May 6, 1930. L. ESPENSCHIED 1,757,181

PRIVACY SYSTEM FOR TELEPHONE TRANSMISSION

Filed Dec. 4, 1928 2 Sheets-Sheet 1

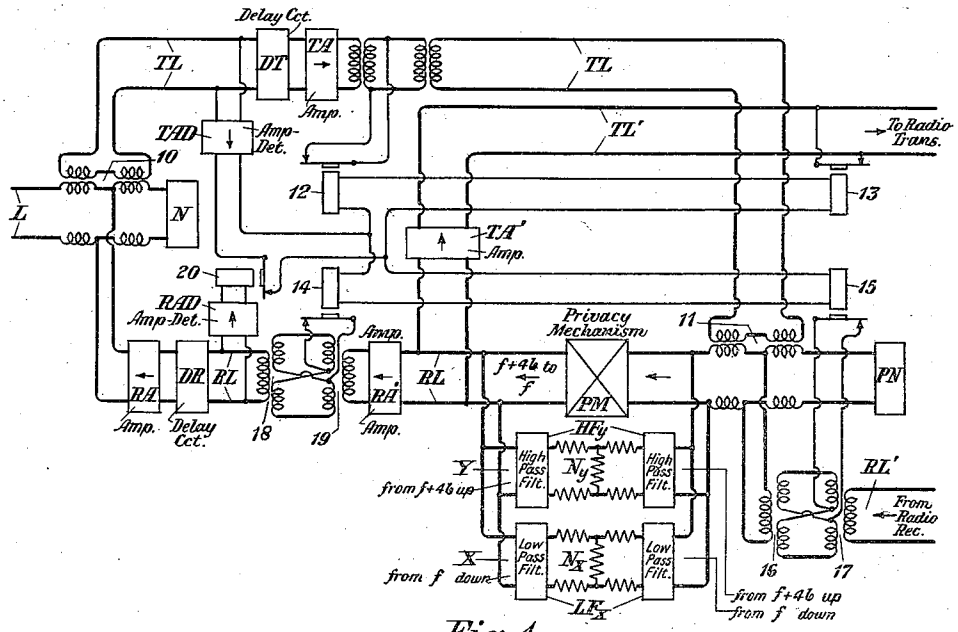


Fig. 1

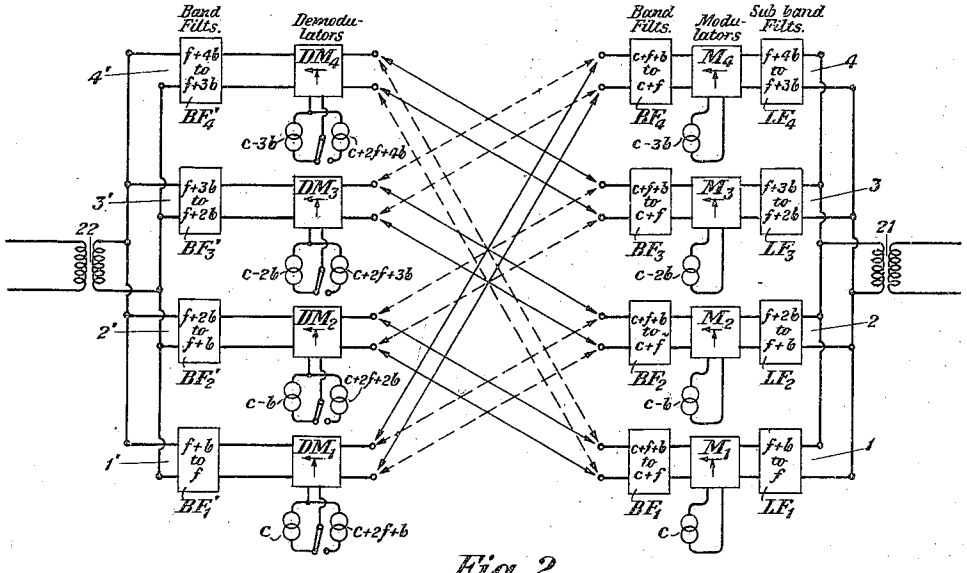


Fig. 2

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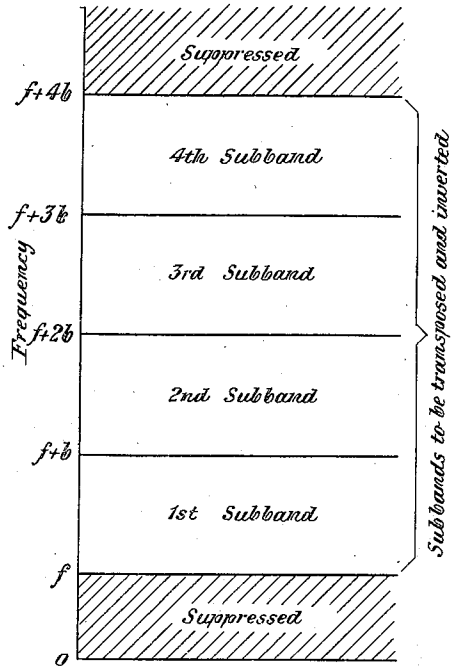


Fig. 3

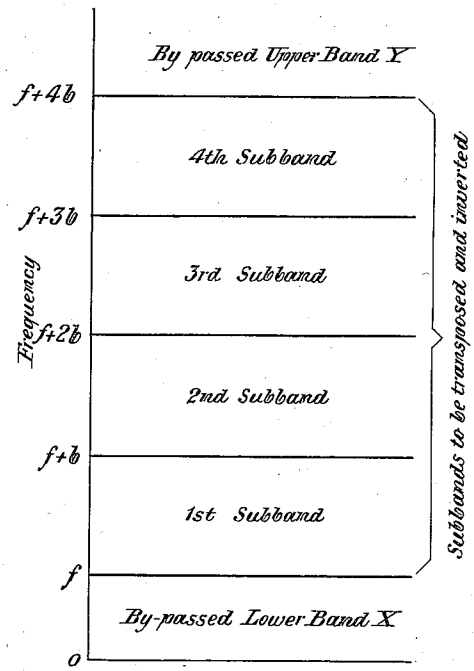


Fig. 4

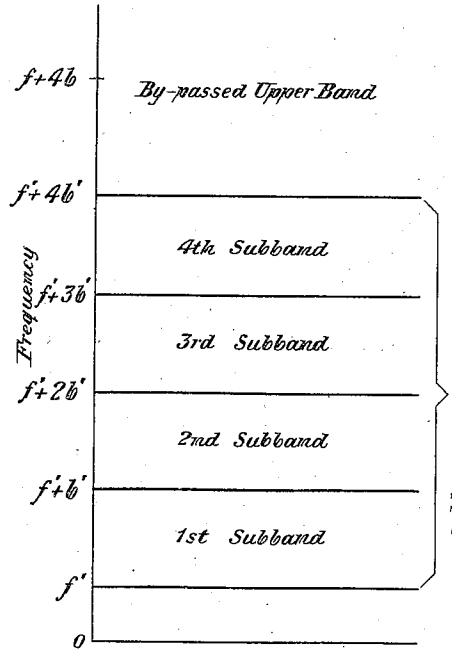


Fig. 5

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PRIVACY SYSTEM FOR TELEPHONE TRANSMISSION

Application filed December 4, 1928. Serial No. 323,698.

This invention relates to telephone transmission systems, and more particularly to arrangements for rendering telephone conversations secret. The invention, while particularly applicable to radio telephone systems, is also applicable to telephone transmission over wires.

In radio telephone transmission it would be possible, if no privacy arrangements were provided, for anyone having a suitable radio receiving set to tune in and listen to a conversation. In order to overcome this difficulty, a privacy arrangement has been proposed for telephone systems, this privacy system operating to divide the transmitted band into sub-bands which may be transposed in their order in the frequency spectrum and, if desired, may be inverted. Various combinations of transposed and inverted sub-bands are possible so that by frequently changing the combination employed it becomes practically impossible for an eavesdropper to listen in, even though he may know the principle upon which the secrecy of transmission is obtained and have available suitable means for re-transposing and reinverting the sub-bands to their normal positions.

With such an arrangement the width of the total band which may be transmitted is limited, due to certain practical considerations. The frequencies which are most important from the standpoint of intelligibility are below about 2,000 cycles, the most essential frequencies being in the neighborhood of 1,000 cycles, although frequencies as low as a few hundred cycles are important. Frequencies somewhat above 2,000 cycles are also desirable from the standpoint of improving the quality. The limited band transmitted should therefore extend at least from a few hundred cycles to somewhat above 2,000 cycles. Now the cost of the privacy apparatus increases with the number of sub-bands into which the transmitted band is divided for the purpose of obtaining secrecy. In practice, the maximum width of a sub-band should not exceed certain limits because a sub-band of greater width in the neighborhood of or below 1,000 cycles would contain the essential speech frequencies to such an extent as to enable an eavesdropper to tune to this particular sub-band and thus obtain a sufficient degree of intelligibility for eavesdropping purposes, although the intelligibility could not be tolerated from the standpoint of ordinary commercial standards. Since the sub-bands to be interchangeable must all be of the same width, the system was designed to transmit such a number of sub-bands of the maximum width consistent with secrecy, as would include all frequencies from a few hundred up somewhat over 2,000 cycles. To increase the number of sub-bands would improve the quality but at an expense of apparatus disproportionate to the benefit derived.

In designing a system of the type above reverred to, it was assumed that all frequencies of the total band transmitted should be transposed in position with respect to each other in order to obtain secrecy. It was, therefore, necessary to make the sub-bands of the greatest width possible in order to obtain the necessary total band width for the authorized listener. In accordance with the present invention, however, arrangements are provided whereby the frequencies outside of the sub-bands subjected to the action of the privacy device may be transmitted to the subscriber independently of the privacy apparatus. If desired, the width of the sub-bands may even be decreased to a considerable extent without increasing the intelligibility so far as the unauthorized listener is concerned. At the same time there is an increase in the quality from the standpoint of the authorized listener, by reason of the transmission without secrecy translation of frequencies lying outside the sub-bands assigned to the privacy arrangement.

The present invention takes advantage of the discovery that a band of considerable width above about 2,000 cycles may be transmitted without conveying much intelligence to the listener, particularly if, at the same time, the listener hears the frequencies below 2,000 cycles transmitted in such scrambled form as to constitute mere noise. Therefore, by providing the privacy arrangement with by-pass circuits having suitable filters to selectively by-pass the frequencies above and/or

below the sub-bands transmitted through the privacy arrangement, the frequencies lying outside of the total band to be scrambled may be transmitted in normal relationship and position in the frequency spectrum, particularly if a suitable network be provided to subject such frequencies to the same loss as that encountered by the scrambled frequencies in the privacy device. The present invention, while of general application, is of particular utility in connection with short wave radio telephone systems because in such systems the design of the radio apparatus itself permits of the transmission of a band of frequencies somewhat wider than is usually possible with long wave radio apparatus as heretofore designed.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawing in which Figure 1 is a schematic diagram illustrating the general lay-out of one terminal arrangement of a two-way radio telephone circuit employing the privacy arrangement of the present invention; Fig. 2 is a schematic diagram of the privacy mechanism for transposing and inverting the sub-bands; while Figs. 3, 4 and 5 are curves illustrating the principles of the invention.

Fig. 1 shows the circuit arrangement of one terminal of a two-way radio telephone system, it being understood that the terminal arrangement at the distant end will be similar to that shown in Fig. 1. Referring to Fig. 1, L designates a telephone line balanced by a network N and connected through a hybrid coil 10 to a transmitting path TL and a receiving path RL in such a manner that the two paths will be substantially conjugate. The transmitting path TL is connected to the radio transmitter (not shown) and the receiving path RL is likewise connected to the radio receiving apparatus (not shown), these connections being effected through circuit arrangements to be described hereinafter.

The transmitting path TL includes a one-way amplifier TA and a delay circuit DT whose functions will appear later, this delay circuit being any known type of network, such, for example, as a Campbell filter, which will introduce the desired delay in transmission. Likewise, the receiving path RL includes an amplifier RA, a delay circuit DT, and an amplifier RA'. The delay circuit DR may be similar to the delay circuit DT.

The privacy mechanism PM, which will be described in more detail later, is common to both the transmitting path TL and the receiving path RL. In order to effect this common connection, the input side of the privacy mechanism is connected through a hybrid coil 11 to the path TL and also to a path RL' which extends to the radio receiver and comprises an extension of the receiving path RL. The path RL' is connected to the midpoints of the hybrid coil so that the paths TL and RL' are substantially conjugate. In other words, signals received over the path RL' will not pass through the hybrid coil to the path TL but will enter the privacy mechanism and the balancing network PN. Likewise signals coming over the path TL will not pass through the hybrid coil to the path RL' but will be transmitted in a circuit including the privacy mechanism and the balancing network PN.

The output side of the privacy mechanism has two branches, one branch leading into the receiving path RL through the one-way amplifier RA' and the other branch leading through the amplifier TA' to the branch TL' which extends to the radio transmitter.

The privacy mechanism PM is of such a character that a telephone message from the line L transmitted over the path TL to the privacy mechanism and thence over the path RL' to the radio transmitter, will be rendered unintelligible. With respect to speech which has been rendered unintelligible at the distant terminal, and, after being transmitted, is received over the path RL' at the station shown, the same privacy mechanism PM functions (in a manner which will appear in more detail later) to restore the speech to intelligibility before transmission over the path RL to the line L. It is therefore necessary that the path TL leading to the radio transmitter, and the path RL leading from the radio receiver, should be so arranged that when transmission is taking place over the one, transmission cannot take place over the other, as otherwise both transmission paths would be effectively connected to the privacy mechanism at the same time.

In order to accomplish this result, the path TL has associated therewith an amplifier-detector unit conventionally indicated at TAD, this amplifier-detector unit being of the type commonly used in connection with echo suppressor circuits to operate suitable relays in response to applied voice currents. The output of the amplifier-detector unit TAD is connected to operate four relays, 12, 13, 14, and 15, whenever voice currents are applied to the input of the amplifier-detector TAD over the path TL. The relay 12 normally applies a short-circuit across the path TL on the output side of the amplifier TA as shown. Likewise the relay 13 normally applies a short-circuit to the path TL' beyond the amplifier TA' as indicated. Consequently, under normal conditions transmission cannot pass over the path TL to the privacy mechanism PM because of the short-circuit applied to the relay 12, and transmission from the output of the privacy mechanism cannot pass over the path TL' to the radio transmitter because of the short-circuit applied to the relay 13.

The receiving paths RL′ and RL on the contrary are normally connected to the privacy mechanism in such a manner that transmission may take place from the radio receiver through the privacy mechanism to the line L. But the contacts of the relays 14 and 15 are arranged to disable the paths RL′ and RL when said relays are operated in response to voice currents applied to TAD over the path TL.

The control of the path RL′ which is exercised by the relay 15 is effected through a balancing transformer arrangement comprising transformers 16 and 17, each having balanced windings connected as shown, so that when the contact of the relay 15 is open the two halves of the two transformers oppose each other and thereby prevent transmission over the path RL′ to the input of the privacy mechanism PM. When, however, the contact of the relay 15 is closed, as is normally the case, the two halves of the secondary winding of the transformer 17 are connected directly together so that in effect the two halves of the two transformers form parallel aiding transmission paths to permit transmission to take place from the path RL′ to the input of the privacy mechanism.

In a similar manner the control exercised by the relay 14 over the path RL is effected through a balanced transformer arrangement comprising transformers 18 and 19 similar in all respects to the transformers 16 and 17 already described, these transformers being connected between the output of the amplifier RA′ and the delay circuit DR. When the contact of the relay 14 is open, the two halves of the two transformers 18 and 19 are connected in opposing relation so that transmission cannot take place from the output of the privacy mechanism over the path RL to the line L. When the contact is closed, however, two parallel aiding paths are provided through the two transformers so that transmission can take place.

With the arrangement above described, the path from the radio receiver through the privacy mechanism to the line L is normally operative, while the path from the line L through the privacy mechanism to the radio transmitter is normally nonoperative, and in fact the privacy mechanism is electrically isolated from the paths TL and TL′. This condition of affairs may be reversed, however, at any time when transmission enters the path TL from the line L. In order to insure, however, that when the distant subscriber is talking he will retain control of the circuit until he ceases talking, the path RL has associated therewith an amplifier-detector unit RAD similar to the unit TAD, already described, the output of which controls a relay 20 which when operated opens the output circuit of the amplifier-detector unit TAD associated with the transmitting path, thereby preventing the switching relays 12, 13, 14, and 15 from being energized to transfer the control of the circuit from the receiving path to the transmitting path.

The operation of the apparatus so far described is briefly as follows: When a subscriber talks over the line L, the band of voice frequencies is transmitted through the transformer 10 and over the path TL to the delay circuit DT. Some of the voice energy actuates the amplifier-detector unit TAD, thereby energizing the switching relays 12, 13, 14, and 15. Relays 14 and 15 by opening their contacts prevent transmission from the receiving path RL′ to the privacy mechanism PM and from the privacy mechanism PM to the receiving path RL. Relays 12 and 13 at the same time open the short-circuits across paths TL and TL′, respectively, so that these paths are now in effective transmission relation with the privacy mechanism.

The operations above described take place while the voice currents are being transmitted through the delay circuit DT. The voice currents are then transmitted through the amplifier TA and over the remainder of the path TL to the hybrid coil 11. By means of the hybrid coil 11 the voice currents are applied to the privacy mechanism, but owing to the balanced relation of the hybrid coil circuit, are prevented from entering the receiving path RL′. Upon passing through the privacy mechanism the voice currents are rendered unintelligible in a manner which will be described later, and then pass through the amplifier TA′ and over the path TL′ to the radio transmitter. Transmission to the path RL is prevented at this time by reason of the open contact of relay 14.

The receiving operation at the distant terminal may be understood from a description of the receiving operation at the illustrated terminal in response to transmission from the distant terminal. The latter operation is as follows: Received radio waves modulated in accordance with speech waves which have been rendered unintelligible by the privacy mechanism at the distant terminal are received by means of the radio receiving apparatus (not shown) and translated into waves corresponding to the unintelligible voice waves transmitted from the distant terminal. Assuming that speech is not incoming from the line L at this time, the contacts of relays 14 and 15 will be closed so that transmission may take place through the transformers 17 and 16 to the hybrid coil 11 where the transmission divides, part of the energy flowing to the privacy mechanism and part to the artificial line PN, without, however, entering the path TL. The privacy mechanism functions to render intelligible the received unintelligible waves in a manner to be described later. Since the path TL′ is short-circuited by the contact of the

relay 13, the received message waves are transmitted through the amplifier RA′ and through the transformers 19 and 18 to the delay circuit DR. Some of the energy transmitted to the delay circuit DR also actuates the amplifier-detector RAD to energize the relay 20, thereby opening the output circuit of the amplifier-detector TAD. Consequently the relays 12, 13, 14, and 15 are prevented from being operated, and hence maintain the circuit in the condition shown so long as the distant subscriber is talking. The operation of the relay 20 takes place while the voice waves are being transmitted through the delay circuit DR. The voice waves are then passed through the amplifier RA to the line L.

The privacy mechanism hitherto referred to may take the form illustrated schematically in Fig. 2. Briefly, the idea is to divide the essential part of the voice band into several equal sub-bands which, in the case assumed may each have a width of b cycles. These sub-bands by suitable modulating operations may be transposed with respect to each other in various combinations, and if desired, any or all of the sub-bands may be inverted from time to time. The order of transposition and inversion of the sub-bands may be changed to render it more difficult for an eavesdropper to listen in, even when he knows the principle upon which the voice band is rendered unintelligible. In this form the now unintelligible voice band is applied to the radio apparatus and transmitted to the distant receiving station.

The same apparatus may be used for retransposing and reinverting the sub-bands of a voice band which has been rendered unintelligible in the manner described. Since the apparatus merely selects certain sub-bands and then transposes and inverts the sub-bands, it is obvious that there will always be a combination of connections whereby a group of sub-bands, which have already been transposed and inverted, can be retransposed and reinverted to their normal relationship.

The apparatus shown in Fig. 2 as comprising the privacy mechanism includes an input transformer 21 for bringing the band to be operated upon to a number of channels 1, 2, 3, and 4. These channels include sub-band filters F_1, F_2, etc., which may be of the band pass type so designed as to each pass a different sub-band of the voice band. A different sub-band is therefore applied to each of the four channels and enters the input circuits of each of the four modulators M_1, M_2, M_3, and M_4. The carrier frequencies applied to these modulators differ from each other and are so chosen that the upper side-bands resulting from the modulating operation will all lie in the same frequency range.

In the case assumed where each sub-band is to be b cycles wide, the several carrier frequencies differ from each other by b cycles. Therefore, if a carrier current of frequency c is supplied to modulator M_1, the carrier current applied to modulator M_4 should have a frequency of $c+4b$. If we assume that only frequencies from f to $f+4b$ cycles are to be transmitted, and that the band to be so transmitted is to be divided into four sub-bands each b cycles wide, it will be evident that the upper side-band in the output of each of the modulators will extend from frequency $c+f$ to $c+f+b$. The lower side-bands will not be the same, however, as that of modulator M_1 extending from $c-f$ down to $c-(f+b)$, while that of modulator M_4 extends from $c-(f+6b)$ down to $c-(f+7b)$.

Band filters having exactly the same cut-off limits may be included in the other channels as indicated at BF_4, BF_3, BF_2, and BF_1, the cut-off limits of the filters corresponding to the upper side-bands of the modulators. Consequently in the case of the modulator M_3, the upper side-band of whose output ranges from $c+f$ cycles to $c+f+b$ cycles, the band filter BF_3 selects just this range of frequencies. In this case, the selected range corresponds to the third sub-band from the bottom of the total voice band passed. In other words, it corresponds to the original sub-band extending from $f+2b$ to $f+3b$. Similarly, the range of frequencies from $c+f$ to $c+f+b$ is also selected by the band filter BF_2, but in this case it corresponds to the sub-band of the original voice band extending from $f+b$ to $f+2b$. The corresponding bands selected by the filter BF_1 and BF_4 corresponds to the lower and upper sub-bands extending from f to $f+b$, and from $f+3b$ to $f+4b$, respectively. Consequently we have (referring to Fig. 3) the first, second, third, and fourth sub-bands of the original voice band brought to exactly the same frequency level. Each channel is now transmitting the same range of frequencies but the range in any given channel corresponds to a different original sub-band from that of the other channels.

The output portion of the privacy mechanism comprises four corresponding channels 1′, 2′, 3′, and 4′, each connected to a common output transformer 22. Each of these channels comprises a demodulator such as DM_1, and a band filter such as BF'_4. Demodulators DM_4, DM_3, etc., are similar to the modulators M_4, M_3, etc., except that each of the demodulators is provided with a choice of two carrier frequencies, one higher than the band applied to it, and the other lower; the lower frequency being so chosen as to shift down the applied sub-band to the position of a particular one of the original sub-bands but with the frequencies in their normal order; and the higher frequency being so chosen as to shift

down the applied sub-band to the same position but with the component frequencies in inverted order.

For example, let us suppose the selected sub-band extending from $c+f$ to $c+f+b$ cycles from channel 3, is connected to the input of the demodulator DM_4 of channel 4'. The applied sub-band, it will be noted, corresponds to the third sub-band of Fig. 3. If a carrier of $c-3b$ cycles be applied to the demodulator DM_4 the resultant lower side-band will extend from $f+3b$ to $f+4b$ cycles, and this sub-band may be selected by the band filter BF'_4 to the exclusion of all other frequencies. Consequently, the final output sub-band of channel 4' will be a band of frequencies b cycles wide, corresponding to the third sub-band of Fig. 3, shifted, however, in the frequency spectrum to the position of the fourth sub-band of Fig. 3 but with the frequencies in their normal relation; that is, the upper frequency of $f+4b$ cycles of the output corresponding to the upper frequency $f+3b$ of the third sub-band, and the lower frequency $f+3b$ of the output corresponding to the lower frequency $f+2b$ of the third sub-band.

Conversely, if the carrier frequency of $c+2f+4b$ cycles is applied to the demodulator DM_4 and the same input band, namely, the band extending from $c+f$ cycles to $c+f+b$ cycles, taken from channel No. 3, is applied to the demodulator, the resultant lower side-band will be the same as before, from $f+3b$ to $f+4b$ cycles. In this case, however, while the final resultant sub-band is in the frequency range corresponding to the fourth sub-band of Fig. 3, and corresponds with the third sub-band of Fig. 3, the order of the frequencies in the final sub-band is inverted. In other words, the $f+4b$ cycle frequency corresponds to the $f+2b$ cycle frequency of the third original sub-band and the $f+3b$ frequency of the final sub-band corresponds to the $f+3b$ frequency of the third original sub-band.

Without further description, it will be obvious that the outputs of each of the four channels 1, 2, 3, and 4 may be variously connected to the demodulators of the channels 1', 2', 3', and 4' to effect various transpositions of the four sub-band shown in Fig. 3. Also, by using either of the two choices of carrier frequencies for demodulators, any desired sub-band, in addition to being shifted in frequency, may be inverted. By shifting the connections of the channels and the carrier frequencies in various combinations from time to time in such manner that corresponding combinations are simultaneously employed at the two terminals at the same time, it will become practically impossible for an unauthorized listener to eavesdrop.

It will be noted that in the arrangement above described, the final band filter, such as BF'_1, BF'_2, etc., select sub-bands b cycles wide, arranged one immediately above the other, so that the effect of the privacy apparatus is to suppress all frequencies (in the assumed case) above $f+4b$ cycles and below f cycles. Assuming that a range of frequencies from f to $f+4b$ was necessary to give commercial quality, the system as heretofore employed, was limited to the number of sub-bands of maximum width necessary to transmit this range, as the provision of more channels than required for the range from f to $f+4b$ increased the expense of the apparatus out of proportion to the ultimate intelligibility, as seen from the standpoint of the authorized subscriber. A less number of channels would be impractical because even with a sub-band of maximum width, the total range of frequencies transmitted to the subscriber would be less than the range f to $f+4b$, which would not conform to existing standards of intelligibility. It was not possible to widen the sub-bands beyond a given maximum without rendering it possible for an eavesdropper (who would naturally be less critical of quality) to receive a properly chosen single sub-band with sufficient intelligibility to enable him to understand the message, particularly if he became experienced in listening to the sort of transmission he would receive.

Now, where the character of the system is such as to permit the transmission of a wider total band than will be passed by the privacy mechanism, the apparatus as above described, being limited to a range from f to $f+b$ cycles, prevents the subscriber from receiving the benefit of the increased intelligibility and better quality due to the frequencies lying outside the range of the privacy apparatus. Applicant has discovered, however, that if the band of frequencies below the lower limit of the privacy mechanism be transmitted without either inversion or shifting in the frequency spectrum, such band of frequencies, when added to the distorted or translated band acted upon by the privacy mechanism, does not confer any appreciable increase in intelligibility to the output when picked up by an unauthorized listener. The same holds true if the band of frequencies encountered in ordinary speech above the upper limit of the privacy mechanism be transmitted in addition to the transposed and inverted sub-bands. Therefore it is proposed to transmit either or both of these additional bands to the authorized subscriber without subjecting them to the action of the privacy mechanism, thereby enabling the authorized subscriber to receive with greater intelligibility and faithfulness in reproduction. This is accomplished, as shown in Fig. 1, by bridging about the privacy mechanism a by-pass arrangement comprising two parallel paths X and Y. Path X includes a low pass

filter LF_x which is divided into two halves so that a network or pad N_x may be included between the two halves of the filter to introduce a loss at the frequencies passed by the filter equivalent to the loss imposed on the bands of frequencies passing through the privacy mechanism. In the case where the privacy mechanism passes the band from f cycles to $f+4b$ cycles, the filter LF_x may be a low-pass filter having a range from 0 to f cycles.

Similarly, the path Y includes the high-pass filter arrangement HF_y likewise divided into two units with a network or pad N_y to impose upon the frequencies passed by this branch a loss corresponding to that introduced by the privacy mechanism. The filter HF_y may be arranged, where the privacy mechanism passes a total band from f to $f+b4$ cycles, to pass all frequencies above $f+4b$.

With the by-pass arrangement above described, the frequency allocation is as indicated by the chart of Fig. 4. Here it will be observed that the main sub-bands, which are subjected to transposition and inversion, are the same as in Fig. 3. The band immediately below the first sub-band is, however, transmitted by the by-pass circuit X and the band immediately above the fourth sub-band is transmitted by the by-pass path Y.

It has been ascertained that the frequencies which are most important from the standpoint of intelligibility are, for the most part, below about 2,000 cycles. The frequencies above this limit tend to give color and character to the sounds but are of less importance from the standpoint of intelligibility. It is therefore only essential that the band shifting and band inversion processes be applied to the frequencies below about 2,000 cycles. It is also desirable, if possible, to make each sub-band narrower than the width heretofore discussed. This is for the reason that any eavesdropper who tunes his receiving set to pick out an individual band will find the band so narrow that it will be well below the limit of intelligibility.

In order to take care of this possibility, the frequencies heretofore described as being applied to the apparatus of Figs. 1 and 2 may be altered so that each sub-band is only b cycles wide and that the sub-bands cover the frequency range from f' cycles to $f'+4b'$ cycles, when b' and f' are less than f and b, and $f+4b$ is a frequency in the neighborhood of 2,000 cycles. Then, as shown in Fig. 5, the first sub-band will extend from f' cycles to $f'+b'$ cycles, the second from $f'+b'$ to $f'+2b'$ cycles, the third from $f'+2b'$ to $f'+3b'$ cycles and the fourth from $f'+3b'$ to $f'+4b'$ cycles. This gives a much narrower sub-band, and yet, as will be seen from Fig. 5, substantially the whole range below $f'+4b'$ cycles is subjected to the band transposition and band inversion operations. Consequently, the intelligible part of the frequency range is rendered unintelligible. The frequencies above $f'+4b'$ may be by-passed without change by means of the by-pass path Y of Fig. 1, the lower cut-off point of the filters, however, in this instance being set at $f'+4b'$ instead of $f+4b$. The frequencies below f' may be transmitted by the lower by-pass path X by making the cut-off of the filter LF_x f' instead of f. If desired, however, these frequencies, as being relatively unimportant, may be omitted, in which case the second by-pass path X will be unnecessary.

The frequency assignments for the various pieces of apparatus in Fig. 2, with the alternative arrangement of sub-bands as indicated in Fig. 5, will be obvious without detailed description. For example, the four modulators, such as M_4, M_3, etc., will be supplied with carrier frequencies which differ from each other by b' cycles instead of b cycles, and the same holds true for the carrier frequencies applied to the demodulators, such as DM_4, DM_3, etc. The various band filters, such as BF_4, BF_3, etc., will have their upper and lower cut-off frequencies separated by f' cycles, instead of f cycles as indicated in Fig. 2. The band filters F to F_4, as well as BF'_1 to BF'_4 will have cut-off frequencies corresponding to the marginal frequencies of the four sub-bands, as indicated in Fig. 5.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

What is claimed is:

1. In a telephone system, a transmission circuit, a privacy apparatus associated therewith, said privacy apparatus comprising means to divide the important range of telephone frequencies from the standpoint of intelligibility into a plurality of sub-bands of such width as to be substantially unintelligible when received alone, means to variably transpose the sub-bands, and a by-pass for selecting and transmitting without transposition telephone frequencies of small intelligibility lying without the range of the privacy apparatus.

2. In a telephone system, a transmission circuit, a privacy apparatus associated therewith, said privacy apparatus comprising means to divide the important range of telephone frequencies from the standpoint of intelligibility into a plurality of sub-bands of such width as to be substantially unintelligible when received alone, means to variably transpose the sub-bands and to variably invert the order of the frequencies within certain of said sub-bands, and a by-pass for transmitting without transposition or inversion telephone frequencies of small

intelligibility lying without the range of the privacy apparatus.

3. In a telephone system, a transmission circuit, a privacy apparatus associated therewith, said privacy apparatus comprising means to provide the important range of telephone frequencies from the standpoint of intelligibility into a plurality of sub-bands of such width as to be substantially unintelligible when received alone, means to variably transpose the sub-bands, a by-pass for transmitting frequencies around said privacy apparatus without transposition, and means to select into said by-pass telephone frequencies of small intelligibility without the range of the privacy apparatus.

4. In a telephone system, a transmission circuit, a privacy apparatus associated therewith, said privacy apparatus comprising means to divide the important range of telephone frequencies from the standpoint of intelligibility into a plurality of sub-bands of such width as to be substantially unintelligible when received alone, means to variably transpose the sub-bands and to variably invert the order of the frequencies within certain of said sub-bands, a by-pass for transmitting frequencies around said privacy apparatus without transposition or inversion, and means to select into said by-pass telephone frequencies of small intelligibility without the range of said privacy apparatus.

5. In a telephone system, a transmission circuit, a privacy apparatus associated therewith, said privacy apparatus comprising means to divide the important range of frequencies from the standpoint of intelligibility into a plurality of sub-bands of such width to be substantially unintelligible when received alone, means to variably transpose the sub-bands, a by-pass for transmitting frequencies around said privacy apparatus without transposition, means to select into said by-pass frequencies without the range of said privacy apparatus, and means in said by-pass to subject the frequencies so selected to substantially the same loss as is encountered by the frequencies passing through the privacy apparatus.

6. In a telephone system, a transmission circuit, a privacy apparatus associated therewith, said privacy apparatus comprising means to divide the important range of frequencies from the standpoint of intelligibility into a plurality of sub-bands of such width as to be substantially unintelligible when received alone, means to variably transpose the sub-bands and to variably invert the order of the frequencies within certain of said sub-bands, a by-pass for transmitting frequencies around said privacy apparatus without transposition or inversion, means to select into said by-pass frequencies without the range of said privacy apparatus, and means in said by-pass to subject the frequencies so selected to substantially the same loss as is encountered by the frequencies passing through the privacy apparatus.

7. In a telephone system, the method of obtaining secrecy of transmission which consists in selecting from the total telephone band the range of frequencies most essential to intelligibility, dividing the range into sub-bands too narrow to be substantially intelligible when received alone, transposing the position of the sub-bands within the selected range, and transmitting telephone frequencies of small intelligibility outside the selected range without transposition.

8. In a telephone system, the method of obtaining secrecy of transmission which consists in selecting from the total telephone band the range of frequencies most essential to intelligibility, dividing the range into sub-bands too narrow to be substantially intelligible when received alone, transposing the position of the sub-bands within the selected range, inverting the order of the component frequencies of certain sub-bands, and transmitting telephone frequencies of small intelligibility outside the selected range without transposition or inversion.

In testimony whereof, I have signed my name to this specification this 1st day of December, 1928.

LLOYD ESPENSCHIED.