

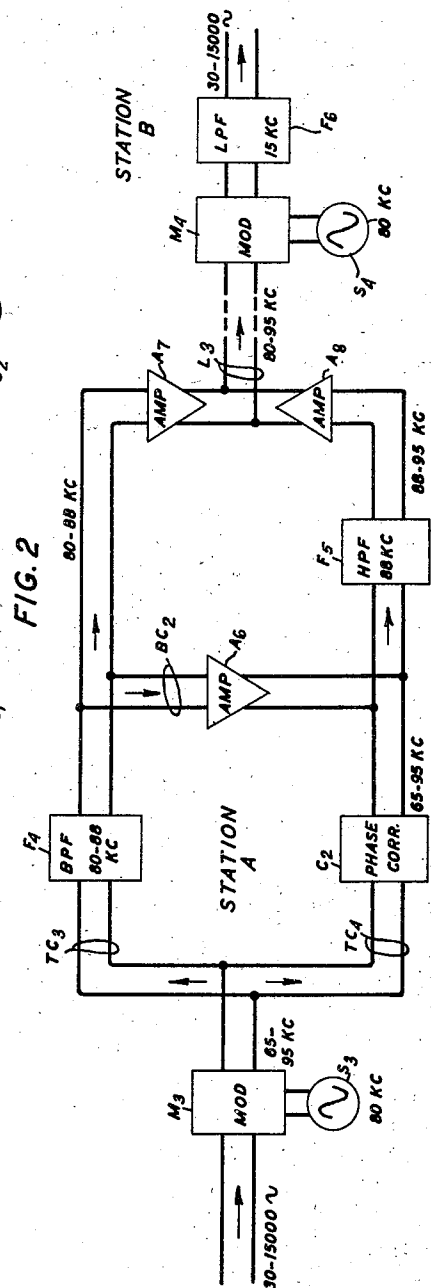
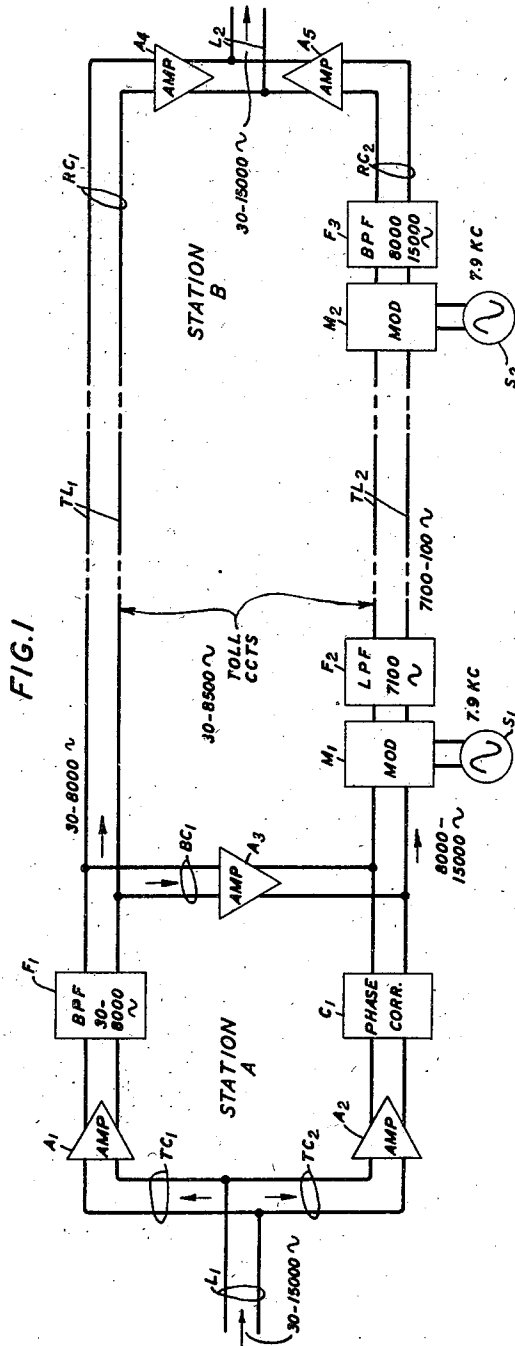
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SIGNAL WAVE TRANSMISSION SYSTEM

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SIGNAL WAVE TRANSMISSION SYSTEM

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This invention relates to signal wave transmission systems and particularly to systems for transmitting a wide band of signal frequencies.

An object of the invention is to transmit efficiently and economically a signal wave comprising a wide band of frequencies.

A related object is to transmit efficiently a signal wave comprising a wide band of frequencies, utilizing available transmission lines inherently capable of transmitting efficiently only a narrower frequency band.

Another object is to cheapen the cost of terminal filtering equipment in a wide frequency band carrier wave signaling system without appreciably reducing the quality of transmission.

These objects are attained in accordance with the invention by a particular method for dividing the signal wave of wide frequency band, or a complex carrier wave, into two or more parts on a frequency basis, and for recombining them later after transmission over separate circuits to reproduce the original signal wave or desired signal side-band component.

In one embodiment, a signal wave of wide frequency band is first divided into two energy portions each containing the whole band of frequencies; a narrower frequency subband is selected from one energy portion of the wave; a part of the energy of the selected subband is used to balance out corresponding frequencies in the other energy portion of the wave; the remaining frequencies in the latter energy portion of the signal wave, and the selected frequency subband in the first energy portion are transmitted over separate available transmission circuits of limited transmission frequency range to a receiving point, utilizing frequency shifting operations, if necessary, to bring them within the frequency limits of the available circuits before transmission and to restore them to their original frequencies after transmission; and at the receiving point the two frequency subbands are combined to reproduce the original signal wave.

In another embodiment, a similar process is employed at the transmitting end of a single side-band carrier signaling system for efficiently separating the side-band component to be transmitted from the other side-band component and the carrier, utilizing relatively cheap filters.

The various objects and features of the invention will be better understood from the following detailed description when read in conjunction with the accompanying drawing in which are shown in block schematic form, different

modifications of the invention applied to program transmission systems.

Fig. 1 illustrates the application of the method of the invention to the transmission of a program with frequencies ranging from, say 30 to 15,000 cycles, between two widely separated points A and B where the only transmission media available between those points are a plurality of toll transmission circuits or lines TL₁, TL₂ each capable of transmitting efficiently only a portion, say 30 to 8,500 cycles, of that frequency range.

At station A in the system of Fig. 1, the program wave comprising frequencies ranging from about 30 cycles to 15,000 cycles received over the line L₁ from a source (not shown), which may be a microphone or a telephone line, is fed in multiple into two branch transmission circuits TC₁ and TC₂ which may include one-way amplifying means A₁, A₂ for providing a desired amount of amplification in the equal energy portions of the wide frequency band wave transmitted over the respective branch circuits. In the upper branch circuit TC₁ is a band-pass filter F₁ which is adapted to pass a relatively narrow frequency subband, 30 to 8,000 cycles, of the impressed wave (this filter could be a low-pass filter having a cut-off at 8,000 cycles) and to then cut off in a reasonable frequency interval to very high loss at, say 8,500 cycles. A portion of the energy of the selected 30 to 8,000 cycles subband is transmitted out over the available (30 to 8,500 cycle) toll line TL₁ to the receiving station B where it is transmitted over the receiving circuit RC₁ through the one-way amplifying device A₄ to the circuit or line L₂ leading to signal reproducing apparatus. Another energy portion of the selected 30 to 8,000 cycle frequency subband in the output of filter F₁ at station A passes into the input of the by-pass circuit BC₁ including the one-way amplifying device A₁.

In the other branch circuit TC₂ at station A, the entire 30 to 15,000 cycle band of the impressed program wave is transmitted through the transmission loss device C₁, which may be a phase corrector if tests indicate that phase correction is necessary. The amplified 30 to 8,000 cycle wave output of the by-pass circuit BC₁ is applied to the branch circuit TC₂ in the output of the device C in such phase and magnitude as to effectively cancel the frequencies below 8,000 cycles in the 30 to 15,000 cycle wave in that branch circuit. In addition, the frequencies in the latter wave in the region from 8,000 to 8,500 cycles are partially canceled, leaving some pro-

gram frequencies between 8,000 and 8,500 cycles and the complete frequency band between 8,500 and 15,000 cycles.

The resulting wave comprising frequencies ranging from 8,000 to 15,000 cycles, in the lower transmission branch TC₂ then passes to the modulator M₁ in which they are combined with a carrier wave of 7.9 kilocycles supplied from the carrier source S₁, to produce signal side-bands of frequencies ranging from 0.1 kilocycle to 7.1 kilocycles and from 15.9 kilocycles to 22.8 kilocycles, respectively. A cheap band-pass filter F₂ in the output of the modulator M₁, adapted for passing frequencies up to 7.1 kilocycles and cutting off at 7.9 kilocycles and higher frequencies, selects from the modulation products a subband of frequencies ranging from 7,100 cycles to 100 cycles, which is within the frequency transmission range of the (30 to 8,000 cycle) toll transmission circuit TL₂. This 7100-100 cycle subband is then transmitted over the toll transmission circuit TL₂ to station B.

A variation having certain advantages would be to use for the carrier wave source S₁ associated with modulator M₁, one generating a carrier wave frequency of say 16 kilocycles, and to use for F₂ in the output of the modulator M₁ a low-pass filter cutting off above 8 kilocycles with very high loss at 16 kilocycles and above, which would be cheaper than the band-pass filter. Also with the latter modification, the frequencies just above 8,000 cycles in the original program wave would still be near 8,000 cycles on the line TL₂ and would be delayed in transmission over that line about the same amount as the nearby frequencies in the other line TL₁. This might aid in reproducing the original wave when the two frequency parts are combined at the receiving end of the system.

At the receiving station B, the received frequency subband, 7,100 to 100 cycles, is combined in the modulator M₂ with the carrier wave of 7.9 kilocycles from the associated source S₂, to step it up to the original frequency position, 8,000 to 15,000 cycles, which it had at the input of the modulator M₁ in the transmitting station A. This frequency band, 8,000 to 15,000 cycles, is selected by the cheap band-pass filter F₃ in the output of the modulator M₂. The selected subband is then transmitted over the receiving circuit branch RC₂ through the one-way amplifier A₅ to the circuit L₂ in which by proper poling it may be made to combine with the amplified 30 to 8,000 cycle subband received from the receiving circuit branch RC₁, to reproduce the original 30 to 15,000 cycle band program wave.

The phase corrector C₁ in the transmitting branch TC₂ at the station A, should preferably be so designed that, with a turn-over of the frequencies, the band from 30 to about 8,000 cycles in its output will be almost exactly out of phase with the corresponding frequency output of the by-pass circuit BC₁ when they are combined at the transmitting station A. If this is not accomplished, there will be frequencies below 8 kilocycles at the input of the first modulator M₁, and another filter will be required there for cutting off those frequencies. For the alternative scheme referred to above, employing a 16-kilocycle carrier wave for the modulator M₁ and a low pass filter cutting off above 8 kilocycles for the filter F₂ in the output of the modulator, this might not be necessary. In either case, a very cheap filter could be used if complete cancellation could be obtained, say for a few hundred or a

thousand cycles below 8 kilocycles. In the region from 8 to 8.5 kilocycles, phase correction for the filter F₁ in the upper transmitting branch TC₁ would be of advantage, but is perhaps not essential. For example, suppose that at 8.2 kilocycles, the wave in the output of the by-pass circuit BC₁ and the wave in the output of the phase corrector C₁ in the lower branch circuit TC₂ would be exactly in phase, instead of out of phase, at the point of combination. With a loss for the filter F₁ in the upper branch circuit TC₁ of, say, 10 decibels, the level of the currents in the lower branch circuit TC₂ should be reduced by about 3.3 decibels by the combination, but with 180 degrees phase error would be increased by 2.4 decibels. With no line distortion, however, there would be no final error at the receiving end of the line so that the only effect would be to slightly change the power on the line. Of course, delays which are great enough to cause echo effects could not be tolerated.

It is apparent, of course, that a system based on the same principles described above in connection with Fig. 1, could be devised to transmit a band which is wider than 30 to 15,000 cycles, or to transmit a frequency band by dividing it into more than two parts. For example, let us suppose it is desired to transmit a 30 to 22,000 cycle band of signal frequencies. The upper branch circuit TC₁ with the 30 to 8,000 cycle band-pass filter F₁, and the by-pass circuit BC₁, could be used as shown, and the wave in the lower transmitting circuit TC₂ resulting from the combination of the 30 to 22,000 cycle band in the output of the phase corrector C₁, with the wave output of the by-pass circuit BC, would have frequencies ranging from 8,000 to 22,000 cycles. This wave then could be split into two frequency parts by transmitting it in multiple into two auxiliary band circuits, similar to TC₁ and TC₂, one with an 8,000 to 15,000 cycle band-pass (or 15 kilocycle low-pass) filter. A portion of the energy of the frequency subband in the output of that filter could be used in the same way as described for the arrangement of Fig. 1 to cancel out corresponding frequencies in the wave in the other auxiliary branch. After shifting all three frequency subbands thus obtained to some desired place in the frequency spectrum determined by the frequency limits of three transmission lines available and transmitting them so shifted over those lines to the receiving station, they can be there shifted back to their original frequency values and be combined in reverse order to obtain the original signal frequency band of 30 to 22,000 cycles. Another possibility would be to produce an 8 kilocycle program circuit from two 4 kilocycle message circuits by similar means.

It is also apparent that different levels and pre-distortion could be used for the two or more branches on the transmission line, since the energy content will be quite different. Companders could be used on some or all of the bands separately. Some rearrangements of the filter cut-offs and the selection of different carrier frequencies might be desirable in order to have the two branches transmit more nearly the same frequency bands.

The method which has been described above in connection with Fig. 1, is superior to that of using two filters for selecting the frequencies to be transmitted over the two lines, one transmitting 0 to 8 kilocycles and the other 8 to 15 kilocycles, because of the lower cost of the second (lower) branch than an 8 to 15 kilocycle filter, and be-

cause the requirements on the correspondence around 8 kilocycles of the two filters in the latter scheme to give perfect transmission of the total frequency band, are extremely difficult and perhaps impossible to obtain. No such requirement is necessary with the scheme illustrated in Fig. 1 or the modifications thereof described above.

A second useful application of the method of the invention is illustrated in Fig. 2 which shows schematically a high frequency carrier wave system utilized for transmitting a program wave of frequencies ranging from 30 to 15,000 cycles, from station A to station B.

As indicated, at station A in Fig. 2 the program band of 30 to 15,000 cycles is combined in a modulator M_3 with a carrier wave of 80 kilocycles from an associated source S_3 , to produce modulation products of frequencies ranging from 65 to 95 kilocycles. It is desired to transmit only the upper side-band, 80 to 95 kilocycles, of the modulation products. It is technically difficult to make a band-pass filter passing 80 to 95 kilocycles with sufficiently sharp cut-off to eliminate the carrier and lower side-band. On the other hand, an 80 to 88 kilocycle band-pass filter and an 88 kilocycle high-pass filter or an 88 to 95 kilocycle band-pass filter may be produced easily, particularly of a few hundred or a thousand cycles for cutting off below 88 kilocycles are unimportant.

In the arrangement of Fig. 2, the energy of the modulation products of frequencies ranging from 65 to 95 kilocycles in the output of the modulator M_3 is divided between the upper transmission branch TC_3 and the lower transmission branch TC_4 . The wave in the upper branch TC_3 is transmitted through a band-pass filter F_4 adapted to pass the frequency subband, 80 to 88 kilocycles, and to cut off with great loss at, say 88.5 kilocycles. The other energy portion of the complex carrier wave in the output of the modulator M_3 passes through a phase corrector C_2 in the lower circuit branch TC_4 , having a function similar to that of the phase corrector C_1 in the system of Fig. 1. The 65 to 95 kilocycle wave in the output of the phase corrector C_2 is combined with the amplified 80 to 88 kilocycle wave in the output of the by-pass circuit BC_2 including the one-way amplifier A_6 , the input of which is fed from the upper transmission branch TC_3 in the output of the band-pass filter F_4 , in such phase and magnitude as to eliminate from the 65 to 95 kilocycle wave transmitted over the branch TC_4 the frequencies below 88 kilocycles. The remaining frequencies 88 to 95 kilocycles of the wave in the lower branch TC_4 are transmitted through the high-pass filter F_5 having a cut-off at 88 kilocycles, which eliminates the lower side-band, 80 to 88 kilocycles, and the carrier component of 80 kilocycles. The remaining frequencies 88 to 95 kilocycles in the output of the filter F_5 pass through the one-way amplifier A_8 to the outgoing line L_3 in which they are combined with the other energy portion of the 80 to 88 kilocycle wave selected by the band-pass filter F_4 in the upper branch TC_3 and transmitted over the output of that branch through the one-way amplifier A_7 to the line L_3 . Thus, the wave transmitted over the line L_3 to station B comprises a single side-band with frequencies ranging from 80 to 95 kilocycles, approximately, the carrier component and the other side-band having been suppressed in the manner just described.

It may be pointed out that when the 88 kilo-

cycle high-pass filter is used for the filter F_5 in the lower branch TC_4 , an equivalent effect could be obtained by using only an 80 kilocycle high-pass filter for the filter F_4 in the upper branch TC_3 connected to the output of modulator M_3 . The use of an 88 to 95 kilocycle band-pass filter in place of the high-pass filter F_5 is a preferred arrangement.

Since the filtering and balancing circuits above described are all located at the input terminal of the line L_3 in the system of Fig. 2, phase or amplitude distortion in that line does not affect the output, and phase corrector C_2 may not be necessary except to avoid echo effects. At the receiving station B in the system of Fig. 2, the received side-band, 80 to 95 kilocycles, is combined with an 80 kilocycle carrier wave from the source S_4 in the modulator M_4 to provide in the output of that modulator, side-bands of frequencies ranging from 0 to 15 kilocycles and from 160 to 165 kilocycles, and a simple low-pass filter F_6 in the output of the modulator, cutting off somewhat above 15 kilocycles could be used to suppress the carrier and upper side-band to reproduce the 30 to 15,000 cycle program wave applied to the input of the system.

In the case of Fig. 2, also, more than two divisions of the band in the output of the modulator M_3 could be used, either for a wider band or to permit cheaper filters than the 8 kilocycle filters.

It is obvious that the methods described in connection with Figs. 1 and 2 offer certain practical advantages. For example, the methods would have considerable economical advantage in the case where most program circuits are to have an 8 kilocycle band and the 15 kilocycle band is only rarely required.

Various modifications of the circuits illustrated and described which are within the spirit and scope of the invention will occur to persons skilled in the art.

What is claimed is:

1. The method of transmission which consists in selecting from one energy portion of a wave comprising a wide band of frequencies, a relatively narrow frequency subband, utilizing one energy part of the selected subband to effectively balance out the corresponding frequencies in another energy portion of said wave, selecting a second frequency subband from the remaining frequencies in said other energy portion of said wave, transmitting said second frequency subband and another energy part of the first selected subband over separate paths to a receiving point and combining the received subbands thereat to produce a combination wave containing all of their frequencies.

2. In a signal transmission system comprising a plurality of signal transmission lines of limited frequency transmission range extending between geographically separated stations, the method of transmitting efficiently between said stations a signal wave comprising a wide range of frequencies, which consists in dividing said wave at one of said stations into two energy portions each comprising said wide range of frequencies, selecting from one of said energy portions a frequency subband within the frequency range of one of said lines, transmitting one energy part of the selected subband over said one line to the other station, utilizing another energy part of said selected subband at said one station to effectively balance out corresponding frequencies in the other energy portion of said wave, shifting the frequencies remaining in said other energy

portion of said wave to a position in the frequency spectrum within the frequency transmission range of another of said lines and transmitting the frequency band in its shifted position thereover to said other station, shifting the frequency band received over said other line back to its original position in the frequency spectrum, and combining at said other station the latter frequency band so shifted with the frequency subband received over said one line in such manner as to reproduce the original signal wave.

3. The method of separating one side-band component from the other side-band component and the carrier component in a complex carrier wave, which consists in dividing said complex wave into two energy portions each containing all its component frequencies, selecting from one of said energy portions a frequency subband comprising a portion of the frequencies in said one side-band component, combining one energy part of the selected frequency subband with the other energy portion of said complex wave in such phase and magnitude as to effectively balance out the corresponding frequencies in said other energy portion, selecting from the remaining frequencies in said other energy portion of said wave a second subband of frequencies corresponding to those in the other portion of said one side-band component, and combining said second selected frequency subband with the other energy part of the first selected frequency subband to produce said one signal side-band component.

4. The method of transmitting a signal wave of a wide band of signal frequencies which consists in modulating said wide frequency band signal wave at a transmitting point with a high frequency carrier wave to produce a complex carrier wave comprising upper and lower side-band components and a carrier component, dividing said complex carrier wave into two energy portions each containing all of its frequencies, selecting from one of said energy portions a frequency

subband comprising a portion of the frequencies within one of said side-band components, combining a part of the energy of the selected subband with the other energy portion of said complex wave in such phase and magnitude as to effectively balance out corresponding frequencies in said other energy portion of said wave, selecting from the remaining frequencies in said other energy portion of said wave a second frequency subband comprising the other portion of the frequencies in said one side-band component, combining said second selected frequency subband with the other energy part of the first selected frequency subband so as to produce said one side-band component, transmitting said one side-band component to a receiving point, modulating the received side-band component thereat with a carrier wave of the same frequency as that of the high frequency carrier wave utilized in the modulating step at the transmitting point, to produce modulation products including as one side-band component the original wide band of signal frequencies and selecting that side-band component.

5. The method of transmission which consists in dividing a wave of a wide band of frequencies into a plurality of energy portions, selecting a relatively narrow frequency subband from one of said energy portions of said wave, utilizing one energy part of the selected frequency subband to effectively balance out the corresponding frequencies in another energy portion of said wave, effectively transmitting at least a portion of the remaining frequencies in said other energy portion of said wave and the other energy part of said selected frequency subband over respectively different circuits to a given point and there combining them in a common circuit to produce a combination wave containing all their frequencies.

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