April 28, 1931. E. I. GREEN 1,802,420

METHOD OF UTILIZING A WIDE FREQUENCY RANGE FOR SIGNALING CHANNELS

Filed Jan. 30, 1930 2 Sheets-Sheet 1

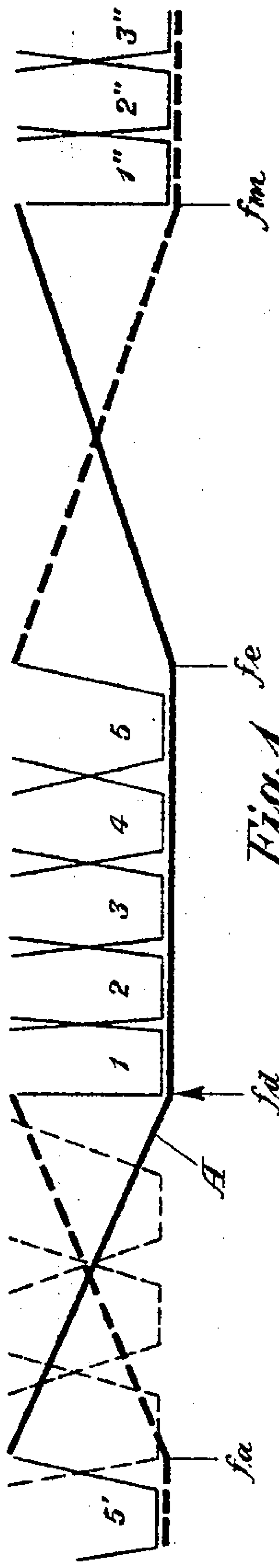

Fig. 1

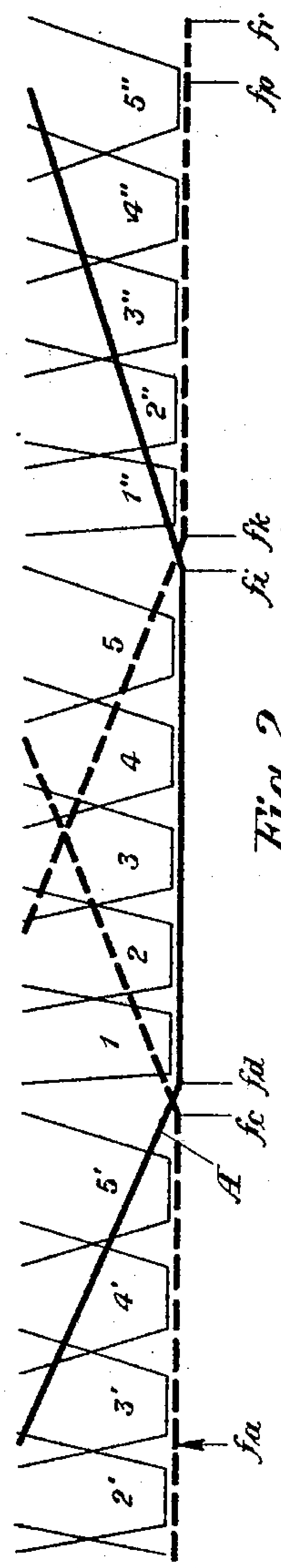

Fig. 2

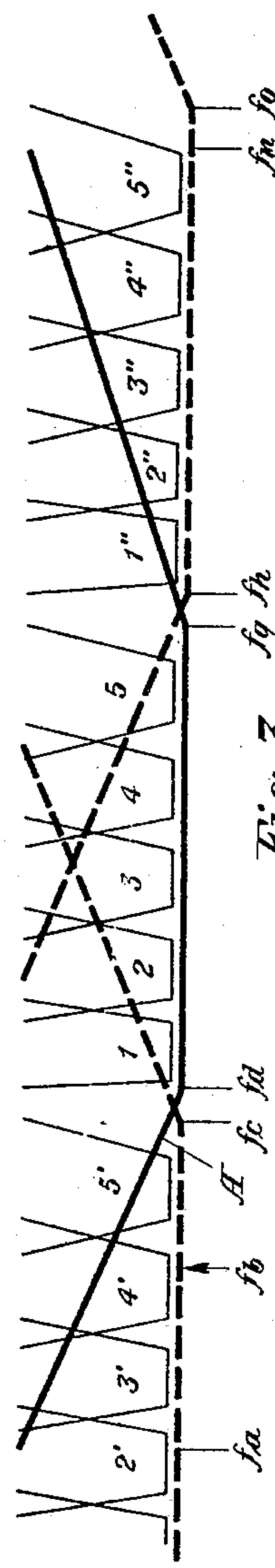

Fig. 3

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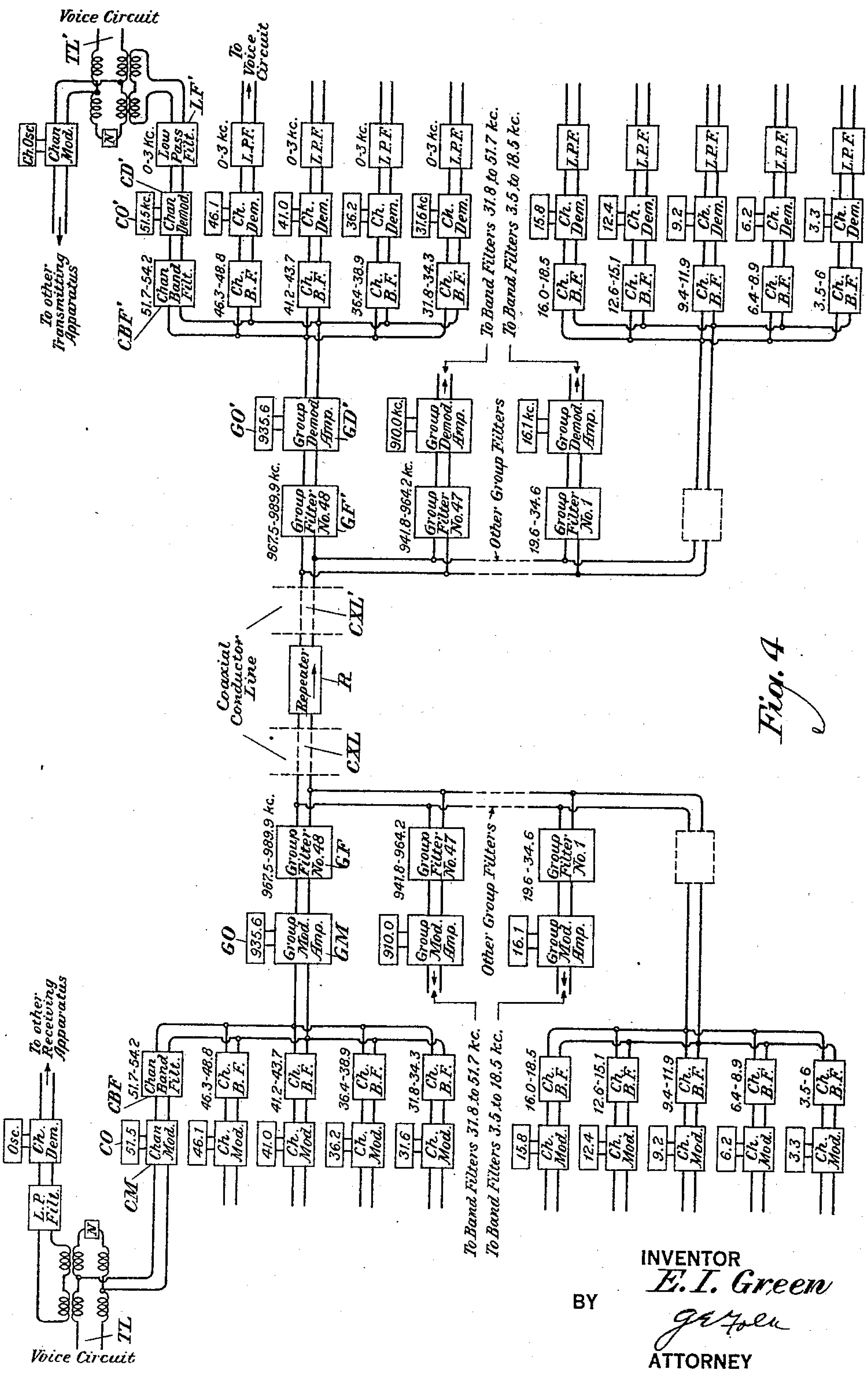

Fig. 4

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METHOD OF UTILIZING A WIDE FREQUENCY RANGE FOR SIGNALING CHANNELS

Application filed January 30, 1930. Serial No. 424,676.

This invention relates to transmission systems capable of transmitting such a wide range of frequencies that a large number of signaling channels may be carved out of the available range by employing different carrier frequencies.

It has been proposed that a circuit comprising two coaxial conductors be utilized for the transmission of a wide range of frequencies, and that this range be employed either for television purposes or for ordinary telephone or telegraph channels. Where such a wide range of frequencies is to be divided up among a number of signaling channels the problem of selecting between the different channels at the terminals becomes one of considerable difficulty because of the high frequencies involved.

Various terminal arrangements for selecting between the channels have been proposed. It has been proposed, for example, to select each channel from the other channels at high frequency and regardless of its position in the frequency spectrum by means of a filter individual to the channel, as is done in ordinary carrier telephony over open wire lines. Another scheme is to divide the channels into groups occupying a considerably larger frequency range than a single channel and at the receiving terminal select a wanted group from all of the other groups by means of a high frequency filter. The selected group is then stepped down in the frequency range to a part of the spectrum as near zero frequency as possible and then the individual channels in the group are selected from each other at low frequency, the signals being finally detected from the channels after selection.

As will be shown later, the first of these methods is very wasteful of the available frequency spectrum by reason of the fact that for channels high in the frequency spectrum a greater separation or dead space must be left between channels in order to obtain sufficient discrimination near the filter cut-offs than is required for channels low in the frequency spectrum. The second of the two methods enables the channels in each group to be closely spaced regardless of the location of the group in the frequency spectrum because the ultimate selection as between channels occurs at low frequency.

Even with the second method, however, there is a considerable waste of frequency space for separating the different groups because the selection of the group occurs at high frequency, with the consequence that the filter cut-offs are not sharp enough to permit the neighboring channels of adjacent groups to be brought very close together.

In accordance with the present invention it is proposed to overcome this difficulty by using the high frequency filters merely to roughly select a given group, permitting partially suppressed channels from adjacent groups to be passed through the filter along the sides of the filter characteristic lying without the nominal cut-off point. The channels thus selected are demodulated by beating with a carrier frequency so chosen that the partially suppressed and unwanted channels along the sides of the cut-off characteristic will not lap over upon the channels of the wanted band after demodulation. By selecting the channels of the desired group after such demodulating operation the relatively sharp characteristics of the low frequency filters of the individual channels will suppress the already partially suppressed, and demodulated channels corresponding to the unwanted group. This method of selection enables the adjacent channels of two adjacent groups to be approximately as closely spaced as adjacent channels in the same group.

In order to prevent the unwanted and partially suppressed channels from lapping over into the range of the wanted group after the first demodulating operation it is necessary that the beating carrier frequency be some distance below the lower nominal cut-off frequency of the high frequency filter. For example, if the beating frequency is located below the lower nominal cut-off point of the high frequency filter at the point where the sloping side of the filter characteristic produces a sufficient suppression to reduce transmission below the crosstalk limit, the lowest channel of the wanted group will, after demodulation, be above zero frequency in the frequency spectrum by a frequency range equal to the frequency difference between the beating frequency and the nominal cut-off point of the high frequency filter. This necessarily involves a somewhat greater separation between the individual channels of the group because the low frequency selection between channels takes place at a somewhat higher point in the frequency spectrum.

In order to bring the wanted channels down closer to zero frequency for final selection, the present invention involves, as a further refinement, the location of the beating frequency for the first demodulating operation at a point substantially half-way between the lower nominal cut-off point of the high frequency filter and the point along the sloping side of the filter characteristic where it suppresses the corresponding frequency to a value lower than the crosstalk limit. This results in a doubling up or overlapping upon each other of the frequencies lying to either side of the beating frequency and along the sloping side of the high frequency filter characteristic without such frequencies lapping over into the range above the nominal cut-off point of the filter. As the lowest channel of the desired group will, after demodulation, be located only half as high above zero frequency as in the case previously discussed, the individual channels in the group may be somewhat more closely spaced than in the previous case.

The invention will now be more fully understood from the following description when read in connection with the accompanying drawings, Figures 1, 2 and 3 of which are curves illustrating the principles of the invention and Fig. 4 of which is a schematic circuit arrangement embodying the invention.

In order to better visualize the invention, let us compare two types of terminal arrangements for selecting channels, the first type involving individual channel selection at high frequency with a receiving band filter or selector for each channel, the filters of all of the channels being connected together, and the second type of terminal arrangement involving dividing the entire frequency range into groups of channels with high frequency filters for selecting a desired group at high frequency, the selected group then being brought by demodulation approximately to the bottom of the frequency spectrum, whereupon the individual channels are selected by low frequency filters, after which the individual signals may be detected from each channel.

Before proceeding with the analysis of these two schemes, it will be desirable to consider a general principle and a formula in connection with the division of frequency ranges. With present technique it may be said in general that whenever it is desired to separate two bands or groups of frequencies by means of filters a certain unused frequency interval or "dead space" must be left between the two bands in order to obtain sufficient discrimination near the filter cut-offs. The amount of this "dead space" may be specified in terms of the nominal cut-off frequencies of these filters. It is more convenient, however, and probably sufficiently correct for present purposes, to say that the "dead space" is a certain fraction, s, of the maximum frequency of the lower of the two bands.

Suppose now that it is desired to place frequency bands of width, w, above a certain minimum frequency, m. The maximum working frequency for one band is evidently:

$$B_1 = m + w \quad (1)$$

for two bands the maximum frequency is:

$$B_2 = m + w + s(m + w) + w$$

so that—

$$B_2 = m(1+s) + w(2+s) \quad (2)$$

Similarly for three bands we require a maximum frequency of—

$$B_3 = m(1+2s+s^2) + w(3+3s+s^2) \quad (3)$$

The maximum frequency for n bands can be shown to be:

$$B_n = m(1+s)^{n-1} + \frac{w}{s}\left[(1+s)^n - 1\right] \quad (4)$$

This last formula is a very useful instrument in the study of methods of separating frequency bands.

Let us now proceed to analyze the two methods of handling a wide range of frequencies at the terminals. Let it be assumed for concreteness that a clear frequency range of 1,000,000 cycles is available for transmission in each direction, this range being exclusive of space necessary for the filters which separate the opposite directions of transmission. If it be assumed that the upper range can be reduced in frequency or that separate circuits will be used for transmission in opposite directions, it is sufficient to consider only the range from approximately 0 to 1,000,000 cycles which is available for one direction of transmission. The problem is to determine what will happen if each of the different methods is applied in connection with this frequency range.

Consider first the band filter or single modulation method. In the first place, it may be noted that with present filter technique the separation space necessary between band filters for bands transmitted in the same direction is roughly .06 times the maximum frequency of the lower band. Let us assume that the necessary frequency width in each channel is 2,500 cycles. The value of the minimum frequency m may be taken as 3,500 cycles. Although the precise values assumed may be open to some question, they are of value in giving the problem a quantitative basis. Substituting these values in Formula (4), we find that the number of channels derivable by the band filter method from a total frequency range of 1,000,000 cycles is only 54. This means that the frequency range is being used at an efficiency of only

$$\frac{54\times 2500}{1,000,000},$$

or 13 per cent.

We now come to the second scheme in which double modulation is employed. It will be recalled that the principle embodied in this second scheme is that of dividing a complete range (for one direction of transmission) into groups and that these groups after being brought near to the bottom of the frequency scale are divided by means of the individual channel band filters. It is not essential to this scheme that the number of channels be the same for each group. It is convenient, however, to assume that this is the case. Fortunately, the maximum number of channels obtainable is not appreciably effected by this assumption. If the number of channels to be put in each group is known, the frequency band required for the group may be determined by Formula (4). The number of groups that can be placed in a range of 1,000,000 cycles may then be determined with the aid of the same formula. Considering the interval between groups, however, there may be some question as to whether the selectivity fraction should not be modified. One reason for this is that the space used for separation between groups at the terminals may also be used in dividing up the range for amplification at repeater points. Accordingly, it is of interest to assume, first, that sufficient space between groups is obtained when $s=.06$, and second, that the value of s should be .12.

As has been noted, the total number of groups can be found if the number of channels per group is known. The product of the two which is the total number of channels available, will vary according to the number of channels per group and will reach a maximum for a particular value of channels per group. By successive computations for different number of channels per group, the optimal value is found. When s has a value of .06 for both the grouping and the channel filters, it appears that the number of channels is a maximum when about 10 channels are assigned to each group. The width of each group is about 35,000 cycles, the number of groups is 17, and the total number of channel bands is 170. When $s=.12$ for the grouping interval, the most favorable number of channels per group is 18, the width of each group is about 83,000 cycles, the number of groups is 8, and the total number of channels is 144. The frequency range is used at an efficiency of 42 per cent. in the former case and 36 per cent. in the latter case. Thus, we have increased the efficiency over that of scheme (1) by about 25 or 30 per cent.

In order to obtain the foregoing spacing of the channels, it has been assumed that the band constituting a desired group of channels is completely selected by the first selecting operation at high frequency before the first demodulation. In order to obtain the closest spacing between individual channels of the same group, it has been assumed that the carrier or beating frequency for the first demodulating step is located at the lower nominal cut-off point of the high frequency group selecting filter, so that the lowest channel of the desired group will after demodulation be as close as possible to zero frequency.

Such an arrangement is illustrated by the curves of Fig. 1 where the heavy line curve A represents the attenuation characteristic of a high frequency filter having nominal cut-off points at f_d and f_e, the filter serving to select channels 1, 2, 3, 4 and 5 of a group from the nearest adjacent channels, such as 5′ and 1″, of two adjacent groups. The individual channels are represented by the filter characteristics of the corresponding low frequency filters which are to be ultimately used to separate the individual channels of a group after first being demodulated to the lower part of the frequency spectrum. With respect to the characteristic A of the high frequency filter for selecting the desired group, and also with respect to the characteristics (shown in heavy dotted lines) of the high frequency filters for selecting the adjacent groups, it will be noted that the sloping sides outside the nominal cut-off points are relatively flat because the selection takes place at high frequency. Consequently, in the case of the filter characteristic A, the nearest channel 5′ of the group immediately below the desired group must be spaced such distance away from the cut-off frequency f_d that any frequencies of the channel 5′ passing through the filter A will be below the crosstalk limit.

Assuming that the crosstalk limit on the lower sloping side of the filter A is at the frequency f_a, and that the carrier frequency for demodulation be located at frequency f_d, it will be evident that if any individual channels such as indicated in dotted lines, are included in the range between f_a and f_d, such channels will be lapped over into the range of the channels 1 to 5 inclusive, as a result of the first demodulating operation which brings the channel 1 as nearly as possible to the zero frequency range. In order to prevent this overlapping of unwanted frequencies from adjacent groups into the range of the desired group after demodulation, it is necessary to provide a wasted frequency space, such as the range f_a to f_d, between the desired group and the nearest group below.

A somewhat wider spacing f_e to f_m will be required between the desired group and the nearest group above, this wider separation being due to the fact that at this point the selection takes place higher in the frequency spectrum.

By having the beating frequency located at the lower cut-off point of the filter A the desired channels of the group will, after demodulation, be located as close as possible to the zero frequency point, with the result that the channels of the group will have the closest possible frequency separation. It will also be noted from the filter curves of the channels 1 to 5 inclusive that the spacing between the channels increases as the channels go up in the frequency range. This spacing is determined, however, by the position of the channel in the frequency range after the first demodulation, and hence is much closer than is possible between adjacent groups at high frequency. Furthermore, the sloping sides of the filter characteristics of the channels 1 to 5 inclusive are much more nearly vertical than in the case of the high frequency filter A, as these characteristics represent the characteristics of the low frequency filters after the channels have been stepped down by demodulation.

In accordance with the present invention it is proposed to reduce the separation between groups, as shown in Fig. 1, at the expense of a slightly greater separation between the individual channels of the group. This is accomplished by depending upon the high frequency filter to effect only a rough selection of the desired group, thus permitting channels of adjacent groups to be partially transmitted along the sides of the filter characteristic, and then stepping down the group by a properly chosen beating frequency, so that after demodulation the partially suppressed channels of the adjacent groups will be completely eliminated by the selectivity of the individual channel filters which are effective at relatively low frequencies.

In order to accomplish this result the location of the beating frequency with respect to the nominal cut-off of the group band filter is important. Fig. 2 shows the principle underlying one arrangement in accordance with the invention. Here the characteristic of a high frequency band filter is shown at A, this band filter passing at high frequencies the group of channels designated 1 to 5, inclusive. The sloping sides of the filter characteristic A partially pass channels such as 3′, 4′ and 5′ of an adjacent group which, in this case, is crowded much more closely to the nominal cut-off frequency f_d of the filter whose characteristic is shown at A. The suppression for channels in the adjacent group increases with the distance of the channel from the chosen group, so that the frequencies falling within channel 3′ are suppressed much more than the frequencies of channel 5′, for example.

Instead of locating the beating frequency at the lower nominal cut-off point f_d of the group filter as in the case of Fig. 1, the carrier frequency may be located at f_a, which is the point at which the sloping side of the filter characteristic suppresses the transmission below the allowable crosstalk limit. Consequently, when the various frequencies passed by the group selecting filter are demodulated by the beating frequency none of the unwanted frequencies between f_a and f_d will lap over onto the desired channels 1 to 5, inclusive. After demodulation the channel frequency corresponding to f_a will be stepped down approximately to zero, and consequently the frequency f_d corresponding to the lower nominal cut-off point of the high frequency group filter will be stepped down to a frequency equal to $f_d - f_a$ instead of to zero frequency, as in the case of Fig. 1. It follows, therefore, that channel 1, instead of being stepped down to a point as near as possible to zero frequency, is somewhat above zero frequency, with the result that the desired channels 1 to 5, inclusive, must be spaced somewhat further apart than in the case of Fig. 1 to allow for the fact that the low frequency selection takes place somewhat higher in the frequency spectrum. Notwithstanding that the width of the group is greater than in the case of Fig. 1, a large number of channels may be carved out of the available frequency spectrum due to the fact that the channels of the adjacent groups can be permitted to approach along the sides of the filter characteristic A toward the nominal cut-off points f_d and f_i. No appreciable interchannel interference results from this due to the fact that the low frequency filters corresponding to 1 to 5, inclusive, will, by their relatively sharp characteristics for low frequency selection, effectively eliminate the frequencies of channels of adjacent groups which fall within the sloping sides of the high frequency filter characteristic.

The outstanding advantage of the arrangement just described is that the frequency separation or "dead space" between groups need not be as great as in the arrangement of Fig. 1. While, as shown in Fig. 2, neighboring channels of adjacent groups are spaced somewhat further apart than adjacent channels within a given group, this is not necessary in order to obtain the desired selectivity and is merely so shown in this instance in order to make more clear from observation of the diagram the arrangement of the channels in groups. In actual practice neighboring channels of adjacent groups may be substantially as closely spaced as neighboring channels within the group.

The disadvantage of the arrangement is that the beating frequency cannot be at the lower nominal cut-off point of the group filter as in Fig. 1, but must be some distance below as otherwise there will be some overlapping of the partially suppressed unwanted channels of the group below and the desired channels which lie between the nominal cut-off points of the filter. This limitation on the location of the beating frequency renders it impossible to step the group down as low in the frequency spectrum for final selection as in the case of Fig. 1, and hence the individual channels of the selected group must be spaced somewhat further apart. An alternative arrangement which permits as close spacing between groups as in the case of Fig. 2 but which permits of somewhat closer spacing of the channels within a group, is shown in Fig. 3.

In this figure the beating frequency, instead of being located at f_a where the suppression of the filter whose characteristic is shown at A is sufficient to bring the transmission below the allowable crosstalk limit, is located at f_b about half-way between the frequuency f_a and the lower nominal cut-off frequency f_d of the filter. After demodulation the frequencies between f_a and f_b overlap upon the frequencies between f_b and f_d, so that in effect the unwanted channels lying along the side of the filter characteristic between f_a and f_d are doubled or folded over upon each other without overlapping into the range of the desired channels 1 to 5, inclusive. After demodulation channel 1 will only be spaced above zero by an amount approximating f_d-f_b instead of by an amount approximating f_d-f_a, as in Fig. 2. Selection of individual channels of the desired group will, therefore, take place somewhat lower in the frequency spectrum in the case of Fig. 3 than in the case of Fig. 2, permitting of somewhat closer spacing of the channels in each group. As before, the relatively sharp characteristics of the individual channel filters operating at low frequency are effective to suppress any channels of adjacent groups which were partially transmitted due to the upper and lower sloping sides of the high frequency filter characteristic A.

It will be obvious from a comparison of Figs. 1, 2 and 3 that the arrangements of Figs. 2 and 3 reduce the "dead space" between groups by a very large factor. On the basis of the same assumptions as were used in determining the number of channels available in a given frequency space by employing the arrangement of Fig. 1, it is estimated that the number of channels obtainable from a band of 1,000,000 cycles by using the arrangement of Fig. 3 will be about 245 as compared with 170 for the arrangement of Fig. 1. The efficiency with which the frequency range is utilized is about 61 per cent. for the arrangement of Fig. 3 as compared with about 42 per cent. for the arrangement of Fig. 1.

Fig. 4 is a diagram of a possible arrangement of terminal apparatus for applying the method of Fig. 3 to a coaxial conductor system which permits transmission up to 1,000,000 cycles. For convenience it has been assumed that four-wire operation will be used, with a separate coaxial circuit for each direction of transmission. This, of course, is not essential to the scheme. It is also assumed that the channels will be arranged in groups of five channels each and that only two steps of demodulation or modulation (one for each group and one for each channel) will be employed. In all cases a frequency interval of .06 times the nominal cut-off frequency is assumed necessary to attain the desired suppression of unwanted frequencies. The scheme provides 49 groups of five channels each, or a total of 245 channels, in a frequency band from about 3.5 to 990 kilocycles. The corresponding frequency allocations are given in the following table:

Group No.	Low frequency position	High frequency position	Location of group carrier
	k. c.	*k. c.*	*k. c.*
0	3.5-18.5	3.5- 18.5	0
1	do	19.6- 34.6	16.1
2	do	35.7- 50.8	32.2
3	do	51.9- 66.9	48.4
4	do	68.0- 83.0	64.5
5	do	84.1- 99.1	80.6
6	do	100.2-115.2	96.7
7	do	116.4-131.4	112.9
8	6.4-22.1	132.5-148.2	126.1
9	do	149.6-165.2	143.2
10	do	166.7-182.4	160.3
11	do	183.8-199.5	177.4
12	do	200.8-216.6	196.4
13	9.4-25.9	217.9-234.5	208.5
14	do	236.0-252.6	226.7
15	do	254.3-270.8	244.9
16	do	272.4-288.9	263.0
17	do	290.5-307.0	281.1
18	12.6-30.0	308.6-326.0	296.0
19	do	327.8-345.2	315.2
20	do	347.0-364.4	334.4
21	do	366.2-383.6	353.6
22	do	385.4-402.8	372.8
23	16.0-34.3	404.6-422.9	388.6
24	do	425.0-443.3	409.0
25	do	445.3-463.6	429.3
26	do	465.7-484.0	449.7
27	do	486.0-504.3	470.0
28	do	506.4-524.7	490.4
29	do	526.7-546.0	510.7
30	19.6-38.9	548.3-567.5	528.7
31	do	570.0-589.2	550.4
32	do	591.6-610.0	571.9
33	do	613.1-632.4	593.5
34	do	634.7-653.9	615.1
35	23.5-43.7	656.3-676.5	632.8
36	do	679.1-699.4	655.7
37	do	702.0-722.3	678.6
38	do	724.9-745.1	701.4
39	do	747.7-768.0	724.3
40	27.5-48.9	770.6-791.9	743.1
41	do	794.9-816.2	767.4
42	do	819.1-840.4	791.6
43	do	843.3-864.7	815.9
44	do	867.6-888.9	840.1
45	do	891.8-913.1	864.3
46	31.8-54.2	916.1-938.5	884.3
47	do	941.8-964.2	910.0
48	do	967.5-989.9	935.6

By increasing the number of channels in each group it would be possible to effect a substantial reduction in the number of grouping filters and group demodulators or modulators, but this would be obtained at the expense of a decrease in the total number of channels. Conversely, a decrease in the number of channels per group would increase the total number of channels at the cost of a great increase in the apparatus required. In the extreme case in which only one channel might be assigned to a group, a total of two demodulators or modulators and two filters would be needed per channel at each terminal. This compares with a requirement of about 1.2 demodulators or modulators and 1.2 filters per channel when groups of five channels each are used. It is thought that the assignment of from five to ten channels to each group represents a reasonable compromise between the desire to avoid too great complexity of apparatus and the desire to obtain the maximum number of channels.

The circuit arrangement shown in Fig. 4 is readily understood. Voice currents transmitted over an ordinary low frequency line TL, for example, pass from a hybrid coil into a channel modulator CM which is supplied with a carrier frequency from a source CO. The desired sideband (or bands) is passed through a channel band filter CBF and is combined with similar channel bands from other channel band filters of the group. The bands corresponding to the group of channels are then applied to a group modulator GM (which may include amplifying apparatus), the group modulator being supplied with a carrier frequency from a source GO for the purpose of stepping the group of channels up in the frequency spectrum. The stepped-up channels are then passed through the group filter GF and applied with groups from other group filters to a common circuit, such as a coaxial conductor line CXL of any known type. Intermediate repeaters may be provided in the line at one or more points, as shown at R, for amplifying the frequencies transmitted over the line. The several groups received from the distant end of the coaxial conducting system CXL′ are then selected by the group filter, such as GF′. The group of channels selected by a given high frequency or group filter is then applied to a group demodulator GD′ supplied with a beating frequency from a source GO′, the beating frequency being located with respect to the channels of the group, as shown in Fig. 3, so that the channels of the group may be stepped down as near to zero frequency in the frequency spectrum as is possible without causing interlapping with neighboring channels of an adjacent group. The particular channel which is desired is, after demodulation, selected by a channel band filter, such as CBF′, and the final signal band is detected by a suitable channel demodulator CD′ which may, if desired, be supplied with a carrier frequency from a source CO′ corresponding to the original carrier from the source CO at the sending end. A low pass filter LF′ is provided to suppress harmonics and high frequencies from the desired signal band which is then impressed upon the outgoing voice circuit TL′.

For transmission in the opposite direction, that is from TL′ to TL, the transmission passes through a channel modulator shown in the upper right hand corner of the diagram and thence through other transmitting apparatus similar to that already described in connection with the line TL. After passing over another coaxial conducting arrangement similar to that illustrated, the channel will pass through receiving apparatus similar to that associated with the receiving end of the coaxial conductor CXL′, this receiving apparatus including the final channel demodulator and low pass filter, as illustrated in the upper left hand corner of the diagram, the band passed by the low pass filter being applied through the hybrid coil to the voice circuit TL.

It will be noted that the lower group of channels need not be stepped up in the frequency spectrum by a second modulating step and hence the group modulating apparatus, and if desired, the group filter at the sending end, need not be provided. It follows, of course, that the group demodulator and if desired the group filter at the receiving end, will be unnecessary.

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 system in which a large number of transmission channels are arranged in groups along the frequency spectrum, the method of receiving which consists in roughly selecting at high frequency a desired group falling within the nominal cut-off point of the selecting device together with partially suppressed channels of adjacent groups lying within the range between the nominal cut-off point and the point at which the selecting device substantially extinguishes unwanted frequencies, and stepping down the desired group of channels in the frequency spectrum by demodulating them with a beating frequency located such distance away from the nominal cut-off point of the selecting device that frequency components corresponding to the partially suppressed channels of the adjacent group will not after demodulation lap over into the range of the stepped down channels of the desired group.

2. In a system in which a large number of transmission channels are arranged in groups along the frequency spectrum, the method of receiving which consists in roughly selecting at high frequency a desired group falling within the nominal cut-off point of

the selecting device together with partially suppressed channels of adjacent groups lying within the range between the nominal cut-off point and the point at which the selecting device substantially extinguishes unwanted frequencies, stepping down the desired group of channels in the frequency spectrum by demodulating them with a beating frequency located such distance away from the nominal cut-off point of the selecting device that frequency components corresponding to the partially suppressed channels of the adjacent group will not after demodulation lap over into the range of the stepped-down channels of the desired group, and selecting the channels of the desired group at their stepped-down position in the frequency spectrum while substantially extinguishing the partially suppressed channels of the adjacent group passed as the result of the high frequency selecting operation.

3. In a system in which a large number of transmission channels are arranged in groups along the frequency spectrum, the method of receiving which consists in roughly selecting at high frequency a desired group falling within the nominal cut-off point of the selecting device together with partially suppressed channels of adjacent groups lying within the range between the nominal cut-off point and the point at which the selecting device substantially extinguishes unwanted frequencies, stepping down the desired group of channels in the frequency spectrum by demodulating them with a beating frequency located such distance away from the nominal cut-off point of the selecting device that frequency components corresponding to the partially suppressed channels of the adjacent group will not after demodulation lap over into the range of the stepped-down channels of the desired group, selecting the channels of the desired group at their stepped-down position in the frequency spectrum while substantially extinguishing the partially suppressed channels of the adjacent group passed as the result of the high frequency selecting operation, and detecting the signal from each channel after such selection.

4. In a system in which a large number of transmission channels are arranged in groups along the frequency spectrum, the method of receiving which consists in roughly selecting at high frequency a desired group falling within the nominal cut-off point of the selecting device together with partially suppressed channels of adjacent groups lying within the range between the nominal cut-off point and the point at which the selecting device substantially extinguishes unwanted frequencies, and stepping down the desired group of channels in the frequency spectrum by demodulating them with a beating frequency located substantially midway between the nominal cut-off point of the selecting device and the point at which it substantially extinguishes unwanted frequencies, whereby frequency components corresponding to the partially suppressed channels of the adjacent group will lap over each other after demodulation without overlapping the range of the stepped-down channels of the desired group.

5. In a system in which a large number of transmission channels are arranged in groups along the frequency spectrum, the method of receiving which consists in roughly selecting at high frequency a desired group falling within the nominal cut-off point of the selecting device together with partially suppressed channels of adjacent groups lying within the range between the nominal cut-off point and the point at which the selecting device substantially extinguishes unwanted frequencies, stepping down the desired group of channels in the frequency spectrum by demodulating them with a beating frequency located substantially midway between the nominal cut-off point of the selecting device and the point at which it substantially extinguishes unwanted frequencies, whereby frequency components corresponding to the partially suppressed channels of the adjacent group will lap over each other after demodulation without overlapping the range of the stepped-down channels of the desired group, and selecting the channels of the desired group at their stepped-down position in the frequency spectrum while substantially extinguishing the partially suppressed channels of the adjacent group passed as the result of the high frequency selecting operation.

6. In a system in which a large number of transmission channels are arranged in groups along the frequency spectrum, the method of receiving which consists in roughly selecting at high frequency a desired group falling within the nominal cut-off point of the selecting device together with partially suppressed channels of adjacent groups lying within the range between the nominal cut-off point and the point at which the selecting device substantially extinguishes unwanted frequencies, stepping down the desired group of channels in the frequency spectrum by demodulating them with a beating frequency located substantially midway between the nominal cut-off point of the selecting device and the point at which it substantially extinguishes unwanted frequencies, whereby frequency components corresponding to the partially suppressed channels of the adjacent group will lap over each other after demodulation without overlapping the range of the stepped-down channels of the desired group, selecting the channels of the desired group at their stepped-down position in the frequency spectrum while substantially extinguishing the partially suppressed channels of the adjacent group passed as the result of the high frequency selecting operation, and detecting the

signal from each channel after such selection.

7. In a system in which a large number of transmission frequencies are arranged in groups along the frequency spectrum, the method of receiving which consists in roughly selecting at high frequency a desired group falling within the nominal cut-off point of the selecting device, together with partially suppressed frequencies of adjacent groups lying within the range between the nominal cut-off point of the high frequency selecting device and the point at which this device substantially extinguishes unwanted frequencies, stepping down the selected frequencies by demodulating them with a beating frequency located at such a point that the partially suppressed frequencies of at least one of the adjacent groups will overlap one another after demodulation without overlapping the desired group of frequencies.

8. The method of allocating frequencies for transmission over a medium capable of handling a wide frequency range, which consists in arranging the transmission frequencies in groups along the frequency spectrum, and separating these groups by such an interval that the high frequency selection of a desired group only partially suppresses frequencies of adjacent groups, the said interval between groups being so determined, however, that these partially suppressed frequencies are substantially extinguished in the process of low frequency selection subsequent to demodulation with a beating frequency located at such a point that the partially suppressed frequencies of at least one of the adjacent groups overlap one another after demodulation.

9. In a system in which a large number of transmission channels are arranged in groups along the frequency spectrum, the method of receiving which consists in roughly selecting at high frequency a desired group falling within the nominal cut-off point of the selecting device together with partially suppressed channels of adjacent groups lying within the range between the nominal cut-off point and the point at which the selecting device substantially extinguishes unwanted frequencies, and stepping down the desired group of channels in the frequency spectrum by demodulating them with a beating frequency located between the nominal cut-off point of the selecting device and the point at which it substantially extinguishes unwanted frequencies, whereby frequency components corresponding to the partially suppressed channels of the adjacent group will lap over each other after demodulation without overlapping the range of the stepped-down channels of the desired group.

10. In a system in which a large number of transmission channels are arranged in groups along the frequency spectrum, the method of receiving which consists in roughly selecting at high frequency a desired group falling within the nominal cut-off point of the selecting device together with partially suppressed channels of adjacent groups lying within the range between the nominal cut-off point and the point at which the selecting device substantially extinguishes unwanted frequencies, stepping down the desired group of channels in the frequency spectrum by demodulating them with a beating frequency located between the nominal cut-off point of the selecting device and the point at which it substantially extinguishes unwanted frequencies, whereby frequency components corresponding to the partially suppressed channels of the adjacent group will lap over each other after demodulation without overlapping the range of the stepped-down channels of the desired group, and selecting the channels of the desired group at their stepped-down position in the frequency spectrum while substantially extinguishing the partially suppressed channels of the adjacent group passed as the result of the high frequency selecting operation.

11. In a system in which a large number of transmission channels are arranged in groups along the frequency spectrum, the method of receiving which consists in roughly selecting at high frequency a desired group falling within the nominal cut-off point of the selecting device together with partially suppressed channels of adjacent groups lying within the range between the nominal cut-off point and the point at which the selecting device substantially extinguishes unwanted frequencies, stepping down the desired group of channels in the frequency spectrum by demodulating them with a beating frequency located between the nominal cut-off point of the selecting device and the point at which it substantially extinguishes unwanted frequencies, whereby frequency components corresponding to the partially suppressed channels of the adjacent group will lap over each other after demodulation without overlapping the range of the stepped-down channels of the desired group, selecting the channels of the desired group at their stepped-down position in the frequency spectrum while substantially extinguishing the partially suppressed channels of the adjacent group passed as the result of the high frequency selecting operation, and detecting the signal from each channel after such selection.

In testimony whereof, I have signed my name to this specification this 29th day of January, 1930.

ESTILL I. GREEN.