April 17, 1928. 1,666,651

R. A. HEISING

PLURAL CHANNEL SECRECY SYSTEM

Filed Dec. 30, 1922 2 Sheets-Sheet 1

Inventor:
Raymond A. Heising.
by E W Griggs Att'y.

April 17, 1928. 1,666,651

R. A. HEISING

PLURAL CHANNEL SECRECY SYSTEM

Filed Dec. 30, 1922 2 Sheets-Sheet 2

Fig.3.

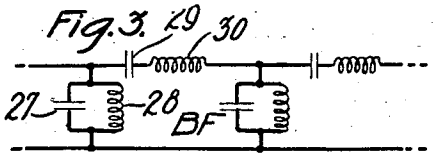


Fig.4.

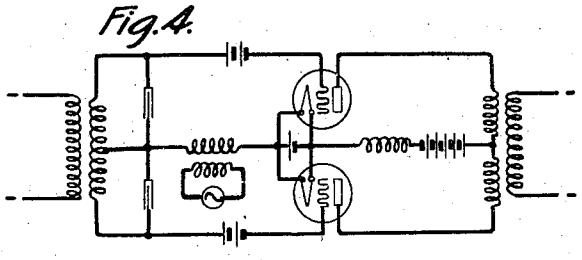


Fig.5.

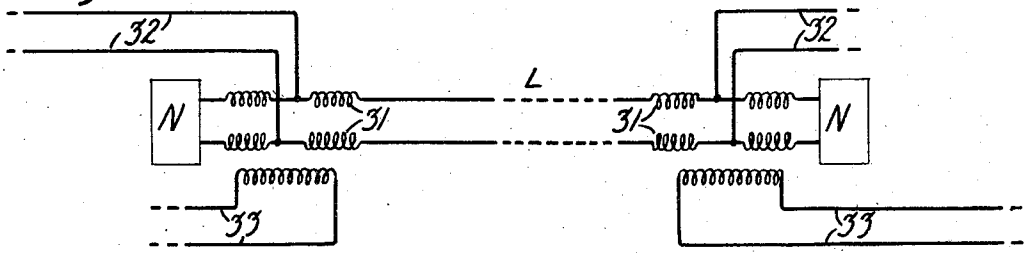


Fig.6.

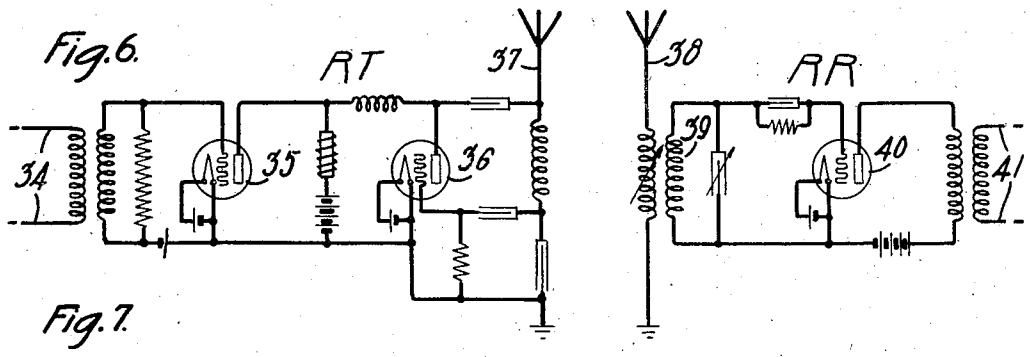
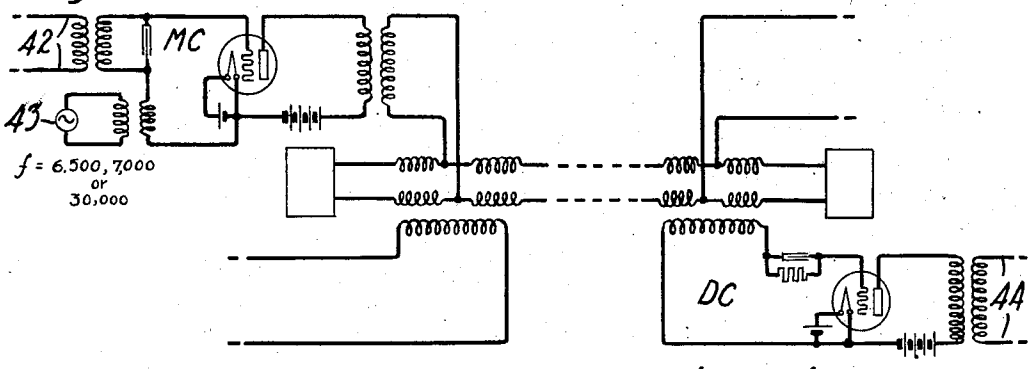


Fig.7.



Inventor:
Raymond A. Heising.
by E.W.Griggs Att'y

Patented Apr. 17, 1928. 1,666,651

UNITED STATES PATENT OFFICE.

RAYMOND A. HEISING, OF MILLBURN, NEW JERSEY, ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

PLURAL CHANNEL SECRECY SYSTEM.

Application filed December 30, 1922. Serial No. 609,933.

This invention relates to multiplex wave transmission systems.

An object of the invention is to provide for the transmission of several messages over the same line or circuit in such a manner as to make it very difficult for those not in possession of a special and peculiar receiving apparatus to separate and distinguish the various messages from each other.

Consequently, an important feature of the invention is the element of secrecy which is introduced.

A further object of the invention is to so scramble or intermingle the wave frequency components characteristic of several sets of waves representing messages, that their unscrambling or separation can be effected only by specially designed and constructed apparatus.

A further object is to provide for the transmission of a maximum number of messages through a channel comprising a minimum range of frequencies or wave lengths.

A still further object is to provide for the transmission of several telephone conversations over a line without utilizing the ranges of frequencies below about 300 to 500 cycles, thereby leaving available this range for Morse transmission or other purposes; and furthermore, leaving available a considerable range of frequencies above the general region of 6500 cycles to 10,000 cycles for carrier or other transmission.

A still further object is to provide for duplex communication in which the foregoing objects are fulfilled for transmission in each direction.

In a preferred embodiment of the invention there is provided at a transmitting terminal apparatus which may be generally designated as scrambling or intermingling apparatus, and at a receiving terminal separating or unscrambling apparatus. Several speech bands at the transmitting terminal are each subdivided into several portions by means of band-pass filters or equivalent means. These several speech sub-bands are then translated in frequency and so superimposed upon one another in a common circuit that their frequency ranges lie one above the other. The various band subdivisions when superimposed are so arranged that no two subdivisions or sub-bands constituting a portion of the same message lie adjacent each other. At the receiving terminal the various band subdivisions are first separated from each other by means of band-pass filters or equivalent elements and thereafter translated in frequency to reproduce the original band subdivisions which are then recombined to reproduce the original voice frequency speech bands.

The invention is more particularly described hereinafter in connection with the accompanying drawings wherein Fig. 1 is a diagram indicating how the frequencies corresponding to several conversations designated "Speech A", "Speech B" and "Speech C" are recombined and superimposed one upon the other to constitute a scrambled combination of the three messages; Fig. 2 is a circuit diagram of a transmitting terminal for scrambling or confusing the messages, and a receiving terminal for unscrambling or separating the messages; Fig. 3 is a preferred type of band-pass filter which is made use of in several portions of the circuit of Fig. 2 all such band filters being marked BF; Fig. 4 is a detailed circuit showing a preferred type of modulating and detecting or demodulating circuit which is made use of in the circuit of Fig. 2; Fig. 5 is a circuit diagram indicating a preferred manner of applying the circuit of Fig. 2 in duplex or two-way systems; Fig. 6 illustrates the application of the circuit of Fig. 2 to radio transmission; Fig. 6[a] illustrates the application of the system of Fig. 2 to duplex or two-way radio communication; and Fig. 7 indicates a method of combining the arrangements of Fig. 2 with additional modulating apparatus for carrier wave transmission.

In the left hand portion of Fig. 1 are diagrams indicating how several bands of speech frequencies are to be divided. Taking the band marked "Speech A" for example, it will be seen that the band from zero to 500 cycles is discarded and the band from 500 cycles to 2500 cycles is divided into three sub-bands, A_1 extending from 500 cycles to 900 cycles, A_2 extending from 900 cycles to 1600 cycles, and A_3 extending from 1600 cycles to 2500 cycles. Frequencies above 2500 cycles are also discarded.

It is somewhat unusual in telephone work to discard speech frequencies below 500 cycles, but, as has been shown by the recently published data of certain investigators, the range of frequencies extending from 200 cycles to 500 cycles is of less importance than

they have heretofore been considered. However, the principles involved in the present invention do not in any wise depend upon discarding the range of frequencies below 500 cycles, and if desired all or any portion of this range can be utilized as a portion of the sub-band A_1, or as another sub-band if desired. Furthermore, the band of speech frequencies may be divided into sub-bands in many different ways and these sub-bands may be large or small, and equal or unequal in frequency range as desired. It is preferred, however, to divide each speech band into several sub-bands of different widths, inasmuch as this will increase the difficulties of any one who should perchance attempt to construct apparatus designed to separate the various messages. By making the upper frequency bands of greater width the total energy and importance of the bands is made more nearly equal than would be the case with bands of equal width.

Having considered the separation of several conversations, as for example, "Speech A", "Speech B", and "Speech C" into several sub-bands, consideration will now be given to apparatus for reassembling these bands in a single circuit in the scrambled or intermingled relation indicated in the right hand diagram of Fig. 1.

In Fig. 2, "Speech A" is assumed to be incoming over a line or circuit 1, "Speech B" over a line or circuit 2 and "Speech C" over a line or circuit 3. Appropriate band filters *a* having transmission ranges as indicated on the drawing, serve to separate the waves constituting "Speech A", other band filters *a* serve to separate the waves of "Speech B", and other band filters *a* serve to separate the waves of "Speech C".

Using the terminology indicated on the diagram of Fig. 1, one sub-band from each conversation is transmitted to the channel 4 which, as we may assume, will carry sub-bands which are designated as A_1, B_2 and C_3. Sub-bands B_1, C_2 and A_3 are impressed together upon a modulating circuit 5 of the type hereinafter described. The frequency of the carrier wave which is supplied to the modulating circuit 5 from a source 6 is 10,000 cycles. A band filter 7 in the output circuit of the modulator 5 passes a range of frequencies of from 10,500 to 12,500. In a similar manner the sub-bands C_1, A_2 and B_3 are applied to the input circuit of a modulator 8 in the output circuit of which is a band filter 9 which passes waves of the range of frequencies of from 12,500 to 14,500, which result from the application to the modulator 8 of a carrier wave the frequency of which is 12,000 cycles. All the waves transmitted through band filters 7 and 9 are impressed upon the input circuit of a modulator 10 to which is supplied a carrier frequency of 8,000 cycles. In the output circuit of the modulator 10 there will be present among other frequencies, a band of frequencies of from 2,500 to 6,500 cycles. These may be passed through a band filter 11 which passes frequencies within this range and excludes other frequencies. However, the band filter 11 may be omitted if desired. Waves of a range of frequencies of from 500 to 6,500 are consequently impressed upon the terminals 12 of a transmission line L.

These waves are transmitted over the line L, which may be any suitable transmission circuit of any nature whatsoever, to the line terminals 13. It will be observed that a total of three conversations is traversing the line L and that all three of them occupy a frequency range of only 6,000 cycles, leaving available for other purposes the range below 500 cycles and the range above 6,500 cycles. Furthermore, the various frequencies of the three conversations are so intermingled with each other that it would be a matter of considerable difficulty to one, unacquainted with the terminal apparatus, to separate out the waves representing any particular conversation. If it is desired to insure that some noise currents will always be present upon the line, there may be substituted for one of the conversations A, B or C, a noise producing device such as a phonograph record running forward or backward, or other similar arrangement. Such an arrangement is illustrated by the noise producing device or phonograph 50 impressing speech or noise upon the microphone 51 included in the circuit 52 which supplies noise currents to the three part channel A. When currents of any particular range of frequencies are introduced upon the line for the express purpose of producing noise it will not be necessary to provide apparatus for selecting and receiving currents of those particular frequencies as they represent no message. It is not essential however, that a noise producing device that utilizes a range of frequencies numerically equal to that occupied by a voice signalling band be used, but noise currents may be applied to the circuit in a narrow band or bands of frequencies. A special single channel may be provided to put these on the line instead of using a three part channel as for the conversation A, B and C. For example, the noise currents may be applied to the channel A and the circuits of the 900–1600 and 1600–2500 filters may be opened by switches S thereby causing the noise currents to pass through the 500–900 filter to the line. If it is so desired the 500–900 filter may be replaced by a filter adapted to pass without appreciable attenuation a range of frequencies above the highest frequency used in the system for transmitting intelligible signals, for example, 6500–8000 cycles. The frequencies of the

noise band or bands of frequencies may be above, below or intermingled with the signalling frequencies on the line L depending on the frequency value of the applied noise currents and their frequency translation before being applied to the line L.

The apparatus for separating and reassembling the sub-bands arriving at the line terminals 13 will now be described. The sub-bands A_1, B_2 and C_3 pass directly over the channel 14 to certain appropriate band filters 26 which serve to separate them. The waves corresponding to sub-bands B_1, C_2 and A_3 traverse a band filter 16 in the channel 15, and are translated successively in frequency by the demodulators 17 and 18 which are supplied with carrier waves of frequency of 6,000 and 8,000 cycles respectively. The band filter 19 which passes a range of frequencies from 8,500 to 10,500 is interposed between the demodulators 17 and 18. The sub-bands corresponding to sub-bands C_1, A_2 and B_3 are similarly selected and translated in frequency successively by band filter 20, demodulator 21, band filter 22 and demodulator 23. Band filters 24 and 25 each pass a range of frequencies of from 500 to 2,500 cycles. Within this range is one sub-band corresponding to each of the original signal bands which are to be separated out and recombined with the appropriate sub-band which traverses the circuit 14. It will be observed that the nine band filters 26 serve to perform the final separation and reassembling of the various sub-bands in the manner necessary to reproduce the original signalling bands corresponding to the speech signals A, B and C, respectively.

In the preceding discussion it has been assumed that the various band filters have an exact and definite cut-off limit. While this is true in theory, it is not true in practice. Therefore it must be assumed that each band filter is constructed to transmit freely the band indicated within the required limits of approximation. Thus, for example, one of the band filters having a transmission limit of from 900 to 1,600 cycles may in practice be designed to have a transmission range of from 925 to 1,575 cycles, inasmuch as the loss of the small band of frequencies which are thus highly attenuated will not seriously interfere with understanding the conversations transmitted over the system. On the other hand the band filters may be so arranged as to allow a slight overlapping of frequencies, or the original sub-bands may be so chosen and translated to higher frequencies as to leave a small zone of about 25 to 100 cycles between each sub-band so as to allow for a certain degree of imperfection in the selectivity of the various band filters.

Fig. 3 illustrates a typical band filter circuit such as might be used in any part of the system of Fig. 2 for the band filters marked BF. The band filter BF of Fig. 3 is one of many types which may be employed and consists of any suitable number of sections each having shunt capacity 27 in parallel with shunt inductance 28, and series capacity 29 in series with series inductance 30. The information necessary to enable one skilled in the art to construct a band filter for the purposes herein described is found in Campbell Patent No. 1,227,113, May 22, 1917.

Fig. 4 is a circuit diagram of a typical form of balanced modulator or demodulator circuit which may be used for translating wave frequencies up or down. The circuits 5, 8, 10, 17, 18, 21 and 23 of Fig 2 are such circuit arrangements as shown in Fig. 4 or the equivalent thereof. The information necessary to enable one skilled in the art to construct and utilize such circuits in the manner and for the purposes herein described is found in Carson Patent No. 1,343,307, June 15, 1920, together with Osborne Patents Nos. 1,361,487 and 1,361,488 December 7, 1920.

Fig. 5 is a circuit diagram indicating one manner of applying the invention to a system of duplex or two-way communication. At each terminal of the transmission line L is a three winding transformer or so called hybrid coil 31 which is connected at one end to the line L and at the other end to a balancing network N which simulates the impedance of the line. This enables a transmitting branch 32 and a receiving branch 33 to be connected in conjugate relation with respect to each other at each end of the line. A scrambling or intermingling circuit such as shown at the left in Fig. 2 is to be connected to each transmitting branch 32 by connecting the terminals 12 of the apparatus at the left of Fig. 2 to the terminals of the branch 32, and an unscrambling or separating circuit is to be applied to each receiving branch 33 by connecting the terminals 13 of the apparatus at the right of Fig. 2 to the terminals 33. In such duplex systems it will be seen that the element of confusion or secrecy is increased in case conversations are being carried on over each channel at the same time because, in general, either one party or the other will be talking all the time.

Fig. 6 illustrates the applicability of the invention to radio transmission. In this case the circuit to the left of the line terminals 12 is connected at these terminals to the input terminals 34 of a radio transmitting circuit RT. The radio transmitting circuit as illustrated is of a well known type and includes a modulating vacuum tube or variable impedance device 35, which serves to modulate high frequency waves produced

by an oscillating vacuum tube 36 which is connected to an antenna 37 to radiate the modulated high frequency waves produced. The radiated high frequency oscillations will be modulated in accordance with the scrambled combination of waves impressed upon the input circuit 34. The radio transmitting circuit RT is described by the applicant in an article published in the Proceedings of the Institute of Radio Engineers, Volume 9, No. 4, August, 1921, page 334. The waves radiated from the antenna 37 are received by the antenna 38 at a distant receiving station and impressed upon a tuned circuit 39 or equivalent selective arrangement such as a band filter, which is connected to the input circuit of any suitable detector. The circuit 39 may be sufficiently broadly tuned to transmit both side bands of the incoming waves representing the combination of messages, or if desired, it may be so adjusted as to select one side band and the carrier frequency and discriminate against the other side band. The vacuum tube detector 40 in combination with the receiving antenna 38 and circuit 39 constitute a radio receiver RR of a well known type which needs no further description. To the output circuit of the detector 40 is coupled a line 41 which is to be connected to line terminals 13 leading to an unscrambling or separating circuit such as illustrated at the right of terminals 13 in Fig. 2. The arrangement just described constitutes a one-way radio transmitter, but the invention is equally applicable to two-way or duplex radio transmission. For this purpose an arrangement such as that shown in Fig. 6[a] may be used. The line terminals 12 are connected to a modulating device 55 supplied with high frequency waves by the source 56. Modulated high frequency waves are impressed upon the antenna 57 from which they are radiated. Incoming high frequency modulated waves intercepted by the antenna 57 pass through the trap circuit 58 to the detecting device 59 and the resultant detected waves are impressed upon the line terminals 13. The trap circuit 58 comprises an inductance connected in parallel with a capacity to constitute an anti-resonant circuit which offers high impedance to waves of the transmitting frequency and low impedance to incoming waves to be detected. Both the scrambling and separating circuits will, of course, be applied at each radio terminal.

Fig. 7 illustrates an arrangement permitting the system of Fig. 2 to be combined with an additional modulating arrangement whereby the scrambled band of frequencies may be used to modulate a carrier wave in a manner similar to well known methods of carrier current transmission. The circuit to the left of line terminals 12, Fig. 2, is connected to input circuit terminals 42 of a modulating circuit MC of either of the kinds described in the Proceedings of the Institute of Radio Engineers for August, 1921, on pages 311 and 325. At the receiving terminal the modulated carrier waves are impressed upon a detector circuit DC of a well known type. To the output circuit 44 of the detector circuit DC that portion of the circuit of Fig. 2 to the right of the line terminals 13 is connected. The circuit arrangement of Fig. 7 is arranged for duplex or two-way communication in the manner described in connection with Fig. 5. The source 43 which supplies carrier waves to the modulating circuit MC may, if desired, have a frequency of 6,500 cycles which will produce a lower side band extending from zero to 6,500. The source 43 may also have a frequency of 7,000 cycles which will serve to produce a lower side band of frequencies corresponding in range to the original scrambled band but having the several frequencies inverted. The source 43 may also have any other suitable carrier frequency as, for example, 10,000 cycles or 30,000 cycles.

The operation of the various systems described will be well understood from the foregoing description so that no more than a general survey of the operation is necessary. Incoming speech waves from any suitable circuits 1, 2 and 3 are designated A, B and C. Each band of waves is divided into sub-bands by means of band filters. A number of these sub-bands A_1, B_2 and C_3 are transmitted directly to the outgoing line. The remaining sub-bands are translated in frequency by means of modulating and selecting apparatus so that their frequencies are above those transmitted directly to the line. Waves of frequencies corresponding to all the sub-bands are thus impressed upon the outgoing line, but the various sub-bands are so intermingled with each other that no two sub-bands belonging to the same signaling band lie adjacent each other. At the receiving terminal a separating circuit serves to separate out sub-bands corresponding to the various sub-bands of the original signaling waves and to translate them back to their original frequencies, whereupon they are assembled to reproduce the original speech bands which are those impressed upon receiving circuits corresponding to messages designated A, B and C.

The novel features believed to be inherent in the invention are pointed out in the following claims.

What is claimed is:

1. The method of multiplex signal transmission from one station to another which comprises dividing each of several bands of frequencies of signal representing waves at one station into sub-bands, translating at least some of the sub-bands to other frequencies and interleaving the sub-bands whereby

each sub-band except a boundary sub-band is adjacent on each side to a sub-band of another band, and transmitting the resultant composite band as a unit to the other station.

2. The method of multiplex speech transmission from one station to another which comprises subdividing each of a plurality of speech wave bands at one station into sub-bands, interleaving the sets of sub-bands corresponding to the various bands, transmitting the interleaved bands to the other station, separating the sub-bands at said other station, and reassembling them to reproduce the original speech waves.

3. In a transmission system, two stations, means at one station for separating each of a plurality of bands of frequencies of signal representing waves into sub-bands, means for translating at least one sub-band of each band to a different frequency, means for superimposing on a common circuit all the sub-bands resulting from the translation together with the untranslated bands and means at the other station for separating the sub-bands, translating the translated sub-bands back to their original values and reassembling the resultant sub-bands to reproduce the original bands.

4. In a speech transmission system, two stations, means at one station for separating several bands of speech frequencies into sub-bands, means for assembling the sub-bands into groups of sub-bands equal in number to the number of sub-bands into which each band is separated, means for translating certain groups of sub-bands, means for combining the translated and untranslated groups of sub-bands, means for transmitting them together to the other station, means at the other station for selecting the translated groups of sub-bands and translating them back to their original values, and means for recombining the translated and untranslated sub-bands into bands corresponding to the original bands of speech waves.

5. The method of confusing bands of frequencies of waves representing signals which comprises subdividing the bands into sub-bands so that the sub-bands containing the less important frequencies will have a proportionately larger number of frequencies and superimposing several sub-bands thus produced in such a manner that they cover a continuous range of frequencies substantially equal to the sum of the ranges of frequencies of the original bands.

6. The method of subdividing a speech band into sub-bands which comprises subdividing the speech band into more than two bands of successively greater frequency range as the frequencies within the band become higher.

7. The method of confusing signals which comprises placing a relatively wide sub-band of frequencies of one signaling band adjacent a relatively narrow sub-band of frequencies of another signaling band.

In witness whereof, I hereunto subscribe my name this 28th day of December A. D., 1922.

RAYMOND A. HEISING.