April 21, 1936. C. L. WEIS, JR 2,038,202

CARRIER WAVE SYSTEM

Filed Nov. 2, 1933 2 Sheets-Sheet 1

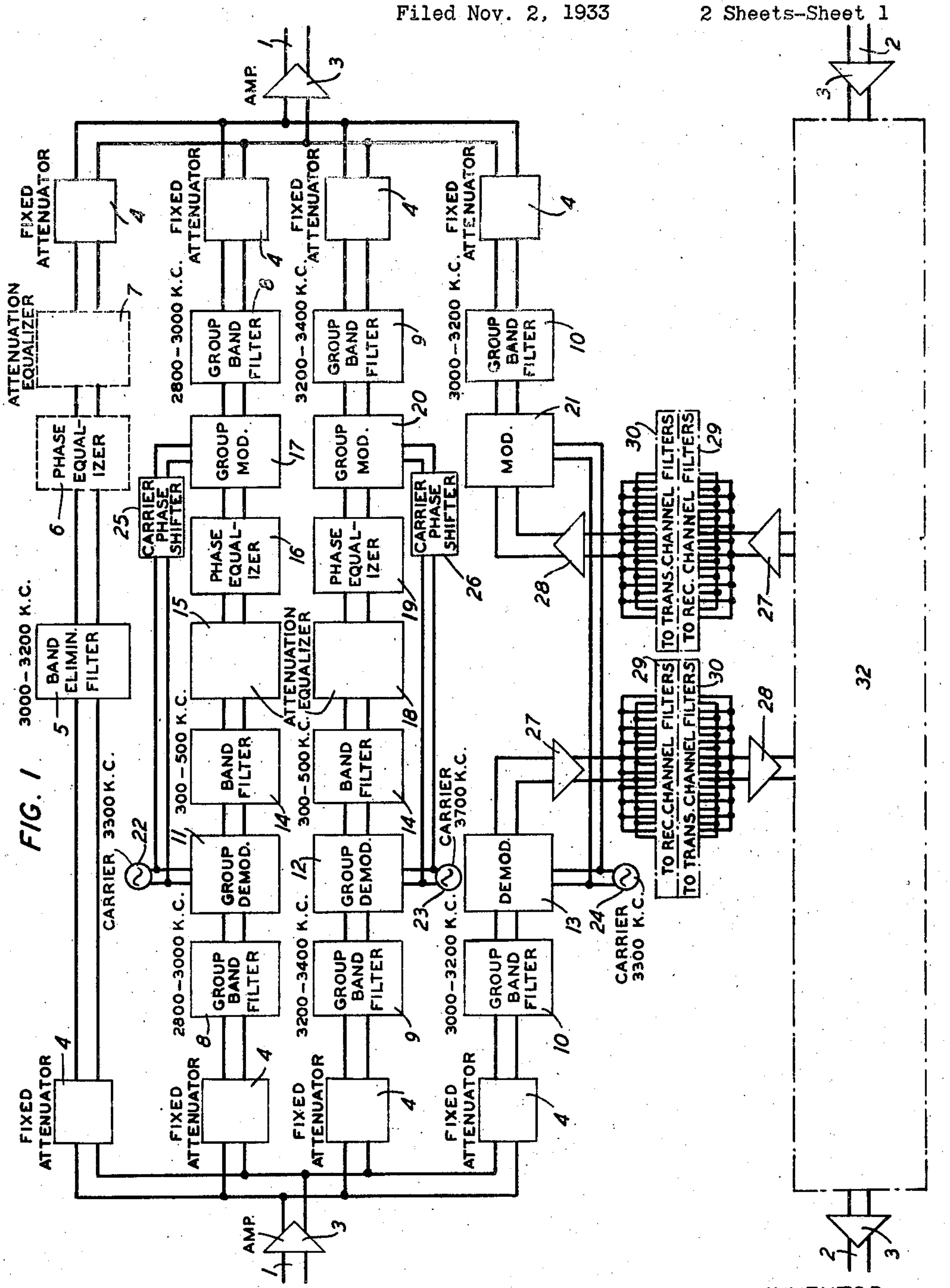

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FIG. 2

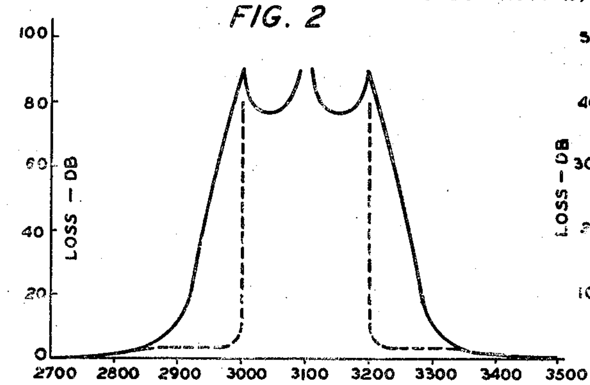


FIG. 5

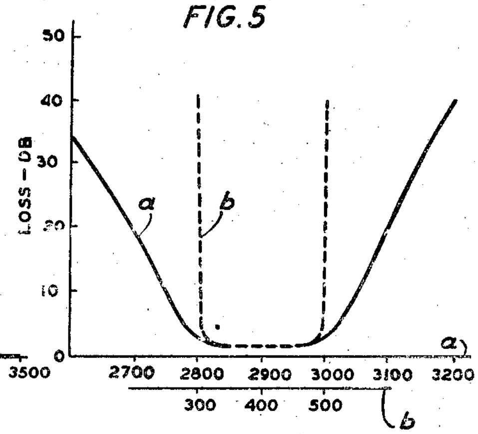


FIG. 3

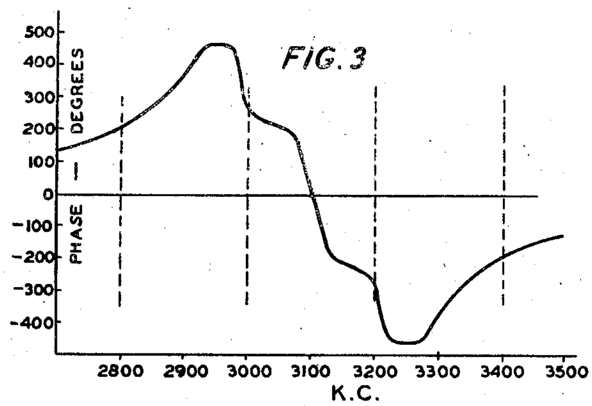


FIG. 6

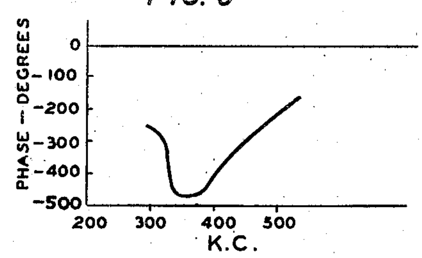


FIG. 4

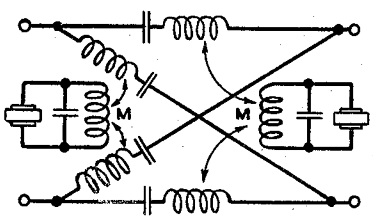


FIG. 7

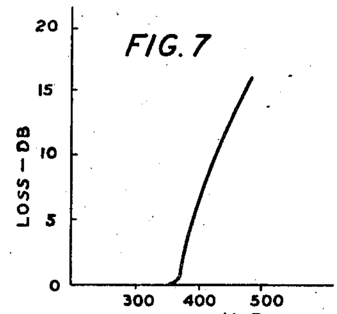
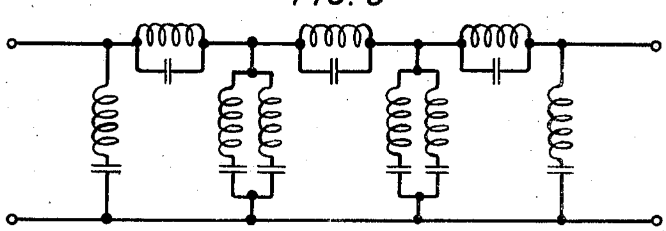


FIG. 8



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Patented Apr. 21, 1936

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UNITED STATES PATENT OFFICE

2,038,202

CARRIER WAVE SYSTEM

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Application November 2, 1933, Serial No. 696,319

7 Claims. (Cl. 179—15)

The present invention relates to a multiplex carrier wave transmission system and more particularly to a means of diverting from or adding to the system at an intermediate point of the system a portion only of the total number of carrier waves or channels of the system.

An object of the invention is to permit the taking from or adding to the system at an intermediate point of the system a portion only of the total number of carrier waves or channels of the system at the same time permitting normal transmission through the remaining channels of the system.

In a multiplex carrier wave transmission system the channels must be placed as close together as possible in frequency if the most efficient use of the available frequency range is to be made. Complicated modulating and demodulating systems employing very complex systems of frequency selective devices have sometimes proven advantageous economically as aids in achieving this end. With the advent of improved transmission mediums, such as the concentric conductor and carrier cables and of improved carrier apparatus the usable frequency range for wire transmission has been in some cases greatly extended.

A definite trend toward increasing the number of channels per system gives the problem of terminating or originating channels at intermediate points along the system an increased importance.

To solve this problem it is necessary to provide a means of effectively separating the channels that are to be diverted, or added, from the through channels without interfering with normal transmission over the latter. It is also necessary to provide a means of isolating effectively one portion of the transmission system from the other at the frequencies utilized by the channels which are to be diverted, or added, at the same time permitting normal transmission over the through channels.

The invention provides a solution of the above problems and makes possible the transmission not only of through channels between terminals but also of channels between a terminal and an intermediate point and of channels between two intermediate points along the route of a system. By means of extension systems connecting with convenient intermediate points the main transmission system may be utilized to serve a broad area along its entire route.

In accordance with one feature of the invention, for example, a band elimination filter is placed in the line at a point at which channels are to be diverted from or added to the system. This filter has a suppression range corresponding to the frequencies included in the channels that are to be diverted from or added to the system. It therefore effectively severs the line into two portions isolated from each other with respect to these particular frequencies but allows free transmission of other frequencies over the line. Band-pass filters passing the frequencies suppressed by the band elimination filter are then connected to the line at each side of the band elimination filter. One of these serves to divert channels from the line to suitable carrier receiving apparatus and the other to add channels to those on the line from suitable carrier transmitting apparatus. The receiving and transmitting apparatus may be at the intermediate point or be connected to a distant point by a suitable carrier transmission line.

In accordance with the invention, a filter of the piezo-crystal type may be used as the band elimination filter at reasonably high frequencies, for example, up to the order of 1000 kilocycles. At higher frequencies the problem becomes more difficult and it is found necessary or advantageous to supplement the filter with other circuits in order to obtain effective separation between the desired channels without introducing distortion into the through channels.

In accordance with a further feature of the invention therefore, circuits are shunted around the band elimination filter to produce a more complete separation between the waves of the channels that are to be taken from the line or added to it and the adjacent through channels and to compensate for the band edge effects on adjacent channels of the band elimination filter. The necessary degree of separation may be obtained in these shunt circuits by demodulating to a much lower frequency band for which a band filter of sufficiently sharp selectivity can be built. Equalization for attenuation and phase distortion are also more readily introduced at the lower frequencies. The band is then modulated back to its original frequency range and placed on the line at the output side of the band elimination filter.

The invention may now be more fully understood by reference to the following description of an illustrative embodiment when read in connection with the accompanying drawings, in which:

Fig. 1 is a schematic diagram of a system embodying one form of the invention;

Fig. 2 shows the attenuation characteristic of a typical band elimination filter in solid line with the modifications effected in the characteristic by the shunting circuits of Fig. 1 indicated in dotted lines;

Fig. 3 shows a typical phase characteristic of a band elimination filter;

Figs. 4 and 8 show schematic diagrams of filters to be described more in detail later; and

Figs. 5, 6, and 7 show characteristics of filters or equalizers used in the system as will be indicated later.

In the illustration of Fig. 1 the lines 1 and 2 are multiplex carrier transmission lines of a system using the well known four-wire arrangement in which one pair of conductors, shown as transmission path or line 1, is used to transmit a multiplicity of carrier channels in one direction and the other pair, 2, transmits a like number of channels in the opposite direction between the terminals of the line. It is assumed in this example that the pairs are able to transmit efficiently a wide range of frequencies say from approximately 500 to 5000 kilocycles. Some types of concentric conductor pairs could be used for such a system.

It is also assumed that the pairs constituting line 1 and line 2 of Fig. 1 are of the same kind and that therefore the apparatus necessary in line 1 which will be described in detail will be suitable for use in line 2. Hence the block 32 of Fig. 1 can be assumed to be a duplication of the apparatus shown in the upper portion of Fig. 1 and described hereunder. However it should be noted that since the direction of transmission along line 2 is assumed to be opposite to that along line 1 the apparatus for line 2 must be arranged from right to left in the order given for line 1 from left to right.

Signals transmitted along line 1 from the left are amplified by the line amplifier 3 whose output is connected to four fixed attenuators, 4, the input terminals of the latter being connected in parallel. These attenuators serve to prevent interaction between the filters 5, 8, 9, and 10. This is necessary where, as assumed, the theoretical transmitting ranges of these filters overlap slightly and troublesome distortion might result were the attenuators removed. In this example, these attenuators need introduce approximately 12 decibel attenuation. Assume, by way of example, that the band of frequencies between 3000 and 3200 kilocycles inclusive, is to be employed in the channels connecting to the intermediate point between the terminals in the main transmission line. Band elimination filter, 5, is employed to eliminate this band of frequencies between 3000 to 3200 kilocycles inclusive. The attenuation characteristic of this filter is shown in the solid line curve of Fig. 2 and its schematic diagram in Fig. 8. The function of this filter is to isolate the left portion of line 1 from the right portion of line 1 at all frequencies between 3000 to 3200 kilocycles inclusive. However it is not possible for it to effectively do this without introducing attenuation distortion in the adjacent frequency bands 2800 to 3000 kilocycles and 3200 to 3400 kilocycles respectively. The phase characteristic of the band elimination filter is shown in Fig. 3. Phase equalizer 6 and attenuation equalizer 7 may be used if desired to compensate more remote frequencies for phase and attenuation distortion but cannot fully compensate for the large amount of distortion of the band elimination filter in the immediately adjacent bands without destroying its effectiveness. In the more usual cases equalizers 6 and 7 may be omitted.

However, each of the adjacent frequency bands can be compensated for the distortion of the band elimination filter by providing for each a parallel circuit shunted around the circuit containing the band elimination filter. For the lower adjacent group this circuit consists as shown in Fig. 1 of a fixed attenuator 4; the group band filter 8, whose attenuation characteristic is shown by curve "a" of Fig. 5; the group demodulator 11 which being supplied by oscillator 22 with a carrier of 3300 kilocycles demodulates the lower adjacent group "upside down" to the frequency range 300 to 500 kilocycles. These frequencies pass through the band filter 14 whose attenuation characteristic is shown by curve "b" of Fig. 5, and whose schematic diagram for any single section is shown in Fig. 4. As shown this is a lattice type band-pass filter employing two piezo-electric crystal elements per section. Ordinarily several sections like Fig. 4 are connected in tandem, each section contributing a portion only of the total selectivity. In the present embodiment five such sections are used in tandem. The function of filter 14 is to exclude all unwanted frequencies present in the output of demodulator 11 and to give sharp selectivity for the band 2800—3000 kilocycles now demodulated to 300 to 500 kilocycles. The gain in selectivity obtained by demodulating so as to use the lower frequency band filter is illustrated graphically in the difference between curves "a" and "b" of Fig. 5. The next step in the shunt circuit is to introduce the proper attenuation and phase equalization by means of equalizers 15 and 16 respectively whose characteristics are shown in Figs. 7 and 6 respectively. In this example the equalization is directed to combine in proper phase and amplitude frequencies between 2800 and 3000 kilocycles which pass through the band elimination filter with the same frequencies which pass through this special shunting circuit to the end that the effective attenuation characteristic of the combination of the band elimination filter and the special shunting circuit will differ from that of the band elimination filter above as indicated by the dotted line shown at 3000 kilocycles and below in Fig. 2. An added advantage is that equalization is more readily introduced at the lower frequencies. After equalization the 300 to 500 kilocycle band is modulated by group modulator 17 back to the range 2800 to 3000 kilocycles. By means "carrier phase shifter" 25 an arbitrary phase shift of the entire group can be introduced as necessary to assist in phase equalization. The group band filter 8 is now used to select the proper modulation product such as the lower side-band and to exclude unwanted frequencies present in the modulator output. A fixed attenuator 4 completes the shunting circuit and permits the connection of the output of the shunting circuit in parallel with the output of the band elimination filter circuit without danger of interaction between the two.

The composition and operation of the shunting circuit for the upper adjacent group is exactly the same as for the lower adjacent group as just described except that the group band filter 9 of course selects the upper adjacent group of frequencies; demodulator 12 and modulator 20 are supplied by oscillator 23 with a carrier at 3700 kilocycles and the attenuation and phase equalizers 18 and 19 are designed for the upper adjacent group. The resulting effective modifications in the characteristic of the band elimination filter obtained by means of these shunting circuits are shown by the dotted lines in Fig. 2 and the objective of isolating the left portion of line **1** from the right portion of line **1** at frequencies chosen by way of example between 3000 to 3200 kilocycles and at the same time permitting the free transmission of the other frequencies of the system has been attained. Transmission from the line at frequencies between 3000 to 3200 kilocycles may take place through the lowest fixed attenuator **4**, shown at the left in Fig. 1, the group band filter **10**, the demodulator **13**, the group amplifier **27** and suitable carrier receiving apparatus **29**. Transmission to the line may originate in suitable carrier transmitting apparatus **30**, pass through the group amplifier **28**, the modulator **21**, group band filter **10**, and a fixed attenuator **4** to the line amplifier **3** at the upper right side in Fig. 1.

While Fig. 1 indicates the carrier receiving and transmitting apparatus connecting directly to the line at the intermediate point, the receiving and transmitting apparatus may be located at some more remote point and may be connected to the intermediate point by a suitable carrier transmission line with intermediate repeaters if necessary.

It is to be understood that the circuits shown and described are merely illustrative of a preferred form of practicing the invention but that neither the drawings nor the description should be taken as limiting the invention, the scope of which is defined in the claims.

What is claimed is:

1. The combination with a multiplex carrier current line capable of providing a large number of carrier channels of a circuit for diverting from or adding to the line a portion only of said channels at an intermediate point comprising band-pass filters connected to the line at said point to permit transmission from or to the line of such frequencies only as are included in the channels to be diverted from or added to the line at said point respectively, and a band elimination filter connected in the line between the points to which the above band-pass filters are connected to effectively isolate the portions of the line on either side of said band elimination filter from each other at the frequencies which are included in the channels to be diverted from or added to the line at said point but permitting free transmission along the line over the other carrier channels, and a circuit connected between said line portions in shunt relation to said band elimination filter for the purpose of obtaining sharper selectivity between the band eliminated by said filter and a band of frequencies adjacent to the eliminated band of frequencies, said shunt circuit consisting of an input band-pass filter passing a group of frequencies adjacent to the eliminated band of frequencies, a demodulator for the purpose of changing the absolute frequencies of this adjacent group so as to make possible the use of a band-pass filter having the required sharpness of selectivity, a lower frequency band-pass filter having the noted improved selectivity being included as part of the shunting circuit, suitable attenuation and phase equalizers designed so that frequencies passing through the shunting circuit will appear on the output of the band elimination filter circuit in proper volume and phase relation to the same frequencies which pass through the band elimination filter circuit, a modulator for restoring the frequencies passing through the shunting circuit to their original absolute values and a third band-pass filter similar to the input band-pass filter to attenuate unwanted frequencies present in the modulator output and to pass the desired frequency band from the modulator to the line at the output end of the band elimination filter circuit.

2. The combination with a multiplex carrier current line capable of providing a large number of carrier channels of a circuit for diverting from or adding to the line a portion only of said channels at an intermediate point comprising band-pass filters connected to the line at said point to permit transmission from or to the line of such frequencies only as are included in the channels to be diverted from or added to the line at said point, and a band elimination filter connected in the line between the points to which the above band-pass filters are connected to effectively isolate the portions of the line on either side of said band elimination filter from each other at the frequencies which are utilized by the channels to be diverted from or added to the line at said point but permitting free transmission along the line over the other carrier channels, and a pair of circuits shunted around the circuit arrangement including said band elimination filter for the purpose of compensating frequencies adjacent to the band eliminated by said filter for attenuation or phase distortion introduced by said band elimination filter, each said shunting circuit comprising an input band-pass filter passing frequencies adjacent to the eliminated band of frequencies, and respectively above and below the nominal cut-off frequencies of the band elimination filter, a demodulator for the purpose of changing the absolute frequencies of the respective adjacent band so as to make possible the use of more precise or more readily constructed band-pass filter and phase and attenuation equalizers included as part of the shunting circuit, a band-pass filter of the requisite degree of selectivity to select the desired frequency range after demodulation, the above described phase and attenuation equalizers to modify the adjacent frequencies in a manner to compensate for distortion of the type caused by the band elimination filter in the line, a modulator to restore the frequencies to the range of their original absolute values and a third band-pass filter similar to the input band-pass filter to attenuate unwanted frequencies present in the modulator output and to pass the proper sideband from the modulator to the line at the output end of the band elimination filter circuit.

3. In a line including a four-terminal frequency selective device which distorts waves in the region of its cut-off, a circuit in shunt relation to said device including means to compensate such distortion, said means comprising a demodulator for reducing the frequency of transmitted waves derived from said line on one side of said device including frequencies in the range in which such distortion occurs, an equalizer for counteracting the effect of said distortion in the demodulated wave, and means to raise the frequency of the equalized waves to their original frequency position and to impress them on said line on the other side of said device, the waves being impressed on the line to combine with the waves passed by said device to compensate the distortion therein.

4. In combination with a four-terminal frequency selective device having the characteristic to produce distortion at the edge of the band of frequencies selected, circuits including a four-terminal shunting device connected to one side of said first mentioned device providing a path around the circuit including the first mentioned

device, the shunt circuit including elements arranged to correct for the distortion of the first mentioned device, said elements including means to demodulate waves of frequencies in a band distorted by the first mentioned device, means for sharply discriminating against unwanted frequencies, equalizer means for correction of attenuation and phase distortion, and modulator means to restore the frequencies to their original band prior to placing the corrected frequencies on the opposite side of the first mentioned selective device.

5. The combination with a four-terminal transmission device having an insufficiently sharp cut-off at the high frequencies to be transmitted on a multiplex carrier telephone line, of shunt circuits including a four-terminal shunting device providing a path from one side of said first mentioned device around the circuits including the first mentioned device, means in the shunting device to select and modulate a portion of the frequency range distorted by the first mentioned device to a lower frequency range to make possible the use in the shunting device of equalizing devices of more precise or desired discriminating characteristics, means for filtering in the shunting device more precisely according to the characteristic desired in the first mentioned device, equalizing means for correcting attenuation and phase of signal energy desired to be transmitted by the first device, and modulating means followed by filter means for placing the output of the shunt circuit on the output side of the first mentioned transmission device.

6. The combination with a band pass filter and a line having too slow a rate of change of attenuation adjacent a band to be eliminated from the line, of four-terminal shunting devices providing paths from one side of said filter around the circuit including the filter in the line and adapted to contribute to the filtering action intended for the first mentioned filter, the shunting devices having means arranged to modulate frequencies chosen in ranges sought to be corrected, filters operating in the new frequency ranges having more precise characteristics and cut-off for the signals desired to be eliminated by the filter in the line, attenuation and phase equalizers for producing materially better equalization and phase correction of the signal frequencies desired to be transmitted in the line through the first mentioned filter, modulating means to restore the signal energy to the desired frequency range, and filter means and attenuation means arranged to place the restored frequencies on the line at the output side of the first mentioned filter.

7. The combination with a four terminal frequency selective device having an undesired rate of attenuation change with frequency of a four terminal shunting device providing a parallel path around the circuit including the first-mentioned device and means in said parallel path of greater precision of cut-off for correcting for the distortion arising from the said undesired rate of attenuation change with frequency, thereby obtaining sharper selectivity between the attenuated and the transmitted frequency ranges of the original device.

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