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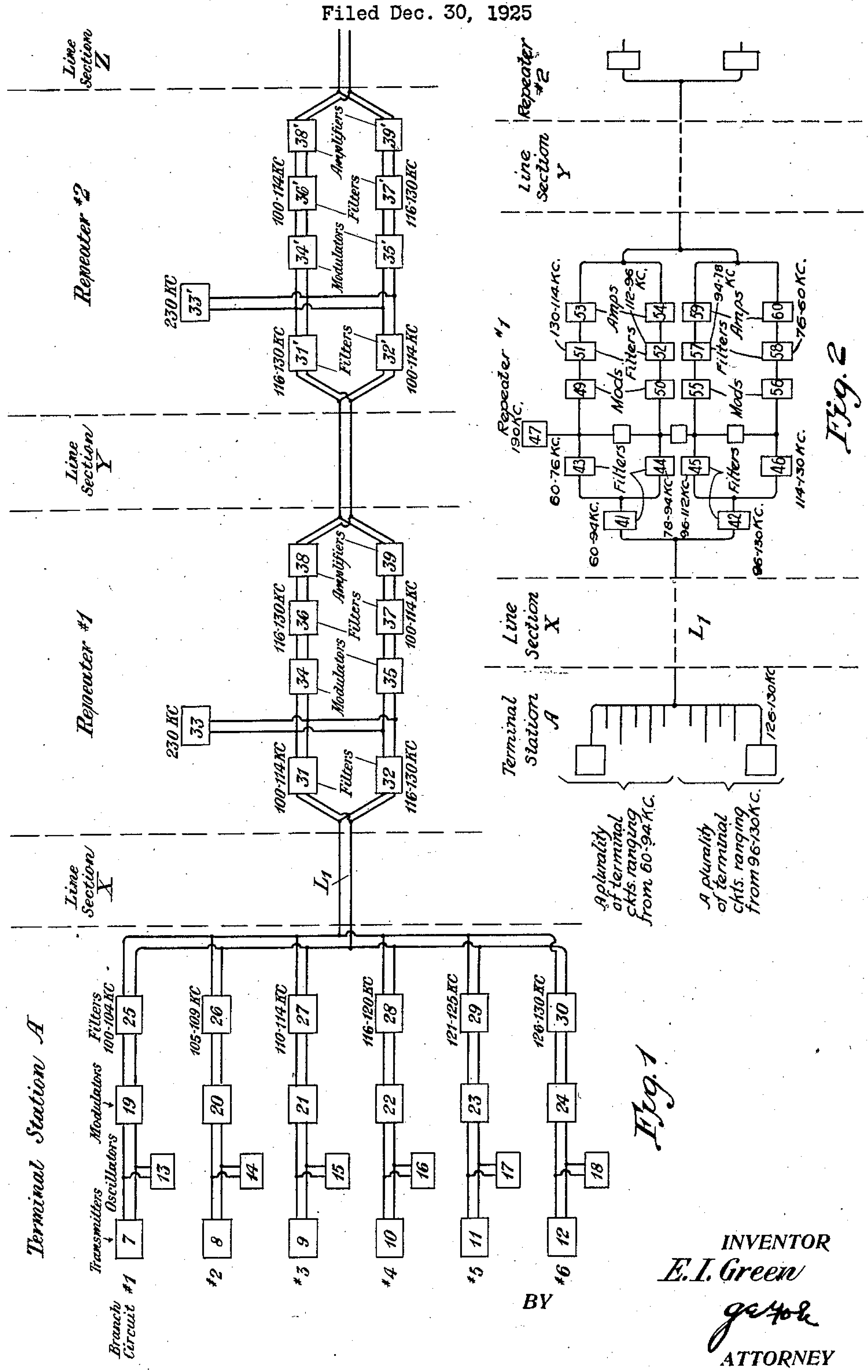

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CARRIER SIGNALING SYSTEM.

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This invention relates to carrier signaling systems, and particularly to a method and means for substantially equalizing the transmission equivalents of a plurality of channels differing in frequency transmitted over or through the same transmitting medium.

In carrier systems having several repeaters, it has been found necesary to equalize the volumes of the various channels before amplifying them at each repeater in order to keep the highest frequency channel (which has the greatest attenuation) above the noise level and at the same time to keep the lowest frequency channel (which has the least attenuation) below the overload point of the repeaters. This equalization of the various channels is ordinarily carried out by means of networks which reduce all channels to the same level at each repeater point. This practice of reducing the volumes of all the channels to substantially the same level, which in practice is the level of the highest frequency channel, is highly inefficient because of the waste of energy of the lower frequency channels.

This invention resides in a method and means for equalizing the transmission equivalents of a plurality of channels of different frequencies transmitted over or through a common transmitting medium, which method consists in inverting the channel frequencies in alternate repeater sections. Such method has distinct advantages over the method heretofore employed in that the present method equalizes the channels with respect to their frequency of transmission, which is the real difference between the channels, rather than with respect to attenuation, which is only a characteristic of the frequency. The equalization of the channels with respect to frequency effectively provides equalization with respect to all the factors which are a function of frequency. such as gain, noise, cross-talk, attenuation variations and other similar functions.

This invention will be clearly understood from the following description when read in connection with the attached drawing of which Fig. 1 shows schematically a form of embodiment of the invention in which the range of frequencies to be transmitted over the common medium is such as to permit the carrying out of the invention by dividing the channels into only two groups; and Fig. 2 shows schematically an arrangement for handling a greater number of groups. In the drawing the line L_1, which represents the medium over which a plurality of channels is transmitted, is made up of a plurality of sections designated X, Y and Z, the adjacent sections being connected through the repeaters, such as Nos. 1 and 2, and the said line being terminated at its ends by a station, such as A. While station A is represented as being adapted only for the transmission of signals, it is to be understood, of course, that it may be readily adapted both for transmission and reception in a manner that is well understood by those familiar with the art. Station A comprises a plurality of branch circuits of which six are shown in the drawing, but the number may vary depending upon the number of channels of communication. Each of the branch circuits comprises a transmitter, as indicated by 7 to 12, a source of carrier oscillations, as indicated by 13 to 18, a modulating device, as indicated by 19 to 24, and a filter, such as is indicated by 25 to 30. The transmitters 7 to 12 may be any device by means of which a modulating current is impressed upon the input side of the modulators to modulate the carrier current from the oscillators. Each oscillator is designed and adjusted to produce a frequency differing from that of the other oscillators.

Considering, for example, branch circuit No. 1, if the transmitter 7 is designed to impress a frequency range from zero to 4 kilocycles upon the input side of the modulator 19 and the oscillator is adjusted to produce 100 kilocycles, the output of the modulator (assuming that it were of the type to suppress the carrier frequency) would comprise two bands, one ranging from 100 to 104 kilocycles and the other ranging from 100 to 96 kilocycles. Assuming single side band transmission, the filter 25 would be adjusted to pass only one band, as, for example, that representing 100 to 104 kilocycles. In like manner, each of the other branch circuits would produce a band of oscillations based upon its individual carrier frequency. Thus circuit No. 2 would produce the band 105 to 109 kilocycles, and the third circuit a band 110 to 114 kilocycles. Circuits 4 to 6, inclusive, would produce three channels ranging from 116 to 130 kilocycles.

All of these frequencies would be impressed upon the line L_1 and transmitted to the repeater No. 1, which comprises the filters 31 and 32, the former passing the frequencies 100 to 114 kilocycles, and the latter the frequencies 116 to 130 kilocycles. These filters are connected with the input circuits of the modulators 34 and 35, respectively, to which are applied oscillations of the carrier frequency from the source 33. The output sides of the modulators are connected with the amplifiers 38 and 39, respectively, the connections including the filters 36 and 37, respectively. The output circuits of the amplifiers are connected with the section Y of the line which extends to repeater No. 2. This repeater is preferably similar to repeater No. 1, and upon the drawing the same parts have at repeater No. 2 been given the same numerals primed. Repeater No. 2 is connected with section Z of the line, which may extend to another repeater or to a terminal station having a plurality of branch circuits, such as A, adapted to receive the channels and to demodulate the frequencies and produce the signal frequency upon each channel.

The principle involved in this invention consists in splitting up the channels into groups at each repeater station and modulating each group by a carrier frequency equal to the sum of the maximum and the minimum transmitted frequencies. This will be made clear by considering a specific case, such as that involved in the transmission of six channels, representing a frequency range of from 100 to 130 kilocycles. These frequencies, which are impressed upon section X of the line, will be attenuated as the result of such transmission, the higher frequencies, of course, suffering greater attenuation than the lower frequencies. It will therefore be apparent that if at the repeater station No. 1 these frequencies are inverted before transmission over section Y of the line, the frequencies having greatest attenuation in section X will have least attenuation in section Y, and vice versa. This desirable result is effected in the following manner:

The frequencies which are present in the channels of transmission are divided at repeater No. 1 into two groups by means of the filters 31 and 32. Thus filter 31 transmits through it the frequencies of 100 to 114 kilocycles, representing channels 1 to 3, and filter 32 transmits frequencies 116 to 130 kilocycles, representing channels 4 to 6. If the intermodulation between frequencies of a group is not serious, it will always be possible to effect the inversion of the frequencies by employing only two groups at each repeater. In case the intermodulation cannot be neglected, the groups must be so chosen that the intermodulation frequencies of any group fall outside that group and the inverted group. If f_1 represents the lowest frequency and f_2 the highest frequency present in the line L_1, inversion of the frequencies may be effected without intermodulation if $2f_1$ is equal to or greater than f_2. Where this condition does not hold, it might be necessary to first divide the channels into two groups and subsequently divide these groups into smaller groups until such a point is reached where the frequencies applied to the repeater branches satisfies the rule just stated. In the case assumed and shown upon the drawing, $f_1=100$ and $f_2=130$. Since $2f_1$ is greater than f_2, that is to say, greater than 130, we can obtain the proper inversion by division of the channels into two groups, as shown in the drawing. If these groups be beaten with the same carrier frequency which is equal to the sum of the lowest frequency in any group and the highest frequency in any group, and the difference frequency is selected from each beating operation, it will be found that the frequencies of the channel have been inverted. Thus when the group representing 100 to 114 kilocycles, which may be termed the low frequency group in the line section X, is beaten with 230 kilocycles, the difference frequencies, namely the group represented by 116 to 130 kilocycles, are the same as the higher frequencies transmitted over the section X, and in like manner, when the group represented by 116 to 130 kilocycles is beaten with 230 kilocycles and the difference frequencies are selected, the resultant frequencies, namely, 110 to 114 kilocycles, are the same as the frequencies of the lowest channels transmitted over section X. In other words, the repeater has inverted the frequencies of the channels. These frequencies are given the required amount of amplification by 38 and 39 and transmitted over section Y to repeater No. 2. At the latter repeater a similar translation process takes place by which the high frequencies present in section Y are changed to low frequencies, and the low frequencies to high frequencies. It will thus be seen that the channels designated 1 to 3, which are relatively low frequencies in section X, become high frequencies in section Y, and in like manner channels 4 to 6, which are of relatively high frequencies in section X, become low frequencies in section Y. By means of this frequency translation or inversion in a plurality of sections of the line, the equivalents of the various channels may be made substantially the same. With the frequency assumed in the foregoing instance no interference will be produced by the intermodulation of the frequencies, so that the inversion may be cared for by a single division of the channels into two groups. If, however, the frequencies of the channels ranged, for example, from 60 to 130 kilocycles, it would be necessary to employ a greater number of dividing processes to prevent intermodulation, such as is shown schematically in Fig. 2. In such system the line L_1 would be connected at repeater 1 with two branches having filters 41 and 42 capable of dividing the entire range of frequencies into two groups, one extending from 60 to 94 kilocycles, and the other from 96 to 130 kilocycles. Since in the first group the frequency 60 is more than half of 94, the inversion of this group may be effected by dividing the group into two sub-groups, by means of the filters 43 and 44 the former of which passes the frequencies between 60 and 76 kilocycles and the latter the frequencies between 78 and 94 kilocycles. Since the lowest frequency of all the channels being transmitted over the system is 60 kilocycles and the highest is 130 kilocycles the beating frequency employed is the sum of those frequencies, namely, 190 kilocycles. This is provided by an oscillator 47 which is connected with the several branch circuits through filters or circuits tuned to the beating frequency which permits the passage of the beating frequency to the branch circuits but prevents interaction between those circuits. The channels between 60 and 76 kilocycles pass through the modulator 49 together with the beating frequency of 190 kilocycles, and the difference frequencies resulting from modulation, which range from 130 to 114 kilocycles, are passed by the filter 51, amplified by the amplifier 53, and are passed to the line section Y. In like manner, the group of frequencies extending from 78 to 94 kilocycles will be beaten with 190 kilocycles in the modulator 50, and the difference frequencies, namely, those extending from 112 to 96 kilocycles, will be passed by the filter 52, amplified by the amplifier 54, and passed to the line. It will be seen that the group of frequencies that was lowest in the frequency scale of all the frequencies transmitted over the line section X now occupies the highest position in the frequency scale. Similarly, the group ranging from 78 to 94 kilocycles, which was next to the lowest in transmission over section X, now occupies the position next to the highest in the frequency scale in transmission over section Y. In like manner the group of frequencies ranging from 96 to 130 kilocycles, which is passed by the filter 42, is subdivided into two groups by the filters 45 and 46 and the frequencies present in each group are beaten with 190 kilocycles supplied by the oscillator 47. The difference frequencies resulting from modulation are passed by the filters 57 and 58 and amplified by amplifiers 59 and 60, respectively. It will be seen that the group ranging from 114 to 130 kilocycles, passed by the filter 46, has, by the process of modulation and selection, become the lowest in the frequency scale of all the groups transmitted over section Y, occupying the range from 76 to 60 kilocycles. In like manner the group ranging from 96 to 112 kilocycles in transmission over section X, ranges from 94 to 78 kilocycles in transmission over section Y. The selected frequencies will be brought together again and transmitted over section Y to repeater No. 2 wherein a similar process would restore the channels to the frequencies possessed by them in section X. While the frequencies assumed for the purpose of describing this invention may seem to range fairly high, such frequencies are not incapable of employment in telephone systems and may be readily employed in carrier communication over power circuits. It is, of course, obvious that any frequencies may be employed without exceeding the scope of the invention.

While this invention has been disclosed as embodied in particular forms, it is capable of embodiment in other and different forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. The method of equalizing transmission of a plurality of carrier channels transmitted over or through the same medium, which consists in dividing the channels into two groups, beating the frequencies in each group by a frequency equal to the sum of the lowest and the highest frequencies in both groups, selecting the frequencies representing the difference between the beating frequency and the frequencies in each group, and impressing upon the same transmitting medium the resulting frequencies as selected.

2. The method of equalizing transmission of a plurality of carrier channels transmitted over or through the same medium, which consists in separating by filtering the said channels to form two groups, one consisting of the higher frequencies and the other the lower frequencies, separately beating each group of frequencies by the same beating frequency which equals the sum of the lowest frequency and the highest frequency present in the channels, selecting the difference frequencies resulting from each beating operation, amplifying the selected frequencies in each group, the degree of amplification of the higher frequencies being greater than the lower frequencies, and recombining the frequencies for transmission over the said medium.

3. The method of equalizing transmission of a plurality of carrier channels transmitted over or through the same medium, which consists in dividing the channels into two groups, changing the frequencies of the first group into those of the second group, and vice versa, by beating separately the frequencies in the two groups by a frequency equal to the sum of the lowest and highest frequencies in both groups, amplifying the

frequencies of both groups as thus translated, and impressing the amplified frequencies upon a common transmitting medium.

4. The method of equalizing transmission of a plurality of carrier channels transmitted over or through the same medium, which consists in transmitting over or through a common medium a plurality of channels of different frequencies which attenuates the channels to different degrees, separating the said channels into two groups by filtering, separately beating the groups of channels by a frequency which equals the sum of the lowest and the highest frequencies in both groups, selecting the difference frequencies resulting from the beating operations, separately amplifying to different degrees each group of selected frequencies, and recombining the groups as thus amplified.

5. The method of equalizing transmission of a plurality of carrier channels transmitted over or through the same medium, which consists in dividing the channels into such a number of groups that the highest frequency in any group shall be at least twice as large as the lowest frequency in the said group, beating the frequencies in two adjacent groups by the sum of the highest and lowest frequencies present in both groups, selecting the difference frequencies of the said beating operation, and amplifying the selected frequencies in each group, the degree of amplification being in accordance with the relative position of the said frequencies in the frequency spectrum, and combining the frequencies as thus amplified.

6. In a carrier signaling system, the combination with a terminal circuit comprising a plurality of branches, each having a source of carrier current, the frequency of which differs from that of the others, a source of signaling current to modulate the said carrier, a transmission circuit connected with the said terminal circuit and common to all of said branches, and a repeater comprising two branches each having a filter, a modulator and an amplifier, and a source of beating oscillations, the frequency being the same for both branches and equal to the sum of the lowest frequency and the highest frequency present in all channels.

7. The method of equalizing the transmission equivalents of a plurality of carrier channels which consists in transmitting a plurality of channels of different frequencies, separating the said channels into a plurality of groups, the number of which will be such that the lowest frequency in any group shall be equal to or greater than half of the highest frequency in that group, separating the channels in each group into two sub-groups and separately beating the channels in each sub-group with a beating frequency equal to the sum of the lowest and the highest frequency in each pair of sub-groups, selecting the difference frequencies resulting from each beating operation, amplifying and transmitting the selected frequencies.

8. In a carrier signaling system, the combination with a transmission line of a repeater inserted between sections thereof, a source of a plurality of channels connected with the said line, said repeater comprising a plurality of branch circuits connected with the said line having mutually exclusive filters, one adapted to pass the lower range of frequencies and the other the higher range, each branch having a modulator and a filter connected with the output thereof, and a source of beating oscillations connected with the input sides of both modulators, the frequency of the said beating oscillations being equal to the sum of the lowest and the highest frequencies in all channels.

9. In a carrier signaling system, the combination with a transmission line of a repeater inserted between sections thereof, a source of a plurality of channels connected with the said line, said repeater comprising a plurality of branch circuits connected with the said line having mutually exclusive filters, one adapted to pass the lower range of frequencies and the other the higher range, each branch having a modulator and a filter connected with the output thereof, a source of beating oscillations connected with the input sides of both modulators, the frequency of the said beating oscillations being equal to the sum of the lowest and the highest frequencies in all channels, and means connected with each branch circuit to amplify the frequencies transmitted by the respective filters.

In testimony whereof, I have signed my name to this specification this 29th day of December, 1925.

ESTILL I. GREEN.