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2,075,920

SHIELDING SYSTEM

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FIG. 1

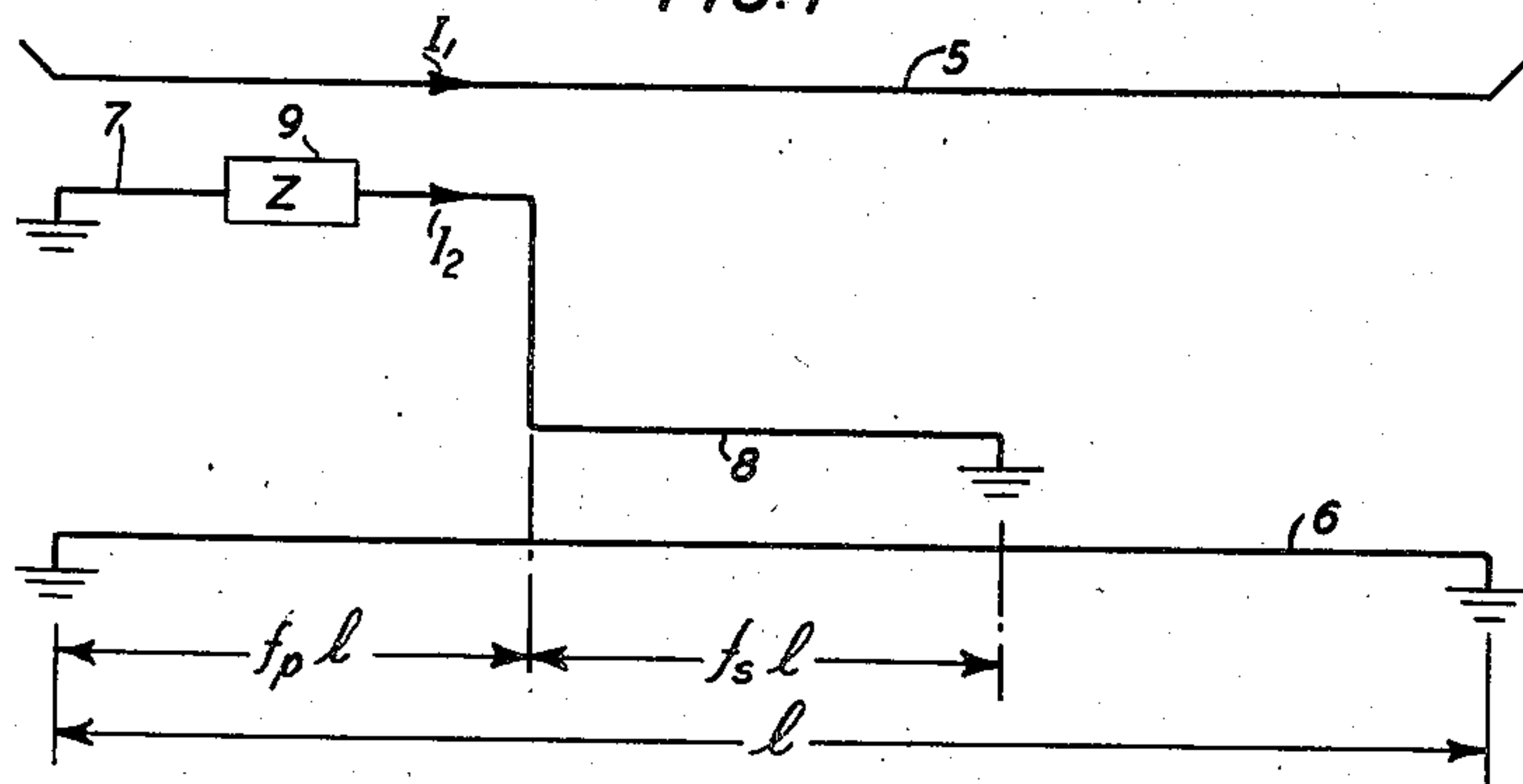


FIG. 2

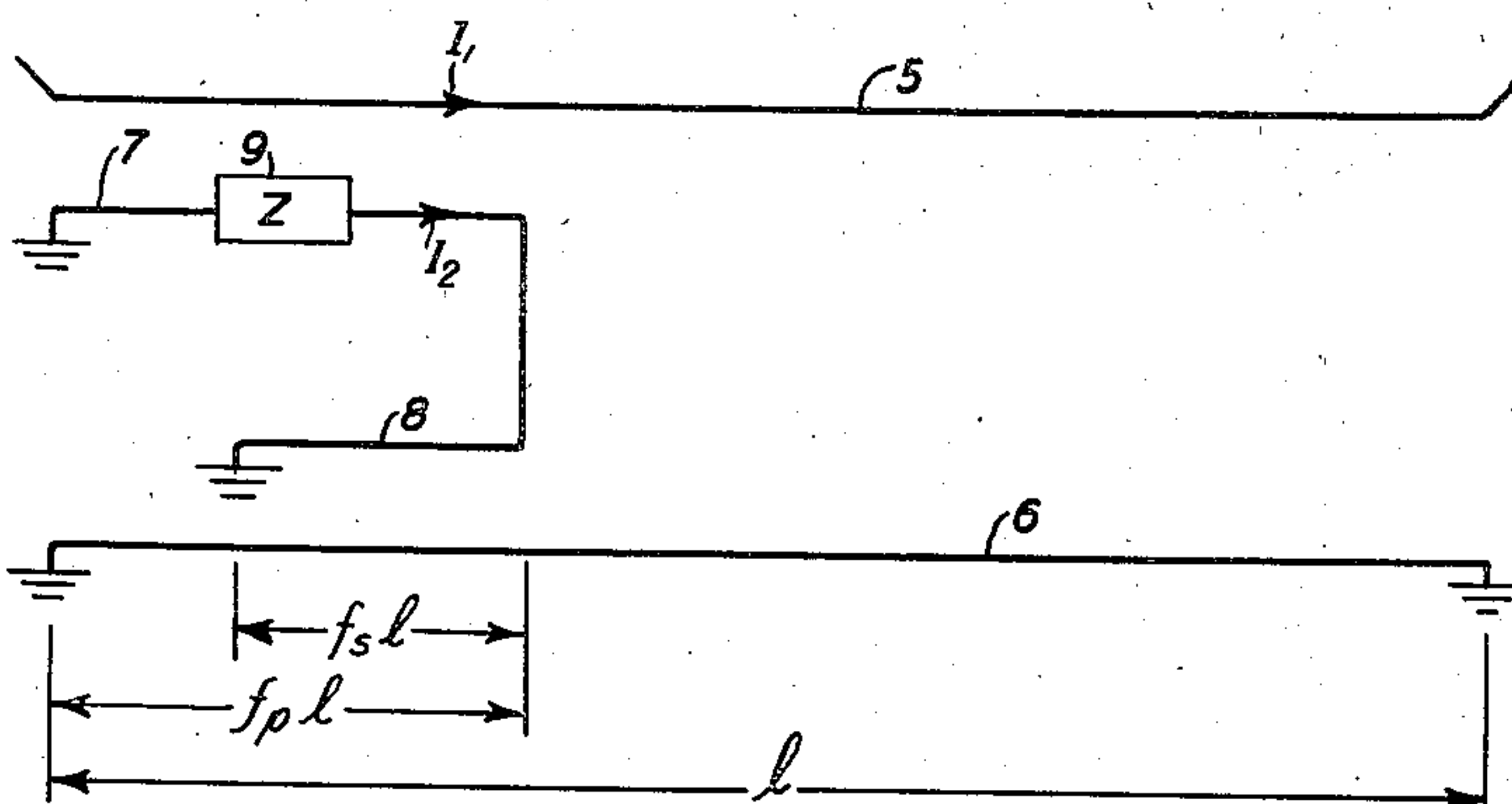
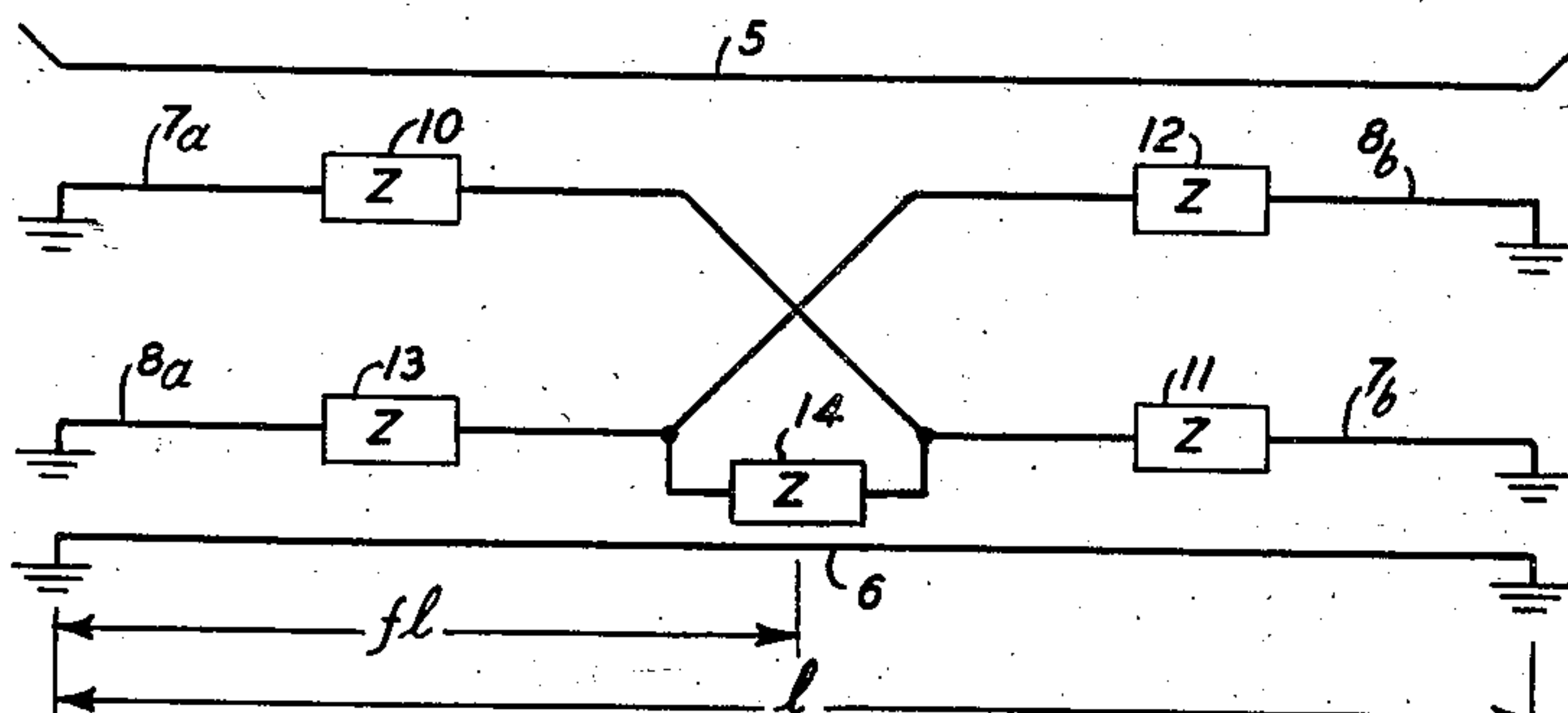


FIG. 3



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SHIELDING SYSTEM

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12 Claims. (Cl. 171—97)

This invention relates to shielding systems and more particularly to systems for shielding intelligence transmitting lines from inductive interference by a power line disposed in the vicinity thereof.

In the construction of intelligence transmitting lines, such as lines for telephone or telegraph systems, it is sometimes necessary or expedient that such lines be erected in proximity to a power line throughout a material distance. As a result of such positioning of the telephone or telegraph lines, a longitudinal inductive effect obtains as a consequence of which undesirable disturbances are produced on the telephone or telegraph lines so that unfaithful transmission over these lines follows and hazardous voltages may appear in these lines.

One object of this invention is to effectively shield a telephone or telegraph line from a power line in proximity thereto. More specifically an object of this invention is to completely shield a telephone or telegraph line against longitudinal induction from a nearby power line.

In one illustrative embodiment of this invention, a shielding system comprises a conductor grounded at opposite ends, the conductor extending adjacent the power line through a part of the inductive exposure and then being transferred or transposed to a position adjacent the telephone or telegraph line. The two portions of the conductor, that is the portion adjacent the power line and the portion adjacent the telephone or telegraph line, may extend in the same direction or one may be reversed so that the two extend in opposite directions. A suitable adjustable series impedance may be provided in one or both portions of the shielding conductor to obtain a desired phase angle for the induced current in the shielding system.

The invention and the various features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing, in which:

Figure 1 is a diagrammatic view of a power line and a telephone line shielded therefrom in accordance with this invention;

Fig. 2 is another diagrammatic view showing another shielding system illustrative of this invention wherein the two portions of the shielding system extend in opposite directions; and

Fig. 3 shows diagrammatically another shielding system illustrative of this invention which

includes a pair of shielding conductors each connected to ground at the ends thereof.

Referring now to the drawing, in each of the several figures there is illustrated a disturbing circuit 5, such for example as a power line, and a disturbed circuit 6, such as a telephone or telegraph line. The two lines 5 and 6 are positioned in the vicinity of each other, and may be substantially parallel, so that they form an inductive exposure of a length designated as l . The disturbed line 6 may be connected to ground as indicated. The disturbing line may have an alternating current I_1 flowing there-through.

As is known in the art, when a telephone or telegraph line is in the vicinity of a power line, the former line may be subjected to highly undesirable longitudinal induction as the result of electromagnetic fields produced by currents flowing in the power line. Such induction, of course, deleteriously affects the transmission characteristics of the telephone or telegraph line so that high fidelity transmission is not attainable. Furthermore, such induction produces, particularly at fundamental frequencies, voltages in the telephone or telegraph line which may be sufficiently great to be hazardous. In accordance with this invention a shielding system is provided adjacent the exposure between the disturbing and disturbed circuits and so designed that the telegraph or telephone line is substantially completely shielded against longitudinal induction whereby disturbances in the telegraph or telephone line are prevented so that the production of hazardous voltages in this line is prevented and also constant transmission characteristics are obtained.

In one illustrative form shown in Fig. 1, a shielding system in accordance with this invention comprises a conductor grounded at opposite ends and having a portion 7 extending adjacent the power line 5 for a distance $f_p l$ and a transposed portion 8 extending adjacent the telephone or telegraph line 6 for a distance $f_s l$. The remainder of the exposure between the disturbing and disturbed lines, then is $(1 - f_p - f_s) l$. As a result of the spacial relation of the shielding conductor 7, 8 and the power line 5, there will be induced in the shielding conductor a current I_2 which will tend to counteract the magnetic field in the exposure attributable to the current I_1 flowing in the power line. An adjustable concentrated impedance 9, which may be resistive, inductive or capacitive or any combination of these, is connected in series with the

shielding conductor 7, 8, and may be utilized to vary the magnitude and phase angle of the current flowing in the shielding system. The counteracting or neutralizing effect of this induced current I_2 will be dependent upon a number of factors among the most important of which are the physical and electrical parameters of the shielding system. The magnitude of such parameters necessary to provide substantially perfect shielding may be ascertained as indicated hereinafter.

In accordance with Kirchhoff's law, the electromotive forces around the shielding and disturbed circuits may be expressed respectively as

$$I_2 Z_{77} (f_p + f_s) l + I_1 (Z_{57} f_p + Z_{58} f_s) l = 0 \quad (1)$$

and

$$V_4 = I_1 Z_{56} l + I_2 (Z_{76} f_p + Z_{86} f_s) l \quad (2)$$

where

V_4 is the terminal voltage of the disturbed line 6,

Z_{nm} is the mutual impedance per unit length, and

Z_{77} is the self-impedance per unit length of the shielding circuit including the resistance of the ground connections at the ends of the telephone or telegraph line and the concentrated series impedance 9.

The shield factor η may be ascertained by solving Equation (1) for I_2 , substituting the value thus obtained in Equation (2), and dividing by $I_1 Z_{56} l$. Hence

$$\eta = 1 - f_p \frac{(Z_{57} + v Z_{58})(Z_{76} + v Z_{86})}{(1 + v) Z_{56} Z_{77}} \quad (3)$$

where

$$v = \frac{f_s}{f_p}$$

In accordance with the method described by C. W. Carter in his article "Graphic Representation of the Impedance of Networks Containing Resistances and Two Reactances", The Bell System Technical Journal, July 1925, Equation (3) may be written as

$$\eta = 1 + \frac{F_+}{2 R_{77}} + \frac{F_-}{2 R_{77}} \frac{R_{77} - j X_{77}}{R_{77} + j X_{77}} \quad (4)$$

or

$$\eta = 1 - \frac{j F_+}{2 X_{77}} + \frac{j F_-}{2 X_{77}} \frac{R_{77} - j X_{77}}{R_{77} + j X_{77}} \quad (5)$$

where

$$F_+ = -f_p \frac{(Z_{57} + v Z_{58})(Z_{76} + v Z_{86})}{(1 + v) Z_{56}} \quad (6)$$

This form of the equation enables the construction of simple graphs for the determination of the shield factor for various values of shield wire resistance and reactance, the other factors being constant.

In order to obtain perfect shielding, the shield factor η should be zero. Accordingly, solving Equation (3) with $\eta = 0$ or by substituting from Equation (6) in Equation (3) and equating to zero,

$$0 = 1 + \frac{F_+}{Z_{77}} \quad (7)$$

F_+ may be written as $F_+ = F_{1+} + j F_{2+}$, where F_{1+} and F_{2+} are real so that Equation (7) becomes

$$0 = \frac{R_{77} + j X_{77} + (F_{1+} + j F_{2+})}{R_{77} + j X_{77}} \quad (8)$$

The values of R_{77} and X_{77} which will result in perfect shielding, then, are

$$R_{77} = -F_{1+} \quad (9)$$

and

$$X_{77} = -F_{2+} \quad (10)$$

F_{1+} and F_{2+} , it will be apparent, are dependent in any particular instance only on the mutual impedances per unit length of the several circuits and on the quantities f_p and v . The mutual impedances may be calculated in ways known to those skilled in the art. The quantities f_p and v , of course, are readily determinable in any given instance. Hence, for every pair of values of f_p and v , the values of the resistance and reactance requisite in the shielding circuit to provide perfect shielding may be ascertained by computation from the above equations. Alternatively, if any pair of the four quantities R_{77} , X_{77} , f_p and v are fixed or assumed, the values of the other two necessary for perfect shielding may be computed from Equations 9 and 10.

In another illustrative embodiment of this invention shown in Fig. 2, the shielding conductor is transposed and reversed at a distance from one end of the inductive exposure between the disturbing and disturbed circuits. As illustrated in this figure, the shielding circuit comprises a conductor grounded at its ends and having a portion 7 adjacent and substantially parallel to the disturbing or power line 5, this portion 7 extending a distance $f_p l$ from one end of the power line 5. The shielding conductor includes also a transposed and reversed portion 8 which is positioned adjacent the disturbed circuit 6, such as a telephone or telegraph line, and extends substantially parallel thereto for a distance $f_s l$, as indicated. A suitable adjustable concentrated impedance 9, which as noted heretofore may be resistive, inductive or capacitive or a combination of these, is connected in series in the shielding conductor.

The various parameters for the shielding circuit shown in Fig. 2 necessary to provide the desired shielding may be ascertained in the same manner as set forth hereinabove with reference to Fig. 1. Specifically, the expressions for the sum of the electromotive forces around the shielding and disturbed circuits are respectively

$$I_2 [Z_{77} (f_p + f_s) - 2 Z_{78} f_s] l + I_1 (Z_{57} f_p - Z_{58} f_s) l = 0 \quad (11)$$

and

$$V_4 = I_1 Z_{56} l + I_2 (Z_{76} f_p - Z_{86} f_s) l \quad (12)$$

Solving Equation (11) for I_2 , substituting in Equation (12) and dividing by $I_1 Z_{56} l$, there is obtained for the shield factor

$$\eta = 1 - f_p \frac{(Z_{57} - v Z_{58})(Z_{76} - v Z_{86})}{Z_{56} [(1 + v) Z_{77} - 2 v Z_{78}]} \quad (13)$$

Following the procedure described by Carter, supra, Equation (13) may be written as

$$\eta = 1 + \frac{F_-}{2 [(1 + v) R_{77} - 2 v R_{78}]} + \frac{F_-}{2 [(1 + v) R_{77} - 2 v R_{78}]} \frac{(1 + v) R_{77} - 2 v R_{78} - j [(1 + v) X_{77} - 2 v X_{78}]}{(1 + v) R_{77} - 2 v R_{78} + j [(1 + v) X_{77} - 2 v X_{78}]} \quad (14)$$

or

$$\eta = 1 - \frac{j F_-}{2 [(1 + v) X_{77} - 2 v X_{78}]} + \frac{j F_-}{2 [(1 + v) X_{77} - 2 v X_{78}]} \frac{(1 + v) R_{77} - 2 v R_{78} - j [(1 + v) X_{77} - 2 v X_{78}]}{(1 + v) R_{77} - 2 v R_{78} + j [(1 + v) X_{77} - 2 v X_{78}]} \quad (15)$$

where

$$F_- = -f_p \frac{(Z_{57} - v Z_{58})(Z_{76} - v Z_{86})}{Z_{56}} \quad (16)$$

and the remaining characters have the same significance as heretofore.

Solving Equation (13) or Equations (14) and

(15), the requisite parameters for perfect shielding may be obtained from the relations

$$R_{77} = -\frac{F_1 - 1}{1 + v} + \frac{2v}{1 + v} R_{78} \quad (17)$$

and

$$X_{77} = -\frac{F_2 - 1}{1 + v} + \frac{2v}{1 + v} X_{78} \quad (18)$$

In another embodiment of this invention illustrated in Fig. 3, the shielding system comprises two shield wires transposed intermediate the ends of the exposure between the disturbing line 5 and the disturbed line 6. One of these shield wires includes a portion 7a adjacent and substantially parallel to the power line 5 and a portion 7b adjacent and substantially parallel to the telephone or telegraph line 6. The other wire includes a portion 8a adjacent and substantially parallel to the telephone or telegraph line 6 and a portion 8b adjacent and substantially parallel to the power line 5. The two wires are connected to ground at their ends and are transposed at a distance fl from one end of the exposure. Suitable lumped impedances 10, 11, 12 and 13, which may be resistive, inductive or capacitive or any combination thereof, may be connected in series with the shield wires as shown to allow adjustment of the magnitude and phase angle of the current in the shielding system.

Following the procedure employed heretofore with reference to the shielding systems shown in Figs. 1 and 2, the shield factor η for the shielding system illustrated in Fig. 3, when the shield wires 7 and 8 are identical, may be expressed as

$$\eta = 1 - \frac{Z_{76}(Z_{57}Z_{77} - Z_{58}Z_{78}) + Z_{86}(Z_{58}Z_{77} - Z_{57}Z_{78})}{Z_{56}(Z_{77}^2 - Z_{78}^2)} - \frac{(2f^2 - 2f)(Z_{76} - Z_{86})(Z_{57} - Z_{58})}{Z_{56}(Z_{77} - Z_{78})} \quad (19)$$

To obtain perfect shielding η must equal 0 in which case Z_{77} may be obtained in terms of the mutual impedances per unit length of the several circuits and the fraction f .

Although, as will be seen from inspection, Equation (19) contains several variable factors, it will be appreciated that in any particular instance and for a given exposure, a number of these factors will be readily ascertainable by computation. Hence, suitable values for the parameters of the shielding system necessary to provide a desired low shield factor also may be computed.

Although in Fig. 3, the shield wires 7 and 8 have been shown as of the same length and grounded adjacent the ends of the inductive exposure, they may be of unequal lengths and grounded at different points between the ends of the exposure or one or more grounds may be provided at the ends of the exposure and the other grounds between the ends. Furthermore, although in Fig. 3, the shield wires have been shown as transposed at the same point, they may be transposed at different points.

It may be noted that, in general, with respect to the various shielding systems shown in the drawing and described hereinabove, it is desirable that the resistance of the shield wires be low, preferably less than 1 ohm per mile including the end grounds. It may be noted also that for relatively wide separations between the disturbing and disturbed lines, that is, separations of several hundred feet, it may be preferable in some cases that the portion of the shield wire adjacent one of the lines be spaced therefrom a distance different

from the spacing between the other portion of the shield wire and the other line. For example, the portion of the shield wire adjacent the telephone line may be spaced three feet therefrom and the portion adjacent the power line may be positioned between the power line and the center of the exposure. Also in some cases it may be preferable to vary the shield wire length to vary the shielding. Furthermore, it may be pointed out that the shield factor may be varied by shifting the point of transposition along the shielding system, the variation in any particular instance being dependent upon the circuit constants. Finally, it may be remarked that the magnitude and phase angle of the current in the shielding system may be varied by adjustment of the series impedances in the shielding system.

In the embodiment shown in Fig. 3, a further adjustment in the phase angle and magnitude of the current in the shielding system may be enabled by bridging the transposed shield wires 7 and 8 by a variable impedance 14 at the point of transposition, whereby the shielding may be improved and the attainment of perfect shielding facilitated.

Although several specific embodiments of the invention have been shown and described, it will be understood that such embodiments are but illustrative of the invention and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. In combination, a pair of transmission lines disposed in proximity to each other, a shield conductor having a portion adjacent one of said lines and a transposed portion adjacent the other of said lines and means in circuit with said conductor for adjusting the phase of the current induced therein.

2. In combination, a power line, a telephone line forming an inductive exposure with said power line, a shield wire grounded at its ends and transposed from a location adjacent said power line to a location adjacent said telephone line, and an adjustable impedance in circuit with said wire.

3. In combination, a power line, a telephone line subject to induction therefrom, a shield wire transposed from a location adjacent said power line to a location adjacent said telephone line, and a lumped impedance in series with said shield wire.

4. In combination, a power line, a telephone line in proximity to said power line and forming an inductive exposure therewith, a shield wire grounded at its ends and having a portion adjacent and substantially parallel to said power line and a transposed portion adjacent said telephone line, and a series impedance in said shield wire.

5. In combination, a pair of transmission lines forming an inductive exposure, a shield wire having a portion adjacent one of said transmission lines, extending from adjacent one end of said exposure to a point intermediate the ends thereof and having another portion adjacent the other of said transmission lines and extending from said point toward the other end of said exposure, and an impedance in series with said shield wire.

6. In combination, a pair of transmission lines forming an inductive exposure, and a shield wire having a portion adjacent one of said transmission lines, extending from one end of said exposure to a point intermediate the ends thereof and having another portion adjacent the other of said

transmission lines and extending from said point toward said one end.

7. In combination, a power line, a telephone line in proximity to said power line and forming an inductive exposure therewith, and a shielding system comprising a wire grounded at opposite ends and including a portion adjacent said power line and a transposed portion adjacent said telephone line, said portions extending in opposite directions to the grounded ends from a point intermediate the ends of said exposure, and a lumped reactance in series with said wire.

8. In combination, a power line, a telephone line in proximity to said power line and forming an inductive exposure therewith, and a shielding system comprising a wire connected to ground at its ends and having a portion adjacent said power line and a transposed portion adjacent said telephone line, said portions extending to the grounded ends in the same direction from a point intermediate the ends of said exposure.

9. In combination, a power line, a telephone line in the vicinity of said power line and forming an inductive exposure therewith, and a shielding system comprising a wire connected to ground at its ends and having a portion adjacent said power line and a transposed portion adjacent said telephone line, the resistance of said wire including the end grounds being not greater than one ohm per mile.

10. In combination, a pair of transmission lines

disposed in the vicinity of each other, a shield wire transposed from a location adjacent one of said lines to a location adjacent the other of said lines, a second shield wire transposed from a location adjacent said other line to a location adjacent said one line, and separate lumped impedances in circuit with each of said wires.

11. In combination, a pair of transmission lines one subject to induction from the other, a shield conductor transposed from a location adjacent one of said lines to a location adjacent the other of said lines, a second shield conductor transposed from a location adjacent said other line to a location adjacent said one line, and a shunt impedance connecting said shield conductors.

12. In combination, a power line, a telephone line in the vicinity of said power line and forming an inductive exposure therewith, a shield wire grounded at its ends and having a portion adjacent said power line and a portion adjacent said telephone line, said portions being transposed at a location intermediate the ends of said exposure, a second shield wire grounded at its ends and having a portion opposite said first portion and adjacent said telephone line and a portion opposite said second portion and adjacent said power line, the portions of said second shield wire being transposed at said location, and an impedance connecting said shield wires at said location.

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