

Nov. 17, 1942.

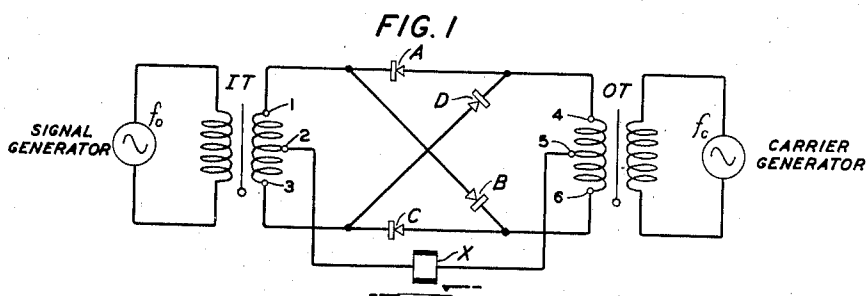
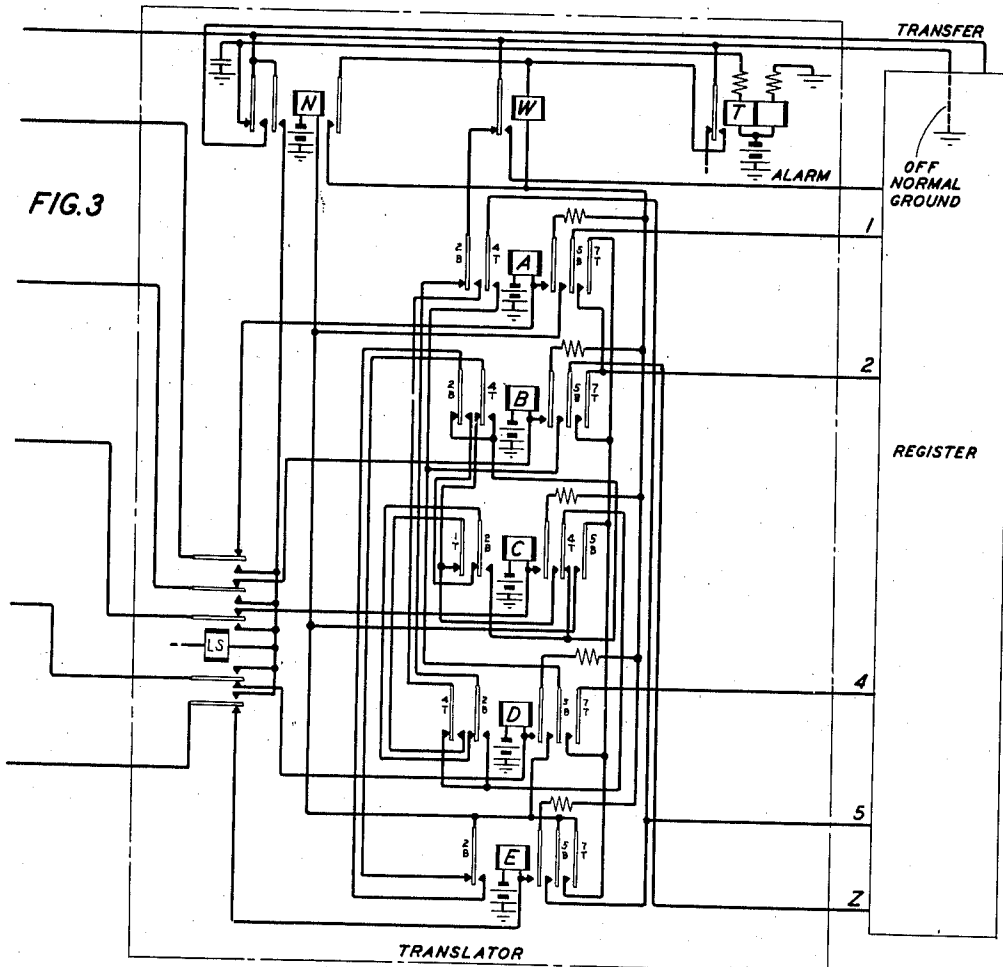
M. A. LOGAN

2,301,961

SIGNALING SYSTEM

Filed Dec. 4, 1941

2 Sheets-Sheet 1



INVENTOR
M. A. LOGAN
BY
P. C. Smith
ATTORNEY

Nov. 17, 1942.

M. A. LOGAN

2,301,961

SIGNALING SYSTEM

Filed Dec. 4, 1941

2 Sheets-Sheet 2

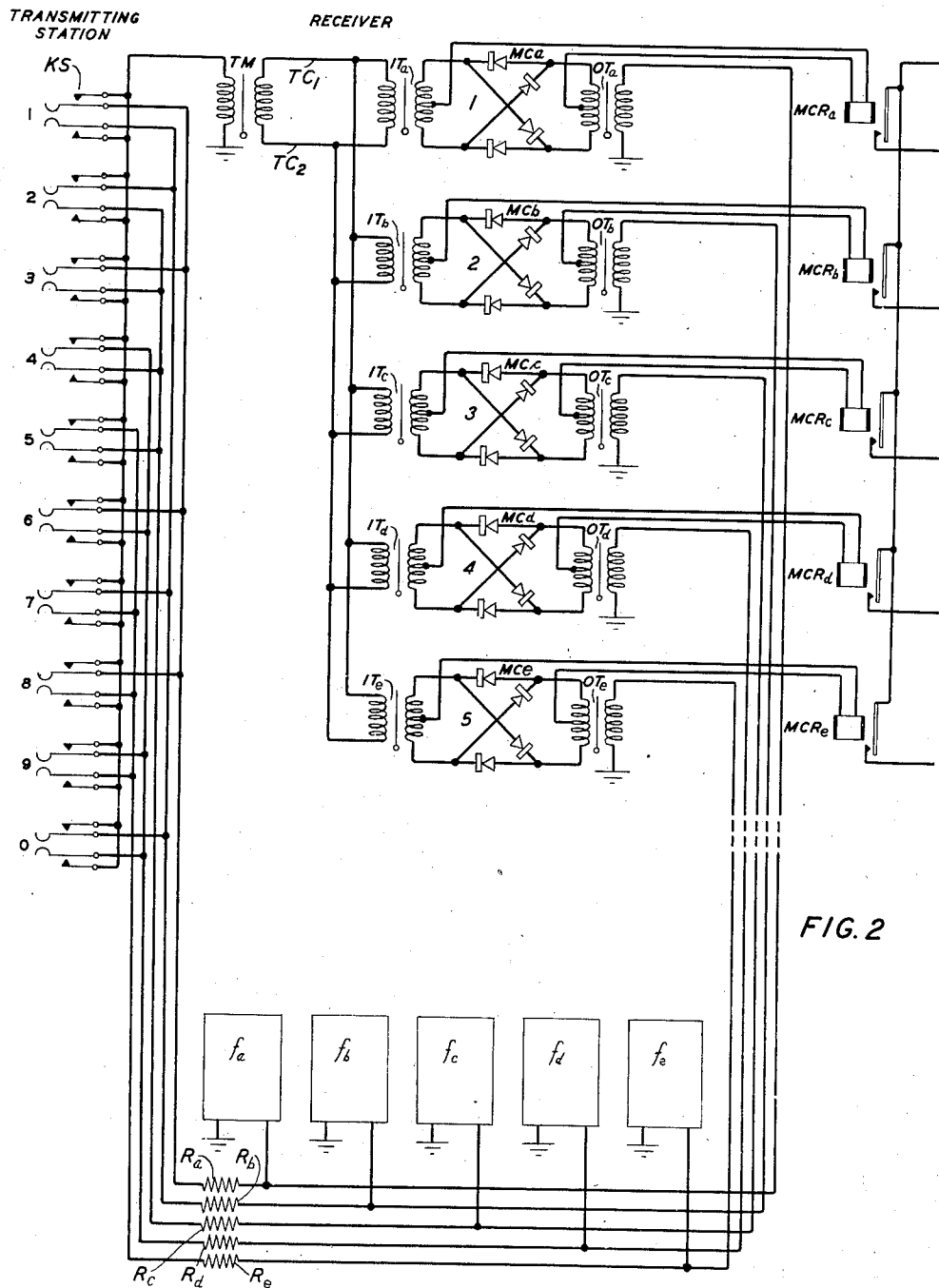


FIG. 2

INVENTOR
M. A. LOGAN
BY
P. C. Smith

ATTORNEY

UNITED STATES PATENT OFFICE

2,301,961

SIGNALING SYSTEM

Mason A. Logan, Summit, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application December 4, 1941, Serial No. 421,615

5 Claims. (Cl. 179—16)

This invention relates to signaling systems and more particularly to a system in which signal impulses comprising one or more alternating current frequencies are transmitted from one point and received at another point by an electrical circuit which is devoid of the usual filter networks ordinarily provided in a circuit adapted for the reception of such alternating current pulses.

In the ordinary alternating current pulse receiver a band-pass filter is usually provided for each frequency of the signal current, each filter having a different mid-band frequency which is equal to the numerical frequency of one of the transmitting signal sources. The output of each band-pass filter is connected to a suitable voltage detector which then operates on the frequency in the signal passed by the band-pass filter, said filter attenuating all other frequencies in the signal current. Suitable responding and registering devices are, of course, connected to the detectors and the different frequencies of which the pulse is composed, in activating their associated several detectors, correspondingly cause the registering devices to be set in accordance with the several frequencies of the pulse which, if transmitted in the form of a suitable code, will cause the registers, when set, to designate the particular intelligence designated by the code.

According to the principle of the present invention, the receiving circuit does not employ band-pass filters but a much simpler and less expensive network comprising, for each of the frequencies to be received, a double-balanced modulator of the rectifier type which is supplied continuously with a carrier frequency equal to the frequency of the signal and in phase therewith. To indicate the presence of the frequency of a signal in the modulator, an ordinary direct current relay is connected to the output terminals of the modulator, and the latter acts both as a filter and as a direct current detector. Since the signal and the carrier are both in phase, the relay is operated directly by the direct current component present in the demodulated signal power. Thus the direct current power for operating the relay connected to the output of the modulator is supplied by the signal itself.

According to one embodiment of the invention, the common frequency sources that provide the several independent signal frequencies (also acting as carrier frequencies) are connected to the receiver circuit whenever the signal system is put in a state to transmit and receive signals, and each of the frequency sources thus "drives" its corresponding modulator, there being, of

course, as many modulators in the receiver of the system as there are signal frequencies to be received. Each frequency source is also connected to the pulse transmitter which may be, for example, a plurality of keys wired to the frequency sources in such a manner as to transmit, over the transmitting medium, the required number of frequencies for the pulse indicated by the key depressed. Since the several frequencies comprising the pulses are also connected continuously to the several respective modulators as the "carriers" thereof, the output of each modulator will contain a direct current component inasmuch as one of the modulator output currents is equal to the "difference" between the frequency of the carrier and that of the signal which, if the difference between the frequency of the carrier and that of the signal is zero, the difference will be a zero; that is, the current component will be a direct current component, in which event this component will operate the direct current relay connected to the output terminals of the modulator.

As stated before, the output terminals of each of the modulators are connected to a direct current relay and, of course, only the relay which is connected to the modulator that has equal carrier and signal frequencies will operate since all other modulators that have carrier frequencies different from that of the carrier frequency of the signal will, in responding to the signal frequency, produce only alternating current components in their output which will not be effective in operating their respective relays because the inductive reactance of the relays discriminates against alternating current components.

A clearer conception of the scope and purpose of the invention may be obtained from the following detailed description and appended claims taken in connection with the following drawings of which Fig. 1 shows the double-balanced modulator used in the invention and Figs. 2 and 3, placed side by side in the order named, show the signal system of my invention as comprising a transmitting station represented by the ten-digit key-set KS, a plurality of modulator channels $MC_a \dots MC_e$, one for each of the frequencies that, in suitable combination of twos for example, make up the signal pulses to be transmitted, a corresponding number of frequency sources $f_a \dots f_e$ interconnected between the key-set KS and the modulator channels $MC_a \dots MC_e$, a plurality of direct current relays $MCR_a \dots MCR_e$, one for each channel, a translator circuit adapted for response to the operation of the di-

rect current relays, a register circuit of any suitable design adapted for response to the setting of the translator when the latter responds to the operation of any two of the relays MCR_a . . . MCR_e, and a transmitting medium TM interconnecting the key-set with the modulator channels.

Before describing the operation of my invention, it would be well to explain the principle of the double-balanced modulator which is used in the invention and is schematically shown in Fig. 1. This modulator comprises an input transformer IT, an output transformer OT, a rectifier bridge A, B, C, D, connected between the input and output transformers, and a direct current relay X connected to the central taps, respectively, of the output terminals of transformers IT and OT.

We may now suppose that a signal frequency f_s is impressed upon the input terminals of transformer IT and that a carrier frequency f_c , the power of which is large compared to that of the signal frequency f_s , is impressed upon the input terminals of transformer OT. By Fourier's equation, the output voltage $e_1(t)$ of the modulator available for the operation of relay X may be expressed by the formula

$$e_1(t) = \frac{2E}{\pi} \cos(\omega_c + \omega_s)t + \frac{2E}{\pi} \cos(\omega_c - \omega_s)t - \frac{2E}{3\pi} \cos(3\omega_c + \omega_s)t - \frac{2E}{3\pi} \cos(3\omega_c - \omega_s)t + \frac{2E}{5\pi} \cos(5\omega_c + \omega_s)t + \frac{2E}{5\pi} \cos(5\omega_c - \omega_s)t \dots \quad (1)$$

in which

$\omega_s = 2\pi$ times the frequency of the signal voltage,
 $\omega_c = 2\pi$ times the frequency of the carrier voltage,
 and
 E = the peak value of the signal voltage appearing across one-half of the center tapped input transformer IT.

If, now, the signal frequency is made equal to the carrier frequency, $\omega_s = \omega_c$ the above equation reduces to

$$e_1(t) = \frac{2E}{\pi} + \frac{4E}{3\pi} \cos 2\omega_s t - \frac{4E}{15\pi} \cos 4\omega_s t + \frac{4E}{35\pi} \cos 6\omega_s t + \dots \quad (2)$$

That is to say, the modulator's output voltage across the relay X in the conjugate path of the modulator consists of a constant or direct current term

$$\left(\frac{2E}{\pi}\right)$$

and a number of sum and difference alternating current components. The direct current component

$$\left(\frac{2E}{\pi}\right)$$

being impressed across the terminal of the direct current relay X, causes said relay to operate, and since the relay will present a high impedance to the alternating current components of the output voltage, the same will have no effect upon the relay.

It is obvious that a signal impulse consisting of, say, two frequencies will be impressed, according to the signal system of my invention as shown in Figs. 2 and 3, on all the channels at once since the same are all electrically coupled to the transmission conductors TC₁ and TC₂ over

which the signal impulses are carried. However, except for the modulators that have the same carrier frequencies applied thereto as the frequencies of the signal, all other modulators will have no direct current output component in their output voltage since, for these modulators, the output voltage is expressed by Formula 1 and not by Formula 2 the former of which, it will be observed, consists exclusively of alternating current components to which the direct current relays of the respective modulators involved offer a high impedance and hence will not respond.

The operation of the modulator will now be traced through one cycle of the signal and carrier voltage. Considering Fig. 1, it will be assumed that point 4 is at a high positive voltage impressed by the carrier current. If the signal voltage is in phase with the carrier voltage, point 1 will also be at a positive potential. The carrier voltage causes current to flow through the copper-oxide elements A and B causing these two elements to assume a low value of resistance. Thus, in effect, points 1, 4 and 6 act as if they were connected together, and the signal current, during the positive half-cycle of the signal and carrier voltage, will flow from point 1, through elements A and B in parallel and through the output transformer OT in parallel opposing to point 5, through the winding of the relay X and back to point 2. When point 6 becomes positive, signal current flows through the relay and transformer OT in the same direction as it did on the previous half-cycle but through the other two rectifiers C and D from point 3. Thus with a high carrier volts-to-signal volts ratio, the modulator can be conceived of as a single-pole, double-throw switch operated at the carrier frequency, the switch connecting one-half of the secondary winding of the input transformer IT to the winding of the relay X when the carrier is of one polarity and the other half of the signal circuit to the load when the carrier is of opposite polarity. If the carrier and signal have the same frequency and phase, the current in the relay is the same as if the signal were fed therein through a full wave rectifier. This current has a direct current component and, as stated above, causes the relay to operate under these conditions. If the carrier voltage and signal voltage are not the same in phase, the direct current component will be reduced and will become zero when the voltages assume a 90-degree phase angle. This explains the desirability of connecting the same frequency source to the key-set KS and to the modulators MC_a . . . MC_e since coincidence of phase, especially for the signal and carrier currents, is then assured thereby and a maximum direct component for operating relay X rendered certain.

Returning, now, to the detailed description of the disposition of the various parts of the circuit apparatus and the explanation of the operation of the invention as a whole and referring to Figs. 2 and 3, the frequency sources f_a . . . f_e , which may be of any suitable construction each capable of emitting, respectively, the single frequencies arbitrarily indicated by the subscripts a . . . e , are each grounded at one terminal and connected at their other terminal to the ungrounded output terminal of the respective output transformers OT_a . . . OT_e of the channels in the order in which each of said frequencies is to act as a carrier frequency for the channel. In parallel with these connections, the frequency sources are further connected respectively, to high

resistances $R_a \dots R_e$, which, in turn, are connected at their other terminals to certain movable springs of the key-set KS, the stationary springs of said key-set being all multiplied and connected to the input side of transformer TM to the output side of which is connected a suitable transmission medium such as, for example a transformer TM and a pair of transmission conductors TC_1 and TC_2 . The reason for connecting the frequency sources $f_a \dots f_e$ to the key-set by way of the resistances $R_a \dots R_e$ is to make the value of the signal voltage applied to the receiving channels small as compared to the "carrier" voltage of the same frequencies applied to the channels as carriers.

The input receiving circuit of my invention comprises as many channels of double-balanced modulators as there are frequencies to be used for signal transmission. In the embodiment of the invention herein disclosed and described by way of example, it is assumed that there will be five signal frequencies, in consequence of which five modulator channels $MC_a \dots MC_e$ are provided, one for each of the frequencies $f_a \dots f_e$ as shown. The number of channels that may be used, however, is limited by the fourth term of Equation 1; that is, by the term

$$\frac{2E}{3\pi} \cos(3\omega_c - \omega_o)t$$

This term will become a constant (in other words, a direct current component) if any signal frequency is equal to three times the value of any carrier frequency in the system, thus making the range less than two octaves. However, as a constant frequency difference between signal frequencies can be maintained for a given degree of selectivity, the lowest signal frequency may be made as high as desirable to include any specified number of channels in a two-octave range.

Each of the modulators $MC_a \dots MC_e$ is identical in electrical properties to the one conventionally shown in Fig. 1 and discussed above except that the lower terminal of the output side of each of the output transformers $OT_a \dots OT_e$ is grounded to complete the circuit to its associated carrier frequency source, which is also grounded. The center taps of the output side of the input transformers $IT_a \dots IT_e$ and those of the input side of the output transformers $OT_a \dots OT_e$ are each connected to the direct current relay that will respond to the direct current component of the frequency in the incoming pulse for which the same frequency is utilized in the channel as the carrier frequency. Thus relay MCR_a is connected to the center taps of the input and output transformers IT_a and OT_a of channel MC_a which is reserved for response to frequency a , the same frequency being used as the carrier frequency for this channel by the connection of frequency source f_a to the output side of the transformer OT_a . In the same way, direct current relay MCR_b is connected to the center taps of the input and output transformers IT_b and OT_b of channel MC_b and so on up to and including relay MCR_e which is connected to the center taps of the input and output transformers IT_e and OT_e of channel MC_e .

Each of the frequency sources $f_a \dots f_e$ is wired to one side of the respective high resistances $R_a \dots R_e$ and the other side of each of said resistances is wired to a moving spring of the key-set KS in accordance with the combination of frequencies called for by the pulse to be transmitted by the depression of the individual numerical

keys 1 . . . 0 of the key-set KS. It may be assumed, by way of illustration, that each pulse will consist of a combination of two frequencies which are chosen in accordance with the following code and that, accordingly, the resistances $R_a \dots R_e$ are wired to the various numerical keys in the manner shown in order that the depression of each of the keys will complete two circuits from the two frequency sources involved to the input side of the transformer TM:

Pulse code

Digit	Frequencies transmitted
1	a, b
2	b, c
3	a, c
4	a, d
5	c, e
6	c, d
7	a, e
8	b, e
9	a, e
0	b, d

Now let it be assumed that, after the receiving channels $MC_a \dots MC_e$ have been made ready for the reception of the signals by the connection of the frequency sources $f_a \dots f_e$ to the output side of their respective output transformers, digit key 1 is depressed. A circuit will then be completed from ground on one side of source f_a , through the circuit of said source, resistance R_a , upper contacts of key 1, input winding of transformer TM to ground. Another circuit will also be completed from ground on one side of source f_b , through the circuit of source f_b , resistance R_b , lower contacts of key 1 to ground over the input winding of transformer TM. The current composed of frequencies a and b will be maintained over the circuit path above traced as long as key 1 is kept depressed and this current is induced in the secondary winding of transformer TM wherefrom it is transmitted over conductors TC_1 and TC_2 and received on the input side of the input transformers $IT_a \dots IT_e$ of all the receiving channels $MC_a \dots MC_e$, the input windings of all said transformers being connected in multiple.

Since the current is composed of frequencies a and b , then, since frequencies a and b are connected as carriers to channels MC_a and MC_b , respectively, frequency a will enter channel MC_a to produce an output voltage across the center taps of transformers IT_a and OT_a that will have a direct current component which, flowing through the winding of relay MCR_a , will cause said relay to operate. In the same manner, frequency b will be impressed upon channel MC_b , and since frequency source f_b is connected to this channel as a carrier, the output voltage across the center taps of transformers IT_b and OT_b will have a direct current component which, flowing through the winding of relay MCR_b will cause said relay to operate. Pulse frequencies a and b will, of course, be impressed upon the remaining channels (as well as upon channels MC_a and MC_b in which frequency a will further be impressed upon channel MC_b and frequency b will further be impressed upon channel MC_a), but since these channels have carrier frequencies different from the signal frequencies, then, as above described, their output voltages will comprise all alternating current components to which the individual channel relays offer a high impedance and, therefore, will remain unaffected thereby.

Relay MCR_a and relay MCR_b remain operated

as long as key 1 remains depressed, after which the signal circuit is disrupted and the relays will release. In the same manner, the depression of other numerical keys will cause the application of corresponding combinations of two frequencies to the transmission medium and the consequent operation of the two relays of the channels to which the signal frequency sources are connected as carriers.

The operation of the channel relays $MCR_a \dots MCR_e$, in combination of twos in response to a pulse of two frequencies, represents a setting of the relays that designates an item of intelligence conveyed by the pulse. And, of course, if this intelligence is to have further utility, the various settings of the channel relays will have to be permanently registered in a suitable device the character and construction of which and the manner of its interconnection to the channel relays will depend upon the code in which this intelligence is to be registered in the registering device. If, for example, the "registering" code is the same as the "transmitting" code given above, then the register may take the form of a plurality of groups of five relays to be operated locally from the contacts of the channel relays $MCR_a \dots MCR_e$ through a suitable switching medium which, after the registration of a pulse, transfers the conductors connected to the contacts of the channel relays from one group of registering relays to the next group of registering relays, the number of such groups of relays being dependent upon the number of pulses which are to be sequentially registered.

On the other hand, if the registering code is different from that of the transmitting code, and the pulse is to be registered on less (or more) than two relays per pulse as received by the channel relays, then a suitable translating device must be interposed between the channel relays and the register relays which will respond to the operation of the channel relays, two at a time, and translate this operation into the activation of the proper number of relays in the register, the operation of which will constitute, in its own code, the registration of the intelligence conveyed by the pulse. The character of the translator will depend, of course, on the construction of the register and the code for which it is adapted for response. Thus, for example and purely by way of illustrating the interconnection of a suitable translator with a register when the transmitting and receiving codes are different, we may suppose a register having a group of five relays 1, 2, 4, 5 and Z per digit which, to register each of the ten digits therein, will require relay 1 to be operated for the digit 1, relay 2 for the digit 2, relays 1 and 2 for the digit 3, relay 4 for the digit 4, relay 5 for the digit 5, relays 1 and 5 for the digit 6, relays 2 and 5 for the digit 7, relays 1, 2 and 5 for the digit 8, relays 4 and 5 for the digit 9 and relay Z for the digit zero. A translator inter-connected between the channel relays and such a register that will function in response to the operation of two channel relays per digit to cause the operation of the relays in the register in the order named for each digit, must be adapted to close circuits to the relays of the register in the order named. Such a translator is shown in Fig. 3 in the boxed portion thereof designated "Translator" to the left of which are shown the channel relays $MCR_a \dots MCR_e$ in response to the operation of two of which, according to the transmitting code, will cause the translator to function, and to the right of which is indicated a register

with conductors 1, 2, 4, 5 and Z interconnecting the translator with a plurality of groups of relays therein (not shown) having the same designation as the conductors, which are transferred from one group of register relays to the next by a suitable switching circuit. The translator shown is that disclosed and claimed in copending application of B. D. Holbrook Serial No. 375,713, filed January 24, 1941, (except for relay LS which is added thereto to provide correct circuit operations in the absence of channels equipped with electronic devices as used in said copending application), and since said translator is not a part of this invention, and since the same is amply described in said copending application, reference is made thereto for an understanding of the principle of translation, the designation of the various relays of the translator as shown in Fig. 3 of my drawings having been made identical with those in the drawing of said copending application in order that the operation of the translator, with the signal system of my invention, may be the more readily followed from the description contained in said copending application.

While I have described the principle of my invention in connection with a specific embodiment thereof relative to its operation with a given code of signal pulses, it is to be understood that various other embodiments thereof may be made by those skilled in the art without departing from the spirit of the invention as defined within the scope of the appended claims.

What is claimed is:

1. A signal receiving circuit for an alternating current signal system having a rectifier network responsive to a signal frequency transmitted over said system, a carrier source of current connected to said network having the same frequency and phase as the signal frequency, and means connected to said network responsive to the direct current component of the output current of the combined carrier and signal frequency applied to said network.

2. An alternating current signal system comprising a transmitting station, a receiving network containing rectifiers, a transmission medium interconnecting said transmitting station and said receiving network, a frequency source connected to said transmitting station and to said receiving network whereby said transmitting station is caused to transmit the frequency from said source over said transmission medium for application to said network as a signal, and means connected to said network responsive to the direct current component of the output current of the frequency applied to the network directly from the source and the frequency applied to the network from the transmission medium as a signal.

3. An alternating current signal system comprising a transmitting station, a receiving network containing rectifiers, a transmission medium interconnecting said transmitting station and said receiving network, a source of signal frequency current connected to said transmitting station and to said receiving network whereby said transmitting station is caused to transmit current from said source over said transmission medium for application to said network as a signal, means for reducing the intensity of the signal current emitted from said transmitting station, and direct current means connected to said network responsive to the direct current component of the output current of the frequency applied to the network directly from the

source and the same current applied to the network from the transmission medium as a signal.

4. In an alternating current signal system, the combination with a transmitting station and a transmitting medium, of a receiving network for a single frequency of a current comprising a plurality of superimposed frequencies transmitted from said station, which comprises a source of signal current, a first transformer electrically coupled to said transmission medium, a second transformer connected to said source of signal current, said source of signal current being also connected to said transmitting station, a double-balanced rectifier interconnecting said two transformers, and a direct current relay connected to the output terminals of said transformers which is responsive to the direct current component of the output current of the frequency applied to said second transformer by said source of signal current and of the same frequency applied by said transmitting station to said first transformer over said transmitting medium.

5. A signal receiving circuit for an alternating

current signal system comprising a transmitting station, a plurality of rectifier networks, one for each signal frequency transmitted over said system, a transmission medium interconnecting said transmitting station and said plurality of rectifier networks, sources of signal frequencies connected in common to said transmitting station and to said plurality of rectifier networks, the connection of said sources to said transmitting station being determined by the combination of signal frequencies to be transmitted by the operation of said station and the connection of each of said sources to each of said rectifier networks being determined, respectively, by the allocation of each of the signal frequencies to each of said networks as carriers therefor, and a direct current relay connected to the output of each of said networks which is responsive to the direct current component of the output current of the network to which the relay is connected and to which the frequency connected as a carrier is applied as a signal.

MASON A. LOGAN.