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J. F. FARRINGTON

HIGH FREQUENCY TRANSMISSION

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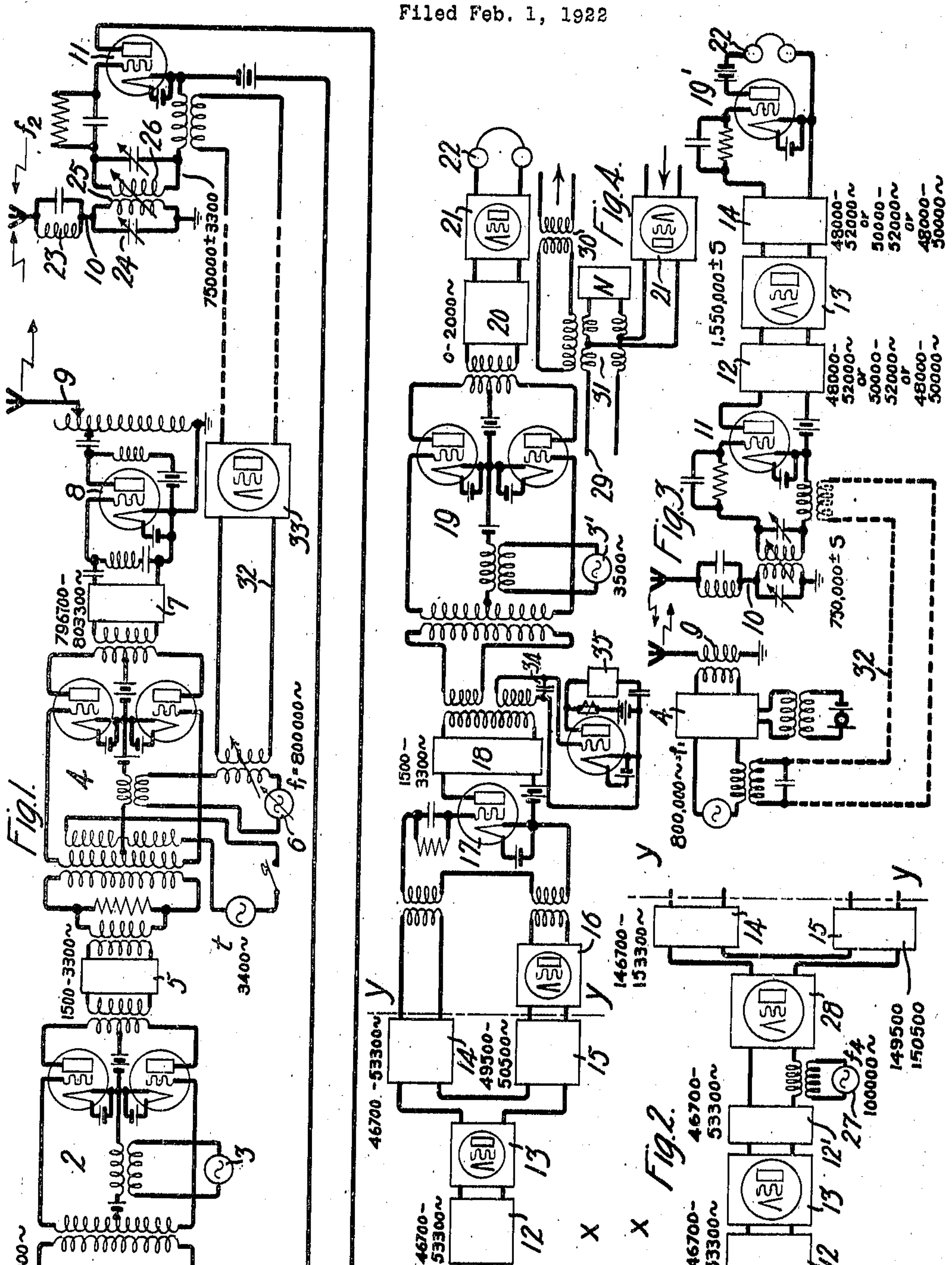

Inventor:
John F. Farrington.
by O.C. Sprague. Att'y.

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JOHN F. FARRINGTON, OF NEW YORK, N. Y., ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

HIGH-FREQUENCY TRANSMISSION.

Application filed February 1, 1922. Serial No. 533,198.

To all whom it may concern:

Be it known that I, JOHN F. FARRINGTON, a citizen of the United States, residing at New York, in the county of Bronx, State of New York, have invented certain new and useful Improvements in High-Frequency Transmission, of which the following is a full, clear, concise, and exact description.

This invention relates to wave transmission systems and especially to radio telephone systems for two-way conversation and other similar systems employing carrier waves.

An object of the invention is to decrease the interference between channels of the same or different carrier wave transmission systems and thereby increase the number of possible channels in a multiplex system or increase the number of simultaneous conversations which can be carried on through the same energy transferring medium as, for example, the ether of a given region. Since the radio field is the principal field of utility of invention, radio signaling systems, are described herein to illustrate the principles involved.

Another object of the invention is to provide improved methods of and means for secret communication.

In one well-known type of carrier wave signaling system two-way communication between distant stations is carried on by modulating a high frequency carrier wave at each of the stations in accordance with the signal to be transmitted to the other station. The carrier waves at the two stations are not of the same frequency but differ from each other by a difference frequency preferably above audibility in the case of telephony but not otherwise limited to any definite range. The receiver at each station receives the carrier wave from its own transmitter as well as that from the distant transmitter. These two different frequency received waves are combined to produce a third carrier wave having a frequency within a range preferably of 8,000 to 100,000 cycles per second but in any case having its frequency dependent upon the frequencies of the two principal carrier waves. The particular range indicated is preferred because it is high enough to act as a carrier for speech frequencies and not high enough to necessitate expensive apparatus for amplification and selection. The wave of the third frequency produced at each station will be styled the "auxiliary carrier wave," to distinguish it from the principal carrier waves which are combined to produce it. The auxiliary carrier wave is modulated in accordance with the signal being sent by the distant transmitter when the operator thereat is sending and is modulated in accordance with the signal of the local transmitter when the local operator is sending. If both are sending, the auxiliary carrier wave will be modulated in accordance with both signals and both signals will be heard at each station. Both principal carrier waves must be transmitted when signals are transmitted from either station to the other.

In another well-known type of system a modulated carrier wave having its unmodulated component suppressed is radiated or otherwise transmitted. This is sometimes styled a "carrier suppression system" and the method employed is called "carrier suppression." In the present system a similar principle is made use of for partial carrier suppression.

A particular object of the present invention is to provide methods and means for combining substantial advantages of the two systems described, that is,—for utilizing partial carrier suppression in duplex systems wherein the incoming and outgoing carrier waves combine to produce an auxiliary carrier wave at each station.

A difficulty which is apparent in applying the method of carrier suppression to two-way systems of the kind described is that the auxiliary carrier frequency at each station will lack an unmodulated component of sufficient amplitude to reproduce a low frequency signaling wave of the original low frequency wave form. See article by Colpitts and Blackwell, "Carrier current telegraphy and telephony," Proceedings of the American Institute of Electrical Engineers, April, 1921, vol. 40, No. 4, page 309. In case the original wave form is not approximately reproduced, the reproduced signal will not be of good quality. This is especially important in telephony.

As hereinafter described, there are provided means and methods for increasing the relative amplitude of the unmodulated component of the auxiliary carrier frequency with respect to its accompanying modulated component.

Use is made of an additional auxiliary carrier wave which is generated at each station of the two-way system. The energy of this wave is utilized at the transmitter in transmission and at the receiver in reception. By means of this additional auxiliary carrier wave, the frequencies of the side bands of the several carrier waves traversing the entire system are caused to be spaced away from the unmodulated or base frequency component accompanying the side band. On account of the function of this additional auxiliary carrier wave, which may be of any relatively low frequency as, for example, from about 3,000 up to 10,000 cycles per second or higher, it is herein styled a "spacing carrier" or "spacing carrier wave" in order to distinguish it from other carrier waves used in the system.

It will later be shown how a spacing carrier wave having a frequency of 3.500 cycles per second may be employed to change the side bands of a speech modulated auxiliary carrier wave which, in the normal case, may be assumed to be of frequency of 50,000 cycles with side band frequencies ranging from 48,000 cycles to 49,800 cycles and 50,200 cycles to 52,000 cycles so that the side frequencies will range from 46,700 cycles to 48,500 cycles and from 51,500 cycles to 53,300 cycles. As a result of this, it becomes practical to receive a very small energy of auxiliary carrier frequency and select it from its side frequencies. After selection its energy is greatly increased by amplification whereupon it is recombined with the unamplified or more slightly amplified side frequency wave and impressed upon a detector.

A feature of the invention is that the "auxiliary carrier" frequency may be equal, if desired, to the sum of the two principal carrier frequencies as an alternative to the case where it is equal to their difference. In special cases this may be advantageous.

Another feature consists in transmission of energy of the local transmitting generator into the local receiving circuit without first passing it through the modulating apparatus of the transmitter. In this way the ratio of modulated and unmodulated energy of the outgoing principal carrier frequency which is impressed upon the local detecting apparatus may be regulated at the will of the operator in any manner necessary to secure the best operation or as particular circumstances necessitate.

A further feature, the advantages of which will be described hereinafter in detail, consists in selecting the intermediate carrier frequency and one or both of the accompanying side frequencies both before and after amplification.

A still further feature is the use, in a system employing a partially suppressed carrier and additionally employing any or all of the other features above mentioned, of a variable frequency carrier to promote secret communication.

Many of the features of the invention are useful not only in connection with systems where incoming and outgoing carrier waves combine to produce an auxiliary carrier wave, but also in systems where a local source of any suitable high frequency is used to beat with the incoming principal carrier wave to produce an auxiliary carrier wave.

The novel system proposed admits of the use of certain desirable features heretofore suggested in connection with other systems, among which may be mentioned:—(1) The selection and transmission of one side band only at any point in the system; (2) the connection of the transmitter and the receiver at a high frequency terminal station to a low frequency telephone line by means of a balanced or other suitable circuit whereby the radio signaling channel may be extended through one or more telephone exchanges to subscribers; (3) suitable selective circuits of other types than iterative band filters; and (4) low frequency selecting apparatus.

Although the translating devices used for modulation, detection, and amplification are described as electron discharge tubes of the thermionic type it will be understood that the principles of the invention may be employed in systems utilizing other equivalent forms of translating devices.

The invention will now be described in detail with reference to the accompanying drawings wherein Fig. 1 represents a complete radio terminal station comprising a transmitter and a receiver connected respectively to separate antennæ; Fig. 2 represents alternative apparatus which may be substituted for the apparatus between the lines X—X and Y—Y of Fig. 1; Fig. 3 represents a simplified radio terminal station in which a spacing carrier is not used; and Fig. 4 illustrates a convenient manner of connecting either of the stations illustrated in Figs. 1 or 3 to a low frequency telephone line.

In Fig. 1, a signaling circuit 1 which represents any suitable source of audible frequency signaling currents is connected to the input circuit of a modulating system 2 of a type described, for example, in United States patent to Carson No. 1,343,306, granted June 15, 1920. A source of spacing carrier waves 3 is also connected to the modulating system. The output circuit of the device 2 is connected to the input circuit of a principal modulating system 4 of a type similar to the system 2. Between the systems 2 and 4 is connected a suitable selective circuit 5 which is preferably a band-pass filter.

A band-pass filter is any network which passes a definite band of frequencies with negligible attenuation and highly attenuates other frequencies. A source 6 of carrier waves constitutes the outgoing carrier wave source. The waves from the source 6 are supplied to the modulator 4, the output circuit of which is connected through a suitable selective circuit, preferably a band-pass filter 7, to the input circuit of a power amplifier 8. The amplified wave energy produced by the amplifier 8 is impressed upon a transmitting antenna 9 of any convenient type.

The receiving system associated at a radio terminal with the transmitting system described consists of a receiving antenna 10 connected by suitable selective circuits to a detecting device 11, the output circuit of which is preferably connected through a selective circuit 12 and an amplifier 13 to two selective circuits 14 and 15, arranged in divergent channels. The waves passing through the circuit 15 are amplified in an amplifying system 16 which may consist of one thermionic amplifier or a plurality of thermionic amplifiers or equivalent devices arranged in tandem. The divergent channels converge and are united by connecting output circuits of the devices 14 and 16 to the input circuit of a detecting circuit 17 in the output circuit of which is a selective circuit 18 followed by another detecting circuit 19 to the input circuit of which is connected a source 3′ of waves of spacing carrier frequency, that is, the same frequency as source 3. The output circuit of the circuit 19 is connected through a filter 20 which is preferably a low pass filter transmitting freely a range of frequencies from 0 to 2000 cycles and an amplifier 21 to a low frequency circuit 22 which contains any suitable indicating means, for example, a telephone head set or other receiver. The selective circuits 12, 14, 15, 18 and 20 are preferably of the band-pass type described in United States patent to Campbell No. 1,227,113, granted May 22, 1917, but may be any selective circuits capable of performing, to a sufficient degree, the functions herein indicated. It is practicable to omit certain selective circuits, amplifiers, and other apparatus without rendering the system inoperative. However, the omission of these may render the system somewhat less selective or less efficient in some respects.

To explain the operation of the system, definite values of frequencies will be stated. This, however, is not intended to limit the invention to the particular values stated, since these may vary over a wide range. For telephony, the microphone circuit 1 will be considered as a source of speech frequency waves covering a range of from 200 to 2000 cycles of which the frequency is represented by "s." The spacing frequency source 3 has a frequency of 3500 cycles. The filter 5 passes a range of frequencies of from 1500 to 3300 cycles. The source 6 supplies outgoing carrier waves of frequency f_1, which is 800,000 cycles. The band filter 7 may pass currents of a range of frequencies of from 796,400 cycles to 803,600 cycles, that is to say,—it may pass both side bands produced by modulating 800,000 cycles with a band of frequencies of from 1500 to 3300 cycles. Filter 7 may, however, and preferably does suppress one of these side bands. It may or may not be designed to discriminate against the carrier frequency f_1, but must in general permit the passage of some current of this frequency. The antenna 9 is preferably tuned to the mean of the frequency which it is to transmit but may be tuned to discriminate against certain frequencies in favor of others. From a distant transmitting station, which is supposed to be like the transmitting station illustrated in Fig. 1 with the exception that its carrier frequency f_2 (corresponding to f_1) is 750,000 instead of 800,000 cycles, are received carrier waves. I will be seen that the incoming wave of frequency f_2 is accompanied by one or more side frequencies which result from modulation at the distant transmitter by means similar to those illustrated. In the receiving antenna 10 a loop or trap circuit 23 is located which may be adjusted to discriminate to any desired extent against waves of frequency f_1 and its accompanying side frequencies. The antenna circuit may consist of a tuned or untuned loop having the trap circuit 23 in series in the loop. The antenna 10 or an equivalent loop circuit may conveniently be arranged to have its maximum receptivity in the direction of the distant station and its minimum receptivity in the direction of the antenna 9. A variable condenser 24 and inductance 25 serve to tune the antenna 10 to the waves from a distant station. Inductance 25 also serves to couple the antenna circuit 10 to the input circuit of a detector 11. A selective circuit 26 is tuned to select desired waves and discriminate against other waves. The carrier waves of frequencies f_1 and f_2 are combined by the detector 11 to produce waves of sum and difference frequencies, that is, f_1+f_2 and f_1-f_2, either of which may be utilized as an auxiliary carrier. Generally it is desirable to select the lower of these frequencies for the auxiliary carrier, that is f_1-f_2 which in the present instance is a frequency of 50,000 cycles. This frequency will be designated as f_3. The auxiliary carrier wave of frequency f_3 will be modulated in accordance with whatever signaling waves are modulating the carrier wave of frequency f_1 at a given instant and likewise with whatever signaling waves are modulating the carrier wave of frequency f_2. Either party may at any time break in and be heard by the other. The circuit 12 selects the auxiliary carrier and its accompanying side frequencies and is therefore adjusted to pass a band of from 46,700 to 53,300 cycles. It may, however, and preferably does exclude one of the side frequencies. For example, if the lower side frequency is to be excluded, the band passed will extend from 50,000 to 53,300 cycles. The selected components are amplified by the amplifier 13 and impressed upon two selective circuits 14 and 15. The circuits 14 and 15 are intended to separate side frequency energy from the energy of the auxiliary carrier freqency. This allows the energy of the auxiliary carrier frequency, that is, the unmodulated component, to be amplified in the amplifying system 16 whereby its energy may be increased relative to that of the side frequencies to any desired extent. The modulating system 4 is of the carrier suppression type and is intended to partially but not completely suppress the unmodulated component of the frequency f_1, while at the distant transmitting station, a similar or equivalent modulating system will partially suppress the unmodulated component of the frequency f_2. No definite extent to which the unmodulated component is suppressed need be assigned herein. It may be assumed, for example, that nine-tenths of the unmodulated component which would otherwise be transmitted, is suppressed. Instead of a band filter, the circuit 15 may consist of a series of sharply tuned circuits each resonant to the frequency of 50,000 cycles and having thermionic amplifiers interposed between them. Such an arrangement is illustrated in the United States patent to Alexanderson, No. 1,173,079, granted February 22, 1916. In that case the elements of the selective circuit 15 and the amplifier 16 are divided up and interposed between each other. The circuit 14 is adapted to pass the same range of frequencies as the circuit 12 is adapted to pass; with this distinction, however, that it may exclude the unmodulated component, that is, f_3 or 50,000 cycles, if desired. On the other hand, the unmodulated component may be transmitted through the circuit 14. The side frequency energy passing the circuit 14 and the amplified unmodulated component from the amplifier 16 are impressed together and combined by the detector 17. In the output circuit of this detector, a component of energy results which has the same frequency range as that transmitted through the circuit 5, for example, 1500 to 3300 cycles, is selected by the circuit 18 and impressed upon the circuit 19 which has been variously designated in the art as a detecting, demodulating, or distorting circuit.

The modulating system 2 at the local station as well as the modulating system of the distant station, which is equivalent thereto, are preferably of the carrier suppression type, hence, the spacing carrier frequency has had its unmodulated component largely or entirely suppressed. When this suppression is moderately well accomplished at the distant station, it becomes impractical to derive the original low frequency speech waves from the waves transferred by the circuit 18 without resupplying the spacing carrier frequency. For this purpose, a source 3′ is provided which impresses waves of the spacing carrier frequency upon the modulating circuit 19. The sources 3 and 3′ are of relatively low frequency and hence may be synchronized without much difficulty whereas if it should be attempted to supply energy of the auxiliary carrier frequency, that is, f_3, to the device 17 from a local source, more difficulty would be experienced in maintaining synchronism within any specified range of allowable variation. The speech frequency waves occurring in the circuit 1 or in the corresponding circuit at the distant station are reproduced in the output circuit of the system 19. These waves are preferably separated from interfering waves of higher frequencies by a filter 20, amplified by a device 21 and impressed upon the telephone circuit 22.

It will be observed that the circuit 22 will receive not only the signal from the distant station but also the local outgoing signal.

The circuit 32 serves to supply a relatively small amount of energy of the outgoing carrier frequency f^1 to the detecting device 11. The circuit 32 need be only slightly coupled to the circuit of the source 6 and only slightly coupled to the circuit of the device 11. If undesirable reaction occurs whereby energy is transferred from the input circuit of the device 11 to the circuit of the source 6, a thermionic amplifier 33 may be included in the circuit 32. This amplifier will repeat only in the direction away from the source 6. Since the coupling and adjustment of the circuit 32 and the adjustment of the device 33 are entirely under the control of the local operator, they may be adjusted from time to time in any manner necessary or desirable to secure the best results. The energy supplied through the circuit 32 is wholly unmodulated, which tends to the production of better quality and more uniform signals. The circuit 32 is not essential and may be omitted. When it is used, however, the spacial configuration and relationship of the antennæ 9 and 10 and their tuning and adjustment may be such as to suppress from the circuit 10 the energy of the frequency f^1 to a more considerable extent than when the circuit 32 is absent. The use of the circuit 32 is not necessarily associated with the use of an unmodulated carrier suppression modulating system 4. Furthermore, neither of these features is wholly dependent upon the use of a spacing carrier frequency or upon a modulating system 2 of the carrier suppression type.

Means for superimposing a telegraph or call channel upon the telephone channel is illustrated. A source *t* of current having a suitable frequency is connected to the input circuit of the modulator 4 by a circuit including a key. When the key is closed the carrier frequency f^1 is modulated by waves from the source *t*. If the source *t* has any frequency without the range of the band 1500 to 3300 cycles, it will interfere little with the speech transmission. When the call channel is used in this manner the various filters through which the resultant modulated wave passed will be modified to pass the additional side frequency thus produced. For example, if *t* has a frequency of 3400 cycles per second, the filters 7, 12, 14 and 18 must be designed or adjusted to pass a frequency removed 3400 cycles from the carrier. A circuit 34 tuned to 3400 cycles and connected to an alternating current relay 35 or equivalent receiving instrument serves for reception of the telegraph or call signal.

The present system offers considerable possibilities in the way of making the unauthorized reception of signals difficult. Partial suppression of the unmodulated component and transmission in each direction on different carrier waves are two features which tend to prevent reception by simple systems. Let it be assumed that the present system radiates the upper side band resulting from the modulation of a carrier of 800,000 cycles with a side band of 1500 to 3300 cycles. Then this signal can be picked up by means of a local source of 803,500 cycles. If both side bands of the 800,000 cycle wave, modulated as stated, are radiated the signal can, nevertheless, be received by means of a properly selective antenna and a local source. If, however, the transmitted carrier wave varies over a range of several hundred cycles, such unauthorized reception becomes more difficult. For secrecy this variation may be purposely introduced. Let it be assumed that the local and distant principal carriers are each varying from 250 cycles above the mean value to 250 cycles below the mean value. If the variations of the principal carriers are not synchronous, a total variation of the intermediate carrier of from 500 cycles above to 500 cycles below the mean value will occur. For transmission of a single side band, that is, upper side band, the following filter values will be needed: filter 7, 799,750 to 803,550 cycles; filter 12, 49,500 to 53,800 cycles; filter 14, 51,000 to 53,800 cycles; and filters 5, 15, 18 and 20 would have the values indicated on the drawing. For transmission of both side bands, the values would be: filter 7, 796,450 to 803,550 cycles; filter 12, 46,200 to 53,800 cycles; filter 14, 46,200 to 53,800 cycles; and filters 5, 15, 18 and 20 as before. When such a variable carrier or variable carriers are used, the telegraph or call frequency of 3400 cycles can still be used. In case this is used each filter through which the wave modulated with 3400 cycles passes must have such a value as to pass a component differing from the carrier by 3400 cycles. If one carrier is maintained constant, the other may be given a total variation of from 500 cycles above to 500 cycles below the mean carrier frequency. In other words, the sum of the total variations of both carriers from their mean values determines the filter values necessary in the receiver circuit. This variation may be divided between the two carriers in any desired proportion. If the variation is an accidental one instead of intentionally produced, the results will be the same.

In Fig. 2, a selective circuit 12′ is connected between the amplifier 13 and the selective circuits 14 and 15. The purpose of this arrangement is to give additional amplification and selectivity. The source 27 indicates the introduction of an additional locally generated frequency which may be utilized either to step up the auxiliary carrier frequency and its associated side frequencies to a higher value, or, if preferred, to step it down to a lower value. In the present instance, it is assumed that the auxiliary carrier frequency is to be stepped up to a higher value, for example, from 50,000 cycles to 150,000 cycles. In this case, the source 27 may have a frequency of 100,000 cycles designated as f_4. This need not be accurately maintained as a slight frequency variation will ordinarily produce no detrimental effect. The modulating device 28 serves to combine the energy transmitted through the filter 12′ with energy from the source 27 thereby producing a supplemental auxiliary carrier frequency of 150,000 as well as a difference carrier frequency of 50,000 which will be ignored as it is suppressed by the circuits 14 and 15. The 150,000 cycle component is, of course, accompanied by one or both side bands as is determined by the transmission of one or two side bands from the local and distant station and the corresponding adjustment of the circuits 12 and 12′. Naturally when both side bands are utilized at one point in the system it is desirable that both be transmitted through all the various filter circuits, and when only one is transmitted, then the filter circuits will be adjusted so that only the corresponding side band will be transmitted and other frequencies suppressed. The advantages of the transmission of only one side band are well known. The present invention is applicable to the transmission of either one or both side bands. The circuits 14 and 15 in Fig. 2 are analogous to the circuits 14 and 15 in Fig. 1 and perform identical functions. Their difference consists only in such design or adjustment as is necessary to render them applicable to a carrier frequency of 150,000 cycles instead of 50,000 cycles. The apparatus between the lines X—X and Y—Y of Figs. 1 and 2 are interchangeable and may be substituted each for the other.

In Fig. 3 is illustrated a simplified system wherein a spacing carrier source is not utilized. In this system the carrier frequency f_1 is directly modulated by a speech or other signaling wave and the resultant energy impressed directly or through amplifiers (not shown) upon a transmitting antenna 9. The receiving antenna 10 is similar to that of Fig. 1 and the detecting device 11 and its associated circuits are likewise similar to the corresponding elements of Fig. 1. The outgoing and incoming carrier frequencies f_1 and f_2, together with such components as result from modulation, are combined by the device 11 to produce sum and difference frequencies, either of which may be selected as an auxiliary carrier. If the sum frequency is to be selected, the amplifying system 13 and the associated filters 12 and 14 are designed to select and amplify the auxiliary carrier frequency $f_1+f_2\pm s$. The double sign before "s" indicates that either one or both side frequencies may be selected. On the other hand, the system 12, 13, 14 may be designed and adjusted to select and amplify the difference frequency, that is, $f_1-f_2\pm s$. The various ranges of frequencies which may be passed by the filters 12 and 14 are indicated on the drawing. The detecting circuit 19 detects the waves transmitted through the filter 14 thereby reproducing the original speech waves which are then impressed upon a telephone receiver circuit 22. In the arrangement of Fig. 3, as so far described, the modulator 4 does not suppress the unmodulated component or suppresses it to such a small extent that reproduction of the original signaling wave by the device 19 is still possible. If desired, however, the modulator 4 at the local station may suppress the unmodulated component as completely as possible, in which case it may be supplied through the circuit 32 as described in connection with Fig. 1. In case the corresponding modulator 4 at the distant cooperating station partially suppresses the unmodulated component, then it becomes necessary to substitute for the system 12, 13, 14 of Fig. 3, an arrangement like that of Fig. 1, consisting of the elements 12, 13, 14, 15 and 16, since otherwise the energy of the unmodulated auxiliary carrier frequency in the input circuit of the device 19′ would be too small to permit good signal reproduction.

Fig. 4 illustrates the manner of connecting a low frequency telephone line 29 to the input circuit of the local radio transmitter and to the output circuit of a local radio receiver so that a two-way conversation may be carried on via radio by a subscriber at the remote end (not shown) of the line 29. The transformer 30 represents the transformer 30 of Fig. 1, and the amplifier 21 represents the amplifier 21 of Fig. 1. The network N balances the line 29 at speech frequencies and the circuits leading to and from the amplifier 21 and the transformer 30 are connected in conjugate relation with respect to each other to the triple winding transformer 31. The systems illustrated in Figs. 1, 2 and 3 or any equivalent system may be connected to a telephone line in a similar manner.

The object of providing duplicate filters 12 and 14 needs brief mention. Assume that the filter 14 is omitted. Incoming impulses would tend to act upon the filter 12 and to set up oscillations having all the possible natural frequencies of the filter. If any of these natural frequencies or possible combination frequencies which might be produced by distortion in amplifier 13 or by detector 14 are within the range passed by the filter 18 they will appear in the line 22 as noise currents. When filter 14 is included, an additional discrimination occurs in that disturbing foreign frequencies resulting from impulsive excitation of filter 12 or distortion in amplifier 13 must not only pass through filter 14 but their combination frequencies must likewise pass filter 18. Assuming filter 12 to be omitted and filter 14 present, then impulsive excitation of filter 14 will cause somewhat similar disturbances and in addition foreign frequencies which cannot pass filter 14 may combine in amplifier 13—owing to the inherent distortion—to produce waves which will pass filter 14. When both filters are employed impulsive disturbances are not allowed to act upon filter 14 and the undesired waves produced by filter 12 and amplifier 13 are largely suppressed by filter 14. Another advantage of filter 12 is an increase of efficiency in the amplifier 13 in consequence of permitting it to handle less energy of undesired and unused frequency components. Likewise when filter 12 is provided any incoming waves which are such as can produce combination frequencies capable of passing filter 14 will not be transmitted to amplifier 13 to cause such combination frequencies. Thus, an important feature of the present invention consists in selecting the intermediate frequency and its accompanying side bands both before and after amplification. A still greater advantage results from selecting a single side band and the unmodulated component of the auxiliary carrier frequency both before and after amplification. The filters used should have sharp and definite cut-off limits if high efficiency and good selectivity are desired. Double selection of the intermediate frequency is not dependent on the use of a spacing carrier or of unmodulated carrier suppression means for its utility.

The use of a spacing carrier permits the auxiliary carrier frequency to be spaced away from its accompanying side bands by any necessary amount. This enables the auxiliary carrier to be selected by means of apparatus of moderate cost and reasonable refinement. Unless the auxiliary carrier can be selected from its accompanying side frequencies, it is difficult to introduce any great amplification by the amplifier 16 because if some of the side frequency components are amplified in the device 16 and others are not amplified, or are only slightly amplified, an undesirable distortion is introduced as a result of increasing the amplitude of certain speech components disproportionately.

If the transmitting modulator 4 and the amplifier 8 are not operated during a time when the receiving system is receiving waves from a distant station, but the source 6 is operating and is supplying energy through the circuit 32 to the device 11, it will be seen that the auxiliary carrier frequency will be produced, selected, amplified and detected in the same manner as if the transmitting station is operating. The source 6 then acts as a local source used solely for aiding reception and not for transmission.

For line wire transmission, the antennæ 9 and 10 are replaced by any suitable wire circuit extending to the distant station.

Before pointing out the novel features of the invention in the claims, the scope of certain expressions used therein will be indicated. The expression "side frequencies" or "side band" includes a single side frequency as well as a band of side frequencies. "Unmodulated component" is an expression adopted from British Patent No. 102,503, of 1916 and is used in the same sense as in that patent. However, it is not intended to limit the present invention to the type of modulator described in that patent. The suppression of the carrier may occur in the modulator itself or result from the action of selective circuits or partially from both.

The novel features believed to be inherent in the invention are defined in the appended claims.

What is claimed is:

1. The method of securing the advantages of partial suppression of the unmodulated component in a wave transmission system employing a detector, which comprises transmitting only feeble energy of the unmodulated component, separating the unmodulated component from its accompanying side frequencies at a point in the system where the total energy is small relative to the transmitted energy, increasing the energy of the selected unmodulated component, and combining at the detector the increased energy of the unmodulated component with its accompanying side frequencies.

2. The method of signaling in a system wherein is transmitted a carrier wave modulated in accordance with a signal and having an unmodulated component too small to reproduce a sufficiently perfect signal, which comprises receiving, selecting out as such, and increasing the energy of the unmodulated component at a receiving station, and recombining the unmodulated component of increased energy with the modulated carrier wave energy to produce a modulated carrier wave having a relatively greater unmodulated component than the received wave.

3. The method which comprises largely suppressing the unmodulated component of a modulated carrier wave at a transmitter, receiving the energy of the unmodulated component and one or more accompanying side frequencies, and producing energy derived from the feeble unmodulated carrier component having an amplitude proportionately greater in relation to the side frequency component than the energy of the unmodulated component received is with respect to the received side frequency energy.

4. The method which comprises transmitting a wave of relatively small amplitude and a side frequency of relatively large amplitude of a modulated wave, receiving the energy of both, deriving energy from the side frequency, deriving energy from the first mentioned wave having a relatively much greater ratio to the received unmodulated component, and combining said derived energies.

5. The method which comprises largely suppressing the unmodulated component of a modulated carrier wave at a transmitter, receiving the energy of the unmodulated component and one or more accompanying side frequencies, converting the frequencies of all the received waves by an equal amount to produce another unmodulated component and one or more accompanying side frequencies, and producing from the converted unmodulated component, energy having its relative amplitude proportionately greater with respect to the side frequency energy than the received unmodulated component is with respect to the received side frequency energy.

6. The method which comprises transmit-

ting an unmodulated component of relatively small amplitude and a side frequency of relatively large amplitude, receiving and converting the energy of both to produce an auxiliary unmodulated component of small amplitude and an auxiliary side frequency, amplifying in relation to the modulated component the energy of the unmodulated component, and combining the resultant energies.

7. The method which comprises successively detecting an unmodulated component and an accompanying side frequency and converting the frequencies thereof, and at one stage amplifying one of the energies representing the unmodulated component and the modulated component disproportionately with respect to the other.

8. In a signaling system, means for transmitting an unmodulated component of relatively small amplitude and a side frequency of relatively large amplitude, means for receiving the energy of both, means for converting the frequencies of both by a fixed amount, means for increasing the energy of the unmodulated component to a relatively high value with respect to the modulated component, and means for combining the amplified unmodulated component and the modulated component to reproduce a signaling component.

9. In a signaling system, a transmitter including means for partially suppressing the unmodulated component of the transmitted wave, means for receiving the energy of the feeble unmodulated component and one or more accompanying side frequencies, means for deriving an unmodulated component of increased amplitude from the unmodulated received component, and means for combining the side frequency energy with the unmodulated component of relatively increased amplitude.

10. A receiving system comprising a detector for combining incoming carrier waves with locally generated waves to produce an auxiliary carrier wave, a selective circuit for selecting the unmodulated component of the auxiliary carrier wave from the modulated components thereof, means for amplifying the selected unmodulated component, and means for recombining the amplified unmodulated component with the modulated components.

11. A signal transmission system comprising two cooperating stations, each transmitting to the other and each supplying high frequency energy of its own carrier frequency to its local receiver, means at each of said stations to transmit a modulated wave having a relatively small unmodulated component, and means at each receiving station to increase the energy of the unmodulated component to an extent disproportionate to any increase of the modulated component.

12. A signal transmission system comprising two cooperating stations, each transmitting to the other and each supplying high frequency energy of its own carrier frequency to its local receiver, frequency changing means at each station for combining the energies received from the local and distant stations and converting the combined energies to an auxiliary carrier frequency energy, means at one of said stations for partially suppressing the unmodulated component of the transmitted carrier frequency energy, and means at one of said stations to increase the energy of the unmodulated component of the auxiliary carrier frequency energy disproportionately with respect to any increase in energy of the modulated component.

13. In a signaling system, a transmitter comprising a source of high frequency waves, a source of signaling waves, and a spacing carrier source for spacing the side frequencies of the modulated carrier wave away from the unmodulated component in combination with a receiver having means for separating the side frequencies from the unmodulated carrier wave.

14. In combination with a receiving system comprising means for producing from received carried waves an auxiliary carrier wave, means for selecting the unmodulated component of the auxiliary carrier wave from the modulated component, means for amplifying the selected unmodulated component, means for recombining the amplified unmodulated component and the modulated component, and means for combining energy of the spacing carrier frequency with the waves produced by the last mentioned combining means.

15. A system comprising two cooperating stations, each provided with means for transmitting its own carrier wave to the other and each provided with means for receiving its own carrier wave and combining its energy with energy of the carrier wave from the distant station to produce an auxiliary carrier wave, and means for decreasing by a substantial amount the amplitude of the unmodulated component of the carrier wave transmitted from one station.

16. In a system in accordance with claim 15, means for decreasing by a substantial amount the amplitude of the unmodulated component of the carrier wave transmitted from the other station.

17. In a signaling system, a source of signaling waves, a spacing carrier source, means for modulating the spacing carrier source with waves from the source of signaling waves, a principal carrier source, means for modulating waves from the principal carrier source with waves resulting from the first mentioned modulation, the system being designed and arranged to partially suppress

the carrier component of the transmitted principal carrier, and means at a cooperating receiving station for combining energy of the spacing carrier frequency with the received waves.

18. A signaling system comprising a receiving channel for incoming high frequency waves, means for supplying locally generated waves to the receiving channel, means for combining energy of the received and locally generated frequencies to produce an auxiliary carrier frequency of frequency higher than the frequency of the combined waves and accompanying side frequencies, and means for amplifying the unmodulated component of the auxiliary carrier frequency without a corresponding amplification of the side frequency energy, and means for combining the amplified unmodulated component with the side frequency energy.

19. A signaling system comprising two cooperating stations, each provided with means for transmitting a modulated carrier wave, means at one of said stations for combining a portion of the energy of the outgoing carrier wave source with energy incoming from the other station to produce an auxiliary carrier frequency equal to the sum of the two carrier frequencies, means for selecting the sum frequency, and means for deriving the signal to be received from the selected frequency.

20. The method of signaling in a system wherein is transmitted a carrier wave modulated in accordance with a signal and having an unmodulated component too small to reproduce a sufficiently perfect signal, which comprises receiving the carrier wave and reducing the frequency thereof, then selecting out as such and increasing the energy of the unmodulated component, and recombining the unmodulated component of increased energy with the modulated carrier wave energy to produce a modulated carrier wave having a relatively greater unmodulated component than the received wave.

21. A signaling system comprising two cooperating stations, each provided with means for transmitting to the other a signal modulated high frequency wave, one of said stations being provided with means for combining energy of the incoming and outgoing carrier frequencies to produce an auxiliary carrier frequency, and one of said stations which may be the same or the other station having means for supplying to this receiving circuit unvaried carrier frequency energy at all times whether the local signaling apparatus is operating or not.

22. In a wave receiving system, means for combining received energy with locally generated energy to produce an auxiliary carrier wave, amplifying means for the auxiliary carrier wave, selecting means both preceding and following said amplifying means, said selecting means each comprising a band pass filter.

23. The method of signal reception which comprises converting a received carrier wave to produce an auxiliary carrier wave, and selecting the carrier and one side band of the auxiliary carrier wave to the exclusion of the other side band both before and after amplification.

24. A signaling system comprising two cooperating stations, each having means to transmit a signal modulated wave to the other, one of said stations having means for receiving energy from a distant transmitter and combining it with energy of the local outgoing carrier wave to produce an auxiliary carrier wave, and means for selecting and amplifying the auxiliary carrier wave comprising a selective circuit, an amplifier and a second selective circuit in tandem arrangement in the order named.

25. In signal reception, the method which comprises producing an auxiliary carrier wave from a received carrier wave, selecting the unmodulated component of the auxiliary carrier wave and a side band before amplifying, amplifying the selected components, then selecting the side band separately from the unmodulated component of the auxiliary carrier wave.

26. In a receiving system, means for selecting a carrier and an accompanying side band before amplifying, means for amplifying the selected components, means for separating the unmodulated component of the carrier from the side band, and means for amplifying the selected unmodulated component separately from the side band.

27. The method of introducing an element of secrecy into carrier wave signal transmission which comprises transmitting a side band based upon a given carrier wave which is variable in frequency, transmitting with the side band energy of the variable carrier wave which is of too small intensity to reproduce a signal of satisfactory intelligibility by direct combination with the side band, receiving said side band and carrier wave, producing from the received energy a wave corresponding to the carrier wave and of energy greatly increased with respect to the energy of the side band, and combining the side band wave and the produced wave.

28. A signalling system comprising a high frequency section connected to a telephone line by means of a high frequency terminal, said high frequency terminal being connected to said telephone line by means of conjugately related input and output voice frequency circuits; said input circuit being connected to a carrier suppression modulator, a spacing frequency source connected to said modulator, a band filter in the output of said modulator adapted to suppress waves

having the frequency of said spacing frequency source, a second carrier suppression modulator supplied by said band filter, a principal carrier frequency source supplying said last mentioned modulator, a band filter for selecting a component from the output of said last mentioned modulator, a power amplifier connected with said last mentioned band filter, a transmitting conductor supplied by said power amplifier; a high frequency receiving circuit terminating in said output circuit, said receiving circuit comprising in tandem relation, (1) selecting means, (2) a detecting device, (3) a band filter, (4) an amplifying device, (5) a two-branched parallel combination consisting of a band filter in each branch and an amplifier in one branch, (6) a detecting device connected to both of said branches, (7) a band filter connected in the output of said detecting device, (8) a detecting circuit connected to the output of said band filter, (9) a source of spacing frequency waves connected to said detecting circuit, and (10) a band filter for passing speech frequencies connected to said last mentioned detecting circuit, said band filter leading into said output circuit.

29. A station comprising means for transmitting a carrier wave, means for combining received energy with energy of the local outgoing carrier wave to produce an auxiliary wave, amplifying means for the auxiliary carrier wave, and selecting means both preceding and following said amplifying means, said selecting means each comprising a band pass filter.

30. In a signaling system, means for combining incoming and outgoing carrier waves to produce an auxiliary carrier wave in combination with means arranged in the order named for selecting, amplifying, and again selecting the auxiliary carrier wave energy before detecting it.

31. A two-way signaling system comprising means for receiving and combining the energy of an incoming carrier wave with energy of the outgoing carrier wave frequency, means for selecting from the resultant waves a modulated component which is of a frequency equal to the difference of the incoming and outgoing carrier frequencies, means for detecting the selected component to produce an audible frequency wave, and a non-signaling channel for supplying energy of the local outgoing carrier frequency to said means for combining.

32. A two-way signaling system comprising means for receiving and combining the energy of an incoming carrier wave with energy of the outgoing carrier wave frequency, means for selecting from the resultant waves a modulated component which is of a frequency equal to the difference of the incoming and outgoing carrier frequencies, means for detecting the selected component to produce an audible frequency wave, and a non-signaling channel for supplying only the unmodulated carrier component of the outgoing carrier wave to said means for combining.

In witness whereof, I hereunto subscribe my name this 31st day of January, A. D. 1922.

JOHN F. FARRINGTON.