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SIGNALING SYSTEM

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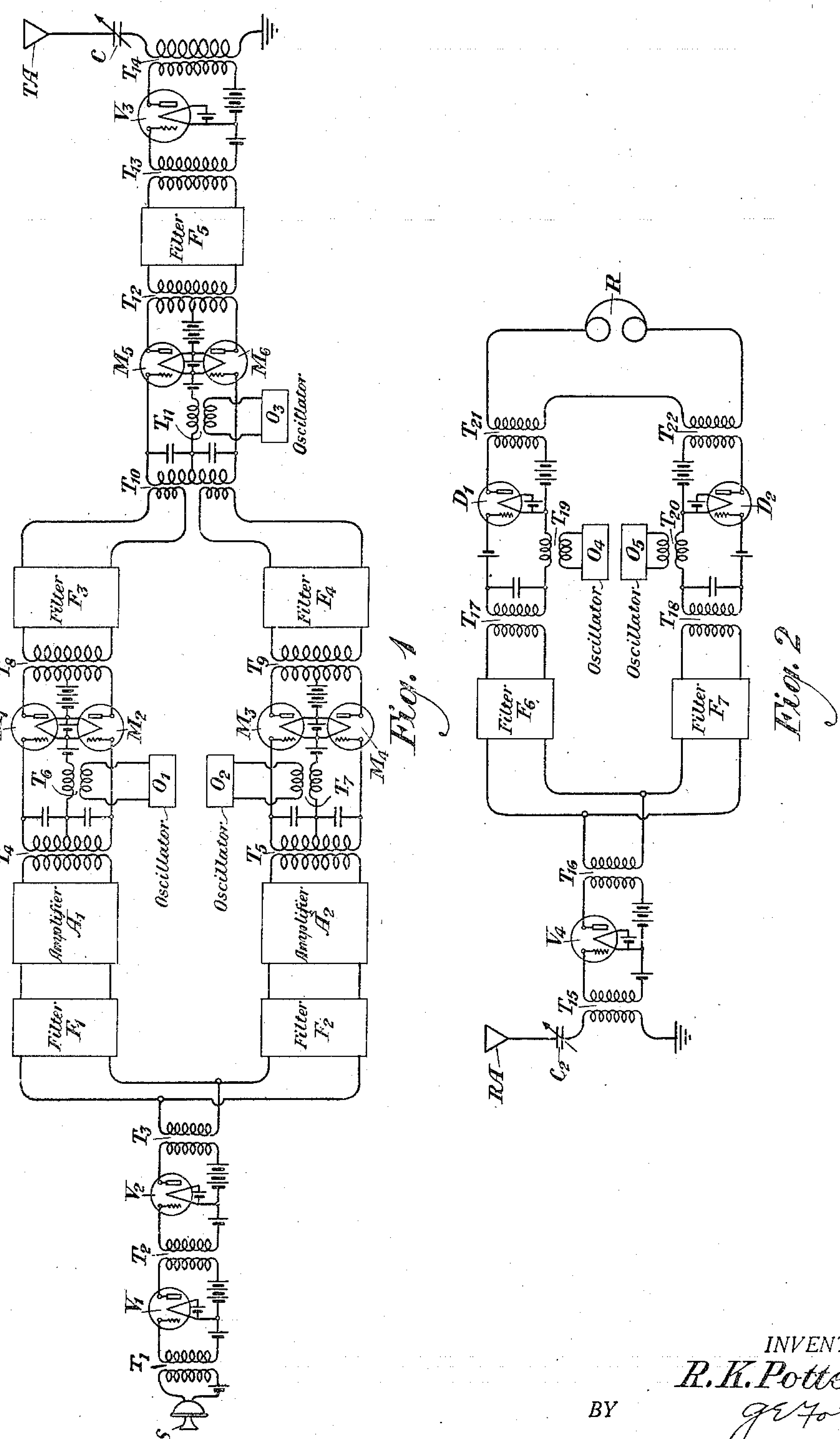

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SIGNALING SYSTEM

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This invention relates to signaling systems, and particularly to systems for the secret transmission of waves.

The invention is particularly applicable to the transmission and reception, with secrecy, of waves, such as signals and the like, lying within a considerable band of frequencies, as in the case of speech.

One method of obtaining privacy in the transmission and reception of waves by radio depends upon the division of a band of frequencies, as in the case of speech, into sub-bands, and the rearrangement of these sub-bands before transmission. At the receiving end of such a system, the sub-bands may be received and selected by suitable means, such as electrical wave filters, so that the original signal may be reconstructed from the component sub-bands.

If highly selective filters are employed to divide the band of signals into sub-bands, the edges of the sub-bands, i. e., frequencies near the cut-off points of the filters, are subjected to considerable undesirable distortion so that upon selection of the various sub-bands at the receiving terminal of the system, unrelated and extraneous frequencies may be introduced from one sub-band to the other.

In order to overcome the loss in intelligibility caused by the suppression of component frequencies and the introduction of unrelated and extraneous frequencies at the edges of the sub-hands, it is proposed, in this invention, to divide the band of signals into a plurality of successive, overlapping sub-bands and to separately modulate the various sub-bands upon spaced carrier frequencies so that side bands of the carrier frequencies corresponding to the various sub-bands may be transmitted through space to a distant receiving station, separated by a small frequency interval. At the receiving terminal of such a system, it is proposed to select the various received side bands into appropriate circuits and to bring these side bands back to their original frequency relations by subjecting these side bands to demodulation employing similar carrier waves spaced at substantially the same intervals as the carrier waves are spaced in modulation at the transmitting station.

Further objects and features of this invention will be more fully apparent from the detailed description hereinafter following, when read in connection with the accompanying drawing, in which Figure 1 represents schematically a transmitting station of such a system, and Fig. 2 is a similar representation of a receiving station adapted to co-operate with the transmitting station of Fig. 1 in carrying on communication.

Referring to Fig. 1 of the drawing, speech currents resulting from speaking into a microphone S may be applied to an amplifier having any number of stages of amplification and of any well-known type, preferably of the vacuum tube type, as shown. These speech currents are applied through a transformer T_1 to the vacuum tube V_1 of the first stage of amplification. The amplified energy is then applied through another transformer T_2 to another stage of amplification having a vacuum tube V_2. After being further amplified, these speech currents are then applied through the transformer T_3 to a plurality of sub-dividing electrical wave filters which may be employed to sub-divide the speech band into a plurality of successive overlapping sub-hands. Only two of these sub-dividing electrical wave filters F_1 and F_2 are shown herein merely for the purpose of illustration. These electrical wave filters are preferably so designed as to pass overlapping portions of the speech frequency range. For example, filter F_1 may selectively transmit frequencies from 200 to 1600 cycles and filter F_2 may selectively transmit frequencies from 1500 to 2600 cycles, it being assumed that the essential speech frequencies are to be found within the range extending from 200 to 2600 cycles. This result may be accomplished by constructing each of these filters in the form of the well-known band filter composed of a plurality of sections, as disclosed in the patent to G. A. Campbell, No. 1,227,113, dated May 22, 1917. It will be obvious that any number of filters may be used as desired and that only two of these are shown herein for illustrative purposes and that the band widths of the respective filters may be suitably chosen to correspond with the number of filters used. It will be obvious that the filters shown herein are employed for the purpose of sub-dividing the speech frequency band into a plurality of successive overlapping sub-bands, each of a relatively narrow frequency range. Each of these sub-bands, if received, may, of itself, normally be incapable of providing intelligible signals.

With the arrangement of two filters shown in the drawing, it will be seen that the lower sub-band may be transmitted by the filter F_1 and that the higher sub-band beginning at a frequency below the upper limit of the lower sub-band may be transmitted by the filter F_2. Obviously, these filters transmit sub-bands which, if properly combined, represent a band of signals corresponding to the speech signals originating in the microphone S.

The sub-bands transmitted by the filters F_1 and F_2 may then be applied to amplifiers A_1 and A_2, respectively. These amplifiers may be of any well-known type, preferably of a vacuum tube type. Clearly, these amplifiers are employed to separately amplify the sub-bands transmitted by the filters in their respective channels.

The sub-bands amplified by the amplifiers A_1 and A_2 are then applied through transformers T_4 and T_5 to corresponding duplex modulators having three-element vacuum tubes M_1 and M_2 and M_3 and M_4, respectively. The transformers T_4 and T_5 are employed to impress the sub-bands amplified by amplifiers A_1 and A_2 upon the input circuits of the vacuum tubes of the corresponding duplex modulators, these vacuum tubes being in push-pull relationship. Oscillators O_1 and O_2 transmit currents of carrier waves through transformers T_6 and T_7 to the branches common to the input circuits of the modulator tubes M_1 and M_2 and M_3 and M_4, respectively. The output circuits of these modulator tubes are in parallel relationship with respect to common plate batteries, these output circuits being connected through the primary windings of the transformers T_8 and T_9, respectively. These modulators are of the carrier suppression type as disclosed in patent to J. R. Carson, No. 1,343,306, dated June 15, 1920. The oscillators O_1 and O_2 may, of course, be of any well-known type, preferably of the vacuum tube type, such as is shown in a patent to R. V. L. Hartley, No. 1,356,763, dated October 26, 1920. Inasmuch as each of the duplex modulators, such as the one having vacuum tubes M_1 and M_2, is supplied by a wave of a carrier frequency by means of an oscillator such as the oscillator O_1 and is also supplied with a sub-band such as is transmitted by the filter F_1 and the amplifier A_1, there will be produced for transmission two side bands corresponding to each sub-band, as is well known in the art. The outputs of the modulators having the vacuum tubes M_1 and M_2 and M_3 and M_4 are then applied to filters F_3 and F_4 through transformers T_8 and T_9, respectively. Filters F_3 and F_4 may, if desired, be of the type described in the aforementioned Campbell patent, each freely transmitting one of the side bands resulting from modulation corresponding to a sub-band, while substantially suppressing the other side band corresponding to the same sub-band as well as all other inter-modulation components. Thus, these filters may, if desired, be designed so as to suppress the lower side bands and freely transmit the upper side bands, these upper side bands being obviously of widths substantially equal to the widths of the sub-bands freely transmitted by the filters and amplifiers in the corresponding transmission paths, though raised in the frequency spectrum as a result of modulation. It will thus be apparent that by properly spacing the frequencies of the oscillators O_1 and O_2, the sub-bands transmitted by the amplifiers A_1 and A_2, will, as a result of the action in the corresponding modulators, be raised in the frequency spectrum and spaced so that the side bands corresponding to the sub-bands will not overlap.

The outputs of the filters F_3 and F_4 are then applied through a transformer T_{10} to another duplex modulator having the vacuum tubes M_5 and M_6, these vacuum tubes being also in push-pull relationship. An oscillator O_3 transmits current of another and preferably higher frequency through a transformer T_{11} to the branch common to the input circuits of the vacuum tubes M_5 and M_6. The output circuits of these vacuum tubes are also in parallel relationship with respect to a common plate battery, these output circuits being connected through the primary of the transformer T_{12}. This duplex modulator is, of course, of the type disclosed in the aforementioned Carson patent and the oscillator O_3 may be of any well-known type, preferably of the vacuum tube type, such as is shown in the aforementioned Hartley patent. Inasmuch as the duplex modulator having the vacuum tubes M_5 and M_6 is supplied by a wave of high frequency emitted by the oscillator O_3 and is also supplied with two side bands corresponding to two sub-bands, there will be produced for transmission four side bands of the wave emitted by the oscillator O_3 corresponding to the two side bands transmitted thereto and impressed upon the input circuits of the vacuum tubes M_5 and M_6, the latter side bands corresponding to the two sub-bands. All four side bands are then transmitted to a filter F_5 through a transformer T_{12}. This filter may be of the general type disclosed in the aforementioned

Campbell patent and is employed primarily to freely transmit two of the side bands impressed thereon by the duplex modulator, while substantially suppressing the other two side bands as well as all intermodulation components. The side bands transmitted by the filter F_5 are also spaced in the frequency spectrum and correspond, of course, to the sub-bands into which the original signals originating in the microphone S were subdivided.

The output of the filter F_5 is then applied through a transformer T_{13} to an amplifier V_3, preferably of the vacuum tube type, as shown. Amplifier V_3 is employed for the purpose of amplifying the side bands of the wave of the oscillator O_3 freely transmitted through transformer T_{13} by the filter F_5. The amplified energy is then impressed upon a transmitting antenna circuit, comprising a transmitting antenna TA, a condenser C and the secondary winding of a transformer T_{14}. Thus, there may be transmitted through space a plurality of side bands of a high frequency wave, one corresponding to each of the sub-bands resulting from one of the portions into which the original speech bands were subdivided.

One form of receiving station based upon the principles of this invention for reproducing intelligible speech from the side bands transmitted from the station of Fig. 1 is illustrated in Fig. 2. The side bands of the carrier or radio wave transmitted through space from the station of Fig. 1 are received on the receiving antenna RA which is connected in the antenna circuit along with a condenser C_2 and the primary winding of a transformer T_{15}. A transformer T_{15} is employed to impress the received side bands upon an amplifier, preferably of the vacuum tube type, comprising a three-element vacuum tube V_4, as shown. The received side bands are thus amplified and then transmitted through a transformer T_{16} to filters F_6 and F_7. These filters are employed for selectively transmitting the side bands received by the antenna circuit of Fig. 2. Thus, filter F_6 may transmit a side band which corresponds to one of the sub-bands into which the speech signals originating in the microphone S at the transmitting station of Fig. 1 were divided and filter F_7 may transmit the side band which corresponds to the other of the sub-bands into which the speech signals originating in this microphone S were divided. It will be obvious that filters F_6 and F_7 may, if desired, be of the aforementioned Campbell type, each freely transmitting one of the side bands corresponding to one of the sub-bands above mentioned, while substantially suppressing all of the other frequencies.

The side bands selected by filters F_6 and F_7 are then transmitted through transformers T_{17} and T_{18} to demodulators or detectors having the vacuum tubes D_1 and D_2, respectively, each of the vacuum tube type. Oscillators O_4 and O_5 transmit currents of spaced frequencies through transformers T_{19} and T_{20} to these detectors or demodulators, respectively. These oscillators may be of any well-known type, preferably of the vacuum tube type such as is described in the aforementioned Hartley patent. These oscillators may be spaced in frequency at substantially the same interval that the frequencies of the currents of oscillators O_1 and O_2 are spaced at the transmitting station of Fig. 1. Moreover, the frequencies of these oscillators are sufficiently high so that, as a result of the action based on the well-known principles of homodyne detection, low frequency waves will be transmitted to the output circuits of these detectors which contain components corresponding to those which were impressed upon the balanced, duplex modulators having the vacuum tubes M_1 and M_2 and M_3 and M_4, respectively, at the transmitting station of Fig. 1. These low frequency waves are transmitted through transformers T_{21} and T_{22} to a receiving device such as a telephone receiver R. These low frequency waves are thus combined in order to reproduce the signals generated in the microphone S at the transmitting station.

The principles of this invention have been shown as applied to a system involving the sub-division of speech signals into two sub-bands merely for the purpose of illustration. If it be assumed that transmission is to take place involving a 3000-cycle voice band extending from 100 cycles to 3100 cycles, four sub-bands may, for example, be employed. Four sub-dividing filters may then be used to sub-divide the speech frequencies into successive overlapping sub-bands. These sub-bands may, for example, extend from 100 to 950 cycles; from 750 to 1700 cycles; from 1500 to 2450 cycles; and from 2250 to 3100 cycles. These sub-bands have widths of 850, 950, 950 and 850 cycles, respectively. If these sub-bands be superimposed upon carrier waves having frequencies of, for example, 40,000, 40,300, 40,600 and 40,900 cycles, respectively, then by suitable modulation and consequent suppression of the unmodulated carrier wave and one of the side bands resulting from modulation, there may be produced side bands corresponding to these sub-bands having frequencies extending from 40,100 to 40,950 cycles; from 41,050 to 42,000 cycles; from 42,100 to 43,050 cycles; and from 43,150 to 44,000 cycles. These side bands may, if desired, be modulated on still another wave and then transmitted through space. At the receiving terminal, they may be beaten with high frequency waves spaced at substantially the same interval as are the waves employed in modulation at the transmitting station, in order to reproduce the signals corresponding to the sub-divided components of the transmitting station. In the latter illustration, it will be obvious that the speech signals are sub-divided into successive, overlapping sub-bands and that, as a result of modulation upon suitably spaced carrier frequencies, the sub-bands are raised in the frequency spectrum, spaced so as not to overlap. At the receiving station, the spaced bands of frequencies are beaten with carrier waves of similarly spaced frequencies in order to reproduce the successive overlapping sub-bands such as are found at the transmitting station.

In the latter illustration, in order to separate the overlapping sub-bands, spaced carrier frequencies were employed in modulation. The side bands resulting from modulation were, therefore, stated to be separated by 100 cycles. Thus, the total width of the frequency band was increased by 10%. Furthermore, the system involving the spacing of the overlapping sub-bands and the reconstruction of the signal from the spaced side bands corresponding to the sub-bands did reduce the losses at the edges of the sub-bands and at the same time afforded a certain amount of privacy. As is well known in systems of single side band reception, if the carrier wave is displaced from its normal position, the quality of the signal is rapidly depreciated and the intelligibility falls off by a corresponding amount. From experiments, it has been determined that at a displacement of, for example, 700 cycles, the intelligibility is less than 10%. From these experiments, it has also been determined that the spacing of the side bands corresponding to sub-bands by 100 cycles might be expected to give an intelligibility of approximately 40%. If, in addition to employing the principles outlined hereinabove, the sub-bands be inverted and then interchanged at the transmitting station, and if the inverse process be employed at the receiving station, it seems reasonable to expect that considerable privacy could be obtained without serious mutilation of the signal.

While this invention has been shown and described in one particular embodiment merely for the purpose of illustration, it is to be distinctly understood that the general principles of this invention may be applied to other and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. The method of transmission of waves having a band of frequency components, which comprises dividing said band into a plurality of sub-bands which overlap each other, modulating said sub-bands on a plurality of carrier waves of different frequencies, one corresponding to each sub-band, so as to produce a plurality of side bands within substantially the same frequency limits as were occupied by these sub-bands before modulation though separated from each other in the frequency spectrum, and transmitting all of said spaced side bands simultaneously.

2. The method of transmission of speech waves comprising sub-dividing the speech waves into a plurality of sub-bands of frequency components which overlap each other in the frequency spectrum, the components comprised in any one sub-band being incapable of reproducing understandable speech, modulating said sub-bands upon a plurality of carrier waves of different frequencies, one corresponding to each sub-band, so as to produce a plurality of side bands of the respective carrier waves, one side band corresponding to each sub-band and occupying the same space in the frequency spectrum as was occupied by the sub-band before modulation, said side bands being spaced from each other by definite frequency intervals, and transmitting all of said side bands simultaneously.

3. The method of speech transmission which comprises sub-dividing speech waves into a plurality of overlapping sub-bands, each of definite frequency limits, modulating said sub-bands upon a plurality of carrier waves of different frequencies, one carrier wave corresponding to each sub-band, suppressing the transmission of the unmodulated carrier component and one of the two side bands resulting from modulation of the carrier wave, whereby a plurality of side bands are produced spaced in the frequency spectrum, and transmitting all of said spaced side bands simultaneously.

4. The method of wave transmission which comprises sub-dividing a band of signals into a plurality of successive overlapping sub-bands, each of which occupies a definite space in the spectrum, modulating said sub-bands upon a plurality of carrier waves of different frequencies so as to produce a plurality of side bands of the carrier waves spaced at definite intervals in the spectrum, and modulating the resultant side bands upon a radio wave of a very high frequency for transmission to a distant point.

5. The method of receiving a plurality of bands of signals spaced in the frequency spectrum which, if combined, overlap and represent all of the frequency components of speech signals, which consists in beating said spaced bands of signals with a plurality of carrier waves of different frequencies, one corresponding to each received band, and combining the resultant products so as to derive the overlapping bands in order to reproduce all of the frequency components representing the speech signals.

6. The method of signaling which consists

in sub-dividing a band of signals into a plurality of successive overlapping sub-bands, modulating said sub-bands upon a plurality of carrier waves of different frequencies, suppressing the unmodulated carrier components and one side band of each carrier wave resulting from modulation and freely transmitting the other side bands which are spaced at definite intervals in the frequency spectrum, receiving the transmitted side bands, beating said received side bands upon a plurality of waves which differ from each other in frequency as do the carrier waves employed in modulation, and combining the beaten products in order to reproduce the original signals.

7. The method of signaling which consists in sub-dividing a band of signals into a plurality of successive overlapping sub-bands, each of which occupies a definite space in the spectrum, and modulating said sub-bands upon a corresponding plurality of carrier waves of different frequencies so as to produce a plurality of side bands of the carrier waves spaced at definite intervals in the spectrum.

8. A wave transmission system comprising means for producing a band of signals, means for sub-dividing said band of signals into a plurality of successive overlapping sub-bands, each of said sub-bands occupying a definite space in the spectrum, means for producing a plurality of carrier waves of different frequencies, one of said carrier waves corresponding to each of said sub-bands, and means for modulating said sub-bands upon the corresponding carrier waves so as to produce a plurality of side bands of the carrier waves spaced at definite intervals in the spectrum.

9. A signaling system comprising means for producing a band of signals, means for sub-dividing said band of signals into a plurality of successive overlapping sub-bands, means for producing a plurality of carrier waves of different frequencies one corresponding to each sub-band, means for modulating said sub-bands upon said carrier waves, means for suppressing the unmodulated carrier component and one side band of each carrier wave resulting from modulation and freely transmitting the other side bands which are spaced at definite intervals in the frequency spectrum, means for deriving from said spaced side bands a plurality of corresponding overlapping sub-bands substantially the same as those derived in sub-dividing said band of signals, and means for combining the resultant overlapping sub-bands in order to reproduce the original signals.

10. A signaling system comprising, in combination, means for producing a band of signals, means for deriving a plurality of overlapping sub-bands therefrom, means for spacing said sub-bands in the frequency spectrum, means for reconverting said spaced sub-bands into the corresponding plurality of overlapping sub-bands, and means for combining the latter overlapping sub-bands to reproduce said signals.

11. A signaling system comprising means for receiving a plurality of spaced bands of high frequency waves corresponding to a plurality of overlapping sub-bands which, if combined, represent low frequency signals, and means to reduce said plurality of spaced bands of high frequency waves into the corresponding overlapping sub-bands in order that said sub-bands may be combined to produce said low frequency signals.

In testimony whereof, I have signed my name to this specification this 18th day of October, 1927.

RALPH K. POTTER.