

Nov. 12, 1929.

E. I. GREEN

1,735,044

FREQUENCY EQUALIZATION CARRIER SYSTEM

Filed Oct. 22, 1927

3 Sheets-Sheet 1

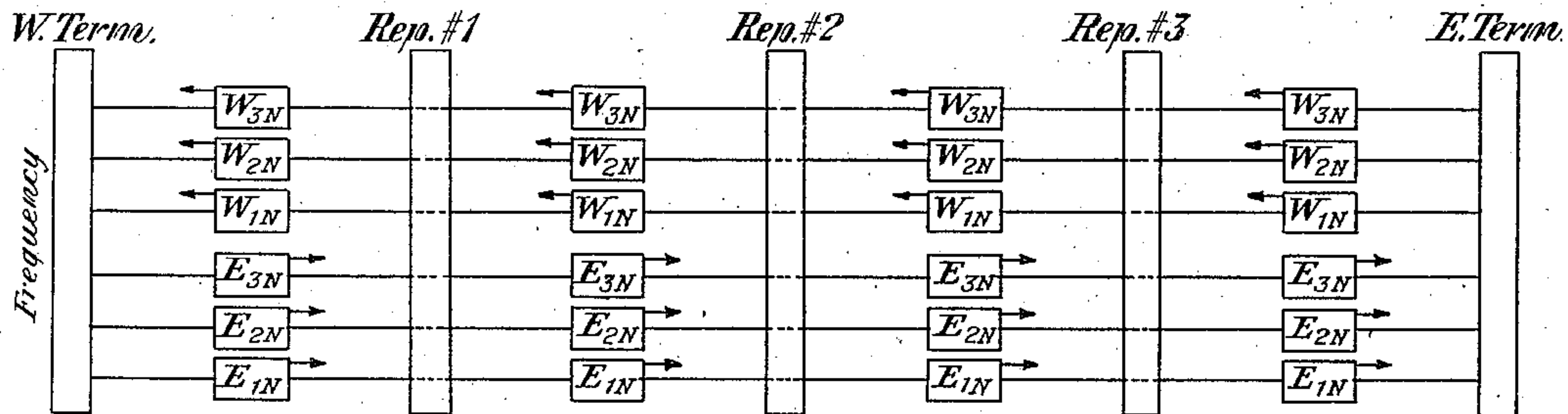


Fig. 1 - Present Multi-Channel Telephone Frequency Arrangement.

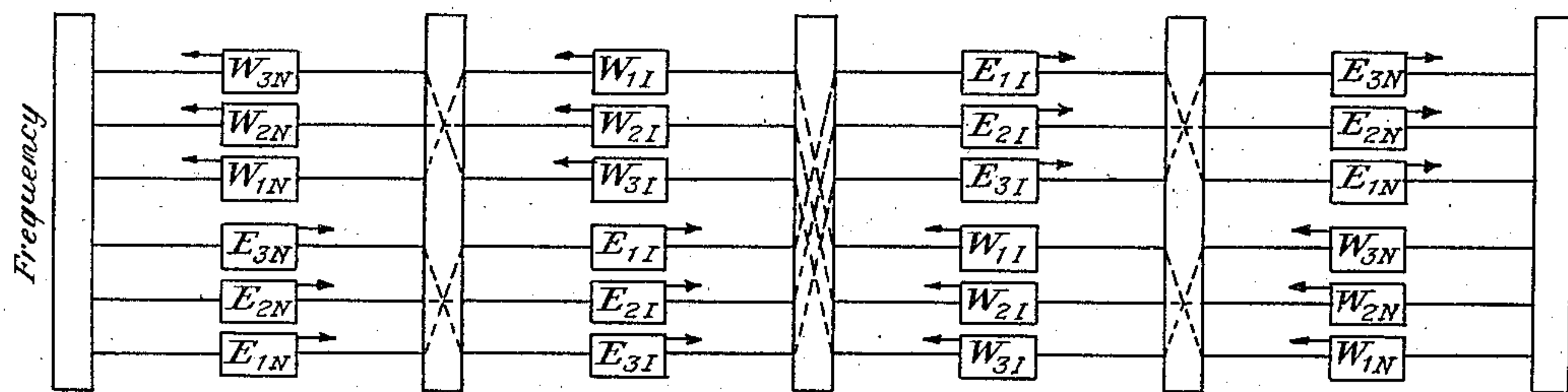


Fig. 2 - Arrangement Providing Frequency Equalization.

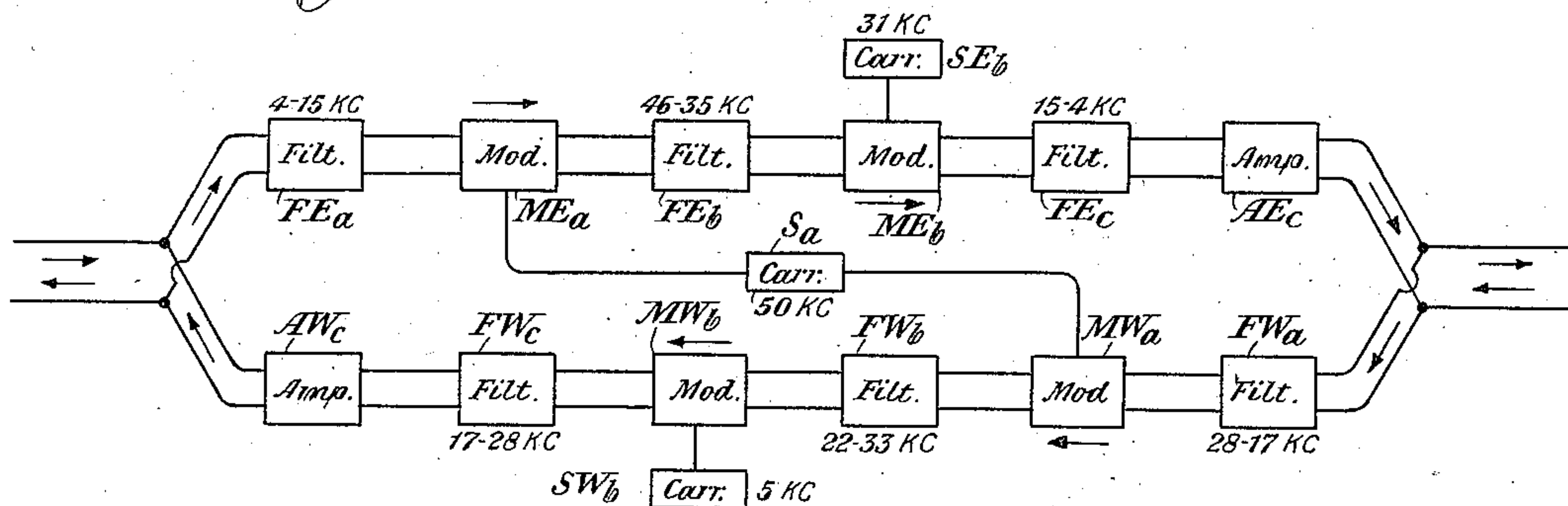


Fig. 3 - Channel and Band Inverter.

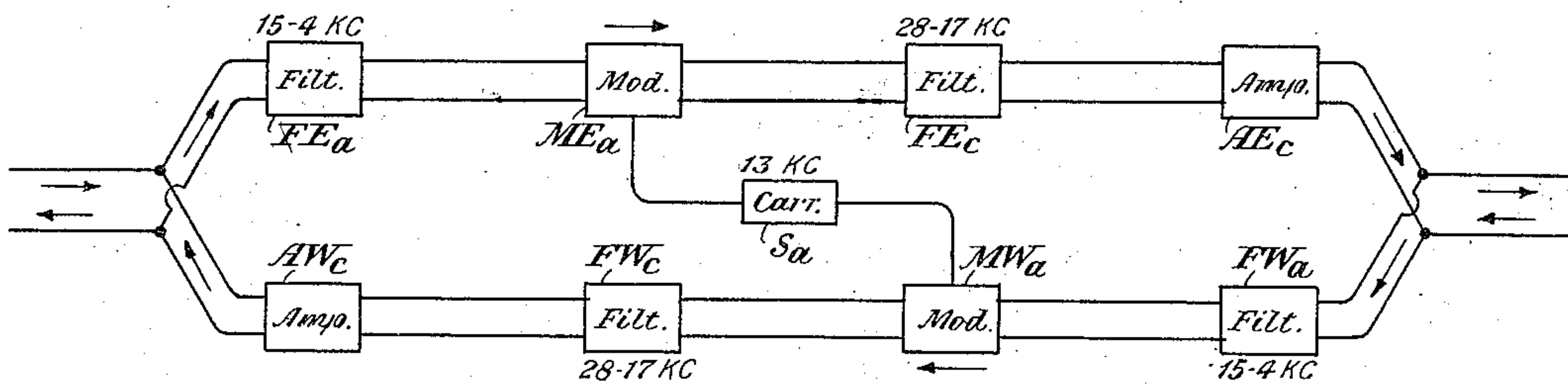


Fig. 4 - Group Inverter

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3 Sheets-Sheet 2

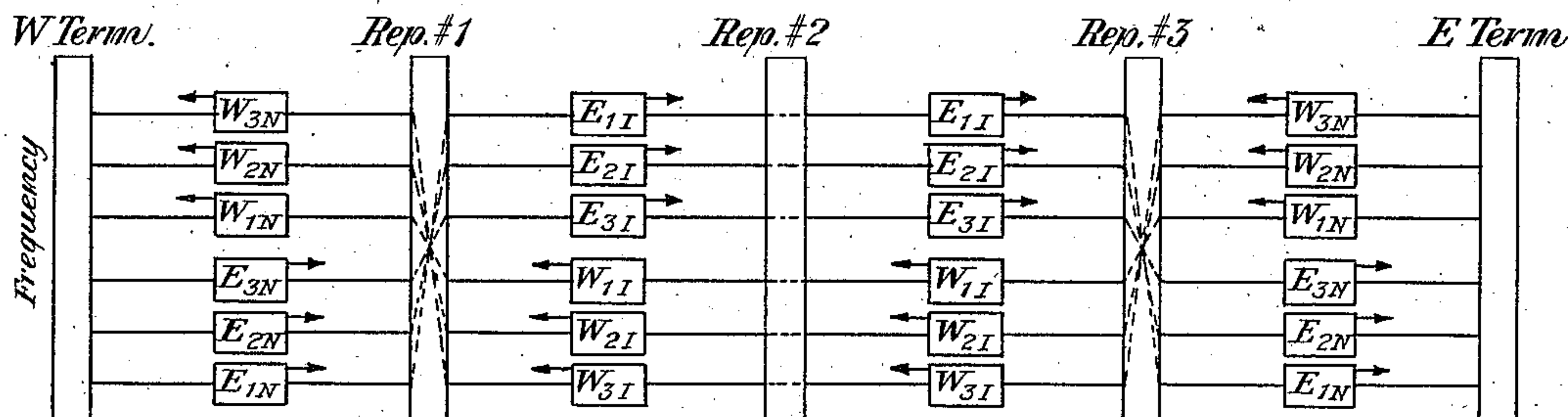


Fig. 5 - Frequency Equalization with Group, Channel and Band Inverter.

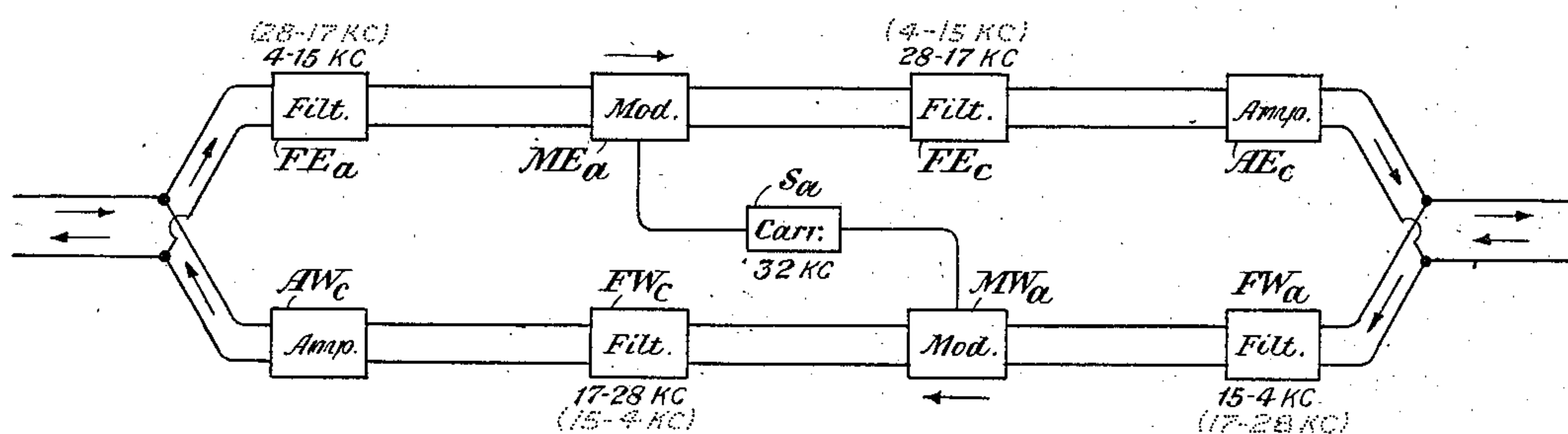


Fig. 6 - Group, Channel and Band Inverter.

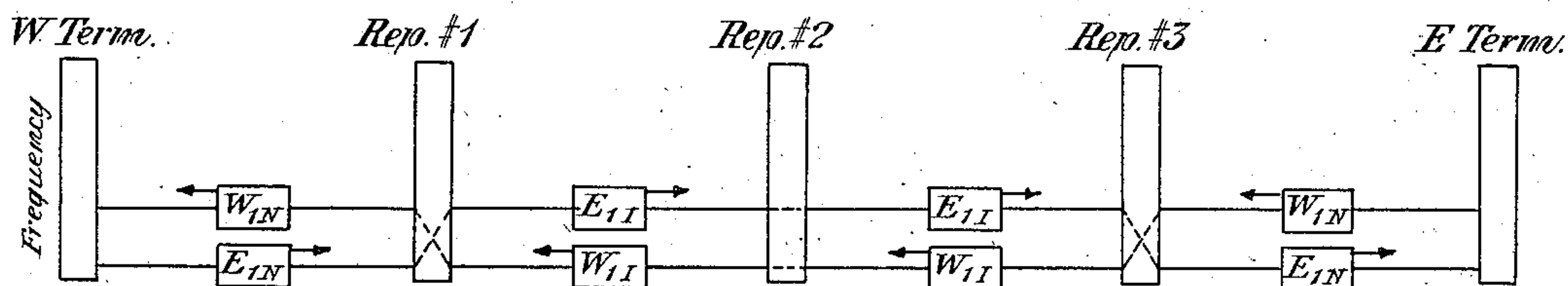


Fig. 7 - Frequency Equalization in Single Channel Telephone System.

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3 Sheets-Sheet 3

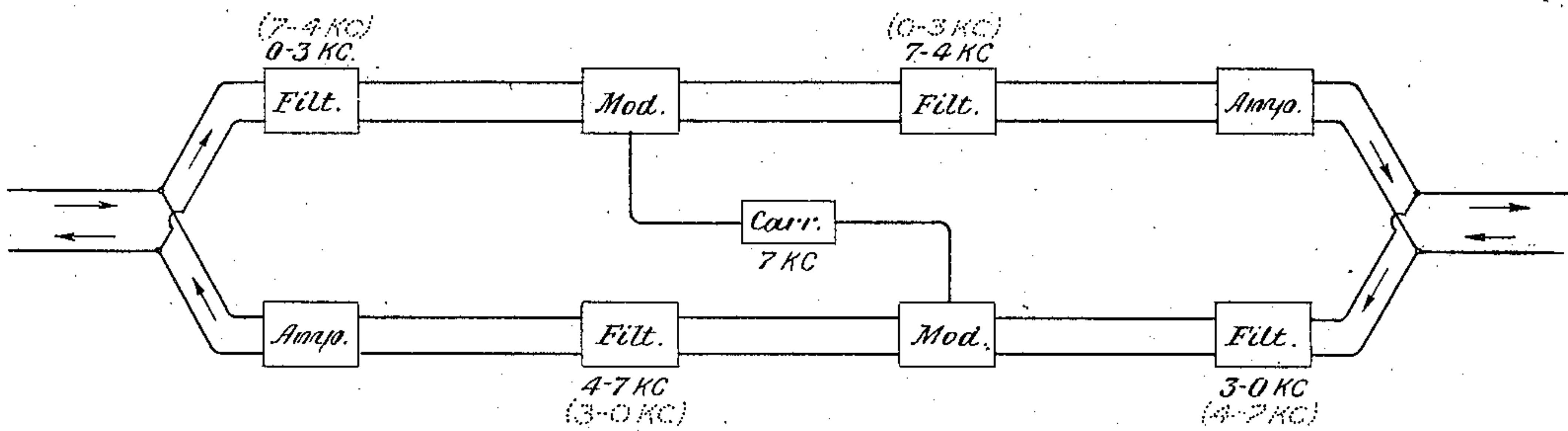


Fig. 8 - Inverter for Single Channel System

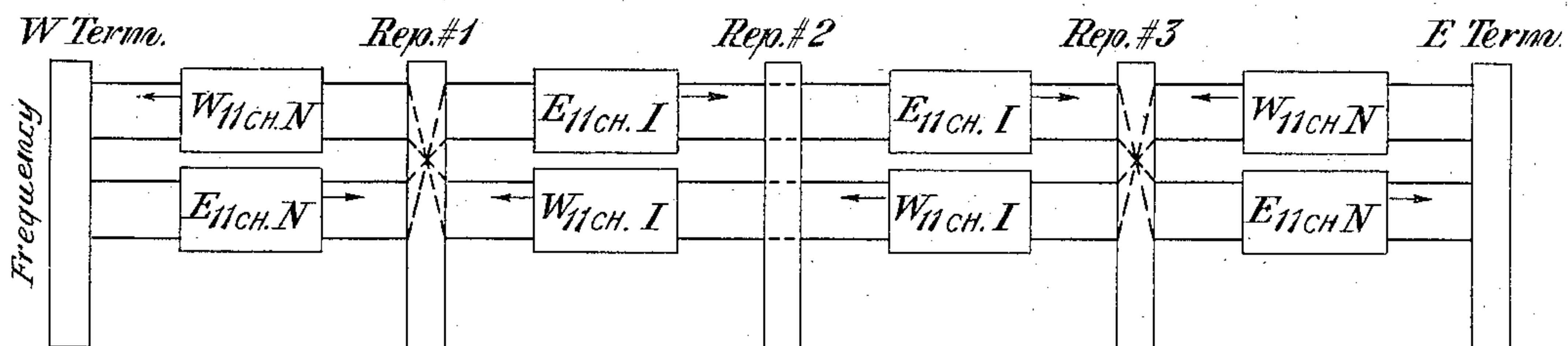


Fig. 9 - Frequency Equalization in Carrier Telegraph System

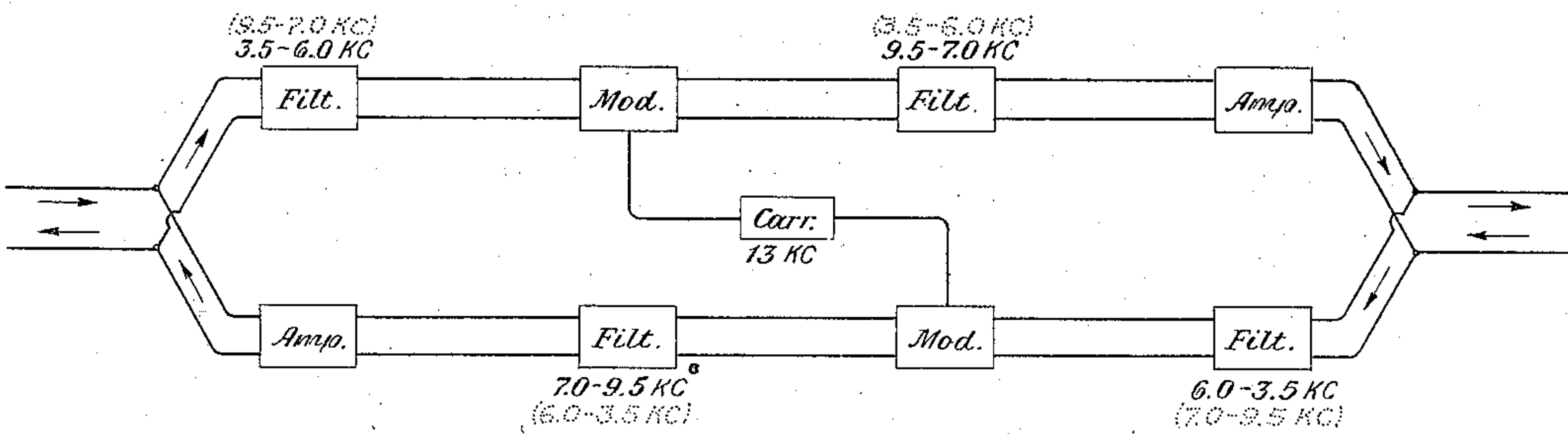


Fig. 10 - Inverter for Carrier Telegraph System

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FREQUENCY-EQUALIZATION CARRIER SYSTEM

Application filed October 22, 1927. Serial No. 228,021.

This invention relates to methods and apparatus for equalizing carrier systems with respect to frequency, or, in other words, making the average frequency of transmission the same for each transmitted signal. The invention relates both to telephone and telegraph systems, and the equalization principle may be applied in the case of the former to every frequency of the sideband.

As is well known, it has been the practice in carrier systems involving two-way transmission to arrange all of the channels which transmit in one direction within one group or range of frequencies, the channels transmitting in the opposite direction being arranged in another group or range of frequencies. Obviously, in such a system, since the attenuation is greater at the higher frequencies, not only will the channel having the highest frequency of a group be more attenuated than the channel of the same group having the lowest frequency, but the difference in attenuation will be even more marked in the case of the channel of highest frequency transmitting in one direction as compared with the channel of lowest frequency transmitting in the opposite direction. In addition to the difference in line attenuation for the different channels, there will be differences in other factors, such as noise, cross-talk, attenuation variation, gain, apparatus distortion, etc., since these factors depend to a considerable extent upon the frequency or frequencies used for a channel.

In order to overcome these difficulties the invention contemplates rearranging or transposing the order of the channels in the frequency spectrum from time to time as they are transmitted along the transmission line, this process being applied to all channels regardless of direction of transmission in such a way that not only will any channel be transmitted at the same average frequency level as any other channel transmitting in the same direction, but also at the same frequency level as any channel transmitting in the opposite direction. Preferably, the method is so carried out that the frequencies in each channel band are transposed so as to be transmitted at the same average frequency level.

The fundamental advantage of such frequency equalization resides in the fact that it provides equalization with respect to all the features which are a function of frequency. The more important of these factors are line attenuation, noise, inter-system or inter-channel cross-talk, attenuation variations, gain, apparatus distortion, etc. It should be noted that the equalization provided in this manner is much superior to that ordinarily accomplished by particular means designed to take care of each one of the above factors individually. This is because frequency equalization makes the condition on all of the channels the same as the average condition, whereas the other means of equalization commonly used degrade all channels to the condition of the worst channel.

The invention may now be more fully understood from the following description when read in connection with the accompanying drawings, in which Figure 1 is a symbolic layout showing the frequency relation of the various channels of a two-way multiplex system as ordinarily operated; Fig. 2 is a similar symbolic layout showing the frequency relations of the channels when inverted and transposed in accordance with one embodiment of the invention; Figs. 3 and 4 are schematic diagrams of repeaters arranged to invert the channels, frequency bands, and groups in accordance with the said layout in Fig. 2; Fig. 5 is a symbolic layout in which the functions of group, channel, and band inversion are carried out simultaneously; Fig. 6 is a schematic diagram of a repeater employed in connection with the system in Fig. 5 for performing the required inverting functions; Fig. 7 is a layout of the system as applied to a single channel two-way telephone system; Fig. 8 is a simplified diagram of a modulating repeater to be used in connection with the system in Fig. 7; Fig. 9 shows the invention applied to a multiplex carrier telegraph system; and Fig. 10 is a symbolic diagram of the repeater to be employed in the system of Fig. 9.

Fig. 1 illustrates the present standard method of operation with respect to frequency allocation of a multi-channel two-

way telephone system having four line sections with three repeaters interconnecting the sections. For convenience, a system having six bands, or three two-way channels, is assumed although it will be understood that the invention is applicable to any number of channels. In the diagram of Fig. 1, as well as in the other layout diagrams, each channel is represented by a straight horizontal line having a rectangular box near the middle thereof to which a legend is applied to indicate the character of the channel. Repeater points are indicated by long vertical rectangles. The direction in which the channel transmits in each line section is indicated by the arrows attached to the rectangles containing the legends of each channel.

With respect to the legends, it should be noted that the letter W of each symbol indicates that the channel to which it is applied transmits from east to west, while the letter E applied to a channel indicates that it transmits from west to east. The subscript numerals applied to the letters W and E of the legends have no relation to the frequencies assigned to the channels, but merely indicate how the channels are paired to form a plurality of two-way communication circuits. Thus, the channel E_1 is paired with the oppositely transmitting channel W_1 , E_2 with W_2 , etc. This numbering of the bands is immaterial, as in practice the bands may be paired in any manner to give the best results regardless of whether they are equalized or not. The frequency assignment or allocation of the various channels or bands is indicated in the diagram of Fig. 1 and other similar diagrams by the vertical position of the channel in the diagram, the higher positions representing higher frequencies. The subscript N, associated with the symbols involving the letters W and E in the diagram of Fig. 1, merely indicates that the various frequencies within the band of a given channel so designated, are in their normal order and have not been inverted. When the subscript I is used instead of N, as indicated in Figs. 2, 5, 7, and 9, it means that the frequency order of the individual frequencies in particular bands so designated has been inverted.

A consideration of Fig. 1 shows that in the arrangement there illustrated the frequency position of each band is unchanged throughout the system, and that none of the bands have been inverted. With such an arrangement there is no attempt at frequency equalization.

Fig. 2 is a layout illustrating one possible arrangement for providing frequency equalization. After a discussion of this arrangement, which will serve to bring out the principles involved, and a description of means for carrying it out in practice, various alternative arrangements will be considered.

A consideration of Fig. 2, which illustrates

the principles of the invention applied to a carrier system involving four line sections, will render it apparent that during transmission over the first line section, which is the section from the west terminal to repeater No. 1, the frequency arrangement is identical with that of the system of Fig. 1 and all the bands are normal and not inverted. Upon arriving at repeater No. 1, however, the bands of the upper group are inverted in position with respect to each other and the frequencies of each band are thus inverted with respect to their normal position, while precisely the same treatment is accorded the bands of the lower group, as indicated by the dotted lines. In short, repeater No. 1 performs the function of inverting the order of the channels and also the function of inverting the order of the frequencies within the channels themselves. It may, therefore, be referred to as a "channel and band inverter".

During transmission over the second section of the line (between repeater No. 1 and repeater No. 2) the channels are transmitted in their rearranged frequency allocation with the bands inverted but the directional groups of channels remain in their original frequency range. On arriving at repeater No. 2, however, the bands of the lower group are transposed to the frequency assignment of the upper group and vice versa, without any change in the relative location of the bands in the group, and without reinversion of the frequencies within the bands. This is indicated by the dotted lines at repeater No. 2. This repeater may, therefore, be called a "group inverter".

During transmission over the third section of the line, the channels are transmitted as rearranged by repeater No. 2. Upon arriving at repeater No. 3 the channels in each group are reinverted, and also the frequencies of the individual bands are reinverted. The groups, however, are not re-transposed. It will be apparent, therefore, that repeater No. 3 performs the same functions as repeater No. 1, so that it is another channel and band inverter. The channels are then transmitted over the fourth section of the line to the east terminal, with the individual channels of each directional group in their original order in the frequency spectrum, although the directional groups are still transposed with respect to each other. If it were desired to repeat the process in a second set of four line stations the east terminal would obviously be replaced by an ordinary repeater, and "group inverters" and "channel and band inverters" would be used at succeeding repeater points.

A little consideration will make it clear that in the system outlined in Fig. 2 the average frequency of transmission is the same for all of the channels. Thus, suppose the six frequency bands occupied by the three

two-way channels are 4—7, 8—11, 12—15, 17—20, 21—24, and 25—28 kilocycles. The frequency allocation of the different bands in the successive sections of the line of Fig. 2 will then be as indicated in the following table:

Band	Section 1	Section 2	Section 3	Section 4	Average frequency
W ₃	25—28	20—17	7—4	12—15	16—16
W ₂	21—24	24—21	11—8	8—11	16—16
W ₁	17—20	23—25	15—12	4—7	16—16
E ₃	12—15	7—4	20—17	25—28	16—16
E ₂	8—11	11—8	24—21	21—24	16—16
E ₁	4—7	15—12	23—25	17—20	16—16

It will be observed that the average frequency of transmission is the same not only for the carrier frequency of each channel but for every frequency within each band.

In carrying out the method illustrated in Fig. 2, it is necessary to employ alternately the two types of repeaters previously mentioned, namely, (1) a channel and band inverter and (2) a group inverter. Suitable circuits and apparatus for these two types of repeaters are illustrated schematically in Figs. 3 and 4, where, for convenience, the frequency assignments above assumed, are again utilized. It will be noted that the channel and band inverter, shown in Fig. 3, consists of two parts or sides, one being utilized for transmission in one direction and the other for transmission in the opposite direction. Each of these sides operates upon the double-modulation principle to produce the desired inversion of the order of the channels and inversion of the bands.

Each one-way path of the repeater at Fig. 3 includes two modulators, three filters and, where necessary, an amplifier. In the upper path, for example, the lower group of channels pass through the filter FE_a to the modulator ME_a, where they beat with a carrier of 50 kilocycles from a source S_a. The filter FE_b then functions to select the lower side band resulting from the modulating action, thus resulting in inverting the order of bands in the group, inverting the order of frequencies in the band, and shifting the group of the channels to a higher range in the frequency spectrum (46 to 35 kilocycles). The selected frequencies are then impressed upon the modulator ME_b to beat with the frequency of 31 kilocycles from the source SE_b. The filter FE_c then selects the lower sideband (15 to 4 kilocycles) so that we now have the individual bands inverted and their order in the frequency spectrum inverted, but the group as a whole lies in the same frequency range as it occupied before entering the repeater. It should be noted that in this second modulating operation the selection of the lower sideband did not result in reinverting the order of the bands or the order of the frequencies within a given band, because the

carrier frequency was lower than the frequencies of the various bands. The amplifier AE_c simply serves to amplify the selected bands to any desired level.

The apparatus in the lower one-way path of the repeater is similar to that in the other path, the principal difference being that the filters have different selective ranges and the second modulator MW_b employs a different carrier source from the corresponding modulator ME_b of the other path. Here again the modulator MW_a, together with the filter FW_b, inverts the order of the bands and also inverts the bands themselves, at the same time shifting the group of bands to a position somewhat higher in the frequency spectrum. The shifted bands then beat with the frequency of 5 kilocycles from the source SW_b in the modulator MW_b, and after the selection of the lower sideband by filter FW_c we have the same channels as before in the same frequency range as before, so far as the group is concerned, but the order of the channels has been inverted, and each band has been inverted.

In determining the carrier frequencies to be applied to the first and second modulator in each path, the frequencies are so chosen that the difference between the two frequencies applied to the two modulators of the path will be equal to the sum of the highest and lowest frequencies of the several bands to be modulated. For example, in the case of the upper path, the bands range from 4 kilocycles to 15 kilocycles. The sum of the upper and lower frequencies of the group is therefore 19 kilocycles. The carrier frequency applied to the first modulator is 50 kilocycles, and that to the second modulator is 31 kilocycles, the difference between them being 19 kilocycles. Similarly, in the case of the lower path, the upper and lower frequencies of the group of bands are 28 kilocycles and 17 kilocycles, respectively, so that their sum is 45 kilocycles. The first modulator uses the same carrier frequency of 50 kilocycles as in the upper path. Therefore, the carrier frequency applied to the second modulator must be 5 kilocycles, so that the difference between the two carriers will be 45 kilocycles.

It would be theoretically possible to use a single-modulation method instead of the double-modulation method which is illustrated in Fig. 3, but the use of the latter facilitates the elimination of the unwanted products of modulation by making these fall in an unused part of the frequency spectrum. It may be noted in this connection that in any double-modulation scheme the frequency of the modulating carriers is not fixed but may be chosen so as to minimize undersirable modulation or other effects.

The group inverter to be employed at repeater No. 2 of Fig. 2 is illustrated in Fig. 4 and is somewhat simpler than the arrange-

ment of Fig. 3, as it merely involves one step of modulation for each path of the repeater. Here the group of bands ranging from 15 to 4 kilocycles is passed through the filter FE_a and at the modulator ME_a beats with a carrier frequency of 13 kilocycles to produce an upper sideband in the range between 28 and 17 kilocycles. This upper sideband contains a group of bands of frequencies corresponding to the bands entering the repeater, arranged in the same order in the frequency spectrum but shifted to a higher position. This upper sideband (group of bands) is selected by the filter FE_c and then passed through the amplifier AE_c to the next line section. The arrangement of apparatus in connection with the lower path of the repeater is exactly like that of the upper path except that transmission is in the reverse direction. In connection with this arrangement, it will be obvious that the double-modulation method might also be used instead of the single-modulation method.

In carrying out the arrangement of Fig. 2, channel and band inverters of the type illustrated in Fig. 3 would be used for repeaters Nos. 1 and 3. The direction of transmission for the two, however, would be reversed, that is to say, at repeater No. 1 the left side of the inverter 2 would face west, while at repeater No. 2 it would face east. The terminal apparatus required in the system is evidently the same as for normal operation, and therefore no description is necessary.

It will be clear that the arrangement shown in Fig. 2 provides perfect frequency equalization for a system having four line sections, and that by repetition of this process it could be used for any system having a total number of line sections evenly divisible by 4. Since it may be impractical to lay out systems with line sections in multiples of 4 in many cases, a system accomplishing the same results with two line sections would have decided advantages. The frequency arrangement of such a system is illustrated in Fig. 5, while the type of repeater required for such a system is shown in Fig. 6.

This particular system, as illustrated in Fig. 5, is shown applied to a line circuit having four sections, and this involves the use, at repeaters Nos. 1 and 3, of a type of repeater which performs the functions of inverting the frequencies within each band, inverting the order of the bands in each group, and transposing the groups. The resultant frequency shifts are indicated by the dotted lines in repeaters No. 1 and No. 3 of Fig. 5. It will be seen that the channels are transmitted in their normal relation over the first section of the line and are then completely transposed at repeater No. 1, so that the eastbound group of channels occupies the range formerly occupied by the westbound channels, and vice versa. It will also be noted that

the order of the channels in the group is inverted. The channels are transmitted in their transposed relation from the second and third line sections and then restored to normal at repeater No. 3 for transmission over the fourth line section.

Repeater No. 2 may obviously be an ordinary type of repeater. The type of repeater used at repeaters No. 1 and No. 3, as already stated, is of the so-called "group, channel and band inverter" type. This type of repeater is illustrated in Fig. 6. It involves the same elements as the group inverter illustrated in Fig. 4, with the essential difference, however, that the carrier frequency supplied to the modulator is chosen upon a different principle. This frequency must be made substantially equal to the sum of the lowest frequency of the lowest band of the lower group and the highest frequency of the highest band of the upper group. In the case assumed, this frequency should be in the neighborhood of 32 kilocycles. In the case of Fig. 4 the carrier frequency is made equal to the difference between the two corresponding frequencies in the two groups, for example, the difference between the upper frequency of the lower group and the upper frequency of the upper group.

In the arrangement of Figs. 5 and 6, perfect frequency equalization is accomplished in each set of two line sections, two being of course the minimum number of sections on which this type of equalization may be obtained. The following table gives the frequency allocation of the bands in this system, on the assumption that the same band frequencies are used as before.

Band	Section 1	Section 2	Section 3	Section 4	Average frequency
W_3 -----	25-28	7-4	7-4	25-28	16-16
W_2 -----	21-24	11-8	11-8	21-24	16-16
W_1 -----	17-20	15-12	15-12	17-20	16-16
E_3 -----	12-15	20-17	20-17	12-15	16-16
E_2 -----	8-11	24-21	24-21	8-11	16-16
E_1 -----	4-7	28-25	28-25	4-7	16-16

The arrangements of Figs. 5 and 6 are relatively simple and represent the preferred method of complete frequency equalization in a multi-channel carrier telephone system. It might be thought of as a system in which a number of frequencies are transmitted in such a manner that each occupies a certain position in the available frequency range half of the time and occupies a conjugate position the other half of the time. While shown as applied to a system of four line sections, it can be used with a system having only two line sections, but in this case a repeater of the type used at No. 1 will be employed between the two line sections, and a repeater of the type of No. 3 at one of the terminals. For the purpose of transposing the channels and then restoring the original relation of the

channels when the system is applied to a line having a larger number of sections than four, it may only be necessary to use two special repeaters of the "group, channel, and band inverter" type, the repeaters, interconnecting the other sections, being of the ordinary type. Each of these special repeaters would be alike except that the bands of free transmission of the one repeater will be complementary to those of the other. The alternative cut-off frequencies for the two different locations are indicated in Fig. 6, the values for the one location being indicated in full lines and the values for the alternative location being indicated in dotted lines.

It should be noted that the voice band may be included as one of the channel bands in the arrangement described. A simple application of the frequency equalization principle to a single channel system, of which one band occupies the voice range, (0—3 kilocycles) and the other range from 4 to 7 kilocycles, is illustrated in Figs. 7 and 8. As before, the full line cut-off values for the filters in Fig. 8 are those for the repeater when used in the position of repeater No. 1, while the dotted figures will be the cut-off values of the filters when the repeater is used at the position of repeater No. 3 of Fig. 7. The layout of the system, as indicated in Fig. 7, will be obvious from the description of the previous arrangements, and need not be further described. The system illustrated in Figs. 7 and 8 might be used as a substitute for the regular voice frequency circuit over which it would have the advantage of avoiding the use of line balance at repeater points.

The general principle of the invention is applicable either to carrier telephone or carrier telegraph systems. Figs. 9 and 10 illustrate a carrier telegraph system arranged for frequency equalization. The system is assumed to have eleven channels which employ frequencies 250 cycles apart in the two groups from 3.5 to 6.0 and 7.0 to 9.5 kilocycles. The following table indicates the frequency position of the channels in the different sections:

Channel	Section 1	Section 2	Section 3	Section 4	Average frequency
W ₁₁ -----	9.5	3.5	3.5	9.5	6.5
W ₁₀ -----	9.25	3.75	3.75	9.25	6.5
W ₉ -----	7.25	5.75	5.75	7.25	6.5
W ₈ -----	7.0	6.0	6.0	7.0	6.5
E ₁₁ -----	6.0	7.0	7.0	6.0	6.5
E ₁₀ -----	5.75	7.25	7.25	5.75	6.5
E ₉ -----	3.75	9.25	9.25	3.75	6.5
E ₈ -----	3.5	9.5	9.5	3.5	6.5

In Fig. 9 the upper pair of lines, together with the associated rectangle, represents a group of eleven channels transmitting in one direction while the lower pair of lines and associated rectangle represent the corresponding eleven channels transmitting in the opposite direction. As in the preceding fig-

ures, the letters W and E indicate the direction of transmission. The subscript 11ch indicates that there are eleven channels, and the subscript letter N or I, as the case may be, indicates whether the frequencies involved are in their normal positions in the frequency spectrum or are inverted. The frequency inverter required is similar to those previously illustrated in Figs. 8 and 6, the filter cut-off frequency for repeater No. 1 being indicated in full lines and those for repeater No. 3 being indicated in dotted lines in Fig. 10. The operation of the system will be obvious without further description.

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

What is claimed is:

1. In a carrier system comprising a plurality of frequency bands normally arranged in a given order in the frequency spectrum for transmitting in one direction, a corresponding number of bands also normally arranged in a given order for transmitting in the opposite direction, the method of equalization with respect to frequency, which consists in transmitting the bands in both directions in normal relation over a portion of the transmission circuit, inverting the order in the spectrum of the bands transmitting in one direction, inverting the order of the bands transmitting in the opposite direction, inverting the order of the individual frequencies in each band, transposing the two sets of bands transmitting in opposite directions so that each set occupies substantially the frequency space normally allotted to the other, and transmitting the bands thus inverted and transposed over another portion of the transmission circuit.

2. In a carrier system comprising a plurality of frequency bands normally arranged in a given order in the frequency spectrum for transmitting in one direction, a corresponding number of bands also normally arranged in a given order for transmitting in the opposite direction, the method of equalization with respect to frequency, which consists in transmitting the bands in both directions in normal relation over a portion of the transmission circuit, inverting the order in the spectrum of the bands transmitting in one direction, inverting the order of the bands transmitting in the opposite direction, transposing the two sets of bands transmitting in opposite directions so that each set occupies substantially the frequency space normally allotted to the other, and transmitting the bands thus inverted and transposed over another portion of the transmission circuit.

3. In a carrier system comprising a plurality of frequency bands normally arranged

in a given order in the frequency spectrum for transmitting in one direction, a corresponding number of bands also normally arranged in a given order for transmitting in the opposite direction, the method of equalization with respect to frequency, which consists in transmitting the bands in both directions in normal relation over a portion of the transmission circuit, inverting the order in the spectrum of the bands transmitting in one direction, inverting the order of the bands transmitting in the opposite direction, inverting the order of the individual frequencies in each band, transposing the two sets of bands transmitting in opposite directions so that each set occupies substantially the frequency space normally allotted to the other, transmitting the bands thus inverted and transposed over another portion of the transmission circuit, and then reinverting and retransposing the bands so that they will assume their original positions.

4. In a carrier system comprising a plurality of frequency bands normally arranged in a given order in the frequency spectrum for transmitting in one direction, a corresponding number of bands also normally arranged in a given order for transmitting in the opposite direction, the method of equalization with respect to frequency which consists in transmitting the bands in both directions in normal relation over a portion of the transmission circuit, then beating the frequencies of all the bands transmitting in both directions with a frequency substantially equal to the sum of the highest frequency in the highest band involved and the lowest frequency of the lowest band involved, selecting the difference frequencies resulting from the modulation of each band by said beating frequency, and applying the selected frequencies to another portion of the transmission circuit whereby, during transmission over said portion of the circuit, the frequencies in each individual band will be in inverted order, the bands of each set transmitting in a given direction will be in inverted order, and the two sets of bands transmitting in opposite directions will be transposed.

5. A carrier system comprising a plurality of frequency bands normally arranged in a given order in the frequency spectrum for transmitting in one direction, a corresponding number of bands also arranged in a given order for transmitting in the opposite direction, means for transmitting the bands of both groups in normal relation over a portion of a transmission circuit, means comprising repeater arrangements for inverting the order in the frequency spectrum of the bands transmitting in one direction, inverting the order of the bands transmitting in the opposite direction, at the same time inverting the order of the individual frequencies in each band, and for transposing the two sets of bands trans-

mitting in opposite directions so that each set occupies substantially the frequency space normally allotted to the other, and means to transmit the bands thus inverted and transposed over another portion of the transmission circuit.

6. A carrier system comprising a plurality of frequency bands normally arranged in a given order in the frequency spectrum for transmitting in one direction, a corresponding number of bands also arranged in a given order for transmitting in the opposite direction, means for transmitting the bands of both groups in normal relation over a portion of a transmission circuit, means comprising repeater arrangements for inverting the order in the frequency spectrum of the bands transmitting in one direction, inverting the order of the bands transmitting in the opposite direction, and for transposing the two sets of the bands transmitting in opposite directions so that each set occupies substantially the frequency space normally allotted to the other, and means for transmitting the bands thus inverted and transposed over another portion of the transmission circuit.

7. A carrier system comprising a plurality of frequency bands normally arranged in a given order in the frequency spectrum for transmitting in one direction, a corresponding number of bands also arranged in a given order for transmitting in the opposite direction, means for transmitting the bands of both groups in normal relation over a portion of a transmission circuit, means comprising repeater arrangements for inverting the order in the frequency spectrum of the bands transmitting in one direction, inverting the order of the bands transmitting in the opposite direction, at the same time inverting the order of the individual frequencies in each band, and for transposing the two sets of bands transmitting in opposite directions so that each set occupies substantially the frequency space normally allotted to the other, means to transmit the bands thus inverted and transposed over another portion of the transmission circuit, and means to reinvert and re-transpose the bands so that they will assume their original positions.

8. A carrier system comprising a plurality of frequency bands normally arranged in a given order in the frequency spectrum for transmitting in one direction, a corresponding number of bands also arranged in a given order for transmitting in the opposite direction, means for transmitting the bands of both groups in normal relation over a portion of a transmission circuit, means to beat the frequencies of all of the bands transmitting in both directions with a frequency substantially equal to the sum of the highest frequency in the highest band involved and the lowest frequency of the lowest band involved, means to select the difference frequencies re-

sulting from the modulation of each band by said beating frequencies, means to apply the selected frequencies to another portion of the transmission circuit whereby, during transmission over said portion of the circuit, the frequencies in each individual band will be in inverted order, the bands of each set transmitting in a given direction will be in inverted order, and the two sets of bands transmitting in opposite directions will be transposed.

9. In a multi-channel carrier signaling system, the method of equalizing all channel bands with respect to frequency, which consists in transposing at a single point the frequency location with respect to each other of all of the channel bands transmitted in both directions over the high frequency line circuit.

10. In a multi-channel carrier signaling system, the method of equalizing all channel bands with respect to frequency, which consists in transposing at each of several repeater points the frequency location with respect to each other of all of the channel bands transmitted in both directions over the high frequency line circuit.

11. In a multi-channel carrier signaling system means for transposing the frequency location of all signal bands transmitted over the high-frequency circuit comprising filters to separate the bands transmitted in opposite directions and a modulator for changing the position of each group of bands transmitted in a single direction and for changing the relative position of the bands within each group.

In testimony whereof, I have signed my name to this specification this 21st day of October, 1927.

ESTILL I. GREEN.

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