

May 25, 1926.

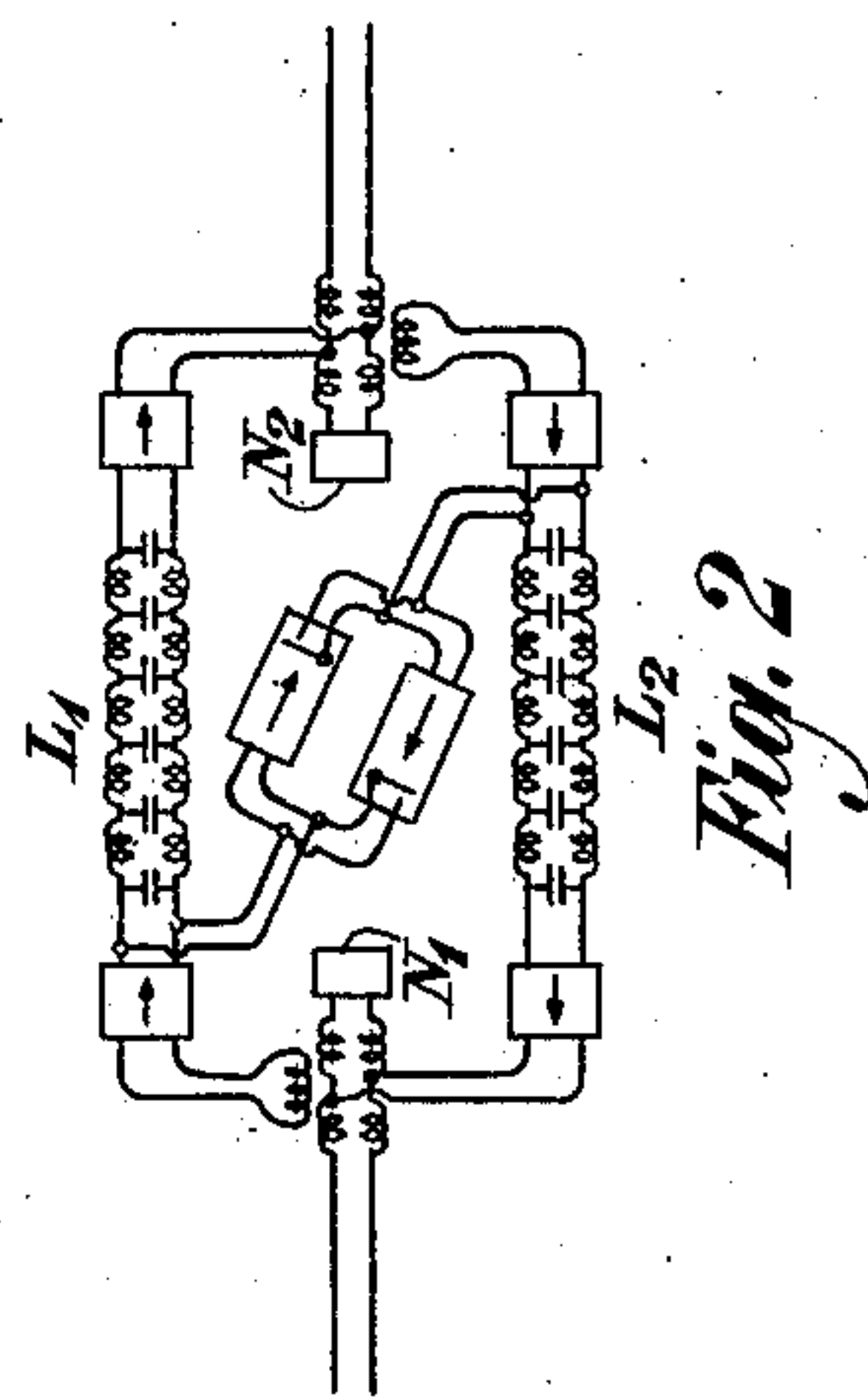
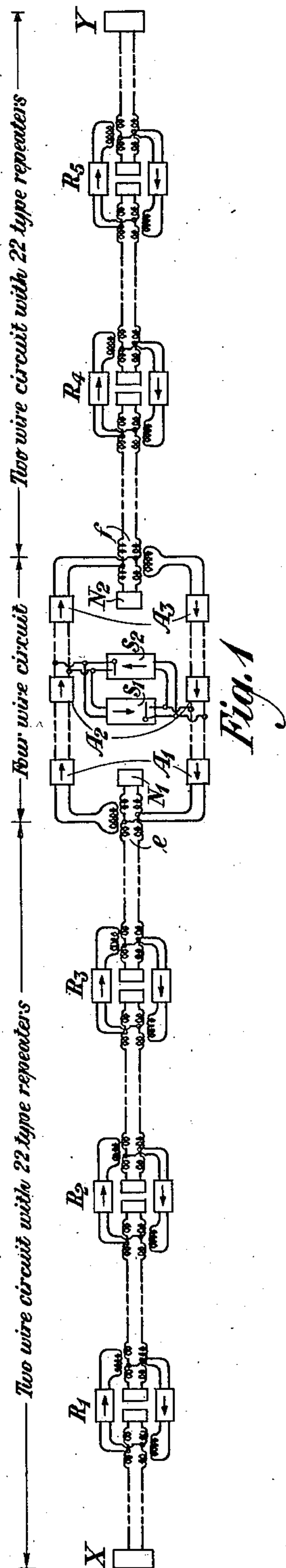
1,585,702

A. B. CLARK

ECHO SUPPRESSOR FOR TWO-WIRE SYSTEMS

Filed August 22, 1923

2 Sheets-Sheet 1



INVENTOR
A. B. Clark
BY
g r f o k
ATTORNEY

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2 Sheets-Sheet 2

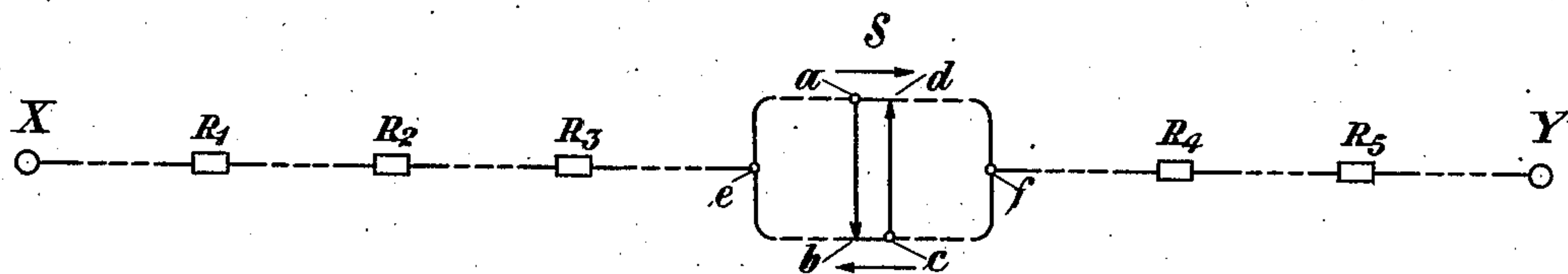


Fig. 1a

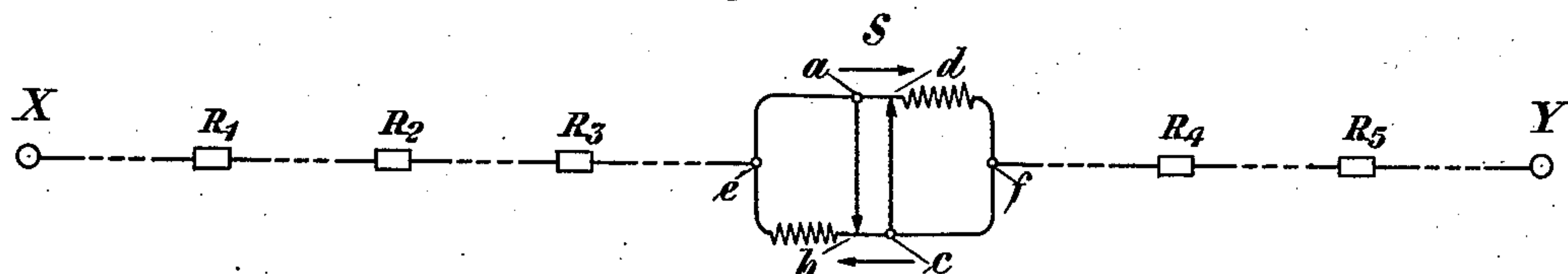


Fig. 2a

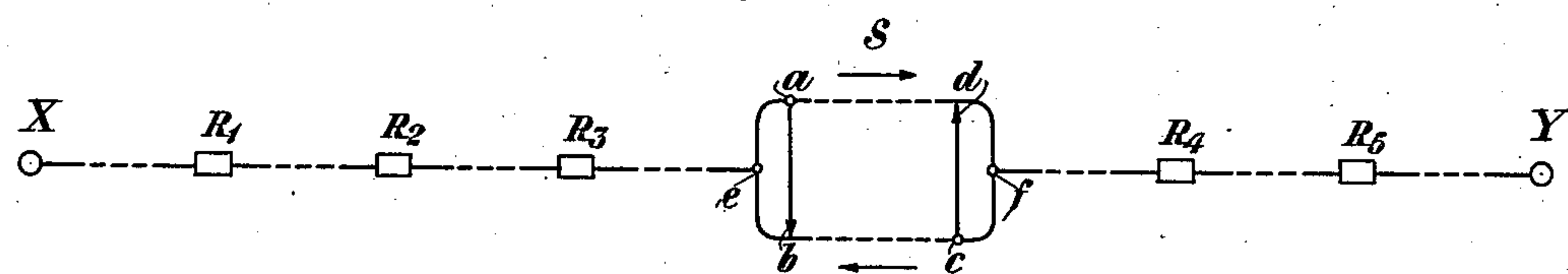


Fig. 3a

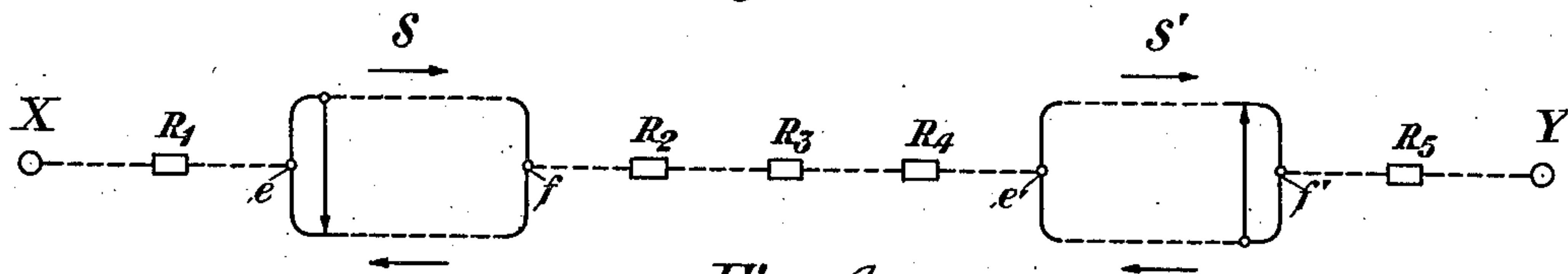


Fig. 4a

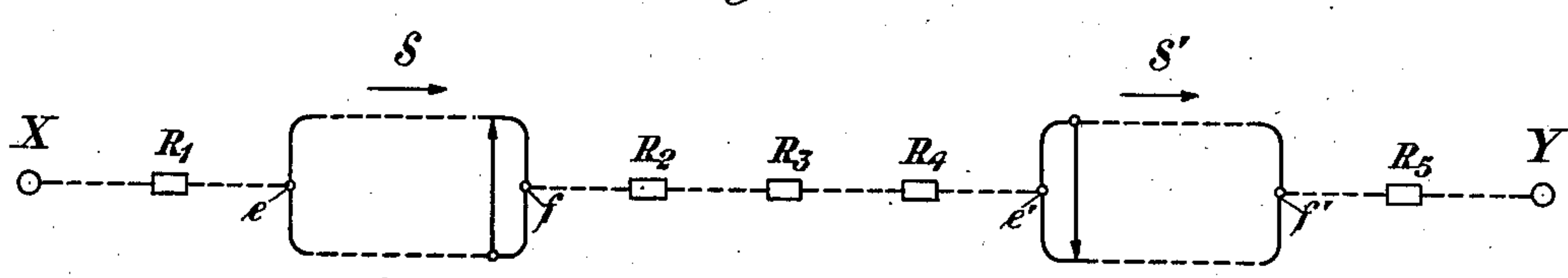


Fig. 5a

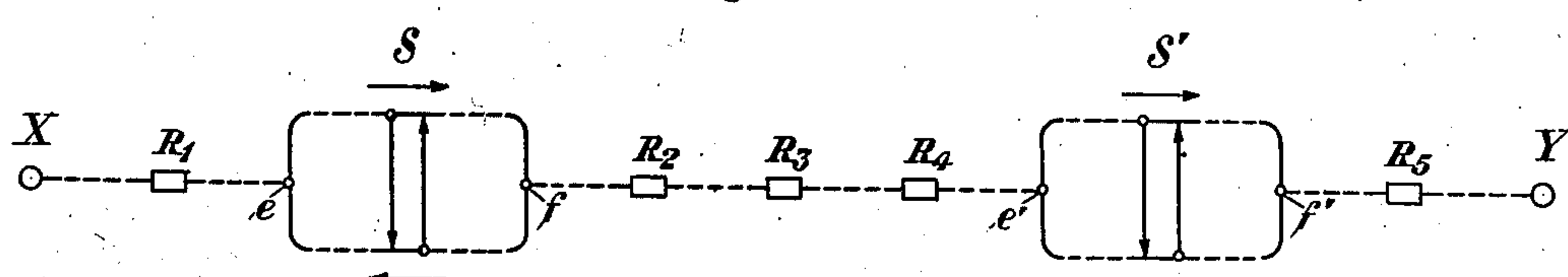


Fig. 6a

INVENTOR
A. B. Clark
BY
g r y o l e
ATTORNEY

Patented May 25, 1926.

1,585,702

UNITED STATES PATENT OFFICE.

ALVA B. CLARK, OF BROOKLYN, NEW YORK, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

ECHO SUPPRESSOR FOR TWO-WIRE SYSTEMS.

Application filed August 22, 1923. Serial No. 658,781.

This invention relates to arrangements for the suppression of echoes in two-wire telephone systems employing 22-type repeaters.

It has been demonstrated that a long four-wire circuit may be operated commercially with a transmission equivalent of zero even when the circuit is several thousand miles long, provided the echo effects are suppressed. Before echo suppressors were available, it was necessary in practice to reduce the gain to a point considerably below that at which singing would occur in order to keep the volume of the echo currents low. By providing a voice responsive means in connection with each one-way line of the four-wire circuit to disable the line for transmission in the opposite direction, the echo currents are eliminated from the four-wire circuit thus permitting of operating the one-way amplifiers at a greater gain.

In accordance with the present invention, it is proposed to obtain the benefits of echo suppression upon a two-wire circuit including 22-repeaters. If a two-wire repeater circuit be electrically long, the circuit will not, in general, sing, even with the comparatively imperfect commercial balances now obtainable, until the net equivalent of the circuit is reduced to a very low value, for example, zero. In such a circuit, however, echoes would occur, due to reflection at every point of considerable impedance irregularity. Such an irregularity occurs at every repeater point, and consequently the total effect of the cumulative echo currents is so great that in practice no long two-wire repeater circuits have been obtained with an equivalent better than six miles. In fact, usually it is necessary, in the case of long circuits, to stand for a transmission loss of as much as ten miles in order to reduce echo effects to reasonable proportions. If we had two lengths of two-wire repeatered circuit, each of which were capable of giving a ten-mile net equivalent when worked alone, a total transmission loss of about twenty miles would be encountered if we attempted to connect the two circuits in tandem.

In accordance with the present invention, it is proposed to interconnect such circuits by means of a length of four-wire circuit, or the equivalent thereof, to which echo-suppressing arrangements have been applied. With such an arrangement all echo currents depending upon a return path through the

four-wire part of the circuit, will be suppressed with the result that the two lengths of circuit, each having a transmission loss of ten miles, may be operated with an overall equivalent approximately zero, instead of twenty miles. The reduction of the net equivalent might be obtained either by increasing the gain of the 22-repeaters or by providing a sufficient amount of gain in the four-wire part of the system.

As a practical proposition, suppose it is necessary to reduce the net equivalent between two cities connected by a two-wire repeatered circuit. By inserting a four-wire echo suppressing link at some suitable point in the circuit sufficient gain might be provided by means of the four-wire link to reduce the net equivalent to zero without any alteration in the two-wire circuit or in the gain of its repeaters. Or, to take another case, let us assume it is required to connect together two two-wire repeatered circuits which are each operating at their echo limit. If the two circuits are connected by a four-wire echo suppressing link, the suppressor may be set to provide enough gain to reduce the net equivalent of the over-all connection at least to the average of the net equivalents of the two circuits thereby connected, and in most cases the over-all equivalent could be reduced to zero.

The invention may now be more fully understood from the following detailed description when read in connection with the accompanying drawing, Fig. 1 of which illustrates a simple circuit arrangement embodying the use of a four-wire echo suppressing link in a two-wire repeatered circuit; Fig. 2 of which shows an arrangement equivalent to the four-wire echo suppressing link of Fig. 1, in which all of the apparatus may be located at one point, while Figs. 1^a to 6^a inclusive indicate schematically different arrangements and locations of the echo suppressing elements to be used in connection with two-wire repeatered circuits.

Referring to Fig. 1, a long two-wire circuit is shown interconnecting terminal stations X and Y, said circuit having 22-type repeaters located as indicated conventionally at R_1 , R_2 , R_3 , R_4 , and R_5 . At an intermediate point of the circuit, as, for example, between the repeater points R_3 and R_4 , a four-wire circuit link is interposed between two sections of the two-wire line. This

four-wire link includes the usual balancing networks N_1 and N_2 for balancing sections of the two-wire line and one-way amplifiers, as indicated at A_1 , A_2 and A_3 . In order to suppress echoes, devices S_1 and S_2 are provided, these devices being merely conventionally shown in the drawing. In practice, the echo suppressing devices may comprise voice operated relays of any type well known in the art bridged across each two-wire line of the four-wire circuit, and each operating contacts whereby the opposite two-wire circuit may be disabled, as, for example, by short-circuiting it. The length of four-wire circuit need only be sufficiently long so that enough time lag will be introduced in the two sides to enable the relays to operate and disable the opposite line in response to transmission in one direction before the operating current will have time to pass on around the loop and return to the point at which the disabling occurs. In practice, a length of line in the neighborhood of 100 or 200 miles would be adequate for this purpose.

As an alternative to the use of an actual four-wire circuit at an intermediate point of the two-wire line, the arrangement shown in Fig. 2 may be employed in which all of the four-wire apparatus, including the echo suppressing arrangements, may be located at one station. In this figure, the necessary time lag to enable the relay to operate is provided by means of two artificial lines in the form of low pass filters, consisting of coils and condensers as shown. Amplifiers may also be included in circuit with the low pass filters, as illustrated, the amplifiers being for the purpose of reducing the over-all equivalent of the circuit.

In order to understand the operation of the circuit arrangement of Fig. 1, reference is made to the conventional showing of the circuit indicated in Fig. 1^a. Here, each line section, consisting of two wires, is represented by a single dotted line, the 22-repeater points being indicated by small rectangles and the four-wire link by two dotted lines as shown. The echo suppressors are represented symbolically by the arrows joining the two sides of the four-wire circuit. For example, point a represents the input of the voice operated relay mechanism which short-circuits the return circuit at b . Likewise, c represents the input of the voice operated relay arrangement which short-circuits the opposite one-way line at d . With this arrangement, it is necessary for the "make" time of the relay at b to be less than the time of propagation over the path from a through f to b .

In the arrangement of Fig. 1, all echoes whose paths include the suppressor are, of course, eliminated. These include particularly the long echo paths where time lag is

of the greatest importance, and among these is the longest path from terminal X to terminal Y and back, the echoes taking place over this path being the ones which chiefly limit the net equivalent of a circuit.

Echo currents in general are of two kinds—talker echoes, which are currents transmitted from a point of origin to some point where an impedance irregularity occurs, from which point they are reflected back to the point of origin; and listener echoes which are reflected more than once, or, in other words, currents which are transmitted from a point of origin to a point at which an impedance irregularity occurs, from which they are reflected back towards the point of origin there encountering some intermediate impedance irregularity which causes them to be reflected again in a direction away from the point of origin or towards the listener.

In Fig. 1^a talker echoes set up in the portion of the circuit between the talker at station X and the four-wire link will not be eliminated. Talker echoes set up in the portion of the circuit adjacent the listener at Y will be eliminated, however, for the reason that their return path will be through the disabled part of the four-wire circuit at b . For example, suppose a voice wave is being transmitted from X towards Y. The wave reflected back towards X from repeater point R_2 will not be eliminated, but as the original wave passes on to repeater point R_5 and sets up a new reflection wave propagated in a direction towards X, the latter wave will be eliminated because it must pass through the point b .

Listener echoes, which are reflected between points on either side of the four-wire link will be suppressed. For example, a wave propagated from X to repeater point R_5 and reflected back to repeater R_2 , from which point it is again reflected towards Y, will be suppressed because the original wave passing through point a will open the return circuit at b . Listener echoes, which are set up in the two-wire portion of the circuit nearest the talker or in the two-wire circuit between four-wire link and the listener will not be eliminated, but this is of little consequence, as in neither case will the reflected waves be greatly delayed behind the original wave. For example, suppose a wave is transmitted from X towards Y and is reflected at repeater point R_3 back to repeater point R_2 , where it is again reflected in a direction towards Y and is propagated on through the point a to Y. Such a listener echo will not be suppressed, but will only be delayed in propagation, as compared with the original wave, by the time taken to pass from reflection point R_3 to R_2 and back again to R_3 .

Fig. 2^a indicates symbolically a circuit employing the arrangement of Fig. 2. The

operation of this circuit, so far as the suppression of echoes is concerned, will be the same as that described in connection with Fig. 1^a and need not be further discussed.

A modified arrangement is symbolically indicated in Fig. 3^a in which the suppressor units are separated and located at the two ends of a four-wire link. This arrangement allows a longer time for the suppressor to operate and short-circuit, or otherwise disable the line transmitting in the opposite direction, as it is only necessary that the suppressor operate within the time of propagation from *a* through *f* to *b*. With an arrangement of this type, however, care must be taken in designing the suppressor so that, while it will respond to talking currents transmitted from the terminal, it will not respond to reflected currents. Otherwise, if a subscriber at X were talking, echoes might be reflected from the Y terminal or from the repeater points *R*₄ or *R*₅ to operate the suppressor at *d* and interrupt the transmission from X. It is also theoretically possible with this arrangement for subscribers at both terminal stations to begin talking at the same time and both operate the corresponding suppressors so that neither could hear the other. As a practical matter, however, this is of little or no consequence, as in ordinary conversations subscribers do not talk at the same time and, even when they do, the probability is very remote that two subscribers would commence talking at the exact instant which would enable them to block each other out. The operation of the arrangement of Fig. 3^a, so far as the suppression of echoes is concerned, will be similar to that of Figs. 1^a and 2^a and need not be further described.

A more effective arrangement from the standpoint of echo suppression may be obtained by splitting the echo suppressor and putting the two halves at or near the ends of the circuit as shown in Fig. 4^a. This involves the use of two four-wire links. With this arrangement, as is the case in the arrangement of Fig. 3^a, the suppressor should be designed to avoid the possibility of its operation by echoes. It is also theoretically possible with this arrangement for both subscribers to operate their suppressors simultaneously and each prevent the other from talking through the circuit. As has already been stated, however, this is a matter of small consequence.

The arrangement of Fig. 4^a will eliminate all talker echoes if the suppressors are arranged sufficiently close to the terminals. As actually shown, however, talker echoes might be reflected back from any impedance irregularities between X and *e* when X is talking. Such echoes are of little consequence, however, as they would not be greatly delayed with respect to the original cur-

rents. Interior listener echoes, that is, echoes reflected more than once between impedance irregularities located in the line section intervening between the two elements of the suppressor, would not be eliminated. For example, a wave transmitted from X to *R*₄ and reflected back to *R*₂ and from this point reflected toward Y will not be suppressed. Such listener echoes are, however, usually of small magnitude and are only subject to moderate delay in transmission and are consequently not troublesome. Some listener echoes involving a listener terminal will also be transmitted. For example, a wave from X passing to the terminal Y and then reflected back to *R*₅ and from *R*₅ reflected again to Y will not be suppressed. Such an echo will, however, be but little delayed with respect to the original wave and consequently will not be troublesome. Listener echoes reflected from points external to both four-wire sections will be suppressed. For example, a wave from X passing to *R*₅, then reflected back to *R*₁, from which point it is again reflected towards Y, will be suppressed by means of the suppressor section S. It will thus be seen that the arrangement of Fig. 4^a suppresses the most important echoes, that is, those which travel over long paths, and hence are considerably delayed with respect to the original waves.

Fig. 5^a shows symbolically an arrangement in which the relation of the echo suppressors to the terminals is reversed with respect to Fig. 4^a. By this arrangement, a wave from station X must pass to point *e'* to disable the return path, and likewise a wave from Y must pass to *f* before disabling the other return path. It possesses the advantage however, that it reduces the likelihood of both stations being able to cut each other out simultaneously by talking at the same time.

From the standpoint of echo suppression, this arrangement might not be so satisfactory as the arrangement of Fig. 4^a, as it does not suppress some of the important echoes. It will only suppress talker echoes reflected from points beyond *e'* as a result of propagation of original waves from station X. Talker echoes reflected back from points between *e'* and X would not be suppressed, and these waves might, in the case of a long circuit, be considerably delayed with respect to the original wave. Likewise only listener echoes transmitted from X and reflected back from points beyond *f'* to points intermediate between X and *e'* to be again reflected towards Y will be suppressed. Listener echoes arising between X and *e'* would not be suppressed.

Fig. 6^a shows an arrangement in which two complete echo suppressors are provided at or near the ends of the two-wire line.

With this arrangement there is no possibility of the echo suppressor being operated by echoes although there remains a slight possibility of two talkers cutting each other out simultaneously. As has been previously stated, this objection is, however, merely academic.

From the standpoint of echo suppression, this arrangement is in many ways superior to the other arrangements disclosed. It eliminates all talker echoes except those reflected back from points intermediate between the terminal station and the first four-wire link, and obviously these may be eliminated by arranging the first four-wire link adjacent the terminal station. All listener echoes which are reflected back through either suppressor point will be eliminated. For example, a wave passing from X to R_1 and then being reflected back to R_1 and from the point R_1 being reflected toward the terminal Y will be suppressed. Similarly a wave transmitted from X to R_5 and reflected back to R_2 , from which point it is again reflected towards Y, will be suppressed. Interior listener echoes, that is, echoes reflected back and forth between impedance irregularities intermediate the four-wire sections, will not be eliminated, this being a characteristic common to the arrangements of Figs. 4^a, 5^a, and 6^a. It is, of course, impossible to provide echo suppressors in what is essentially a two-wire circuit which will eliminate all echoes.

In circuits of the kind above disclosed the circuit is normally cut through in both directions, and if too great a gain were provided the circuit would sing. This would cause the suppressor relays to chatter and intermittently interrupt the singing. Consequently the gain must always be adjusted to such a point that singing will not take place. The seriousness of this limitation depends upon the extent to which the numerous return currents add up in phase. If all of the echo paths are small and there are many of them, it is justifiable to assume that the return currents do not all add up in the same phase, but that on the average they will be out of phase with each other so that they add up in proportion to the square root of the sum of their squares. That this assumption is justified is evidenced by the known fact that circuits employing repeaters are operated at gains which would not be possible if all the echo currents added up in phase.

It will be obvious 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. A transmission system comprising a

two wire telephone line having two-way repeaters inserted at intervals therein, a four-wire link included in said line, said four-wire link comprising two one-way paths, one for transmission in each direction, means associated with each path whereby when transmission takes place over said path in one direction the path transmitting in the opposite direction is disabled, and means in said paths to delay the transmission of currents from one path to the other until said last mentioned means has operated.

2. A transmission system comprising a two-wire telephone line having two-way repeaters inserted at intervals therein, a four-wire link included in said line, said four-wire link comprising two one-way paths, one for transmission in each direction, means to render said paths substantially conjugate with respect to each other, means associated with each path whereby when transmission takes place over said path in one direction the path transmitting in the opposite direction is disabled, and means in said paths to delay the transmission of currents from one path to the other until said last mentioned means has operated.

3. A transmission system comprising two line sections, each having two-way repeaters therein, and means for interconnecting said line sections comprising a four-wire link, said four-wire link including a pair of one-way paths transmitting in opposite directions, means associated with each path whereby when transmission takes place in one direction the path transmitting in the opposite direction is disabled, and means in said paths to delay the transmission of currents from one path to the other until said last mentioned means has operated.

4. A transmission system comprising two line sections, each having two-way repeaters therein, and means for interconnecting said line sections comprising a four-wire link, said four-wire link including a pair of one-way paths transmitting in opposite directions, means for rendering said paths substantially conjugate with respect to each other, means associated with each path whereby when transmission takes place over said path in one direction the path transmitting in the opposite direction is disabled, and means in said paths to delay the transmission of currents from one path to the other until said last mentioned means has operated.

5. In a transmission system, a telephone line extending between distant terminal stations, said telephone line having two-way repeaters included at intervals therein, four-wire links included in said line near each terminal, each four-wire link including a pair of one-way paths for transmitting in opposite directions, means associated with the path of one of said links whereby in re-

8 sponse to transmission over said path, the
path transmitting in the opposite direction
will be disabled, means associated with a
path of the four-wire link near the other
10 terminal station whereby in response to
transmission in said opposite direction the
path transmitting in said first mentioned
direction will be disabled, and means in said
paths to delay the transmission of currents
15 from one path to the other until said dis-
abling means has operated.

6. In a transmission system, a telephone
line extending between distant terminal sta-
tions, said telephone line having two-way
15 repeaters included at intervals therein, four-
wire links included in said line near each
terminal, each four-wire link including a
pair of one-way paths for transmitting in
opposite directions, means to render said
20 paths substantially conjugate with respect
to each other, means associated with the
path of one of said links whereby in response
to transmission over said path, the path
transmitting in the opposite direction will
25 be disabled, means associated with a path
of the four-wire link near the other terminal

station whereby in response to transmission
in said opposite direction the path trans-
mitting in said first mentioned direction will
be disabled, and means in said paths to de- 30
lay the transmission of currents from one
path to the other until said disabling means
has operated.

7. A transmission system comprising a
two-wire telephone line having two-way re- 35
peaters inserted at intervals therein, a plu-
rality of four-wire links included in said
line, each four-wire link comprising two one-
way paths, one for transmission in each di-
rection, means associated with each path 40
whereby when transmission takes place over
said path in one direction the path trans-
mitting in the opposite direction is disabled,
and means in said paths to delay the trans-
mission of currents from one path to the 45
other until said last mentioned means has
operated.

In testimony whereof I have signed my
name to this specification this 17th day of
August, 1923.

ALVA B. CLARK.