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E. I. GREEN

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COUPLING BETWEEN CARRIER AND TRANSMISSION LINES

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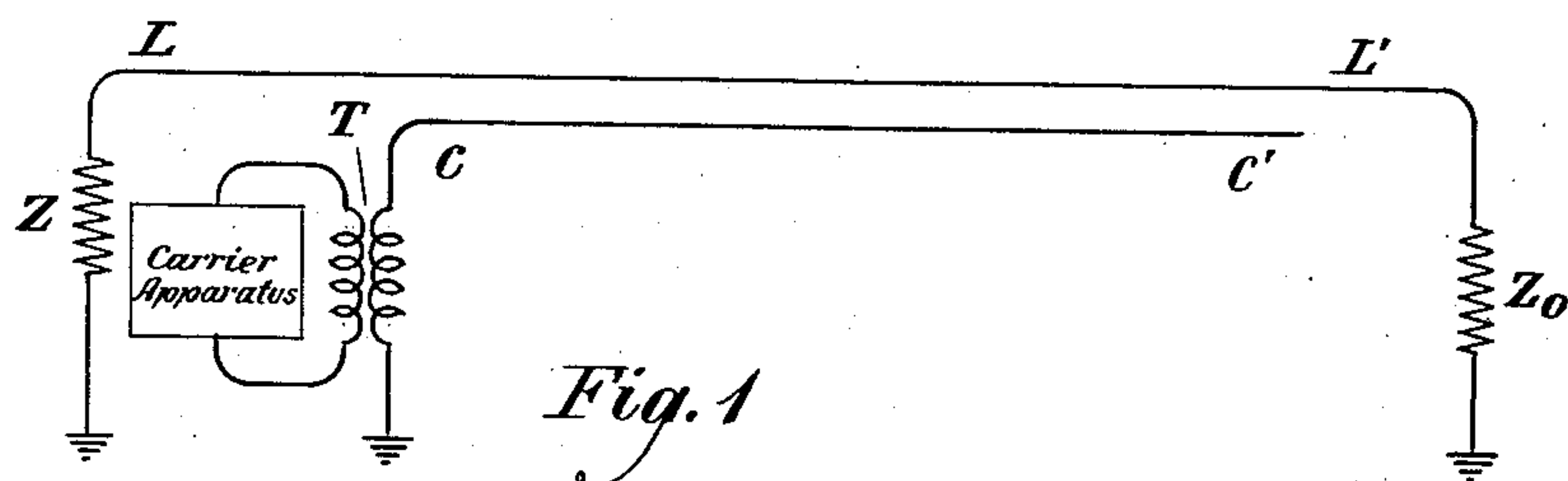


Fig. 1

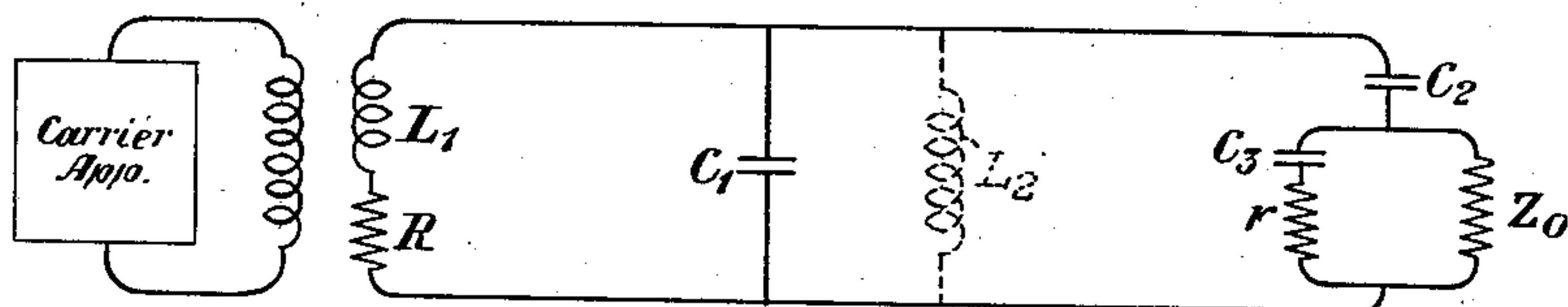


Fig. 2

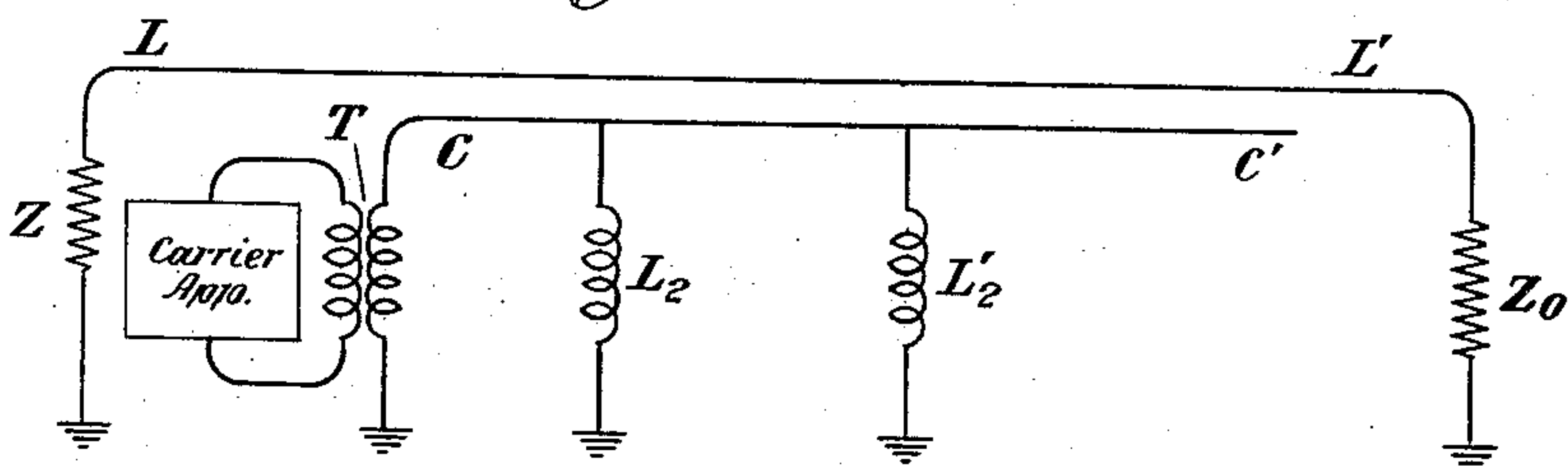


Fig. 3

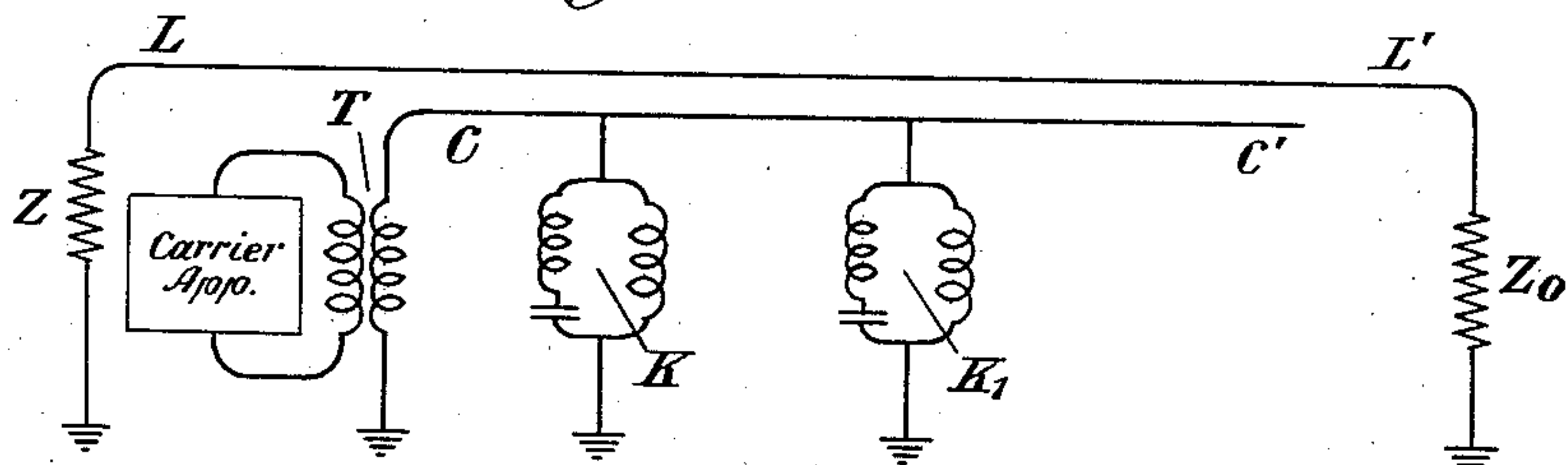


Fig. 4

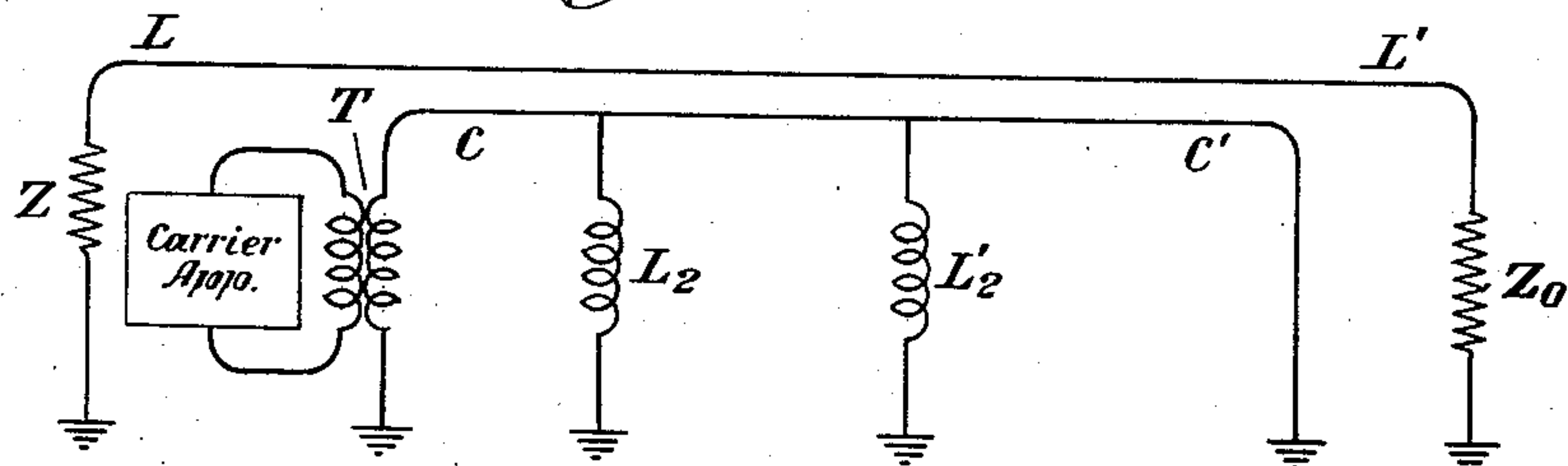


Fig. 5

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COUPLING BETWEEN CARRIER AND TRANSMISSION LINES

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This invention relates to transmission lines and more particularly to arrangements for improving the efficiency of coupling between carrier apparatus and transmission lines.

The arrangements of the invention are particularly applicable to cases where it is impossible or undesirable to associate carrier apparatus directly with the line circuit over which the carrier transmission is accomplished, and where some form of coupling device such as a loop or antenna must therefore be employed. Such cases frequently arise in connection with power line carrier systems, in many of which a coupling antenna or loop is employed in order to separate the carrier apparatus from the high voltage on the power lines. A further field of application for the arrangements of the invention may be in connection with carrier systems for communication with moving vehicles, such as trains, where it is impossible to connect the carrier apparatus directly to the transmission line.

It has been found that coupling devices, such as a loop or antenna, utilized in arrangements of the above type will ordinarily have considerable capacity to ground, and, when transmitting to a ground return circuit or to a metallic wire circuit which has appreciable capacity to ground, this capacity of the coupling device will constitute a source of loss. It is the primary object of the arrangements of this invention to utilize loading to raise the impedance of the coupling device to ground, thereby annulling the undesired effect of this capacity to ground and greatly increasing the efficiency of the coupling device. Other objects, features, and applications of the invention will appear more fully from the detailed description hereinafter given.

The invention may be more fully understood from the following description together with the accompanying drawings in the Figures 1, 2, 3, 4 and 5 of which the invention is illustrated. In Fig. 1 is shown a power line having carrier apparatus coupled thereto. Fig. 2 is a schematic equivalent of Fig. 1. In Fig. 3 is shown carrier

apparatus coupled to a power line with the arrangements of this invention. Figs. 4 and 5 illustrate modifications of the invention. Similar reference characters have been utilized to denote like parts in all of the figures.

A common method of coupling carrier apparatus to a power line is shown schematically in Fig. 1. The carrier apparatus is connected through a suitable transformer T to a coupling wire or antenna CC', whereby the carrier current may be transmitted to the power line LL' by electrostatic induction. The power line LL', which will ordinarily consist of several wires, is shown as terminating at the sending end in the impedance to ground, shown as Z, of the transformer which supplies power to the wires LL'. At the distant end the power line may be assumed for a long line at carrier frequencies to be terminated in the characteristic impedance to ground Z_0 . For practical purposes, this characteristic impedance Z_0 becomes at carrier frequencies a pure resistance.

In Fig. 2 is shown the approximate equivalent of the arrangements shown in Fig. 1. The impedance looking back into the transformer T is shown as consisting of the inductance L, and resistance R. The capacity of the coupling wire to the power wires is shown as C_2 , the capacity of the coupling wire to ground is shown as C_1 , and the power transformer impedance to ground Z is shown as a capacity C_3 , with a loss, ordinarily small, represented by r .

For the circuit of Fig. 2 the efficiency is the ratio of the power utilized in Z_0 to the total power delivered to the circuit. Neglecting for the moment the power transformer capacity and loss, it can be shown that to obtain maximum efficiency the following three conditions should be fulfilled.

First,

$$R = Z_0 \quad (1)$$

where R is the resistance component looking into the transformer T, and Z_0 is the characteristic impedance of the power wire to ground. In other words, the resistance components of the impedance of the generating

device and of the load impedance should be matched.

Second,

$$L_1\omega = \frac{1}{C_2\omega} \quad (2)$$

where ω is equal to 2π times the frequency at which maximum efficiency is desired. This would amount to annulling the reactances, or in other words, properly tuning the circuit arrangement for the working carrier frequency. It may be pointed out that the principles embodied in the above two conditions are well known with respect to circuits in general. Thus it is generally stated that the maximum power is delivered from the terminals of a generating device which has a given generated voltage and a fixed internal resistance and reactance when the external resistance equals the internal resistance, and the external reactance is equal to the internal reactance but of opposite sign. However, the special application of these principles in order to materially increase the efficiency of the coupling in a circuit similar to that of Fig. 2 has not been previously pointed out.

The third condition for maximum efficiency is that an additional inductance L_2 (shown in dotted lines) should be connected in parallel with C_1 , and that L_2 should be chosen so that

$$L_2\omega = \frac{1}{C_1\omega} \quad (3)$$

The fulfillment of the third condition, which involves the use of means not shown in Fig. 1 to obtain an anti-resonant circuit between the coupling wire and ground, is one of the primary objects of this invention. The power transformer capacity which was neglected may have some slight effect on the validity of the first two conditions, but can have none of the third. From a physical standpoint the third condition amounts to giving the coupling wire a very high impedance to ground so that most of the energy will choose the low impedance path to the power line. This high impedance to ground is obtained by loading the coupling wire with one or more inductance elements, such as L_2 and L_2' as shown in Fig. 3. The spacing of the load points may be determined in the usual manner, depending on the frequency employed. For the ordinary coupling wire, which is electrically short, one or two loading coils or networks should be sufficient. The idea is to make the critical frequency of the loading the same as the operating frequency of the carrier apparatus. Where more than one coupling wire is used, each one should be loaded.

In case it is desired to connect two sets of carrier apparatus operating at different frequencies to the coupling wire it might be de-

sirable to utilize the loading arrangements shown in Fig. 4. In this case two loading networks, such as K and K_1 , would be connected to the coupling wire. The constants of these networks would be chosen so as to give two different points of anti-resonance with the wire capacity.

Another method of coupling, in which the coupling wire CC' is grounded at the distant end, is shown in Fig. 5. This is obviously a type of electromagnetic induction, in contrast to the electrostatic method heretofore illustrated. Here the effect of the capacity of the coupling wire to ground will be to shunt off the current, and the efficiency of the arrangement will be improved by raising the impedance to ground so that all the current enters the ground at C' . This is accomplished as heretofore explained by the loading devices L_2 and L_2' . Coupling devices which utilize a combination of electrostatic and electromagnetic coupling may be similarly loaded.

The same general plan of loading may be applied to other arrangements differing from those described. For example, when a metallic loop is used instead of a "ground wire" loop the capacity of the loop will still introduce loss which can be eliminated by loading. Likewise, when the coupling is made with a metallic circuit on the transmission line this circuit will have considerable capacity to ground, so that it is still advantageous to eliminate the effect of the capacity of the coupling device to ground. In every case the loading is entirely independent of other expedients, such as tuning the coupling device, matching impedance, etc., which are also employed to improve the efficiency of the system for a particular frequency or frequencies. Accordingly, while the invention has been described as embodied in certain specific arrangements which are deemed desirable, it is understood that it is capable of embodiment in many and other widely varied forms without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. A transmission line, carrier apparatus, a coupling device associated with said carrier apparatus and said line whereby carrier currents may be superimposed on said line from said carrier apparatus, means for raising the impedance to ground of said coupling device at substantially the carrier frequencies utilized, and means in said coupling device for so adjusting the impedance of the carrier source that it shall be equal in magnitude and of an equal but opposite angle to the impedance looking from the coupling device into the transmission line.

2. A transmission line, carrier apparatus, a coupling device associated with said carrier apparatus and said line whereby carrier cur-

rents may be superimposed on said line from said carrier apparatus, means for raising the impedance to ground of said coupling device at substantially the carrier frequencies utilized, and means in said coupling device for so adjusting the impedance of the carrier source with respect to the impedance looking from the coupling device into the transmission line that the resistance components of the two impedances are substantially equal and the reactance components of the two impedances are substantially equal in magnitude but of opposite sign.

In testimony whereof, I have signed my name to this specification this 1st day of November 1926.

ESTILL I. GREEN.