

July 20, 1926.

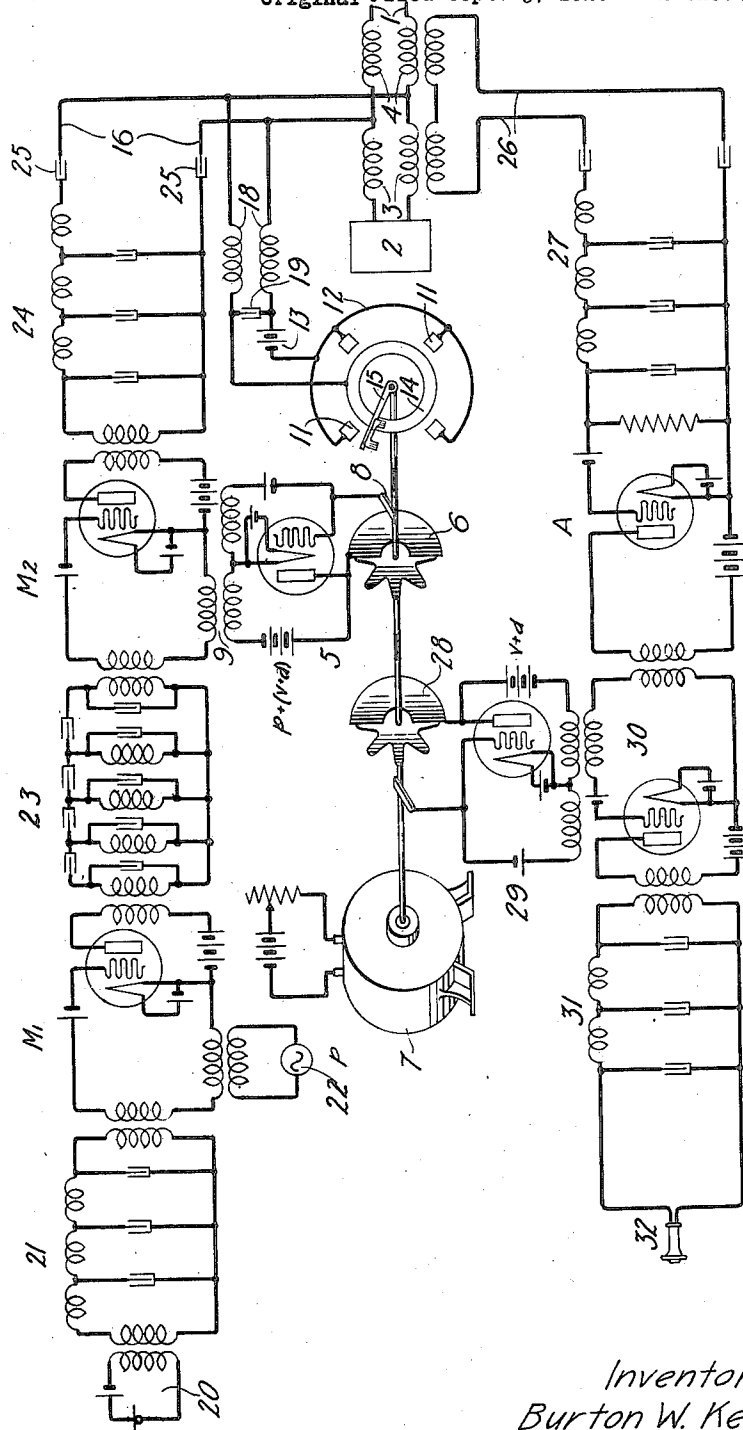
1,592,940

B. W. KENDALL

SECRET SIGNALING

Original Filed Sept. 9, 1920. 2 Sheets-Sheet 1

Fig. 1



Inventor:
Burton W. Kendall
by C. C. Sprague. Atty.

July 20, 1926.

1,592,940

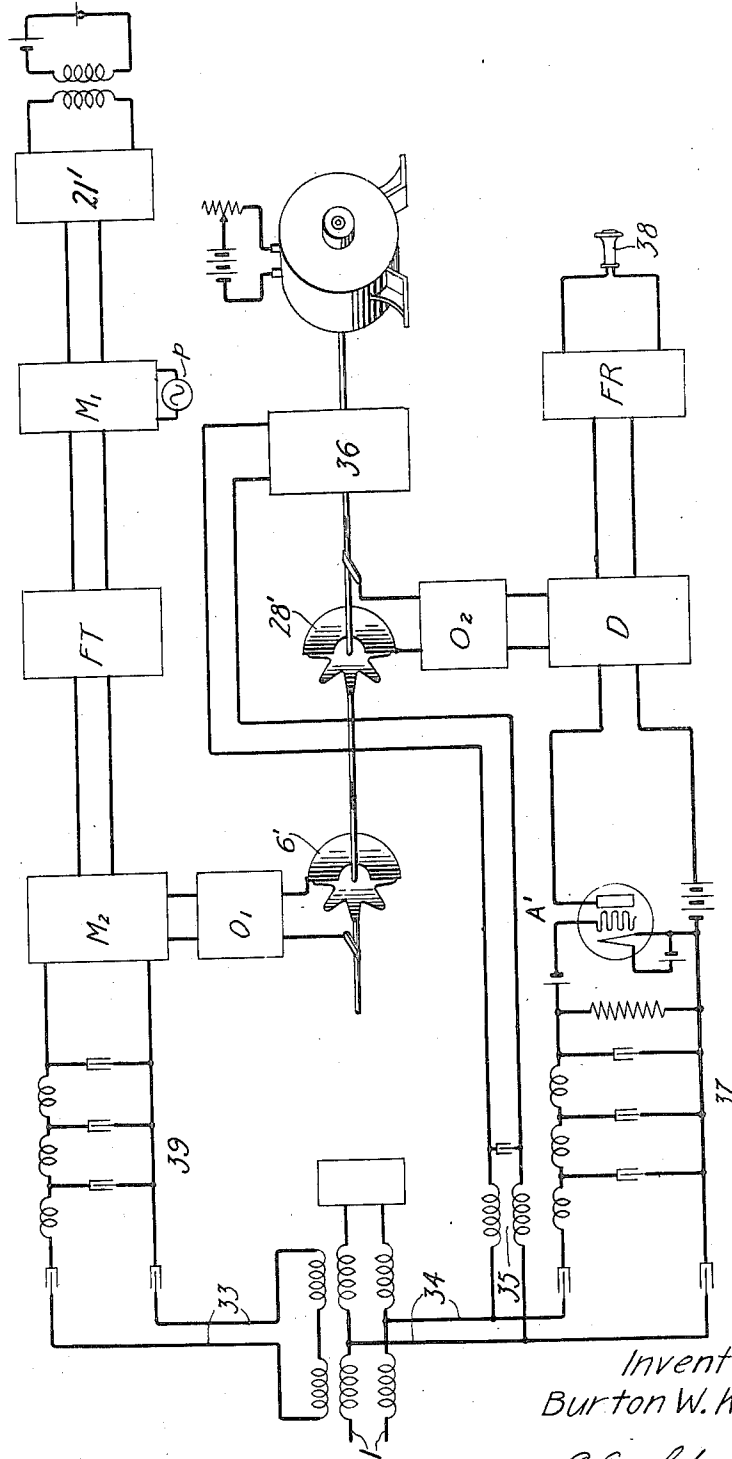
B. W. KENDALL

SECRET SIGNALING

Original Filed Sept. 9, 1920

2 Sheets-Sheet 2

Fig. 2



Inventor:
Burton W. Kendall
by C. A. Sprague. Att'y.

Patented July 20, 1926.

1,592,940

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.

SECRET SIGNALING.

Application filed September 9, 1920, Serial No. 409,073. Renewed September 30, 1925.

The present invention relates to the control of electrical waves for the transmission of signals or for other purposes.

More particularly the invention relates to secret signaling and especially to secret telephone communication or to the secret transmission of sound by electrical means.

Secret signaling by means of secret codes previously agreed upon by the communicating parties has long been used. In such systems the signal elements themselves are not necessarily concealed from outsiders, for unless the code is known the signal elements cannot be assembled to make up the transmitted message. The transmission of the signal elements such as telegraphic letters or visual signs could therefore be carried on openly.

In secret telephony, however, the message cannot readily be decoded after reception, but must be received as a restored and recognizable sound wave. This means that the receiving system must act automatically to untangle the confused jumble purposely produced at the transmitter and to deliver intelligible sounds at the receiver. The types of apparatus available in a practical system for accomplishing the deciphering of confused currents are of limited variety and the order of secrecy obtained depends, of course, upon the degree to which the voice current elements that are transmitted can be concealed from the possibility of detection by an outsider who may be skilled in the use of this fairly familiar apparatus. The use of commutators, interrupters and similar apparatus for breaking up the speech still permits the transmission of actual speech current elements and it is conceivable that from the study of a phonograph record or other record of the waves transmitted the frequency of the commutator and the nature of the speech mutilation used might be discovered. Other, fairly simple methods of disguising the voice are subject to similar limitations as to the degree of secrecy.

It has been proposed to transmit speech as modulations of a high frequency carrier wave, the carrier wave itself being suppressed and being continuously varied in frequency. In order to receive the speech it is necessary to supply at the receiver a wave of the carrier frequency, and the possibility of an outsider doing this is greatly

lessened by making the frequency of the carrier wave vary continuously in a predetermined manner. Such a system is disclosed in the United States patent to W. E. Beatty, No. 1,454,532, dated May 8, 1923. The system disclosed in that patent is particularly adapted to radio communication, but would have its limitations when applied to a line. For instance, when the system disclosed in that patent is used for secret radio communication it is not necessary to suppress currents of the voice frequency at the output circuit of the transmitting modulator since the voice frequency waves would not be radiated and this fact somewhat simplifies the apparatus that would be necessary in a radio system. In the case of the wire line, however, the balanced modulator used in the system referred to should preferably suppress both the unmodulated carrier component and the voice currents completely, but if a filter is used to suppress the unmodulated carrier component, the variation of the carrier frequency is limited to a comparatively small range. The reason for this limitation in the range of variation of the carrier frequency in such a system is more fully pointed out in the application to R. V. L. Hartley, Serial No. 408,890, filed September 8, 1920.

It is a main object of the present invention to provide secret telephone transmission by modulated waves of preferably variable frequency in which no components of the original frequency either of the sound wave currents or the carrier wave find their way to the line, in which the waves transmitted to the line yield only unintelligible signals by detection and in which the character of the transmitted currents makes deciphering of the scheme of carrier frequency variation practically impossible. An auxiliary object is to provide such a system in which the range of variation of the carrier frequency capable of use is very large.

These and other objects of the invention are obtained by the means and in the manner hereinafter more fully described, and illustrated in the accompanying drawing in which Fig. 1 is a schematic circuit diagram of the apparatus at one terminal of a two-way system, and Fig. 2 is a similar representation of the apparatus at the cooperating distant station.

In the system to be described a carrier

wave of a varying frequency is modulated by the signal wave, the unmodulated component of the carrier wave is completely suppressed, giving a pure modulated wave, the signal wave is suppressed except as it appears as a modulation component of the carrier wave, and only one of the resulting side bands of the modulated carrier wave is transmitted. It is essential, of course, not to allow the currents of signal frequencies, which for convenience will be referred to as voice frequencies, to pass to the line even in a very small amount since it might be possible to separate them by filtering and to amplify them to a desired degree. It is important to suppress the unmodulated carrier wave component to prevent an outsider from learning the carrier frequency and the scheme of varying it, and it is necessary to suppress one side band of the modulated carrier wave since if both side bands were transmitted a simple detector would yield currents of the double frequencies of the voice which are to a certain degree intelligible.

In Fig. 1, the line 1 is balanced by the usual network 2 and is provided with conjugate coils 3 and 4 to enable two-way communication thereover without interference between the transmitting and receiving circuits. The transmitting apparatus is shown in the upper portion of the figure and the receiving apparatus is shown in the lower portion. The transmitting oscillator generates a wave of preferably continuously varying frequency from which wave the carrier wave is derived. The oscillator is of a well-known type employing a thermionic tube having a filamentary cathode, a grid and a plate or anode or equivalent electric discharge device and having a tuned circuit for controlling the frequency of the generated wave. The tuning of this circuit is continuously varied and for purpose of illustration in the present case the capacity element 6 of the tuned circuit is represented as being continuously varied by having one of its plates rotatively driven by the motor 7. Connection is made from the plate of the oscillator to the fixed condenser-plate and the grid is connected to the movable plate of the condenser through the brush 8 which bears upon the shaft employed for rotating the condenser plate. This shaft is indicated as being made up of conducting and insulating portions shown as respectively white and black in the drawing in order to isolate the condenser electrically from the rest of the apparatus. By properly shaping the condenser plate or plates the frequency of the oscillator can be made to vary cyclically in a desired manner. The oscillator is coupled by means of the coils 9 to the input circuit of the modulator M_2 .

In the present system it is necessary, in

order to receive the transmitted signal to have at the receiver a wave of the carrier frequency, which means that the supplied wave at the receiver must vary in frequency continuously in the same manner as does the received carrier wave. A motor similar to 7 is therefore provided at the distant station for controlling the frequency of the wave generated at that station but since it is in practice impossible to maintain two such independently driven motors for a very long time in step with each other a correcting system is preferably employed. The details of this correcting system form no part of the present invention and any known system which is suitable may be used in the system of the present invention. However, the synchronizing system indicated in the drawing is preferably that disclosed in the patent to R. A. Heising No. 1,501,711, dated July 15, 1924.

At each station the motor is made to drive a contact making mechanism. At the controlling station these contacts cause the transmission through the system of synchronizing impulses and at the receiving station the contacts control the reception of these impulses by a local correcting mechanism. If the two driven devices are in step the correcting impulses produce no result, but if the distant driven device is either lagging or leading with respect to the distant controlling device the correcting impulse causes a phase shift in the driven device with respect to its driving motor to restore the device to the in-phase position. The contact making mechanism at the transmitter consists of any desired number of conducting segments 11 all connected by a wire 12 to battery 13, and an inner conducting ring 14 adapted to be periodically connected to the segments 11 by the rotating brush arm 15 driven by the motor 7. The ring 14 is connected to one side of the transmitting loop 16 and the opposite side of the circuit 16 is connected to battery 13 so that each time the brush arm places ring 14 in connection with the segment 11 the battery 13 is closed across the circuit 16 and an impulse is transmitted to the line 1. These impulses are merely phase-correcting impulses and have no significance whatever as to the signals transmitted. Since the number of impulses transmitted per revolution of the condenser plate may be varied at will, as may be also the number of scallops on the condenser plate, the gear ratio, etc., these correcting impulses give no clue to the manner of variation of the carrier frequency. Choke coils 18 and condenser 19 act as a low pass filter, permitting the transmission of the correcting impulses but keeping the path through the commutator free of the energy of the high frequencies used in transmitting the signals.

The signals to be sent, assumed in the present case to be sounds and particularly speech, produce currents in the microphone circuit 20, shown as including a microphone and a battery. This circuit is coupled to the filtering circuit including the low pass filter 21 so designed as to transmit freely currents of the frequencies from zero to an upper limit preferably about 2200 cycles or at least sufficiently high to include the essential frequencies comprised in the voice range, but to suppress higher and unessential harmonics. This and the other filters throughout the system may be designed in accordance with the principles set forth in the United States patent to G. A. Campbell 1,227,113 issued May 22, 1917. The essential voice frequency currents so transmitted are impressed upon the input circuit of the thermionic modulator M_1 to which is also supplied a high frequency wave of frequency p from the source 22 which may be an oscillating tube or other suitable generator of sustained and constant high frequency p . By the well-known action of the modulator combination frequencies will be produced involving p and s , where s represents the individual frequencies of the currents transmitted by filter 21. The most important of these combination frequencies will be p , s , $2p$, $2s$, $p+s$ and $p-s$. If p is chosen considerably above the highest frequency represented by s the only components of high frequency than p will be $2p$ and $p+s$. The component of frequency p and the other lower frequency currents and the component of frequency $2p$ may be suppressed by the band pass filter 23. The currents of $p+s$ frequency together with the variable frequency current supplied from the oscillator 5 are impressed upon the input circuit of the modulator M_2 . The frequency of the current from oscillator 5 may be represented by $p+v+d$ where p and v are fixed, but d varies from zero to a fixed limit in accordance with a prearranged scheme. As explained above, this variation in the oscillator frequency is effected by the variable capacity 6. The frequency v may be audible but is preferably above 2200 cycles as is also the frequency p . As a product of modulation of current of the frequency $p+v+d$ by currents of the frequencies $p+s$ there will result components of the frequencies involving p such as $p+v+d+p+s$, etc., and one prominent component of frequency $(p+v+d)-(p+s)=v+d-s$ not involving the frequency p . Since the frequency p may be made as high as desired, this side band of frequency $v+d-s$ can be made of much lower frequency than $p+s$, the lowest of the other frequency components of the output current of modulator M_2 , and so may easily be separated by the low pass filter 24 which is so designed as to cut off all frequencies including p and those higher. The condensers

25 freely transmit to the line 1 currents of the frequencies involved in signal transmission but keep the correcting impulses out of the signaling set.

It will be seen from the above description, therefore, that none of the currents of signaling frequency s can get to the line on account of the band pass filter 23, and that no current components of the frequency p or frequency $p+v+d$ can get to the line on account of the filters 23 and 24 and that only one side band $v+d-s$ can be transmitted. These filters may be designed with precision and may be made up of a large number of sections with the result that they accomplish for all practical purposes complete suppression of the undesired frequencies.

It is to be understood that any modulation or modification of a sinusoidal carrier wave produces a complex resultant which is no longer a pure sinusoidal wave but at least at the initiation and termination of the modulating operation and, in general, throughout its duration includes sinusoidal components of one or more frequencies different from that of the unmodulated carrier wave. It is customary in the carrier wave transmission art to denote all components of a modulated wave of lower frequency than the unmodulated carrier wave by the term "lower side band" and those of higher frequency as the "upper side band". In the case of speech modulated waves, as is well known, each side band extends over a considerable frequency range. If, on the other hand, the modulating wave be of a single frequency, that is sinusoidal, each of the resulting side bands will likewise be of a single frequency. It is in this generic sense that the term "side band" is used in this specification and in the appended claims and it therefore is applied to modulating operations of any kind whatever and irrespective of the nature of the modifying signal or agency.

Before considering the apparatus at the distant station on the line, the receiving portion of the circuit of Fig. 1 will be described. The receiving branch 26 coupled to the coils 3 and 4 contains the filtering circuit 27 which may be designed to suppress currents of all frequencies except those used in the one channel indicated. If the line 1 is not composited or multiplexed the filter 27 may be dispensed with. It is assumed in the present case that the same synchronized driving devices control the variation of the carrier current used in transmitting in both directions over the line. This does not necessitate the use of the same frequencies for transmission in both directions, however, nor the use of the same or similar variations in the frequency since the condenser 28, for instance, which controls the frequency of generator 29, although it is driven from the

shaft of motor 7 which is assumed to be at all times in step with the driving shaft at the distant station, may have any suitable capacity and its plates may be so designed
 5 as to introduce variations of any desired character into the carrier frequency. For convenience, however, it is assumed that the oscillator 29 supplies a wave of frequency $v+d$ to the input circuit of the detector 30
 10 and that the wave received over the line 1 from the distant station has its frequency represented by $v+d-s$. Currents of these frequencies combine in the detector in accordance with the well-known homodyne method of U. S. Patent 1,330,471 granted
 15 February 10, 1920, to B. W. Kendall, to give a resultant current having a component of frequency s and the current of this frequency is selected from the higher frequency components by the low pass filter 31 and is received in the telephone receiver 32. The amplifier A in addition to amplifying the received wave acts as a one-way transmission element to prevent the wave from the
 20 oscillator 29 from passing to line 1.

In Fig. 2 the line 1 is shown as having a line balance as in Fig. 1, a transmitting branch 33 and a receiving branch 34. Synchronizing impulses received from the line 1
 30 pass selectively through the filtering circuit 35 to the correcting mechanism indicated at 36. This correcting mechanism is located between the driving motor and the driven portion of the shaft controlling the condensers 6' and 28' and, as explained, shifts the phase of this shaft relative to the motor shaft when necessary in order to bring the driven members at the intercommunicating stations into step. Since, as above stated,
 35 the details of this correcting mechanism may be of known character and the mechanism is preferably of the type clearly disclosed in the Heising application above referred to, but forms no part of this invention, further details are not deemed necessary to the present disclosure.

The wave received from the station in Fig. 1 and having a component of frequency $v+d-s$ is selectively transmitted from the
 50 filter 37 through amplifier A' to the detector D which is also supplied with a wave of variable frequency $v+d$ from the oscillator O₂, the frequency of which is controlled by condenser 28'. The signal component of
 55 frequency s yielded by the action of the detector is selectively passed by the receiving filter FR and produces an audible signal in the receiver 38.

The station in Fig. 2 is illustrated as
 60 equipped with transmitting apparatus which may be similar in every respect to that illustrated and described in connection with Fig. 1. The oscillator O₁ has its frequency varied by condenser 6' in a manner corresponding to the variations of the distant receiving

generator 29. The speech wave from the microphone circuit after passing through filter 21' is combined with a wave of frequency p in the modulator M₁, the upper side band of the resulting modulated wave is selectively transmitted by the transmitting filter
 70 FT, the wave of variable frequency $p+v+d$ from the oscillator O₁ is combined in the modulator M₂ with the upper side frequency component from the filter FT and the lower
 75 side band of the resulting wave is selectively passed to the line by the low pass filter 39.

It should be noted that the current component of frequency $v+d-s$ transmitted over the line may be audible or inaudible
 80 depending entirely upon the frequency of $v+d$. This current may be of the frequencies used for carrier waves in radio or carrier current transmission or it may be of about the upper limit of the essential speech
 85 frequencies. In the latter case, the band represented by the components of frequency $v+d-s$ will occupy substantially the same range as the original speech currents but will be unintelligible.

Although the method described for combining and utilizing the waves of different frequencies is preferred, there are obviously other ways of arriving at the same result.
 95 For instance, if instead of selecting the band including frequency $p+s$ from the modulated wave in the output circuit of the first modulator, the lower side band of frequency $p-s$ is selected, and impressed on
 100 the input circuit of the second modulator together with a wave of varying frequency $p-(v+d)$ the side band of frequency $v+d-s$ of the resulting modulated wave will still be obtained for transmission. But
 105 if components of frequency $p+s$ and $p-(v+d)$ are supplied to the second modulator, the resulting band of frequency $v+d+s$ will be obtained for transmission and as in the other case this same band
 110 $v+d+s$ may be obtained by combining waves of frequencies $p-s$ and $p+v+d$. Although the invention has been disclosed as embodied in a conductive transmission system, the principles of the invention are obviously applicable as well to radio transmission. The system is also capable of variation in other respects from the precise form that has been illustrated and described and the invention is not to be construed as limited to the specific circuit arrangements shown, but its scope is defined in the appended claims.

What is claimed is:

1. The method of secret signaling which comprises modulating a wave by currents of
 125 signaling frequency, suppressing the unmodulated components of both the signaling frequency and the wave, transmitting only one side band of the modulated wave, modulating a second wave by the trans-

mitted band and transmitting to the distant station only one side band of the second modulated wave, the frequency of one of said waves being continuously varied.

2. The method of secretly transmitting signals consisting of a plurality of frequency components which comprises modulating a wave in accordance with said signals, producing a wave of varying frequency, modulating said varying frequency wave by one side band only of the signal-modulated wave and transmitting one side band only of the frequencies resulting from the modulation of said varying frequency wave.

3. The method of secret signaling which comprises modulating by currents of signaling frequencies a wave of varying frequency, suppressing all the unmodified components of both said varying frequency and said signaling frequency waves and transmitting only one side band of the resulting modulated variable frequency wave, supplying a wave at the receiver, transmitting discontinuous control impulses to the receiving point to cause the wave supplied thereto to vary in frequency at all times substantially in the same manner as that of said varying frequency wave and combining the transmitted side band with the wave generated at the receiver to reproduce the signaling current.

4. The method of deriving waves for secret transmission of signals having a range of frequency components, comprising modulating a wave in accordance with said signals, modulating a varying frequency wave by the signal-modulated wave, thereby producing waves of frequencies equal respectively to the sum and the difference of said varying frequency and said signal-modulated wave frequency and each modulated by the signal, and selecting one of the modulated waves thus produced from the other waves.

5. The method of transmitting a pure modulated wave which comprises modulating a wave in accordance with variations to be transmitted occupying a range of frequencies, selectively transmitting resulting wave components of the upper side frequencies only, combining said upper side frequency components with a varying frequency wave of a different order of frequency to produce a modulated varying frequency wave having frequencies represented by the difference between the frequencies of the waves so combined, and transmitting only the lower side frequency components of the modulated wave so produced.

6. The method of secret signaling which comprises producing a pure-modulated carrier wave having a cyclically varying frequency, transmitting one side band component of the wave so modulated but suppress-

ing transmission of currents of all other frequencies, producing at the receiver a cyclically varying wave similar in frequency to the component of the wave transmitted, transmitting independently of the waves used in signal transmission control impulses for maintaining in step the frequency-variations in the transmitted wave and the said wave generated at the receiver and combining said transmitted component with the wave produced at the receiver to reproduce the signal.

7. In a system of secret signaling, means for modulating a high frequency wave in accordance with signals having a plurality of component frequencies and for deriving as a component a single side band of frequencies of the modulated wave, means for generating a wave of varying frequency and for modulating said wave by the single side band from said first means and means for transmitting a single side band of the frequencies resulting from the action of said second means and for preventing transmission of components of other frequencies.

8. In a system of secret signaling, means for generating a wave of fixed frequency and a wave of varying frequency, means for modulating one of said waves in accordance with signals having a plurality of component frequencies and for modulating the other of said waves in accordance with the signal-modulated wave so produced, and means for selectively transmitting one side band of the frequency resulting from the second modulating operation and for suppressing the transmission of currents of the other frequencies.

9. In a secret signaling system, a source of current of sustained frequency, means for modulating said currents in accordance with signals having a plurality of component frequencies, a filter for transmitting only one side band of the frequency components comprised in the modulated wave, a source of waves of varying frequency and means for modulating said waves of varying frequency in accordance with the currents comprised in said side band of frequencies to produce frequency bands representing the sum and difference frequencies of said varying frequency waves and said side band frequencies and a filter for transmitting one of said frequency bands only and for suppressing transmission of the other frequency components.

10. In a secret signaling system, stations, a generator of high frequency waves at each station, a driven control member for each of said generators for introducing similar variations in the character of the generated waves and independent driving members at the respective stations for said control members, means for maintaining said separately driven control members in step, means at

one station for modulating a generated wave in accordance with signals having a plurality of component frequencies and for transmitting only the resulting frequencies comprised in a single side band and means at another station for combining the transmitted side band with the wave produced at said other station to reproduce said signals.

11. A system for producing a pure-modulated high frequency wave and for suppressing currents of all frequencies incident to the production of said wave except those comprised in a single side band, said system comprising means for producing an unmodulated wave, means connected thereto for modulating said wave, a filter for selectively passing frequencies lying to one side of said unmodulated wave frequency but preventing the transmission of said unmodulated wave and currents of all frequencies to the opposite side of said unmodulated wave frequency, means for modulating a high variable frequency wave in accordance with current of the frequencies passed by said filter and a filter for selecting for transmission only those currents comprised in a single side band resulting from the modulation of said high variable frequency wave which lacks the component representing either of said different high frequencies.

12. In combination, a modulator for modulating a high frequency wave in accordance with speech, circuits for impressing a wave of said high frequency and currents of speech frequency upon said modulator, and a low pass filter in the speech current circuit for transmitting to said modulator currents of essential speech frequencies but for suppressing the higher harmonics of speech.

13. The method of suppressing the unmodulated component of a varying frequency carrier wave, which comprises producing a modulating wave, increasing the effective frequency of said modulating wave by a fixed amount, producing a varying frequency wave, modulating said varying frequency wave by said increased frequency modulated wave, and selecting for transmission from the resulting modulated wave a modulated component, to the exclusion of any unmodulated component of varying frequency.

14. In modulation of varying frequency carrier waves, the method of suppressing transmission of an unmodulated component of said varying frequency which comprises producing a modulating wave, increasing the frequency of said modulating wave, producing a varying frequency wave, modulating said wave of varying frequency by said increased frequency modulating wave to yield modulated and unmodulated components having wide frequency separation, and selecting out from the resultant modu-

lated wave a wave having no unmodulated component.

15. A system for suppressing the unmodulated component of a varying frequency carrier wave, which comprises means for producing a modulating wave, means for increasing the effective frequency of said modulating wave by a fixed amount, means for producing a carrier wave of varying frequency, means for modulating said carrier wave by said increased frequency wave, and means for selecting out from the resultant modulated wave and transmitting to the exclusion of unmodulated components thereof a wave having no unmodulated component.

16. A transmission system comprising means for producing a varying frequency carrier wave, means for producing a modulating wave, means for increasing the frequency of said modulating wave, means for modulating said carrier wave by said increased frequency wave to yield modulated and unmodulated components having wide frequency separation, and means for selecting out from the resultant modulated wave and transmitting to the exclusion of unmodulated components thereof a wave having no unmodulated component.

17. In a carrier telephone system, a line circuit, a carrier transmitting circuit including a vacuum tube modulator connected to said line, a speech transmission circuit connected to said modulator, a low pass filter in said speech transmission circuit for restricting the range of frequencies impressed on said modulator to the lower essential range of speech frequencies, a source of carrier waves connected to the input of said modulator and a second filter between the modulator and the line for suppressing one side band of the modulated wave and selectively transmitting to line a range of frequencies including the other side band.

18. The method which comprises inverting speech waves to produce an unintelligible inverted audio-frequency band of waves and subjecting the various components of said inverted frequency band to a cyclic frequency variation.

19. A signaling system comprising means for producing speech waves, means for inverting said waves to produce an unintelligible inverted audio-frequency band of waves, and means for subjecting the various components of said inverted frequency band to a cyclic frequency variation.

20. The method of inverting the frequency order of a band of frequency components, comprising modulating a wave of a frequency higher than any of the frequencies in said band by said band of frequency components, selecting one side-band of the resulting modulated wave, while suppressing the other

side-band and the unmodulated component of said wave of higher frequency, modulating a second wave by the selected side-band, and selecting from the wave so modulated the side-band having a frequency order the inverse of that of the original band, while suppressing the other side-band and the unmodulated component of said second wave.

21. The method of inverting the frequency order of a band of frequency components to secure an inverted frequency band overlapping the frequency range of the original band, comprising modulating a wave of a frequency as high as the highest frequency of the original band in accordance with the original band of components, filtering the wave so modulated to pass only one side-band, modulating a second wave by said side-band, said second wave being of such frequency relative to the first wave as to cause the resulting side-band in which the frequency order is the inverse of that of the original band to overlap the frequency range of the original band, and selecting said inverse frequency side-band.

22. The method of inverting the frequency order of a band of frequency components to secure an inverted frequency band overlapping the frequency range of the original band, comprising modulating a wave of a frequency higher than the highest frequency of the original band in accordance with the original band of components, filtering the waves so modulated to pass only the frequency components of higher frequency than the highest component of the original band whereby transmission of all components of the original band is suppressed, modulating a second wave by the components so passed, said second wave being of such frequency relative to the first wave as to cause the resultant side-band in which the frequency order is the inverse of that of the original band to overlap the frequency range of the original band, and selecting said inverse frequency side-band.

23. In a signaling system, a source of waves of a band of frequency components, a source of waves of a single frequency, a

modulator for modulating said waves of single frequency in accordance with said band of frequency components, means to suppress from transmission said wave of single frequency and components of lower frequency, means to selectively transmit from the resultant modulated waves frequency components higher than the highest frequency of said band, a second source of waves of a single frequency, a second modulator for modulating said waves from said second source in accordance with the frequency components passed by said selective means, and a low pass filter for selecting from the resultant modulated wave in the output of said second modulator a band of frequency components having a frequency order the inverse of the original band of frequency components and for suppressing the other components of said resultant modulated wave.

24. In combination, means to generate a wave having a band of frequency components, means to generate a wave of a single frequency as high as the highest frequency in said band of frequency components; means to modulate said single frequency by said band of frequency components, means to filter the resultant modulated wave so as to pass only frequencies higher than the highest frequency in said band, means to generate a second single frequency wave, means to modulate said second single frequency wave in accordance with the frequencies passed by said filtering means, said second single frequency wave having such a frequency relative to the first-mentioned single frequency wave as to cause the production in a second-mentioned modulating process of a band of frequency components having a frequency order the inverse of the original band and overlapping the frequency range of said original band, and means to select said inverse overlapping band of frequency components.

In witness whereof, I hereunto subscribe my name this 7th day of September A. D., 1920.

BURTON W. KENDALL.