

Aug. 17, 1937.

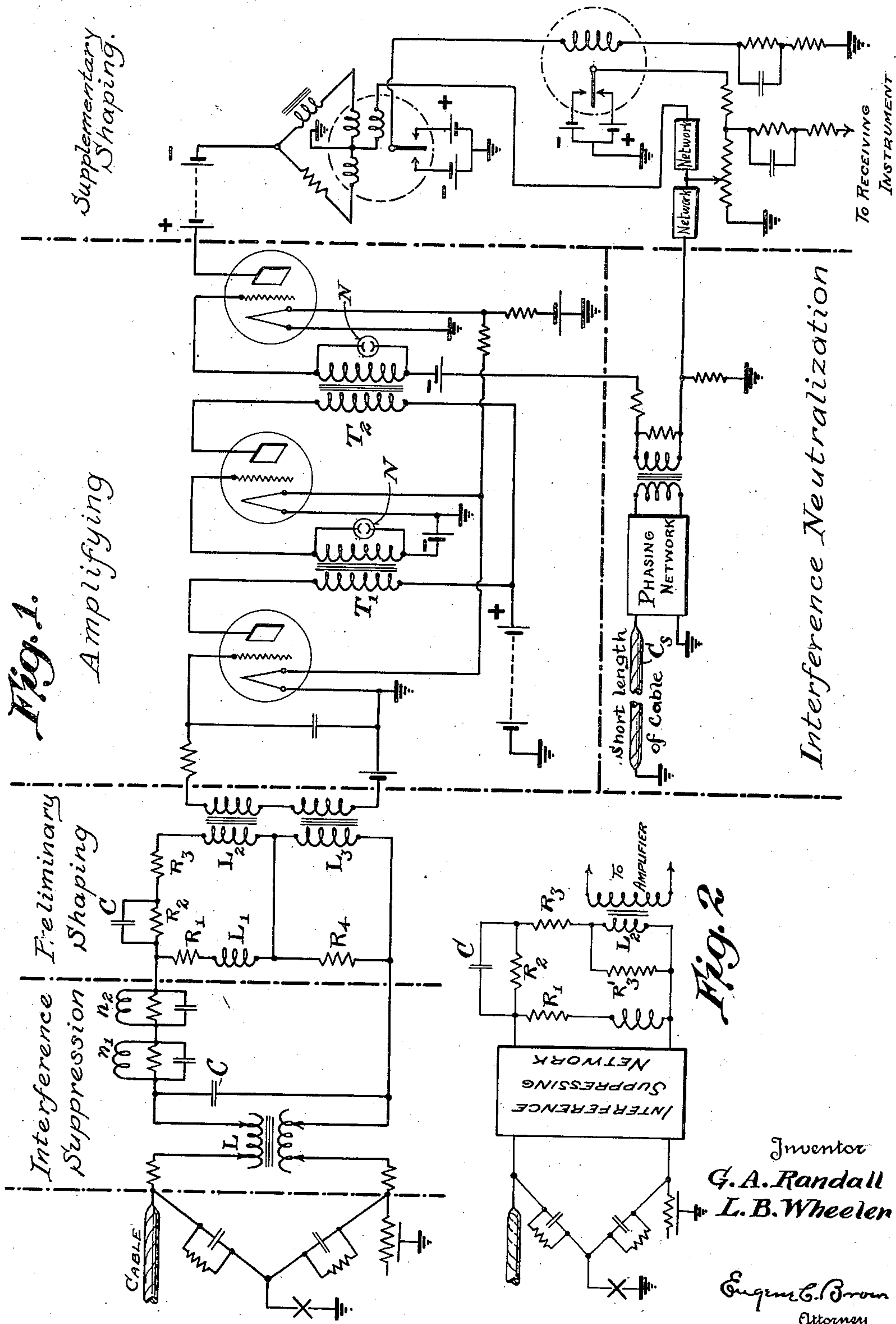
G. A. RANDALL ET AL

2,090,230

SUBMARINE CABLE AMPLIFYING SYSTEM

Filed Feb. 14, 1936

4 Sheets-Sheet 1



Aug. 17, 1937.

G. A. RANDALL ET AL

2,090,230

SUBMARINE CABLE AMPLIFYING SYSTEM

Filed Feb. 14, 1936

4 Sheets-Sheet 2

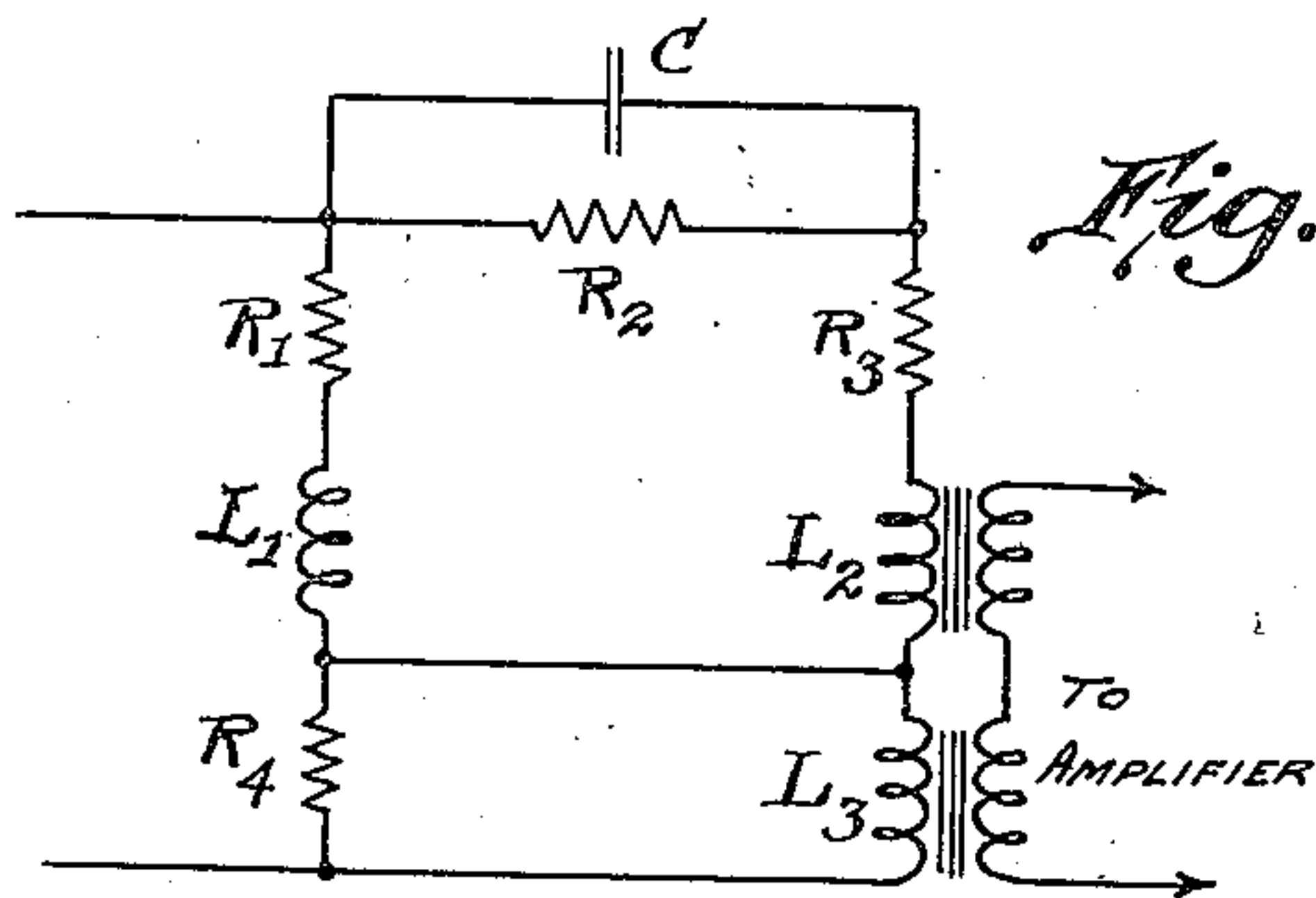


Fig. 3.

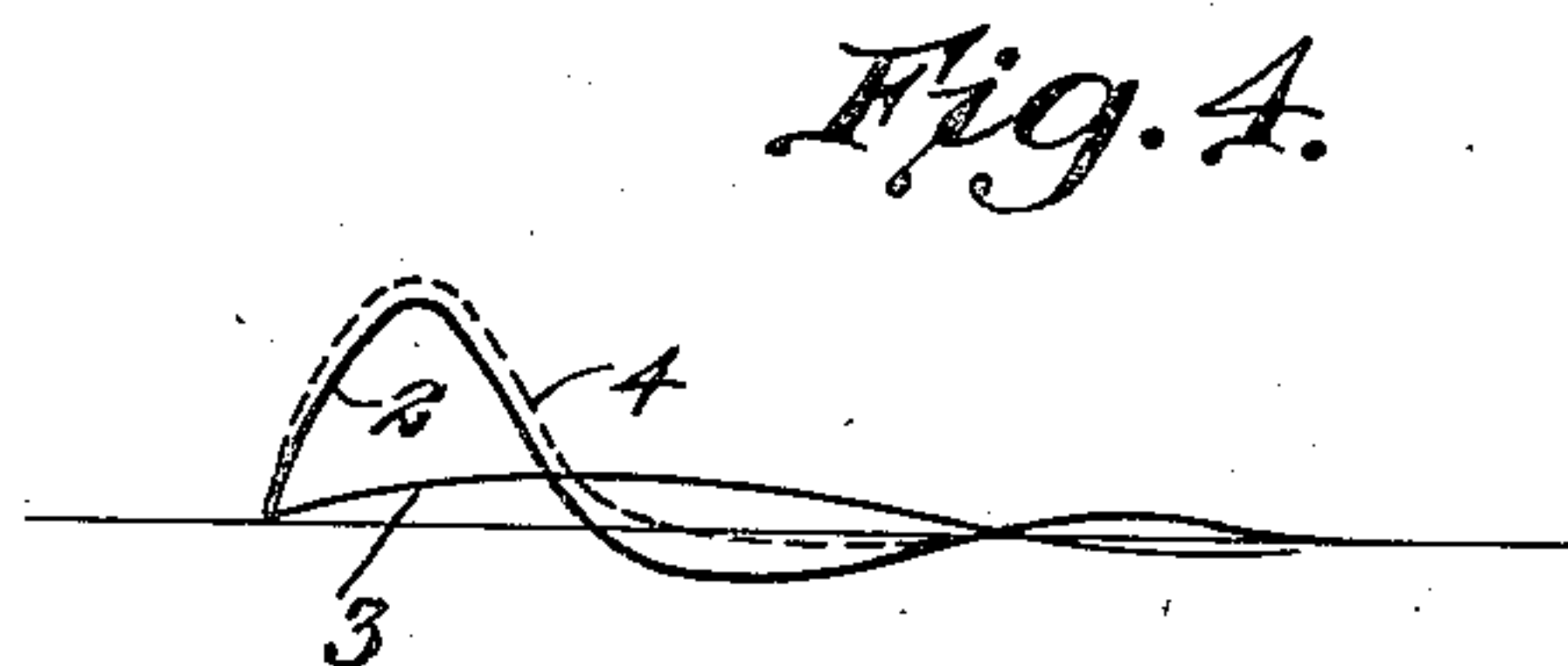


Fig. 4.

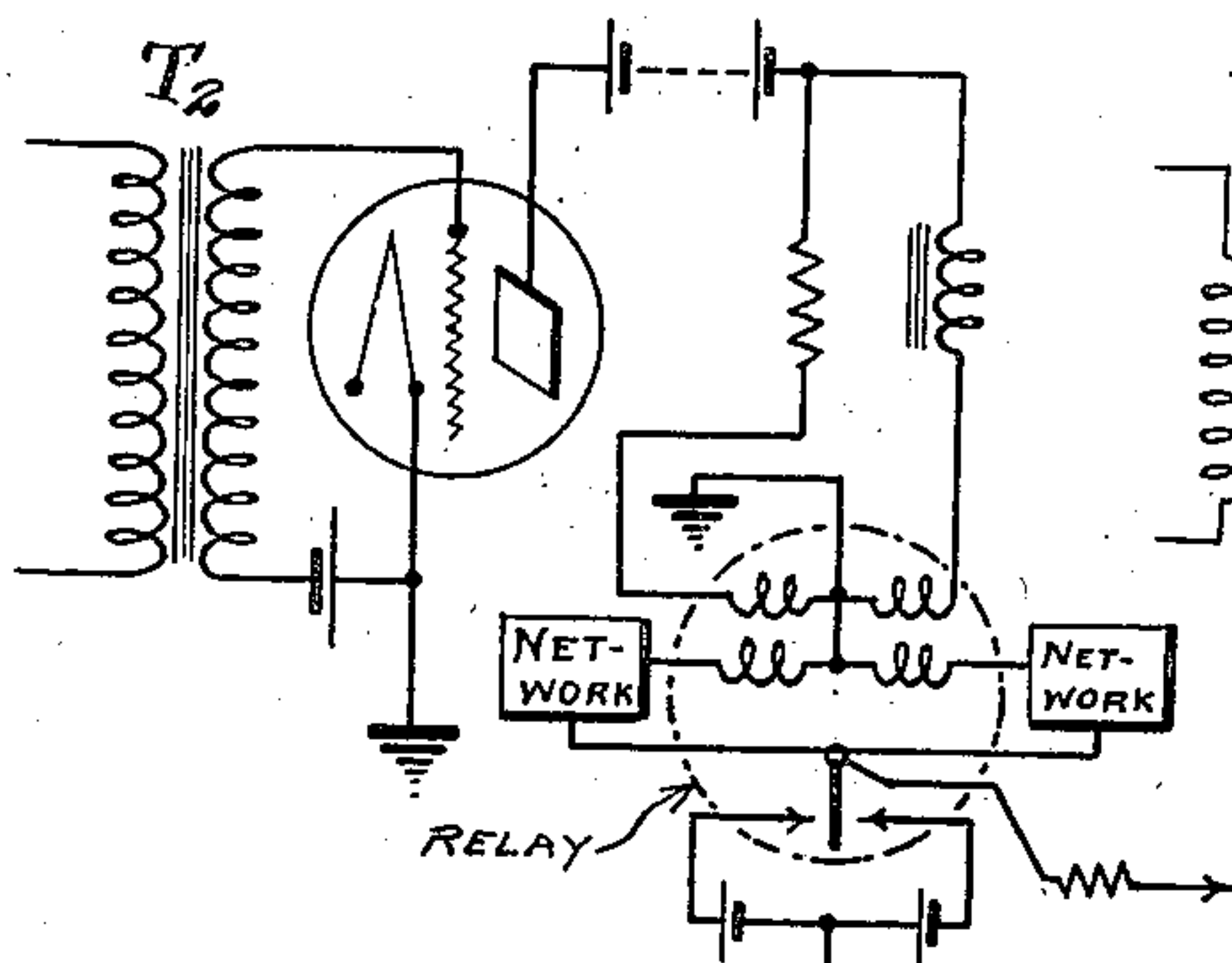


Fig. 5.

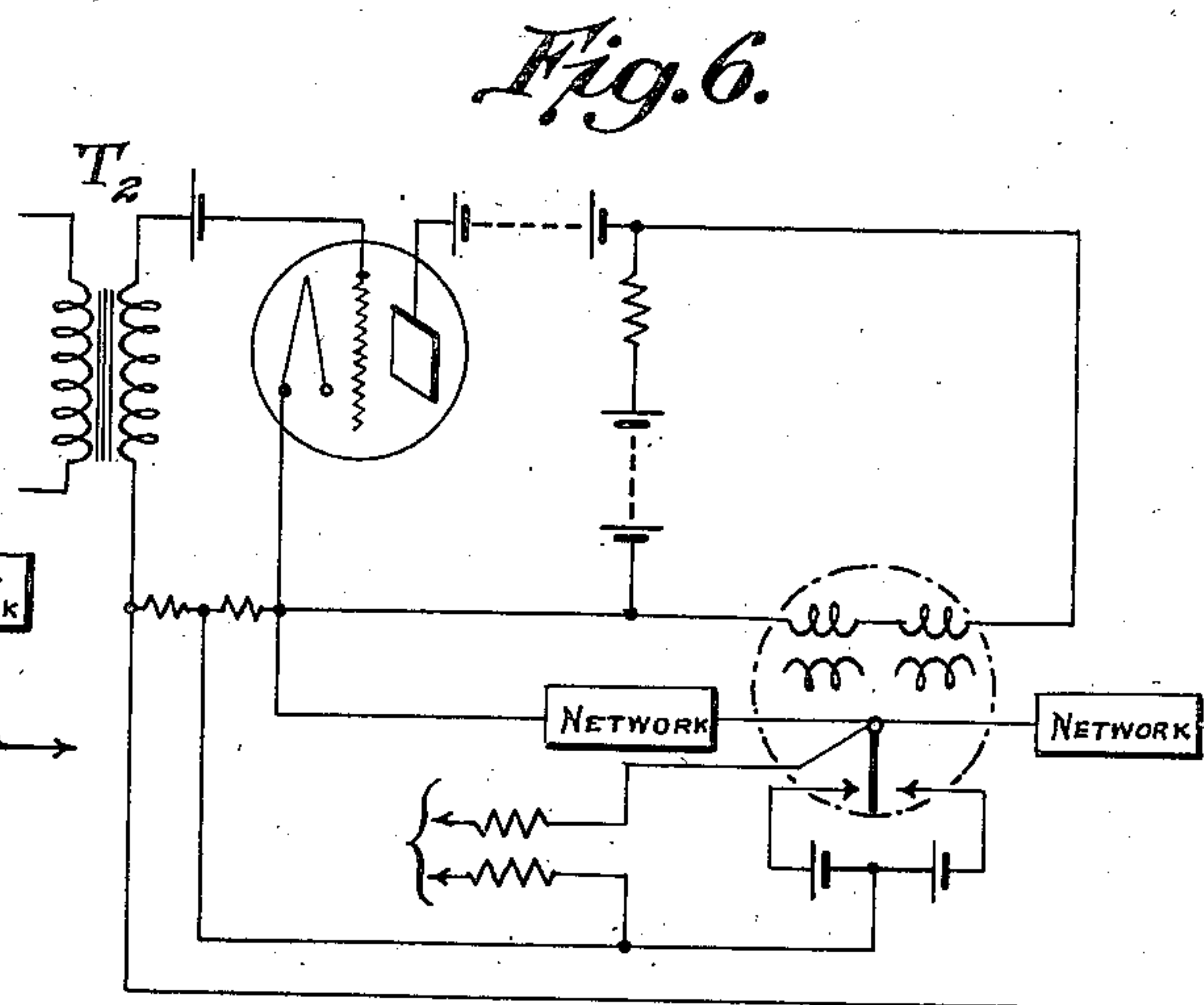


Fig. 6.

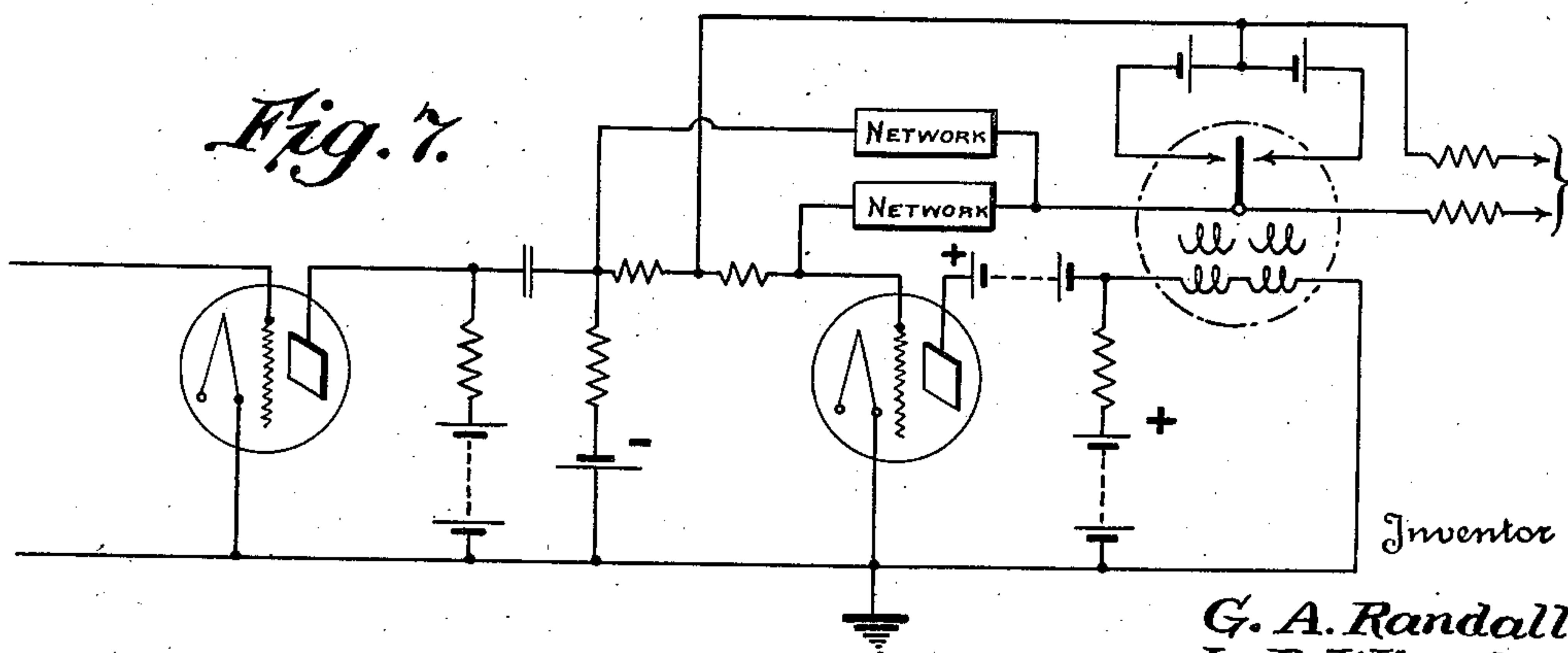


Fig. 7.

G. A. Randall
L. B. Wheeler

Eugene C. Brown
Attorney

Aug. 17, 1937.

G. A. RANDALL ET AL

2,090,230

SUBMARINE CABLE AMPLIFYING SYSTEM

Filed Feb. 14, 1936

4 Sheets-Sheet 3

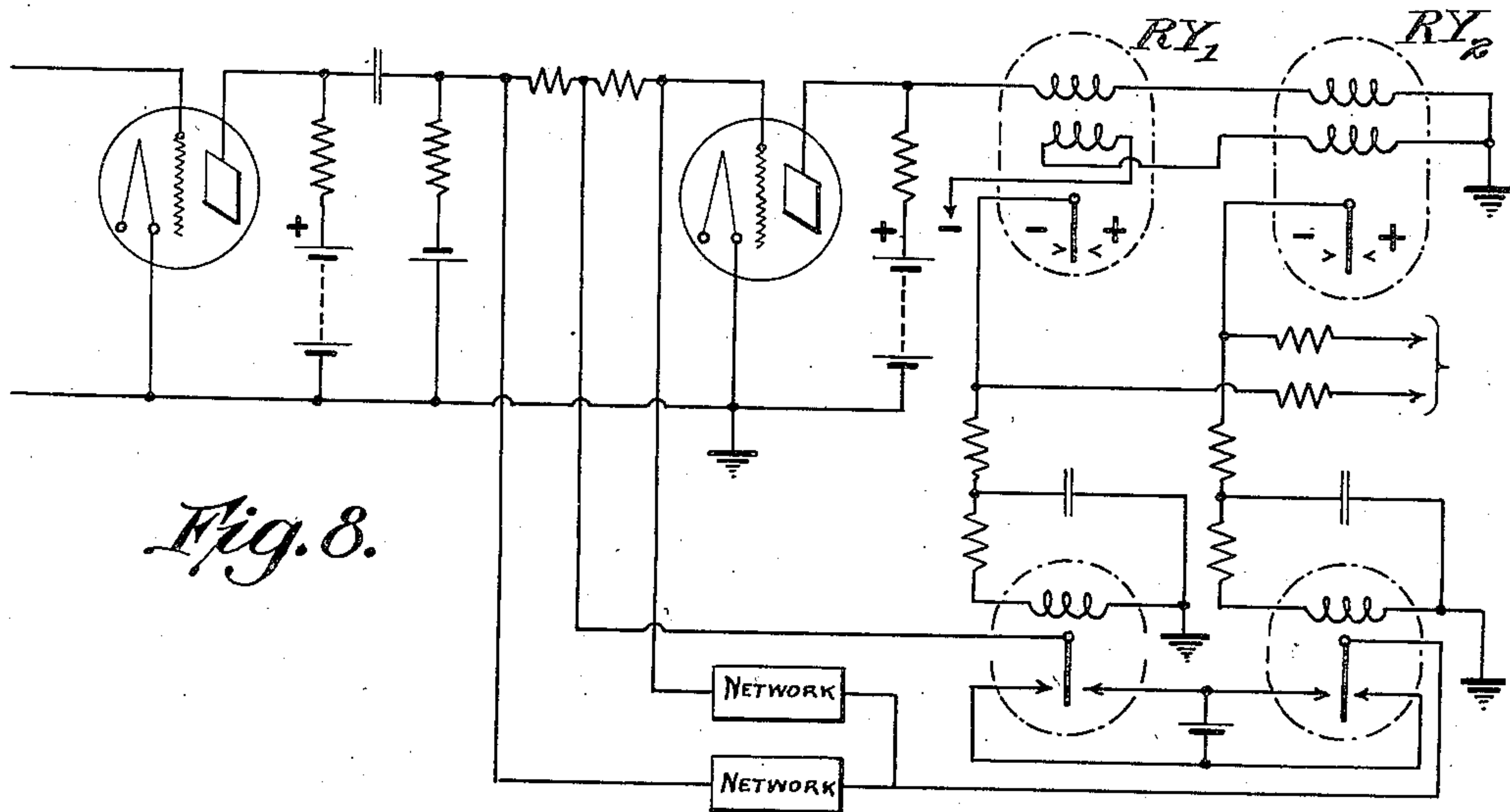


Fig. 8.

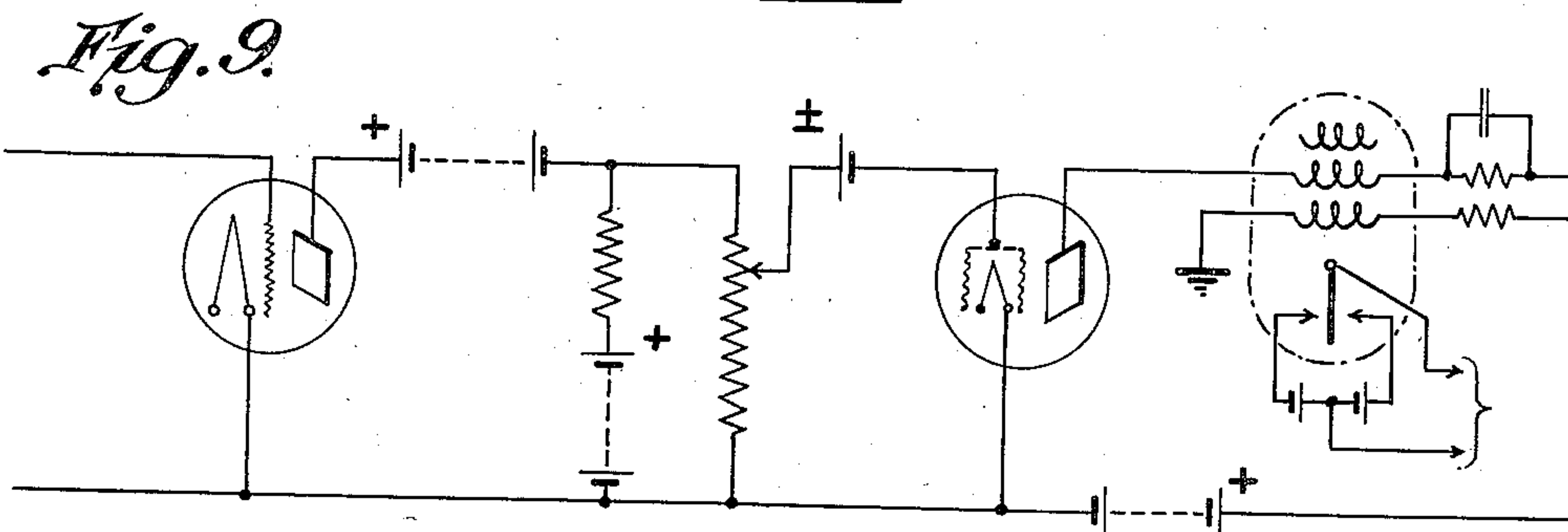


Fig. 9.

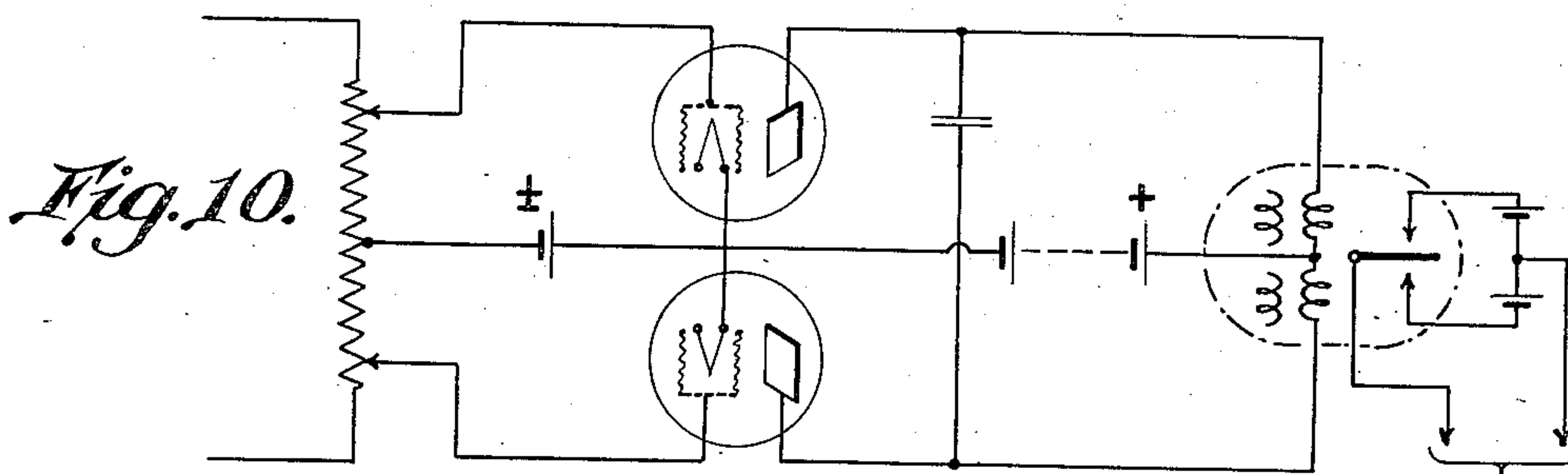


Fig. 10.

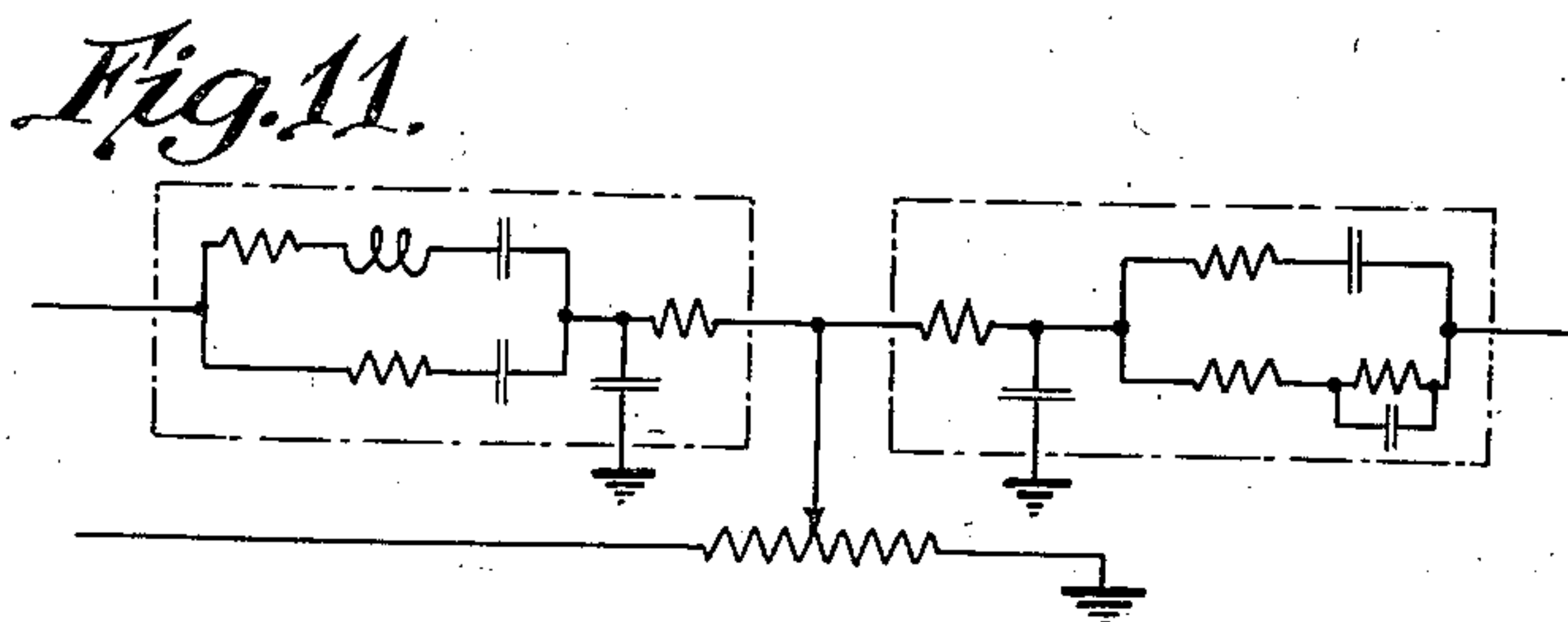


Fig. 11.

Inventor
G. A. Randall
L. B. Wheeler

Eugene C. Brown
Attorneys

Aug. 17, 1937.

G. A. RANDALL ET AL

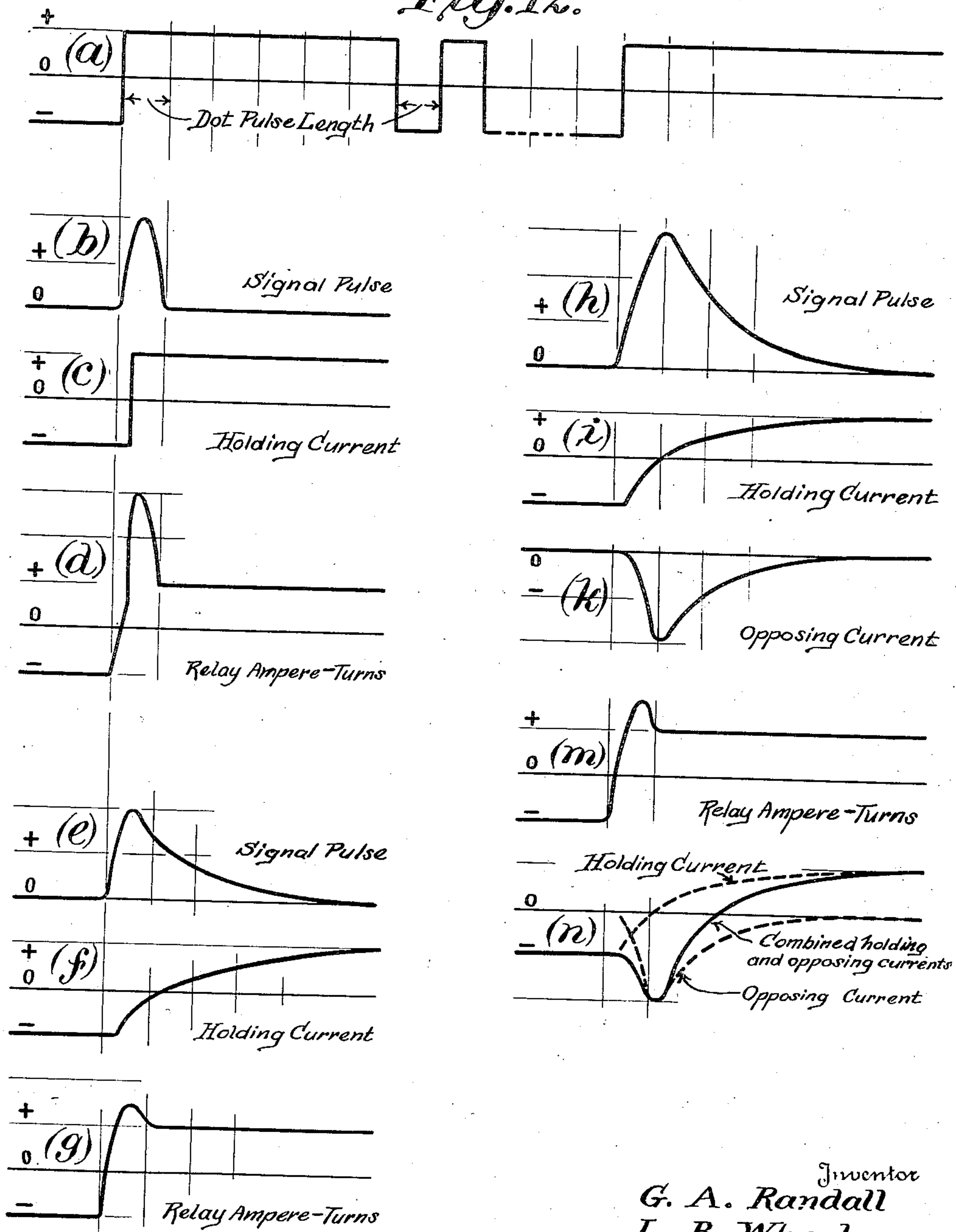
2,090,230

SUBMARINE CABLE AMPLIFYING SYSTEM

Filed Feb. 14, 1936

4 Sheets-Sheet 4

Fig. 12.



Inventor
G. A. Randall
L. B. Wheeler

Eugene C. Brown
Attorney

UNITED STATES PATENT OFFICE

2,090,230

SUBMARINE CABLE AMPLIFYING SYSTEM

Gerald A. Randall, Bayside, N. Y., and Lester B. Wheeler, Chatham, N. J., assignors to The Western Union Telegraph Company, New York, N. Y., a corporation of New York

Application February 14, 1936, Serial No. 63,944

9 Claims. (Cl. 178—70)

This invention relates to submarine cable telegraph signaling and more particularly to receiving systems for shaping and amplifying the incoming signals with fidelity so that the recorded signals shall be faithful copies of the transmitted signal wave-forms while permitting greater speed of transmission.

It is well known that telegraphic or other signals transmitted over long conductors of high capacity such as submarine cables are subject to serious distortion and attenuation which greatly interferes with proper reception and the faithful reproduction of the original signal waves.

Distortion of the signal waves due to components of the higher range of frequencies, increases with the speed of signaling. For the purpose of suppressing such undesired frequencies in the upper range it has been the practice to employ interference suppressing networks in advance of the amplifier which increases the power of the signals to the degree required for effective reception at the cable terminal or for retransmission over a land line or another cable.

The main object of our invention is to provide a preliminary shaping of the selected low frequency components of the signal wave in a manner to produce a relatively short pulse and after amplification of the shaped transient to further mold the signal wave by locally fed back transients so that the resultant wave is less susceptible to most cable interference and therefore permits more reliable operation at higher speeds of transmission.

The novel features which are considered characteristic of this invention are set forth with particularity in the appended claims. The invention, both as to its organization and method of operation together with other objects and advantages thereof, will be further explained by reference to the following description taken in connection with the accompanying drawings consisting of the following figures:

Fig. 1 illustrates schematically a duplex cable telegraph system employing a multi-stage electron discharge amplifier at the receiving terminal, and with both preliminary and final wave shaping apparatus.

Figs. 2, 3, 5, 6, 7, 8, 9, and 10, show modifications of the receiving apparatus.

Fig. 4 illustrates the manner in which the signal wave is shaped in passing through the shaping arrangement shown in Fig. 3.

Fig. 11 shows two of the shaping networks which may be employed.

Fig. 12 illustrates the manner of shaping the signal waves by introducing local transients.

The general features of the receiving system are disclosed in Figure 1. In this illustration the system is divided into five portions which serve individually the following functions:

- (1) Suppression of interfering frequencies lying outside the signaling range.
- (2) Preliminary shaping to produce a signal transient which can be conveniently amplified.
- (3) Amplification of the shaped transient.
- (4) Supplementary shaping by feedback.
- (5) Interference neutralization (where desirable).

These separate agencies cooperate to produce a receiving system operating on the following plan. After eliminating interference insofar as possible, the lower frequency components of the signals are selected and shaped by a unique method to form a relatively short pulse; this pulse is then passed through an amplifier which need not be entirely distortionless, and in the final output portion of the system, the signal is further supplemented locally so as to produce a satisfactory effect on the final receiving instrument.

Interference suppression

Treating the system somewhat in the order of the illustration, as indicated in Fig. 1, the interference suppressing network comprises first a series inductance L followed by a shunt condenser C . This combination serves to suppress the higher range of frequencies. In addition, one or more damped parallel resonant networks, n_1, n_2 may be added to further suppress undesired frequencies in the upper range. These elements used for this purpose are well known in the art.

Preliminary shaping

The preliminary shaping network which follows is designed to carry out the principle that the incoming signal as modified, amplified and supplemented in the final local shaping shall fulfill the following conditions:

1. It shall have sufficient energy to actuate the output relay, printer, gaseous tubes or other devices.

2. After a period of time equal to from one-half to the whole of the shortest received signal, the output current and voltage which actuates the receiving device (and any magnetic or electric transients induced by the output current or voltage) shall have reached a steady state value—or substantially so. (This steady state value may be zero or some positive value.)

3. In order that the system shall not be unnecessarily susceptible to interference, it is desirable that the wavefront should be smooth, and slope so as to reach its peak value not sooner than, say, half the time for reaching a steady state value. When mechanical relays and certain other devices are to be actuated in the output circuit it may be desirable also, to have a small "overthrow" on the signal front as shown, for example, in Fig. 12m, also to have (or to supply locally) a certain amount of steady state current to insure that the output device shall not operate again until the next cable signal is received.

We have illustrated in Fig. 12 several suitable signal shapings which can be obtained with the circuit described herein. Fig. 12b shows a shaped signal which falls to zero in unit time. This fulfills the requirements as outlined above, and constitutes one of the simplest conditions of signal operation. The output device or relay, unless it has considerable inertia or a mechanical (or other) locking means, should preferably cause a certain amount of holding current to flow in an auxiliary locking winding; or a holding component may be added directly or indirectly to the shaped and amplified signal about as indicated in Fig. 12c and Fig. 12d. This result may be accomplished in the manner indicated in Figs. 5 to 8.

The signal shown at Fig. 12e is of a type which is generally less susceptible to interference than that of Fig. 12b. This signal, when combined with a local holding current of suitable shape (see Fig. 12f) produces a satisfactory output signal, as shown in Fig. 12g.

The signal of Fig. 12h represents an important application of the principles outlined above. It has greater amplitude than that of Fig. 12e and the same general shape but if used according to the methods indicated in Figs. 12e-f-g, it would be satisfactory for a signaling speed only one-half as great as for Fig. 12e; i. e. full amplitude is not reached until after the expiration of a full pulse length. However, by combining with the signal of Fig. 12h, a suitable aiding transient (Fig. 12i) and a suitable opposing transient (Fig. 12k), the effective signal in the output device will be as shown in Fig. 12m. A "molded" signal of this type is much less susceptible to most cable interference and therefore permits more reliable operation at a given speed than the other types mentioned, or higher speeds may be used before equal susceptibility to interference is suffered.

The reason for this greater immunity from interference is that the signal of Fig. 12h is comprised largely of low frequency components where the interference level relative to the signal level is proportionately much less. By employing added amplification the signal reaches a magnitude satisfactory for relay working in the same time as did the signal of Figs. 12b or 12e which are composed largely of higher frequencies, and then the excess magnitude of Fig. 12h is neutralized by the timed opposing pulse of Fig. 12k.

The general method of shaping consists in terminating the cable—either directly, or following suitable interference suppressing networks—with a highly damped tuned circuit consisting of a condenser and an inductance in series, together with such series and shunt resistances as are required to provide suitable damping or as desired to modify the transient characteristic. This damped tuned circuit should be shunted preferably at its junction with the cable circuit by an impedance of a few hundred or a

few thousand ohms. This shunting impedance is preferably a resistance or an inductance or a combination of resistance and inductance.

A circuit such as has been described is shown in Fig. 2. The series damping resistance R_3 may be replaced or augmented if desired by a shunt damping resistance R'_3 across the inductance L_2 . Usually, however, the single series damping resistance R_3 has been found adequate and preferable. The procedure for shaping a pulse of the form of Fig. 12e follows these general lines. With R_1 reduced to a few hundred ohms so that the effect of the cable impedance and interference suppressing networks upon the shaping circuit is largely eliminated, yet the signals are not too highly attenuated, L_2 and C are adjusted for series resonance at about one and one-half times dot frequency. If now slow reversals are received, a highly damped oscillation of approximately dot frequency will be applied to the amplifier input. By further adjustment of the elements shown, the magnitude, shape and damping can be varied to produce the best possible shape of signal at the desired speed.

With the shaping circuit and procedure as just described, the shaped pulse tends to swing below the zero line. A moderate amount of underswing is not serious and can usually be compensated for in the local holding and opposing circuits. However, for speeds in excess of 15 cycles per second an auxiliary transformer and circuit may be used as shown in Fig. 3. The auxiliary transformer primary L_3 has a very high time constant. The output voltage is a transient which can be made to largely neutralize the underswing produced by the main shaping circuit. The manner in which this is effected is illustrated in Fig. 4. In this figure, curve 2 represents the damped transient produced in the secondary of the transformer L_2 , while curve 3, represents the more highly damped transient of the transformer L_3 . These two wave shapes supplement each other to produce the dotted line curve 4 which as is evident, is free of pronounced underswing.

The mathematical theory of the shaping networks is extremely complex inasmuch as we are concerned with the transient response to a transient excitation of the network. Furthermore, the constants of the cable and the interference suppressing networks have some effect on the shaping, thus rendering difficult the isolated treatment of the shaping devices. In view of the above, the comparatively easy experimental method has been largely relied upon in making the ultimate adjustments of the various elements of the shaping system.

Amplifier

The amplifier employed in this receiving system may be of any conventional type and constructed in accordance with the usual principles obtaining for low frequency high gain amplifiers such as are employed for submarine cable signals. In Fig. 1, a transformer coupled type of amplifier is illustrated. Since the very low frequency signal components are initially suppressed and since a considerable amount of distortion can be corrected in the initial and final shaping, the time constant requirements are not severe.

Neon tubes N are shown in parallel with the secondaries of the interstage transformers T_1 , T_2 . The purpose of these tubes is to protect the secondary winding against high voltage surges which may be induced while making adjustments.

Feedback shaping

A variety of schemes for combining local transients with the incoming signal transient may be used, some of which are shown in Figs. 5 to 8.

Fig. 5 shows an arrangement for use with two-element signals. One network shapes the aiding transient and the other shapes the opposing transient. These local transients are combined with the signal transient only in their common effect on the relay.

Fig. 6 shows an arrangement in which the local transients may be combined with the signal transient directly in a transformer coupled amplifier. Fig. 8 illustrates the same principle for a resistance coupled amplifier.

It should be understood that the locally produced transients may have their origin in any circuit controlled directly or indirectly by the receiving relay or other device. Sometimes an indirectly controlled circuit is to be preferred as this will permit the insertion of a "delay circuit" to better control the time relation between the signal transient and the transients of local origin which are to be combined with it.

The foregoing methods are not restricted to use with output devices of the type embodying a magnetically operated relay: Gaseous arc tubes can be used equally well with a circuit similar to Figs. 7 or 8. Fig. 9 illustrates how connection could be made to a gaseous arc tube of the start-stop type. Fig. 10 illustrates gaseous arc tubes connected as in Patent 1,947,984 to Haglund. It is to be understood that the relay contacts could feed back into auxiliary relay coils, or into preceding amplifier stages, for improving the signal shape.

A diagram of a circuit suitable for use with a three-element code is shown in Fig. 8. A pair of oppositely biased relays RY_1 and RY_2 are employed so that one relay operates on signals of positive polarity and the other on signals of negative polarity.

The same principle of combining local transients with a signal transient may, of course, be used with push-pull amplifiers and any type of impedance coupling between stages of the amplifier. The receiving instrument or repeating relays may be associated in any suitable manner with the primary receiving relay. Suitable connections are shown in Figs. 1 and 5 to 8.

The shape of the opposing or holding current fed back from the tongue of the local receiving device can readily be controlled in any required manner. Delay circuits of the artificial line type are well known in the art. Figure 11 illustrates two networks of somewhat different type which have been found satisfactory. It may be noted that the high time constants required for this type of shaping are obtained primarily by combinations of capacity and resistance. In these networks, as indeed in the entire shaping system, all of the impedance elements should be variable in order to secure the best working combination for any given cable.

Interference neutralization

Included in Fig. 1 is an arrangement for neutralizing interfering frequencies induced in the shore end of the cable. A short length of cable C_s having the distant end grounded a few miles at sea along the route of the main cable is connected via phase and voltage regulating networks to the grid of the final amplifying stage. The neutralization could be applied equally well to

any of the preceding stages. This voltage is so adjusted in magnitude and phase as to largely neutralize the disturbances arising in the shore end of the cable.

We have described our invention with particular reference to submarine cable signaling but it will be evident to engineers that it is also applicable to other signaling systems.

We claim:

1. The method of shaping a submarine cable telegraph signal, which comprises producing oscillatory transients in two frequency ranges from the lower frequency components of the received signal waves, combining these transients to form a resultant shaped relatively short wave, amplifying the resultant wave and further adding both aiding and opposing components shaped and phased to produce a repeated signal corresponding substantially in wave shape to the original transmitted signal.

2. The method of shaping a submarine cable telegraph signal which comprises shaping the low frequency components of the received signal to produce a transient whose frequency corresponds substantially to one-half dot signal speed, amplifying said transient and supplying locally both aiding and opposing transient components shaped and phased to produce a repeated signal corresponding substantially in wave shape to the original transmitted signal.

3. The method of shaping a telegraph signal which comprises initially shaping selected lower frequency components of the signal wave to produce a short pulse transient suitable for transmission at less than the normal signal speed and further shaping said transient by supplying locally a holding current component to produce a resultant wave which reaches a steady state at the end of a dot pulse period and is thereby suitable for transmission at a greater speed.

4. The method of shaping a telegraph signal which comprises initially shaping selected lower frequency components of the signal wave to produce a short pulse transient suitable for transmission at less than the normal signal speed and further shaping said transient by locally supplying supplementary aiding and opposing components to produce a resultant wave suitable for transmission at a greater speed.

5. In a submarine cable telegraph terminal apparatus, a receiving circuit comprising a preliminary signal shaping unit embodying a highly damped series circuit adjusted to resonance with the signals at about one and one-half times unit or dot frequency and an impedance in shunt thereto, an electron discharge amplifying device connected to said signal shaping unit to amplify the resultant shaped signal and a final wave shaping unit connected to the output of said amplifying device having means to supply a transient component, to prolong the amplitude of the signal wave through the operating period.

6. In a submarine cable telegraph terminal apparatus, means for reconstructing the received signal waves, comprising a shaping unit having a highly damped series resonant circuit shunted by an impedance to produce a relative phase shift and amplitude equalization of certain of the component frequencies, a multi-stage electron discharge amplifying device connected to receive the resultant wave from said unit and a second shaping unit connected to the amplifier output having means to supply assisting and opposing components to the signal wave to sustain the am-

plitude of the signal wave through the operating period.

7. In a submarine cable telegraph terminal apparatus, an initial shaping unit having means
5 to shift the relative phase of certain component frequencies of the received signal with a simultaneous amplitude rearrangement to produce a resultant transient corresponding to substantially one-half unit or dot signal frequency, means
10 to amplify the resultant transient, and a second shaping unit connected to the output of the amplifier to supply local components in both aiding and opposing directions to produce a resultant signal wave corresponding in shape substantially
15 ly to the original transmitted signal.

8. In a submarine cable telegraph terminal apparatus, a signal shaping means comprising a highly damped tuned circuit resonant to the sig-

nal frequency and a pair of transformers connected to repeat the damped oscillations of said circuit to an amplifier, one transformer being more highly damped than the other and so
5 phased as to substantially neutralize the first negative half cycle of the damped oscillations produced by said other transformer.

9. An arrangement for shaping telegraph signals comprising means to initially shape selected
10 lower frequency components of the received signal to produce a transient wave suitable for transmission at a speed lower than the signal speed and auxiliary means to add shaping components both aiding and opposing which said
15 transient to produce a resultant signal wave adapted for transmission at a greater speed.

GERALD A. RANDALL.

LESTER B. WHEELER.