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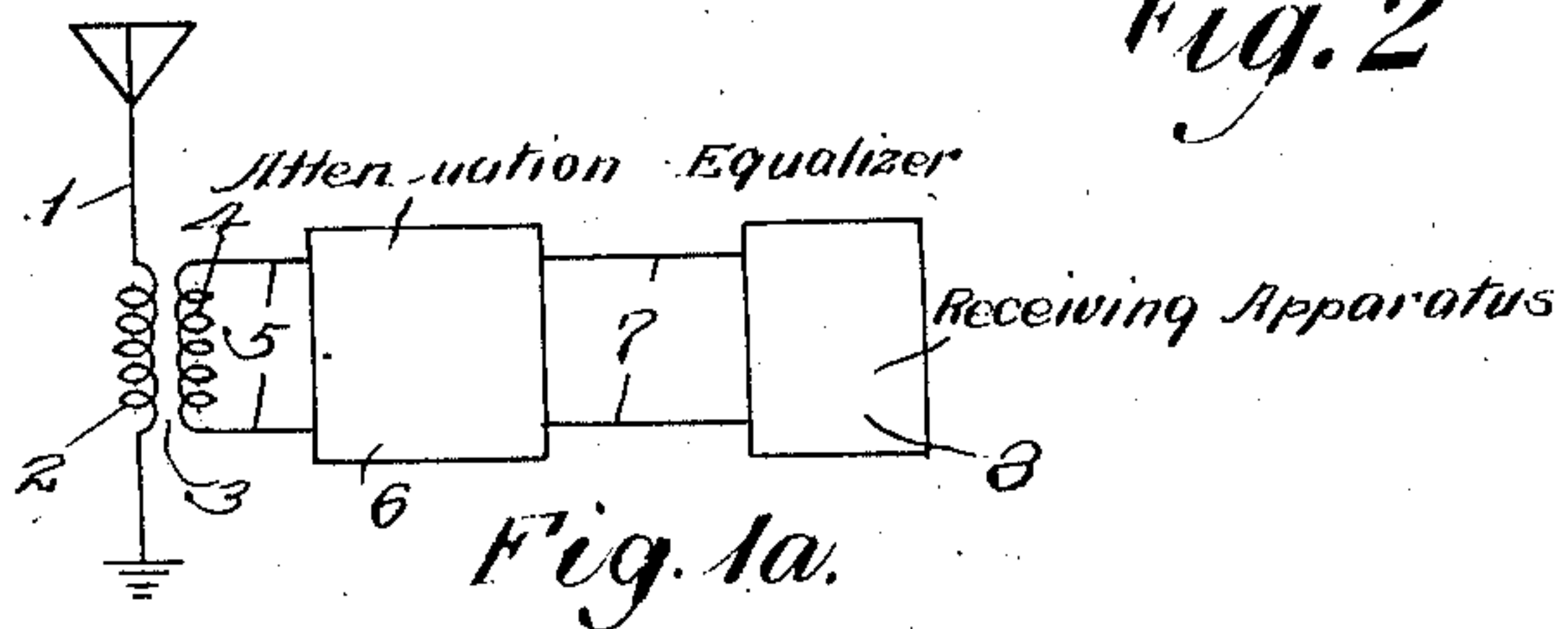
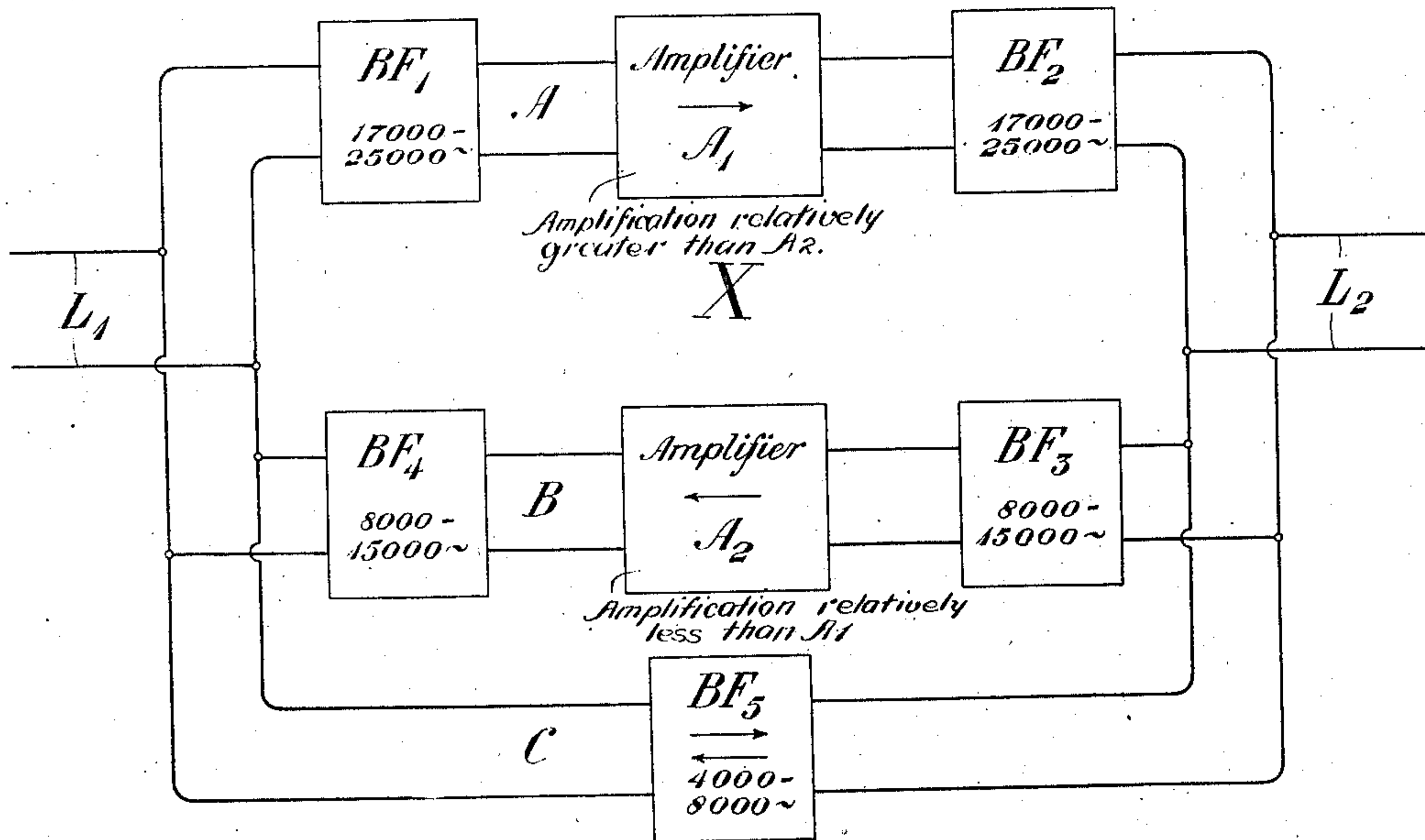
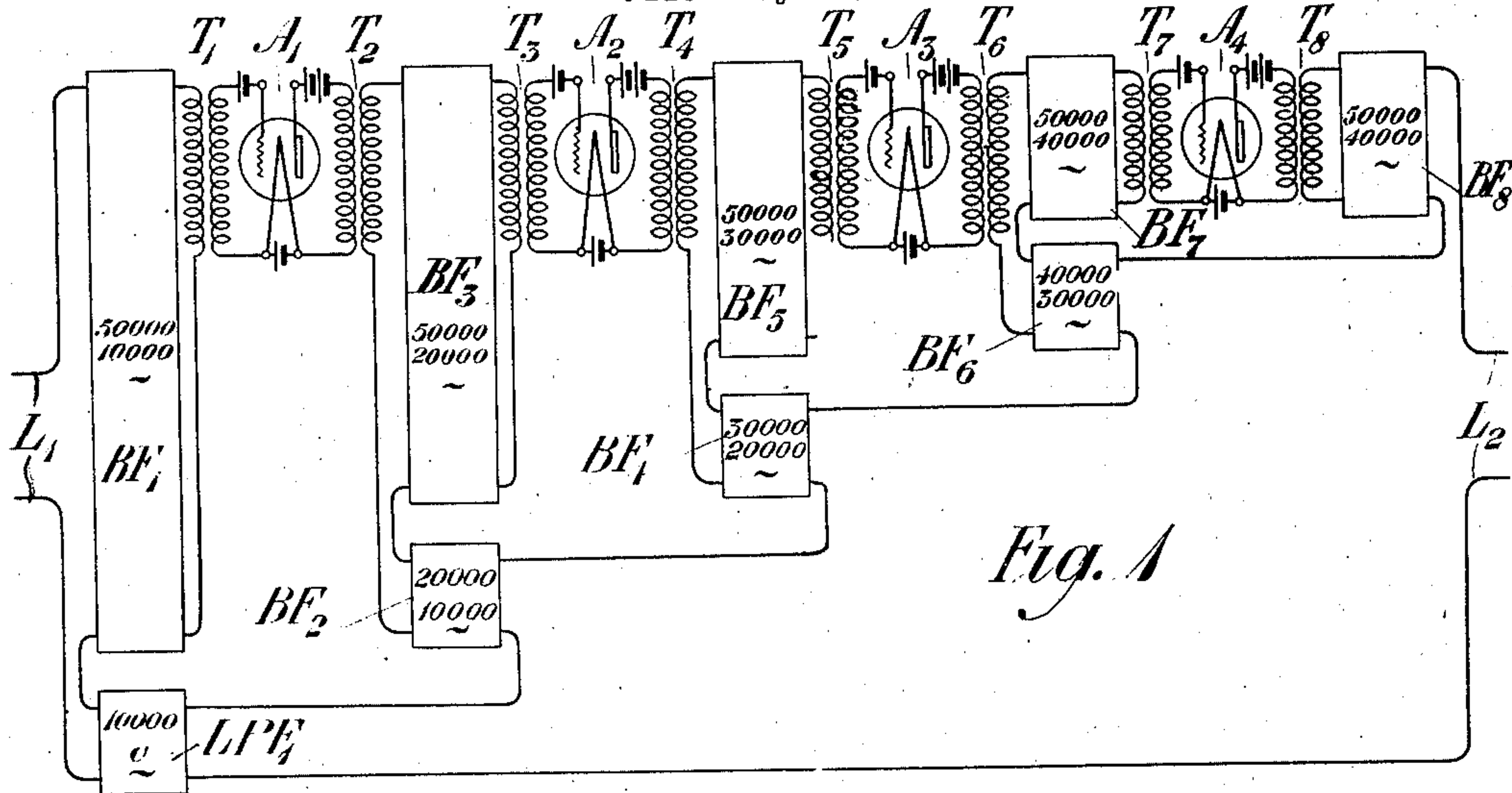
1,572,757

H. A. AFFEL

MULTIPLEX SIGNALING SYSTEM

Filed May 24, 1920

2 Sheets-Sheet 1



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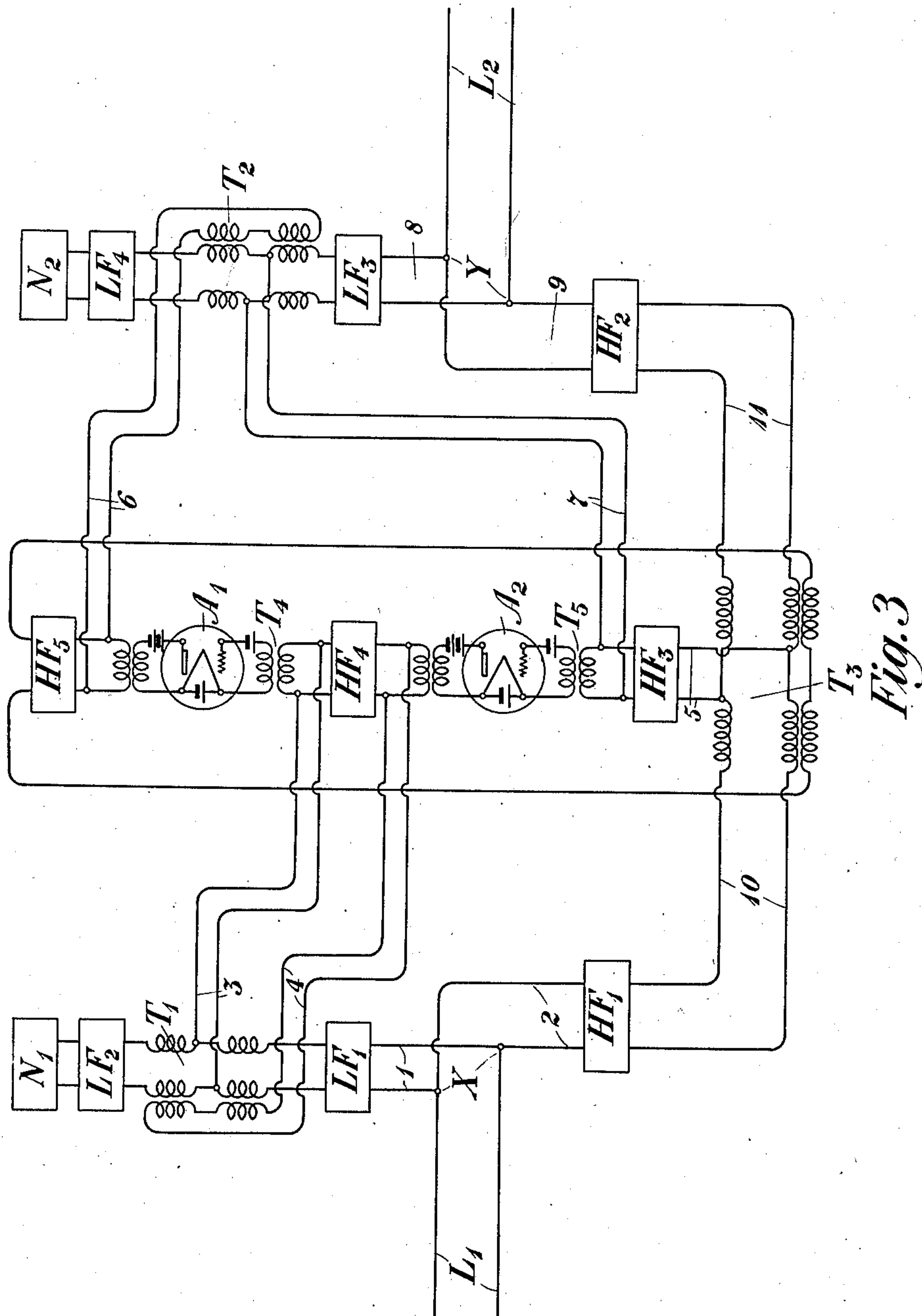
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MULTIPLEX SIGNALING SYSTEM

Filed May 24, 1920

2 Sheets-Sheet 2



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UNITED STATES PATENT OFFICE.

HERMAN A. AFFEL, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

MULTIPLEX SIGNALING SYSTEM.

Application filed May 24, 1920. Serial No. 383,941.

To all whom it may concern:

Be it known that I, HERMAN A. AFFEL, residing at Brooklyn, in the county of Kings and State of New York, have invented certain Improvements in Multiplex Signaling Systems, of which the following is a specification.

This invention relates to high frequency multiplex signaling systems, and especially to an arrangement for separating the signaling channels or groups of such channels transmitted over the same transmission line, and amplifying to varying degrees the currents of the said channels by means of a plurality of amplifiers differing in their amplification constants.

In arrangements designed to amplify a wide range of frequencies transmitted over a long wire circuit it is desirable to employ means to control the degree of amplification of the various frequencies, so that the relatively low frequencies which are attenuated less in transmission over the circuit are not disproportionately increased in amount by excessive amplification. Heretofore this has been effected by an arrangement known as an attenuation equalizer which comprised a selective network connected between the line and the input side of the amplifying element which introduced a loss in the circuit that in a general way bore a complementary relation to the loss introduced by the transmission line itself; that is, at the high frequencies a low loss is introduced and at the low frequencies a high loss is introduced. The combined attenuation of the line and the equalizer is roughly a constant, independent of the frequency, therefore when it is used with a repeater element such as a vacuum tube repeater whose gain also is substantially independent of the frequency, approximately equal current will be obtained at the output side of the repeater for all frequencies within the desired range. It will be seen that the foregoing method of equalizing the attenuation of a plurality of frequencies results in the introduction of a loss by the selective network resulting from the artificial attenuation of the lower frequencies and in consequence thereof the repeating element must be of such capacity

as to be capable of transmitting with the same gain all the channels involved in a multiplex signaling system.

It is one of the objects of this invention to avoid the loss that results from this method of attenuation equalization by first separating the various frequencies or bands of frequencies representing channels or groups of channels of transmission and amplifying each to such a degree that all the frequencies in the output side of the amplifier will bear the proper relation to each other. Another object of this invention consists in so arranging the amplifying elements that the same elements may be used in different combinations depending upon the frequencies to be amplified.

Other and further objects of this invention will be apparent from the following description when read in connection with the attached drawings of which Figure 1 shows an attenuation equalizing arrangement which embodies the basic principle of this invention, and Figure 1^a shows schematically the method of using an attenuation equalizer such as is shown in Figure 1 with a radio antenna, and Figures 2 and 3 show specific applications of the invention.

In Figure 1, L_1 represents a line over which may be transmitted currents ranging in frequency, for example, from 0 to 50,000 cycles. This line is bridged across the input side of the attenuation equalizer, being connected directly with the band filter BF_1 and the low pass filter LPF_1 connected in series. The output side of the band filter BF_1 is connected by means of transformer T_1 with the amplifying element A_1 . The output side of the amplifier A_1 is connected by means of the transformer T_2 with the input side of the band filters BF_2 and BF_3 connected serially. In like manner the output side of the band filter BF_3 is connected by means of the transformer T_3 with an amplifier A_2 , the output side of which is connected by means of the transformer T_4 with the input side of the band filters BF_4 and BF_5 connected serially. Similarly the band filter BF_5 is connected with the amplifier A_3 , which in turn is connected with the band filters BF_6 and BF_7 and the latter filter,

BF₇, is in turn connected with the amplifier A₄, the output side of which is connected with the band filter BF₈. The output side of the attenuation equalizer is connected with the line L₂. The filters LPF₁ and BF₁ to BF₈ inclusive may be of the well known type disclosed in the patents to Campbell, Nos. 1,227,113 and 1,227,114 dated May 22nd, 1917, and may of course be so designed to operate connected effectively in series as illustrated and in parallel if desired. The filters LPF₁ and BF₁ are designed for example to separate the impressed currents into two groups having ranges from 0 to 10,000 and from 10,000 to 50,000 cycles respectively. When a plurality of currents having a frequency range of from 0 to 50,000 cycles are impressed across the input side of the equalizer, currents ranging in frequency between 0 to 10,000 cycles will pass to the output side of the equalizer through the filter LPF₁, which is adapted to transmit this range of frequencies with negligible attenuation and will be impressed upon the line L₂ without amplification. Currents of the frequencies between 10,000 and 50,000 cycles will not pass through filter LPF₁ due to its high attenuating characteristics at these frequencies but will pass through the band filter BF₁ and be impressed by the transformer T₁ upon the amplifier A₁. The currents as amplified will then be impressed by the transformer T₂ across the band filters BF₂ and BF₃ connected serially. Since the band filter BF₂ is designed to transmit therethrough currents having frequencies within the range of 10,000 to 20,000 cycles, such currents will pass to the output side of the equalizer without amplification; but currents of higher frequencies ranging from 20,000 to 50,000 cycles will pass through the band filter BF₃ and be impressed by the transformer T₃ upon the amplifier A₂. The amplified currents of these frequencies will be impressed by the transformer T₄ upon the filters BF₄ and BF₅ connected serially. Since the filter BF₄ is adapted to transmit a band of frequencies between 20,000 and 30,000 cycles the currents of these frequencies will pass therethrough and will be impressed upon the line L₂ without further amplification. Those currents lying within the range of 30,000 to 50,000 cycles will pass through the band filter BF₅ and be impressed upon the amplifier A₃ by a transformer T₅. The currents thus amplified will be impressed by the transformer T₆ upon the band filters BF₆ and BF₇ connected serially. Currents lying within the range of 30,000 to 40,000 cycles will pass through the filter BF₆ and without further amplification will be impressed upon the line L₂. Currents having a range of 40,000 to 50,000 cycles will pass through the filter BF₇ and be impressed by the transformer

T₇ upon the amplifier A₄. The amplified currents resulting therefrom will be impressed by the transformer T₈ upon the filter BF₈ having a range of from 40,000 to 50,000 cycles and without further amplification will be impressed upon the output circuit L₂. By adjusting the amplifying elements A₁, A₂, etc. the proper degree of amplification may be given to the currents of the selected frequencies.

The arrangement shown in Figure 1, which is designed to effect the substantially uniform amplification of currents of a plurality of frequencies, discloses novel means adapted to select from a common transmission system different bands of frequencies superimposed on the said system, to pass unamplified the band or bands of frequencies requiring no amplification and to amplify to various degrees by a process of selection and amplification the remaining bands of frequencies.

It will be seen that no amplification is given to the band containing the lowest frequencies, which are least attenuated by the line impedance, that the minimum amount of amplification is given to the band next higher in the frequency scale, and that the amount of amplification increases with rise in frequency, so that the band of highest frequencies, which are most attenuated by line impedance, receives the maximum amplification. In such an arrangement, the amplifiers need supply only the required amount of energy to each band of frequencies necessary to counteract the loss that each particular band of frequencies has suffered due to line impedance.

Another feature of this invention lies in the novel arrangement of the selecting elements and the amplifying elements whereby the amplification of all the bands of frequencies is effected by a single group of amplifying elements in tandem formation instead of by single amplifiers or groups of amplifiers designated and intended to serve only a particular channel or band of frequencies. Thus in the arrangement shown in Figure 1, the band of ten to twenty thousand cycles receives one stage of amplification; the band of twenty to thirty thousand cycles receives two stages; thirty to forty thousand cycles, three stages and forty to fifty thousand cycles, four stages, making a total of ten stages of amplification which is performed by four amplifier elements.

Although the drawing shows an arrangement adapted for one-way operation only, it is to be understood that such arrangement may readily be connected into the well known twenty-two or twenty-one repeater circuit by means of which the arrangement is adapted for two-way operation. Furthermore, it is to be understood that the fre-

quency ranges of the line and of the respective selective networks shown in the drawing, are merely for purposes of illustrating and are not to be construed as limiting the invention, which, of course, may be adapted to any range of frequencies.

The use of the attenuation equalizer in a circuit including an antenna is shown in Figure 1^a. In the figure, the antenna 1, which is designed and adjusted for the reception of radio signals, is coupled by means of the windings 2 and 4 of the transformer 3 with the circuit containing the attenuation equalizer and the receiving apparatus. The winding 4 is connected by conductors 5 with an attenuation equalizer which may be of any of the types illustrated or described herein. The attenuation equalizer 6 is connected by means of conductors 7 with receiving apparatus 8, which may be of any well-known type. In the operation of this circuit, oscillations of the frequencies or the bands of frequencies to which the antenna is responsive will be impressed by the transformer 3 upon the attenuation equalizer, and the currents of the various component frequencies will be separated and amplified to certain predetermined degrees, depending upon the degree of attenuation to which the said frequencies were subjected in transmission to the antenna 1. The resultant currents of the various component frequencies will be combined and impressed by the conductors 7 upon the receiving apparatus 8.

In Figure 2, L_1 and L_2 represent two transmission lines extending, for example, east and west respectively from the repeater station X shown in the drawing. Let it be assumed for purposes of illustration that over the lines L_1 and L_2 there are being transmitted a plurality of telegraph channels ranging between 4,000 and 8,000 cycles and two channels for telephone transmission ranging between 8,000 and 15,000 cycles from east to west i. e. from L_2 to L_1 and two telephone channels ranging from 17,000 to 25,000 cycles from west to east, i. e. from L_1 to L_2 . The line L_1 is bridged across one side of the repeater circuit and the line L_2 across the other side of the said circuit, the said circuit comprising three branches, A, B and C. Connected in branch A of the repeater circuit are band filters BF_1 and BF_2 , which are adapted to transmit a range of frequencies for example between 17,000 and 25,000 cycles, and an amplifier A_1 which may be of any well known type adapted to transmit currents in the direction shown by the arrow. Similarly connected in branch B of the repeater circuit are the band filters BF_3 and BF_4 , designed to transmit frequencies within the range for example of 8,000 to 15,000 cycles and an amplifier A_2 designed to transmit currents in the direction shown by the arrow. A third branch

C of the repeater circuit contains the band filter BF_5 , which is adapted to transmit frequencies ranging between 4,000 and 8,000 cycles. This branch contains no amplifier since it is not desirable to amplify this low range of frequencies. In view of the fact that the range of frequencies in branch A is relatively higher than the frequencies in branch B the said amplifier A_1 shall provide two stages of amplification, whereas the amplifier A_2 shall be but a single stage.

Currents lying within the range of 4,000 to 8,000 cycles transmitted either east or west over the lines L_1 and L_2 will pass through the branch C of the repeater circuit containing the band filter BF_5 , without amplification. Such currents will not, of course, pass into the branches A and B, since the band filters are so designed as to sharply attenuate frequencies outside the range desired to pass through these branches. Currents having a frequency range of 8,000 to 15,000 cycles transmitted over the line L_2 to the line L_1 will pass through the band filter BF_3 to the input side of the amplifier A_2 which, as stated may be a single stage amplifier. The amplified currents will pass through the filter BF_4 and thence to the line L_1 . Similarly the bands of frequencies embraced within the range of 17,000 to 25,000 cycles transmitted over the line L_1 to the line L_2 will pass through the band filter BF_1 and be impressed upon the two stage amplifier A_1 , which may be so operated as to give to each band of frequencies the proper degree of amplification dependent upon the degree of attenuation of the particular frequencies. Thus, for example, we may insert for the amplifier A_1 an arrangement embodying the principle set forth in Figure 1 whereby the lower frequencies within the transmitted range would receive slight amplification and the higher frequencies greater amplification.

In Fig. 3 L_1 and L_2 represent two transmission lines over which currents of a plurality of frequencies may be transmitted in each direction, the said currents lying within two ranges of frequencies hereafter referred to as the low frequency and the high frequency currents or oscillations. Bridged across the line L_1 are the low frequency circuit 1 and the high frequency circuit 2. The low frequency circuit 1 has associated therewith a low pass filter LF_1 , adapted to transmit readily currents within a given range of relatively low frequencies and adapted to attenuate sharply currents of what may be termed the high frequency group. Also associated with the circuit 1 is a triple winding transformer T_1 with which are connected the low pass filter LF_2 , adapted to balance the filter LF_1 and a network or artificial line N_1 , adapted to balance the line L_1 for low frequencies. The trans-

former T_1 is of the well known conjugate type, in which oscillations set up in the circuit 3 will produce no disturbance in the circuit 4 and vice versa, so long as the line L_1 and its associated apparatus is balanced by the network N_1 and its associated apparatus. The low frequency circuits 3 and 4 are connected with the input and the output sides of the amplifiers A_1 and A_2 , respectively.

The high frequency circuit 2 has associated therewith a high pass filter HF_1 , designed to transmit readily oscillations of the high frequency group, and to attenuate sharply oscillations of the low frequency group. The high frequency circuit 10 is connected with two of the windings of the triple winding transformer T_3 , which is of the same general type as the transformer T_1 . Bridged across the midpoints of the said two windings of the transformer T_3 , is the input side 5 of the translating circuit, having associated therewith high pass filters HF_3 , HF_4 and HF_5 of the same general type as the filter HF_1 , and also the amplifying units A_1 and A_2 . The output side of the translating circuit is connected with the third winding of the triple winding transformer T_3 . Bridged across the translating circuit are the low frequency output and input circuits 6 and 7, which are connected with the windings of the transformer T_2 similar to transformer T_1 . The transmission line L_2 has associated therewith a low frequency circuit 8 and a high frequency circuit 9. Associated with the circuit 8 is the low pass filter LF_3 and LF_4 corresponding to LF_1 and LF_2 and the network N_2 is designed to balance the line L_2 for low frequencies. Associated with the high frequency circuit 9 is a high pass filter HF_2 , similar to HF_1 .

This invention will be more clearly understood from the following description of its mode of operation: Let it be assumed that over the the line L_1 there are being transmitted, simultaneously or otherwise, currents of two groups or ranges of frequencies. At the junction point X the low frequency currents will pass into the circuit 1 through the low pass filter LF_1 and will be impressed upon the windings of the transformer T_1 . These oscillations will not pass into the circuit 10, being prevented by the high pass filter HF_1 . The low frequency currents will be impressed on the circuit 3 and in turn, will be impressed by the transformer T_4 , upon the input side of the amplifier A_1 . These low frequency currents will be amplified thereby and the amplified currents flow through circuit 6, transformer T_2 , low pass filter LF_3 into the circuit 8 and will be impressed upon the Line L_2 at the point Y. The high pass filter HF_2 prevents these amplified low fre-

quency currents from passing into high frequency circuit 11. Currents of low frequency transmitted over the line L_2 from a distant point thereon, will be impressed upon the low frequency circuit 8 at the point Y. Passing through the low pass filter LF_3 , these low frequency currents will enter the circuit 7 and will be impressed by the transformer T_5 upon the amplifier A_2 , and, as amplified, will be transmitted by the circuit 4 to the windings of the transformer T_1 and will pass through the low pass filter LF_1 and the circuit 1 to the line L_1 at the point X. The low frequency currents amplified by amplifier A_2 are prevented from passing to the amplifier A_1 by the high pass filter HF_4 . This filter serves to keep the oppositely travelling low frequency currents in their separate paths, thereby preventing interference.

It will be apparent from the foregoing description that the currents within the low frequency range pass through a translating circuit which is in effect a two-way, two-unit circuit, the amplification in one direction being that given by the amplifier A_1 and in the other direction that given by the amplifier A_2 .

Currents within the high frequency range transmitted over the line L_1 , will pass into the circuit 2 and through the high pass filter HF_1 into the high frequency circuit 10. These high frequency currents will be impressed upon the translating circuit 5 and passing through the high pass filter HF_3 will be impressed upon the input side of the amplifier A_2 . The amplified currents will then pass through the high pass filter HF_4 and be again amplified by the amplifier A_1 . The high frequency current from the output side of this amplifier, passing through the high pass filter HF_5 will be impressed by the transformer T_3 upon the high frequency output circuit and will pass to the line L_2 . In a similar manner oscillations of the high frequency group transmitted from a remote point of the line L_2 will be impressed upon the circuit 9 and passing through the high pass filter HF_2 will be impressed by the circuit 11 upon the windings of the transformer T_3 . These high frequency oscillations will be amplified by passing through the amplifiers A_2 and A_1 , and the amplified high frequency oscillations resulting therefrom will finally be impressed upon the line L_1 at the point X.

It will be seen from the foregoing description that the oscillations of the high frequency group pass through a translating circuit which is in part common to the low frequency translating circuit but adapted to amplify the high frequency oscillations to a greater degree than the low frequency oscillations where amplified. It may be pointed out that the circuit arrangement shown in

the drawing is designed to be located at a point in a transmission circuit where the lines in each direction have substantially the same characteristics and are of such length that little or no terminal reflection losses manifest themselves at the repeating point for the higher frequencies. It will be noticed, therefore, that the lines L_1 and L_2 are not balanced by artificial lines or networks for the high frequency transmission. By using a common translating circuit in which the amplifiers are connected in tandem a proportionally greater amplification may be obtained at the higher frequencies where the attenuation is relatively large. It will also be apparent that the separation between the two groups of frequencies may be accomplished by properly designed filters and by a parallel connection of the filter circuits as shown in the drawing. These filters are of the well known type disclosed in the patents to George A. Campbell, 1,227,113 and 1,227,114, issued May 22, 1917, which are designed to have high impedance outside their transmission range, in order that little or no loss may be introduced into the adjacent frequency range.

Although the invention is shown embodied in a form in which the low frequency oscillations are amplified by a 22 type of circuit and the high frequency oscillations by a 21 type of circuit, it is obvious that a reversed arrangement may readily be effected by changing the high frequency filters and the low frequency filters into low and high frequency filters respectively and by adapting the networks N_1 and N_2 to balance their respective lines for high frequency currents.

Although this invention has been described and illustrated in connection with a a multiplex system over wire lines, it is not limited to such use but may be used in any multiplex system involving a broad range of frequencies, such as, for example, in radio system. Where the amplifying arrangement is intended to constitute a radio repeating station, the two sides of the repeating arrangement with which in the drawings the lines L_1 and L_2 are connected, would be connected directly with the antenna circuits of the radio system, and where the amplifying arrangement is to be employed as a repeater between a radio and a wire system, one of the sides of the amplifying arrangement would be connected with the antenna circuit and the other side with the wire line.

It will, of course, be understood that although this invention has been disclosed as embodied in certain specific forms, that it is capable of embodiment in other and different forms without departing from the scope of the appended claims.

What is claimed is:

1. In a multiplex signaling system, the

method of equalizing the transmission of a plurality of frequencies transmitted by a common transmitting medium which consists in separating the currents of different frequencies into individual circuits amplifying the current of each of said circuits to a degree depending upon the degree of attenuation of the current of the said circuit caused by transmission through the medium and combining the resulting currents.

2. In a multiplex signaling system, the method of equalizing the transmission of a plurality of channels of different frequencies transmitted by a common transmitting medium which consists in separating the different channels into individual circuits amplifying the currents of each of said circuits to varying degrees depending upon the degree of attenuation of the current of the respective channel caused by transmission through the medium and combining the resulting currents.

3. In a multiplex transmission system, the combination with a transmission medium adapted to transmit a plurality of bands of frequencies of a repeater having means to select and means to amplify each band to a degree depending upon its attenuation during transmission over the said medium, and a second transmission means upon which all of the amplified bands are impressed.

4. In a multiplex transmission system, the combination with a transmission medium adapted to transmit a plurality of frequencies of a repeater having means to select and means to amplify each of said frequencies to a degree depending upon its attenuation during transmission over said medium, and a second transmission means upon which all of the amplified frequencies are impressed.

5. In a multiplex transmission system adapted for the simultaneous transmission of a plurality of bands of frequencies, the combination with means for transmitting a plurality of bands of frequencies with different degrees of attenuation of a repeater having means to select and means to amplify each band to a degree approximately inversely proportional to the efficiency of transmission of the said band and means to combine the amplified bands of frequencies.

6. In a multiplex transmission system adapted for the simultaneous transmission of a plurality of frequencies, the combination with means for transmitting a plurality of bands of frequencies with different degrees of attenuation of a repeater having means to select and means to amplify each of said frequencies to a degree approximately inversely proportional to the efficiency of transmission of the said frequencies and means to combine the amplified frequencies.

7. In a multiplex transmission system adapted for the simultaneous transmission

of a plurality of bands of frequencies, the combination with transmitting means of a repeater comprising a plurality of selecting circuits and amplifying units individual to
 5 certain of said selecting circuits and combined in other of said selecting circuits.

8. In a multiplex transmission system adapted for the simultaneous transmission of a plurality of bands of frequencies, the
 10 combination with means for transmitting a plurality of bands of frequencies, of a repeater comprising a plurality of amplifying units arranged in tandem formation; and a plurality of selective output circuits each
 15 responsive to a definite band of frequencies and connected with the group of amplifying units in such way that the number of stages of amplification is dependent upon the relative position of the band in the frequency
 20 spectrum.

9. In a multiplex transmission system adapted for the simultaneous transmission of a plurality of bands of frequencies, the combination with transmitting means of a
 25 repeater comprising a plurality of amplifying units arranged in tandem formation in an amplifying circuit, means for impressing a plurality of frequencies upon the input side of said amplifying circuit and
 30 means individual to the output circuit of each of said amplifying units to separate out the respective frequencies after they have received the required degree of amplification.

35 10. In a signaling system the combination with a transmission circuit of a translating circuit interposed between two sections of said transmission circuit and having means to amplify to different degrees oscillations
 40 of different groups of frequencies.

11. In a high frequency signaling system, the combination with a transmission circuit carrying a plurality of frequencies of a translating circuit interposed between sections
 45 of the said transmission circuit, comprising means to amplify to different degrees each of the said frequencies, and frequency selecting means to separate the various amplified frequencies and to impress
 50 them upon the said transmission circuit.

12. In a high frequency signaling system, the combination with a transmission line adapted to transmit a plurality of groups of frequencies, of a repeater circuit situated
 55 approximately midway electrically between the ends of the said line embracing a two way two path amplifying circuit having artificial lines associated therewith to balance said transmission line with respect to
 60 one group of frequencies and a two way one path amplifying circuit designed to be balanced with respect to the other group of frequencies by the lines themselves the amplifying units being common to both ampli-
 65 fying circuits, and means associated with

each of said amplifying circuits to select oscillations of the proper frequency for each respective circuit.

13. In a telephone repeater circuit, the combination of a two way two path circuit
 70 adapted to amplify oscillations of one group of frequencies, a two way one path circuit adapted to amplify oscillations of a second group of frequencies and a plurality of amplifying elements common to both circuits,
 75 one half of the said elements being connected in each path of the said two path circuit and all of said elements being connected in tandem in the said one path circuit whereby a higher degree of amplifica-
 80 tion is obtained in said one path circuit than in said two path circuit.

14. In a telephone repeater circuit, the combination of means for impressing thereon a plurality of groups of frequencies, a
 85 plurality of amplifying circuits each adapted to amplify the oscillations embraced within one group of frequencies, means associated with each amplifying circuit to select the oscillations of the group which
 90 the said circuit is designed to amplify and means to combine the amplified oscillations.

15. In a multiplex transmission system, the combination with a radio frequency transmission means of a repeater, means to
 95 impress radio frequency oscillations upon the said repeater, the said repeater having means to select and means to amplify to different degrees the impressed oscillations of different frequencies, and a transmission circuit
 100 arranged to have all of the amplified oscillations impressed thereon.

16. In an attenuation equalizer, the combination with a group of amplifiers in tandem formation of a group of filters each
 105 interposed between successive amplifiers, and all adjusted to narrow the band of frequencies that may be transmitted through the group of amplifiers.

17. In an attenuation equalizer, the combination with a group of amplifiers in tandem formation of a group of filters each
 110 interposed between successive amplifiers and adjusted to narrow the band of frequencies that may be transmitted through the group of amplifiers, and a second group of filters each of which has its input side connected
 115 with the input side of a filter of the said first group and is so adjusted as to transmit the frequency or frequencies not transmitted by the corresponding filter in said first group.
 120

18. In a signaling system, the combination with transmitting means of a group
 125 of amplifiers, a group of filters each of which is interposed between successive amplifiers and all adjusted to narrow the band of frequencies transmitted through the group of amplifiers.

19. In a signaling system, the combina- 130

tion with transmitting means of a group of amplifiers, a group of filters each of which is interposed between successive amplifiers and adjusted to narrow the band of frequencies transmitted through successive amplifiers, and a second group of filters each of which has its input side connected with the input side of a filter of the said first group and is so adjusted as to impress upon the said transmitting means the frequency or frequencies not transmitted by the corresponding filter of the said first group.

In testimony whereof, I have signed my name to this specification this 21st day of May 1920.

HERMAN A. AFFEL.