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S. D. WILBURN

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BRIDGE DUPLEX TELEGRAPH SYSTEM

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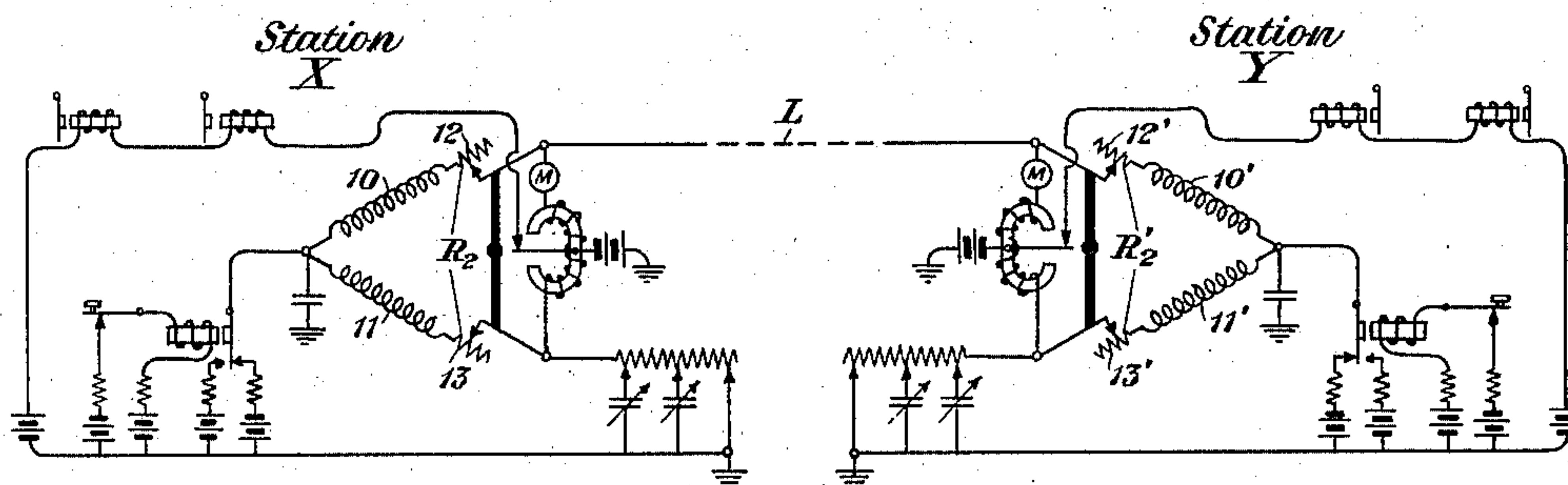


Fig. 1

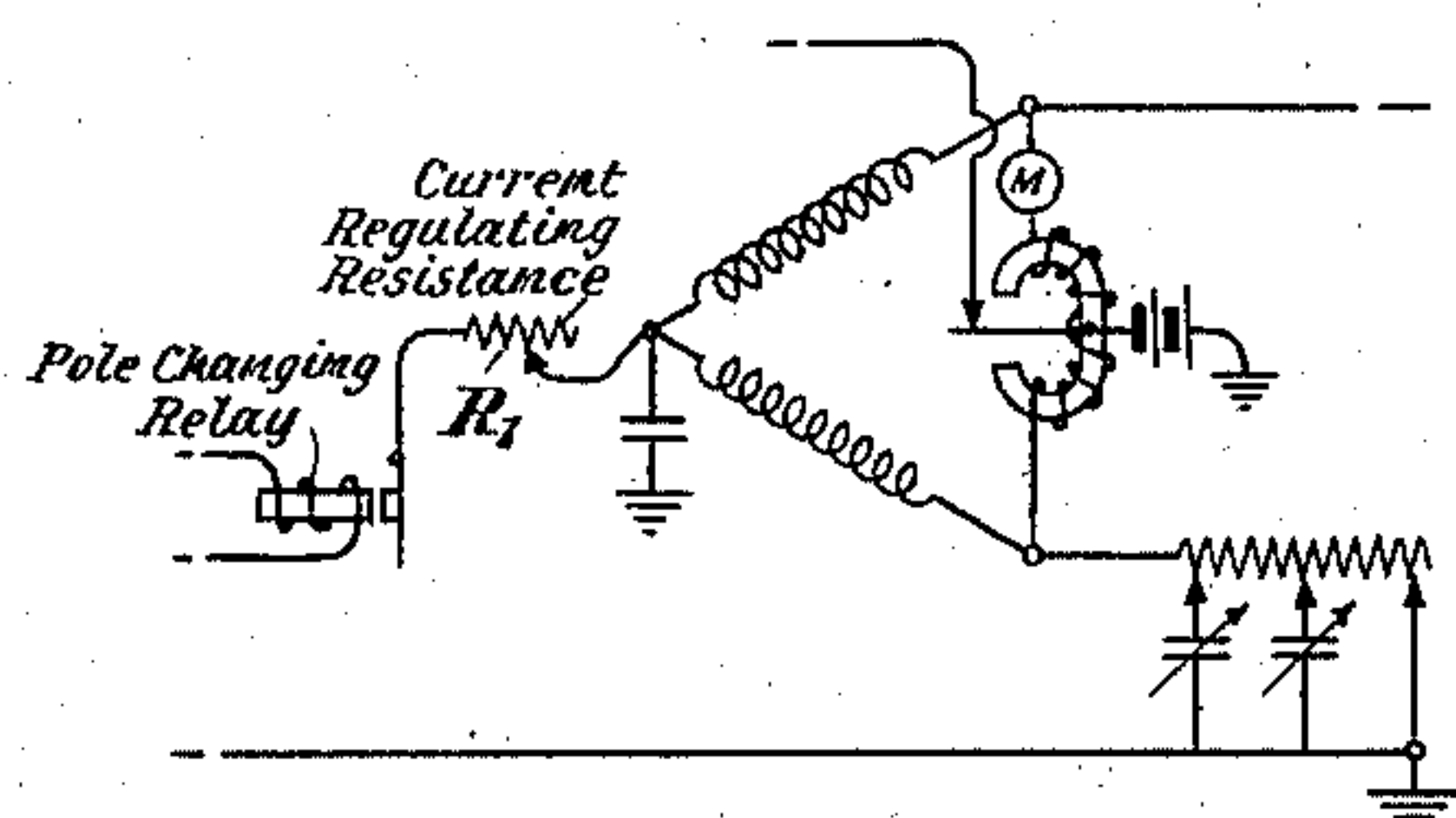


Fig. 1a

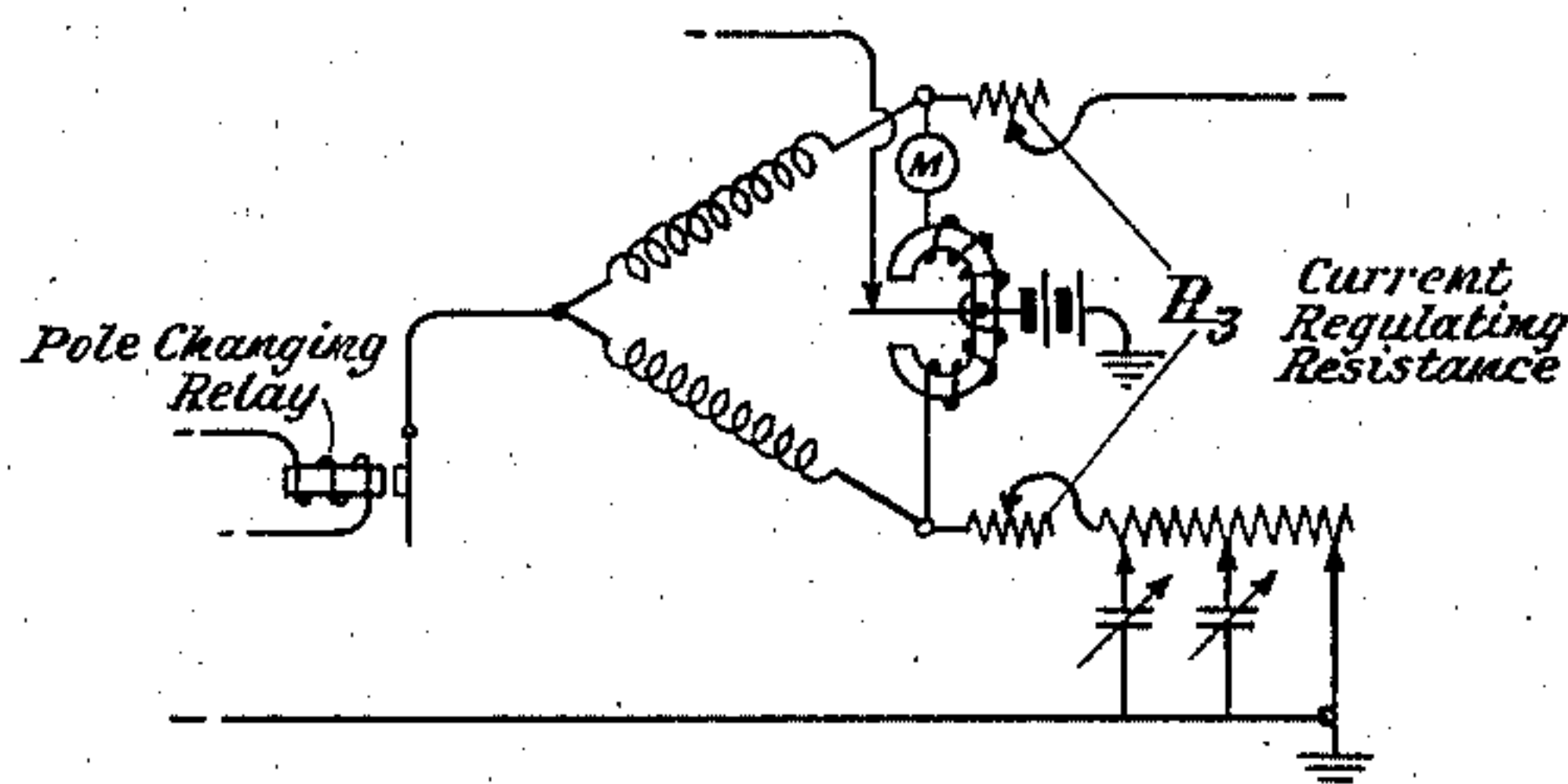


Fig. 1b

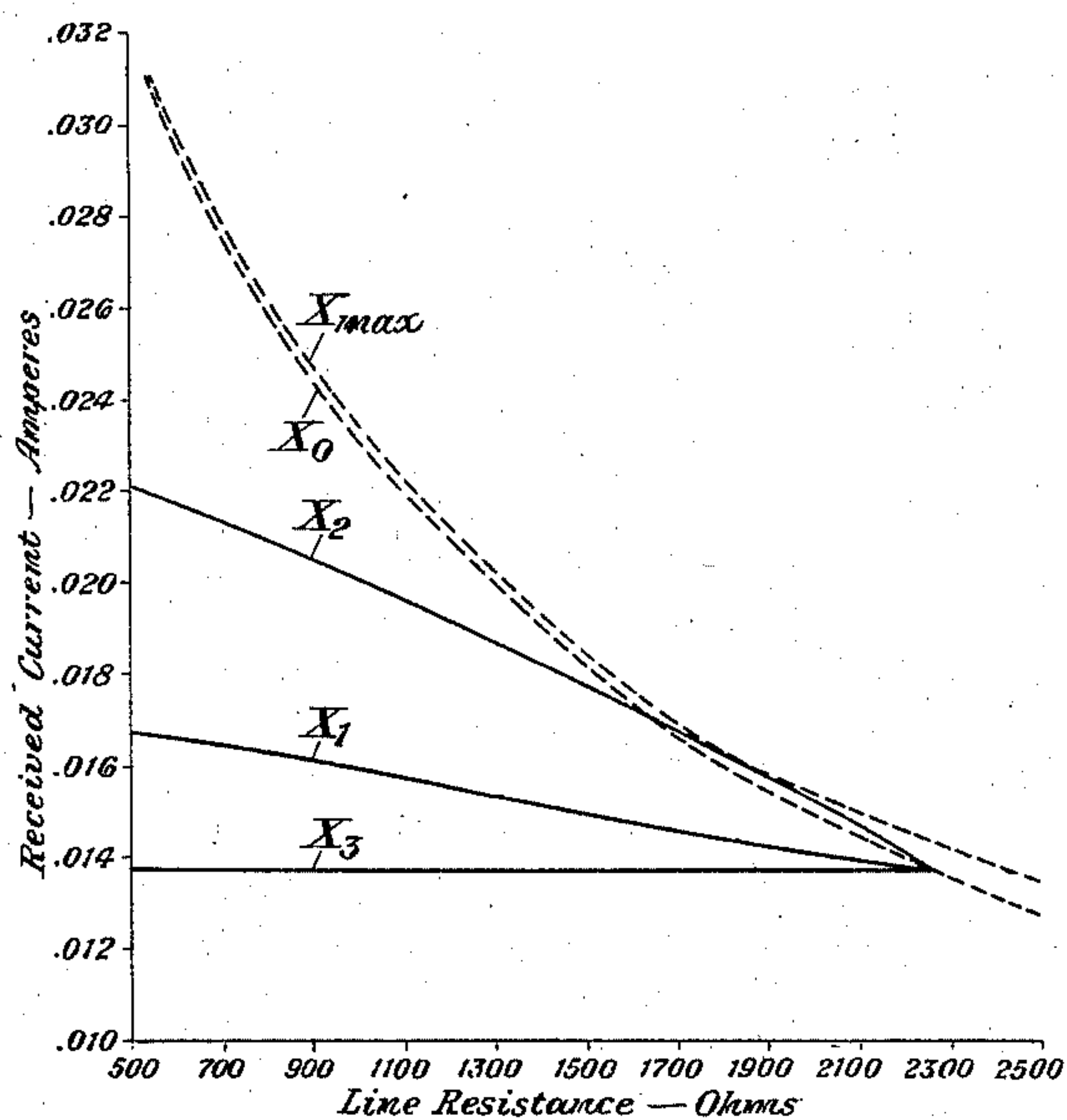


Fig. 2

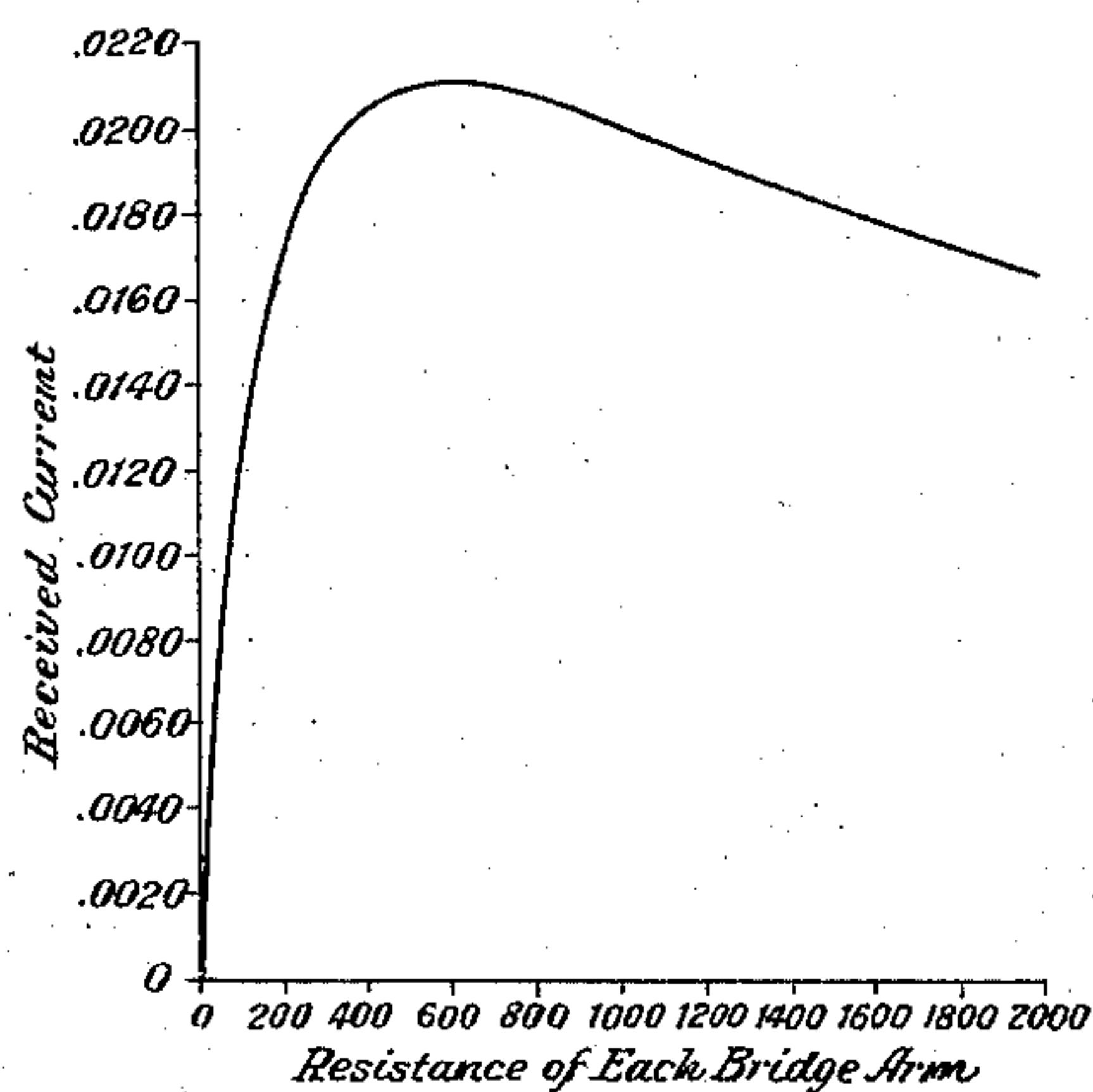


Fig. 3

INVENTOR
S. D. Wilburn
BY *g e f o r*
ATTORNEY

UNITED STATES PATENT OFFICE

SIDNEY D. WILBURN, OF ENGLEWOOD, NEW JERSEY, ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK

BRIDGE DUPLEX TELEGRAPH SYSTEM

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This invention relates to bridge polar duplex telegraph systems and particularly to means for regulating the line current in the said system which means ensures the maximum steady-state received current for a given applied line voltage.

In the operation of polar duplex telegraph circuits, it is desirable to maintain the line current within predetermined limits, which limits depend upon the type of line and apparatus used. The regulation of the line current is usually effected by varying the resistance of the circuit. The variable resistance employed for that purpose is generally associated with the duplex set instead of with the line because, as is well known, it is frequently desirable to switch a duplex set from one line to another that may differ in resistance from the former. As will be seen from subsequent description of the invention, the current regulating resistance may be located in the bridge duplex circuit at either of three places, namely, (1) a single resistance in series with the battery branch of the circuit or (2) equal resistances in series with each of the bridge arms or (3) equal resistances in series with the line and the artificial line of the duplex set.

My invention resides in the placing of equal resistance in series with each bridge arm of the duplex set, and in so proportioning such resistances (the manner of doing which is hereinafter set forth) that the maximum steady-state received current may be attained with a given applied line voltage.

Other objects of this invention will be apparent from the following description when read in connection with the attached drawing of which Figure 1 shows schematically a bridge duplex telegraph circuit having the current limiting resistances in the bridge arms of the duplex set; Figs. 1^a and 1^b which are portions of a duplex circuit and show other possible positions for the current limiting resistance or resistances are, together with Figs. 2 and 3, intended to illustrate the description of the invention.

In Fig. 1, the bridge arms at station X comprise the windings 10 and 11 and the variable resistances 12 and 13. In subse-

quent equations the value of 10 and 12 is represented by R_1 and the value of 11 and 13 is also represented by R_2 . The duplex set is connected with the line and the artificial line as shown in the figure and has a receiving relay connected across the bridge arms. The bridge arms of the duplex set connected with the other end of the line at station Y are similar to those just described. The circuit needs no further description because it is of a type well known in the art. The resistances 12 and 13 are in the form of a double rheostat with movable arms mechanically connected to facilitate adding equal amounts of resistance simultaneously to both arms. It is to be understood that, although the elements 10 and 11 (and their primes) have been shown as inductances, such elements are not so limited inasmuch as resistances may be substituted for the said inductances.

In Fig. 1^a, the current regulating resistance which is indicated by the symbol R_1 is located in the battery branch of the circuit.

In Fig. 1^b, the current regulating resistances indicated by the symbol R_2 are connected between the line and the artificial line and the duplex set, the said resistances being in the form of a double rheostat as in Fig. 1.

As will be subsequently shown, the arrangement in Fig. 1 produces the maximum steady-state received current for a given applied line voltage and is also most satisfactory from a transmission standpoint in that it does not adversely affect the shape of the received current wave. In fact, the said arrangement appears to improve the wave shape of the received current and the field trials of that arrangement upon actual operating circuits showed an improvement in transmission over other arrangements of the regulating resistances.

That the arrangement shown in Fig. 1 is superior to those shown in Figs. 1^a and 1^b, and also to other known arrangements, will be apparent from consideration of the following equations representing the relationships that exist between parts of the arrangements shown in Figs. 1, 1^a and 1^b.

In setting up the equations for the received current and the line current, certain prac-

tical operating conditions of the circuit are assumed; first, that the circuit, as a whole, be kept symmetrical by using the same amount of regulating resistance at each station, and, second, that the duplex set be maintained in a state of balance for direct currents; furthermore, line leakage will be neglected.

In order to avoid cumbersome quotations without substantially sacrificing accuracy,

T, the resistance of the line between the duplex sets. R_1 , R_2 and R_3 are the regulating resistances in the different locations corresponding to the subscripts. In the equations for arrangement (1), G is assumed to be contained in R_1 and in the equations for arrangement (2), a is assumed to be contained in R_2 . The equations for the parameters, r_1 , r_2 and r_3 are as follows:

$$r_1 = \sqrt{1/4T^2 + R_1T + \frac{aT(a+b) + ab(a+2R_1)}{2a+b}} - 1/2T \quad (7)$$

$$r_2 = \sqrt{1/4T^2 + GT + \frac{R_2T(R_2+b) + bR_2(R_2+2G)}{2R_2+b}} - 1/2T \quad (8)$$

$$r_3 = \sqrt{1/4T^2 + GT + R_3(T + R_3 + 2G) + \frac{2aR_3(a+b) + aT(a+b) + ab(a+2G)}{2a+b}} - 1/2T \quad (9)$$

the determination has been shortened by representing the overall network resistance of the duplex set from the line terminal to ground by a parameter or second independent variable r which is itself a quadratic function of the regulating resistance represented in the equations by R (with suitable subscripts).

The equations expressing the relation between the received currents i_1 , i_2 and i_3 and the regulating resistance in each location, viz, R_1 , R_2 and R_3 , respectively, are as follows:

$$i_1 = \frac{aE}{(T + R_1 + r_1)(2a + b) + ab + a^2} \quad (1)$$

$$i_2 = \frac{R_2E}{(T + G + r_2)(2R_2 + b) + bR_2 + R_2^2} \quad (2)$$

$$i_3 = \frac{aE}{(T + R_3 + G + r_3)(2a + b) + ab + a^2} \quad (3)$$

and the expressions for the ratios of the received currents to corresponding line currents, I_1 , I_2 and I_3 are:

$$\frac{i_1}{I_1} = \frac{a(1/2T + r_1)}{(T + r_1)(2a + b) + ab} \quad (4)$$

$$\frac{i_2}{I_2} = \frac{R_2(1/2T + r_2)}{(T + r_2)(2R_2 + b) + R_2b} \quad (5)$$

$$\frac{i_3}{I_3} = \frac{a(1/2T + r_3)}{(R_3 + T + r_3)(2a + b) + ab} \quad (6)$$

where,

a , represents the constant resistance of each bridge arm in arrangements (1) and (3);

b , the resistance of the receiving relay;

E , the voltage of the line battery which is assumed to be equal at both stations and may be either negative or positive;

G , the constant resistance in series with the line battery taps in arrangements (2) and (3);

While the line current and the received current can be calculated for any values of R and T from Equations (1) to (9) inclusive, explicit line current equations are needed for calculating the received current for a definite value of line current, such as shown by curves x_1 , x_2 and x_3 , Fig. 2. It is clear that these curves cannot be calculated from Equations (1) and (9) alone, as the first step necessary is to determine the value of R which, with a given value of T , will result in the specified value of I (.070 ampere). With line current equations, R can, of course, be calculated by substituting .070 for I . While the line current equations can be set up fairly readily, they are of an extremely cumbersome character. For that reason curves x_1 , x_2 and x_3 , Fig. 2, were calculated by the following method:

From Equations (1) to (9) inclusive, the line current was calculated for the various values of T from 500 to 3000 ohms with various values of R from 0 to 2000 ohms in steps of 250 ohms. For each value of T the line current was then plotted against R and the required value of the latter read from the intersection of the curve and the .070 ordinate. The values of R thus obtained were then substituted in Equations (7) to (9) for calculating r . These values of R and r in turn were substituted in Equations (1) to (3). By the above method of values of R within plus or minus two or three ohms can be determined. This possible error in R will not appreciably affect the points on the curves. The point of intersection of x_1 , x_2 , x_3 and x_0 , Fig. 2 was calculated by equating the right hand of Equation (10) to .0138.

Referring to Equations (1), (2) and (3) showing the relations between the regulating resistances and the received currents, it will be noted that in the right hand member of (1) and (3), R_1 and R_3 , respectively, appear only as positive terms in the denominator. This shows that the received current will inevita-

resistance and a battery tap resistance of 120 ohms, Equation (11) becomes

From this equation, it is found that the bridge arms, each consisting of a 500 ohm bridge coil only, as shown by Fig. 1, are too small for maximum received current if the line resistance is greater than approximately 555 ohms. With line circuits ranging in resistance from 1000 to 2500 ohms, the respective values of R_2 necessary for maximum received current strength, range from approximately 624 to 935 ohms. If, then, resistance be added in the proper amounts by the devices 12 and 13, Fig. 1, the received current will be increased thereby and at the same time, the line current will be reduced. If the line circuit resistance is approximately 1650 ohms or more the amount of resistance needed from 12 and 13 to make the received current maximum will be sufficient to reduce the line current to .070 ampere or less. This is illustrated by the three upper curves in Fig. 2. The lower broken curve, designated x_0 represents the received current which will be obtained with no regulating resistance in the circuit at either point. It will be seen that this curve passes below curve x_2 at a point corresponding to a line resistance of 1650 ohms. With approximately that value of line resistance and no regulating resistance, the line current is approximately .086 ampere and the received current is .0171 ampere. If approximately 410 ohms be added by 12 and 13 the line current will be reduced to .070 ampere and the received current will first rise to about .0174 ampere as the first resistance is added and then recede to its original point of .0171 ampere. Thus, the line current will have been reduced without reducing the received current. On the other hand, had the regulating resistance been add-

In order to determine the value of R_2 corresponding to the maximum i_2 , it is necessary to differentiate Equation (2) with respect to R_2 and to equate it to zero. The expression to be dealt with in this differentiation is that which results from the substitution of the right hand member of Equation (8) for r_2 in Equation (2). This substitution gives the following equation for the steady-state current in receiving relays of a balanced symmetrical bridge duplex telegraph circuit.

Since the differentiations of Equation (10) results in an equation involving powers of R_2 up to the sixth together with an unusual large number of terms, it is impractical to use this. It has been found, however, that for values of R_2 and T within the practical ranges of 600 to 1750 ohms for R_2 and 500 to 3000 ohms for T , r_2 is nearly equal to $1/3R_2 + 2\sqrt{T} + 200$. If this expression be substituted for r_2 in Equation (2) and this result differentiated and equated to zero, it leads to the following equation which gives values of R_2 approximating closely the point of maximum received current. This equation is:

Assuming the receiving relay of 400 ohms

ed as shown by Figs. 1^a and 1^b, the received current would have been reduced to .0147 and .0138 ampere, respectively. Curve $x_{\max}$ shows the maximum received current which can be realized by adding correct amounts of resistance to the bridge arms. The upper curve touches curve x_2 at a point corresponding to a line resistance of 1850 ohms. That is, with a line resistance of this value, the regulating resistance required to reduce the line current to .070 ampere is just sufficient to bring the received current up to the maximum. For lines of this resistance or greater, the line current can be reduced to .070 ampere or less and at the same time the received current is increased. It will be seen from Fig. 2, that as compared to locations shown in Figs.

1^a and 1^b for the regulating resistance, the advantage of location in Fig. 1 from a steady-state received current standpoint, becomes greater with lines of low resistance and amounts to 32.3% and 60.1% respectively, with a line of 500 ohms resistance. On the other hand, the increase in received current due to arrangement in Fig. 1, as compared to the condition of no regulating resistance, becomes greater with lines of higher resistance, as shown by the divergence of the x_2 and x_{max} curves, Fig. 2.

Fig. 3 represents Equation (10) plotted for a 1200 ohm line and it will be seen that it is better to have the bridge arm too great in magnitude rather than too small, since the received current rises rapidly to a maximum and then descends slowly. On the other hand, if resistances be added at the points shown in Figs. 1^a and 1^b, the operating point on the received current curve will, in all cases, be moved further away from the maximum and this movement will take place on the side of the maximum which has the greatest affect in reducing the received current.

It will be apparent that from the foregoing disclosure of the relationship existing between the received current and the line current and the regulating resistance under the situations represented by Figs. 1, 1^a and 1^b, that the employment of the current regulating resistances in the bridge arms of the duplex set results in the attainment of the maximum received current for any given value of applied line voltage. Furthermore, as briefly referred to hereinbefore, the oscillographic tests made upon the circuit shown in Fig. 1 indicates that the arrangement therein employed improves the wave shape of the received current as compared with other possible arrangements considered.

While the invention has been shown as embodied in a particular form, it is capable of embodiment in other and different forms without departing from the spirit and scope of the appended claims.

What is claimed is:

1. In a bridge polar duplex telegraph system, the combination with a line of a bridge polar duplex terminal circuit connected with each end thereof, each terminal circuit including a polar receiving relay, an artificial line, two ratio arms, and a line battery tap containing a resistance connected with the apex of the said arms, the said resistance in each ratio arm being in value equal to

$$\sqrt{3/4b(T+2T^{1/2}+G+200)},$$

where b is the resistance of the receiving relay, T is the resistance of the line between duplex sets, and G is the constant resistance in series with the line battery tap.

2. In a bridge polar duplex telegraph system, the combination with a line of a bridge polar duplex terminal circuit connected with

each end thereof, each circuit comprising ratio arms, an artificial line, a polar receiving relay connected across said ratio arms between the line and the artificial line and a battery tap connected with the apex of the ratio arms, the said ratio arms, each comprising the same amount of resistance, which amount equals

$$\sqrt{3/4b(T+2T^{1/2}+G+200)},$$

where b equals the resistance of the receiving relay, T is the resistance of the line between duplex sets, and G is the constant resistance in series with the line battery tap.

3. The method of controlling the magnitude of the line current in a bridge polar duplex telegraph system comprising a line having a bridge polar duplex terminal circuit connected with each end thereof, each terminal circuit including a polar receiving relay, an artificial line, two ratio arms, and a line battery tap containing a resistance connected with the apex of the said arms, which method consists in introducing an equal amount of resistance in each ratio arm of such magnitude that the resistance of the ratio arm shall be equal to

$$\sqrt{3/4b(T+2T^{1/2}+G+200)},$$

where b is the resistance of the receiving relay, T is the resistance of the line between duplex sets, and G is the constant resistance in series with the line battery tap.

4. The method of controlling the magnitude of the line current and of improving the wave shape in a bridge polar duplex telegraph system which consists in introducing in the ratio arms of the bridge equal amounts of resistance of such value as to give maximum received current for a given applied line voltage.

In testimony whereof, I have signed my name to this specification this 28th day of January, 1928.

SIDNEY D. WILBURN.