May 18, 1943. W. E. MOUGEY 2,319,744

SHIELDING FOR COMMUNICATION CIRCUITS

Filed Oct. 30, 1941 2 Sheets-Sheet 1

FIG. 1

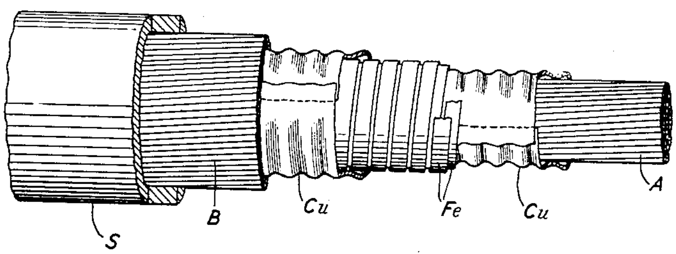

FIG. 2

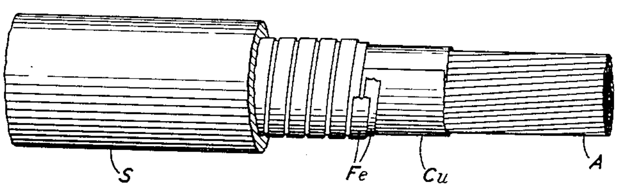

FIG. 3

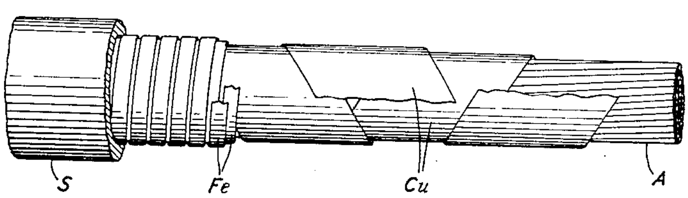

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FIG. 4

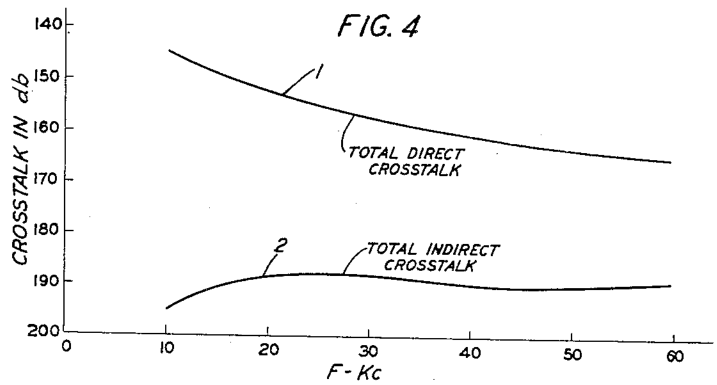


FIG. 5

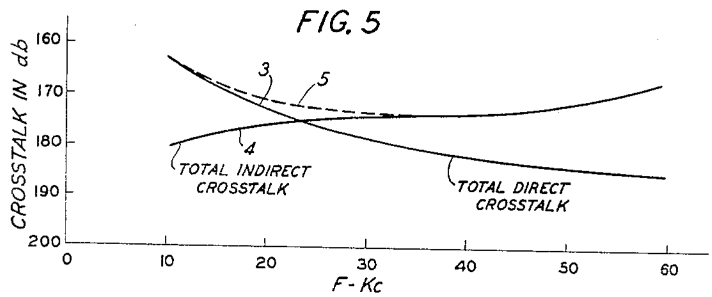
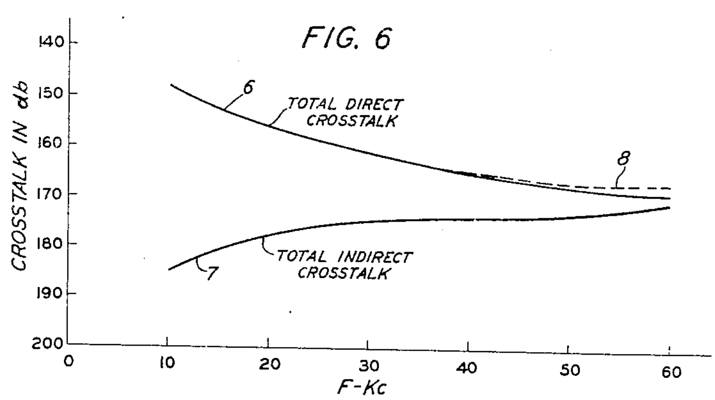


FIG. 6



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SHIELDING FOR COMMUNICATION CIRCUITS

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Application October 30, 1941, Serial No. 417,183

19 Claims. (Cl. 179—78)

The invention relates to shielding for communication circuits against interference and more particularly to such shielding of communication conductors in cables for carrier current transmission.

In the building of multicircuit cable lines for carrier current communication it has been found to be advantageous for shielding purposes to separate the circuits which are used for transmission in one direction from the circuits which are used for transmission in the other direction. In some cases two cables are used, one for each direction of transmission, which has been found advantageous for aerial and buried cables; in other cases the two groups of circuits are included in a single cable and separated from each other by shielding, which has been found to be advantageous when the cables are laid in ducts. When a separate cable is used for each direction of transmission the group of conductors in a suitable length of one or the other cable may be surrounded by a shield, usually termed static shield, and the main object is to protect the circuits against static or other external interference. This shield is in addition to the lead sheath which also serves to protect against static interference. In the cable containing circuits for both directions of transmission one group of conductors is usually arranged in the center and surrounded by a shield, usually called layer shield, and the other group of conductors is arranged in one or more layers outside the shield. In such a cable there may further be provided a static shield immediately under the lead sheath.

The shield used in the past in communication cables has been effective in reducing the crosstalk between the two groups of circuits and other interference to within tolerable limits at voice and low carrier frequencies. Such shields have been composite shields of copper and iron, the copper being applied as tape helically wound in one direction about the core with medium lay or pitch and the iron being applied as tape helically wound with about the same lay as the copper tape but in the opposite direction of the copper tape. Reference may be had to U. S. Patents 1,933,261, issued to Harris on October 31, 1933, and 1,979,402, issued to Nyquist on November 6, 1934, for disclosures of cable shielding of this type.

It has, however, been found that in cables for higher frequency carrier currents the prior art shielding would not be effective in reducing interference between circuits to within such limits as may be tolerated in high grade communication circuits.

Crosstalk interference between two communication circuits involves two main components, namely:

(1) Direct or transverse crosstalk acting directly between the primary or disturbing circuit and the secondary or disturbed circuit transversely of the shield layer; and

(2) Indirect or longitudinal crosstalk between the primary and secondary circuits acting through intermediary circuits and forcing currents lengthwise of the cable along groups of conductors, shield and sheath.

It has been found that the direct crosstalk decreases with the transmission frequency and that the indirect crosstalk increases with the transmission frequency and would become controlling above frequencies of about 30 to 40 kc. in cables with the prior art shielding.

It is therefore an object of the invention to provide an efficient shielding for a communication circuit which will attenuate to within tolerable limits the indirect or longitudinal crosstalk at transmission frequencies up to 60 kc. and higher, and more particularly to provide such shielding for communication circuits in cables.

In accordance with a feature of the invention the copper layer or layers of the shield consist of tapes applied about the core to produce little or no longitudinal magnetic flux due to lengthwise currents in the copper layers. This may be accomplished in two ways:

(*a*) By applying the tapes substantially or nearly parallel with the axis of the cable, or

(*b*) By applying the tapes in pairs, with the tapes of each pair wound in opposite directions.

In accordance with another feature of the invention the magnetic layer or layers of the shield consist of tapes helically applied in the same or opposite directions with such short lay or pitch as to have the turns nearly at right angles to the cable axis, and the tapes may be of any suitable material exhibiting paramagnetic properties, such as iron and iron alloys.

Considering the system of indirect crosstalk transfer between two carrier frequency circuits in their respective groups of circuits separated by a shield, due to inevitable small defects in symmetry of the primary circuit and the consequent unbalance of that circuit with respect to an adjacent bunch of conductors, voltages are induced in the bunch which send unbalance currents lengthwise along the bunch. This lengthwise current finds a return path in the shield where it tends to flow mainly in the surface near the primary bunch. The current which consequently will flow in the far surface of the shield depends on the configuration and properties of the shield and on the transmission frequency, and it finds a return path in the other bunch of conductors adjacent the secondary circuit, where it induces disturbing crosstalk voltages due to inevitable small defects in the symmetry of that circuit. It is therefore evident that the smaller the longitudinal current in the far surface of the shield the more effective will be the shield.

Whereas the explanation of the system of indirect crosstalk transfer, just given above, has been based on the effect of one circuit upon another through the medium of longitudinal currents in the intervening shield, it will readily be understood that similar longitudinal currents may flow in one surface of a shield due to disturbing sources other than a communication circuit, namely, sources such as static discharges and power lines in the neighborhood of the shield, and that such currents may be similarly transferred over the far side of the shield and a bunch of conductors to the disturbed circuit.

Considering now a shield of copper and assuming that a disturbing voltage or voltage gradient is induced or otherwise established therein in a direction parallel with the cable axis, it is evident that, in the case where the copper tape is applied helically in one direction about the primary circuit, the current due to this voltage gradient will mainly follow the turns of the tape, thereby setting up a magnetic flux which will have a circular component at right angles to the axis and a longitudinal component parallel with the axis of the cable. Thus, the current finds a path of comparatively high resistance along the helix of the copper tape and, at carrier frequencies, the path also includes an inductive impedance, due to the solenoid effect of the tape, which will be predominant at higher carrier frequencies. At lower frequencies the distribution of current in an inner and an outer surface or layer of such a shield for a given voltage gradient will mainly be determined by the ohmic resistances of the multipled paths formed by the two layers. However, as the solenoid effect of the inner layer due to the longitudinal flux increases with frequency, an increasing current will be induced in the outer layer, which, as already explained, will produce crosstalk interference in the secondary circuit.

In accordance with the invention this solenoid effect may be reduced by placing the tape or tapes of a copper shield parallel or nearly parallel with the cable axis and so that they completely surround the core. In this case the lengthwise currents will flow substantially parallel with the cable axis and consequently the resultant magnetic flux may be free of longitudinal components and may be directed practically at right angles to the cable axis.

In accordance with the invention the resultant solenoid effect may be reduced by an alternative arrangement in which a plurality of copper tapes are paired and the tapes of each pair are wound helically in opposite directions about the core. Thus, the currents in each tape of a pair will produce a magnetic flux with a right-angle and a longitudinal component, as in the case of the prior art shields referred to above, but the longitudinal components of the two paired fluxes and therefore the solenoid effects of the two tapes will be opposed. At frequencies where the difference in ohmic resistances of the tapes may be disregarded the lengthwise currents due to the disturbing circuit will be divided between the two tapes in such a manner that they will meet minimum impedance, or, in other words in such a manner that the resultant longitudinal flux will approach zero The currents in the tapes of a pair will thus be inversely proportional to the number of helical turns per unit length, and thus may readily be made equal by applying the tapes of a pair with the same number of turns. This relation may, however, be disturbed at high frequencies by the skin effect which tends to concentrate the current in the tape which is wound inside the other tape. This may then be offset by making the number of helical turns of a pair per unit length of cable unequal, with the general object of reducing the longitudinal flux component to the desired extent required for practical operation.

From what has just been explained, it will be understood that, in the more general case of lengthwise currents induced by the primary circuit in a composite shield of copper and iron tapes, the proportions of these currents flowing in the copper layer and in the iron layer also will be such that the total inductive impedance will be a minimum, which condition again will be more nearly approached as the longitudinal flux component due to the currents in the two layers is reduced to zero. With either of the two arrangements of the copper layer referred to above in which currents in the copper layer produce no longitudinal flux, a portion of the current flowing in the helical turns in the iron layer of the shield would produce a longitudinal flux and thus would increase the total inductive impedance of the shield; therefore, no portion of the lengthwise current in the shield would flow in the iron layer. Thus, when the copper layer is placed between the primary group of circuits and the iron layer no voltage gradient due to longitudinal flux will be established in the outer surface and the longitudinal current will be confined to the copper layer, and neither of the proposed two arrangements of the copper tapes in combination with a layer of helical iron tapes will produce an appreciable longitudinal flux.

When still another copper layer is placed outside the iron layer to form a layer shield and when further the tapes in each copper layer are arranged in accordance with either or both of the two proposed arrangements for reducing the longitudinal flux component and the solenoid effect of the layer, no current due to this source can be induced in the outer copper layer. Some current will pass through the iron layer to the outside copper layer at lower carrier frequencies, but this current will be small and no appreciable disturbance would be produced thereby. At higher frequencies this effect would be greatly reduced by the well-known shielding effect produced by the skin effect.

From the discussion presented above it will be apparent that at the higher carrier frequencies the shielding is called upon to prevent disturbances due to fluxes of entirely different forms from those for which shields were designed in the past. As already stated, indirect crosstalk becomes predominant over direct crosstalk at frequencies above 30 or 40 kc. and the fluxes involved in indirect crosstalk include both longitudinal components and components following a circular path about the cable. The longitudinal fluxes are not involved in the direct crosstalk. The reduction or elimination of these longitudinal fluxes is accomplished by two different arrangements in accordance with the invention, as has been discussed above.

In accordance with the invention the iron layer of the composite shield is adapted to as nearly as possible confine the circular flux and thus to reduce as far as necessary for practical requirements any stray fields of this flux.

In accordance with the invention either of the two proposed arrangements of the copper layers is supplemented by an arrangement of the iron layer whereby a low reluctance path is provided for the circular right-angle flux component of the magnetic flux produced by the copper layer or layers.

In accordance with this feature the iron tape is applied helically with a short lay and for this reason is made comparatively narrow, so that the helical turns will be more nearly at right angles to the cable axis, thus more nearly conforming to the path of the circular flux. The tape is furthermore applied with considerable overlap to reduce the air-gaps. The flux thus may be practically confined within the iron layer and no appreciable stray flux will be produced.

Thus, by the arrangements proposed in accordance with the invention it is possible to confine the lengthwise currents involved in indirect crosstalk interference to the inner copper layer of the shield and to confine the magnetic flux to the iron layer at carrier frequencies within a wide band, thereby securing a high degree of shielding.

In the following description of preferred embodiments of the invention reference will be made to the attached drawings, in which:

Fig. 1 shows the end portion of a cable with two concentrically arranged groups of circuits separated by a layer shield arranged in accordance with certain features of the invention;

Fig. 2 shows an end portion of a cable having one group of circuits surrounded by a static shield arranged in a manner similar to that of the shield shown in Fig. 1;

Fig. 3 shows an end portion of a cable similar to that in Fig. 2 in which the static shield is arranged in accordance with alternative features of the invention; and

Figs. 4, 5 and 6 show graphical representations of variations with frequency of crosstalk and its components in three types of cable shields.

It should be understood that the preferred embodiments described hereinafter and shown in the drawings are disclosed merely as examples of the application of the invention to practical use and that various other arrangements may be provided within the scope of the invention without departing from the spirit of the invention as defined by the appended claims.

It should particularly be noted that the drawings show and the description refers to only the essential elements of the cable as they relate to the invention and that, in practice, cables such as those disclosed, will include other elements which may serve various purposes. Thus, paper wrappings may be applied between certain of the layers for the purpose of mechanical cushioning and of electrical protection, as against static discharges.

Referring now to Fig. 1, the cable comprises a bundle of conductors A which may be arranged in units of pairs or quads in any suitable manner and the units may be arranged in layers or may merely be bunched together. Surrounding the bunch of conductors is a layer shield comprising an inner copper layer Cu, an intermediate iron layer Fe and an outer copper layer Cu. A second conductor group B is placed in an annular layer about the shield and is, in turn, surrounded by the outer protecting sheath S. The sheath S is usually an extruded layer of lead, which may or may not be combined with an outer additional protecting layer of any desirable kind, which thus may include insulating compounds and metallic or fibrous armoring.

The inner and outer layers Cu are similar and each comprises a wide thin copper tape folded about the core substantially longitudinally of the cable with overlapping edges; these tapes may be transversely corrugated previous to their application to the cable to provide flexibility. The iron layer Fe comprises an inner narrow steel tape applied helically about the inner copper layer Cu with a small pitch and with a small spacing between the turns to allow for bending of the cable, and an outer similar iron tape placed helically to cover the spacings of the inner iron tape.

Considering the indirect crosstalk phenomenon at high carrier frequencies in a cable of this type, let it be assumed that the disturbing or primary circuit is included in the group A and that the disturbed or secondary circuit is included in the group B. It should, however, be understood that in the following discussion these disturbing and disturbed circuits may be interchanged without affecting the conclusions. The primary circuit, due to imperfect symmetry with respect to other circuits in the same group, induces a longitudinal current in those other circuits of group A, which current finds a return path along the shield Cu-Fe-Cu. Due to the absence of a longitudinal flux and of any solenoid effects from the two copper layers, this longitudinal return current will be largely confined to the inner layer or surface of the shield. This current, as already explained, produces a resultant flux at right angles to the cable which follows more or less accurately the turns of the iron layer. A circular stray flux external of the iron layer would induce a longitudinal current in the outer copper layer which would find a return path lengthwise through a bunch of the conductor group B and in turn would induce a disturbing current in the secondary circuit due to incomplete symmetry of that circuit. However, with the various layers of the shield arranged in accordance with the invention and as shown in Fig. 1, the crosstalk produced in this manner may be kept within tolerable limits even at high carrier frequencies.

The construction shown in Fig. 1 may, of course, be completed by the addition of cable elements other than those shown in the drawing and these may include a paper wrapping between the conductor group A and the contiguous copper layer to act as a cushion and, if necessary, to furnish additional dielectric strength against core-to-sheath potentials induced by lightning; a similar wrapping of paper may be placed between the shield and the outer conductor group B. A wrapping of paper may also be placed between the conductor group B and the sheath. It may furthermore be desirable to add a static shield between the conductor group B and the lead sheath S, the construction of which may be similar to that shown in Fig. 2 or 3 and serving a similar purpose, as described hereinafter.

The design of the shield may be varied from that shown in Fig. 1 for mechanical reasons by applying the longitudinal copper tape in either or both copper layers Cu with a helix of very long lay depending upon the degree of freedom from crosstalk which is desired. It is furthermore possible to replace the single copper tape by two or more parallel longitudinally applied tapes with overlapping edges.

In a cable of the type shown in Fig. 1 the layer shield may be built up of 5-mil copper tape in each layer applied substantially longitudinally with considerable overlap, and of two steel tapes each of a width approximately equal to the enclosed diameter and 5 mils thick and applied in the same or opposite directions. A shield of this type and within the specified dimensions has been found to effectively reduce crosstalk between the two groups of conductors to within tolerable limits at transmission frequencies up to at least 60 kc.

Referring now to Fig. 2, the cable shown comprises a bundle of conductors A for transmission in one direction and arranged in units of pairs or quads in any suitable manner. Surrounding the group of conductors is a static shield comprising an inner copper layer Cu and an outer iron layer Fe, which in turn is surrounded by the outer protecting sheath S.

The copper layer Cu is formed of a thin copper tape applied longitudinally of the conductor core and wide enough to surround the core with an overlap. If desired, this copper tape may be transversely corrugated as shown in Fig. 1 for the purpose of increasing the flexibility of the cable. The iron layer Fe is similar to that shown in Fig. 1, comprising an inner narrow steel tape applied helically about the copper layer Cu with a small pitch and an outer similar iron tape placed helically to cover the spacings of the inner iron tape.

The shielding effect of the arrangement shown in Fig. 2 is similar to that of the arrangement shown in Fig. 1 and about the same attenuation of disturbances may be secured in both types of shield with the same amounts of iron and copper per unit length of cable.

The shields shown in Figs. 1 and 2 definitely provide low resistance and low inductance against lengthwise currents in the copper and low reluctance against the resultant transverse flux due to the lengthwise currents in the copper.

With a lead sheath surrounding the shield shown in Fig. 2 additional shielding is provided so that the requirements for attenuation of disturbances by the copper-iron shield may be correspondingly reduced.

Referring now to Fig. 3 the cable shown in this figure is similar to that shown in Fig. 2 but differs therefrom mainly in the construction of the copper layer Cu. The group of conductors A, the iron layer Fe and the outer sheath S may be exactly like those shown in Fig. 2.

The copper layer in this embodiment comprises an inner copper tape applied helically with overlap to the conductor core A and another similar copper tape wound helically upon the first tape but in the opposite direction.

In this construction the lengthwise current due to a longitudinal voltage gradient in the copper layer will be forced to follow the convolutions of the copper tape and will divide between the two tapes in such proportions that the current will meet minimum impedance, as explained above, and the resultant flux consequently will be substantially at right agnles to the cable axis. With an equal number of turns per unit length in the two copper tapes, as shown in the drawing, currents in the symmetrical tapes will be substantially equal.

Since the copper layer shown in Fig. 3, similar to that shown in Fig. 2, produces a resultant flux which is at right angles to the cable, this flux will substantially coincide with the turns of the iron layer Fe and the total shielding effect of the arrangement shown in Fig. 3 will be similar to that of the arrangement shown in Fig. 2. For purposes similar to those referred to above for the cable shown in Fig. 2, the shield shown in Fig. 3 may be built of two 3-mil copper tapes of a width about equal to that of the enclosed diameter and with such a lay as is found mechanically convenient.

Supplemental elements may be included in this cable similar to those referred to above and the pitch of the paired tapes may be varied within wide limits.

It should be understood that the construction shown in Fig. 1 may be modified by replacing the longitudinal copper tape in each layer by a pair of oppositely wound helical copper tapes, such as shown in Fig. 3; it should also be understood that a greater plurality of copper tapes may be used in the copper layer or layers of the shield in any of the constructions shown in Figs. 1, 2 and 3 provided that the tapes are paired in the manner described above or else are wound with relative turns per unit length in opposite directions with the effect that the longitudinal component of the magnetic flux due to lengthwise currents in the copper will be reduced to a required minimum.

The shielding effect secured by a shielding arrangement, such as that shown in Fig. 1, may be visualized by examination of the curves shown in the diagram Fig. 4. These curves have been obtained from computations based upon measured data of a 100-quad cable with two groups of conductors separated by a copper-iron-copper shield in which each copper layer is made of a single longitudinal copper tape substantially as shown in Fig. 1 and the iron layer is made of two 1⅜-inch wide and 5-mil thick tapes. The length of the cable is 17.5 miles.

In Fig. 4 curve 1 shows the variation in the total direct crosstalk for frequencies from 10 to 60 kc. In accordance with this curve the direct crosstalk is greater (fewer db.) at the lower frequencies than at the higher frequencies.

Curve 2 of Fig. 4 shows variation in the total indirect crosstalk over the same range of frequencies, from which it appears that the indirect crosstalk is practically constant for almost the entire range and is much lower than the direct crosstalk. In fact, the indirect crosstalk is so small that it forms an imperceptible part of the total crosstalk, and a curve representing the summation of the two types of interferences coincides completely with the curve for the direct crosstalk. From these curves it appears conclusively that this desirable condition would prevail at frequencies much higher than 60 kc.

Fig. 5 shows similar curves for direct and indirect crosstalk for a cable similar to that shown in Fig. 1, except that the two copper layers and the intermediate iron layer are arranged in accordance with prior art practices, namely, with the copper tapes applied helically in the same direction about the core and with a medium length of lay and four iron tapes are applied helically with about the same lay. The length of the cable is 11 miles.

In Fig. 5 the variation in total direct crosstalk with frequency is shown by curve 3 and the variation in total indirect crosstalk is shown by curve 4. Comparing these curves representing prior art practices with the curves of Fig. 4 representing arrangements in accordance with the invention, it will be noted that the direct crosstalk decreases with frequency in both cases, but that the indirect crosstalk increases rapidly with frequency in the prior art cable and predominates at frequencies above 25 to 30 kc., as will appear from the dotted curve 5 which represents a summation of the direct and indirect crosstalk; on the other hand, the indirect crosstalk in the cable arranged in accordance with the invention is insignificant over the entire frequency range, as shown by curves 1 and 2.

Thus, Fig. 5 gives a clear picture of the serious interference in a typical prior art cable which would arise at frequencies above 30 kc. and Fig. 4 clearly shows that such interference in the same type of cable may be reduced to become negligible when the shielding is arranged in accordance with the particular features of the invention illustrated by the embodiment shown in Fig. 1.

In Fig. 6 the curves 6 and 7 show variations in total direct crosstalk and total indirect crosstalk, respectively, for a cable similar to that shown in Fig. 1, but modified in accordance with the invention by having each copper tape replaced by a pair of oppositely wound helical 3-mil copper tapes, such as shown in Fig. 3. The length of this cable is 17.5 miles.

It will be noted that in this case the direct crosstalk also decreases with the frequency and that the indirect crosstalk increases with the frequency, but that within a frequency range up to 60 kc. the indirect crosstalk is substantially less than the direct crosstalk; from the dotted curve 8, representing a summation of the direct and indirect crosstalks, it will appear that the direct crosstalk is predominant for frequencies at least up to 60 kc.

It should be understood that the invention is not limited to shields using iron in the magnetic layer thereof. As is well known, iron may have various substances added to it for the purpose of improving its physical properties and of affecting its conductivity, without appreciably affecting its magnetic properties and particularly without impairing its magnetic properties beyond their usefulness for shielding purposes. It is also well known that iron may have added to it various substances in small or large proportions with the object of securing a magnetic composition or alloy with magnetic properties of greater magnitude or of different characteristics for similar magnetizing forces and useful for shielding purposes.

These various forms of iron or iron compositions thus being suitable for the purposes of the invention and possibly being preferred under specific circumstances for shielding, it should be understood that the term iron, as it is used in the specification and claims, is intended as a generic term including the different magnetic materials, referred to above, in which iron contributes characteristically to the magnetic properties, as well as iron in its more common commercial forms.

What is claimed is:

1. A longitudinal shield for enclosing a high frequency circuit which is effective in establishing a longitudinally directed voltage gradient upon the surface of said shield nearest to the circuit, said shield comprising an iron layer and a copper layer between said iron layer and the circuit, said copper layer being comprised of copper tape so disposed about the circuit that currents therein due to said voltage gradient will produce a resultant magnetic flux directed substantially at right angles to the longitudinal direction of said shield, and said iron layer being comprised of iron tape wound about said copper layer with turns substantially concidental with the general direction of said resultant magnetic flux.

2. A longitudinal tubular shield for enclosing a high frequency circuit which is effective in establishing a longitudinally directed voltage gradient upon the surface of said shield nearest to the circuit, said shield comprising a highly conductive layer having low inductive impedance to currents flowing lengthwise of said shield due to said voltage gradient, and a layer of magnetic material having low reluctance to components of magnetic flux produced by the said currents and directed at a substantially right angle to the longitudinal direction of said shield.

3. A longitudinal tubular composite shield of copper and iron for enclosing a high frequency circuit which is effective in establishing a longitudinally directed voltage gradient upon the surface of said shield nearest to the circuit, the copper in said shield being applied about said circuit to present a low inductive impedance to currents flowing lengthwise of said shield due to said voltage gradient, and the iron in said shield being applied to present a low reluctance path to components of magnetic flux produced by the said lengthwise currents in a direction transverse of the longitudinal direction of said shield.

4. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied about said layer of copper, said layer of copper being adapted to conduct carrier frequency currents therein, due to axially directed interference voltage gradients in said layer of copper, along such paths that any resultant magnetic flux due to said currents will be directed nearly at right angles to the axis of the cable.

5. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, and a composite shielding layer of copper and iron closely surrounding said core, the iron in said shielding layer comprising iron tape helically applied with short lay and the copper in said shielding layer being applied to conduct carrier frequency currents along paths in the various portions thereof about a unit length of the core, said currents being due to axially directed interference voltage gradients in said various portions, and said paths being so directed that any resultant magnetic flux due to said currents will be directed nearly at right angles to the axis of the cable.

6. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied with short lay about and closely surrounding said layer of copper, said layer of copper presenting a plurality of paths about a unit length of the cable for currents traveling lengthwise of the cable due to interference voltage gradients parallel to the axis of the cable, said paths being symmetrically

directed about said layer of copper for the production of a resultant flux nearly coincidental with the turns of said short lay iron tape.

7. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied with short lay about and closely surrounding said layer of copper, said layer of copper being adapted to conduct carrier frequency currents therein, due to axially directed interference voltage gradients in said layer of copper, along paths nearly parallel with the axis of the cable for production of a resultant magnetic flux nearly at right angles to the axis of the cable.

8. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied with short lay about and closely surrounding said layer of copper, said layer of copper being adapted to conduct carrier frequency currents therein, due to axially directed interference voltage gradients in said layer of copper, along differently directed paths and so proportioned as to current strength that the resultant magnetic flux due to said currents in a unit length of said cable will be nearly at right angles to the axis of the cable.

9. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied with short lay about and closely surrounding said layer of copper, said layer of copper being adapted to conduct carrier frequency currents therein, due to axially directed interference voltage gradients in said layer of copper, along a pair of paths helically and oppositely directed about said layer for the production of a magnetic flux for each of said paths having a longitudinal magnetic flux component that will be nearly neutralized by that of the other of said paths.

10. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied with short lay about and closely surrounding said layer of copper, said layer of copper being adapted to conduct carrier frequency currents therein, due to axially directed interference voltage gradients in said layer of copper, along two symmetrical helical paths and of nearly equal current strength in said two paths for the production of two mutually neutralizing longitudinal magnetic flux components.

11. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied with short lay about and closely surrounding said layer of copper, said layer of copper being of thin tape applied about the core to have low inductive impedance to currents flowing lengthwise of said layer of copper due to a voltage gradient impressed upon said layer of copper by one of the circuits in said core.

12. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied about said layer of copper, said layer of copper comprising a thin tape folded longitudinally about said core with overlapping edges, and the lay of said iron tape being so short that the turns of iron tape will be nearly at right angles to said thin tape.

13. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied about said layer of copper, said layer of copper comprising a thin tape wound in a helix about said core in the direction opposite that of said iron tape, and a second thin tape wound in a similar helix about said core in the direction opposite that of the first said copper tape.

14. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied with short lay about and closely surrounding said layer of copper, said layer of copper comprising two copper tapes wound in symmetrical oppositely directed helixes about said core.

15. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied with short lay about and closely surrounding said layer of copper, said layer of copper comprising two copper tapes wound helically in opposite directions about said core.

16. A multicircuit communication cable for carrier frequencies including a core of insulated conductors, a shielding layer of copper closely surrounding said core, and a shielding layer of iron tape helically applied with short lay about and closely surrounding said layer of copper, said layer of copper comprising two similar thin tapes wound in symmetrical helixes in opposite directions about said core, and the lay of said iron tape being so short that the turns of iron tape will be nearly at right angles to the axis of the cable.

17. A longitudinal tubular shield for separating two high frequency circuits which each is effective in establishing a longitudinally directed voltage gradient upon the surface of said shield nearest to the circuit, said shield comprising a first highly conductive layer of metal such as copper and having low inductive impedance to currents flowing lengthwise of said shield due to the said voltage gradient established by one of said circuits, a second highly conductive layer of metal such as copper and having low inductive impedance to currents flowing lengthwise of said shield due to the said voltage gradient established by one of said circuits, and a third low conductivity layer of metal such as iron, placed intermediate said first and second layer, and having low reluctance to components of magnetic flux produced by the said currents in said first and second layers and directed at substantially right angles to the longitudinal direction of said tubular shield.

18. A multiconductor communication cable for carrier frequency transmission in opposite directions including a first group of insulated conductors for transmission in one direction and forming a core, a first shielding layer of copper closely surrounding said core, a second shielding layer of iron tape helically wound about said

first shielding layer, a third shielding layer of copper closely surrounding said second shielding layer, and a second group of conductors for transmission in the other direction and placed in an annular layer about said third shielding layer, said first and third layers of copper each comprising a thin tape folded longitudinally about said core with overlapping edges.

19. A multiconductor communication cable for carrier frequency transmission in opposite directions including a first group of insulated conductors for transmission in one direction and forming a core, a first shielding layer of copper closely surrounding said core, a second shielding layer of iron tape helically wound with short lay about and closely surrounding said first shielding layer, a third shielding layer of copper closely surrounding said second shielding layer, and a second group of conductors for transmission in the other direction and placed in an annular layer about said third shielding layer, said first and third layers of copper each comprising two copper tapes wound in symmetrical oppositely directed helixes about said core.

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