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TELEPHONE SYSTEM

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

In the ordinary alternating current pulse receiver, a band-pass filter is usually provided for each frequency in the signal, each filter having a different mid-band frequency substantially equal to the numerical frequency of the corresponding transmitting signal oscillator. The output of each band-pass filter is connected to a suitable voltage detector which then operates on the frequency in the signal current passed by the band-pass filter, said filter attenuating all other frequencies in the signal. 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 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 in the signal current to be received, a pair of double-balanced modulators of the rectifier type, each of which is supplied continuously with a carrier frequency substantially equal to the frequency of the signal. However the carrier current supplied to one modulator of a pair is shifted 90° in phase from the same carrier current supplied to the other modulator. To indicate the presence of the frequency in a signal, a double wound relay with mechanically linked armatures is provided, one of its windings being connected to the output of one of the modulators and the other connected to the output of the other modulator. The linked armatures cause the pull on each armature to add directly to actuate the contact springs.

In my copending application Serial No. 421,615, filed Dec. 4, 1941, a system of the above type is disclosed in which one double-balanced modulator is used for each channel and a frequency supply source is used therein both as the signal and as the carrier in order to provide an identity of frequency and phase between the two so that a

direct current component will be available at the output terminals of the modulator. It is this component of the modulated currents that is effective to operate a direct current relay provided thereat. Such a system, however, limits the signaling distance since it requires negligible phase shift between the signal voltage received by the detector from the transmitting station and the voltage that drives the balanced modulator, a condition which also makes it necessary to use the same frequency source both for the transmitter and the receiver.

According to the present invention, phase requirements between the signal and carrier voltages are entirely eliminated and, further, some frequency deviation is also permitted between the signal frequency supply sources at the transmitting station and those applied to the receiving modulators. Hence the transmitting and receiving stations may, according to the present invention, be remote from each other and entirely independent sources of signal and carrier currents may be used at the transmitting and receiving stations, respectively.

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 drawing in which Fig. 1 shows the paired modulators used in the invention while Fig. 2 shows the signal system of my invention as comprising a transmitting station represented by the key-set KS with five sources of frequency currents $f_a \dots f_e$ wired to the key-set KS in accordance with a code that permits the application of said frequencies to the transmission conductors TC and RC two at a time by the depression of the individual keys of the key-set, and a receiving station comprising five channels $MC_a \dots MC_e$, one for each of the frequencies that enter into the signal currents to be transmitted, a source of carrier current supply for each channel corresponding to the nominal frequency to be passed by the channel, said frequency source being connected by a suitable network to each of the paired modulators so as to be displaced in phase by 90° with respect to each other, and a relay $MCR_a \dots MCR_e$ for each channel, said relay being a double wound relay with two armatures mechanically linked as, for example, the one disclosed in Patent 1,207,736 issued to O. F. Forsberg on December 12, 1916.

Before describing the operation of my invention, reference is directed to Fig. 1 which shows the fundamental principle of the invention. At the sending end, an oscillator of frequency f_0

feeds the transmission line, this line having both attenuation and phase shift. The received voltage from the transmission line is applied to two modulators connected in parallel and each comprising an input transformer IT, an output transformer OT and a double-balanced rectifier bridge connected to the output and input windings, respectively, of the input and output transformers. Between the central taps of the input and output transformers of the upper modulator is connected one winding of a relay MCR— and between the central taps of the input and output transformers of the lower modulator is connected the other winding of relay MCR—, the armatures of both windings being mechanically linked together so that the operation of either winding will close a common pair of contacts. Each of the modulators is supplied by a carrier frequency f_c (nominally the same as f_0) but having a phase difference of 90° with respect to each other, introduced by the network comprising condenser CN and resistance RN connected series aiding between the high input impedance amplifiers AMP of the two channels and the carrier frequency source f_c . Of course, separate oscillators differing in phase by 90° could be connected to each output transformer of the modulators.

If frequencies f_0 and f_c are of slightly different frequency, the current in each winding of the relay MCR— primarily will consist of a low frequency alternating current. The frequency of this current will be equal to that produced by the difference frequency between the carrier and signal voltage. There will also be present higher frequency terms due to other modulation products. These frequencies, however, are high and only a small amount of high frequency current will flow in the coils of the relay MCR— because of the inductive reactance of its windings. Hence the current which will be effective to operate relay MCR— will be only that which is due to the low frequency output voltage of each of the modulators. In the event, however, that the signal frequency is identical with that of the carrier frequency, that is, no frequency deviation exists between the two, a steady direct current component will be available in either or both windings of relay MCR—.

As noted above, carriage voltage fed to one modulator is shifted 90° in phase from the voltage supplied to the other associated modulator. When a signal source f_0 is applied to a pair of modulators having carrier voltages differing in phase by 90° , the output frequency equal to the difference frequency of the signal f_0 and carrier f_c will be shifted in one modulator output 90° out of phase with respect to the output of the other modulator. This is true regardless of the phase of the input signal source. Since one winding of relay MCR— is connected to the output of one of the modulators and the other winding of the relay is connected to the output of the other modulator, the modulated signal voltage applied to one winding of the relay will be 90° out of phase with the modulated signal voltage applied to the other winding, and since the impedances of the two windings are nominally equal, the steady state current in the two windings are 90° out of phase. Thus, if the current in one winding is designated as $I \sin \omega t$, the current in the other winding can be designated as $I \cos \omega t$. The armature pull due to each winding is, however, approximately proportional to the square of the current, and since the total armature pull is equal to

the sum of the pulls exerted by the two armatures, the total steady state pull P is:

$$P = KI^2(\cos^2 \omega t + \sin^2 \omega t) = KI^2 = \text{constant}$$

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 Fig. 2, the frequency sources $f_a \dots f_e$, which may be of any suitable construction each capable of emitting, respectively, the single frequencies arbitrarily indicated by the subscripts $a \dots e$, are connected, at the transmitting station, on the one side to conductor RC extending to the receiving channels and, on the other side over high resistances $R_a \dots R_e$, to certain moving springs of the key-set KS, the stationary springs of which are all multiplied and connected to conductor TC, also extending to the receiving channels.

The input side of the receiving portion of the circuit of my invention comprises as many channels of paired 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 channels $MC_a \dots MC_e$ are provided, each comprising one pair of double-balanced modulators for each of the frequencies $f_a \dots f_e$ as shown.

Each of the pair of modulators in each channel is identical in electrical properties to the one conventionally shown in Fig. 1 discussed above, and the conductors TC and RC are multiplied to the input windings of the input transformers $IT_a \dots IT_{2a}$ of each of the modulators. The center taps of the output windings of the input transformers $IT_a \dots IT_e$ and the center taps of the input windings of the output transformers $OT_a \dots OT_e$ of the upper modulators of each channel are each connected to one winding, respectively, of relays $MCR_a \dots MCR_e$ while the center taps of the output windings of the input transformers $IT_{2a} \dots IT_{2e}$ and the input windings of the output transformers $OT_{2a} \dots OT_{2e}$ are each connected, respectively, to the other winding of said relays. Thus, the upper winding of relay MCR_a is connected to the center taps of the transformers IT_a and OT_a of the upper modulator of channel MC_a , which is adapted for response to frequency a , while the lower winding is connected to the center taps of transformers IT_{2a} and OT_{2a} of the lower modulator of this channel. In the same way, the two windings of relay MCR_e are connected to the center taps of the input and output transformers of the two modulators of channel MC_e , the connection of corresponding relays to the paired modulators of other channels (channels MC_b , MC_c and MC_d being merely indicated in the drawing) being the same.

Each pair of modulators of a channel is supplied, through suitable high input impedance amplifiers AMP, by a separate carrier oscillator the nominal frequency of which is the same as the signal frequency which the channel is adapted to detect and, in any pair of modulators, the carrier supplied to one member is shifted 90° in phase from the carrier in the other member because the voltage drop across a condenser CN— in series with a resistor RN— lags 90° behind the voltage drop across the resistor RN—. The registration of any digit is then accomplished by the simultaneous operation of two of the channel relays $MCR_a \dots MCR_e$.

As already stated, the frequency sources at the

transmitting station are wired to the conductor RC and to the moving springs 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 $R_a . . . R_e$ are wired to the various numerical keys of key-set KS in the manner shown in order that the depression of each of the digit keys will complete two circuits from the two frequency sources involved to the input side of the parallel transformers $IT_a . . . IT_e$ of the receiving channels $MC_a . . . MC_e$.

Pulse code

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

Now let it be assumed that after the receiving channels $MC_a . . . MC_e$ have been made ready for the reception of the signals by the connection of the carrier frequency sources $f_a . . . f_e$ to the amplifiers AMP of the paired modulators of the various channels, digit key 8 is depressed. A circuit will then be completed from one side of signal frequency source f_a , resistance R_a , left contacts of key 8, conductor TC, the input windings of the transformers $IT_a . . . IT_e$ in parallel, conductor RC, to the other side of signal frequency source f_a . Another circuit will be completed from one side of signal frequency source f_e , resistance R_e , right contacts of key 8, thence as previously traced to conductor RC, to the other side of signal frequency source R_e . The current composed of frequencies a and e will be maintained over the circuit path above traced as long as key 8 is kept depressed.

Since the current is composed of frequencies a and e , then, since frequencies a and e are connected to channels MC_a and MC_e , respectively, as carriers, frequency a will enter the two modulators of channel MC_a to produce a low frequency two phase current one phase of which, available across the center taps of the windings IT_a and OT_a , will flow through the upper winding of relay MCR_a while the other phase, available across the center taps of transformers IT_{2a} and OT_{2a} , will flow through the lower winding of relay MCR_a . In the same manner, frequency e will be impressed upon the two modulators of channel MC_e , and since the frequency source f_e is connected to this channel as a carrier, the output voltage across the center taps of the input and output transformers of its two modulators will be productive of a similar two phase current that will flow through the windings of relay MCR_e causing its operation. Pulse frequencies a and e will, of course, be impressed on the remaining channels (as well as upon channels MC_a and MC_e with frequency a impressed upon channel MC_e and frequency e 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 currents of higher frequency components to which the individual channel relays MCR will offer a high impedance and will remain unaffected thereby.

The input receiving channel of my invention comprises as many channels of paired 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 $MC_a . . . MC_e$ are provided, one for each of the frequencies $f_a . . . f_e$ shown. The number of channels that can be used, however, is limited by the fourth term of Fourier's equation; that is by the term

$$\frac{2E}{3\pi} \cos (3\omega_c - \omega_0) t$$

This term will become a constant (in other words, a direct current component) if any 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 frequency range.

Relay MCR_a and relay MCR_e remain operated as long as key 8 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 conductors TC and RC and the consequent operation of the two relays of the channels to which the signal frequency sources are connected on their output side as carriers.

The operation of the channel relays $MCR_a . . . MCR_e$, in combination of twos in response to a pulse of two frequencies, represents a setting of the relays that designates the intelligence to be 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. Since the invention is not concerned with the manner or means in which the transmitted intelligence is either registered or utilized, such means are not disclosed except schematically as a "registering circuit" responsive to the operated contacts of the channel relays, reference being made to my above-mentioned copending application for a disclosure of one type of device by which the received pulses may be registered.

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 pair of rectifier networks for each signal frequency trans-

mitted over said system, a carrier source of current connected to each of said rectifier networks having substantially the same frequency as the signal frequency and displaced in phase by 90° from each other, and means connected to said pair of rectifier networks which is responsive to the low frequency two phase components of the output current of the combined carrier and signal frequencies applied to said pair of networks.

2. An alternating current signal system comprising a transmitting station, a receiving network including a pair of balanced ring modulators, a transmission medium interconnecting said transmitting station and said receiving station, a frequency source connected to said transmitting station for application as a signal to said pair of balanced ring modulators, a carrier frequency source connected to each of said modulators of substantially the same frequency as the signal frequency and displaced in phase by 90° from each other, and electromagnetic means connected to each of said modulators which is responsive to the low frequency two phase components of the output current of the frequencies applied to said pair of modulators as carriers and the signal frequency applied to the said pair of modulators from the transmission medium as a signal.

3. An alternating current signal system comprising a transmitting station, a receiving station comprising a pair of balanced rectifier networks, a transmission medium interconnecting said transmitting station and said receiving station, a source of signal frequency current connected to said transmitting station whereby current of the frequency generated by said source is transmitted from said transmitting station over said transmission medium for application to said receiving station as a signal, a two phase current supply of substantially the same frequency as the signal frequency connected to said pair of balanced rectifier networks, an electromechanical device having two mechanically linked armatures and a winding connected, respectively, to each of said balanced rectifier networks, each one of which winding is responsive to one of the two phases of the low frequency component of the output current produced by the frequency applied to the network as a signal from the transmitting station and the frequencies applied to the network as a carrier.

4. In an alternating current signal system, the combination with a transmitting station and transmitting medium of a receiving network for signal frequency signals transmitted from said station which comprises a source of signal cur-

rent of a certain frequency at said transmitting station, a pair of double-balanced rectifier networks, a pair of conductors interconnecting said transmitting station and said networks, a source of current of substantially the same frequency as the signal current connected to one of said double balanced rectifiers, a source of current substantially of the same frequency as the signal current connected to the other of said double-balanced rectifiers but displaced 90° in phase from the source connected to said one of said pair of double-balanced rectifiers, and a two winding relay having two separate armatures mechanically interlinked, one of said windings being connected to the output terminals of one of said pair of double-balanced rectifiers and the other of said windings being connected to the output terminals of the other of said pair of double-balanced rectifiers, whereby each of said windings operates both armatures in response to the low frequency components of the output current produced by the modulation of the signal current applied to each of said double-balanced rectifiers from said transmitting station over said transmission medium and each of the sources of current separately applied to each of said balanced rectifiers.

5. A signal receiving circuit for an alternating current signal system comprising a transmitting station, a plurality of pairs of double-balanced rectifiers, one pair for each signal frequency transmitted over said station, a transmission medium interconnecting said transmitting station with said plurality of pairs of double-balanced rectifiers, sources of signal frequencies connected to said transmitting station, the connection of said sources to said station being determined by the combination of signal frequencies to be transmitted by the operation of said station, a source of signal frequency connected to each of one of said double-balanced rectifiers, the sources connected to each pair of said double-balanced rectifiers being substantially of the same frequency as the signal frequency allocated to each of said pairs of double-balanced rectifiers and shifted in phase by 90° from each other, and a direct current responsive means connected to the output of each pair of said double-balanced rectifiers which is responsive to the low frequency current components of the output current produced by the signal frequency transmitted from said station and applied to the pair of double-balanced rectifiers which are allocated to pass said frequency, and the frequencies produced by the frequency sources connected to each of said pair of rectifiers.

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