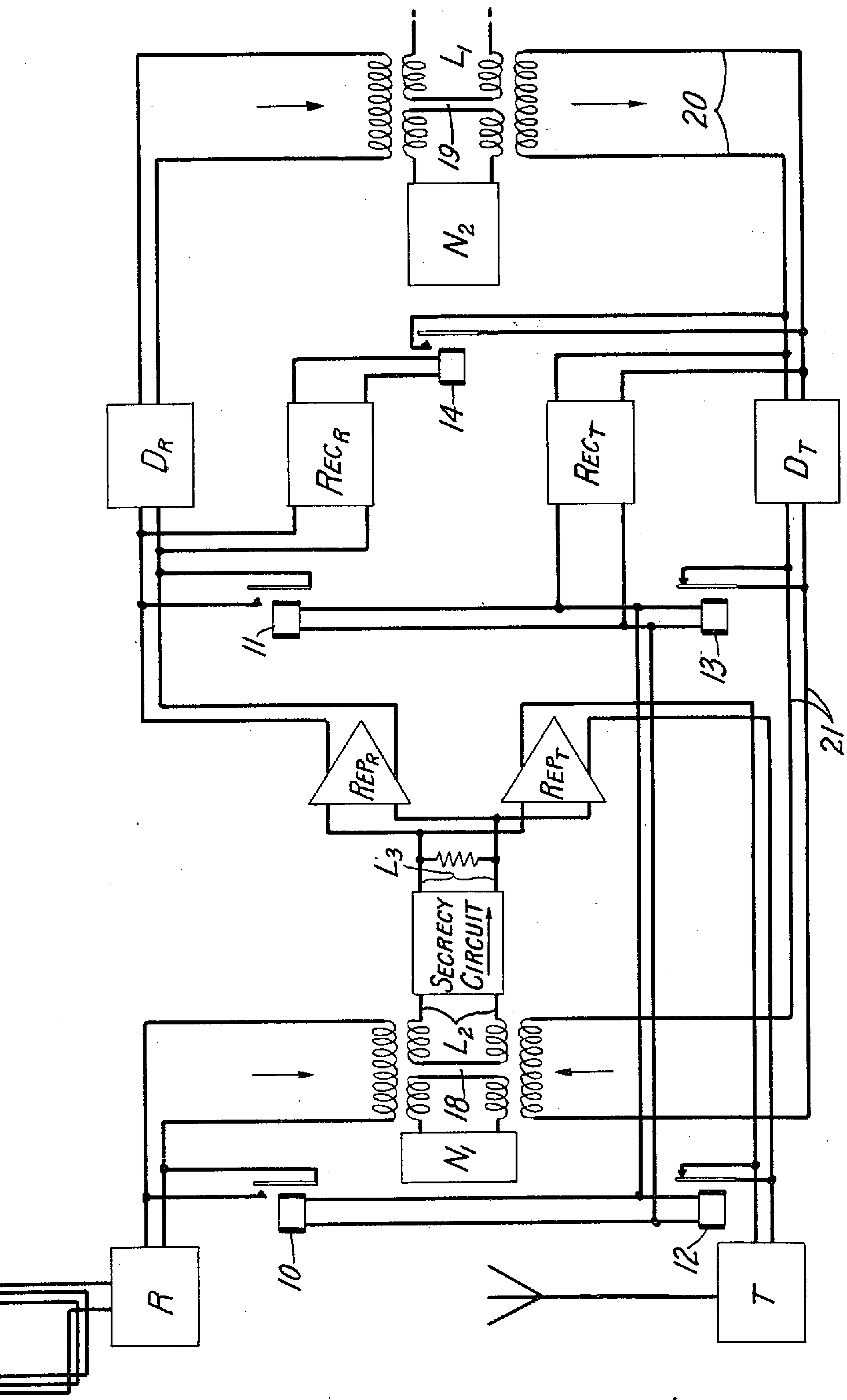
Aug. 20, 1929. C. L. WEIS, JR 1,725,032

SECRET COMMUNICATING SYSTEM

Filed July 6, 1927 3 Sheets-Sheet 1

FIG. 1.



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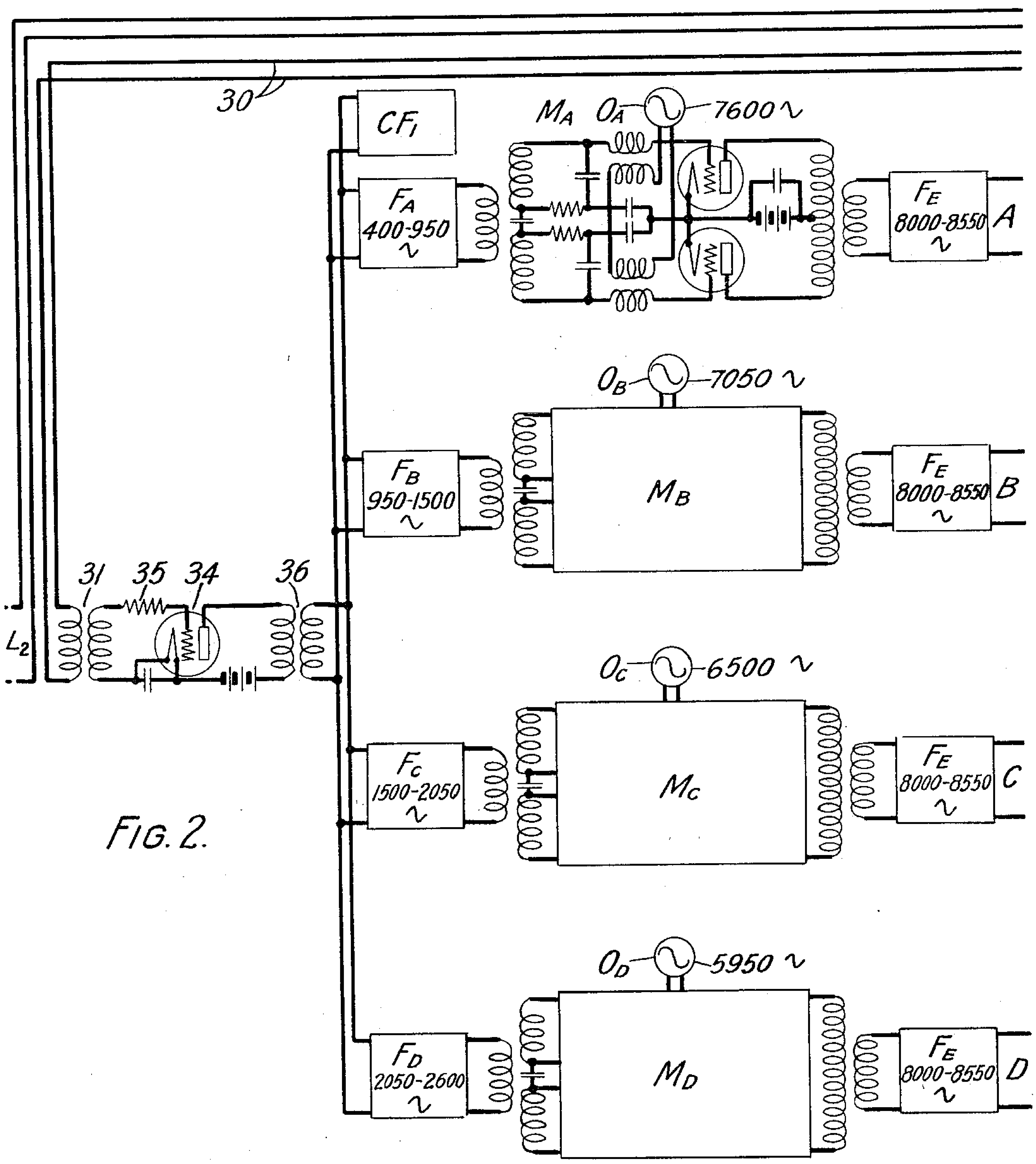

FIG. 2.

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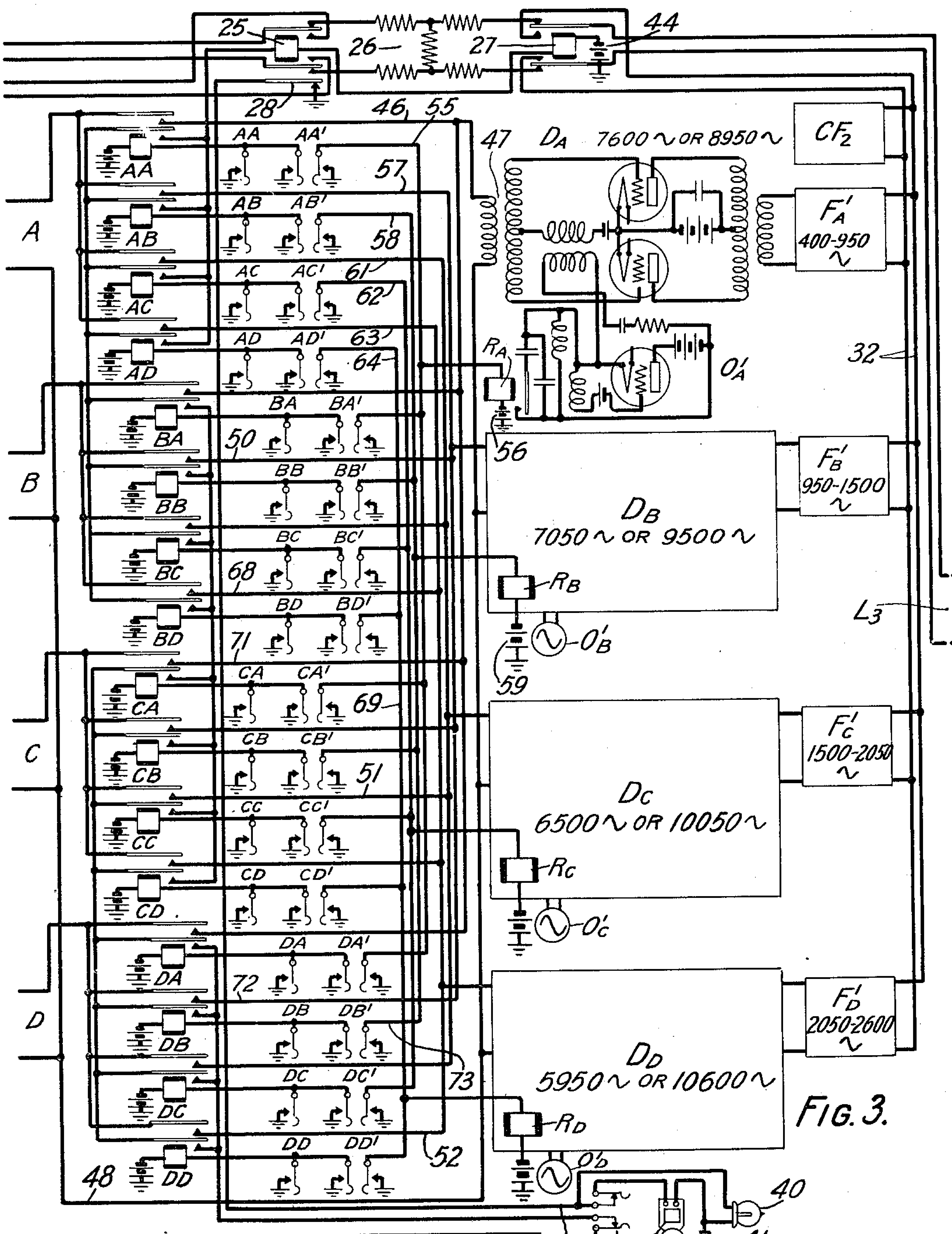

FIG. 3.

AA	AA'	AB	AB'	AC	AC'	AD	AD'
BA	BA'	BB	BB'	BC	BC'	BD	BD'
CA	CA'	CB	CB'	CC	CC'	CD	CD'
DA	DA'	DB	DB'	DC	DC'	DD	DD'

AA	AA'	BA	BA'	CA	CA'	DA	DA'
AB	AB'	BB	BB'	CB	CB'	DB	DB'
AC	AC'	BC	BC'	CC	CC'	DC	DC'
AD	AD'	BD	BD'	CD	CD'	DD	DD'

FIG. 4.

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UNITED STATES PATENT OFFICE.

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SECRET COMMUNICATING SYSTEM.

Application filed July 6, 1927. Serial No. 203,703.

This invention relates to transmission systems and more particularly to the method of and means for providing secrecy in the transmission of messages over such systems.

The basic principle of this invention is disclosed in Patent No. 1,573,924 to H. Fletcher, February 23, 1926, and the invention is a modification of the secrecy system disclosed in this patent. It is, in brief, a system in which the normally transmitted frequency band is divided into a number of sub-bands which are then reorganized either by relocating the positions of the sub-bands or by inverting the frequencies within certain sub-bands, or both, into the original frequency band spectrum for further transmission. As shown in the Fletcher patent, a multiplicity of combinations are possible possessing varying degrees of secrecy which may be shifted at periodic intervals to provide a system which has a high degree of secrecy. In the invention to be described herein, the method used in shifting, relocating and inverting the sub-bands is by modulation or demodulation and the method of segregation is by the use of band filters as described in the above mentioned patent disclosure.

It is an object of this invention to increase the secrecy of the system referred to above by increasing the number of possible secret combinations and to facilitate the shifting from one combination to a different combination.

Another object is to simplify the means for confusing the sub-bands and reorganizing them.

A further object is to improve the efficiency of transmission through a secrecy system such as disclosed in the above mentioned patent and to simplify two-way transmission through such a system.

The advantages of this invention will be brought out in the detailed description of the accompanying drawings in which:

Fig. 1 is a schematic drawing of a radio transmission terminal showing the method of arranging the secrecy circuit for two-way operation;

Figs. 2 and 3 are schematic drawings of the secrecy circuit itself, Fig. 3 being the key or switching arrangement for confusing or "scrambling" the sub-bands after being reduced to the same frequency level, and then recombining them; and

Fig. 4 is a chart of a complementary key arrangement.

The secrecy circuit to be disclosed herein is essentially a one-way device and when used in a complete transmission channel or two-way circuit, it becomes necessary either to employ two identical secrecy circuits or provide for transmission in either direction by transferring a single secrecy circuit from one line to the other. In the present system only one secrecy circuit is used, an arrangement of voice-operated relays being provided to shift the circuit from the receiving line to the transmitting line. The shifting is performed by short-circuiting the input and output of the line not in service, the time of shift being controlled by the direction of the signals. While the invention is applicable to many different types of two-way circuits, for purposes of illustration, it is here shown applied to a radio telephone circuit such as a transoceanic system.

In Fig. 1 is shown schematically the necessary terminal apparatus for such a two-way radio system to properly control transmission through the secrecy circuit. In the normal condition as shown, relays 10, 11, 12, 13 and 14 are so arranged that the incoming line through the terminal apparatus is open to incoming signals while the transmission line is short circuited. The signal received on the antenna system R will pass to the hybrid coil 18 with its balancing network N_1 since relay 10 is not energized and the incoming line is open. The signal then passes from the hybrid coil 18 through the secrecy circuit, the operation of which will be explained later, in the direction of the arrow and into repeaters Rep_R and Rep_T. The output of repeater Rep_T is short circuited by the armature of relay 12 preventing the incoming signal from reaching the transmitting system T. The output of repeater Rep_R, however, is not short circuited by the armature of relay 11 and it reaches a delay circuit D_R and a rectifier Rec_R simultaneously. The delay circuit may be of any suitable type such as described in the R. C. Mathes application Serial No. 747,164, filed November 1, 1924. The signal from the delay circuit then passes through hybrid coil 19 and into the outgoing line L_1 to receiving lines such as subscriber sets. The hybrid coil 19 may not, of course, be perfectly balanced by its network N_2, in which case the output circuit of the coil is short circuited by the armature of relay 14 in the output of the rectifier Rec_R. The delay circuit D_R delays the signal sufficiently to allow relay 14 to short circuit the line before the signal reaches it. This is the action of certain non-singing circuits well known in the art.

In transmitting, the signal comes into the hybrid coil 19 over line L_1 and leaves over line 20 in the direction shown by the arrow, arriving at a rectifier Rec_T and a delay circuit D_T simultaneously. The rectifier Rec_T and delay circuit D_T are similar to rectifier Rec_R and delay circuit D_R, respectively. The line 20 is not short circuited by relay 14 except when signals are being received so it is normally open and the signals to be transmitted reach the rectifier Rec_T and the delay circuit D_T. The outgoing line 21, however, is not normally open for transmission, it being short circuited by relays 12 and 13 in their normal position. To make this line operative, these relays are actuated by the output of rectifier Rec_T, the signal being delayed sufficiently by delay circuit D_T to allow the short circuits to be removed. The output of this rectifier also actuates relays 10 and 11, putting short circuits on both sides of the secrecy circuit in the receiving path. The path of the signal to be transmitted is now into hybrid coil 18, through the secrecy circuit in the direction of the arrow and through repeaters Rep_R and Rep_T. The output of repeater Rep_R is now short circuited, however, by relay 11, but the output of repeater Rep_T may pass into the transmitting system T. Any transmitted signals picked up by the receiving apparatus R from the transmitter T will not reach the hybrid coil 18 since relay 10 is energized and a short circuit exists on the incoming line.

The operation of the terminal apparatus just described causes both the incoming and the outgoing signals to pass through the secrecy circuit in the same direction while short circuits exist on the input and output of the secrecy circuit on either line when the other is operative.

Figs. 2 and 3, taken together, show in detail the circuit schematic of the portion of Fig. 1 designated as the secrecy circuit. With the secrecy circuit removed from the system, the signals from the hybrid coil pass on line L_2 through the armatures of relay 25, through network 26 which is designed to have a loss equal to that of the secrecy circuit, through armatures of relay 27 to line L_3 which may terminate at repeaters Rep_R and Rep_T shown in Fig. 1. When relays 25 and 27 are actuated, the upper armatures of relay 25 connect line L_2 to line 30, line 30 terminating at transformer 31, the input of the secrecy circuit, while the armatures of relay 27 connect line L_3 to line 32, line 32 being the termination of the secrecy circuit. In case any difficulty arises in the functioning of the secrecy circuit apparatus, the network 26 may be substituted therefor without interference to straightforward transmission. When the network is being used and the secrecy circuit not functioning, armature 28 of relay 25 connects ground to line 29 and lamp 40 through battery 41 for alarm purposes. With the upper contact of key 42 closed, a bell is put in parallel with lamp 40 for the same purpose. The lower contact of key 42 controls the substitution of the network 26.

The input to the secrecy system is a vacuum tube 34 having a high resistance 35 in series with its grid. This arrangement is employed as a voltage limiting device to protect later apparatus.

The output of the voltage limiter is connected through the transformer 36 to band filters F_A, F_B, F_C, F_D and compensating filter CF_1. These band filters are of the type disclosed in the Campbell Patent 1,227,113, May 22, 1917, and the compensating filter, of the type disclosed in the Mills Patent 1,616,193, February 1, 1927, which serves to improve the cut-off characteristics of filters F_A and F_D at the extreme limits of the signal band. The band filters divide a signal band and as in this case the speech band, into four equal frequency ranges or sub-bands, namely, 400–950, 950–1500, 1500–2050 and 2050–2600 cycles. The total range is from 400 to 2600 covering the important speech frequencies.

Each sub-band now has an individual channel to be known as the A, B, C and D channels or sub-bands for purposes of description. Each channel has a modulator associated with filters F_A, F_B, F_C and F_D of the type disclosed in the Carson Patent 1,343,306, June 15, 1920, designated as M_A, M_B, M_C and M_D in the drawings. These are balanced modulators which eliminate the oscillator frequency from the outgoing line. The modulators are supplied by Hartley type oscillators O_A, O_B, O_C and O_D of 7600, 7050, 6500 and 5950 cycle frequencies, respectively. Modulation with these particular frequencies reduces all the sub-bands to the same frequency level if only the proper frequency products of modulation are selected. This is accomplished by four filters F_E, with the same frequency discrimination, in the outputs of the four modulators, maintaining the four distinct channels. In this manner, sub-band A of 400–950 cycles modulated with 7600 cycles becomes a band of 8000–8550 cycles selected by filter F_E in channel A. Sub-band B of 950–1500 cycles modulated with 7050 cycles becomes a band of the same frequency range and selected by filter F_E in channel B and so on for channels C and D.

The outputs of the four filters F_E are connected to the armatures of sixteen relays, four for each channel, designated as AA, AB, AC, etc., to DD as shown in the drawing. These relays are controlled by 32 keys, two to each relay and designated as AA to AD′ for channel A, BA to BD′ for channel B and so on for channels C and D, the operation of which will be described later.

The outputs of the key circuits terminate in the four channels mentioned above in which are four demodulators or modulators D_A, D_B, D_C and D_D. These demodulators are similar to the modulators M_A, M_B, M_C and M_D as shown by the detailed circuit of demodulator D_A. These demodulators are supplied with frequencies from oscillators O'_A, O'_B, O'_C and O'_D of the Hartley type. By varying the tuning of the oscillators, each oscillator furnishes two modulating frequencies. Oscillator O'_A supplies demoluator D_A with frequencies of 7600 cycles or 8950 cycles; while oscillator O'_B supplies demodulator D_B with frequencies of 7050 or 9500 cycles, oscillator O'_C furnishes demodulator D_C with frequencies of 6500 or 10,500 cycles, and oscillator O'_D furnishes demodulator D_D with frequencies of 5950 or 10,600 cycles. Just what frequency is supplied by each oscillator is determined by the operation of relays R_A, R_B, R_C and R_D, associated therewith, and which are controlled by the preceding switches.

The outputs of the demodulators D_A, D_B, D_C and D_D connect to band filters F'_A, F'_B, F'_C, F'_D and compensating filter CF_2. These band filters are similar to the band filters F_A, F_B, F_C and F_D, respectively, and compensating filter CF_2 is similar to compensating filter CF_1 and is for the same purpose. The band filters are selective to the same frequencies as filters F_A, F_B, F_C and F_D, respectively, the combination of their outputs having the same overall range as the input speech band. The outputs of the band filters are connected in parallel to line 32, which passes the band onto the outgoing line L_3 through the armatures of relay 27.

Returning now to the key circuits proper, what occurs when certain keys are operated will now be described to explain the operation of the circuit and to show the ability of this arrangement to procure every possible combination of frequency sub-bands in a simple manner. A simplification over prior arrangements is obtained by reducing all the sub-bands to the same frequency level which in this instance is 8000–8550 cycles.

The lettering on the key relays and the keys themselves designates their function with respect to the particular channels they control. For instance, the first letter of the markings designates the channels entering the key circuits, while the second letter of the markings shows to which channels or demodulators the bands are going, while the prime letters indicate that the band is inverted in frequency.

For example, with the contacts of key 42 closed, and keys AA, BB, CC and DD operated, relays AA, BB, CC, DD are actuated through individual circuits and relays 25 and 27 are actuated by a circuit traceable through ground, battery 44, windings of relays 27 and 25, lower armatures of relays AA, BB, CC and DD in succession, and lower contact of key 42 to ground. The operation of relays 25 and 27 puts the secrecy circuit in the transmission system. The circuit of lamp 40 is broken at armature 28 and a signal registered to show that the secrecy circuit is in the system. It will be observed that the operation of four relays in the four channels is necessary to form a combination, that is one relay to each channel, suffices to cause the actuation of relays 25 and 27 through the lower armature circuits of the lettered relays although the failure of any relay allows the system to operate through the network.

With the keys above mentioned closed, filter F_E in the A channel is connected to demodulator D_A through the upper armature of relay AA, conductor 46, primary of transformer 47 and conductor 48. This band of 8000–8550 cycles is demodulated with a frequency of 7600 cycles and the lower sideband selected by filter F'_A which is 400–950 cycles, bringing the sub-band back to its original frequency level. A similar circuit may be traced connecting filter F_E of channel B to demodulator D_B as follows, through upper armature of relay BB, conductor 50, demodulator D_B, and conductor 48. For filter F_E of channel C, the circuit is through upper armature of relay CC, conductor 51, demodulator D_C and conductor 48, and for filter F_E of channel D, it is through the upper armature of relay DD, conductor 52, demodulator D_D and conductor 48. The frequencies in channels B, C and D are demodulated by frequencies of 7050, 6500, and 5950 cycles, respectively, reducing sub-bands B, C and D of 950–1500, 1500–2050 and 2050–2600 respectively to their original frequency positions. The lettering of the keys used, that is, AA, BB, CC and DD denotes this combination, the lettters pointing out that each band remains in its own channel and is not inverted.

In the foregoing paragraph, the circuits of one combination of four keys has been traced. All the possible circuits for one particular sub-band will now be described and what is true of this sub-band applies to the others. Choosing channel A, which, like the other channels, has a frequency band of 8000–8550 cycles at filter F_E, the effect of closing key AA has just been traced. When key AA′ is closed, the same circuit is completed to the demodulator D_A by the left-hand contact of the key as by key AA, while the right-hand contact closes a circuit through conductor 55, windings of relay R_A and battery 56, thus actuating relay R_A and causing the oscillator

O'_A to supply a frequency of 8950 cycles to the demodulator. The lower sideband of the demodulation frequencies is procured, therefore, with a frequency range of from 400–950 cycles and which will pass filter F'_A. The frequencies, however, which passed through filter F_A are now inverted, that is, the portion of the signal at 400 cycles now lies at 950 cycles.

When key AB is closed, relay AB connects channel A to demodulator D_B or channel B through the upper armature of relay AB, conductor 57, demodulator D_B and conductor 48. This connection demodulates the 8000–8550 band with 7050 cycles providing a sideband of 950–1500 cycles or the frequency range of channel B. Thus, the frequencies of channel A are now relocated in channel B. Key AB′ places the band of channel A of 400–950 cycles in channel B and inverts it by energizing relay R_B through conductor 58, winding of the relay and battery 59, causing oscillator O'_B to furnish a frequency of 9500 cycles. Demodulating a band of 8000–8550 cycles with a frequency of 9500 cycles gives the inverted sideband of 1500–950, which will pass filter F'_B.

Key AC connects channel A to demodulator D_C through upper armature of relay AC, conductor 61, demodulator D_C and conductor 48, modulates the frequency band 8000 to 8550 cycles with a frequency of 6500 cycles thereby shifting the 400–950 band to the 1500–2050 frequency range or C channel. Key AC′, through conductor 62, causes the oscillator O'_C to furnish a frequency of 10,050, the lower side band of which inverts and shifts the 400–950 cycle sub-band to the C channel range as a band of 2050 to 1500 cycles.

Keys AD and AD′ perform the same function with respect to channels A and B through conductors 63 and 64 respectively.

Taking another combination of four keys, for example, AC, BD′, CA and DB′, we have a secret combination the circuits in brief of which are as follows. Key AC connects channel A to demodulator D_C through the upper armature of relay AC, conductor 61 and conductor 48, stepping up the 400–950 cycle range to the 1500–2050 range. Key BD′ connects channel B to the demodulator D_D modulating with a frequency of 10,600 cycles through the upper armature of relay BD, conductor 68 and conductor 48 for the channel and conductor 69 for the oscillator O'_D, stepping up the 950–1500 band to the 2050–2600 range and inverting it. Key CA connects channel C to demodulator D_A through the upper armature of relay CA, conductor 71 and conductor 48 stepping the 1500–2500 frequency band to the 400–950 range by modulating it with 7600 cycles. Lastly, key DB′ connects channel D to demodulator D_B at 9500 cycles through the armature of relay DB, conductor 72 and conductor 48 for the channel and conductor 73 for the oscillator.

In the forming of combinations, it is seen that there may be three channels in normal order while the fourth is inverted. This combination will not have as high a degree of secrecy as certain other combinations, such as the one just traced. This difference in degree of secrecy is ably discussed in the Fletcher patent above mentioned.

It is possible, with the circuit just described, however, to invert a sub-band in its own frequency channel and to obtain all possible combinations with, consequently, a large number of secret combinations. It is also possible to invert the whole signal band by the closing of keys AD′, BC′, CB′ and DA′. The apparatus shown in Fig. 3, can, therefore, shift any sub-band from its normal channel to any other channel and invert it in that channel. The closing of the four keys may be done in one operation making practical a rapid change from one combination to another.

Referring to Fig. 4, two charts are shown, one to be used at each terminal of the transmission line. These charts show the manner of decoding or unscrambling a message from a sending station which has been scrambled in accordance with the system described herein. These charts are complementary in position of keys, that is, key AB′ is located on one chart in the same position as key BA′ on the other chart, key BB is located on one in the same position as key BB on the other, etc., meaning that if key AB′ is closed at the transmitting station, the pressing of key BA′ in the same position at the receiving station will return channel A to its proper position in the frequency spectrum. For example, the closing of key AB′ takes sub-band A of 400–950 cycles, relocates it in the B channel inverted, and the closing of key BA′ takes the inverted signal of the B channel to the A channel and reinverts it to return it to its normal position. In practice, the positions on these charts may be designated by numbers to increase the transmission of code combinations.

The frequencies of the four sub-bands, namely, 400–950, 950–1500, 1500–2050 and 2050–2600, cover a total range of 400–2600 cycles. To simplify the method of scrambling these bands are modulated with frequencies of 7600, 7050, 6500 and 5950 cycles to reduce them all to a band 550 cycles wide ranging from 8000 to 8550 cycles. The choosing of these particular frequencies means that all higher order products of the modulation of a carrier frequency and any associated voice frequency up to and including the fifth order product are eliminated by the filters from further transmission except in the instance of the carrier plus twice the voice frequency, of which a very small amount is present in the 400–950 cycle range.

This invention has been disclosed as embodied in a certain specific arrangement, but it is capable of embodiment in many other types of circuits without departing from the spirit of the invention as defined by the claims.

What is claimed is:

1. In a signaling system, a plurality of means for dividing the signaling band into a corresponding number of sub-bands of different frequency ranges, means for shifting the frequency positions of said sub-bands, and for, alternatively, transmitting certain or all of said sub-bands while maintaining them in their frequency positions with respect to one another, a plurality of circuits each selective of a different sub-band, and means intermediate said first means and said circuits for inverting the frequency order within the selected sub-bands.

2. In a signaling system, a plurality of means for dividing the signaling band into a corresponding number of sub-bands of different frequency ranges, frequency shifting and switching means for producing in an outgoing circuit from the incoming sub-bands every possible complete combination producible by shifting the frequency positions of said sub-bands with and without frequency inversions of individual sub-bands and by inverting the frequencies without shifting the frequency level of a sub-band as a whole.

3. In a signaling system, a plurality of means for sub-dividing signaling components into a number of fragmentary portions on a frequency basis, means to reduce all portions to a common frequency level in a series of separate circuits, a corresponding series of circuits each selective of a different portion of the frequency range of said signaling components, said last mentioned circuits including means for shifting the individual portions of the signaling components from the common frequency level to the respective frequency ranges of which said circuits are individually selective, an outgoing circuit common to said last mentioned series of circuits, and switching means positioned between said two series of circuits for variously and individually interconnecting respective circuits of one series with those of the other to alter the frequency positions of the signaling portions in the outgoing circuit.

4. In a signaling system, means for dividing the signaling band into a plurality of sub-bands, modulators to reduce all of said sub-bands to the same frequency level, second stage modulators to return said sub-bands to their original range of frequencies in said signaling band, and switching means intermediate said first and second stage modulators for inverting the frequencies within any of said sub-bands and interchanging any of said sub-bands with each other to form any one of all possible combinations of interchanges and inversions.

5. In a signaling system, an incoming line and an outgoing line, means connected to said incoming line for dividing the signaling band into a plurality of frequency ranges, modulators individual to each of said frequency ranges for reducing each to a common frequency level, means for maintaining each of said ranges in individual channels, a plurality of secondary modulators, means connected to the outputs of said secondary modulators for combining said plurality of frequency ranges into said signaling band for transmission to said outgoing line, and means intermediate said secondary modulators and said second means for connecting any of said channels to any of said secondary modulators and for interchanging and inverting the frequency order of any of said ranges.

6. In a signaling system, an incoming line and an outgoing line, means connected to said incoming line for dividing the signaling band into a corresponding number of sub-bands, means individual to each of said sub-bands for reducing each to the same range of frequency components, means for converting said respective sub-bands of the same frequency components into sub-bands having the same total range as said signaling band for transmission to said outgoing line, and means for impressing any of said sub-bands of the same frequency components on said modulating means in any sequence and combination.

7. A frequency changing system for a band of frequency components comprising a filter and modulator for shifting the band to a new frequency level and selecting one sideband only of a modulated wave, a plurality of second stage modulators, circuit connections for selectively impressing the resulting sideband in the first modulator on any one of the second stage modulators, each last mentioned modulator operating at either of two shifting frequencies such that with one of the frequencies operative, a sideband results occupying a predetermined absolute frequency range with the frequency components in their normal order, and with the other mentioned shifting frequency operative, a sideband results occupying said predetermined absolute frequency range with the frequency components in the inverse of their normal order, the absolute frequency range of the output of each second stage modulator being different from the others, and switching means to determine on which of the two shifting frequencies the second stage modulators operate.

8. In a signaling system, an incoming line and an outgoing line, a secrecy circuit intermediate said lines comprising a plurality of means for dividing a signaling band on said incoming line into sub-bands, means for con-

fusing said sub-bands, means for reuniting said sub-bands after confusion and impressing them on said outgoing line, a network having a transmission loss substantially equal to that of said secrecy circuit, and means associated with said confusing means for substituting said network for said secrecy circuit.

9. In a signaling system, an incoming line and an outgoing line, a secrecy circuit intermediate said line comprising a plurality of means for dividing a signaling band on said incoming line into sub-bands, a series of relay circuits for confusing said sub-bands certain of which are operated as combinations, means for reuniting said sub-bands after confusion and impressing them on said outgoing line, a network having a transmission loss substantially equal to that of said secrecy circuit, and a second series of relay circuits associated with said first series for controlling the substitution of said network upon the incomplete operation of any one of a combination of said first mentioned series of relay circuits.

10. In a secrecy signaling system, a plurality of filters for dividing a signaling band of the order of 400 to 2600 cycles per second into sub-bands of frequencies extending from 400 to 950, 950 to 1500, 1500 to 2050, and 2050 to 2600 cycles per second, modulators for reducing said sub-bands to four bands each extending from 8000 to 8550 cycles, demodulators for shifting said 8000 to 8550 cycle bands to occupy said original transmission band of frequency limits of the order of 400 to 2600 cycles per second, and switching means intermediate said modulators and demodulators for interchangeably impressing said 8000 to 8550 cycle bands on said demodulators in different orders for varying the order of occurrence of the resulting sub-bands in said transmission band.

11. In a secrecy signaling system, a plurality of filters for dividing a signaling band into a plurality of sub-bands, modulators each having a different modulating frequency individual to said filters, means in the output circuits of said modulators all selective to a side-band occupying the same range of frequencies, resulting from the modulation in said modulators, the modulating frequencies being so related to the frequencies of the sub-bands and of the side bands selected after modulation that substantially all products of modulation except those falling in the individual selected sideband are eliminated, demodulators for shifting said sidebands of the same frequency range to the same and other positions in the original signaling band, and switching means intermediate said selective means and said demodulators for impressing any of said sidebands on any of said demodulators in any combination.

In witness whereof, I hereunto subscribe my name this 30th day of June A. D., 1927.

CHARLES L. WEIS, Jr.