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CARRIER REPEATER SYSTEM

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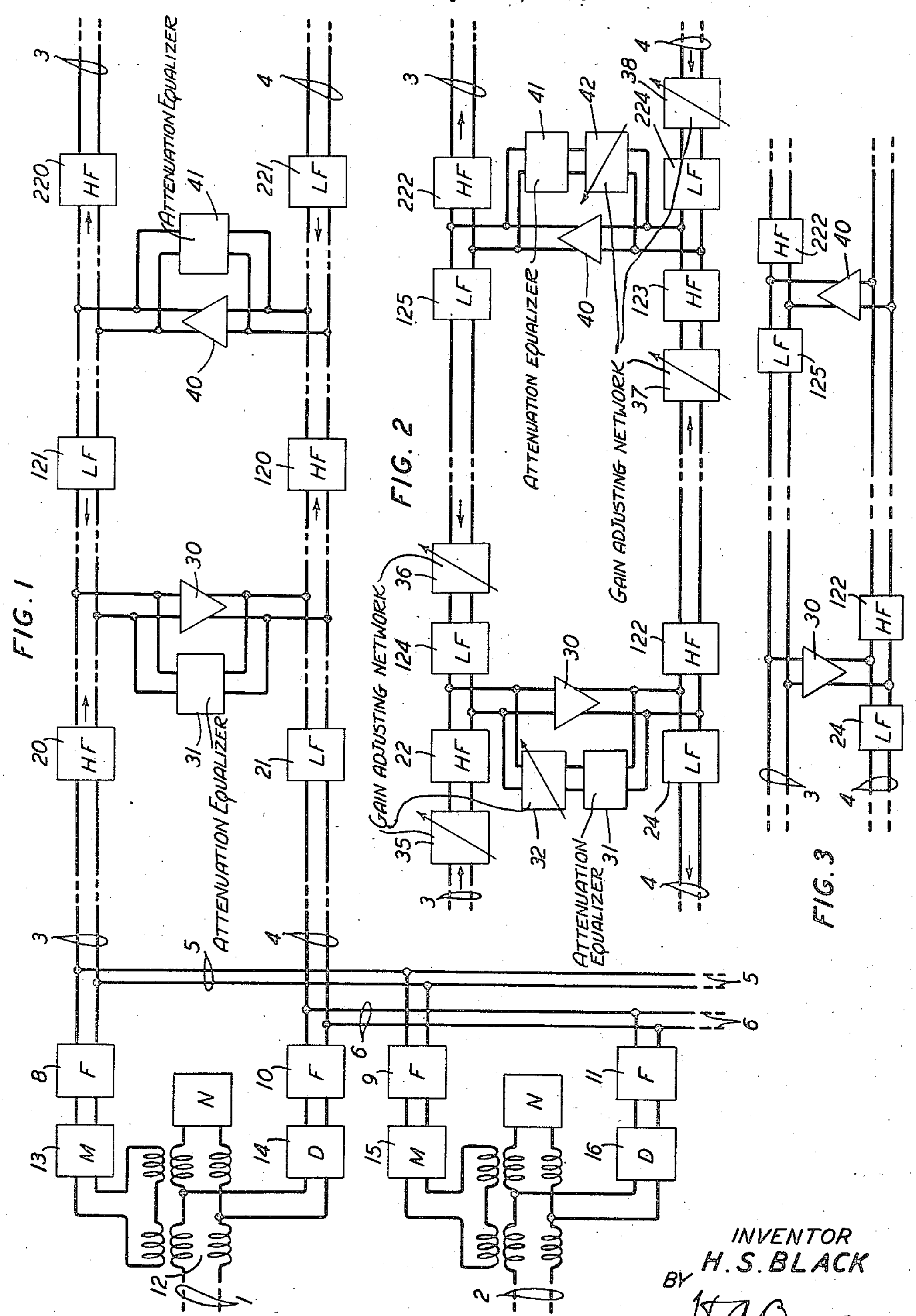

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CARRIER REPEATER SYSTEM

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1 Claim. (Cl. 178—44)

The present invention relates to the two-way transmission of signals over separate transmission lines and more particularly to the application of repeaters to this type of transmission.

An object of the invention is a simplification and improvement in two-way transmission of signals over separate lines with amplifiers.

The so called four-wire transmission known in the prior art involves transmission in the eastward direction over one line and transmission in the westward direction over a separate line. Each of these lines may contain one-way repeaters spaced at appropriate intervals. Since these repeaters only amplify in one direction, no separation between frequency bands, such as bands used in opposite directions, need be made at the repeater points as would be the case in a two-way, two-wire repeater, for example, using carrier waves in different frequency ranges for opposite directions of transmission over the same line. Except for cross-talk difficulties, the same frequency range can be used on both lines of a four-wire system.

In applying multiplex carrier transmission to cable circuits, cross-talk or other difficulties may, in some cases, make it necessary or desirable to transmit different bands of frequencies on lines that are transmitting in opposite directions. The use of separate repeaters in the individual lines to amplify the different frequency ranges makes the repeater cost run high particularly as such auxiliary apparatus as attenuation equalizers and gain control equipment must be duplicated at some or all of the repeater points on both lines.

The present invention secures the advantages of four-wire transmission with a saving of about half the number of repeaters that would be required if separate repeaters were used in the individual lines. While this saving is offset to some extent by the necessity of using filters in connection with the repeaters for separating the two directional groups, these filters can be of relatively simple construction and fairly inexpensive since the requirements placed upon them by the circuit arrangement used in accordance with the invention are not particularly severe.

A better and more complete understanding will be had of the invention from the following detailed specification taken in connection with the accompanying drawing.

Fig. 1 is a simplified diagrammatic showing of a two-way carrier transmission system in accordance with the invention;

Fig. 2 shows a modification in the repeater and filter arrangement of Fig. 1; and

Fig. 3 shows a further modification.

Referring to Fig. 1 two telephone lines **1** and **2** representative of a larger group of lines, are shown connected for two-way repeating with the lines **3** and **4** through the medium of terminal carrier apparatus. The multiplex carrier wave transmission line **3** terminates in a transmitting branch **5** leading to individual transmitting channel filters of which two are shown at **8** and **9**. There will be as many of these channel filters as there are low frequency lines **1**, **2** to be connected with the multiplex transmission system.

The multiplex line **4** terminates in a receiving branch **6** which leads to individual receiving channels of which two, at **10** and **11**, are shown.

Telephone line **1** is provided with the usual hybrid coil **12** and balancing network, the transmitting branch of which leads to modulator **13** which is assumed to contain a source of carrier frequency waves to be modulated by the speech waves on the line **1**. The other branch of the hybrid coil leads to detector or demodulator **14**. Line **2** is similarly connected through carrier transmitting apparatus including modulator **15**, and carrier receiving apparatus including demodulator **16**.

The terminal carrier circuit, as disclosed, operates to modulate the carrier wave sources associated with modulators **13** and **15** with speech waves received over the individual lines **1** and **2**. A side-band resulting from the operation of modulator **13** is selectively transmitted through the filter **8** to the transmitting branch **5** and a side-band resulting from the operation of modulator **15** is selectively transmitted through the filter **9** to the same transmitting branch **5**. Other lines, not shown, would operate similarly to impress on the transmitting branch **5** a succession of side-bands spaced in frequency, all of these side-bands occupying a relatively high frequency range within the transmission band limits of the high frequency filter **20** included in the first repeater section of the transmission line **3**.

The receiving branch **6** receives from the line **4** a similar succession of side-bands spaced in frequency, all of these side-bands occupying a lower range of frequencies within the transmission band limits of the low frequency filter **21** shown located in the first repeater section of the line **4**. These various side-bands as received from the branch **6** are separated by the individual line filters **10**, **11**, etc. and impressed on the individual demodulators **14**, **16**, etc. by which they are demodulated to produce voice currents that are then impressed on the individual lines **1**, **2**, etc.

Associated with the lines 3 and 4 at intervals along the line is a succession of repeaters 30, 40, etc. arranged to amplify the waves on one line and impress them on the opposite line. The successive repeaters are reversed in direction as shown. These repeaters may be thought of as dividing the lines into repeater sections. Considering the line 3 each repeater section contains a filter preferably located near the center of the respective section and these filters alternate between high frequency filters, similar to 20, and low frequency filters similar to 21. The line 3, for example, is shown as including in successive repeater sections, high frequency filter 20, low frequency filter 121 and high frequency filter 220. Similarly, the line 4 is shown as including in successive repeater sections, low frequency filter 21, high frequency filter 120 and low frequency filter 221.

In operation, the high frequency groups of waves impressed on the line 3 from the transmitting branch 5 are selectively transmitted through the high frequency filter 20 and then along the line 3. These waves can not pass through the low frequency filter 121, but they are permitted to pass into the input of the amplifier 30 where they are amplified and impressed on the line 4. These waves are prevented from passing back into the receiving terminal circuit 6 since they will not pass the low frequency filter 21. They do, however, traverse the line 4 toward the right and are allowed to pass through the high frequency filter 120. After traversing this repeater section they pass into the input of repeater 40 and are amplified by this repeater and impressed on the line 3. Progress is then to the right through the high frequency filter 220 to the next repeater station or to the terminal station (not shown) at the right cooperating with the terminal station shown at the left.

Waves traversing the lower line 4 from the terminal station (not shown) assumed to be at the right of the figure, are waves comprised in a lower frequency group. These waves are selectively transmitted through the low filter 221 to the input of amplifier 40 where they are amplified and impressed on line 3. They traverse the next section of line 3 including low frequency filter 121 and after arriving at the next repeater station are impressed on the input of repeater 30 where they are amplified and impressed on line 4. Traversing the last repeater section of this line toward the left they are selectively transmitted through the low filter 21 and eventually to the receiving terminal circuit 6.

It is thus seen that each repeater 30, 40, etc. is utilized over the entire frequency range transmitted over both lines 3 and 4. These repeaters are preferably, though not necessarily, of the type disclosed and claimed in an application by H. S. Black, Serial No. 606,871, filed April 22, 1932. They are preferably of the stabilized feed-back type disclosed and claimed in that application by which is meant that they have a feed-back path, usually gain-reducing, from the output to the input, resulting, in accordance with the disclosure of that application, in greater stability of operation and in markedly less distortion. As further disclosed in said application, these amplifiers preferably include in the feed-back circuit an attenuation equalizer 31, 41, etc. which unequally attenuates components of different frequencies in the feed-back circuit in a manner similar to the unequal attenuation of the transmission lines 3 and 4 over the frequency range.

Fig. 2 differs mainly from Fig. 1 in the provision of four filters per repeater. One pair of filters, high filter 22 and low filter 124 are associated with the input of repeater 30, whereas low filter 24 and high filter 122 are associated with its output. Similarly, in connection with repeater 40, high filter 123 and low filter 224 are associated with its input while low filter 125 and high filter 222 are associated with its output. The waves coming from the left in Fig. 2 on the line 3 pass through the gain control network 35, high pass filter 22 and are prevented by low filter 124 from going toward the right in the line 3. These waves are amplified at 30 and are prevented by the low filter 24 from going toward the left in the line 4. These waves are selectively passed by the high filter 122 to the repeater section on the right. At the next repeater station they pass through the gain adjusting network 37, and high pass filter 123 to the input of amplifier 40, etc.

Similarly, low frequency waves on the line 4 coming in at the right-hand side of the figure, pass through gain adjusting network 38, low pass filter 224 to the input side of repeater 40 and thence through the repeater and the low filter 125 to the outgoing line section. At the next repeater station they pass through the gain adjusting network 36, low pass filter 124 to the input of amplifier 30, etc.

It will be noted that the gain adjusting networks 35 and 37 are individual to line sections which transmit only waves in a high frequency group. Similarly, the gain adjusting networks 36 and 38 are individual to line sections which transmit only the waves in the low frequency group. Independent adjustment may be made in each of these networks to suit the particular conditions.

In repeater 30 the attenuation equalizer 31 is shown as in the case of Fig. 1 and in addition there is variable network 32. Similar elements 41 and 42 are associated with the repeater 40. The variable elements 32 and 42 may be adjustable gain control pads in the feed-back circuit of the amplifier. It will be understood that similar variable gain control pads may be associated with the repeaters in Fig. 1. By the use of these adjustable networks the gain of the repeater may be varied from time to time either manually or automatically by known methods to take care of variations in line attenuation. The individual pads 35, 36, 37 and 38 may then be used as supplemental gain adjusting devices of simple construction and with a relatively narrow range of adjustment. In fact, it will probably not be necessary to supply these supplemental networks at every repeater station. Attenuation compensating networks individual to the line sections may also be included similarly to the networks 35, 36, 37 and 38, or may be incorporated as a part of these networks or as a part of the filters 22, 124, 123, 224, etc. Thus, the attenuation equalizers 31 and 41 may effect the principal attenuation equalization and a supplemental network located in the line adjacent the input to the repeaters may be used to give the rest of the equalization that is required.

It was noted above that the circuit of Fig. 1 by virtue of its simple arrangement represents an economy of apparatus. With the filters in the middle of the repeater sections the level difference between currents in the high frequency and low frequency groups approaches zero, thus placing very easy modulation requirements on the filters. This makes for simplicity and low cost in filter construction. Also each filter is terminated by reasonable impedances, which also makes for low cost filter construction. The repeaters have no rigid impedance requirements to meet, the main requirement being sufficiently high input and output impedance, which can be readily obtained by repeater designs of types disclosed in applicant's copending application above referred to.

A limitation to the circuit of Fig. 1 is the cross-talk which may arise from the fact that the high level output currents are allowed to traverse half of a repeater section in a direction opposite to their useful direction of transmission and because of this they may cross-talk into the adjacent oppositely-directed line. For example, low frequency currents amplified at **30** in Fig. 1 pass to the right on line **4** until they reach filter **120** and in so doing they may cross-talk into the section of line **3** immediately above in the figure.

A circuit which avoids this cross-talk tendency but offers economy of design is the circuit shown in Fig. 3. This is similar in circuit configuration to Fig. 2 with the input filters omitted. For example, repeaters **30** and **40** have no filters adjacent their input side, but retain output grouping filters as in Fig. 2, these being filters **24** and **122** in the case of repeater **30** and filters **125** and **222** in the case of repeater **40**. The individual filters may differ in loss characteristics from those of Fig. 2. For example, they may have loss characteristics similar to the filters of Fig. 1 or such other characteristics as may be required in particular cases. The near-end cross-talk (e. g. that arising from the high frequency currents output from repeater **30** through filter **122** cross-talking into the section of line **3** immediately above in the figure) can be kept sufficiently low in any practical case by keeping the repeater gain sufficiently low, which in turn requires a sufficiently close repeater spacing. The near-end cross-talk is generally so low that a practical margin remains for repeater gain, leaving the requisite repeater spacing at a practical value, say 10 to 25 miles in the case of a typical cable installation transmitting up to the order of 40 kilocycles.

The showing of the feed-back paths for the repeaters is to be taken as illustrative and not as limiting since any suitable manner of associating this path with the repeaters and any suitable path may be used. The copending application referred to above discloses a number of ways of associating feed-back paths with amplifiers, as by connecting the feed-back paths between the input and output transformers and the respective input and output lines, or on the amplifier side of such transformers, or using a bridge circuit on one or each end of the feed-back paths, or still other ways. It is contemplated in the practice of the present invention to resort to any of those or other suitable types of circuit.

It will be understood that the invention is not limited to the specific circuits and apparatus that have been described, but modifications may be made within the spirit and scope of the appended claim.

What is claimed is:

In a wave transmission system two lines, means to impress waves in a low range of frequencies on one line, means to impress waves in a high range of frequencies on the other line at the opposite end thereof, said lines being divided into sections by repeaters bridged across from one line to the other, and filter means directing the waves of each range through the first section of its respective line, thence through the respective repeater at the end of that section, thence through the next section of the opposite line, and so on, said repeaters comprising feed-back amplifiers each containing in the feed-back loop an attenuation equalizer which gives the amplifier different gain at different frequencies such as to compensate for unequal attenuation on both of the two line sections to which the repeater input is connected for the respective frequency ranges utilized on said sections

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