

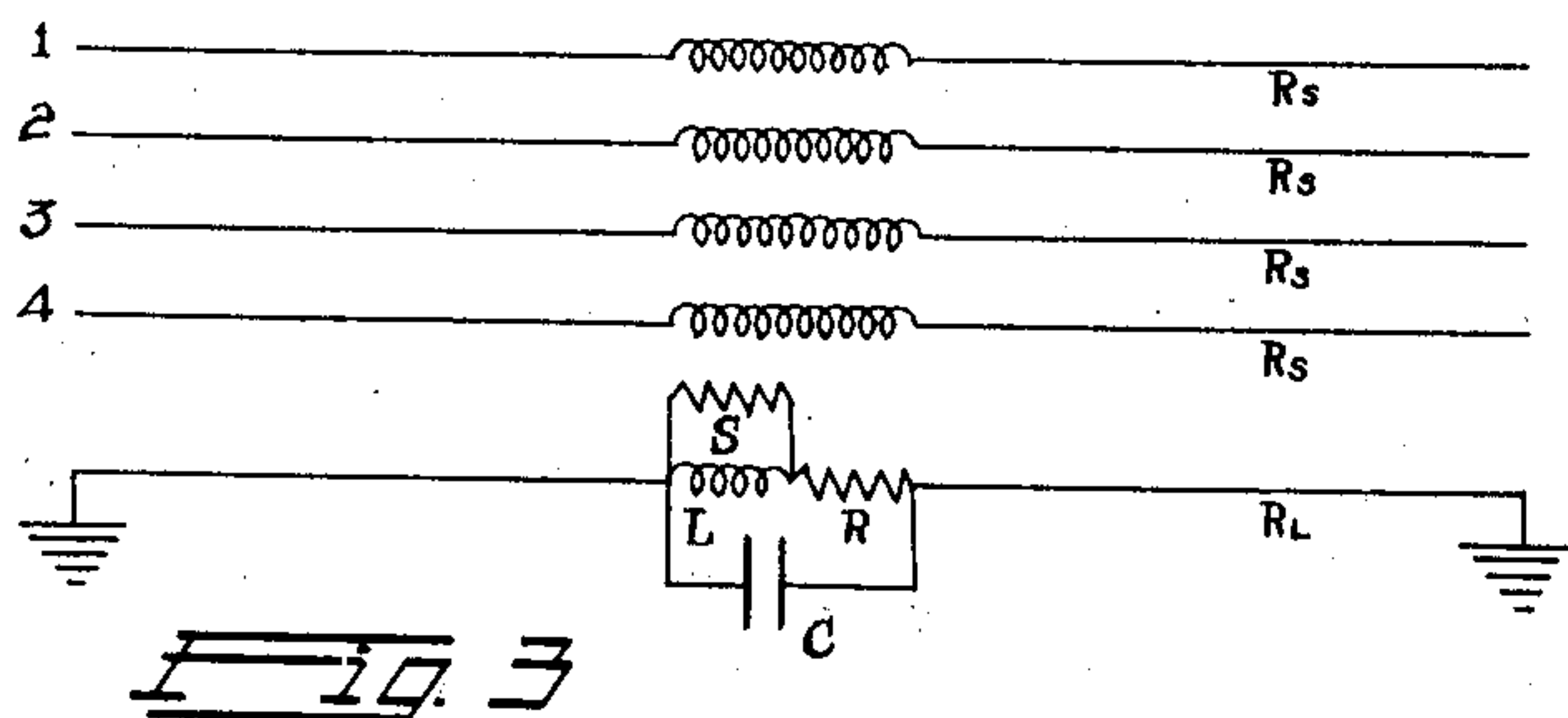
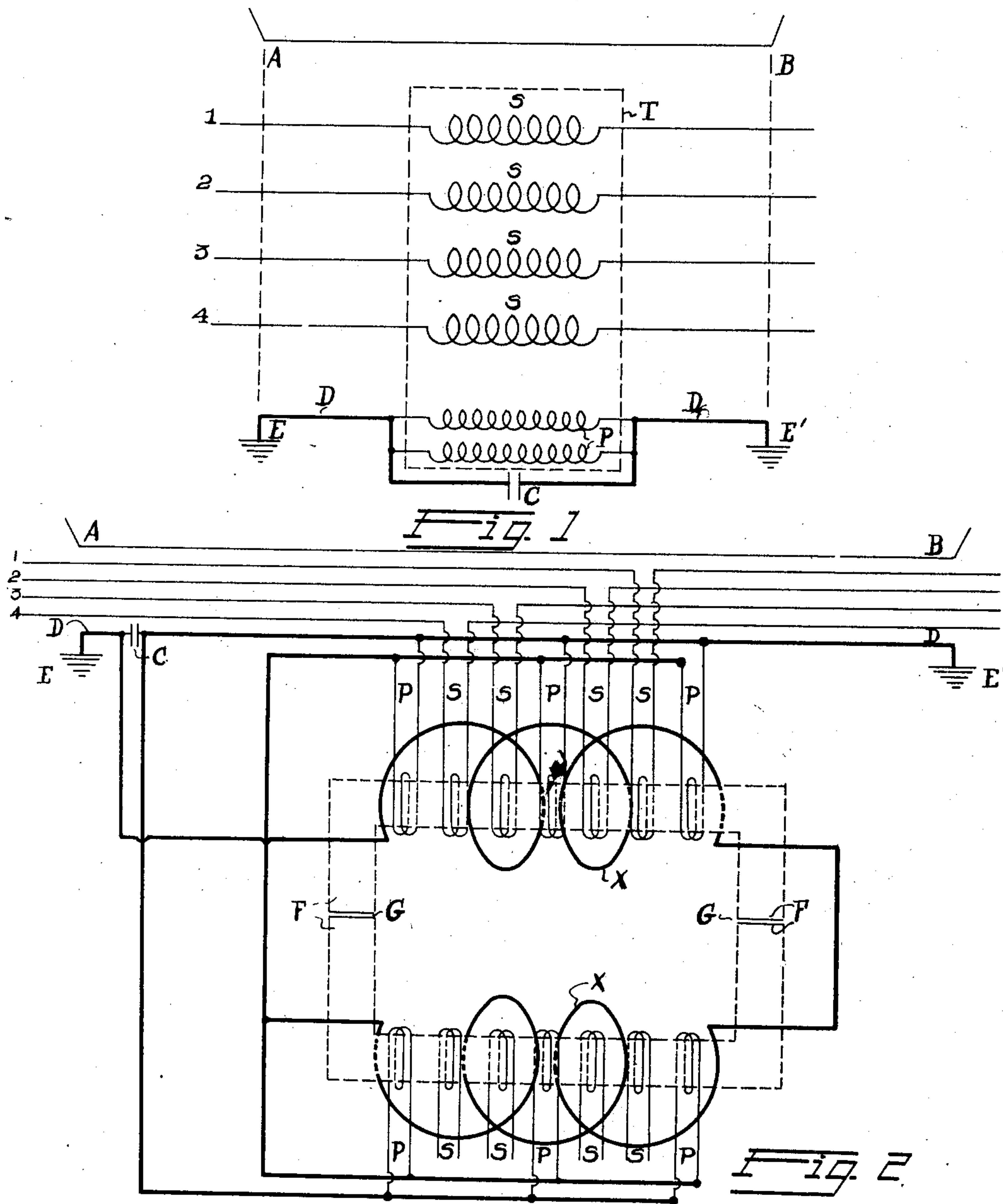
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NEUTRALIZING INTERFERING DISTURBANCES IN ELECTRIC CIRCUITS

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NEUTRALIZING INTERFERING DISTURBANCES IN ELECTRIC CIRCUITS.

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This invention relates to means for neutralizing interference between adjacent transmission circuits, and in particular to means for protecting intelligence transmission circuit from disturbing influences of adjacent circuits.

My invention is embodied in a system in which a neutralizing current is induced in an auxiliary circuit which parallels the circuits to be protected, and neutralizing voltages, equal and opposite to the disturbing voltages, are introduced into the circuits to be protected by an inductive coupling between these circuits and the auxiliary circuit.

One of the objects of my invention is to provide an improved form of transformer for coupling the auxiliary circuit to the circuits to be protected.

Another object of my invention is to provide simple and efficient means for adjusting the phase angle between the disturbing voltage and the neutralizing voltage to the proper value.

Still another object of my invention is to devise a neutralizing system in which the cross-fire between adjacent circuits to be protected is reduced to a minimum.

A further object of my invention is to provide a neutralizing system in which the detrimental effect of ground currents, or direct current, flowing in the auxiliary circuit is substantially eliminated.

My invention is illustrated in the accompanying drawings in which:—

Figure 1 is a diagrammatic showing of the neutralizing transformer and its circuit connections.

Figure 2 shows the manner of arranging the primary and secondary coils upon the transformer core and other details of the transformer construction.

Figure 3 is an equivalent circuit diagram useful in explaining the invention.

In the drawing, 1, 2, 3 and 4 represent four communication wires which are to be protected against inductive disturbances caused by an adjacent transmission circuit carrying disturbing currents. The disturbing circuit

exposure is shown extending between points A and B. This circuit may be a power line carrying alternating current or a telegraph line, or any other circuit carrying varying or alternating currents.

The neutralizing transformer is indicated at T, the primary windings of which are connected in parallel in the auxiliary circuit and a secondary coil is connected in each of the communication wires. Single coils may be used for communication circuits consisting of a single wire, while coils consisting of a plurality of windings, suitably associated, may be used for communication in circuits consisting of a plurality of wires, such as a telephone pair or phantom. The auxiliary circuit consists of a very low resistance wire D extending throughout the length of the disturbing circuit exposure A—B and is provided at each end with low resistance ground connections E and E'. The wire D is arranged in close proximity to the communication wires and in such manner that it has induced therein disturbing currents similar to those induced in the communication wires.

Through the action of transformer T, the disturbing currents flowing in the auxiliary circuit induce voltages in the communication wires equal and opposite to the disturbing voltages directly induced from the exposure A—B. In this manner the disturbances induced in the communication wires are neutralized. An adjustable condenser C is connected across the primary winding of the neutralizing transformer for the purpose of adjusting the phase angle of the neutralizing current to cause proper neutralization. If desired, condensers may be used across the secondary windings of the transformer, and telephonic transmission over the communication wires will be somewhat improved due to the by-pass afforded by the condensers to telephone currents.

The conditions necessary for proper neutralization are as follows:—The fundamental requirement is that the neutralization shall be as complete as possible. Referring to Fig. 3, it may be readily shown that the induc-

tion is completely neutralized both in magnitude and phase if,

$$p\left(1 + \frac{R + R_L}{S} + \frac{CRR_L}{L}\right) = 1 \quad (1)$$

and

$$\frac{CL\omega^2\left(1 + \frac{R}{S}\right)}{1 + \frac{R}{R_L}} = 1, \quad (2)$$

where

L = self inductance of primary circuit of transformer.

R = resistance of primary circuit of transformer.

S = resistance to simulate core losses in primary coil.

p = ratio; number primary turns/number secondary turns.

R_L = resistance of primary wire.

$\omega = 2\pi \times$ frequency.

R_s = resistance of each secondary circuit.

n = number of secondary circuits.

C = total capacitance across primary circuit or secondary coils of transformer.

$j = \sqrt{-1}$

In a commercial transformer R is small, and these become approximately,

$$p\left(1 + \frac{R_L}{S}\right) = 1 \quad (3)$$

$$CL\omega^2 = 1 \quad (4)$$

These formulæ show that (with limitations given later) it is readily possible to neutralize the induced alternating voltage correctly, since most of the values in the formulæ may be controlled in the design of the system.

It was formerly customary to design transformers with a fixed value of p , then to adjust the value of R_L to suit. However, as shown later herein, it is desirable that R_L be as low as economically practicable, and after considerable investigation I discovered that the number of primary turns must be adjusted accurately in order to obtain maximum efficiency. I also found that it is not feasible to design a transformer with the correct number of turns before installation, but the arrangement must be such that the number of turns can be accurately adjusted in the field. The procedure adopted is to construct the transformer with the primary coils in permanent form having the number of turns which is most likely to be used under various conditions, and at the time of installation to add or subtract magnetically from the fixed turns by winding additional turns over the coils, the added turns being connected in the primary circuit in a manner either to oppose or assist the fixed turns as the case may require. The extra turns wound over the fixed coils are indicated at X in

Fig. 2. Early transformers usually had a value of p in the neighborhood of 0.85; I have found it advisable to use a value of p equal to 0.98 to 0.99.

It was formerly customary for a transformer to have a closed iron magnetic circuit. Such a transformer has a value of L which changes considerably, according to the value of the induced voltage which it is called upon to neutralize. (It is understood that in an exposure to induction, the value of induction is not ordinarily steady, but varies from time to time through wide limits, at times becoming zero.) Moreover, the secondary coils of a transformer carry telegraph currents at various frequencies from zero up to the working speed of the circuit. In addition, the primary circuit is liable to have stray direct currents flowing in it by conduction from neighboring D. C. trolley systems, if there are any within a few miles; this is especially likely to happen if R_L is low (see next section). The presence of telegraph currents in the secondaries, and the presence of stray direct currents in the primary coils, both tend partly to magnetize the core of the transformer, which tends to change the value of L . Any change in the value of L causes the neutralization of the induction to be less efficient. (See Equation 4.) (C is set at a final value at time of installation). These effects are all largely reduced by placing a suitable air gap in the magnetic circuit of the transformer. The air gap, of course, reduces the value of L ; this is compensated for by increasing the value of C . It is preferable that the gap be arranged so that at the time of installation it may be adjusted in length if desired, as this assists in obtaining the value of L which best suits the particular conditions applying at a given transformer.

The effect of the air gap in the magnetic circuit is to increase the reluctance, make it more constant throughout the range of flux densities used, and to prevent saturation of the iron, thereby rendering the induction practically proportional to the inducing force. Due to the variable reluctance, and therefore the variable value of L , of a transformer having a closed iron magnetic circuit it has not heretofore been found practicable to use phase shifting devices for adjusting the phase of the neutralizing current, however, the transformer of my invention has practically a constant value of L and I am thereby enabled to use effectively a shunt condenser as a phase controlling device. It is obvious that the air gap might be formed by a single gap, or by two or more gaps at different parts of the magnetic core; or by employing a core made of iron dust or other divided magnetic materials, which provides multiple air gaps throughout the material.

Referring to Fig. 2, F indicates the iron core of the neutralizing transformer which

is divided into two portions by air gaps G. The two core portions are adjustably held in proper spaced relation by suitable clamping means in order that the length of gaps G may be adjusted to the proper value. From Fig. 2 it will be seen that the primary of the transformer comprises several windings P sandwiched between secondary windings S at frequent intervals along the entire core, the primary windings being connected in parallel in the auxiliary circuit. The extra turns X are wound with heavy wire, and connected in series with regular turns P; all primary turns being in parallel with condenser C and directly in series with wire D.

The most severe limitation to the efficiency of a transformer is the tendency of the transformer to cause crossfire, or interference between the various communication circuits carried through the secondary coils. Let it be assumed that one communication circuit is carrying a current I of frequency $\frac{\omega}{2\pi}$. Then it may be shown (neglecting R) that a voltage E is induced in each of the other secondary coils, having the value

$$E = \frac{I}{\frac{n-1}{R_s} + \frac{p^2}{S} + \frac{p^2}{R_L} + jp^2 \left(C\omega - \frac{1}{L\omega} \right)} \quad (5)$$

It is apparent that the value of E reaches a maximum when the telegraph frequency happens to be the same as the power system frequency for which the transformer is designed. Under these conditions, the imaginary term becomes zero, and the value is

$$E = \frac{I}{\frac{n-1}{R_s} + \frac{p^2}{S} + \frac{p^2}{R_L}} \quad (6)$$

Substituting the value or p as calculated from (3), this becomes

$$E = \frac{I}{\frac{n-1}{R_s} + \frac{S}{R_L^2 + R_L S}} \quad (7)$$

In the following table are given a series of values of E, for various values of R_L . For this calculation the value of S has been taken at 1000; the value of R_s at 2500, and the value of n at 20. These figures represent average conditions in practice.

R_L	E
5	4.8 I
10	9.3 I
20	17.7 I
40	31.7 I
100	60.0 I
200	85.0 I
400	106.5 I
1000	123.5 I
2000	128.8 I

From the above it is apparent that the crossfire can be very materially reduced by

using a low value of primary wire resistance R_L , preferably not more than about 15 ohms. If the length of the exposure is say 20 miles, this requires a primary wire of conductivity equivalent to No. 1 B. & S. gauge. This condition represents a radical change from previous practice, in which it was customary to use for the primary a circuit having from 50 to 100 ohms.

It is readily apparent that for given line conditions and a certain permissible value of E, the correct value of the resistance R_L of the auxiliary circuit may be determined from Equation (7) above.

While I have described my invention in detail and worked out one specific example, it is for the purpose of explanation and not by way of limitation, and I do not intend to be limited as to details except as pointed out in the claims.

What I claim is:

1. In combination, two circuits located in a disturbing magnetic field, a transformer having its primary winding connected in one circuit and its secondary winding in the other, said transformer having a magnetic circuit of substantially uniform reluctance whereby the induction is substantially proportional to the inducing current, and an adjustable condenser connected across one of said windings for adjusting the phase relation between the disturbing voltage and the neutralizing voltage induced in one of said windings.

2. In combination, a plurality of communication circuits located in a disturbing magnetic field, an auxiliary circuit adjacent the communication circuits, a transformer coupling said auxiliary circuit to the communication circuits whereby the disturbing voltages are neutralized by voltages induced from the auxiliary circuit, said auxiliary circuit having an abnormally low resistance as compared with the resistance of a communication circuit whereby cross-fire between the communication circuits is substantially eliminated.

3. In a system for neutralizing disturbing voltages in a communication line in which the neutralizing voltages are induced into the line from an auxiliary circuit by a neutralizing transformer having a condenser connected across one of its windings, the method of securing proper neutralization which consists in varying the ratio of turns of the primary to the secondary to satisfy the equation

$$p \left(1 + \frac{R_L}{S} \right) = 1$$

and in varying the capacity of the condenser to satisfy the equation

$$CL\omega^2 = 1.$$

4. In a system for neutralizing disturbing voltages in a communication line in which

the neutralizing voltages are induced in the line from an auxiliary circuit by a neutralizing transformer, the method of securing proper neutralization which consists in varying the effective ratio of turns of the primary to the secondary by adding turns in series with the primary to assist or oppose the primary to satisfy the equation

$$p\left(1 + \frac{R_L}{S}\right) = 1$$

5. In a system for neutralizing disturbing voltages in communication lines in which the neutralizing voltages are induced into the lines from an auxiliary circuit by a neutralizing transformer, the method of securing proper neutralization and reducing the cross-fire between the lines to a permissible value E which consists in adjusting the constants of the elements of the system to satisfy the equation

$$E = \frac{I}{\frac{n-1}{R_s} - \frac{S}{R_L^2 + R_L S}}$$

6. In combination, in communication circuits, each circuit having a resistance R_s , one of said circuits carrying a current I, an auxiliary circuit, a transformer having a primary winding connected in said auxiliary circuit and having an equivalent core loss resistance S in said auxiliary circuit, and secondary windings connected in each of said communication circuits, said auxiliary circuit having a resistance R_L of such value that the voltage induced in adjacent communication circuits by the current I does not exceed a permissible value E, said resistance being determined from the equation

$$E = \frac{I}{\frac{n-1}{R_s} + \frac{S}{R_L^2 + R_L S}}$$

7. In combination, two circuits located in a

disturbing magnetic field, a transformer having its primary winding connected in one circuit and its secondary winding in the other, said transformer having a magnetic circuit of substantially uniform reluctance.

8. In combination, two circuits located in a disturbing magnetic field, a transformer having a winding connected in each circuit, said transformer having a core of magnetic material with one or more air gaps in the magnetic circuit, and an adjustable condenser connected across one or more of said windings for adjusting the phase relation of the neutralizing voltage and disturbing voltage.

9. In combination, a plurality of communication circuits located in a disturbing magnetic field, an auxiliary circuit adjacent to the communication circuits, a transformer having a core of substantially uniform reluctance and having a plurality of windings, one winding connected in each of said circuits, and a condenser or condensers connected across one or more of said windings whereby the phase relation of the neutralizing voltage and disturbing voltage may be adjusted.

10. In combination, a plurality of communication circuits located in a disturbing magnetic field, an auxiliary circuit adjacent to the communication circuits, said auxiliary circuit having an abnormally low resistance as compared with the resistance of the communication circuits whereby the creation of cross-fire among the communication circuits is substantially avoided, a transformer coupling said auxiliary circuit to the communication circuits, said transformer having a magnetic circuit of substantially uniform reluctance whereby the neutralizing voltage in the communication circuits is substantially proportional to the inducing current in said transformer.

In testimony whereof I affix my signature.

JOSEPH W. MILNOR.