May 23, 1933. C. L. WEIS, JR 1,910,977

WAVE TRANSMISSION SYSTEM

Filed Aug. 14, 1931 3 Sheets-Sheet 1

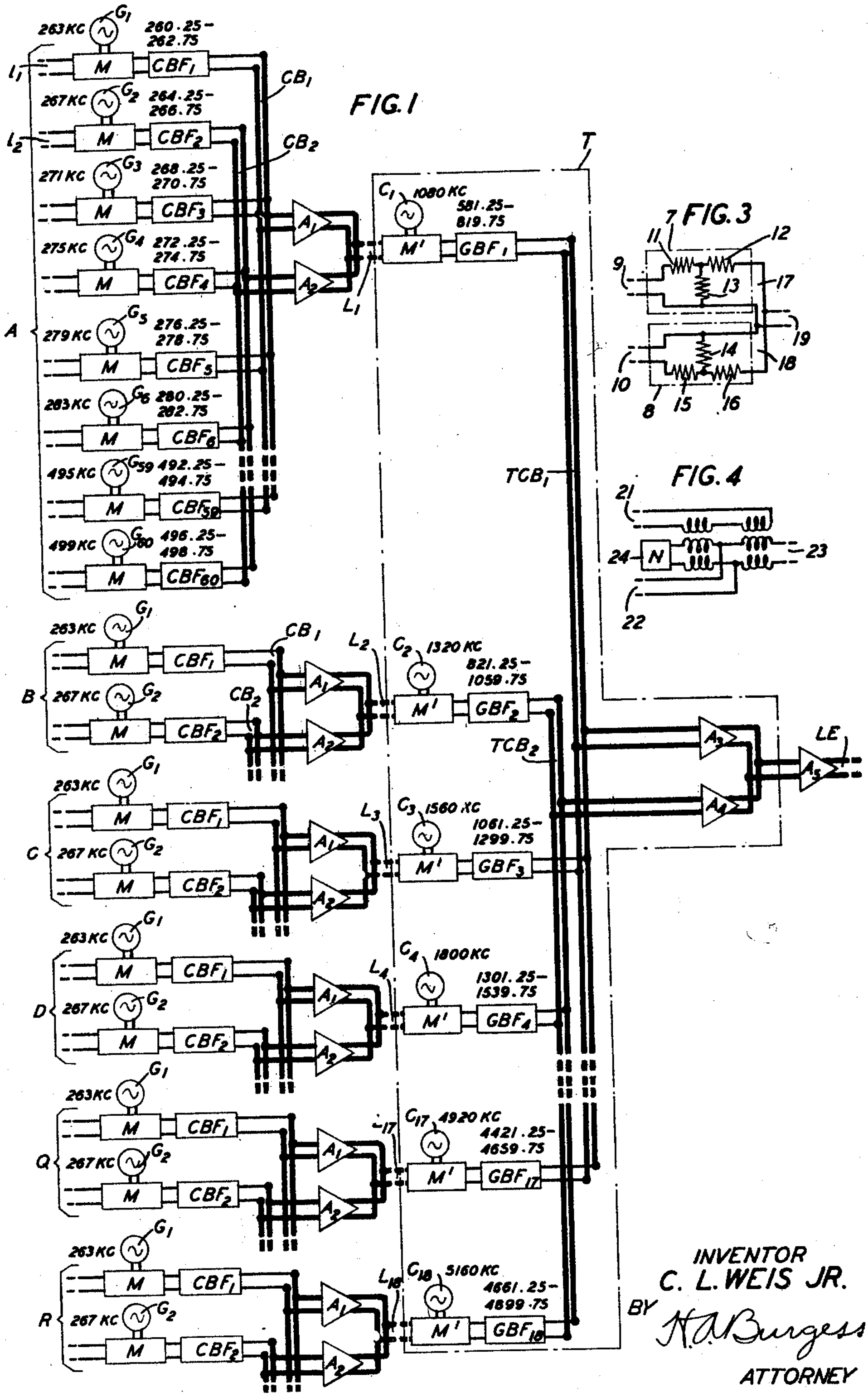

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FIG. 2

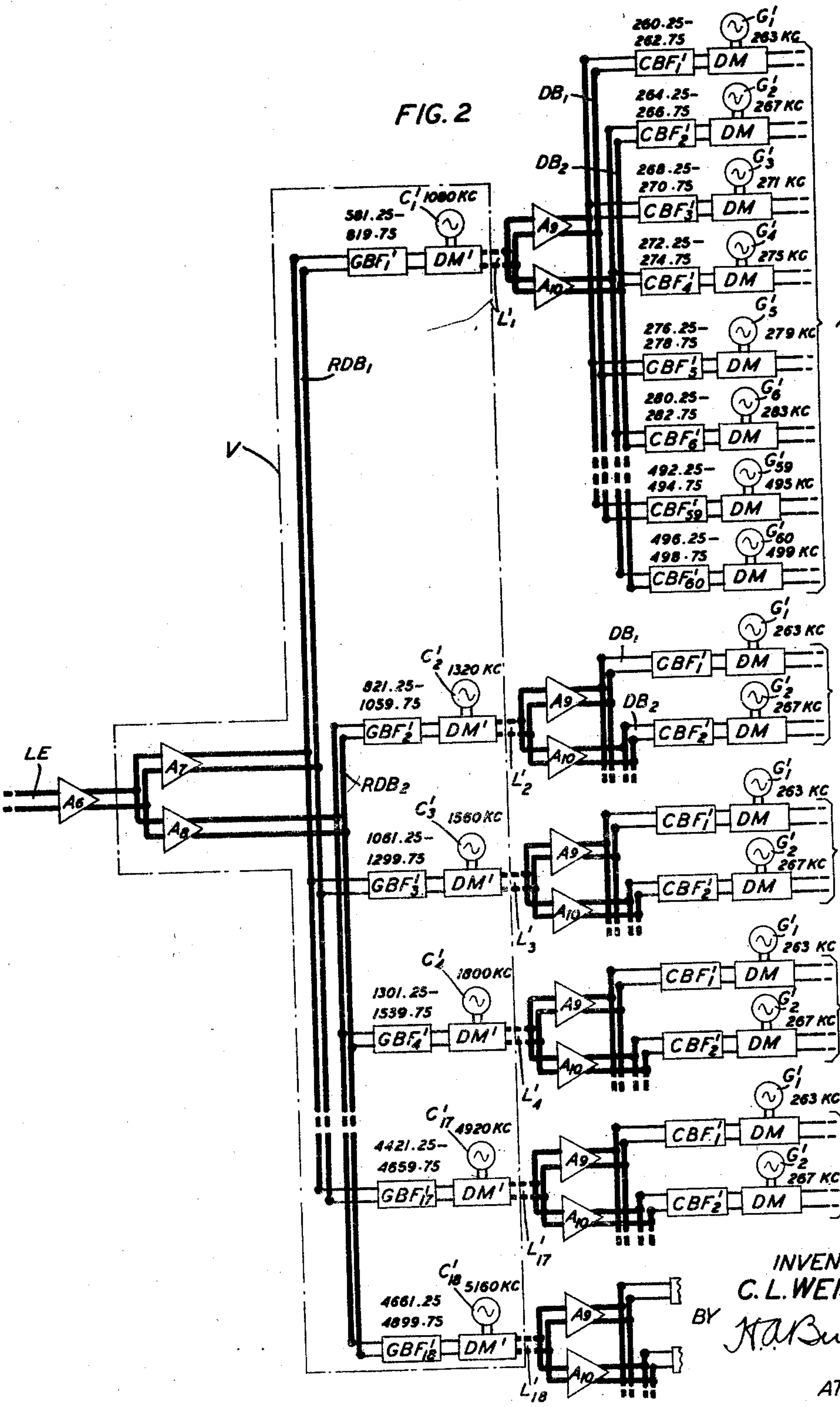

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FIG. 5

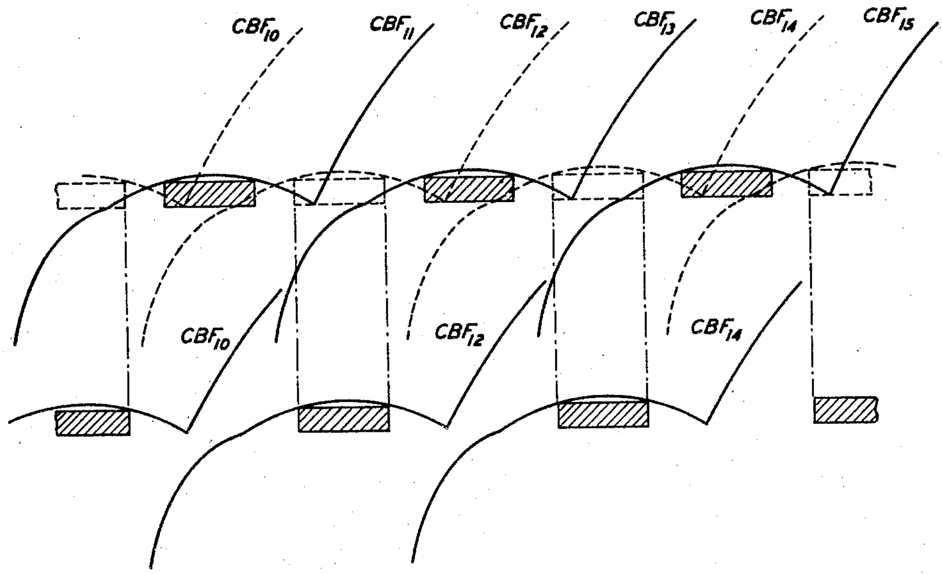
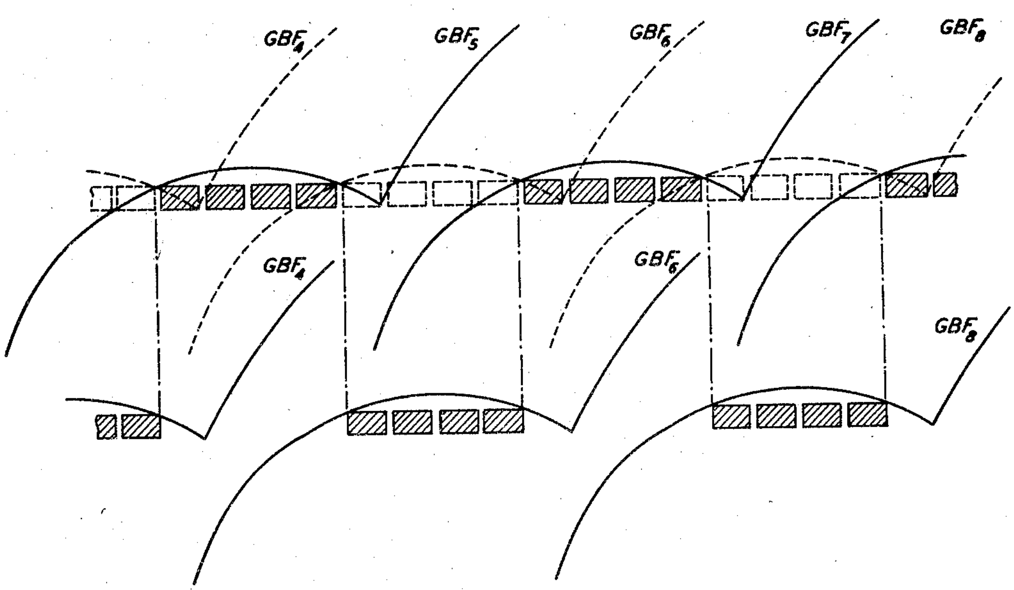


FIG. 6



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Patented May 23, 1933 1,910,977

UNITED STATES PATENT OFFICE

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WAVE TRANSMISSION SYSTEM

Application filed August 14, 1931. Serial No. 556,949.

This invention relates to wave transmission systems and more particularly to wave transmission systems utilizing a plurality of frequency ranges for multiplex transmission.

It is an object of the invention to increase the number of wave transmission channels that may be superposed within a given range of frequency. More specifically the object of the present invention is to decrease the frequency interval between adjacent channels in a multiplex carrier wave signaling system without detrimentally affecting the quality of transmission.

In another aspect of the invention its object is to increase the effectiveness of frequency selective devices.

In carrier wave communication systems in which a plurality of bands of high frequency signals are transmitted over a common circuit, it is desirable from the standpoint of efficient utilization of the frequency range which the circuit is capable of transmitting that the frequency interval between the several signaling bands be as small as possible. It is not feasible with apparatus and circuits now available to eliminate entirely this inter-band waste space. The lack of selectivity in the filtering apparatus for separating different frequency bands at the terminal stations has been a decided limitation. A perfect filter would have no attenuating effect on waves in the signal frequency band it was designed to transmit; at all frequencies outside that band it would have infinite attenuation. In any filter that may actually be constructed, however, the attenuation within the selective band is not zero, and at frequencies considerably removed from the band the attenuation is finite and relatively high, but between these regions the attenuation increases only gradually as the frequency departs from the extreme frequencies of the band. Therefore, if the frequency interval between bands in a multiplex system is very small, waves near the edge of one band will be passed to a certain extent by the receiving filter in an adjacent frequency channel and interference will be set up. Similarly, where several channels are applied to a common conductor each channel filter passes not only a desired band of signals but also above and below that band, undesired waves, such as, in the direction of transmission, a part of a signal side band that is to be suppressed, or in the opposite direction, signals from the adjacent, parallel-connected channel.

Where an attempt is made to place the channels very closely together another detrimental effect arises. With a number of filters at a transmitting station connected in parallel to a common output circuit, the impedance presented by the filter in one channel to the filter in an adjacent channel may be quite low and irregular within the pass band of the latter. Since each filter is designed to work into a particular impedance, reflection phenomena and distortion may arise, especially at frequencies near the edges of the bands of waves. At a receiving station a similar distortion may occur. A band of waves in a given frequency range, arriving at a group of parallel connected receiving filters, is admitted by the filter in the corresponding receiving channel. At the same time, however, since the impedance presented to this filter may be altered by virtue of the relatively low impedance within its pass band of the filters in the adjacent frequency channels, reflection may occur. The distortion thus arising may seriously affect the quality of transmission.

In a multiplex system in accordance with applicant's invention the frequency interval between adjacent channels may be considerably decreased without introducing the detrimental effects briefly pointed out above. In general, applicant's system is characterized by a division into two or more groups at the terminal stations of the channels that tend to interfere with each other. Each group is isolated from the others but connected in energy transfer relation with the common transmission circuit. Where the channels are separated into two groups, each group may contain channels in alternate frequency bands. With the channels connected in parallel in each group thus separated from each other by the width of a channel, the mutual shunting effect of the filters within the group is practically negligible. A filter in a channel of one group can have no effect on signals in either of the two immediately adjacent frequency channels, as the latter are in the other group and are isolated therefrom. Where the filters in each group are connected in series instead of in parallel, advantage is also derived by isolating the groups in accordance with the present invention.

The group isolating means may take any one of several forms. In one of its embodiments applicant's invention is featured by unilaterally conducting devices inserted in the respective group connections to isolate one group from another. A space discharge amplifier can be used to good advantage for this purpose. Waves in a given frequency channel in one group are freely transmitted either to or from the common circuit. They are not affected by the filter in either of the two adjacent frequency channels, these filters being in another group, because they are isolated therefrom by virtue of the unilaterally conducting properties of the device.

In accordance with a further feature of applicant's invention certain relations are maintained between the extreme frequencies of each channel and the frequency of a carrier wave with which the waves in said channel may be combined for the purposes of modulation or demodulation. The frequency range in which modulation products of certain orders will fall is determined by the relation of these frequencies. Third order products, which are especially troublesome, will fall within the signal band if the lowest frequency of the band to be modulated is less than half the highest frequency. When the lowest frequency is exactly half the highest one, the band of third order products will lie on both sides of the modulated signal band and be contiguous therewith. Since waves of such frequencies are attenuated incompletely by the filter, it is preferred that a ratio somewhat less than 2 to 1 be observed between the extreme band frequencies. The third order products may thereby be removed to a sufficient extent from the borders of the signaling bands that they are effectively suppressed by the filter. In the demodulating stage it is likewise desirable that the lowest frequency of the band as demodulated be more than half the highest one so that third order products will not fall within it.

Other features and objects of the present invention will appear in the following detailed description of a specific embodiment thereof. It will be obvious that while the invention may be employed to reduce the frequency intervals between signaling channels, it may be used alternatively to decrease the selectivity requirements imposed on the selective devices. In the drawings,

Fig. 1 shows the present invention as incorporated in the transmitting circuit of a carrier wave transmission system employing successive stages of modulation and successive stages of demodulation;

Fig. 2 shows the receiving circuit associated with the transmitting circuit of Fig. 1;

Figs. 3 and 4 show alternative forms of the group separating means;

Fig. 5 shows the impedance characteristics of the frequency selective devices employed in the channels of the first stage of modulation and the second stage of demodulation of said system; and

Fig. 6 shows the impedance characteristics of the frequency selective devices employed in the second stage of modulation and in the first stage of demodulation of said system to pass groups of doubly modulated waves.

Referring now to Fig. 1, there is shown schematically a terminal station for translating the waves in a multiplicity of low frequency circuits to their respective positions in the wide frequency spectrum that is used for transmission purposes. The frequency translation is accomplished in two steps. The low frequency circuits are first divided into a plurality of groups A, B, C, etc. Within each group the signal waves are then transferred to respective positions in a band of carrier signal frequencies. These several groups of carrier signals are next translated, as groups, to positions in a still wider range of frequencies and applied to a transmission line.

Within each group, as in group A, for example, there may be represented perhaps sixty low frequency lines l_1, l_2, etc., adapted to transmit telephone, telegraph or other signaling waves. For each of these lines there is an individual modulator M of any suitable type for applying the signaling waves to respective high frequency or carrier waves supplied by the respective generators G_1, G_2, etc. The modulators are preferably of the carrier suppressing type such as disclosed in J. R. Carson Patent 1,343,306, June 15, 1920. The relative frequencies of the carrier wave generators may be accurately maintained by controlling them with a common base frequency wave, as shown, for example in B. W. Kendall Patent 1,773,901, August 26, 1930. For the transmission of speech, a band of frequencies ranging from 250 to 2750 cycles may be required. The band passing filters CBF_1, CBF_2, etc., to which the two signal side bands from the preceding respective modulators are applied are accordingly designed each to transmit a band of modulated carrier waves 2500 cycles in width. One side band, preferably the upper, is suppressed in order to conserve the available frequency range. The filters are preferably of the type utilizing piezo-electric crystals, such as described in an application of W. P. Mason bearing Serial No. 489,268, filed October 17, 1930, although any other suitable type of selecting circuit may be used in accordance with this invention. The frequency separation of the carrier waves may be 4000 cycles. With this spacing and with the carrier of the lowest frequency at 263 kilocycles per second and the highest at 499 kilocycles per second, sixty channels may be accommodated.

In each group, two collecting buses, CB_1 and CB_2, are provided. To each of these buses are connected the band passing filters in alternate frequency channels. Thus, to CB_1 are connected in parallel the output terminals of filters CBF_1, CBF_3, CBF_5, etc., while to CB_2 are connected the terminals of filters CBF_2, CBF_4, etc. Signals from the first bus are passed through a vacuum tube amplifier A_1 to one of the group output lines L_1, L_2, etc. Signals from the other bus are passed through a similar amplifier A_2 to the same outgoing line. A shunt resistance across the input circuit of each amplifier may provide a suitable terminating impedance for the filters.

The characteristic impedance-frequency curves of the filters connected to the respective collecting buses CB_1 and CB_2 are shown in Fig. 5. Frequency is represented along the horizontal axis, the characteristic or terminal impedance, along the vertical axis. The signal bands in each of the two groups, as represented by the two rows of shaded rectangles, are separated from each other by somewhat more than a single band width, viz., by a band width plus twice the final inter-band spacing interval, or 5500 cycles. A filter in one channel, filter CBF_{11}, for example, has but little effect, therefore, on the band of signals issuing from the filter CBF_{13} in the next parallel connected channel. At the lowest frequency of the latter band, it will be noted that the characteristic impedance of filter CBF_{11} is high and that this filter therefore has a negligible effect on the impedance presented to the filter in the adjacent channel. A similar condition obtains in the group represented by the lower row of rectangles. Since the vacuum tube amplifiers A_1 and A_2 are connected in the leads from the collecting buses, the signals from filter CBF_{13}, or from any other filter of that group, are not affected by the filters CBF_{12} and CBF_{14}, for example, which are in the other group. The latter filters are faced by the practically uniform input impedance of the space discharge device in amplifier A_2. Any unilaterally conductive device could be made to serve the same purpose, as it would prevent the reflection of the filter characteristics through it.

If the impedance rise of the filters outside their bands were found to be so gradual that a serious overlapping of their characteristics occurred even though the channels in each group were more than one removed from each other, three or more groups could be formed, each isolated by an amplifier and each containing only every third or higher numbered channel. This would provide a frequency interval between channels of several times the width of a channel and would either permit the use of less selective filters or provide a higher degree of separation of the channels.

Had these same groups of filters all been connected in parallel to a single bus, a quite different situation would exist. Superposing the characteristics of the two groups of filters as has been done in Fig. 5, it is seen that because of the overlapping of these characteristics the signals from filter CBF_{13}, for example, would be seriously distorted. They would be shunted especially at the upper and at the lower frequencies by the filters CBF_{12} and CBF_{14} whose impedance is not only low throughout the signal band between them, but also is not uniform throughout that band. Any shunting effect at all is undesirable, but when distortion occurs also the difficulty cannot be remedied by amplification alone and an equalizer is required.

Referring again to Fig. 1, there is shown at T a circuit for translating the wide bands of singly-modulated carrier waves arriving from the several identical groups A, B, C, etc., over lines L_1, L_2, etc., to respective positions in a second carrier frequency range for application to transmission line LE. The apparatus required for this second stage of modulation may be the same as that used for the first stage except as to the frequency range for which it is designed. The band of waves applied to each of the modulators M′ extends from 260.25 to 498.75 kilocycles per second in the embodiment herein described. With the frequencies of the carrier wave generators C_1, C_2, etc., spaced 240 kilocycles apart, the frequency interval between the upper band of one translated group and the lower band of the adjacent translated group will be the same as that between the bands within the groups, viz., 1500 cycles. The output of this second stage will therefore be a multiplicity of signal bands, each 2500 cycles wide and separated from adjacent channels by 1500 cycles. The frequency of the lowest group carrier is 1080 kilocycles per second. Eighteen groups may be accommodated where the highest carrier frequency is 5160 kilocycles per second as shown. The group band-passing filters GBF_1, GBF_2, etc., are designed to pass only the lower of the side bands created. They are preferably of the electrical type shown in G. A. Campbell Patent 1,227,113, issued May 22, 1917.

The group modulators M′ are divided into two groups each containing alternate frequency bands. The output filters GBF_1, GBF_3, etc., are connected to the collecting bus TCB_1, while filters GBF_2, GBF_4, etc., are associated with bus TCB_2. The first group is connected to a vacuum tube amplifier A_3, the second to a similar amplifier A_4. A shunt resistance may again be used as a terminating impedance. These amplifiers may be connected directly to the transmission line LE, or through a power amplifier A_5 as illustrated. For efficient transmission of frequencies of the order of 5000 kilocycles per second, it is preferred to use a pair of coaxial conductors, a structure such as shown in H. R. Nein Patent 1,781,124, November 11, 1930, being suitable. It is not essential that the channel modulating circuit and the group modulating circuit be immediately associated with each other, and the lines L_1, L_2, etc., connecting them may be transmission lines of coaxial or any other suitable type.

Fig. 6 shows the typical impedance-frequency characteristics of the group band-passing filters GBF_1, GBF_2, etc. For purposes of illustration only, four signal bands, represented by the shaded rectangles, are shown in each group, although in the embodiment herein described, the sixty channels of each of the groups A, B, C, etc., would actually be present. Because of the alternate grouping arrangement, there is a wide frequency separation between the groups of channels connected to either bus. Fig. 6 shows that the impedance of the filters, GBF_5 for example, rises rapidly in this frequency interval. At even the lowest frequency of the group passed by filter GBF_7, the characteristic impedance of filter GBF_5 is so high that the latter filter has practically no shunting effect. The same holds true as to the effect of filter GBF_9 on the highest frequency of this same group passed by filter GBF_7. By virtue of the vacuum tube amplifiers A_3 and A_4 connecting the two collecting buses to the common transmission line, the shunting effect of a filter in one group on signals from a group connected to the other bus is eliminated. This isolation of the groups is identical with that provided in the channel circuits by the amplifiers A_1 and A_2. Preferably, the amplifiers are of the push-pull type and capacitively balanced against feed-back effects.

If the group band filters of the two groups were connected to the same collecting bus, the effect on signals in adjacent frequency groups would be much more serious. As shown by the dotted lines of Fig. 6 the impedance of one group filter, such as GBF_6, is very low in the frequency ranges of the groups immediately above and below it and distortion would therefore be introduced, especially in the frequency bands at the edges of those groups.

In Fig. 2 is shown a receiving terminal circuit for separating the carrier frequency signals arriving over transmission line LE and for reducing these signals to telephone frequencies for application to a multiplicity of telephone circuits. The first stage or group separation and demodulation occurs in the apparatus V. Each separated and demodulated group is then completely divided into its component signaling bands, which are then finally demodulated. The grouping arrangement of these receiving circuits may follow that of the transmitting circuits, as illustrated here, although this is not essential. This arrangement is preferable, however, since it permits the use of a common carrier wave source for modulation and demodulation and reduces the number of different selective circuits required.

Signals from line LE are passed through an amplifier A_6 and through two paths containing amplifiers A_7 and A_8, respectively. To amplifier A_7 is connected a distributing bus RDB_1, and to amplifier A_8, distributing bus RBD_2. The band-passing filters GBF'_1, GBF'_3, etc., connected to bus RDB_1 select alternate frequency groups of the signals applied to the bus from line LE. filters GBF'_1, GBF'_3, etc., connected to bus RDB_2 select the other set of alternate frequency groups. Following each group filter is a demodulator DM′, preferably of the balanced type disclosed in the J. R. Carson patent supra. The demodulating waves are supplied by the high frequency generators C'_1, C'_2, etc. Their frequencies may be the same as those of the corresponding carrier wave generators in the modulating circuits. The waves issuing from each of demodulators DM′ represent in the embodiment shown, sixty carrier wave signal channels extending in frequency from 260.25 kilocycles to 498.75 kilocycles.

The characteristics of the several group filters GBF'_1, GBF'_2, etc., may be the same as those of filters GBF_1, GBF_2, etc., shown in Fig. 6. Because of the wide frequency separation of the groups connected to either bus, there is practically no tendency for signals in one frequency group to be affected by the band filters of the adjacent groups connected to the same bus. There is no tendency for the signals transmitted through amplifier A_7 to filter GBF'_7, for example, to be shunted by the filters GBF'_6 and GBF'_8 in the adjacent frequency channels since the latter are isolated by amplifier A_8. The selectivity requirements on the group filters may be considerably reduced in view of the fact that the ultimate separation of the channels is effected by the channel filters. At the same time, the amplifiers prevent the interaction between group circuits that would ordinarily attend this broadening of the attenuation-frequency characteristic.

The course of the carrier wave band applied to the groups A′, B′, C′, etc., of the channel circuits, is similar to the course of the groups of bands through the circuit V. In group A′, for example, the incoming waves are applied to the two amplifiers A_9 and A_{10}, the first of which is connected to the distributing bus DB_1 and the second, to distributing bus DB_2. To bus DB_1 are connected filters CBF'_1, CBF'_3, etc., in alternate frequency channels; the remaining alternate frequency channels are passed by the filters CBF'_2, CBF'_4, etc., connected to bus DB_2. The succeeding demodulators DM and the high frequency wave sources G'_1, G'_2, etc., connected thereto, may be similar to the elements DM′ of the first demodulating stage and to the corresponding elements G_1, G_2, etc., of the first modulating stage, respectively. The low frequency signals resulting from this second stage of demodulation may be applied to telephone circuits, which as in the case of Fig. 1, may lead to a telephone exchange system. The band-passing filters in the channel circuits at the receiving terminal are preferably of the piezo-electric crystal type referred to hereinbefore, although other types may be employed within the scope of this invention.

In Figs. 3 and 4 are shown circuits alternative to the amplifier circuits used to separate the groups of alternate channels in a transmitting or a receiving station. In Fig. 3 a resistance pad 7, 8 is inserted in each of the group connections instead of an amplifier. For a transmitting station, the leads 9 of pad 7 and leads 10 of pad 8 are connected to the respective collecting buses with which the two groups of filters are associated. Leads 19 may be connected to the common transmission lines L_1, L_2, etc., in the embodiment shown in Fig. 1. Signals in a given frequency band applied, for example, to leads 10 are attenuated by the resistance pad 8 and pass to the transmission line through leads 19. The adjacent frequency channels are in the group connected to leads 9 and the filters therein are practically isolated, so far as their effect on signals from pad 8 is concerned, by pad 7. Although these latter filters may tend to have a high shunting effect in the frequency range of the band issuing from pad 8, this effect is made negligible by virtue of the attenuation of pad 7. An attenuation of 15 decibels was found a satisfactory value for the pads 7, 8 in one particular case. The isolating action may be expressed also in terms of reflected waves. One component of the waves issuing from pad 8 passes out through leads 19; another component passes through pad 7, is reflected and returns at a level at least 30 decibels lower than that at which it entered. Any distortion in this reflected wave due to the action of the filter connected to leads 9 will have a negligible effect on the resultant wave. It is obvious that additional resistance pads may be connected to leads 19 to accommodate other groups should lack of selectivity in the filters make it necessary to divide the preceding circuit into more than two groups. Similarly, at a receiving terminal, waves arriving through leads 19 are substantially unaffected by the characteristics of the filtering devices connected to leads 9 and 10.

In Fig. 4 is shown a hybrid coil for isolating one group from a second one. With a network 24 to balance the common transmission line 23, the nominal input and output leads 22 and 21 respectively of the hybrid coil are in conjugate relation with each other but in bilateral energy transfer relation with leads 23. Signals to or from a filter group connected to either of the leads 21 or 22, are therefore not affected by the filters of the other group.

Another feature of the present invention comprises the proportioning of carrier and signal frequencies observed in its preferred embodiment. Besides the two groups of signal side bands, there are created by the group modulators other and undesired modulation products. Third order products are usually of high level and difficult to suppress. Their position in the frequency spectrum is determined by the frequency c of the carrier wave and by the highest and lowest frequencies, f_h and f_l, respectively, of the signal waves applied to the modulator. One group of products ranges from a frequency $2c\pm f_h$ to a frequency $2c\pm f_l$, another lies between $c\pm 2f_l$ and $c\pm 2f_h$, and another between $c+f_h-f_l$ and $c-f_h+f_l$. Where f_l is less than half f_h some of these products will fall in the desired signal band, which, in a lower side band system, ranges from $c-f_h$ to $c-f_l$. Where the ratio between f_h and f_l is exactly 2 to 1, these products do not fall within the signal band, but on just either side of it. The attentuation of the filters is not great at these frequencies and accordingly the waves are readily passed. To remove the third order products to a frequency position where the filter can effectively suppress them, a ratio somewhat less than 2 to 1 may be employed. Accordingly, the band of waves applied to the group modulators M′ of Fig. 1 is limited to an approximately 240 kilocycle band extending from 260.25 kilocycles per second to 498.75 kilocycles per second, these extreme frequencies having a ratio of 1.92 to 1. Similarly, at the receiving station, it is desirable that the highest frequency of the demodulated groups be less than twice the lowest frequency of the groups to prevent third order products from falling in any of the desired signaling channels. The control over the extreme frequencies of the telephone signal bands in the channel modulating circuits can, of course, be only limited. Third order products must, therefore, be controlled in some other manner, as by modulating at low power levels.

While the present invention has been described as embodied in a particular carrier wave transmission system, it may also be applied to systems differing widely therefrom within the spirit and scope of the appended claims.

What is claimed is:

1. In a system transmitting waves in a plurality of frequency bands, a common transmission circuit for said waves, a plurality of filters adapted to pass respective ones of said bands of waves, said filters being connected in a plurality of groups, the frequency bands represented in each of said groups being respectively intermediate those in the other of said groups, and means to connect said groups simultaneously to said transmission circuit while effectively isolating said groups from each other.

2. In a multiplex signaling system, a plurality of selective devices adapted to transmit waves in respective frequency ranges, a circuit adapted to transmit waves in all of said frequency ranges, bilaterally conducting circuits each connecting together a plurality of said devices lying in non-adjacent frequency ranges, and respective means simultaneously connecting said bilaterally conducting circuits and said first mentioned circuit, said means being adapted to reduce the mutual effect of selectve devices in adjacent frequency ranges.

3. In a multiplex wave transmission system, means to transmit waves in a plurality of frequency channels, a plurality of means to transmit waves in respective ones of said frequency channels, means or separating said latter means into groups, each of said groups being comprised of transmitting means in alternate frequency channels, and means for associating said groups with said first mentioned transmitting means including means impeding the transmission of waves between said groups.

4. A combination as in claim 3 in which said impeding means comprises a unilaterally translating device.

5. In combination, a plurality of circuits for translating waves in individual frequency ranges, a pair of conductors for transmitting waves in a plurality of said frequency ranges, bilaterally conducting means to connect said plurality of circuits in a plurality of groups, the circuits included in each of said groups being adapted to transmit waves in non-adjacent frequency ranges, and unilaterally translating means associating said groups with said pair of conductors, said translating means comprising a space discharge device.

6. In a multiplex signaling system, a plurality of circuits adapted to transmit waves in individual frequency ranges, frequency selective means in each of said circuits, said means being of such selectivity that they are capable of transmitting with relatively small attenuation waves in adjacent frequency ranges, means to connect said circuits in a plurality of groups, the frequency ranges in each group being respectively intermediate those of another of said groups, a multiplex transmission circuit and respective means simultaneously connecting said groups thereto, said latter means each being adapted to reduce the effect of the frequency selective means in the group associated therewith on waves from others of said groups.

7. A combination in accordance with claim 6 in which the means to connect said groups with said multiplex circuit comprises unilaterally translating devices.

8. In a system transmitting waves in a plurality of frequency bands, a common transmission circuit for said waves, a group of filters adapted to pass respective ones of said bands of waves, a filter adapted to pass a band of waves intermediate in frequency bands passed by said group of filters, and means simultaneously connecting said filters in energy transfer relation with said transmission circuit, said means providing a path of low transmission efficiency between said filter and said group of filters.

9. A plurality of signaling circuits, modulating means for applying the waves in each thereof to individual carrier waves, frequency selective means adapted to pass respective bands of the waves produced by said modulators, each of said selective means passing in common with the corresponding means for adjoining frequency bands frequencies lying in the range between signal bands, means to connect said circuits in parallel in a plurality of groups, the signal bands represented in each of said groups being separated from each other by at least the width of one single band, a common signaling circuit and individual means to connect said groups thereto, each of said last mentioned means having a high attenuation in at least one direction of transmission, the range of frequencies applied to each of said modulators being substantially less than 2:1.

10. In combination with a circuit for transmitting carrier frequency signals in a plurality of frequency bands, a plurality of signaling circuits, frequency selective

means in each of said latter circuits adapted to pass respective ones of said plurality of frequency bands, said selective means passing in common with the corresponding means for adjoining frequency bands, frequencies lying in the range between signal bands, means to connect said plurality of circuits in parallel in a plurality of groups, the signal bands represented in each of said groups being separated by at least the width of one signal band, individual means to connect said groups to said first mentioned circuit, each of said last mentioned means having a high attenuation in at least one direction of transmission, means in each of said plurality of circuits for combining the signal waves therein with a demodulating wave, the range of frequencies produced by each of said demodulating means being substantially less than 2:1.

11. In a signaling system, a plurality of circuits adapted to translate waves in different frequency bands, means to connect said circuits in two groups, the frequency bands translated by the circuits of each of said groups being respectively intermediate those in the other of said groups, a circuit adapted to transmit waves in all of said frequency bands, and means to connect said groups in energy transfer relation with said last mentioned circuit and in conjugate relation with each other.

12. A combination as in claim 3 in which said impeding means comprises a network of resistance elements.

13. In a multiplex signaling system, a circuit translating waves in a plurality of frequency channels, a plurality of filters for dividing said waves into a plurality of adjacent frequency groups, adjacent ones of said filters transmitting certain intergroup frequencies in common, means for connecting certain of said filters together and to said first mentioned circuit, means for similarly connecting filters in frequency groups respectively intermediate those of said certain filters, said connecting means being adapted effectively to isolate each group from adjacent frequency groups, means associated with each of said filters for partially demodulating the waves passed thereby, the range of frequencies of said waves as demodulated being substantially less than 2:1, and means for separating and finally demodulating the waves in each of said demodulating groups.

In witness whereof, I hereunto subscribe my name this 12th day of August 1931.

CHARLES L. WEIS, Jr.