

Nov. 3, 1931.

R. W. CHESNUT ET AL

1,829,783

METHOD AND SYSTEM OF SECRET SIGNALING

Filed Nov. 8, 1929

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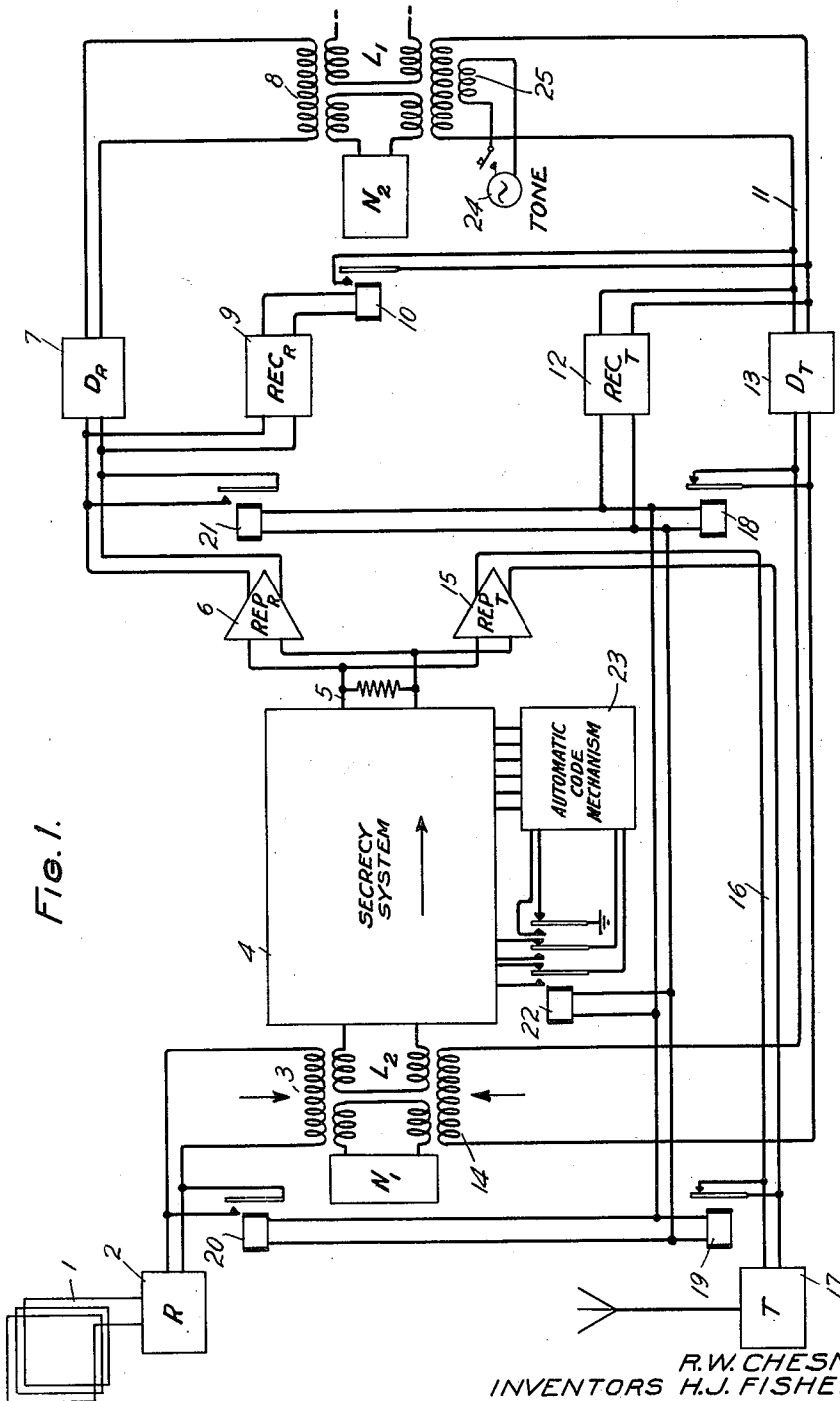


Fig. 1.

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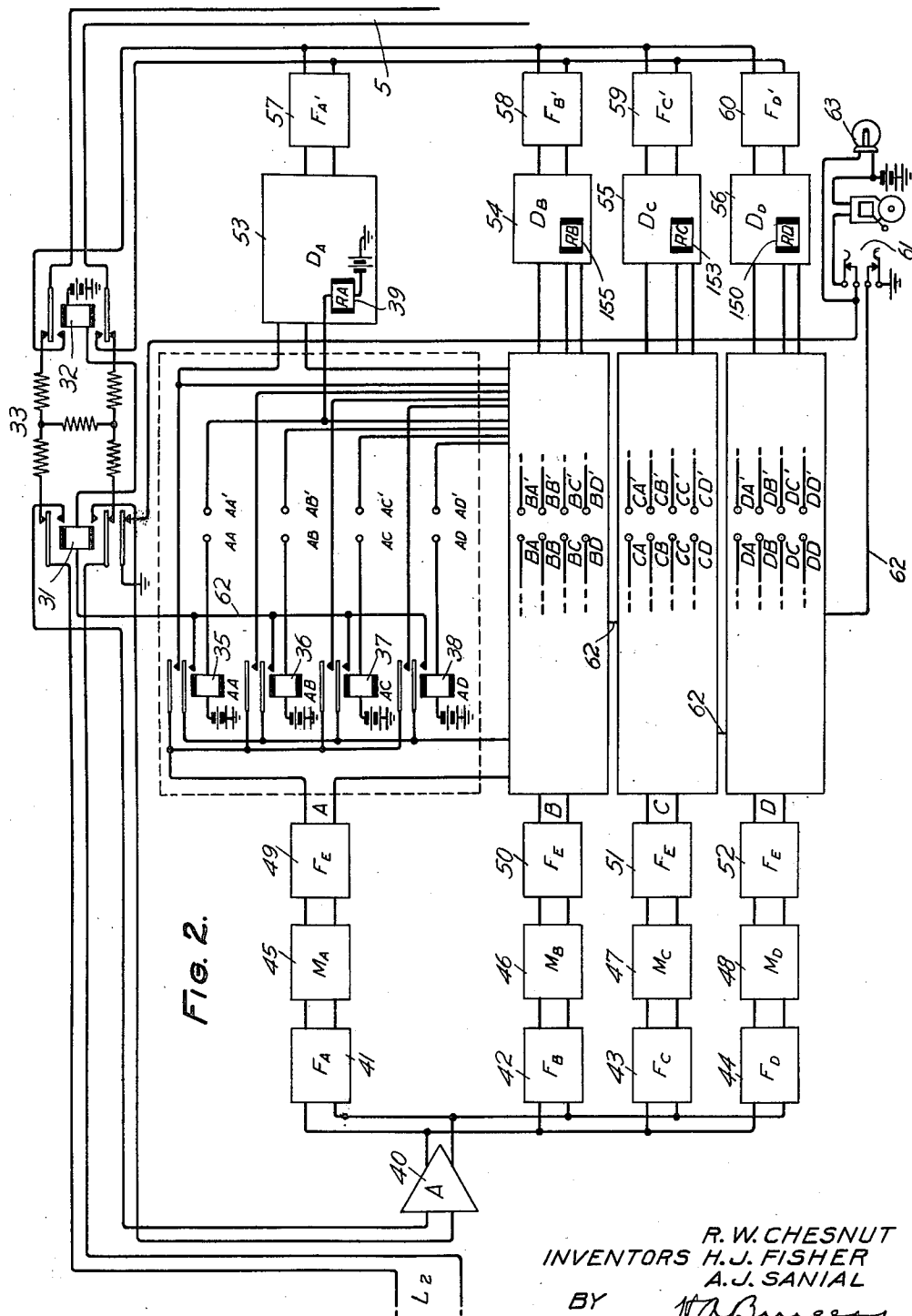
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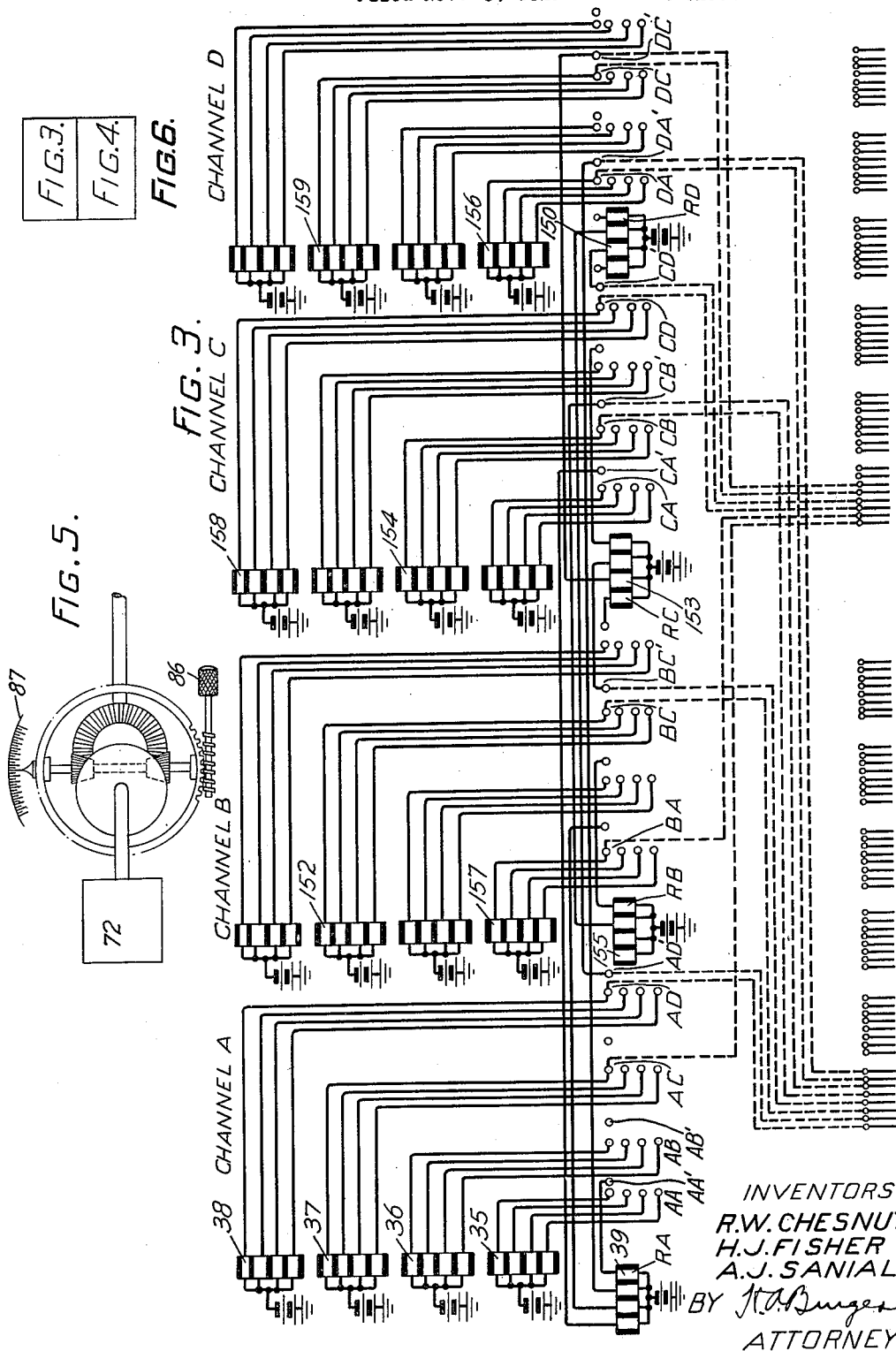
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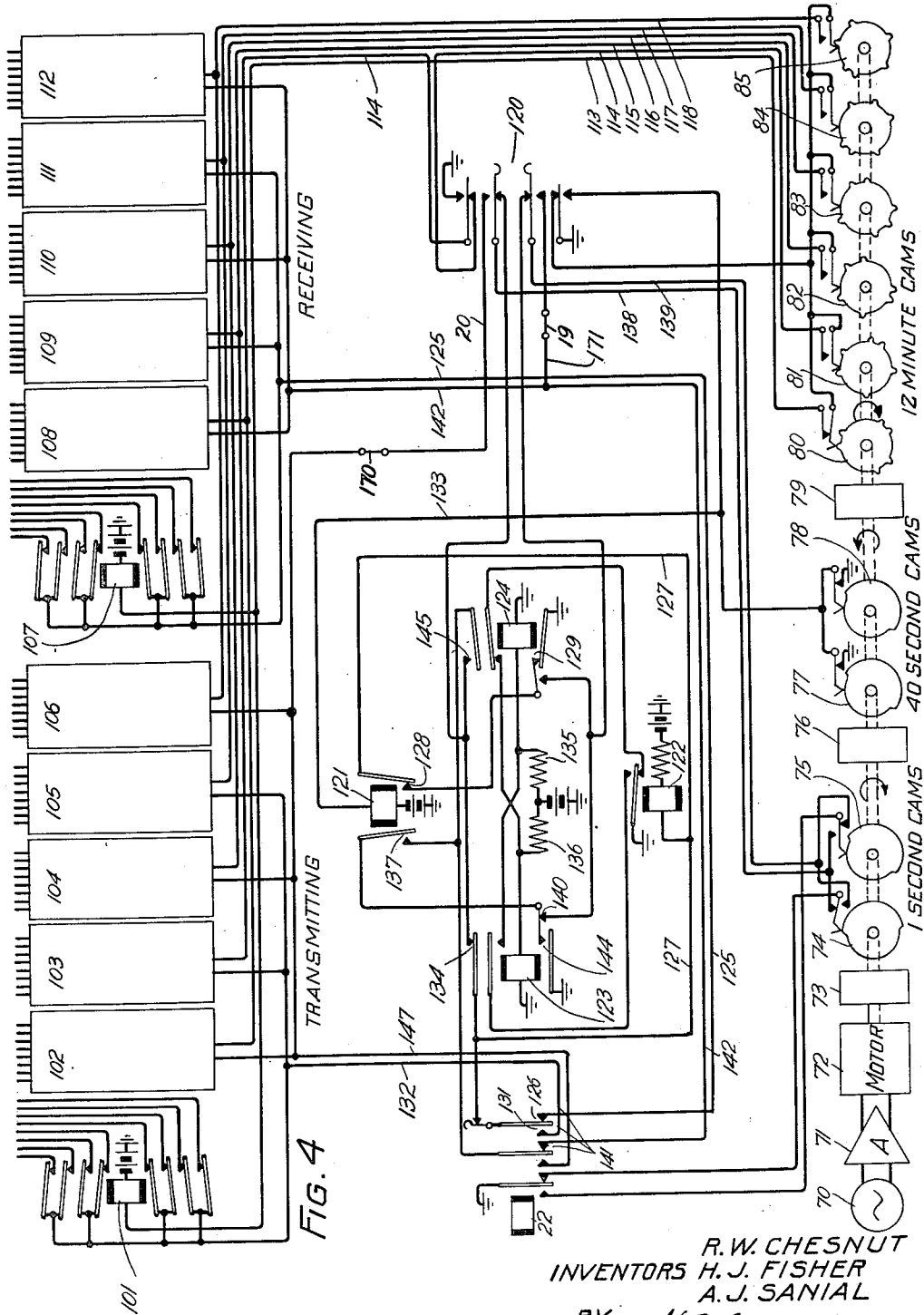


FIG. 4

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METHOD AND SYSTEM OF SECRET SIGNALING

Application filed November 8, 1929. Serial No. 405,602.

The present invention relates to transmission systems, and more particularly to a method of and means for providing secrecy in the transmission of messages.

In the U. S. patents to Espenschied et al. 1,709,901, granted April 23, 1929 and C. L. Weis, jr. 1,725,032, dated August 20, 1929 are disclosed secret signaling systems adapted for the transmission with secrecy of speech or similar signals. The speech or signal waves are divided on a frequency basis into sub-bands which are transposed among themselves or which have their frequency orders inverted prior to transmission. In order to receive and understand the signals thus transmitted, it is necessary at the receiving point to retranspose the sub-bands to their original positions. In case any of the sub-bands have had their frequency order inverted, it is necessary to reinvert the frequencies to their original order. In this specification both of these transformations will be understood as included in the meaning of the word "transpose". This type of purposeful distortion of waves has also been referred to as scrambling. In the case of the Espenschied et al. patent referred to the degree of secrecy is increased by providing automatic means for changing the scheme of transposition of the sub-bands in accordance with a prearranged code. By changing the scheme of the transpositions at frequent intervals an unauthorized listener has greater difficulty in discovering how to render any portion of the signal intelligible.

The present invention is an improved method and means of transmitting signals with secrecy. It resembles the systems of the patents referred to in that it provides for the separation of the signal waves into sub-bands, which are interchanged among themselves. Also the frequency order within any sub-band may be inverted whether the sub-band is shifted to a different frequency position or not, as is fully disclosed in the Weis patent. The present invention employs a novel shifting system for changing from one scheme or combination of frequency transposition to another and provides greater flexibility, a

higher degree of secrecy and includes a number of features subservient to these ends.

One object of the present invention is to increase the secrecy by enabling the scheme of frequency transposition to be changed entirely under local control and without the sending of switching waves or impulses between the communicating stations.

A further object is to provide for simultaneously and accurately shifting the frequency transposition scheme at all stations.

A further object is to enable different transposition schemes to be used for the different directions of transmission through such a system.

A further object is to use automatically the same combinations of sub-bands over and over again, but in successively altered sequence.

Other objects and features of the invention will be made clear from the following specification and drawings, in which Fig. 1 is a schematic representation of a radio terminal circuit for two-way operation in accordance with the invention; Fig. 2 shows more in detail the secrecy system for scrambling or transposing the frequency bands before transmission and unscrambling or retransposing them after reception; Figs. 3 and 4 when placed adjacent each other with Fig. 3 above Fig. 4 as in Fig. 6 show the automatic coding mechanism for controlling the secrecy system; and Fig. 5 shows a detail of the synchronizing and phasing mechanism.

In the specific embodiment of the invention to be described the shifting from one combination or scheme of transposition to another is made under control of timing cams which are independently driven by accurately controlled driving members at the different stations. These separate driving members can be kept in proper step in any suitable manner and may be frequently checked up in order to maintain proper quality of transmission through the system.

In order to shift from one combination to the next at an instant determined with a high degree of accuracy, the shifting is made dependent upon the operation of a high speed cam in cooperation with certain relays.

Other cams operating at lesser speed preselect the combinations in the order in which they are to be used. The shift is made from one combination to the next in order until all of the available combinations have been utilized. The same combinations are then employed in a different sequence and thereafter are successively employed in still other sequences. These sequences as well as the shifting from one combination to the next are carried out under control of continuously operating cam members at the respective stations.

For two-way operation, provision is made for transmitting totally different and unrelated combinations in the two opposite directions. When any combination is set up for transmitting from a given station there is also set up another combination for receiving purposes. These two combinations may be unrelated to each other but are complementary to the respective receiving and transmitting combinations at a distant station with which communication is being carried on. That is, the cam arrangement at the different stations is such that for transmitting from one and receiving at the other station complementary combinations are provided, while for transmitting in the opposite direction complementary combinations are also provided, but these latter are not in anywise dependent upon the former. The transfer from the transmitting to the receiving combination at any station is carried out under control of the speech waves and is performed simultaneously with the changeover of the station from the transmitting to the receiving condition or vice versa.

Referring first to Fig. 1, a two-way radio station is shown which is substantially identical with that shown in Fig. 1 of the Weiss patent supra, except for the addition of the automatic code mechanism to be referred to.

The station illustrated in Fig. 1 is shown in condition for receiving which is the normal condition. Waves intercepted on receiving antenna 1 are detected and suitably amplified at 2 and pass into the circuit leading to the hybrid coil 3 through which they are transmitted into the circuit L_2 . This circuit leads to the secrecy system 4. In this system the waves undergo a transformation to render them intelligible, it being assumed that they have been transmitted from a similar distant station at which their frequency components have been interchanged so as to render them incapable of being understood. The waves as restored to intelligible form by the secrecy system 4 pass into the output circuit 5, through repeater 6, delay network 7, hybrid transformer 8 into telephone line L_1 .

Waves originating on the telephone line L_1 for transmission to a distant point by the two-way circuit of Fig. 1 pass into the circuit 11, through delay network 13, hybrid coil 14, line

L_2 and into the secrecy system 4. Here they undergo a transformation to render them incapable of being understood. The waves so distorted appear in the outgoing circuit 5 from the secrecy system 4, pass through amplifier 15 into line 16 and thence into the radio transmitter 17 from which they are sent to a distant point.

Before such transmission can take place, however, over the circuit just traced, it is necessary to clear the path of certain obstructions which normally exist since the circuit as stated is normally in condition to receive and not in condition to transmit. In order to do this the waves in circuit 11 as received from the line L_1 pass into the amplifier rectifier 12 and cause the operation of relays 18, 19, 20, 21 and 22 all of which attract their armatures. Relay 18 in energizing opens the normal shunt path across the output side of delay network 13. The delay introduced by this network is sufficient to enable the relays 18 to 22 inclusive to operate before the waves traverse the network 13. Relay 19 opens a similar shunted path adjacent the transmitter. Relay 22 in shifting its armatures sets up a new circuit condition in the secrecy system 4 so that the waves as transmitted undergo a different transformation from that which is made in the waves as received. That is, the scheme of alteration made in the waves as sent out from the station of Fig. 1 is different from the scheme of alteration of the received waves. Relays 20 and 21 disable the receiving side of the circuit to prevent singing around the four-wire loop and to prevent false operation.

When a pause occurs in the conversation and the waves incoming from line L_1 cease for a sufficiently long time, relays 18 to 22 inclusive release, again placing the system in condition for receiving. Relay 22 in releasing its armatures effects a circuit change in the secrecy system 4 to cause the waves as received to undergo a different transformation from that which is used for transmitting. The amplifier rectifier 9 and relay 10 operate in response to received energy to place an additional shunt across line 11 ahead of the amplifier rectifier 12 to prevent false operation.

Relay 22 by its three armatures indicated controls circuits associated with the automatic code mechanism 23 to be described more in detail hereinafter. This code mechanism as will be described contains continuously moving switching devices which operate in cyclic order to effect a circuit change in the secrecy system 4 periodically in order to render reception of the waves more difficult. These switches in the code mechanism operate in timed relation in synchronism and in phase with a similar distant station so that corresponding changes are produced in the

secrecy system of each station at corresponding instants of time.

Before describing further the code mechanism, it will be necessary to refer to the secrecy system 4 and to the nature of the wave transformations which are effected therein.

This secrecy system 4 is shown diagrammatically in Fig. 2. The secrecy system shown in this figure is identical with that disclosed in Figs. 2 and 3 of the Weis patent supra to which reference may be made for greater detail than is given in present Fig. 2.

In Fig. 2 the line L_2 which is the input line to the secrecy system for both the received radio waves and the waves received from the telephone line L_1 is shown at the left of the figure; the output circuit 5 is shown at the right. The input waves in line L_2 pass either through the substitute network 33 at the top of the figure if the system is to be operated non-secretly or into the amplifier 40 and through the four channels A, B, C and D respectively if the system is to operate with secrecy. Key 61 if operated to remove ground from its lower contact substitutes the network 33 for the secrecy system as is explained in the Weis patent. If key 61 remains unoperated however, relays 31 and 32 are energized over a circuit from battery through both relays in series, conductor 62 and through the front contact of one of the relays 35, 36, 37 and 38 in the A channel and through the front contact of one relay in each of channels B, C and D and conductor 62 to ground. As will be explained later, these relays in the channels A, B, C and D will be operated when the secrecy system is adjusted to make any complete transformation in the waves suitable for transmission or reception with secrecy. The use of substitute network 33 and the circuits controlling it are shown in the Weis patent and form no part of the present invention. These elements may, of course, be omitted if desired.

The waves pass from amplifier 40 into the four sub-dividing filters 41, 42, 43 and 44, each of which leads to an individual modulator circuit 45, 46, 47 or 48, the output of which connects to individual filters 49—52 respectively. As explained in the Weis patent the filters 41—44 subdivide the speech into narrow bands and the modulators 45—48 raise the frequencies of the sub-band components to the same level so that in the output circuits of the filters 49—52 there will appear for example, four sub-bands each occupying the range 8000 to 8550 cycles but taken from different portions of the speech band and representing in the aggregate the total frequency range of say 400 to 2600 cycles per second.

By means of the switching relays 35—38 in channel A and similar relays in channels B, C and D, these frequency bands may be impressed individually in any combination

on the demodulators 53—56 where they undergo either of two transformations. In the first place, they are stepped downward in the frequency scale so that they again occupy the speech level, demodulator 53 stepping whatever band is impressed upon it down to the A level, that is, the lowest of the four bands into which the speech wave was originally divided by the filters 41—44. Similarly demodulator 44 steps the band impressed upon it down to the B position and the demodulators 55 and 56 step the bands impressed upon them down to the C and D positions respectively. In addition to stepping the bands downward to the A, B, C or D position each demodulator may also invert the frequency order of the frequency components in the resulting sub-band. This inversion takes place if the relay 39 of the demodulator 53 or the corresponding relay in any of the other demodulators is energized, the effect of such energization being to shift the wave frequency of the demodulator oscillator as is disclosed in the Weis patent.

In the Weis patent disclosure a number of keys are provided for energizing relays 35—38 in any of the four channels, or any of the four relays 39, 150, 153 or 155, to introduce the various frequency transpositions of which the system is capable. In Fig. 2 of this application the energizing circuits for these relays are shown for simplicity of disclosure as brought out to terminals labeled respectively, AA, AA', AB, AB', etc. throughout the four channels. By applying ground to any of these terminals the corresponding relay is energized. The manner in which the relays are actuated will be described in connection with the automatic code mechanism the function of which is to place a ground on various ones of these terminals in Fig. 2 and to shift from time to time the grounding of these terminals in such a way as to set up different combinations in the system.

Before passing to a description of the coding mechanism the significance of the terminal designations will be explained. If the contact AA has ground applied to it this means that the A sub-band (e. g. occupying frequencies corresponding to the range 400 to 950 cycles) which is selected by filter 41 is sent out through filter 57 unchanged in its frequency position or frequency order. In other words AA means that the incoming A sub-band is sent out in the A position. Thus, if the contacts AA, BB, CC and DD were all grounded the speech waves would be sent through the secrecy system with no frequency transformations whatsoever, and they would emerge in the same condition in which they entered. Grounding contact AB, however, means that the A band is shifted to the B position. Grounding contact AC means

that the A band is shifted to the C position, etc.

In order to invert the frequency order of the band it is necessary to ground a primed terminal such as AA' together with the grounding of its paired contact AA. Thus if in addition to the grounding of the AA, BB, etc. contacts, ground is also connected to the contact of AA', BB', CC' and DD', each of the four bands subdivided from the speech wave will be sent out in its original position in the speech band but with its frequency components in inverted order. Similarly, if the contacts AB and AB' are both grounded, the A band will be shifted to the B position and inverted. With this explanation it will be a simple matter to designate the nature of any transformation that may be made in the waves.

Reference will now be made to Figs. 3 and 4 for a description of the switching control circuits for changing from one secret combination to another.

In accordance with the present disclosure there is provision for using six different secrecy schemes for each direction of transmission. It will be understood, of course, that by duplication the system could be readily modified to accommodate any number of secret combinations up to the maximum capacity of the system.

Each combination is determined in Fig. 4 by a corresponding one of the relays 101 to 112 inclusive, only two of which are shown in detail. Relays 101 to 106 determine the six different combinations used for transmitting, while relays 107 to 112 determine the six receiving combinations. Each relay is provided with eight armatures, the contacts of which are variously cross connected to the switching relays of Fig. 2, i. e., to the relays 35 to 38 and relay 39 in channel A and the corresponding relays in channels B, C and D. The manner of connection will be described hereinafter in connection with Fig. 3.

The relays 101 to 112 and the circuits controlled by them are in turn controlled by a series of cam switches shown in the lower part of Fig. 4. The secret combinations controlled by these relays are under the further control of voice-operated relay 22 which is the same as relay 22 of Fig. 1. When the system is in receiving condition, the three armatures of relay 22 are retracted. When in the transmitting condition these three armatures are attracted. The movement of these armatures determines whether the setting of the secrecy system is controlled by one of the six relays 101 to 106, or by one of the relays 107 to 112. Thus the relay 22 in shifting its armatures to change the system from transmitting to receiving, or vice versa, also changes the secrecy system from one combination to another to correspond to transmitting or receiving respectively.

The cam switches are shown attached to a common shaft driven by motor 72 which is a synchronous motor energized from a constant frequency oscillator 70 the output of which is amplified at 71. The oscillator 70 is a vacuum tube oscillator constructed as known in the art to maintain a constant frequency to a high degree of accuracy as by being protected from temperature variations and other disturbing factors. A gear box 73 is connected between motor 72 and the two high speed cams 74 and 75. A second gear box 76 transmits the driving power to the next lower speed cams 77 and 78 while a third gear box 79 transmits driving power to the remaining cams 80 to 85. Cams 74 and 75 may revolve at 60 R. P. M., i. e., these are 1-second cams. Cams 77 and 78 revolve at 1½ R. P. M. and consequently make one revolution in 40 seconds (40-second cams). Cams 80 to 85 make one revolution in 12 minutes. Each of these 12-minute cams has its surface cut to provide six contacts corresponding to six secret combinations. The exact arrangement of these will be described later and it will suffice to state here that as the cams rotate they close in succession contacts to provide for shifting from one secret combination to the next every 20 seconds.

The gear boxes 73, 76 and 79 provide reduction gearing and also contain a phase adjusting differential gear which may be of the type shown in Fig. 5. This is provided with an adjusting screw 86 and suitable scale 87 to enable the phase adjustment of the three sets of cams to be accurately determined.

The cams 80 to 85 inclusive control a group of six circuits 113 to 118, each leading to the winding of two relays, one in the 101 to 106 group and the other in the 107 to 112 group. With the circuit in the position shown in the drawing with the cam 80 closing its contact, relays 101 and 107 are both energized over a circuit extending from battery, through the winding of each relay, conductor 113, contact of cam 80 and ground at the front contact of key 120. As the cams 80 to 85 rotate cam 81 will presently close a circuit through the windings of relays 102 and 108 causing both of these relays to attract their armatures. This circuit extends from battery, through the windings of the relays (not shown), conductor 114, normally closed upper contacts of key 120, conductor 114, contacts of cam 81 to ground. In a similar manner the relays 101 to 112 are energized in pairs in succession under control of the code cams 80 to 85.

The cams 77 and 78 determine, with the assistance of cams 74 and 75, the precise instant of shift from one secret combination to the next. This is accomplished also with the aid of the auxiliary relay circuit comprising the four relays 121, 122, 123 and 124, the action of which will be best understood

by tracing through typical operational steps.

With the circuit in the condition shown the system is in the receiving position and is set to operate on secret combination No. 1 for receiving and secret combination No. 1 for transmitting. As explained above, the No. 1 receiving combination bears no necessary relation to the No. 1 transmitting combination and it is preferable not to have a complementary relation between them, but to choose for them any two arbitrary combinations. Relays 101 and 107 both being energized, ground is supplied over the armatures of one or the other, depending on relay 22. With the armature 22 deenergized for receiving, ground is supplied to the eight armatures of relay 107, over conductor 125, contact 126, conductor 127, contacts 128 and 129 to ground. If the party who is now receiving starts to talk as explained in connection with Fig. 1, relay 22 attracts its armature opening its back contacts and closing its front contacts. The ground just now traced from contact 126 is transferred to contact 131, conductor 132 and the armatures of relay 101 causing the secrecy system to be shifted to the No. 1 transmitting combination instead of the No. 1 receiving combination.

The foregoing circuit for placing ground on the switching relays through the contacts of relays 101 and 107 assumed relays 121 and 124 to be operated. Relay 122 is also operated at this time. The energizing circuit for relay 121 extends through conductor 133 and the springs of cams 77 and 78 to ground. Relay 121, therefore, remains energized until these cams break the circuit. Relay 122 is energized from battery through the winding of the relay, conductor 127, contacts 128 and 129 to ground, this circuit being a holding circuit. The energizing circuit for relay 122 was closed through contact 134 of relay 123, contact of key 120 and contact spring of cam 74 or 75 to ground at one of the contacts of relay 22 in a manner which will be made clear as the description proceeds. When relay 122 was thus energized shifting its contact to its lower position, it opened at its back contact a shunting circuit previously closed around relay 123 so that the latter released and left relay 124 unshunted, relay 124 being thus energized through resistance 135 and battery to ground.

Assuming that the station remains in the receiving condition, the circuit relations as above traced remain unchanged until cams 77 and 78 complete the half-revolution now in progress as represented by the circuit conditions of Fig. 4, and open their respective contacts. This determines roughly the completion of a 20-second interval. The accurate determination of the end of this interval is however, determined by the 1-second cams 74 and 75.

When cams 77 and 78 open their contacts,

relay 121 releases, opening contact 128 and closing contact 137. This has no immediate effect however, since the ground which previously extended through contacts 129 and 128 and conductor 127 to contact 126 is maintained through contact spring of cam 74. This ground is derived at the back contact of relay 22 and extends through upper contact of cam 74, conductor 138, normal contact of key 120, and contact 134. It will be assumed at this point that the station continues in the receiving condition and that therefore relay 22 is to remain deenergized. When the spring of cam 74 falls, the ground from the back contact of relay 22 is shifted to conductor 139 and extends through normal lower contact of key 120, contact 140, contact 137 now closed, contact 141, conductor 142 to the armatures of relay 108. Relays 102 and 108 have in the meantime been energized by cam 81 over a circuit (previously traced) extending from ground, contact springs of cam 81, conductor 114, normal contacts of key 120, conductor 114, windings of relays 102 and 108. The cutting of the cams 80 to 85 is such that there is an overlap in the period of attraction of one pair of relays corresponding to one transmitting and receiving secret combination and the next pair corresponding to the next transmitting and receiving secret combinations. The period during which relays 101 and 107 are operated therefore extends over into the period during which the next pair to be actuated are operated, in this case relays 102 and 108.

The end of one secret combination and the beginning of the next is therefore determined by the time of shift of the spring of cam 74 and of course the time of operation of the relays 35 to 38, etc. of Fig. 2. This time can be made very short, and for practical purposes will be instantaneous.

When cam 74 operated to shift the ground from conductor 138 to 139, the previously existing ground extending from conductor 138, key 120, contact 134 and conductor 127 through relay 122 was removed, causing relay 122 to release. The shunt previously existing around relay 123, that is, from resistance 136, inner upper armature of relay 124 and lower contact of relay 122 is broken, allowing relay 123 to attract its armatures. At the same time, relay 122 at its back contact places a ground through inner upper armature of relay 123, now energized, to the end of resistance 135, thus shunting out relay 124 and releasing the latter. When relay 123 thus energizes, ground extends from its lower armature, contact 144, contact 137 to the middle armature of relay 22 and over the previously traced circuit through contact 141 and conductor 142 to maintain ground on the contacts of relay 108.

As the cams continue to rotate the cams 74 and 75 will periodically apply ground from

the armature of relay 22 to conductors 138 and 139, but these will be without effect since the ground applied to conductor 138 merely supplements the ground through contacts 144 and 137, while the grounds applied to conductor 139 will find contact 128 open at this time. The ground on conductor 142 remains therefore, for a 20-second interval at the end of which time (approximately) cams 77 and 78 again close their contacts, causing relay 121 to be energized. In the meantime, of course, cam 82 has energized relays 103 and 109 and has released relays 101 and 107, relays 102 and 108 also being energized.

Relay 121 in energizing opens contact 137 and closes contact 128. The ground previously extending through contact 137 is now maintained solely by the cam 74 through contact 145 (at this time closed), contact of key 120, conductor 138 and spring of cam 74. As soon as cam 74 shifts the ground contact from conductor 138 to 139, the previously existing ground just traced through contacts 137 and 141 and conductor 142 to the contacts of the relay 108 is removed and is transferred to the contacts of relay 109. This circuit extends from ground at the back contact of relay 22, switch spring of cam 74, conductor 139, contact of key 120, lower normal contact of relay 124 (at this instant released), contact 128, conductor 127, contact 126, and conductor 125 to the armatures of relay 109. The provision of this same ground energizes relay 122 which shifts its armature to the lower contact, opening the previously existing shunt circuit around relay 124 which therefore attracts its armatures. When contact 129 thus closes, the previously traced ground for the contacts of relay 109 is replaced by ground from the lower armature of relay 124, and contacts 129 and 128. When relay 124 attracted its armatures, relay 123 released due to the closing of a shunt circuit through the inner upper armature of relay 124 and armature of relay 122 to ground.

As will appear from the foregoing description, a transmitting control relay in the group 101 to 106 and a corresponding receiving control relay in the group 107 to 112 are both energized together. When relay 22 energizes as the station is shifted from receiving to transmitting condition, the ground which has existed through either contact 126 or 141 and either conductor 125 or 142 to the corresponding receiving control relay armatures, is now shifted to either conductor 132 or 147, causing any receiving secret combination that was set up to be replaced by the corresponding transmitting combination. It will be noted that the two conductors 125 and 142 are each multiplied to the contacts of three of the receiving control relays 107 to 112, while the two conductors 132 and 147 are each multiplied to the transmitting control relay contacts. The use of

two conductors instead of one for applying ground to each set of control relay contacts gives a greater margin for the cutting of the cams 80 to 85 and permits two successive relays such as 107 and 108, or 101 and 102 to be energized together with a considerable time of overlap.

Two cams 74 and 75 are provided in order to take care of the time of transmission between two distantly separated stations. For example, consider transmission between New York and London. The difference in setting between cams 74 and 75 represents twice the transmission time between these two points. The corresponding cam at London is mid-way between the setting of cams 74 and 75, a single cam sufficing at that station.

Consider now that the springs of cams 74 and 75 are both riding over the high portions of these cams and that cams 77 and 78 have just shifted their springs either to closed or open position to change to a new combination. If the armature of relay 22 is attracted at this particular time, so that the station is in transmitting condition, cam 75 will control the shifting of the ground from conductor 139 to 138, and therefore the time of bringing in a new combination. Cam 75, at New York as stated, is set in advance of the cam at London so that the contact at cam 75 will shift a short interval previous to the corresponding shift at London, and will bring in the new transmitting combination at exactly the correct moment to maintain a proper timed relation between the two stations. Suppose on the other hand, at the instant when a shift is to be made to a new combination, that relay 22 is released and the station is therefore in receiving condition. Cam 74 will control the instant of transfer and since this cam lags behind the cam at London, the transfer at the New York station will be made slightly after the transfer has been made at London by just the right amount to take care of the transmission interval.

In order further to increase the amount of secrecy, the cams 80 to 85 are cut so as to run through the six receiving and six transmitting combinations in different sequences successively. For example, the order of the combinations as they are first run through may be 1, 2, 3, 4, 5, 6. In the next cycle the order may be 3, 4, 5, 6, 1, 2. In the next cycle the order may be 5, 6, 1, 4, 3, 2. In the next cycle the order may be 1, 2, 5, 4, 3, 6. Then the order may be 5, 6, 3, 2, 1, 4, and in the final sequence the order will be 5, 4, 3, 2, 1, 6. As stated the number of combinations used and the order in which they are used may, of course, be varied within wide limits in accordance with the invention.

Two cams 77 and 78 are shown with their contacts operating in multiple. Two cams are provided in order to secure greater accuracy of switching time with a given ac-

curacy of cutting of the cams. The use of two cams in this manner permits one cam to control the break in lead 133 and the other the make. This enables a very accurate adjustment to be made in the timing of the 20 second period.

Reference will now be made together to Figs. 3 and 4 to illustrate the manner of cross connecting the leads extending from relays 101 to 112 to the switching relays in order to effect any one of the several different types of transpositions that are to be used in the signaling waves. For simplicity, the wiring of Fig. 3 illustrates only two frequency combinations corresponding to relays 101 and 107, but it will be understood from these two examples how the other combinations corresponding to the other relays 102 to 106, and 108 to 112 may be produced.

In Fig. 3 relays 35 and 38 are shown at the left, these being relays 35 to 38, channel A, of Fig. 2 previously explained, except that in Fig. 3 the switching relays have been shown as each provided with four separate windings and four separate energizing circuits, as will be explained more fully later on. Relay 39 is also shown adjacent these. The channel B, C and D relays are indicated in a similar manner.

The eight leads extending from the contacts of relay 101 are shown in dotted lines extending to eight different contacts which are respectively the lettered contacts referred to above in connection with Fig. 2.

The two left-hand leads extending from contacts of relay 101 are connected to contacts AD and AD' respectively. In accordance with the nomenclature above described, this means that when ground is applied to these two leads, relays 38 and 150 (RD) are both energized causing the A sub-band to be shifted to the D position and inverted. The next two leads from the contacts of relay 101 are connected to the terminals BC and BC', meaning that the B sub-band is shifted to the C position and inverted. Relays 152 and 153 are energized to accomplish this. The next two leads are connected to the CB and CB' contacts, meaning that the C sub-band is shifted to the B position and inverted. Relays 154 and 155 are energized to accomplish this. The two remaining leads are connected to the contacts DA and DA', energizing relays 39 and 156 and shifting the D sub-band to the A position and inverting it.

With the 101 relay energized, therefore, the foregoing eight switching relays are energized when ground is applied to the armatures of relay 101 over circuit 132 of Fig. 4 as previously explained, when the station is in transmitting condition and relay 22 is energized to close contact 131.

The combination represented as being set up by the 107 relay is controlled by six leads, the other two not being used for this combi-

nation. These leads are also shown in dotted lines in Fig. 3. The left-hand lead extends to contact AC controlling energization of relay 37, which when energized, shifts the A sub-band to the C position. The second lead extends to the contact BA, controlling energization of relay 157, causing when energized, the shifting of the B sub-band to the A position. The next two leads connect to contacts CD and CD' leading respectively to relays 158 and 150 and shifting the C sub-band to the B position and inverting it. The last two leads go to the contacts DC and DC' controlling relays 159 and 153 and causing the D sub-band to be shifted to the C position and inverted. Thus with relay 107 energized as assumed, when the relay 22 releases, corresponding to receiving condition, the switching relays controlled by the six leads extending from relay 107 are all energized while those controlled from relay 101 are deenergized, except for certain individual relays which may happen to be used in both combinations. The new combination controlled by relay 107 is therefore substituted for the previous combination controlled by relay 101.

The showing of the switching relays 35 to 39 and the corresponding relay of channels B, C and D, in Fig. 2, is diagrammatic only. In practice, as shown in Fig. 3, these relays would need to be multiple wound, as illustrated, in order to avoid interference between different combinations, and controlled partly in common by the individual relays. For example, in the two combinations above referred to, relays 150 and 153 are common to both combinations. These relays are shown as multiple wound relays. By providing four energizing windings on each of these relays, interference between the different combinations is avoided.

In Fig. 3 only part of the wiring of relays RA, RB, etc., is shown, but enough is given to indicate the entire scheme of connections.

In order to synchronize the two stations, a synchronizing oscillator labeled "Tone" in Fig. 1 and indicated at 24 has its circuit closed through winding 25 to impress a tone of, say, 1000 cycles per second on the outgoing circuit 11. This operates the voice controlled relays in the system and is transmitted from radio transmitter 17 to the distant station.

Except for differences that have been noted above the two terminal stations (for example New York and London) may be considered identical with the following slight change in wiring of the synchronizing key 120. Referring to Fig. 4, the lead 20 from key 120 at the London station is broken at a point indicated at 170. At the New York station lead 19 adjacent key 120 is broken at point 171.

When synchronizing key 120 is operated

at the New York station therefore, the armatures of relay 102 have ground supplied to them from the upper contact of cams 74 and 75 while the lower contacts of these two cams are rendered inoperative on account of the break in lead 19 above referred to.

At the London station, on the other hand, the circuits controlled by the armatures of relay 108 have ground applied to them from the lower contacts of the single 1-second cam at the London station corresponding to cams 74 and 75. At the London station relay 102 is rendered without effect by the break in lead 20 above referred to.

As a result of these circuit changes produced by operating key 120 at each of the two terminal stations, the 1000-cycle tone is transmitted from the New York station intermittently under control of cam 75, relay 22 being at this time pulled up by the application of the 1000-cycle tone. This 1000-cycle tone is transmitted through the secrecy system and through the radio channel to the London station.

If both stations are in synchronism and phase the tone will not be received at the London station during the intervals when the secrecy system at London is disabled due to the fact that the relays 35 to 38, etc., are deenergized by the removal of ground from the contacts of relay 108 since the 1-second contact at London during these intervals removes ground from the lead corresponding to lead 142. Under these circumstances the tone will not be heard by the receiver attendant at London, assumed to be listening to the output of the secrecy system thereat.

Assuming that the two stations are slightly out of phase, the tone from the New York station will arrive at the London station at an instant when the 1-second cam thereat is applying ground to the relays of the secrecy system. This may be due to the fact that the cam at the London station is either ahead of or behind its correct phase position. In either case there will be a short instant when the secrecy system at the London station will be in receiving condition and the tone will get through the secrecy system and be heard in the receiver. When this condition exists the operator at the London station adjusts the phase of the 1-second cam until the tone disappears. The operator can readily determine by trial the exact adjustment at which the tone entirely disappears, such that a slight shift from this position again makes the tone discernible. It is found by experience that a very precise adjustment can very readily be made in the phase adjustment of the two stations by this method.

The adjustment of the 40-second and 12-minute cams can be made with sufficient accuracy by the operators at the two stations calling off the respective scale readings as shown on scale 87 of Fig. 5 for example.

After one or more trials a sufficiently accurate setting of these cams can be made.

It will be understood that the invention is not limited to the use of any particular number of sub-bands nor to the particular values of frequencies or times that have been disclosed, but that these values have been given in order to disclose the preferred embodiment. The scope of the invention is to be ascertained from the claims.

What is claimed is:

1. In a secret signaling system in which secrecy is obtained by transposing frequency components of the signals, the method comprising changing the scheme of transposition at separated stations of the system simultaneously and automatically under local control thereat.

2. In secret signaling, obtaining secrecy by interchanging certain frequency components of a signal wave with others, shifting the scheme of interchange from time to time, and controlling the instant of making the shift locally at the different signal stations.

3. In secret signaling, masking the signals by interchanging certain frequency components of the signal with others, shifting the scheme of interchange to make detection of the scheme difficult, and variably controlling the shifting independently of transmitted waves.

4. In signaling, masking the signals by interchanging certain frequency components of the signal with others, and using the signal waves to effect a change in the scheme of interchange.

5. In signaling, obscuring the signals by frequency transposition of frequency components of the signal waves, and shifting the scheme of transposition under conjoint control of the signals and locally operating mechanism.

6. In a secret signaling system, means to interchange frequency components of an outgoing signal to render reception difficult, means to interchange frequency components of secretly transmitted signals as received in order to restore the signals to intelligible form, a common secrecy system for effecting both of said interchanges, means acting in response to signal energy for shifting the action of said secrecy system from one of said types of interchange to the other, and means acting independently of signal energy for controlling said secrecy system to shift to a new scheme of interchange.

7. In a secret signaling system for the two-way transmission of signals, a common frequency-transposing circuit for the outgoing and incoming signals, and means acting in response to signal energy to change the scheme of frequency-transposition effected by said common circuit from that to be applied to the transmitted signals to that to be applied to the received signals, and vice versa.

8. In a secret signaling system, a signal transforming circuit capable of transposing the frequency components of signal waves in accordance with any one of a number of schemes, and means acting in response to signal energy for shifting the action of said circuit from one scheme of transposition to another.

9. In a secret signaling system, a circuit for transposing the frequency components of speech or similar waves to render them unintelligible, said circuit being capable of transposing the frequency components in different manners each in accordance with a different scheme or pattern of transposition, time-controlled mechanism for shifting the operation of said circuit from one scheme of transposition to another, and means operated by the speech for shifting the operation of said circuit from one scheme of transposition to another.

10. In a secret signaling system, a circuit for transposing the frequency components of speech or other signal waves to render them unintelligible for transmission and intelligible for reception, said circuit being capable of transposing the frequency components in accordance with any one of a number of schemes or patterns, and means for causing the circuit to effect one scheme of transposition in transmitted waves, and a different scheme of transposition in received waves.

11. A system according to claim 10 comprising also means acting from time to time automatically to shift both the transmitting scheme of transposition and the receiving scheme of transposition each to a respectively new scheme.

12. In a secret signaling system, a circuit for variably transposing the frequency components of a signal wave in accordance with any one of a number of schemes, control means for shifting the setting of said circuit to effect each of a given number of schemes of transposition successively, and means to effect thereafter in succession the same schemes of transposition throughout in a different order.

13. In a secret signaling system, means to transpose the frequency components of signal waves in different ways in succession, and means to repeat the transpositions cyclically in successively different orders.

14. In a secret signaling system, a circuit for scrambling signal waves in any one of a number of different ways, to alter their intelligibility, relay means corresponding to each type of scrambling, means to operate a relay means to effect one type of scrambling and simultaneously to operate another relay means to prepare the circuit in advance for the effecting of another type of scrambling.

15. In a secret telephone system, a circuit for scrambling speech-conveying waves in any one of a number of different ways to alter

their intelligibility, means to select simultaneously two different types of scrambling and prepare the circuit for effecting either, and voice controlled means for determining which of the two types of scrambling is effected in the speech-conveying waves.

16. In a secret telephone system, a two-way secrecy circuit for scrambling outgoing and incoming speech-conveying waves to render them respectively unintelligible and intelligible, means to set said circuit to effect either of two types of scrambling, and voice-operated means for rendering each setting effective in turn depending on whether the circuit is to transmit or to receive.

17. A system according to claim 16, comprising means for replacing each of said types of scrambling by still another type.

18. A system according to claim 16 comprising also a time-controlled mechanism for periodically substituting for said two types of scrambling, two other types, whereby said circuit effects different types of scrambling in transmitted and received waves from time to time.

19. A system according to claim 16 comprising also a time-controlled mechanism for pre-selecting a new setting of the circuit to introduce a different type of scrambling into the transmitted waves and for pre-selecting a new setting also to introduce a new type of scrambling into the received waves, and means for substantially instantaneously substituting the pre-selected types for the previously effected types of scrambling.

20. In a secret telephone system, a two-way circuit for transposing the frequency-components of transmitted and received speech-conveying waves to render them respectively unintelligible and intelligible, continuously operating control means for periodically altering the circuit to effect different types of transposition in the transmitted and received waves, and voice-operated means for altering the circuit to effect, for any given setting of the circuit by said control means, a different type of transposition for the transmitted waves from that effective for the received waves.

21. A system comprising two cooperating stations, each according to claim 20, separately operating constant-speed driving mechanisms for the said control means at each station, each operating independently of the other in synchronism and phase with each other.

In witness whereof, we hereunto subscribe our names this 6th day of November, 1929.

ROY W. CHESNUT.

HAROLD J. FISHER.

ARTHUR J. SANIAL.