

Dec. 11, 1928.

1,694,473

B. W. KENDALL

HIGH FREQUENCY SIGNALING

Original Filed April 21, 1919

4 Sheets-Sheet 1

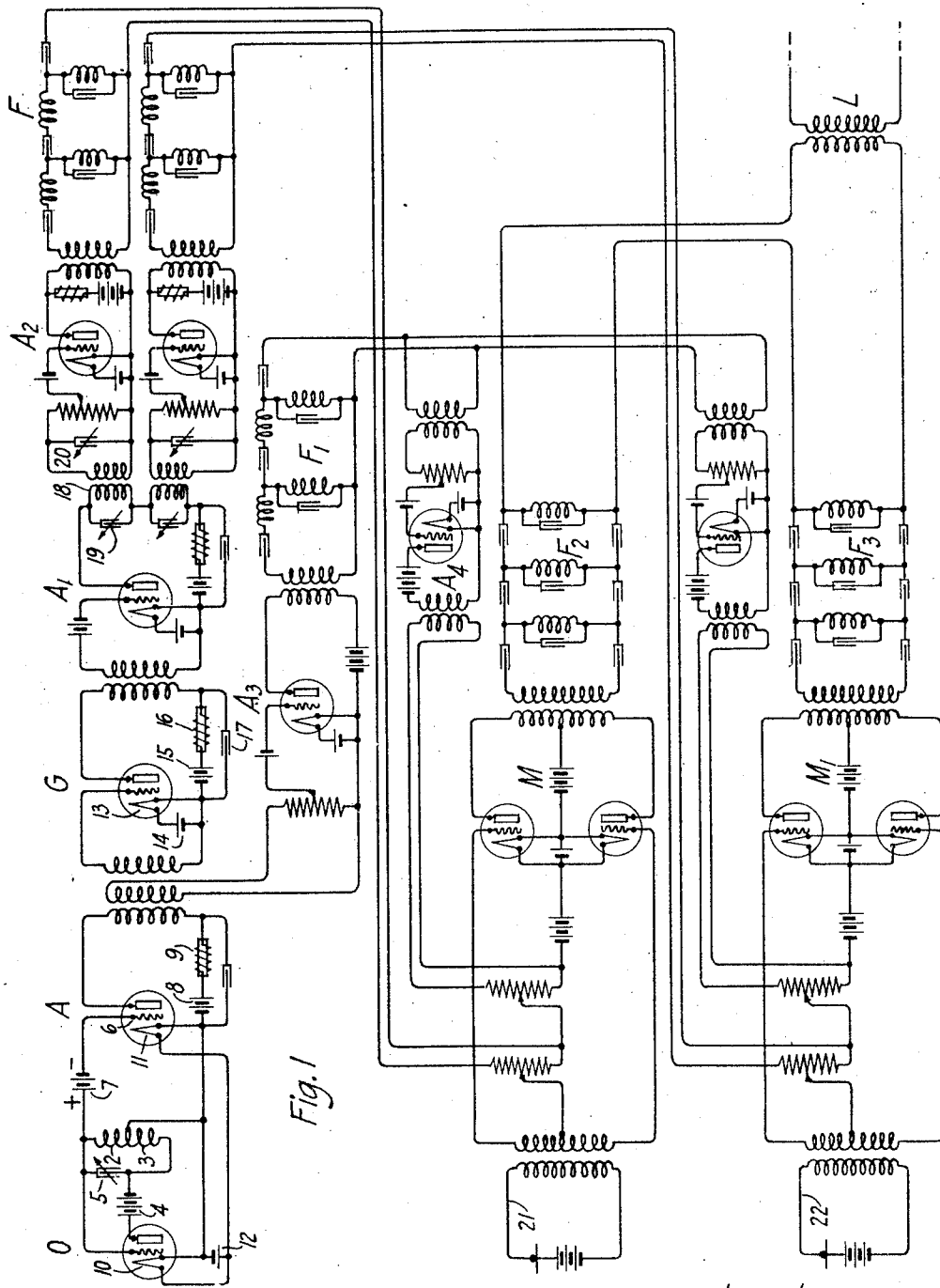


Fig. 1

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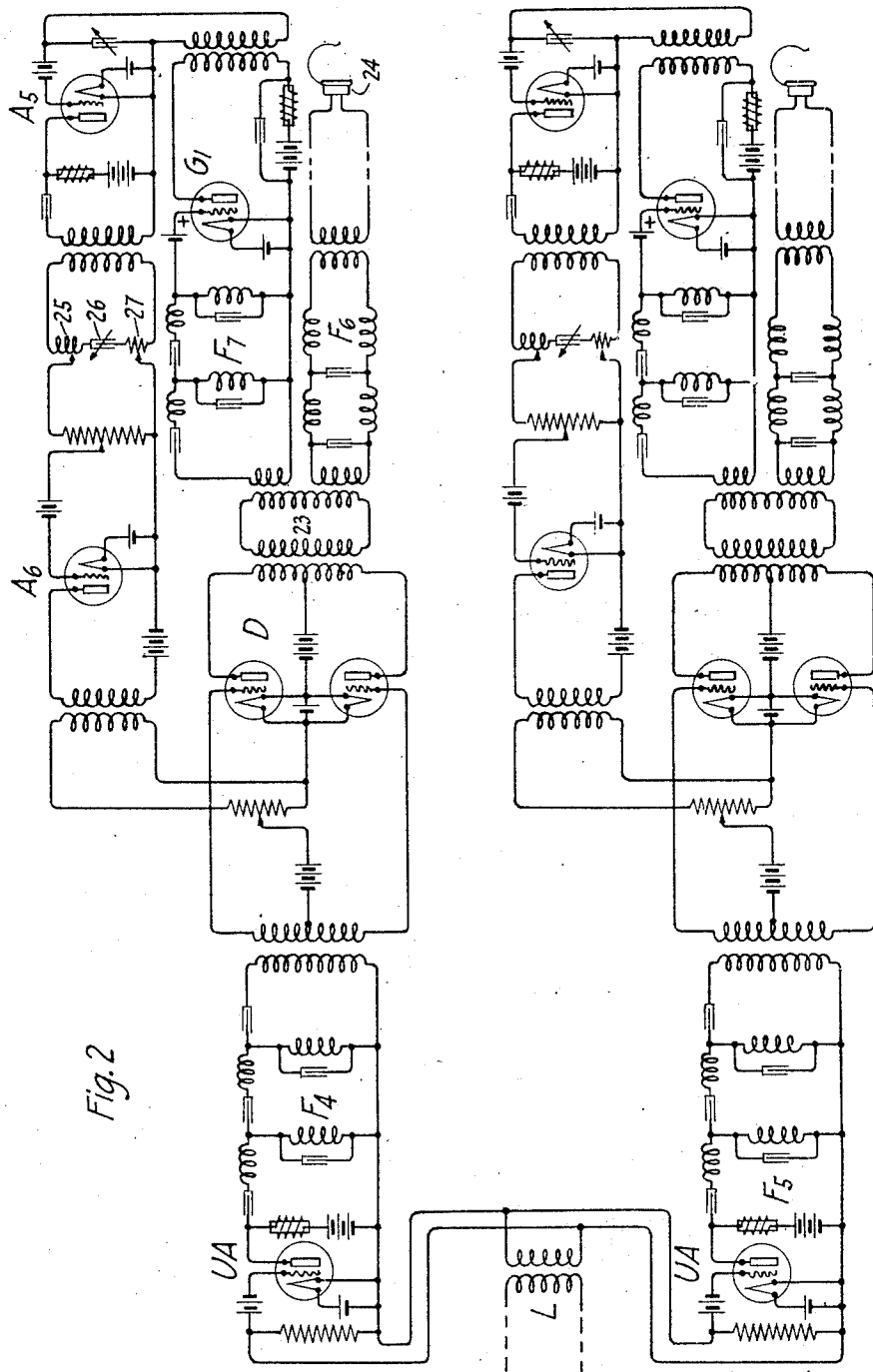
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4 Sheets-Sheet 3

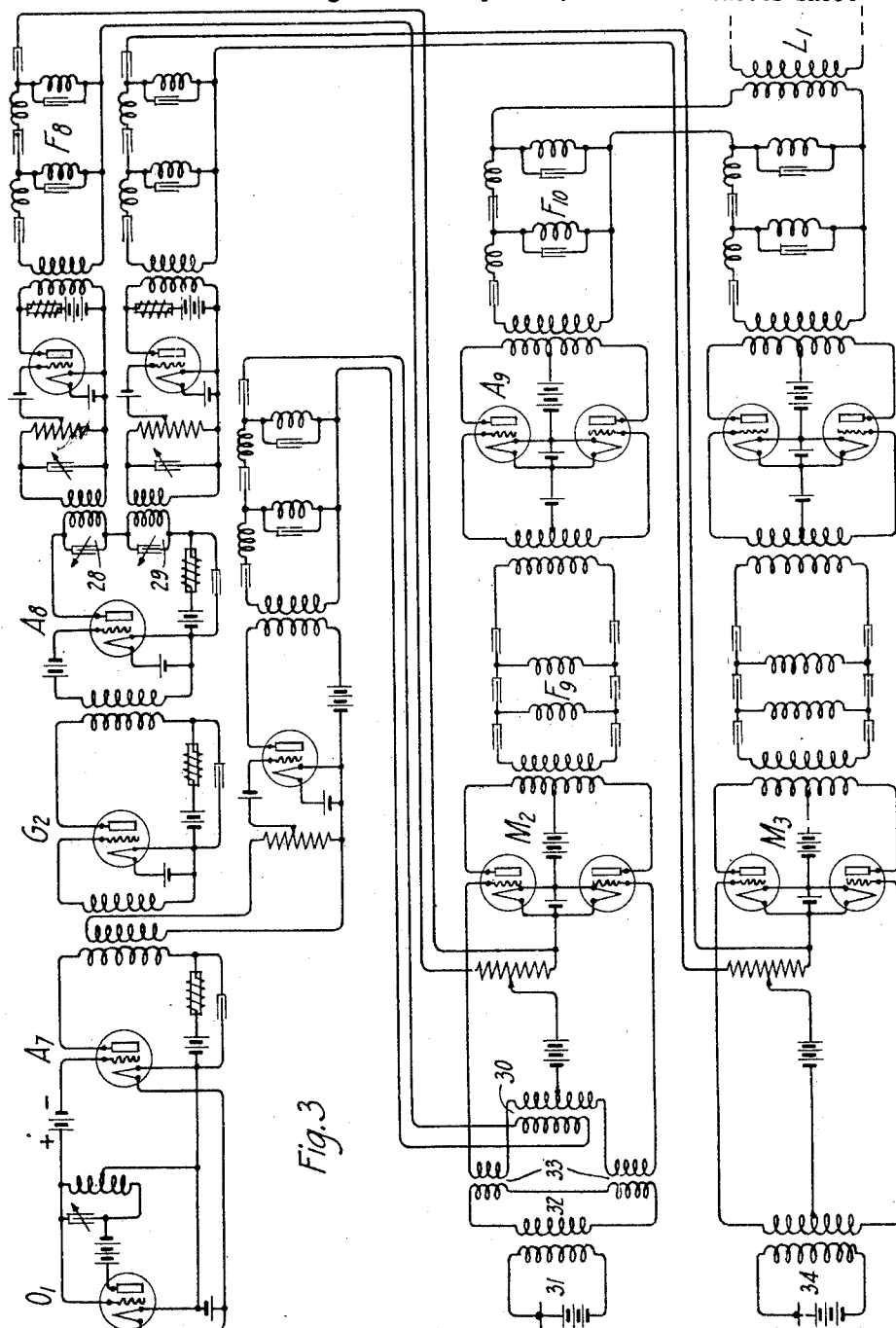


Fig. 3

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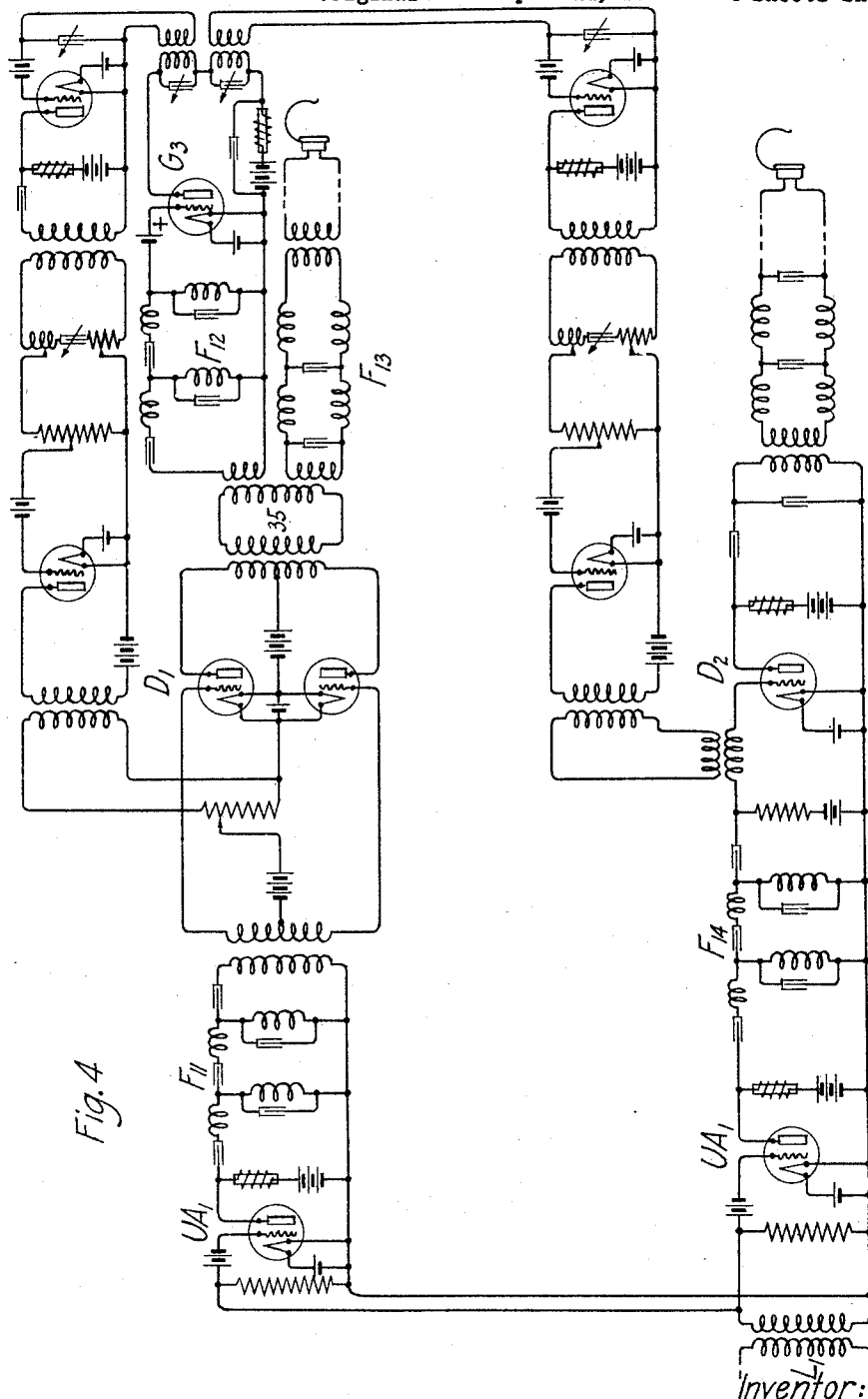


Fig. 4

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UNITED STATES PATENT OFFICE.

BURTON W. KENDALL, OF EAST ORANGE, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

HIGH-FREQUENCY SIGNALING.

Application filed April 21, 1919, Serial No 291,449. Renewed September 16, 1927.

This invention relates to high frequency signaling in which signals are transmitted as variations or interruptions of a carrier wave.

According to the homodyne method of carrier wave reception for telephony the amplitude of the detected signal is intensified by combining the received modulated carrier wave oscillations with locally generated oscillations of the carrier frequency. The locally generated oscillations will herein be termed reinforcing oscillations to differentiate them from the received carrier oscillations. If the carrier oscillations differ in frequency from the reinforcing oscillations, beats of the difference frequency are produced and may be manifested as a sound or noise which is superimposed upon the signal being received, thus interfering with a clear distinct reception of the signal.

The present invention has for an object to provide a method and means for insuring that the carrier oscillations and the reinforcing oscillations shall have substantially the same frequency. Another object of the invention is to provide a multiplex carrier telephone system. A further object of the invention is to provide a homodyne signaling system in which the phase of the reinforcing oscillations generated at the receiving station may be regulated with respect to that of the received carrier oscillations. A still further object of the invention is to provide means for generating a plurality of different frequency carrier waves, of suitable amplitude for multiplex transmission, from a single control or base frequency wave.

According to this invention control or base frequency oscillations are generated at one station. The wave form of a portion of the control oscillation energy is distorted and one or more harmonics are selected from the resulting wave and then amplified to serve as carrier waves. A particular carrier wave so produced is modulated in accordance with both the signal or other teledynamic impulses which it is desired to transmit and the original or undistorted control frequency oscillations. The transmitted carrier wave thus "carries" simultaneously, the signal and the control oscillations. At the receiving station the received carrier wave is detected and the resulting detected signal and control oscillation components are separated. The wave form of the control oscillation compo-

nent is distorted in the same manner as at the transmitting station so as to enable the selection of reinforcing harmonic oscillations of the same frequency as the transmitted carrier wave. The reinforcing oscillations are then supplied to the detector simultaneously with the received carrier wave and at the proper phase with respect thereto and serve to intensify the detected signal. Since there is a single source of control oscillations from which both the carrier and the reinforcing oscillations are derived, the carrier and reinforcing oscillations will always be of equal frequency although the absolute value of the frequency may vary in consequence of variations in the control frequency. This scheme of frequency control may be embodied in a multiplex system by causing the harmonic producing means at the transmitting station to produce a plurality of harmonic frequency carrier waves from the distorted control wave and then transmitting each of these carrier waves modulated both in accordance with the control wave and its individual message wave, as previously described.

Where the receiving stations are comparatively close to each other, instead of transmitting the control oscillations as modulations of each individual carrier, the control oscillations may be transmitted continuously as modulations of a single carrier. The wave form of the detected control oscillations may then be distorted and reinforcing oscillations of each of the transmitted carrier frequencies derived therefrom. This enables a single carrier wave to transmit the control oscillations and permits transmission of the remaining carrier waves modulated in each in accordance only with its individual message. The unmodulated carrier waves may be suppressed in each instance to increase the efficiency of the transmitting station and to lessen the probability of crosstalk. One side band of the modulated carrier frequency may be suppressed to decrease the range of the transmission band required for a single message or transmission and to correspondingly increase the number of simultaneous non-interfering transmissions.

Further objects and advantages of the invention will appear from the following detailed description taken in connection with the accompanying drawing, in which Fig. 1 illustrates a transmitting station, and Fig.

2 the corresponding receiving station of a
multiplex signaling system according to this
invention, and Figs. 3 and 4 illustrate the
transmitting and receiving stations respec-
tively of a modified system.

Referring to Fig. 1, the oscillation genera-
tor 0 comprises a three-element vacuum tube,
preferably highly evacuated, the input circuit
of which is electrically connected to the
output circuit by the oscillatory circuit
formed by coils 2 and 3 and variable con-
denser 5. A source 4 supplies space current
to the tube. By means of the variable con-
denser 5 of the oscillatory circuit, the fre-
quency of the oscillations produced by the
generator may be given any desired value.
This oscillation generator which produces
control oscillations is connected to the input
circuit of amplifier A of the vacuum tube
type. The impedance control element 6 of
this amplifier is negatively charged with re-
spect to the cathode by source 7. The space
current of the amplifier is supplied by source
8 through the impedance 9. Cathodes 10 and
11 of the oscillation generator and amplifier
respectively, are heated by current from the
common source 12. Amplified oscillations
in the output circuit of the amplifier A are
supplied by a transformer connection to the
input circuit of the harmonic generator or
producer G which consists primarily of a
three-element vacuum tube.

The tube of the harmonic generator G is
overloaded so as to produce a maximum dis-
tortion in the output circuit of the wave form
of the repeated control oscillations supplied
to its input circuit. This is done by apply-
ing to its input terminals an alternating po-
tential such that the maximum value carries
the operation of the tube beyond that portion
of its characteristic which is substantially
linear, thus substantially distorting the wave
form of the applied alternating potential as
repeated in the output circuit. This applied
alternating potential may be such that the
maximum positive value will exceed that nec-
essary to cause the tube to become saturated
and the maximum negative value will ex-
ceed that negative value required to reduce
the output current substantially to zero, or
one of these conditions may exist alone to
the substantial exclusion of the other.

Since a distorted or non-sinusoidal peri-
odic wave may be analyzed into a pure sine
wave component of the frequency of the dis-
torted wave and a plurality of harmonic com-
ponents of higher frequencies, it remains to
select the particular harmonic components
which it is desired to utilize as carrier waves.

The cathode 13 of the harmonic generator
is heated by current source 14 and the space
current of the tube is supplied by source 15
through the impedance 16. The condenser 17
in shunt to the impedance 16 and source 15
provides a low impedance path for high fre-

quency currents. The harmonic generator
is coupled by means of a transformer to an
amplifier A_1 which is similar to amplifier A,
previously described. The output circuit of
amplifier A_1 includes a plurality of tuned
loop circuits 18, corresponding in number to
the number of harmonics which it is desired
to select and each circuit 18 is tuned by means
of its variable capacity element 19 to the par-
ticular harmonic which it is to select. Cou-
pled by a transformer to one of the tuned
loop circuits 18 is an amplifier A_2 similar to
the amplifiers described and having an input
circuit 20 coupled to circuit 18 and similarly
tuned. The input terminals of each amplifier
 A_2 are connected by a potentiometer coupling
to the terminals of the condenser of the tuned
circuit 20. This permits the particular har-
monic selected to be amplified to the desired
degree and the amplitudes of the various
harmonics can thus be made of substantially
the same magnitude if desired. Amplifier A_2
is connected by a transformer to a band filter
F which passes a narrow band including the
selected harmonic with substantially no at-
tenuation, and extinguishes currents of fre-
quency differing considerably therefrom.
Filter F terminates in a potentiometer cou-
pled to the common input path of a balanced
modulator M of the type disclosed in U. S.
patent to Carson No. 1,343,306, dated June
15, 1920.

The output circuit of amplifier A is also
coupled to the input circuit of an amplifier
 A_3 , the latter being connected through a band
filter F_1 , and another amplifier A_4 to a poten-
tiometer in the common input path of modu-
lator M. Filter F_1 passes a narrow band of
frequencies including the control oscillation
frequency. A circuit 21, illustrated as a tele-
phone circuit, but which may be taken as rep-
resentative of any low frequency current line
transmitting signal currents or other teledy-
namic electrical variations, is coupled to the
divided input circuit of modulator M. The
modulator M is connected by a band filter F_2
to high frequency circuit L which may be an
antenna or a transmission circuit. The char-
acteristic of modulator M is such that it trans-
mits no energy to filter F_2 except at such times
as variation currents traverse circuit 21 and
set up corresponding variation electromotive
forces in the divided input circuit of the
modulator. During the existence of these
variation currents the modulator transmits to
filter F_2 oscillations of the frequency selected
by tuned circuits 18 and 20 modulated both
in accordance with the variation currents of
line 21 and the control oscillations supplied
from amplifier A_4 .

The other tuned loop circuit 18 is similarly
connected by an amplifier and band filter to
a modulator M_1 similar in every respect to
modulator M. It will of course be understood
that each tuned loop circuit 18 selects a par-

particular harmonic and that the circuit connecting that tuned loop circuit with its individual modulator is designed to transmit the particular harmonic selected. A low frequency circuit 22 similar to circuit 21 is associated with modulator M_1 . A band filter F_3 connects modulator M_1 to circuit L. Control oscillations are supplied from filter F_1 to modulator M_1 by a circuit identical with that which connects filter F_1 to modulator M.

Preferably, each of the band filters F_2 , F_3 transmits only one side band of the modulated wave supplied by its individual modulator M or M_1 . In other words, if the frequency of the carrier oscillations supplied to modulator M is 30,000, so that the resulting modulated wave comprises a band of frequency components extending equally above and below this frequency, either the portion of the band above the carrier frequency or the portion below it is suppressed by the filter F_2 , and the filter is so designed as to pass only the remaining side band.

Only two low frequency circuits 21, 22 and the corresponding high frequency transmission channels are illustrated, but it is to be understood that as many more as desired may be provided, each being designed to select, modulate and transmit an individual carrier frequency wave.

Referring to Fig. 2, a high frequency receiving circuit L, which may be either an antenna or a transmission circuit, is connected by unidirectional amplifiers UA to two similar receiving channels by band filters F_4 and F_5 effectively in parallel with respect to circuit L. Band filter F_4 is designed to pass the same band of frequencies as filter F_2 at the transmitting station. Filter F_4 supplies modulated oscillations from circuit L to detector D which may be of the balanced type and which is coupled by loop circuit 23 to filters F_6 and F_7 respectively. Upon detection the received modulated carrier wave passed by filter F_4 yields in the output circuit of the detector a current component corresponding to the variation currents of circuit 21. Filter F_6 is designed to pass a low frequency band, within which these currents fall, to receiving instrument 24 illustrated as a telephone receiver but which, as will be understood, may be any signaling or other tele-dynamic receiving device, depending upon the nature of the variable currents or impulses of circuit 21 and the operation which the receiving instrument is designed to perform. In the case of speech transmission, the filter F_6 will preferably suppress substantially all currents of frequencies above 2500 cycles and will readily transmit all frequency currents below this value. The detected carrier wave also yields a component of the control oscillation frequency and this is transmitted from circuit 23 through a filter F_7 which is similar in electrical characteristics to

filter F_1 . From filter F_7 the detected control oscillations pass to a harmonic producer G_1 . Connected to the output circuit of harmonic produced G_1 is an amplifier A_5 having an input circuit tuned to the frequency of the carrier oscillations selected by circuit 20 of Fig. 1. Amplifier A_5 transmits the selected harmonic reinforcing oscillations to a circuit including a phase regulating device which consists of a variable inductance 25, a variable capacity 26, and a variable resistance 27. The reinforcing oscillations after phase regulation are passed to amplifier A_6 having a potentiometer input circuit and from the amplifier, amplified reinforcing oscillations are supplied to the common input path of detector D to be combined with the received carrier oscillations.

The phase regulating device is variable and it is accordingly possible to secure any desired phase relation between the received carrier oscillations and the reinforcing oscillations. For some purposes the amplification is increased by bringing these two sets of oscillations into phase agreement.

The reinforcing oscillations combine with the received oscillations to produce intensified control oscillation components and signal current components in the output circuit of the detector.

The element G_1 serves both as a harmonic generator or producer and a power limiting device. The potential of its grid or impedance control element is maintained positive with respect to the cathode by a source of unidirectional current. The positive grid attracts the electrons emitted by the cathode and when the potential supplied to the device G_1 reaches a sufficiently high positive value, the electrons will be attracted to the grid to such an extent that no further increase in the space current in the cathode-anode circuit occurs. The minimum value of the space current in device G_1 being zero, it is evident that the power delivered by this tube is limited. This power limiting action is desirable in order to prevent singing in the circuit F_7 , G_1 , A_5 and A_6 , which couples the output circuit of the detector to the input circuit. Any other form of power limiting device may be employed without departing from this feature of the invention.

Filter F_5 and the apparatus in the receiving channel associated therewith are similar to filter F_4 and its associated channel, previously described, except that the carrier frequency received is different. The tuning of the various filters and circuits of this channel bears the same relation to that of the transmitting channel of circuit 22 as the corresponding values of the channel of filter F_4 bear to those of the transmitting channel of circuit 21.

Since the transmitted carrier oscillations and the reinforcing oscillations are derived

from a common source and since both are the same harmonic of the oscillations supplied by that source, it follows that the carrier frequency and the reinforcing frequency will always be identical, which is very desirable for the proper reception of telephonic signals. It is to be noted that the selecting devices, i. e., tuned circuits and filters employed, will properly differentiate between the various frequency currents involved, even though the control frequency and its multiple or harmonic are subject to small variations.

Referring to Figs. 3 and 4, which illustrate the sending and receiving stations respectively of a modified system, the various oscillators, amplifiers and harmonic generators are similar to those described in connection with Figs. 1 and 2. The control oscillations produced by oscillation generator O_1 are amplified by amplifier A_7 which transmits amplified control oscillations to the input circuit of a harmonic generator G_2 . The several carrier oscillations produced by harmonic generator G_2 are amplified by an amplifier A_8 , the output circuit of which comprises two tuned circuits 28 and 29, each of which is tuned to a different one of the harmonics supplied by the harmonic generator G_2 . Carrier oscillations supplied by the tuned circuit 28 are amplified by an amplifier similar in every respect to amplifier A_8 , and are transmitted by means of filter F_8 corresponding to filter F of Fig. 1, to the common input circuit of a balanced modulator M_2 . Control oscillations are also transmitted from amplifier A_7 through an amplifier and filter corresponding respectively to amplifier A_8 and filter F_1 of the system of Fig. 1. These control oscillations are transmitted by a transformer 30 to the divided input circuit of modulator M_2 .

Modulator M_2 has a characteristic similar to that of modulator M_1 and accordingly transmits energy at such times as variation electromotive forces are impressed upon its divided input circuit and at all other times transmits substantially no energy. Oscillations of the carrier frequency supplied by circuit 28, modulated in accordance with the control frequency, will therefore be continuously transmitted through filter F_9 , amplifier A_9 and filter F_{10} to the high frequency circuit L_1 .

A low frequency signaling or variation current circuit 31 similar to circuits 21 and 22, is connected by loop circuit 32 and divided transformer 33 to the divided input circuit of modulator M_2 . Whenever variation currents traverse circuit 31, carrier oscillations modulated in accordance with these variation currents will also be transmitted to circuit L_1 .

A second low frequency circuit 34 is connected to the divided input circuit of a modulator M_3 upon which carrier oscillations selected by circuit 29 are impressed. The cir-

cuits connecting circuit 29 to modulator M_3 are like those connecting circuit 28 to modulator M_2 , with the exception that their tuning and transmission range is designed to select and transmit a different harmonic frequency carrier wave, namely, that selected by circuit 29. However, the control frequency oscillations are not supplied to modulator M_3 and accordingly the carrier wave impressed upon its input circuit is suppressed except when variation currents in circuit 34 cause the modulator to transmit pure modulated waves to circuit L_1 . The modulator M_3 is connected to circuit L_1 by a circuit similar to that connecting modulator M_2 to circuit L_1 . The filter F_9 is designed to suppress currents of the order of frequencies of those occurring in circuit 31, so as to prevent overloading amplifier A_9 to which it is connected. A band filter F_{10} connects amplifier A_9 to circuit L_1 and serves to transmit only the band of frequencies corresponding to the pure modulated carrier wave and if desired, it may be designed to transmit one side band only of the pure modulated wave. As was explained in connection with Fig. 1, the number of channels may be made much larger, each additional channel being similar in every respect to the channel of circuit 34, with the exception that each channel would be so designed as to select, modulate and transmit a particular carrier wave individual to that channel.

In the sending arrangement illustrated in Fig. 3, one channel serves to continuously modulate its carrier wave in accordance with control oscillations and to transmit the resulting modulated carrier wave to circuit L_1 . The remaining channels (of which that of circuit 34 only is illustrated) transmit individual carrier waves modulated only in accordance with the currents of their respective variation circuits 34, and suppress their respective carrier waves when the corresponding variation current circuits are idle.

Fig. 4 illustrates the receiving station which operates in conjunction with the sending station of Fig. 3. A high frequency receiving circuit L_1 , which may be an antenna or a transmission circuit, has connected thereto through unidirectional amplifiers UA_1 , band filters F_{11} and F_{14} corresponding to the band filters immediately connected to the circuit L_1 of Fig. 3. Filter F_{11} , which transmits the same band of frequencies as filter F_{10} , receives the continuously modulated carrier wave energy transmitted from filter F_{10} and transfers it successively to detector D_1 , circuit 35, and filters F_{12} and F_{13} , these various elements corresponding respectively for the particular carrier frequency involved to elements D , 23, F_6 and F_7 of Fig. 2. The control oscillations transmitted by filter F_{12} are therefore continuously supplied to harmonic generator G_3 by which the reinforcing

oscillations of each of the different carrier frequencies are continuously produced. Reinforcing oscillations of its received carrier frequency are continuously supplied to detector D_1 over a circuit arrangement substantially identical with that connecting the output circuit of harmonic generator G_1 to the input circuit of detector D in the receiving system of Fig. 2. Harmonic generator G_3 also serves to produce reinforcing oscillations of the carrier frequency received by filter F_{14} and to cause them to be impressed upon detector D_2 associated with filter F_{14} . As many additional receiving channels may be provided as there are additional transmitting channels 34, each being similar in the arrangement of its parts to the receiving channel of filter F_{14} and having its electrical values correspondingly assigned with relation to the particular carrier frequency individual thereto.

Unidirectional amplifiers are of particular advantage in the present system to prevent reverse transmission. Amplifier A_4 of Fig. 1 prevents the carrier frequency applied to modulator M from reacting upon the output of filter F_1 and hence upon the input circuit of modulator M_1 . In a similar manner the unidirectional amplifiers UA in the receiving channels prevent transmission of the reinforcing oscillations to the high frequency receiving circuit.

The homodyne method of signaling is of course not limited to telephony but is equally applicable for other teledynamic transmission. The drawing illustrates one-way transmission only, but it should be understood that the invention is applicable as well to two-way signaling. It is also possible to widely separate the various transmitting and receiving stations. For example, low frequency circuits 21 and 22 may be of considerable length and may be subscribers' lines terminating in a central exchange at which the high frequency circuits terminate. The system of Figs. 1 and 2 particularly lends itself to separate high frequency station operation since the high frequency receiving channels have no other association than connection to the common transmission line L . The sending stations each require a high frequency connecting circuit to the harmonic generator which serves as the common source of carrier oscillations.

Various features of the systems disclosed herein are claimed by applicant in other co-pending applications. The homodyne method of reception is disclosed and claimed in U. S. patent to Kendall, No. 1,330,471, patented October 10, 1920. The harmonic generator is disclosed and claimed in U. S. patent to Kendall, No. 1,446,572, granted February 27, 1923. The derivation of the various carrier and reinforcing frequencies as harmonics of a single control frequency is disclosed and

claimed in application Serial No. 130,350, filed November 9, 1916, of which the present application is in part a continuation.

It will of course be understood by those skilled in the art that the specific circuits herein shown and described are not only illustrative of particular arrangements that may be employed, and that the details of the circuits and the relative arrangement and position of the various elements may be materially varied from what is set forth, without departing from the spirit and scope of the invention. Only such limitations are to be imposed on the invention as are indicated in the appended claims.

What is claimed is:

1. In multiplex signaling the method of producing carrier waves for a plurality of different message transmissions and of fixing the relative frequencies and amplitudes of said carrier waves, which method comprises producing control oscillations, deriving therefrom different harmonic oscillations, selecting the harmonic oscillation waves of the desired carrier wave frequencies and separately amplifying each of said selected harmonic oscillation waves to give said waves the desired relative amplitudes.

2. In a multiplex transmission system, a source of control frequency oscillations, means for deriving from said control oscillations different harmonic frequency oscillations, and means for separately amplifying said harmonic frequency oscillations to substantially the same magnitude.

3. In a system for the simultaneous transmission of a plurality of indications over the same medium, means for supplying carrier waves comprising a common wave generator, means to derive therefrom a plurality of waves of different frequencies, including frequency-selective circuits for selecting individual waves, an individual amplifier associated with each of said circuits for amplifying the wave of respective frequency, means associated with each amplifier for determining the degree of amplification of the respective wave, and a corresponding plurality of wave-control devices connected to the respective amplifiers for modifying each wave in accordance with a different indication.

4. A multiplex transmission system comprising a source of control oscillations, means for deriving from said control oscillations a plurality of different frequency harmonic oscillations, means for modulating each of said harmonic oscillations both in accordance with low frequency variations individual thereto and said control oscillations, and means for simultaneously transmitting each of said modulated oscillations.

5. The method of transmission which comprises deriving a carrier wave from base frequency oscillations, modulating said carrier

wave in accordance with another wave, suppressing all components except one side band of the modulated carrier wave; deriving other waves from said base frequency oscillations and reinforcing said side band with said other waves.

6. The method of transmission which comprises deriving a carrier wave from base frequency oscillations, modulating said carrier wave in accordance with a signal and said base frequency oscillations, suppressing all components except one side band of the modulated carrier wave, utilizing the component of the modulated wave resulting from the modulation of the carrier wave by the base frequency to reproduce oscillations of the carrier frequency and reenforcing said side band with said reproduced oscillations.

7. The method of multiplex carrier wave transmission which comprises producing base frequency oscillations, deriving therefrom harmonic waves of a plurality of different frequencies, selecting one of said harmonic waves to serve as a carrier wave, modulating said carrier wave in accordance with another wave, suppressing all components of said modulated wave except one side band, transmitting and receiving said side band, deriving reinforcing oscillations of said carrier frequency from said base frequency oscillations, and utilizing said reinforcing oscillations to reinforce said received side band.

8. The method of multiplex carrier wave transmission which comprises producing base frequency oscillations, deriving therefrom harmonic waves of a plurality of different frequencies, selecting one of said harmonic waves to serve as a carrier wave, modulating said carrier wave in accordance with a signal and with said base frequency oscillations, suppressing all components of the modulated wave except one side band, transmitting and receiving said side band, utilizing the component of the side band produced by the modulation of said carrier wave by the base frequency oscillations to reproduce oscillations of the carrier frequency, and reenforcing said side band by said reproduced oscillations.

9. A transmission system comprising a source of base frequency oscillations, means for deriving a carrier wave therefrom, means for modulating said carrier wave in accordance with another wave, means for suppressing all components except one side band of the modulated carrier wave, means for deriving reinforcing oscillations from said base frequency oscillations, and means for reenforcing said side band with said reinforcing oscillations.

10. A transmission system comprising a source of base frequency oscillations, means for deriving a carrier wave therefrom, means for modulating said carrier wave in accordance with a signal and with oscillations from

said source, means for suppressing all components except one side band of the modulated carrier wave, means for reproducing from a component of said side band oscillations of the carrier frequency, and means for reenforcing said side band with the reproduced oscillations.

11. A multiplex carrier wave transmission system comprising means for producing base frequency oscillations, means for deriving therefrom harmonic waves of a plurality of different frequencies, means for selecting one of said harmonic waves to serve as a carrier wave, means for modulating said carrier wave in accordance with another wave, means for suppressing all components of said modulated wave except one side band, means for transmitting and receiving said side band, means for deriving reinforcing oscillations of said carrier frequency from said base frequency oscillations, and means for causing said reinforcing oscillations to reinforce said received side band.

12. A multiplex carrier wave transmission system comprising means for producing base frequency oscillations, means for deriving therefrom harmonic waves of a plurality of different frequencies, means for selecting one of said harmonic waves to serve as a carrier wave, means for modulating said carrier wave in accordance with a signal and with said base frequency oscillations, means for suppressing all components of said modulated wave except one side band, means for transmitting and receiving said side band, means for reproducing from a component of the side band reenforcing oscillations of said carrier frequency, and means for causing said reenforcing oscillations to reenforce the received side band.

13. In a multiplex signaling system, means to modulate a carrier wave in accordance with signals to be transmitted, means for suppressing the unmodulated component of said carrier wave, means to modulate a carrier wave of a different frequency in accordance with other signals and in accordance with a control wave, and a receiving station comprising means operable by the control wave modulation for restoring the unmodulated component to the first mentioned modulated wave.

14. In combination, means for supplying carrier waves, means for modulating said carrier waves by other waves of higher than the essential speech frequencies, a filter connected to said modulating means to transfer the modulated carrier wave to a transmitting circuit, said filter having a frequency transmission range lying entirely above the range of essential speech frequencies but including at least a portion of the frequency range occupied by said modulated carrier wave, means connected to said filter for transmitting the modulated energy transferred therethrough,

and means for receiving and detecting said transmitted wave.

15 15. The method of signaling comprising deriving carrier oscillations from a base frequency source, utilizing the derived oscillations to produce a signal-modulated wave comprising upper and lower side bands, suppressing all components of the modulated wave except one side band, transmitting and
20 receiving said side band, producing under control of said base frequency source waves of the carrier frequency and utilizing the waves so produced to reenforce the received side band.

15 16. The method of signaling comprising deriving a carrier wave from a base frequency source, controlling the carrier wave in accordance with signals to be transmitted to produce a resultant modulated wave having side
20 bands, suppressing all of the components of the modulated wave except one side band, transmitting and receiving said side band, utilizing waves from said base frequency source to reproduce at the receiving point
25 a wave of the carrier frequency and utilizing the wave so reproduced to reenforce the received side band.

17. The method of multiplex signaling, which consists in transmitting a plurality of
30 currents of different frequencies all harmonic to a certain basic frequency and each modulated according to one or more messages, and receiving these messages by detection with the aid of locally generated currents of the
35 same harmonic frequencies, and synchronizing said locally generated currents by means of one of the said transmitted harmonic frequency currents appropriated to that purpose.

40 18. In a multiplex carrier current system, a line, means to generate a composite alternating current of a certain fundamental frequency and to separate the component currents of other frequencies to respective chan-

nels associated with said line, means at the sending end to modulate one of the higher
45 frequency component currents at the rate of the fundamental, and means at the receiving end governed by the said currents so modulated to control the generation of a current corresponding to the composite current generated at the other end of the line.

19. In a multiplex carrier current system, a line, means at one station on the line to generate a composite alternating current of a certain fundamental frequency, means to
55 separate its components to various conductors and to modulate them for signaling and specially to modulate one such component regularly at the rate of the fundamental alternating current and to put all the components so modulated on the line, and means
60 at another station controlled by said specially modulated component current to generate an alternating current like that generated at the first mentioned station.

20. In a multiplex carrier current system, a line, means at one station on the line to generate a composite alternating current of a certain fundamental frequency, means to
65 separate its components to various conductors and to modulate them for signaling and specially to modulate one such component regularly at the rate of the fundamental alternating current and to put all the components so modulated on the line, and means at
70 another station controlled by said specially modulated component current to generate an alternating current like that generated at the first-mentioned station, and means to utilize the components of said alternating current
75 generated at said other station for homodyne reception thereat.

In witness whereof, I hereunto subscribe my name this 15th day of April A. D., 1919.

BURTON W. KENDALL.