

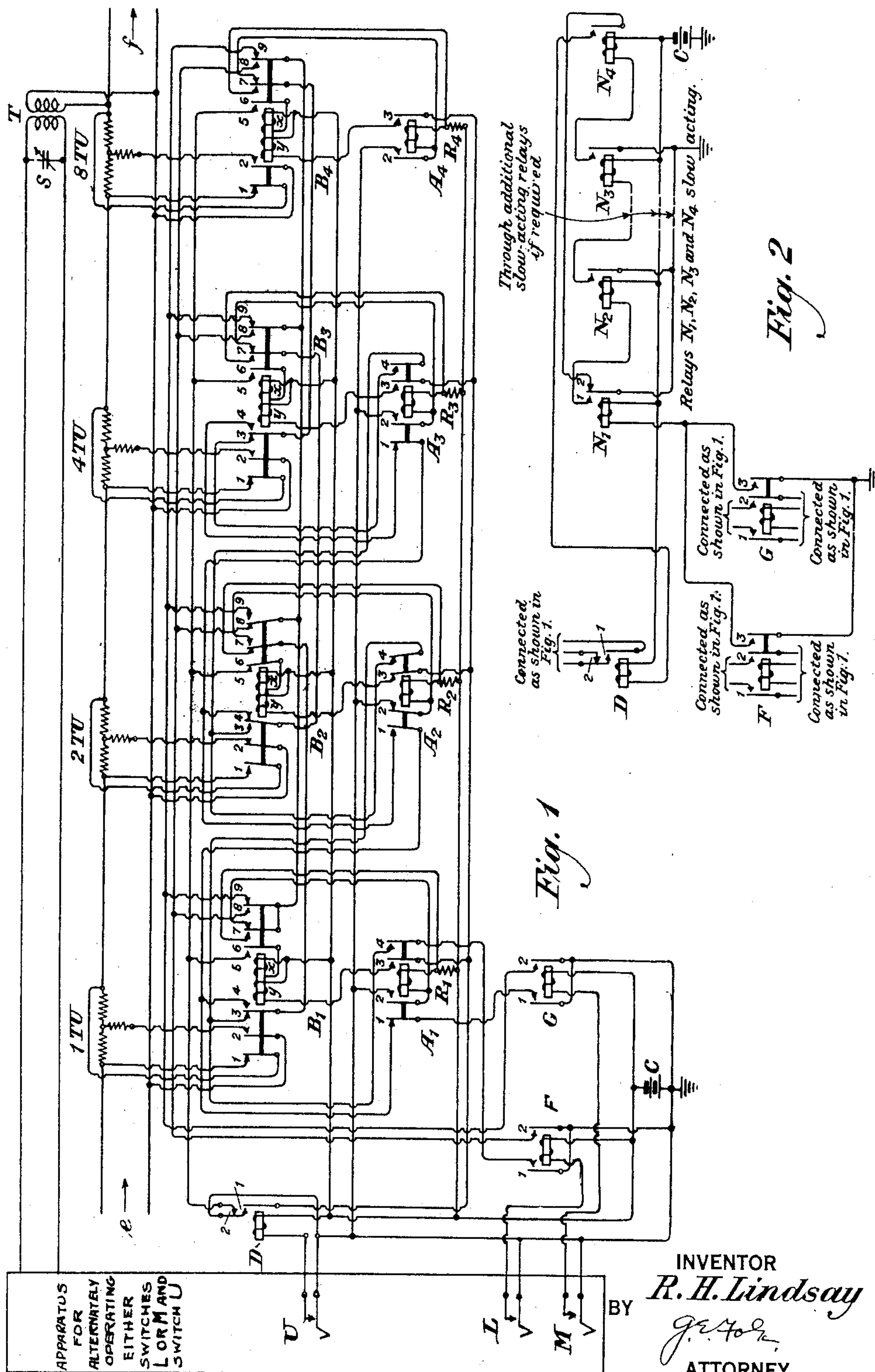
April 14, 1931.

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1,800,305

RELAY REGULATING CIRCUITS

Filed Nov. 1, 1928



Through additional
slow-acting relays
if required

Connected
as shown in
Fig. 1.

Fig. 2

Connected as
shown in Fig. 1.

Connected
as shown
in Fig. 1.

Connected
as shown
in Fig. 1.

Relays N_1, N_2, N_3 and N_4 slow acting.

Fig. 2

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RELAY-REGULATING CIRCUITS

Application filed November 1, 1928. Serial No. 316,606.

This invention relates to regulating circuits for telephone systems and for signaling systems generally, and particularly to regulating circuits employing trains of relays.

5 In this invention, there will be described regulating circuits consisting principally of trains of relays the purpose of which is to correct for variations in the magnitude of alternating current flowing in a telephone
10 or signaling circuit. Due to the substantial variations in attenuation in the transmitting medium employed in a telephone or signaling system caused by changes in numerous conditions, as, for example, in the weather,
15 a regulating circuit of the above-mentioned type is deemed necessary. It is the object of the regulating circuit to correct for such variations in attenuation in order to maintain the transmission equivalent of the transmitting medium highly constant. The principles of this invention may be applied to the automatic pilot channel of a carrier system to produce automatic corrections in the transmission equivalent of the circuit.

20 While this invention will be pointed out with particularity in the appended claims, the invention itself, both as to its further objects and features, will be better understood when read in connection with the accompanying drawing, in which Figure 1 shows
25 a regulating circuit which includes a pair of trains of relays for changing the total attenuation in arithmetical progression, introduced by a plurality of attenuation pads having magnitudes in geometric progression,
30 and in which Fig. 2 shows a circuit arrangement which may be associated with the pair of trains of relays to accomplish the same end.

40 Referring to Fig. 1 of the drawing, there is shown a pair of relay trains, there being two relays for each step, one in each train. A transmission circuit is shown between the reference characters e and f and signaling
45 energy flows thereover. Four attenuation pads may be associated with the transmission circuit, and these may have magnitudes corresponding to one, two, four and eight transmission units. Relays A_1 and B_1 of
50 the respective trains comprise the first step

and control the first attenuation pad of one transmission unit, relays A_2 and B_2 , the second, and so on, the number of pairs of relays employed depending upon the number of attenuation pads there are in the system. Each
55 of the A relays has a single winding, and, with the exception of the last A relay, four armatures, the first and last two of which are mechanically coupled by means of a bar of insulation. The last A relay has but two
60 armatures. Each of the B relays includes two windings, designated x and y , which are wound inductively, and, with the exception of the last B relay, six armatures, the first three and the last three of each relay
65 being mechanically coupled by a similar bar of insulation. The last B relay has but five armatures, the first two and the last three being similarly coupled, respectively.

These relay trains are under the control
70 of two main relays F and G which are operated by switches or keys L and M, respectively, and a trigger relay D which is operated by a switch or key U. A change in the total attenuation interposed by the at-
75 tenuation pads may be accomplished by closing and opening either of the main relays F or G and by subsequently closing and opening the trigger relay D, switch M being
80 responsible for increasing the total effective attenuation, and switch L being responsible for decreasing the total effective attenuation.

The arrangement shown in the drawing represents the relay regulating circuit complete except for the apparatus required for
85 the control mechanism actuating switches M, L and U. Alternating current is transmitted over the transmission circuit from the input side e to the output side f , and,
90 while the input at e may vary within certain limits, it is desired to maintain the output at f automatically within much smaller limits. This is accomplished by cutting into
95 or out of the transmission circuit one or more of the artificial line pads which are shown in units of 1, 2, 4 and 8 transmission units (TU) of attenuation, as has been stated hereinabove.

When the input at e varies to such an extent as to require adjustment of the number
100

of pads in order to keep the output at f within the prescribed limits, the circuit is made automatically responsive to control mechanism which picks up through a high impedance transformer T a small portion of the output current. This control mechanism may be any one of a number of suitable devices as, for example, the one known as the pilot indicator panel and Brown controller used in carrier telephone pilot channels, it being understood that other satisfactory devices may equally well be employed herein. This control mechanism will interconnect the secondary winding of transformer T with the switches L, M and U in any well-known manner, permitting switch U to be periodically closed and opened and either switch L or M to be periodically closed and opened as the output at f goes beyond the predetermined lower or upper limit, respectively. The closing and opening of switch U will be effective only after either switch L or M has been closed and opened. Changes in the attenuation will continue to take place after the periodic closing and opening of either switch L or M and of switch U, until, however, the output f has been brought within the prescribed limits by the interposition of the proper amount of attenuation in response to the actions of the relay regulating circuit.

The variations in alternating current flowing in the transmission circuit may, of course, be due to any cause the effect of which it is desired to counteract, the most common cause arising from variations in weather conditions, as stated hereinabove. It is to be noted that an alternating current of suitable frequency will ordinarily be transmitted over the transmission circuit for the purpose of actuating the control mechanism so that the control mechanism may respond to changes in the magnitude of this current caused, for example, by the above-mentioned weather variations. Since, in the case of a telephone circuit, there are also transmitted, at the same time other currents of widely different and rapidly changing frequencies and magnitudes, it is then necessary for the control mechanism to be responsive only to the current of the frequency transmitted for regulating purposes. The proper sensitiveness and responsiveness may be obtained by tuning the input circuit of the control mechanism, i. e., the circuit of the secondary winding of transformer T, to the regulating frequency by means of a variable condenser, such as S, or the like. If the variations in the alternating current used for regulating purposes which flows over the transmission circuit do not occur too rapidly to allow sufficient time for the control mechanism to function, the mechanism will keep the out-

put at f within or close to the prescribed limits.

Each attenuation pad is controlled by contacts 1 and 2 of the associated B relay, relays B_1 , B_2 , B_3 and B_4 being each controlled by relays A_1 , A_2 , A_3 and A_4 , respectively, and by the trigger relay D. When the output current at f departs beyond the prescribed limits, the control mechanism becomes responsive and the relay regulating circuit functions to operate or release certain of the relays A_1 , A_2 , A_3 and A_4 , the particular operation of relays A_1 and A_2 being described hereinafter. As will be understood hereinafter, after a short interval of time, the operation of relays A_1 and A_2 is followed by the operation of the trigger relay D, causing the grounding of contact 1 of relay D and the operation of the corresponding B relays, relays B_1 and B_2 , particularly, through the contacts 3 of relays A_1 and A_2 and the windings designated γ of relays B_1 and B_2 . An instant later, contact 2 of relay D is opened, causing the release of any previously operated B relays, as, for example, relay B_3 which may have been previously operated and locked through its contact 5 and its α winding.

The following table shows the values of attenuation obtainable from the four attenuation pads having magnitudes of 1, 2, 4 and 8 transmission units (TU) and the condition of relays B_1 , B_2 , B_3 and B_4 which respectively control these pads and which must be operated to obtain the proper magnitude of attenuation:

Attenuation	Relays operated			
0	None			
1	B_1			
2		B_2		
3	B_1	B_2		
4			B_3	
5	B_1		B_3	
6		B_2	B_3	
7	B_1	B_2	B_3	
8				B_4
9	B_1			B_4
10		B_2		B_4
11	B_1	B_2		B_4
12			B_3	B_4
13	B_1		B_3	B_4
14		B_2	B_3	B_4
15	B_1	B_2	B_3	B_4

It should be noted that relay B_1 is alternately operated and released for each successive value of attenuation. It should also be noted that relay B_2 is alternately operated and released at each second value of attenuation. The same is true of relay B_3 , which is successively operated at every fourth value of attenuation, and so on with other relays in the geometrical progression indicated. The relay regulating circuit

shown in Fig. 1 is arranged so that the required geometrical progression in the number of times the various relays operate and release is obtained. To show in greater detail how this takes place, it is necessary to trace this circuit in its operation through several typical steps.

The total attenuation may be stepped up by means of switch M which controls relay G, and this attenuation may be stepped down by means of switch L which controls relay F. Relay A₁ is under the control of both relays F and G. When either relay F or G operates, relay A₁ operates, if released, or, if relay A₁ has been previously operated, it releases, and this is always the case except at each end of the range of attenuation, as will be described hereinafter.

When the relay regulating circuit is in the condition shown in Fig. 1, the total attenuation interposed in the transmission circuit is two transmission units. Suppose the input at *e* rises sufficiently to start the control mechanism in operation. In order to keep the output at *f* within narrow limits, the attenuation interposed in the transmission circuit must be increased. The control mechanism closes switch M. It will be observed, upon an inspection of the above enumerated table, that a change in the attenuation from two to three transmission units requires the operation of relay B₁ while relay B₂ remains operated.

When switch M closes, relay G operates, current flowing through the winding of relay G from battery C. A circuit is completed extending from ground through contact 2 of relay G, contact 9 of relay B₁, contact 7 of relay B₁, the winding of relay A₁, and resistance R₁ to the ungrounded side of battery C. Accordingly, relay A₁ operates. Relay A₁ then becomes locked by the connection of one terminal of its winding to the grounded side of battery C through its contact 2. The closure of contact 1 of relay G accomplishes nothing at this time because, although contact 1 of relay A₁ is closed for an instant before relay A₁ operates, contact 4 of relay B₁ and contact 1 of relay A₂ are both open.

After a short interval, the control mechanism opens switch M, thereby releasing relay G. Shortly thereafter, the control mechanism closes switch U, causing the tripping relay D to operate by the flow of current through its winding from the battery C. The closure of contact 1 of relay D completes a circuit from ground through contact 3 of relay A₁ and through winding γ of relay B₁ to the ungrounded side of battery C. Accordingly, relay B₁ operates, and, upon closure of its contact 2 and upon opening of its contact 1, adds the attenuation pad of one transmission unit to the transmission circuit. Due to the make-be-

fore-break action of relay D, the opening of contact 2 of relay D an instant later does not release relay B₂, because one terminal of winding γ of relay B₂ is connected to the grounded side of battery C through contact 3 of relay A₂ and contact 1 of relay D, battery C supplying winding γ of relay B₂ with energizing current. This condition continues as long as relay D remains operated.

After a short interval of time, however, the control mechanism opens relay U, thereby releasing relay D. Relays B₁ and B₂ become locked by the flow of current from battery C through their α windings and their contacts 5, respectively, and also contact 2 of relay D which leads to the grounded side of battery C.

It will be apparent that the total attenuation interposed in the transmission circuit has been changed from two transmission units to three, and that this has been accomplished by successively closing and opening switch M followed successively by closing and opening switch U. The action of switch U is effective only after switch M has been operated and released.

If the output at *f* is within the prescribed limits, the control mechanism will cease to operate. If, however, the output at *f* tends to go beyond the upper prescribed limit, the control mechanism will function to introduce additional attenuation. Switch M will again be closed. The table given hereinabove shows that a change in the total attenuation from three transmission units to four requires the release of both relays B₁ and B₂ and the operation of relay B₃. Upon the closure of switch M, it will be apparent that relay G operates. Thus, the grounded side of battery C is connected through contact 2 of relay G, contact 9 of relays B₃ and B₄, which are in parallel relationship, and contact 6 of relay B₁ to the junction of the winding of relay A₁ and the resistance R₁. Accordingly, the winding of relay A₁ becomes short-circuited, causing its release. Resistance R₁ prevents excessive current from flowing through the short-circuiting contacts.

Upon the release of relay A₁, a circuit is established from the grounded side of battery C through contact 1 of relay G, contact 1 of relay A₁, contact 4 of relay B₁ and contact 6 of relay B₂ to the junction of the winding of relay A₂ and the resistance R₂. Accordingly, the winding of relay A₂ becomes short-circuited and this relay releases. Immediately upon the release of relay A₂, a circuit is established from the grounded side of battery C through contact 1 of relay G, contact 1 of relay A₁, contact 1 of relay A₂, contact 4 of relay B₂, contact 7 of relay B₃, the winding of relay A₃, and the resistance R₃ to the ungrounded side of battery

C. Accordingly, relay A_3 operates, and it becomes locked by virtue of the connection of one terminal of its winding to the grounded side of battery C through contact 2 of relay A_3 . Thus, relays A_1 and A_2 have been released and relay A_3 has been operated.

Subsequently, the control mechanism opens switch M, thereby releasing relay G. Shortly thereafter, switch U closes, operating relay D. Upon the closure of contact 1 of relay D, the grounded side of battery C becomes connected, through contact 3 of relay A_3 and winding y of relay B_3 , to the ungrounded side of battery C. Accordingly, relay B_3 operates. Shortly thereafter, contact 2 of relay D is opened, causing the release of relays B_1 and B_2 . Upon the opening of switch U and the release of relay D, relay B_3 remains operated by virtue of the connection of the grounded side of battery C through contact 2 of relay D, contact 5 of relay B_3 and winding x of relay B_3 to the ungrounded side of battery C.

Thus, a step has been completed for increasing the total attenuation interposed in a transmission circuit from a value corresponding to three transmission units to one corresponding to four transmission units. If it be assumed that this change in the total attenuation is sufficient to bring the output at f down within the prescribed limits, the control mechanism will cease to operate and switch M will not be closed again.

Assuming the total attenuation to be at a value corresponding to four transmission units, and that the output at f decreases below the lower prescribed limit, it will then be necessary to decrease the effective attenuation. A step downward may be taken by changing the attenuation from a value corresponding to four transmission units to one corresponding to three units, this being accomplished by releasing the relays controlling the attenuation pad of four units and operating the relays controlling the attenuation pads of one and two transmission units.

Switch L, when closed by the control mechanism, will cause relay F to operate, the winding of relay F being connected to battery C by means of switch L. A circuit will then be completed, extending from the grounded terminal of battery C through contact 2 of relay F, contact 8 of relay B_3 , contact 7 of relay B_1 to winding of relay A_1 and the resistance R_1 to the ungrounded terminal of battery C. Accordingly, relay A_1 operates, and, upon closure of its contact 2, which is connected to the grounded terminal of battery C, becomes locked. Immediately upon the operation of relay A_1 , another circuit is established from the grounded terminal of battery C through

contact 1 of relay F, contact 4 of relay A_1 , contact 3 of relay B_1 , contact 7 of relay B_2 , the winding of relay A_2 and the resistance R_2 to the ungrounded terminal of battery C. Accordingly, relay A_2 operates, and, upon closure of its contact 2, which is also connected to the grounded terminal of battery C, becomes locked. Immediately upon the operation of relay A_2 , a circuit is completed from the grounded terminal of battery C through contact 1 of relay F, contact 4 of relay A_1 , contact 4 of relay A_2 , contact 3 of relay B_2 and contact 6 of relay B_3 to the junction of the winding of relay A_3 and the resistance R_3 . Since both terminals of the winding of relay A_3 are now connected to the grounded side of battery C, this winding is in effect short-circuited and its armatures become released. Thus, relays A_1 and A_2 have been operated, and relay A_3 released.

Subsequently, the control mechanism closes switch U, operating relay D. A circuit is established from the grounded side of battery C through contact 1 of relay D, contact 3 of relay A_1 , winding y of relay B_1 to the ungrounded side of battery C. Accordingly, relay B_1 operates. A circuit is also established from the grounded side of battery C through contact 1 of relay D, contact 3 of relay A_2 , winding y of relay B_2 to the ungrounded side of battery C. Therefore, relay B_2 operates. Subsequently, upon the opening of contact 2 of relay D, contact 3 of relay A_3 having previously been opened, relay B_3 releases by virtue of the fact that neither of its windings is connected in series with the battery C.

It is well to note that when the control mechanism opens switch U, a circuit is established from the grounded side of battery C through contact 2 of relay D, contact 5 of relay B_1 , winding x of relay B_1 to the ungrounded side of battery C. Accordingly, relay B_1 becomes locked. Moreover, a similar circuit is established from the grounded side of battery C through contact 2 of relay D, contact 5 of relay B_2 , winding x of relay B_2 to the ungrounded side of battery C. Therefore, relay B_2 is also locked.

Thus, it has been shown that in decreasing the total attenuation from a value corresponding to four transmission units to one corresponding to three, it is necessary to release relays A_3 and B_3 and to operate relays A_1 and B_1 and relays A_2 and B_2 , the latter pairs of relays controlling the attenuation pads corresponding to one and two transmission units, respectively. In decreasing the total effective attenuation, it was necessary to operate the control mechanism so as to close and open switch L and to subsequently close and open switch U. Further decreases in the total effective attenuation

may be made in a similar manner, as required.

In general, then, it may be said that the circuit operates in such a manner while increasing the attenuation in successive steps corresponding to one transmission unit each, that any certain B relay, except relay B_1 , for instance, relay B_3 , becomes operated when a step is taken only after all the preceding B relays in ascending numerical order, in this case, relays B_1 and B_2 , have been in the operated condition on the preceding step. And furthermore, the operation of any B relay, as the said B_3 , on the step in question, is accompanied by the release of all the preceding B relays, as the said B_1 and B_2 . This will also be apparent upon inspection of the above table. Similarly, in decreasing the total attenuation in successive steps in magnitudes of one transmission unit each, any certain B relay, except relay B_1 , as, for example, relay B_3 , becomes released when a step is taken only when all of the preceding B relays in ascending numerical order, as, for example, relays B_1 and B_2 , have been in the released condition on the preceding step. And furthermore, the release of any B relay, as the relay B_3 , on the step in question, is accompanied by the operation of all the preceding B relays, as, for example, relays B_1 and B_2 . This condition will also be apparent upon further inspection of the above table. Relays A_1 and B_1 , however, are both alternately operated and released for each successive step in attenuation, for it will be apparent from the table that an attenuation pad corresponding to one transmission unit must be alternately cut into and out of the circuit for each step, whether that step is taken upwardly or downwardly.

In stepping upwardly over the entire range of attenuation without interruption, or downwardly, it will be apparent that relay B_1 is operated twice as often as relay B_2 , relay B_2 twice as often as relay B_3 , and so on. The associated A relays operate also with the same frequency. This geometric progression in relay operation represents one of the novel features of this invention and results in what seems to be a relay switching scheme having a minimum of relays for the switching operations.

An effective cut-off of the relay circuit is provided at each end of the range of attenuation. If all of the attenuation pads are interposed in the transmission circuit, and if the output at f goes above the upper prescribed limit, no further correction is possible. The control mechanism, however, continues to open and close switch M in response to the abnormally high output. The next step after all of the attenuation pads have been switched into the transmission circuit would result in switching all of the

pads out of the transmission circuit, if not prevented. Such an undesirable condition is indeed eliminated by making further stepping action, due to the movement of switch M and the action of the associated relay G, impossible when all of the B relays have been operated. It will be seen that contacts 9 of all of these B relays are connected in parallel between contact 2 of relay G and the winding of relay A_1 , and, since all of the contacts 9 of these relays are opened, relay A_1 will not operate. Stepping action due to the movement of switch M cannot result as long as this condition continues.

In a similar manner, contacts 8 of all of the B relays are connected in parallel between contact 2 of relay F and the winding of relay A_1 , and, since all of these contacts 8 are opened when all of the B relays are released, any further stepping action due to the movement of switch L and the action of relay F will be prevented even though the output at f is below the lower prescribed limit.

The relay circuit of this invention can be extended to cover any desired range of attenuation, no matter how large, by using the proper number of attenuation pads which are also of the proper size, under the condition, however, that each consecutive attenuation pad in the series is twice as large as the next smaller one. In the arrangements shown in the drawing, if it is desired to extend the range of the relay circuit by one step, an attenuation pad corresponding to sixteen transmission units and an associated pair of relays can be added at the upper limit, or, on the other hand, an attenuation pad corresponding to one-half of a transmission unit and the associated pair of relays can be added at the lower limit.

As suggested hereinabove, the relay arrangement of this invention is greatly advantageous over any other known relay arrangement because of the small number of relays required, and this is particularly so if the range of attenuation to be covered is large and the size of each step in that range is small. In applying the described relay arrangement to a transmission circuit requiring, for example, seven pads, only seventeen relays are required, seven pairs corresponding to the seven pads and three additional relays similar to relays F, G and D. In a particular arrangement of the prior art, it has been found necessary to employ approximately one hundred and forty relays to control the seven pads.

In the arrangement shown in Fig. 1 of the drawing, the regulating circuit is designed primarily for use with control mechanism which closes and opens either switch L or M and then closes and opens switch U, these switches being periodically closed and opened as long as the level of energy flow-

ing in the transmission circuit requires a change. A particular relay regulating circuit, i. e., one having a pair of relays for each attenuation pad, may also be applied to the type of control mechanism of the prior art, which merely closes and opens switches L or M, as required, and is not equipped with a switch U. Fig. 2 shows the two relays F and G which are controlled by switches L and M, respectively, and a relay D without the corresponding switch U. In the arrangement of this figure, contacts 1 and 2 of relay D, and contacts 1 and 2 of relays F and G, perform their functions in exactly the same manner as do the corresponding elements in Fig. 1, and it is therefore not deemed necessary to show the complete relay regulating circuit of Fig. 1.

Both relays F and G have a third contact, designated 3, this contact controlling the action of a train of slow-acting relays N_1, N_2, N_3 and N_4 . This train of slow-acting relays controls the action of relay D. When either relay F or relay G is operated in the usual manner, contact 3 of the relay operated completes a circuit from ground through contact 3, the winding of relay N_1 to the ungrounded side of battery C. Accordingly, relay N_1 operates, and yet, due to the slow-acting properties of this relay, it requires a definite interval before contact 1 of this relay becomes closed. Upon the closure of contact 1 of relay N_1 , a circuit is completed from ground through winding of relay N_1 to the ungrounded side of battery C. Accordingly, relay N_2 operates, its contact being also closed after a definite time interval. Similarly, relays N_3 and N_4 are in turn operated, each requiring a further time interval for the closure of their associated contacts. When relay G releases, relay N_1 also releases. A circuit is now completed extending from ground through contact 2 of relay N_1 , the contact of relay N_4 , the winding of relay D to the ungrounded side of battery C. Accordingly, relay D operates and accomplishes the same purposes as are set forth in connection with the arrangements shown in Fig. 1. After the release of relay N_1 , however, relays N_2, N_3 and N_4 become released in succession. Finally, upon the opening of the contact of relay N_4 , relay D releases.

It will be clearly understood, however, that while only four slow-acting relays have been shown herein for the purpose of illustration, any desired number of similar relays may be employed so that the associated relay D may be operated and released within any desired space of time.

While the general principles of this invention have been applied to certain particular arrangements merely for the purpose of illustration, it will be understood that these principles may be embodied in other

and widely varied organizations without departing from the spirit of the invention and the scope of the appended claims.

What is claimed is:

1. The combination of a plurality of elements of attenuation of magnitudes arranged in geometric progression, a plurality of pairs of relays, one pair of relays corresponding to each element of attenuation, means for operating one of the relays of each pair before the other relay of that pair is operated, and means for operating said pairs of relays in a predetermined order to change the attenuation by equal increments.
2. The combination of a plurality of elements of attenuation having magnitudes in geometric progression, a plurality of pairs of relays, one pair of said relays corresponding to and controlling each element of attenuation, means for operating one of the relays of each pair before the other relay of that pair is operated, means for operating said pairs of relays in a predetermined order to successively increase the attenuation in arithmetical progression, and means to operate said pairs of relays in the reverse order to successively decrease the attenuation in arithmetical progression.
3. The combination of a plurality of attenuation pads having magnitudes which are successively in geometric progression, a plurality of pairs of relays, one pair of said relays corresponding to and controlling each attenuation pad, means for operating one of the relays of each pair before the other relay of that pair is operated, means for successively operating said pairs of relays in groups in a predetermined order to increase the total attenuation of said pads in arithmetical progression, and mean for successively operating said pairs of relays in groups in a different order to decrease the total attenuation of said pads in arithmetical progression.
4. The combination of a transmission circuit in which signals may be transmitted, a plurality of attenuation elements which may be added to or subtracted from said transmission circuit to change its gain by any desired amount, a pair of control relays, one control relay controlling the increase in the number of attenuation elements, the other control relay controlling the decrease in the attenuation elements, a master relay operatively associated with both of said control relays, means to successively and alternately operate and release the first of said control relays and the master relay to increase the number of attenuation elements, and means to successively and alternately operate and release the second of the control relays and the master relay as the number of attenuation elements is to be decreased.
5. The combination of a plurality of at-

tenuation elements, a pair of control relays, a master relay operatively associated with both of said control relays, means to successively and alternately operate one of the control relays and the master relay as the
5 attenuation of said elements is to increase, means to successively and alternately operate and control the other of the control relays and the master relay as the attenuation of said elements is to decrease, and
10 means whereby said control relays and said master relay may effectively change the attenuation of said elements by any predetermined amount.

15 6. A regulating arrangement for a signal transmission circuit comprising a plurality of attenuation elements of magnitudes which are arranged in geometrical progression, a plurality of pairs of relays, one pair
20 of relays corresponding to each attenuation element and controlling its connection to the transmission circuit, means to operate one of the relays of each pair before the other relay of that pair has been operated, means
25 to operate said pairs of relays in selected groups so as to consecutively change the total attenuation of said elements in arithmetical progression, means to prevent the simultaneous release of all of said pairs of
30 relays after all have become operated, and means to prevent the simultaneous operation of all of the pairs of relays after all have become released.

35 7. The combination of a transmission circuit transmitting signals, a plurality of attenuation elements which may be added to or taken from the transmission circuit to change the total attenuation of the transmission circuit by any desired amount, a
40 pair of control relays, a third relay operatively associated with said control relay, one of said control relays and said third relay being successively and alternately operated and released to increase the total attenuation,
45 the other of said control relays and said third relay being successively and alternately operated and released to decrease the total attenuation, and means whereby said pair of control relays and said third
50 relay may effectively change the total attenuation of said elements by any desired amount.

In testimony whereof, I have signed my name to this specification this 31st day of
55 October, 1928.

RUSSELL H. LINDSAY.