

Dec. 22, 1931.

B. F. LEWIS

1,837,327

TRANSMISSION NETWORK

Filed Aug. 22, 1930

2 Sheets-Sheet 1

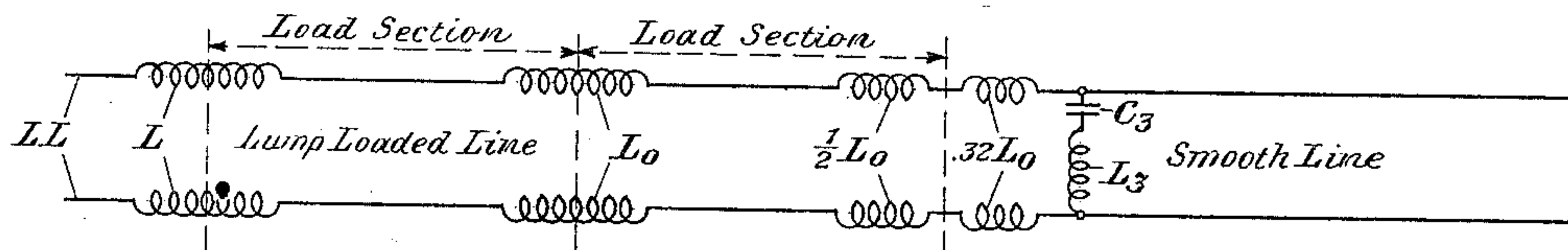


Fig. 1

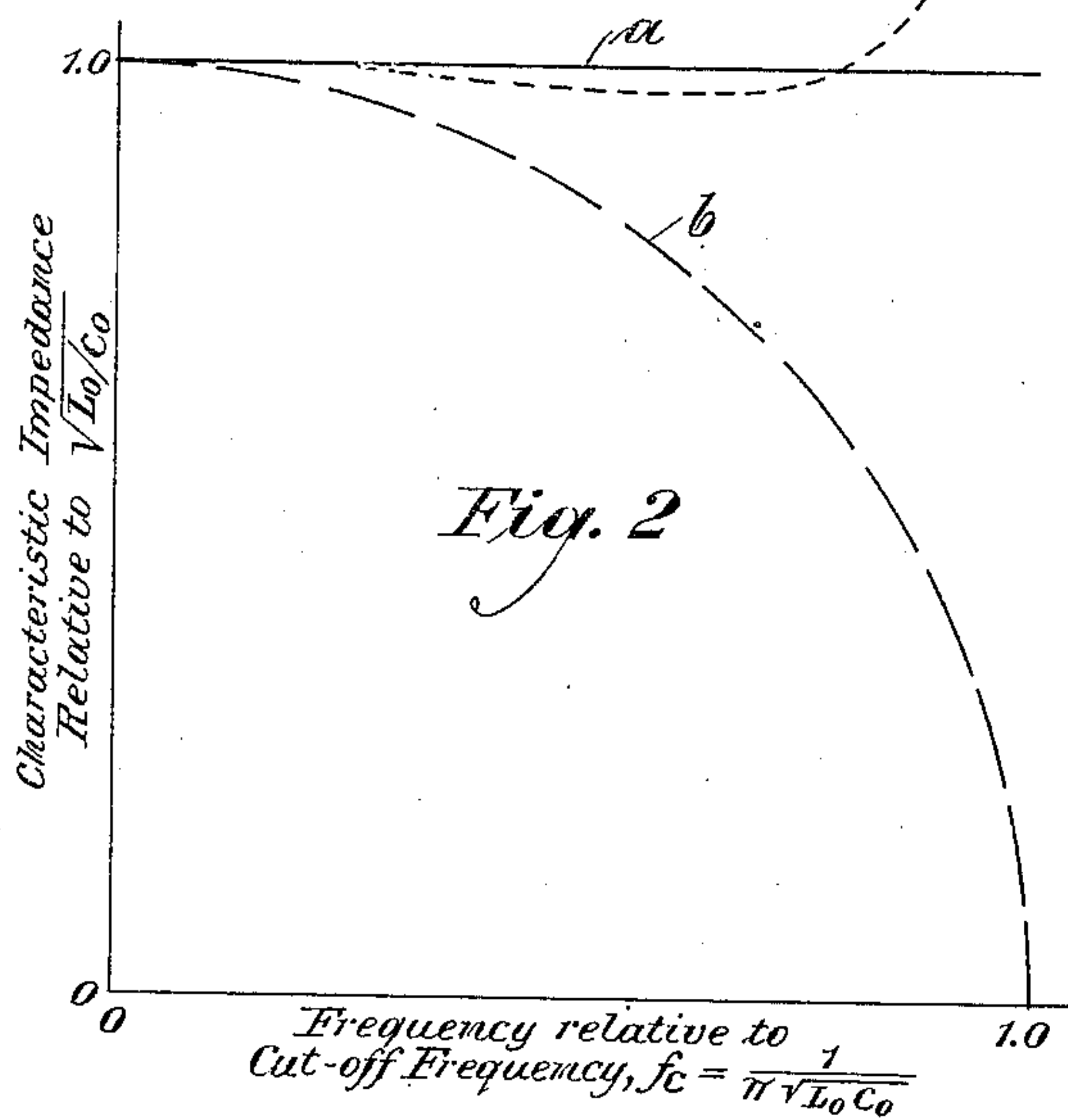


Fig. 2

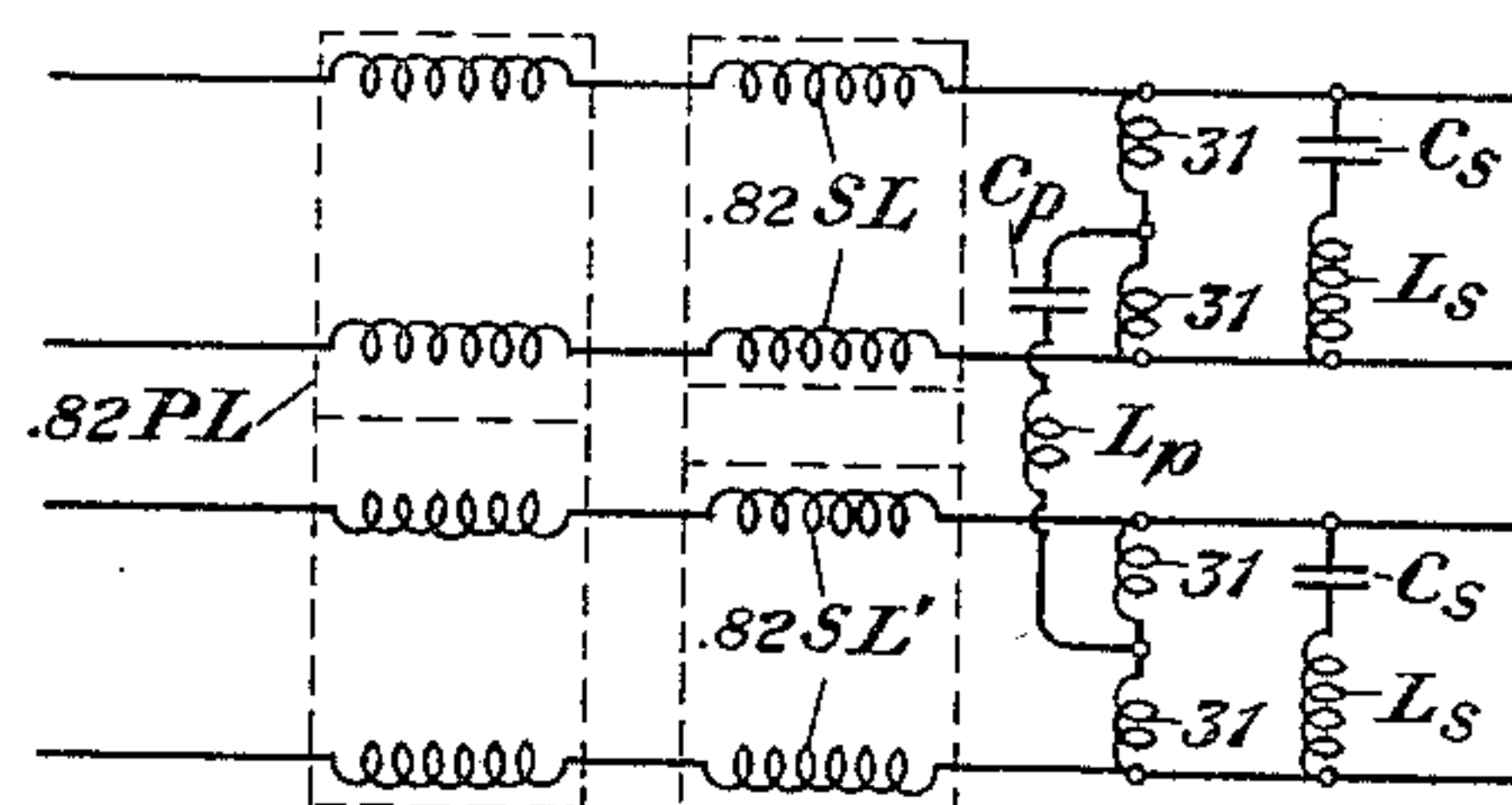


Fig. 3

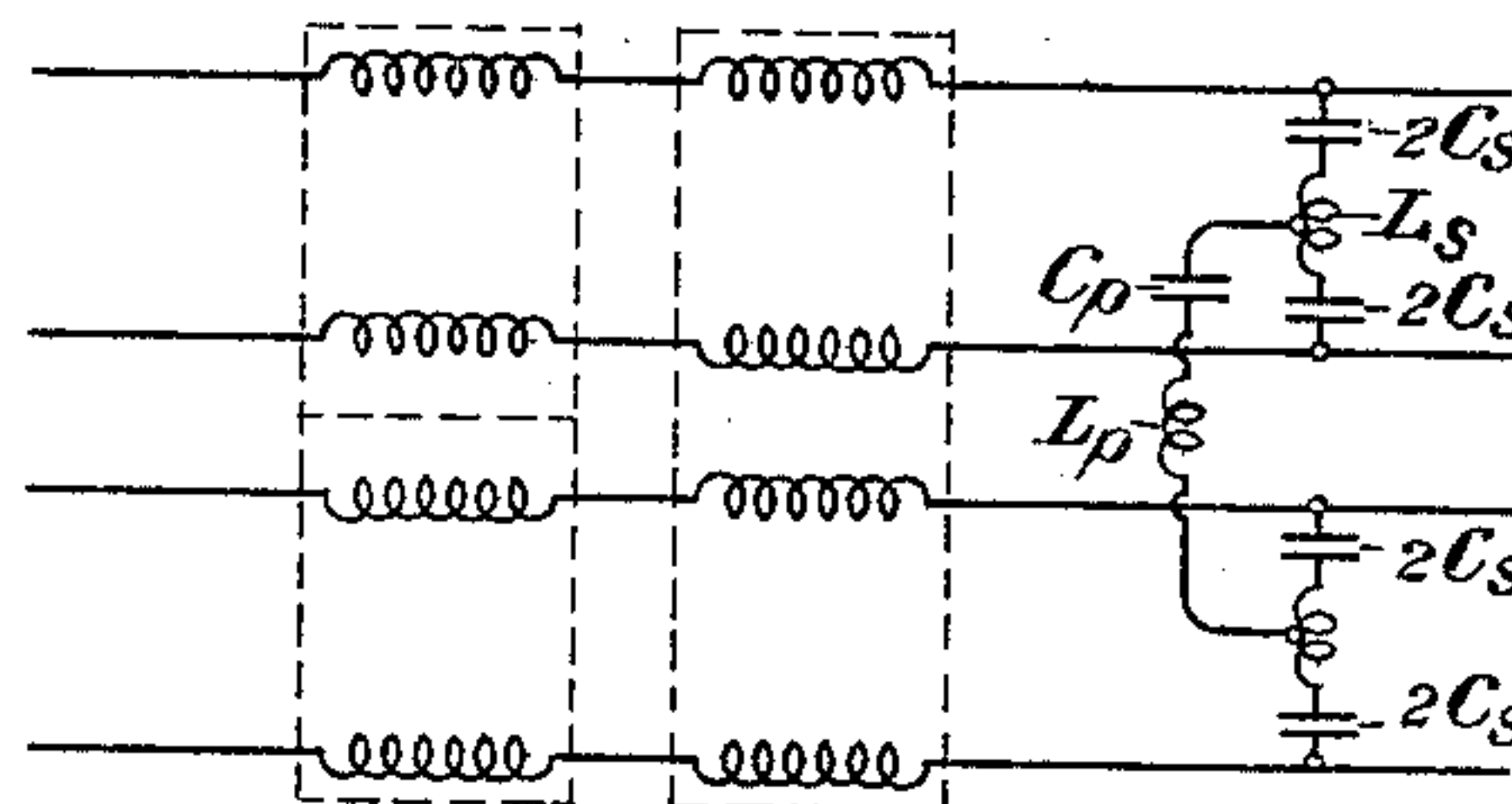


Fig. 4

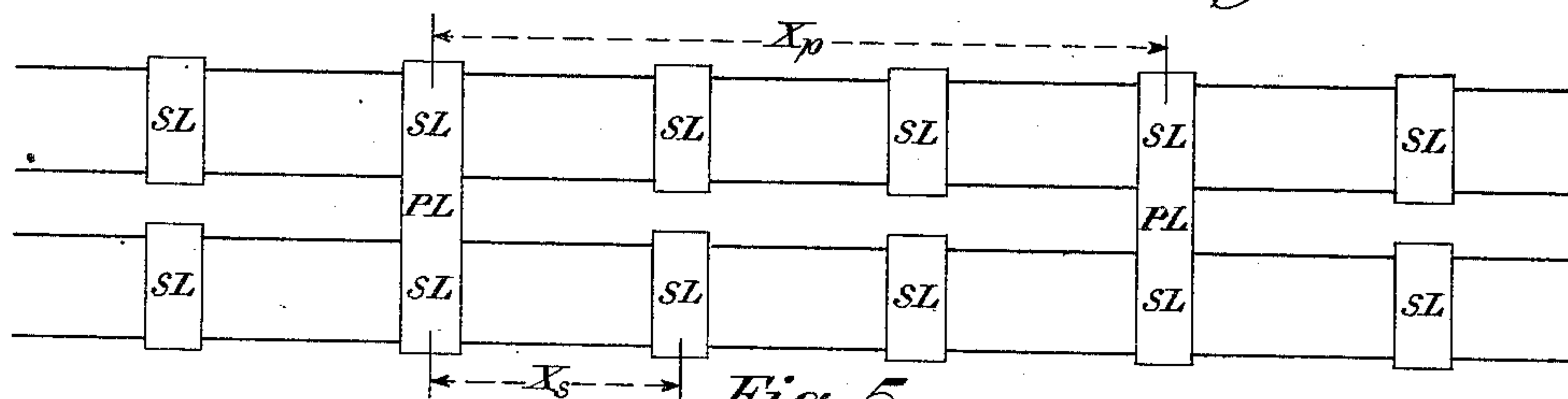


Fig. 5

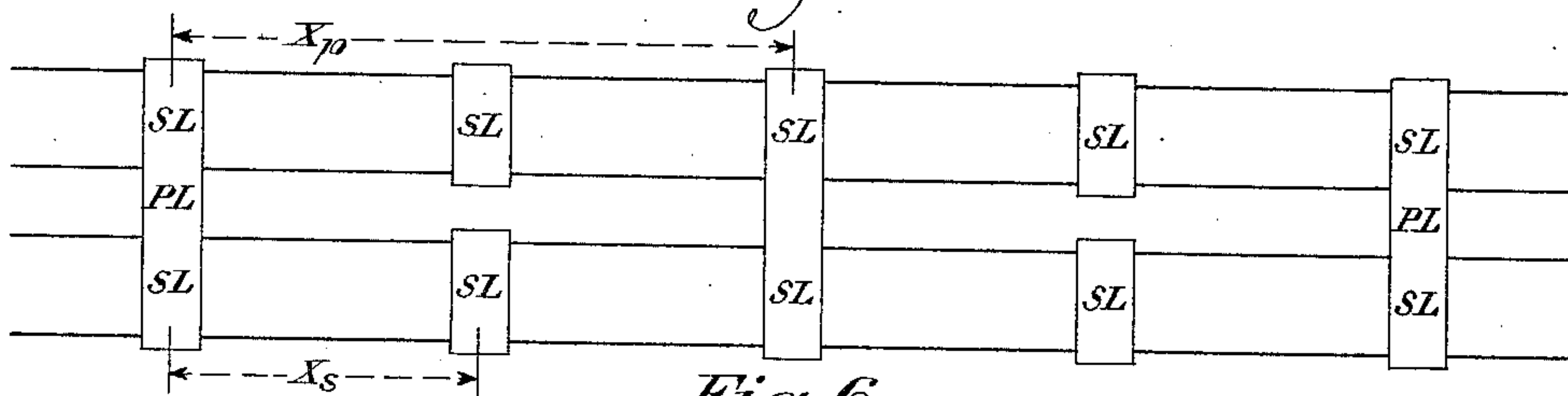


Fig. 6

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2 Sheets-Sheet 2

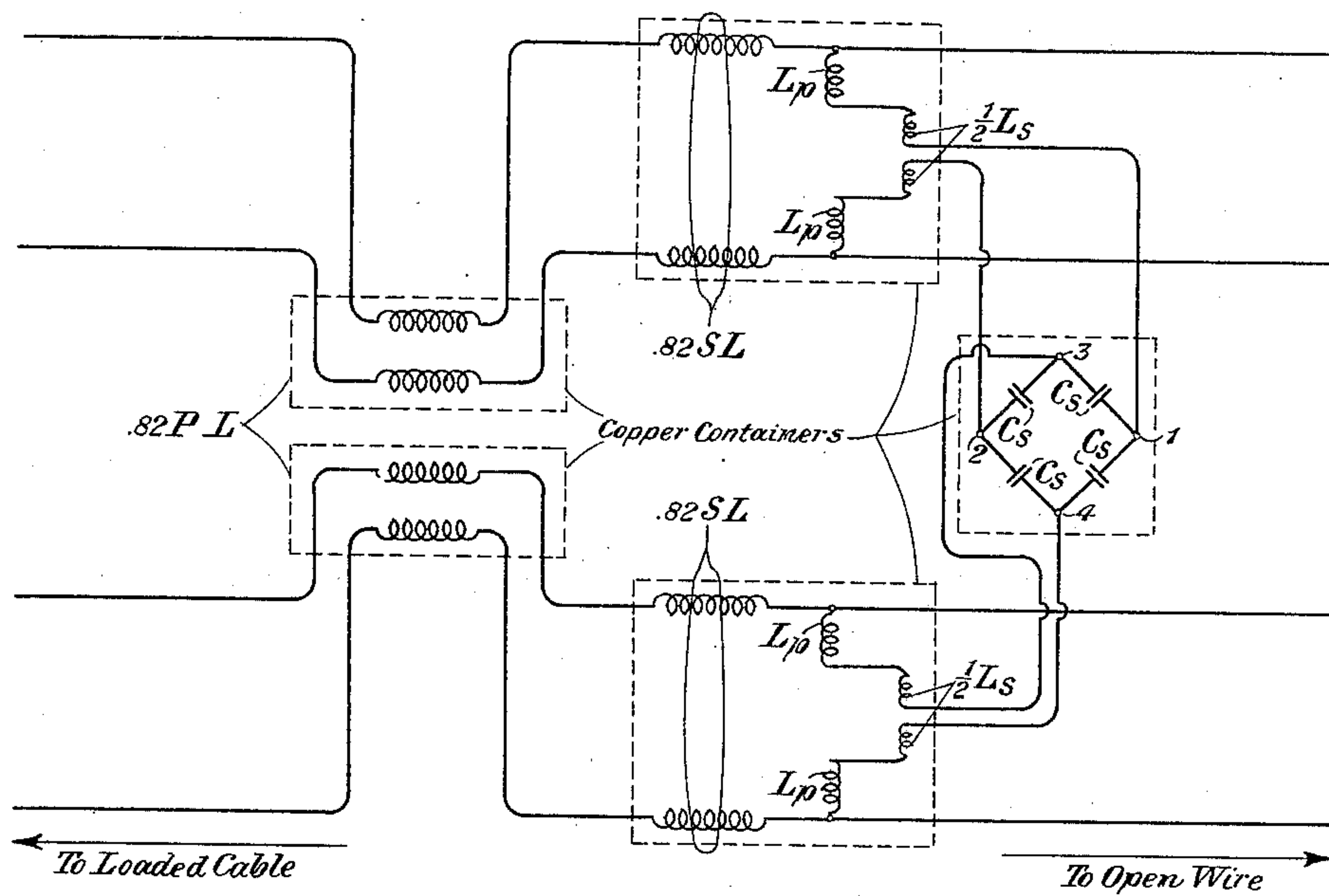


Fig. 7

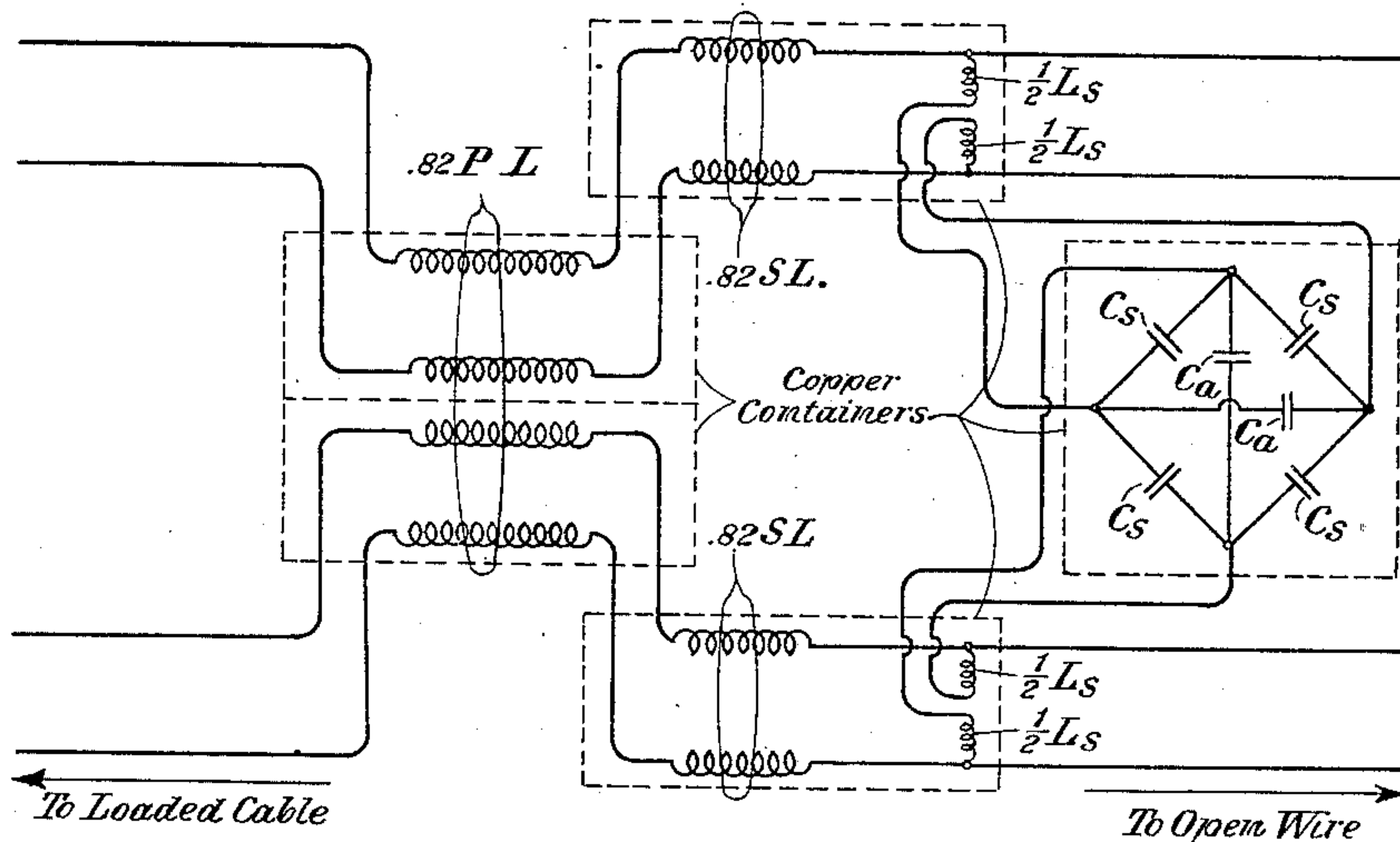


Fig. 8

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TRANSMISSION NETWORK

Application filed August 22, 1930. Serial No. 477,164.

This invention relates to a transmission network, and more particularly to a network for associating a periodically loaded circuit with a smooth line.

5 In U. S. Patent No. 1,475,997, issued to Ray S. Hoyt, December 4, 1923, arrangements are described for associating a periodically loaded circuit with a smooth line such as an open wire line or a continuously loaded circuit. 10 Since a smooth line has a different characteristic impedance from a periodically loaded line, an irregularity will result at the junction of the two circuits causing reflection losses and other undesirable effects unless a 15 terminating network is provided for the loaded line which will give it a characteristic impedance similar to that of the smooth line.

20 In accordance with the principles of the Hoyt patent this is accomplished by terminating the loaded line in a fractional loading coil, preferably having an inductance about .82 times the inductance of a full loading coil and then bridging across the terminal of the 25 loaded line a shunt comprising a series combination of an inductance and a capacity each of which is related to the inductance and capacity of one full section of the loaded line.

30 When a periodically loaded line is terminated in this manner, both the resistance and reactance components of its characteristic impedance will closely approximate the corresponding components of a smooth line over the greater part of the frequency range transmitted by the periodically loaded line. 35

While the Hoyt, patent describes arrangements for terminating the phantom and both side circuits of a periodically loaded quad, so that the impedance of each circuit will correspond to that of the corresponding phantom or side circuit, as the case may be, of a smooth line, the arrangements described in the Hoyt patent are only suitable where the phantom and the side circuits of the loaded 40 quad are loaded to about the same cut-off.

Where it is necessary to load the phantom and the side circuits to substantially different cut-off frequencies as, for example, where the side circuits are used for carrier frequencies 45 and the phantom is used only for voice fre-

quencies, or where the carrier frequencies transmitted over the phantom are materially lower than those to be transmitted over the side circuit, the phantom loading coils must be differently spaced from the side loading 55 coils and the arrangements described in the Hoyt patent will not permit the obtaining the proper ratio between the capacity in the phantom shunt and the capacity in the side circuit shunt. 60

In accordance with the present invention, a circuit arrangement has been devised in which the inductance and capacity elements of the shunt circuits of the phantom and side circuits may be common to all of the circuits 65 and the common capacity elements are so related to the phantom and to the two side circuits that a much higher ratio of phantom shunt capacity to side shunt capacity is obtained than is possible with the arrange- 70 ments of the Hoyt patent. Specifically, the common capacity elements in accordance with the present invention comprise four condensers arranged in a bridge formation with its points so connected to the conductors of 75 the quad that there will be four times as much capacity in the phantom circuit as in the side circuit.

The invention will now be more fully understood from the following description, 80 when read in connection with the accompanying drawings, in which Figure 1 shows a simple network for associating a periodically loaded line with a smooth line; Fig. 2 comprises certain curves illustrating the 85 principles of Fig. 1; Figs. 3 and 4 show circuit arrangements for associating a periodically loaded quad with a quad of a smooth line where the phantom circuit and the side circuits have substantially the same cut-off; 90 Figs. 5 and 6 show schematically two different types of loading arrangements where the phantom circuit and the side circuits are loaded to different cut-offs; Fig. 7 shows one type of network for terminating a periodical- 95 ly loaded quad in accordance with the principles of the invention; and Fig. 8 shows another form of network for terminating a periodically loaded quad in accordance with the present invention. 100

Fig. 2 illustrates the impedance characteristic of a smooth line, and those of a periodically loaded line for two different methods of terminating the latter. The curves apply to lines having negligible resistance, for which case the reactance component of the impedance is zero. In actual lines, the effect of the resistance upon the characteristic impedance is to add an increasing increment to the resistance component, and to introduce an increasing negative reactance component at low frequencies as zero frequency is approached. But the presence of resistance in the lines does not affect appreciably their impedances at the higher frequencies, which are more important from the standpoint of the present explanation of the problem of terminating a periodically loaded line.

Curve *a* on Fig. 2 illustrates the impedance characteristic of a smooth line; it is constant and equal to

$$\sqrt{L_0/C_0},$$

where L_0 and C_0 are respectively the distributed inductance and capacity of the line in the same unit length. The characteristic impedance of a periodically loaded line, however, depends upon how the line is terminated. Let it be required to connect a periodically loaded line to a smooth line as shown in Fig. 1. It is well known that in order to connect the two lines with a minimum of reflection at their junction, it is first necessary to design the loading of the periodically loaded line so that the ratio

$$\sqrt{L_0/C_0}$$

is equal to the corresponding ratio for the smooth line. Secondly, it is necessary to select the size of the copper conductors used for the periodically loaded line so that the ratio R/L_0 will be equal to the corresponding ratio for the smooth line; this requirement is necessary to make the impedances of the two lines equal at low frequencies. When these two design requirements have been met, the reflection can be further reduced only by properly adjusting the termination of the periodically loaded line. If it is terminated in mid-coil, its characteristic impedance will appear as shown by curve *b* on Fig. 2. It will be noted that this impedance falls off with increasing frequency; so that a large impedance irregularity at frequencies near the cut-off frequency will be present at its junction with the smooth line.

This impedance irregularity can be substantially eliminated, however, by connecting between the smooth line and the mid-coil termination of the periodically loaded line a special network as shown in Fig. 1. As disclosed in the Hoyt patent (No. 1,475,997) above referred to, this network has a series element comprising a coil having an inductance about .32 times the inductance of a full-

weight loading coil, and a shunt element comprising a series combination of an inductance L_3 and a capacity C_3 . As pointed out on page 3 of the Hoyt patent, the elements L_3 and C_3 may be designed in accordance with the approximate formulas,

$$L_3 = 8/15 L_0$$

and

$$C_3 = 3/10 C_0$$

where L_0 and C_0 are in the inductance and capacity, respectively, in a loading section of the periodically loaded line. When the network just described has been added to the periodically loaded line at mid-coil, the impedance of this line as seen through the network will then appear as shown by curve *c* on Fig. 2. It will be noted that the impedance of the periodically loaded line has now been made to approximate closely that of the corresponding smooth line over the greater portion of the transmitted frequency range.

The foregoing principles are set forth in the Hoyt patent above referred to and are applied to the problem of associating both the phantom and side circuits of a loaded quad with the corresponding circuits of a smooth line quad for the case where both the phantom and side circuit of the loaded quad have substantially the same cut-off frequency. Where the side circuits are loaded to a much higher cut-off than the phantom circuit, the arrangements described in the Hoyt patent do not meet the exigencies of the situation.

Let us assume a conductor quad loaded as shown in Fig. 5. This is a typical loading system in which the side circuits are so loaded, at intervals of about 900 feet, that they may be used effectively for transmission up to about 30 kilocycles per second while the phantom is only loaded for transmission up to about 10 kilocycles, for which a load spacing of about 2700 feet is adequate. In this type of system, the side circuit can be employed for 3-channel carrier telephone transmission above the usual voice frequency channel but the phantom circuit can only be used for carrier telegraph transmission above the usual voice frequency channel. Owing to the lower cut-off of the phantom, the phantom load spacing x_p is three times that of the side circuit load spacing x_s . The rectangles marked PL and SL in Fig. 5 indicate that at the points where these rectangles occur in the circuit both phantom loading coils and side circuit loading coils are provided. The rectangles marked simply SL designate side circuit loading coils.

A circuit of the type illustrated in Fig. 5 presents a special problem from the standpoint of providing a suitable termination for the circuit so that it may be connected to a smooth conductor quad. Let us assume that in a loading section such as x_s , each side circuit has a capacity between the line conduc-

tors and coil conductors of C_0 . From this value the value of a condenser C_s corresponding to Fig. 1 may be obtained in accordance with the formula above given. In the usual quadded cable, the capacity in the same length of phantom will be about $1.62 C_0$. The phantom loading section, however, is three times as long as the side circuit loading section and the total capacity in a phantom loading section will be $4.86 C_0$. Since the capacity in the terminating shunt corresponding to C_s of Fig. 1 in the phantom is proportional to the capacity of a loading section of the phantom in accordance with the formula already given, it follows that the effective capacity in the terminating shunt of the phantom must be nearly five times as great as the effective capacity in the terminating shunt of the side circuit. Similar considerations apply to the inductances of the terminating shunts of the phantom and the side circuits, respectively, but the design of these inductances is a relatively simple matter since the inductances in the phantom shunt may be designed to have the desired value with respect to the phantom while being so wound as to be non-inductive with respect to the side circuit, and vice versa. With respect to the capacities, however, the phantom shunt capacity and the side shunt capacities are necessarily interrelated so that any change in one affects the other.

In order to approximate as closely as possible the desired relationship between the capacity of the phantom shunt and the capacity of the side circuit shunt, the terminal circuit arrangement shown in Fig. 7 may be employed. As shown, each side circuit is terminated in .82 of a side circuit loading coil SL and similarly, the phantom circuit is terminated in .82 of a full phantom loading coil PL.

The terminating shunts for the phantom and side circuits are obtained as follows: Four capacities C_s are arranged in the form of a bridge, as shown. Two opposite points of the bridge are connected to the conductors of the side circuits and in these wires are included phantom inductances L_p and side circuit inductances $1/2 L_s$, as shown. The two phantom inductances L_p are wound on the same core but one is reversed with respect to the other so that the two inductances will be non-inductive with respect to the side circuit. Similarly, the two inductances $1/2 L_s$ are non-inductive to the phantom current. The other two points of the condenser bridge are connected to the conductors of the other side circuit, and in these connections are included phantom coils L_p and side circuit coils $1/2 L_s$ as shown.

With respect to the capacity in the terminating shunt, let it be assumed that in accordance with the formula previously given the effective capacity in the side circuit is

found to be C_s . If, now, we examine the bridge arrangement of capacities shown in Fig. 7, the capacity bridged across the upper side circuit will be the capacity between terminals 1 and 2 of the bridge. This capacity comprises two capacities C_s in series, this combination being in parallel with a similar series combination of two equal capacities. In other words, the capacity 1—3—2 is $1/2 C_s$ and this is in parallel with the capacity 1—4—2, which also comes out $1/2 C_s$, so that the total capacity between 1 and 2 becomes C_s . Similarly, the effective capacity in the shunt of the lower side circuit will be C_s .

With respect to the phantom, the effective capacity in the shunt becomes $4 C_s$ because all four capacities of the bridge are in parallel with each other in the phantom. This may be readily seen if we consider that phantom currents flowing over the two side conductors of the upper side circuit would produce the same potential at terminals 1 and 2 so that these two terminals may be joined together without disturbing the phantom. Similarly, phantom currents flowing over the two side conductors of the lower side circuit will produce the same potential at points 3 and 4 so that these two points may be connected together without disturbing the phantom. If points 1 and 2 be merged and points 3 and 4 be merged in the manner just suggested, it will be obvious at once that the four capacities C_s are in parallel with each other in the phantom, and consequently, the total capacity in the phantom shunt will be $4 C_s$.

While the arrangement just described gives a ratio of 4 to 1 between the phantom shunt capacity and the side circuit shunt capacity, this ratio is somewhat less than the optimum ratio of 4.86 to 1 prescribed by theory. However, it is a much higher ratio than it has been possible to obtain with any other arrangement hitherto known and will give a sufficiently satisfactory termination for the circuit arrangement of Fig. 5 where the phantom is only used for transmission up to about 10 kilocycles, especially when it is considered that the phantom is loaded to a cut-off of about 16 kilocycles, and hence, is only employed for transmission up to about two-thirds of the cut-off. As the side circuit is loaded to a cut-off of about 42 kilocycles, depending upon the type of circuit, and is used for transmission up to about 30 kilocycles, it is desirable that the termination be designed to be accurate for the side circuit, leaving the departure from optimum ratio to be effective only upon the phantom, where a greater latitude can be permitted.

While the foregoing arrangement does not give the desired optimum ratio between phantom shunt capacity and side circuit shunt capacity of 4.86 to 1, it does give a sensible approach to the optimum value and it certainly gives a much higher ratio than has

been possible by any previously known circuit arrangement. For example, let us consider the arrangement of Fig. 3 which is based on Fig. 6 of Hoyt Patent 1,475,997. Here the side circuit shunt comprising capacity C_s and inductance L_s can be designed in accordance with the requirements of the side circuit, and the capacity and inductance in the shunt of the side circuit are ineffective in the phantom. By connecting the phantom shunt to the midpoints of inductance coils 31, as shown, the phantom capacity C_p and the phantom inductance L_p may be designed in accordance with the requirements of the phantom without producing any effect in the side circuit. Unfortunately, however, this arrangement is not practical because the phantom must be connected to the midpoints of impedances 31 and these impedances produce in the side circuit low-frequency irregularities which cannot be tolerated. Furthermore, as the side circuit conductors are ordinarily composited for telegraph transmission, large condensers should be included in series with the impedances 31 to prevent direct currents from flowing from one side conductor to the other side conductor. These condensers at once affect both the side circuit shunt and the phantom shunt, and hence, the apparent independence of the design of the side circuit shunt and the phantom shunt falls down and the circuit becomes, from the standpoint of the design of the phantom and side circuit shunt capacities, equivalent to the arrangement of Fig. 4, which is based on Fig. 7 of Hoyt Patent 1,475,997.

In the arrangement of Fig. 4, two capacities $2 C_s$ are bridged across each side circuit so that the effective capacity shunt across each side circuit will be C_s . These capacities are also effective in the phantom which includes the capacity C_p and inductance L_p . Capacity C_p in the phantom being in series with the effective capacity in the phantom due to the four capacities $2 C_s$, has the effect of reducing the total capacity in the phantom. Hence, the maximum ratio of phantom capacity to side circuit capacity will occur when capacity C_p is infinite. The effective capacity in the phantom then becomes $2 C_s$ so that the maximum possible ratio of phantom capacity to side circuit capacity is only 2 to 1. This is a satisfactory arrangement where both the phantom and the side circuit are arranged to have the same cut-off, as in such case both the phantom and the side circuit loads have the same spacing and the desired ratio of phantom shunt capacity to side circuit shunt capacity would be 1.62 to 1. This ratio may be readily obtained by inserting a capacity C_p of such value as to bring the effective phantom capacity from 2 down to 1.62 times the side circuit shunt capacity. Such an arrangement would not be satisfactory, however, for a loading arrangement

such as that of Fig. 6 where the desired ratio should be of the order of 5 to 1.

The arrangement of the invention may be also employed for a loading system such as that shown in Fig. 6. Here the phantom load section is twice as long as the side circuit load section. Such a system may be used where the phantom is intended to transmit voice current only (up to, say, 3,000 cycles) while the side circuits are used for single channel carrier telephone transmission or for carrier telegraph transmission above the usual voice channel up to about 10,000 kilocycles. The load arrangement illustrated involves a cut-off of about 13 kilocycles for the side circuit and 7.2 kilocycles for the phantom, the load spacings being about 3,000 feet for the side circuit and about 6,000 feet for the phantom.

For this type of loading system we may employ the terminating arrangement illustrated in Fig. 8. As the phantom loading section is of twice the length of the side circuit loading section, the desired ratio between phantom shunt capacity for the termination and side circuit shunt capacity for the termination will be 3.2 to 1, assuming standard multiple-turn quadded cables in which the normal phantom-to-side capacity ratio per unit length is about 1.6 to 1. If the condenser arrangement of Fig. 8 should be used, we would obtain an actual ratio of 4 to 1 due to the use of the condensers C_s . This ratio may be reduced, however, by introducing two additional condensers C_a between diagonal terminals of the network so as to be effective in the side circuits, while being effectively short-circuited so far as the phantom is concerned. On this basis, the effective capacity of the network in each side circuit is $C_s + C_a$ and in the phantom circuit the effective capacity is $4 C_s$. In the 6-condenser network illustrated in Fig. 8, a phantom-to-side circuit capacity ratio of 3.2 to 1 can be obtained by having condensers C_a one-fourth as large as the condensers C_s . Any other desired ratio of phantom-to-side capacity less than 4 to 1 can be obtained by properly proportioning the condensers C_a and C_s .

An additional difference between the terminal network arrangements of Fig. 8 and Fig. 7 is that in Fig. 8 the shunt coils of the phantom terminal are omitted. As has already been stated, the loading system of Fig. 6 is so designed that the cut-off frequency of the phantom will be 7,200 cycles while it is only used for transmission up to 3,000 cycles, or less than half of the cut-off frequency. It has been found that phantom coils such as L_p of the circuit of Fig. 7 play an important part in the impedance modifying action of the shunt for frequencies higher than about .6 of the cut-off frequency, but are not necessary for frequencies materially lower than one-half the cut-off. Consequent-

ly, these phantom shunt coils would be ineffective in a termination for the system of Fig. 6 in the range of frequencies for which the phantom is intended to be employed, namely, frequencies up to 3,000 cycles. The phantom shunt coils of Fig. 7 are used because of expectations that the phantom circuit will be used for carrier transmission up to frequencies about .6 of the cut-off frequency, or higher; however, if in individual situations the service over the phantom should be limited to voice frequency operation, then the phantom shunt coils could be discarded.

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.

20 What is claimed is:

1. A terminating network for a periodically loaded quad, said network including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a shunt for each side circuit, and a shunt for the phantom, each shunt including capacity means common to said shunts to provide at least a portion of the capacity thereof, said means being so connected in the several shunts that the ratio of capacity in the phantom shunt to that in the side circuit shunt is greater than 2 to 1.

2. A terminating network for a periodically loaded quad, said network including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a shunt for each side circuit, and a shunt for the phantom, each shunt including capacity means common to said shunts to provide at least a portion of the capacity thereof, said capacity means being so connected in the several shunts that the capacity in the phantom shunt due to said means will be four times as great as the capacity in the side circuit shunt due to said means.

3. A terminating network for a periodically loaded quad, said network including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a shunt for each side circuit, and a shunt for the phantom, each shunt including capacity means common to said shunts to provide at least a portion of the capacity thereof, said means including four condensers connected in bridge formation, connections leading from a pair of opposite points of said bridge to the conductors of one side circuit, and connections leading from the other pair of opposite points of

said bridge to the conductors of the associated side circuit of the quad.

4. A terminating network for a periodically loaded quad, said network including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a shunt for each side circuit, and a shunt for the phantom, each shunt including capacity means common to said shunts to provide at least a portion of the capacity thereof, said means including four condensers connected in bridge formation, connections leading from a pair of opposite points of said bridge to the conductors of one side circuit, connections leading from the other pair of opposite points of said bridge to the conductors of the associated side circuit of the quad, and coils in the connections leading to the side circuit conductors, said coils being inductive with respect to the side circuit and non-inductive with respect to the phantom.

5. A terminating network for a periodically loaded quad, said network including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a shunt for each side circuit, and a shunt for the phantom, each shunt including capacity means common to said shunts to provide at least a portion of the capacity thereof, said means including four condensers connected in bridge formation, connections leading from a pair of opposite points of said bridge to the conductors of one side circuit, connections leading from the other pair of opposite points of said bridge to the conductors of the associated side circuit of the quad, coils in the connections leading to the side circuit conductors, said coils being inductive with respect to the side circuit and non-inductive with respect to the phantom, and additional coils in the connection leading to the side circuit conductors, said last mentioned coils being inductive in the phantom and non-inductive in the side circuits.

6. A transmission system comprising a quad of four conductors connected to form two side circuits and a phantom, said side circuits being periodically loaded for one cut-off and the phantom being periodically loaded for another cut-off, a terminating network for said quad including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a terminating shunt for each side circuit and a terminating shunt for the phantom, each side circuit shunt including capacity proportional to the capacity of a side circuit loading section, the phantom circuit shunt also including capacity proportional to the capacity of a phantom load-

ing section, means common to said shunts to provide at least a portion of the capacity thereof, said means being so connected in the several shunts that the ratio of capacity in the phantom shunt to that in the side circuit shunt is greater than 2 to 1.

7. A transmission system comprising a quad of four conductors connected to form two side circuits and a phantom, said side circuits being periodically loaded for one cut-off and the phantom being periodically loaded for another cut-off, a terminating network for said quad including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a terminating shunt for each side circuit and a terminating shunt for the phantom, each side circuit shunt including capacity proportional to the capacity of a side circuit loading section, the phantom circuit shunt also including capacity proportional to the capacity of a phantom loading section, means common to said shunts to provide at least a portion of the capacity thereof, said means being so connected in the several shunts that the ratio of capacity in the phantom shunt to that in the side circuit shunt may be any value greater than 2 to 1 up to 4 to 1.

8. A transmission system comprising a quad of four conductors connected to form two side circuits and a phantom, said side circuits being periodically loaded for one cut-off and the phantom being periodically loaded for another cut-off, a terminating network for said quad including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a terminating shunt for each side circuit and a terminating shunt for the phantom, each side circuit shunt including capacity proportional to the capacity of a side circuit loading section, the phantom circuit shunt also including capacity proportional to the capacity of a phantom loading section, means common to said shunts to provide at least a portion of the capacity thereof, said capacity means being so connected in the several shunts that the capacity in the phantom shunt due to said means will be four times as great as the capacity in the side circuit shunt due to said means.

9. A transmission system comprising a quad of four conductors connected to form two side circuits and a phantom, said side circuits being periodically loaded for one cut-off and the phantom being periodically loaded for another cut-off, a terminating network for said quad including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a terminating shunt for

each side circuit and a terminating shunt for the phantom, each side circuit shunt including capacity proportional to the capacity of a side circuit loading section, the phantom circuit shunt also including capacity proportional to the capacity of a phantom loading section, means common to said shunts to provide at least a portion of the capacity thereof, said capacity means being so connected in the several shunts that the capacity in the phantom shunt due to said means will be any desired value up to four times as great as the capacity in the side circuit shunt due to said means.

10. A transmission system comprising a quad of four conductors connected to form two side circuits and a phantom, said side circuits being periodically loaded for one cut-off and the phantom being periodically loaded for another cut-off, a terminating network for said quad including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a terminating shunt for each side circuit and a terminating shunt for the phantom, each side circuit shunt including capacity proportional to the capacity of a side circuit loading section, the phantom circuit shunt also including capacity proportional to the capacity of a phantom loading section, means common to said shunts to provide at least a portion of the capacity thereof, said means including four condensers connected in bridge formation, connections leading from a pair of opposite points of said bridge to the conductors of one side circuit, and connections leading from the other pair of opposite points of said bridge to the conductors of the associated side circuit of the quad.

11. A transmission system comprising a quad of four conductors connected to form two side circuits and a phantom, said side circuits being periodically loaded for one cut-off and the phantom being periodically loaded for another cut-off, a terminating network for said quad including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a terminating shunt for each side circuit and a terminating shunt for the phantom, each side circuit shunt including capacity proportional to the capacity of a side circuit loading section, the phantom circuit shunt also including capacity proportional to the capacity of a phantom loading section, means common to said shunts to provide at least a portion of the capacity thereof, said means including four condensers connected in bridge formation, connections leading from a pair of opposite points of said bridge to the conductors of one side circuit, connections leading from the other pair of

opposite points of said bridge to the conductors of the associated side circuit of the quad, and coils in the connections leading to the side circuit conductors, said coils being non-inductive with respect to the phantom but producing inductance in the side circuit shunts proportional to the inductance in a side circuit loading section.

12. A transmission system comprising a quad of four conductors connected to form two side circuits and a phantom, said side circuits being periodically loaded for one cut-off and the phantom being periodically loaded for another cut-off, a terminating network for said quad including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a terminating shunt for each side circuit and a terminating shunt for the phantom, each side circuit shunt including capacity proportional to the capacity of a side circuit loading section, the phantom circuit shunt also including capacity proportional to the capacity of a phantom loading section, means common to said shunts to provide at least a portion of the capacity thereof, said means comprising four condensers connected in bridge formation, connections leading from a pair of opposite points of said bridge to the conductors of one side circuit, connections leading from the other pair of opposite points of said bridge to the conductors of the associated side circuit of the quad, coils in the connections leading to the side circuit conductors, said coils being non-inductive with respect to the phantom but producing inductance in the side circuit shunts proportional to the inductance in a side circuit loading section, and additional coils in the connections leading to the side circuit conductors, said coils being non-inductive with respect to the side circuits but producing inductance in the phantom proportional to the inductance of a phantom loading section.

13. A transmission system comprising a quad of four conductors connected to form two side circuits and a phantom, said side circuits being periodically loaded for one cut-off and the phantom being periodically loaded for another cut-off, a terminating network for said quad including phantom circuit and side circuit loading coils having values which are fractional parts of the regular full weight loading coils of the quad, in combination with a terminating shunt for each side circuit and a terminating shunt for the phantom, each side circuit shunt including capacity proportional to the capacity of a side circuit loading section, the phantom circuit shunt also including capacity proportional to the capacity of a phantom loading section, means common to said shunts to provide at least a portion of the capacity

thereof, said means including four condensers connected in bridge formation, connections leading from a pair of opposite points of said bridge to the conductors of one side circuit, connections leading from the other pair of opposite points of said bridge to the conductors of the associated side circuit of the quad, and an additional pair of condensers bridged across opposite points of said bridge so as to be effective in the side circuit and ineffective in the phantom.

14. A transmission system including a loaded quad having side circuits and a phantom, smooth lines adapted to be connected to said side circuits and phantom, and an impedance correcting network interposed between the smooth lines and said loaded lines, said network being so proportioned and connected as to make the impedance looking into the loaded line substantially the same as that looking into the smooth line when the side circuits of the loaded quad are loaded to transmit frequencies several times as high as those transmitted by the phantom.

In testimony whereof, I have signed my name to this specification this 20th day of August, 1930.

BENJAMIN F. LEWIS.