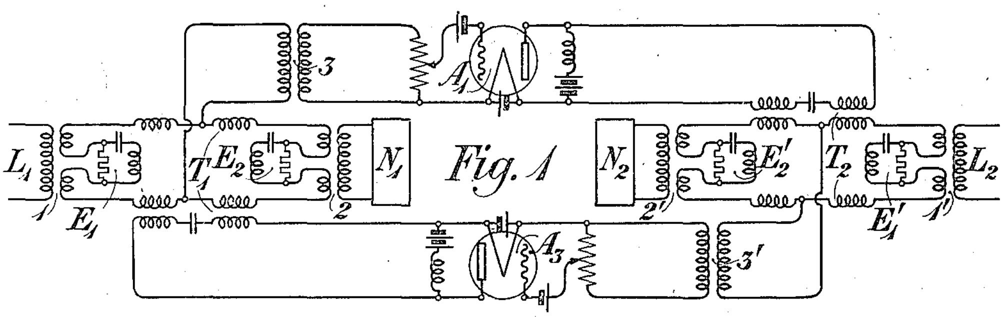
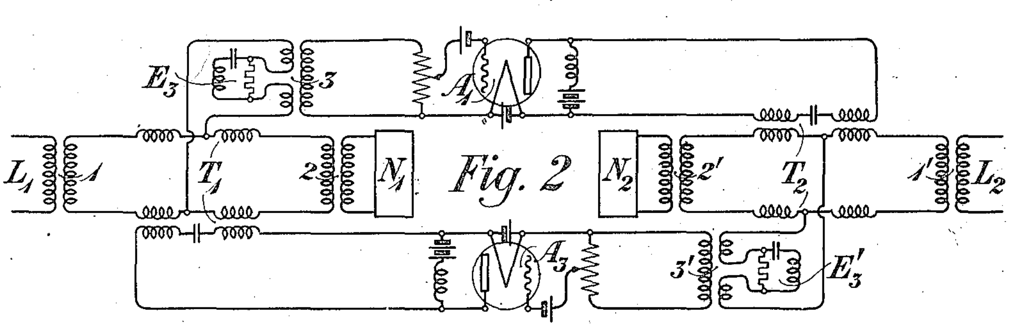
May 1, 1923. 1,454,011

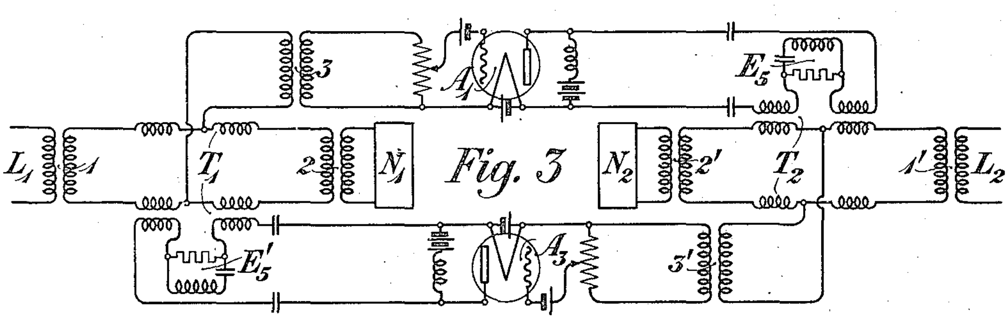
O. B. BLACKWELL

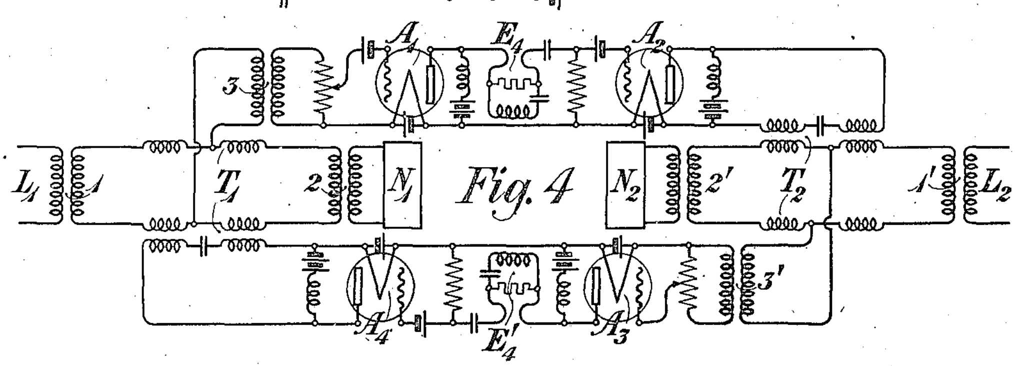
SYSTEM FOR ATTAINING UNIFORM ATTENUATION

Filed June 29, 1918 3 Sheets-Sheet 1









INVENTOR.

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ATTORNEY.

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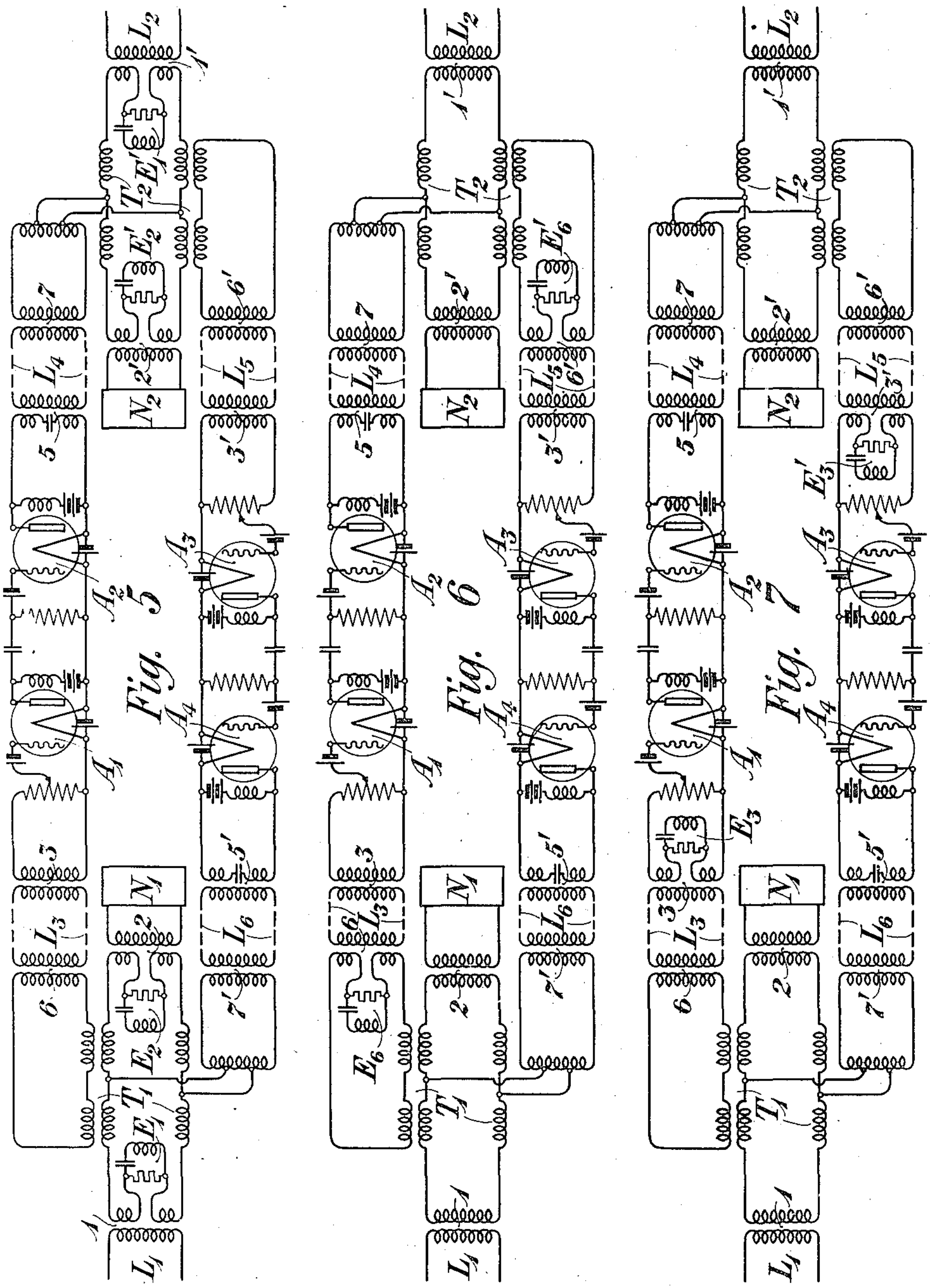
O. B. BLACKWELL

SYSTEM FOR ATTAINING UNIFORM ATTENUATION

Filed June 29, 1918 3 Sheets-Sheet 2



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May 1, 1923. **1,454,011**

O. B. BLACKWELL

SYSTEM FOR ATTAINING UNIFORM ATTENUATION

Filed June 29, 1918 3 Sheets-Sheet 3

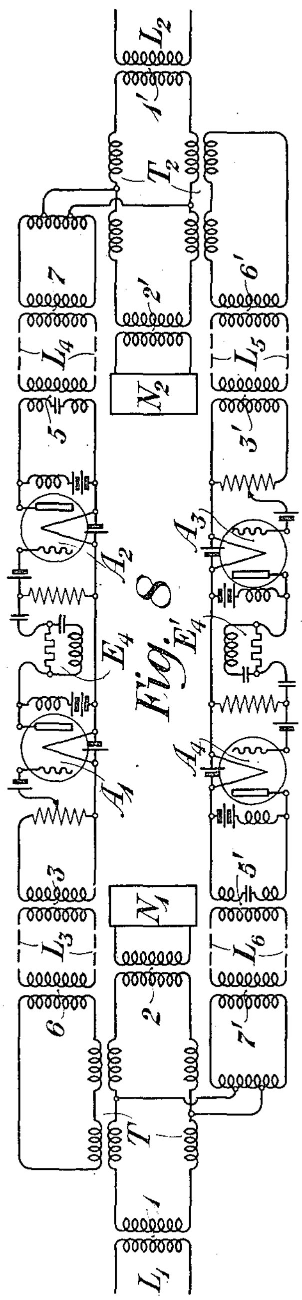
Fig. 8

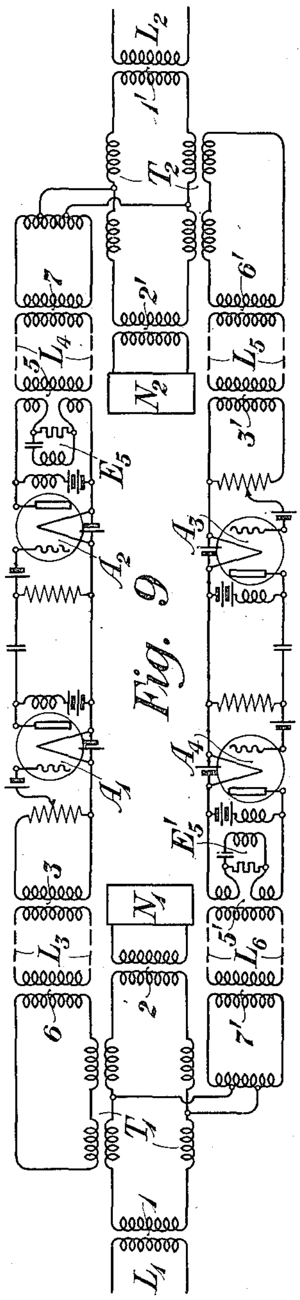
Fig. 9

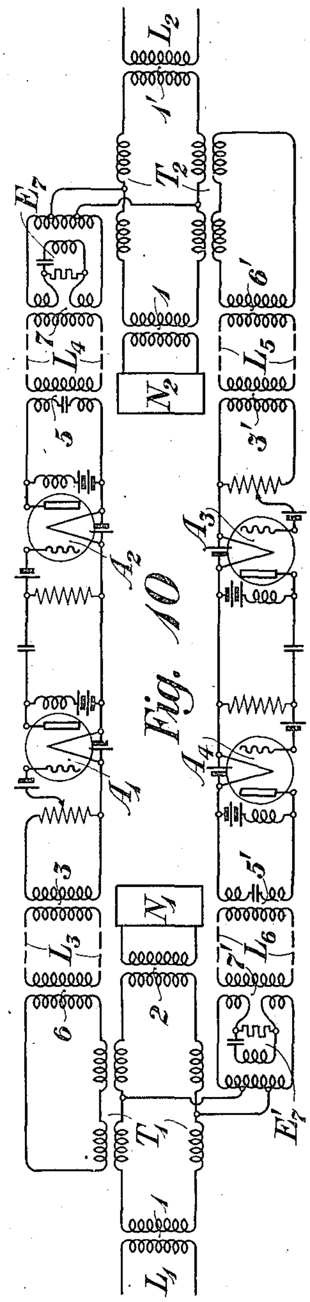
Fig. 10

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Patented May 1, 1923. **1,454,011**

UNITED STATES PATENT OFFICE.

OTTO B. BLACKWELL, OF GARDEN CITY, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

SYSTEM FOR ATTAINING UNIFORM ATTENUATION.

Application filed June 29, 1918. Serial No. 242,566.

To all whom it may concern:

Be it known that I, OTTO B. BLACKWELL, residing at Garden City, in the county of Nassau and State of New York, have invented certain Improvements in Systems for Attaining Uniform Attenuation, of which the following is a specification.

This invention relates to transmission systems and more particularly to transmission systems over which telephonic or multifrequency signals are transmitted.

In a system used for the transmission of frequencies varying over a considerable range, the attenuation varies for different frequencies, and in the case of telephonic signals, the higher frequencies are usually attenuated to such an extent as compared with the lower frequencies that a considerable degree of distortion results, and this is true even where the transmission line is loaded. It is possible, however, to design an auxiliary system, such as a network, so that the lower frequencies are attenuated to a greater degree than the higher frequencies. By associating such an auxiliary system with the transmission system proper, the attenuation as regards the combination may be made substantially the same for all frequencies within a desired range. By proper design of the auxiliary system or network it is possible, when uniform transmission is not desired, to cause the attenuation of the combined system to vary with frequency in any desired manner.

Such an arrangement is unsatisfactory, however, for the reason that the introduction of an auxiliary system into the transmission line for the purpose of equalizing the attenuation increases the transmission loss of the system as a whole. Furthermore, the impedance of such an auxiliary system ordinarily varies with the frequency in a manner differing radically from that of the transmission line. The introduction of the auxiliary system into the transmission line consequently results in irregularities which may produce reflection losses over and above the transmission losses due to the auxiliary system itself.

It is one of the objects of this invention to overcome the losses due to the introduction of the auxiliary system, by so associating the auxiliary system with the transmission line and an amplifying arrangement, that the amplifying arrangement will make up the losses due to the auxiliary system.

Another object of the invention is to reduce and in some instances substantially eliminate the above-mentioned reflection losses due to the auxiliary system by so associating the auxiliary system with the amplifying arrangement that the reaction of the varying impedance of the auxiliary system upon the transmission line is prevented either in whole or part.

These objects as well as other objects which will be clear from the detailed description of the invention are accomplished by introducing into the transmission line a repeater arrangement, preferably of the two-way two-repeater type, or of the so-called four-wire type, and by introducing the auxiliary system into some element of the repeater circuit, preferably in the local branches including the repeater elements in the case of the two-way two-repeater arrangement and in the pair of one-way lines interconnecting two stations in the case of the four-wire circuit.

By this location of the auxiliary system it will be rendered electrically more remote from the transmission line than if it were directly included therein, so that its variable impedance produces less reaction upon the line. Where two-stage amplifiers are used in the repeater circuits, by locating the auxiliary system between two amplifying elements, its reaction upon the line may be eliminated, as the amplifying elements are one-way devices.

The invention may now be more fully understood from the following description, when read in connection with the accompanying drawings, Figures 1, 2, 3 and 4 of which are circuit diagrams showing four possible arrangements of the auxiliary system or attenuation equalizer in a two-way two-repeater circuit, while Figures 5 to 10, inclusive, are circuit diagrams of six different arrangements of the auxiliary system or attenuation equalizer in a four-wire repeater circuit.

Referring to Fig. 1, two lines L_1 and L_2 are shown, said lines being interconnected through a two-way two-repeater circuit, including amplifiers A_1 and A_2. The lines are associated with the repeater circuit through transformers 1 and 1′, and are balanced with respect to repeater circuits by means of artificial lines or networks N_1 and N_2, transformers 2 and 2′ being associated with the artificial lines for the purpose of balancing the transformers 1 and 1′. The usual three winding transformers T_1 and T_2 are provided, the input circuit of the amplifier A_1 being associated with the bridge across the mid-points of the windings of the transformer T_1, through a transformer 3, the output circuit of the amplifier including the third winding of the transformer T_2. In a similar manner the input circuit of the amplifier A_3 is associated with the bridge across the windings of the transformer T_2 by means of a transformer 3′, the output circuit of the amplifier A_3 including the third winding of the transformer T_1.

The arrangement so far described is that of a standard type of repeater circuit and is merely shown for purposes of illustration, it being understood that the circuits may be modified in any well known manner in so far as the present invention is concerned. Thus the amplifiers A_1 and A_3 which are shown as being of the well known vacuum tube type may be of any other well known type such as the so-called mechanical repeater. In order to equalize the attenuation due to the characteristics of the transmission lines L_1 and L_2 and other factors (such, for instance, as terminal reflection effects), or to cause the attenuation to vary with frequency in any desired manner, auxiliary systems or attenuation equalizers E_1 and E_2, E_1' and E_2' are provided. These attenuation equalizers, as illustrated, are of the series impedance type disclosed in a copending application of Ray S. Hoyt, Serial No. 242,567, filed June 29, 1918, and the theory of the operation of this type of equalizer is fully set forth in said application. In so far as the purposes of this invention are concerned, however, any of the other types of attenuation equalizers disclosed in the said application may be used in place of the series impedance type or in fact any other well known type of equalizer may be employed, provided it is associated with the transmission line and the repeater arrangement in such manner as to secure the objects sought by this invention.

Certain of the desired results may be obtained by locating the attenuation equalizer between the two halves of one of the windings of the transformers 1 and 1′ associating the transmission lines with the repeater circuit. Thus the equalizer E_1 is associated with the right-hand winding of the transformer E_1 and the equalizer E_1' is associated with the lefthand winding of the transformer 1′. In order to balance these equalizers with respect to the repeater equalizers E_2 and E_2' are similarly connected to the transformers 2 and 2′ upon the artificial line side. By means of this arrangement the attenuation equalizers, when taken in connection with the transmission lines, constitute circuits in which all frequencies within a definite range are transmitted with approximately the same attenuation, the equalizer being proportioned with regard to the electrical characteristics of the line and the frequencies transmitted to secure this result as described in the above mentioned application of Ray S. Hoyt. The losses due to the attenuation equalizer are overcome by means of the gain in transmission introduced by the repeater; and by providing the attenuation equalizers in pairs upon the line and artificial line side of the repeater, singing may be avoided. The arrangement shown in Fig. 1, however, may introduce some difficulty because of the fact that ordinarily its impedance varies with the frequency in a manner different from that of the transmission line, so that irregularities may result which may produce reflection losses over and above the transmission losses due to the equalizer itself.

While this difficulty is not of sufficient importance to inhibit the use of the arrangement shown in Fig. 1, it may to a considerable extent be eliminated by the arrangement shown in Fig. 2 in which, instead of associating the equalizers directly with the line through a transformer, the equalizers are included in the input bridges of the repeater. Thus the equalizer E_3 is inserted between the two halves of the primary winding of transformer 3, while the equalizer E_3' is inserted in the primary winding of the transformer 3′. While in this arrangement the impedance of the attenuation equalizer ordinarily varies with the frequency as before, it is electrically more distant from the transmission line than in the arrangement of Fig. 1. This arrangement has a further advantage over that of Fig. 1 that only two attenuation equalizers are required due to the fact that the equalizer is not included in a balanced part of the circuit.

Substantially the same results may be obtained by means of the arrangement shown in Fig. 3, in which the attenuation equalizers are included in the output circuits of the amplifiers A_1 and A_3 respectively. Thus the attenuation equalizer E_5 is inserted between the two halves of the third winding of the transformer T_2, while the equalizer E_5' is inserted between the two halves of the third winding of the transformer T_1. Here again, as in Fig. 2, the variable impedance of the attenuation equalizer produces a relatively smaller effect upon the total impedance of the repeater as seen from the line.

The effect of the variable impedance of the attenuation equalizer upon the total impedance of the repeater circuit, as seen from the line, may be eliminated by employing the arrangement shown in Fig. 4. In this figure, two-stage amplifiers are employed. Thus for transmission from line L_1 to line L_2 two amplifiers A_1 and A_2 are employed, while for transmission from L_2 to L_1 amplifiers A_3 and A_4 are employed. By inserting the attenuation equalizer E_4 between the amplifiers A_1 and A_2 and the equalizer E_4' between the amplifiers A_3 and A_4, the effect of the variable impedance of the equalizer upon the impedance as viewed from the line is eliminated, due to the fact that the amplifiers are one-way devices. The arrangement shown in Fig. 4, while preferable in this respect to the other three circuit arrangements, might be disadvantageous in an installation where two stage amplifiers are unnecessary in order to secure the desired transmission gain.

The above described arrangements, while in many respects equivalent, are in fact electrically slightly different but any one of these arrangements permits of the use of an attenuation equalizer in a transmission system without reducing the transmission of the system as a whole. It will be understood moreover that various combinations of the above described arrangements of the attenuation equalizers may be employed, if desired.

Similar arrangements of the attenuation equalizers, with respect to the line and repeater arrangement, may be employed in connection with a four-wire circuit, as shown in Figs. 5 to 10, inclusive. A typical form of four-wire circuit is illustrated in Fig. 5 in which lines L_1 and L_2 terminating at two distant stations are interconnected through a four-wire circuit, including line sections L_3 and L_4 for transmission in one direction and line sections L_5 and L_6 for transmission in the opposite direction. Two-stage amplifiers A_1 and A_2 are inserted between the line sections L_3 and L_4 at an intermediate station and amplifiers A_3 and A_4 are inserted between the line sections L_5 and L_6 at said intermediate station. It will be understood, however, that this arrangement is symbolical of a large number of possible arrangements, since single-stage amplifiers might be used, or, if desired, additional amplifiers might be inserted in the four-wire lines at other intermediate points. The four-wire circuit is associated with the terminating two-wire lines through the usual three-winding transformers T_1 and T_2 and the transformers 1 and 1′. Lines L_1 and L_2 are balanced by artificial lines N_1 and N_2 associated with which are transformers 2 and 2′ for balancing the transformers 1 and 1′. The line section L_3 is associated with the input circuit of the amplifier by a transformer 3 and with the input connection from the line L_1 by means of a transformer 6. The line section L_4 is associated with the output circuit of the amplifier A_2 by means of a transformer 5 and with the output connection to the line L_2 by means of a transformer 7. In a similar manner line sections L_5 and L_6 are associated with corresponding elements by means of transformers 3′, 6′ and 5′, 7′ respectively. As shown in Fig. 5, the attenuation equalizers E_1 and E_1' are inserted between the two halves of one of the windings of the transformers 1 and 1′ respectively, while the attenuation equalizers E_2 and E_2' are similarly connected to the transformers 2 and 2′ on the artificial line side. This arrangement of the attenuation equalizers is substantially the same as that shown in Fig. 1, the only difference being that the arrangement is shown as applied to a four-wire circuit instead of a two-way two-repeater system.

Attenuation equalizers may be used to great advantage in connection with the four-wire system, due to the fact that in such a system losses may be inserted in each side of the four-wire circuit without limiting the transmission of the system, since any loss introduced may be made up by the introduction of a corresponding amplification without any resulting increased tendency to singing. Such a system, therefore, admits of considerable latitude so far as the location of the attenuation equalizers is concerned, since any losses due to the location of the equalizer in the four-wire link may be made up by means of the amplifiers in the circuit. This possibility is taken advantage of by the arrangements shown in Figs. 6 to 10, inclusive. Thus in Fig. 6 the attenuation equalizer E_6 is inserted between the two halves of the primary winding of the transformer 6, associating the line section L_3 with the input connection to the line L_1. In a similar manner the attenuation equalizer E_6' is connected with the transformer 6′ in the path used for transmission in the opposite direction. This arrangement is somewhat similar to that disclosed in Fig. 2 and has the same advantages.

In Fig. 7 the equalizer E_3 is inserted between the two halves of the secondary winding of the transformer 3 in the input circuit of the amplifier A_1. The attenuation equalizer E_3' is similarly associated with the transformer 3′ in the other half of the four-wire link. This arrangement is slightly better than that of Fig. 6, since the attenuation equalizer is electrically farther away from the terminating two-wire line so that the variation in the impedance of the equalizer produces a correspondingly smaller effect on the impedance of the four-wire link as seen from the terminating two-wire line.

Still another modification is shown in Fig. 8 in which the attenuation equalizer E_4 is inserted between the amplifiers A_1 and A_2

in the half of the four-wire link, while the attenuation equalizer E_4' is inserted between the amplifiers A_3 and A_4 in the other half. By means of this arrangement a line section of the four-wire link and the one-way amplifier separates the attenuation equalizer from the terminating two-wire line, so that the variable impedance of the former produces no effect upon the latter.

In Fig. 9 an arrangement is shown having substantially the same advantages as that shown in Fig. 7. In accordance with this circuit arrangement the attenuation equalizer E_5 is inserted between the two halves of the primary winding of the transformer 5 which associates the output circuit of the amplifier with the line section L_4. Similarly the attenuation equalizer E_5' is associated with the transformer 5' between the amplifier A_4 and the line section L_6. Here again the effect of the variable impedance of the equalizer upon the terminating two-wire line is reduced by reason of the fact that it is separated therefrom by means of a section of the line making up the four-wire link. A further modification is shown in Fig. 10 in which the attenuation equalizer E_7 is inserted between the two halves of the secondary winding of the transformer 7 associated with the outgoing connection to the two-wire line L_2. In a similar manner the attenuation equalizer E_7' is connected to the transformer 7' associated with the outgoing circuit to the terminating two-wire line L_1. This arrangement presents substantially the same advantages, so far as impedance relations are concerned, as the circuit shown in Fig. 6.

In the four-wire system, it will be understood that where the four-wire link is divided into additional sections by means of additional repeater units that additional positions for the location of attenuation equalizers will be provided. Furthermore it will be understood that various combinations of the above described arrangements may be employed, if desired.

Other arrangements in addition to those already described might be suggested, but the arrangements already disclosed are believed to sufficiently illustrate the principles upon which this invention is based, the essential requirement being that the attenuation equalizer be so associated with a transmission line and a repeater arrangement that the losses introduced by the attenuation equalizer may be made up by the repeater, the equalizer being preferably so arranged with regard to the repeater circuit that the latter will reduce the reaction between the attenuation equalizer and the transmission line. It will be clear that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention, as defined in the following claims.

What is claimed is:

1. In a transmission system, a transmission line the attenuation of which varies with frequency, a repeater system associated with said transmission line, said repeater system including two amplifying transmission paths, one for transmitting in one direction, and the other for transmitting in the opposite direction, and a non-amplifying attenuation equalizing means associated with the repeater system and said transmission line, said equalizing means being so proportioned with reference to the line that the resultant attenuation of currents transmitted over the system will vary with frequency in a predetermined manner.

2. In a transmission system, a transmission line the attenuation of which varies with the frequency, a non-amplifying auxiliary system the attenuation of which varies with the frequency in a manner complemental to that of the transmission line so that the resultant transmission of the line and auxiliary system is substantially constant over a desired range of frequencies, and a repeater system associated with said line and auxiliary system.

3. In a transmission system, a transmission line the attenuation of which varies with the frequency, a non-amplifying auxiliary system the attenuation of which varies with the frequency in a manner complemental to that of the transmission line so that the resultant transmission of the line and auxiliary system is substantially constant over a desired range of frequencies, and a repeater system associated with said line and auxiliary system, said repeater system including two amplifying transmission paths, one for transmitting in one direction and the other for transmitting in the opposite direction.

4. In a transmission system, a transmission line the attenuation of which is greater for high frequencies than low frequencies, a non-amplifying auxiliary system the attenuation of which varies with the frequency in a manner complemental to that of the transmission line so that the resultant attenuation of the line and auxiliary system is substantially constant over a desired range of frequencies, and a repeater system associated with said line and auxiliary system to make up the losses introduced by the auxiliary system.

5. In a transmission system, a transmission line the attenuation of which is greater for high frequencies than low frequencies, a non-amplifying auxiliary system the attenuation of which varies with the frequency in a manner complemental to that of the

transmission line so that the resultant attenuation of the line and auxiliary system is substantially constant over a desired range of frequencies, and a repeater system associated with said line and auxiliary system to make up the losses introduced by the auxiliary system, said repeater system including two amplifying transmission paths, one for transmitting in one direction and the other for transmitting in the opposite direction.

6. In a transmission system, a transmission line the attenuation of which varies with the frequency, a repeating system associated with said transmission line, said repeating system comprising two amplifying transmission paths, one for transmitting in one direction and the other for transmitting in the opposite direction, and non-amplifying auxiliary systems whose attenuation varies with the frequency in a manner complemental to that of the line, said auxiliary systems being included in the two transmission paths of the repeater system at points such that a portion of each path of considerable attenuation intervenes between the auxiliary system and the junction of the line and repeater system.

7. In a transmission system, two geographically separated stations, terminating lines at said stations, a pair of transmission paths, interconnecting said stations, one path being used for transmission in one direction and the other path for transmission in the opposite direction, the attenuation over a circuit including the two terminating lines and one of said transmission paths varying with the frequency, non-amplifying auxiliary systems whose attenuation varies with the frequency in a manner complemental to that of said circuit, said auxiliary systems being inserted in said transmission paths at intermediate points, and amplifying means in said paths.

8. In a transmission system, a transmission line the attenuation of which varies with the frequency, non-amplifying means associated with said line to equalize the attenuation of the system so that all frequencies within a desired range are transmitted with practically uniform attenuation, and amplifying means to make up the loss introduced by said first mentioned means.

9. In a transmission system, a transmission line the attenuation of which varies with the frequency, non-amplifying means associated with said line to equalize the attenuation of the system so that all frequencies within a desired range are transmitted with practically uniform attenuation, and amplifying means to make up the loss introduced by said first mentioned means, and to increase the transmission efficiency of the system.

10. In a transmission system, a transmission line the attenuation of which varies with frequency in accordance with a known law, non-amplifying means associated with said line and having a characteristic such that the attenuation varies progressively with the frequency, so that the resultant attenuation of the combination varies with frequency in a different predetermined manner from that of the line above, and amplifying means to make up the losses introduced by said first mentioned means.

11. In a transmission system, a transmission line the attenuation of which varies with frequency in accordance with a known law, a non-amplifying auxiliary system the attenuation of which is predeterminable at different frequencies, said auxiliary system being so designed that the attenuation varies progressively with the frequency, so that when associated with the transmission line the resultant attenuation varies with the frequency in accordance with a predetermined law, and amplifying means to make up the losses introduced by said auxiliary system.

In testimony whereof, I have signed my name to this specification this twenty-six day of June, 1918.

OTTO B. BLACKWELL.