obtain the desired intelligence, or tells him to stand by for further information subsequently to be transmitted. These receivers, containing mechanical frequency selection apparatus, are subject to the disadvantages common to mechanical systems. Thus, for example, physical shocks and vibrations can result in false calls, temperature variations can cause malfunction because of temperature sensitive components, mechanical wear causes the reeds to detune easily since there is loss of mass in the resonant device due to such wear, standardization of the frequency of a number of the resonant reeds having the same nominal natural frequency is difficult to achieve, and the range of resonant frequencies practically available is severely limited.

Another type of system employs an "inductive loop" usually located on the periphery of the calling region which, when energized, induces a signal in the receiver. The induced signal may be applied in the receiver to a frequency discriminating circuit such as a resonant reed or a piezo-electric device. However, the disadvantages of resonant reeds have already been mentioned and piezo-electric crystals at the usual audio frequencies are relatively large, are fragile, and some, such as chelate crystals, cannot withstand high environmental temperatures. The above mentioned prior art systems involve a number of receivers each adapted to be actuated by a different selected signal frequency. Such systems are practically limited in the number of receivers that may be selectively alerted.

The prior art also contains systems in which particular receivers are actuated in response to a group of transmitted pulses. However, if it is desired to use pulse systems for general commercial use, the limitations imposed by the Federal Communications Commission as to permissible side band radiation are so rigorous that in practice they constitute effective economic and technical barriers against their widespread use.

It is therefore a principal object of the present invention to provide selective paging systems which possess inherent operational and frequency stability.

Another object of the present invention is to provide selective paging systems which permit the use of a much greater number of receivers than is ordinarily possible with mechanically resonant-type devices.

Still another object of the invention is to provide selective paging systems in which frequency sensitivity of the frequency-selective parts of the receivers may be easily standardized.

Another object is to provide paging systems which are very compact.

Another aim of the invention is to provide a frequency discriminating system of much greater selectivity than has hitherto been available.

Still another object of the invention is to provide a frequency discriminating system whose bandwidth and/or central frequency is easily adjustable.

In accordance with my invention I provide a transmitter which transmits a group of signals having different frequencies, each of which corresponds to a certain character or digit of a predetermined selected group of characters or digits that constitute a call number. Each transmitted signal will actuate those of the circuits in the receivers which are set therefor. When all the signals representative of the digits of the call number have been transmitted, those of the receivers which have circuits responsive to *all* of the tones transmitted in the proper sequence will produce an audible or visible "alert" signal, for example, which informs the carriers of those receivers that there is a message to be received. All receivers have provision for enabling the alert signal to be shut off when the carrier of the receiver is alerted. The called carrier then communicates with a designated switchboard which discloses the message to him. In one form of the invention I provide for the transmission of a so-called "cancel signal" after the transmission of the tone representing the last digit of the number. This signal prevents false calls by disabling all circuits in all receivers which have circuits which have responded to some, but not all, of the tones of the just-called number.

The invention will now be explained in more detail. It should first be remarked that each tone transmitted by the central station actually consists of an RF carrier modulated by a selected audio frequency. Each receiver has provision for (1) demodulating the audio from the RF carrier, (2) using each cycle of the demodulated audio to generate a pulse, and (3) integrating the resultant chain of pulses, whose repetition rate corresponds to the modulating audio frequency, to obtain a D.C. signal whose amplitude is uniquely a function of the audio frequency. The integrated D.C. signal is simultaneously supplied to all of a number of switching or "relay" circuits that are found in each receiver. There is one switching circuit in each receiver for each digit of the group of numbers which identify a particular receiver so that if the call numbers have three digits, for example, each receiver will have three switching circuits.

Each of the switching circuits is so designed that it can be actuated only when the integrated D.C. voltage applied to it is within a certain range of amplitude values. Thus, since each transmitted tone will cause the production of a distinctively different integrated D.C. voltage it is seen that each switching circuit can respond only when a certain one of the possible tones is transmitted.

The switching circuits in each receiver are connected serially and are so designed that when any one of them (except the last of the series) is actuated by a transmitted audio tone, it produces an output "enabling signal" which must be applied to the next switching circuit in the series to enable the latter circuit to be actuated by a

transmitted audio tone for which said next circuit is set. The last circuit in the series, however, produces an output "alert" signal when the previous circuit applies an "enabling" signal to it simultaneously with the application thereto of a transmitted tone for which said last circuit is set. This "alert" signal may consist of an audible signal like a ring, buzz, etc., or a visual signal such as a flashing light, or may be used to turn on apparatus for receiving the ensuing message.

After the last of the tones has been transmitted, the "cancel" signal, which has a frequency which will cause each receiver to produce an integrated D.C. voltage of such a value as to turn off the first of the switching circuits, is transmitted. When the first circuit is turned off, it no longer produces an enabling signal with the consequence that the following switching circuit, and the ones after that (except the last) are similarly disabled. The last one is so constructed that once it has begun to produce an alerting signal, it can only be deactivated by a *manual* operation by the carrier of the receiver. Since all other circuits of all other receivers have been "cleared" or "reset" by the cancel signal they are again free to respond, or not respond, as the case may be, to subsequently transmitted groups of transmitted tones representative of other call numbers. This cancel signal serves to prevent "false calls" as will be explained in some detail hereinafter.

The invention may be understood from a perusal of the drawings in which:

FIGURE 1 is a block diagram of an overall system constructed in accordance with my invention;

FIGURE 2 is a schematic diagram illustrating the forms which certain of the components illustrated in FIG. 1 may take;

FIGURE 3 is a group of three graphs illustrating the operation of the apparatus shown in FIG. 2; and

FIGURES 4 and 5 are schematic circuit diagrams of still other components of the system shown in FIG. 1.

Overall Operation of the System

Referring to FIG. 1 a transmitter **11** is located at a point near the calling area in which paging is to be effective. The transmitter **11** may comprise conventional apparatus for transmitting (1) an RF carrier which is modulated at different audio frequencies to correspond to different digits and (2) the so-called "cancel" signal. Let us assume, for purposes of illustration, that it is desired to alert or summon the individual (or individuals) carrying a receiver which is set to respond to the number 756. The operator at the transmitter **11** accordingly transmits, in sequence, a carrier modulated at say, 7 kc., 5 kc., and 6 kc. In the right-hand part of FIG. 1 are shown the constituent components of the receivers used in conjunction with the transmitter **11**.

The transmitted modulated carriers are applied, in sequence, to signal receiving and demodulating circuits **15** which produce audio signals at 7 kc., 5 kc. and 6 kc. respectively. Circuits **15** may comprise conventional RF and audio demodulation circuits, or may consist of superregenerative detection circuits, or other well-known equivalents. The detected audio signals are applied in sequence to a conventional audio amplifier **17** whence they are applied to a clipper and differentiator **19** (which may be of conventional design) where substantially only the positive half cycles of the audio signal are first extracted and then shaped by the differentiator into positive and negative "pips," the latter being used to trigger a "one-shot" multivibrator **21**. The latter, which may be of conventional construction, produces a positive-going rectangular pulse corresponding to each clipped half-cycle as shown in the output of the multivibrator **21**. It will be apparent that the higher the frequency of the demodulated audio is, the greater will be the number of rectangular pulses in the output of the multivibrator **21**. These pulses are then applied to an integrator **23**, which may be of conventional design, which is constructed to produce an output D.C. voltage whose amplitude is a function of the frequency of the audio modulation of the signal then being received. Hence, for each transmitted digit-representative signal, the output of the integrator at point K will have a unique amplitude. The output signal of integrator **23** is compared in voltage with reference voltages supplied by the voltage reference circuit **31** as will be explained in more detail in connection with FIGS. 2, 4 and 5. Circuit **31** is connected to each of the relays at the several terminals shown (C, H, L and their primed counterparts) for reasons which will be considered below.

Operation of "Relays"

One of the most important features of the invention resides in the switching circuits or "relays" **25, 27** and **29** all of which receive simultaneously at point K the output signals from integrator **23**. Each of these relays has a number of characteristics in common with the other relays and a number of distinguishing features. Each relay may be considered to be voltage-sensitive, that is, it is so arranged that it will turn on and produce an output signal only when the integrator signal at K has a predetermined amplitude. Therefore each relay is, in essence, responsive only to the reception of a different one of the possible transmitted audio-modulated-RF signals and hence may be considered as being digit-responsive.

There are as many relays in each receiver as there are digits in the transmitted call-numbers. For example, if only numbers in the hundreds are to be called there will be three relays such as the relays **25, 27**, and **29** in each receiver. Relay **25** corresponds, and is responsive to, the first digit, relay **27** corresponds, and responds to, the second digit, and relay **29** corresponds to the third digit of a selected call-number. In the illustrative case the relay **25** would be set so as to be activated when the 7 k.c. audio signal is transmitted, the relay **27** would be set to respond to the 5 k.c. audio signal, and the relay **29** would be set to respond to the 6 k.c. audio signal.

When the first digit-representative signal (7 k.c.) is received the integrator **23** will produce an output signal of say, x amplitude units (which is within the predetermined range) that is applied to input terminal A of the first relay **25**. The latter thereupon is turned on and produces an output "enabling" signal at output terminal O which, when applied to the B input of relay **27**, conditions the latter to operate whenever a 5 k.c. signal is transmitted and received.

When the second (5 k.c.) signal is transmitted it causes the integrator **23** to produce an output signal exceeding an amplitude value of say z units, which is applied to the inputs A, A′, and A″ of the relays. However, since only relay **27** is constructed so that it can be turned on by a signal having more than z amplitude and since it has received an enabling signal from the relay **25**, it alone will be actuated by the (z) signal at input terminal A′. As the two requisite conditions do co-exist, the relay **27** is turned on and, in turn, will provide an output or "enabling signal" to the B′ input of the last or nth relay **29**.

When the transmitter **11** sends out the 6 k.c. modulated carrier signal the integrator **23** will produce an output signal exceeding a value of y amplitude units which is within the predetermined amplitude range that will cause relay **29** to be turned on when applied to the A″ input of that relay, since an enabling signal is already present at the B′ input thereof. When this occurs the relay **29** will produce an output signal which actuates an altering device such as the audio oscillator **33**, which may be of conventional design, whose output is connected to a loudspeaker **35** which thereupon emits an audible "alert" tone. When the carrier of this particular receiver hears the "alert signal" he turns off his receiver and, for example, communicates with a pre-arranged station to ascertain what message there is for him. Since the relays of all other receivers are set for different call numbers, however, their respective alerting devices will not be actuated

and hence their carriers will not be aware of the fact that *anyone* is being called.

Since other receivers may also possess relays which are set to respond to some of the digits contained in the just-called number 756, e.g., receivers set to respond to the number 563, and since the first digit of the next number to be called may be a 3, it is necessary to "clear" all relay circuits in all receivers; otherwise the receiver set for call number 563 may respond erroneously to the next number called. Accordingly, a "cancel signal" is sent immediately after the transmission of the signal corresponding to the last digit of the number just called. This "cancel signal" resembles the transmitted digit-representative signal except for the fact that its frequency is higher than any frequency used to represent a digit. As was stated above, this cancel signal will turn off all receivers except the one or ones responsive to the just-called number by turning off the first switching circuit or relay in such receivers.

There is therefore provided in the first relay **25** of the just-called receiver as well as in the first relays of all other receivers a cancelling circuit which, when the D.C. voltage at point K corresponds to the cancel signal, turns off the relay **25** so that no output signal or enabling signal can be applied to the relay **27** thereby cutting off the latter and its production of an enabling signal. However, since relay **29** is so constructed that once it has been turned on it can be disabled only by a manual operation, it is not affected by reception of the cancel signal.

Operation of the First Relay

FIGURE 2 shows a preferred form that the first relay **25** and the associated integrator **23** and voltage reference circuit **31** may take. It is helpful to consider the first relay as consisting of two main parts: (1) a part which produces a self-sustaining regenerative output signal and (2) a part which determines if and when the relay will produce an output signal.

Part 1 of the relay **25** comprises the regenerative output-signal producing part and includes TR1, TR2, R1, R_0 and the battery **30**. In order for the relay to produce an output signal the negative terminal of battery **30** must be connected, temporarily to the base of transistor TR1. In actuality this is accomplished by turning on TR5 as will be explained below in connection with the explanation of part 2. When this happens TR5 will conduct and there will be a first current flowing from battery **30** through the emitter and collector of TR1 causing the base of TR2 to go more positive. This will cause TR2 to conduct so that a second current will flow from the battery **30** through R1, through TR2, through the output resistor R_0 and back to the battery. It is seen that the second current through R1 will tend to keep the base of TR1 negative thereby causing it to conduct so that TR2 will likewise conduct whereupon the drop across R1 will tend to keep TR1 conductive. This condition is illustrated by the dashed-line curve **60** of part C of FIG. 3 which shows the current or voltage through R1 (which is also representative of the current through R_0) attaining and then exceeding the critical value beyond which the current is self-sustaining. If the voltage across R1 fails to reach the critcal level within a specified time and TR5 is subsequently cut off (part B, FIG. 3) the signal across R_0 will not be self-sustaining. However, once the voltage across R1 attains the critical level, the circuit of part 1 of relay **25** will produce a signal across R_0 which will continue even if the base of TR1 is subsequently disconnected from the negative terminal of the battery **30** if TR5 is cut off. R1 is preferably a negative-coefficient resistor, e.g., a thermistor, in order to stabilize the regenerative circuit for variations in ambient temperature, although other known forms and methods of temperature compensation may alternatively be employed. For example, another thermistor may be placed between the base and emitter of TR2.

Part 2 of the relay comprises the circuits connected with transistors TR3, TR4, and TR5. In order to produce an output signal across R_0, as stated above, a negative voltage must be applied from the battery **30** to base of TR1. Therefore, if there is applied between K and Q a positive D.C. voltage which, when algebraically combined with x volts at terminal L, produces a negative voltage at the base of TR5, the latter will commence conduction and the negative side of the battery **30** will be connected to the base of TR1. It will be seen that the voltage between K and Q must exceed x volts before there will be current flow through R1 which may, after the lapse of a predetermined interval of time, reach the critical level (FIG. 3, part C) at which the signal across R_0 is self-sustaining. However, until the current does reach the critical level, the voltage across R_0 will be neither self-sustaining or large enough to "enable" the subsequent relay **27** to be turned on should there be subsequently applied between K and L′ an appropriate signal.

Once the critical level is reached, withdrawal or diminution of the voltage between K and Q cannot prevent the circuit of part 1 from continuing to operate as explained previously. In such case, the voltage across R_0 will be sufficient, when applied to the subsequent relay **27**, to enable the latter to be turned on should the transmitter send out a signal modulated at 5 kc., the frequency for which relay **27** is set.

I have also constructed relay **25** so that if the voltage between K and Q, after having exceeded x volts, subsequently exceeds x' volts (FIG. 2) TR5 will be rendered inoperative by virtue of the action of the "anti-trigger" circuit TR4. It will be noted that the base of TR4 is connected via resistor **26** to the terminal H which in turn is connected to the terminal of the battery **31** at which x' is obtained, the latter voltage being of the same polarity but of greater magnitude than the voltage x (with reference to Q). Thus if the voltage between K and Q exceeds x' volts the transistor TR4 will conduct thereby effectively shorting the base of TR5 to K. This will, of course, cut off TR5 and effectively disconnect the base of TR1 from the negative terminal of battery **30**. The disconnection of the battery **30** from the base of TR1, however, may or may not prevent the production of an enabling voltage across R_0.

Which of the latter alternatives will occur depends upon a special circuit which I have incorporated for preventing the production of an enabling signal across R_0 if the value of the voltage between K and Q does not remain between x and x' volts for a predetermined minimum time interval. Were it not for this circuit the relay **25** would respond not only to a relatively steady state voltage within the x—x' range for which it is set, but also would respond to the build-up to any greater voltage of the same polarity when the latter voltage temporarily had values in the aforesaid range. This would happen inasmuch as the current through R1 would immediately exceed the critical level. The converse is also true, i.e., when a voltage between K and Q in excess of x' was diminishing it might, when temporarily in the x—x' range, cause relay **25** to produce an enabling signal.

The circuit which prevents the production of a self-sustaining enabling signal by relay **25** unless the voltage between K and Q stays within the x—x' range for at least the minimum interval comprises the capacitor C1 and the resistances of the various transistors in part 1 of the circuit. This time constant circuit prevents the voltage across R1 from attaining immediately the critical value (part C, FIG. 3). The time constant circuit does *not* affect the build up of the voltage applied between A and Q even though the capacitor is connected to terminal A. Rather the time constant circuit operates only in conjunction with the circuit of part 1, i.e., TR1, TR2, R1, R_0 and battery **30**, to cause the buildup of current

through R1 to lag behind the voltage between A and the other input terminals.

The choice of the position of the time constant capacitor C1 and its counterparts in the other relays is influenced by the fact that it is desirable to employ the least value of capacitance which will enable the circuit 25 to function properly. Accordingly, in the position shown in FIG. 2, the capacitor C1 may have a value of say, one microfarad which, in conjunction with the parameters of the transistors, gives a time constant between .05 and 2 seconds. Alternatively, this capacitor can be disposed between the emitter and the base of TR2 but this arrangement will necessitate a greater value of capacitance than was required in the first arrangement.

Thus when the applied voltage at K and Q at the time t_0 (part A, FIG. 3) begins to exceed x volts TR5 will start to conduct (part B, FIG. 3) thereby causing some curernt to flow through R1 (part C). It will be seen by reference to the solid line curve 61 that the current through R1 at a subsequent predetermined time t_1 is insufficient to cause the critical voltage level across R1 to be attained. Also, at t_1 the applied voltage (part A) starts to exceed x' volts thereby causing the anti-trigger transistor TR4 to commence operation (part B) thereby starting to turn off TR5. The anti-trigger transistor TR4 is thus turned on when the voltage between A and Q exceeds x' volts. When TR4 is conducting the voltage between K and X is diminished to a point where TR5 is effectively cut off (part B, FIG. 3). This prevents the negative voltage from battery 30 from being applied via TR5 to the base of TR1 and as a result the regenerative circuit (TR1, TR2, etc.) will be inoperative and no self-sustaining output "enabling signal" across R_0 will appear between terminals O and A.

The elements of relay 25 that have been described thus far are common to all the relays 25, 27 and 29. There is, however, another part of the first relay circuit which is unique, i.e., the so-called "cancel circuit." This circuit is the one which responds to the transmitted "cancel signal" by turning off the first relay 25 which thereupon produces no output enabling signal and causes the next relay to turn off, and so on down the line (with the exception of the last relay which can only be manually turned off) as has been previously explained. It responds to a signal higher in frequency than any other signal transmitted.

This circuit comprises the transistor TR3 which is set to respond to a voltage applied between A and Q of say u volts which corresponds to a transmitted 13KC cancel signal. Upon receiving this signal, TR3 conducts and shorts out R1 which it shunts, reducing the negative voltage to TR1 below the value required to maintain self-sustaining regeneration and causing the regeneration to cease thereby preventing the production of an output enabling signal across R_0. It should be remembered that the difference between the operation of the "anti-trigger" transistor TR4 and the "cancel circuit" transistor TR3 is that the latter *can* turn off the relay 25 even after the regenerative signal-producing transistors TR1 and TR2 are made conductive, whereas the "anti-trigger" transistor TR4 *cannot*.

Description of Intermediate Relay

The intermediate relay 27 shown in block form in FIG. 1 is shown in schematic form in FIG. 4. As explained previously, it contains many of the features of the first relay 25 and includes "trigger" or low-limit, and "anti-trigger" or high-limit circuits for determining when it is to be turned on. It also contains a part which produces a regenerative signal at the output.

The part of the circuit which regenerates comprises transistors TR1*a*, TR2*a*, R1*a* and R_0' which are the counterparts in the similarly numbered components shown in FIG. 2. The trigger circuit comprises TR5*a* which is connected via a base resistor to terminal L' and serves the same function as did TR5 in FIG. 2. Thus when a certain trigger voltage in excess of z volts is present between A and terminal Q, TR5*a* conducts so that a current flows from battery 30' and through resistor R1*a* causing the voltage across R1*a* to increase until the base of TR1*a* goes sufficiently negative that it conducts to the point where regeneration commences resulting in the production of a self-sustaining output signal across the output resistor R_0' at the terminal O'.

Transistor TR4*a* which is coupled to the terminal H' via a base resistor serves the same function as its counterpart in FIG. 2, i.e., if the voltage applied between K and terminal H' exceeds the range of voltages for which the relay 27 is set to respond, it will prevent the input signal from causing the transistor TR5 to conduct thereby preventing regeneration in the circuit and preventing the production of a self-sustaining output signal.

Transistor TR3*a*, which constitutes the "enabling" circuit, is connected via a base transistor to the output terminal O of the previous relay 25. As was mentioned earlier in connection with the general description of the system of FIG. 1, no intermediate or final relay can be operative unless and until the previous relay is producing a self-sustaining regenerative output signal. So long as the first relay 25 is producing an output signal which is applied to the base of TR3*a*, the terminal O will remain relatively positive, with respect to K, the transistor TR3*a* will be non-conductive, and an output signal can appear at O'. Should the previous relay not be actuated, however, there will appear between K and terminal O, the voltage which appears across the battery 30 in the preceding stage. This voltage causes the transistor TR3*a* to conduct and hence the batery 30' has its positive side connected directly to K thereby shorting resistor R1*a* and preventing regeneration in the circuit. Attention is drawn to the fact that, unlike its counterpart, the "cancel" transistor TR3 of FIG. 2 which is connected to a reference battery, the base of the "enabling" transistor TR3*a* is connected to the output O of the previous relay.

Actually, the output voltage wave of the integrator 23 is compared, in effect, before application to the relays 25, 27 and 29 with reference voltages in circuit 31. Since it is necessary for each of the relays to respond to different voltage levels, the base of TR5 will be biased to a certain value (x volts), whereas the similar transistors TR5*a* and TR5*b* in the subsequent relays will be biased to respectively different voltages (z, y volts) so that each relay is, in essence, sensitive to different integrator output voltages at K. One way of accomplishing this is by connecting batteries having selected voltage ratings in series (as shown in block 31, FIG. 2) and tapping off at different terminals thereof. The output voltage of the integrator 23 is applied in series to this chain of batteries and the differential voltage (i.e., the algebraic sum of the battery voltage and the integrator output voltage) is the effective voltage across the trigger transistors TR5, TR5*a* and TR5*b* as the case may be.

The same sort of arrangement exists for determining the voltages at which the "anti-trigger" transistors TR4, TR4*a*, and TR4*b* will operate in relays 25, 27 and 29, i.e., x', z' and y' volts.

The nth Relay

FIGURE 5 shows the constitution of the final or *n*th relay 29. Those transistors shown therein which are identical to those shown in the preceding figures bear similar designations except for the subscript *b*. TR1*b* and TR2*b*, together with the resistors R1*b* and the battery 30'' comprise the regenerative, output-signal producing circuit. TR5*b* is the trigger transistor and TR4*b* prevents the relay 31 from being turned on if a higher than predetermined voltage is applied at K.

TR6, the enabling transistor, is connected differently and performs somewhat different functions than the transistors in the previous relays. Its base is connected via a re-

sistor to the output terminal O' of the previous relay 27, and its emitter is coupled to the base of the trigger transistor TR5*b* (and to the collector of TR4*b*). When the previous relay 27 is non-conductive the voltage between K and O' is sufficient to cause the transistor TR6 to conduct thereby preventing the trigger signal from being applied to the base of the trigger transistor TR5*c*. When the previous relay 27 is on, however, the voltage between K and O' decreases and the transistor TR6 is non-conductive so that the proper trigger voltage can be applied to the base of TR5*b* to trigger the relay 29 to turn the latter "on."

Unlike the enabling transistors of the intermediate relays, which can turn off those relays once they have been turned on by shorting the resistor in series with the base of TR1*a*, TR6 cannot turn the relay off once it has been on as it does not short out the resistor R1*b* when it is conductive. The only thing it can do is to by-pass the input signal at the base of TR5*b* to K whenever the previous stage is inactive and thereby prevent initiation of operation of the relay 29. This arrangement is deliberately made because it is desirable to require a manual operation to turn off the final relay (and hence the alert signal) after it has once been turned on.

For this purpose a manual reset switch 50, which shunts the resistor R1*b*, is provided. When it is closed by the carrier of the receiver the voltage across R1*b* is reduced so that the circuit 29 will no longer regenerate.

General Remarks

While the invention has been described as a complete system used for signalling purposes, its potential uses are many and diverse. It has been demonstrated that the receiver has components which respond to different incoming modulating signal frequencies. It is therefore evident that it can be used as a frequency discriminating and/or detecting device. For frequencies in the lower ranges, i.e., up to about 450 kc. it has definite advantages. In the lower part of that range conventional filters of the LC type are too large, require many components, and require component changes in the event that one desires to change the frequency response thereof. By using the apparatus constructed according to the present invention relatively few components are involved, the apparatus can be extremely small and compact, and there is no need to use different components if it is desired to change to frequency to which it is to respond.

For example, all that is necessary to change the response frequency of the intermediate relay 27 from 5 kc. to another frequency is to change the bias voltages on TR5*a* and TR4*a* by connecting to different points on the voltage reference circuit 31. For changes of a substantial nature it may also be necessary to make an adjustment of component values in the integrator 23. Incidentally, the circuit 31 is designed with several considerations in mind. The difference between the trigger and anti-trigger voltages is governed by a number of factors. One of these, of course, is that this differential will depend upon the desired selectivity and/or bandwidth to which the relay is to respond. Another consideration is the fact that some of the components of the receiver may possibly be temperature-sensitive and cause minor variations in frequency response. Still another consideration is the frequency stability of the transmitter and the desired tolerances in the overall apparatus.

Also, if it is desired to change the passband of any one of the relays it is only necessary to increase the difference between the voltages applied to the trigger and anti-trigger transistor bases. Conversely, if it is desired to narrow the passband, the difference between the voltages applied to these bases can be made smaller. While FIG. 2 shows that the circuit 31 is constructed so that there is a difference between the voltage required to operate the anti-trigger circuit of one relay and the trigger circuit of the next, it is entirely possible to have them the same thereby permitting the use of fewer batteries. Of course, the entire battery circuit may be supplanted by appropriate voltage divider networks as are well known in the art.

It is also characteristic of these circuits that the passband curve has extremely steep skirts which characteristic is especially valuable when these frequency discriminating circuits are to be used as switches as in telemetering applications where the device to be controlled can be activated or deactivated directly from the frequency responsive relay. Resort to conventional techniques to obtain these features would probably necessitate employing expensive and complicated circuits.

The relay circuits have been shown as having certain transistors of the PNP type and others of the NPN type. It is apparent to those skilled in the art that other circuit configurations are possible using NPN transistors instead of PNP and vice versa. It is likewise apparent that circuits other than the novel relay circuits shown and explained previously can be used alternatively in their place, provided they respond to the voltages at the output of the integrator in the same manner. The novel circuits shown have proved eminently satisfactory for the purpose, but circuits using tubes or other analogs of the transistors undoubtedly could be devised to perform the same functions in the system.

It should be remarked that with the system as shown, there should not be within any given receiver two successive relays which are set to respond to the same voltage ranges, i.e., two relays which are responsive to signals representing the same digit. By the same token, with the system as shown hereinbefore the transmitted call number should not contain two successive identical digits. However, variations of the general system as shown are possible in which the call number *can* have successive characters which are the same.

This may be accomplished by resort to any one of several ways which are based on variation in the duration of the time that each digit-representative signal is transmitted and/or variations in the time constants of the relays within any receiver. By way of illustration, one possible arrangement could be to employ a receiver whose relays were set for the digits 4, 4 and 5 respectively. The time constant of the first relay might be .1 second and the time constant of the second relay might be .2 second for example. The transmitter could be designed to transmit variable length bursts of sinusoidal waves of the same frequency. Thus, in order to call 445 the operator would send out a first burst of a 4 kc. modulated carrier having a duration of .15 second (or more than .1 second but less than .2 second) which would be of sufficient duration to turn on the first relay in the receiver which would thereupon produce an output signal for enabling the second relay. However, the first burst would be too short to cause the second relay to turn on despite the application thereto of an enabling signal from the first relay.

To actuate the second relay of that receiver the operator next transmits a burst of a 4 kc. modulated carrier having a duration of at least .2 second. Since the first relay has already been turned on, it will ignore the second burst, but the second relay will thereupon turn on and the operator then needs only to transmit a 5 kc. modulated carrier to alert the person carrying that receiver.

Another variation would be to employ identical time constants in the two successive relays for responding to the 4-representative signal. Assuming this time constant was .1 second, the operator would transmit a first burst of a 4 kc. modulated carrier for between .1 and .2 second. This would turn on the first relay which would then produce an enabling signal that would be applied to the next relay. However, the latter relay would not be turned on inasmuch as it has had the benefit of the enabling signal only after .1 second has elapsed and then only for a period shorter than the required .1 second. However,

when the next burst arrives, the first relay will ignore it as it is already producing an enabling signal, but since it has a duration of at least .1 second the second relay will turn on. Many other variations are possible, as will be apparent to one skilled in the art.

The present invention is useful even in wired signalling systems in which case it is not necessary to employ a carrier for the digit-representative signal. Where bandwidth and radiation are not a problem, the transmitter could be made to send out different sets of pulse trains which would correspond to the output of the multivibrator, and hence the preliminary parts of the receiver up to the integrator could be dispensed with.

What I claim is:

1. A signalling system comprising: means for transmitting in a predetermined sequence a plurality of signal waves having different frequencies which respectively represent selected characters, means for receiving said transmitted signal waves, said receiving means including means responsive to said signal waves for producing different voltage waves respectively representative of the different frequencies of said signal waves, and means selectively responsive to said different voltage waves for producing an output signal only when said transmitted signal waves have selected frequencies and occur in said sequence.

2. A signalling system comprising: means for transmitting in a predetermined sequence a plurality of signal waves having different frequencies corresponding respectively to selected characters of a call number, means for receiving said transmitted signal waves which comprises means responsive to said signal waves for producing a plurality of sets of pulses, each set having a repetition rate which corresponds to one of said signal wave frequencies, means responsive to said plurality of sets of pulses for producing a plurality of different voltage waves corresponding respectively to said sets of pulses, and means selectively responsive to said voltage waves for producing an output signal only when said transmitted signal waves have selected frequencies and occur in said predetermined sequence.

3. A signalling system comprising: means for transmitting in a predetermined sequence a plurality of sinusoidal waves having different frequencies corresponding respectively to different characters of a predetermined group of characters, and means for receiving said transmitted sinusoidal waves which includes means for clipping part cycles of said waves, means for producing sets of pulses of substantially uniform amplitude, each of said pulses corresponding to one of said clipped part cycles, means for integrating said sets of pulses to produce different values of voltage which are respective functions of the repetition rates of said sets of pulses, a plurality of switching means, one for each character of said groups of characters, said plurality of switching means being constructed to receive said voltages and to produce an output signal only when said voltages have predetermined values corresponding to selected ones of said predetermined groups of characters and occur in the same relative sequence as said transmitted waves.

4. A signalling system comprising: means for transmitting in a predetermined sequence a plurality of signal waves representing selected numbers of a series of call numbers, each of said signal waves comprising a carrier wave modulated at a different audio frequency, and a receiver for said transmitted signal waves which includes means for demodulating the audio component of said transmitted waves, means for clipping substantially half cycles from said demodulated audio component, means for producing a plurality of sets of substantially rectangular pulses having substantially uniform amplitude, each pulse of each of said sets corresponding to one of said substantially half cycles, means for integrating the pulses of each set to produce respective output voltage waves which have amplitude values which are functions of the repetition rates of said pulses, and a plurality of switching circuits being constructed to produce an output signal only when the applied voltage waves have amplitude values which correspond to transmitted signal waves representing selected call numbers and occur in said predetermined sequence.

5. A system for receiving a plurality of transmitted signals having different frequencies which respectively represent different characters and occur in a predetermined sequence, said system comprising means for producing a plurality of voltage waves in response to said transmitted signals, each of said voltage waves representing one of said transmitted signals, and means selectively responsive to said plurality of voltage waves for producing an output signal only when said transmitted signals have selected frequencies which occur in said sequence.

6. A system for receiving a plurality of different signal waves having respectively different frequencies corresponding to different selected characters, said system comprising means responsive to said signal waves for producing corresponding different sets of pulses having respective repetition rates related to the respective frequencies of said signal waves, means responsive to said different sets of pulses for producing respective voltage waves corresponding thereto, and means selectively responsive to said voltage waves for producing an output signal only when said waves have respective predetermined ranges of amplitude and occur in a predetermined sequence.

7. A system for receiving a plurality of different sinusoidal waves transmitted in a predetermined sequence having respectively different frequencies corresponding to different characters of a series of call numbers, said system comprising: means to which said sinusoidal waves are applied for clipping substantially half cycles of said waves, means responsive to said clipped half cycles for producing sets of rectangular pulses of substantially uniform amplitude, the number of pulses of each set corresponding to the number of said clipped half cycles, means for integrating said sets of pulses thereby to produce different voltage waves having amplitude values which are functions of the repetition rates of the said sets of pulses, and means responsive to said different voltage waves for producing an output signal only when said voltage waves have respective amplitudes which fall within predetermined ranges and occur in a sequence corresponding to said predetermined sequence.

8. The receiver according to claim 7 wherein said means for producing said output signal comprises a plurality of means each of which is responsive to a different selected one of said voltage waves, there being one of said last-mentioned means for each character of selected ones of the series of call numbers, said plurality of voltage-responsive means being further constructed and arranged to receive each of said voltage waves and to produce an output signal substantially only when selected ones of said voltage waves have amplitudes within selected predetermined ranges.

9. A signalling system comprising means for transmitting a plurality of signal waves having selected frequencies respectively corresponding to selected characters of desired call numbers, said transmitting means being constructed to transmit signal waves corresponding to two successive identical characters of a selected call number for predetermined different time intervals, and means for receiving said transmitted signal waves which comprises means for producing a set of pulses in response to each of said signal waves, the repetition rate of each set corresponding to one of said selected frequencies, said receiving means also comprising means for producing a voltage wave in response to each of said sets of pulses, the amplitude of said voltage wave being a function of the repetition rate of the set of pulses to which it corresponds, and a plurality of circuits having substantially the same time constants for producing cooperatively an output signal substantially

only when said voltage waves have selected amplitude values.

10. A signalling system comprising means for transmitting a plurality of signal waves having selected frequencies respectively corresponding to selected characters of desired call numbers, said transmitting means being constructed to transmit signal waves corresponding to two successive identical characters of a selected call number for predetermined different time intervals, and means for receiving said transmitted signal waves which comprises means for producing a set of pulses in response to each of said signal waves, the repetition rate of each set corresponding to one of said selected frequencies, said receiving means also comprising means for producing a voltage wave in response to each of said sets of pulses, the amplitude of said voltage wave being a function of the repetition rate of the set of pulses to which it corresponds, and a plurality of circuits for producing cooperatively an output signal substantially only when said voltage waves have selected amplitude values, those of said circuits which are

directly connected to one another and set to respond to voltage waves having the same amplitude values being constructed to respond thereto only when said same voltage waves are applied thereto for predetermined different time intervals.

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