J. R. CARSON.
DISTORTION CORRECTING CIRCUIT.
APPLICATION FILED JULY 3, 1918.

1,315,539.

Patented Sept. 9, 1919.
3 SHEETS—SHEET 1.

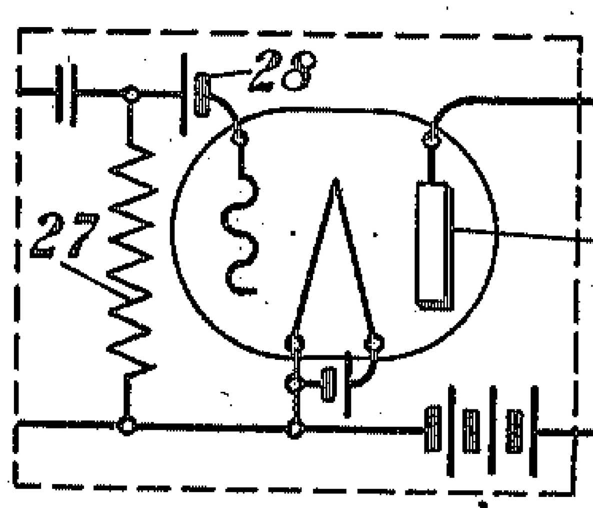

Fig. 2

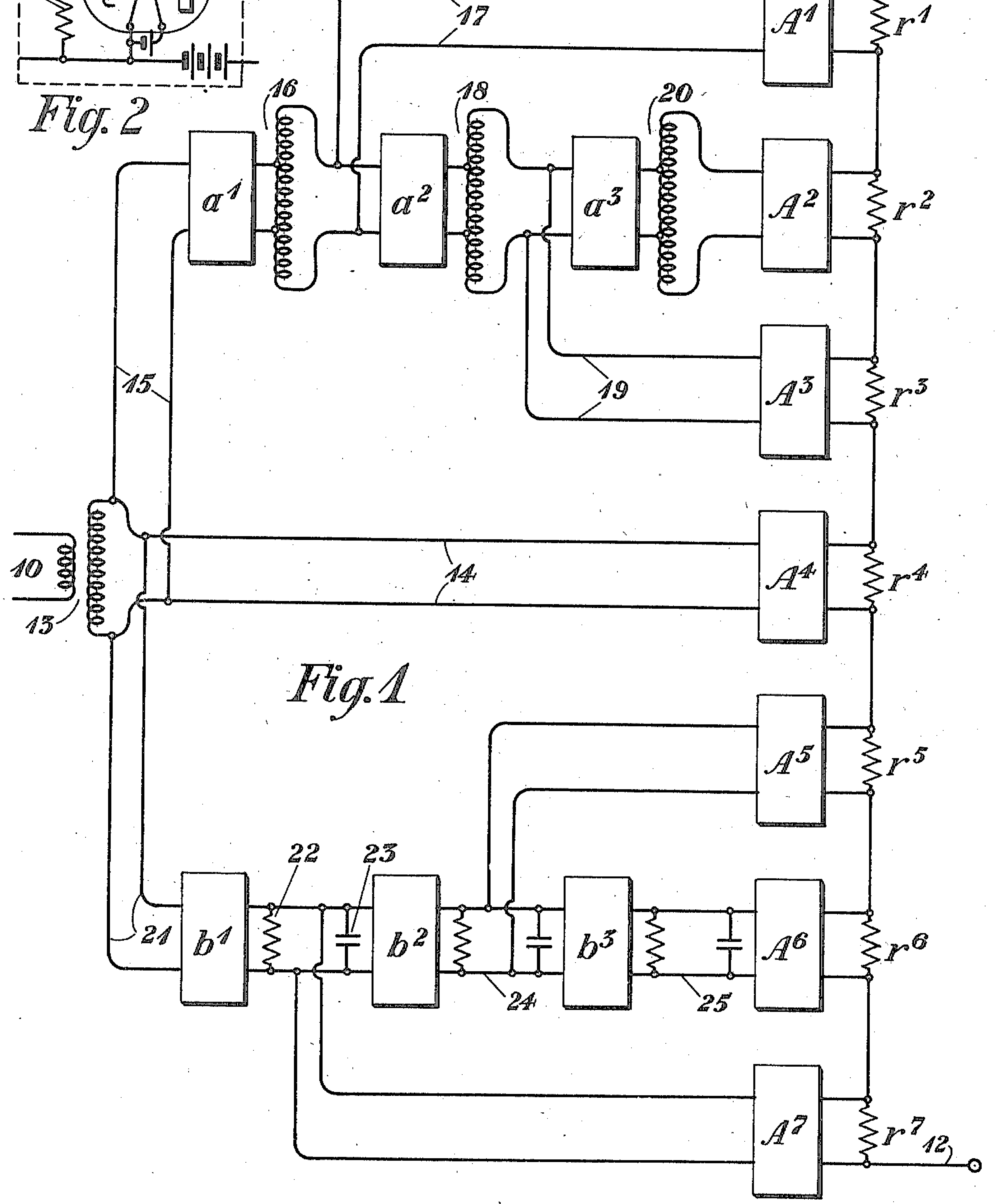

Fig. 1

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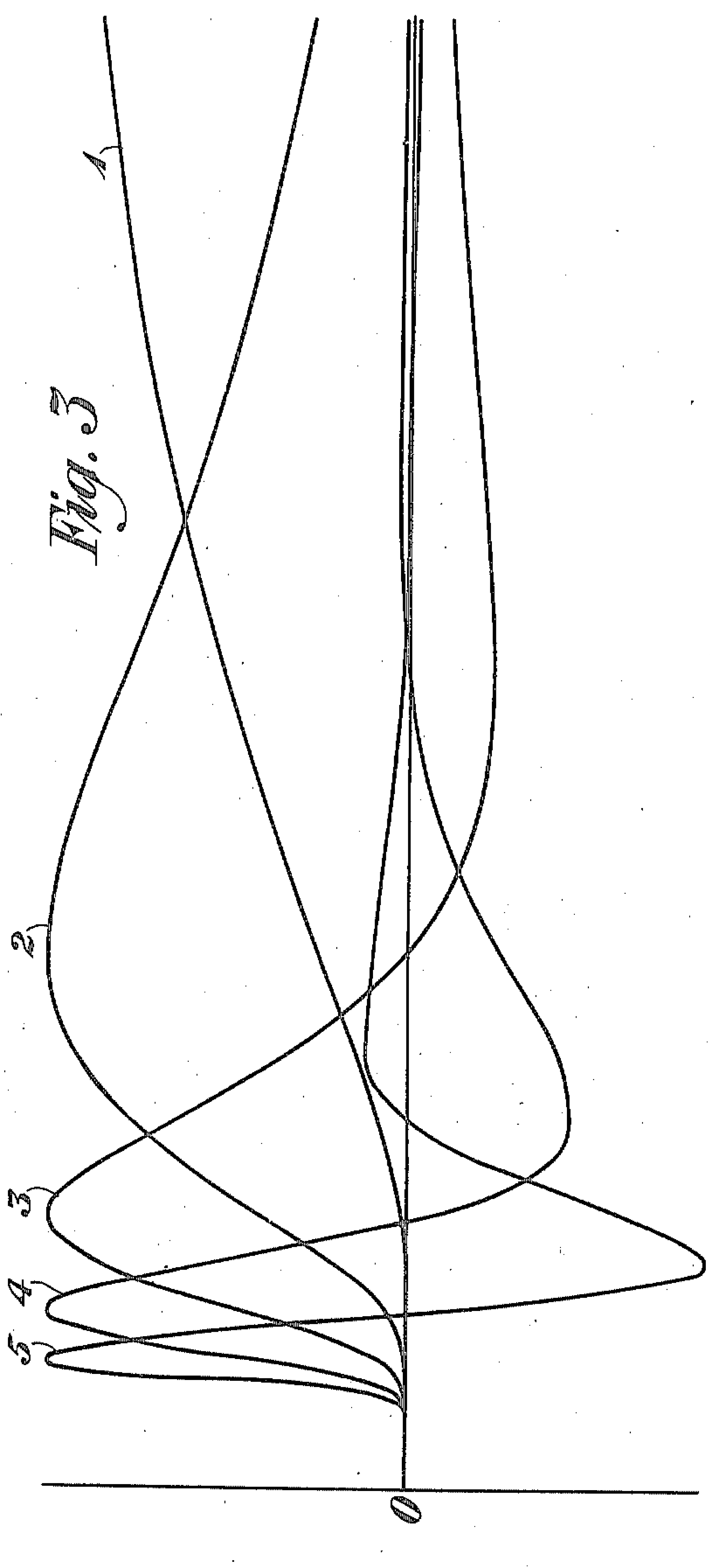

Fig. 3

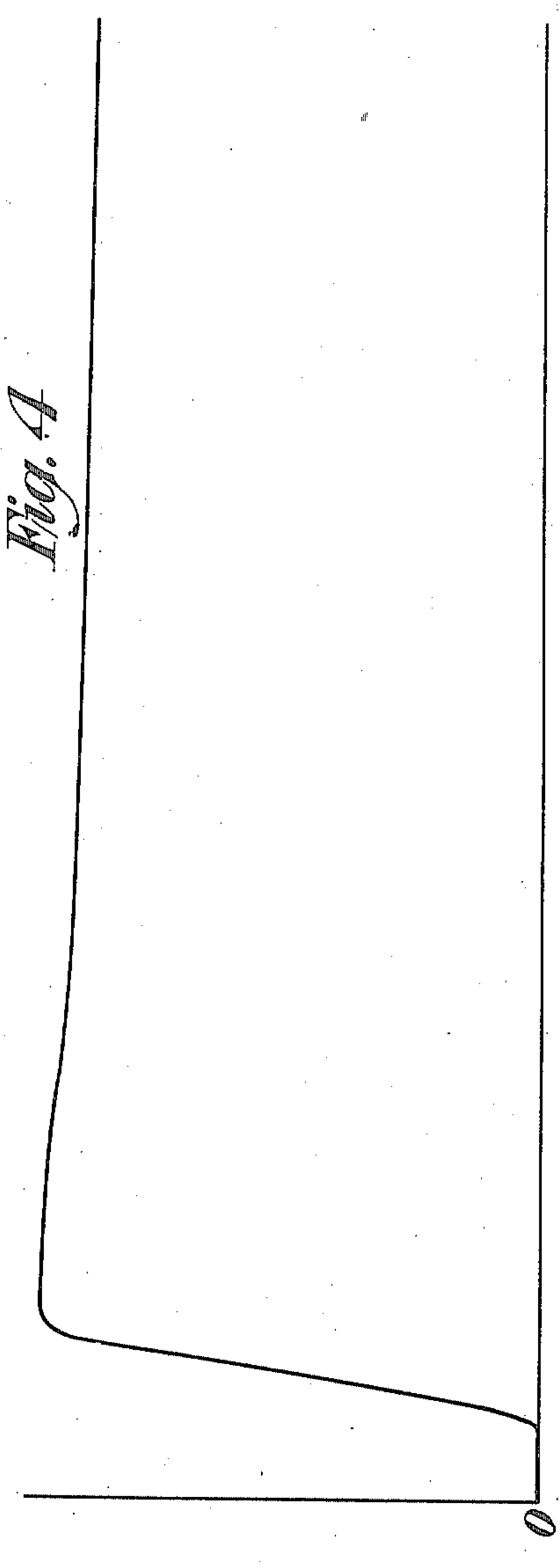

Fig. 4

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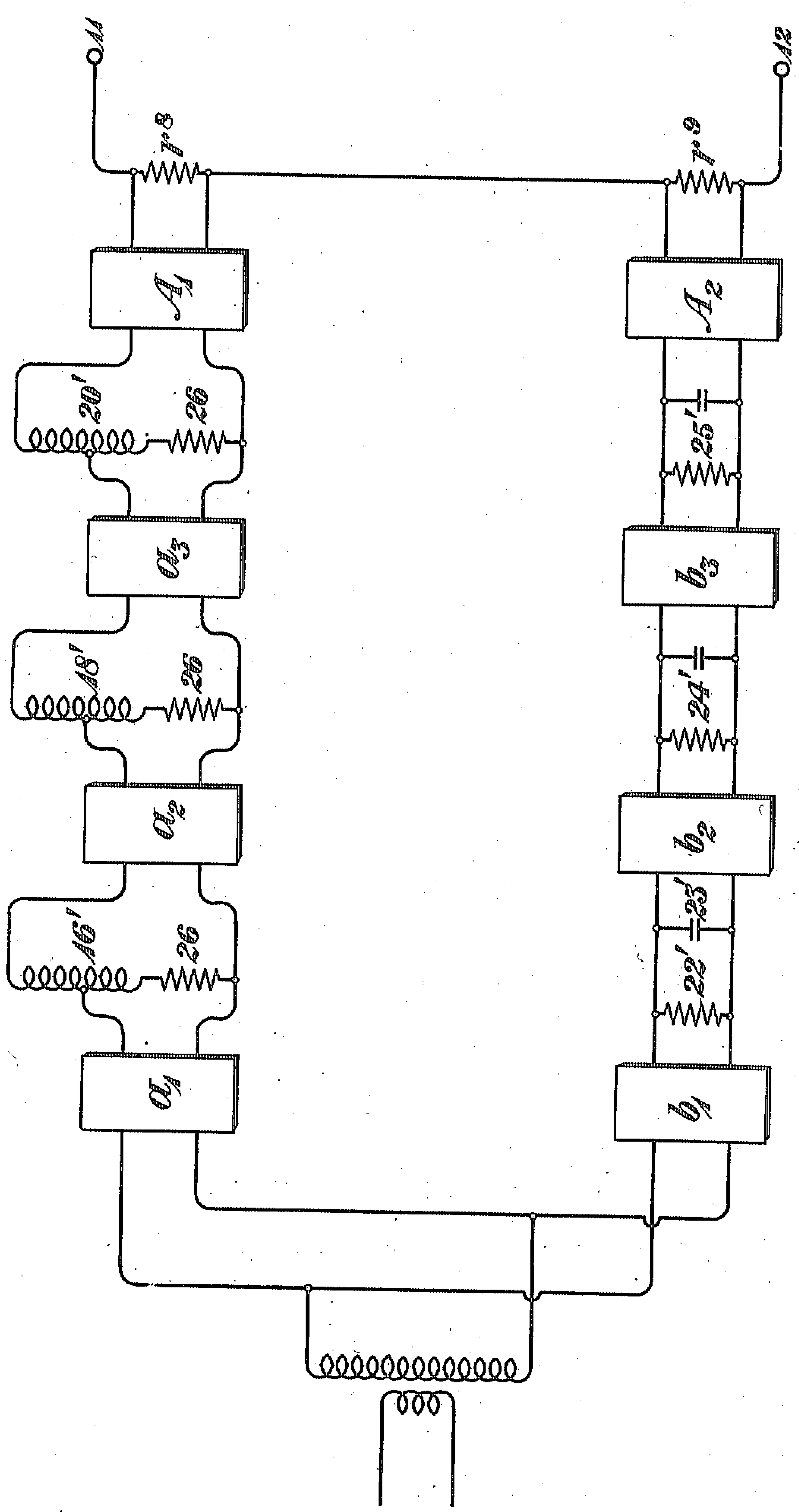

Fig. 5

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UNITED STATES PATENT OFFICE.

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DISTORTION-CORRECTING CIRCUIT.

1,315,539. Specification of Letters Patent. Patented Sept. 9, 1919.

Application filed July 3, 1918. Serial No. 243,203.

To all whom it may concern:

Be it known that I, JOHN R. CARSON, residing at New York, in the county of New York and State of New York, have invented certain Improvements in Distortion-Correcting Circuits of which the following is a specification.

This invention relates to systems for transmitting electrical energy and is especially applicable to signaling systems in which it is desired to correct the wave form of signaling impulses which has been destroyed by the distorting effect of the transmission line. In ocean cables, for instance, the transmitting voltage at the sending end mav be represented by a curve of rectangular square topped form while the wave received at the distant end is a very flattened curve which requires a relatively long time to build up to its steady value. For receiving purposes it is important to have an arrival curve whose wave form approximates that of the voltage impressed on the sending end. It is the purpose of the present invention to provide a distortion correcting network capable of reforming the arrival curve in cases of the kind above indicated. The invention will be more fully described in connection with the accompanying drawings in which Figure 1 illustrates diagrammatically one embodiment thereof; Fig. 2 is a detail of the amplifier circuits represented by the rectangles in Figs. 1 and 5; Fig. 3 is a set of curves representing a typical arrival curve and its derivatives; Fig. 4 is a curve indicating the form of arrival curve which may be derived by the employment of this invention and Fig. 5 illustrates a modification of the arrangement shown in Fig. 1.

The invention, includes an arrangement embodying correcting networks *per se* and amplifiers, preferably of the thermionic type, which may be arranged to introduce no distortion of their own. The amplifiers, in the present case, perform the very important function of separating the different sections of correcting network so that one does not react upon its neighbor and the value of the elements in the networks may, therefore, be readily calculated to give the desired result without having to estimate the modifying effect of one network upon another. When the process of distortion correction is attended by diminution in the strength of the received signal or when it is desired to increase the intensity thereof the amplifiers may be adjusted to perform the double function of distortion correction and amplification simultaneously.

The requirements for a correcting circuit of the kind above indicated may best be understood by a consideration of Fig. 3. In this figure, curve 1 represents approximately the arrival current in a signaling system of high distortion and attenuation such as an ocean cable. A current of this wave form makes rapid signaling impossible because of its slow rate of building up. If a current of this form flows through an inductive device such as the windings of a transformer or a plain inductance coil, the voltage developed in said device will be the first derivative of the arrival current which will have a wave form approximately as indicated at 2 in Fig. 3,—the derivative representing the time rate of change of the arrival curve. Similarly if a current of the form of derivative 2 flow through an inductance coil the voltage across the terminals of said coil will be the second derivative of the arrival current which has a wave form indicated at 3 in Fig. 3. Continuing by the same process successive derivatives may be obtained, the third and fourth being indicated at 4 and 5 respectively in Fig. 3. It will be observed that the derivatives have a sharper and sharper rise in value which is one of the characteristics essential for good recording. On the other hand the curves of the successive derivatives fall off more and more rapidly as indicated in the drawing and the best current for receiving purposes should have not only a sharp rise but a sustained tail. It will be understood that the successive derivatives do not normally all have the same maximum value as shown but are so indicated merely to compare their characteristics conveniently. It is possible, however, by the use of amplifiers to give any particular derivative any desired value and it will be obvious from a consideration of the curves shown in Fig. 3 that by giving the various derivatives the proper value and combining them in a single circuit a resultant current may be obtained which has not only a very sharp rise but is also well sustained in value. Such a current is illustrated in Fig. 4, the curve there shown being the resultant of the combination of an arrival current with the first four derivatives in the proper proportions.

Referring to Fig. 1, 10 indicates the receiving end of a transmission line or other circuit in which it is desired to correct the wave form of the arrival curve for use in the output circuit 11—12. Line 10 is closed through the primary of a transformer 13, the secondary of which is connected to the input circuits of vacuum tube amplifiers A^4, a^1, and b^1 in parallel by means of circuits 14, 15 and 21 respectively. The introduction of the transformer, while not essential to my invention is desirable in that it permits of stepping up the voltage and obviates the necessity of a metallic connection between the line and said amplifiers. Owing to the fact that the input circuits of amplifiers of the vacuum tube type are of substantially infinite impedance, the secondary of transformer 13 is to all intents and purposes open circuited, and the voltage developed across its terminals unaffected by the presence of the amplifiers. Under such conditions it may be shown that the voltage developed across the terminals of either primary or secondary of the transformer 13 approximates the first derivative of the arrival curve of the cable itself, provided the inductance of the primary is relatively small, this first derivative being of the form illustrated in curve 2 of Fig. 5. Consequently the voltage impressed in the input circuits of amplifiers a^1, A^4 and b^1 is substantially proportional to the first derivative of the arrival curve itself.

Across the circuit 11, 12 is connected a series of resistances r^1, r^2, r^3, r^4, r^5, r^6, and r^7, which are respectively connected in the output circuits of amplifiers A^1, A^2, A^3, A^4, A^5, A^6 and A^7. The voltage developed between the terminals of said circuit is therefore equal to the sum of the voltage drops across said resistances which are individually proportional to the currents flowing in the output circuits of said amplifiers.

Since, as stated above, the voltage impressed on amplifier A^4 is proportional to the first derivative of the arrival curve the voltage drop across resistance r^4 is similarly proportional to said first derivative.

The input circuit of amplifier A^1 is connected by circuit 17 to the high side of autotransformer 16 whose low side is connected in series with the output circuit of amplifier a^1. With this arrangement the voltage drop across the input circuit of amplifier A^1 is substantially the second derivative of the arrival curve since the voltage impressed on the input circuit of amplifier a^1 is the first derivative thereof. Consequently the voltage drop across resistance r^4 is proportional to the second derivative of the arrival curve and its magnitude is controllable by either adjusting the amplifier A^1 or adjusting the value of the resistance r^1. The autotransformer may be replaced by an inductance coil if desired; it is practically preferable to retain the arrangement as shown since a substantial voltage step up is obtained by the inductive action of the autotransformer. This is particularly advantageous because the inductance in the output circuit of amplifier A^1 should be very small compared with the internal resistance of the tube if the voltage drop across said inductance is to closely approximate the second derivative of the arrival curve.

Connected in parallel with the input circuit of amplifier A^1 is that of amplifier a^2 in the output circuit of which is connected the low side of autotransformer 18. Across the high side of said transformer is connected the input circuit of amplifier A^3 through circuit 19; consequently it will be readily seen in the light of the foregoing explanation that the voltage drop across resistance r^3 is proportional to the third derivative of the arrival curve.

Connected in parallel with the input circuit of amplifier A^3 is that of amplifier a^3 in the output circuit of which is connected the low side of autotransformer 20, to the high side of which is connected the input circuit of amplifier A^2. Consequently the voltage drop across resistance r^2 is proportional to the fourth derivative of the arrival curve.

The resultant voltage drop across resistances r^1, r^2, r^3, and r^4 is thus made up of the sum of individual voltage drops whose respective wave forms are those of the second, fourth, third and first derivatives of the arrival curve in predeterminate readily adjustable proportion.

It is obvious that the system shown may be extended to provide derivatives of higher orders than the fourth by adding additional derived circuits. In practice the number of derived circuits required will depend upon, and increase with, the distortion introduced by the line and the desired speed of signaling.

Without addition of a voltage corresponding to the arrival curve itself or a substantial equivalent thereof, the combination of the derivatives will give a wave which is not sufficiently sustained. This will be obvious from a consideration of the curves shown in Fig. 3. The branch circuit 21 leading from the transformer 13 to the amplifier b^1 with its associated apparatus supplies this voltage. As already indicated the amplifier b^1 has a voltage corresponding approximately to the first derivative applied to its input circuit. Its output circuit is connected to a distortion network comprising the resistance 22 and the capacity 23 in parallel. The effect of these is to convert the wave form of the voltage existing across the terminals of transformer 13 into a voltage across said parallel elements approximating the integral of this derivative which would be substantially the same as the arrival current itself. This voltage is impressed on the input circuit of an amplifier A^7 in whose output circuit is connected a resistance r^7. Theoretically one section of such a network could be designed to provide a voltage drop across resistance r^7 of practically the form desired but a more convenient and exact way of securing the desired result is to provide successive stages of a network as indicated on the drawing, applying the output from the successive stages to separate resistances in circuit 11—12. Thus there are shown in addition, amplifiers b^2 and b^3 feeding networks 24 and 25 respectively, which latter feed the input circuits of amplifiers A^5 and A^6 respectively. The amplifiers A^5, A^6, like A^7, are each connected to a resistance (r^5 and r^6 respectively) in the circuit 11—12. The aggregate effect of the voltages across resistances r^5, r^6 and r^7 will then be to add a voltage to those across resistances r^1 to r^4, substantially like that indicated by curve 1 in Fig. 5, which when combined with voltages having wave forms corresponding to the several derivatives as above described will give the desired wave form for recording. The results obtained by the system are dependent upon proper relations among the constants of the apparatus, as will be readily understood, and these must be chosen with due regard to the wave form to be received and the wave form it is desired to produce.

In order that the output from the amplifiers A^1 to A^7 inclusive, may affect the circuit 11—12 in just the proportions represented by the values assigned to the resistances r^1 to r^7 inclusive, it is important that the circuit represented by 11—12 be of high impedance. A long transmission line of high impedance would substantially satisfy the requirements. The result may be perfectly attained, however, if the circuit 11—12 is connected to the input side of a thermionic amplifier (not shown) since no appreciable current will then flow in circuit and the current emanating from one of the amplifiers A^1—A^7 cannot affect the potential drop across the resistances connected to the other amplifiers.

For the sake of simplicity the amplifying devices have been indicated merely by rectangles in Fig. 1, Fig. 2, however, illustrates the circuit represented by the rectangle in each instance. It comprises the well known form of thermionic amplifier 26 having a high resistance 27 connected across its input circuit and a condenser 28 in series. It will be observed that the capacity 28 and the resistance 27 will, in practice, be metallically connected with the distortion networks with which the amplifiers are associated but they do not constitute any part thereof and in order that they may not interfere with the operation of the networks, the resistance 27 should have a very high value. The capacity 28 should also be large, especially in the circuits dealing with the arrival current or its lower derivatives, in order not to shorten the time period of the applied voltages in these components of the signaling current.

In operation the system shown in Fig. 1 may be adjusted to give practically any desired form of voltage or current in circuit 11—12 by changing the relative values of the different components of the voltage drops across the resistances in said circuit. This may be done partially by adjusting the amplifiers A^1 to A^7 to give varying values to the components transmitted through them respectively. A very simple method of adjusting the wave form, however, is afforded by the resistances r^1 to r^7 since upon the value of any one of these depends the amount of the corresponding voltage component which is impressed upon the line 11—12.

It is to be observed that the amplifiers in the circuits shown serve not only to compensate for the loss in amplitude due to the correcting networks and the attenuation in the line 10, but they separate each of the correcting networks from all of the others and this without disturbing its modifying effect upon the wave form. This is by reason of the fact that the thermionic amplifier is essentially a one-way device which consumes no appreciable energy in its input circuit. This makes it possible to calculate and adjust the form of the network for giving any one of the various components as above described without the complications introduced when one network reacts upon its neighbor.

The modification shown in Fig. 5 differs from that shown in Fig. 1 in that the circuits for obtaining the successive derivatives are connected in series instead of in parallel and a series arrangement for the "integral" branch of the circuit is also used in place of the parallel arrangement of Fig. 1. In this case the distortion networks 16′, 18′ and 20′ each includes a resistance 26 in series with the inductance. The effect of this resistance is to preserve in the succeeding circuit the component introduced by the preceding circuit. The result is that the current applied to the resistance r^8 in the circuit 11—12 is a combination of the first, second, third and fourth derivatives of the arrival current.

The arrangement is simpler than that shown in Fig. 1 and requires fewer amplifiers but it does not have the flexibility of the more elaborate circuit.

The invention is not to be regarded as limited to the particular forms herein illustrated and described as it is obvious that various modifications may be made without departing from the spirit of the invention as set forth in the appended claims.

What is claimed is:

1. In a wave-form correcting device, means for producing from the arrival current separate currents having wave forms corresponding substantially to the arrival current itself and one or more of its derivatives respectively, and means for superimposing the separate currents in a single output circuit.

2. In a wave-form correcting device, means for producing from the arrival current separate currents having wave forms corresponding substantially to the arrival current itself and one or more of its derivatives respectively, a single circuit for receiving the several currents so produced, and means for determining the relative values of said currents applied to said circuit.

3. In a wave-form correcting device, means for producing from the arrival current separate currents having wave forms corresponding substantially to the arrival current itself and one or more of its derivatives respectively, means for amplifying separately the currents so produced, and connections for superimposing said amplified currents upon a single output circuit in desired proportions.

4. In a wave-form correcting device, means for producing from the arrival current a plurality of currents having wave forms of varying degrees of abruptness and duration, separate circuits into which the several currents are respectively introduced, a single output circuit, and means for imposing the several separate currents upon the output circuit in desired proportions.

5. In a wave-form correcting device, means for producing from the arrival current a plurality of currents having wave forms of varying degrees of abruptness and duration, separate circuits into which the several currents are respectively introduced, means in each separate circuit for amplifying the current therein, and means for superimposing the separate amplified currents upon a single output circuit.

6. The method of correcting the wave form of current impulses which consists in producing from the arrival current a plurality of currents having wave forms of varying degrees of abruptness and duration, separating the several currents into distinct circuits, and applying the separate currents to a single output circuit in desired proportions.

7. The method of correcting the wave form of current impulses which consists in producing from the arrival current a plurality of currents having wave forms of varying degrees of abruptness and duration, separating the several currents into distinct circuits, amplifying the currents separately and applying the separate currents to a single output circuit in desired proportions.

8. The method of correcting the wave form of current impulses which consists in producing from the arrival current a plurality of separate currents corresponding substantially in wave form to the successive derivatives of the arrival current, and combining in a single output circuit the currents so produced with a current whose wave form corresponds substantially with the arrival current itself.

9. The method of correcting the wave form of current impulses which consists in producing from the arrival current a plurality of currents of varying wave forms, separating each of the currents from the others to prevent reaction of one upon another, amplifying the produced currents separately to desired strength, and superimposing the separate currents in a single output circuit in a proportion to give the desired resulting wave form.

10. In a signal receiving circuit, an inductive device in which the arriving impulses are received, parallel circuits connected to said inductive device one of which is provided with means for producing a current having a wave form approximating the wave form of the arrival current, and another of which is provided with means for producing currents having wave forms corresponding substantially to derivatives of said arrival current, and means for imposing the currents in said parallel circuits upon a single output circuit in desired proportions.

11. In a signal receiving circuit, an inductive device in which the arriving impulses are received, parallel circuits connected to said inductive device, means located in certain of said parallel circuits for producing in them separately, current impulses of different slopes and duration but all more sustained than the impulses taken from the inductive device, and means in the other parallel circuits for producing in them separately current impulses of different slopes and duration but all more abrupt than the impulses taken from the inductive device, and means for imposing currents from the parallel circuits and said inductive device upon a single output circuit in desired proportions.

In testimony whereof, I have signed my name to this specification this 2nd day of July, 1918.

JOHN R. CARSON.