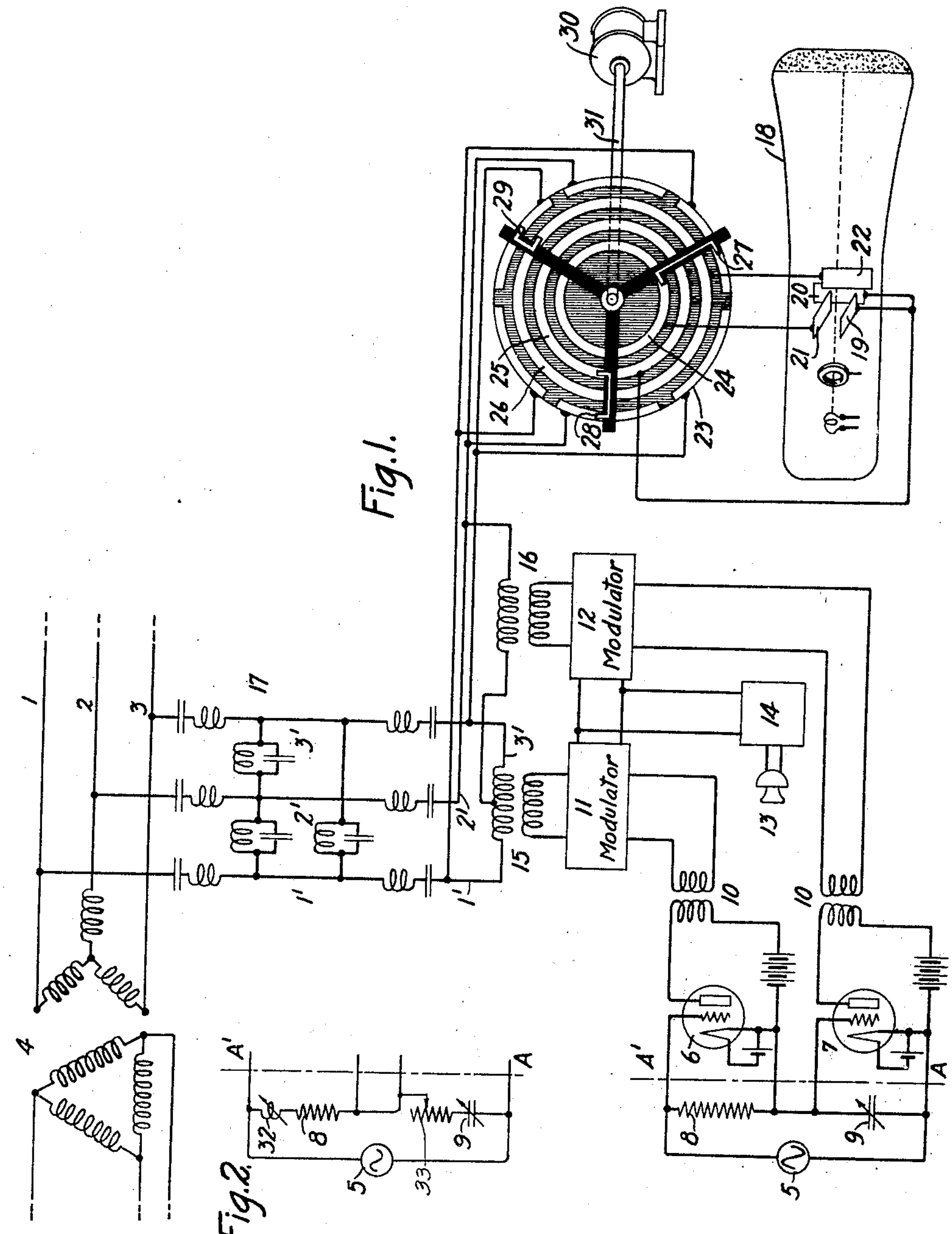
May 12, 1931. F. X. RETTENMEYER 1,804.952

WAVE SIGNALING SYSTEM

Filed Nov. 21, 1925



Inventor:
Francis X. Rettenmeyer
by E. W. Adams Att'y.

Patented May 12, 1931 **1,804,952**

UNITED STATES PATENT OFFICE

FRANCIS X. RETTENMEYER, OF MONTCLAIR, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

WAVE SIGNALING SYSTEM

Application filed November 21, 1925. Serial No. 70,529.

This invention relates to three-phase carrier wave communication systems and more particularly to systems for selectively transmitting three-phase modulated waves.

An object of the invention is to provide a power-line carrier wave signaling system which utilizes all three phases of a three-phase power line, and in which the currents in the different phases are mutually balanced, whereby the stray, or interfering, field of the system is reduced to a minimum.

An object is to generate a three-phase modulated carrier wave in which the mutual three-phase balance is secured for both carrier and side band waves.

A further object is to provide a greater degree of secrecy in power line signaling systems. In very high voltage power lines, the conductors are spaced apart by substantial amounts, and if one only or two of the wires are used for signaling purposes, the signaling currents create a field in the neighborhood of the line sufficiently strong to permit the signals to be intercepted by unauthorized persons using properly adapted receivers. This is particularly true with regard to systems employing high frequency carrier waves, such, for example, as systems in which the power line is used as a trunk connection for transmitting entertainment programs between distribution centers. The balanced distribution of the currents in the three phase wires reduces the external field and increases the secrecy of transmission.

In accordance with the invention a three phase carrier wave is produced from a single phase wave in two steps, the first step being the production of a two-phase wave and the second step being a conversion from two-phase to three-phase by means of the well-known Scott transformer. Modulation is effected by modulating simultaneously both phases of the two-phase wave. The conversion from two to three-phase takes place without any modification of the phases of the side band waves, since the Scott type of transformation is but little affected by changes of frequency.

For the successful operation of the invention it is necessary to provide, in addition to the means for generating the three-phase waves, means for selecting and transmitting exclusively the waves of the desired frequency, and also means for maintaining the correct mutual balance of the three phases.

Special features of the invention include a three phase broad band wave filter, and an indicating device for indicating the balance of the phases.

The nature of the invention and the mode of its operation will be fully understood by referring to the following detailed description and the accompanying drawings which forms a part thereof, and of which Fig. 1 shows the embodiment of the invention in a power line carrier signaling system; and Fig. 2 shows a preferred source of the two-phase carrier wave.

In the figures 1, 2, and 3, are the three conductors of a three-phase power line which is connected to a three-phase power generator through transformer 4. A single phase source of carrier waves is shown at 5, waves from which are impressed in quadrature upon the input terminals of vacuum tube amplifiers 6 and 7, the quadrature relationship being secured by the series connection of resistance 8 and condenser 9 in the input circuits of amplifiers 6 and 7 respectively.

The output waves from amplifiers 6 and 7 are transmitted through similar transformers 10 to separate modulating amplifiers 11 and 12 which are shown conventionally and in which the carrier waves are modulated in accordance with speech waves from microphone 13 which are impressed upon the two modulators jointly after amplification in amplifier 14.

The modulation process in each case is merely the modulation of a simple carrier wave, and the modulating devices 11 and 12 may be of the customary space discharge type using three-electrode vacuum tubes. A suitable type, for example, is the simplexed modulator disclosed in the U. S. Patent 1,343,307, issued June 15, 1920 to J. R. Carson, the input circuits preferably being arranged so that the low frequency waves are impressed on the balanced system in parallel and are suppressed in the output circuit.

In order that the quadrature of the two-phase waves may be maintained right through to the output of the modulating devices is is desirable that the apparatus in the channel of each phase be closely matched with the corresponding apparatus in the other channel.

Amplifier 14 serves merely to strengthen the speech singles, and may be of any well-known type.

As the result of modulation there is produced in the output circuit of each of modulators 11 and 12, an unmodulated component of carrier frequency components accompanied by two side band components. The carrier components are in quadrature, and the side bands are in quadrature with the corresponding side bands in the other channel.

For conversion from two-phase to three-phase the output waves from modulators 11 and 12 are impressed upon the primary windings of transformers 15 and 16, respectively, in which the conversion is accomplished in accordance with the Scott system. Transformer 15 has a secondary winding which is tapped at its mid-point, and which is connected at its outer terminals through two of the line wires of a three-phase filter 17, to power line conductors 1 and 3. The secondary winding of 16 is connected at one end to the mid-point of the secondary winding of 15, and at the other end it is connected through the third line wire of filter 17 to power conductor 2. The transformation ratios of 15 and 16 should have the relative values 1 and 0.867 respectively.

An advantage of the method used to convert from two to three phase is that the carrier and side band waves are all changed in phase by equal amounts, due to the fact that the transformers are uniformly efficient over a wide range of frequencies. If the conversion were effected by other phase changing means, such as wave filters, it would be necessary to perform the modulation in each of the three phases separately to avoid phase displacements of the side bands.

The modulated three-phase waves produced by the Scott transformation are transmitted to the line 1, 2, 3, through the three-phase broad band filter 17 which serves, not only to select the proper frequencies from the output of the modulators, but also to prevent the high voltage power currents from entering the carrier apparatus.

The filter is similar to the broad band filters described in U. S. Patent No. 1,227,113, issued May 22, 1917 to G. A. Campbell, but differs therefrom in that it is adapted to the transmission of a three-phase wave. The particular example of the filter shown is characterized by the combination of simple resonant circuits in series with the lines and simple anti-resonant circuits in shunt between the lines, the lines and the shunt circuits being resonant at the same frequency. The individual series circuits are all exactly alike in their electrical constants and the shunt circuits are also uniform. This type is adapted to transmit freely a band of frequencies centered around the common resonance frequency and determined in width by the ratio of the series to the shunt inductance.

It will be shown later that the design of the three-phase filter may be accomplished in accordance with the rules for the design of simple two-wire filters. It follows, then, that a three-phase filter can be constructed to correspond to each type of simple filter, and consequently that many other types than that shown may be used in the three-phase system.

The filter illustrated contains only one complete section, of symmetrical form and series terminated. Additional sections may be added if desired.

The method of designing the three-phase filter may be understood very readily by considering the transmission therethrough of the two-phase waves from modulators 11 and 12. By means of the Scott system of transformation these waves combine in three-phase relationship in the three-phase conductors, but it is nevertheless permissible, and for the present purpose, more convenient, to regard them as retaining their separate existences in the three wire system.

The waves from modulator 11 are impressed through transformer 15 upon the two lines 1′ and 3′ of the filter and thereafter on conductors 1 and 3 of the power line. Since the system is balanced the current waves from source 11 are confined to the circuits mentioned and do not traverse the third power conductor 2 of the third filter line 2′. Filter 17 must therefore act as a simple two-wire filter with reference to these waves. The effective elements are the four series resonant circuits in lines 1′ and 3′, the sum of the impedances of which constitutes the full series impedance of the effective filter section, and the three-shunt anti-resonant circuits, these being disposed in two parallel shunt circuits, one having two of the circuits in series. The effective shunt circuit is therefore equivalent to a single anti-resonant circuit having an impedance equal to two-thirds of that of the individual circuits.

This effective filter section may be proportioned to have the desired transmission range and to match the impedance of the wave channel in which it is effective. For detail design formulæ to determine the impedance elements in terms of the band limiting frequencies and the impedance, reference should be made to the patent to Campbell already mentioned, and to a paper in the Bell System Technical Journal Volume II, No. 1, January 1923, entitled, "Theory and design of uniform and composite electric wave filters" by Otto J. Zobel.

The formulæ in the latter of these references are explicit for the full series and the full shunt values of the impedance elements. Since four of the individual series circuits of filter 17 are combined to give the full series impedance of the effective filter, the inductances determined by the formulæ must be divided by four and the capacities multiplied by four to get the values for the individual circuits. Similarly, the shunt inductances computed from the formulæ must be multiplied by 1.5 and the capacities divided by 1.5. The procedure described enables the coefficients of the individual circuits to be determined and hence, by virtue of the symmetry of the structure, gives the design of the complete filter.

The waves from transformer 16 transverse line 2′ of the filter and return by lines 1′ and 3′ in parallel. In this case the effective filter section comprises a total series impedance equal to three times that of the individual series circuits, and a total shunt impedance equal to one half that of the individual shunt circuits. This filter section so comprised is found to have an iterative impedance three quarters of that of the filter effective to waves from transformer 15, but this is just as it should be, since the different transformation ratios of transformers 11 and 12 cause the impedances looking back into the two modulators to be in ratio of 1 to 0.75.

The invention as described so far provides for the production of three-phase modulated waves balanced with respect to both carrier and side band components, and also for the selection of the desired wave frequencies. A system constructed in accordance with the principles described would operate satisfactorily to transmit modulated three-phase waves, but due to changes that occur from time to time to upset the impedance balance of the system, the three-phase current balance does not remain constant and in consequence the secrecy of communication would be greatly reduced.

To prevent the loss of secrecy, means is provided for observing the condition of balance and also for restoring the system to a balanced condition.

The indicating means comprises a vacuum tube cathode ray oscillograph, having four deflecting electrodes 19, 20, 21 and 22 arranged in a square around the path of the cathode ray, and a motor driven commutator 23 by means of which the oscillograph deflecting plates may be connected severally to the three line wires of the filter 17. Two of the deflectors adjacent to each other are connected together so that in effect there are only three deflectors one for each phase. If the tube contained three deflectors symmetrically disposed about the ray a balanced three-phase voltage wave impressed upon the three deflectors would deflect the cathode ray so that the trace on the fluorescent screen of the tube would be a true circle. The effect of the unsymmetrical arrangement shown is to make the trace more like an ellipse.

When the wave is balanced, that is, when the phase voltages are equal in amplitude and phase difference, it makes no difference which deflector is connected to which phase or line, the trace produced has always the same form. If, however, the wave is unbalanced the trace will be distorted and the distortion will be different according to the order in which the lines are connected to the deflectors.

By means of motor-driven commutator 23, the order of interconnection between the lines and the deflectors is cyclically changed at a moderately rapid rate, whereby any lack of balance in the three-phase wave shows up as a rapid motion or blurring of the cathode ray trace.

The commutator comprises four concentric conducting rings, of which the three inner rings 24, 25, 26 are continuous, and the outer ring is divided into 6 equal parts. The rings and segments are insulated from each other by a solid insulating base on which they are mounted. Contact is made between the outer ring segments and the inner rings 24, 25 and 26, respectively by brushes 27, 28 and 29 which are carried on three radial insulating arms spaced apart 120° and mounted on a revolving shaft 31 which is driven by motor 30.

Deflectors 21, 19, and 22 are connected permanently to rings 24, 25 and 26 respectively, and the outer ring segments are connected together in diametrically opposite pairs, which are permanently connected to line wire 1′, 2′, and 3′, respectively, at the input end of filter 17.

This arrangement, by means of the rotating brushes, provides for the cyclic interchange of connections between the three phases of the system and the three deflectors of the indicating device.

Means for restoring the balance of an unbalanced system is shown in Fig. 2 which represents the preferred arrangement of the part of Fig. 1 to the left of the dotted line AA′. A small variable inductance 32 is inserted in series with resistance 8 and a small variable resistance 33 is inserted in series with condenser 9. Normally, the potential differences across 8 and 9 are in quadrature and their relative amplitudes can be adjusted by varying the capacity of condenser 9. If the system becomes unbalanced the balance may be restored by changing the relative amplitudes of the two-phase waves or by changing their phase difference, or, again, inductance 32 serves to increase the phase displacement and increasing resistance 33 operates to decrease it. Therefore by adjusting one or other of these elements, and by varying the capacity of condenser 9 if necessary, any unbalance of the three phase system can be corrected.

The method described has the advantage that it does not disturb the impedance and transmission characteristics of the two-phase and three-phase parts of the system when the adjustment is made.

What is claimed is:

1. A system for generating and transmitting modulated three-phase carrier waves comprising a single phase high frequency wave source having connected thereto an impedance network upon which the single phase waves are impressed to produce two waves differing in phase, separate transmission channels for said two waves, modulating devices included in said respective channels, a source of speech waves connected in common to said modulating devices whereby the said high frequency waves may be modulated simultaneously in accordance with a common speech wave, and a system of transformers having primary windings connected to receive the modulated waves, and having secondary windings adapted by interconnection and by their respective impedances to convert the modulated waves from said modulators to three-phase waves in balanced relationship.

2. A system for generating modulated three-phase waves comprising a single phase wave source, a phase splitting circuit connected thereto including in series relation an impedance substantially resistive and a second impedance substantially reactive, a space discharge amplifying system adapted to repeat the wave component impressed upon said resistive impedance, a second space discharge amplifying system adapted to repeat the wave component impressed upon said reactive impedance, means for modulating said repeated wave components in accordance with a common speech wave, and a system to receive the modulated waves and having secondary windings adapted by interconnection and by their respective impedances to convert the modulated waves into three-phase waves in balanced relationship.

3. A system in accordance with claim 2 characterized in this that the substantially resistive impedance included in the phase-splitting circuit consists of a resistance in series with a small variable inductance, and the substantially reactive impedance consists of a condenser in series with a small variable resistance, whereby the relative phases of the wave components impressed upon the amplifying systems may be varied without substantially changing their relative amplitudes.

4. A system for generating modulated three-phase waves comprising a three-phase line, a single phase source wave, a phase splitting network adapted to produce, from the wave supplied by said source, two electromotive force components of equal amplitude and in phase quadrature; a pair of similar space discharge amplifiers, means for impressing said electro-motive force components upon said respective amplifiers, a pair of similar modulating devices respectively adapted to receive the waves repeated by said amplifiers, a source of speech waves connected in common to said modulating devices, whereby said repeated waves may be modulated simultaneously in accordance with a common speech wave, and means for converting the modulated waves to three-phase modulated waves, said means comprising two transformers having equal primary windings connected to receive respectively the modulated waves, and having unequal voltage ratios of relative values 1 and 0.867, the secondary winding of the higher ratio transformer being connected at its two ends to two conductors of said three-phase line and the secondary winding of the lower ratio transformer being connected between the third conductor of said line and a mid-winding tap in the secondary winding of the other transformer.

5. In a three-phase wave transmitting system, a source of high frequency two-phase current, means for modulating said two-phase current with voice frequency currents, means for deriving a three-phase modulated current from said two-phase modulated current, a broad band wave filter comprising equal reactive impedances connected in series in each phase of said three-phase current and equal reactive impedences connected between the phases, said impedances being substantially free from resistance and having values such that the structure freely transmits a wave lying within a preassigned band of frequencies and attenuates waves outside said frequency band.

6. In a three-phase wave transmitting system, a source of two-phase modulated carrier current, means for deriving three-phase current from said modulated two-phase current, a three-phase line and a wave filter connected between the source of said three-phase current and said line, said wave filter comprising equal reactive impedance elements connected in series in each phase and equal reactive impedance elements connected in shunt between phases, said impedance ele-

ments having values precomputed in terms of two limiting frequencies and of the impedance of said source, whereby waves from said source having frequencies between said limiting frequencies are transmitted with small attenuation through the filter and waves of other frequencies are strongly attenuated.

7. In combination with a system in accordance with claim 2, means for selectively transmitting to a three-phase line the three-phase modulated waves converted by said transformer system, said means comprising a three-phase broad-band wave filter, having three line circuits including similar and similarly disposed reactive elements, and having shunt reactive elements constituting a symmetrical delta connection between said line circuits, said elements having values pre-computed in terms of the impedance of said transformer system and of the limiting frequencies of the side bands produced by modulation, whereby waves between said limiting frequencies are transmitted with small attenuation and waves of other frequencies are strongly attenuated.

8. In a wave transmission system the combination with a source of high frequency single phase current and means for deriving a three-phase modulated current from said source, of a balance indicator for said three-phase current comprising a cathode ray oscillograph having three deflecting electrodes adapted to deflect the cathode ray by electrostatic action, a commutating device, connections between contacts on said commutating device and said electrodes, additional connections between other contacts on said commutator and the separate phases of the transmission system, means for interconnecting said contacts, whereby the deflecting electrodes of the oscillograph are respectively connected to the three-phase conductors of the transmitting system, and means for cyclically interchanging the connections between the electrodes and the phase conductors.

9. In a wave transmission system, a polyphase power transmission line, a source of high frequency two-phase current, means for modulating said high frequency current with voice frequency current, means for deriving three-phase modulated high frequency signaling current from said two-phase modulated current, and means for transmitting said three-phase modulated current to the power transmission line, said last mentioned means comprising a broad band filter interposed between said source of current and said transmission line for selecting and transmitting the polyphase modulated signaling current from said modulating means to the transmission line.

10. In a wave transmission system, a polyphase power transmission line, a source of high frequency single-phase current, means for deriving two-phase current from said single-phase current and for effecting modulation with voice frequency current, means for deriving three-phase current from said two-phase modulated current and means comprising a broad band filter for selecting and transmitting the three-phase polyphase modulated signaling current to the transmission line.

In witness whereof, I hereunto subscribe my name this 17th day of Nov., A. D., 1925.

FRANCIS X. RETTENMEYER.