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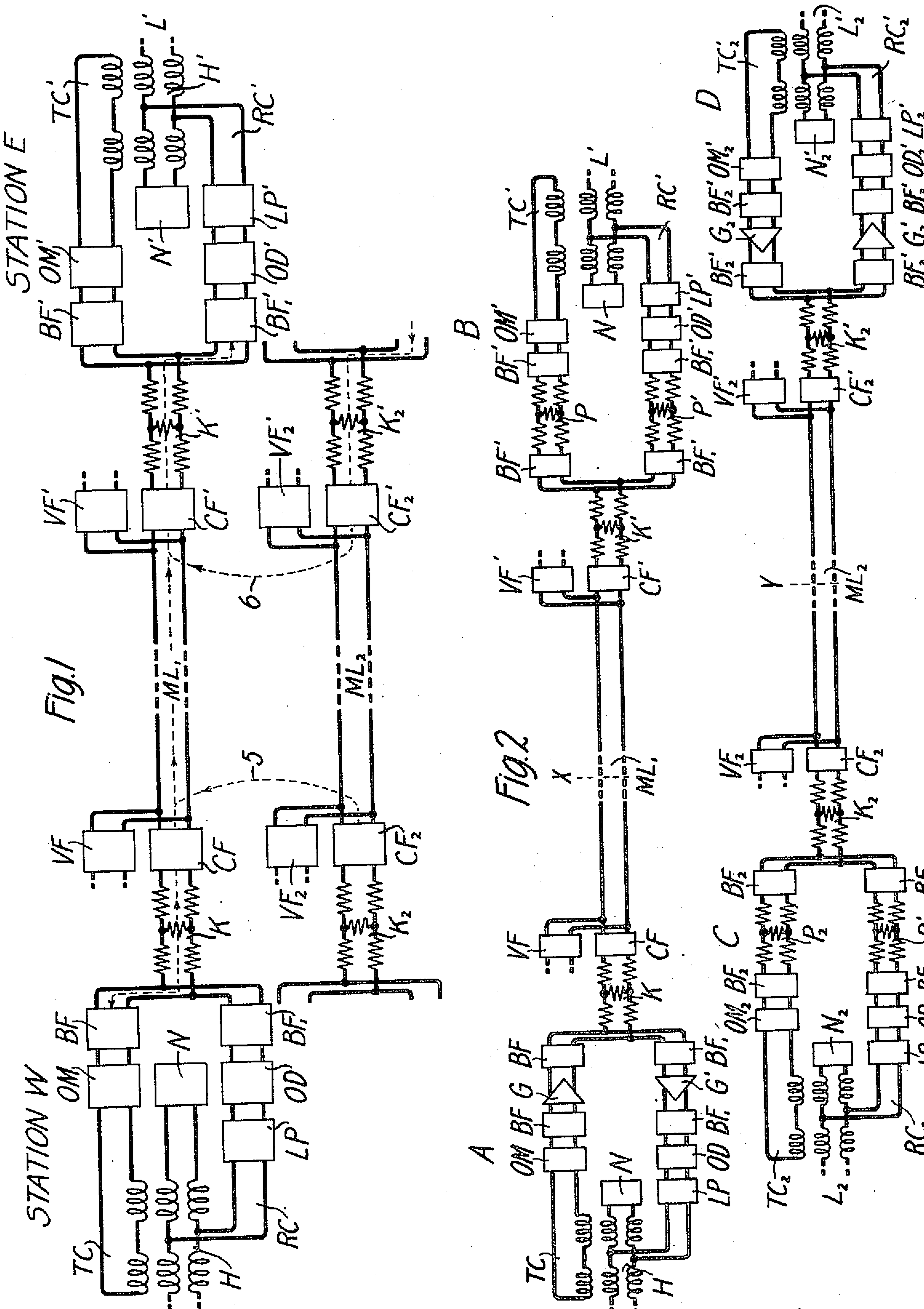

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METHOD AND MEANS FOR REDUCING CROSS TALK IN CARRIER-CURRENT SIGNALING SYSTEMS.

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This invention relates to methods and means for reducing crosstalk in carrier current signaling systems.

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

A related object of the invention is to reduce reflection effects such as are commonly caused by impedance irregularities in electric signaling systems.

The invention provides a simple and efficient arrangement for reducing crosstalk between adjacent carrier current signaling systems which consists in attenuating reflected waves at one terminal of each system to such an extent that their effect at a distant terminal is negligible, and also in maintaining the currents transmitted in the same direction in each system at substantially the same energy level at all points where the transmission lines run adjacent 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 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 can usually be done without hardship 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 that crosstalk can be materially reduced by reducing reflection effects which appear in the form of waves which are reflected from terminal or repeater devices which are connected to a transmission line but do not accurately match the impedance of the line. A method of reducing such reflection effects is disclosed, for example, in a copending application of C. W. Green, Serial No. 132,670, filed Aug. 31, 1926, in which a loss element is arranged to be traversed by the reflected waves a greater number of times than by the signal, so that a discrimination is made in favor of the signal. One advantage of this method is that waves which are reflected back over one transmission line due to impedance mismatching are attenuated to such an extent that they can produce only negligible crosstalk in an adjacent line.

According to a feature of the present invention, a loss element is inserted between a transmission line and a terminal grouping filter or other device from which the crosstalk components are reflected so that the crosstalk components will be greatly attenuated in traversing the loss element twice, once before they are reflected and again after they are reflected. By thus reducing crosstalk reflection effects at one terminal of a transmission line their effect at a distant terminal is materially reduced and the problem of transposing the line circuits is greatly simplified.

According to another feature of the invention, crosstalk is reduced by maintaining similarly directed signaling currents on adjacent lines at substantially the same energy level. A special case of this to which the invention applies is where a number of carrier lines are carried on the same pole line and terminate at different geographical points. For example, in a single channel carrier current telephone system, such as that hereinafter described, one such carrier line may extend from A to B, while another carrier line may come in on the same pole line at some intermediate point C and extend beyond the point B. According to this invention, crosstalk between such systems is reduced by employing the same energy levels on the lines where they run adjacent each other. This is preferably accomplished 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.

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, In the drawing:

Fig. 1 is a diagrammatic illustration showing two single channel carrier current telephone sytems having adjacent transmission lines, and provided with means for reducing reflection from the terminal grouping filters; and

Fig. 2 is a diagrammatic illustration showing two similar systems, in which mutual interaction is reduced by employing the same energy levels on both transmission lines where they run adjacent each other.

In Fig. 1, the terminal circuits of two single channel carrier current telephone systems, located at stations W and E, are interconnected by the main transmission lines ML_1 and ML_2, respectively, which are located on the same pole line or in the same cable. The single channel systems per se form no part of the present invention, but may be of the types disclosed in U. S. Patent No. 1,602,019, issued Oct. 5, 1926 to C. L. Weis, Jr., or in my U. S. Patent No. 1,653,837, issued Dec. 27, 1927.

The two systems shown in Fig. 1 may be similar in all respects and hence only the circuits associated with the line ML_1 will be described in detail. This system is composited for simultaneous low frequency and carrier current communication. This is accomplished by carrier composite sets, the set at station W comprising the voice frequency filter VF and the carrier frequency filter CF, and the set at station E comprising similar filters VF′ and CF′. The filters VF and VF′ are positioned in the voice frequency telephone branch, and the filters CF and CF′ in the carrier current branch, of the transmission line. These filters serve to separate the currents corresponding to the frequencies used in their respective types of transmission. Obviously, the system could be used for carrier transmission only, in which case these filters could be eliminated.

The filters of the carrier composite sets, described above, and each of the other filters shown throughout the systems may be designed in accordance with the principles set forth in U. S. Patent No. 1,227,113 to G. A. Campbell, issued May 22, 1917.

The terminal apparatus at station W includes a transmitting channel TC and a receiving channel RC, and the terminal apparatus at station E includes a transmitting channel TC′ and a receiving channel RC′. Carrier currents of different frequencies are utilized for transmission in opposite directions over the line ML_1, the currents transmitted from station E to station W being chosen of higher frequency than the currents transmitted from station W to station E.

The transmitting channel TC includes an oscillator-modulator OM and a low frequency band filter BF, while the receiving channel RC includes a low pass filter LP, an oscillator-detector OD and a high frequency band filter BF_1. The filters BF and BF_1 serve to separate the directional bands of frequencies to the respective terminal transmitting and receiving channels, the lower band of carrier frequencies being assigned to channel TC and the upper band of frequencies being assigned to channel RC. The corresponding elements at station E are designed by similar reference characters with primes affixed thereto.

A low frequency line L, which may be an ordinary subscriber's telephone line, is associated with channel TC—RC at station W for communication over the line ML_1 with a similar low frequency line L′ associated with channel TC′—RC′ at station E. The low frequency lines L and L′ are provided with balancing artificial lines or networks N and N′, respectively, and with differential repeating coils H and H′, commonly known as hybrid coils, for enabling independent transmission in two directions between the lines and the terminal circuits.

Voice frequency currents originating in the low frequency line L at station W pass through the associated hybrid coil H into the oscillator-modulator OM where they are combined with carrier currents of the frequency assigned to channel TC. Of the components of modulation appearing in the output circuit of the oscillator-modulator OM, the low frequency band filter BF suppresses all but one side band, for example, the lower side band, which it transmits or passes to the transmission line ML_1.

The side band currents incoming at station E pass through the low frequency band filter BF_1' in the receiving channel RC′, and are detected in the oscillator-detector OD′. Voice frequency components of demodulation appearing in the output circuit of oscillator-detector OD′ are selectively transmitted by the low pass filter LP′ and pass through hybrid coil H′ to the low frequency line L′. Transmission from station E to station W is accomplished in the same manner, except that higher frequency carrier currents are employed.

In order to prevent near end crosstalk between transmission lines ML_1 and ML_2, the carrier currents utilized for transmission in each direction are of the same frequency in both systems. That is, the currents transmitted from station W to station E are of the same frequency in both systems, and the currents transmitted from station E to station W are likewise of the same frequency in both systems. It will thus be seen that even though a signal modulated carrier wave of the lower frequency band transmitted over line ML_2 from station W appears in line ML_1 as crosstalk, currents of this frequency are not passed by the band filter BF_1, in the receiver channel RC and, of course, can-not pass backwards through the transmitting channel TC. This frequency allocation likewise prevents objectionable near end crosstalk from line ML_1 into line ML_2.

If, however, impedance irregularities exist in the terminal apparatus at station W, for example, if the band filter BF is improperly terminated, signal modulated waves following the path 5 from line ML_2 to line ML_1 and meeting a change in impedance in the filter BF will be reflected over the line ML_1 and, being readily transmitted by the band filter BF_1' will appear in the receiving channel RC′ as far end crosstalk. The same effect is produced when a portion of the lower frequency signal modulated carrier current transmitted over line ML_2 from station W to station E is reflected from the low frequency band filter associated with the line ML_2 at station E, taking the path 6 directly into the band filter BF_1'. Similar crosstalk may occur in the upper frequency band transmitted in the opposite direction.

It is very difficult to prevent reflection in the terminal grouping filters for the reason that only a slight error in the impedance of the elements of a filter is sufficient to produce considerable reflection. It is practically impossible with present manufacturing methods to build commercial condenser elements to closer than 0.8% accuracy or to wind coils to closer than 1.2% accuracy, making a total of 2% gross error in the filter elements. This is sufficient to produce an impedance irregularity of as much as 60% near the edge of the frequency scale of the filter.

In order to compensate for the effect of improper filter termination, acording to this invention, a resistance pad K is inserted between the terminal grouping filters and the carrier composite set at station W and a similar resistance pad K′ is inserted between the terminal grouping filters and carrier composite set at station E. Similar resistance pads K_2 and K_2' are provided in the line ML_2. With the pad K in the position shown, the energy which is reflected passes through the pad twice, once in each direction, whereas the outgoing and incoming signaling currents pass through the pad but once. This produces a definite discrimination between crosstalk components and the signaling components. The resistance pads may be of the type disclosed in U. S. Patent No. 1,591,073 issued July 6, 1926 to O. J. Zobel, having a constant resistance characteristic impedance suitable for terminating the carrier circuits.

Where a large number of single channel systems are operated on the same pole line it is often desirable to terminate the systems at different geographical points, as illustrated in Fig. 2. The line ML_1 in Fig. 2, for example, may extend from A to B, a distance of say 200 miles, while the line ML_2 may come in at some intermediate point C and extend to the point D, some distance beyond the point B. Crosstalk between these systems is materially reduced by employing the same energy level for similarly directed currents on the lines ML_1 and ML_2 where they run adjacent each other. This is accomplished by inserting level adjusting pads in certain instances on the drop sides of the carrier terminal apparatus, and by the use of terminal amplifiers to control the gain levels. At the terminal A, an amplifier G is inserted in the transmitting channel TC between the two sections of a split band filter BF to raise the outgoing currents to the desired level, and at the terminal B a resistance pad P′ is inserted between the two sections of a similar band filter BF_1' to reduce the level of the incoming currents to the desired value for reception. At the terminal C a resistance pad P_2 is inserted between the sections of the band filter BF_2 and serves to bring the energy level of the currents transmitted to the line ML_2 down to the point where it is equal to the energy level of the currents transmitted in the same direction over the line ML_1 at the point X where the line ML_2 comes in on the same pole line with the line ML_1. At the terminal D an amplifier G_2' is inserted between the sections of filter BF_3' in the receiving channel RC_2' to raise the level of the incoming currents which were reduced at station C in the manner described. Since this terminal is at the far end of the pole line, an amplifier G_2 is included in the transmitting channel TC_2' to raise the outgoing currents to the desired level, and a resistance pad P_2' similar to the pad P′ at terminal B is inserted in the receiving channel RC_2 at terminal C. A resistance pad P is also provided in the channel TC′ at terminal B to bring the energy level of the currents transmitted to the line ML_1 down to the same level as similarly directed currents at the point Y on the line ML_2.

It will be noted that in carrying out the invention described in connection with Fig. 2, the upper bands of carrier currents are transmitted in the same direction over both transmission lines, while the lower bands of carrier currents are transmitted in the opposite direction. It is therefore evident that the energy levels of the currents transmitted in the same direction on both transmission lines will remain the same after being adjusted in the manner described above, since they are of the same frequency and are affected by substantially the same conditions causing attenuation.

The resistance pads P, P′, etc. in the transmitting and receiving channels are connected between the sections of the respective terminal grouping filters and if properly designed and terminated play a negligible part in the termination of the main transmission lines. These pads and the gain adjusting amplifiers are preferably variable in order to render them suitable for universal application. These elements may therefore be applied to existing systems to control the energy levels without otherwise changing the circuits. In addition to these pads and amplifiers, the resistance pads K, K′, etc., described in connection with Fig. 1, are also used to reduce reflection due to mis-matching of terminal impedances.

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

What is claimed is:

1. The method of reducing crosstalk between adjacent signaling circuits which comprises attenuating the crosstalk components at the terminals of said circuits a greater number of times and to a greater extent than the effective signaling currents therein.

2. The method of reducing crosstalk between adjacent signaling circuits in which crosstalk currents are reflected at a terminal, which comprises attenuating the reflected currents at said terminal to a greater extent than the signaling currents traversing the circuit to reduce the effect of the reflected currents at a distant terminal.

3. The method of reducing crosstalk between adjacent carrier current signaling circuits in which crosstalk currents are reflected at one terminal, which comprises attenuating the reflected currents a greater number of times and to a greater extent than the effective signaling currents transmitted from said terminal, to reduce the effect of said reflected currents at a distant terminal.

4. The method of reducing crosstalk between adjacent carrier current signaling systems which comprises maintaining the currents transmitted in the same direction in both systems at substantially the same energy level.

5. The method of reducing crosstalk between carrier current signaling systems having transmission lines which are adjacent each other for only a limited portion of their length, which comprises maintaining substantially the same energy level of transmission on adjacent portions of said transmission lines.

6. The method of reducing crosstalk between carrier current signaling systems employing substantially the same frequencies and energy levels of transmission in the respective transmitting circuits and having transmission lines which are adjacent each other for only a limited portion of their length, which comprises reducing the energy level of the currents at one transmitting terminal to substantially the same value as the current at a point intermediate the terminals of an adjacent transmission line.

7. The method of reducing crosstalk between carrier current signaling systems employing substantially the same frequencies and energy levels of transmission in the respective transmitting circuits and having transmission lines which are adjacent each other for only a limited portion of their length, which comprises reducing the energy level of the currents at one transmitting terminal to substantially the same value as the currents at a point intermediate the terminals of an adjacent transmission line, 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.

8. In a system for transmitting waves of different frequencies, a transmission line, a terminal circuit including a filter connected to said line causing certain waves to be reflected, and a loss element between said circuit and said line to attenuate the reflected waves.

9. In a system for transmitting waves of different frequencies, a transmission line, a terminal circuit containing an impedance irregularity connected to said line, and a loss element between said circuit and said line to reduce reflection caused by the mismatching of terminal impedances.

10. In a system for transmitting waves of different frequencies, a transmission line, a terminal circuit containing a frequency discriminating device connected to said line and having an impedance which differs from that of the line at certain frequencies, and a loss element between said circuit and said line to duce reflection from said device.

11. In a system for transmitting waves of different frequencies, a transmission line, terminal transmitting and receiving circuits connected to sail line, grouping filters in said circuits for selectively transmitting directional bands of frequencies, said filters containing impedance irregularities causing waves in a portion of the frequency band to be reflected, and a resistance pad between said circuits and said line to reduce the reflected waves.

12. The combination with a pair of carrier current signaling systems having adjacent transmission lines employing substantially the same directional bands of carrier frequencies of means associated with each line to maintain the currents transmitted in one direction thereover at substantially the same energy level as the currents transmitted in the same direction on the other line.

13. The combination with a pair of carrier current signaling systems employing substantially the same frequencies and energy levels of transmission in the respec-

tive transmitting circuits and having transmission lines which are adjacent each other for only a limited portion of their length, of a resistance element in the transmitting circuit of one system to reduce the energy level of the currents impressed upon the associated transmission line to substantially the same value as the currents at the same geographical point on the other transmission line.

14. The combination with a pair of carrier current signaling systems comprising terminal transmitting and receiving circuits and employing substantally the same frequencies and energy levels of transmission in the respective transmitting circuits, of transmission lines which are adjacent each other for only a limited portion of their length, a resistance pad in the transmitting circuit of each system which is adjacent the transmission line of the other system to reduce the energy level of the currents impressed upon each transmission line to substantially the same value as the currents at the same geographical point on the adjacent transmission line, and amplifiers in the associated receiving circuits of said system to compensate for the reduction in energy in the transmitting circuits thereof.

In witness whereof, I hereunto subscribe my name this 27th day of August A. D., 1926.

HAROLD S. BLACK.