June 10, 1930. H. S. BLACK 1,762,755

METHOD AND MEANS FOR REDUCING CROSSTALK IN CARRIER CURRENT SIGNALING SYSTEMS

Filed May 31, 1928 2 Sheets-Sheet 1

FIG. 1

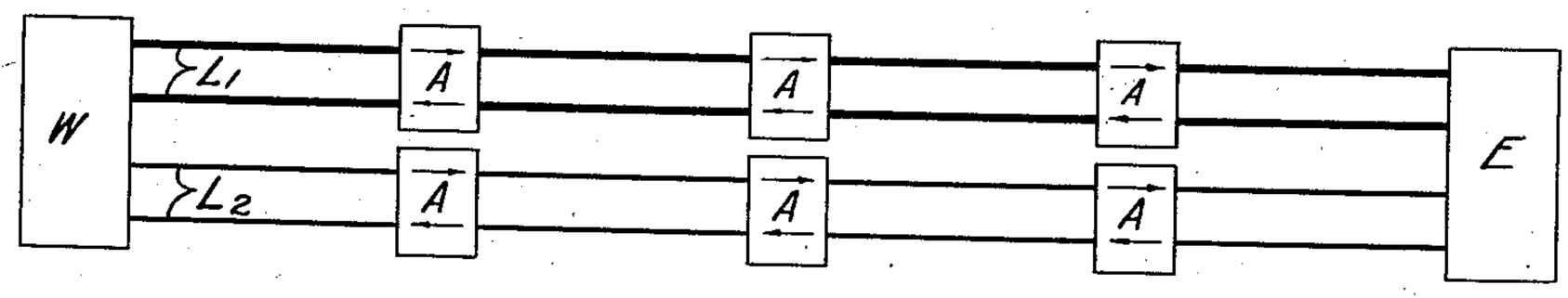

FIG. 2

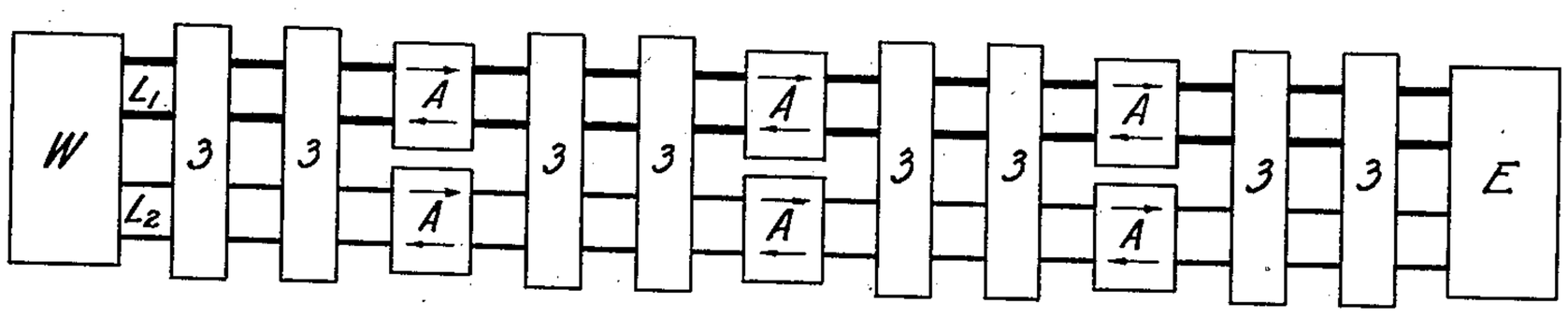

FIG. 3

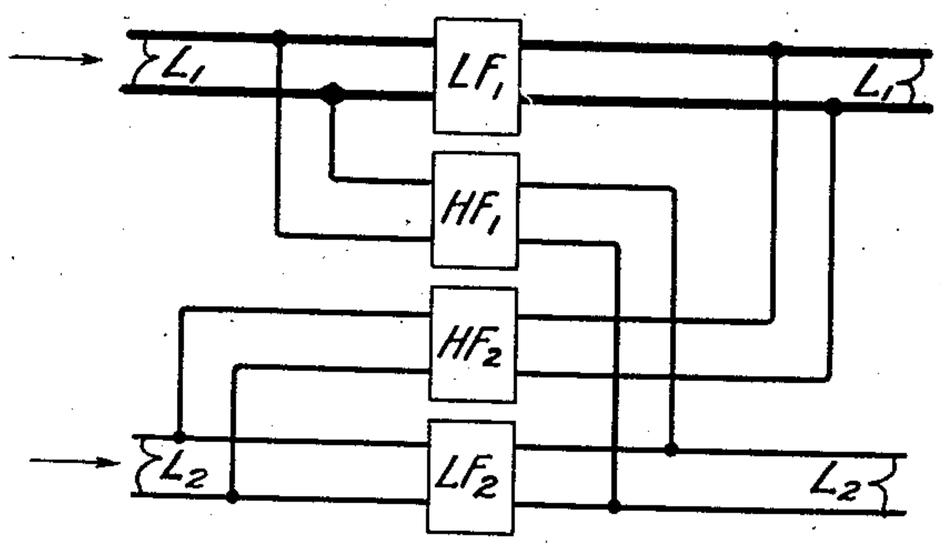

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FIG. 4

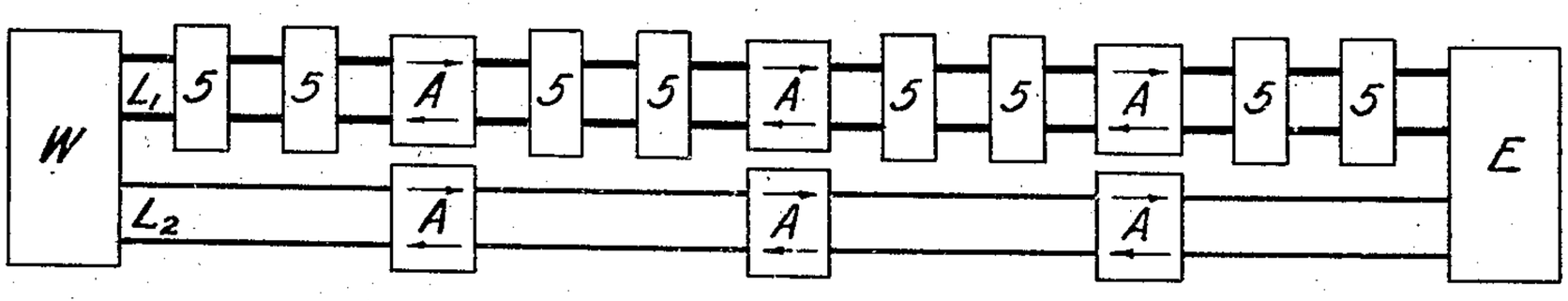
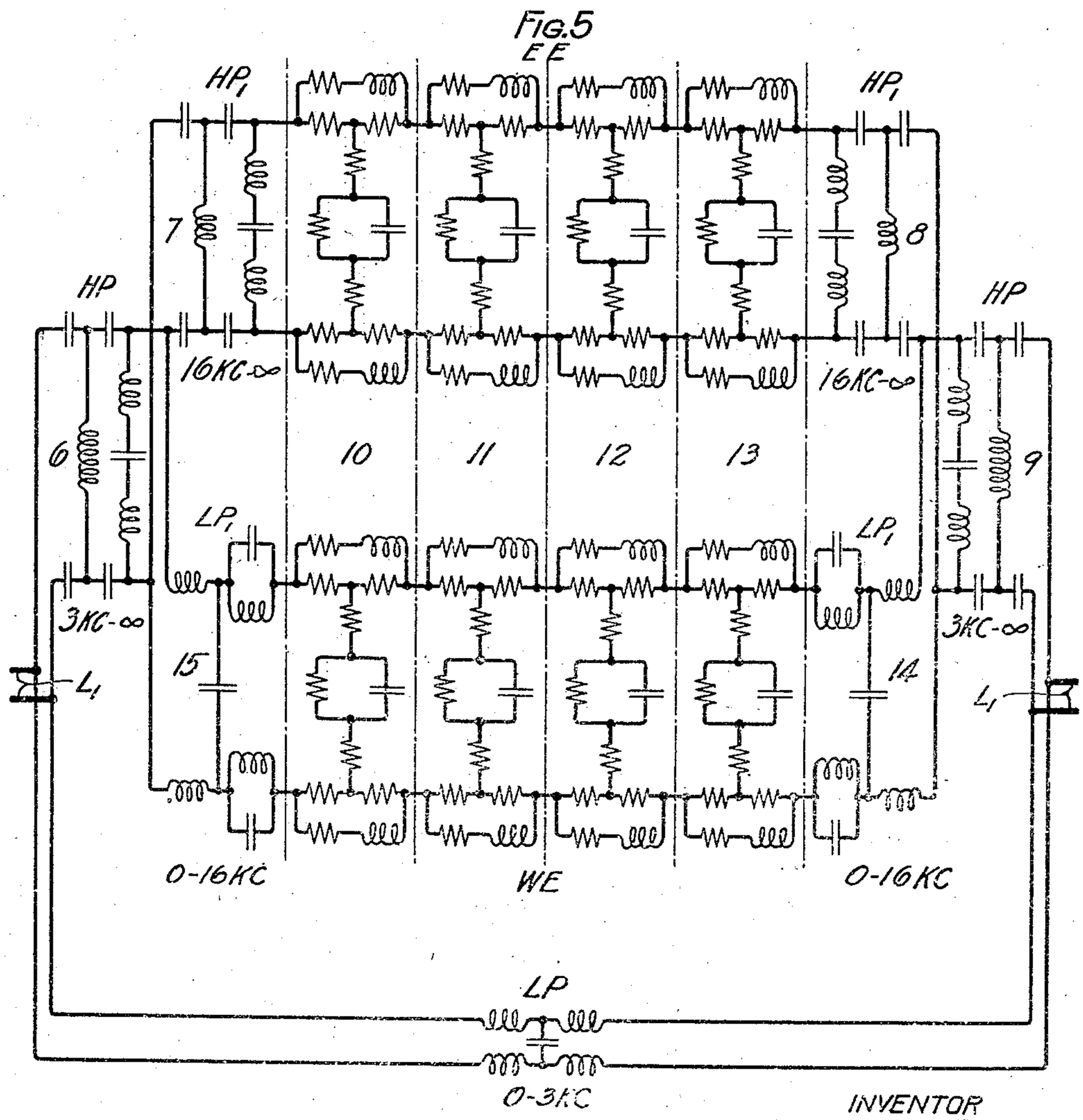


FIG. 5



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UNITED STATES PATENT OFFICE

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METHOD AND MEANS FOR REDUCING CROSSTALK IN CARRIER-CURRENT SIGNALING SYSTEMS

Application filed May 31, 1928. Serial No. 281,698.

This invention relates to methods and means for reducing cross-talk between signaling systems.

An object of the invention is to reduce crosstalk between paralleling signaling systems.

The invention provides a simple and efficient arrangement for reducing crosstalk between paralleling signaling systems which operates to maintain the currents transmitted in the same direction in each system at substantially the same energy level at all points where the transmission lines run parallel and adjacent to each other.

When two or more signaling systems are operated on the same pole line or in the same cable, one of the principal problems encountered is to reduce crosstalk or mutual interaction due to the inductive or capacity effects between adjacent systems.

In order to prevent crosstalk in voice frequency signaling systems, it is customary to transpose the pairs of wires at intervals which are short relative to the wave lengths of the currents employed. This is practicable in such systems since the frequencies are relatively low and the wave lengths correspondingly long. In carrier current signaling systems, however, where the wave lengths involved are relatively short, transpositions are required at much more frequent intervals and the problem of reducing crosstalk becomes increasingly difficult.

It has been found, as described in my Patent No. 1,676,627, issued July 10, 1928, that crosstalk can be reduced by maintaining similarly directed signaling currents on adjacent lines at substantially the same energy level by raising the energy level of one line by amplification at the transmitter and by lowering the energy level of the other line by a resistance pad at the transmitter, compensation being effected at the receivers by a pad and amplifier respectively. However, when the adjacent lines are not of the same gauge wire, or otherwise differ in transmission characteristics, considerable crosstalk will be produced especially at the higher frequencies due to the different attenuation characteristics of the lines.

According to a feature of the present invention when paralleling carrier transmission systems use conductors for one line which are not of the same gauge as the conductors used on the other line, carrier line transfer connections are employed at intervals between the limits within which the lines parallel each other to transfer the carrier currents from the system operated over the smaller gauge line to the larger gauge line and to transfer the carrier currents from the larger gauge line to the smaller. Since in multiplex systems, the carrier frequency terminus and the voice frequency terminus are in many cases not the same, it is desirable to have the voice currents continuously transmitted over the same line and low pass filters can be employed for this purpose.

According to another feature of the present invention, when the paralleling carrier transmission systems employ conductors having different attenuation characteristics and over which relatively high carrier frequencies are transmitted or where there are a plurality of adjacent parallel systems, non-amplifying auxiliary devices having attenuation characteristics which vary with the frequency are employed at intervals between the limits within which the lines parallel each other so that the resultant transmission level of said auxiliary system and the line in which they are used is substantially the same over the range of frequencies transmitted as that of the other lines.

The invention will be described in connection with its application to single channel carrier current telephone systems, but it will be evident that it is also applicable to other types of signaling systems.

Referring to the drawings, Fig. 1 shows two adjacent transmission lines employing conductors having different attenuation characteristics to which the invention is applicable.

Fig. 2 shows one method of reducing the crosstalk between the lines shown in Fig. 1 in accordance with the invention.

Fig. 3 is a detailed drawing which will be referred to later in connection with Fig. 2.

Fig. 4 shows another method of reducing the crosstalk between the lines shown in Fig. 1 in accordance with the invention.

Fig. 5 is a detailed drawing which will be referred to later in connection with Fig. 4.

Referring to Fig. 1, W and E designate two distant stations between which there are two two-way carrier transmission systems employing bands of frequencies for transmission in the same direction over each line. The transmission lines are located on the same pole line or in the same cable. One of the systems employs a line L_1, the conductors of which are of a larger gauge wire than the conductors of line L_2 employed in the other system. The two-way systems may be of the types disclosed in U. S. Patent 1,602,019, issued October 15, 1926 to C. L. Weis, Jr., or in my Patent 1,653,837, issued December 27, 1927. Two-way repeaters A are located at intervals in lines L_1 and L_2. These repeaters may be of the type disclosed in U. S. Patent 1,413,357 issued to P. A. Raibourn, April 18, 1922.

Assume that we transmit east on both lines, starting from the west terminal W at a transmission level of +15 TU with a frequency of 27 KC, that at this frequency the loss of a 250 mile span of the No. 8 gauge wire line is 40 TU, and the loss of the No. 12 gauge line is 56 TU, then the transmission level at the east end of the span will be −25 TU for the No. 8 gauge line and −41 TU for the No. 12 gauge line. This is a 16 TU level difference between the lines at this point. By transmission level is meant the strength of the signal current, expressed in transmission units (TU) above or below the arbitrary standard. Since the two lines have different attenuation characteristics, the only point along the two lines at which the transmission level is equal is at the starting point.

At the other points along the lines the signaling levels on the 8 gauge line will be above those on the 12 gauge line and on account of this level difference the crosstalk introduced into the 12 gauge line from the 8 gauge line will be more predominant than that introduced into the 8 gauge line from the 12 gauge line when the currents are amplified at a repeater or terminal station to the desired level. This crosstalk is reduced in one form of the invention by causing the signaling currents representing one message to traverse one line for part of the distance and the other line for the rest of the distance. Suitable circuit connections for accomplishing this are illustrated in Figs. 2 and 3, to which reference will now be made.

Referring to Fig. 2, carrier line transfer filters 3 may be located at intervals in lines L_1 and L_2 of the transmission system shown in Fig. 1 and are composed entirely of filters. These filters are employed to transfer the carrier currents from the system operated over the line L_2 having the smaller gauge conductors, to the line L_1, having the larger gauge conductor and to transfer the carrier currents from the higher gauge line L_1 to the smaller gauge line L_2, and for transmitting the voice frequency currents along lines L_1 and L_2.

Fig. 3 shows the arrangement of the transfer filters 3. Interconnecting the line L_1, having the larger diameter conductors, with the line L_2 having the smaller diameter conductors, are high pass filters HF_1 and HF_2. These filters, HF_1 and HF_2, are arranged to transmit the desired carrier frequencies, while substantially suppressing all other frequencies. In order to transmit the voice frequencies over their respective lines L_1 and L_2 and to suppress the carrier frequencies from continuing along lines L_1 and L_2, filters LF_1 and LF_2 are located in lines L_1 and L_2 between the connections to filters HF_1 and HF_2. Filters LF_1 and LF_2 are designed to substantially suppress carrier frequencies which it is desired to transfer from line L_1 to L_2 and from L_2 to line L_1 while freely transmitting such frequencies as it is desired to transmit along lines L_1 and L_2.

The filters in the arrangements just described may be of any desired character, the only requirement being that they shall transmit the desired ranges of frequencies to the substantial exclusion of other frequencies. Preferably these filters should be of the general type disclosed in U. S. patents to G. A. Campbell 1,227,113 and 1,227,114, dated May 22, 1917.

It will be seen from the drawing that the carrier currents are transferred at intervals from one line to the other, so that the resultant paths for the currents transmitted over the two systems have substantially the same attenuation characteristics and therefore the resultant energy level at any point along the line will be substantially the same for currents transmitted in the same direction over both systems and the resultant crosstalk becomes substantially as small as where paralleling systems employ conductors of the same gauge wire.

Instead of transferring each message from one line to the other at intervals in order to provide paths which have substantially the same overall attenuation, loss may be introduced at intervals in the higher level line in accordance with a second form of the invention, to reduce crosstalk between the lines. The circuit connections and apparatus for these will now be described referring to Figs. 4 and 5.

Referring to Fig. 4, crosstalk attenuators 5 may be located at intervals in the line L_1 of the transmission system shown in Fig. 1 so that the resultant transmission loss of line L_1 and the attenuators is substantially

the same as line L_2. The type of crosstalk attenuator which applicant prefers to employ is shown diagrammatically in Fig. 5. The voice frequency currents are transmitted freely along the line L_1 through the low-pass filter LP, while the carrier currents are substantially suppressed by this filter. The carrier currents from west to east are transmitted from the line L_1 through high-pass filters 6 and 7, eastward attenuators 10 to 13, high-pass filters 8 and 9 to line L_1. The carrier currents from east to west are transmitted from line L_1 through the high-pass filter 9, low-pass filter 14, westward attenuators 10 to 13, low-pass filter 15 and high-pass filter 6 to the line L_1.

The attenuators 10 to 13 are designed so that the individual attenuators will attenuate for different lengths of line and may represent, for example, spans of 12½, 25, 50 and 75 mile lengths respectively. Those not needed for any given length may be omitted or effectively shunted out by short-circuiting the connections. Where a single installation is made in a 150 mile span, 50 miles east of the west terminal, all but the 50 mile unit will be shunted out in the eastward attenuator and the 12½ and 50 mile units will be shunted out in the westward attenuators. The attenuator units 10 to 13 may be of the type disclosed in U. S. Patent 1,591,073, issued July 6, 1926 to O. J. Zobel, having a constant resistance characteristic impedance suitable for terminating the carrier circuits.

The amount of crosstalk between the two lines will depend upon the number of attenuator units 5 installed in any given span. For example, as stated above, under certain conditions the attenuation of a 250 mile span of No. 8 gauge wire will be 40 TU while the attenuation of the No. 12 gauge line will be 56 TU. If an attenuator 5 is placed mid-way between the west and east terminals and is so designed that the attenuation of the No. 8 gauge line plus the attenuation of the equalizer is equal to the attenuation of the No. 12 gauge line at the output of the attenuator 5, the transmission levels on both lines at this point will then be the same and the transmission level at the east end of the No. 8 gauge line will be 8 TU above the level of the No. 12 gauge line. The difference in transmission levels being decreased, the resultant crosstalk from the line L_1, having the higher transmission level, to the line L_2, having the lower transmission level, will be decreased.

If this attenuator 5 placed mid-way between the west and east terminals is designed not to exactly equalize the levels at this point but to bring the level of the No. 8 gauge line to a point below the level of the No. 12 gauge line such that the level difference will be zero at a point mid-way between the attenuator and the east terminal, the level difference at the end of the line will then be the same as the level difference at the output of the equalizer and the crosstalk from the No. 8 gauge line L_1 to the No. 12 gauge line L_2 will be still further reduced. It is apparent, however, that this condition will increase the crosstalk from the No. 12 gauge line L_2 to the No. 8 gauge line L_1 since for a portion of the length of the span the transmission level of the No. 12 gauge line L_1 will be greater than that of the No. 8 gauge line L_2.

The level difference between the two lines may be still further decreased by reducing the transmission level of the output at the west terminal on the No. 8 gauge line L_1 so that the level difference between the lines becomes zero at a point mid-way between the west terminal and the attenuator centrally located. This may be accomplished by actually reducing the output level or by the use of an attenuator. The latter method is preferable for the attenuator may be designed to attenuate the different frequencies transmitted so that all frequencies will have the zero level difference at the desired point. This attenuator, located at the output of the terminal or amplifier, would have loss characteristics which are one-half those of the adjacent attenuator.

Additional crosstalk attenuators 5 located half way between the terminals of the line and the crosstalk attenuator 5 centrally located will reduce the resultant crosstalk to a still greater extent and further increase in the number of crosstalk attenuators 5 will still further reduce the crosstalk between the two lines. The number of units to be employed in any given system will depend upon the maximum allowable amount of crosstalk.

The invention is also capable of use for reducing the crosstalk where the lines having different gauge wire parallel each other for only part of their length. In such case the use of attenuators such as disclosed in Fig. 5 need be used only between the limits within which said lines parallel each other. The transmission level of the two lines at the point of intersection can be adjusted to the desired level either by locating an attenuator at the junction of said lines or at the sending terminal or amplifier to provide the desired level at the point of intersection.

The invention is also capable of other modifications and adaptations not specifically referred to, but included within the scope of the appended claims.

Although specific examples have been referred to in the specification in order to make the invention clear, it is understood that the references to a given length of span, to the No. 8 and No. 12 gauge lines, and to a frequency of 27 KC or to other numerical

values are to be taken as illustrative and not in any way limiting the invention.

For the purposes of this specification the transmission equivalent of a line refers to the difference in transmission levels between the two ends of the line.

What is claimed is:

1. A signal transmission system comprising adjacent lines paralleling each other and having different transmission characteristics, terminal stations therefor, and means intermediate said terminal stations for providing two transmission paths over said lines of substantially the same transmission equivalent between the extreme limits within which said lines parallel each other, said means comprising a plurality of frequency discriminating attenuating elements inserted in the line having the higher transmission level.

2. The method of reducing the crosstalk between adjacent carrier current signaling systems having different transmission characteristics, which comprises introducing loss elements at frequent intervals in one of said systems between the extreme limits in which said lines parallel each other and maintaining the transmission characteristics of both systems substantially the same between said limits.

3. The method of reducing the crosstalk between adjacent carrier current signaling systems, which comprises attenuating the currents in one of said systems at frequent intervals between the extreme limits within which said systems parallel each other to maintain substantially the same transmission equivalent in both systems at the frequencies transmitted between said limits, and thereby maintain the currents transmitted in the same direction in both systems at substantially the same energy level.

4. In a transmission system, a pair of parallel adjacent transmission lines, the respective attenuations of which vary with frequency, said transmission lines having different transmission characteristics, a plurality of auxiliary systems in one of said lines intermediate the terminal stations of said transmission system, said auxiliary systems having attenuation characteristics which vary with the frequency in a manner such that the resultant transmission of said auxiliary system and said last mentioned line is substantially the same over the range of frequencies transmitted as that of the other of said lines.

5. The combination with a plurality of carrier current signaling systems having adjacent transmission lines of respectively different transmission characteristics, employing substantially the same directional bands of carrier frequencies, of frequency discriminating means associated with at least one of said lines to maintain the currents transmitted in one direction thereover at substantially the same energy level in the respective lines.

6. The combination with a pair of carrier current signaling systems having adjacent transmission lines of different transmission characteristics, employing substantially the same directional bands of carrier frequencies, of frequency discriminating attenuating means associated with one of said systems to maintain the currents transmitted in one direction thereover at substantially the same energy level as the energy level of the other of said systems between the extreme limits within which said systems parallel each other.

7. In a transmission system, a pair of adjacent parallel transmission lines having different transmission characteristics the respective attenuations of which vary with the frequency, repeating systems associated with each of said transmission lines, and a plurality of auxiliary systems inserted in at least one of said lines at points intermediate said repeaters and intermediate the terminal stations and the repeaters adjacent to said terminal stations, said auxiliary systems having attenuation characteristics which vary with the frequency in a manner such that the resultant transmission equivalent of said auxiliary system and said lines is substantially the same for both of said lines.

8. In a transmission system, two geographically separated stations, terminating lines at said stations, a pair of transmission paths interconnecting said stations, both paths being used for transmission in one direction of substantially the same bands of carrier frequencies, said paths having different transmission characteristics, auxiliary systems inserted in the path having the higher transmission level and so designed and proportioned as to maintain the resultant transmission characteristics of said path having the higher transmission level and the auxiliary systems associated therewith substantially the same as the transmission characteristics of the other of said paths between the extreme limits in which said paths parallel each other.

9. In a signalling system a plurality of transmission lines, terminal stations therefor, means for simultaneously transmitting over said lines in one direction signals having substantially the same carrier frequency, certain of said lines having transmission characteristics which differ from the characteristics of the others of said lines, repeating apparatus in each of said lines for amplifying the currents transmitted, and frequency discriminating means associated with said certain lines at intervals between said individual repeating stations and between said terminal stations and the adjacent repeating station for maintaining the com-

bined transmission characteristics of said certain lines and the frequency discriminating means associated therewith substantially the same as that of the others of said lines between the extreme limits in which said lines parallel each other.

10. The combination with a pair of carrier current signaling systems comprising terminal transmitting and receiving circuits and employing substantially the same frequencies in the respective transmitting circuits, of transmission lines which are adjacent each other for at least a portion of their length and which have respectively different transmission characteristics, and attentuation equalizers associated with at least one of said transmission lines to maintain the currents transmitted in one direction thereover at substantially the same energy level in both of said signaling systems between the extreme limits within which said transmission lines parallel each other.

11. The method of reducing crosstalk between carrier current signaling systems employing substantially the same frequencies in the respective transmitting circuits and having transmission lines which are adjacent each other for only a limited portion of their length and which have substantially different transmission characteristics, which comprises reducing the energy level of the currents at the transmitting terminal associated with one of said lines to substantially the same value as the currents at a point intermediate the terminals of an adjacent transmission line, maintaining said currents along the respective lines at substantially the same value between the extreme limits in which said systems parallel each other, and amplifying the currents received at the distant terminal of said first mentioned transmission line to compensate for the reduction in energy level at the transmitting terminal thereof.

12. In a multi-channel carrier signaling system, employing a plurality of paralleling lines having different frequency-attenuation characteristics, and over which lines carrier currents having the same frequency are transmitted in the same direction, the method of substantially equalizing the attenuation of said paralleling lines at the frequencies transmitted in the same direction which comprises reducing the energy level of the carrier currents transmitted over the lines having the higher transmission level at periodic intervals between repeater stations and between the terminals and the adjacent repeater stations to substantially the same transmission level as the other lines.

13. In a multi-channel carrier signaling system, employing a plurality of paralleling lines having different frequency-attenuation characteristics, and over which lines carrier currents having the same frequencies are transmitted in the same direction, terminal stations and repeaters associated with said lines means for substantially equalizing the attentuation of said paralleling lines at the frequencies transmitted in the same direction, said means comprising frequency discriminating devices associated with said lines having the higher transmission levels at intervals between said repeaters and between said terminal stations and the adjacent repeaters to provide substantially the same transmission level as the other lines.

14. In a multi-channel carrier signaling system, employing a plurality of paralleling lines having different frequency-attenuation characteristics, and over which lines carrier currents having the same frequencies are transmitted in the same direction, terminal stations and amplifier stations associated with said lines, means for substantially equalizing the attenuation of said paralleling lines at the frequencies transmitted in the same direction, said means comprising frequency discriminating devices associated with said lines having the higher transmission levels at equal intervals between said amplifier stations and between said terminal stations and the adjacent amplifier stations to provide substantially the same transmission level as the other lines, and attenuation equalizers located at the sending end of said terminal stations and said amplifier stations, having loss characteristics which are one-half those of the adjacent non-amplifying devices at all frequencies transmitted.

In witness whereof, I hereunto subscribe my name this 29th day of May, 1928.

HAROLD S. BLACK.