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F. J. SINGER

1,665,283

SIGNALING SYSTEM

Filed April 2, 1927

2 Sheets-Sheet 1

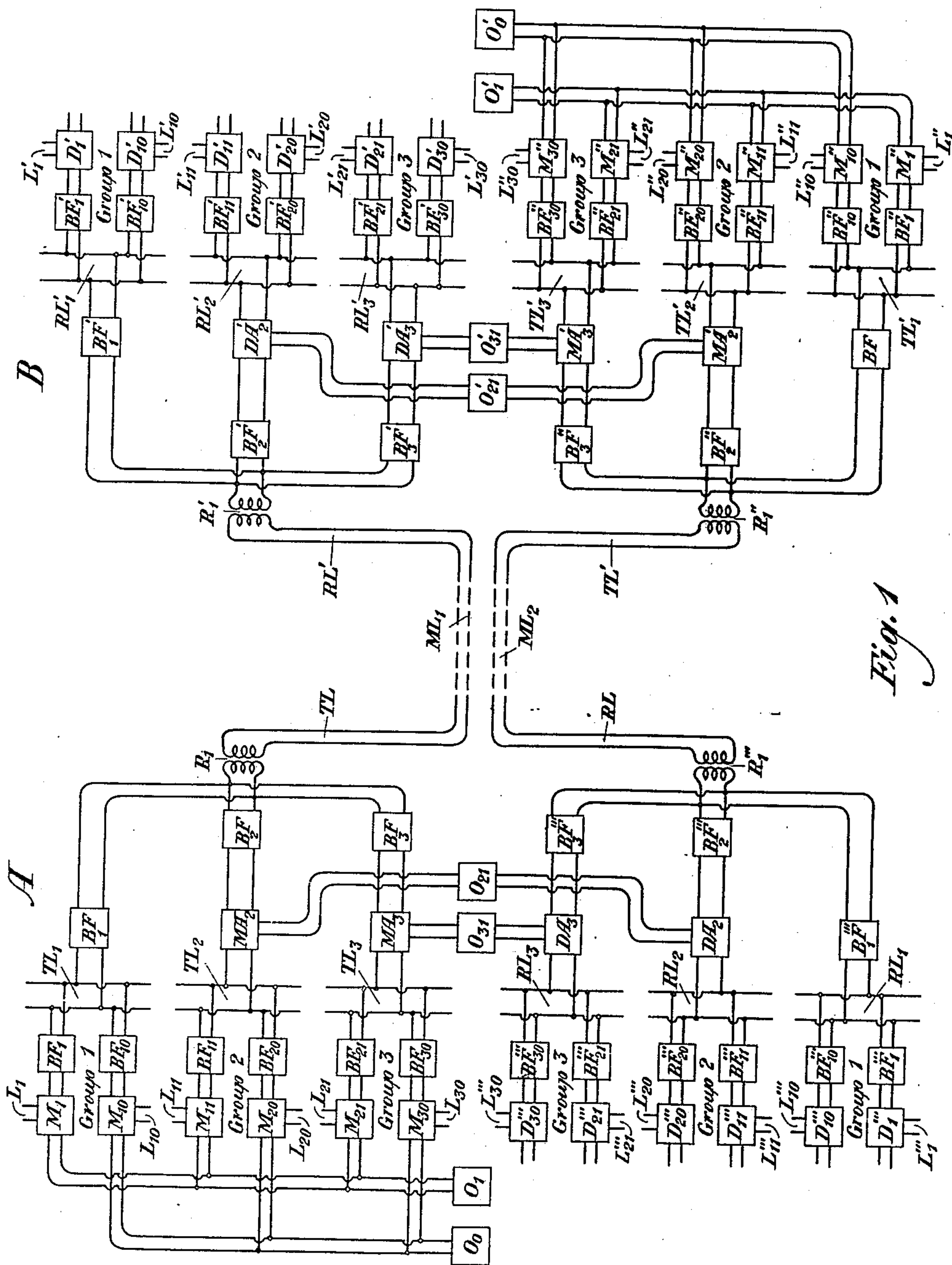


Fig. 1

INVENTOR.
F. J. Singer
BY
g v 40 r
ATTORNEY

April 10, 1928.

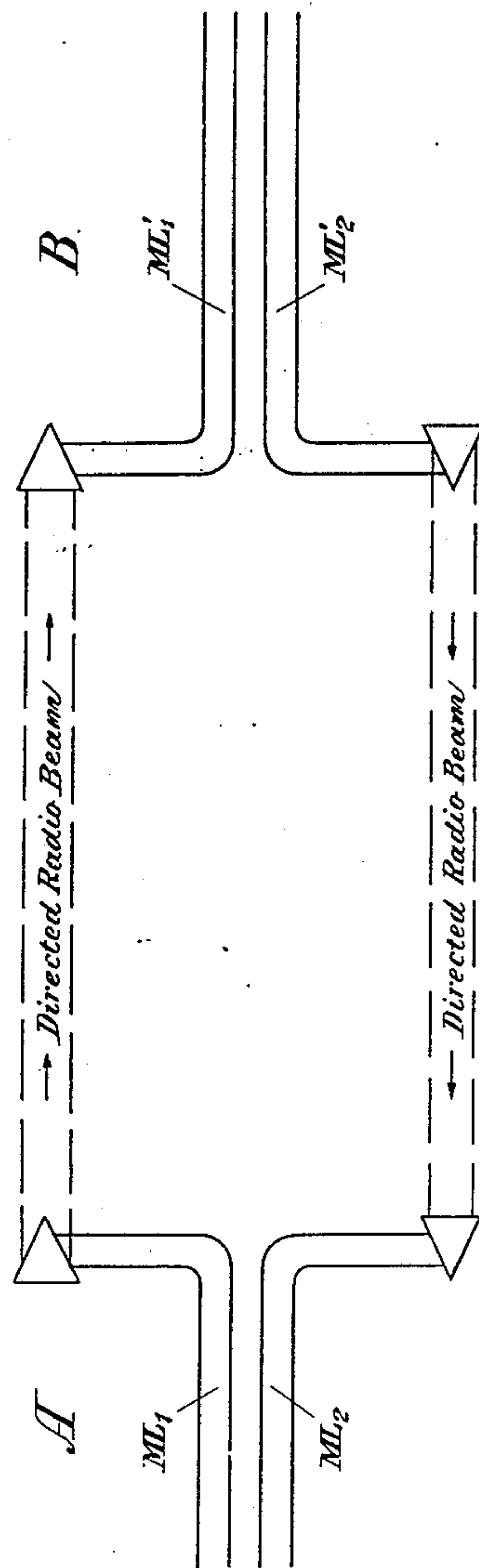
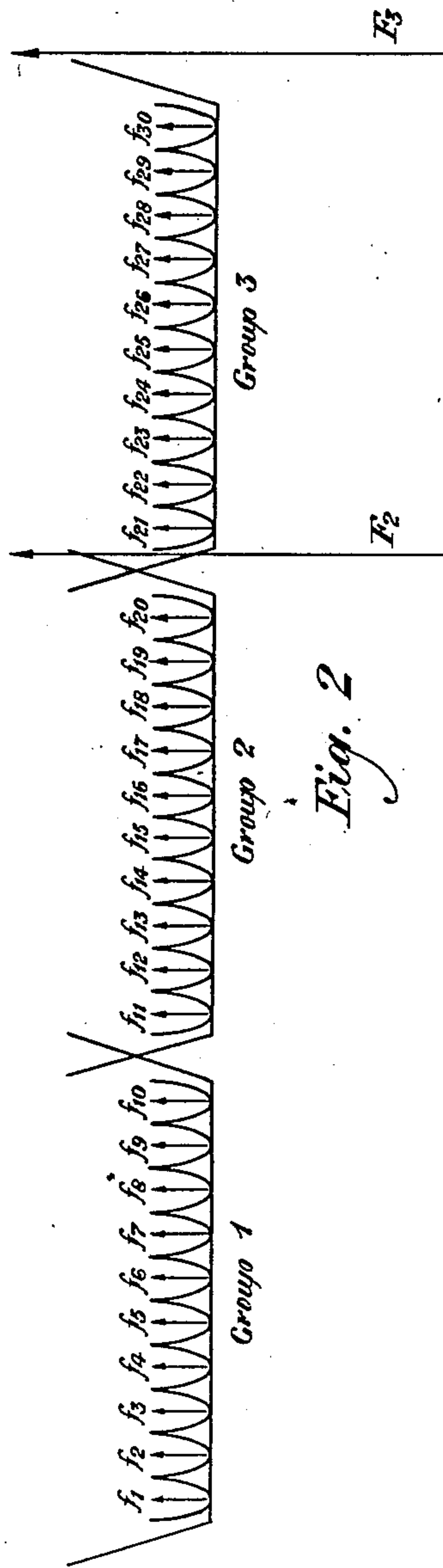
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F. J. SINGER

SIGNALING SYSTEM

Filed April 2, 1927

2 Sheets-Sheet 2



INVENTOR.
F. J. Singer
BY *gr 40*
ATTORNEYS.

UNITED STATES PATENT OFFICE.

FRED J. SINGER, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

SIGNALING SYSTEM.

Application filed April 2, 1927. Serial No. 180,521.

This invention relates to multiplex signaling systems, and more particularly to multiplex systems in which low frequency currents and high frequency currents, often designated carrier currents, are simultaneously employed for the transmission of signals.

The invention comprises a system in which multiplex transmission is applied to a circuit of the four-wire type, that is, a circuit in which one transmission line is used for transmission in one direction and another transmission line is used for transmission in the opposite direction.

This invention further comprises a signaling system in which signals from a plurality of signaling sources or stations may be simultaneously transmitted in one direction to a plurality of distant stations over a common signaling path while signals from distant sources or stations may be simultaneously transmitted over another signaling path in the opposite direction.

This invention further comprises a signaling system in which a plurality of oscillators of successive odd harmonics of a fundamental frequency are simultaneously modulated by low frequency signals from various low frequency signaling sources, and in which the modulated currents are again modulated upon a plurality of other successive harmonics, preferably even harmonics of the same fundamental frequency. By employing odd and even harmonics for the oscillators used in modulation, any harmonic products introduced into the circuits by loading coils, transformers and the like will be greatly prevented from causing troublesome interference.

A four-wire arrangement is advantageous where it is desired to apply to lines currents of the same frequencies for transmission in both directions and particularly so when these lines are constructed entirely of cable. In this application, two of the wires will be employed for transmission in one direction and the other two of the wires will be used for transmission in the opposite direction. Accordingly, amplifiers may be interposed which introduce greater gains than those which may be interposed in a two-wire circuit. Moreover, the amplifiers required in an arrangement of the four-wire type may be separated by greater distances than similar amplifiers may be separated in a two-

wire circuit. Furthermore, the four-wire circuit avoids the high degree of capacity balance required between two wire cable circuits for the transmission of currents of the same frequencies. Whatever capacity balance would be required in a four-wire circuit may be considerably reduced by grouping together respectively the east and west bound circuits, and electrically separating the groups by choosing non-adjacent pairs of conductors in the cable, by shielding the two groups of conductors, by employing separate cables for the two groups, etc. The methods of separation form no part of this invention, however, and need not be described herein for these are already well known to those skilled in the art.

While this invention will be pointed out with particularity in the appended claims, the invention itself, both as to its further objects and features, will be better understood from the detailed description hereinafter following when read in connection with the accompanying drawing, in which Figure 1 represents one embodiment of the invention shown here merely for the purpose of illustration, Fig. 2 shows curves illustrating the principles of this invention, and Fig. 3 shows the use of directional transmitters and receivers to replace the four wires shown in Fig. 1 for transmission between various stations.

Referring to Fig. 1 of the drawing, a four-wire system is disclosed embodying apparatus shown herein as located at stations A and B. Ordinary low frequency signaling lines capable of transmitting a comparatively wide band of frequencies, such as lines ML_1 and ML_2 are shown extending between stations A and B.

In order to provide for four-wire carrier transmission over the above mentioned lines, a common carrier transmitting circuit TL is interposed between the line ML_1 and the secondary winding of a repeating coil R_1 at station A. The primary winding of the repeating coil R_1 is connected to apparatus for freely transmitting frequencies between definite limits in the frequency spectrum and for substantially suppressing the transmission of frequencies lying outside of these limits. Such apparatus are usually referred to as filters, the filters connected to the primary winding of the repeating coil R_1 being preferably band filters, designated by the

reference characters B_1F , B_2F and B_3F . These filters should preferably be of the broad band type as disclosed in the patents to G. A. Campbell, Nos. 1,227,113 and 1,227,114, dated May 22, 1917. Where it is desired to suppress one of the side bands resulting from the modulation of a carrier current by a single signaling current or by a group of signaling currents, the filter connected to the circuit should be so designed as to transmit a band of frequencies extending either above or below the assigned carrier frequency by an amount substantially equal to the range of the frequency spectrum required by the signaling current or currents.

In a similar manner, a common carrier receiving circuit RL is interposed between the main line ML_2 and the primary winding of a repeating coil R_1''' . The secondary winding of the repeating coil R_1''' is connected to three band filters B_1F''' , B_2F''' and B_3F''' , which are in all respects similar to the filters B_1F , B_2F , and B_3F connected to the primary winding of the repeating coil R_1 .

L_1 and L_{10} , L_1''' and L_{10}''' , L_{11} and L_{20} , L_{11}''' and L_{20}''' , L_{21} and L_{30} and L_{21}''' and L_{30}''' , respectively, designate similar low frequency signaling circuits, such as telegraph or telephone circuits, in groups, 1, 2 and 3, respectively. The lines L_1 , L_{10} , L_{11} , L_{20} , L_{21} and L_{30} are to be used for the transmission of signals from station A to station B, and lines L_1''' , L_{10}''' , L_{11}''' , L_{20}''' , L_{21}''' and L_{30}''' are to be used for the reception of signals at station A transmitted from station B.

In order to translate the low frequency signals originating in lines L_1 , L_{10} , L_{11} , L_{20} , L_{21} and L_{30} into higher frequency currents, a plurality of modulating arrangements are provided, the reference characters M_1 , M_{10} , M_{11} , M_{20} , M_{21} and M_{30} designating these modulating arrangements respectively. Oscillators of electrical currents of definite frequencies, preferably oscillators of odd or of even harmonics of some fundamental frequency, are designated by the reference characters O_0 and O_1 . In the case under consideration, let it be assumed that these oscillators sustain oscillations of different odd harmonics of a definite fundamental frequency. The oscillator O_1 is common to the modulators M_1 , M_{11} and M_{21} , and the oscillator O_0 is common to the modulators M_{10} , M_{20} and M_{30} . It will be obvious that the modulating arrangements shown herein are indicated merely schematically and may be organizations whereby moderately high frequency oscillations from any source may be modulated in accordance with lower frequency signals, these modulating arrangements being preferably of any well known vacuum tube type.

In order that the modulated carrier currents received at station A from station B may be translated into the original low frequency signals, a plurality of demodulating arrangements are provided, designated herein as D_1''' , D_{10}''' , D_{11}''' , D_{20}''' , D_{21}''' and D_{30}''' . These demodulating arrangements may also be of any well-known type, preferably of some well-known vacuum tube type. In the particular illustration of this application, the ordinary method of detection and demodulation is involved and no carrier current need be supplied. If, however, the carrier current and one side band were suppressed at station B by the band filters BF_1''' , BF_{10}''' , BF_{11}''' , BF_{20}''' , BF_{21}''' and BF_{30}''' in each respective case, the so-called homodyne method of detection or demodulation could then be employed, necessitating the application of a definite carrier frequency to each demodulating arrangement at the same time that the received modulated carrier wave were applied thereto. Accordingly, it would be necessary to connect to the demodulators shown at station A oscillators of the same frequencies as are used in modulation at the distant station. Therefore, to accomplish this purpose, an oscillator, such as O_1 , could be connected in common to the demodulators D_1''' , D_{11}''' and D_{21}''' , and an oscillator, such as O_0 , could be connected in common to the demodulators D_{10}''' , D_{20}''' and D_{30}''' .

The outputs of the modulators M_1 , M_{10} , M_{11} , M_{20} , M_{21} and M_{30} are impressed upon band filters BF_1 , BF_{10} , BF_{11} , BF_{20} , BF_{21} and BF_{30} , respectively, these band filters being adaptable to freely transmit either of the side bands resulting from modulation while substantially suppressing the carrier frequency and the other side band if the homodyne method of detection were employed. If the ordinary method of detection mentioned hereinabove were employed, however, the carrier wave and both side bands would be transmitted by these filters. In the particular illustration of this application the latter method is involved and the carrier wave and both side bands resulting from modulation are freely transmitted and all other frequencies are substantially suppressed.

The currents impressed upon the demodulators D_1''' , D_{10}''' , D_{11}''' , D_{20}''' , D_{21}''' and D_{30}''' are received from the band filters BF_1''' , BF_{10}''' , BF_{11}''' , BF_{20}''' , BF_{21}''' and BF_{30}''' , respectively, these band filters being similar in all respects to the band filters BF_1 , BF_{10} , BF_{11} , BF_{20} , BF_{21} and BF_{30} employed in transmitting the products of modulation. The transmitting channels TL_1 , TL_2 and TL_3 receive the useful products of modulation after transmission through the band filters BF_1 and BF_{10} , BF_{11} and BF_{20} and BF_{21} and BF_{30} , respectively.

tively. Similar receiving channels RL_1 , RL_2 and RL_3 receive the moderately high frequency currents which are to be impressed upon the band filters BF_1''' and BF_{10}''' , BF_{11}''' and BF_{20}''' and BF_{21}''' and BF_{30}''' , respectively, which are to become subsequently demodulated.

In order to translate the modulated currents of groups 2 and 3, which are impressed upon the transmitting channels TL_2 and TL_3 , into still higher frequency modulated currents, modulator-amplifiers MA_2 and MA_3 are provided, each modulator-amplifier including any well-known modulating arrangement for modulation and any well-known amplifying arrangement for amplifying the products of modulation. Oscillators O_{21} and O_{31} are connected to the modulator-amplifiers MA_2 and MA_3 , respectively, these oscillators being of any well-known type, preferably of some vacuum tube type. These oscillators may sustain oscillations of any frequency, preferably currents of some definite odd or even harmonics of the same fundamental frequency common to oscillators O_0 and O_1 . In the particular illustration of this application these oscillators may preferably sustain oscillations of even harmonics of the fundamental frequency common to the oscillators O_0 and O_1 . The products of modulation after amplification are transmitted to the band filters B_2F and B_3F , respectively, each of these band filters preferably transmitting one of the side bands resulting from the latter modulation and substantially suppressing the carrier frequency, the other side band and all other products of modulation.

Demodulator-amplifiers DA_2 and DA_3 are connected to the receiving channels RL_2 and RL_3 , respectively, at station A. Inasmuch as the homodyne principle is involved throughout the illustrated case, the same frequencies that are impressed upon the modulator at the transmitting station in modulation are also impressed upon the demodulators in demodulation. Accordingly, the oscillators O_{21} and O_{31} are also connected to the demodulator-amplifiers DA_2 and DA_3 , respectively, transmitting currents of the same frequencies that are used in modulation, to these demodulators, namely, currents of frequencies equal to those impressed upon the modulator-amplifiers MA_2 and MA_3 , respectively, and which are preferably even harmonics of the same fundamental frequency which is common to the oscillators O_0 and O_1 . The currents which are impressed upon the demodulator-amplifiers DA_2 and DA_3 at station A are received from band filters B_2F''' and B_3F''' , respectively, these band filters being similar in all respects to the band filters B_2F and B_3F which receive the products of modulation from the

modulator-amplifiers MA_2 and MA_3 , respectively.

The currents transmitted by the band filters B_1F , B_2F and B_3F are transmitted through the repeating coil R_1 , through the main transmitting channel TL and through the main line ML_1 to the main receiving channel RL' at station B and the repeating coil R_1' thereat. The apparatus at station B is similar in all respects to the apparatus at station A, similar reference characters being employed to designate similar parts, the reference characters designating apparatus at station B being differently primed, however.

It will be apparent that the system just described is one in which the channels of transmission in one direction are confined to one pair of wires ML_1 in the four-wire circuit, and those of transmission in the other direction to the other pair of wires ML_2 , the channels of transmission in each direction being divided into a number of groups (only three of which are shown), each group being subdivided into a finite number of channels, such as ten (only two of which are shown). Group 1 is operated on the principle of single modulation, that is, low frequency signals are modulated but once to produce modulated currents for transmission to the distant station. Groups 2 and 3 operate on the principle of double modulation, that is, the currents within these groups are modulated first on one carrier wave and then on another carrier wave, these doubly modulated products being then transmitted to the distant station.

For the purpose of illustration one of the channels in group 1, i. e., the channel originating in line L_1 , will be traced from station A to station B. An oscillator O_1 of a definite frequency, preferably of an odd harmonic of a fundamental frequency, is transmitted to the modulator M_1 . Signals coming in over line L_1 also are impressed upon the modulator M_1 . In the case of telegraphy, the modulator may comprise a relay controlled by a telegraph key, a printer or any other sending device, or, in general, it may be any other type of modulator well-known in the art which will cause the current of oscillator O_1 to become modulated in accordance with the signals coming in over the line L_1 . The products of modulation pass through the filter BF_1 , this filter suppressing extraneous frequencies not required for the transmission of intelligence while allowing a band of frequencies to freely pass therethrough, which in the case of telegraphy may extend from a few cycles below the carrier frequency of the oscillator O_1 to a few cycles above that frequency. It will be understood that in signaling systems employing the homodyne principle of demodulation only one of the side bands, either the lower or the upper side band, need be trans-

mitted, while the carrier frequency and the undesired side band may preferably be suppressed. After passing through the filter BF_1 , the modulated signals are transmitted through a transmitting channel TL_1 to another band filter B_1F which has a wider range of transmission inasmuch as it must freely transmit not only the modulated currents transmitted by the band filter BF_1 , but also the modulated currents transmitted by the band filter BF_{10} and any other modulated currents which may be developed in the channels of group 1 and lie between definite limits of frequency. After passing the band filter B_1F the currents are transmitted through the repeating coil R_1 at station A, then through the main transmission channel TL , over the main line ML_1 , to station B, where, after passing through the main receiving channel RL' and through the repeating coil R_1' , the modulated currents are impressed upon a band filter B_1F' , all extraneous currents being suppressed thereby. These modulated currents then pass through the band filter B_1F' through the receiving channel RL_1' , through the band filter BF_1' to the demodulator or detector D_1' , so that the received modulated currents may be properly demodulated in order to derive the signals originating at station A in line L_1 , these derived signals being received at station B in the line L_1' . It will be understood that if the homodyne method of detection were employed, then the carrier current and one side band thereof would be suppressed. Current of an oscillator such as O_1' , which sustains oscillations substantially equal in frequency to those sustained by the oscillator O_1 at station A, might then be transmitted to the demodulator D_1' for the purposes of demodulation. The band pass filters B_2F and B_3F at station A and the band filters B_2F' and B_3F' at station B are designed to have very high impedances for currents of all frequencies flowing between station A and station B lying in group 1. Similarly, the other band filters connected to the repeating coils mutually exclude all the frequencies of currents in neighboring groups, thereby permitting the currents in one group to flow over the corresponding and appropriate channel and main line to be received by the proper band filter at the receiving station. It will be apparent that the channels of group 1 operate on the principle of single modulation and that, in the case of telegraphy, it is possible and perhaps desirable to transmit the carrier along with both side bands over the main line. The channels within groups 2 and 3 operate on the principle of double modulation, and the transmission of current through one of these channels will now also be considered in some detail.

The oscillator O_1 similarly supplies current to the modulator M_{11} to modulate the signals coming in over the line L_{11} . In a telegraph system, the side bands of the current of oscillator O_1 may be transmitted along with the carrier current, the band filter BF_{11} suppressing extraneous currents and currents of neighboring channels which would ordinarily tend to interfere with the faithful transmission of signals. The output of the band filter BF_{11} is then transmitted through the transmitting channel TL_2 to the modulator-amplifier MA_2 . Current of the oscillator O_{21} is also impressed upon the modulator-amplifier MA_2 , current of this oscillator representing preferably an even harmonic of a fundamental frequency of oscillator O_1 , the frequency of oscillator O_{21} being preferably higher than the frequency of oscillator O_1 . The modulator-amplifier MA_2 therefore modulates the signals originating in line L_{11} a second time and on a still higher frequency and transmits the products of modulation to the band filter B_2F . At the same time the modulator-amplifier MA_2 modulates the signals coming in over another line L_{20} , which have been modulated on current of the oscillator O_0 . The modulator-amplifier MA_2 also modulates the modulated current passed by the band filter BF_{20} . As a result of the modulation, upper and lower side bands of the frequency of the oscillator O_{21} may be transmitted to the band filter B_2F , each side band representing current coming in over one or more of the lines such as L_{11} or L_{20} modulated upon the current of the corresponding oscillators such as O_1 or O_0 , respectively. The band pass filter B_2F may freely transmit the lower side bands resulting from the latter modulation, while substantially suppressing the carrier frequency, the upper side bands and all other products of modulation.

In accordance with this invention, the currents in each group which represent successive odd harmonics of a fundamental frequency are successively raised in the frequency spectrum as a result of modulation, so that these successive odd harmonics may assume positions in the frequency spectrum adjacent to each other. That is to say, the products of modulation of the currents of group 2 are raised in the frequency spectrum as a result of modulation with current of the oscillator O_{21} so that the currents of group 2 may be elevated in the frequency spectrum with respect to the currents of group 1. By so elevating the currents of each of the successive groups it is possible to simultaneously transmit these currents through repeating coil R_1 and over the main line ML_1 without undue interference. Yet it will be understood that while reference has been made herein to the transmission of

the lower side bands of the currents of oscillators O_{21} and O_{31} , the system may also be arranged so that the oscillators O_{21} and O_{31} transmit currents, the upper side bands of which may be similarly employed for transmission over a common transmission path such as ML_1 , without undue interference. It will also be understood that, while oscillators O_0 and O_1 have been referred to as oscillators of odd harmonics of a fundamental frequency and oscillators O_{21} and O_{31} have been referred to as oscillators of higher, even harmonics of the same fundamental frequency, it is within the scope of this invention to have oscillators O_0 and O_1 transmit even harmonics of a fundamental frequency and oscillators O_{21} and O_{31} transmit currents which may be odd harmonics of the same fundamental frequency.

The bands of frequencies passing band pass filter B_2F at station A are transmitted through the repeating coil R_1' at station B, through the band pass filter B_2F' to the demodulator-amplifier DA_2' . Current of the oscillator O_{21}' , which sustains oscillations of a frequency substantially equal to the frequency of those oscillations sustained by the oscillator O_{21} at station A, is also transmitted to the demodulator-amplifier DA_2' . As a result of demodulation there appears in the output circuit of the demodulator-amplifier DA_2' a number of singly modulated currents substantially the same as the currents resulting from modulation at station A and passing the band filters BF_{11} and BF_{20} . These singly modulated currents are selectively transmitted by the band pass filter BF_{11}' and BF_{20}' and are transmitted to the respective demodulator D_{11}' and D_{20}' . As a result of demodulation, the original signals are reproduced and are transmitted to the line L_{11}' and L_{20}' , respectively.

Fig. 2 shows a number of curves illustrating the principles of this invention. Ten signaling sources are assumed to be present in each group, the frequencies f_1 to f_{10} , inclusive, being used for the first modulation of the currents of these sources, respectively. After the first modulation has been effected there are present a plurality of similar groups of currents each representing successive harmonics, preferably odd harmonics of some common fundamental frequency. The currents within groups 2 and 3 are then modulated a second time upon still higher frequencies which may preferably be even harmonics of the same common fundamental frequency, F_2 and F_3 , representing the frequencies upon which the currents within groups 2 and 3 may be respectively modulated. The band pass filters freely transmit the lower side bands resulting from modulation while substantially suppressing the upper side bands. Thus, modulating the

currents within groups 2 and 3 a second time it is possible to raise these currents in the frequency spectrum so that they assume positions adjacent to each other and to the position in the frequency spectrum occupied by the currents in group 1.

Fig. 3 shows how it is possible to use directed radio beams in this invention to supplant the four-wire line circuits described hereinabove for transmission between two stations, such as A and B. ML_1 and ML_2 are comparatively short four-wire line circuits which connect one radio terminal to apparatus similar to that shown in Fig. 1 located at station A. ML_1' and ML_2' are four-wire line circuits which connect the other radio terminal to apparatus similar to that shown in Fig. 1 located at station B. The line ML_1 terminates in a directional transmitter which emits a directed beam to a directional receiver connected to the line ML_1' . Similarly, a directional transmitter receives the currents flowing in the line ML_2' and directs a corresponding beam to station A to be received by a similar directional receiver and then by the line ML_2 . To operate such a system with high efficiency, it may be found desirable to raise the frequencies of currents impressed upon the various lines by modulating these currents a third time upon still higher frequencies, all of which is within the scope of this invention.

By employing oscillators throughout the system which produce either odd or even harmonics of a common fundamental frequency, it is possible to substantially decrease the interference and distortion introduced by such apparatus as loading coils, transformers, etc. It is well-known that such apparatus necessarily interposed in any transmission path introduce harmonics which frequently interfere with the faithful transmission of signals. By employing frequencies which simulate those introduced by the apparatus present in the transmission line it is possible to minimize the interfering and distorting effect introduced by such apparatus.

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

What is claimed is:

1. In a system in which signals are to be transmitted substantially free from the distortion introduced by transformers, loading coils, and the like, the combination of a plurality of sources of low frequency signals, a plurality of low frequency oscillators each of a different odd harmonic of a fundamental frequency, one corresponding to each

low frequency signaling source, a plurality of high frequency oscillators each of a different even harmonic of the same fundamental frequency, one corresponding to each low frequency signaling source, means for beating the signals of each low frequency signaling source with the oscillations of a corresponding low frequency oscillator, and means for beating the resultant waves with the oscillations of the high frequency oscillator corresponding to the same signaling source.

2. In a system in which signals are to be transmitted free from the harmonic distortion introduced by transformers, loading coils, and the like, the combination of a plurality of oscillators of successive odd harmonics of a fundamental frequency, a plurality of oscillators of successive even harmonics of the same fundamental frequency, a plurality of signaling sources, means for modulating the current of each of said odd harmonics by the signals originating in a predetermined number of said signaling sources, means for modulating the modulated odd harmonics upon the currents of said even harmonics corresponding thereto, and a transmitting medium over which said doubly modulated signals may be transmitted.

3. The combination of a plurality of oscillators of successive odd harmonics of a fundamental frequency, a plurality of oscillators of successive even harmonics of the same fundamental frequency, a plurality of signaling sources, means for modulating the signals originating in a predetermined number of said signaling sources upon the currents of each odd harmonic, means for modulating a predetermined number of said modulated odd harmonics upon the currents of each of the even harmonics, a transmitting medium over which the signals thus doubly modulated may be transmitted, means for demodulating the plurality of doubly modulated signals with the currents of even harmonics employed in modulation so as to derive a plurality of odd harmonics modulated with said signals, said odd harmonics being substantially the same as those employed in modulation, and means for demodulating the plurality of modulated odd harmonics with substantially the same currents of the odd harmonics as were employed in modulation in order to derive the signals transmitted by said sources.

4. The combination of a transmitting station comprising a plurality of oscillators of successive odd harmonics of a fundamental frequency, a plurality of oscillators of successive even harmonics of the same fundamental frequency, a plurality of signaling

sources, means for modulating the signals originating in said signaling sources upon the currents of said odd harmonics of the fundamental frequency, a predetermined number of said signaling sources corresponding to the current of each odd harmonic, and means for again modulating the modulated odd harmonics of the fundamental frequency upon the currents of said even harmonics of the fundamental frequency, a predetermined number of said modulated odd harmonics corresponding to the current of each even harmonic, and a receiving station comprising means for demodulating the plurality of doubly modulated signals with the currents of the same even harmonics employed in modulation at the transmitting station in order to derive a plurality of odd harmonics modulated with said signals, and means for detecting and deriving from the plurality of modulated odd harmonics the signals transmitted from the transmitting station by said signaling sources.

5. The combination of a plurality of groups of oscillators of successive odd harmonics of a fundamental frequency, each group having substantially similar successive odd harmonic oscillators, a plurality of oscillators of predetermined frequencies one corresponding to each group, and means for beating all of the currents within the respective groups with the currents of the corresponding oscillators of predetermined frequencies so as to produce a plurality of groups of frequencies one beside another in the frequency spectrum.

6. The combination of a plurality of groups of substantially equal successive odd harmonics of a fundamental frequency, a plurality of signaling sources one corresponding to each odd harmonic in each group, means for modulating the signals of each signaling source upon the current of the corresponding odd harmonic frequency, a plurality of oscillators of predetermined frequencies one corresponding to each group, and means for modulating all of the modulated currents of all the groups upon the currents of the predetermined frequencies, all of the modulated currents of any one group being modulated upon the current of only one of the predetermined frequencies, thereby producing a plurality of groups of signals adjacent to each other in the frequency spectrum.

In testimony whereof, I have signed my name to this specification this 30th day of March 1927.

FRED J. SINGER.